

FISHERY ECOSYSTEM PLAN for the HAWAII ARCHIPELAGO



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Working Draft: 2/23/2016 8:47 AM

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PREFACE

In 2005, the Council recommended to establish and implement fishery ecosystem plans for archipelagic, pelagic, and remote island areas in the Western Pacific Region. In order to accomplish this directive, Council staff conducted a series of ecosystem-based fishery management (EBFM) workshop between 2005 and 2007: Ecosystem Science (2005); Social Science (2006); and Management Policy (2007). Previously, the Council managed fisheries in these areas using the single-species management paradigm. Ecosystem-based fishery management addresses a geographically-specified system of fishery-associated organisms (including humans), and the environment and the processes that control its dynamics. It includes noncommercial and commercial fisheries, and recognizes the physical, biological, economic and social interactions among the affected components of the ecosystem. Perhaps most importantly, EBFM seeks to manage for a spectrum of goals society has for fishery ecosystems – some of which may be in competition.

The Council's first fishery ecosystem plans were approved by the Secretary of Commerce in September 2009. However, ecosystem-based fishery management thinking has an extended history in our region. For example, the Council's Executive Director, Kitty Simonds, was an active participant in one of the National Oceanic and Atmospheric Administration's (NOAA) first ecosystem management workshops, in 1986. In 2001, the Council took final action to recommend the first fishery ecosystem management plan in the nation. The Coral Reef Ecosystem Fishery Management Plan encompassed Council-associated coral reef fishery ecosystems in the U.S. Pacific Islands. Among other things, the plan established a process to assess and control ecosystem effects on coral reef environments from bottomfish, precious coral, and crustacean fisheries operating in federal waters under then-existing fishery management plans.

The Hawaiian Archipelago FEP is the framework under which the Council will manage place-based fishery ecosystem resources, including the integration of important ecosystem elements important to decision-making. These elements include social, cultural, and economic dimensions, protected species, habitat considerations, climate change effects, and the implications to fisheries from various spatial uses of the marine environment. Successful ecosystem-based fisheries management requires an increased understanding of a range of social and scientific issues, including the societal goals society appropriate management objectives, biological and trophic relationships, ecosystem indicators and models, and the ecological effects of nonfishing activities on the marine environment. Future fishery management actions are anticipated to utilize this information as it becomes available, and flexible, adaptive management will be used to further advance the implementation of ecosystem science and principles. In this regard, the success of the EBFM approach relies heavily on the data collection and synthesis process established by the pelagic and archipelago annual fishery ecosystem reports (SAFE Reports). In 2015, the Council, in partnership with the National Marine Fisheries (NMFS) Pacific Islands Fishery Science Center, local fishery resource management agencies, and the NMFS Pacific Islands Regional Office began the process to revise and expand the contents of these reports to include the range of ecosystem elements described above.

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EXECUTIVE SUMMARY

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) is the primary domestic legislation governing management of the nation's marine fisheries. The United States Congress has amended and reauthorized the MSA several times since 1976. The 1996 reauthorization included, among other things, a new emphasis on the precautionary approach. In 2006, an annual catch limit requirement was written in. The MSA contains ten national standards, with which all fishery management plans and plan amendments must conform. The MSA also requires U.S. fisheries management be consistent with the requirements of other regulations including the National Environmental Policy Act, Marine Mammal Protection Act, the Endangered Species Act, the Migratory Bird Treaty Act, and several other Federal laws and Executive Orders.

Under the Magnuson-Stevens Act, the Western Pacific Regional Fishery Management Council (Council) is authorized to prepare and submit to the Secretary of Commerce for approval, disapproval or partial approval, a Fishery Management Plan (FMP) and any necessary amendments, for fisheries that are under its authority and that require conservation and management. The Council transitioned to Fishery Ecosystem Plans (FEPs) from FMPs in 2009. The Council conducts public hearings so that all interested persons may have opportunities to participate in the development of FEPs and amendments.

This Fishery Ecosystem Plan (FEP) governs federal fisheries of the Hawaiian archipelago. The management area is the United States (U.S.) Exclusive Economic Zone (EEZ) of the archipelago. The Plan covers bottomfish, coral reef fish, crustacean, and precious coral stocks and fisheries. The FEP was implemented on September 24, 2009. It replaced a set of species-based FMPs that covered the Western Pacific Region. This version of the FEP was implemented on [REDACTED]. It strengthens the ecosystem-based fishery management approach, provides the public with additional information regarding the management process, conforms to new information requirements, and is a framework for a clearer understanding of fishery and conservation and management measures promulgated by the FEP and subsequent amendments to it.

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1 INTRODUCTION

1.1 Mission

The mission of the Western Pacific Regional Fishery Management Council (Council), a federal instrumentality established and authorized by Congress in 1976, is to “plan, coordinate and realize all responsibilities as delegated under the MSA for effective conservation and prudent development of the region’s fishery resources for the benefit of the region and the nation.” To meet this mission, the Council established the following Guiding Principles:

1. Support quality research and obtain the most complete scientific information available to assess and manage fisheries;
2. Promote an ecosystem approach in fisheries management, including reducing waste in fisheries and minimizing impacts on marine habitat and impacts on protected species;
3. Conduct education and outreach to foster good stewardship principles and broad and direct public participation in the Council’s decision making process;
4. Recognize the importance of island cultures and traditional fishing practices in managing fishery resources and foster opportunities for participation;
5. Promote environmentally responsible fishing and the utilization of sustainable fisheries that provide long term economic growth and stability;
6. Promote regional cooperation to manage domestic and international fisheries; and
7. Encourage development of technologies and methods to achieve the most effective level of monitoring, control and surveillance and to ensure safety at sea.

The Council is responsible for developing fishery management policies for the western Pacific region, which includes the State of Hawaii, Territories of American Samoa and Guam, the Commonwealth of the Northern Mariana Islands and other U.S. Pacific remote island areas (Figure 1). All management plans, amendments to them, and regulations implementing them, must comply with the MSA and all other applicable laws – such as the National Environmental Policy Act (NEPA). The Council’s primary responsibility is to develop and recommend fishery management measures for any federal managed fishery, stock, or stock complex, as well as measure to protect important ecosystem components, such as protected species and fish habitat.

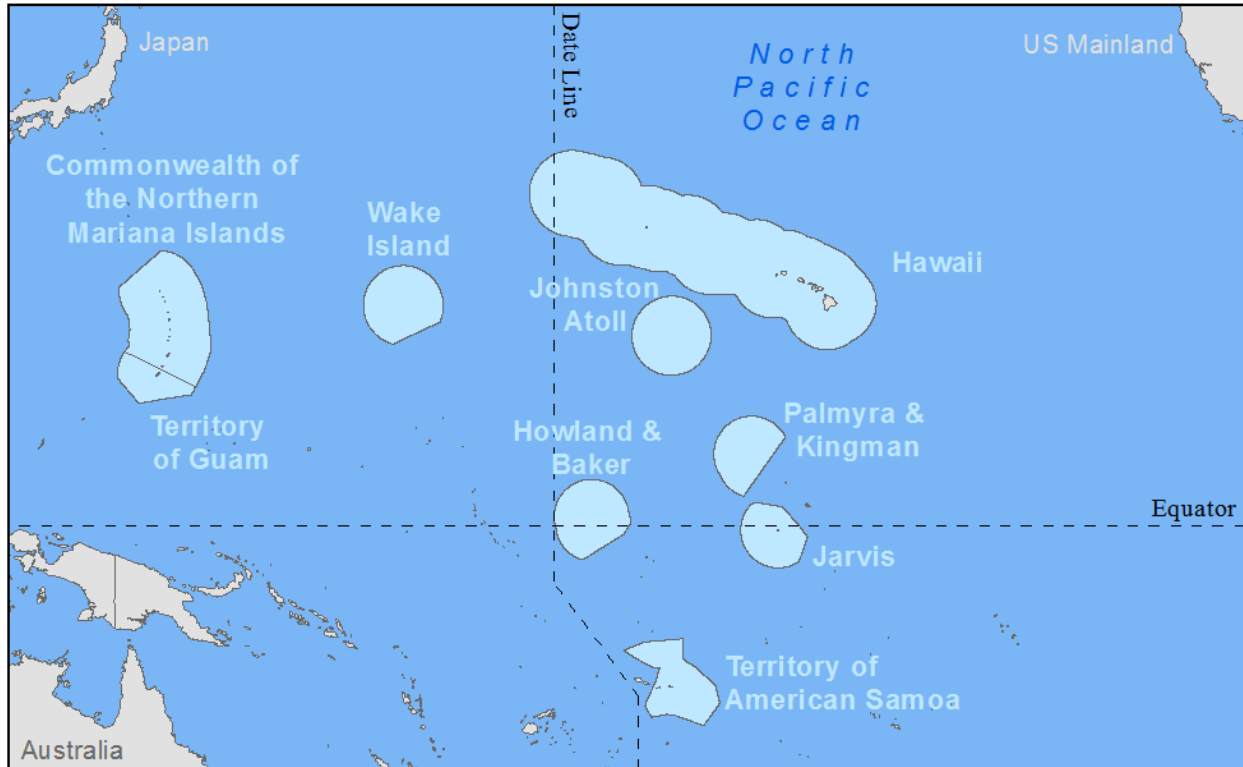


Figure 1: The Western Pacific Region with US EEZ in light blue

The region's archipelagos have distinct cultures, communities, and marine resources. For thousands of years, the indigenous people of these islands relied on healthy marine ecosystems to sustain themselves, their families, and their island communities. Although the past century has brought enormous advancements in transportation and diet, these islanders continue to depend on healthy marine ecosystems, owing to the remoteness of the islands, and their intact cultural practices. Even in the modern period, much ecological, economic, and social benefit is realized from sustainably managing island resources.

Because of the interconnections between various species, habitats, and human communities, the Council opted in the mid-2000s to take an archipelagic ecosystem-based approach, and spent several years revising its five existing species/complex-based fishery management plans (FMPs) (Precious Corals FMP became effective in September 1983; Crustaceans FMP (March 1983); Bottomfish and Seamount Groundfish (August 1986); Pelagics FMP (March 1987); Coral Reef Ecosystems FMP (February 2004)) to place-based fishery ecosystem plans (FEPs). The five FEPs approved by the Council in 2007 and implemented in 2009 include the American Samoa Archipelago FEP, Mariana Islands Archipelago FEP, Hawaii Archipelago FEP, Pacific Remote Island Area FEP, and Pacific Pelagic FEP.

1.2 Authorities and Primary Management and Process Drivers

1.2.1 Magnuson-Stevens Fisheries Conservation and Management Act

In 1976, the United States Congress passed the Fishery Conservation and Management Act to promote domestic fisheries and establish management authority over fishery and related resources within the 200 mile federal Exclusive Economic Zone (EEZ). The statute has been subsequently amended and reauthorized over the ensuing years and is now known as the Magnuson-Stevens Fishery Conservation and Management Act (MSA).¹ It is the primary law governing federal management of United States fisheries.

Under the MSA, the United States (U.S.) has exclusive fishery management authority over all fishery resources found within its Exclusive Economic Zone (EEZ). For purposes of the MSA, the inner boundary of the U.S. EEZ extends from the seaward boundary of each coastal state to a distance of 200 nautical miles from the baseline from which the breadth of the territorial sea is measured. In the Hawaii Archipelago, the Western Pacific Regional Fishery Management Council (Council) has authority over the fisheries based in, and surrounding, the State of Hawaii.

The management system created by the MSA is unique in U.S. natural resource management. In order to avoid top-down, centralized fishery resource management, Congress established eight regional fishery management councils and provided them with responsibility for developing fishery management plans and recommending amendments to those plans on an ongoing basis, as well as regulatory language for implementation. As such, the Councils have a unique relationship with their primary partner federal agency, the National Marine Fisheries Service (NMFS). Councils are composed of federal, state, and territorial fishery management officials, participants in commercial and recreational fisheries, and other individuals with experience, scientific expertise, or training that give them knowledge about fishery conservation and management or commercial or recreational harvest. In addition, the MSA mandates certain advisory bodies (and authorized the Councils to create others) so as to provide the Councils with technical advice and guidance in fishery policy decision making. The MSA mandates an open, public process for the development of fishery management measures and actions through the Council system.

As in other regions, responsibility for the management of marine resources in the Western Pacific is shared by a number of federal and local government agencies. At the federal level are the Council, the NMFS (also known as the NOAA Fisheries Service), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service (U.S. Department of the Interior) and the U.S. Department of State. The U.S. Coast Guard, in the U.S. Department of Homeland Security, as well as the Department of Defense, through the Air Force, Army, Navy and Marine Corps, also controls access, enforcement, and use of various marine waters throughout the region.

¹ The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended through 2006, is available at: http://www.nmfs.noaa.gov/sfa/magact/MSA_Amended_2007%20.pdf

The sixteen members of the Council include the following:

- Regional Administrator, Pacific Islands Regional Office, National Marine Fisheries Service
- Director, Department of Marine and Wildlife Resources, Territory of American Samoa
- Secretary, Department of Land and Natural Resources, Commonwealth of the Northern Mariana Islands
- Director, Department of Agriculture, Territory of Guam
- Chair, Department of Land and Natural Resources, State of Hawaii
- One obligatory member from each of the four island areas nominated by their respected governors and appointed by the Secretary of Commerce
- Four at-large members nominated by the region's Governors and appointed by the Secretary of Commerce.
- District Commander, US Coast Guard 14th District (non-voting member)
- Director, Office of Marine Conservation, US State Department (non-voting member)
- Director, US Fish and Wildlife Service (non-voting member)

The basic functions of the Council as required by the MSA are diverse. For fisheries under its authority that require conservation and management the Council has the following responsibilities:

1. Prepares and transmits to the Secretary fishery ecosystem plans (FEPs) and amendments to such plans as necessary to address changing needs in conservation and management;
2. Prepares comments on any application for foreign fishing transmitted to the Council, and any fishery management plan or amendment transmitted to the Council;
3. Conducts public scoping, meetings and hearings at appropriate times and in appropriate locations in its geographic area² so as to allow all interested persons an opportunity to be heard in the development of FEPs and amendments to such plans, and other matters with respect to the administration and implementation of the provisions of the Magnuson-Stevens Act and other Statutory requirements;
4. Submits to the Secretary such periodic reports as the Council deems appropriate and any other relevant report that may be requested by the Secretary;
5. Reviews on a continuing basis, and revises as appropriate, the following for each fishery within its geographical area of authority: assessments and related specifications with respect to the optimum yield (OY); the capacity and extent to which US fish processors will process US harvested fish; and the total allowable level of foreign fishing;
6. Develops annual catch limits (ACLs) for managed fisheries that may not exceed the fishing level recommendations of its Scientific and Statistical Committee (SSC) or similar peer-review process;

² "Geographic area" may include an area under the authority of another Council if the fish in the fishery concerned migrate into, or occur in, that area or if the matters being heard affect fishermen of that area.

7. Develops, in conjunction with its SSC, five-year research priorities for fisheries, fisheries interactions, habitats and other areas of research that are necessary for management purposes; update them as necessary; and submit them to the Secretary of Commerce (Secretary) and the Pacific Islands Fisheries Science Center (PIFSC) of the National Marine Fisheries Service (NMFS) for their consideration in developing research priorities and budgets for the Pacific Islands/Western Pacific Region;
8. May review and provide comments on any federal or state action that may affect fishery habitat under the Council's jurisdiction; and
9. Conducts any other activities that are required by, or provided for in, the MSA or which are necessary and appropriate to the foregoing functions.

1.2.1.1 National Standards

To carry out the above functions, the Council pays particular attention to 10 National Standards (NS) described in the MSA, against which the Council's recommendations to the Secretary are measured:

1. Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the OY from each fishery for the United States fishing industry.
2. Conservation and management measures shall be based upon the best scientific information available.
3. To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range and interrelated stocks of fish shall be managed as a unit or in close coordination.
4. Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be fair and equitable to all such fishermen; reasonably calculated to promote conservation; and carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.
5. Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.
6. Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources and catches.
7. Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.
8. Conservation and management measures shall, consistent with the conservation requirements of the MSA (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities by utilizing economic and social data that meet the requirements of NS 2 in order to provide for the sustained participation of such communities, and, to the extent practicable, minimize adverse economic impacts on such communities.

9. Conservation and management measures shall, to the extent practicable, minimize bycatch and, to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.
10. Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

1.2.1.2 Essential Fish Habitat

In 1996, Congress passed the Sustainable Fisheries Act, which amended the MSA and added several new FMP provisions. From an ecosystem management perspective, the identification and description of essential fish habitat (EFH) for all federally managed species were among the most important of these additions.

According to the MSA, EFH is defined as “those waters and substrate necessary to fish for spawning, breeding or growth to maturity.” This new mandate represented a significant shift in fishery management. Because the provision required councils to consider a MUS’s ecological role and habitat requirements in managing fisheries, it allowed Councils to move beyond the traditional single-species, multispecies, or species complex management to a broader ecosystem-based approach. In 1999, NMFS issued guidelines intended to assist Councils in implementing the EFH provision of the MSA, and set forth the following four broad tasks:

1. Identify and describe EFH for all species managed under an FMP.
2. Describe adverse impacts to EFH from fishing activities.
3. Describe adverse impacts to EFH from non-fishing activities.
4. Recommend conservation and enhancement measures to minimize and mitigate the adverse impacts to EFH resulting from fishing and non-fishing related activities.

The guidelines recommended that each Council prepare a preliminary inventory of available environmental and fisheries information on each managed species. Such an inventory is useful in describing and identifying EFH, as it also helps to identify missing information about the habitat utilization patterns of particular species. The guidelines note that a wide range of basic information is needed to identify EFH. This includes data on current and historic stock size, the geographic range of the managed species, the habitat requirements by life history stage, and the distribution and characteristics of those habitats. Because EFH has to be identified for each major life history stage, information about a species’ distribution, density, growth, mortality, and production within all of the habitats it occupies, or formerly occupied, is also necessary.

The guidelines also state that the quality of available data used to identify EFH should be rated using the following four-level system:

- | | |
|----------|--|
| Level 1: | All that is known is where a species occurs based on distribution data for all or part of the geographic range of the species. |
| Level 2: | Data on habitat-related densities or relative abundance of the species are available. |
| Level 3: | Data on growth, reproduction, or survival rates within habitats are available. |
| Level 4: | Production rates by habitat are available. |

With higher quality data, those habitats most utilized by a species could be identified, allowing a more precise designation of EFH. Habitats of lesser value to a species may also be essential, depending on the health of the fish population and the ecosystem. For example, if a species is overfished, and habitat loss or degradation is thought to contribute to its overfished condition, all habitats currently used by the species may be essential.

The EFH provisions are especially important because of the procedural requirements they impose on both Councils and federal agencies. First, for each FMP, Councils must identify adverse impacts to EFH resulting from both fishing and non-fishing activities, and describe measures to minimize these impacts. Under § 305(b)(2) of the MSA, federal agencies are required to consult with NMFS on any action authorized, funded, or undertaken by the agency that may adversely affect EFH identified by the Council. Councils are not required to provide conservation and enhancement recommendations except for anadromous species. In 2002, NMFS revised the guidelines by providing additional clarifications and guidance to ease implementation of the EFH provisions by Councils.

Based on the best available information on habitats in waters of the Hawaiian Archipelago and the existing fisheries, the Council has determined that the fisheries operating in Hawaii are not expected to have adverse impacts on EFH or Habitat Areas of Particular Concern (HAPC; a subset of EFH) for managed species. Continued and future operations of fisheries under the Hawaiian Archipelago FEP are not likely to lead to substantial physical, chemical, or biological alterations to the habitat, or result in loss of, or injury to, these species or their prey.

The description and identification of EFH and HAPC for fisheries managed under this FEP can be found in Section 3, Management Regime and Fishery Information. Life history and habitat information on managed species, on which the EFH descriptions are based, may be found in Appendix F. Information related to activities that may adversely affect EFH and EFH maps can be found in Appendices G and H.

1.2.2 National Marine Fisheries Service Guidance

Primary authority for implementing and enforcing management action developed under the MSA rests with the U.S. Secretary of Commerce (Secretary), who has delegated this responsibility to the NMFS. The NMFS develops guidance to aid the Councils, fishermen and others to develop, implement and comply with fishery regulations. In addition, the Council and NMFS have established operating agreements to help define specific roles and responsibilities for developing, approving, and implementing fishery management plans and other actions under the auspices of the MSA. Such guidance documents and agreements include, but are not limited to, *Operational Guidelines for Fishery Management Process* and *Regional Operating Agreements*.

1.2.3 National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires federal agencies to assess and consider the effects of major federal actions on the quality of the human environment by considering the environmental impacts of proposed actions and reasonable alternatives to those actions. The Act also requires that the public be provided the opportunity to help identify, review and comment on

such effects, particularly in cases where an environmental impact statement (EIS) is being prepared.

NEPA requires an environmental impact statement (EIS) for major federal actions that significantly affect the quality of the human environment. Agencies may conduct an environmental assessment to determine whether an EIS is necessary or whether a Finding of No Significant Impact (FONSI) or a Categorical Exclusion (CE) is warranted.

At the time of the final decision (and in the case of an EIS, at least 30 days after the Final EIS is noticed and at least 90 days after the Draft EIS is noticed), agencies must have prepared a record of decision (ROD), FONSI, or determined that a CE applies. It is important to be aware of the interaction of NEPA and MSA timing requirements. For example, the deadline for the Secretary to approve, disapprove, or partially approve a Council-submitted FMP or Amendment (i.e., 30 days after the close of the comment period on the FMP or Amendment and often referred to as “Day 95”) should not occur prior to signing the ROD or the FONSI. If it is an FEIS, the ROD may not be signed sooner than 30 days after noticing the availability of the FEIS.

1.2.4 Endangered Species Act

The Endangered Species Act (ESA) provides for the conservation of species that are endangered or threatened, and the conservation of the ecosystems on which they depend. Section 7(a)(2) of the ESA requires each federal agency to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat of such species. To “jeopardize” means to reduce appreciably the likelihood of survival and recovery of a species in the wild by reducing its numbers, reproduction, or distribution. As described in the NMFS policy for Integration of Endangered Species Act Section 7 with the Magnuson-Stevens Act Processes (PD 01-117), the Council plays an integral role in these consultations.

When a federal agency’s action “may affect” an ESA-listed species, that agency is required to consult formally with NMFS (for marine species, some anadromous species, and their designated critical habitats) or the U.S. Fish and Wildlife Service (USFWS; for terrestrial and freshwater species or their designated critical habitat). The product of formal consultation is the agency’s biological opinion (BiOp). Federal agencies are exempt from this formal consultation requirement if they have concluded that an action “may affect, but is not likely to adversely affect” ESA-listed species or their designated critical habitat, and NMFS or USFWS concur with that conclusion (see 50 CFR § 402.14(b)).

The ESA also prohibits the taking³ of listed species except under limited circumstances. Western Pacific regional fisheries are operated in accordance with terms of ESA consultations that consider the potential interactions of fisheries with listed species, the impacts of interactions on the survival and recovery of listed species, and the protection of any designated critical habitat.

³ The definition of “take” includes to harass, harm, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct.

As provided in 50 CFR § 402.16, NMFS is required to reinitiate formal consultation if:

- (1) the amount or extent of the incidental take is exceeded;
- (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in an opinion;
- (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in the opinion; or
- (4) a new species is listed or critical habitat designated that may be affected by the action.

Fisheries operating under this FEP have the potential to interact with a range of protected species. A current list of ESA listed species applicable to the Hawaii FEP is included in the Annual Report (SAFE). Additional information regarding protected species interactions in this FEP is included in Section 3.4.2.

1.2.5 Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) prohibits, with certain exceptions, the take of marine mammals in the U.S. EEZ and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the United States. The MMPA gives the Secretary authority and duties for the protection and conservation of all cetaceans (whales, dolphins, and porpoises) and pinnipeds (seals and sea lions, except walruses). The MMPA requires NMFS to prepare and periodically review marine mammal stock assessments (see 16 U.S.C. § 1361, *et seq.*).

Pursuant to the MMPA, NMFS has promulgated specific regulations that govern the incidental take of marine mammals during fishing operations (50 CFR 229). Under section 118 of the MMPA, NMFS must publish, at least annually, a List of Fisheries that classifies U.S. commercial fisheries into three categories, based on relative frequency of incidental mortality and serious injury to marine mammals in each fishery:

- Category I designates fisheries with frequent serious injuries and mortalities incidental to commercial fishing. Annual mortality and serious injury of a stock in a given fishery is by itself responsible for the annual removal of greater than or equal to 50 percent or more of any stock's potential biological removal (PBR) level.
- Category II designates fisheries with occasional serious injuries and mortalities incidental to commercial fishing. Annual mortality and serious injury of a stock in a given fishery is, collectively with other fisheries, responsible for the annual removal of greater than 10 percent of any stock's PBR level, and is by itself responsible for the annual removal of between 1 and less than 50 percent, exclusive, of any stock's PBR level.
- Category III designates fisheries with a remote likelihood or no known serious injuries or mortalities. A Category III fishery is, collectively with other fisheries, responsible for the annual removal of 10 percent or less of any stock's PBR level; or collectively with other fisheries, more than 10 percent of any stock's PBR level, but is by itself responsible for the annual removal of 1 percent or less of PBR level.

Owners of vessels or gear engaging in a Category I or II fishery are required under 50 CFR 229.4 to obtain authorization to lawfully incidentally take non-ESA listed marine mammals by registering with NMFS' marine mammal authorization program. Fishermen participating in Category I or II fisheries are also required to accommodate an observer onboard upon request by NMFS, and are required to comply with any applicable take reduction plans. Current List of Fisheries classifications for fisheries operating under the Hawaii FEP are included in the archipelagic annual fishery report (SAFE Report).

Section 101 (a)(5)(E) of the MMPA requires the Secretary of Commerce to allow the incidental, but not intentional, taking of individuals from marine mammal stocks that are designated as depleted because of listing as threatened or endangered under the ESA in the course of commercial fishing operations if it is determined that three criteria are met:

1. Incidental mortality and serious injury will have a negligible impact on the affected species or stock;
2. A recovery plan has been developed or is being developed; and
3. Where required under section 118 of the MMPA, a monitoring program has been established, vessels engaged in such fisheries are registered in accordance with section 118 of the MMPA, and a take reduction plan (TRP) has been developed or is being developed for such species or stock.

1.3 Hawaiian Archipelago

1.3.1 Geography

The Hawaiian Archipelago is an island chain in the central North Pacific Ocean. It runs for approximately 1,500 miles in a northwest direction, from Hawaii Island in the southeast to Kure Atoll in the northwest and is among the most isolated island areas in the world. The chain can be divided according to the large and mountainous Main Hawaiian Islands (MHI) (Hawaii, Maui, Lanai, Molokai, Kahoolawe, Oahu, Kauai, and Niihau) and the small, low-lying Northwest Hawaiian Islands (NWHI), which include Necker, French Frigate Shoals, Laysan, and Midway atoll. The largest of the MHI is Hawaii Island at just over 4,000 square miles – the largest in Polynesia, while Kahoolawe is the smallest, at 44.6 square miles.

The archipelago developed as the Pacific plate moved slowly over a hotspot in the Earth's mantle. Thus, the islands on the northwest end of the archipelago are older; it is estimated that Kure Atoll is approximately 28 million years old while Hawaii Island is approximately 400,000 years old. The highest point in Hawaii is Mauna Kea, at approximately 13,800 feet.

The Main Hawaiian Islands (MHI) are all in tropical latitudes. The archipelago becomes subtropical at about French Frigate Shoals (23° 46' N). The climate of the Hawaiian Islands is generally tropical, but there is great climactic variation, due primarily to elevation and leeward vs. windward areas. Easterly trade winds bring much of the rain, and so the windward sides of all the islands are typically wetter. The south and west (leeward) sides of the islands tend to be drier. Hawaii receives the majority of its precipitation from October to April, while drier conditions generally prevail from May to September. Tropical storms and hurricanes occur in the northern hemisphere hurricane and typhoon season, which runs from June through November.

There is a fairly little shallow water habitat in Hawaii, owing to the islands' steep rise from the abyssal deep. However, there are some larger areas, such as Penguin Bank between Oahu and Molokai, which are relatively shallow. Hawaii has extensive coral reef habitat, though the MHI, because they are much younger, have more fringing reef habitat than the NWHI, which has more shallow reef habitat overall.

1.3.2 People

1.3.2.1 Indigenous Culture

The first settlers to Hawaii brought with them their contemporary Polynesian traditions and customs, which had evolved over generations on the islands from which they migrated. These ancient practices continued to evolve in response to new surroundings, and a distinct subculture took shape. Hawaiian culture became truly unique, highly structured and sophisticated once the era of transpacific migrations ended. At its zenith, Hawaiian language, mythology, song, dance, artistry, and cuisine would have been familiar to other Pacific Islanders, but they would have been unable to immediately and effortlessly operate within Hawaiian practices and norms.

Modern Hawaii culture is based on a mix of ancient and newer practices, especially those from places like Japan, southeast Asia, other Pacific islands, and the U.S. Mainland. For example, it is customary in Hawaii when visiting a home to bring a small gift for the host (often food), and thus, gatherings are usually potluck. It is also typical to remove one's shoes before entering a home and Hawaiian families, regardless of ethnicity, usually celebrate a child's first birthday with a luau (traditionally known as an *'aha'aina*). However, the glue that binds these disparate practices together remains that of *aloha* – more of a bundle of concepts than a single word.

1.3.2.2 Current Demographics

According to the U.S. Census Bureau, Hawaii's estimated population in 2014 was a little more than 1.4 million people. This was an increase of 4.4% from the 2010 Census, due to natural increase (births minus deaths) and an increase in net migration. However, some of Hawaii's population is comprised of relatively short duration military residents as well as transient or tourist residents (as of 2011, the U.S. military reported it had 39,827 personnel on the islands).⁴ More than 80% of Hawaii's residents lived on the heavily-population island of Oahu.

Just over 50% of the population is male. The racial composition of Hawaii is: Asian 38.6%, White 24.7%, Mixed 23.6%, Native Hawaiian and Other Pacific Islander 10.0%, Hispanic or Latino 1.6%, Black or African American 1.2%, and American Indian and Alaskan Native 0.3%.

The average projected lifespan of people born in Hawaii in 2000 is 79.8 years; 77.1 years if male, 82.5 if female. This is the longest projected average lifespan of any U.S. state.

⁴ <http://www.globalsecurity.org/military/library/report/2011/hst1103.pdf>

The government of Hawaii is a constitutional government reminiscent of the Constitutional Monarchy of the Kingdom of Hawaii in 1840, and the statehood model of the U.S. Federal Government. The Hawaii Government's current structure was established in its constitution. It follows a general republic model, in that the government is divided into three branches: the executive, legislative, and judiciary.

The state government is fairly centralized – most executive powers are concentrated in the Governor's office. The primary unit of local government is the county. Hawaii is divided into four counties: Kauai County, the City and County of Honolulu, Maui County, and Hawaii County. The counties operate under a mayor-council model and have some governing autonomy. However, the state House of Representatives and the Senate determine the county council budgets. Two of the eight Main Hawaiian Islands, Lanai and Niihau, are nearly or completely privately owned.

1.3.2.3 Fishing Communities

The MSA defines a fishing community as a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew and United States fish processors that are based in such community.

The Hawaiian Islands are like other island communities in the Western Pacific, where the surrounding ocean and its resources have long provided residents with a source of food and opportunities for maritime commerce and recreation. Because participants in Hawaii's various marine fisheries are not concentrated in specific locales but rather reside in villages and small towns across the islands, and because fishing, seafood, and fishing-related businesses assume extensive social and economic importance throughout the region, the Council recommended in 2002 that the Secretary of Commerce designate each of the Main Hawaiian Islands as fishing communities under the MSA⁵.

The social and economic interplay between Hawaii residents and the surrounding ocean environment is central to an understanding of community life in the archipelago. The islands are relatively small and most towns and villages are located along the coastal zone. As such, the ocean is an ongoing visual presence in the lives of all residents. Because Hawaii is one of the most isolated island chains on the planet, goods must be transshipped on or over thousands of miles of ocean. This has led to a relatively high cost of living and limited availability of certain goods and services. The tourism economy is closely related to recreation and leisure opportunities along the coastal zone, and it too is conditioned by distance of travel to the islands. Fishing activities are important across the Hawaii, and living marine resources are used for commercial sale, household consumption, and as a source of recreation. Various aspects of local and indigenous history, culture, and society are closely related to the surrounding ocean and use of its resources.

⁵Federal Register Vol. 68, No. 150, August 5, 2003, 46112

2 MANAGEMENT POLICY, GOALS, AND OBJECTIVES

2.1 Council Management Policy

The Council's management policy is to apply responsible and proactive management practices, based on sound scientific data and analysis and inclusive of fishing community members, to conserve and manage fisheries and their associated ecosystems of the Hawaiian archipelago.

2.2 Hawaii FEP Purpose and Need

The Hawaiian archipelago contains various stocks and stock complexes that are found in federal waters and which provide important benefits to the people of the state and by extension, the nation. Since these resources are in need of management, the Council is required under the MSA to develop management plans to accomplish this. In addition, the habitats for these fish, as well as other elements of the marine ecosystem, such as sea turtles, cetaceans, and corals, are also locally and nationally important. Since all of these are interconnected, the Council opted in the mid-2000s⁶ to take an archipelagic ecosystem-based approach to fisheries management and spent the next several years revising its species/complex-based fishery management plans (FMPs) to place-based fishery ecosystem plans (FEPs). The Council's Precious Corals FMP (1983), Crustaceans FMP (1983), Bottomfish and Seamount Groundfish (1986), Pelagics FMP (1987), and Coral Reef Ecosystems FMP (2001) were transitioned to the place-based five FEPs in 2009 that include the American Samoa Archipelago FEP, Mariana Islands Archipelago FEP, Hawaiian Archipelago FEP, Pacific Remote Island Area FEP, and Pacific Pelagic FEP.

The Council's decision to transition to ecosystem-based fishery management (EBFM) followed Congressional direction in 1996 to the NMFS to establish an Ecosystem Principles Advisory Panel (Panel; EPAP). The Panel was tasked with assessing the extent to which ecosystem principles were being or could be used in fisheries management and recommending how to further ecosystem principle use to improve the status and management of marine resources. The Panel was composed of members of academia, fishery and conservation organizations, and fishery management agencies (see below). The NMFS finalized an EBFM Policy Directive in 2016.

2.3 Hawaiian Archipelago Fishery Ecosystem Plan Goals

The Hawaiian Archipelago FEP establishes a framework under which the Council can recommend management measures required by federal law and best available scientific information. The NMFS EPAP described above reached consensus that the Councils and NMFS should develop and implement Fishery Ecosystem Plans in order to manage U.S. fisheries and marine resources in a more comprehensive and integrated manner (NMFS 1999).

The National Oceanic and Atmospheric Administration (NOAA) defines an ecosystem approach as "management that is adaptive, specified geographically, takes account of ecosystem

⁶ At its 130th meeting held December 20, 2005, the Council took final action to recommend implementation of place-based FEPs for the Western Pacific Region.

knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives” In addition, because of the wide-ranging nature of ecosystems, successful implementation of ecosystem approaches will need to be incremental and collaborative (NOAA 2004).

On international, national, and local levels, institutions and agencies tasked with managing marine resources are moving toward an ecosystem approach to fisheries management. One reason for this shift is a growing awareness that many of Earth’s marine resources are stressed and the ecosystems that support them are degraded. In addition, increased concern regarding the potential impacts of fishing and non-fishing activities on the marine environment, and a greater understanding of the relationships between ecosystem changes and population dynamics, have all fostered support for a holistic approach to fisheries management that is science based and forward thinking (Pikitch et al. 2004). For the recent information on fishery ecosystem linkages, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

In order to achieve EBFM, this plan:

1. identifies the management objectives of the Hawaiian Archipelago FEP;
2. delineates the boundaries of the Hawaiian Archipelago FEP;
3. designates the management unit species included in the Hawaiian Archipelago FEP;
4. details the federal fishery regulations applicable under the Hawaiian Archipelago FEP; and
5. establishes appropriate Council structures and advisory bodies to provide scientific and management advice to the Council regarding the Hawaiian Archipelago FEP.

In addition, this plan provides the information and rationale for these measures; discusses the key components of the Hawaiian archipelago ecosystem, including an overview of the region’s non-pelagic fisheries; and explains how the measures contained here are consistent with the MSA and other applicable laws.

This FEP has four goals:

- Goal 1. Conserve and manage target and non-target stocks;
- Goal 2. Protect species and habitats of special concern;
- Goal 3. Understand and account for important ecosystem parameters and their linkages, and;
- Goal 4. Meet the needs of fishermen, their families, and communities in the Hawaiian archipelago.

2.4 Hawaiian FEP Objectives

To achieve the policy and goals of the Hawaiian Archipelago FEP, the Council has adopted the following objectives:

OBJECTIVE 1. Support Fishing Communities

- a. Identify the various social and economic groups within the region’s fishing communities and their interconnections.
- b. Ensure that regulations designed to meet conservation objectives are written to be as minimally-constraining as possible.
- c. Select alternatives that minimize adverse economic impacts to fishing communities when possible.

- d. Eliminate regulations that are no longer necessary (i.e., eliminate access barriers).
- e. Increase communication between fishery sectors.
- f. Support fishery development, training and processing opportunities.
- g. Support projects, programs and policies that increase sustainable fishing opportunities.

OBJECTIVE 2: Prevent Overfishing on Council-managed Stocks

- a. Develop status determination criteria for all stocks and stock complexes in the fisheries.
- b. Monitor fisheries to understand when overfishing may be close to occurring.

OBJECTIVE 3. Improve Fishery Monitoring and Data Collection

- a. Increase the number of fishery ecosystem elements being monitored.
- b. Improve the timeliness of data availability.
- c. Improve the quantity and quality of relevant fishery data.
- d. Encourage research to improve precision of data regarding protected species populations and distributions.
- e. Increase research coordination between the Council, the state, and federal agencies.

OBJECTIVE 4. Promote Compliance

- a. Understand factors that may result in non-compliance.
- b. Consider ways to develop or increase buy-in from affected parties.
- c. Ensure that regulations are written and implemented so as to be easy to follow and enforce.
- d. Develop codes of conduct specific to individual fisheries.

OBJECTIVE 5. Reduce Bycatch and Minimize Interactions and Impacts to Protected Species to the Extent Practicable

- a. Promote viable methods and technologies that may reduce interactions with seabirds, marine mammals, sea turtles, corals, and other protected species.
- b. Increase fishermen's knowledge about protected species issues and regulations and ways to minimize interactions.
- c. Continue to work with federal and state agencies to protect relevant threatened and endangered species.
- d. Encourage programs to obtain or improve information regarding the status of relevant threatened or endangered species.
- e. Encourage research that examines whether and to what extent bycatch is an issue in the fisheries covered by this management plan.

OBJECTIVE 6. Refine and Minimize Impacts to Essential Fish Habitat.

- a. Review and update EFH and HAPC designations on regular schedule (5-years) based on the best available scientific information of a higher EFH level than was used for the original designation.
- b. Identify and prioritize research to: assess adverse impacts to EFH and HAPC from fishing and non-fishing activities, including, but not limited to, offshore energy

developments, aquaculture, and mining; and activities that introduce non-point source pollution into the coastal environment.

OBJECTIVE 7. Increase Traditional and Local Knowledge in Decision-making

- a. Identify relevant indigenous and local practices and knowledge that may improve scientific inquiry regarding Council-managed fisheries.
- b. Utilize cultural practitioners, concepts, and bodies in the analysis of management alternatives.
- c. Utilize fishermen knowledge in the analysis of management alternatives.

OBJECTIVE 8: Rebuild Overfished Stocks

- a. Maintain the Hancock Seamounts Ecosystem Area.
- b. Maintain the fishing moratorium within the Hancock Seamounts Ecosystem Area, until surveys show that the armorhead stock has been rebuilt.
- c. Participate in international conservation and management efforts to rebuild armorhead stocks.
- d. Identify research priorities for armorhead and other relevant species within the Hancock Seamounts Ecosystem Area.

OBJECTIVE 9. Consider the Implications of Spatial Management Arrangements in Council Decision-making

- a. Identify and prioritize research that examines the positive and negative consequences of current no-take fishing areas to fisheries, fishery ecosystems, and fishermen, such as the Bottomfish Fishing Restricted Areas, military installations, NWHI restrictions, and Marine Life Conservation Districts.
- b. Consider whether the goals of any spatial-based fishing restrictions proposed in federal waters appear to be achievable.
- c. Establish effective spatially-based fishing zones
- d. Remove spatial-based fishing restrictions that are no longer necessary.

OBJECTIVE 10. Consider the Implications of Climate Change in Council Decision-making

- a. Identify and prioritize research that examines the effects of climate change on Council-managed fisheries and fishing communities.
- b. Ensure climate change considerations are incorporated into the analysis of management alternatives.
- c. Monitor climate-change related variables via the Council's Annual Reports.
- d. Engage in climate change outreach with US Pacific Islands communities.

3 MANAGEMENT REGIME AND FISHERY INFORMATION

3.1 Main Hawaiian Islands Fisheries

The Main Hawaiian Islands (MHI) consists of the populated islands in the Southeastern portion of the Hawaiian archipelago. These are: Hawaii Island, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai and Niihau. It also includes the various offshore banks (e.g. Penguin Bank, Cross Seamount, etc.) and islets (e.g. Kaula Rock) that surround the waters of these islands.

3.1.1 Bottomfish and Seamount Groundfish Fishery

3.1.1.1 Description (commercial, charter, recreational)

Bottomfish fishing was a part of the economy and culture of the indigenous people of Hawaii long before European explorers first visited the islands. Descriptions of traditional fishing practices indicate that Native Hawaiians harvested the same deep-sea bottomfish species as the modern fishery and used some of the same specialized gear and techniques employed today.

The deep-slope bottomfish fishery in Hawaii concentrates on species of eteline snappers (e.g., opakapaka), carangids (e.g., jacks), and a single species of grouper (hapuupuu) concentrated at depths of 30–150 fathoms. The management unit species are found in Table 1.

In the small-boat bottomfish fishery that is active around the MHI, the distinction between recreational and commercial fishermen is extremely tenuous, with many otherwise recreational fishermen selling small amounts of fish to cover trip expenses. With the exception of noncommercial fishing participants fishing in federal waters, the MHI bottomfish fishery is not subject to federal permit or reporting requirements but commercial fishermen (those who sell one fish during the year) are required to obtain commercial marine licenses (CML) and to submit State catch reports of fishing activity, including all catches and bycatch (discards), on a per trip basis (5 days after completion of the trip). It is difficult to separate catches originating from State (0-3 miles from shore) vs. Federal (3-200 miles from shore) waters as HDAR uses catch reporting forms which do not differentiate these areas. As a result, information on MHI catches is not spatially separated and, unless otherwise noted, represents catches from both State and Federal waters around the MHI.

The number of fishermen engaged in commercial bottomfish fishing in the MHI increased dramatically in the 1970s and peaked at nearly 600 vessels in the mid-1980s. Participation declined in the early 1990s, but rebounded somewhat in the late 1990s. By 2003 participation had reached its lowest level since 1977 with only 325 active vessels (WPRMC 2004). Since then, participation has increased slightly to 401 active vessels reporting sales of bottomfish. Data from various surveys indicate that the importance of the MHI bottomfish fishery varies significantly among fishermen of different islands. According to a 1987 survey of boat fishing club members, bottomfish represented roughly 13 percent of the catch of Hawaii fishermen, 25 percent of the catch of Oahu and Kauai fishermen, and 75 percent of the catch of Maui fishermen (Meyer Resources 1987). A survey of licensed commercial fishermen conducted about the same time indicated that the percentage of respondents who used bottomfish fishing methods was 25 percent on Hawaii, 28 percent on Kauai, 29 percent on Oahu, 33 percent on Lanai, 50 percent on

Molokai, and 51 percent on Maui (Harman and Katekaru 1988). Presumably, the differences among islands relate to the proximity of productive bottomfish fishing grounds.

Oahu-based landings account for roughly 30 percent of the MHI commercial landings of deepwater bottomfish species from 1998 to 2004. Maui landings from the same time period represent 36 percent of total MHI deepwater bottomfish landings, with Hawaii, Kauai and Molokai/Lanai representing 18, 10 and 5 percent, respectively (Kawamoto and Tao 2005). Specific bottomfish fishing locales favored by fishermen vary seasonally according to sea conditions and the availability and price of target species. Historically, Penguin Bank is one of the most important bottomfish fishing grounds in the MHI, as it is the most extensive shallow shelf area in the MHI and within easy reach of major population centers. Penguin Bank is particularly important for the MHI catch of uku, one of the few bottomfish species available in substantial quantities to Hawaii consumers during summer months.

Figure 2 provides a map of the MHI with bottomfish management areas and Essential Fish Habitat.

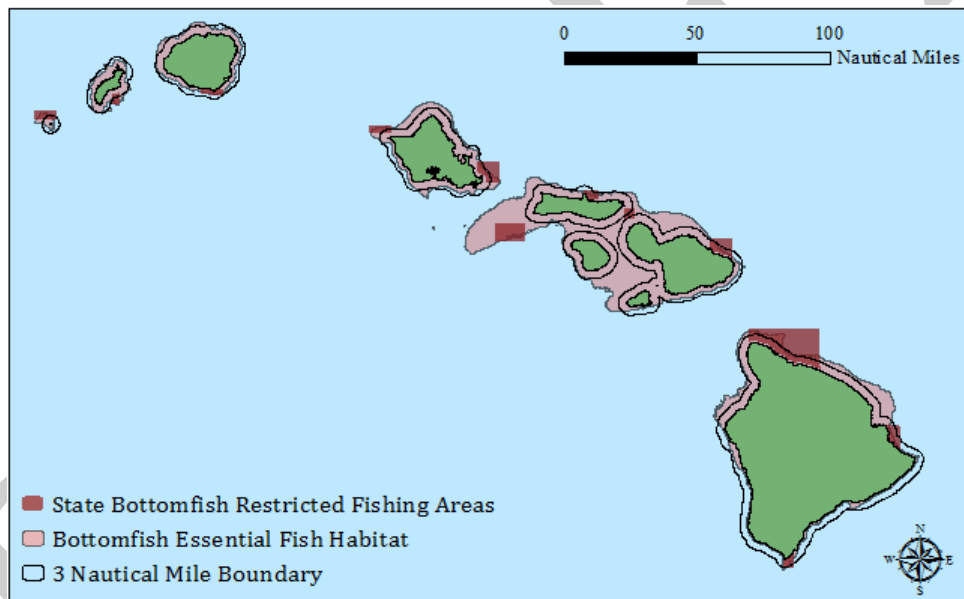


Figure 2: MHI Bottomfish Management Map.

3.1.1.2 Type and Quantity of Fishing Gear

Bottomfish gear and fishing strategies are highly selective for desired species and sizes. Bottomfishers use a hook-and-line method of fishing in which weighted and baited lines are lowered and raised with electric, hydraulic, or hand-powered reels. The main line is typically 400–450 pounds test, with hook leaders of 80–120 pound test monofilament. The hooks are circle hooks, and a typical rig uses six to eight hooks branching off the main line. The weight is typically 5–6 pounds. The hook leaders are typically 2–3 feet long and separated by about 6 feet along the main line. Squid is the bait typically used. It is sometimes supplemented with a chum bag containing chopped fish or squid suspended above the highest hook. The bottomfish fishery

may also utilize pelagic trolling gear (rod and reels) during transit to and from bottomfish fishing grounds.

3.1.1.3 Catch in Number or Weight

The 2004-2014 average catch of Hawaii BMUS (Figure 3) was 294,167 lbs. with a high of 425,844 (2004) and a low of 192,318 (2011). Over the same period, an average of 83% of the catch was sold. For current information regarding revenue of the fishery, price per pound, total direct employment, and fisheries-dependent services or industries, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

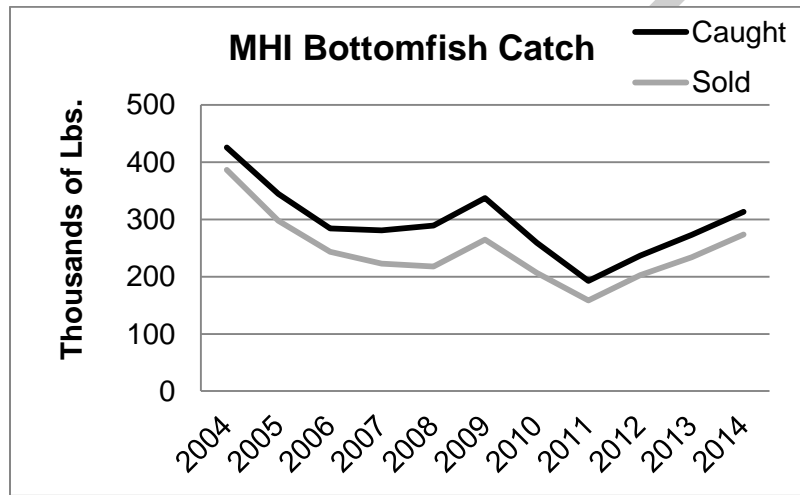


Figure 3. MHI Bottomfish Catch Trend 2004-2014 (source: Hawaii Division of Aquatic Resources Commercial Marine License Reports)

3.1.1.4 Economics

The 2004-2014 average for direct revenue from Hawaii BMUS was \$1,462,008 with a high of \$1,968,285 (2004) and a low of \$980,403 (2011). For current information regarding revenue of the fishery, price per pound, total direct employment, and fisheries-dependent services or industries, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.1.5 Present and Probably Future Condition of the Fishery

Currently the MHI bottomfish fishery is managed through annual catch limits which are based on stock assessments periodically produced by the PIFSC. The MHI deep-7 fishery has not exceeded its ACL in the past three years (2012-2015), indicating that the fishery is still in a good condition. Annual specifications are monitored through the State of Hawaii CML and dealer reporting programs. Should the fishery reach its ACL prior to the end of the fishing year, coordinated state and federal closures would be processed through the Chapter 91 and FEP regulatory processes, respectively. Accountability measures would then be considered by the Council prior to the opening of the fishery in the next fishing year. The NWHI bottomfish remains closed after the establishment of the NWHI Marine National Monument.

For current and past fishery performance statistics refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.1.6 Maximum Sustainable Yield

A 2011 stock assessment report by PIFSC (Brodziak et al. 2011) provides recent estimates of MSY for Hawaii's deep-7 bottomfish complex. A stock assessment update was produced in 2014 but was rejected by the CIE reviewers (Apostolaki 2014, Cadigan 2014, Haist 2014, and Neilson 2014). The best science available was determined to be the Brodziak et al 2011 with data updated to 2013 (Boggs memo dated March 3, 2015). Although the report's stock assessment considers the Hawaiian bottomfish stocks to be a single, archipelago-wide multispecies complex, annual MSY estimates for the MHI is 0.404 million pounds. The harvest rate at MSY was estimated at 3.8% and the biomass at MSY was at 14.51 million pounds. MSY is estimated every three years. For current MSY estimates, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.1.7 Optimum Yield

Optimum yield for Hawaii's bottomfish fishery is defined as the amount of fish that will be caught by fishermen fishing in accordance with applicable fishery regulations in this plan, in the EEZ and adjacent waters around the Hawaiian archipelago.

3.1.1.7.1 Extent to Which Fishing Vessels will Harvest OY

Domestic vessels have sufficient capacity to harvest the entire OY. Therefore, the domestic processing capacity and domestic processing levels will equal or exceed the harvest for the foreseeable future. Therefore the level of Total Allowable Foreign Fishing (TALFF) appears to be zero.

3.1.1.7.2 Extent to Which U.S. Fish Processors will Process OY

Bottomfish harvested in Hawaii are marketed as fresh product with little processing done to each piece. What processing is done is conducted by each vessel, usually at catch at sea.

3.1.1.8 Temporary Adjustments for the Safe Conduct of the Fishery

Due to the nature of the bottomfish fishery and associated regulations, the Council has not established temporary adjustments to existing FEP conservation and management measures that facilitate access to the fishery to vessels that otherwise would be preventing from harvesting because of weather or other ocean conditions affecting the safe conduct of the fishery. To the extent that temporary adjustments may be necessary in the future, the Council will consult with the US Coast Guard, fishery participants and the public in the development of temporary adjustments and will ensure that such measures will not adversely affect conservation efforts in other fisheries or discriminate among participants in the affected fishery.

3.1.1.9 MSA Conservation and Management Measures

Below are several important conservation and management measures for this fishery. Federal regulations governing this fishery can be found in the Code of Federal Regulations, [Title 50, Part 665, Subpart G](#) and Appendix C. Contact the Council or the National Marine Fisheries Service Pacific Islands Regional Office for and the fishery compliance guides (www.pir.noaa.gov).

Table 1 provides a description of which bottomfish species are being managed under the FEP.

Table 1: Hawaiian Archipelago Bottomfish Management Unit Species

Scientific Name	English Common Name	Local Name
Deep-7 BMUS		
<i>Aphareus rutilans</i>	silver jaw jobfish	lehi
<i>P. filamentosus</i>	pink snapper	‘ōpakapaka
<i>P. seiboldii</i>	pink snapper	kalekale
<i>P. zonatus</i>	snapper	gindai
<i>E. quernus</i>	sea bass	hāpu‘upu‘u
<i>Etelis carbunculus</i>	red snapper	ehu
<i>E. coruscans</i>	longtail snapper	onaga or ‘ula‘ula koa‘e
Non-deep 7 BMUS		
<i>Lutjanus kasmira</i>	blue stripe snapper	ta‘ape
<i>Pristipomoides auricilla</i>	yellowtail snapper	kalekale
<i>Aprion virescens</i>	gray jobfish	uku
<i>Caranx ignobilis</i>	giant trevally	white papiro/ulua au kea
<i>C. lugubris</i>	black jack	ulua la‘uli
<i>Pseudocaranx dentex</i>	thicklip trevally	pig ulua, butaguchi
<i>Seriola dumerili</i>	amberjack	kahala
Seamount Groundfish		
<i>Hyperoglyphe japonica</i>	raftfish	NA
<i>Beryx splendens</i>	alfonsin	NA
<i>Pseudopentaceros wheeleri</i>	armorhead	NA

3.1.1.9.1 Management Areas and Sub-areas

The fishery management area in the Hawaiian Archipelago FEP is divided into three sub-areas: (1) Main Hawaiian Islands (MHI); (2) Northwestern Hawaiian Islands (NWHI); and (3) Hancock Seamount. The NWHI sub-area is further divided into the Ho‘omalua Zone (that portion of the EEZ around the NWHI west of 165°W. longitude) and the Mau Zone (that portion of the EEZ around the NWHI between 161° W longitude and 165° W longitude). Figure 4 shows the management areas and sub areas.

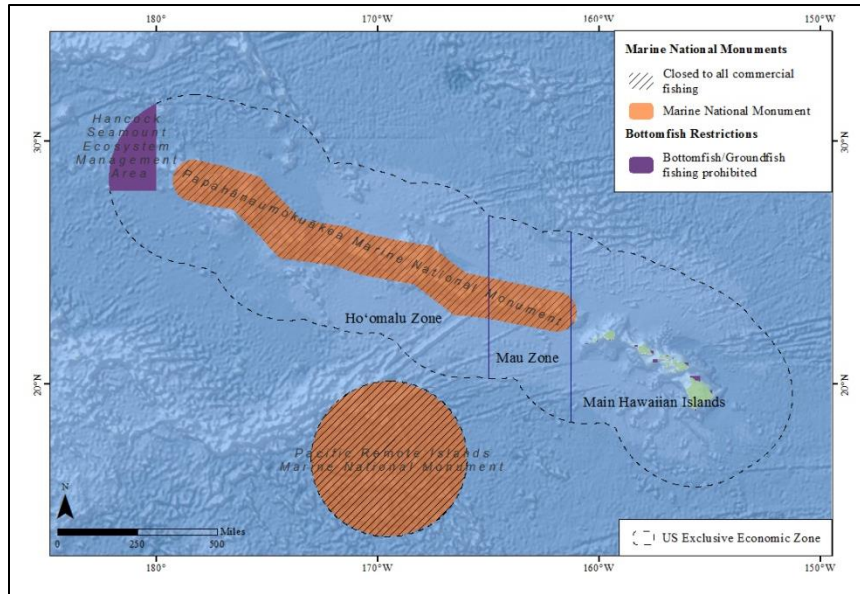


Figure 4: Bottomfish Fishery Management Areas in the Hawaii Archipelago

3.1.1.9.2 Permit and Reporting Requirements

A Federal bottomfish permit is required for vessel owners and fishermen to conduct vessel-based non-commercial fishing for any bottomfish management unit species in Federal waters around the MHI (except customers of charter fishing trips). The operators and owners of non-commercial fishing vessels must submit daily Federal logbooks that document bottomfish fishing effort and catch for each fishing trip. Fishery participants have the option of using NMFS approved electronic logbooks in lieu of paper logbooks.

To date, there are no Federal permitting or reporting requirements for commercial vessel operators targeting or harvesting bottomfish MUS in the MHI; however, commercial fishery participants (those who sell at least one fish during the year) must obtain commercial marine licenses from HDAR and submit monthly fishing reports (this reporting requirement is reinforced by a Federal regulation requiring compliance with State reporting requirements).

3.1.1.9.3 Gear Restrictions and Prohibitions

Gear restrictions include prohibitions against the use or possession of bottom trawls and bottom set gillnets; and the use or possession of poisons, explosives, or intoxicating substances to harvest bottomfish or seamount groundfish in the bottomfish fishery.

3.1.1.9.4 At-sea Observer Coverage

All fishing vessels with bottomfish permits must carry an on-board observer when directed to do so by NMFS. Vessel owners or operators will be given at least 72 hour prior notice by NMFS of an observer requirement. Required standards of treatment and accommodations for observers must be followed.

3.1.1.9.5 Framework Procedures for Regulatory Adjustments

By June 30 of each year, a Council-appointed bottomfish monitoring team will prepare an annual report on the fishery by area covering the following topics: fishery performance data; summary

of recent research and survey results; habitat conditions and recent alterations; enforcement activities and problems; administrative actions (e.g., data collection and reporting, permits); and state and territorial management actions. Indications of potential problems warranting further investigation may be signaled by the following indicator criteria: mean size of the catch of any species in any area is a pre-reproductive size; ratio of fishing mortality to natural mortality for any species; harvest capacity of the existing fleet and/or annual landings exceed best estimate of MSY in any area; significant decline (50 percent or more) in bottomfish catch per unit of effort from baseline levels; substantial decline in ex-vessel revenue relative to baseline levels; significant shift in the relative proportions of gear in any one area; significant change in the frozen/fresh components of the bottomfish catch; entry/exit of fishermen in any area; per-trip costs for bottomfishing exceed per-trip revenues for a significant percentage of trips; significant decline or increase in total bottomfish landings in any area; change in species composition of the bottomfish catch in any area; research results; habitat degradation or environmental problems; and reported interactions between bottomfish fishing operations and protected species.

The team may present management recommendations to the Council at any time. Recommendations may cover actions suggested for federal regulations, state/territorial action, enforcement or administrative elements, and research and data collection. Recommendations will include an assessment of urgency and the effects of not taking action. The Council will evaluate the team's reports and recommendations, and the indicators of concern. The Council will assess the need for one or more of the following types of management action: catch limits, size limits, closures, effort limitations, access limitations, or other measures. The Council may recommend management action by either the state/territorial governments or by federal regulation.

If the Council believes that management action should be considered, it will make specific recommendations to the NMFS Regional Administrator after requesting and considering the views of its Scientific and Statistical Committee and Bottomfish Advisory Panel and obtaining public comments at a public hearing. The Regional Administrator will consider the Council's recommendation and accompanying data, and, if he or she concurs with the Council's recommendation, will propose regulations to carry out the action. If the Regional Administrator rejects the Council's proposed action, a written explanation for the denial will be provided to the Council within two weeks of the decision. The Council may appeal denial by writing to the Assistant Administrator, who must respond in writing within 30 days.

3.1.1.9.6 Bycatch Measures

Bycatch in Hawaii's bottomfish fisheries comes from a mixed, commercial, subsistence and recreational fishery in the MHI. The MHI fishery participants tend to be selective and generally keep every fish caught. Federal regulatory measures in place to reduce bycatch include prohibitions on the use of non-selective fishing methods including bottom trawls, bottom gillnets, explosive and poisons. As there is a moratorium on the seamount groundfish fishery, there is no bycatch or bycatch mortality associated with the fishery.

Five types of non-regulatory measures aimed at reducing bycatch and bycatch mortality, and improving bycatch reporting are also being implemented. They include: 1) outreach to fishermen and engagement of fishermen in management, including research and monitoring activities, to increase awareness of bycatch issues and to aid in development of bycatch reduction methods; 2)

research into fishing gear and method modifications to reduce bycatch quantity and mortality; 3) research into the development of markets for discard species; 4) improvement of data collection and analysis systems to better quantify bycatch and 5) outreach and training of fishermen in methods to reduce barotrauma in fish that are to be released.

3.1.1.9.7 Annual Catch Limit

3.1.1.9.7.1 Specification Mechanism

The MSA requires the determination of acceptable biological catch and the specification of annual catch limits for the MHI bottomfish fishery. This specification follows the mechanism described in Appendix E. The ACL is specified annually by NMFS based on recommendations from the Council.

3.1.1.9.7.2 Limit

For the recent MHI Deep-7 and non-deep 7 Bottomfish Annual Catch Limits, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.1.9.7.3 Accountability Measures

Accountability measures are specified on an annual basis by NMFS based on recommendations by the Council. There is near-real-time monitoring of MHI Deep-7 bottomfish catches at a one-week lag. Other BMUS have a one-month lag. Catches are monitored through the State of Hawaii CML reporting system. The specification of accountability measures follows the process described in Appendix E.

3.1.1.9.8 Criteria for Determining Overfishing

Biological and fishery data are poor for all bottomfish species in Hawaii. Generally, data are only available on commercial landings by species and catch-per-unit-effort (CPUE) for the multi-species complexes as a whole. At this time, it is not possible to partition these effort measures among the various bottomfish MUS for any fishery except the MHI, where effort data are available for the four major species caught.

The overfishing criteria and control rules are applied to individual species within the multi-species stock whenever possible. When this is not possible, they are based on an indicator species for the multi-species stock. It is important to recognize that individual species are affected differently based on this type of control rule, and it is important that for any given species, fishing mortality does not exceed a level that would lead to its required protection under the Endangered Species Act (ESA). For the seamount groundfish stocks, armorhead serves as the indicator species. No indicator species are used for the four bottomfish multi-species stock complexes (American Samoa, CNMI, Guam and Hawaii). Instead, the control rules are applied to each of the four stock complexes as a whole.⁷

⁷ The National Standards Guidelines allow overfishing of “other” components in a mixed stock complex if (1) long-term benefits to the nation are obtained, (2) similar benefits cannot be obtained by modification of the fishery to prevent the overfishing, and (3) the results will not necessitate ESA protection of any stock component or ecologically significant unit.

The MSY control rule is used as the maximum fishing mortality threshold (MFMT). The MFMT and minimum stock size threshold (MSST) are specified based on recommendations in Restrepo et al. (1998) and both are dependent on the natural mortality rate (M). The range of M among species within a stock complex is taken into consideration when estimating and choosing the M to be used for the purpose of computing the reference point values.

In addition to the thresholds MFMT and MSST, a warning reference point, B_{FLAG} , is also specified at a point above the MSST to provide a trigger for consideration of management action prior to B reaching the threshold. MFMT, MSST, and B_{FLAG} are specified as indicated in Table 2: Overfishing Threshold Specifications: Bottomfish and Seamount Groundfish Stocks.

Table 2: Overfishing Threshold Specifications: Bottomfish and Seamount Groundfish Stocks.

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY} B}{c B_{MSY}} \quad \text{for } B \leq c B_{MSY}$ $F(B) = F_{MSY} \quad \text{for } B > c B_{MSY}$	$c B_{MSY}$	B_{MSY}
where $c = \max(1-M, 0.5)$		

Standardized values of fishing effort (E) and catch-per-unit-effort (CPUE) are used as proxies for F and B , respectively, so E_{MSY} , $CPUE_{MSY}$, and $CPUE_{FLAG}$ are used as proxies for F_{MSY} , B_{MSY} , and B_{FLAG} , respectively. In cases where reliable estimates of $CPUE_{MSY}$ and E_{MSY} are not available, they will be estimated from catch and effort times series, standardized for all identifiable biases. $CPUE_{MSY}$ would be calculated as half of a multi-year average reference CPUE, called $CPUE_{REF}$. The multi-year reference window would be objectively positioned in time to maximize the value of $CPUE_{REF} \cdot E_{MSY}$ will be calculated using the same approach or, following Restrepo et al. (1998), by setting E_{MSY} equal to E_{AVE} , where E_{AVE} represents the long-term average effort prior to declines in CPUE. When multiple estimates are available, the more precautionary one is used.

3.1.1.10 Regulations implementing International Recommendations and other Applicable Laws

There are presently no international recommendations or applicable laws that relate to bottomfish and seamount groundfish in Hawaii. However, the North Pacific Seamount Regional Fishery Management Organization's (RFMO) efforts may include actions aimed at seamount groundfish, and potentially bottomfish, in the future. Such actions may have the potential to impact Hawaii bottomfish and seamount groundfish fisheries.

3.1.1.11 Bycatch Amount and Type

For the most recent bycatch numbers in Hawaii bottomfish fishery, see the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

Two data sources have been used to assess bycatch rates in this fishery. Logbook data compiled by the Hawaii Division of Aquatic Resources (HDAR) indicate the reported disposition of the catch from all trips. Data were also compiled from 26 NWHI fishing trips that carried observers

between October 1990 and December 1993 (Nitta 1999). The observer coverage represented 12 percent of the 209 trips made during that period. Two species, kahala (*Seriola dumerili*) and butaguchi (*Pseudocaranx dentex*), made up the majority of the bycatch. Less than 5 percent of the catch of kahala was retained, and between about 50 and 75 percent of the catch of butaguchi was retained. Relatively large percentages of the catch of certain other species, including white ulua (*Caranx ignobilis*), were discarded, but these species' contribution to the catch was relatively small, so their contribution to absolute discards was relatively small. Non-BMUS that had relatively high-percentage discard rates (but relatively low absolute discard rates) in the observer data included opelu (*Decapturus* spp.), sharks, and a number of reef-associated species.

Target species are often discarded if they are damaged by predators. Sharks are responsible for most damage, but Hawaiian monk seals and bottlenose dolphins also cause damage. The carangids tend to be discarded because of their short shelf life and low market value. Butaguchi, for example, is palatable but of generally low value. Kahala, once a major component of commercial and recreational landings, is now seldom retained because it has been implicated in incidents of ciguatera poisoning (Kasaoka 1989).

Although the logbook and observer data represent two different time periods and cannot be strictly compared, substantial differences between the two indicate probable shortcomings in the logbook data. The average overall discard rate indicated by the logbook data is 13 percent, compared with 25 percent for the observer data. The differences suggest that the logbook data—at least for some species—probably do not reliably reflect actual bycatch rates. The biggest differences were for the two most commonly discarded species: butaguchi and kahala. The two datasets indicated similar percentage discard rates for kahala, but the logbook data indicated a substantially lower contribution of kahala to the total catch. The same was true for butaguchi, but the percentage bycatch rates indicated in the two datasets were also substantially different. Thus, as is common in many fisheries, underreporting of commonly discarded species appears to be a shortcoming of the logbook data. In 2003, NMFS redeployed observers to the NWHI bottomfish fishery, in part, to collect additional bycatch observations and to calibrate the shortfall in discard reporting.

3.1.1.11.1 Standardized Reporting Methodology

Disposition of fish caught and released in the MHI bottomfish fishery is recorded through trip reporting as required by the State CML and Federal Bottomfish permit.

3.1.1.12 Identification and Description of EFH and HAPC

Except for several of the major commercial species, very little is known about the life histories, habitat utilization patterns, food habits, or spawning behavior of most adult bottomfish and seamount groundfish species. Furthermore, very little is known about the distribution and habitat requirements of juvenile bottomfish.

Generally, the distribution of adult bottomfish in the Western Pacific Region is closely linked to suitable physical habitat. Unlike the U.S. mainland with its continental shelf ecosystems, Pacific islands are primarily volcanic peaks with steep drop-offs and limited shelf ecosystems. The BMUS under the Council's jurisdiction are found concentrated on the steep slopes of deepwater banks. The 100-fathom isobath is commonly used as an index of bottomfish habitat. Adult

bottomfish are usually found in habitats characterized by a hard substrate of high structural complexity. The total extent and geographic distribution of the preferred habitat of bottomfish is not well known. Bottomfish populations are not evenly distributed within their natural habitat; instead, they are found dispersed in a non-random, patchy fashion. Deepwater snappers tend to aggregate in association with prominent underwater features, such as headlands and promontories.

There is regional variation in species composition, as well as a relative abundance of the MUS of the deepwater bottomfish complex in the Western Pacific Region. In American Samoa, Guam, and the Northern Mariana Islands, the bottomfish fishery can be divided into two distinct fisheries: a shallow- and a deep-water bottomfish fishery, based on species and depth. The shallow-water (0–100 m) bottomfish complex comprises groupers, snappers, and jacks in the genera *Lethrinus*, *Lutjanus*, *Epinephelus*, *Aprion*, *Caranx*, *Variola*, and *Cephalopholis*. The deep-water (100–400 m) bottomfish complex comprises primarily snappers and groupers in the genera *Pristipomoides*, *Etelis*, *Aphareus*, *Epinephelus*, and *Cephalopholis*. In Hawaii, the bottomfish fishery targets several species of eteline snappers, carangids, and a single species of grouper. The target species are generally found at depths of 50–270 meters.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for bottomfish assemblages pursuant to Section 600.805(b) of 62 FR 66551. The species complex designations include deep-slope bottomfish (shallow water and deep water) and seamount groundfish complexes. The designation of these complexes is based on the ecological relationships among species and their preferred habitat. These species complexes are grouped by the known depth distributions of individual BMUS throughout the Western Pacific Region.

3.1.1.12.1 Description and Identification of EFH

At present, there are insufficient data on the relative productivity of different habitats to develop EFH designations based on Level 3 or Level 4 data. Given the uncertainty concerning the life histories and habitat requirements of many BMUS, the Council designated EFH for adult and juvenile bottomfish as the water column and all bottom habitat extending from the shoreline to a depth of 400 meters (200 fathoms) encompassing the steep drop-offs and high-relief habitats that are important for bottomfish throughout the Western Pacific Region.

The eggs and larvae of all BMUS are pelagic, floating at the surface until hatching and subject thereafter to advection by the prevailing ocean currents. There have been few taxonomic studies of these life stages of snappers (lutjanids) and groupers (epinepheline serranids). Presently, few larvae can be identified to species. As snapper and grouper larvae are rarely collected in plankton surveys, it is extremely difficult to study their distribution. Because of the existing scientific uncertainty about the distribution of the eggs and larvae of bottomfish, the Council designated the water column extending from the shoreline to the outer boundary of the EEZ to a depth of 400 meters as EFH for bottomfish eggs and larvae throughout the Western Pacific Region.

3.1.1.12.2 Identification of Habitat Areas of Particular Concern

On the basis of the known distribution and habitat requirements of adult bottomfish, the Council designated all escarpments/slopes between 40–280 meters throughout the Western Pacific Region, including the Hawaiian Archipelago, as bottomfish HAPC. In addition, the Council designated the three known areas of juvenile opakapaka habitat (two off Oahu and one off

Molokai) as HAPC. The basis for this designation is the ecological function that these areas provide, the rarity of the habitat, and the susceptibility of these areas to human-induced environmental degradation. Off Oahu, juvenile snappers occupy a flat, open bottom of primarily soft substrate in depths ranging from 40 to 73 meters. This habitat is quite different from that utilized by adult snappers. Surveys suggest that the preferred habitat of juvenile opakapaka in the waters around Hawaii represents only a small fraction of the total habitat at the appropriate depths. Areas of flat featureless bottom have typically been thought of as providing low-value fishery habitat. It is possible that juvenile snappers occur in other habitat types, but in such low densities that they have yet to be observed.

The discovery of concentrations of juvenile snappers in relatively shallow water and featureless bottom habitat indicates the need for more research to help identify, map, and study nursery habitat for juvenile snapper.

3.1.1.13 Seamount Groundfish Essential Fish Habitat

In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. The seamount groundfish complex consists of three species (pelagic armorheads, alfonsons, and ratfish). These species are found at 200–600 meters on the submarine slopes and summits of seamounts. A collapse of the seamount groundfish stocks greatly reduced yield in recent years. Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

3.1.1.13.1 Description and Identification of EFH

The life histories and distributional patterns of seamount groundfish are also poorly understood. Data are lacking on the effects of oceanographic variability on migration and recruitment of individual management unit species. On the basis of the best available data, the Council designated the EFH for the adult life stage of the seamount groundfish complex as all waters and bottom habitat bounded by latitude 29°–35° N and longitude 171° E–179° W between 80–600 meters. EFH for eggs, larvae, and juveniles is the epipelagic zone (0–200 m) of all waters bounded by latitude 29°–35° N and longitude 171° E–179° W. This EFH designation encompasses the Hancock Seamounts, part of the northern extent of the Hawaiian Ridge, located 1,500 nautical miles northwest of Honolulu.

3.1.1.13.2 Identification of Habitat Areas of Particular Concern

There is no HAPC for seamount designated within the Hawaiian Archipelago.

3.1.2 Coral Reef Fishery

3.1.2.1 Description (commercial, charter, recreational)

The majority of the total commercial catch of inshore fishes, invertebrates, and seaweed comes from nearshore reef areas around the MHI; however harvests of some coral reef species also occur in federal waters (e.g., around Penguin Bank). Total catches of coral reef ecosystems species are dominated by bigeye scad and mackerel scad, and variations in their harvests have largely driven the downward trend observed in the 2000–2005 time period. Other species reported by commercial fishermen include surgeonfishes, goatfishes, squirrelfishes and

parrotfishes. Because Hawaii state reporting grids do not account for state versus federal waters, catch and other fishery data that come from state reporting forms are aggregated across state and federal water surrounding the Hawaiian archipelago. Information on the number of fishery participants is unavailable.

In recent decades, there appears to have been a decline in nearshore fishery resources in the MHI. Excessive fishing is considered to be one of the major causes of this decline. Coastal construction, sedimentation, and other effects of urbanization have also caused extensive damage to coral reefs and benthic habitat near the populated islands affecting productivity of the coral reef fish stocks.

With the exception of the FEP's special permit requirement, there are no reporting requirements for recreational and other non-commercial catches from waters around the Hawaiian archipelago, but creel surveys at Kaneohe, Hanalei, and Hilo Bays suggest that these catches are at least equivalent to the reported commercial catch, and may be two or three times greater. The majority of these catches is believed to be from State waters; however, the ecosystem approach, as well as National Standard 3, compels the Council to consider inshore fisheries and stocks as they interrelate with those in Federal waters.

3.1.2.2 Type and Quantity of Fishing Gear

All gears used to catch coral reef species are essentially artisanal in nature. Catch rates are minimal, usually only a few pounds per man hour or other unit of effort. Large catches thus depend on fishing methods employing a lot of people, such as driven-in-net fishing or group spear fishing. Four fishing gears predominate in Hawaiian archipelago coral reefs and lagoons: hook and line (including handline), spearguns, fish traps, and gillnets.

3.1.2.3 Catch in Numbers or Weight

For the recent catch of coral reef fish, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.2.4 Fishing Areas

Coral reef taxa are currently harvested primarily in Hawaii State waters. No permits for collection of potentially-harvested coral reef taxa (PHCRT) in federal waters have yet been issued, thus there appears to be no fishery for PHCRT. The majority of the total commercial catch of inshore fishes, invertebrates, and seaweed comes from nearshore reef areas around the MHI; however, harvests of some currently-harvested coral reef taxa (CHCRT) also occur in federal waters (e.g., around Penguin Bank). The total catches of coral reef ecosystems species are dominated by mostly coastal pelagics followed by strict reef fished. Other species reported by commercial fishermen include surgeonfishes, goatfishes, squirrelfishes and parrotfishes.

3.1.2.5 Time of Fishing

Fishing for coral reef fish occurs day or night and any time of the year in Hawaii – depending upon the biology of the species.

3.1.2.6 Number of Hauls

The coral reef fishery is has a diverse set of small-scale gear, but the unit of effort measure are not defined as number of hauls. Nets and hook-and-line gear effort is mostly defined as the number of hours fished.

3.1.2.7 Economics

Cesar et al. (2002) examined the direct revenue associated with Hawaii's coral reef fisheries. Based on assumptions about non-bottomfish and non-pelagics species represented in the state of Hawaii data file, the authors estimate a value of US \$1.8 million/year for reef-associated commercial fisheries in Hawaii, out of a total value of \$385 million/year for Hawaii's coral reefs.

3.1.2.8 Present and Probable Future Condition of the Fishery

The status of the current coral reef fisheries is largely unknown. Stock assessment data across the MUS is limited. However, length-based indicators showed 47% of the 19 representative species analyzed may be overfished (based on <30% SPR), while the rest are slightly impacted by fishing or other factors (Nadon et. al, 2015).

3.1.2.9 Maximum Sustainable Yield

National Standard 1 guidelines define MSY as “the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological, environmental conditions and fishery technological characteristics (e.g., gear selectivity), and the distribution of catch among fleets.” Given the diversity of the fishery and the species it harvest, coral reef fisheries are considered data-limited due to the absence of stock assessments. The Western Pacific region utilizes a data-limited approach to estimate sustainable yield levels.

For ACL specification purposes, Maximum Sustainable Yields in the coral reef fisheries are determined by using the Biomass-Augmented Catch-MSY approach (Sabater and Kleiber 2014). This method estimates MSY using a plausible combination rate of population increase (denoted by r) and carrying capacity (denoted by k) assumed from the catch time series, resilience characteristics (from FishBase), and biomass from existing underwater census surveys done by the Pacific Island Fisheries Science Center. This method is applied to species complexes grouped by taxonomic families. For current MSY estimates, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.2.10 Optimum Yield

The MSA defines OY as “the amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems as prescribed on the basis of the MSY from the fishery, as reduced by any relevant economic, social, or ecological factor.” National Standard 1 guidelines define OY as “is a long-term average amount of desired yield from a stock, stock complex, or fishery after economic, social or ecological factors are considered.” OY for coral reef ecosystem associated species is defined as 75 percent of their MSY.

3.1.2.10.1 Extent to Which Fishing Vessels will Harvest OY

Domestic harvesting capacity is unknown, because participation in the fishery is unknown. However, the biomass to fishing effort ratio for most species is likely favorable in terms of sustainability.

3.1.2.10.2 Extent to Which U.S. Fish Processors will Process OY

Reef fish are sold whole via fresh fish retailers or directly by the fishermen along the roadside. Little to no processing is involved in the fishery.

3.1.2.11 Temporary Adjustments for the Safe Conduct of the Fishery

Due to the nature of the coral reef ecosystem fishery and associated regulations, the Council has not established temporary adjustments to existing FEP conservation and management measures that facilitate access to the fishery to vessels that otherwise would be preventing from harvesting because of weather or other ocean conditions affecting the safe conduct of the fishery. To the extent that temporary adjustments may be necessary in the future, the Council will consult with the US Coast Guard, fishery participants and the public in the development of temporary adjustments and will ensure that such measures will not adversely affect conservation efforts in other fisheries or discriminate among participants in the affected fishery.

3.1.2.12 MSA Conservation and Management Measures

Below are several important conservation and management measures for this fishery. Federal regulations governing this fishery can be found in the Code of Federal Regulations, Title 50, Part 665, Subpart G and Appendix C. Contact the Council or the National Marine Fisheries Service Pacific Islands Regional Office for and the fishery compliance guides (www.pir.noaa.gov).

3.1.2.12.1 Management Unit Species

Table 3 and Table 4 provide which coral reef ecosystem species are managed under the FEP and designated as Management Unit Species (MUS).

Table 3: Hawaiian Archipelago Coral Reef Ecosystem Management Units Species, Currently Harvested Coral Reef Taxa

Family Name	Scientific Name	English Common Name	Local Name
Acanthuridae (Surgeonfishes)	<i>Acanthurus olivaceus</i>	orange-spot surgeonfish	na'ena'e
	<i>Acanthurus xanthopterus</i>	yellowfin surgeonfish	pualu
	<i>Acanthurus triostegus</i>	convict tang	manini
	<i>Acanthurus dussumieri</i>	eye-striped surgeonfish	palani
	<i>Acanthurus nigroris</i>	blue-lined surgeon	maiko
	<i>Acanthurus leucopareius</i>	whitebar surgeonfish	maiko or maikoiko

Family Name	Scientific Name	English Common Name	Local Name
Acanthuridae (Surgeonfishes)	<i>Acanthurus nigricans</i>	whitecheek surgeonfish	NA
	<i>Acanthurus guttatus</i>	white-spotted surgeonfish	‘api
	<i>Acanthurus blochii</i>	ringtail surgeonfish	Pualu
	<i>Acanthurus nigrofuscus</i>	brown surgeonfish	mai‘i‘i
	<i>Ctenochaetus strigosus</i>	yellow-eyed surgeonfish	kole
	<i>Ctenochaetus striatus</i>	striped bristletooth	NA
	<i>Naso unicornus</i>	bluespine unicornfish	kala
	<i>Naso lituratus</i>	orangespine unicornfish	kalalei or umaumalei
	<i>Naso hexacanthus</i>	black tongue unicornfish	kala holo
	<i>Naso annulatus</i>	whitemargin unicornfish	kala
	<i>Naso brevirostris</i>	spotted unicornfish	kala lolo
	<i>Naso caesius</i>	gray unicornfish	NA
	<i>Zebrasoma flavescens</i>	yellow tang	lau‘ipala
Balistidae (Triggerfish)	<i>Melichthys vidua</i>	pinktail triggerfish	humuhumu hi‘ukole
	<i>Melichthys niger</i>	black triggerfish	humuhumu ‘ele‘ele
	<i>Rhinecanthus aculeatus</i>	picassofish	humuhumu nukunuku apua‘a
	<i>Sufflamen fraenatum</i>	bridled triggerfish	NA
Carangidae (Jacks)	<i>Selar crumenophthalmus</i>	bigeye scad	akule or hahalu
	<i>Decapterus</i>	mackerel scad	‘opelu or ‘opelu mama

Family Name	Scientific Name	English Common Name	Local Name
	<i>macarellus</i>		
Carcharhinidae (Sharks)	<i>Carcharhinus amblyrhynchos</i>	grey reef shark	manō
	<i>Carcharhinus galapagensis</i>	galapagos shark	manō
	<i>Carcharhinus melanopterus</i>	blacktip reef shark	manō
	<i>Triaenodon obesus</i>	whitetip reef shark	manō lalakea
Holocentridae (Soldierfish/ Squirrelfish)	<i>Myripristis berndti</i>	bigscale soldierfish	menpachi or 'u'u
	<i>Myripristis amaena</i>	brick soldierfish	menpachi or 'u'u
	<i>Myripristis chryseres</i>	yellowfin soldierfish	menpachi or 'u'u
	<i>Myripristis kuntee</i>	pearly soldierfish	menpachi or 'u'u
	<i>Sargocentron microstoma</i>	file-lined squirrelfish	'ala'ihī
	<i>Sargocentron diadema</i>	crown squirrelfish	'ala'ihī
	<i>Sargocentron punctatissimum</i>	peppered squirrelfish	'ala'ihī
	<i>Sargocentron tiere</i>	blue-lined squirrelfish	'ala'ihī
	<i>Sargocentron xantherythrum</i>	Hawaiian squirrelfish	'ala'ihī
	<i>Sargocentron spiniferum</i>	saber or long jaw squirrelfish	'ala'ihī
<i>Neoniphon</i> spp.	spotfin squirrelfish	'ala'ihī	
Kuhliidae (Flagtails)	<i>Kuhlia sandvicensis</i>	Hawaiian flag-tail	'aholehole
Kyphosidae (Rudderfish)	<i>Kyphosus biggibus</i>	rudderfish	nenuē
	<i>Kyphosus cinerascens</i>	rudderfish	nenuē
	<i>Kyphosus vaigiensis</i>	rudderfish	nenuē
Labridae (Wrasses)	<i>Bodianus bilunulatus</i>	saddleback hogfish	'a'awa
	<i>Oxycheilinus</i>	ring-tailed wrasse	po'ou

Family Name	Scientific Name	English Common Name	Local Name
	<i>unifasciatus</i>		
	<i>Xyrichtys pavo</i>	razor wrasse	laenihi or nabeta
	<i>Cheilio inermis</i>	cigar wrasse	kupoupou
	<i>Thalassoma purpureum</i>	surge wrasse	ho'u
	<i>Thalassoma quinquevittatum</i>	red ribbon wrasse	NA
	<i>Thalassoma lutescens</i>	sunset wrasse	NA
	<i>Novaculichthys taeniourus</i>	rockmover wrasse	NA
Mullidae (Goatfishes)	<i>Mulloidichthys</i> spp.	yellow goatfish	weke
	<i>Mulloidichthys pfleugeri</i>	orange goatfish	weke nono
	<i>Mulloidichthys vanicolensis</i>	yellowfin goatfish	weke'ula
	<i>Mulloidichthys flavolineatus</i>	yellowstripe goatfish	weke'a or weke a'a
	<i>Parupeneus</i> spp.	banded goatfish	kumu or moano
	<i>Parupeneus bifasciatus</i>	doublebar goatfish	munu
	<i>Parupeneus cyclostomas</i>	yellowsaddle goatfish	moano kea or moano kale
	<i>Parupeneus pleurostigma</i>	side-spot goatfish	malu
	<i>Parupeneus multifasciatus</i>	multi-barred goatfish	moano
	<i>Upeneus arge</i>	bandtail goatfish	weke pueo
Mugilidae (Mulletts)	<i>Mugil cephalus</i>	stripped mullet	'ama'ama
	<i>Neomyxus leuciscus</i>	false mullet	uouoa
Muraenidae (Moray eels)	<i>Gymnothorax flavimarginatus</i>	yellowmargin moray eel	puhi paka
	<i>Gymnothorax</i>	giant moray eel	puhi

Family Name	Scientific Name	English Common Name	Local Name
	<i>javanicus</i>		
	<i>Gymnothorax undulatus</i>	undulated moray eel	puhi laumilo
	<i>Enchelycore pardalis</i>	dragon eel	puhi
Octopodidae (Octopus)	<i>Octopus cyanea</i>	octopus	he'e maui or tako
	<i>Octopus ornatus</i>	octopus	he'e or tako
Polynemidae	<i>Polydactylus sexfilis</i>	threadfin	moi
Priacanthidae (Big-eyes)	<i>Heteropriacanthus cruentatus</i>	glasseye	'aweoweo
	<i>Priacanthus hamrur</i>	bigeye	'aweoweo
Scaridae (Parrotfish)	<i>Scarus</i> spp.	parrotfish	uhu or palukaluka
	<i>Calotomus carolinus</i>	stareye parrotfish	panuhunuhu
Sphyracidae (Barracuda)	<i>Sphyracna helleri</i>	Heller's barracuda	kawele'a or kaku
	<i>Sphyracna barracuda</i>	great barracuda	kaku
Turbinidae	<i>Turbo</i> spp.	green snails turban shells	NA
Zanclidae	<i>Zanclus cornutus</i>	moorish idol	kihikihi
Chaetodontidae	<i>Chaetodon auriga</i>	butterflyfish	kikakapu
	<i>Chaetodon lunula</i>	raccoon butterflyfish	kikakapu
	<i>Chaetodon ephippium</i>	saddleback butterflyfish	kikakapu
Sabellidae		featherduster worm	NA

Table 4: Hawaiian Archipelago Coral Reef Ecosystem Management Unit Species, Potentially Harvested Coral Reef Taxa

Scientific Name	English Common Name	Local Name
Labridae	wrasses (Those species not listed as CHCRT)	hinalea
Carcharhinidae Sphyrnidae	sharks (Those species not listed as CHCRT)	manō

Scientific Name	English Common Name	Local Name
Dasyatididae Myliobatidae	rays and skates	hihimanu
Serrandiae	groupers, seabass (Those species not listed as CHCRT or in BMUS)	roi, hapu'upu'u
Malacanthidae	tilefishes	NA
Carangidae	jacks and scads (Those species not listed as CHCRT or in BMUS)	dobe, kagami, pa'opa'o, papa, omaka, ulua,
Holocentridae	solderfishes and squirrelfishes (Those species not listed as CHCRT)	'u'u
Mullidae	goatfishes (Those species not listed as CHCRT)	weke, moano, kumu
Acanthuridae	surgeonfishes (Those species not listed as CHCRT)	na'ena'e, maikoiko
Echeneidae	remoras	NA
Muraenidae Congridae Ophichthidae	eels (Those species not listed as CHCRT)	puhi
Apogonidae	cardinalfishes	'upapalu
Clupeidae	herrings	NA
Engraulidae	anchovies	nehu
Caracanthidae	coral crouchers	NA
Gobiidae	gobies	'o'opu
Lutjanidae	snappers (Those species not listed as CHCRT or in BMUS)	to'au
<i>Aulostomus chinensis</i>	trumpetfish	nunu
<i>Fistularia commersoni</i>	cornetfish	nunu peke
Zanclidae	moorish Idols	kihikihi

Scientific Name	English Common Name	Local Name
Chaetodontidae	butterflyfishes	kikakapu
Pomacanthidae	angelfishes	NA
Pomacentridae	damsel fishes	mamo
Scorpaenidae	scorpionfishes, lionfishes	nohu, okoze
Blenniidae	blennies	pa o'o
Sphyraenidae	barracudas (Those species not listed as CHCRT)	kaku
Pinguipedidae	sandperches	NA
Bothidae Soleidae Pleurnectidae	flounders and soles	paki'i
Ostraciidae	trunkfishes	makukana
Balistidae	trigger fishes (Those species not listed as CHCRT)	humuhumu
Kyphosidae	rudderfishes (Those species not listed as CHCRT)	nenu
Cirrhitidae	hawkfishes (Those species not listed as CHCRT)	po'opa'a
Tetraodontidae	puffer fishes and porcupine fishes	'o'opu hue or fugu
Antennariidae	frogfishes	NA
Syngnathidae	pipefishes and seahorses	NA
Echinoderms	sea cucumbers and sea urchins	namako, lole, wana
Mollusca	(Those species not listed as CHCRT)	NA
Azooxanthellates	ahermatypic corals	ko'a
Fungiidae	mushroom corals	ko'a
	small and large coral polyps	ko'a
	soft corals and gorgonians	NA

Scientific Name	English Common Name	Local Name
Actinaria	anemones	NA
Zoanthinaria	soft zoanthid corals	NA
Solanderidae	hydroid corals	NA
Stylasteridae	lace corals	ko‘a
Crustaceans	lobsters, shrimps, mantis shrimps, true crabs and hermit crabs (Those species not listed as CMUS)	ula, a‘ama, mo‘ala, ‘alakuma
Hydrozoans and Bryzoans		NA
<i>Pinctada margaritifera</i>	black lipped pearl oyster	NA
Other Bivalves	other clams	NA
Tunicates	sea squirts	NA
Porifera	sponges	NA
Cephalopods	octopi	tako, he‘e
Gastropoda	sea snails	NA
Opisthobranchs	sea slugs	NA
Algae	seaweed	limu
Live rock		NA
Annelids	segmented worms (Those species not listed as CHCRT)	NA
All other coral reef ecosystem management unit species that are marine plants, invertebrates, and fishes that are not listed in the preceding tables or are not bottomfish management unit species, crustacean management unit species, Pacific pelagic management unit species, precious coral or seamount groundfish.		

3.1.2.12.2 Permit and Reporting Requirements

Special permits are required for any directed fisheries on potentially harvested coral reef taxa (PHCRT) or to fish for any CRE MUS with any gear not normally permitted. Those issued a Federal permit to fish for non-CRE MUS but whom incidentally catch CRE MUS are exempt from the CRE permit requirement. Those fishing for currently harvested coral reef taxa (CHCRT) outside of an MPA and do not retain any incidentally-caught PHCRT, or any person collecting marine organisms for scientific research are also exempt from the CRE permit requirement. Permits are only valid for fishing in the fishery management subarea specified on the permit.

The harvest of live rock and living corals is prohibited throughout the federally managed U.S. EEZ waters of the region; however, under special permits with conditions specified by NMFS following consultation with the Council, indigenous people could be allowed to harvest live rock or coral for traditional uses, and aquaculture operations could be permitted to harvest seed stock. A Federal reporting system for all fishing under special permits is in place. Fishery participants have the option of using NMFS approved electronic logbooks in lieu of paper logbooks. Resource monitoring systems administered by state, territorial, and commonwealth agencies continue to collect fishery data on the existing coral reef fisheries that do not require special permits.

Any special permit holder must contact the appropriate NMFS enforcement agent in Hawaii at least 24 hours before landing any CRE MUS harvested under a special permit, and report the port and the approximate date and time at which the catch will be landed.

3.1.2.12.3 Gear Restrictions and Prohibitions

Allowable gear types include: (1) Hand harvest; (2) spear; (3) slurp gun; (4) hand/dip net; (5) hoop net for Kona crab; (6) throw net; (7) barrier net; (8) surround/purse net that is attended at all times; (9) hook-and-line (powered and unpowered handlines, rod and reel, and trolling); (10) crab and fish traps with vessel ID number affixed; and (11) remote operating vehicles/submersibles. New fishing gears that are not included in the allowable gear list may be allowed under the special permit provision. CRE MUS may not be taken by means of poisons, explosives, or intoxicating substances. Possession and use of these materials is prohibited.

All fish and crab trap gear used by permit holders must be identified with the vessel number. Unmarked traps and unattended surround nets or bait seine nets found deployed in the CRE regulatory area will be considered unclaimed property and may be disposed of by NMFS or other authorized officers.

3.1.2.12.4 Framework Procedures for Regulatory Adjustments

A framework process, providing for an administratively simplified procedure to facilitate adjustments to management measures previously analyzed in the CRE FMP, is an important component of the FEP. These framework measures include designating “no-anchoring” zones and establishing mooring buoys, requiring vessel monitoring systems on board fishing vessels, designating areas for the sole use of indigenous peoples, and moving species from the PHCRT to the CHCRT list when sufficient data has been collected. A general fishing permit program could also be established for all U.S. EEZ coral reef ecosystem fisheries under the framework process.

The framework process can be used for either established or new measures. Established measures are management measures that, at some time, have been included in regulations implementing the FMP or FEP, and for which the impacts have been evaluated in Council/NMFS documents in the context of current conditions. Under these conditions, the Council may recommend to the NMFS Regional Administrator that established measures be modified, removed, or re-instituted. Such recommendation shall include supporting rationale and analysis, and shall be made after advance public notice, public discussion, and consideration of public comment. NMFS may implement the Council’s recommendation by rulemaking if approved by the Regional Administrator.

New measures are management measures that have not been included in regulations implementing the FMP or FEP, or for which the impacts have not been evaluated in Council/NMFS documents in the context of current conditions. The Council will publicize, including by a Federal Register document, and solicit public comment on, any proposed new management measure. After a Council meeting at which the measure is discussed, the Council will consider recommendations and prepare a Federal Register document summarizing the Council's deliberations, rationale, and analysis for the preferred action, and the time and place for any subsequent Council meeting(s) to consider the new measure. At subsequent public meeting(s), the Council will consider public comments and other information received to make a recommendation to the Regional Administrator about any new measure. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

3.1.2.12.5 Bycatch Measures

Almost all coral reef fishes caught in Hawaii are considered food fishes and are kept, regardless of size or species. There is no specific information available on bycatch from coral reef fisheries, particularly inshore fisheries. However implementation of Federal prohibitions on the use of non-selective fishing methods including bottom trawls, bottom gillnets, explosive and poisons are intended to reduce or avoid bycatch in this fishery in EEZ waters. These restrictions further reduce the potential for bycatch in this fishery. In addition any fishing vessel (commercial or non-commercial) operating in the territorial seas or EEZ of the U.S. in a fishery identified through NMFS' annual determination process must carry an observer when directed to do so.

3.1.2.12.6 Annual Catch Limit

3.1.2.12.6.1 Specification Mechanism

For the coral reef fishery, specification of the acceptable biological catch and annual catch limits are required by the MSA and follows the mechanism described in Appendix E. The specification will be done on an annual basis by NMFS based on recommendations from the Council.

3.1.2.12.6.2 Limit

For the recent Hawaii Coral Reef Annual Catch Limits, please refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.2.12.6.3 Accountability Measures

Accountability measures will be specified on an annual basis by NMFS based on recommendations by the Council. The specification of accountability measures will follow the process described in Appendix E.

3.1.2.12.7 Criteria for Determining Overfishing

MSY Control Rule and Stock Status Determination

Available biological and fishery data are poor for all coral reef ecosystem management unit species in the Mariana Islands. There is scant information on the life histories, ecosystem dynamics, fishery impact, community structure changes, yield potential, and management reference points for many coral reef ecosystem species. Additionally, total fishing effort cannot be adequately partitioned between the various management unit species (MUS) for any fishery or

area. Biomass, maximum sustainable yield, and fishing mortality estimates are not available for any single MUS. Once these data are available, fishery managers can establish limits and reference points based on the multi-species coral reef ecosystem as a whole.

When possible, the MSY control rule is applied to the individual species in a multi-species stock. When this is not possible, MSY may be specified for one or more species; these values can then be used as indicators for the multi-species stock's MSY.

Individual species that are part of a multi-species complex will respond differently to an OY-determined level of fishing effort (F_{OY}). Thus, for a species complex that is fished at F_{OY} , managers still must track individual species' mortality rates in order to prevent species-specific population declines that would lead to depletion.

When possible, available data for a particular species are used to evaluate the status of individual MUS stocks in order to prevent recruitment overfishing. When better data and the appropriate multi-species stock assessment methodologies become available, all stocks will be evaluated independently, without proxy.

Establishing Reference Point Values

Standardized values of catch per unit effort (CPUE) and effort (E) are used to establish limit and reference point values, which act as proxies for relative biomass and fishing mortality, respectively. Limits and reference points are calculated in terms of $CPUE_{MSY}$ and E_{MSY} included in Table 5.

Table 5: CPUE-based Overfishing Limits and Reference Points for Coral Reef Species

Value	Proxy	Explanation
MaxFMT (F_{MSY})	E_{MSY}	$0.91 CPUE_{MSY}$
F_{OY}	$0.75 E_{MSY}$	suggested default scaling for target
B_{MSY}	$CPUE_{MSY}$	operational counterpart
B_{OY}	$1.3 CPUE_{MSY}$	simulation results from Mace (1994)
MinSST	$0.7 CPUE_{MSY}$	suggested default $(1-M)B_{MSY}$ with $M=0.3^*$
B_{FLAG}	$0.91 CPUE_{MSY}$	suggested default $(1-M)B_{OY}$ with $M=0.3^*$

When reliable estimates of E_{MSY} and $CPUE_{MSY}$ are not available, they are generated from the available time series of catch and effort values, standardized for all identifiable biases using the best available analytical tools. $CPUE_{MSY}$ is calculated as one-half a multi-year moving average reference CPUE ($CPUE_{REF}$).

Other Measures

There are other non-regulatory measures consistent with plan objectives that are being undertaken by the Council outside of the regulatory regime. These include a process and criteria for EFH consultations; formal plan team coordination to identify and to address coral reef

ecosystem impacts from existing fisheries; a system to facilitate consistent state and territorial level management; and research and education efforts.

3.1.2.13 Regulations Implementing International Recommendations and other Applicable Laws

There are currently no international recommendations or applicable laws in the coral reef fishery for the Hawaiian archipelago. However, to ensure that Pacific Islands coral reef fisheries are adequately represented, the Council participates in meetings of the U.S. Coral Reef Task Force, established by Executive Order 13089 to protect coral reefs and coral reef ecosystems.

3.1.2.14 Bycatch

Almost all coral reef fishes caught in Hawaii are considered food fishes and are kept, regardless of size or species. There is no specific information available on bycatch from coral reef fisheries, particularly inshore fisheries. However implementation of Federal prohibitions on the use of non-selective fishing methods including bottom trawls, bottom gillnets, explosive and poisons are intended to reduce or avoid bycatch in this fishery in EEZ waters. These restrictions further reduce the potential for bycatch in this fishery. In addition any fishing vessel (commercial or non-commercial) operating in the territorial seas or EEZ of the U.S. in a fishery identified through NMFS' annual determination process must carry an observer when directed to do so.

3.1.2.14.1 Standardized Reporting Methodology

Disposition of fish and invertebrates caught and released in the coral reef ecosystem fishery is recorded through trip reporting as required by the State CML and Federal Coral Reef Fishery permit.

3.1.2.15 Identification and Description of EFH and HAPC

In designating EFH for Coral Reef Ecosystem MUS, MUS are linked to specific habitat "composites" (e.g., sand, live coral, seagrass beds, mangrove, open ocean) for each life history stage, consistent with the depth of the ecosystem to 50 fathoms and to the limit of the EEZ.

Except for several of the major coral reef associated species, very little is known about the life histories, habitat utilization patterns, food habits, or spawning behavior of most coral reef associated species. For this reason, the Council, through the CRE-FMP, designated EFH using a two-tiered approach based on the division of MUS into the Currently Harvested Coral Reef Taxa (CHCRT) and Potentially Harvested Coral Reef Taxa (PHCRT) categories. This is also consistent with the use of habitat composites.

3.1.2.15.1 Description and Identification of EFH for CHCRT

In the first tier, EFH has been identified for species that (a) are currently being harvested in state and federal waters and for which some fishery information is available and (b) are likely to be targeted in the near future based on historical catch data.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for species assemblages pursuant to 50 CFR 600.815 (a)(2)(ii)(E). The designation of these complexes is based on the ecological relationships among species and their preferred habitat. These species complexes are grouped by the known

depth distributions of individual MUS. The textual EFH designations for CHCRT throughout the Western Pacific Region are found in Table 6.

3.1.2.15.2 Description and Identification of EFH for PHCRT

EFH has also been designated for the second tier, PHCRT. These taxa include literally thousands of species encompassing almost all coral reef fauna and flora. However, there is very little scientific knowledge about the life histories and habitat requirements of the thousands of species of organisms that compose these taxa. In fact, a large percentage of this biota has not been described by science. Therefore, the Council has used the precautionary approach in designating EFH for PHCRT so that enough habitat is protected to sustain managed species.

EFH for all life stages of Potentially Harvested Coral Reef Taxa is designated as the water column and bottom habitat from the shoreline to the outer boundary of the EEZ to a depth of 50 fathoms (Table 6). As with CHCRT, the Council has designated EFH for species assemblages pursuant to the federal regulations cited above.

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Table 6: EFH Designations for Coral Reef Taxa.

Species Assemblage/Complex	EFH (Egg and Larvae)	EFH (Adult and Juvenile)
Acanthuridae	The water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All bottom habitat and the adjacent water column from 0 to 50 fm.
Balistidae	The water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All bottom habitat and the adjacent water column from 0 to 50 fm.
Carangidae	The water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All bottom habitat and the adjacent water column from 0 to 50 fm.
Carcharhinidae	N/A	All bottom habitat and the adjacent water column from 0 to 50 fm to the outer extent of the EEZ.
Holocentridae	The water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All rocky and coral areas and the adjacent water column from 0 to 50 fm.
Kuhliidae	The water column from the shoreline to the outer limits of the EEZ to a depth of 50 fm.	All bottom habitat and the adjacent water column from 0 to 25 fm.
Kyphosidae	Egg, larvae, and juvenile: the water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All rocky and coral bottom habitat and the adjacent water column from 0 to 15 fm.
Labridae	The water column and all bottom habitat extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	
Mullidae	The water column extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All rocky/coral and sand-bottom habitat and adjacent water column from 0 to 50 fm.
Mugilidae	The water column from the shoreline to the outer limits of the EEZ to a depth of 50 fm.	All sand and mud bottoms and the adjacent water column from 0 to 25 fm.

Species Assemblage/Complex	EFH (Egg and Larvae)	EFH (Adult and Juvenile)
Muraenidae	The water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All rocky and coral areas and the adjacent water column from 0 to 50 fm.
Octopodidae	Larvae: The water column from the shoreline to the outer limits of the EEZ to a depth of 50 fm.	EFH for the adult, juvenile phase, and demersal eggs is defined as all coral, rocky, and sand-bottom areas from 0 to 50 fm.
Polynemidae	The water column extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 50 fm.
Priacanthidae	The water column extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 50 fm.
Scaridae	The water column from the shoreline to the outer limit of the EEZ to a depth of 50 fm.	All bottom habitat and the adjacent water column from 0 to 50 fm
Siganidae	The water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All bottom habitat and the adjacent water column from 0 to 50 fm.
Scombridae	EFH for all life stages of dogtooth tuna is designated as the water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	
Sphyraenidae	EFH for all life stages in the family Sphyraenidae is designated as the water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	
Turbinidae	The water column from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	All bottom habitat and the adjacent water column from 0 to 50 fm.
All Potentially Harvested Coral Reef Taxa	EFH for all life stages of Potentially Harvested Coral Reef Taxa is designated as the water column and bottom habitat from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.	

3.1.2.15.3 Identification of Habitat Areas of Particular Concern

Because of the already-noted lack of scientific data, the Council considered locations that are known to support populations of Coral Reef Ecosystem MUS and meet NMFS criteria for HAPC. Although not one of the criteria established by NMFS, the Council considered designating areas that are already protected—for example, wildlife refuges—as HAPC because such areas have been singled out for their ecological values during their designation as a protected area, and therefore would likely meet the HAPC criteria as well. The Coral Reef Ecosystem MUS HAPCs identified in Table 7 have met at least one of the four criteria listed above, or the fifth criterion just identified (i.e., protected areas). However, a great deal of life history work needs to be done in order to adequately identify the extent of HAPCs and link them to particular species or life stages. Table 7 shows Hawaiian Archipelago Coral Reef HAPCs.

Table 7: Coral Reef Ecosystem HAPC Designations in the Hawaiian Archipelago

	Rarity of Habitat	Ecological Function	Susceptibility to Human Impact	Likelihood of Developmental Impacts	Existing Protective Status
NWHI					
All substrate 0–10 fm	x	x	x		x
Laysan: All substrate 0–50 fm	x	x			
Midway: All substrate 0–50 fm	x	x	x		x
FFS: All substrate 0–50 fm	x	x	x	x	
Main Hawaiian Islands					
Kaula Rock (entire bank)		x	x		x
Niihau (Lehua Island)	x	x	x		
Kauai (Kaliu Point)		x	x		
Oahu					
Pupukea (MLCD)		x	x	x	x
Shark’s Cove (MLCD)			x	x	x

	Rarity of Habitat	Ecological Function	Susceptibility to Human Impact	Likelihood of Developmental Impacts	Existing Protective Status
Waikiki (MLCD)			x	x	x
Makapuu Head/Tide Pool Reef Area		x	x	x	
Kaneohe Bay	x	x	x	x	
Kaena Point		x	x		
Kahe Reef		x	x		
Maui					
Molokini	x	x	x	x	x
Olowalu Reef Area		x	x	x	
Honolua-Mokuleia Bay (MLCD)		x	x		x
Ahihi Kinau Natural Area Reserve	x	x	x		x
Molokai (south shore reefs)		x	x		
Lanai					
Halope Bay		x	x		
Manele Bay		x	x	x	
Five Needles		x	x		
Hawaii					
Lapakahi Bay State Park (MLCD)		x	x		x
Puako Bay and Reef (MLCD)		x	x		x
Kealakekua		x	x		x

	Rarity of Habitat	Ecological Function	Susceptibility to Human Impact	Likelihood of Developmental Impacts	Existing Protective Status
Waialea Bay (MLCD)	x	x	x		x
Kawaihae Harbor-Old Kona Airport (MLCD)		x	x		x
Additional Areas					
All Long-term Research Sites		x	x		
All CRAMP sites		x	x		

3.1.3 Crustacean Fishery

Hawaii's crustacean fishery is comprised primarily of lobster (ula), deepwater shrimp, and Kona crab.

3.1.3.1 Description (commercial, charter, recreational)

Lobsters

Ula was a traditional source of food for Native Hawaiians and was sometimes used in early religious ceremonies (Titcomb, 1972). After the arrival of Europeans in Hawaii, the lobster fishery became by far the most productive of Hawaii's commercial shellfish fisheries. It was reported that the MHI commercial lobster catch in 1901 was 131,200 pounds (Cobb 1902). However, by the early 1950s, the commercial catch of spiny lobsters (*P. penicillatus*) around the MHI had dropped by 75 percent to 85 percent (Shomura 1987). A statewide analysis of MHI commercial lobster catch data by Kelly and Messer (2005) found that 185,263 pounds of lobster were caught between 1984 and 2004 with annual landings ranging between 7,000 and 12,000 pounds.

Kona Crab

The MHI commercial Kona crab fishery began very small and was concentrated around the Oahu and Hawaii Island. Landings and participation increased throughout the 1950s and 1960s, and the fishery expanded to Maui Nui and Kauai around that time (Thomas, 2011). Data on the Kona recreational fishery crab is not available, but Kona crab is known to be targeted by recreational fishermen and catch may not be insubstantial (Brown, 1985 and Pooley, 1993).

Deepwater Shrimp

Around Hawaii, *Heterocarpus laevigatus* and *H. ensifer* have been reported in both the MHI and the NWHI (Gooding, 1984; Dailey and Ralston, 1986; Ralston and Tagami, 1992; Moffitt and

Parrish, 1992). Submersible surveys of shrimp densities on different habitats in the MHI reported that *Heterocarpus ensifer* tended to group around large anemones and other benthic relief over an otherwise flat, sandy bottom and were very active in the presence of a baited trap (Gooding et al., 1988; Moffitt and Parrish, 1992; Ralston and Tagami, 1992). However, *Heterocarpus laevigatus* were solitary and showed little activity around baited traps and greater densities of *Heterocarpus laevigatus* were observed on volcanic substrata rather than on coralline substrata (Moffitt and Parrish, 1992).

Trapping surveys in the MHI reported that the exploitable biomass of *H. laevigatus* was greatest at 460- 640 meters and negligible amounts occurred shallower than 350 meters or deeper than 830 meters (Ralston and Tagami, 1992). In the NWHI, the highest catch rates for *H. laevigatus* were made between 500 and 800 meters while the highest catch rates for *H. ensifer* occurred between 350 and 600 meters (Gooding, 1984). Specific information pertaining to habitat characteristics in the MHI or the NWHI is not available.

An intermittent deepwater shrimp fishery began in Hawaii 1967 (Tagami and Ralston 1988) and continues to vary from year to year with an average of three vessels reporting the catch of deepwater shrimp to the state of Hawaii. Vessels ranged in size from 7.5 to 40 m in length, though the number of smaller vessels increased as larger vessels left the fishery (Tagami and Barrows 1988). To date, the highest landings (~275,000 lbs.) of deepwater shrimp in Hawaii occurred in 1984; however, in 1989 nearly 270,000 lbs. were landed, with an estimated ex-vessel value of more than \$1 million. In 2005, vessels from the Pacific Northwest fished for *Heterocarpus* spp. in Hawaii and landed over 100,000 lbs. Between 1982 and 2005, the cumulative landings of *H. laevigatus* amounted to over 1.5 million lbs.; while during the same time period, *H. ensifer* landings totaled over 20,000 lbs.

3.1.3.2 Type and Quantity of Fishing Gear

In the MHI, ula are harvested using nets and hand harvest, as lobsters do not enter traps in the MHI. The Kona crab fishery utilizes strings of baited tangle-nets set on the sea floor with an average soak time of one hour during day-trips from small boats (Thomas, 2011).

Deepwater shrimp are caught using either trawls or traps. In areas where there is a continental shelf adjacent to a land mass, trawls are more effective. However, in Pacific island areas where there are more steep slopes, baited traps are more efficient (King, 1993). Traps are primarily used in the Western Pacific Region to catch deepwater shrimp.

Traps are made from steel, wire, and/or plastic with conical entrances that allow the shrimp to get into the trap, but not out. Trap lines are marked with flags and spaced out at approximately 30 meters apart. The traps are left out overnight to fish and collected the next day (King, 1993). In Hawaii, shrimp trapping vessels have employed large pyramidal traps of about 2 m³ in volume, setting up to 50 traps per day (Polovina, 1993).

3.1.3.3 Catch in Numbers or Weight

Catch information regarding crustaceans in state and federal waters around the MHI is limited to commercial catch data from the State of Hawaii, as there is no federal permit, nor are there any state or federal reporting requirements for recreational fishery participants.

The 2004-2014 average for crustacean catch (Figure 5) was 74,672 lbs. with a high of 156,509 lbs. (2004) and a low of 44,902 lbs. (2004). During that period, the percent of catch sold averaged approximately 40% (gray line). For current information regarding revenue of the fishery, price per pound, total direct employment, and fisheries-dependent services or industries, refer to the current Archipelagic Fishery Ecosystem Report (SAFE Report).

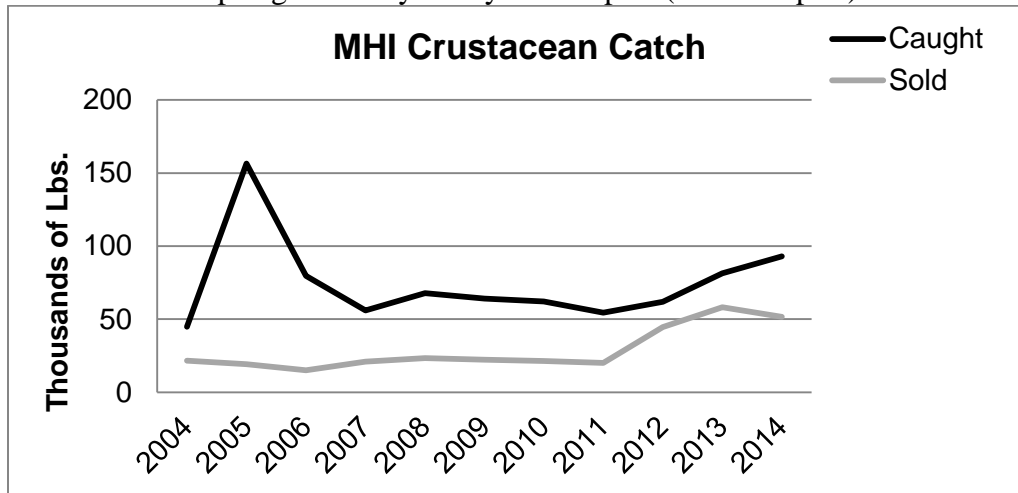


Figure 5. MHI Crustacean Catch Trend 2004-2014 (source: Hawaii Division of Aquatic Resources Commercial Marine License Reports).

3.1.3.4 Fishing Areas

Lobsters

Lobsters in the MHI are caught by hand or by net in relatively shallow water on or near coral reefs in nearshore waters. Maui has the largest catch and effort of the commercial harvest of lobsters in the MHI, followed by Hawaii Island, Oahu and Kauai (Kelly and Messer, 2005).

Kona Crab

Penguin Bank accounts for the majority of the commercial Kona crab fishery, but landings have been reported from across the MHI (Thomas, 2011). Recreational (and commercial) fisheries may operate in any area with a sandy substrate adjacent to coral reefs in depths from 2 to 200 m (Vasant, 1978).

Deepwater Shrimp

Deepwater shrimp are generally found at depths of 200 to 1,200 meters on the outer reef slopes that surround islands and deepwater banks. Species distribution tends to be stratified by depth with some overlap. The deepwater trap fisheries have primarily targeted *Heterocarpus ensifer* and *H. laevigatus* intermittently at these locations.

3.1.3.5 Time of Fishing

Fishing for lobsters, Kona crab, and deepwater shrimp occurs year-round, during the day and at night.

3.1.3.6 Number of Hauls

For up to date information on number of crustacean hauls⁸, refer to the current refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.3.7 Economics

The 2004-2014 average for direct revenue from Hawaii crustaceans was \$196,774 with a high of \$346,757 (2013) and a low of \$98,782 (2006). The price per pound across all species averaged \$7.24 for that period. For current information regarding revenue of the fishery, price per pound, total direct employment, and fisheries-dependent services or industries, please refer to the current WPFMC Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.3.8 Present and Probable Future Condition of the Fishery

The MHI Crustacean fishery has not been determined to be overfished or subject to overfishing.

3.1.3.9 Maximum Sustainable Yield

In the absence of more complete and accurate data, the MSY for the spiny lobster stock around the MHI can be provisionally estimated as approximately 15,000 – 30,000 lobsters per year of 8.26 cm carapace length or longer. There are insufficient data to estimate MSY values for MHI slipper lobsters or Kona crabs. MSY for deepwater shrimp is estimated for the Hawaiian Islands at 40 kg/nm² (Tagami and Ralston, 1988 in King, 1993). For current MSY estimates, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.3.10 Optimum Yield

For the MHI spiny lobster fishery, OY is defined as the greatest amount of non-berried spiny lobster with a carapace length of 3¹/₄ in. (8.26 cm) that can be taken each year from EEZ waters around the MHI by vessels fishing in accordance with the measures in this plan. No OY estimates for MHI slipper lobsters or Kona crabs are available.

For heterocarpus in the MHI, OY has not been determined. Improved catch reports have been recommended to enhance information available to fishery managers about deepwater shrimp in the MHI and allow for improved fishery management in the future.

3.1.3.10.1 Extent to Which Fishing Vessels will Harvest and Process OY

Lobsters harvested in the Hawaiian archipelago are marketed as fresh product or as frozen lobster tails, with each vessel processing its catch at sea. In general, shrimp are considered luxury food items; therefore care in handling is practiced. Smaller vessels normally wash the shrimp and store them in iced sea-water for transportation to protect the shrimp from enzyme-induced reactions (King, 1993). Larger vessels have the space on board to process the shrimp by quick freezing them, which preserves their quality and allows them to be easily exported. Different processing

⁸ Due to the nature of the fishery, deepwater shrimp information is not available due to the State of Hawaii's policy on confidential data.

methods are acceptable for different uses of deepwater shrimp. Local markets, restaurants, and hotels use whole, fresh, chilled shrimp. Shrimp tails are less likely to be used because of low meat recovery rates which are not commercially attractive (Oishi 1983). The domestic processing capacity and domestic processing levels will equal or exceed the harvest for the foreseeable future.

Domestic vessels likely have the capability to harvest the entire OY from the fishery. Therefore the TALFF appears to be zero.

3.1.3.11 Temporary Adjustments for the Safe Conduct of the Fishery

Due to the nature of the crustaceans fishery and associated regulations, the Council has not established temporary adjustments to existing FEP conservation and management measures that facilitate access to the fishery to vessels that otherwise would be prevented from harvesting because of weather or other ocean conditions affecting the safe conduct of the fishery. To the extent that temporary adjustments may be necessary in the future, the Council will consult with the US Coast Guard, fishery participants and the public in the development of temporary adjustments and will ensure that such measures will not adversely affect conservation efforts in other fisheries or discriminate among participants in the affected fishery.

3.1.3.12 MSA Conservation and Management Measures

Below are several important conservation and management measures for this fishery. Federal regulations governing this fishery can be found in the Code of Federal Regulations, Title 50, Part 665, Subpart G and Appendix C. Contact the Council or the National Marine Fisheries Service Pacific Islands Regional Office for and the fishery compliance guides (www.pir.noaa.gov).

3.1.3.12.1 Management Unit Species

Table 8 provides which crustacean species are managed under the FEP and designated as Management Unit Species (MUS).

Table 8: Hawaiian Archipelago Crustaceans Management Unit Species

Scientific Name	English Common Name	Local Name
<i>*Panulirus marginatus</i>	spiny lobster	ula
<i>*Panulirus penicillatus</i>	spiny lobster	ula
Family Scyllaridae	slipper lobster	ula papapa
<i>Ranina ranina</i>	Kona crab	papa'i kua loa
<i>*Heterocarpus</i> spp.	deepwater shrimp	NA

3.1.3.12.2 Management Areas

The fishery management area for the Hawaiian Islands crustacean fisheries is divided into two Permit Areas: (1) Permit Area 1 is the EEZ around the NWHI; and (2) Permit Area 2 is the EEZ around the MHI.

3.1.3.12.3 Permit and Reporting Requirements

Each vessel used to fish for deepwater shrimp in Permit Areas 1 or 2 must have a permit issued for that vessel. The owner of any vessel used to fish for lobster in Permit Area 2 must have a permit issued for such a vessel. No vessel owner will have permits for a single vessel to harvest lobsters in Permit Areas 1 and 2 at the same time. A limited access permit is valid for fishing only in Permit Area 1.

Permits may be transferred or sold, but no one individual, partnership or corporation will be allowed to hold a whole or partial interest in more than one permit, except that an owner who qualifies initially for more than one permit may maintain those permits, but may not obtain additional permits. Layering of partnerships or corporations shall not insulate a permit holder from this requirement. If 50 percent or more of the ownership of a limited access permit is passed to persons other than those listed on the permit application, NMFS must be notified of the change in writing and provided copies of the appropriate documents confirming the changes within 30 days. Upon the transfer or sale of a limited access permit, a new application must be submitted by the new permit owner. The transferred permit is not valid until this process is completed.

The operator of any fishing vessel must maintain on board the vessel an accurate and complete record of catch, effort, and other data on report forms provided by the NMFS Regional Administrator. All information specified on the forms must be recorded on the forms within 24 hours after the completion of each fishing day. The original logbook form for each day of the fishing trip must be submitted to the Regional Administrator within 72 hours of each landing of crustacean management unit species. Each form must be signed and dated by the fishing vessel operator. Fishery participants have the option of using NMFS approved electronic logbooks in lieu of paper logbooks.

The operator of any fishing vessel must submit to the Regional Administrator, within 72 hours of offloading of crustacean management unit species, an accurate and complete sales report on a form provided by the Regional Administrator. The form must be signed and dated by the fishing vessel operator.

3.1.3.12.4 Gear Restrictions and Prohibitions

Prohibitions

In Permit Area 2, it is unlawful for any person to:

- (1) Fish for, take, or retain lobsters by methods other than lobster traps or by hand; or during a closed season.
- (2) Retain or possess on a fishing vessel any lobster taken in Permit Area 2 that is less than the minimum size.
- (3) Possess on a fishing vessel any lobster or lobster part taken in Permit Area 2 in a condition where the lobster is not whole and undamaged.

- (4) Retain or possess on a fishing vessel, or remove the eggs from, any egg-bearing lobster.
- (5) Possess on a fishing vessel that has a permit for Permit Area 2 any lobster trap in Permit Area 2 when fishing for lobster in the main Hawaiian Islands is prohibited during the months of May, June, July and August.

In any Permit Area, it is unlawful for any person to:

- (1) Fish for, take, or retain deepwater shrimp without a permit.
- (2) Falsify or fail to make, keep, maintain, or submit Federal reports and records of harvests of deepwater shrimp.

Notifications

Vessel operators must report not less than 24 hours, but not more than 36 hours, before landing, the port, the approximate date and the approximate time at which spiny and slipper lobsters will be landed. They must also report not less than six hours, and not more than twelve hours, before offloading, the location and time that offloading spiny and slipper lobsters will begin. The Regional Administrator will notify permit holders of any change in the reporting method and schedule required at least 30 days prior to the opening of the fishing season.

Size Restrictions

In Permit Area 2 only spiny lobsters with a carapace length of 8.26 cm or greater may be retained and any lobster with a punctured or mutilated body, or a separated carapace and tail, may not be retained. In addition, a female lobster of any size may not be retained if it is carrying eggs externally and eggs may not be removed from female lobsters.

Closed Seasons

In Permit Area 2 lobster fishing is prohibited during the months of May, June, July, and August.

Gear Identification and Restrictions

In Permit Area 2 lobsters may be taken only with lobster traps or by hand. Lobsters may not be taken by means of poisons, drugs, other chemicals, spears, nets, hooks, or explosives.

3.1.3.12.5 At-sea Observer Coverage

All NWHI fishing vessels must carry an observer when requested to do so by the NMFS Regional Administrator. In addition, any fishing vessel (commercial or non-commercial) operating in the territorial seas or EEZ of the U.S. in a fishery identified through NMFS' annual determination process must carry an observer when directed to do so.

3.1.3.12.6 Framework Procedures for Regulatory Adjustments

New management measures may be added through rulemaking if new information demonstrates that there are biological, social, or economic concerns in Permit Areas 1 or 2. By June 30 of each year, the Council-appointed Crustaceans Plan Team will prepare an annual report on the fisheries in the management area. The report shall contain, among other things, recommendations for Council action and an assessment of the urgency and effects of such action(s).

Established measures are management measures that, at some time, have been included in regulations implementing the FMP, and for which the impacts have been evaluated in Council/NMFS documents in the context of current conditions. Following the framework procedures of Amendment 9 to the FMP, the Council may recommend to the NMFS Regional Administrator that established measures be modified, removed, or re-instituted. Such recommendation shall include supporting rationale and analysis, and shall be made after advance public notice, public discussion, and consideration of public comment. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

New measures are management measures that have not been included in regulations implementing the FMP, or for which the impacts have not been evaluated in Council/NMFS documents in the context of current conditions. Following the framework procedures of Amendment 9 to the FMP, the Council will publicize, including by a Federal Register document, and solicit public comment on, any proposed new management measure. After a Council meeting at which the measure is discussed, the Council will consider recommendations and prepare a Federal Register document summarizing the Council's deliberations, rationale, and analysis for the preferred action, and the time and place for any subsequent Council meeting(s) to consider the new measure. At subsequent public meeting(s), the Council will consider public comments and other information received to make a recommendation to the Regional Administrator about any new measure. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

3.1.3.12.7 Bycatch Measures

Bycatch of non-targeted species accounts for a small percentage of the total catch in the NWHI lobster fishery. This is due to the requirement that all lobster traps fished in the NWHI are required to be equipped with escape vents. In addition, to prevent the entrapment of juvenile monk seals, the smallest opening of an entry way may not allow any sphere or cylinder greater than 6.5 inches in diameter to pass from outside the trap to inside the trap. Section 5.5.10 describes measures which would be taken if the lobster fishery interacted in any way with a Hawaiian monk seal. Bycatch in the MHI is also likely to be low as the most common harvest method for MHI lobsters is hand harvest; however details on gear types and bycatch are not available. No specific measures are currently needed to reduce interactions with the other protected species groups based on the absence of interactions.

3.1.3.12.8 Annual Catch Limit

3.1.3.12.8.1 Limit

For the recent Hawaii Crustacean Annual Catch Limit, please refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.3.12.8.2 Specification Mechanism

The Hawaii crustaceans ACL specification is governed by the control process described in Appendix E. The deepwater shrimp stocks are considered as Tier 4 stocks. Spiny lobster stock was deemed as a Tier 3 stock while slipper lobsters and Kona crabs are designated as Tier 5 stock. ACLs are specified on a multiyear level (maximum of 4 years) but NMFS shall

promulgate regulations on an annual basis. Evaluations of the catches will be assessed through the annual meetings of the Fishery Ecosystem Plan Team.

3.1.3.12.8.3 Accountability Measures

There is no real-time monitoring for catches in the Hawaii crustacean fisheries. Catches are monitored through the State of Hawaii CML reporting system. The Plan Team shall review the previous year landings and if an overage occurred, an overage adjustment is applied to subsequent ACLs. Such reduction would be equivalent to the amount of overage in the previous fishing year. If the ACLs are exceeded in two consecutive years, the Council will revisit the ACL specification.

3.1.3.12.9 Criteria for Determining Overfishing

Application of National Standard 1

The MSY control rule is used as the maximum fishing mortality threshold (MFMT). The specifications for MFMT, minimum stock size threshold (MSST), and B_{FLAG} are specified as indicated in Table 9. The MFMT is more conservative than the default recommendation in Restrepo et al. (1998), as the inflection point would be at a higher level of B (B_{MSY} rather than some level less than B_{MSY}). The MSST specification is based on the default recommendation of Restrepo et al. (1998) and is dependent on the natural mortality rate (M). The value of M to be used to determine the MSST is not specified in this document. The latest estimate, published annually in the SAFE report, is used, and the value is occasionally re-estimated using the best available information.

Table 9: Overfishing Threshold Specifications: NWHI Lobster Stocks

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY} B}{B_{MSY}} \quad \text{for } B \leq B_{MSY}$ $F(B) = F_{MSY} \quad \text{for } B > B_{MSY}$	$c B_{MSY}$	B_{MSY}
where $c = \max(1-M, 0.5)$		

Target Control Rule and Reference Points

While there is an established OY, it is quantified or in the form of a target control rule for lobster stocks of the Hawaiian archipelago.

Rebuilding Control Rule and Reference Points

A rebuilding control rule is specified for the NWHI lobster stocks such that for levels of B where the rebuilding control rule is applicable (i.e., between 0 and the rebuilding target, B_{MSY}), as specified in Table 10.

Table 10: Rebuilding Control Rule Specifications: NWHI Lobster Stocks

$F_{REBUILDING}$	
$F(B) = 0$	for $B \leq c B_{MSY}$

$F_{\text{REBUILDING}}$	
$F(B) = \frac{r F_{\text{MSY}} B}{B_{\text{MSY}}}$	for $c B_{\text{MSY}} < B \leq B_{\text{MSY}}$
where $c = \max(1-M, 0.5)$ and r is the value such that fishing at $r F_{\text{MSY}}$ would result in a 10% chance of SPR falling to 0.20	

Stock Status Determination Process

Stock status determinations involve three procedural steps. First, the appropriate MSY, target or rebuilding reference points are specified. However, because environmental changes may affect the productive capacity of the stocks, it may be necessary to modify the specifications of some of the reference points or control rules on occasion. Modifications may also be desirable when better assessment methods become available, when fishery objectives are modified (e.g., OY), or better biological, socio-economic, or ecological data become available.

Second, the values of the reference points are estimated. Third, the status of the stock is determined by estimating the current or recent values of fishing mortality and stock biomass or their proxies and comparing them with their respective reference points.

The second step (including estimation of M , on which the values of the overfishing thresholds would be dependent) and third step will be undertaken by NMFS and the latest results published annually in the Annual Archipelagic Fishery Ecosystem Report (SAFE Report). In practice, the second and third steps may be done simultaneously. In other words, the reference point values could be re-estimated as often as the stocks' status. No particular stock assessment period or schedule is specified, but in practice the assessments are likely be conducted annually in coordination with the preparation of the Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

The best information available is used to estimate the values of the reference points and to determine the status of stocks in relation to the status determination criteria. The determinations are based on the latest available stock and fishery assessments. Information used in the assessments includes logbook data, vessel observer data, and the findings of fishery-independent surveys when they are conducted.

Measures to Address Overfishing and Overfished Stocks

At present, no crustacean stocks in Hawaii have been determined to be overfished and overfishing does not appear to be occurring. If in the future it is determined that overfishing is occurring, a stock is overfished, or either of those two conditions is being approached, the Council will establish additional management measures using the FEP amendment process or the framework adjustment process. A potential measure would be adjustments to the harvest rate. Other potential measures include additional area closures and adjustments to the NWHI seasonal closure.

The combination of control rules and reference points is illustrated in Figure 6. Note that the positions of the MSST and F_{OY} are illustrative only; their values would depend on the best estimates of M and r at any given time. As noted in Section 4.3.3, the NWHI lobster fishery has

been closed since 2000 due to uncertainty regarding NMFS' population models, as well as the imposition of the NWHI Marine National Monument which stipulates that any commercial lobster fishing permit shall be subject to a zero annual harvest limit.

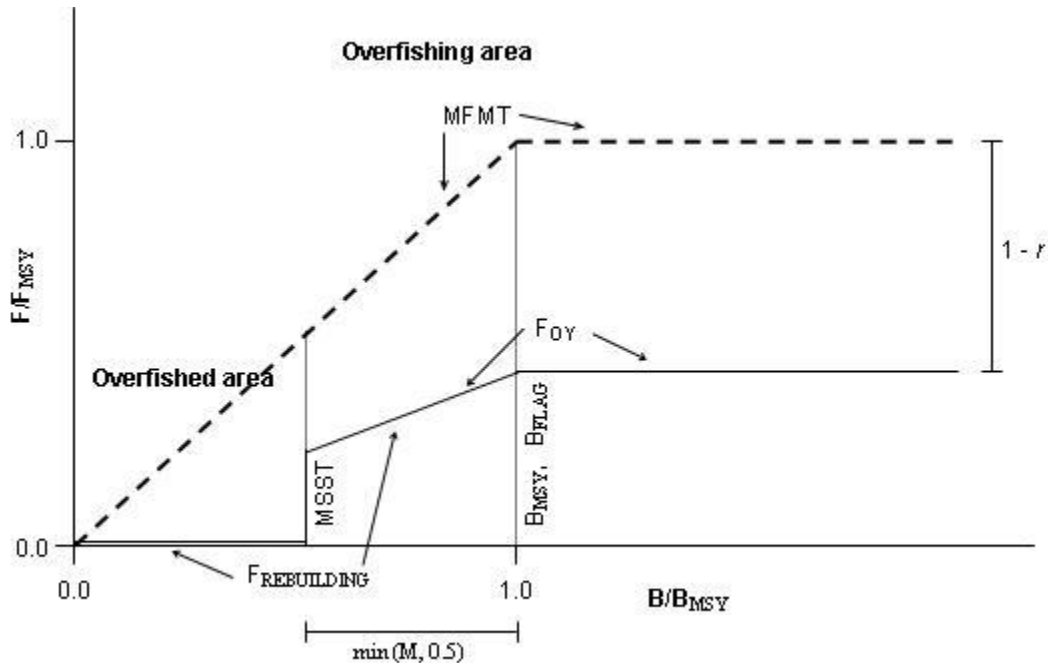


Figure 6: Combination of Control Rules and Reference Points for NWHI Lobster Stocks.

3.1.3.13 Regulations Implementing International Recommendations and other Applicable Laws

There are no international recommendations or other applicable laws for the crustacean fishery in the Hawaiian Archipelago.

3.1.3.14 Bycatch Amount and Type

Lobsters are almost exclusively harvested by hand, which does not allow for bycatch. The Kona Crab fishery is a targeted fishery and will only catch Kona Crabs in their nets. Currently, there is little information about any bycatch that might be associated with the *Heterocarpus* fishery.

Non-targeted species account for a small percentage of the total catch in the NWHI lobster fishery, as the traps are designed for high selectivity. Using data from 1976–1991 (wire traps) and 1986–2003 (plastic traps) from research cruises in the NWHI, Moffitt et al. (2005) examined the diversity of catch composition. The traps used for the research were more conservative than commercial traps as they did not have escape vents, but otherwise they conformed to fishery regulations. Both wire and plastic traps were found to be highly selective; that is, they primarily caught lobsters. Wire traps caught a total of 82 species over the study period, of which the two target species of lobsters accounted for 90.5 percent by number. Plastic traps caught a total of 258 species over the study period, of which 73.1 percent by number were the two target species. Because lobsters are one of the larger organisms captured, they would be a much higher

percentage of the total catch if measured by weight. Of the organisms that were caught incidentally, hermit crabs made up the largest component followed by moray eels and small reef fish.

Octopus abundance was also evaluated due to its potential as a prey species for the Hawaiian monk seal. A total of 83 individuals were captured during the entire 1986–2003 study period, and examination of the data showed no significant decline or increase in their capture rate over time. Based on the data, the study found that it is unlikely that lobster-trapping activities have lowered octopus abundance to such a degree that monk seal populations would be negatively impacted (Moffitt et al. 2005).

Overall, Moffitt et al. (2005) concluded that lobster-trapping activities are responsible for changes in abundance of a few species (target species have declined, and some crab species have increased due to competitive replacement) of the benthic community in the NWHI, but do not appear to have resulted in major changes to the ecosystem. Moffitt et al. (2005) also stated that gear lost in this fishery has not been found to be “ghost fishing” (still catching organisms), and that although direct damage to the benthic habitat by the traps has not been studied, it is not likely to be substantial due to the low-relief, hard substrate that characterizes the fishing grounds.

Currently, there is little information about bycatch associated with the *Heterocarpus* fishery and what is known comes primarily from research sampling.

3.1.3.14.1 Standardized Reporting Methodology

Disposition of crustaceans caught and released in the crustaceans fishery is recorded through trip reporting as required by the State CML and Federal Crustaceans permit.

3.1.3.15 Identification and Description of EFH and HAPC

Spiny lobsters are found through the Indo-Pacific region. All spiny lobsters in the Western Pacific Region belong to the family Palinuridae. The slipper lobsters belong to the closely related family, Scyllaridae. There are 13 species of the genus *Panulirus* distributed in the tropical and subtropical Pacific between 35° N and 35° S. *P. penicillatus* is the most widely distributed, the other three species are absent from the waters of many island nations of the region. Spiny lobsters are typically found on rocky substrate in well-protected areas, in crevices, and under rocks. Unlike many other species of *Panulirus*, the juveniles and adults of *P. marginatus* are not found in separate habitats apart from one another. Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize a separate shallow-water nursery habitat apart from the adults as do many Palinurid lobsters. Similarly, juvenile and adult *P. penicillatus* also share the same habitat. *P. marginatus* is found seaward of the reefs and within the lagoons and atolls of the islands. The reported depth distribution of *P. marginatus* is 3–200 meters. While this species is found down to depths of 200 meters, it usually inhabits shallower waters. *P. marginatus* is most abundant in waters of 90 meters or less. Large adult spiny lobsters are captured at depths as shallow as 3 meters.

In the southwestern Pacific, spiny lobsters are typically found in association with coral reefs. Coral reefs provide shelter as well as a diverse and abundant supply of food items. *Panulirus penicillatus* inhabits the rocky shelters in the windward surf zones of oceanic reefs and moves on to the reef flat at night to forage.

Very little is known about the planktonic phase of the phyllosoma larvae of *Panulirus marginatus*. Evidence (found in Hawaii) suggests that fine-scale oceanographic features, such as eddies and currents, serve to retain phyllosoma larvae (Polovina and Moffitt 1995).

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for crustacean species assemblages. The species complex designations are spiny and slipper lobsters and Kona crab. The designation of these complexes is based on the ecological relationships among species and their preferred habitat.

At present, there are not enough data on the relative productivity of different habitats of CMUS to develop EFH designations based on Level 3 or Level 4 data. There are little data concerning growth rates, reproductive potentials, and natural mortality rates at the various life history stages. The relationship between egg production, larval settlement, and stock recruitment is also poorly understood. Although there is a paucity of data on the preferred depth distribution of phyllosoma larvae in Hawaii, the depth distribution of phyllosoma larvae of other species of *Panulirus* common in the Indo-Pacific region has been documented. Later stages of panulirid phyllosoma larvae have been found at depths between 80 and 120 meters.

3.1.3.15.1 Description and Identification of EFH for Spiny and Slipper Lobster and Kona Crab

For these reasons, the Council designated EFH for spiny and slipper lobster and Kona crab eggs and larvae as the water column from the shoreline to the outer limit of the EEZ down to a depth of 150 meters throughout the Western Pacific Region. The EFH for juvenile and adult spiny and slipper lobster and Kona crab is designated as the bottom habitat from the shoreline to a depth of 100 meters throughout the Western Pacific Region.

3.1.3.15.2 Identification of Habitat Areas of Particular Concern

Research from the Northwestern Hawaiian Islands indicates that banks with summits less than 30 meters support successful recruitment of juvenile spiny lobster while those with summit deeper than 30 meters do not. For this reason, the Council has designated all banks with summits less than 30 meters as HAPC. The basis for designating these areas as HAPC is the ecological function provided the rarity of the habitat type, and the susceptibility of these areas to human-induced environmental degradation. The complex relationship between recruitment sources and sinks of spiny lobsters is poorly understood. The Council believes that in the absence of a better understanding of these relationships, the adoption of a precautionary approach to protect and conserve habitat is warranted.

The relatively long pelagic larval phase for palinurids results in very wide dispersal of spiny lobster larvae. Panulirid larvae are transported up to 2,000 nautical miles by prevailing ocean currents. Because phyllosoma larvae are transported by the prevailing ocean currents outside of EEZ waters, the Council has identified habitat in these areas as “important habitat.” To date HAPC has not been identified or designated for deepwater shrimp.

3.1.3.16 Deepwater Shrimp Essential Fish Habitat

Adult deepwater shrimp species of the genus *Heterocarpus* have been reported throughout tropical waters of the Pacific including Hawaii (Clarke 1972, Struhsaker and Aasted; 1974, Dailey and Ralston 1986; Gooding et al. 1988; Tagami and Barrows 1988; Moffitt and Parrish 1992; Ralston and Tagami 1992; Polovina 1993), Guam (Wilder 1977), Western Samoa (King 1980), and the Northern Mariana Islands (Moffitt 1983, Ralston 1986). They are generally found in benthic deepwater habitats between 200-900 meters in depth, primarily on the steep outer reef slopes which surround the islands and deepwater banks. However, because they are found at such deep depths, accurate description and characterization of preferred habitats are difficult to obtain and virtually non-existent in the scientific literature.

The distribution of these species tends to be stratified by depth with each species occupying different but often overlapping depths (Ralston 1986). Eight species belonging to the genus *Heterocarpus* (*Heterocarpus ensifer*, *H. laevigatus*, *H. sibogae*, *H. gibbosus*, *H. lepidus*, *H. dorsalis*, *H. tricarinatus* and *H. longirostris*) have been reported from the Western Pacific Region, although *Heterocarpus ensifer* and *H. laevigatus* have been the primary focus of fishery operations and research surveys.

Around Hawaii, *Heterocarpus laevigatus* and *H. ensifer* have been reported in both the MHI and the NWHI (Gooding 1984; Dailey and Ralston 1986; Ralston and Tagami 1992; Moffitt and Parrish 1992). Submersible surveys of shrimp densities on different habitats in the MHI reported that *Heterocarpus ensifer* tended to group around large anemones and other benthic relief over an otherwise flat, sandy bottom and were very active in the presence of a baited trap (Gooding et al., 1988; Moffitt and Parrish, 1992; Ralston and Tagami, 1992). However, *Heterocarpus laevigatus* were solitary and showed little activity around baited traps and greater densities of *Heterocarpus laevigatus* were observed on volcanic substrata rather than on coralline substrata (Moffitt and Parrish, 1992).

Trapping surveys in the MHI reported that the exploitable biomass of *H. laevigatus* was greatest at 460- 640 meters and negligible amounts occurred shallower than 350 meters or deeper than 830 meters (Ralston and Tagami, 1992). In the NWHI, the highest catch rates for *H. laevigatus* were made between 500 and 800 meters while the highest catch rates for *H. ensifer* occurred between 350 and 600 meters (Gooding 1984). Specific information pertaining to habitat characteristics in the MHI or the NWHI was not reported in any detail.

The species complex designation includes all eight species of deepwater shrimp extant in the Western Pacific Region (*Heterocarpus ensifer*, *H. laevigatus*, *H. sibogae*, *H. gibbosus*, *H. lepidus*, *H. dorsalis*, *H. tricarinatus* and *H. longirostris*). This designation is consistent with the Code of Federal Regulations (CFR) §600.815 (a)(1)(iv)(E).

3.1.3.16.1 Description and Identification of EFH for Deepwater Shrimp

To reduce the complexity and the number of EFH identifications required for each individual species and life stages of the genus *Heterocarpus* in the Western Pacific Region, and based upon the above information, the Council has recommended EFH for the complete assemblage of adult and juvenile *Heterocarpus* spp. as the outer reef slopes between 300 and 700 meters surrounding every island and submerged banks in the Western Pacific Region.

At present, there are not enough data on the relative productivity of different habitats of *Heterocarpus* to develop EFH designations based on Level 3 (growth, reproduction and survival rates by habitat area) or Level 4 (production rates by habitat) data. In fact, there are little to no data available concerning growth rates, reproductive potentials and natural mortality rates at each life history stage.

The relationship between egg production, larval settlement and stock recruitment is also poorly understood and only available for a few specific sites (Wilder 1977; Clarke 1972; Moffitt and Polovina 1987). Mature shrimps may undergo a depth related seasonal migration in synchrony with reproduction and a shift into deeper waters from depths of about 550 meters to 700 meters. For these reasons the Council has designated EFH for *Heterocarpus* spp. eggs and larvae as the water column and outer reef slopes between 550 and 700 meters in the Western Pacific Region.

3.1.3.16.2 Identification of Habitat Areas of Particular Concern

There are no HAPC designated for deepwater shrimp in the Hawaiian Archipelago.

3.1.4 Precious Corals Fishery

3.1.4.1 Description (commercial, charter, recreational)

Collection of black coral from depths of 30–100 meters by scuba divers has continued in Hawaii since black coral beds were discovered off Lahaina, Maui, in the late 1950s, although harvest levels have fluctuated with changes in demand. Since 1980, virtually all of the black coral harvested around the Hawaiian Islands has been taken by hand from a bed located in the Auau Channel. Most of the harvest has come from State of Hawaii waters; however, a portion of the black coral bed in the Auau Channel is located in the EEZ. In 1999, concern about the potential for greater harvesting pressure on the black coral resources led the State of Hawaii to prohibit the harvest of black coral with a base diameter of less than 3/4 inches from state waters.

After two decades of minimal activity, the domestic fishery for pink, gold, and bamboo precious corals in the EEZ of Hawaii resumed in December 1999. One company used two one-man submersibles to survey and harvest pink and gold corals at depths between 400–500 meters during 1999 and 2001. However, they did not continue their operations after that time, and the actual harvests cannot be reported here because of data confidentiality policies that prohibit the publication of proprietary information unless there are at least three separate operations included in the dataset.

There is no known recreational component to this fishery.

3.1.4.2 Type and Quantity of Fishing Gear

Various fishing enterprises have used tangle net dredges (now prohibited), cameras and maneuverable tools, and one-man submersibles to harvest precious corals.

3.1.4.3 Harvest in Numbers or Weight

Recent harvest figures for black coral in Hawaii cannot be presented because there have been fewer than three harvest operations. However, between 1990 and 1997, the annual harvest of black coral averaged 3,084 lbs., with a low of 864 lbs. (1993) and a high of 6,017 lbs. (1995).

3.1.4.4 Fishing Areas

Precious corals may be caught in any part of the Hawaiian archipelago with suitable habitat. Some areas that are known to have precious corals are classified beds known as “established,” “conditional,” or “exploratory” depending on the amount of precious corals in the area.

3.1.4.5 Time of Fishing

Fishing for precious corals can be done day or night, but most black coral harvest is done during the day due to the use of SCUBA.

3.1.4.6 Number of Hauls

Precious coral haul numbers are not available due to the nature of the data set (confidential data with the Hawaii Division of Aquatic Resources in the case of black coral), or nonexistent information (in the case of pink, gold and black coral). For the recent information on precious coral hauls, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.4.7 Economics

Recent revenue figures for black coral in Hawaii cannot be presented because there have been fewer than three harvest operations. However, between 1990 and 1997, the annual revenue in the fishery averaged \$48,407, with a low of 10,394 (1997) and a high of \$122,765 (1995).

3.1.4.8 Present and Probable Future Condition of the Fishery

To date, Hawaii’s precious corals fishery has not been determined to be overfished or subject to overfishing.

For current information regarding the condition of, and statistics from, the precious coral fishery, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.4.9 Maximum Sustainable Yield

To date, beds of pink, gold and/or bamboo corals have been found at various locations in EEZ waters around the Hawaii Archipelago. Within the EEZ, the Makapuu Established Bed has experienced the greatest level of documented exploitation and scientific research, and thus is the source of much of the available information about Hawaii’s precious corals. Density of occurrence estimates for precious corals colonies in their habitat, based on in situ observations made at the Makapuu Bed, reveal a fairly dense habit of growth. This bed was surveyed in the 1970s, and again in 1997.

In 1971, densities of commercial species were determined in an unexploited section of the bed, and the size frequency distribution of pink coral was determined (Grigg 1976). The average density of pink coral in the Makapuu Bed was 0.022 colonies per square meter. Extrapolation of this figure to the entire bed (3.6 million m²) results in a standing crop of 79,200 colonies. The 95

percent confidence limits of the standing crop are 47,200 to 111,700 colonies. Conversion of standing crop colonies to biomass produced an estimate of 43,500 kg for *C. secundum* in the Makapuu Bed.

The estimates of density for gold coral (*Gerardia* spp.) and bamboo coral (*Lepidisis olapa*) in the Makapuu Bed were 0.003 colonies/m² and 0.01 colonies/m² respectively. However, the distributional patterns of both of these species were found to be very patchy, much more so than *C. secundum*, and the area where they occurred was only about half that for pink coral, or 1.8 million m². The corresponding estimates of unfished abundance for gold and bamboo colonies are 5,400 and 18,000 colonies respectively. Data for the mean weight of colonies in the populations of gold and bamboo coral in the Makapuu Bed are lacking, but rough estimates were 2.2 kg for gold coral and 0.6 kg for bamboo coral. Multiplying mean weights by densities leads to rough estimates of standing crop of about 11,800 kg for *Gerardia* spp. and 10,800 for *Lepidisis* spp. A 1997 resurvey which used a newer technology enabling deeper dives, found the Makapuu bed to be about 15 percent larger than previously estimated (Grigg 2002).

MSYs for the Makapuu Established Bed have been estimated using a Beverton and Holt cohort production model (Beverton and Holt 1957) where data are available for *Corallium secundum*, and the Gulland Model (MSY = 0.4 MBo, where M=natural mortality and Bo is virgin biomass) for *Gerardia* and *Lepidisis* (Gulland 1970). The Gulland (1969) method to estimate MSY was used for gold and bamboo corals at the Makapuu Bed, where information on population dynamics is lacking. MSY is 40 percent of the natural mortality rate times virgin stock biomass (estimated from the product of area of the bed, average colony density and weighted average weight of a virgin colony; MSY = 0.4 x M x B). The mortality rate for pink coral (M=0.066) is used as a proxy for other species.

Table 11: MSY Estimates for Precious Corals in the Makapuu Bed

Species (common name)	MSY (kg/yr)	Method of calculation
<i>Corallium secundum</i> (pink)	1,185	Beverton and Holt Cohort production model
<i>Corallium secundum</i> (pink)	1,148	Gulland model
<i>Gerardia</i> spp. (gold)	313	Gulland model
<i>Lepidisis olapa</i> (bamboo)	285	Gulland model

Harvest quotas for Hawaii's four Conditional Beds have been extrapolated, based on bed size, by comparison with that of the Makapuu Established Bed using the following formula for Conditional Beds for which detailed data are unavailable (see Table 12).

$$\frac{\text{MSY for Makapuu Bed}}{\text{Area of Makapuu Bed}} = \frac{\text{MSY for Conditional Bed}}{\text{Area of Conditional Bed}}$$

As discussed below, the harvest quotas represent OY values and are based on extrapolations from "rounded down MSY values" for the Makapuu Bed.

Commercial harvests of black coral have occurred in waters around Hawaii for more than three decades. Significant harvests have been made from the Auau Channel and around Kauai. In 1976, Grigg estimated black coral MSYs of 6,174 kg/yr for the Auau Channel and 1,480 kg/year for the area around Kauai using a Beverton and Holt yield production model (Grigg 1976). More recently, Grigg discovered a greater impact to the black coral resource from an invasive soft coral, *Carijoa riisei*, and based on that, coupled with harvesting impacts, estimated a reduced MSY of 3,750 kg/yr (Grigg 2004) for this area.

No MSY estimates are available for the Exploratory Areas; however harvest quotas have been implemented based on available information (see below). For current MSY estimates, refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.4.10 Optimum Yield

As discussed above, OY values for the six Established and Conditional beds are based on MSY estimates for the Makapuu Bed, which were rounded downward for ecological reasons. The rounded down MSY values were then extrapolated to the Conditional Beds based on relative bed size. The OY for the Makapuu Bed is expressed as a two-year harvest quota because it is economically disadvantageous to utilize the expensive specialized equipment required for selective harvesting of precious coral for only part of each year on only one coral bed. The more flexible biannual schedule makes it easier for harvesters to deploy in other areas once the two-year Makapuu Bed quota is taken.

The OY values are used as the harvest quotas for all species except black coral (Table 12). The harvest quota for the Hawaii Exploratory Area comprises 1,000 kg/year of all species of precious corals combined (except black coral). This harvest quota was set when non-selective gear was allowed to be used and today is considered to be conservative as selective gear has very low bycatch rates and does not damage nearby colonies during the harvesting process.

Table 12: OY values (Harvest Quotas) for Hawaii Precious Corals

Type of coral bed	Name of coral bed	Harvest quota in kilograms	Number of years
Established Beds	Auau Channel	Black: 5,000	2
	Makapu‘u	Pink: 2,000	2
		Gold: 0 (zero) Bamboo: 500	-- 2
Conditional Beds	180 Fathom Bank	Pink: 222	1
		Gold: 67	1
		Bamboo: 56	1
	Brooks Bank	Pink: 17	1
		Gold: 133	1
		Bamboo: 111	1
Kaena Point	Pink: 67	1	
	Gold: 20	1	
	Bamboo: 17	1	

	Keahole Point	Pink: 67 Gold: 20 Bamboo: 17	1 1 1
Refugia	Westpac	All: 0 (zero)	--
Exploratory Areas	Hawaii, American Samoa, Guam, CNMI, U.S. Pacific Remote Island Areas	1,000 per area (all species combined except black corals)	1

Notes:

1. The final rule implementing the FMP lists the harvest quota for pink coral at Brooks Bank as 17 kg. This is a typographical error; the correct harvest quota is 444 kg.
2. No fishing for coral is authorized in refugia.
3. A moratorium on gold coral harvesting is in effect through June 30, 2018.

3.1.4.10.1 Extent to Which Fishing Vessels will Harvest OY

Based on available information, domestic vessels can harvest the Precious Coral OY from the Established and Conditional Beds. Therefore the TALFF for these beds appears to be zero. The TALFF for each Exploratory Area shall be its quota minus two times of the amount harvested by domestic vessels between July 1 and December 31 of the preceding year. The TALFF may be made available for foreign fishing under a scientific research plan approved by NMFS in consultation with the Council and State agencies.

3.1.4.10.2 Extent to Which U.S. Fish Processors will Process OY

There is sufficient domestic processing capacity to accommodate increased harvests. The U.S. imports semi-processed coral for finishing into jewelry. Under the FEP, domestic production could replace these imports. It is anticipated that domestic processing capacity and domestic processing levels will equal or exceed the domestic harvest for the foreseeable future.

3.1.4.11 Temporary Adjustments for the Safe Conduct of the Fishery

Due to the nature of the precious coral fishery and associated regulations, the Council has not established temporary adjustments to existing FEP conservation and management measures that facilitate access to the fishery to vessels that otherwise would be prevented from harvesting because of weather or other ocean conditions affecting the safe conduct of the fishery. To the extent that temporary adjustments may be necessary in the future, the Council will consult with the US Coast Guard, fishery participants and the public in the development of temporary adjustments and will ensure that such measures will not adversely affect conservation efforts in other fisheries or discriminate among participants in the affected fishery.

3.1.4.12 MSA Conservation and Management Measures

Below are several important conservation and management measures for this fishery. Federal regulations governing this fishery can be found in the Code of Federal Regulations, Title 50, Part 665, Subpart G and Appendix C. Contact the Council or the National Marine Fisheries Service Pacific Islands Regional Office for and the fishery compliance guides (www.pir.noaa.gov).

3.1.4.12.1 Management Unit Species

Table 13 provides which precious coral species are managed under the FEP and designated as Management Unit Species (MUS).

Table 13: Hawaiian Archipelago Precious Corals Management Unit Species

Scientific Name	English Common Name	Local Name
<i>Corallium secundum</i>	pink coral (also called red coral)	NA
<i>Corallium regale</i>	pink coral (also called red coral)	NA
<i>Corallium laauense</i>	pink coral (also called red coral)	NA
<i>Gerardia</i> spp.	gold coral	NA
<i>Narella</i> spp.	gold coral	NA
<i>Lepidisis olapa</i>	bamboo coral	NA
<i>Antipathes dichotoma</i>	black coral	NA
<i>Antipathes grandis</i>	black coral	NA
<i>Antipathes ulex</i>	black coral	NA

3.1.4.12.2 Management Areas

The MHI precious coral fishery is designated by management areas that include established beds, conditional beds, and an exploratory area. The Makapu‘u and ‘Au‘au Channel Beds are the only two established precious coral beds in the Hawaiian archipelago. Conditional beds in the MHI include Keahole Pint (Hawaii Island) and Kaena Point (Oahu). All remaining areas are included as exploratory areas.

3.1.4.12.3 Permit and Reporting Requirements

Any vessel of the United States fishing for, taking or retaining precious corals in any precious corals permit area must have a permit. Each permit will be valid for fishing only in the permit area. No more than one permit will be valid for any one person at any one time. The holder of a valid permit to fish one permit area may obtain a permit to fish another permit area only upon surrendering to the NMFS Regional Administrator any current permit for the precious corals fishery.

The operator of any fishing vessel must maintain on board the vessel an accurate and complete record of catch, effort, and other data on report forms provided by the NMFS Regional Administrator. All information specified on the forms must be recorded on the forms within 24 hours after the completion of each fishing day. The original logbook form for each day of the fishing trip must be submitted to the Regional Administrator within 72 hours of each landing of precious corals management unit species. Each form must be signed and dated by the fishing

vessel operator. Fishery participants have the option of using NMFS approved electronic logbooks in lieu of paper logbooks.

3.1.4.12.4 Gear Restrictions and Prohibitions

Only selective gear may be used to harvest coral from any precious corals permit area. Selective gear means any gear used for harvesting corals that can discriminate or differentiate between type, size, quality, or characteristics of living or dead corals.

Size Restrictions

The height of a live coral specimen shall be determined by a straight line measurement taken from its base to its most distal extremity. The stem diameter of a living coral specimen shall be determined by measuring the greatest diameter of the stem at a point no less than one inch (2.54 cm) from the top surface of the living holdfast. Live pink coral harvested from any precious corals permit area must have attained a minimum height of 10 inches (25.4 cm). Live black coral harvested from any precious corals permit area must have attained either a minimum stem diameter of 1 inch (2.54 cm), or a minimum height of 48 inches (122 cm).

Seasons and Quotas

The fishing year for precious corals begins on July 1 and ends on June 30 the following year, except at the Makapuu and Auau Channel Beds, which have a two-year fishing period that begins July 1 and ends June 30, two years later. Precious coral permit areas are the areas encompassing the precious coral beds in a management area. Each bed is designated by a permit area code and assigned to one of the following four categories: Established, Conditional, Exploratory or Refugium.

Closures

If the NMFS Regional Administrator determines that the harvest quota for any coral bed will be reached prior to the end of the fishing year, or the end of the 2-year fishing period at Makapuu Bed or Auau Channel Bed, NMFS will issue a Federal Register notice closing the bed and the public will be informed through appropriate news media. Any such field order must indicate the reason for the closure, delineate the bed being closed, and identify the effective date of the closure. A closure is also effective for a permit holder upon the permit holder's actual harvest of the applicable quota.

3.1.4.12.5 Framework Procedures for Regulatory Adjustments

Established management measures may be revised and new management measures may be established and/or revised through rulemaking if new information demonstrates that there are biological, social, or economic concerns in a precious corals permit area. By June 30 of each year, the Council-appointed Precious Corals Plan Team will prepare an annual report on the fishery in the management area. The report will contain, among other things, recommendations for Council action and an assessment of the urgency and effects of such action(s).

Established measures are management measures that, at some time, have been included in regulations implementing the FMP, and for which the impacts have been evaluated in Council/NMFS documents in the context of current conditions. According to the framework procedures of Amendment 3 to the FMP, the Council may recommend to the Regional Administrator that established measures be modified, removed, or re-instituted. Such

recommendation will include supporting rationale and analysis and will be made after advance public notice, public discussion, and consideration of public comment. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

New measures are management measures that have not been included in regulations implementing the FMP, or for which the impacts have not been evaluated in Council/NMFS documents in the context of current conditions. Following the framework procedures of Amendment 3 to the FMP, the Council will publicize, including by a Federal Register document, and solicit public comment on, any proposed new management measure. After a Council meeting at which the measure is discussed, the Council will consider recommendations and prepare a Federal Register document summarizing the Council's deliberations, rationale, and analysis for the preferred action and the time and place for any subsequent Council meeting(s) to consider the new measure. At a subsequent public meeting, the Council will consider public comments and other information received before making a recommendation to the Regional Administrator about any new measure. If approved by the Regional Administrator, NMFS may implement the Council's recommendation by rulemaking.

3.1.4.12.6 Bycatch Measures

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. Such organisms include *onaga* (*Etelis coruscans*), *kahala* (*Seriola dumerallii*), and the shrimp (*Heterocarpus ensifer*), however, there is no evidence that these species or others significantly depend on precious coral beds for shelter or food. Given the highly selective nature of this fishery, and the absence of reported or expected protected species interactions, no specific measures to reduce protected species interactions are considered necessary at this time. In addition any vessel (commercial or non-commercial) operating in the territorial seas or EEZ of the U.S. in a fishery identified through NMFS' annual determination process must carry an observer when directed to do so.

3.1.4.12.7 Annual Catch Limit

3.1.4.12.7.1 Specification Mechanism

For the precious coral fishery, specification of the acceptable biological catch and annual catch limits are required by the MSA and follows the mechanism described in Appendix E. The ACL is specified on an annual basis by NMFS based on recommendations from the Council.

3.1.4.12.7.2 Limit

For the recent Hawaii Precious Coral Annual Catch Limits, please refer to the current Annual Archipelagic Fishery Ecosystem Report (SAFE Report).

3.1.4.12.7.3 Accountability Measures

Accountability measures are specified on an annual basis by NMFS based on recommendations by the Council. There is no real time monitoring of catches in the Hawaii precious coral fisheries. Catches are monitored through the State of Hawaii CML reporting system. The specification of accountability measures will follow the process described in Appendix E.

3.1.4.12.8 Criteria for Determining Overfishing

Application of National Standard 1

MSY Control Rule

Pink, gold and bamboo corals occur in all six known beds, although only the “Established” Makapuu Bed has been quantitatively surveyed. While it is believed that harvestable quantities of precious corals may exist in other areas of the Western Pacific Region, no information exists on their distribution, abundance or status.

The definition of overfished for all species of precious corals is when the total spawning biomass is less than or equal to 20 percent of its unfished condition ($SPR \leq 20$ percent), based on cohort analysis of the pink coral, *Corallium secundum*. This definition takes into account the mean survivorship, yield, age at maturity, reproductive potential and MSY of the coral populations. It also protects 20 percent of the spawning stock biomass. For beds other than the “Established” Makapuu bed more information is needed before the overfishing definition can be applied.

If recruitment is constant or independent of stock size, then MSY can be determined from controlling the fishing mortality rate (F) to maximize the yield per recruit (MYPR), i.e., $MSY = MYPR(g/recruit) \times R(recruits/yr)$. MYPR is a function of area of the bed, average colony density and natural mortality. If a stock-recruitment relationship exists, recruitment is reduced as a function of reduced stock size, and MSY will also be reduced. The assumption of constant recruitment appears to be reasonable based on the robust recovery and verification of annual growth rings from a recent resurvey (Grigg 1976).

Alternatively, the Gulland (1969) method to estimate MSY is especially useful for gold and bamboo coral, where information on population dynamics is lacking. MSY is 40 percent of the natural mortality rate times virgin stock biomass (estimated from the product of area of the bed, average colony density and weighted average weight of a virgin colony; $MSY = 0.4 \times M \times B$). The mortality rate for pink coral ($M=0.066$) is used as a proxy for other species. Values for species with sufficient information to estimate MSY are summarized in Table 14 below.

Table 14: Estimates of MSY of Precious Corals in the Makapuu Bed

Species (common name)	MSY (kg/yr)	MSY (rounded)	Method of calculation
<i>Corallium secundum</i> (pink)	1,185	1,000	Beverton and Holt Cohort production model
<i>Corallium secundum</i> (pink)	1,148	1,000	Gulland model
<i>Gerardia</i> spp. (gold)	313	300	Gulland model
<i>Lepidisis olapa</i> (bamboo)	285	250	Gulland model

Harvest quotas for Hawaii’s four Conditional Beds have been extrapolated (see Table 15), based on bed size as compared to that of the Makapuu Bed. The harvest quotas represent OY values and are based on extrapolations from the rounded down MSY values for the Makapuu Bed.

MSY has also been estimated to correspond to a 30 percent SPR level to maintain 30 percent of the spawning stock biomass. The Council currently manages at the MSY level. From the mid-1960s to late 1970s, annual landings from the Makapuu bed averaged 685 kg (below the MSY of

1,000 kg). No known harvesting of precious corals has occurred in the U.S. EEZ for the past 20 years. The 1997 resurvey found that pink coral in the Makapuu bed has recovered to 74-90 percent of its pristine biomass, while recruitment of gold coral is low.

Table 15: Precious Coral Harvest Quotas

Type of coral bed	Name of coral bed	Harvest quota in kilograms	Number of years
Established Beds	Auau Channel	Black: 5,000	2
	Makapuu	Pink: 2,000	2
		Gold: 0 (zero) Bamboo: 500	-- 2
Conditional Beds	180 Fathom Bank	Pink: 222	1
		Gold: 67	1
		Bamboo: 56	1
	Brooks Bank	Pink: 17	1
Gold: 133 Bamboo: 111		1 1	
Kaena Point	Pink: 67	1	
	Gold: 20 Bamboo: 17	1 1	
Keahole Point	Pink: 67	1	
	Gold: 20 Bamboo: 17	1 1	
Refugia	Westpac	All: 0 (zero)	--
Exploratory Areas	Hawaii, American Samoa, Guam, CNMI, U.S. Pacific Remote Island Areas	1,000 per area (all species combined except black corals)	1

Notes:

1. The final rule implementing the FMP lists the harvest quota for pink coral at Brooks Bank as 17 kg. This is a typographical error; the correct harvest quota is 444 kg.
2. No fishing for coral is authorized in refugia.
3. A moratorium on gold coral harvesting is in effect through June 30, 2013.

Measures to Address Overfishing and Overfished Stocks

At present no stocks of precious corals have been determined to be overfished and overfishing does not appear to be occurring. The provisions of the Precious Corals FMP, including minimum sizes and harvest quotas, are sufficient to prevent overfishing and these measures are carried over

into this FEP. Precious coral beds are classified as Established (with fairly accurate estimated harvest levels), Conditional (with extrapolated MSY estimates) and Refugia (reproductive reserves or baseline areas). Exploratory Areas are all other EEZ waters and are available for harvesting with an Exploratory Permit, subject to the above quotas.

3.1.4.13 Regulations Implementing International Recommendations and other Applicable Laws

As a signatory to the Convention on International Trade in Endangered Species (CITES), the United States is required to abide by regulations include in this international agreement. CITES includes regulations on international trade of endangered species through import and export permits. Currently, Black Coral is listed as an Appendix II species, which requires an export permit for international commercial trade. *Corallium* (Red/Pink corals) continues to be proposed as an Appendix II species and may end up on the list in the near future.

3.1.4.14 Bycatch

Allowable harvest gear are selective (i.e., with submersibles or by hand), and so federal precious coral fisheries in Hawaii have no bycatch associated with them.

3.1.4.14.1 Standardized Reporting Methodology

Disposition of precious corals caught and released in the precious coral fishery is recorded through trip reporting as required by the State CML and Federal Precious Corals permit.

3.1.4.15 Precious Corals Essential Fish Habitat

In the Hawaiian Islands, precious coral beds have been found only in the deep interisland channels and off promontories at depths between 300 and 1,500 meters and 30 and 100 meters. There are currently eight known beds of pink, gold, and bamboo corals including Keahole Point, Makapu'u, Ka'ena Point, Wespac, Brooks Bank, and 180 Fathom Bank; and two recently discovered beds, one near French Frigate Shoals in the NWHI, and a second on Cross Seamount, approximately 150 nm south of Oahu. The approximate areas of six of these eight beds have been determined. These beds are small; only two of them have an area greater than 1 km², and the largest is 3.6 km² in size. The Keahole Bed off Hawaii's Kona coast, however, is substantially larger than originally thought. Scientists and industry are currently assessing its actual size. Initial calculations appear to increase its size twenty-fold. There are also three known major black coral beds in the Western Pacific Region, in addition to several minor beds (Grigg 1998). Most of these are located in Hawaii's state waters (0-3 nm). However the largest (the Auau Channel Bed) extends into federal waters.

Makapuu is the only bed that has been surveyed accurately enough to estimate MSY. The Wespac bed, located between Necker and Nihoa Islands in the NWHI, has been set aside for use in baseline studies and as a possible reproductive reserve. The harvesting of precious corals is prohibited in this area. Within the Western Pacific Region, the only directed fishery for precious corals has occurred in the Hawaiian Islands. At present, there is no commercial harvesting of precious corals in the EEZ, but several firms have expressed interest.

Precious corals may be divided into deep- and shallow-water species. Deep-water precious corals are generally found between 350 and 1,500 meters and include pink coral (*Corallium secundum*),

gold coral (*Gerardia* spp. and *Parazoanthus* spp.), and bamboo coral (*Lepidisis olapa*). Shallow-water species occur between 30 and 100 meters and consist primarily of three species of black coral: *Antipathes dichotoma*, *Antipathes grandis*, and *Antipathes ulex*. In Hawaii, *Antipathes dichotoma* accounts for around 90 percent of the commercial harvest of black coral, and virtually all of it is harvested in state waters.

Precious corals are non-reef building and inhabit depth zones below the euphotic zone. They are found on solid substrate in areas that are swept relatively clean by moderate-to-strong (> 25 cm/sec) bottom currents. Strong currents help prevent the accumulation of sediments, which would smother young coral colonies and prevent settlement of new larvae. Precious coral yields tend to be higher in areas of shell sandstone, limestone, and basaltic or metamorphic rock with a limestone veneer.

Black corals are most frequently found under vertical drop-offs. Such features are common off Kauai and Maui in the MHI, suggesting that their abundance is related to suitable habitat (Grigg 1976). Off Oahu, many submarine terraces that otherwise would be suitable habitat for black corals are covered with sediments. In the MHI, the lower depth range of *Antipathes dichotoma* and *A. grandis* coincides with the top of the thermocline (ca. 100 m; Grigg 1993).

Pink, bamboo, and gold corals all have planktonic larval stages and sessile adult stages. Larvae settle on solid substrate where they form colonial branching colonies. The length of the larval stage of all species of precious corals is unknown. Like other cnidarians, black corals have life cycles that include both asexual and sexual reproduction. Asexual reproduction (budding) builds the colony by adding more living tissue that, in turn, secretes more skeleton. Regular growth rings laid down as the skeleton thickens can be used to estimate the age of the colony. Sexual reproduction involves the production of eggs and sperm to create young that can disperse and settle new areas. Polyps are either male or female, but a single colony may be hermaphroditic, with both male and female polyps. The larval stage, called a planula, can drift with currents until a suitable surface is found. Once the larva settles, it metamorphoses into a polyp form and secretes skeletal material that attaches it to the seafloor. Then it begins budding, creating more polyps that will form a young colony. Asexual reproduction can also occur naturally by fragmentation of branch ends. In one Hawaiian species that have been studied (*A. dichotoma*), the colony may grow about 2.5 inches (6.4 cm) per year. Reproductive maturity may be reached after 10 to 12 years and reproduction may occur annually. A large six-foot (1.8 m) tall coral tree is estimated to be between 30 and 40 years old; a colony life span may be 70 years. Some species may live even longer.

On Hawaii's deep reef slopes and throughout the world, black corals host unique communities of marine life. Their tree-like colonies create habitat for crustaceans, bivalves, and fish. Each coral may host a different combination of species. Some residents are commensals --dependent partners that live only on the black coral. Many species in this deep reef community are new to science. The habitat sustaining precious corals is generally believed to be in good condition. However, an alien species called snowflake coral, *Carijoa riisei*, has recently begun smothering native deep reef sea life including precious corals. In 2001 deepwater surveys in the Auau Channel found a maximum impact between 70-110 m where more than 50 percent of black corals had snowflake coral overgrowth (Kahng and Grigg 2005). A second survey in 2006

reexamined conditions in the Auau Channel and found that the impact of snowflake corals had not worsened and it was possible that conditions in some areas had stabilized or improved. This led researchers to conclude that the ecological impact of snowflake coral on black corals may have stabilized or possibly abated slightly (Kahng 2007).

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council designated EFH for precious coral assemblages. The species complex designations are deep- and shallow-water complexes. The designation of these complexes is based on the ecological relationships among the individual species and their preferred habitat.

3.1.4.15.1 Description and Identification of EFH

The Council considered using the known depth range of individual PCMUS to designate EFH, but rejected this alternative because of the rarity of the occurrence of suitable habitat conditions. Instead, the Council designated the six known beds of precious corals as EFH. The Council believes that the narrow EFH designation will facilitate the consultation process. In addition, the Council designated three black coral beds in the MHI—between Milolii and South Point on Hawaii, Auau Channel between Maui and Lanai, and the southern border of Kauai—as EFH.

3.1.4.15.2 Identification of Habitat Areas of Particular Concern

The Council designated three of the six precious coral beds—Makapuu, Wespac and Brooks Bank—as habitat areas of particular concern. Makapuu bed was designated as HAPC because of the ecological function it provides, the rarity of the habitat type, and its sensitivity to human-induced environmental degradation. The potential commercial importance and the amount of scientific information that has been collected on Makapuu bed were also considered. Wespac bed was designated as HAPC because of the ecological function it provides and the rarity of the habitat type. Its refugia status was also considered. Brooks Bank was designated HAPC because of the ecological function it provides and the rarity of the habitat type. Its possible importance as foraging habitat for the Hawaiian monk seal was also considered. For black corals, the Council designated the Auau Channel as HAPC because of the ecological function it provides, the rarity of the habitat type and its sensitivity to human-induced environmental degradation. Its commercial importance was also considered.

3.2 Northwestern Hawaiian Islands Fisheries

Archaeological evidence indicates that the Northwestern islands in the Hawaiian Archipelago were settled as far back as 1000 AD, and evidence of fishing has been found. Throughout this period, up until the 20th Century, the NWHI was a well-utilized fishing area, from the Native Hawaiians to western sailing ships, and later directed fishing operations for pearl oysters, coral reef fish, bottomfish and crustaceans. Large commercial fishing in the NWHI didn't occur until after World War II, including foreign fishing from Japan and the Soviet Union, until the passing of the FCMA in 1976. More recently, the issuance of Executive Orders 13178 and 13196 and the subsequent Presidential Proclamations 8031 and 8112 have closed the fisheries within 50 nm around the NWHI. The following sections provide a description of the NWHI fisheries that have or have been known to occur.

3.2.1 NWHI Bottomfish Fishery

For management purposes, the NWHI fishery was separated into sub-management zones in 1989, the closer open-access Mau Zone between 165° W and 161°20' W, and the more northwestern limited entry Ho‘omaluku Zone to the west of 165° W. The entire NWHI bottomfish fishery occurred within Federal waters as fishing was prohibited in State waters. All vessels were required to carry active vessel monitoring systems. The NWHI bottomfish fishery closed in June 2011, in accordance with the provisions of the Papahānaumokuākea Marine National Monument, which was established in the NWHI through Presidential Proclamation No. 8031 on June 15, 2006. Bottomfish fishing in the NWHI was conducted solely by commercial fishermen, and the vessels used tend to be larger than those fishing around the MHI, as the distance to fishing grounds is greater. Participation in the NWHI bottomfish fishery was controlled through limited access programs in each of the two management zones (Ho‘omaluku zone in 1989 and Mau zone in 1999). These zones were established to reduce the risk of biological overfishing and to improve the economic health and stability of the bottomfish fishery in the NWHI. The NWHI fishery provided nearly half of the bottomfish sold in the market in Hawaii annually. The programs provided for a limited number of federal fishing permits to be issued each calendar year. Permits could not be sold, leased, or chartered. Based on the biological, economic, and social characteristics of the bottomfish fisheries in the two zones, the long-term target fleet sizes for the Ho‘omaluku and Mau Zones was determined to be seven and ten vessels, respectively. Through attrition and the inability to re-issue lapsed permits, on four vessels fished in the Ho‘omaluku Zone, and four fished in the Mau Zone in 2006. All of these vessels were independent, owner-operated fishing operations.

Figure 4 provides the Council’s zones for bottomfish fishing, noting the split of the NWHI into the Mau and Ho‘omaluku Zones. The figure also includes restricted fishing areas in both the NWHI and MHI due to various regulations including the Papahānaumokuākea Marine National Monument.

Federal permits are required for any vessel fishing for bottomfish MUS in the NWHI Subarea and the permit must be registered for use with the vessel, outside of the Monument boundaries. Also, to reduce the number and impact of potential protected species interactions in the NWHI bottomfish fishery, primary and relief operators (captains) in the NWHI limited access program are required to complete a one-time protected species workshop. For more on bottomfish fishing regulations in the NWHI, see Appendix C.

Seamount Groundfish in the NWHI

The seamount bottom trawl fishery for armorhead was initiated by trawlers of the former Soviet Union in November 1967; the Japan trawl fleet entered this fishery in 1969. This fishery initially focused on the northern large tablemount seamounts (Koko, Yuryaku, N. Kammu, and S. Kammu) of the southern Emperor Seamount chain. The fishery soon expanded southward to encompass the much smaller northern Hawaiian Ridge guyot type seamounts including Colahan, C-H, and the Hancock Seamounts. By the end of 1975, the combined catches of the former Soviet and Japan trawl fleet had reached some 1 million mt of armorhead harvested from the SE-NHR seamounts. The majority of this catch was harvested from the Milwaukee Seamount Group (Yuryaku and Kammu Seamounts). However, with the steady decline in trawl CPUE after the 1972 peak, the former Soviet Union fleet left the fishery after 1975. The Japan trawl fleet

continues to harvest armorhead on the seamounts outside the U.S. EEZ. Current and historic catch and effort data has relied on the commercial data of the Japan trawl fleet; useful data from the former Soviet trawl fleet remains unavailable. From the inception of this fishery to the present, U.S. fishermen have never participated in the seamount armorhead trawl fishery.

The inclusion in 1977 of the southernmost seamounts of the SE-NHR (i.e., Northwest and Southeast Hancock Seamounts) into the U.S. EEZ allowed for a small portion (> 5%) of the historic fishing grounds to be managed in a limited way. A Preliminary Management Plan was developed that year which provided for limited foreign harvesting at the Hancock Seamounts under a permit system during 1978-1984. Japan trawlers were the only vessels to apply for such permits and were subject to a combined annual harvest quota of 1,000 mt and required to carry a U.S. fishery observer aboard each permitted vessel. By the end of 1984, armorhead trawl catches remained low with harvest quotas never attained in any of the years during 1978-1984. Subsequently, under the bottomfish and seamount groundfish FMP, a 6-year fishing moratorium was imposed on the Hancock Seamounts in 1986. Beginning in 1985, the National Marine Fisheries Service Honolulu Laboratory began a series of stock assessment cruises to the Hancock Seamounts to monitor and assess armorhead abundance. These research cruises focused on Southeast (SE) Hancock Seamount and were conducted using bottom longline gear as opposed to trawl operations. This was necessary due to our limited trawl capabilities and the advantage that bottom longline gear offered in extending the sampling over irregular terrain that allowed the entire population to be sampled. The last assessment cruise was conducted in 1993; a total of 12 assessment cruises were conducted.

Since 1975, CPUE values have remained depressed which necessitated a moratorium on fishing for armorhead at the Hancock seamount. The fishing moratorium at the Hancock Seamounts remains the only management attempt thus far to enhance the depressed stock levels of armorhead throughout the SE-NHR seamounts and if anything may prove helpful as a “good faith attempt” by our government in any future management discussions with Japan and other participating nations.

3.2.2 NWHI Coral Reef Fishery

The original establishment of the Coral Reef Ecosystem Fishery Management Plan included regulations for no-take Marine Protected Areas in the NWHI. However, due to the establishment of the Papahānaumokuākea Marine National Monument in 2006, there are no active coral reef fisheries in the NWHI.

3.2.3 NWHI Crustaceans Fishery

The NWHI Crustaceans fishery changed over the years in terms of target species and product. Participants in the NWHI lobster fishery used plastic dome-shaped, single-chambered traps with two entrance funnels located on opposite sides. By regulation, all traps must have escape vents to allow unwanted organisms to exit. The traps are typically fished in strings of several hundred that are set before sunset in depths from 20 to 70 meters, and retrieved the next day. Both spiny and slipper lobsters may be caught in the same trap, but fishermen can affect the proportion of each species by selecting the trapping area and depth (Polovina 1993).

In the early years of the fishery (1977-1984) landings consisted mainly of spiny lobsters. However, for a three-year period from 1985 to 1987 the fishery targeted a previously lightly exploited population of slipper lobsters (Polovina 1993). In the mid-1980s, the NWHI lobster fishery was Hawaii's most lucrative fishery (Pooley 1993). Between 1988 and 1997 the target was again spiny lobsters, but the catch in 1998 and 1999 consisted mainly of slipper lobsters. Almost all lobsters harvested from the NWHI were sold as a frozen tails; however, from 1996 to 1998, the fleet also landed a significant quantity of live lobsters.

In 1990 NWHI lobster catch rates fell dramatically, although overfishing is not thought to be responsible for the decline (Polovina and Mitchum 1992). Rather, the decrease was found to be likely due to a climate-induced change in oceanic productivity (Polovina et al. 1994). The proportion of fishing effort and reported catch at each bank within the NWHI varied both spatially and temporally. While as many as 16 banks within the NWHI were fished on an annual basis, the majority of fishing effort was been directed at Maro Reef, Gardner Pinnacles, St. Rogatien, and Necker Island. The NWHI lobster fishery was closed in 2000 because of growing uncertainty in the population models used to assess stock status (DeMartini et al 2003).

The NWHI was historically dominated by spiny lobster (*Panulirus marginatus*) with a lower density of slipper lobster (*Scyllarides squammosus*). An oceanic regime shift may have caused a switch in the species dominance in the early 1990s, but the commercial fishery, combined with the spatial structure of the lobster populations and larval transport, may have played a large role in this switch as well (DiNardo 2004).

In 2001, Executive Orders 13178 and 13196 declared the NWHI a Coral Reef Ecosystem Reserve and essentially ended commercial harvest of lobsters in the NWHI. Subsequent to those EO, a Presidential Proclamation in 2006 established the Papahānaumokuākea Marine National Monument which prohibited all crustacean fishing within 50 miles of the NWHI. The designation of the Monument essentially closed the NWHI fishery as under the monument's regulations the annual harvest guideline was set at 0 lbs. until 2011, at which point commercial fishing was prohibited in the Monument.

While the Monument did close waters within 50 nm to fishing, the waters outside are still subject to the Hawaii Archipelago FEP management measures, including management areas, gear restrictions, and other measures. For more information on NWHI crustacean fishery management measures, see Appendix C.

3.2.4 NWHI Precious Coral Fishery

While there have been no targeted fishing for precious corals in the Northwestern Hawaiian Islands (NWHI), there have been impacts to precious corals from mobile bottom-tending gear in the Emperor Seamount Chain (including Hancock Seamount) from foreign fisheries (Parrish et al, 2009). The interest in harvest of precious corals in the area resulted in the council designated WESTPAC Bank as a Precious Coral refugia to be set aside from harvesting in the NWHI, due to the abundance of *Corallium*. However, domestic harvest has never occurred in the NWHI and with the establishment of the NWHI Coral Reef Ecosystem Reserve through Executive Order (13178 and 13196) in 2001 and a Presidential Proclamation in 2006 establishing the

Papahānaumokuākea Marine National Monument, precious coral fishing was prohibited within 50 miles of the NWHI.

Although the Monument did close waters within 50 nm to fishing, the waters outside are still subject to the Hawaii Archipelago FEP management measures, including management areas, gear restrictions, and other measures. For more information on NWHI precious coral fishery management measures, see Appendix C.

3.3 Small Boat Pelagic Fisheries

The largest, non-pelagic longline fishery in the Hawaiian archipelago is the small-boat pelagic fleet. These fishermen utilize handline, troll, and other rod-and-reel methods that fish for offshore pelagic species such as tunas, mahimahi, wahoo and marlin. This fishery has deep connections to Hawaii's fishing communities and the social and cultural fabric of the islands. The pelagic troll fishery accounts for the majority of the commercial fishing licenses in Hawaii and is the second largest commercial fishery (averaging over 3 million pounds caught per year). Between 2003 and 2013, there was an average of 1,535 commercial fishermen who fished for an average of over 29,000 days fished combined. During the same period, there was an average of 468 fishers that fished a combined average of 4,639 days, and 11 offshore handline fishers that fished 276 days. The non-commercial catch and effort is unknown but likely to be equal to, or greater than that of, the commercial fishery.

Pelagic trolling may be employed by the bottomfish fishing vessels, and other fisheries, as they transit to bottomfish fishing grounds in the MHI. Because of the distance from populated areas, the only small boat pelagic fishing done in the NWHI occurred at Midway through the US Fish and Wildlife Service. Effort and catch was very minimal. Small boat pelagics fisheries are regulated under the Council's Pacific Pelagic Fishery Ecosystem Plan and detailed information about them can be found in that FEP or the Pelagic Fishery Ecosystem Annual Report (SAFE Report).

3.4 Other Information Necessary for FEP Implementation

3.4.1 Sociocultural Data

Fishing culture and fishing dependence in Hawaii and the other U.S. Pacific islands are unique and distinct from a national perspective. Islanders have relied heavily on fishery resources to sustain themselves and their cultures for millennia. The ecosystem-based fishery management recognizes and attempts to manage for the interconnectedness of biological, ecological, geological, and social management dimensions. For many in islands communities, a fishery is social system that includes fish as well as fishermen, their families and friends, and, in the case of more commercialized fisheries, the associated support infrastructure and industry. Even those who buy and eat fish on a regular basis might be thought of as being part of a fishery.

Because of the importance of managing fishery resources as public trust, and because of the cultural uniqueness of the Pacific Islands, the Council has established several elements in its management process to incorporate science-based social data and traditional ecological knowledge. In fact, the Council from its inception has been very sensitive to traditional and indigenous fishing issues and considerations, and the Council's Guiding Principle #4 is to

“recognize the importance of island cultures and traditional fishing practices in managing fishery resources and foster opportunities for participation.” These issues include ensuring fishermen participation in setting ACLs, preserving indigenous way of life, navigating the relationship between federal processes and requirements and local custom and norms, and the dependence, on nearshore and pelagic resource, even in the modern era.

These process elements include formal social science input science the late 1980s via social science recommendations to the newly-established Pelagic Fisheries Research Program, and SSC subcommittee on social science, and a Council Cultural and Social Science Research Plan. In 1988, the Council spearheaded a request for proposals focused on native fishery rights issues and was instrumental in getting a Western Pacific Community Development Program and Plan included in 1996 reauthorization of the MSA. Following and in response to that, the Council established a Community Development Planning Committee. This committee is utilized under this FEP to assist with addressing Marianas Archipelago FEP Objective: Increase Traditional and Local Knowledge in Decision-making.

In Hawaii, the Council has encouraged, supported, and sometimes spearheaded efforts to reintroduce or strengthen traditional resource management ethos and/or practices. These include sponsoring a series of conferences (Puwalu) in the mid-2000s to bring together ahupua‘a practitioners to discuss a community and cultural consultation process. The Council also supported an outgrowth of the Puwalu series: a resolution to uphold and continue Hawaiian traditional practices through konohiki management, the kapu system, and the creation of an ‘aha moku and ahupua‘a management system – a site-specific and resource-based methodology to sustain healthy thriving communities based on Native Hawaiian generational knowledge. Finally, the Council has supported several individual projects such as the creation of lunar calendars, fishing koa identification, and the Hōkūle‘a Mālama Honua Worldwide Voyage.

Between 1999-2002, the Council worked to have the Secretary of Commerce formally designate fishing communities in American Samoa, the CNMI, Guam, and Hawaii under the MSA’s fishing communities provision (National Standard 8) for the purposes of assessing the effects of fishery conservation and management measures on fishing communities, providing for the sustained participation of such communities, and minimizing adverse economic impacts on such communities. To date, ours is the only region that has done so. Fishing communities so designated in Hawaii are: Kauai, Niihau, Oahu, Maui, Molokai, Lanai, and Hawaii.

In 2002, the Council established a formal Social Science Research and Planning Committee (known now as the Social Science Committee). Among other things, this Committee vets social science information needs as part of the Council’s identification of fishery research priorities. During the mid-2000s, as it worked to transition to ecosystem-based fishery management planning, the Council conducted a series of ecosystem planning workshops, including one dedicated to sociocultural considerations. The Council has used the recommendations from this workshop to improve the incorporation of social science in the management process.

Finally, the Council works to address sociocultural considerations via its “SEEM” process and its annual fishery (SAFE) reports. The SEEM assessment quantifies social, economic, and ecological factors, as well as management uncertainty dimensions and SEEM working groups

thus recommend whether the ACL is set equal or lower than the ABC based on these considerations. The Council's annual/SAFE report was overhauled in 2015 to monitor a host of social variables.

To assist in identifying and analyzing sociocultural impacts on fisheries, the WPRFMC employs both an Indigenous Coordinator and a Social Scientist.

3.4.2 Protected Species Information

Bottomfish, precious coral, coral reef and crustacean fisheries managed under this FEP have limited impacts to protected species, and no specific regulations are in place to mitigate protected species interactions. Destructive gear such as bottom trawls, bottom gillnets, explosives and poisons are prohibited under this FEP, and these provide benefit to protected species by preventing potential interactions with non-selective fishing gear.

NMFS has determined that the bottomfish fishery operating under the Hawaii FEP is likely to adversely affect but not likely to jeopardize green sea turtles and are not likely to adversely affect other ESA-listed sea turtles, marine mammals (including Hawaiian monk seals and cetaceans), seabirds. All other fisheries operating under the Hawaii FEP are not likely to adversely affect ESA-listed sea turtles, marine mammals, and seabirds. The current list of ESA Section 7 consultations applicable to this FEP are listed in the archipelagic annual fishery report (SAFE Report). NMFS will reinitiate consultation if a new species is listed or critical habitat is designated that may be affected by Hawaii FEP fisheries. These fisheries are not known to interact with non-ESA listed marine mammals or seabirds.

Fisheries operating under the Hawaii FEP currently do not have federal observers on board. The NWHI component of the bottomfish fishery had federal observer coverage from 2003 to 2005. The Council monitors protected species interactions in the Hawaii FEP fisheries in the archipelagic annual fishery report (SAFE Report).using other proxy indicators such as fishing effort and changes in gear types.

3.4.3 Climate Change and Marine Planning

3.4.3.1 Climate Change

Changing climate is already adversely impacting island communities, ecosystems, resources, cultures and economies. Increasing pressures on valuable marine and coastal habitats and resources due to changing demands for food, energy, economic growth and community sustainability make climate change an issue of community, national and regional security. In addition to economic considerations such as commercial fisheries, Pacific Island communities must address threats to culturally important species and places as well as community health and food security. Ultimately, for many low-lying coral atoll nations, climate change is a direct threat to national security as rising sea level and changes in the availability of freshwater may make at least some of those nations uninhabitable. To escape these impacts, human migration is anticipated.

The *Executive Summary of the 2012 Pacific Islands Regional Climate Assessment (PIRCA)* notes that the indicators of climate change suggest multiple concerns for human and natural

communities in the Pacific Islands region: decreased freshwater supplies, especially on atolls and low-lying islands; increased coastal flooding and erosion; increased coral bleaching; unknown, negative consequences for the entire marine ecosystem; declines in open-ocean fisheries; increased risk of species extinctions; threats to the traditional lifestyles of indigenous communities making it difficult for Pacific Island communities to sustain their connection with a defined place and their unique set of customs, beliefs, and languages; and human migration from low islands to high islands and continental sites.

At its 157th meeting in June 2013, the Council restructured its Coastal and Marine Spatial Planning (CMSP) Committee into a Marine Planning and Climate Change (MPCC) Committee. The MPCC Committee advises the Council on new and developing research and happenings related to marine planning and climate change as it relates to Western Pacific fisheries, provides input on Council actions and associated analyses and documents as it relates to marine planning and climate change, and recommends research and program priorities, including outreach and education, to address marine planning and impacts of climate change in fisheries and fishing communities. The Committee includes up to 20 members, including at least three representatives each from Hawaii, American Samoa, Guam and the Commonwealth of the Northern Mariana Islands (one of the three is a community representative), three members representing the federal government and an ecosystem modeler. The basic criteria for Committee membership is expertise and interest in marine planning and climate change, with a focus on fisheries and fishing communities. Members of the Committee are selected by the Council and serve three-year terms.

In 2015, the Council adopted the MPCC Policy and action plan drafted by the MPCC Committee. The definition of climate change included in the MPCC Policy is the one used by the Intergovernmental Panel on Climate Change, which includes natural climate variability such as El Niño Southern Oscillation and other patterns of natural variability as well as long-term changes in climate associated with anthropogenic (human) influence on greenhouse gases and other aspects of the Earth's climate system. The definition of climate change in the Council's MPCC policy also includes ocean acidification. The MPCC policy notes that, in the Pacific Ocean, anticipated climate change impacts include ocean acidification; changing migratory patterns of tuna, other commercially valuable stocks and protected species, among other species; changes in coastal and marine habitats with associated changes in socially, culturally and economically valuable coastal fisheries and other sources of ocean economy; changing patterns of El Niño and other patterns of climate variability; changes in water level including, but not limited to sea level change, increased severity of extreme weather, coral reef changes; and human migration, among others. The MPCC policy recognizes a set of overarching and specific principles and specific policy points for the Council, its advisory bodies and its staff to consider and incorporate in the Hawaii Archipelago FEP as well as in Council programs and other actions. The policy can be found on the Council's website.

The Council's MPCC Action Plan prioritizes and provides guidance on implementing climate change measures adopted by the Council, including items related to climate change research and data needs.

A working group of the MPCC Committee, with additional support from PIFSC, tentatively identified climate indicators to monitor initially for the annual reports on the Council's FEPs. This work was completed by the Council's 2015 restructured Plan Team. The Plan Team members responsible for the climate change modules determined that each 2015 annual report would include 10 preliminary climate change indicators. Preliminary Climate Indicators for 2015 Archipelagic Annual Reports include a) atmospheric Concentration of CO₂; b) ocean pH; c) Oceanic Nino Index; d) Pacific Decadal Oscillation (PDO); e) Sea Surface Temperature and anomaly; f) Sea Surface Height and anomaly; g) ocean pH; h) bad/extreme weather (including lulls); i) wave data; and j) near-surface wind velocity. The Plan Team members discussed including additional climate change indicators in future annual reports such as sea level pressure for the Archipelagic Annual Report.

The WPRFMC is working with its MPCC Committee to hold community meetings to garner feedback on the annual reports and other public input related to the region's climate change needs, knowledge and impacts, including potential climate change impact indicators, such as socioeconomic indicators.

To identify the climate change impact indicators to be monitored in the Hawaii Archipelago, the Council intends to work with the Hawaii Department of Land and Natural Resources and Hawaii Office of State Planning, Coastal Zone Management, as well as community members, schools and policymakers in the Territory.

In addition to the FEPs, themselves, climate change issues are incorporated, by process, into annual catch limit specifications, amendments to the FEPs and elements in the plans, such as the threatened status of the green sea turtle.

3.4.3.2 Marine Planning

In the Hawaii Archipelago, fisheries compete with other activities for fishing grounds and access to them. These activities include, but are not limited to, military bases and training activities, commercial shipping, marine protected areas, recreational activities and off-shore energy initiatives.

Marine planning is a tool utilized regionally, nationally and globally to identify and address issues of multiple human uses, ecosystem health and cumulative impacts and is a component of the National Ocean Policy. Since 2010, CMSP has been the focus of several of the Council's advisory body meetings and outreach activities. During this time, the Council also began transforming its Marine Protected Area Committee first into a CMSP Committee and then into the current Marine Planning and Climate Change Committee (see above for details on the Committee).

In 2015, the Western Pacific Regional Fishery Management Council adopted its MPCC Policy, which was drafted by the Council's MPCC Committee. The policy uses the definition of marine planning as defined in the National Ocean Policy Implementation Plan. The MPCC policy

recognizes a set of overarching and specific principles and specific policy points for the Council, its advisory bodies and its staff to consider and incorporate in the Hawaii Archipelago FEP as well as in Council programs and other actions. The policy notes that marine planning can be used to determine ocean management priorities across jurisdictions and identify common objectives. The MPCC Policy recognizes that traditional resource management systems, such as the `Aha Moku, can provide an appropriate context for marine planning. A key component of the policy is collaboration with existing organizations in data and information collection, dissemination and outreach. The Council intends to work with the Hawaii Department of Land and Natural Resources, Hawaii Office of State Planning and the Pacific Islands Regional Planning Body, as well as community members, the private-sector, schools, policymakers and others in the State. The MPCC Policy can be found on the Council's website, www.wpcouncil.org. The Council's Plan Team (restructured in 2015) includes a marine planning expert, and a section on marine planning is included in the Hawaii Archipelago FEP annual reports.

3.4.4 Aquaculture

Aquaculture is a growing industry in the U.S. producing an ever-increasing proportion of marine consumer products once solely harvested from the wild. NMFS defines aquaculture as the propagation and rearing of aquatic organisms for any commercial, recreational, or public purpose. In the Pacific it has evolved into a multi-million dollar industry producing a range of marine products including algae, pearls, and fish. In the twentieth century, most aquaculture in the U.S. was conducted at land-based facilities and was focused on freshwater species. Technical innovations, declines in wild marine stocks, and greater demand for seafood have led to a recent expansion of the industry into marine environments.

The Council and NMFS are responsible for managing fisheries in federal water and NOAA determined that aquaculture is included in the definition of "fishing" under the Magnuson-Stevens Fishery Conservation and Management Act (MSA)⁹. This designation provides the statutory authority for NMFS and the regional fishery management councils (FMCs) to regulate aquaculture projects in federal waters. NMFS and the FMCs are just beginning to establish management plans for aquaculture activities. In 2009, The Gulf of Mexico FMC established the first fishery management plan for offshore aquaculture. That same year, the Council voted to consider including management measures for offshore aquaculture in the FEPs at its 146th Meeting in October 2009.

The WPRFMC defines aquaculture as the raising and cultivation of plants or animals, both freshwater and marine, for food or other purposes. Aquaculture, as defined by the Council, includes fish farming, fish culturing, ocean ranching, and mariculture. The Western Pacific Regional Fishery Management Council recognizes that aquaculture is a rapidly developing industry in the Western Pacific Region as well as the rest of the world, and that aquaculture

⁹ A 1993 legal opinion issued by NOAA's General Counsel supports the agency's position that the MSA confers authority on the Council and NMFS to manage aquaculture activities (NOAA Aquaculture Policy Statement June 2011).

presents both potential benefits and potential negative impacts to the environment and society. The Council's Aquaculture Policy can be found at the Council's website, www.wpcouncil.org.

Currently, there are two aquaculture projects on-going in waters around Hawaii (in State waters) with more being planned. As the number and size of similar projects increase, NMFS and the Council must ensure that these endeavors are environmentally sustainable.

3.4.5 Fishing Rights of Indigenous People

The Council addresses the economic and social consequences of militarization, colonization and immigration on the aboriginal people in its area of responsibility and authority through its FEPs. Generally, the resultant cultural hegemony has manifested in poverty, unemployment, social disruption, poor education, poor housing, loss of traditional and cultural practices, and health problems for indigenous communities. These social disorders affect island society. Rapid changes in the patterns of environmental utilization are disruptive to ecological systems that developed over millennia into a state of equilibrium with traditional native cultural practices. The environmental degradation and social disorder impacts the larger community by reducing the quality of life for all island residents. The result is stratification along social and economic lines and conflict within the greater community.

The primary process for the indigenous community to formally participate in the Council process is through their participation in the Advisory Panel discussions. Grant workshops and other Council public fora provide additional opportunity for the indigenous community to participate in the Council process. The Council has sponsored the Ho'ohanohano I Nā Kūpuna (Honoring our Ancestors) conference series in partnership with the Association of Hawaiian Civic Clubs (AOHCC) and in consultation with the native Hawaiian community. The conference received the support of the Kamehameha Schools/Bishop Estate, Office of Hawaiian Affairs, various departments of the State of Hawaii, the Hawaii Tourism Authority and numerous community organizations and projects throughout the State of Hawaii. Fishery ecosystem management provides the Council with the opportunity to utilize the *mana'o* (thoughts) and *'ike* (knowledge) of our *kūpuna* (elders) – ideas and practices that have sustained *nā kanaka maoli* (native Hawaiian) culture for millennia.

The conference series was initiated by the Council to engage the Kanaka Maoli community in the development of the Hawaiian Archipelago FEP and to increase their participation in the management of fisheries under the FEP's authority. A series of workshops with the Kanaka Maoli community to promote the concept of ahupua'a (traditional natural resource unit) management began in 2003 through the AOHCC. This endeavor was continued by the Council in order to take the ahupua'a concept to the next level, the development of a process to implement traditional resource management practices into today's management measures.

Under the Hawaiian Archipelago FEP, this conference series will continue in Hawaii and will subsequently be extended to the other areas of the Western Pacific Region. Although the specific format will be tailored to each area's cultures and communities, in all cases the Council will seek to increase the participation of indigenous communities in the harvest, research, conservation and management of marine resources as called for in Section 305 of the MSA.

There are two programs specifically mandated by the MSA for these communities to participate in the Council process: the Western Pacific Community Development Program and the Western Pacific Community Demonstration Project Program.

3.4.5.1 Western Pacific Community Development Program

The Western Pacific Regional Fishery Management Council (Council), since its inception, has continuously worked on issues related to indigenous fishing rights for Pacific Islanders. In 1996, amendments to the Magnuson-Stevens Fishery Conservation and Management Act recognized special fishing practices for native peoples in American Samoa, Guam, Hawaii and the Northern Mariana Islands in part through establishment of the Western Pacific Community Development Program (CDP). The CDP was further defined in the 2006 reauthorization of the MSA (MSRA). In developing the criteria for eligible communities provisions of the MSRA mandate that the Council shall base the criteria on “traditional fishing practices in or dependence on the fishery, the cultural and social framework relevant to the fishery, and economic barriers to access to the fishery.”

The CDP was established with broad latitude in program development and implementation. The Western Pacific CDP provides flexibility in the method by which benefits can be delivered to indigenous communities. Because of the program’s flexibility, different implementing approaches have been used to date. There is potential for a broad variety of community initiatives to come forward for consideration under the CDP, therefore, to facilitate the process the Council seeks to establish a standard procedure to receive, review, approve and implement future CDP initiatives. In addition, CDP initiatives may include the need to provide access to fisheries which would otherwise be restricted.

A community is eligible to participate in a western Pacific community development program and submit a Project proposal if they meet criteria developed by the WPRFMC and approved by the Secretary. The criteria and regulations for the CDP can be found in Appendix C.

3.4.5.2 Western Pacific Community Demonstration Project Program

The Community Demonstration Project Program (CDPP) is a grant program. The Council has an advisory panel which reviews and ranks proposals and forwards to the Council for approval and transmittal to the Secretary of Commerce.

The purpose of the Western Pacific Demonstration Project Program is to promote the involvement of western Pacific communities in fisheries by demonstrating the application and/or adaptation of methods and concepts derived from traditional indigenous practices. Projects may demonstrate the applicability and feasibility of traditional indigenous marine conservation and fishing practices; develop or enhance community-based opportunities to participate in fisheries; involve research, community education, or the acquisition of materials and equipment necessary to carry out a demonstration project.

To support this program, region wide grant application trainings and workshops are conducted by the Council. These workshops also provide a forum for the community to make recommendations and participate in the Council process. The Council develops the funding priorities.

4 MANAGEMENT PROCESS

4.1 Council Process

4.1.1 Overview of Council Process

The Council process to develop or change regulations involves many stages and includes many steps and opportunities for public input and comment. The Council considers proposals, options papers, draft amendment documents, National Environmental Policy Act analysis documents, and eventually votes on preferred alternatives, which may result in regulations at the end of the process.

The Council generally follows this process:

- An issue is brought to the Council's attention – presented from the public, an advisory body, or other avenue;
- The Council reviews the issue and decides whether to initiate an analysis of alternatives;
- If such an analysis is initiated, then:
 - Council staff develops alternatives, analysis and other needed documents for review;
 - There is a review by the Council, its advisory bodies and the public; and
 - The Council may select a preferred alternative, initiate further analysis or decide on no further action.
- After a preferred alternative is selected, the Council decision is forwarded to the Secretary of Commerce in the form of a plan or amendment for review and approval; The Secretary of Commerce may do either of the following:
 - Reject the plan/amendment;
 - Approve the plan/amendment;
 - Partially approve the plan/amendment.
- If the plan/amendment is approved, draft rules are published for public comment;
- After the rules are noticed and comments are addressed, a final decision is made by the Secretary of Commerce; and
- If approved, the rules and regulations from the plan/amendment are implemented through the Code of Federal Regulations.
- If the plan/amendment is rejected or partially approved, it is returned to the Council, with rationale for rejection/partial approval, for the Council's consideration.

4.1.1.1 Development and Approval Process for Management Actions

The MSA and OALs set forth specific analytical and procedural requirements that interact with NMFS' and Councils decision-making processes under the MSA. Mandates placed on NMFS, as the federal action agency, are distinct from the requirements pertaining to the activities of the Council, in their role as an advisory body. The Council is not precluded from developing analyses and documentation to support compliance with the OALs; in fact, this practice is recommended. However, legal responsibility for most requirements lies with the NMFS. The Council desires to have as complete analysis and documentation as possible available during its deliberations.

a. MSA Role of the Councils

As set forth in sections 302(h), 303, and 304 of the MSA, Councils are responsible for:

- Conducting public hearings to allow for public input into the development of FMPs and amendments,
- Reviewing pertinent information,
- Preparing fishery management plans and amendments for fisheries requiring conservation and management
- Drafting or deeming regulations to implement the plans or amendments
- Developing ACLs,
- Identifying research priorities, and
- Transmitting complete packages containing documentation necessary for NMFS to initiate a review of compliance with all applicable laws including NEPA.

b. MSA Role of NMFS

As set forth in section 304(a) of the MSA, the role of NMFS with respect to fishery management plans and plan amendments developed by the Council is to review— and approve, disapprove, or partially approve—those plans and amendments in accordance with specified procedures, including:

- Immediately upon transmittal of the FMP or FMP amendment: publish a plan or amendment in the Federal Register for a 60-day comment period.
- Approve, disapprove, or partially approve a plan or amendment within 30 days of the end of the comment period on the plan or amendment. Disapproval must be based on inconsistency with the MSA or other applicable law. In addition, disapprovals must provide guidance on what was inconsistent and how to remedy the situation, if possible (see MSA section 304(a)(3)(A)-(C)).

In addition, as set forth in section 304(b) the role of NMFS with respect to Council-recommended draft regulations is to:

- Immediately upon transmittal of the proposed regulations: initiate an evaluation of whether they are consistent with the fishery management plan, plan amendment, the MSA, and other applicable law.
- Within 15 days make a determination of consistency, and—
 - if that determination is affirmative: publish the regulations for a public comment period of 15 to 60 days; or,
 - if that determination is negative: notify the Council in writing of the inconsistencies and provide recommendations on revisions that would make the proposed regulations consistent.
- Consult with the Council before making any revisions to the proposed regulations,
- Promulgate final regulations within 30 days after the end of the comment period and

publish in the Federal Register an explanation of any differences between the proposed and final regulations.

The MSA, at section 304(c), also authorizes NMFS to prepare a fishery management plan or amendment if:

(a) the Council fails to develop and submit to NMFS, after a reasonable period of time, a fishery management plan for such fishery, or any necessary amendment to such a plan, if such fishery requires conservation and management;

(b) the NMFS disapproves or partially disapproves any such plan or amendment, or disapproves a revised plan or amendment, and the Council involved fails to submit a revised or further revised plan or amendment; or

(c) the NMFS is given authority to prepare such plan or amendment under the MSA. NMFS may also develop regulations to implement Secretarial plans and amendments (MSA section 304(c)(6), (7)).

c. Other Applicable Laws Roles for NMFS and Councils

As described in section D in Appendix 2 of the OG, the OALs set forth a variety of requirements for analysis, documentation, determinations, and procedures. Because of the close relationship between NMFS' actions and the Council's recommendations, compliance with the OALs will be most effective if NMFS and the Councils coordinate closely. The ROAs explain how these relationships work for each Council/Region pair. Council staff can often be responsible for drafting supporting analyses and documentation; however, it is the NMFS' responsibility to ensure the final documents are legally sufficient.

4.1.1.1.1 Specific Elements and their Relationship to Decision-making

The MSA and OALs set forth specific analytical and procedural requirements that interact with NMFS's and the Councils' decision-making processes under the MSA. The mandates on NMFS, as the federal action agency, are distinct from the requirements pertaining to the activities of the Councils, in their role as advisory bodies. Nothing precludes a Council's development of analyses and documentation to support compliance with the OALs, and in fact this practice is recommended. However, ultimate legal responsibility for most requirements lies with NMFS. It is the goal to have as complete analysis and documentation as possible available during Council deliberations.

MSA Role of the Councils

As set forth in sections 302(h), 303, and 304 of the MSA, Councils are responsible for:

- Conducting public hearings to allow for public input into the development of FMPs and amendments,
- Reviewing pertinent information,
- Preparing fishery management plans and amendments for fisheries requiring conservation and management
- Drafting or deeming regulations to implement the plans or amendments
- Developing ACLs,

- Identifying research priorities, and
- Transmitting complete packages containing documentation necessary for NMFS to initiate a review of compliance with all applicable laws including NEPA.

MSA Role of NMFS

As set forth in section 304(a) of the MSA, the role of NMFS with respect to fishery management plans and plan amendments developed by the Council is to review – and approve, disapprove, or partially approve – those plans and amendments in accordance with specified procedures, including:

- Immediately upon transmittal of the FMP or FMP amendment publish a plan or amendment in the Federal Register for a 60-day comment period.
- Approve, disapprove, or partially approve a plan or amendment within 30 days of the end of the comment period on the plan or amendment. Disapproval must be based on inconsistency with the MSA or other applicable law. In addition, disapprovals must provide guidance on what was inconsistent and how to remedy the situation, if possible (see MSA section 304(a)(3)(A)-(C)).

In addition, as set forth in section 304(b) the role of NMFS with respect to Council-recommended draft regulations is to:

- Immediately upon transmittal of the proposed regulations initiate an evaluation of whether they are consistent with the fishery management plan, plan amendment, the MSA, and other applicable law.
- Within 15 days make a determination of consistency, and—
 - if that determination is affirmative, publish the regulations for a public comment period of 15 to 60 days; or,
 - if that determination is negative, notify the Council in writing of the inconsistencies and provide recommendations on revisions that would make the proposed regulations consistent.
- Consult with the Council before making any revisions to the proposed regulations,
- Promulgate final regulations within 30 days after the end of the comment period and publish in the Federal Register an explanation of any differences between the proposed and final regulations.

The MSA, at section 304(c), also authorizes NMFS to prepare a fishery management plan or amendment if:

- (a) the appropriate Council fails to develop and submit to NMFS, after a reasonable period of time, a fishery management plan for such fishery, or any necessary amendment to such a plan, if such fishery requires conservation and management;
- (b) NMFS disapproves or partially disapproves any such plan or amendment, or disapproves a revised plan or amendment, and the Council involved fails to submit a revised or further revised plan or amendment; or
- (c) NMFS is given authority to prepare such plan or amendment under the MSA. NMFS may also develop regulations to implement Secretarial plans and amendments. (MSA section 304(c)(6), (7)).

Other Applicable Laws Roles for NMFS and COUNCIL

As described in section D in Appendix 2 of the OG, the OALs set forth a variety of requirements for analysis, documentation, determinations, and procedures. Because of the close relationship between NMFS's actions and the Council's recommendations, compliance with the OALs will be most effective if NMFS and the Councils coordinate closely. The ROAs explain how these relationships work for each Council/Region pair. Council staff can often be responsible for drafting supporting analyses and documentation; however, it is NMFS's responsibility to ensure the resulting documents fully comply with all law.

4.1.1.1.2 Advisory Panels

Advisory Panels are established as necessary to assist in carrying out the functions of the Council under the MSA. Section 302(g)(4) of the MSA establishes Advisory Panels to "assist in the evaluation of information relevant to the development of any fishery management plan or plan amendment for a fishery." The Western Pacific Regional Fishery Management Council's Advisory Panel includes representation from various sectors of the fisheries. Members of the Subpanels are selected by the Council and serve four-year terms with an overall Advisory Panel Chair and a Vice-Chair, with a Chair for each Advisory Panel sub-panel. Sub-panels are designated by the Archipelago FEPs and have representation from user groups and interests concerned with management of the fishery including fair representation of commercial fishing interests in the Council's geographical area of authority. The Advisory Panel provides advice on the content and effects of management plans, amendments and pre-season and in-season management measures, as well as issues to be discussed at Council Meetings.

The Hawaiian Archipelago FEP Sub-Panel meets prior to Council Meetings to discuss action items and provide comments and recommendations on issues of concern to the Council. Recommendations from the Advisory Panel and its Sub-Panels are provided to the Council for its consideration at Council Meetings. The Council's SOPP provides the most recent description and policy for this advisory group.

4.1.1.1.3 Plan Teams

Plan teams are a form of advisory panel authorized under Section 302(g) of the MSA. FEP Plan Teams are comprised of Federal, State and non-government specialists that are appointed by the Council and serve indefinite terms. The Council created an Archipelagic FEP Plan Team to oversee the ongoing development and implementation of the American Samoa, Hawaii, Mariana, and PRIA FEPs. The Team is also responsible for reviewing information pertaining to the performance of all the fisheries, the status of all the stocks managed under the four Archipelagic FEPs, monitoring the performance of the FEP through the production of an annual stock assessment and fishery evaluation (SAFE) report, providing information on the status of the fish stocks and other components of the ecosystem, and recommending conservation and management adjustments under framework procedures to better achieve management objectives. The Archipelagic Plan Team's findings and recommendations are reported to the Council at its regular meetings. The Archipelagic Plan Team meets at least once annually and its chair is appointed by the Council Chair after consultation with the Council's Executive Standing Committee. The Council's SOPP provides the most recent description and policy for this advisory group.

4.1.1.1.4 Science and Statistical Committee

The Scientific and Statistical Committee (SSC) is mandated under MSA 302(g) to "assist the Council in the development, collection, evaluation, and peer review of such statistical, biological, economic, social, and other scientific information as is relevant to such Council's development and amendment of any fishery management plan." The Western Pacific Regional Fishery Management Council's SSC is composed of experts with scientific or technical credentials and experience from State and Federal agencies, academic institutions, and other sources. SSC Members represent a wide range of disciplines required for preparation and review of Fishery Ecosystem Plans.

The SSC typically meets several days prior to a Council meeting to identify scientific resources required for the development of management plans and amendments and recommend resources for Plan Teams; Identify scientific resources required for the development of management plans and amendments and recommend resources for Plan Teams; Provide ongoing multi-disciplinary review of management plans or amendments and advise the Council on their scientific content, including recommendations for acceptable biological catch, preventing overfishing, maximum sustainable yield and achieving rebuilding targets, and reports on stock status and health, bycatch, habitat status, social and economic impacts of management measures and sustainability of fishing practices; Assist the Council in the development, collection, evaluation and peer review of such statistical, biological, economic, social, and other scientific information as is relevant to the Council's activities, and recommend methods and means for the development and collection of such information; Recommend to the Council the composition of Plan Teams; and provide scientific advice to the Council through recommendations on issues and action items. The Council's SOPP provides the most recent description and policy for this advisory group.

4.1.1.1.5 Fishing Industry Advisory Committee

Section 302(g) of the MSA requires the Council to establish a Fishing Industry Advisory Committee (FIAC). It includes representation from various fishing sectors of the Western Pacific region. Members of the committee are selected by the Council and serve four year terms, with representation from each of the island jurisdictions. The FIAC reports to the Council and has representation from industry user groups concerned with the management of the fishery for which a plan is being prepared or reviewed, with fair representation of the fishing industry interests in the Council's geographical area of authority. The functions of the FIAC are to advise the Council on fishery management problems; to provide input to the fishery management planning efforts; and to advise the Council on the content and effects of management plans, amendments, and pre-season and in-season management measures. The FIAC includes members from each Archipelagic FEP (with the PRIA FEP included with the Hawaii FEP). The Council's SOPP provides the most recent description and policy for this advisory group.

4.1.1.1.6 REAC and other Council Committees

The Regional Ecosystem Advisory Committee (REAC)'s primary role is to provide a forum for government agencies, organizations and other entities to share information to better integrate and coordinate ocean and coastal management. Sub-committees for each area are created with members that include representation from the Council, various Federal, State and local agencies, non-government specialists and private business from each respective area. Members of the

REAC are appointed by the Council with the Chair of each area sub-committee appointed by the Council Chair after consultation with the Executive and Budget Committee. The Council's SOPP provides the most recent description and policy for any other advisory group created by the Council.

Other Council Committees created to assist the Council in carrying out its statutory functions, as provided under section 302(g)(2) of the MSA include:

- Protected Species Advisory Committee
- Social Science Planning Committee
- Community Demonstration Projects Advisory Panel
- Community Development Program Advisory Panel
- Fishery Data Collection and Research Committee
- Marine Planning and Climate Change Committee
- Education Committee
- Non-Commercial Fisheries Advisory Committee

4.1.1.1.7 Ad-hoc Committees and Working Groups

The Council develops different ad-hoc committees and working groups to deal with specific issues relevant to the FEP and assist it in carrying out its statutory function.

4.1.1.1.8 Federal, State, and Local Agencies/Entities

4.1.1.1.8.1 National Marine Fisheries Service

The NMFS implements Council recommendations and is a primary federal enforcement agency for fisheries and other marine resource regulations. Recommendations from the Council, including transmitted amendments and plans, are provided to the NMFS and the Department of Commerce for approval. The Secretary of Commerce may approve, partially-approve, or reject any amendment or plan, in which case the Council will revisit or revise any partially-approved or rejected amendment or plan.

Regionally, the Council works in conjunction with the NMFS Pacific Islands Regional Office (PIRO) and the Pacific Islands Fisheries Science Center (PIFSC).

4.1.1.1.8.2 US Fish and Wildlife Service

The US Fish and Wildlife Service is a non-voting member of the Council and provides information as needed. In the Hawaiian archipelago, the USFWS, along with NMFS, is responsible for managing parts of the Northwestern Hawaiian Islands. Good coordination between the Council and USFWS is crucial for the success of any regulations issued in the area.

4.1.1.1.8.3 United States Coast Guard

The United States Coast Guard, District 14, is responsible for fishery regulation enforcement in the Hawaiian archipelago, including enforcing regulations listed in the FEP, and is a non-voting member of the Council.

4.1.1.1.9 Local Agencies

The Council works with the State of Hawaii Department of Land and Natural Resources (DLNR), including, but not limited to, its Division of Aquatic Resources (DAR), Division of Boating and Ocean Recreation (DOBOR), Division of Conservation and Resource Enforcement (DOCARE) and Aha Moku Advisory Committee, on fishery issues and concerns. The MHI Deep-7 bottomfish fishery is co-managed with DLNR for improved data collection, compliance, and near-real time quota monitoring. The State of Hawaii is responsible for the management of fisheries within nearshore waters (0-3 miles) and has their own fishing regulations and policies which fishermen must adhere to while fishing. These regulations may be found on the State of Hawaii DLNR, DAR website.

The Council has also worked with the City and County of Honolulu on fishery issues as they have jurisdiction over the NWHI as well. Through the REAC, the Council is also able to work with other local agencies and local non-governmental organizations.

4.1.1.1.10 Other Federal Entities

4.1.1.1.10.1 Papahānaumokuākea Marine National Monument

On June 15, 2006, President Bush issued Executive Order 8031 designating the NWHI a Marine National Monument under the Antiquities Act for the purpose of protecting the natural and cultural resources of the area. This portion of the Hawaiian archipelago, once open to fishing under the Council's FEP, closed nearly 140,000 square miles to fishing. The Council's regulations for the NWHI were superseded within 50 miles of the islands, and management within the waters of Papahānaumokuākea is divided between the State of Hawaii, the Secretary of Commerce, and the Secretary of the Interior.

While fishing is prohibited for all purposes but sustenance while in the monument, fishing can and may occur outside of the monument boundaries. In that area of the PMNM, the Council's FEP regulations are still in effect. The Council also participates in the NWHI Reserve Advisory Committee that serves as a defacto advisory council to PMNM.

4.1.1.1.10.2 Hawaiian Islands Humpback Whale National Marine Sanctuary

The Hawaiian Islands Humpback Whale National Marine Sanctuary was created by Congress in 1992 to protect Humpback Whales. The Sanctuary includes both Federal and State waters (from shoreline to 100 fm isobaths) in the Main Hawaiian Islands and uses education, outreach and regulations on boaters and ocean activities to protect humpback whales and their habitat. It is co-managed between the State of Hawaii and the National Ocean Service. The Council is a voting member of the Sanctuary Advisory Council, which provides advice to the Sanctuary on operations. While the Sanctuary's designation document does not provide for the management of fishing operations at this time, the Council continues to be involved in the sanctuary operations to determine and minimize impacts on fishing should future expansions bring changes (NOAA 1997).

4.1.1.1.10.3 Department of Defense

A number of Executive Orders have given administrative authority over territories and possessions to the Army, Navy, or the Air Force for use as military airfields and for weapons testing. In particular, Executive Order 8682 of 1941 authorizes the Secretary of the Navy to

control entry into the Naval Defensive Sea Areas (NDSA) around Johnston and Midway Atolls. The NDSA includes “territorial waters between the extreme high-water marks and the three-mile marine boundaries surrounding” the areas noted above. The objectives of the NDSA are to control entry into naval defensive sea areas; to provide for the protection of military installations; and to protect the physical security of, and ensure the full effectiveness of, bases, stations, facilities, and other installations (32 CFR Part 761). In addition, the Navy has joint administrative authority with the USFWS of Johnston Atoll. In 1996 Executive Order 13022 rescinded the Midway Atoll NDSA.

The Navy exerts jurisdiction over Kaula Rock in the MHI, which is used as a military bombing range. The Navy also exerts jurisdiction over a variety of waters offshore from military ports and air bases in the Hawaiian archipelago.

4.1.1.1.11 Regional Entities and International Coordination

International coordination is an important component of marine resource management within the island areas of the Western Pacific Region. For example, fish stocks and other marine resources that found within the Hawaiian archipelago may be part of larger populations that occur on larger geographic scales. However, there are no current regional entities involved in fisheries management in the Hawaiian archipelago, though there is a North Pacific Seamount Regional Fishery Management Organization (RFMO) that may deal with seamount groundfish and potentially bottomfish in the future that may impact Hawaii bottomfish and seamount groundfish fisheries and Precious Coral fisheries. Pelagic fisheries based out of Hawaii may be involved in fisheries management of pelagic species through multiple RFMOs and their description and coordination with Hawaii pelagic fisheries can be found in the Pacific Pelagics Fishery Ecosystem Plan.

4.1.2 Fishery Impact Statement

The Magnuson-Stevens Act requires that fishery management plan and plan amendments submitted to the Secretary after October 1, 1990 assesses the likely biological and socioeconomic effects of the conservation and management measures on fishery participants and their communities; participants in the fisheries conducted in adjacent areas under the authority of another Council; and the safety of human life at sea. This is typically referred to as a Fishery Impact Statement (FIS). Appendix D contains a list of all relevant amendments that predate this FEP, as well as amendments that were approved subsequent to its adoption. The elements of a FIS are integrated into the environmental impact analyses prepared for these amendment documents, as required. To find a FIS for a specific management measure contained in this FEP, see Appendix D.

4.1.3 Public Consultation Process

The public is provided opportunity to comment on, and provide testimony at, all meetings noticed through the Federal Register. The Council also accepts comments and testimony by phone, email and fax.

4.2 The Role of Agreements, Statement of Organization Practices and Procedures, etc

The Council enters into agreements to define specific roles and responsibilities of the agencies in developing, approving, and implementing fishery management plans and actions under the MSA.

In 2014, the Council entered into a Regional Operating Agreement with the NMFS PIRO and PIFSC to define specific roles and responsibilities of the Council and NMFS Offices in developing, approving and implementing fishery actions under the MSA. The ROA sets forth procedures and review processes to ensure that proposed management actions are adequately and completely analyzed upon decision making. The ROA functions with the general framework of the “Operational Guidelines” set forth by NOAA and can be amended as need for consistency.

In addition to external agreements, the Council establishes internal working policies and procedures through which the Council conducts business and carries out its functions under the MSA. The Statement of Organization Practices and Procedures (SOPP) is updated periodically as needed. The SOPP defines the Council’s organizational structure, standards of conduct, policies and procedures, advisory bodies and their role and responsibilities and administrative system.

4.3 Council Communications

Communication is an essential component of the Council’s bottom-up approach to fisheries management and is one of the Council’s seven Guiding Principles: “Conduct education and outreach to foster good stewardship principles and broad and direct public participation in the Council’s decision making process.”

The Council’s Public Involvement and Outreach Plan was prepared in 1995 and serves as the basis for the Council’s ongoing communication efforts. The plan identifies training sessions, programs, information sessions, special events and product development (audio-visual, printed materials and displays) for three targeted audiences: fishing communities, regulatory/policy setting agencies and the general public.

In 2010 and 2011, fishermen focus groups were conducted in Hawaii to assess the effectiveness of the Council’s outreach efforts and elicit suggestions for improving it. This research was conducted by an independent research firm, which also conducted interviews to gauge the effectiveness of particular Council outreach projects in the Territories and the Commonwealth. The results indicated that fishermen were aware of the Council; however, their understanding of what the Council does could be improved. In 2011, in response to these comments, the Council developed a Communications Framework among other activities.

The Council publishes meeting notices in local publications in English and, in American Samoa, also in the Samoan language. Other regular Council outreach materials include a quarterly newsletter, a monograph series, brochures, displays, magazine articles and press releases and occasional videos, public serve announcements, proceedings and books.

The Council’s regularly scheduled outreach and education activities, some of which have been conducted annually for more than a decade, include Fishers Forums, student art contests with teacher resources on various themes of fishery importance, traditional lunar calendars highlighting student art and traditional fishery information, and high school summer courses. The Council also occasionally conducts International Fishers Forums, teacher workshops, student symposiums, community workshops, fishermen workshops and other special events locally, regionally, nationally and internationally.

In 2013, the Council established an Education Committee, which spearheaded a memorandum of understanding signed by federal and local governments and higher education institutions in the Western Pacific Region. The aspiration of the MOU is to improve the capacities of the US Pacific Island territories to manage their fisheries and to enhance tertiary education in fisheries science and management offered in Hawai`i. In 2015, the first outcomes of the MOU included the implementation of the US Pacific Territories Fishery Capacity-Building scholarship and internship program.

The Council has increased its outreach through social media, including the Council website, Facebook, Twitter and Constant Contact distribution. It also works with the education and outreach staff of the other seven Regional Fishery Management Councils on the fisherycouncils.org website, Managing Our Nation's Fisheries conferences and occasional publications, displays and events.

4.4 Council Five Year Research Priorities

The reauthorized Magnuson-Stevens Fishery Conservation and Management Act (MSRA), created new responsibilities and authorities for domestic regional fishery management councils and their advisory bodies. Following is the relevant MSRA text regarding the development and implementation of five-year regional research priorities by Councils. Section 302 (h) Each Council shall develop, in conjunction with the scientific and statistical committee, multi-year research priorities for fisheries, fishery interactions, habitats, and other areas of research that are necessary for management purposes that shall –

- (A) establish priorities for 5-year periods;
- (B) be updated as necessary; and
- (C) be submitted to the Secretary and the regional science centers of the National Marine Fisheries Service for their consideration in developing research priorities and budgets for the region of the Council.

The research priority document is vetted through the Council advisory groups and submitted to the Secretary of Commerce and NMFS on an annual basis for their consideration. These priorities are also the basis for Federal funding opportunities such as the Saltonstall-Kennedy Grant Program. A process of addressing and monitoring these research priorities is yet to be developed by the Council and NMFS PIFSC.

Stock assessments for Council managed fisheries remains the highest research priority. For current research priorities, see the Council's website at www.wpcouncil.org.

4.5 Western Pacific Sustainable Fisheries Fund

MSA Section 204(e)(7) provides for a Western Pacific Sustainable Fisheries Fund (WPSFF) “into which any payments received by the Secretary (of Commerce) under a Pacific Insular Area fishery agreement and any funds or contributions received in support of conservation and management objectives under a marine conservation plan for any Pacific Insular Area other than American Samoa, Guam, or the Northern Mariana Islands shall be deposited.” These funds are used to implement Marine Conservation Plans (MCPs) developed under MSA Section 204(e)(4)

for the Pacific Insular Areas. The WPSFF may also be used for projects to support Hawaiian archipelago fisheries if there is remaining funding after funding MCP projects. The Council utilizes the WPSFF to assist in fisheries development, research, and characterization in the Western Pacific.

4.6 Annual Fishery Reports and their Use

The Council's annual fishery reports serve as Stock Assessment and Fishery Evaluation (SAFE) reports for the Western Pacific region and contain information beyond the SAFE report requirements found in National Standard 2. Because they contain the most recent information about the fisheries, they serve as the basis for developing management measures and evaluating management alternatives as well as tracking the performance of this FEP.

The reports are generated by members of the Council's Plan Team and contain information about the MUS and their associated ecosystems derived from fishery dependent and fishery independent data collection systems. The SAFE Reports will typically contain information related to describing the fisheries, the ecosystem elements the fisheries influence and are in turn influenced by, and integrated characterizations of the fisheries. The specific elements of SAFE Reports may change due to availability of information or other factors. The current contents of the SAFE Reports can be obtained by contacting the Council or reviewing the most recent reports.

A comprehensive report will be created every 3 years, while a shorter report that describes more dynamic data elements will be generated during the interim years.

4.7 Other Applicable Laws and their Role

Section 303(a)(1)(C) of the MSA requires federal fishery management plans to be consistent with other applicable laws. These other laws impose additional procedural, substantive, and timing requirements on the decision process and their applicability must be assessed on a case-by-case basis. This FEP is consistent with the Magnuson-Stevens Act (16 USC 1851), including the ten National Standards, and other applicable law. These laws typically include the following:

- Administrative Procedure Act
- Coastal Zone Management Act
- Endangered Species Act
- National Monument
- Information Quality Act
- Marine Mammal Protection Act
- National Environmental Policy Act
- National Marine Sanctuaries Act
- Paperwork Reduction Act
- Regulatory Flexibility Act
- Executive Orders 12291 (*cost-benefit and avoiding duplication*), 12630 (*governmental actions and interference with constitutionally protected property rights*), 12866 (*regulatory planning and review*), 12898 (*environmental justice*), 13089 (*coral reef protection*), 13132 (*federalism implication of federal actions*), 13158 (*marine protected areas*), 13175 (*consultation and coordination with Indian tribal*

governments), 13196 (Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve), 13272 (stewardship of the ocean, our coasts, and the Great Lakes), 13547 (National Ocean Policy) and 12962 (recreational fisheries).

- *Presidential Proclamation 8031 and 8112 (establishing the Papahānaumokuākea Marine National Monument)*

Specific information regarding the implications of each of these can be in the Operational Guidelines for the Fishery Management Process developed by NMFS in consultation with the Council Coordinating Committee at [www _____](#). The statutes themselves, along with their guidance language, regulations, and associated case law are controlling in the instance of any discrepancy between them and this document.

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5 REFERENCES

- Apostolaki, P. 2015. Independent Peer Review of Stock Assessment Update for the Main Hawaiian Islands Deep 7 Bottomfish Complex Through 2013 With Projected Annual Catch Limits Through 2016. Center for Independent Excellence Review Meeting, 9-12 December, 2014, Honolulu, Hawaii.
- Beverton, R.J. H. and S.J. Holt. 1957. On the dynamics of fish populations. Chapman and Hall. London.
- Brodziak J., Courtney D., Wagatsuma L., O'Malley J., Lee H-H., Walsh W., Andrews A., Humphreys R., DiNardo G. 2011. Stock assessment of the main Hawaiian Islands Deep7 bottomfish complex through 2010. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-29, 176 p. + Appendices.
- Brown, I.W., 1985. The Hawaiian Kona crab fishery: Report on a visit to Honolulu in January 1983. Queensland Department of Primary Industries and Fisheries, Brisbane, Report Number QS 85005: 1-18.
- Cadigan, N. 2015. Independent Peer Review of Stock Assessment Update for the Main Hawaiian Islands Deep 7 Bottomfish Complex Through 2013 With Projected Annual Catch Limits Through 2016. Center for Independent Excellence Review Meeting, 9-12 December, 2014, Honolulu, Hawaii.
- Cesar, H. S. J., P. J. H. van Beukering, W. Pintz, and J. Dierking. 2002. Economic valuation of the coral reefs of Hawai'i. Hawai'i Coral Reef Initiative, University of Hawai'i, Honolulu. 123 pp
- Clarke, T. A. 1972. Exploration for deep benthic fish and crustacean resources in Hawaii. University of Hawaii, Hawaii Institute of Marine Biology. Tech. Rep. 29:1-18.
- Cobb, J. 1902. Commercial fisheries of the Hawaiian Islands. Extracted from the U.S. Fish Commission Report for 1901, U.S. Government Printing Office, Washington, D.C.
- Dailey, M.D. & S. Ralston. 1986. Aspects of the reproductive biology, spatial distribution, growth and mortality of the deepwater caridean shrimps *Heterocarpus laevigatus* in Hawaii. Fish. Bull. 84 (4), 915-925.
- DeMartini E.E., DiNardo G.T., Williams H.A. 2003. Temporal changes in population density, fecundity, and egg size of the Hawaiian spiny lobster (*Panulirus marginatus*) at Necker Bank, Northwestern Hawaiian Islands. Fishery Bulletin 101: 22-31.
- DeMartini, E., F. Parrish, and R. Boland. 2002. Comprehensive evaluation of shallow reef fish populations at French Frigate Shoals and Midway Atoll, Northwestern Hawaiian Islands. NOAA Technical Memorandum. NOAA Fisheries.

- DiNardo, G. T. 2005. Causes for the switch of lobster-species dominance in the Northwestern Hawaiian Islands. Presented at: Northwestern Hawaiian Islands' Third Scientific Symposium; 2004 Nov 2-4; Honolulu, HI.
- Gooding R.M. 1984. Trapping surveys for the deep water caridean shrimps, *Heterocarpus laevigatus* and *H. Ensifer*, in the NWHI. Mar. Fish Rev. 46(2):18-26.
- Gooding, R. M., J. J. Polovina, and M. D. Dailey. 1988. Observations of deepwater shrimp, *Heterocarpus ensifer*, from a submersible off the island of Hawaii. Mar. Fish. Rev. 50(1):32-39.
- Grigg, R. 1976. Fishery management of precious and stoney corals in Hawaii. Sea Grant Tech. Rept. UNIHI-SEAGRANT-TR-77-03, University of Hawaii, Honolulu.
- Grigg R. 1998 *Status of the black coral fishery in Hawaii -1998*. Report prepared under contract with Office of Scientific Authority, U.S. Fish and Wildlife Service.
- Grigg, R.W. 2002. Precious Corals in Hawaii: Discovery of a New Bed and Revised Management Measures for Existing Beds. Mar. Fish. Rev. 64(1):13-20.
- Grigg, R. 2004. Harvesting Impacts and Invasion by an Alien Species Decrease Estimates of Black Coral Yield off Maui, Hawai'i. Pac. Sci. 58(1):1-6.
- Gulland, J. 1969. *Manual of methods for fish stock assessment. Pt. 1. Fish population analysis*. FAO Man. Fish. Sci. 4.
- Gulland, J. 1970. "The fish resources of the ocean." FAO Tech. Paper 97, Food and Agriculture Organization, Rome.
- Haist, V. 2015. Independent Peer Review of Stock Assessment Update for the Main Hawaiian Islands Deep 7 Bottomfish Complex Through 2013 With Projected Annual Catch Limits Through 2016. Center for Independent Excellence Review Meeting, 9-12 December, 2014, Honolulu, Hawaii.
- Harman, R.F. and A.Z. Katekaru. 1988. Hawaii commercial fishing survey: Summary of results. Division of Aquatic Resources, Department of Land and Natural Resources, Honolulu, Hawaii.
- Kelly, K.E., and A. Messer. 2005. Main Hawaiian Island Lobsters: Commercial catch and dealer data analysis (1984-2004). Final report prepared for Western Pacific Regional Fishery Management Council and the State of Hawaii Department of Land and Natural Resources, Division of Aquatic Resources. October 2005 Honolulu, Hawaii: Western Pacific Regional Fishery Management Council.

- Khang, S.E. 2007. Ecological impacts of *Carijoa riisei* on black coral habitat. Report to the Western Pacific Fisheries Management Council, January 2007. Honolulu, HI.
- Khang S.E. and R. Grigg. 2005. Impact of an alien octocoral, *Carijoa riisei*, on black corals in Hawaii. *Coral Reefs*. 24:556-562.
- Kasaoka, L. 1989. *Summary of small boat economic surveys from American Samoa, Guam and the Northern Mariana Islands*. NMFS Southwest Fisheries Center Honolulu Laboratory Administrative Report H-89-4C.
- Kawamoto K. and P. Tao. 2005. Summary of bottomfishing effort in the main Hawaiian Islands by commercial marine license holders, 2000-2003. NMFS Pacific Islands Science Center Internal Report IR-05-011. Honolulu, HI.
- King, M. 1993. Deepwater shrimps. In *Nearshore Marine Resources of the South Pacific*, A. Wright & L. Hill (eds). Suva: Institute of Pacific Studies, Honiara: Forum Fisheries Agency & Halifax: International Centre for Ocean Development, 513-538.
- Meyer Resources. 1987. A report on resident fishing in the Hawaiian Islands. NMFS Southwest Fisheries Center Honolulu Laboratory Administrative Report H-87-8C. Honolulu, HI.
- Moffitt, R. B. 1983. *Heterocarpus longirostris* MacGilchrist from the Northern Mariana Islands. *Fish. Bull.*, U.S. 81:434-436.
- Moffitt, R. B., and F. A. Parrish. 1992. Comparison of submersible observed shrimp densities with trap catches of *Heterocarpus laevigatus* in Hawaii. *Fish. Bull.*, U.S. 90(3): 476-482.
- Moffitt, R., Johnson, J. and DiNardo, G. 2005. Spatiotemporal analysis of lobster trap catches: impacts of trap fishing on community structure. NMFS Pacific Islands Fisheries Science Center. Honolulu, HI.
- Nadon, M. O., Ault, J. S., Williams, I. D., Smith, S. G., & DiNardo, G. T. (2015). Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwestern Hawaiian Islands. *PloS one*, 10(8), e0133960.
- Neilson, J.D. 2015. Independent Peer Review of Stock Assessment Update for the Main Hawaiian Islands Deep 7 Bottomfish Complex Through 2013 With Projected Annual Catch Limits Through 2016. Center for Independent Excellence Review Meeting, 9-12 December, 2014, Honolulu, Hawaii.
- NMFS (National Marine Fisheries Service). 1999. Ecosystem-based fishery management. A report to Congress by the Ecosystems Principles Advisory Panel. U.S. Department of Commerce, Silver Spring, MD.

- NOAA (National Oceanic and Atmospheric Administration). 1997. Hawaiian Islands Humpback Whale National Marine Sanctuary Final Environmental Impact Statement/Management Plan.
- NOAA (National Oceanic and Atmospheric Administration). 2004. New priorities for the 21st century. *NOAA's Strategic Plan Updated for FY 2005–FY 2010*.
- Nitta, E. 1999. Draft. Summary report. Bottomfish observer trips in the Northwestern Hawaiian Islands. October 1990 to December 1993. NMFS Pacific Islands Area Office, Pacific Islands Protected Species Program, Honolulu, HI.
- Oishi, F. 1983. Shrimp industry Development Project. Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii. 22 p.
- Parrish FA, Grigg RW, DeMello J, Montgomery AD. 2009. *The status of Corallium spp. in Hawaii and the US Pacific: population status, trends and threats, fisheries, trade, management, enforcement and conservation*. In: Bruckner, AW and GG Roberts (eds.). Proceedings of the First International Workshop on Corallium Science, Management and Trade. NOAA Technical Memorandum NMFS-OPR-43 and CRCP-8, p. 87-108. Pacific Islands Fisheries Science Center, PIFSC Working Paper, WP-09-001, 19 p.
- Pikitch, E. K., C. Santora, E. Babcock, A. Bakun, R. Bonfil, D. O. Conover, P. Dayton, P. Doukakis, D. Fluharty, B. Heneman, E. D. Houde, J. Link, P. A. Livingston, M. Mangel, M. K. McAllister, J. Pope, and K. J. Sainsbury. 2004. Ecosystem-based fishery management. *Science*. 305:1–2.
- Polovina, J. 1993. The lobster and shrimp fisheries in Hawaii. *Marine Fisheries Review* 55(2):28-33.
- Polovina, J. and G. Mitchum. 1992. Variability in spiny lobster *Panulirus marginatus* recruitment and sea level in the Northwestern Hawaiian Islands. *Fish. Bull., U.S.* 90:483-493.
- Polovina, J. and R. Moffitt. 1995. Spatial and temporal distribution of the phyllosoma of the spiny lobster, *Panulirus marginatus*, in the Northwestern Hawaiian Islands. *Bull. Mar. Sci.* 56:406-417.
- Polovina, J. J. E., G. Mitchum, N. Graham, M. Craig, E. DeMartini, and E. Flint. 1994. Physical and biological consequences of a climate event in the central North Pacific. *Fisheries Oceanography*. 3:15–21.
- Pooley, S. G., 1993. Hawaii's Marine fisheries: some history, long-term trends, and recent developments. *Fisheries Review* 55:5-19.
- Ralston, S. 1986. An intensive fishing experiment for the caridean shrimp, *Heterocarpus laevigatus* at Alamagan Island in the Mariana Archipelago. *Fish Bull., U.S.*

84:927-934.

- Ralston, S., and D. T. Tagami. 1992. An assessment of the exploitable biomass of *Heterocarpus laevigatus* in the main Hawaiian Islands. Part 1: trapping surveys, depletion experiment, and length structure. Fish. Bull. 90(3):494-504.
- Restrepo, V. R., G. G. Thompson, P. M. Mace, W. L. Gabriel, L. L. Low, A. D. MacCall, R. D. Methot, J.E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig 1998. Technical guidance on the use of Precautionary Approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum NMFS-F/SPO-31, 54 p.
- Sabater, M. and Kleiber, P. 2014. Augmented catch-MSY approach to fishery management in coral-associated fisheries. S.A. Bortone (Ed.), *Interrelationships between Corals and Fisheries*, CRC Press, Boca Raton, FL (2014), pp. 199–218 321 pgs.
- Shomura, R. 1987. "Hawaii's marine fishery: yesterday and today." NMFS Southwest Fisheries Center Honolulu Laboratory Administrative Report H-87-21.
- Struhsaker, P. and Aasted DC. 1974. Deepwater shrimp trapping in the Hawaiian Islands. Mar. Fish. Rev. 36(10):24-30.
- Tagami, D.T. and S. Barrows. 1988. Deep-sea shrimp trapping for *Heterocarpus laevigatus* in the Hawaiian Archipelago by a commercial fishing vessel. NOAA Technical Memorandum, NMFS, 14 pp.
- Tagami, D.T. and S. Ralston. 1988. An assessment of exploitable biomass and projection of maximum sustainable yield for *Heterocarpus laevigatus* in the Hawaiian Islands. Southwest Fisheries Center Administration Report H-88-14, 22 pp.
- Titcomb, M. 1972. *Native Use of Fish in Hawaii*. The University of Hawaii Press, Honolulu.
- Thomas, L., 2011. Characterizing the Kona crab (*Ranina ranina*) fishery in the Main Hawaiian Islands. Report to the Western Pacific Regional Fishery Management Council. 52 pp.
- Vansant, J.P. 1978. A survey of the Hawaiian Kona crab fishery. Thesis for the degree of Master of Science, Oceanography, University of Hawaii:1-59.
- Wilder, M.J. 1979. A handbook of Deepwater Shrimp Trapping. Guam Economic Development Authority, Agana, Guam, 26 pp.
- WPRFMC (Western Pacific Regional Fishery Management Council). 2004. Bottomfish and Seamount Groundfish Fisheries of the Western Pacific 2002 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, Hawaii.

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Appendix A: List of Acronyms

APA:	Administrative Procedure Act
B:	Stock biomass
B _{FLAG} :	Minimum Biomass Flag
B _{MSY} :	Biomass Maximum Sustainable Yield
B _{OY} :	Biomass Optimum Yield
BMUS:	Bottomfish Management Unit Species
CFR:	Code of Federal Regulations
CITES:	Council on International Trade and Endangered Species
CNMI:	Commonwealth of the Northern Mariana Islands
CPUE:	Catch per unit effort at the reference point
CPUE _{MSY} :	Catch per unit effort Maximum Sustainable Yield
CPUE _{REF} :	Catch per unit effort at the Reference Point
CRAMP:	Coral Reef Assessment and Monitoring Program
CRE:	Coral Reef Ecosystem
CRE-FMP:	Coral Reef Ecosystem Fishery Management Plan
CRTF:	Coral Reef Task Force
DAR:	Division of Aquatic Resources, State of Hawaii
DOC:	United States Department of Commerce
DOD:	United States Department of Defense
DOI:	United States Department of the Interior
EEZ:	Exclusive Economic Zone
EFH:	Essential Fish Habitat
EIS:	Environmental Impact Statement

E _{MSY} :	Effort Maximum Sustainable Yield
ENSO:	El Niño Southern Oscillation
EO:	Executive Order
EPAP:	Ecosystem Principals Advisory Panel
ESA:	Endangered Species Act
F:	Fishing mortality
F _{MSY} :	Fishing mortality Maximum Sustainable Yield
F _{OY} :	Fishing mortality Optimum Yield
FEP:	Fishery Ecosystem Plan
FLPMA:	Federal Land Policy and Management Act
fm:	fathoms
FMP:	Fishery Management Plan
FR:	Federal Register
FRFA:	Final Regulatory Flexibility Analysis
ft:	feet
FWCA:	Fish and Wildlife Coordination Act
GIS:	Geographic information systems
GPS:	Global Positioning System
HAPC:	Habitat Areas of Particular Concern
IQA:	Information Quality Act
IRFA:	Initial Regulatory Flexibility Analysis
kg:	kilograms
km:	kilometers
lb:	pounds
LOF:	List of Fisheries

m:	meters
mt:	metric tons
MFMT:	maximum fishing mortality threshold
MHI:	Main Hawaiian Islands
min SST:	minimum spawning stock threshold
mm:	millimeters
MMPA:	Marine Mammal Protection Act
MPA:	Marine Protected Area
MSA:	Magnuson-Stevens Fishery Conservation and Management Act
MSST:	Minimum Stock Size Threshold
MSY:	Maximum Sustainable Yield
MUS:	Management Unit Species
NDSA:	Naval Defense Sea Areas
NEPA:	National Environmental Policy Act
nm or nmi:	nautical miles
NMFS:	National Marine Fisheries Service (also known as NOAA Fisheries Service)
NOAA:	National Oceanic and Atmospheric Administration
NWHI:	Northwestern Hawaiian Islands
NWR:	National Wildlife Refuge
NWRSAA:	National Wildlife Refuge System Administration Act
OMB:	Office of Management and Budget
OY:	Optimum Yield
PBR:	Potential Biological Removal
PIFSC:	Pacific Islands Fisheries Science Center, NMFS
PIRO:	Pacific Islands Regional Office, NMFS

PRA:	Paperwork Reduction Act
PRIA:	Pacific Remote Island Areas
RFA:	Regulatory Flexibility Act
RIR:	Regulatory Impact Review
SFA:	Sustainable Fisheries Act
SLA:	Submerged Lands Act
SPR:	Spawning Potential Ratio
SSC:	Scientific and Statistical Committee
TALFF:	Total Allowable Level of Foreign Fishing
TSLA:	Territorial Submerged Lands Act
USCG:	United States Coast Guard
USFWS:	United States Fish and Wildlife Service
VMS:	Vessel Monitoring System
WPacFIN:	Western Pacific Fisheries Information Network, NMFS
WPRFMC:	Western Pacific Regional Fishery Management Council

Appendix B: List of Definitions

Adaptive Management: A program that adjusts regulations based on changing conditions of the fisheries and stocks.

Bycatch: Any fish harvested in a fishery which are not sold or kept for personal use, and includes economic discards and regulatory discards.

Barrier Net: A small-mesh net used to capture coral reef or coastal pelagic fishes.

Bioprospecting: The search for commercially valuable biochemical and genetic resources in plants, animals and microorganisms for use in food production, the development of new drugs and other biotechnology applications.

Charter Fishing: Fishing from a vessel carrying a passenger for hire (as defined in section 2101(21a) of Title 46, United States Code) who is engaged in recreational fishing.

Commercial Fishing: Fishing in which the fish harvested, either in whole or in part, are intended to enter commerce or enter commerce through sale, barter or trade. For the purposes of this Fishery Ecosystem Plan, commercial fishing includes the commercial extraction of biocompounds.

Consensual Management: Decision making process where stakeholders meet and reach consensus on management measures and recommendations.

Coral Reef Ecosystem (CRE): Those species, interactions, processes, habitats and resources of the water column and substrate located within any waters less than or equal to 50 fathoms in total depth.

Council: The Western Pacific Regional Fishery Management Council (WPRFMC).

Critical Habitat: Those geographical areas that are essential for bringing an endangered or threatened species to the point where it no longer needs the legal protections of the Endangered Species Act (ESA), and which may require special management considerations or protection. These areas are designated pursuant to the ESA as having physical or biological features essential to the conservation of listed species.

Dealer: Any person who (1) Obtains, with the intention to resell management unit species, or portions thereof, that were harvested or received by a vessel that holds a permit or is otherwise regulated under this FEP; or (2) Provides recordkeeping, purchase, or sales assistance in obtaining or selling such management unit species (such as the services provided by a wholesale auction facility).

Dip Net: A hand-held net consisting of a mesh bag suspended from a circular, oval, square or rectangular frame attached to a handle. A portion of the bag may be constructed of material, such as clear plastic, other than mesh.

Ecology: The study of interactions between an organism (or organisms) and its (their) environment (biotic and abiotic).

Ecological Integrity: Maintenance of the standing stock of resources at a level that allows ecosystem processes to continue. Ecosystem processes include replenishment of resources, maintenance of interactions essential for self-perpetuation and, in the case of coral reefs, rates of accretion that are equal to or exceed rates of erosion. Ecological integrity cannot be directly measured but can be inferred from observed ecological changes.

Economic Discards: Fishery resources that are the target of a fishery but which are not retained because they are of an undesirable size, sex or quality or for other economic reasons.

Ecosystem: A geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics.

Ecosystem-Based Fishery Management: Fishery management actions aimed at conserving the structure and function of marine ecosystems in addition to conserving fishery resources.

Ecotourism: Observing and experiencing, first hand, natural environments and ecosystems in a manner intended to be sensitive to their conservation.

Environmental Impact Statement (EIS): A document required under the National Environmental Policy Act (NEPA) to assess alternatives and analyze the impact on the environment of proposed major Federal actions significantly affecting the human environment.

Essential Fish Habitat (EFH): Those waters and substrate necessary to a species or species group or complex, for spawning, breeding, feeding or growth to maturity.

Exclusive Economic Zone (EEZ): The zone established by Proclamation numbered 5030, dated March 10, 1983. For purposes of the Magnuson Act, the inner boundary of that zone is a line coterminous with the seaward boundary of each of the coastal states, commonwealths, territories or possessions of the United States.

Exporter: One who sends species in the fishery management unit to other countries for sale, barter or any other form of exchange (also applies to shipment to other states, territories or islands).

Fish: Finfish, mollusks, crustaceans and all other forms of marine animal and plant life other than marine mammals and birds

Fishery: One or more stocks of fish that can be treated as a unit for purposes of conservation and management and that are identified on the basis of geographical, scientific, technical, recreational and economic characteristics; and any fishing for such stocks.

Fishery Ecosystem Plan: A fishery ecosystem management plan that contains conservation and management measures necessary and appropriate for fisheries within a given ecosystem to prevent overfishing and rebuild overfished stocks, and to protect, restore, and promote the long-term health and stability of the fishery.

Fishing: The catching, taking or harvesting of fish; the attempted catching, taking or harvesting of fish; any other activity that can reasonably be expected to result in the catching, taking or harvesting of fish; or any operations at sea in support of, or in preparation for, any activity described in this definition. Such term does not include any scientific research activity that is conducted by a scientific research vessel.

Fishing Community: A community that is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs and includes fishing vessel owners, operators and crews and United States fish processors that are based in such community.

Food Web: Inter-relationships among species that depend on each other for food (predator-prey pathways).

Framework Measure: Management measure listed in an FEP for future consideration. Implementation can occur through an administratively simpler process than a full FEP amendment.

Ghost Fishing: The chronic and/or inadvertent capture and/or loss of fish or other marine organisms by lost or discarded fishing gear.

Habitat: Living place of an organism or community, characterized by its physical and biotic properties.

Habitat Area of Particular Concern (HAPC): Those areas of EFH identified pursuant to Section 600.815(a)(8). In determining whether a type or area of EFH should be designated as a HAPC, one or more of the following criteria should be met: (1) ecological function provided by the habitat is important; (2) habitat is sensitive to human-induced environmental degradation; (3) development activities are, or will be, stressing the habitat type; or (4) the habitat type is rare.

Harvest: The catching or taking of a marine organism or fishery MUS by any means.

Hook-and-line: Fishing gear that consists of one or more hooks attached to one or more lines.

Live Rock: Any natural, hard substrate (including dead coral or rock) to which is attached, or which supports, any living marine life-form associated with coral reefs.

Longline: A type of fishing gear consisting of a main line which is deployed horizontally from which branched or dropper lines with hooks are attached.

Low-Use MPA: A Marine Protected Area zoned to allow limited fishing activities.

Main Hawaiian Islands (MHI): The islands of the Hawaiian Islands archipelago consisting of Niihau, Kauai, Oahu, Molokai, Lanai, Maui, Kahoolawe, Hawaii and all of the smaller associated islets lying east of 161° W longitude.

Marine Protected Area (MPA): An area designated to allow or prohibit certain fishing activities.

Marine National Monument (MNM):

Maximum Sustainable Yield (MSY): The largest long-term average catch or yield that can be taken, from a stock or stock complex under prevailing ecological and environmental conditions and fishery technological characteristics (e.g., gear selectivity), and the distribution of catch among fleets.

National Marine Fisheries Service (NMFS): The component of the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, responsible for the conservation and management of living marine resources. Also known as NOAA Fisheries Service.

No-Take MPA: A Marine Protected Area where no fishing or removal of living marine resources is authorized.

Northwestern Hawaiian Islands (NWHI): the islands of the Hawaiian Islands archipelago lying to the west of 161°W longitude.

Optimum Yield (OY): With respect to the yield from a fishery “optimum” means the amount of fish that: (a) will provide the greatest overall benefit to the nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems; (b) is prescribed as such on the basis of the MSY from the fishery, as reduced by any relevant economic, social or ecological factor; and (c) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery.

Overfished: A stock or stock complex is considered “overfished” when its biomass has declined below a level that jeopardizes the capacity of the stock or stock complex to produce maximum sustainable yield on a continuing basis.

Overfishing: (to overfish) occurs whenever a stock or stock complex is subjected to a level of fishing mortality or total annual catch that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield on a continuing basis.

Pacific Remote Island Areas (PRIA): Baker Island, Howland Island, Jarvis Island, Johnston Atoll, Kingman Reef, Midway Atoll, Wake Island and Palmyra Atoll.

Passive Fishing Gear: Gear left unattended for a period of time prior to retrieval (e.g., traps, gill nets).

Precautionary Approach: The implementation of conservation measures even in the absence of scientific certainty that fish stocks are being overexploited.

Recreational Fishing: Fishing for sport or pleasure.

Recruitment: A measure of the weight or number of fish which enter a defined portion of the stock such as fishable stock (those fish above the minimum legal size) or spawning stock (those fish which are sexually mature).

Reef: A ridgelike or moundlike structure built by sedentary calcareous organisms and consisting mostly of their remains. It is wave-resistant and stands above the surrounding sediment. It is characteristically colonized by communities of encrusting and colonial invertebrates and calcareous algae.

Reef-obligate Species: An organism dependent on coral reefs for survival.

Regulatory Discards: Any species caught that fishermen are required by regulation to discard whenever caught, or are required to retain but not sell.

Resilience: The ability of a population or ecosystem to withstand change and to recover from stress (natural or anthropogenic).

Restoration: The transplanting of live organisms from their natural habitat in one area to another area where losses of, or damage to, those organisms has occurred with the purpose of restoring the damaged or otherwise compromised area to its original, or a substantially improved, condition; additionally, the altering of the physical characteristics (e.g., substrate, water quality) of an area that has been changed through human activities to return it as close as possible to its natural state in order to restore habitat for organisms.

Rock: Any consolidated or coherent and relatively hard, naturally formed, mass of mineral matter.

Rod-and-Reel: A hand-held fishing rod with a manually or electrically operated reel attached.

Scuba-assisted Fishing: Fishing, typically by spear or by hand collection, using assisted breathing apparatus.

Secretary: The Secretary of Commerce or a designee.

Sessile: Attached to a substrate; non-motile for all or part of the life cycle.

Slurp Gun: A self-contained, typically hand-held, tube-shaped suction device that captures organisms by rapidly drawing seawater containing the organisms into a closed chamber.

Social Acceptability: The acceptance of the suitability of management measures by stakeholders, taking cultural, traditional, political and individual benefits into account.

Spear: A sharp, pointed, or barbed instrument on a shaft, operated manually or shot from a gun or sling.

Adaptive Management: A program that adjusts regulations based on changing conditions of the fisheries and stocks.

Bycatch: Any fish harvested in a fishery which are not sold or kept for personal use, and includes economic discards and regulatory discards.

Barrier Net: A small-mesh net used to capture coral reef or coastal pelagic fishes.

Bioprospecting: The search for commercially valuable biochemical and genetic resources in plants, animals and microorganisms for use in food production, the development of new drugs and other biotechnology applications.

Charter Fishing: Fishing from a vessel carrying a passenger for hire (as defined in section 2101(21a) of Title 46, United States Code) who is engaged in recreational fishing.

Commercial Fishing: Fishing in which the fish harvested, either in whole or in part, are intended to enter commerce or enter commerce through sale, barter or trade. For the purposes of this Fishery Ecosystem Plan, commercial fishing includes the commercial extraction of biocompounds.

Consensual Management: Decision making process where stakeholders meet and reach consensus on management measures and recommendations.

Coral Reef Ecosystem (CRE): Those species, interactions, processes, habitats and resources of the water column and substrate located within any waters less than or equal to 50 fathoms in total depth.

Council: The Western Pacific Regional Fishery Management Council (WPRFMC).

Critical Habitat: Those geographical areas that are essential for bringing an endangered or threatened species to the point where it no longer needs the legal protections of the Endangered Species Act (ESA), and which may require special management considerations or protection. These areas are designated pursuant to the ESA as having physical or biological features essential to the conservation of listed species.

Dealer: Any person who (1) Obtains, with the intention to resell management unit species, or portions thereof, that were harvested or received by a vessel that holds a permit or is otherwise regulated under this FEP; or (2) Provides recordkeeping, purchase, or sales assistance in obtaining or selling such management unit species (such as the services provided by a wholesale auction facility).

Dip Net: A hand-held net consisting of a mesh bag suspended from a circular, oval, square or rectangular frame attached to a handle. A portion of the bag may be constructed of material, such as clear plastic, other than mesh.

Ecology: The study of interactions between an organism (or organisms) and its (their) environment (biotic and abiotic).

Ecological Integrity: Maintenance of the standing stock of resources at a level that allows ecosystem processes to continue. Ecosystem processes include replenishment of resources, maintenance of interactions essential for self-perpetuation and, in the case of coral reefs, rates of accretion that are equal to or exceed rates of erosion. Ecological integrity cannot be directly measured but can be inferred from observed ecological changes.

Economic Discards: Fishery resources that are the target of a fishery but which are not retained because they are of an undesirable size, sex or quality or for other economic reasons.

Ecosystem: A geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics.

Ecosystem-Based Fishery Management: Fishery management actions aimed at conserving the structure and function of marine ecosystems in addition to conserving fishery resources.

Ecotourism: Observing and experiencing, first hand, natural environments and ecosystems in a manner intended to be sensitive to their conservation.

Environmental Impact Statement (EIS): A document required under the National Environmental Policy Act (NEPA) to assess alternatives and analyze the impact on the environment of proposed major Federal actions significantly affecting the human environment.

Essential Fish Habitat (EFH): Those waters and substrate necessary to a species or species group or complex, for spawning, breeding, feeding or growth to maturity.

Exclusive Economic Zone (EEZ): The zone established by Proclamation numbered 5030, dated March 10, 1983. For purposes of the Magnuson Act, the inner boundary of that zone is a line coterminous with the seaward boundary of each of the coastal states, commonwealths, territories or possessions of the United States.

Exporter: One who sends species in the fishery management unit to other countries for sale, barter or any other form of exchange (also applies to shipment to other states, territories or islands).

Fish: Finfish, mollusks, crustaceans and all other forms of marine animal and plant life other than marine mammals and birds

Fishery: One or more stocks of fish that can be treated as a unit for purposes of conservation and management and that are identified on the basis of geographical, scientific, technical, recreational and economic characteristics; and any fishing for such stocks.

Fishery Ecosystem Plan: A fishery ecosystem management plan that contains conservation and management measures necessary and appropriate for fisheries within a given ecosystem to prevent overfishing and rebuild overfished stocks, and to protect, restore, and promote the long-term health and stability of the fishery.

Fishing: The catching, taking or harvesting of fish; the attempted catching, taking or harvesting of fish; any other activity that can reasonably be expected to result in the catching, taking or harvesting of fish; or any operations at sea in support of, or in preparation for, any activity described in this definition. Such term does not include any scientific research activity that is conducted by a scientific research vessel.

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Marine Protected Area (MPA): An area designated to allow or prohibit certain fishing activities.

Marine National Monument (MNM): Marine protected area designated by Presidential Proclamation, via the Antiquities Act of 1906.

Maximum Sustainable Yield (MSY): The largest long-term average catch or yield that can be taken, from a stock or stock complex under prevailing ecological and environmental conditions and fishery technological characteristics (e.g., gear selectivity), and the distribution of catch among fleets.

National Marine Fisheries Service (NMFS): The component of the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, responsible for the conservation and management of living marine resources. Also known as NOAA Fisheries Service.

No-Take MPA: A Marine Protected Area where no fishing or removal of living marine resources is authorized.

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the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery.

Overfished: A stock or stock complex is considered “overfished” when its biomass has declined below a level that jeopardizes the capacity of the stock or stock complex to produce maximum sustainable yield on a continuing basis.

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Restoration: The transplanting of live organisms from their natural habitat in one area to another area where losses of, or damage to, those organisms has occurred with the purpose of restoring the damaged or otherwise compromised area to its original, or a substantially improved, condition; additionally, the altering of the physical characteristics (e.g., substrate, water quality) of an area that has been changed through human activities to return it as close as possible to its natural state in order to restore habitat for organisms.

Rock: Any consolidated or coherent and relatively hard, naturally formed, mass of mineral matter.

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Scuba-assisted Fishing: Fishing, typically by spear or by hand collection, using assisted breathing apparatus.

Secretary: The Secretary of Commerce or a designee.

Sessile: Attached to a substrate; non-motile for all or part of the life cycle.

Slurp Gun: A self-contained, typically hand-held, tube-shaped suction device that captures organisms by rapidly drawing seawater containing the organisms into a closed chamber.

Social Acceptability: The acceptance of the suitability of management measures by stakeholders, taking cultural, traditional, political and individual benefits into account.

Spear: A sharp, pointed, or barbed instrument on a shaft, operated manually or shot from a gun or sling.

Stock Assessment: An evaluation of a stock in terms of abundance and fishing mortality levels and trends, and relative to fishery management objectives and constraints if they have been specified.

Stock of Fish: A species, subspecies, geographical grouping or other category of fish capable of management as a unit.

Submersible: A manned or unmanned device that functions or operates primarily underwater and is used to harvest fish.

Subsistence Fishing: Fishing to obtain food for personal and/or community use rather than for profit sales or recreation.

Target Resources: Species or taxa sought after in a directed fishery.

Trophic Web: A network that represents the predator/prey interactions of an ecosystem.

Trap: A portable, enclosed, box-like device with one or more entrances used for catching and holding fish or marine organism.

Western Pacific Regional Fishery Management Council (WPRFMC or Council): A Regional Fishery Management Council established under the MSA, consisting of the State of Hawaii, the Territory of American Samoa, the Territory of Guam, and the Commonwealth of the Northern Mariana Islands which has authority over the fisheries in the Pacific Ocean seaward of such States, Territories, Commonwealths, and Possessions

of the United States in the Pacific Ocean Area. The Council has 13 voting members including eight appointed by the Secretary of Commerce at least one of whom is appointed from each of the following States: Hawaii, the Territories of American Samoa and Guam, and the Commonwealth of the Northern Mariana Islands.

Stock Assessment: An evaluation of a stock in terms of abundance and fishing mortality levels and trends, and relative to fishery management objectives and constraints if they have been specified.

Stock of Fish: A species, subspecies, geographical grouping or other category of fish capable of management as a unit.

Submersible: A manned or unmanned device that functions or operates primarily underwater and is used to harvest fish.

Subsistence Fishing: Fishing to obtain food for personal and/or community use rather than for profit sales or recreation.

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Western Pacific Regional Fishery Management Council (WPRFMC or Council): A Regional Fishery Management Council established under the MSA, consisting of the State of Hawaii, the Territory of American Samoa, the Territory of Guam, and the Commonwealth of the Northern Mariana Islands which has authority over the fisheries in the Pacific Ocean seaward of such States, Territories, Commonwealths, and Possessions of the United States in the Pacific Ocean Area. The Council has 13 voting members including eight appointed by the Secretary of Commerce at least one of whom is appointed from each of the following States: Hawaii, the Territories of American Samoa and Guam, and the Commonwealth of the Northern Mariana Islands.

Appendix C: Regulations Implementing the Hawaiian Archipelago Fishery Ecosystem Plan

PART 665—FISHERIES IN THE WESTERN PACIFIC

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- §665.2 Relation to other laws.
- §665.3 Licensing and registration.
- §665.4 Annual catch limits.
- §§665.5-665.11 [Reserved]
- §665.12 Definitions.
- §665.13 Permits and fees.
- §665.14 Reporting and recordkeeping.
- §665.15 Prohibitions.
- §665.16 Vessel identification.
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- §665.18 Framework adjustments to management measures.
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- §665.20 Western Pacific Community Development Program.

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- §665.241 Definitions.
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Figure 1 to Part 665—Carapace Length of Lobsters

Figure 2 to Part 665—Length of Fishing Vessels

Figure 3 to Part 665—Sample Fabricated Arceneaux Line Clipper

AUTHORITY: 16 U.S.C. 1801 *et seq.*

SOURCE: 75 FR 2205, Jan. 14, 2010, unless otherwise noted.

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Subpart A—General

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§665.1 Purpose and scope.

(a) The regulations in this part govern fishing for western Pacific fishery ecosystem MUS by vessels of the United States that operate or are based inside the outer boundary of the U.S. EEZ around American Samoa, Hawaii, Guam, the Northern Mariana Islands, Palmyra Atoll, Kingman Reef, Jarvis Island, Baker Island, Howland Island, Johnston Atoll, and Wake Island.

(b) General regulations governing fishing by all vessels of the United States and by fishing vessels other than vessels of the United States are contained in 50 CFR part 600.

(c) Regulations governing the harvest, possession, landing, purchase, and sale of shark fins are found in 50 CFR part 600 subpart N.

(d) This subpart contains regulations that are common to all western Pacific fisheries managed under Fishery Ecosystem Plans (FEPs) prepared by the Western Pacific Fishery Management Council under the Magnuson-Stevens Act.

(e) Regulations specific to individual areas and fisheries are included in subparts B through F of this part.

(f) Nothing in subparts B through F of this part is intended to supersede any valid state or Federal regulations that are more restrictive than those published here.

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§665.2 Relation to other laws.

NMFS recognizes that any state law pertaining to vessels registered under the laws of that state while operating in the fisheries regulated under this part, that is consistent with this part and the FEPs implemented by this part, shall continue in effect with respect to fishing activities regulated under this part.

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§665.3 Licensing and registration.

Any person who is required to do so by applicable state law or regulation must comply with licensing and registration requirements in the exact manner required by applicable state law or regulation.

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§665.4 Annual catch limits.

(a) *General.* For each fishing year, the Regional Administrator shall specify an annual catch limit, including any overage adjustments, for each stock or stock complex of management unit species defined in subparts B through F of this part, as recommended by the Council, and considering the best available scientific, commercial, and other information about the fishery for that stock or stock complex. The annual catch limit shall serve as the basis for invoking accountability measures in paragraph (f) of this section.

(b) *Overage adjustments.* If landings of a stock or stock complex exceed the specified annual catch limit in a fishing year, the Council will take action in accordance with 50 CFR 600.310(g), which may include recommending that the Regional Administrator reduce the annual catch limit for the subsequent year by the amount of the overage or other measures, as appropriate.

(c) *Exceptions.* The Regional Administrator is not required to specify an annual catch limit for a management unit species that is statutorily excepted from the requirement pursuant to 50 CFR 600.310(h)(2), or that the Council has identified as an ecosystem component species. The Regional

Administrator will publish in the FEDERAL REGISTER the list of ecosystem component species, and will publish any changes to the list, as necessary.

(d) *Annual catch target.* For each fishing year, the Regional Administrator may also specify an annual catch target that is below the annual catch limit of a stock or stock complex, as recommended by the Council. When used, the annual catch target shall serve as the basis for invoking accountability measures in paragraph (f) of this section.

(e) *Procedures and timing.* (1) No later than 60 days before the start of a fishing year, the Council shall recommend to the Regional Administrator an annual catch limit, including any overage adjustment, for each stock or stock complex. The recommended limit should be based on a recommendation of the SSC of the acceptable biological catch for each stock or stock complex. The Council may not recommend an annual catch limit that exceeds the acceptable biological catch recommended by the SSC. The Council may also recommend an annual catch target below the annual catch limit.

(2) No later than 30 days before the start of a fishing year, the Regional Administrator shall publish in the FEDERAL REGISTER a notice of the proposed annual catch limit specification and any associated annual catch target, and request public comment.

(3) No later than the start of a fishing year, the Regional Administrator shall publish in the FEDERAL REGISTER and use other methods to notify permit holders of the final annual catch limit specification and any associated annual catch target.

(f) *Accountability measures.* When any annual catch limit or annual catch target is projected to be reached, based on available information, the Regional Administrator shall publish notification to that effect in the FEDERAL REGISTER and shall use other means to notify permit holders.

(1) The notice will include an advisement that fishing for that stock or stock complex will be restricted beginning on a specified date, which shall not be earlier than 7 days after the date of filing the notice for public inspection at the Office of the Federal Register. The restriction may include, but is not limited to, closure of the fishery, closure of specific areas, changes to bag limits, or restrictions in effort. The restriction will remain in effect until the end of the fishing year, except that the Regional Administrator may, based on a recommendation from the Council, remove or modify the restriction before the end of the fishing year.

(2) It is unlawful for any person to conduct fishing in violation of the restrictions specified in the notification issued pursuant to paragraph (f)(1) of this section.

[76 FR 37286, June 27, 2011]

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§§665.5-665.11 [Reserved]

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§665.12 Definitions.

In addition to the definitions in the Magnuson-Stevens Act, §600.10 of this chapter, and subparts B through F of this part, general definitions for western Pacific fisheries have the following meanings:

American Samoa FEP means the Fishery Ecosystem Plan for American Samoa.

Bottomfish FMP means the Fishery Management Plan for Bottomfish and Seamount Groundfish of the Western Pacific Region established in 1986 and replaced by FEPs.

Carapace length means a measurement in a straight line from the ridge between the two largest spines above the eyes, back to the rear edge of the carapace of a spiny lobster (see Figure 1 to this part).

Circle hook means a fishing hook with the point turned perpendicularly back towards the shank.

Commercial fishing means fishing in which the fish harvested, either in whole or in part, are intended to enter commerce or enter commerce through sale, barter, or trade. All lobster fishing in Crustacean Permit Area 1 is considered commercial fishing.

Commonwealth of the Northern Mariana Islands (CNMI) means the Northern Mariana Islands.

Coral Reef Ecosystems FMP means the Fishery Management Plan for Coral Reef Ecosystems of the Western Pacific Region established in 2004 and replaced by FEPs.

Council means the Western Pacific Fishery Management Council.

Crustacean receiving vessel means a vessel of the United States to which lobsters taken in a crustacean management area are transferred from another vessel.

Crustaceans FMP means the Fishery Management Plan for Crustacean Fisheries of the Western Pacific Region established in 1982 and replaced by FEPs.

Currently harvested coral reef taxa (CHCRT) means coral reef associated species, families, or subfamilies, as defined in §§665.121, 665.221, 665.421, and 665.621, that have annual landings greater than 454.54 kg (1,000 lb) as reported on individual state, commonwealth, or territory catch reports or through creel surveys. Fisheries and research data from many of these species have been analyzed by regional management agencies.

Customary exchange means the non-market exchange of marine resources between fishermen and community residents, including family and friends of community residents, for goods, and/or services for cultural, social, or religious reasons. Customary exchange may include cost recovery through monetary reimbursements and other means for actual trip expenses, including but not limited to ice, bait, fuel, or food, that may be necessary to participate in fisheries in the western Pacific. Actual trip expenses do not include expenses that a fisherman would incur without making a fishing trip, including expenses relating to dock space, vessel mortgage payments, routine vessel maintenance, vessel registration fees, safety equipment required by U.S. Coast Guard, and other incidental costs and expenses normally associated with ownership of a vessel.

Dead coral means any precious coral that no longer has any live coral polyps or tissue.

Ecosystem component species means any western Pacific MUS that the Council has identified to be, generally, a non-target species, not determined to be subject to overfishing, approaching overfished, or overfished, not likely to become subject to overfishing or overfished, and generally not retained for sale or personal use.

EFP means an experimental fishing permit.

First level buyer means:

(1) The first person who purchases, with the intention to resell, management unit species, or portions thereof, that were harvested by a vessel that holds a permit or is otherwise regulated under crustacean fisheries in subparts B through E of this part; or

(2) A person who provides recordkeeping, purchase, or sales assistance in the first transaction involving MUS (such as the services provided by a wholesale auction facility).

Fishing gear, as used in regulations for the American Samoa, CNMI, Hawaii, and PRIA bottomfish fisheries in subparts B through E of this part, includes:

(1) Bottom trawl, which means a trawl in which the otter boards or the footrope of the net are in contact with the sea bed;

(2) Gillnet, (see §600.10);

(3) Hook-and-line, which means one or more hooks attached to one or more lines;

(4) Set net, which means a stationary, buoyed, and anchored gill net; and

(5) Trawl, (see §600.10).

Fishing trip means a period of time during which fishing is conducted, beginning when the vessel leaves port and ending when the vessel lands fish.

Fishing year means the year beginning at 0001 local time on January 1 and ending at 2400 local time on December 31, with the exception of fishing for Hawaii Restricted Bottomfish Species and any precious coral MUS.

Freeboard means the straight line vertical distance between a vessel's working deck and the sea surface. If the vessel does not have gunwale door or stern door that exposes the working deck, freeboard means the straight line vertical distance between the top of a vessel's railing and the sea surface.

Harvest guideline means a specified numerical harvest objective.

Hawaiian Archipelago means the Main and Northwestern Hawaiian Islands, including Midway Atoll.

Hawaii FEP means the Fishery Ecosystem Plan for the Hawaiian Archipelago.

Hookah breather means a tethered underwater breathing device that pumps air from the surface through one or more hoses to divers at depth.

Incidental catch or incidental species means species caught while fishing for the primary purpose of catching a different species.

Land or landing means offloading fish from a fishing vessel, arriving in port to begin offloading fish, or causing fish to be offloaded from a fishing vessel.

Large vessel means, as used in this part, any vessel equal to or greater than 50 ft (15.2 m) in length overall.

Length overall (LOA) or length of a vessel as used in this part, means the horizontal distance, rounded to the nearest foot (with any 0.5 foot or 0.15 meter fraction rounded upward), between the foremost part of the stem and the aftermost part of the stern, excluding bowsprits, rudders, outboard motor brackets, and similar fittings or attachments (see Figure 2 to this part). “Stem” is the foremost part of the vessel, consisting of a section of timber or fiberglass, or cast forged or rolled metal, to which the sides of the vessel are united at the fore end, with the lower end united to the keel, and with the bowsprit, if one is present, resting on the upper end. “Stern” is the aftermost part of the vessel.

Live coral means any precious coral that has live coral polyps or tissue.

Live rock means any natural, hard substrate, including dead coral or rock, to which is attached, or which supports, any living marine life form associated with coral reefs.

Low-use marine protected area (MPA) means an area of the U.S. EEZ where fishing operations have specific restrictions in order to protect the coral reef ecosystem, as specified under area restrictions in subparts B through F of this part.

Main Hawaiian Islands (MHI) means the islands of the Hawaii Archipelago lying to the east of 161° W. long.

Mariana Archipelago means Guam and the Northern Mariana Islands.

Mariana FEP means the Fishery Ecosystem Plan for the Mariana Archipelago.

Medium vessel, as used in this part, means any vessel equal to or more than 40 ft (12.2 m) and less than 50 ft (15.2 m) LOA.

Non-commercial fishing means fishing that does not meet the definition of commercial fishing in the Magnuson-Stevens Fishery Conservation and Management Act, and includes, but is not limited to, sustenance, subsistence, traditional indigenous, and recreational fishing.

Non-precious coral means any species of coral other than those listed under the definitions for precious coral in §§665.161, 665.261, 665.461, and 665.661.

Non-selective gear means any gear used for harvesting coral that cannot discriminate or differentiate between types, size, quality, or characteristics of living or dead coral.

Northwestern Hawaiian Islands (NWHI) means the islands of the Hawaiian Archipelago lying to the west of 161° W. long.

No-take MPA means an area of the U.S. EEZ that is closed to fishing for or harvesting of any MUS, as defined in subparts B through F of this part.

Offload means to remove MUS from a vessel.

Offset circle hook means a circle hook in which the barbed end of the hook is displaced relative to the parallel plane of the eyed end, or shank, of the hook when laid on its side.

Owner, as used in the regulations for the crustacean fisheries in subparts B through E of this part and §665.203(i) and (j), means a person who is identified as the current owner of the vessel as described in the Certificate of Documentation (Form CG-1270) issued by the United States Coast Guard (USCG) for a documented vessel, or in a registration certificate issued by a state, a territory, or the USCG for an undocumented vessel. As used in the regulations for the precious coral fisheries in subparts B through E of this part and §665.203(c) through (h), the definition of “owner” in §600.10 of this chapter continues to apply.

Pacific Islands Regional Office (PIRO) means the headquarters of the Pacific Islands Region, NMFS, located at 1845 Wasp Blvd., Bldg. 176, Honolulu, HI 96818; telephone number: 808-725-5000.

Pacific remote island areas (PRIA, or U.S. island possessions in the Pacific Ocean) means Palmyra Atoll, Kingman Reef, Jarvis Island, Baker Island, Howland Island, Johnston Atoll, Wake Island, and Midway Atoll.

Pelagics FEP means the Fishery Ecosystem Plan for Pacific Pelagic Fisheries of the Western Pacific Region.

Pelagics FMP means the Fishery Management Plan for Pelagic Fisheries of the Western Pacific Region that was established in 1987 and replaced by the western Pacific pelagic FEP.

Potentially harvested coral reef taxa (PHCRT) means coral reef associated species, families, or subfamilies, as defined in §§665.121, 665.221, 665.421, and 665.621, for which little or no information is available beyond general taxonomic and distribution descriptions. These species have either not been caught in the past or have been harvested annually in amounts less than 454.54 kg (1,000 lb).

Precious Corals FMP means the Fishery Management Plan for Precious Corals of the Western Pacific Region established in 1983 and replaced by fishery ecosystem plans (FEPs).

PRIA FEP means the Fishery Ecosystem Plan for the Pacific Remote Island Areas of Palmyra Atoll, Kingman Reef, Jarvis Island, Baker Island, Howland Island, Johnston Atoll, and Wake Island.

Protected species means an animal protected under the MMPA, as amended, listed under the ESA, as amended, or subject to the Migratory Bird Treaty Act, as amended.

Receiving vessel means a vessel that receives fish or fish products from a fishing vessel, and with regard to a vessel holding a permit under §665.801(e), that also lands western Pacific pelagic MUS taken by other vessels using longline gear.

Recreational fishing means fishing conducted for sport or pleasure, including charter fishing.

Regional Administrator means Regional Administrator, Pacific Islands Region, NMFS (see Table 1 of §600.502 of this chapter for address).

Selective gear means any gear used for harvesting coral that can discriminate or differentiate between type, size, quality, or characteristics of living or dead coral.

Special Agent-In-Charge (SAC) means the Special Agent-In-Charge, NMFS, Pacific Islands Enforcement Division, located at 1845 Wasp Blvd., Bldg. 176, Honolulu, HI 96818; telephone number: 808-725-6100, or a designee.

Special permit means a permit issued to allow fishing for coral reef ecosystem MUS in low-use MPAs or to fish for any PHCRT.

SSC means the Scientific and Statistical Committee of the Western Pacific Fishery Management Council.

State of Hawaii commercial marine license means the license required by the State of Hawaii for anyone to take marine life for commercial purposes (also known as the commercial fishing license).

Transship means to offload or otherwise transfer MUS or products thereof to a receiving vessel.

Trap means a box-like device used for catching and holding lobsters or fish.

U.S. harvested coral means coral caught, taken, or harvested by vessels of the United States within any fishery for which an FMP or FEP has been implemented under the Magnuson-Stevens Act.

Vessel monitoring system unit (VMS unit) means the hardware and software owned by NMFS, installed on vessels by NMFS, and required to track and transmit the positions of certain vessels.

Western Pacific fishery management area means those waters shoreward of the outer boundary of the EEZ around American Samoa, Guam, Hawaii, CNMI, Midway, Johnston and Palmyra Atolls, Kingman Reef, and Wake, Jarvis, Baker, and Howland Islands.

[75 FR 2205, Jan. 14, 2010, as amended at 76 FR 37286, June 27, 2011; 78 FR 33003, June 3, 2013; 79 FR 64111, Oct. 28, 2014]

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§665.13 Permits and fees.

(a) *Applicability.* The requirements for permits for specific western Pacific fisheries are set forth in subparts B through I of this part.

(b) *Validity.* Each permit is valid for fishing only in the specific fishery management areas identified on the permit.

(c) *Application.* (1) An application for a permit to operate in a Federal western Pacific fishery that requires a permit and is regulated under subparts B through I of this part may be obtained from NMFS PIRO. The completed application must be submitted to PIRO for consideration. In no case shall PIRO accept an application that is not on a Federal western Pacific fisheries permit application form.

(2) A minimum of 15 days after the day PIRO receives a complete application should be allowed for processing the application for fisheries under subparts B through I of this part. If an incomplete or improperly completed application is filed, NMFS will notify the applicant of the deficiency. If the applicant fails to correct the deficiency within 30 days following the date of the letter of notification of deficiency, the application will be administratively closed.

(d) *Change in application information.* Any change in the permit application information or vessel documentation, submitted under paragraph (c) of this section, must be reported to PIRO in writing within 15 days of the change to avoid a delay in processing the permit application. A minimum of 10 days from the day the information is received by PIRO should be given for PIRO to record any change in information from the permit application submitted under paragraph (c) of this section. Failure to report such changes may result in a delay in processing an application, permit holders failing to receive important notifications, or sanctions pursuant to the Magnuson-Stevens Act at 16 U.S.C. 1858(g) or 15 CFR part 904, subpart D.

(e) *Issuance.* After receiving a complete application submitted under paragraph (c) of this section, the Regional Administrator will issue a permit to an applicant who is eligible under this part, as appropriate.

(f) *Fees.* (1) PIRO will not charge a fee for a permit issued under §§665.142, 665.162, 665.242, 665.262, 665.442, 665.462, 665.642, or 665.662 of this part, for a Ho'omalulu limited access permit issued under §665.203, or for a Guam bottomfish permit issued under §665.404.

(2) PIRO will charge a non-refundable processing fee for each application (including transfer and renewal) for each permit listed in paragraphs (f)(2)(i) through (f)(2)(xiii) of this section. The amount of the fee is calculated in accordance with the procedures of the NOAA Finance Handbook for determining the administrative costs incurred in processing the permit. The fee may not exceed such costs. The appropriate fee is specified with each application form and must accompany each application. Failure to pay the fee will preclude the issuance, transfer, or renewal of any of the following permits:

- (i) Hawaii longline limited access permit.
- (ii) Mau Zone limited access permit.
- (iii) Coral reef ecosystem special permit.
- (iv) American Samoa longline limited access permit.
- (v) MHI non-commercial bottomfish permit.
- (vi) Western Pacific squid jig permit.

- (vii) Crustacean permit.
- (viii) CNMI commercial bottomfish permit.
- (ix) Marianas Trench Monument non-commercial permit.
- (x) Marianas Trench Monument recreational charter permit.
- (xi) Pacific Remote Islands Monument recreational charter permit.
- (xii) Rose Atoll Monument non-commercial permit.
- (xiii) Rose Atoll Monument recreational charter permit.

(g) *Expiration.* A permit issued under subparts B through I of this part is valid for the period specified on the permit unless revoked, suspended, transferred, or modified under 15 CFR part 904.

(h) *Replacement.* Replacement permits may be issued, without charge, to replace lost or mutilated permits. An application for a replacement permit is not considered a new application.

(i) *Transfer.* An application for a permit transfer under §§665.203(d), 665.242(e), or 665.801(k), or for registration of a permit for use with a replacement vessel under §665.203(i), must be submitted to PIRO as described in paragraph (c) of this section.

(j) *Alteration.* Any permit that has been altered, erased, or mutilated is invalid.

(k) *Display.* Any permit issued under this subpart, or a facsimile of such permit, must be on board the vessel at all times while the vessel is fishing for, taking, retaining, possessing, or landing MUS shoreward of the outer boundary of the fishery management area. Any permit issued under this section must be displayed for inspection upon request of an authorized officer.

(l) *Sanctions.* Procedures governing sanctions and denials are found at subpart D of 15 CFR part 904.

(m) *Permit appeals.* Procedures for appeals of permitting and administrative actions are specified in the relevant subparts of this part.

[75 FR 2205, Jan. 14, 2010, as amended at 78 FR 33003, June 3, 2013; 78 FR 39583, July 2, 2013]

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§665.14 Reporting and recordkeeping.

(a) Except for precious coral and crustacean fisheries, any person who is required to do so by applicable state law or regulation must make and/or file all reports of MUS landings containing all data and in the exact manner required by applicable state law or regulation.

(b) *Fishing record forms—(1) Applicability.* (i) The operator of a fishing vessel subject to the requirements of §§665.124, 665.142, 665.162, 665.203(a)(2), 665.224, 665.242, 665.262, 665.404, 665.424, 665.442, 665.462, 665.603, 665.624, 665.642, 665.662, 665.801, 665.905, 665.935, or 665.965 must maintain on board the vessel an accurate and complete record of catch, effort, and other data on paper report forms provided by the Regional Administrator, or electronically as specified and approved by the Regional Administrator, except as allowed in paragraph (b)(1)(iii) of this section.

(ii) All information specified by the Regional Administrator must be recorded on paper or electronically within 24 hours after the completion of each fishing day. The logbook information, reported on paper or electronically, for each day of the fishing trip must be signed and dated or otherwise authenticated by the vessel operator in the manner determined by the Regional Administrator, and be submitted or transmitted via an approved method as specified by the Regional Administrator, and as required by this paragraph (b).

(iii) In lieu of the requirements in paragraph (a)(1)(i) of this section, the operator of a fishing vessel registered for use under a Western Pacific squid jig permit pursuant to the requirements of §665.801(g) may participate in a state reporting system. If participating in a state reporting system, all required information must be recorded and submitted in the exact manner required by applicable state law or regulation.

(2) *Timeliness of submission.* (i) If fishing was authorized under a permit pursuant to §§665.142, 665.242, 665.442, 665.404, 665.162, 665.262, 665.462, 665.662, or 665.801, the vessel operator must submit the original logbook information for each day of the fishing trip to the Regional Administrator within 72 hours of the end of each fishing trip, except as allowed in paragraph (iii) of this section.

(ii) If fishing was authorized under a permit pursuant to §665.203(a)(2), the vessel operator or vessel owner must submit the original logbook form for each day of the fishing trip to the Regional Administrator within 72 hours of the end of each fishing trip.

(iii) If fishing was authorized under a PRIA bottomfish permit pursuant to §665.603(a), PRIA pelagic troll and handline permit pursuant to §665.801(f), crustacean fishing permit for the PRIA (Permit Area 4) pursuant to §665.642(a), or a precious coral fishing permit for Permit Area X-P-PI pursuant to §665.662, the original logbook form for each day of fishing within EEZ waters around the PRIA must be submitted to the Regional Administrator within 30 days of the end of each fishing trip.

(iv) If fishing was authorized under a permit pursuant to §§665.124, 665.224, 665.424, 665.624, 665.905, 665.935, or 665.965, the original logbook information for each day of fishing must be submitted to the Regional Administrator within 30 days of the end of each fishing trip.

(c) *Transshipment logbooks.* Any person subject to the requirements of §§665.124(a)(2), 665.224(a)(2), 665.424(a)(2), 665.624(a)(2), or 665.801(e) must maintain on board the vessel an accurate and complete NMFS transshipment logbook containing report forms provided by the Regional Administrator. All information specified on the forms must be recorded on the forms within 24 hours after the day of transshipment. Each form must be signed and dated by the receiving vessel operator. The original logbook for each day of transshipment activity must be submitted to the Regional Administrator within 72 hours of each landing of western Pacific pelagic MUS. The original logbook for each day of transshipment activity must be submitted to the Regional Administrator within 7 days of each landing of coral reef ecosystem MUS.

(d) *Sales report.* The operator of any fishing vessel subject to the requirements of §§665.142, 665.242, 665.442, or 665.642, or the owner of a medium or large fishing vessel subject to the requirements of §665.404(a)(2) must submit to the Regional Administrator, within 72 hours of offloading of crustacean MUS, an accurate and complete sales report on a form provided by the Regional Administrator. The form must be signed and dated by the fishing vessel operator.

(e) *Packing or weigh-out slips.* The operator of any fishing vessel subject to the requirements of §§665.142, 665.242, 665.442, or 665.642 must attach packing or weighout slips provided to the operator by the first-level buyer(s), unless the packing or weighout slips have not been provided in time by the buyer(s).

(f) *Modification of reporting and recordkeeping requirements.* The Regional Administrator may, after consultation with the Council, initiate rulemaking to modify the information to be provided on the fishing record forms, transshipment logbook, and sales report forms and timeliness by which the information is to be provided, including the submission of packing or weighout slips.

(g) *Availability of records for inspection.* (1) Western Pacific pelagic MUS. Upon request, any fish dealer must immediately provide an authorized officer access to inspect and copy all records of purchases, sales, or other transactions involving western Pacific pelagic MUS taken or handled by longline vessels that have permits issued under this subpart or that are otherwise subject to subpart F of this part, including, but not limited to, information concerning:

- (i) The name of the vessel involved in each transaction and the owner and operator of the vessel.
- (ii) The weight, number, and size of each species of fish involved in each transaction.
- (iii) Prices paid by the buyer and proceeds to the seller in each transaction.

(2) *Crustacean MUS.* Upon request, any first-level buyer must immediately allow an authorized officer and any employee of NMFS designated by the Regional Administrator, to access, inspect, and copy all records relating to the harvest, sale, or transfer of crustacean MUS taken by vessels that have permits issued under this subpart or §§665.140 through 665.145, 665.240 through 665.252, 665.440 through 665.445, or 665.640 through 665.645 of this part. This requirement may be met by furnishing the information on a worksheet provided by the Regional Administrator. The information must include, but is not limited to:

- (i) The name of the vessel involved in each transaction and the owner or operator of the vessel.
- (ii) The amount, number, and size of each MUS involved in each transaction.
- (iii) Prices paid by the buyer and proceeds to the seller in each transaction.

(3) *Bottomfish and seamount groundfish MUS.* Any person who is required by state laws and regulations to maintain records of landings and sales for vessels regulated by this subpart and by §§665.100 through 665.105, 665.200 through 665.212, 665.400 through 665.407, and 665.600 through 665.606 of this part must make those records immediately available for Federal inspection and copying upon request by an authorized officer.

(4) *Coral reef ecosystem MUS*. Any person who has a special permit and who is required by state laws and regulations to maintain and submit records of catch and effort, landings and sales for coral reef ecosystem MUS by this subpart and §§665.120 through 665.128, 665.220 through 665.228, 665.420 through 665.428, or 665.620 through 665.628 of this part must make those records immediately available for Federal inspection and copying upon request by an authorized officer as defined in §600.10 of this chapter.

(h) *State reporting*. Any person who has a permit under §§665.124, 665.203, 665.224, 665.404, 665.424, 665.603, or 665.624 and who is regulated by state laws and regulations to maintain and submit records of catch and effort, landings and sales for vessels regulated by subparts B through F of this part must maintain and submit those records in the exact manner required by state laws and regulations.

[75 FR 2205, Jan. 14, 2010, as amended at 78 FR 33003, June 3, 2013; 78 FR 39583, July 2, 2013]

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§665.15 Prohibitions.

In addition to the prohibitions in §600.725 of this chapter, it is unlawful for any person to:

(a) Engage in fishing without a valid permit or facsimile of a valid permit on board the vessel and available for inspection by an authorized officer, when a permit is required under §§665.13 or 665.17, unless the vessel was at sea when the permit was issued under §665.13, in which case the permit must be on board the vessel before its next trip.

(b) File false information on any application for a fishing permit under §665.13 or an EFP under §665.17.

(c) Fail to file reports in the exact manner required by any state law or regulation, as required in §665.14.

(d) Falsify or fail to make, keep, maintain, or submit any logbook or logbook form or other record or report required under §§665.14 and 665.17.

(e) Refuse to make available to an authorized officer or a designee of the Regional Administrator for inspection or copying, any records that must be made available in accordance with §665.14.

(f) Fail to affix or maintain vessel or gear markings, as required by §§665.16, 665.128, 665.228, 665.246, 665.428, 665.628, or 665.804.

(g) Violate a term or condition of an EFP issued under §665.17.

(h) Fail to report any take of or interaction with protected species as required by §665.17(k).

(i) Fish without an observer on board the vessel after the owner or agent of the owner has been directed by NMFS to make accommodations available for an observer under §§665.17, 665.105, 665.145, 665.207, 665.247, 665.407, 665.445, 665.606, 665.645, or 665.808.

(j) Refuse to make accommodations available for an observer when so directed by the Regional Administrator under §§665.105, 665.145, 665.207, 665.247, 665.407, 665.445, 665.606, 665.645, or 665.808, or under any provision in an EFP issued under §665.17.

(k) Fail to notify officials as required in §§665.126, 665.144, 665.205, 665.226, 665.244, 665.426, 665.444, 665.626, 665.644, 665.803, or 665.808.

(l) Fish for, take or retain within a no-take MPA, defined in §§665.99, 665.199, 665.399, or 665.599, any bottomfish MUS, crustacean MUS, western Pacific pelagic MUS, precious coral, seamount groundfish or coral reef ecosystem MUS.

(m) Fail to comply with a term or condition governing the vessel monitoring system in violation of §665.19.

(n) Fish for, catch, or harvest MUS without an operational VMS unit on board the vessel after installation of the VMS unit by NMFS, in violation of §665.19(e)(2).

(o) Possess MUS, that were harvested after NMFS has installed the VMS unit on the vessel, on board that vessel without an operational VMS unit, in violation of §665.19(e)(2).

(p) Interfere with, tamper with, alter, damage, disable, or impede the operation of a VMS unit or attempt any of the same; or move or remove a VMS unit without the prior permission of the SAC in violation of §665.19(e)(3).

(q) Make a false statement, oral or written, to an authorized officer, regarding the use, operation, or maintenance of a VMS unit, in violation of §665.19(e).

(r) Interfere with, impede, delay, or prevent the installation, maintenance, repair, inspection, or removal of a VMS unit, in violation of §665.19(e).

(s) Interfere with, impede, delay, or prevent access to a VMS unit by a NMFS observer, in violation of §665.808(f)(4).

(t) Connect or leave connected additional equipment to a VMS unit without the prior approval of the SAC, in violation of §665.19(f).

(u) Fail to comply with the restrictions specified in the notification issued pursuant to §665.4(f)(1), in violation of §665.15(f)(2).

[75 FR 2205, Jan. 14, 2010, as amended at 76 FR 37287, June 27, 2011]

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§665.16 Vessel identification.

(a) Applicability. Each fishing vessel subject to this part, except those identified in paragraph (e) of this section, must be marked for identification purposes, as follows:

(1) A vessel that is registered for use with a valid permit issued under §665.801 and used to fish on the high seas within the Convention Area as defined in §300.211 of this title must be marked in accordance with the requirements at §§300.14 and 300.217 of this title.

(2) A vessel that is registered for use with a valid permit issued under §665.801 of this part and not used to fish on the high seas within the Convention Area must be marked in accordance with either:

(i) Sections 300.14 and 300.217 of this title, or

(ii) Paragraph (b) of this section.

(3) A vessel that is registered for use with a valid permit issued under subparts B through E and subparts G through I of this part must be marked in accordance with paragraph (b) of this section.

(b) Identification. Each vessel subject to this section must be marked as follows:

(1) The vessel's official number must be affixed to the port and starboard sides of the deckhouse or hull, and on an appropriate weather deck, so as to be visible from enforcement vessels and aircraft. Marking must be legible and of a color that contrasts with the background.

(2) For fishing and receiving vessels of 65 ft (19.8 m) LOA or longer, the official number must be displayed in block Arabic numerals at least 18 inches (45.7 cm) in height, except that vessels in precious coral fisheries that are 65 ft (19.8 m) LOA or longer must be marked in block Arabic numerals at least 14 inches (35.6 cm) in height.

(3) For all other vessels, the official number must be displayed in block Arabic numerals at least 10 inches (25.4 cm) in height.

(c) The vessel operator must ensure that the official number is clearly legible and in good repair.

(d) The vessel operator must ensure that no part of the vessel, its rigging, or its fishing gear obstructs the view of the official number from an enforcement vessel or aircraft.

(e) The following fishing vessels are exempt from the vessel identification requirements in this section:

(1) A vessel registered for use under a MHI non-commercial bottomfish permit that is in compliance with State of Hawaii bottomfish vessel registration and marking requirements.

(2) A vessel less than 40 ft (12.2 m) LOA registered for use under a CNMI commercial bottomfish permit that is in compliance with CNMI bottomfish vessel registration and marking requirements.

[75 FR 2205, Jan. 14, 2010, as amended at 75 FR 3417, Jan. 21, 2010; 78 FR 33003, June 3, 2013; 78 FR 39583, July 2, 2013]

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§665.17 Experimental fishing.

(a) *General.* The Regional Administrator may authorize, for limited purposes, the direct or incidental harvest of MUS that would otherwise be prohibited by this part. No experimental fishing may be conducted unless authorized by an EFP issued by the Regional Administrator in accordance with the criteria and procedures specified in this section. EFPs will be issued without charge.

(b) *Observers.* No experimental fishing for crustacean MUS may be conducted unless a NMFS observer is aboard the vessel.

(c) *Application.* An applicant for an EFP must submit to the Regional Administrator at least 60 days before the desired date of the EFP a written application including, but not limited to, the following information:

(1) The date of the application.

(2) The applicant's name, mailing address, and telephone number.

(3) A statement of the purposes and goals of the experiment for which an EFP is needed, including a general description of the arrangements for disposition of all species harvested under the EFP.

(4) A statement of whether the proposed experimental fishing has broader significance than the applicant's individual goals.

(5) For each vessel to be covered by the EFP:

(i) Vessel name.

(ii) Name, address, and telephone number of owner and operator.

(iii) USCG documentation, state license, or registration number.

(iv) Home port.

(v) Length of vessel.

(vi) Net tonnage.

(vii) Gross tonnage.

(6) A description of the species (directed and incidental) to be harvested under the EFP and the amount of such harvest necessary to conduct the experiment.

(7) For each vessel covered by the EFP, the approximate times and places fishing will take place, and the type, size, and amount of gear to be used.

(8) The signature of the applicant.

(d) *Incomplete applications.* The Regional Administrator may request from an applicant additional information necessary to make the determinations required under this section. An applicant will be

notified of an incomplete application within 10 working days of receipt of the application. An incomplete application will not be considered until corrected in writing.

(e) *Issuance.* (1) If an application contains all of the required information, NMFS will publish a notice of receipt of the application in the FEDERAL REGISTER with a brief description of the proposal and will give interested persons an opportunity to comment. The Regional Administrator will also forward copies of the application to the Council, the USCG, and the fishery management agency of the affected state, accompanied by the following information:

(i) The current utilization of domestic annual harvesting and processing capacity (including existing experimental harvesting, if any) of the directed and incidental species for which an EFP is being requested.

(ii) A citation of the regulation or regulations that, without the EFP, would prohibit the proposed activity.

(iii) Biological information relevant to the proposal.

(2) At a Council meeting following receipt of a complete application, the Regional Administrator will consult with the Council and the Director of the affected state fishery management agency concerning the permit application. The applicant will be notified in advance of the meeting at which the application will be considered, and invited to appear in support of the application, if the applicant desires.

(3) Within 5 working days after the consultation in paragraph (e)(2) of this section, or as soon as practicable thereafter, NMFS will notify the applicant in writing of the decision to grant or deny the EFP and, if denied, the reasons for the denial. Grounds for denial of an EFP include, but are not limited to, the following:

(i) The applicant has failed to disclose material information required, or has made false statements as to any material fact, in connection with his or her application.

(ii) According to the best scientific information available, the harvest to be conducted under the permit would detrimentally affect any species of fish in a significant way.

(iii) Issuance of the EFP would inequitably allocate fishing privileges among domestic fishermen or would have economic allocation as its sole purpose.

(iv) Activities to be conducted under the EFP would be inconsistent with the intent of this section or the management objectives of the FEP.

(v) The applicant has failed to demonstrate a valid justification for the permit.

(vi) The activity proposed under the EFP would create a significant enforcement problem.

(4) The decision to grant or deny an EFP is final and unappealable. If the permit is granted, NMFS will publish a notice in the FEDERAL REGISTER describing the experimental fishing to be conducted under the EFP. The Regional Administrator may attach terms and conditions to the EFP consistent with the purpose of the experiment including, but not limited to:

- (i) The maximum amount of each species that can be harvested and landed during the term of the EFP, including trip limits, where appropriate.
- (ii) The number, sizes, names, and identification numbers of the vessels authorized to conduct fishing activities under the EFP.
- (iii) The times and places where experimental fishing may be conducted.
- (iv) The type, size, and amount of gear which may be used by each vessel operated under the EFP.
- (v) The condition that observers be carried aboard vessels operating under an EFP.
- (vi) Data reporting requirements.
- (vii) Such other conditions as may be necessary to assure compliance with the purposes of the EFP consistent with the objectives of the FEP.
- (f) *Duration.* Unless otherwise specified in the EFP or a superseding notice or regulation, an EFP is effective for no longer than one (1) year from the date of issuance, unless revoked, suspended, or modified. EFPs may be renewed following the application procedures in this section.
- (g) *Alteration.* Any EFP that has been altered, erased, or mutilated is invalid.
- (h) *Transfer.* EFPs issued under subparts B through F of this part are not transferable or assignable. An EFP is valid only for the vessel(s) for which it is issued.
- (i) *Inspection.* Any EFP issued under subparts B through F of this part must be carried aboard the vessel(s) for which it was issued. The EFP must be presented for inspection upon request of any authorized officer.
- (j) *Sanctions.* Failure of the holder of an EFP to comply with the terms and conditions of an EFP, the provisions of subparts A through F of this part, any other applicable provision of this part, the Magnuson-Stevens Act, or any other regulation promulgated thereunder, is grounds for revocation, suspension, or modification of the EFP with respect to all persons and vessels conducting activities under the EFP. Any action taken to revoke, suspend, or modify an EFP will be governed by 15 CFR part 904 subpart D. Other sanctions available under the statute will be applicable.
- (k) *Protected species.* Persons fishing under an EFP must report any incidental take or fisheries interaction with protected species on a form provided for that purpose. Reports must be submitted to the Regional Administrator within 3 days of arriving in port.

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§665.18 Framework adjustments to management measures.

Framework measures described below for each specific fishery are valid for all management areas, except where specifically noted in this section.

(a) *Pelagic measures—(1) Introduction.* Adjustments in management measures may be made through rulemaking if new information demonstrates that there are biological, social, or economic concerns in the fishery. The following framework process authorizes the implementation of measures that may affect the operation of the fisheries, gear, harvest guidelines, or changes in catch and/or effort.

(2) *Annual report.* By June 30 of each year, the Council-appointed pelagics monitoring team will prepare an annual report on the fisheries in the management area. The report shall contain, among other things, recommendations for Council action and an assessment of the urgency and effects of such action(s).

(3) *Procedure for established measures.* (i) Established measures are regulations for which the impacts have been evaluated in Council or NMFS documents in the context of current conditions.

(ii) The Council may recommend to the Regional Administrator that established measures be modified, removed, or reinstated. Such recommendation shall include supporting rationale and analysis, and shall be made after advance public notice, public discussion, and consideration of public comment. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

(4) *Procedure for new measures.* (i) New measures are regulations for which the impacts have not been evaluated in Council or NMFS documents in the context of current conditions.

(ii) The Council will publicize, including by FEDERAL REGISTER notice, and solicit public comment on, any proposed new management measure. After a Council meeting at which the measure is discussed, the Council will consider recommendations and prepare a FEDERAL REGISTER notice summarizing the Council's deliberations, rationale, and analysis for the preferred action, and the time and place for any subsequent Council meeting(s) to consider the new measure. At subsequent public meeting(s), the Council will consider public comments and other information received to make a recommendation to the Regional Administrator about any new measure. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

(b) *Crustacean measures—(1) Introduction.* New management measures may be added through rulemaking if new information demonstrates that there are biological, social, or economic concerns in Permit Areas 1, 2, or 3. The following framework process authorizes the implementation of measures that may affect the operation of the fisheries, gear, harvest guidelines, or changes in catch and/or effort.

(2) *Annual report.* By June 30 of each year, the Council-appointed team will prepare an annual report on the fisheries in the management area. The report shall contain, among other things, recommendations for Council action and an assessment of the urgency and effects of such action(s).

(3) *Procedure for established measures.* (i) Established measures are regulations for which the impacts have been evaluated in Council or NMFS documents in the context of current conditions.

(ii) The Council may recommend to the Regional Administrator that established measures be modified, removed, or reinstated. Such recommendation shall include supporting rationale and analysis, and shall be made after advance public notice, public discussion, and consideration of public comment. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

(4) *Procedure for new measures.* (i) New measures are regulations for which the impacts have not been evaluated in Council or NMFS documents in the context of current conditions.

(ii) The Council will publicize, including by a FEDERAL REGISTER document, and solicit public comment on, any proposed new management measure. After a Council meeting at which the measure is discussed, the Council will consider recommendations and prepare a FEDERAL REGISTER document summarizing the Council's deliberations, rationale, and analysis for the preferred action, and the time and place for any subsequent Council meeting(s) to consider the new measure. At subsequent public meeting(s), the Council will consider public comments and other information received to make a recommendation to the Regional Administrator about any new measure. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

(c) *Bottomfish measures—(1) Annual reports.* By June 30 of each year, a Council-appointed bottomfish monitoring team will prepare an annual report on the fishery by area covering the following topics:

(i) Fishery performance data.

(ii) Summary of recent research and survey results.

(iii) Habitat conditions and recent alterations.

(iv) Enforcement activities and problems.

(v) Administrative actions (e.g., data collection and reporting, permits).

(vi) State and territorial management actions.

(vii) Assessment of need for Council action (including biological, economic, social, enforcement, administrative, and state/Federal needs, problems, and trends). Indications of potential problems warranting further investigation may be signaled by the following indicator criteria:

(A) Mean size of the catch of any species in any area is a pre-reproductive size.

(B) Ratio of fishing mortality to natural mortality for any species.

(C) Harvest capacity of the existing fleet and/or annual landings exceed best estimate of MSY in any area.

(D) Significant decline (50 percent or more) in bottomfish catch per unit of effort from baseline levels.

(E) Substantial decline in ex-vessel revenue relative to baseline levels.

(F) Significant shift in the relative proportions of gear in any one area.

(G) Significant change in the frozen/fresh components of the bottomfish catch.

- (H) Entry/exit of fishermen in any area.
- (I) Per-trip costs for bottomfish fishing exceed per-trip revenues for a significant percentage of trips.
- (J) Significant decline or increase in total bottomfish landings in any area.
- (K) Change in species composition of the bottomfish catch in any area.
- (L) Research results.
- (M) Habitat degradation or environmental problems.
- (N) Reported interactions between bottomfish fishing operations and protected species in the NWHI.
- (viii) Recommendations for Council action.
- (ix) Estimated impacts of recommended action.

(2) *Recommendation of management action.* (i) The team may present management recommendations to the Council at any time. Recommendations may cover actions suggested for Federal regulations, state/territorial action, enforcement or administrative elements, and research and data collection. Recommendations will include an assessment of urgency and the effects of not taking action.

(ii) The Council will evaluate the team's reports and recommendations, and the indicators of concern. The Council will assess the need for one or more of the following types of management action: Catch limits, size limits, closures, effort limitations, access limitations, or other measures.

(iii) The Council may recommend management action by either the state/territorial governments or by Federal regulation.

(3) *Federal management action.* (i) If the Council believes that management action should be considered, it will make specific recommendations to the Regional Administrator after requesting and considering the views of its Scientific and Statistical Committee and Bottomfish Advisory Panel and obtaining public comments at a public hearing.

(ii) The Regional Administrator will consider the Council's recommendation and accompanying data, and, if he or she concurs with the Council's recommendation, will propose regulations to carry out the action. If the Regional Administrator rejects the Council's proposed action, a written explanation for the denial will be provided to the Council within 2 weeks of the decision.

(iii) The Council may appeal a denial by writing to the Assistant Administrator, who must respond in writing within 30 days.

(iv) The Regional Administrator and the Assistant Administrator will make their decisions in accord with the Magnuson-Stevens Act, other applicable law, and the bottomfish measures of the FEPs.

(v) To minimize conflicts between the Federal and state management systems, the Council will use the procedures in paragraph (c)(2) of this section to respond to state/territorial management actions.

Council consideration of action would normally begin with a representative of the state or territorial government bringing a potential or actual management conflict or need to the Council's attention.

(4) *Access limitation procedures.* (i) Access limitation may be adopted under this paragraph (c)(4) only for the NWHI, American Samoa, and Guam.

(ii) If access limitation is proposed for adoption or subsequent modification through the process described in this paragraph (c)(4), the following requirements must be met:

(A) The bottomfish monitoring team must consider and report to the Council on present participation in the fishery; historical fishing practices in, and dependence on, the fishery; economics of the fishery; capability of fishing vessels used in the fishery to engage in other fisheries; cultural and social framework relevant to the fishery; and any other relevant considerations.

(B) Public hearings must be held specifically addressing the limited access proposals.

(C) A specific advisory subpanel of persons experienced in the fishing industry will be created to advise the Council and the Regional Administrator on administrative decisions.

(D) The Council's recommendation to the Regional Administrator must be approved by a two-thirds majority of the voting members.

(5) *Five-year review.* The Council will conduct a comprehensive review on the effectiveness of the Mau Zone limited access program 5 years following implementation of the program. The Council will consider the extent to which the FEP objectives have been met and verify that the target number of vessels established for the fishery is appropriate for current fishing activity levels, catch rates, and biological condition of the stocks. The Council may establish a new target number based on the 5-year review.

(d) *Precious coral measures—(1) Introduction.* Established management measures may be revised and new management measures may be established and/or revised through rulemaking if new information demonstrates that there are biological, social, or economic concerns in a precious coral permit area. The following framework process authorizes the implementation of measures that may affect the operation of the fisheries, gear, quotas, season, or levels of catch and/or in effort.

(2) *Annual report.* By June 30 of each year, the Council-appointed precious coral team will prepare an annual report on the fisheries in the management area. The report will contain, among other things, recommendations for Council action and an assessment of the urgency and effects of such action(s).

(3) *Procedure for established measures.* (i) Established measures are regulations for which the impacts have been evaluated in Council or NMFS documents in the context of current conditions.

(ii) The Council may recommend to the Regional Administrator that established measures be modified, removed, or reinstated. Such recommendation will include supporting rationale and analysis and will be made after advance public notice, public discussion, and consideration of public comment. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

(4) *Procedure for new measures.* (i) New measures are regulations for which the impacts have not been evaluated in Council or NMFS documents in the context of current conditions.

(ii) The Council will publicize, including by a FEDERAL REGISTER document, and solicit public comment on, any proposed new management measure. After a Council meeting at which the measure is discussed, the Council will consider recommendations and prepare a FEDERAL REGISTER document summarizing the Council's deliberations, rationale, and analysis for the preferred action and the time and place for any subsequent Council meeting(s) to consider the new measure. At a subsequent public meeting, the Council will consider public comments and other information received before making a recommendation to the Regional Administrator about any new measure. If approved by the Regional Administrator, NMFS may implement the Council's recommendation by rulemaking.

(e) *Coral reef ecosystem measures—(1) Procedure for established measures.* (i) Established measures are regulations for which the impacts have been evaluated in Council or NMFS documents in the context of current conditions.

(ii) The Council may recommend to the Regional Administrator that established measures be modified, removed, or reinstated. Such recommendation shall include supporting rationale and analysis, and shall be made after advance public notice, public discussion and consideration of public comment. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

(2) *Procedure for new measures.* (i) New measures are regulations for which the impacts have not been evaluated in Council or NMFS documents in the context of current conditions. New measures include, but are not limited to, catch limits, resource size limits, closures, effort limitations, reporting and recordkeeping requirements.

(ii) The Regional Administrator will publicize, including by FEDERAL REGISTER notice, and solicit public comment on, any proposed new management measure. After a Council meeting at which the measure is discussed, the Council will consider recommendations and prepare a document summarizing the Council's deliberations, rationale, and analysis for the preferred action, and the time and place for any subsequent Council meeting(s) to consider the new measure. At subsequent public meeting(s), the Council will consider public comments and other information received to make a recommendation to the Regional Administrator about any new measure. NMFS may implement the Council's recommendation by rulemaking if approved by the Regional Administrator.

(A) The Regional Administrator will consider the Council's recommendation and supporting rationale and analysis, and, if the Regional Administrator concurs with the Council's recommendation, will propose regulations to carry out the action. If the Regional Administrator rejects the Council's proposed action, the Regional Administrator will provide a written explanation for the denial within 2 weeks of the decision.

(B) The Council may appeal a denial by writing to the Assistant Administrator, who must respond in writing within 30 days.

(C) The Regional Administrator and the Assistant Administrator will make their decisions in accordance with the Magnuson-Stevens Act, other applicable laws, and the FEPs.

(D) To minimize conflicts between the Federal and state/territorial/commonwealth management systems, the Council will use the procedures in this paragraph (e)(2)(ii) to respond to state/territorial/commonwealth management actions. The Council's consideration of action would normally begin with a representative of the state, territorial or commonwealth government bringing a potential or actual management conflict or need to the Council's attention.

(3) *Annual report.* By July 31 of each year, a Council-appointed coral reef ecosystem monitoring team will prepare an annual report on coral reef fisheries of the western Pacific region. The report will contain, among other things:

(i) Fishery performance data, summaries of new information and assessments of need for Council action.

(ii) Recommendation for Council action. The Council will evaluate the annual report and advisory body recommendations and may recommend management action by either the state/territorial/commonwealth governments or by Federal regulation.

(iii) If the Council believes that management action should be considered, it will make specific recommendations to the Regional Administrator after considering the views of its advisory bodies.

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§665.19 Vessel monitoring system.

(a) *Applicability.* The holder of any of the following permits is subject to the vessel monitoring system requirements in this part:

(1) Hawaii longline limited access permit issued pursuant to §665.801(b);

(2) American Samoa longline limited entry permit, for vessel size Class C or D, issued pursuant to §665.801(c);

(3) Vessels permitted to fish in Crustacean Permit Area 1 VMS Subarea; or

(4) CNMI commercial bottomfish permit, if the vessel is a medium or large bottomfish vessel, issued pursuant to §665.404(a)(2).

(b) *VMS unit.* Only a VMS unit owned by NMFS and installed by NMFS complies with the requirement of this subpart.

(c) *Notification.* After a permit holder subject to §665.19(a) has been notified by the SAC of a specific date for installation of a VMS unit on the permit holder's vessel, the vessel must carry and operate the VMS unit after the date scheduled for installation.

(d) *Fees and charges.* During the experimental VMS program, the holder of a permit subject to §665.19(a) shall not be assessed any fee or other charges to obtain and use a VMS unit, including the communication charges related directed to requirements under this section. Communication charges

related to any additional equipment attached to the VMS unit by the owner or operator shall be the responsibility of the owner or operator and not NMFS.

(e) *Permit holder duties.* The holder of a permit subject to §665.19(a) and master of the vessel must:

- (1) Provide opportunity for the SAC to install and make operational a VMS unit after notification.
- (2) Carry and continuously operate the VMS unit on board whenever the vessel is at sea.
- (3) Not remove, relocate, or make non-operational the VMS unit without prior approval from the SAC.

(f) *Authorization by the SAC.* The SAC has authority over the installation and operation of the VMS unit. The SAC may authorize the connection or order the disconnection of additional equipment, including a computer, to any VMS unit when deemed appropriate by the SAC.

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§665.20 Western Pacific Community Development Program.

(a) *General.* In accordance with the criteria and procedures specified in this section, the Regional Administrator may authorize the direct or incidental harvest of management unit species that would otherwise be prohibited by this part.

(b) *Eligibility.* To be eligible to participate in the western Pacific community development program, a community must meet the following criteria:

(1) Be located in American Samoa, Guam, Hawaii, or the Northern Mariana Islands (collectively, the western Pacific);

(2) Consist of community residents descended from aboriginal people indigenous to the western Pacific who conducted commercial or subsistence fishing using traditional fishing practices in the waters of the western Pacific;

(3) Consist of individuals who reside in their ancestral homeland;

(4) Have knowledge of customary practices relevant to fisheries of the western Pacific;

(5) Have a traditional dependence on fisheries of the western Pacific;

(6) Are currently experiencing economic or other constraints that have prevented full participation in the western Pacific fisheries and, in recent years, have not had harvesting, processing or marketing capability sufficient to support substantial participation in fisheries in the area; and

(7) Develop and submit a community development plan to the Council and the NMFS that meets the requirements in paragraph (c) of this section.

(c) *Community development plan.* An eligible community seeking access to a fishery under the authority of the Council and NMFS must submit to the Council a community development plan that includes, but is not limited to, the following information:

(1) A statement of the purposes and goals of the plan.

(2) A description and justification for the specific fishing activity being proposed, including:

(i) Location of the proposed fishing activity.

(ii) Management unit species to be harvested, and any potential bycatch.

(iii) Gear type(s) to be used.

(iv) Frequency and duration of the proposed fishing activity.

(3) A statement describing the degree of involvement by the indigenous community members, including the name, address, telephone and other contact information of each individual conducting the proposed fishing activity.

(4) A description of how the community and or its members meet each of the eligibility criteria in paragraph (b) of this section.

(5) If a vessel is to be used by the community to conduct fishing activities, for each vessel:

(i) Vessel name and official number (USCG documentation, state, territory, or other registration number).

(ii) Vessel length overall, displacement, and fish holding capacity.

(iii) Any valid federal fishing permit number(s).

(iv) Name, address, and telephone number of the vessel owner(s) and operator(s).

(d) *Council review.* The Council will review each community development plan to ensure that it meets the intent of the Magnuson-Stevens Act and contains all required information. The Council may consider advice of its advisory panels in conducting this review. If the Council finds the community development plan is complete, it will transmit the plan to the Regional Administrator for review.

(e) *Agency review and approval.* (1) Upon receipt of a community development plan from the Council, the Regional Administrator will review the plan for consistency with paragraphs (b), (c), and (d) of this section, and other applicable laws. The Regional Administrator may request from the applicant additional information necessary to make the determinations pursuant to this section and other applicable laws before proceeding with the review pursuant to paragraph (e)(2) of this section.

(2) If the Regional Administrator determines that a plan contains the required information and is consistent with paragraphs (b), (c), and (d) of this section, and other applicable laws, NMFS will publish a

notice in the FEDERAL REGISTER to solicit public comment on the proposed plan and any associated environmental review documents. The notice will include the following:

(i) A description of the fishing activity to be conducted.

(ii) The current utilization of domestic annual harvesting and processing capacity (including existing experimental harvesting, if any) of the target, incidental, and bycatch species.

(iii) A summary of any regulations that would otherwise prohibit the proposed fishing activity.

(iv) Biological and environmental information relevant to the plan, including appropriate statements of environmental impacts on target and non-target stocks, marine mammals, and threatened or endangered species.

(3) Within 90 days from the end of the comment period on the plan, the Regional Administrator will notify the applicant in writing of the decision to approve or disapprove the plan.

(4) If disapproved, the Regional Administrator will provide the reasons for the plan's disapproval and provide the community with the opportunity to modify the plan and resubmit it for review. Reasons for disapproval may include, but are not limited to, the following:

(i) The applicant failed to disclose material information or made false statements related to the plan.

(ii) The harvest would contribute to overfishing or would hinder the recovery of an overfished stock, according to the best scientific information available.

(iii) The activity would be inconsistent with an applicable law.

(iv) The activity would create a significant enforcement, monitoring, or administrative problem, as determined by the Regional Administrator.

(5) If approved, the Regional Administrator will publish a notice of the authorization in the FEDERAL REGISTER, and may attach limiting terms and conditions to the authorization including, but not limited to, the following:

(i) The maximum amount of each management unit species and potential bycatch species that may be harvested and landed during the term of the authorization.

(ii) The number, sizes, names, identification numbers, and federal permit numbers of the vessels authorized to conduct fishing activities.

(iii) Type, size, and amount of gear used by each vessel, including trip limits.

(iv) The times and places where fishing may or may not be conducted.

(v) Notification, observer, vessel monitoring, and reporting requirements.

(f) *Duration.* Unless otherwise specified, and unless revoked, suspended, or modified, a plan may be effective for no longer than five years.

(g) *Transfer.* Plans authorized under this section are not transferable or assignable.

(h) *Sanctions.* The Regional Administrator may revoke, suspend or modify a community development plan in the case of failure to comply with the terms and conditions of the plan, any other applicable provision of this part, the Magnuson-Stevens Act, or other applicable laws.

(i) *Program review.* NMFS and the Council will periodically review and assess each plan. If fishery, environmental, or other conditions have changed such that the plan's goals or requirements are not being met, or the fishery has become in an overfished state or overfishing is occurring, the Regional Administrator may revoke, suspend, or modify the plan.

[75 FR 54046, Sept. 3, 2010]

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Subpart C—Hawaii Fisheries

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§665.198 Management area.

The Hawaii fishery management area is the EEZ seaward of the State of Hawaii, including the Main Hawaiian Islands (MHI) and Northwestern Hawaiian Islands (NWHI), with the inner boundary a line coterminous with the seaward boundaries of the State of Hawaii and the outer boundary a line drawn in such a manner that each point on it is 200 nautical miles from the baseline from which the territorial sea is measured.

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§665.199 Area restrictions [Reserved]

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§665.200 Hawaii bottomfish and seamount groundfish fisheries. [Reserved]

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§665.201 Definitions.

As used in §§665.200 through 665.219:

Hawaii bottomfish management unit species (Hawaii bottomfish MUS) means the following species:

Local name	English common name	Scientific name
Lehi	silver jaw jobfish	<i>Aphareus rutilans</i> .
Uku white papio, ulua au	gray jobfish	<i>Aprion virescens</i> .
kea	giant trevally	<i>Caranx ignobilis</i> .
ulua la`uli	black jack	<i>Caranx lugubris</i> .
hpu`upu`u	sea bass	<i>Epinephalus quernus</i> .
Ehuonaga, `ula`ula	red snapper	<i>Etelis carbunculus</i> .
koa`e	longtail snapper	<i>Etelis coruscans</i> .
ta`ape	blue stripe snapper	<i>Lutjanus kasmira</i> .
kalekale	yellowtail snapper	<i>Pristipomoides auricilla</i> .
`pakapaka	pink snapper	<i>Pristipomoides filamentosus</i> .
kalekale	pink snapper	<i>Pristipomoides seiboldii</i> .
gindai	snapper	<i>Pristipomoides zonatus</i> .
pig ulua, butaguchi	thicklip trevally	<i>Pseudocaranx dentex</i> .
kahala	amberjack	<i>Seriola dumerili</i> .

Hawaii restricted bottomfish species fishing year means the year beginning at 0001 HST on September 1 and ending at 2400 HST on August 31 of the next calendar year.

Main Hawaiian Islands non-commercial bottomfish permit means the permit required by §665.203(a)(2) to own or fish from a vessel that is used in any non-commercial vessel-based fishing, landing, or transshipment of any Hawaii bottomfish MUS in the MHI Management Subarea.

Protected species study zone means the waters within 50 nm, as designated by the Regional Administrator pursuant to §665.208, around the following islands of the NWHI and as measured from the following coordinates:

Name	N. lat.	W. long.
Nihoa Island	23°05'	161°55'
Necker Island	23°35'	164°40'
French Frigate Shoals	23°45'	166°15'
Gardner Pinnacles	25°00'	168°00'
Maro Reef	25°25'	170°35'
Laysan Island	25°45'	171°45'
Lisianski Island	26°00'	173°55'
Pearl and Hermes Reef	27°50'	175°50'
Midway Island	28°14'	177°22'
Kure Island	28°25'	178°20'

Seamount Groundfish means the following species:

Common name	Scientific name
Armorhead	<i>Pseudopentaceros wheeleri</i> .
Alfonsin	<i>Beryx splendens</i> .
Raftfish	<i>Hyperoglyphe japonica</i> .

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§665.202 Management subareas.

(a) The Hawaii fishery management area is divided into subareas with the following designations and boundaries:

(1) Main Hawaiian Islands means the U.S. EEZ around the Hawaiian Archipelago lying to the east of 161°20' W. long.

(2) Northwestern Hawaiian Islands means the EEZ around the Hawaiian Archipelago lying to the west of 161°20' W. long. For the purposes of regulations issued under this subpart, Midway Island is treated as part of the NWHI Subarea.

(i) Ho'omaluu Zone means that portion of the EEZ around the NWHI west of 165° W. long.

(ii) Mau Zone means that portion of the EEZ around the NWHI between 161°20' W. long. and 165° W. long.

(3) Hancock Seamounts Ecosystem Management Area means that portion of the EEZ in the Northwestern Hawaiian Islands west of 180° W. long. and north of 28° N. lat.

(b) The inner boundary of each management subarea is a line coterminous with the seaward boundaries of the State of Hawaii.

(c) The outer boundary of each management subarea is a line drawn in such a manner that each point on it is 200 nautical miles from the baseline from which the territorial sea is measured.

[75 FR 2205, Jan. 14, 2010, as amended at 75 FR 69015, Nov. 10, 2010]

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§665.203 Permits.

(a) *Applicability*—(1) *Northwestern Hawaiian Islands*. The owner of any vessel used to fish for, land, or transship Hawaii bottomfish MUS shoreward of the outer boundary of the NWHI subarea must have a permit issued under this section, and the permit must be registered for use with that vessel. PIRO will not register a single vessel for use with a Ho'omaluu Zone permit and a Mau Zone permit at the same time. Mau Zone permits issued before June 14, 1999, became invalid June 14, 1999, except that a permit issued to a person who submitted a timely application under paragraph (b)(3) of this section is valid until the permit holder either receives a Mau Zone limited entry permit or until final agency action is taken on the permit holder's application. The Ho'omaluu Zone and the Mau Zone limited entry systems described in this section are subject to abolition, modification, or additional effort limitation programs.

(2) *MHI non-commercial*. The owner of a vessel that is used for and any person who participates in non-commercial, vessel-based fishing, landing, or transshipment of Hawaii bottomfish MUS in the MHI management subarea is required to obtain an MHI non-commercial bottomfish permit or a State of Hawaii Commercial Marine License. If one or more persons on a vessel-based bottomfish fishing trip holds an

MHI non-commercial permit, then the entire trip is considered non-commercial, and not commercial. However, if any commercial fishing occurs during or as a result of a vessel-based fishing trip, then the fishing trip is considered commercial, and not non-commercial. Charter boat customers are not subject to the requirements of the section.

(b) *Submission.* (1) An application for a permit required under this section must be submitted to PIRO as described in §665.13.

(2) Ho'omalau Zone limited access permit. In addition to an application under §665.13(c), each applicant for a Ho'omalau Zone permit must also submit a supplementary information sheet provided by PIRO, which must be signed by the vessel owner or a designee and include the following information:

(i) The qualification criterion that the applicant believes he or she meets for issuance of a limited access permit;

(ii) A copy of landings receipts or other documentation, with a certification from a state or Federal agency that this information is accurate, to demonstrate participation in the NWHI bottomfish fishery; and

(iii) If the application is filed by a partnership or corporation, the names of each of the individual partners or shareholders and their respective percentages of ownership of the partnership or corporation.

(3) Mau Zone limited access permit. PIRO will not accept applications for a new Mau Zone permit after June 14, 1999. In addition to an application under §665.13(c), each applicant for a Mau Zone permit must also submit a supplementary information sheet provided by PIRO, which must be signed by the vessel owner or a designee and include the following information:

(i) The qualification criterion that the applicant believes he or she meets for issuance of a limited access permit;

(ii) Copy of State of Hawaii catch report(s) to demonstrate that the permitted vessel had made qualifying landings of bottomfish from the Mau Zone; and

(iii) If the application is filed by a partnership or corporation, the names of each of the individual partners or shareholders and their respective percentage of ownership of the partnership or corporation.

(c) Sale or transfer of Ho'omalau limited access permits to new vessel owners.

(1) A Ho'omalau zone permit may not be sold or otherwise transferred to a new owner.

(2) A Ho'omalau zone permit or permits may be held by a partnership or corporation. If 50 percent or more of the ownership of the vessel passes to persons other than those listed in the original application, the permit will lapse and must be surrendered to the Regional Administrator.

(d) Transfer of Ho'omalau Zone limited access permits to replacement vessels.

(1) Upon application by the owner of a permitted vessel, the Regional Administrator will transfer that owner's permit to a replacement vessel owned by that owner, provided that the replacement vessel does

not exceed 60 ft (18.3 m) LOA. The replacement vessel must be put into service no later than 12 months after the owner applies for the transfer, or the transfer shall be void.

(2) An owner of a permitted vessel may apply to the Regional Administrator for transfer of that owner's permit to a replacement vessel greater than 60 ft (18.3 m) LOA. The Regional Administrator may transfer the permit upon determining, after consultation with the Council and considering the objectives of the limited access program, that the replacement vessel has catching power that is comparable to the rest of the vessels holding permits for the fishery, or has catching power that does not exceed that of the original vessel, and that the transfer is not inconsistent with the objectives of the program. The Regional Administrator shall consider vessel length, range, hold capacity, gear limitations, and other appropriate factors in making determinations of catching power equivalency and comparability of the catching power of vessels in the fishery.

(e) Ho'omaluu Zone limited access permit renewal.

(1) A qualifying landing for Ho'omaluu Zone permit renewal is a landing of at least 2,500 lb (1,134 kg) of Hawaii bottomfish MUS from the Ho'omaluu Zone or a landing of at least 2,500 lb (1,134 kg) of fish from the Ho'omaluu Zone, of which at least 50 percent by weight was Hawaii bottomfish MUS. A permit is eligible for renewal for the next calendar year if the vessel covered by the permit made three or more qualifying landings during the current calendar year.

(2) The owner of a permitted vessel that did not make three or more qualifying landings of bottomfish in a year may apply to the Regional Administrator for a waiver of the landing requirement. If the Regional Administrator finds that failure to make three landings was due to circumstances beyond the owner's control, the Regional Administrator may renew the permit. A waiver may not be granted if the failure to make three landings was due to general economic conditions or market conditions, such that the vessel operations would not be profitable.

(f) Issuance of new Ho'omaluu Zone limited access permits. The Regional Administrator may issue new Ho'omaluu Zone limited access permits under §665.13 if the Regional Administrator determines, in consultation with the Council, that bottomfish stocks in the Ho'omaluu Zone are able to support additional fishing effort.

(g) Eligibility for new Ho'omaluu Zone limited access permits. When the Regional Administrator has determined that new permits may be issued, they shall be issued to applicants based upon eligibility, determined as follows:

(1) *Point system.* (i) Two points will be assigned for each year in which the applicant was owner or captain of a vessel that made three or more of any of the following types of landings in the NWHI:

(A) Any amount of Hawaii bottomfish MUS, regardless of weight, if made on or before August 7, 1985;

(B) At least 2,500 lb (1,134 kg) of Hawaii bottomfish MUS, if made after August 7, 1985; or

(C) At least 2,500 lb (1,134 kg) of any fish lawfully harvested from the NWHI, of which at least 50 percent by weight was bottomfish, if made after August 7, 1985.

(ii) One point will be assigned for each year in which the applicant was owner or captain of a vessel that landed at least 6,000 lb (2,722 kg) of bottomfish from the MHI.

(iii) For any one year, points will be assigned under either paragraph (g)(1)(i) or (g)(1)(ii) of this section, but not under both paragraphs.

(iv) Before the Regional Administrator issues a Ho'omalau zone permit to fish for bottomfish under this section, the primary operator and relief operator named on the application form must have completed a protected species workshop conducted by NMFS.

(2) *Restrictions.* An applicant must own at least a 25 percent share in the vessel that the permit would cover, and only one permit will be assigned to any vessel.

(3) *Order of issuance.* New permits shall be awarded to applicants in descending order, starting with the applicant with the largest number of points. If two or more persons have an equal number of points, and there are insufficient new permits for all such applicants, the new permits shall be awarded by the Regional Administrator through a lottery.

(4) *Notification.* The Regional Administrator shall place a notice in the FEDERAL REGISTER and shall use other means to notify prospective applicants of the opportunity to file applications for new permits under this program.

(h) Eligibility for new Mau Zone limited access permits.

(1) PIRO will issue an initial Mau Zone permit to a vessel owner who qualifies for at least three points under the following point system:

(i) An owner who held a Mau Zone permit on or before December 17, 1991, and whose permitted vessel made at least one qualifying landing of Hawaii bottomfish MUS on or before December 17, 1991, shall be assigned 1.5 points.

(ii) An owner whose permitted vessel made at least one qualifying landing of Hawaii bottomfish MUS during 1991 shall be assigned 0.5 point.

(iii) An owner whose permitted vessel made at least one qualifying landing of Hawaii bottomfish MUS during 1992 shall be assigned 1.0 point.

(iv) An owner whose permitted vessel made at least one qualifying landing of Hawaii bottomfish MUS during 1993 shall be assigned 1.5 points.

(v) An owner whose permitted vessel made at least one qualifying landing of Hawaii bottomfish MUS during 1994 shall be assigned 2.0 points.

(vi) An owner whose permitted vessel made at least one qualifying landing of Hawaii bottomfish MUS during 1995 shall be assigned 2.5 points.

(vii) An owner whose permitted vessel made at least one qualifying landing of Hawaii bottomfish MUS during 1996 shall be assigned 3.0 points.

(viii) Before PIRO issues a Mau Zone permit to fish for bottomfish under this section, the primary operator and relief operator named on the application form must have completed a protected species workshop conducted by NMFS.

(2) For purposes of this paragraph (h), a “qualifying landing” means any amount of Hawaii bottomfish MUS lawfully harvested from the Mau Zone and offloaded for sale. No points shall be assigned to an owner for any qualifying landings reported to the State of Hawaii more than 1 year after the landing.

(3) More than one Mau Zone permit may be issued to an owner of two or more vessels, provided each of the owner's vessels for which a permit will be registered for use has made the required qualifying landings for the owner to be assigned at least three eligibility points.

(4) A Mau Zone permit holder who does not own a vessel at the time initial permits are issued must register the permit for use with a vessel owned by the permit holder within 12 months from the date the permit was issued. In the interim, the permit holder may register the permit for use with a leased or chartered vessel. If within 12 months of initial permit issuance, the permit holder fails to apply to PIRO to register the permit for use with a vessel owned by the permit holder, then the permit shall expire.

(5) For each of paragraphs (h)(1)(i) through (h)(1)(viii) of this section, PIRO shall assign points based on the landings of one permitted vessel to only one owner if the vessel did not have multiple owners during the time frame covered by the subordinate paragraphs. If a vessel had multiple owners during a time frame covered by any of paragraphs (h)(1)(i) through (h)(1)(viii) of this section (including joint owners, partners, or shareholders of a corporate owner), PIRO will assign the points for that subordinate paragraph to a single owner if only one owner submits an application with respect to the landings of that vessel during that time frame. If multiple owners submit separate applications with respect to the same landings of the same vessel during the same time frame, then PIRO shall:

(i) Adhere to any written agreement between the applicants with respect to who among them shall be assigned the aggregate point(s) generated by landings during such time frame(s), or

(ii) If there is no agreement:

(A) Shall issue the applicants a joint permit provided the vessel's landings during such time frames generated at least three points, or

(B) In the event the vessel's landings during such time frame(s) generated less than three points, shall not assign any points generated by the vessel's landings during such time frame(s).

(i) Ownership requirements and registration of Mau Zone limited access permits for use with other vessels.

(1) A Mau Zone permit may be held by an individual, partnership, or corporation. No more than 49 percent of the underlying ownership interest in a Mau Zone permit may be sold, leased, chartered, or otherwise transferred to another person or entity. If more than 49 percent of the underlying ownership of the permit passes to persons or entities other than those listed in the original permit application supplemental information sheet, then the permit expires and must be surrendered to PIRO.

(2) A Mau Zone permit holder may apply under §665.13 to PIRO to register the permit for use with another vessel if that vessel is owned by the permit holder, and is no longer than 60 ft (18.3 m) LOA.

(3) If a Mau Zone permit holder sells the vessel for which the permit is registered for use, the permit holder must, within 12 months of the date of sale, apply to PIRO to register the permit for use with a vessel owned by the permit holder. If the permit holder has not applied to register a replacement vessel within 12 months, then the permit expires.

(4) If a permitted vessel owned by the permit holder is sold or becomes unseaworthy, the Mau Zone permit with which the vessel was registered may be registered for use with a leased or chartered vessel for a period not to exceed 12 months from the date of registration of the leased or chartered vessel. If by the end of that 12-month period the permit holder fails to apply to PIRO to register the permit for use with a vessel owned by the permit holder, then the permit expires.

(j) Mau Zone limited access permit renewal.

(1) A Mau Zone permit will be eligible for renewal if the vessel for which the permit is registered for use made at least five separate fishing trips with landings of at least 500 lb (227 kg) of Hawaii bottomfish MUS per trip during the calendar year. Only one landing of bottomfish MUS per fishing trip to the Mau Zone will be counted toward the landing requirement.

(2) If the vessel for which the permit is registered for use fails to meet the landing requirement of paragraph (j)(1) of this section, the owner may apply to the Regional Administrator for a waiver of the landing requirement. Grounds for a waiver are limited to captain incapacitation, vessel breakdowns, and the loss of the vessel at sea if the event prevented the vessel from meeting the landing requirement. Unprofitability is not sufficient for waiver of the landing requirement.

(3) Failure of the permit holder to register a vessel for use under the permit does not exempt a permit holder from the requirements specified in this paragraph.

(k) Appeals of permit actions.

(1) Except as provided in subpart A of 15 CFR part 904, any applicant for a permit or a permit holder may appeal the granting, denial, or revocation of his or her permit to the Regional Administrator.

(2) In order to be considered by the Regional Administrator, such appeal must be in writing, must state the action appealed, and the reasons therefore, and must be submitted within 30 days of the appealed action. The appellant may request an informal hearing on the appeal.

(3) The Regional Administrator, in consultation with the Council, will decide the appeal in accordance with the FEP and implementing regulations and based upon information relative to the application on file at NMFS and the Council, the summary record kept of any hearing, the hearing officer's recommended decision, if any, and any other relevant information.

(4) If a hearing is requested, or if the Regional Administrator determines that one is appropriate, the Regional Administrator may grant an informal hearing before a hearing officer designated for that purpose. The applicant or permit holder may appear personally and/or be represented by counsel at the hearing and submit information and present arguments as determined appropriate by the hearing officer.

Within 30 days of the last day of the hearing, the hearing officer shall recommend in writing a decision to the Regional Administrator.

(5) The Regional Administrator may adopt the hearing officer's recommended decision, in whole or in part, or may reject or modify it. The Regional Administrator's decision on the application is the final administrative decision of the Department of Commerce, and is effective on the date the Administrator signs the decision.

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§665.204 Prohibitions.

In addition to the general prohibitions specified in §600.725 of this chapter and §665.15, it is unlawful for any person to do any of the following:

- (a) Fish for Hawaii bottomfish or seamount groundfish MUS using gear prohibited under §665.206.
- (b) Fish for, or retain on board a vessel, Hawaii bottomfish MUS in the Ho'omaluu Zone or the Mau Zone without the appropriate permit registered for use with that vessel issued under §665.13.
- (c) Serve as primary operator or relief operator on a vessel with a Mau or Ho'omaluu Zone permit without completing a protected species workshop conducted by NMFS, as required by §665.203.
- (d) Fail to notify the USCG at least 24 hours prior to making any landing of bottomfish taken in the Ho'omaluu Zone, as required by §665.205.
- (e) Fish within any protected species study zone in the NWHI without notifying the Regional Administrator of the intent to fish in these zones, as required under §664.205.
- (f) Falsify or fail to make or file reports of all fishing activities shoreward of the outer boundary of the MHI management subarea, in violation of §665.14(a) or (b).
- (g) Own a vessel or fish from a vessel that is used to fish non-commercially for any Hawaii bottomfish MUS in the MHI management subarea without either a MHI non-commercial bottomfish permit or a State of Hawaii Commercial Marine License, in violation of §§665.2 or 665.203(a)(2).
- (h) Fish for or possess any Hawaii Restricted Bottomfish Species as specified in §665.210, in the MHI management subarea after a closure of the fishery, in violation of §665.211.
- (i) Sell or offer for sale any Hawaii Restricted Bottomfish Species, as specified in §665.210, after a closure of the fishery, in violation of §665.211.
- (j) Harvest, possess, or land more than a total of five fish (all species combined) identified as Hawaii Restricted Bottomfish Species in §665.210 from a vessel in the MHI management subarea, while holding a MHI non-commercial bottomfish permit, or while participating as a charter boat customer, in violation of §665.212.

(k) Fish for or possess any Hawaii bottomfish or seamount groundfish MUS in the Hancock Seamounts Ecosystem Management Area, in violation of §665.209.

[75 FR 2205, Jan. 14, 2010, as amended at 75 FR 69015, Nov. 10, 2010]

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§665.205 Notification.

(a) The owner or operator of a fishing vessel subject to §665.203(a)(1) must inform PIRO at least 72 hours (not including weekends and holidays) before leaving port, of his or her intent to fish within the protected species study zones defined in §665.201. The notice must include the name of the vessel, name of the operator, intended departure and return date, and a telephone number at which the owner or operator may be contacted during the business day (8 a.m. to 5 p.m.) to indicate whether an observer will be required on the subject fishing trip.

(b) The operator of a fishing vessel that has taken Hawaii bottomfish MUS in the Ho'omalulu Zone must contact the USCG, by radio or otherwise, at the 14th District, Honolulu, HI; Pacific Area, San Francisco, CA; or 17th District, Juneau, AK, at least 24 hours before landing, and report the port and the approximate date and time at which the bottomfish will be landed.

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§665.206 Gear restrictions.

(a) *Bottom trawls and bottom set gillnets.* Fishing for Hawaii bottomfish and seamount groundfish MUS with bottom trawls and bottom set gillnets is prohibited.

(b) *Possession of gear.* Possession of a bottom trawl and bottom set gillnet by any vessel having a permit under §665.203 or otherwise established to be fishing for Hawaii bottomfish or seamount groundfish MUS in the management subareas is prohibited.

(c) *Poisons and explosives.* The possession or use of any poisons, explosives, or intoxicating substances for the purpose of harvesting Hawaii bottomfish and seamount groundfish MUS is prohibited.

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§665.207 At-sea observer coverage.

(a) All fishing vessels subject to §§665.200 through 665.212 must carry an observer when directed to do so by the Regional Administrator.

(b) PIRO will advise the vessel owner or operator of any observer requirement within 72 hours (not including weekends or holidays) of receipt of the notice provided pursuant to §665.205(a). If an observer is required, the owner or operator will be informed of the terms and conditions of observer coverage, and the time and place of embarkation of the observer.

(c) All observers must be provided with sleeping, toilet, and eating accommodations at least equal to that provided to a full crew member. A mattress or futon on the floor, or a cot, is not acceptable in place of a regular bunk. Meal and other galley privileges must be the same for the observer as for other crew members.

(d) Female observers on a vessel with an all-male crew must be accommodated either in a single-person cabin or, if reasonable privacy can be ensured by installing a curtain or other temporary divider, in a two-person cabin shared with a licensed officer of the vessel. If the cabin assigned to a female observer does not have its own toilet and shower facilities that can be provided for the exclusive use of the observer, then a schedule for time-sharing of common facilities must be established and approved by the Regional Administrator prior to the vessel's departure from port.

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§665.208 Protected species conservation.

The Regional Administrator may change the size of the protected species study zones defined in §665.201 of this subpart:

(a) If the Regional Administrator determines that a change in the size of the study zones would not result in fishing for bottomfish in the NWHI that would adversely affect any species listed as threatened or endangered under the ESA.

(b) After consulting with the Council.

(c) Through notification in the FEDERAL REGISTER published at least 30 days prior to the effective date or through actual notice to the permit holders.

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§665.209 Fishing moratorium at Hancock Seamounts.

Fishing for, and possession of, Hawaii bottomfish and seamount groundfish MUS in the Hancock Seamounts Ecosystem Management Area is prohibited until the Regional Administrator determines that the armorhead stock is rebuilt.

[75 FR 69016, Nov. 10, 2010]

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§665.210 Hawaii restricted bottomfish species.

Hawaii restricted bottomfish species means the following species:

Local name	English	Scientific name
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	common name	
lehi	silver jaw jobfish	<i>Aphareus rutilans.</i>
ehu	squirreelfish snapper	<i>Etelis carbunculus.</i>
onaga	longtail snapper	<i>Etelis coruscans.</i>
opakapaka	Pink snapper	<i>Pristipomoides filamentosus.</i>
kalekale	snapper	<i>Pristipomoides sieboldii.</i>
gindai	snapper	<i>Pristipomoides zonatus.</i>
hapu`upu`u	sea bass	<i>Epinephelus quernus.</i>

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§665.211 Total Allowable Catch (TAC) limit.

(a) TAC limits will be set annually for the fishing year by NMFS, as recommended by the Council, based on the best available scientific, commercial, and other information, and taking into account the associated risk of overfishing.

(b) The Regional Administrator shall publish a notice indicating the annual TAC limit in the FEDERAL REGISTER by August 31 of each year, and shall use other means to notify permit holders of the TAC limit for the year.

(c) When the TAC limit specified in this section is projected to be reached based on analyses of available information, the Regional Administrator shall publish a notice to that effect in the FEDERAL REGISTER and shall use other means to notify permit holders. The notice will include an advisement that the fishery will be closed beginning at a specified date, which is not earlier than 7 days after the date of filing the closure notice for public inspection at the Office of the Federal Register, until the end of the fishing year in which the TAC is reached.

(d) On and after the date specified in §665.211(c), no person may fish for or possess any Hawaii Restricted Bottomfish Species as specified in §665.210 in the MHI management subarea, except as otherwise allowed in this section.

(e) On and after the date specified in §665.211(c), no person may sell or offer for sale Hawaii Restricted Bottomfish Species as specified in §665.210, except as otherwise authorized by law.

(f) Fishing for, and the resultant possession or sale of, Hawaii Restricted Bottomfish Species by vessels legally registered to Mau Zone, Ho`omalau Zone, or PRIA bottomfish fishing permits and conducted in compliance with all other laws and regulations, is exempted from this section.

[75 FR 2205, Jan. 14, 2010, as amended at 76 FR 15222, Mar. 21, 2011]

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§665.212 Non-commercial bag limits.

No more than a total of five fish (all species combined) identified as Hawaii Restricted Bottomfish Species as specified in §665.210, may be harvested, possessed, or landed by any individual participating in a non-commercial vessel-based fishing trip in the MHI management subarea. Charter boat customers are also subject to the bag limit.

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§§665.213-665.219 [Reserved]

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§665.220 Hawaii coral reef ecosystem fisheries. [Reserved]

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§665.221 Definitions.

As used in §§665.220 through 665.239:

Hawaii coral reef ecosystem management unit species (Hawaii coral reef ecosystem MUS) means all of the Currently Harvested Coral Reef Taxa and Potentially Harvested Coral Reef Taxa listed in this section and which spend the majority of their non-pelagic (post-settlement) life stages within waters less than or equal to 50 fathoms in total depth.

Hawaii Currently Harvested Coral Reef Taxa:

Family name	Local name	English common name	Scientific name
Acanthuridae (Surgeonfishes)	na`ena`e	orange-spot surgeonfish	<i>Acanthurus olivaceus.</i>
	Pualu	yellowfin surgeonfish	<i>Acanthurus xanthopterus.</i>

	Manini	convict tang	<i>Acanthurus triostegus.</i>
	Palani	eye-striped surgeonfish	<i>Acanthurus dussumieri.</i>
	Maiko	blue-lined surgeon	<i>Acanthurus nigroris.</i>
	maiko, maikoiko	whitebar surgeonfish	<i>Acanthurus leucopareius.</i>
		whitecheek surgeonfish	<i>Acanthurus nigricans.</i>
	`api	white-spotted surgeonfish	<i>Acanthurus guttatus.</i>
	Pualu	ringtail surgeonfish	<i>Acanthurus blochii.</i>
	mai`i`i	brown surgeonfish	<i>Acanthurus nigrofuscus.</i>
	Kole	yellow-eyed surgeonfish	<i>Ctenochaetus strigosus.</i>
	NA	striped bristletooth	<i>Ctenochaetus striatus.</i>
	Kala	bluespine unicornfish	<i>Naso unicornus.</i>
	kalalei, umaumalei	orangespine unicornfish	<i>Naso lituratus.</i>
Acanthuridae (Surgeonfishes)	kala holo	black tongue unicornfish	<i>Naso hexacanthus.</i>
	Kala	whitemargin unicornfish	<i>Naso annulatus.</i>
	kala lolo	spotted unicornfish	<i>Naso brevirostris.</i>

		gray unicornfish	<i>Naso caesius</i> .
	lau`ipala	yellow tang	<i>Zebrasoma flavescens</i> .
Balistidae (Triggerfish)	humuhumu hi`ukole	pinktail triggerfish	<i>Melichthys vidua</i> .
	humuhumu `ele`ele	black triggerfish	<i>Melichthys niger</i> .
	humuhumu nukunuku apua`a	picassofish	<i>Rhinecanthus aculeatus</i> .
		bridled triggerfish	<i>Sufflamen fraenatum</i> .
Carangidae (Jacks)	akule, hahalu	bigeye scad	<i>Selar crumenophthalmus</i> .
	`opelu, `opelu mama	mackerel scad	<i>Decapterus macarellus</i> .
Carcharhinidae (Sharks)	Man	grey reef shark	<i>Carcharhinus amblyrhynchos</i> .
	Man	galapagos shark	<i>Carcharhinus galapagensis</i> .
	Man	blacktip reef shark	<i>Carcharhinus melanopterus</i> .
	man lalakea	whitetip reef shark	<i>Triaenodon obesus</i> .
Holocentridae (Soldierfish/Squirrel- fish)	menpachi, `u`u menpachi, `u`u	bigscale soldierfish brick soldierfish	<i>Myripristis berndti</i> . <i>Myripristis amaena</i> .
	menpachi, `u`u	yellowfin soldierfish	<i>Myripristis chryseres</i> .
	menpachi, `u`u	pearly soldierfish	<i>Myripristis kuntee</i> .

	`ala`ihi	file-lined squirrelfish	<i>Sargocentron microstoma.</i>
	`ala`ihi	crown squirrelfish	<i>Sargocentron diadema.</i>
	`ala`ihi	peppered squirrelfish	<i>Sargocentron punctatissimum.</i>
	`ala`ihi	blue-lined squirrelfish	<i>Sargocentron tiere.</i>
	`ala`ihi	Hawaiian squirrelfish	<i>Sargocentron xantherythrum.</i>
	`ala`ihi	saber or long jaw squirrelfish	<i>Sargocentron spiniferum.</i>
	`ala`ihi	spotfin squirrelfish	<i>Neoniphon</i> spp.
Kuhliidae (Flagtails)	`aholehole	Hawaiian flag-tail	<i>Kuhlia sandvicensis.</i>
Kyphosidae (Rudderfish)	Nenuē	rudderfish	<i>Kyphosus biggibus.</i>
	Nenuē	rudderfish	<i>Kyphosus cinerascens.</i>
	Nenuē	rudderfish	<i>Kyphosus vaigiensis.</i>
Labridae (Wrasses)	`a`awa	saddleback hogfish	<i>Bodianus bilunulatus.</i>
	po`ou	ring-tailed wrasse	<i>Oxycheilinus unifasciatus.</i>
	laenihi, nabeta	razor wrasse	<i>Xyrichtys pavo.</i>
	kupoupou ho`u	cigar wrasse	<i>Cheilio inermis.</i>
		surge wrasse	<i>Thalassoma purpureum.</i>

		red ribbon wrasse	<i>Thalassoma quinquevittatum.</i>
		sunset wrasse	<i>Thalassoma lutescens.</i>
		rockmover wrasse	<i>Novaculichthys taeniourus.</i>
Mullidae (Goatfishes)	Weke	yellow goatfish	<i>Mulloidichthys</i> spp.
	weke nono	orange goatfish	<i>Mulloidichthys pfleugeri.</i>
	weke`ula	yellowfin goatfish	<i>Mulloidichthys vanicolensis.</i>
	weke`a or weke a`a	yellowstripe goatfish	<i>Mulloidichthys flavolineatus.</i>
	kumu, moano	banded goatfish	<i>Parupeneus</i> spp.
	Munu	doublebar goatfish	<i>Parupeneus bifasciatus.</i>
	moano kea, moano kale	yellowsaddle goatfish	<i>Parupeneus cyclostomas.</i>
	Malu	side-spot goatfish	<i>Parupeneus pleurostigma.</i>
	Moano	multi-barred goatfish	<i>Parupeneus multifasciatus.</i>
	weke pueo	bandtail goatfish	<i>Upeneus arge.</i>
Mugilidae (Mulletts)	`ama`ama	stripped mullet	<i>Mugil cephalus.</i>
	Uouoa	false mullet	<i>Neomyxus leuciscus.</i>

Muraenidae (Moray eels)	puhi paka	yellowmargin moray eel	<i>Gymnothorax flavimarginatus.</i>
	Puhi	giant moray eel	<i>Gymnothorax javanicus.</i>
	puhi laumilo	undulated moray eel	<i>Gymnothorax undulatus.</i>
	Puhi	dragon eel	<i>Enchelycore pardalis.</i>
Octopodidae (Octopus)	he`e maui, tako	octopus	<i>Octopus cyanea.</i>
	he`e, tako	octopus	<i>Octopus ornatus.</i>
Polynemidae	Moi	threadfin	<i>Polydactylus sexfilis.</i>
Priacanthidae (Big-eyes)	`aweoweo	glasseye	<i>Heteropriacanthus cruentatus.</i>
	`aweoweo	bigeye	<i>Priacanthus hamrur.</i>
Scaridae (Parrotfish)	uhu, palukaluka	parrotfish	<i>Scarus</i> spp.
	panuhunuhu	stareye parrotfish	<i>Calotomus carolinus.</i>
Sphyraenidae (Barracuda)	kawele`a, kaku	Heller's barracuda	<i>Sphyraena helleri.</i>
	Kaku	great barracuda	<i>Sphyraena barracuda.</i>
Turbinidae		green snails turban shells	<i>Turbo</i> spp.
Zanclidae	kihikihi	moorish idol	<i>Zanclus cornutus.</i>
Chaetodontidae	kikakapu	butterflyfish	<i>Chaetodon auriga.</i>
	kikakapu	raccoon butterflyfish	<i>Chaetodon lunula.</i>
	kikakapu	saddleback	<i>Chaetodon ephippium.</i>

		butterflyfish	
Sabellidae		featherduster worm.	

Hawaii Potentially Harvested Coral Reef Taxa:

Local name	English common name	Scientific name
Hinalea	wrasses (Those species not listed as CHCRT)	Labridae.
Man	sharks (Those species not listed as CHCRT)	Carcharhinidae, Sphyrnidae.
Hihimanu	rays and skates	Dasyatidae, Myliobatidae.
roi, hapu`upu`u	groupers, seabass (Those species not listed as CHCRT or in BMUS)	Serrandiae.
	tilefishes	Malacanthidae.
dobe, kagami, pa`opa`o, papa, omaka, ulua	jacks and scads (Those species not listed as CHCRT or in BMUS)	Carangidae.
`u`u	solderfishes and squirrelfishes (Those species not listed as CHCRT)	Holocentridae.
weke, moano, kumu	goatfishes (Those species not listed as CHCRT)	Mullidae.
na`ena`e, maikoiko	surgeonfishes (Those species not listed as CHCRT)	Acanthuridae.
	remoras	Echeneidae.
Puhi	eels (Those species not listed as CHCRT)	Muraenidae, Congridae,

		Ophichthidae.
ʻupapalu	cardinalfishes	Apogonidae.
	herrings	Clupeidae.
Nehu	anchovies	Engraulidae.
	coral crouchers	Caracanthidae.
ʻo`opu	gobies	Gobiidae.
to`au	snappers (Those species not listed as CHCRT or in BMUS)	Lutjanidae.
Nunu	trumpetfish	<i>Aulostomus chinensis</i> .
nunu peke	cornetfish	<i>Fistularia commersoni</i> .
Kihikihi	moorish Idols	Zanclidae.
Kikakapu	butterflyfishes	Chaetodontidae.
	angelfishes	Pomacanthidae.
Mamo	damsel-fishes	Pomacentridae.
nohu, okoze	scorpionfishes, lionfishes	Scorpaenidae.
pa o'o	blennies	Blenniidae.
Kaku	barracudas (Those species not listed as CHCRT)	Sphyraenidae.
	sandperches	Pinguipedidae.
paki`i	flounders and soles	Bothidae, Soleidae, Pleuronectidae.

Makukana	trunkfishes	Ostraciidae.
humu humu	trigger fishes (Those species not listed as CHCRT)	Balistidae.
Nenuē	rudderfishes (Those species not listed as CHCRT)	Kyphosidae.
po`opa`a	hawkfishes (Those species not listed as CHCRT)	Cirrhitidae.
o`opu hue, fugu	puffer fishes and porcupine fishes	Tetradontidae.
	frogfishes	Antennariidae.
	pipefishes and seahorses	Syngnathidae.
namako, lole, wana	sea cucumbers and sea urchins (Those species not listed as CHCRT)	Echinoderms. Mollusca.
ko`a	ahermatypic corals	Azooxanthellates.
ko`a	mushroom corals	Fungiidae.
ko`a	small and large coral polyps	
	soft corals and gorgonians	
	anemones	Actinaria.
	soft zoanthid corals	Zoanthinaria.
	hydroid corals	Solanderidae.
ko`a	lace corals	Stylasteridae.
ula, a`ama, mo`ala, `alakuma	lobsters, shrimps, mantis shrimps, true crabs and hermit crabs (Those species not listed as	Crustaceans.

	CMUS)	
		Hydrozoans, Bryzoans.
	black-lip pearl oyster	<i>Pinctada margaritifera</i> .
	other clams	Other Bivalves.
	sea squirts	Tunicates.
	sponges	Porifera.
tako, he`e	octopi	Cephalopods.
	sea snails	Gastropoda.
	sea slugs	Opisthobranchs.
Limu	seaweed	Algae.
		Live rock.
	segmented worms (Those species not listed as CHCRT)	Annelids.
All other Hawaii coral reef ecosystem MUS that are marine plants, invertebrates, and fishes that are not listed in the Hawaii CHCRT table or are not Hawaii bottomfish, crustacean, precious coral, seamount groundfish or western Pacific pelagic MUS.		

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§665.222 Management area.

The Hawaii coral reef ecosystem management area is as follows:

- (a) The U.S. EEZ around the Hawaiian Archipelago lying to the east of 160°50' W. long.
- (b) The inner boundary of the management area is the seaward boundary of the State of Hawaii.
- (c) The outer boundary of the management area is the outer boundary of the U.S. EEZ.

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§665.223 Relation to other laws.

To ensure consistency between the management regimes of different Federal agencies with shared management responsibilities of fishery resources within the Hawaii coral reef ecosystem management area, fishing for Hawaii coral reef ecosystem MUS is not allowed within the boundary of a National Wildlife Refuge unless specifically authorized by the USFWS, regardless of whether that refuge was established by action of the President or the Secretary of the Interior.

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§665.224 Permits and fees.

(a) *Applicability.* Unless otherwise specified in this subpart, §665.13 applies to Hawaii coral reef ecosystem permits.

(1) *Special permit.* Any person of the United States fishing for, taking or retaining Hawaii coral reef ecosystem MUS must have a special permit if they, or a vessel which they operate, is used to fish for any:

(i) Hawaii coral reef ecosystem MUS in low-use MPAs as defined in §665.199;

(ii) Hawaii Potentially Harvested Coral Reef Taxa in the coral reef ecosystem management area; or

(iii) Hawaii coral reef ecosystem MUS in the coral reef ecosystem management area with any gear not specifically allowed in this subpart.

(2) *Transshipment permit.* A receiving vessel must be registered for use with a transshipment permit if that vessel is used in the Hawaii coral reef ecosystem management area to land or transship PHCRT, or any Hawaii coral reef ecosystem MUS harvested within low-use MPAs.

(3) *Exceptions.* The following persons are not required to have a permit under this section:

(i) Any person issued a permit to fish under any FEP who incidentally catches Hawaii coral reef ecosystem MUS while fishing for bottomfish MUS, crustacean MUS, western Pacific pelagic MUS, precious coral, or seamount groundfish.

(ii) Any person fishing for Hawaii CHCRT outside of an MPA, who does not retain any incidentally caught Hawaii PHCRT; and

(iii) Any person collecting marine organisms for scientific research as described in §665.17, or §600.745 of this chapter.

(b) *Validity.* Each permit will be valid for fishing only in the fishery management area specified on the permit.

(c) *General requirements.* General requirements governing application information, issuance, fees, expiration, replacement, transfer, alteration, display, sanctions, and appeals for permits are contained in §665.13.

(d) *Special permit.* The Regional Administrator shall issue a special permit in accordance with the criteria and procedures specified in this section.

(1) *Application.* An applicant for a special or transshipment permit issued under this section must complete and submit to the Regional Administrator a Special Coral Reef Ecosystem Fishing Permit Application Form issued by NMFS. Information in the application form must include, but is not limited to a statement describing the objectives of the fishing activity for which a special permit is needed, including a general description of the expected disposition of the resources harvested under the permit (*i.e.*, stored live, fresh, frozen, preserved, sold for food, ornamental, research, or other use, and a description of the planned fishing operation, including location of fishing and gear operation, amount and species (directed and incidental) expected to be harvested and estimated habitat and protected species impacts).

(2) *Incomplete applications.* The Regional Administrator may request from an applicant additional information necessary to make the determinations required under this section. An applicant will be notified of an incomplete application within 10 working days of receipt of the application. An incomplete application will not be considered until corrected in writing.

(3) *Issuance.* (i) If an application contains all of the required information, the Regional Administrator will forward copies of the application within 30 days to the Council, the USCG, the fishery management agency of the affected state, and other interested parties who have identified themselves to the Council, and the USFWS.

(ii) Within 60 days following receipt of a complete application, the Regional Administrator will consult with the Council through its Executive Director, USFWS, and the Director of the affected state fishery management agency concerning the permit application and will receive their recommendations for approval or disapproval of the application based on:

(A) Information provided by the applicant;

(B) The current domestic annual harvesting and processing capacity of the directed and incidental species for which a special permit is being requested;

(C) The current status of resources to be harvested in relation to the overfishing definition in the FEP;

(D) Estimated ecosystem, habitat, and protected species impacts of the proposed activity; and

(E) Other biological and ecological information relevant to the proposal. The applicant will be provided with an opportunity to appear in support of the application.

(iii) Following a review of the Council's recommendation and supporting rationale, the Regional Administrator may:

(A) Concur with the Council's recommendation and, after finding that it is consistent with the goals and objectives of the FEP, the national standards, the Endangered Species Act, and other applicable laws, approve or deny a special permit; or

(B) Reject the Council's recommendation, in which case, written reasons will be provided by the Regional Administrator to the Council for the rejection.

(iv) If the Regional Administrator does not receive a recommendation from the Council within 60 days of Council receipt of the permit application, the Regional Administrator can make a determination of approval or denial independently.

(v) Within 30 working days after the consultation in paragraph (d)(3)(ii) of this section, or as soon as practicable thereafter, NMFS will notify the applicant in writing of the decision to grant or deny the special permit and, if denied, the reasons for the denial. Grounds for denial of a special permit include the following:

(A) The applicant has failed to disclose material information required, or has made false statements as to any material fact, in connection with his or her application.

(B) According to the best scientific information available, the directed or incidental catch in the season or location specified under the permit would detrimentally affect any coral reef resource or coral reef ecosystem in a significant way, including, but not limited to, issues related to spawning grounds or seasons, protected species interactions, EFH, and habitat areas of particular concern (HAPC).

(C) Issuance of the special permit would inequitably allocate fishing privileges among domestic fishermen or would have economic allocation as its sole purpose.

(D) The method or amount of harvest in the season and/or location stated on the permit is considered inappropriate based on previous human or natural impacts in the given area.

(E) NMFS has determined that the maximum number of permits for a given area in a given season has been reached and allocating additional permits in the same area would be detrimental to the resource.

(F) The activity proposed under the special permit would create a significant enforcement problem.

(vi) The Regional Administrator may attach conditions to the special permit, if it is granted, consistent with the management objectives of the FEP, including, but not limited to:

(A) The maximum amount of each resource that can be harvested and landed during the term of the special permit, including trip limits, where appropriate.

(B) The times and places where fishing may be conducted.

(C) The type, size, and amount of gear which may be used by each vessel operated under the special permit.

(D) Data reporting requirements.

(E) Such other conditions as may be necessary to ensure compliance with the purposes of the special permit consistent with the objectives of the FEP.

(4) *Appeals of permit actions.* (i) Except as provided in subpart D of 15 CFR part 904, any applicant for a permit or a permit holder may appeal the granting, denial, conditioning, or suspension of their permit or a permit affecting their interests to the Regional Administrator. In order to be considered by the Regional Administrator, such appeal must be in writing, must state the action(s) appealed, and the reasons therefore, and must be submitted within 30 days of the original action(s) by the Regional Administrator. The appellant may request an informal hearing on the appeal.

(ii) Upon receipt of an appeal authorized by this section, the Regional Administrator will notify the permit applicant, or permit holder as appropriate, and will request such additional information in such form as will allow action upon the appeal. Upon receipt of sufficient information, the Regional Administrator will rule on the appeal in accordance with the permit eligibility criteria set forth in this section and the FEP, as appropriate, based on information relative to the application on file at NMFS and the Council and any additional information, the summary record kept of any hearing and the hearing officer's recommended decision, if any, and such other considerations as deemed appropriate. The Regional Administrator will notify all interested persons of the decision, and the reasons therefore, in writing, normally within 30 days of the receipt of sufficient information, unless additional time is needed for a hearing.

(iii) If a hearing is requested, or if the Regional Administrator determines that one is appropriate, the Regional Administrator may grant an informal hearing before a hearing officer designated for that purpose after first giving notice of the time, place, and subject matter of the hearing in the FEDERAL REGISTER. Such a hearing shall normally be held no later than 30 days following publication of the notice in the FEDERAL REGISTER, unless the hearing officer extends the time for reasons deemed equitable. The appellant, the applicant (if different), and, at the discretion of the hearing officer, other interested parties, may appear personally and/or be represented by counsel at the hearing and submit information and present arguments as determined appropriate by the hearing officer. Within 30 days of the last day of the hearing, the hearing officer shall recommend in writing a decision to the Regional Administrator.

(iv) The Regional Administrator may adopt the hearing officer's recommended decision, in whole or in part, or may reject or modify it. In any event, the Regional Administrator will notify interested persons of the decision, and the reason(s) therefore, in writing, within 30 days of receipt of the hearing officer's recommended decision. The Regional Administrator's action constitutes final action for the agency for the purposes of the Administrative Procedure Act.

(5) Any time limit prescribed in this section may be extended for good cause, for a period not to exceed 30 days, by the Regional Administrator, either upon his or her own motion or upon written request from the Council, appellant or applicant stating the reason(s) therefore.

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§665.225 Prohibitions.

In addition to the general prohibitions specified in §600.725 of this chapter and §665.15 of this part, it is unlawful for any person to do any of the following:

(a) Fish for, take, retain, possess or land any Hawaii coral reef ecosystem MUS in any low-use MPA as defined in §665.199 unless:

(1) A valid permit has been issued for the hand harvester or the fishing vessel operator that specifies the applicable area of harvest;

(2) A permit is not required, as outlined in §665.224; or

(3) The Hawaii coral reef ecosystem MUS possessed on board the vessel originated outside the management area and this can be demonstrated through receipts of purchase, invoices, fishing logbooks or other documentation.

(b) Fish for, take, or retain any Hawaii coral reef ecosystem MUS species:

(1) That is determined overfished with subsequent rulemaking by the Regional Administrator.

(2) By means of gear or methods prohibited under §665.227.

(3) In a low-use MPA without a valid special permit.

(4) In violation of any permit issued under §§665.13 or 665.224.

(c) Fish for, take, or retain any wild live rock or live hard coral except under a valid special permit for scientific research, aquaculture seed stock collection or traditional and ceremonial purposes by indigenous people.

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§665.226 Notifications.

Any special permit holder subject to the requirements of this subpart must contact the appropriate NMFS enforcement agent in American Samoa, Guam, or Hawaii at least 24 hours before landing any Hawaii coral reef ecosystem MUS unit species harvested under a special permit, and report the port and the approximate date and time at which the catch will be landed.

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§665.227 Allowable gear and gear restrictions.

(a) Hawaii coral reef ecosystem MUS may be taken only with the following allowable gear and methods:

(1) Hand harvest;

(2) Spear;

(3) Slurp gun;

- (4) Hand net/dip net;
- (5) Hoop net for Kona crab;
- (6) Throw net;
- (7) Barrier net;
- (8) Surround/purse net that is attended at all times;
- (9) Hook-and-line (includes handline (powered or not), rod-and-reel, and trolling);
- (10) Crab and fish traps with vessel ID number affixed; and
- (11) Remote-operating vehicles/submersibles.

(b) Hawaii coral reef ecosystem MUS may not be taken by means of poisons, explosives, or intoxicating substances. Possession or use of these materials by any permit holder under this subpart who is established to be fishing for Hawaii coral reef ecosystem MUS in the Hawaii management area is prohibited.

(c) Existing FEP fisheries shall follow the allowable gear and methods outlined in their respective plans.

(d) Any person who intends to fish with new gear not included in this section must describe the new gear and its method of deployment in the special permit application. A decision on the permissibility of this gear type will be made by the Regional Administrator after consultation with the Council and the director of the affected state fishery management agency.

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§665.228 Gear identification.

(a) The vessel number must be affixed to all fish and crab traps on board the vessel or deployed in the water by any vessel or person holding a permit under §§665.13 or 665.224 or that is otherwise established to be fishing for Hawaii coral reef ecosystem MUS in the Hawaii management area.

(b) *Enforcement action.* (1) Traps not marked in compliance with paragraph (a) of this section and found deployed in the Hawaii coral reef ecosystem management area will be considered unclaimed or abandoned property, and may be disposed of in any manner considered appropriate by NMFS or an authorized officer.

(2) Unattended surround nets or bait seine nets found deployed in the Hawaii coral reef ecosystem management area will be considered unclaimed or abandoned property, and may be disposed of in any manner considered appropriate by NMFS or an authorized officer.

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§§665.229-665.239 [Reserved][↑ Back to Top](#)**§665.240 Hawaii crustacean fisheries. [Reserved]**[↑ Back to Top](#)**§665.241 Definitions.**

As used in §§665.240 through 665.259:

Hawaii crustacean management area is divided into the following areas:

(1) *Crustacean Permit Area 1 (Permit Area 1)* means the EEZ around the NWHI.

(2) *Crustacean Permit Area 2 (Permit Area 2)* means the EEZ around the MHI.

(3) *Crustacean Permit Area 1 VMS Subarea* means an area within the EEZ around the NWHI 50 nm from the center geographical positions of the islands and reefs in the NWHI as follows:

Name	N. lat.	W. long.
Nihoa Island	23°05'	161°55'
Necker Island	23°35'	164°40'
French Frigate Shoals	23°45'	166°15'
Gardner Pinnacles	25°00'	168°00'
Maro Reef	25°25'	170°35'
Laysan Island	25°45'	171°45'
Lisianski Island	26°00'	173°55'
Pearl and Hermes Reef	27°50'	175°50'

Midway Island	28°14'	177°22'
Kure Island	28°25'	178°20'
The remainder of the VMS subarea is delimited by parallel lines tangent to and connecting the 50-nm areas around the following: from Nihoa Island to Necker Island; from French Frigate Shoals to Gardner Pinnacles; from Gardner Pinnacles to Maro Reef; from Laysan Island to Lisianski Island; and from Lisianski Island to Pearl and Hermes Reef.		

Hawaii crustacean management unit species (Hawaii crustacean MUS) means the following crustaceans:

Local name	English common name	Scientific name
Ula	spiny lobster	<i>Panulirus marginatus, Panulirus penicillatus.</i>
ula papapa	slipper lobster	Scyllaridae.
papa`i kua loa	Kona crab	<i>Ranina ranina.</i>
	deepwater shrimp	<i>Heterocarpus spp.</i>

Interested parties means the State of Hawaii Department of Land and Natural Resources, the Council, holders of permits issued under §665.242, and any person who has notified the Regional Administrator of his or her interest in the procedures and decisions described in §665.248, and who has specifically requested to be considered an “interested party.”

Lobster grounds refers, singularly or collectively, to the following four areas in Crustacean Permit Area 1 that shall be used to manage the lobster fishery:

(1) Necker Island Lobster Grounds—waters bounded by straight lines connecting the following coordinates in the order presented: 24°00' N. lat., 165°00' W. long.; 24°00' N. lat., 164°00' W. long.; 23°00' N. lat., 164°00' W. long.; and 23°00' N. lat., 165°00' W. long.

(2) Gardner Pinnacles Lobster Grounds—waters bounded by straight lines connecting the following coordinates in the order presented: 25°20' N. lat., 168°20' W. long.; 25°20' N. lat., 167°40' W. long.; 24°20' N. lat., 167°40' W. long.; and 24°20' N. lat., 168°20' W. long.

(3) Maro Reef Lobster Grounds—waters bounded by straight lines connecting the following coordinates in the order presented: 25°40' N. lat., 171°00' W. long.; 25°40' N. lat., 170°20' W. long.; 25°00' N. lat., 170°20' W. long.; and 25°00' N. lat., 171°00' W. long.

(4) General NWHI Lobster Grounds—all waters within Crustacean Permit Area 1 except for the Necker Island, Gardner Pinnacles, and Maro Reef Lobster Grounds.

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§665.242 Permits.

(a) *Applicability.* (1) The owner of any vessel used to fish for lobster in Permit Area 1 must have a limited access permit issued for such vessel.

(2) The owner of any vessel used to fish for lobster in Permit Area 2 must have a permit issued for such a vessel.

(3) The owner of any vessel used to fish for deepwater shrimp in Crustacean Permit Areas 1 or 2 must have a permit issued for that vessel.

(4) Harvest of Hawaii crustacean MUS within the Northwestern Hawaiian Islands Marine National Monument is subject to the requirements of 50 CFR part 404.

(b) *General requirements.* General requirements governing application information, issuance, fees, expiration, replacement, transfer, alteration, display, sanctions, and appeals for permits issued under this section, as applicable, are contained in §665.13.

(c) *Application.* An application for a permit required under this section will be submitted to PIRO as described in §665.13. If the application for a limited access permit is submitted on behalf of a partnership or corporation, the application must be accompanied by a supplementary information sheet obtained from PIRO and contain the names and mailing addresses of all partners or shareholders and their respective percentage of ownership in the partnership or corporation.

(d) *Lobster Limited Access Permit Requirements.* (1) A lobster limited access permit is valid for fishing only in Crustacean Permit Area 1.

(2) Only one permit will be assigned to any vessel.

(3) No vessel owner will have permits for a single vessel to harvest lobsters in Permit Areas 1 and 2 at the same time.

(4) A maximum of 15 limited access permits can be valid at any time.

(e) *Transfer or sale of limited access permits.* (1) Permits may be transferred or sold, but no one individual, partnership, or corporation will be allowed to hold a whole or partial interest in more than one permit, except that an owner who qualifies initially for more than one permit may maintain those permits,

but may not obtain additional permits. Layering of partnerships or corporations shall not insulate a permit holder from this requirement.

(2) If 50 percent or more of the ownership of a limited access permit is passed to persons other than those listed on the permit application, PIRO must be notified of the change in writing and provided copies of the appropriate documents confirming the changes within 30 days.

(3) Upon the transfer or sale of a limited access permit, a new application must be submitted by the new permit owner according to the requirements of §665.13. The transferred permit is not valid until this process is completed.

(f) *Replacement of a vessel covered by a limited access permit.* A limited access permit issued under this section may, without limitation as to frequency, be transferred by the permit holder to a replacement vessel owned by that person.

(g) *Issuance of limited access permits to future applicants.* (1) The Regional Administrator may issue limited access permits under this section when fewer than 15 vessel owners hold active permits.

(2) When the Regional Administrator has determined that limited access permits may be issued to new persons, a notice shall be placed in the FEDERAL REGISTER, and other means will be used to notify prospective applicants of the opportunity to obtain permits under the limited access management program.

(3) A period of 90 days will be provided after publication of the FEDERAL REGISTER notice for submission of new applications for a limited access permit.

(4) Limited access permits issued under this paragraph (g) will be issued first to applicants qualifying under paragraph (g)(4)(i) of this section. If the number of limited access permits available is greater than the number of applicants that qualify under paragraph (g)(4)(i) of this section, then limited access permits will be issued to applicants under paragraph (g)(4)(ii) of this section.

(i) First priority to receive limited access permits under this paragraph (g) goes to owners of vessels that were used to land lobster from Permit Area 1 during the period 1983 through 1990, and who were excluded from the fishery by implementation of the limited access system. If there are insufficient permits for all such applicants, the new permits shall be issued by the Regional Administrator through a lottery.

(ii) Second priority to receive limited access permits under paragraph (g) goes to owners with the most points, based upon a point system. If two or more owners have the same number of points and there are insufficient permits for all such owners, the Regional Administrator shall issue the permits through a lottery. Under the point system, limited access permits will be issued, in descending order, beginning with owners who have the most points and proceeding to owners who have the least points, based on the following:

(A) Three points shall be assigned for each calendar year after August 8, 1985, that the applicant was the operator of a vessel that was used to land lobster from Permit Area 1.

(B) Two points shall be assigned for each calendar year or partial year after August 8, 1985, that the applicant was the owner, operator, or crew member of a vessel engaged in either commercial fishing in

Permit Area 2 for lobster, or fishing in Permit Area 1 for fish other than lobster with an intention to sell all or part of the catch.

(C) One point shall be assigned for each calendar year or partial year after August 8, 1985, that the applicant was the owner, operator, or crew member of a vessel engaged in any other commercial fishing in the EEZ surrounding Hawaii.

(5) A holder of a new limited access permit must own at least a 50 percent share in the vessel that the permit would cover.

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§665.243 Prohibitions.

In addition to the general prohibitions specified in 50 CFR §§600.725 and 665.15, it is unlawful for any person to do any of the following:

(a) In Permit Area 1, it is unlawful for any person to—

(1) Fish for, take, or retain lobsters—

(i) Without a limited access permit issued under §665.242.

(ii) By methods other than lobster traps or by hand for lobsters, as specified in §665.245.

(iii) From closed areas for lobsters, as specified in §665.251.

(iv) During a closed season, as specified in §665.250.

(v) After the closure date, as specified in §665.252, and until the fishery opens again in the following calendar year.

(vi) In a lobster grounds after closure of that grounds as specified in §665.252(b).

(2) Fail to report before landing or offloading as specified in §665.244.

(3) Fail to comply with any protective measures implemented under §665.248.

(4) Leave a trap unattended in the Hawaii crustacean management area except as provided in §665.245.

(5) Maintain on board the vessel or in the water more than 1,200 traps per fishing vessel, of which no more than 1,100 can be assembled traps, as specified in §665.245.

(6) Land lobsters taken in Permit Area 1 after the closure date, as specified in §665.252, until the fishery opens again the following year.

(7) Refuse to make available to an authorized officer and employee of NMFS designated by the Regional Administrator for inspection and copying any records that must be made available in accordance with §665.14(g)(2).

(8) Possess on a fishing vessel that has a limited access permit issued under §665.242 any lobster trap in Crustacean Permit Area 1 when fishing for lobster is prohibited as specified in §§665.248, 665.250(a), or 665.252, or except as allowed under §665.245(a)(7).

(9) Possess on a fishing vessel that has a limited access permit issued under this subpart any lobster trap in Crustacean Permit Area 1 VMS Subarea when fishing for lobsters is prohibited as specified in §§665.248, 665.250(a), or 665.252, except as allowed under §665.245(a)(8).

(10) Interfere with, tamper with, alter, damage, disable, or impede the operation of a VMS unit or to attempt any of the same while engaged in the Permit Area 1 fishery; or to move or remove a VMS unit while engaged in the Permit Area 1 fishery without first notifying the Regional Administrator.

(11) Make a false statement, oral or written, to the Regional Administrator or an authorized officer, regarding the certification, use, operation, or maintenance of a VMS unit used in the fishery.

(12) Fail to allow an authorized officer to inspect and certify a VMS unit used in the fishery.

(13) Possess, on a fishing vessel that has a limited access permit issued under this subpart, any lobster trap in a lobster grounds that is closed under §665.252(b), unless the vessel has an operational VMS unit, certified by NMFS, on board.

(b) In Permit Area 2, it is unlawful for any person to—

(1) Fish for, take, or retain lobsters—

(i) By methods other than lobster traps or by hand, as specified in §665.245; or

(ii) During a closed season, as specified in §665.250(b).

(2) Retain or possess on a fishing vessel any lobster taken in Permit Area 2 that is less than the minimum size specified in §665.249.

(3) Possess on a fishing vessel any lobster or lobster part taken in Permit Area 2 in a condition where the lobster is not whole and undamaged as specified in §665.249.

(4) Retain or possess on a fishing vessel, or remove the eggs from, any egg-bearing lobster, as specified in §665.249.

(5) Possess on a fishing vessel that has a permit for Permit Area 2 issued under this subpart any lobster trap in Permit Area 2 when fishing for lobster in the MHI is prohibited during the months of May, June, July, and August.

(c) In Crustacean Permit Areas 1 and 2, it is unlawful for any person to fish for, take, or retain deepwater shrimp without a permit issued under §665.242.

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§665.244 Notifications.

(a) The operator of any vessel subject to the requirements of this subpart must:

(1) Report, not less than 24 hours, but not more than 36 hours, before landing, the port, the approximate date and the approximate time at which spiny and slipper lobsters will be landed.

(2) Report, not less than 6 hours and not more than 12 hours before offloading, the location and time that offloading of spiny and slipper lobsters will begin.

(b) The Regional Administrator will notify permit holders of any change in the reporting method and schedule required in paragraph (a) of this section at least 30 days prior to the opening of the fishing season.

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§665.245 Gear restrictions.

(a) *Permit Area 1.* (1) Lobsters may be taken only with lobster traps or by hand. Lobsters may not be taken by means of poisons, drugs, other chemicals, spears, nets, hook, or explosives.

(2) The smallest opening of an entry way of any lobster trap may not allow any sphere or cylinder greater than 6.5 inches (16.5 cm) in diameter to pass from outside the trap to inside the trap.

(3) Each lobster trap must have a minimum of two escape vent panels that meet the following requirements:

(i) Panels must have at least four unobstructed circular holes no smaller than 67 mm in diameter, with centers at least 82 mm apart.

(ii) The lowest part of any opening in an escape vent panel must not be more than 85 mm above the floor of the trap.

(iii) Panels must be placed opposite one another in each trap.

(4) A vessel fishing for or in possession of lobster in any permit area may not have on board the vessel any trap that does not meet the requirements of paragraphs (a)(1), (2), and (3) of this section.

(5) A maximum of 1,200 traps per vessel may be maintained on board or in the water, provided that no more than 1,100 assembled traps are maintained on board or in the water. If more than 1,100 traps are maintained, the unassembled traps may be carried as spares only, in order to replace assembled traps that may be lost or become unusable.

(6) Traps shall not be left unattended in any permit area, except in the event of an emergency, in which case the vessel operator must notify the SAC of the emergency that necessitated leaving the traps on the grounds, and the location and number of the traps, within 24 hours after the vessel reaches port.

(7) A vessel whose owner has a limited access permit issued under this subpart and has an operating VMS unit certified by NMFS may enter Crustacean Permit Area 1 with lobster traps on board on or after June 25, but must remain outside the Crustacean Permit Area 1 VMS Subarea until the NWHI lobster season opens on July 1.

(8) A vessel whose owner has a limited access permit issued under this subpart and has on board an operational VMS unit certified by NMFS may transit Crustacean Permit Area 1, including Crustacean Permit Area 1 VMS Subarea, with lobster traps on board for the purpose of moving to another lobster grounds or returning to port following the closure date, as specified in §665.252, providing the vessel does not stop or fish and is making steady progress to another lobster grounds or back to port as determined by NMFS.

(9) The operator of a permitted vessel must notify the Regional Administrator or an authorized officer no later than June 15 of each year if the vessel will use a VMS unit in the fishery and allow for inspection and certification of the unit.

(b) Permit Area 2. Lobsters may be taken only with lobster traps or by hand. Lobsters may not be taken by means of poisons, drugs, other chemicals, spears, nets, hooks, or explosives.

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§665.246 Gear identification.

In Permit Area 1, the vessel's official number must be marked legibly on all traps and floats maintained on board the vessel or in the water by that vessel.

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§665.247 At-sea observer coverage.

All fishing vessels subject to §§665.240 through 665.252 and subpart A of this part must carry an observer when requested to do so by the Regional Administrator.

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§665.248 Monk seal protective measures.

(a) *General.* This section establishes a procedure that will be followed if the Regional Administrator receives a report of a monk seal death that appears to be related to the lobster fishery in Permit Area 1.

(b) *Notification.* Upon receipt of a report of a monk seal death that appears to be related to the lobster fishery, the Regional Administrator will notify all interested parties of the facts known about the incident. The Regional Administrator will also notify them that an investigation is in progress, and that, if

the investigation reveals a threat of harm to the monk seal population, protective measures may be implemented.

(c) *Investigation.* (1) The Regional Administrator will investigate the incident reported and will attempt to:

(i) Verify that the incident occurred.

(ii) Determine the extent of the harm to the monk seal population.

(iii) Determine the probability of a similar incident recurring.

(iv) Determine details of the incident such as:

(A) The number of animals involved.

(B) The cause of the mortality.

(C) The age and sex of the dead animal(s).

(D) The relationship of the incident to the reproductive cycle, for example, breeding season (March-September), non-breeding season (October-February).

(E) The population estimates or counts of animals at the island where the incident occurred.

(F) Any other relevant information.

(v) Discover and evaluate any extenuating circumstances.

(vi) Evaluate any other relevant factors.

(2) The Regional Administrator will make the results of the investigation available to the interested parties and request their advice and comments.

(d) *Determination of relationship.* The Regional Administrator will review and evaluate the results of the investigation and any comments received from interested parties. If there is substantial evidence that the death of the monk seal was related to the lobster fishery, the Regional Administrator will:

(1) Advise the interested parties of his or her conclusion and the facts upon which it is based.

(2) Request from the interested parties their advice on the necessity of protective measures and suggestions for appropriate protective measures.

(e) *Determination of response.* The Regional Administrator will consider all relevant information discovered during the investigation or submitted by interested parties in deciding on the appropriate response. Protective measures may include, but are not limited to, changes in trap design, changes in gear, closures of specific areas, or closures for specific periods of time.

(f) *Action by the Regional Administrator.* If the Regional Administrator decides that protective measures are necessary and appropriate, the Regional Administrator will prepare a document that describes the incident, the protective measures proposed, and the reasons for the protective measures; provide it to the interested parties; and request their comments.

(g) *Implementation of protective measures.* (1) If, after completing the steps described in paragraph (f) of this section, the Regional Administrator concludes that protective measures are necessary and appropriate, the Regional Administrator will recommend the protective measures to the Assistant Administrator and provide notice of this recommendation to the Chairman of the Council and the Director of the Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii.

(2) If the Assistant Administrator concurs with the Regional Administrator's recommendation, NMFS will publish an action in the FEDERAL REGISTER that includes a description of the incident that triggered the procedure described in this section, the protective measures, and the reasons for the protective measures.

(h) *Notification of "no action."* If, at any point in the process described in this section, the Regional Administrator or Assistant Administrator decides that no further action is required, the interested parties will be notified of this decision.

(i) *Effective dates.* (1) The protective measures will take effect 10 days after the date of publication in the FEDERAL REGISTER.

(2) The protective measures will remain in effect for the shortest of the following time periods:

(i) Until the Hawaii FEP and this section are amended to respond to the problem;

(ii) Until other action that will respond to the problem is taken under the ESA;

(iii) Until the Assistant Administrator, following the procedures set forth in paragraph (j) of this section, decides that the protective measures are no longer required and repeals the measures; or

(iv) For the period of time set forth in the FEDERAL REGISTER notification, not to exceed 3 months. The measures may be renewed for 3 months after again following procedures in paragraphs (b) through (g) of this section.

(j) *Repeal.* (1) If the Assistant Administrator decides that protective measures may no longer be necessary for the protection of monk seals, the Assistant Administrator will notify the interested parties of this preliminary decision and the facts upon which it is based. The Assistant Administrator will request advice on the proposed repeal of the protective measures.

(2) The Assistant Administrator will consider all relevant information obtained by the Regional Administrator or submitted by interested parties in deciding whether to repeal the protective measures.

(3) If the Assistant Administrator decides to repeal the protective measures—

(i) Interested parties will be notified of the decision; and

(ii) Notification of repeal and the reasons for the repeal will be published in the FEDERAL REGISTER.

(k) *Monk seal emergency protective measures*—(1) *Determination of emergency*. If, at any time during the process described in paragraphs (a) through (j) of this section, the Regional Administrator determines that an emergency exists involving monk seal mortality related to the lobster fishery and that measures are needed immediately to protect the monk seal population, the Regional Administrator will—

(i) Notify the interested parties of this determination and request their immediate advice and comments.

(ii) Forward a recommendation for emergency action and any advice and comments received from interested parties to the Assistant Administrator.

(2) *Implementation of emergency measures*. If the Assistant Administrator agrees with the recommendation for emergency action—

(i) The Regional Administrator will determine the appropriate emergency protective measures.

(ii) NMFS will publish the emergency protective measures in the FEDERAL REGISTER.

(iii) The Regional Administrator will notify the interested parties of the emergency protective measures. Holders of permits to fish in Permit Area I will be notified by certified mail. Permit holders that the Regional Administrator knows are on the fishing grounds also will be notified by radio.

(3) *Effective dates*. (i) Emergency protective measures are effective against a permit holder at 12:01 a.m., local time, of the day following the day the permit holder receives actual notice of the measures.

(ii) Emergency protective measures are effective for 10 days from the day following the day the first permit holder is notified of the protective measures.

(iii) Emergency protective measures may be extended for an additional 10 days, if necessary, to allow the completion of the procedures set out in §665.252.

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§665.249 Lobster size and condition restrictions in Permit Area 2.

(a) Only spiny lobsters with a carapace length of 8.26 cm or greater may be retained (see Figure 1 to this part).

(b) Any lobster with a punctured or mutilated body, or a separated carapace and tail, may not be retained.

(c) A female lobster of any size may not be retained if it is carrying eggs externally. Eggs may not be removed from female lobsters.

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§665.250 Closed seasons.

(a) Lobster fishing is prohibited in Permit Area 1 during the months of January through June, inclusive.

(b) Lobster fishing is prohibited in Permit Area 2 during the months of May, June, July, and August.

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§665.251 Closed areas.

All lobster fishing is prohibited:

(a) Within 20 nm of Laysan Island.

(b) Within the EEZ landward of the 10-fathom curve as depicted on National Ocean Survey Charts, Numbers 19022, 19019, and 19016.

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§665.252 Harvest limitation program.

(a) *General.* Harvest guidelines for the Necker Island Lobster Grounds, Gardner Pinnacles Lobster Grounds, Maro Reef Lobster Grounds, and General NWHI Lobster Grounds for Permit Area 1 will be set annually for the calendar year and shall:

(1) Apply to the total catch of spiny and slipper lobsters.

(2) Be expressed in terms of numbers of lobsters.

(b) *Harvest guideline.* (1) The Regional Administrator shall use information from daily lobster catch reports and lobster sales reports from previous years, and may use information from research sampling and other sources to establish the annual harvest guideline in accordance with the FEP after consultation with the Council.

(2) NMFS shall publish a document indicating the annual harvest guideline in the FEDERAL REGISTER by February 28 of each year and shall use other means to notify permit holders of the harvest guideline for the year.

(3) The Regional Administrator shall determine, on the basis of the information reported to NMFS by the operator of each vessel fishing, when the harvest guideline for each lobster ground will be reached.

(4) Notice of the date when the harvest guideline for a lobster ground is expected to be reached and specification of the closure date of the lobster grounds will be provided to each permit holder and/or operator of each permitted vessel at least 24 hours in advance of the closure. After a closure, the harvest of lobster in that lobster ground is prohibited, and the possession of lobster traps on board the vessel in that lobster ground is prohibited unless allowed under §665.245(a)(8).

(5) With respect to the notification in paragraph (b)(4) of this section, NMFS shall provide each permit holder and operator of each permitted vessel with the following information, as appropriate:

(i) Determination of when the overall harvest guideline for Crustacean Permit Area 1 will be reached;

(ii) Closure date after which harvest of lobster or possession of lobster traps on board the vessel in a lobster grounds is prohibited;

(iii) Closure date after which the possession of lobster traps on board the vessel in Crustacean Permit Area 1 is prohibited by any permitted vessel that is not operating a VMS unit certified by NMFS; and

(iv) Specification of when further landings of lobster will be prohibited by permitted vessels not carrying an operational VMS unit, certified by NMFS, on board.

(c) *Monitoring and adjustment.* The operator of each vessel fishing during the open season shall report lobster catch (by species) and effort (number of trap hauls) data while at sea to NMFS in Honolulu. The Regional Administrator shall notify permit holders of the reporting method, schedule, and logistics at least 30 days prior to the opening of the fishing season.

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§§665.253-665.259 [Reserved]

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§665.260 Hawaii precious coral fisheries. [Reserved]

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§665.261 Definitions.

As used in §§665.260 through 665.270:

Hawaii precious coral management unit species (Hawaii precious coral MUS) means any coral of the genus *Corallium* in addition to the following species of corals:

English common name	Scientific name
Pink coral (also known as red coral)	<i>Corallium secundum</i> , <i>Corallium regale</i> , <i>Corallium laauense</i> .
Gold coral	<i>Gerardia</i> spp., <i>Callogorgia gilberti</i> , <i>Narella</i> spp., <i>Calyptrophora</i> spp.

Bamboo coral	<i>Lepidisis olapa, Acanella spp.</i>
Black coral	<i>Antipathes griggi, Antipathes grandis, Antipathes ulex.</i>

Hawaii precious coral permit area means the area encompassing the precious coral beds within the EEZ around Hawaii. Each bed is designated by a permit area code and assigned to one of the following four categories:

(1) *Established beds.* (i) Makapu'u (Oahu), Permit Area E-B-1, includes the area within a radius of 2.0 nm of a point at 21°18.0' N. lat., 157°32.5' W. long.

(ii) Au'au Channel (Maui), Permit Area E-B-2, includes the area west and south of a point at 21°10' N. lat., 156°40' W. long., and east of a point at 21° N. lat., 157° W. long., and west and north of a point at 20°45' N. lat., 156°40' W. long.

(2) *Conditional beds.* (i) Keahole Point (Hawaii), Permit Area C-B-1, includes the area within a radius of 0.5 nm of a point at 19°46.0' N. lat., 156°06.0' W. long.

(ii) Kaena Point (Oahu), Permit Area C-B-2, includes the area within a radius of 0.5 nm of a point at 21°35.4' N. lat., 158°22.9' W. long.

(iii) Brooks Bank, Permit Area C-B-3, includes the area within a radius of 2.0 nm of a point at 24°06.0' N. lat., 166°48.0' W. long.

(iv) 180 Fathom Bank, Permit Area C-B-4, N.W. of Kure Atoll, includes the area within a radius of 2.0 nm of a point at 28°50.2' N. lat., 178°53.4' W. long.

(3) *Refugia.* Westpac Bed, Permit Area R-1, includes the area within a radius of 2.0 nm of a point at 23°18' N. lat., 162°35' W. long.

(4) *Exploratory areas.* Permit Area X-P-H includes all coral beds, other than established beds, conditional beds, or refugia, in the EEZ seaward of the State of Hawaii.

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§665.262 Permits.

(a) Any vessel of the United States fishing for, taking, or retaining Hawaii precious coral MUS in any Hawaiian Archipelago precious coral permit area must have a permit issued under §665.13.

(b) Each permit will be valid for fishing only in the permit area specified on the permit. Precious Coral Permit Areas are defined in §665.261.

(c) No more than one permit will be valid for any one vessel at any one time.

(d) No more than one permit will be valid for any one person at any one time.

(e) The holder of a valid permit to fish one permit area may obtain a permit to fish another permit area only upon surrendering to the Regional Administrator any current permit for the precious coral fishery issued under §665.13.

(f) General requirements governing application information, issuance, fees, expiration, replacement, transfer, alteration, display, sanctions, and appeals for permits for the precious coral fishery are contained in §665.13.

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§665.263 Prohibitions.

In addition to the general prohibitions specified in 50 CFR 600.725 and in 665.15, it is unlawful for any person to:

(a) Use any vessel to fish for, take, retain, possess or land precious coral in any Hawaii precious coral permit area, unless a permit has been issued for that vessel and area as specified in §665.13 and that permit is on board the vessel.

(b) Fish for, take, or retain any species of Hawaii precious coral MUS in any precious coral permit area:

(1) By means of gear or methods prohibited by §665.264.

(2) In refugia specified in §665.261.

(3) In a bed for which the quota specified in §665.269 has been attained.

(4) In violation of any permit issued under §§665.13 or 665.17.

(5) In a bed that has been closed pursuant to §§665.268 or 665.270.

(c) Take and retain, possess, or land any live pink coral or live black coral from any precious coral permit area that is less than the minimum height specified in §665.265 unless:

(1) A valid EFP was issued under §665.17 for the vessel and the vessel was operating under the terms of the permit; or

(2) The coral originated outside coral beds listed in this paragraph, and this can be demonstrated through receipts of purchase, invoices, or other documentation.

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§665.264 Gear restrictions.

Only selective gear may be used to harvest coral from any precious coral permit area.

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§665.265 Size restrictions.

The height of a live coral specimen shall be determined by a straight line measurement taken from its base to its most distal extremity. The stem diameter of a living coral specimen shall be determined by measuring the greatest diameter of the stem at a point no less than 1 inch (2.54 cm) from the top surface of the living holdfast.

(a) Live pink coral harvested from any precious coral permit area must have attained a minimum height of 10 inches (25.4 cm).

(b) *Black coral*. Live black coral harvested from any precious coral permit area must have attained either a minimum stem diameter of 1 inch (2.54 cm), or a minimum height of 48 inches (122 cm).

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§665.266 Area restrictions.

Fishing for coral on the WestPac Bed is not allowed. The specific area closed to fishing is all waters within a 2-nm radius of the midpoint of 23°18.0' N. lat., 162°35.0' W. long.

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§665.267 Seasons.

The fishing year for precious coral begins on July 1 and ends on June 30 the following year, except at the Makapu'u and Au'au Channel Beds, which have a two-year fishing period that begins July 1 and ends June 30, two years later.

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§665.268 Closures.

(a) If the Regional Administrator determines that the harvest quota for any coral bed will be reached prior to the end of the fishing year, or the end of the 2-year fishing period at Makapu'u Bed or Au'au Channel Bed, NMFS shall publish a notice to that effect in the FEDERAL REGISTER and shall use other means to notify permit holders. Any such notice must indicate the reason for the closure, the bed being closed, and the effective date of the closure.

(b) A closure is also effective for a permit holder upon the permit holder's actual harvest of the applicable quota.

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§665.269 Quotas.

(a) *General.* The quotas limiting the amount of precious coral that may be taken in any precious coral permit area during the fishing year are listed in §665.269(d). Only live coral is counted toward the quota. The accounting period for all quotas begins July 1, 1983.

(b) *Conditional bed closure.* A conditional bed will be closed to all nonselective coral harvesting after the quota for one species of coral has been taken.

(c) *Reserves and reserve release.* The quotas for exploratory area X-P-H will be held in reserve for harvest by vessels of the United States in the following manner:

(1) At the start of the fishing year, the reserve for the Hawaii exploratory areas will equal the quota minus the estimated domestic annual harvest for that year.

(2) As soon as practicable after December 31 each year, the Regional Administrator will determine the amount harvested by vessels of the United States between July 1 and December 31 of the year that just ended on December 31.

(3) NMFS will release to TALFF an amount of Hawaii precious coral for each exploratory area equal to the quota minus two times the amount harvested by vessels of the United States in that July 1-December 31 period.

(4) NMFS will publish in the FEDERAL REGISTER a notification of the Regional Administrator's determination and a summary of the information on which it is based as soon as practicable after the determination is made.

(d) Quotas for precious coral permit areas.

Type of coral bed	Name of coral bed	Harvest quota in kilograms	Number of years
Established Beds	Au'au Channel	Black: 5,000	2
	Makapu'u	Pink: 2,000	2
		Gold: 0 (zero)	
		Bamboo: 500	2

Conditional Beds	180 Fathom Bank	Pink: 222	1
		Gold: 67	1
		Bamboo: 56	1
	Brooks Bank	Pink: 444	1
		Gold: 133	1
		Bamboo: 111	1
	Kaena Point	Pink: 67	1
		Gold: 20	1
		Bamboo: 17	1
	Keahole Point	Pink: 67	1
		Gold: 20	1
		Bamboo: 17	1
Refugia	Westpac	All: 0 (zero)	
Exploratory Area	Hawaii	1,000 per area (all species combined except black corals)	1

Notes:

1. No fishing for coral is authorized in refugia.
2. A moratorium on gold coral harvesting is in effect through June 30, 2013.

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§665.270 Gold coral harvest moratorium.

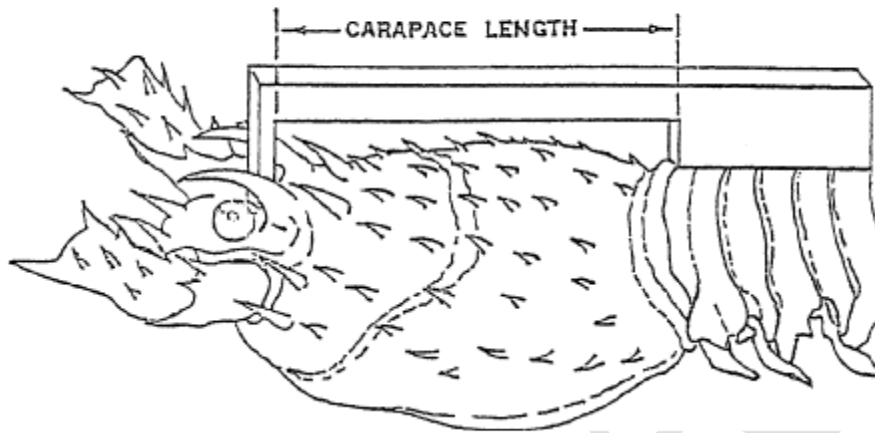
Fishing for, taking, or retaining any gold coral in any precious coral permit area is prohibited through June 30, 2018.

[78 FR 32182, May 29, 2013]

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Figure 1 to Part 665—Carapace Length of Lobsters

FIGURE 1 TO PART 665. CARAPACE LENGTH OF LOBSTERS

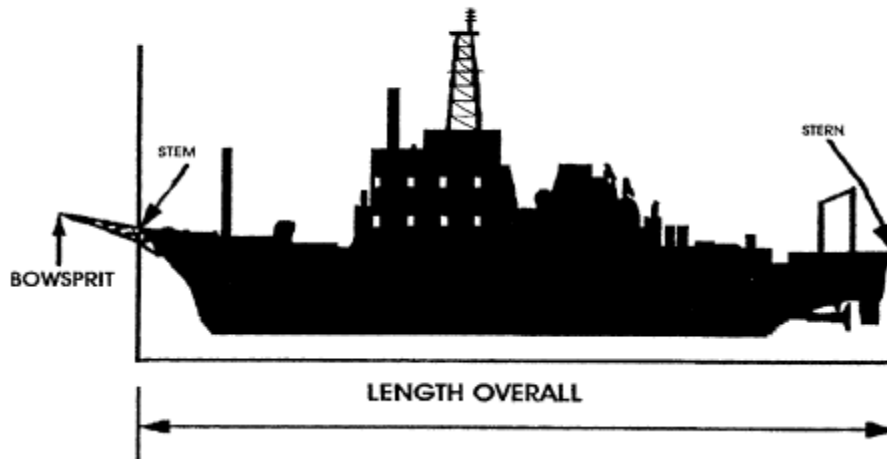


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Figure 2 to Part 665—Length of Fishing Vessels

FIGURE 2 TO PART 665. LENGTH OF FISHING VESSELS

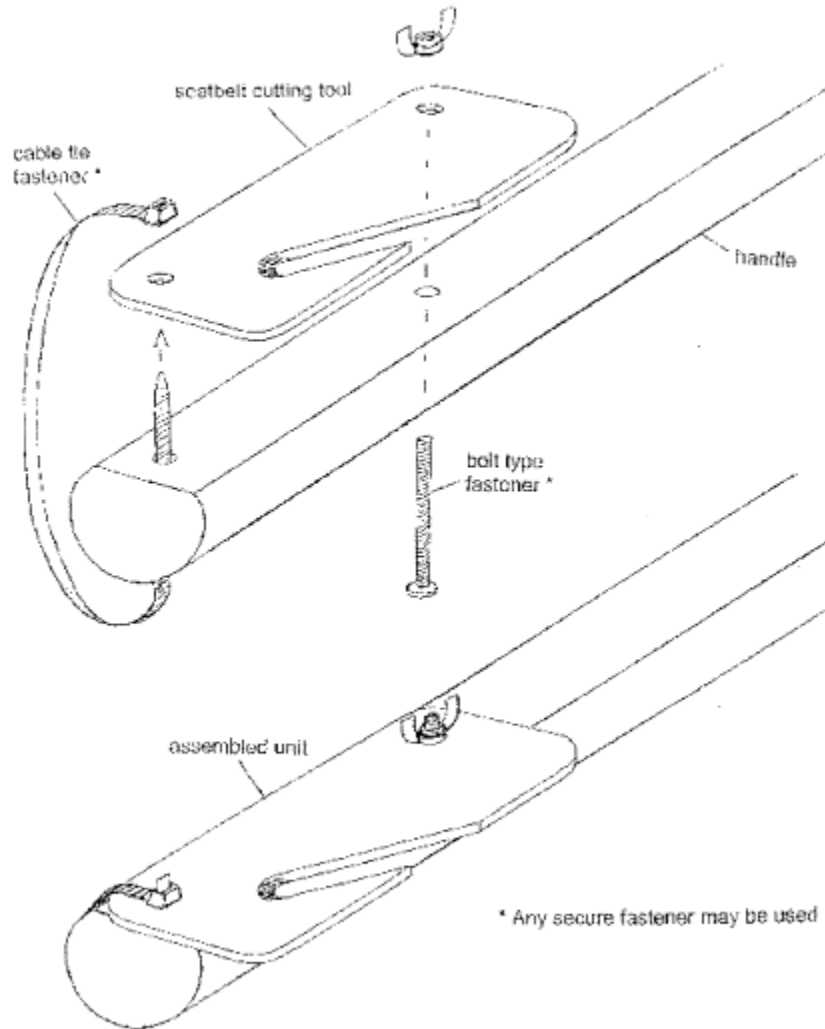


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Figure 3 to Part 665—Sample Fabricated Arceneaux Line Clipper

FIGURE 3 TO PART 665. SAMPLE FABRICATED ARCENEUX LINE CLIPPER



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Appendix D: Summary of Fishery Management Plan and Fishery Ecosystem Plan Amendments

1. Fishery Management Plan Amendments

FMP for Precious Corals of the Western Pacific Region

The fishery management plan (FMP) for Precious Coral Fisheries of the Western Pacific Region was implemented in September 1983 (48 FR 39229, September 29, 1983) and established the plan's management unit species, management areas and classified several known precious coral beds. Since 1983, the FMP has been amended seven times with each amendment summarized in Table 1.

Table 1. Amendments to the Precious Coral FMP

No.	Effective Date/Federal Register Notice	Action
7	8/13/08 73 FR 47098	Designated the Auau Channel bed as an established bed with a harvest quota for black coral of 5,000 kg every two years for Federal and state waters combined. Implemented a five year gold harvest moratorium for the entire region.
6	9/12/06 71 FR 53605	Included Federal waters around CNMI and the Pacific Remote Island Areas within the FMP's management area. Extended existing requirements for Federal permits and logbooks to include all harvests of precious corals in EEZ waters in these areas.
5	2/24/04 69 FR 8336	Prepared in parallel with the Coral Reef FMP. Prohibits the harvest of Precious Coral Management Unit Species in the no-take marine protected areas established under the Coral Reef FMP, including areas around Rose Atoll in American Samoa, Kingman Reef, Jarvis Island, Howland Island, and Baker Island.
4	4/19/99 64 FR 19067 8/5/03 56 FR 14866	Addressed new requirements under the 1996 Sustainable Fisheries Act (SFA). Portions of the amendment that were immediately approved included designations of essential fish habitat, definitions of overfishing and descriptions of bycatch and of some fishing communities. Those provisions became effective on February 3, 1999. Remaining provisions regarding Hawaii fishing communities became effective August 5, 2003.
3	10/19/98 63 FR 55809	Established a framework procedure for adjusting management measures in the fishery.
2	1/28/91 56 FR 3072	Defined overfishing for Established beds as: an Established bed shall be deemed overfished with respect to recruitment when the total spawning biomass (all species combined) has been reduced to 20% of its unfished condition. This definition applies to all species of precious corals and is based on cohort analysis of the pink coral, <i>Corallium secundum</i> .

No.	Effective Date/Federal Register Notice	Action
1	7/21/88 50 FR 27519	Applied the management measures of the FMP to the Pacific Remote Island Areas by incorporating them into a single Exploratory Permit Area, expanded the management unit species to include all species of the genus <i>Corallium</i> , and outlined provisions for the issuance of experimental fishing permits designed to stimulate the domestic fishery

In addition to FMP amendments, the management program for precious coral fisheries has been modified through several regulatory amendments and framework actions as described below.

Regulatory Amendment 1: Removed an exemption allowing fishermen who reported black coral harvest to the State of Hawaii within five years prior to April 17, 2002 to harvest black coral at a minimum base diameter of 3/4 inch. All harvest of black corals must be done at a minimum of 1 inch base diameter or 48 inch minimum height (72 FR 59259, October 15, 2007).

Framework Action 1: Revised the definitions of “live coral” and “dead coral,” suspended the harvest of gold coral at Makapu’u Bed, applied minimum size restrictions only to live precious corals, prohibited the harvest of black coral with a stem diameter of less than one inch or a height of less than 48 inches (with certain exceptions), prohibited the use of non-selective fishing gear to harvest precious corals, and applied the minimum size restrictions for pink coral to all permit areas (67 FR 11941, April 17, 2002).

FMP for Crustacean Fisheries of the Western Pacific Region

The FMP for Crustacean Fisheries of the Western Pacific Region was approved in 1983. Initial provisions of the FMP, which was initially named “Spiny Lobster Fisheries of the Western Pacific Region,” went into effect March 9, 1983 (48 FR 5560, 7 February 1983). The FMP implemented the following management measures for the Northwestern Hawaiian Islands (NWHI) management area: federal permit requirements, a minimum size limit for spiny lobsters, gear restrictions, a ban on the harvest of egg-bearing female spiny lobsters, the closure of waters within 20 nm of Laysan Island, all NWHI waters shallower than 10 fm, and all NWHI lagoons, to fishing for spiny lobsters, a mandatory logbook program, and a requirement to carry a fishery observer if directed by the National Marine Fisheries Service. The FMP also implemented permit, data reporting, and observer requirements within EEZ waters around the Main Hawaiian Islands (MHI), American Samoa, and Guam. Since 1983, the Crustacean FMP has been amended 13 times with each amendment summarized in **Table 2**.

Table 2. Amendments to the Crustaceans FMP

No.	Effective Date/Federal Register Notice	Action
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No.	Effective Date/Federal Register Notice	Action
13	11/21/08 73 FR 70603	Included the deepwater shrimp genus <i>Heterocarpus</i> as Management Unit Species (MUS) within the Crustaceans FMP. Required Federal permits and reporting for deepwater shrimp fishing in all Federal waters of the Western Pacific Region.
12	10/26/06 71 FR 53605	Included federal waters around CNMI and the Pacific Remote Island Areas in the Crustaceans FMP and implemented federal permit and reporting requirements (71 FR 231) for vessels targeting crustacean MUS in these areas.
11	2/24/04 69 FR 8336	Prepared in parallel with the Coral Reef Ecosystems FMP. This amendment prohibits the harvest of Crustacean MUS in the no-take marine protected areas established under the Coral Reef Ecosystems FMP, including Rose Atoll in American Samoa, Kingman Reef, Jarvis Island, Howland Island, and Baker Island. The final rule implementing the Coral Reef Ecosystem FMP (including Amendment 11 to the Crustaceans FMP) became effective 3/25/04.
10	4/19/99 64 FR 19067 8/5/03 68 FR 46112	Addressed new requirements under the 1996 Sustainable Fisheries Act. Portions of the amendment that were immediately approved included designations of essential fish habitat, and descriptions of bycatch and of some fishing communities. Those provisions became effective on February 3, 1999. Remaining portions approved on August 5, 2003, included provisions regarding Hawaii fishing communities, overfishing definitions, and bycatch.
9	7/5/96 61 FR 35145	Established a system by which the annual harvest guideline would be set based on a constant percent of the population (i.e., proportional to the estimated exploitable population size) based on a specified acceptable risk of overfishing. Amendment 9 set this risk level at 10% and specified that annual harvest guidelines be published by NMFS no later than February 28 of each year. Earlier in-season adjustment procedures were eliminated. Earlier minimum size limits and prohibitions on harvesting of egg bearing females were eliminated and a mechanism was provided for certain regulatory adjustments to be made through framework procedures of the FMP.
8	11/10/94 59 FR 56004	Eliminated the NWHI minimum landings requirements for permit renewal, allowed the catch per unit effort target that is used to set the harvest guideline to be changed through the framework process, and modified reporting requirements
7	3/26/92 57 FR 10437	Established a NWHI limited access program, an adjustable fleet-wide NWHI annual harvest guideline, and a closed season (January through June) in the NWHI fishery. Participation was limited to 15 permits (and vessels). Other measures include a maximum limit on the number of traps per vessel (1,100), revisions to reporting requirements, and other provisions

No.	Effective Date/Federal Register Notice	Action
6	1/28/91 56 FR 3071	Defined recruitment overfishing for lobster stocks in terms of reference points expressed in terms of the spawning potential ratio (SPR). The minimum SPR threshold, below which the stock would be considered recruitment overfished, is 20%.
5	1987	Implemented a minimum size for slipper lobster (5.6 cm tail width), required the release of egg-bearing female slipper lobsters, required escape vents in all lobster traps, and revised some of the permit application and reporting requirements. It also changed the name of the FMP from “Spiny Lobster Fisheries” to “Crustaceans Fisheries.”
4	1986	Applied existing NWHI closed areas to slipper lobsters.
3	1985	Revised the minimum spiny lobster size specifications for the NWHI management area to a limit on tail width (5.0 cm).
2	1983	Modified the allowable trap opening dimensions with the intent of minimizing the risk of harm to the Hawaiian monk seal while allowing sufficient flexibility in trap design.
1	1983	Adopted the State of Hawaii’s lobster fishing regulations for the federal waters around the MHI.

In addition to FMP amendments, the management program for crustacean fisheries has been modified through several regulatory amendments described below.

Regulatory Amendment 1: Implemented VMS for the crustacean fishery in the NWHI (64 FR 36820, July 8, 1999).

Regulatory Amendment 2: Allocated 1998 NWHI lobster harvest among three individual banks and a fourth combined area (63 FR 40337, June 29, 1998).

Regulatory Amendment 3: Divided the NWHI into four fishing grounds across which harvest is allocated and allowed fishing vessels with NMFS-certified VMS to transit through fishing grounds during a closure (64 FR 36820, July 8, 1999).

FMP for Bottomfish and Seamount Groundfish of the Western Pacific Region

The FMP for Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region became effective on August 27, 1986 (51 FR 27413). Initial bottomfish fishery management measures prohibited certain destructive fishing techniques, including explosives, poisons, trawl nets, and bottom-set gillnets; established a moratorium on the commercial harvest of seamount groundfish stocks at the Hancock Seamounts, and implemented a permit system for fishing for bottomfish in the waters of the Exclusive Economic Zone (EEZ) around the Northwestern Hawaiian Islands (NWHI). The plan also established a management framework that provided for regulatory adjustments to be made, such as catch limits, size limits, area or seasonal closures, fishing effort limitations, fishing gear restrictions, access limitations, permit and/or catch

reporting requirements, as well as a rules-related notice system. Since 1986, the Bottomfish and Seamount Groundfish FMP has been amended multiple times with each amendment summarized in **Table 3**.

Table 3. Amendments to the Bottomfish and Seamount Groundfish FMP.

No.	Effective Date/Federal Register Notice	Action
14	4/04/08 73 FR 18450	Addressed bottomfish overfishing in the Hawaiian Archipelago by implementing a total allowable catch limit (TAC), federal non-commercial permits and reporting requirements, non-commercial bag limits and a closed season for fishing for Deep 7 species in the Main Hawaiian Islands. It also defined the Main Hawaiian Islands bottomfish fishing year as September 1-August 31, and became effective April 1, 2008 (73 FR 18450) with the permit and reporting requirements effective as of August 18, 2008 (73 FR 41296).
11-13		Amendments 11-13 were intended to address various issues which have now become moot due to changing circumstances.
10	12/12/08 73 FR 75615	Prohibited commercial fishing for bottomfish from vessels greater than 40' long in waters 0-10 miles around the Southern Islands of CNMI and 0-10 miles around the Northern Island of Alamagan. Commercial bottomfishing vessels over 40' long must carry active VMS units owned, installed, and maintained by NMFS. Also, the operators of all vessels commercially fishing for bottomfish in EEZ waters around CNMI must obtain federal permits and complete federal logbooks.
9	11/02/06 71 FR 67774	Prohibited vessels greater than 50' long from targeting Bottomfish species within 50 miles of Guam and required these vessels to obtain federal permits and to submit federal logbooks effective December 4, 2006 (71 FR 69496).
8	9/12/06 71 FR 53605	Included federal waters around CNMI and the Pacific Remote Island Areas in the Bottomfish FMP. Implemented federal permitting and reporting requirements for bottomfish fishing in the PRIA effective 1/2/07 (71 FR 69496).
7	2/24/04 69 FR 8336	Developed in parallel with the Coral Reef Ecosystems FMP. Prohibited harvest of Bottomfish and Seamount Groundfish Management Unit Species (MUS) in the no-take marine protected areas established under the Coral Reef Ecosystems FMP. The Coral Reef Ecosystems established such areas around Rose Atoll in American Samoa, Kingman Reef, Jarvis Island, Howland Island, and Baker Island. The final rule implementing the Coral Reef Ecosystem FMP (including Amendment 7 to the Bottomfish FMP) became effective 3/25/04.
6	4/19/99 64 FR19067	Addressed new requirements under the 1996 Sustainable Fisheries Act. Portions of the amendment that were immediately approved included designations of essential fish habitat, and descriptions of

No.	Effective Date/Federal Register Notice	Action
	8/5/03 68 FR 46112	bycatch and of some fishing communities. Those provisions became effective on 2/3/99. Remaining portions approved on 8/5/03, included provisions regarding Hawaii fishing communities, overfishing definitions, and bycatch.
5	4/28/99 64 FR 22810	Established a limited entry program for the Mau Zone in the NWHI with non-transferable permits and landing requirements for permit renewal. Included in requirements was attendance by the primary vessel operator at a protected species workshop. Also reserved 20% of Mau Zone permits a Western Pacific Community Development Program (CDP), as well as instituting a maximum vessel length of 60' for replacement vessels in the Hoomalu or Mau Zones
4	5/30/91 56 FR 24351	Implemented a requirement for vessel owners or operators to notify NMFS at least 72 hours before leaving port if they intend to fish in a "protected species study zone" that extends 50 nautical miles (nm) around the NWHI to allow federal observers to be placed on board bottomfish vessels to record interactions with protected species if this action is deemed necessary
3	1/16/91 56 FR 2503	Defined recruitment overfishing as a condition in which the ratio of the spawning stock biomass per recruit at the current level of fishing to the spawning stock biomass per recruit that would occur in the absence of fishing is equal to or less than 20%. Amendment 3 also delineated a process by which overfishing would be monitored and evaluated.
2	9/6/88 53 FR 29907	Divided the EEZ around the NWHI into the Hoomalu and Mau zones. A vessel limited access system was established for the Ho'omaluu Zone, with non-transferable permits and landing requirements for permit renewal and for new entry into the fishery. Access to the Mau Zone was left unrestricted, except for vessels permitted to fish in the Hoomalu Zone.
1	11/11/87 52 FR 38102	Established a system to allow implementation of limited access systems for bottomfish fisheries in EEZ waters around American Samoa and Guam within the framework measures of the FMP.

FMP for Pelagic Fisheries of the Western Pacific Region

The FMP for Pelagic Fisheries of the Western Pacific Region became effective on March 23, 1987 (52 FR 5987). The Pelagic Management Unit Species (PMUS) at that time were billfish, wahoo, mahimahi, and oceanic sharks. The FMP's first measures prohibited drift gillnet fishing within the region's waters of the U.S. EEZ and prohibited foreign longline fishing within certain areas of the EEZ. Since 1987, the Pelagic FMP has been amended multiple times with each amendment summarized in **Table 4**.

Table 4. Amendments to the Pelagic FMP.

No.	Effective Date/Federal Register Notice	Action
18	12/10/09 74 FR 65460	Removed 2,120 set limit for Hawaii-based shallow-set longline fishery. Implemented a new loggerhead sea turtle hard cap of 46 annual interactions.
16-17		Was intended to address issues which have now become moot due to changing circumstances.
15	11/21/08 73 FR 70600	Added the following pelagic squid species to the FMP: <i>Ommastrephes bartramii</i> , <i>Thysanoteuthis rhombus</i> , and <i>Sthenoteuthis oualaniensis</i> . Also, required owners of U.S. vessels greater than 50 ft in length overall that fish for pelagic squid in U.S. EEZ of the western Pacific to obtain Federal permits under the Pelagics Fishery Management Plan, to carry Federal observers if requested by NMFS, and to report any Pacific pelagic squid catch and effort either in Federal logbooks or via existing local reporting systems.
14	6/18/07 72 FR 33442	Partially approved by NMFS. This amendment contained recommendations regarding international and domestic management, including a mechanism by which the Council could participate in international negotiations regarding these stocks. Amendment 14 contained measures to implement control dates for Hawaii's non-longline commercial pelagic vessels (70 FR 47781) and purse seine and longline vessels (70 FR 47782), as well as requirements for federal permits and reporting for Hawaii-based non-longline commercial pelagic vessels. NMFS disapproved the Amendment's international measures as premature. NMFS disapproved the domestic permit and reporting requirements as duplicative of existing State requirements. NMFS noted that Amendment 14 met the requirements of the Magnuson-Act regarding overfishing.
12-13		Was intended to address issues which have now become moot due to changing circumstances.
11	5/24/05 70 FR 29646	Effective August 1, 2005, Amendment 11 established a limited access system for pelagic longlining in EEZ waters around American Samoa. Longline vessel operators were required to obtain federal permits, to complete federal logbooks, to carry and use vessel monitoring systems installed, owned and operated by NFMS on vessels greater than 40 ft in length, to carry federal observers if requested by NMFS, and to follow sea turtle handling and resuscitation requirements.
10	2/24/04 69 FR 8336	Amendment 10 prohibits the harvest of Pelagic Management Unit Species in the no-take marine protected areas established under the Coral Reef Ecosystems FMP. The Coral Reef FMP establishes such areas around Rose Atoll in American Samoa, Kingman Reef, Jarvis Island, Howland Island, and Baker Island. The final rule

No.	Effective Date/Federal Register Notice	Action
		implementing the Coral Reef Ecosystem FMP includes Amendment 10 to the Pelagics FMP.
9		Was intended to address issues which have now become moot due to changing circumstances.
8	4/19/99 64 FR 19067 8/5/03 68 FR 46112	Addressed new requirements under the 1996 Sustainable Fisheries Act. Portions of the amendment that were immediately approved (4/19/99) included designations of essential fish habitat and descriptions of some fishing communities. Remaining portions were provisions regarding Hawaii fishing communities, overfishing definitions, and bycatch (approved 8/5/03).
7	5/24/94 59 FR 26979	Replaced Amendment 4 moratorium with a limited entry program for Hawaii-based domestic longline fishery with transferable permits, a limit of 164 vessels, and a maximum vessel size of 101' in length overall. It also established a framework procedure for use with implementation of certain new regulations.
6	11/2/92 57 FR 36637	Specified that all tuna species are designated as fish under U.S. management authority and included tunas and related species as Pelagic Management Unit Species under the FMP. It also applied the longline exclusion zones of 50 nm around the island of Guam and the 25-75 nm zone around the MHI to foreign vessels.
5	3/2/92 57 FR 7661	Created a domestic longline vessel exclusion zone around the Main Hawaiian Islands (MHI) ranging from 50 to 75 nm, and a similar 50 nm exclusion zone around Guam and its offshore banks. A seasonal reduction in the size of the closure was implemented in October 1992; between October and January longline fishing is prohibited within 25 nm of the windward shores of all Main Hawaiian Islands except Oahu, where it is prohibited within 50 nm from the shore.
4	10/14/91 56 FR 52214	Created a 50 nm longline exclusion zone around the NWHI to protect endangered Hawaiian monk seals. It also implemented framework provisions for establishing a mandatory observer program to collect information on interactions between longline fishing and sea turtles.
3	10/14/91 56 FR 52214	Created a 50 nm longline exclusion zone around the NWHI to protect endangered Hawaiian monk seals. It also implemented framework provisions for establishing a mandatory observer program to collect information on interactions between longline fishing and sea turtles.
2	5/26/91 56 FR 24731	Implemented requirements for domestic pelagic longline fishing and transshipment vessel operators to have Federal permits, maintain Federal fishing logbooks, and, if fishing within 50 nm of the Northwestern Hawaiian Islands, to have observers on board if directed by NMFS. It required longline gear to be marked with the official number of the permitted vessel, and incorporated waters of

No.	Effective Date/Federal Register Notice	Action
		the EEZ around CNMI into the area managed under the FMP.
1	3/1/91 56 FR 9686	Defined recruitment overfishing for each PMUS. Defined the optimum yield for PMUS.

In addition to FMP amendments, the management program for pelagic fisheries has been modified through several regulatory amendments and framework actions described below.

Regulatory Amendment 1: Incorporated reasonable and prudent alternative of the March 2001 Biological Opinion issued by NMFS. This amendment prohibited shallow set pelagic longlining north of the equator and closed waters between 0° and 15° N from April-May annually to longline fishing. It instituted sea turtle handling requirements for all vessels using hooks to target pelagic species in the region's EEZ waters and extended the protected species workshop requirement to include the operators of vessels registered to longline general permits (67 FR 40232, July 12, 2002).

Regulatory Amendment 2: Established Federal permit and reporting requirements for any vessel using troll or handline gear to catch PMUS in EEZ waters around the Pacific Remote Island Areas of Kingman Reef, Howland, Baker, Jarvis, Johnston and Wake Islands, and Palmyra and Midway Atolls (67 FR 59813, October 24, 2002 – comment period end)

Regulatory Amendment 3: Implemented measures for the longline fisheries to achieve optimum yield while not jeopardizing the long term existence of sea turtles and other listed species. The amendment established a limited Hawaii-based shallow-set swordfish fishery using circle hooks with mackerel bait. Fishing effort in the shallow-set swordfish fishery was limited to 50% of the 1994-1999 annual average number of sets (just over 2,100 sets) allocated between fishermen applying to participate in the fishery. A 'hard' limit on the number of leatherback (16) and loggerhead (17) turtle interactions that could occur in the swordfish fishery was implemented; the fishery closed for the remainder of the calendar year if either limit was reached. The amendment re-implemented earlier sea turtle handling and resuscitation requirements and included conservation projects to protect sea turtles in their nesting and coastal habitats. This rule implemented the requirement for night setting imposed by the USFWS Biological Opinion on Hawaii-based longline vessels targeting swordfish north of 23 degrees north latitude (69 FR 17329, April 2, 2004).

Regulatory Amendment 4: Included measures to minimize turtle interactions by non-Hawaii based domestic longline vessels operating in the Western Pacific under general longline permits. Vessels with longline general permits making shallow sets north of the equator were required to use 18/0 circle hooks with mackerel-type bait and dehookers to release any accidentally caught turtles. The amendment required vessel operators and owners with general longline permits to

annually attend protected species training workshops. Operators of vessels with general longline permits were required to carry and use specific mitigation gear to aid release of sea turtles accidentally hooked or entangled by longlines. This amendment required operators of non-longline pelagic vessels (e.g. trollers and handliners) to follow handling guidelines and remove trailing gear wherever they fish (70 FR 69282, December 15, 2005).

Regulatory Amendment 5: Allowed operators of Hawaii-based longline vessels fishing north of 23 degrees north latitude, as well as those targeting swordfish south of 23 degrees north, to utilize side-setting to reduce seabird interactions in lieu of the seabird mitigation measures required by Framework Measure 1 (70 FR 75075, January 18, 2006).

Regulatory Amendment 6: Removed the seven day delay in effectiveness when closing the Hawaii based shallow-set longline fishery as a result of reaching interaction limits for sea turtles, allowing instead for an immediate closure of the fishery (72 FR 8289, February 26, 2007).

Regulatory Amendment 7: Provided pelagic fishery participants the option of using NMFS approved electronic logbooks in lieu of paper logbooks (72 FR 19123, April 16, 2007)

Framework Amendment 1: Prohibited fishing for pelagic species by vessels greater than 50 ft in length overall within EEZ waters 0-50 nm around the islands of American Samoa. Exception: vessels that landed PMUS in American Samoa under a Federal longline general permit prior to November 13, 1997 (67 FR 4369, January 30, 2002)

Framework Amendment 2: Incorporated terms and conditions developed by the Council and contained in the November 28, 2000 USFWS seabird Biological Opinion requiring Hawaii-based pelagic longline vessel operators to use blue-dyed bait, strategic offal discards, and line shooters with weighted branch lines when fishing north of 23° N. Also included requirement that all Hawaii-based longline vessel owners and operators annually attend a protected species workshop conducted by NMFS (67 FR 34408, June 13, 2002)

FMP for Coral Reef Ecosystem Fisheries of the Western Pacific Region

The FMP for Coral Reef Ecosystems of the Western Pacific Region was partially approved on June 14, 2002. NMFS disapproved a portion of the plan that governs fishing in the Northwestern Hawaiian Islands (NWHI) west of 160°50' W. long. because it would be inconsistent with or duplicate certain provisions of Executive Orders 13178 and 13196, which together established the NWHI Coral Reef Ecosystem Reserve. A final rule implementing the Coral Reef Ecosystem FMP was published on February 24, 2004 (69 FR 8336). The FMP is the nation's first ecosystem-based plan for fisheries and includes specific measures to promote sustainable fisheries while providing for substantial protection of coral reef ecosystem resources and habitats throughout the Council's jurisdiction. The management measures of the Coral Reef Ecosystems FMP:

- Established a network of marine protected areas (MPA) in the Pacific Remote Island Areas (PRIA). Howland, Baker, Jarvis Islands, Rose Atoll, and Kingman Reef have been designated as no-take MPAs. Palmyra and Johnston Atolls, and Wake Islands are designated as low-use MPAs where fishing is allowed under special fishing permits. Both no-take and low-use MPAs were proposed for the NWHI in the FMP, but were disapproved by NMFS;
- Requires a special permit and federal reporting system for controlling and monitoring the harvest of certain coral reef ecosystem management unit species (MUS) for which there is little or no information. Special permits are also required to fish in all areas designated as low-use MPAs. The FMP also uses data collected under existing local reporting systems to monitor the harvest of currently fished coral reef ecosystem MUS;
- Prohibits the use of destructive and non-selective fishing gears;
- Prohibits harvesting of coral and live rock, but allow limited take under the special permit system for collection of seed stock by aquaculture operations, and religious/cultural use by indigenous peoples;
- Incorporates an adaptive management approach using a framework process for rapid regulatory modifications in the event of major changes within coral reef ecosystems or coral reef fisheries;
- Considers and take into account in management, the historical and cultural dependence of coral reef resources by indigenous people and;
- Identifies and prioritize coral reef related research needs for each island area, including socio-economic and cultural research for future potential allocation of resources.

Since its implementation in 2004, the Coral Reef FMP has not been amended.

2. Fishery Ecosystem Plan Amendments

Omnibus Amendment: Community Development Program Process, 9/3/10

The Council amended all FEPs to establish eligibility requirements and procedures for reviewing and approving community development plans. The intent is to promote participation of island communities in fisheries that they traditionally depend on, but may not have the capabilities to support continued and substantial participation. A second final rule was published 11/05/10 in which OMB approved the collection-of-information requirements (75 FR 68199).

Omnibus Amendment: Establish a Western Pacific Region Process for Specifying Annual Catch Limits and Accountability Measures, 6/27/11

The Council amended all FEPs to establish the mechanism the Council will use to specify ACLs and AMs for each FEP fishery. Specifically, the proposed action described in this document consists of three components that would: 1) in each FEP, establish a mechanism the Council will use to determine ACLs and AMs , including a process for setting acceptable biological catch limits (ABCs); 2) adopt the ecosystem component (EC) species classification described in the NMFS advisory guidelines for National Standard 1 (NS1) so the Council can develop specific

criteria for identifying EC species in subsequent amendments to the FEPs; and 3) identify pelagic management unit species that have statutory exceptions to the ACL and AM requirements.

Amendment to the Pacific Pelagic, American Samoa, Mariana, and Pacific Remote Island Area FEPs: Fishery Management in the Marianas Trench, Pacific Remote Islands, and Rose Atoll Marine National Monuments,

The Council amended the Pacific Pelagics, American Samoa, Pacific Remote Island Areas, and the Mariana Islands FEPs, to establish certain provisions relating to non-commercial fishing practices. Consistent with the monument Proclamations, the amendments:

- Codified the boundaries of the Monuments and their various management units.
- Implemented the prohibition on commercial fishing at Rose Atoll and PRI Monuments, and in the Islands Unit of the Marianas Trench Monument.
- Established management measures for non-commercial and recreational fishing in the Monuments including, but not limited to:
 - Requiring Federal permits and reporting for non-commercial and recreational charter fishing to aid in the monitoring of fishing activities.
 - Limiting fishing permit eligibility to residents and businesses of local fishing communities in the Rose Atoll Monument and Marianas Trench Monument, Islands Unit.
 - Allowing customary exchange in non-commercial fishing in the Marianas Trench Islands Unit and Rose Atoll Monuments to help preserve traditional indigenous and cultural fishing practices.
 - Defining customary exchange as the non-market exchange of marine resources between fishermen and community residents for goods, services, and/or social support for cultural, social or religious reasons, and may include cost recovery through monetary reimbursements and other means for actual trip expenses (ice, bait, food, or fuel) that may be necessary to participate in fisheries in the western Pacific. Customary exchange of fish harvested in the Monuments includes family and friends of residents of the fishing communities.
 - Prohibiting all fishing within 12 nautical miles (nm) of the Pacific Remote Islands, subject to USFWS's authority to allow non-commercial fishing, in consultation with NMFS and the Council.
 - Prohibit all fishing within 12 nm around Rose Atoll.
- Prohibited the conduct of commercial fishing outside of a monument, and noncommercial fishing within a monument, on the same trip.

Amendment 2 to the Pacific Pelagic FEP: Establishment of Longline Prohibited Areas in the Mariana Archipelago, 3/4/2011

The Council amended the Pacific Pelagic FEP to establish a 30 mile longline fishing prohibited areas in the CNMI to promote sustained participation in fishing by Guam and CNMI fishing communities.

Amendment 5 to the Pacific Pelagic FEP: Measures to Reduce Interactions between the American Samoa Longline Fishery and Green Sea Turtles, 8/24/11

The American Samoa longline fishery has been observed to interact with (hook or entangle) with green sea turtles (*Chelonia mydas*) which are listed as threatened under the Endangered Species Act. To address this issue, the Council amended the Pelagics FEP to provide for the longterm survival, recovery, and sustainability of the sea turtles by reducing the number of sea turtle interactions with the fishery.

Amendment 7 to the Pacific Pelagic FEP: Use and Assignment of Catch and Effort Limits of Pelagic Management Unit Species by the U.S. Pacific Island Territories. 3/28/14

Amendment 7 establishes a management framework and process for specifying fishing catch and effort limits and accountability measures for pelagic fisheries in the U.S. Pacific territories (American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands). The framework authorizes the government of each territory to allocate a portion of its specified catch or effort limit to a U.S. fishing vessel or vessels through a specified fishing agreement, and establish criteria, which a specified fishing agreement must satisfy. The framework also includes measures to ensure accountability for adhering to fishing catch and effort limits.

Table 5. Amendments to the Fishery Ecosystem Plans (post-2009).

FEP	No.	Effective Date/Federal Register Notice	Action
AS	1	6/27/11 76 FR 37285	Omnibus amendment. Establishes eligibility requirements and procedures for reviewing and approving community development plans. The intent is to promote participation of island communities in fisheries that they traditionally depend on, but may not have the capabilities to support continued and substantial participation. . A second final rule was published 11/05/10 in which OMB approved the collection-of-information requirements (75 FR 68199).
AS	2	09/03/10 75 FR 54044	Omnibus amendment that establishes a mechanism for specifying annual catch limits.
HI	1	09/03/10 75 FR 54044	Omnibus amendment. Establishes eligibility requirements and procedures for reviewing and approving community development plans. The intent is to promote participation of island communities in fisheries that they traditionally depend on, but may not have the capabilities to support continued and substantial participation. A second final rule was published 11/05/10 in which OMB approved the collection-of-information requirements (75 FR 68199).
HI	2	11/10/10	Establishes the Hancock Seamounts Ecosystem Management

FEP	No.	Effective Date/Federal Register Notice	Action
		75 FR 69015	Area as well as continues the moratorium on armorhead and other seamount groundfish until the armorhead stock is rebuilt.
HI	3	6/27/11 76 FR 37285	Omnibus amendment that establishes a mechanism for specifying annual catch limits
MA	1	09/03/10 75 FR 54044	Omnibus amendment. Establishes eligibility requirements and procedures for reviewing and approving community development plans. The intent is to promote participation of island communities in fisheries that they traditionally depend on, but may not have the capabilities to support continued and substantial participation. A second final rule was published 11/05/10 in which OMB approved the collection-of-information requirements (75 FR 68199).
MA	2	6/27/11 76 FR 37285	Omnibus amendment that establishes a mechanism for specifying Annual Catch Limits.
PRIA	1	6/27/11 76 FR 37285	Omnibus amendment that establishes a mechanism for specifying annual catch limits.
PRIA	2	6/03/13 78 FR 32996	Establishes management measures for non-commercial and recreational fishing within the Pacific Remote Islands Marine National Monument; prohibits commercial fishing within monument
PEL	1	09/03/10 75 FR 54044	Eligibility requirements and procedures for reviewing and approving community development plans. The intent is to promote participation of island communities in fisheries that they traditionally depend on, but may not have the capabilities to support continued and substantial participation.
PEL	2	Disapproval: 7/11/11 76 FR 40764	Establishes a purse seine area closure in American Samoa. The purse seine area closure was disapproved.
PEL	3	6/27/11 76 FR 37287	Establishes a purse seine area closure and longline area closure in CNMI. The final rule only approved the longline closure.
PEL	4	6/27/11 76 FR 37285	Omnibus amendment that establishes a mechanism for specifying annual catch limits.
PEL	5	8/24/11 76 FR 52888	American Samoa longline gear configuration modifications to reduce sea turtle interactions.
PEL	6		
PEL	7		Catch and effort limits for the US Participating Territories; Specification of annual bigeye tuna catch limits for the US Participating Territories.

Appendix E: MSY Control Rule & Stock Status Determination Criteria and Process for Specifying Annual Catch Limits and Accountability Measures

MSY Control Rule and Stock Status Determination Criteria

A MSY control rule is a control rule that specifies the relationship of F to B or other indicator of productive capacity under an MSY harvest policy. Because fisheries must be managed to achieve optimum yield, not MSY, the MSY control rule is a benchmark control rule rather than an operational one. However, the MSY control rule is useful for specifying the “objective and measurable criteria for identifying when the fishery to which the plan applies is overfished” that are required under the MSA. The National Standard Guidelines (74 FR 3178) refer to these criteria as “status determination criteria” and state that they must include two limit reference points, or thresholds: one for F that identifies when overfishing is occurring and a second for B or its proxy that indicates when the stock is overfished.

The status determination criterion for F is the maximum fishing mortality threshold (MFMT). Minimum stock size threshold (MSST) is the criterion for B. If fishing mortality exceeds the MFMT for a period of one year or more, overfishing is occurring. A stock or stock complex is considered overfished when its biomass has declined below a level that jeopardizes the capacity of the stock to produce MSY on a continuing basis (i.e., the biomass falls below MSST). A Council must take remedial action in the form of a new FMP, an FMP amendment, or proposed regulations within two years following notification by the Secretary of Commerce that overfishing is occurring, a stock or stock complex is overfished or approaching an overfished condition¹ or existing remedial action to end previously identified overfishing or to rebuild an overfished stock has not resulted in adequate progress.

The National Standard Guidelines state that the MFMT may be expressed as a single number or as a function of some measure of the stock’s productive capacity. Guidance in Restrepo et al. (1998:17) regarding specification of the MFMT is based on the premise that the MSY control rule constitutes the MFMT. In the example in Figure 1 the MSY control rule sets the MFMT constant at F_{MSY} for values of B greater than the MSST and decreases the MFMT linearly with biomass for values of B less than the MSST. This is the default MSY control rule recommended in Restrepo et al. (1998). Again, if F is greater than the MFMT for a period of one year or more, overfishing is occurring.

¹ A stock or stock complex is approaching an overfished condition when it is projected that there is more than a 50 percent chance that the biomass of the stock or stock complex will decline below MSST within two years (74 FR 3178).

The National Standard Guidelines state that to the extent possible, the MSST should equal whichever of the following is greater: One-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock or stock complex were exploited at the MFMT. The MSST is indicated in Figure 1 by a vertical line at a biomass level somewhat less than B_{MSY} . A specification of MSST below B_{MSY} would allow for some natural fluctuation of biomass above and below B_{MSY} , which would be expected under, for example, an MSY harvest policy. Again, if B falls below MSST the stock is overfished.

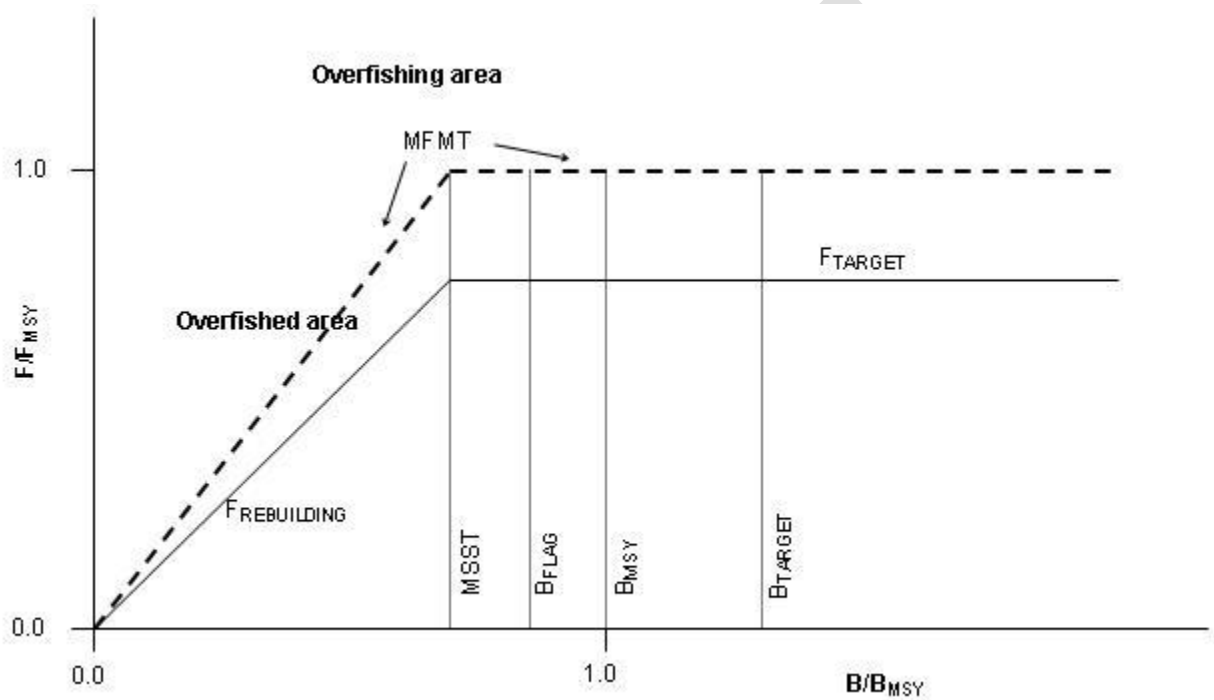


Figure 1. Example of MSY, Target and Rebuilding Control Rules

Source: Restrepo et al. 1998

Warning reference points comprise a category of reference points that will be considered in this FEP together with the required thresholds. Although not required under the MSA, warning reference points could be specified in order to provide warning in advance of B or F approaching or reaching their respective thresholds. Considered in this FEP is a stock biomass flag (B_{FLAG}) that would be specified at some point above MSST, as indicated in Figure 1. The control rule would not call for any change in F as a result of breaching B_{FLAG} – it would merely serve as a trigger for consideration of action or perhaps preparatory steps towards such action. Intermediate reference points set above the thresholds could also be specified in order to trigger changes in F – in other words, the MFMT could have additional inflection points.

Target Control Rule and Reference Points (For Crustacean Management Unit Species only)

A target control rule specifies the relationship of F to B for a harvest policy aimed at achieving a given target. Optimum yield (OY) is one such target, and National Standard 1 requires that conservation and management measures both prevent overfishing and achieve OY on a continuing basis. Optimum yield is the yield that will provide the greatest overall benefits to the nation, and is prescribed on the basis of MSY, as reduced by any relevant economic, social, or ecological factor. MSY is therefore an upper limit for OY.

A target control rule can be specified using reference points similar to those used in the MSY control rule, such as F_{TARGET} and B_{TARGET} . For example, the recommended default in Restrepo et al. (1998) for the target fishing mortality rate for certain situations (ignoring all economic, social, and ecological factors except the need to be cautious with respect to the thresholds) is 75 percent of the MFMT, as indicated in Figure 1. Simulation results using a deterministic model have shown that fishing at $0.75 F_{\text{MSY}}$ would tend to result in equilibrium biomass levels between 1.25 and $1.31 B_{\text{MSY}}$ and equilibrium yields of 0.94 MSY or higher (Mace 1994).

It is emphasized that while MSST and MFMT are limits, the target reference points are merely targets. They are guidelines for management action, not constraints. For example Restrepo et al. (1998) state that target reference points should not be exceeded more than 50% of the time, nor on average.

Rebuilding Control Rule and Reference Points (For Crustacean Management Unit Species only)

If it has been determined that overfishing is occurring, a stock or stock complex is overfished or approaching an overfished condition, or existing remedial action to end previously identified overfishing or to rebuild an overfished stock has not resulted in adequate progress, the Council must take remedial action within two years. In the case that a stock or stock complex is overfished (i.e., biomass falls below MSST in a given year), the action must be taken through a stock rebuilding plan (which is essentially a rebuilding control rule as supported by various analyses) with the purpose of rebuilding the stock or stock complex to the MSY level (B_{MSY}) within an appropriate time frame, as required by MSA §304(e)(4). The details of such a plan, including specification of the time period for rebuilding, would take into account the best

available information regarding a number of biological, social, and economic factors, as required by the MSA and National Standard Guidelines.

If B falls below MSST, management of the fishery would shift from using the target control rule to the rebuilding control rule. Under the rebuilding control rule in the example in Figure 1, F would be controlled as a linear function of B until B recovers to MSST (see $F_{\text{REBUILDING}}$), then held constant at F_{TARGET} until B recovers to B_{MSY} . At that point, rebuilding would have been achieved and management would shift back to using the target control rule (F set at F_{TARGET}). The target and rebuilding control rules “overlap” for values of B between MSST and the rebuilding target (B_{MSY}). In that range of B , the rebuilding control rule is used only in the case that B is recovering from having fallen below MSST. In the example in Figure 1 the two rules are identical in that range of B (but they do not need to be), so the two rules can be considered a single, integrated, target control rule for all values of B .

Measures to Prevent Overfishing and Overfished Stocks

The control rules specify how fishing mortality will be controlled in response to observed changes in stock biomass or its proxies. Implicitly associated with those control rules are management actions that would be taken in order to manipulate fishing mortality according to the rules. In the case of a fishery which has been determined to be “approaching an overfished condition or is overfished,” MSA §303(a)(10) requires that the FMP “contain conservation and management measures to prevent overfishing or end overfishing and rebuild the fishery.”

Use of National Standard 1 Guidelines in FEPs

This FEP carries forward the provisions pertaining to compliance with the Sustainable Fisheries Act which were recommended by the Council and subsequently approved by NMFS (68 FR 16754, April 7, 2003). Because biological and fishery data are limited for all species managed by this FEP, MSY-based control rules and overfishing thresholds are specified for multi-species stock complexes.

Process for Specifying Annual Catch Limits (ACLs) and Accountability Measures (AMs)

In 2012, a mechanism for specifying ACLs was established in the FEPs for American Samoa, Hawaii, the Mariana Archipelago, the Pacific Remote Island Areas, and western Pacific Pelagic fisheries. The ACL mechanism included a tiered system of ABC control rules that the SSC applies to calculate ABC. Included in this is a qualitative method the Council employed to determine an appropriate P^* (P^* denotes risk of overfishing) value for each fishery. The ACL mechanism also includes methods for determining ACLs and AMs for stocks and stock complexes in the fishery. ACLs and AMs developed by the Council are specified by the agency prior to the start of each fishing year. Figure 2 illustrates the method for specifying ACLs, including the procedures for calculating ABC and setting ACL and AMs that are all described in this section.

Calculation of the Acceptable Biological Catch

This section describes how the ABC is calculated and set compared to the OFL using ABC control rules that account for the level of scientific knowledge about the stock or stock complex, scientific uncertainty in the estimate of OFL, and other scientific information. This section also discusses how the acceptable risk of overfishing (P^*) is factored into the ABC control rule and how P^* is determined.

Tiered System of ABC Control Rules

For stocks and stock complexes required to have an ABC, the Council utilizes a five-tiered system of ABC control rules that allows for different levels of scientific information to be considered when calculating ABC. The control rules are organized from data rich down to data poor, with Tier 1 being the highest (data rich) and Tier 5 being the lowest (data poor). Tiers 1-2 involve data rich to data moderate situations and include levels of uncertainty derived from model-based stock assessments. Tiers 3-5 involve data poor situations and include levels of uncertainty derived from ad-hoc procedures including simulation models or expert opinion.

When calculating an ABC for a stock or stock complex, the SSC first evaluate the information available for the stock and assign the stock or stock complex into one of the five tiers. The SSC then applies the control rule assigned to that tier to determine the ABC. The SSC may recommend an ABC that differs from the result of the control rule calculation based on factors such as data uncertainty, recruitment variability, declining trends in population variables, and other factors determined relevant by the SSC, but must explain their rationale. The tiered system of ABC control rules are described below.

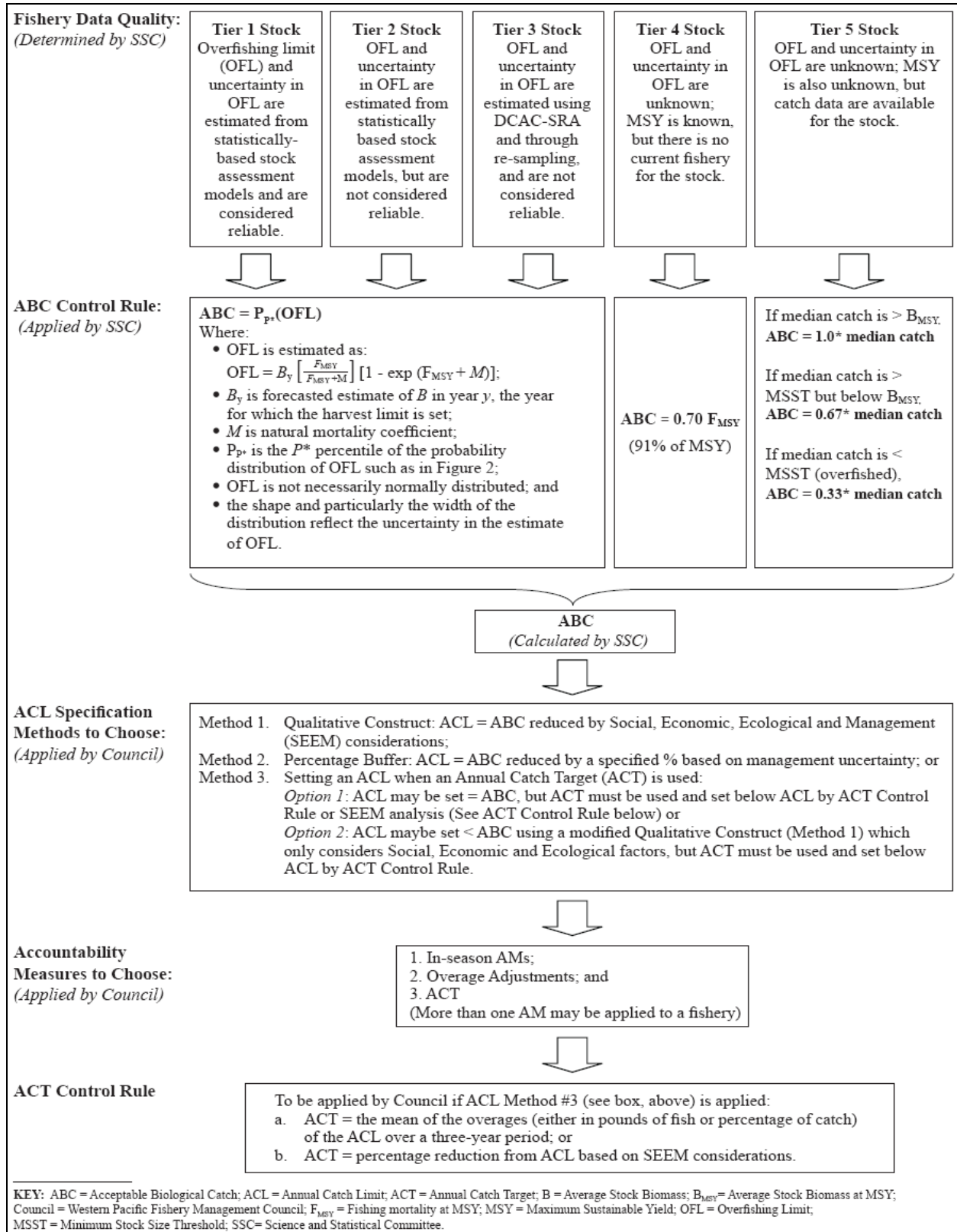


Figure 2. Schematic of method for specifying ABC, ACL and AMs, including ACTs.

Tier 1. Model-Based Probabilistic Approach to Estimating ABCs

In this tier, the data used are reliable and complete enough to be able to utilize statistical-based stock assessment models (e.g., Stock Synthesis 2 (or 3), Multifan-CL (MFCL), C++ Algorithmic Stock Assessment Laboratory (CASAL), and Bayesian production models). From these stock assessments, reliable estimates of MSY , F_{MSY} , B_{MSY} , and B_t are available. Of special relevance to being included in this tier, measures of the uncertainty of F_{MSY} , B_t and B_{t+k} and OFL_{t+k} must be available directly.

In plain English:

ABC is the maximum value for which the probability “p” of exceeding OFL is less than P^* .

Or, in conceptual mathematical terms:

$$ABC = \max (x \mid p(x > OFL) < P^*)$$

Or, as commonly estimated:

$$ABC = P_{P^*}(OFL)$$

Where:

- OFL is estimated as $OFL = B_y \left[\frac{F_{MSY}}{F_{MSY} + M} \right] [1 - \exp(-F_{MSY} + M)]$;
- B_y is forecasted estimate of B in year y , the year for which the harvest limit is set;
- M is natural mortality coefficient;
- P_{P^*} is the P^* percentile of the probability distribution of OFL such as in Figure 2;
- OFL is not necessarily normally distributed; and
- the shape and particularly the width of the distribution reflect the uncertainty in the estimate of OFL.

The Council must advise the SSC on the acceptable P^* to use prior to calculating and recommending the ABC. If the SSC determines that the uncertainty of OFL is underestimated (due to underestimating the uncertainty of F_{MSY} and/or the forecasted estimated B_t), the SSC could appropriately rescale the width of the OFL distribution.

Tier 2. Quasi-Probabilistic Approach to Estimating ABCs

The key difference between assessments in Tier 1 and Tier 2 is that in Tier 2, measures of uncertainty of OFL are not as reliable or are not available from a single, integrated stock assessment model. Reliable data must still be available to be included in this tier, but those used are obtained through some separate analysis or analyses. The methods often involve re-sampling or ad hoc methods. While the statistical-based model characteristic of Tier 1 can occur here, the common assessments are Yield-per-Recruit (Y/R) and Spawning-per-Recruit (SPR). Such assessments involve the use of F_{MSY} proxies, usually $F_{30\%}$ and $F_{60\%}$. The data in Tier 2 may not be as reliable or complete as in Tier 1, though still of sufficient quality to provide fully usable stock assessments.

$F_{30\%}$ = Fishing at the rate that reduces spawning biomass per recruit to 30% of the unfished value. Used as a substitute for F_{MSY} when using Y/R and SPR stock assessments. $F_{60\%}$, as well as others, has also commonly been used.

ABC is estimated using the equation in Tier 1 above, with the uncertainty estimates coming from re-sampling (i.e. method for estimating and re-estimating probability distributions such as bootstrapping). The Council must advise the SSC on the acceptable P^* to use prior to calculating and recommending the ABC.

Tier 3. Data-poor Probabilistic Approach to Setting ABCs

In this tier, the available data are not sufficient for the use of model-based assessment tools. Data are sufficient to apply the data limited approaches such as (but not limited to) Depletion-Corrected Average Catch (DCAC) (MacCall 2009), Stock Reduction Analysis (DCAC-SRA) (Dick and MacCall 2011), Catch-MSY (Martell and Froese 2012), Biomass-augmented catch-MSY (Sabater and Kleiber 2014) with information on the biology of the stock, or DCAC, in which there is some estimate of natural mortality (M), but other life history information is lacking. For a comprehensive list of data limited approaches see Carruthers et al 2014. In these

circumstances, the uncertainty of OFL (the probability distribution of OFL) can be estimated using the Monte Carlo simulation (i.e. a technique that uses algorithms that rely on repeated random sampling to compute results). These tools are to be applied to long-lived species where the natural mortality coefficient M should be less than 0.20 and recruitment should not be highly episodic.

ABC is estimated using the equation in Tier 1 above, with the uncertainty estimates established by the Monte Carlo simulation. Again, the Council must advise the SSC on the acceptable P^* to use prior to calculating and recommending the ABC.

Tier 4. ABC Control Rule for Species without Current Harvest

This ABC control rule is for species or species assemblages with stock assessments and/or MSY estimates, but no current harvest, such as deepwater shrimp (*Heterocarpus*). The ABC is set at $0.70 F_{MSY}$ (= yield 91% OFL = 91% MSY = ABC; see Walters et al. 2005) as a precautionary measure to maximize yield while minimizing biomass impacts and accounting for scientific uncertainty. An alternative target fishing mortality value may be specified if additional data or modeling is available to support it, or the Council chooses to be more precautionary.

Walters et al. (2005) provided an example through the modeling tool, ECOSIM, in which $k = 0.7$ represents a precautionary factor in setting the target fishing mortality (F_{MSY}), which is predicted to have little impact on yield. When $k = 0.7$, the ECOSIM simulations implied a sustainable yield of around 0.9 MSY. “ k ” is a factor that a fishery modeler can vary to represent varying levels of precaution for F_{MSY} within the ECOSIM model. Similarly, NMFS Technical Guidance on implementing NS1 by Restrepo et al. (1998) recommended a default fishing mortality target of 25% below MFMT, or $0.75 F_{MSY}$, which results in an equilibrium yield of 94% MSY or higher. This Tier 4 control rule adopted by the WPFMC is more precautionary than the control rule recommended by Restrepo et al. (1998) and in line with the results of Walters et al. (2005). As Tier 4 involves a fishery with no current harvest, this ABC control rule does not include consideration of P^* ; however if harvest occurs, the fishery may be moved into higher tier where P^* would be need to be considered.

Tier 5. Data-poor Ad-hoc Approach to Setting ABCs

In this tier, catches may be small and/or the catch history may contain gaps or be too variable. Catch history may also be lacking in consistently stable periods or periods with consistent trends for using DCAC-SRA or DCAC. Hence, there is no basis for estimating a reliable MSY or OFL.

For these data poor fisheries, a multiplier of the long-term median catch history will be used. The multiplier will be determined by the biological knowledge of the stock or stock complex, in light of the guidance provided by Restrepo et al. (*Section 2.2.2: Data Poor Situations*). The guidance recommends that the default control rule be implemented by multiplying the average catch from a time period where there is no quantitative or qualitative evidence of declining abundance (“Recent Catch”) by a factor based on a qualitative estimate of relative stock size. The following guidelines were provided:

Above B_{MSY}	Limit catch = 1.00*Recent Catch
Above MSST but below B_{MSY}	Limit catch = 0.67*Recent Catch
Below MSST (i.e. overfished)	Limit catch = 0.33*Recent Catch

However, Restrepo et al. (1998) advises that because it will probably not be possible to analytically determine stock status relative to B_{MSY} for data poor stocks, an approach based on informed judgment will be necessary. The authors further state that “in cases of severe data limitations, qualitative approaches may be necessary, including expert opinion and consensus-building methods.” As Tier 5 involves data poor situations, this ABC control rule does not include consideration of P^* .

Determining the Acceptable Probability of Overfishing used in the ABC Control Rule

The ABC control rule for Tier 1-3 fisheries requires the Council to advise the SSC on the acceptable probability of overfishing (P^*) in order for the SSC to calculate and recommend the ABC. As discussed above, P^* refers to the acceptable probability or risk that actual catch equal to the ABC would exceed the OFL and thus, result in overfishing. NS1 guidelines require that the probability that overfishing will occur cannot exceed 50% and should be a lower value. Consequently, the Council adopted a maximum P^* value of 50%; however, where adequate scientific information is available on the stock or stock complex, the Council will utilize a qualitative method for determining an appropriate P^* that is lower than the maximum of 50%. This qualitative approach is described below.

Qualitative Analysis for Determining P*

The Council developed a process by which the risk of overfishing can be reduced from the 50% maximum P*. This approach, based on the approach developed by the South Atlantic FMC, is a qualitative method of determining P* that considers the amount of information available on the stock or stock complex, including scientific uncertainty, for the following dimensions: 1) assessment information, 2) assessment uncertainty, 3) stock status, and 4) productivity and susceptibility. Information on the four dimensions will be compiled and analyzed by a team that may include Council and SSC members, Council staff, and other individuals knowledgeable in the fishery, including stock assessment experts. Team members will use their knowledge and expertise to assign a single score for each dimension based on the criteria below. The maximum value for each dimension is 12.5 and the sum of the four dimensions has a maximum value of 50. The scores for each dimension will be added together for a final score, then be reduced from the maximum risk of overfishing (P^*_{MAX}) of 50. The team's analysis will be vetted through the Council process with the Council ultimately deciding the final P* value. The Council-approved P* would then be utilized in the calculation of the recommended ABC. An example of the qualitative analysis is provided below, but the exact criteria and scoring values used may change as deemed appropriate by the team for each assessed stock.

1) Assessment Information

Criteria	Score	
Quantitative assessment provides estimates of exploitation and B; includes MSY-derived benchmarks	0.0	
Reliable measures of exploitation or B, no MSY benchmarks, proxy reference points	2.5	X
Relative measures of exploitation or B, absolute measures of stock unavailable, proxy reference points	5.0	
Reliable catch history	7.5	
Scarce or unreliable catch records	12.5	

2) Assessment Uncertainty

Criteria	Score	
Complete. Key determinant – uncertainty in both assessment inputs and environmental conditions included	0.0	
High. Key determinant – reflects more than just uncertainty in future recruitment	2.5	
Medium. Uncertainties are addressed using statistical techniques and sensitivities, but full uncertainty is not carried forward in projections	5.0	X
Low. Distributions of F_{MSY} and MSY are lacking	7.5	
None. Only single point estimates; no sensitivities or uncertainty evaluations	12.5	

3) Stock Status

Criteria	Score	
Neither overfished nor overfishing. Stock is at high B and low exploitation relative to benchmark values	0.0	
Neither overfished nor overfishing. Stock may be in close proximity to benchmark values	2.5	X
Stock is either overfished or overfishing is occurring	5.0	
Stock is overfished and overfishing is occurring	7.5	
Either status criterion is unknown	12.5	

4) Productivity and Susceptibility

Criteria	Score	
Low risk. High productivity, low vulnerability, low susceptibility	0.0	
Medium risk. Moderate productivity, vulnerability, and susceptibility	5.0	X

High risk. Low productivity, high vulnerability, high susceptibility	12.5	
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SCORE SUMMARY

Dimensions	Score
Assessment information	2.5
Assessment uncertainty	5.0
Stock status	2.5
PSA	5.0
Total Score	15.0
Risk of overfishing: ($P^* = 50$ minus Total Score, where 50 equals P^*_{MAX})	35

In the example above, the resulting P^* of 35 could then be used in the ABC control rule equations available for stocks in any of the tiers 1 through 3. Benefits of this include the following: 1) it brings together multiple experts to determine the risk of overfishing based on their diverse knowledge; 2) it can be applied in both data rich and data poor situations, i.e. whether formal stock assessments can be conducted or not; and 3) it need not be repeated annually unless information suggests that circumstances have changed significantly.

Setting the Annual Catch Limit

NS1 guidelines require the Council to determine an ACL that may not exceed the SSC-recommended ABC; however, NS1 does not provide guidance on how to set an ACL below the SSC-recommended ABC. This section describes the methods the Council will use to set ACLs starting in 2011.

ACL will be set by the Council after considering the ABC provided by the SSC, as well as social and economic factors, pertinent ecological considerations, and management uncertainty. Management uncertainty stems from insufficient information about true catch (e.g. late reporting, underreporting and misreporting of landings), lack of management precision, and/or the ability to

close a fishery before a catch limit is exceeded. NS1 guidelines suggest management uncertainty be accounted for during the establishment of AMs for a fishery, including ACTs; however, nothing precludes the Council from accounting for management uncertainty at the ACL step.

Method 1: Qualitative Construct for Setting an ACL

The ACL qualitative construct uses an approach similar to the P* qualitative construct. While the P* qualitative construct considers the amount of biological information (scientific uncertainty) available on the stock or stock complex, the ACL qualitative construct considers the amount of socio-economic information (management uncertainty) on the fishery that targets the stock or stock complex. Specifically, the dimensions that will be used for the ACL qualitative construct would include the following factors: 1) Social; 2) Economic; 3) Ecological; and 4) Management uncertainty (SEEM). Aspects of the SEEM dimensions could include the importance of the fishery both socially and economically; consideration of the ecological importance of the stock or stock complex targeted by the fishery (e.g., is the stock a key indicator species of ecological health of the ocean), and whether managers can effectively constrain catch to planned levels.

Information on the SEEM dimensions will be compiled and analyzed by a team that may include Council and SSC members, Council staff, and other individuals knowledgeable in the fishery. This team will also be responsible for developing the criteria and scoring values regarding the quality and completeness of the information for each dimension. Like the P* qualitative construct, the scores for each dimension will be added together so that the total score is subtracted from a default value of 100% ABC (i.e., 100). Because SEEM analyses will be unique for each fishery, there are no specifics given at this time for the criteria or scoring values within the dimensions.

Method 2: Percentage Buffer for Setting an ACL

Under this method, the ACL would be set as a percentage of the ABC (e.g., ACL = 10% to 100% of the ABC) with the actual percentage dependent upon the amount of management uncertainty that exists in the fishery. For example, if management uncertainty is low, the ACL would be set close to 100% of the ABC. Alternatively, if management uncertainty is high, ACL would be set as a lower percentage. Factors that the Council will consider when selecting the percentage include late reporting, underreporting, and misreporting of landings in the fishery, as these factors contribute to the possibility that the true catch may actually exceed the ABC and ultimately the OFL of a fishery, thus resulting in overfishing. The justification for using this method over method 1 would need to be clearly identified by the Council when setting the ACL,

as it is not a quantitative decision. However, it is useful to note that the ACL is a management decision for the Council to make, not necessarily a numerically-derived limit.

Method 3: Setting an ACL when an ACT will be Utilized

An ACT is an amount of annual catch of a stock or stock complex that is the management target of the fishery, and accounts for management uncertainty in controlling the actual catch at or below the ACL. When an ACT is used, it should be set lower than the ACL with a large enough buffer between the two reference points such that risk of exceeding the ACL is low. NS1 guidelines recommend ACTs in the system of accountability measures so that ACL is not exceeded. See Section 0 for a description of setting the ACT.

If the Council decides to use an ACT as a means to ensure an ACL is not exceeded, there are two options the Council may use in setting an ACT. Under the first option, the Council could simply set the ACT equal to the ABC. If this option is taken, management uncertainty will be accounted for at the ACT level using the ACT control rule. Under this option, in addition to management uncertainty, the Council could also consider social, economic and ecological factors to set the ACT and thus could apply the entire SEEM analysis described under Method 1 to set the ACT below the ACL. While NS1 guidelines do not require social, economic or ecological factors to be considered in setting the ACT, nothing precludes the Council from doing so, although the resulting ACT would be more precautionary than NS1 intends.

Under the second option, the Council would set the ACT less than the ABC using a modified Method 1 (Qualitative construct for setting ACLs) described above whereby the analysis for setting the ACL will only consider sociological, economic, and/or ecological factors. Under this option, management uncertainty will be accounted for at the ACT level using the ACT control rule (3-year running average).

As a performance measure for all ACL managed fisheries, if landings exceed the ACL for any stock or stock complex more than once in a four year period, the Council will re-evaluate the system of ACLs and AMs for the fishery and modify the system as necessary to improve its performance and effectiveness.

Suite of Accountability Measures

In addition to ACLs, the MSA also requires NMFS and the Councils to implement AMs (MSA §303(a)(15)). NS1 guidelines (74 FR 3178; January 16, 2009) explain that AMs are management controls to prevent ACLs from being exceeded and to correct or mitigate overages of the ACLs if they occur. The guidelines recommend FMPs describe AMs and how those measures are triggered. NS1 guidelines also suggest that management uncertainty be accounted for in establishing the AMs for a fishery, including uncertainty in the ability of managers to constrain catch and uncertainty in quantifying the true catch amounts. Since the purpose of ACLs and other harvest controls is to prevent overfishing, AMs are triggered at the ACL level to ensure the ABC and OFL are not exceeded and overfishing does not occur.

In fisheries for which in-season monitoring of catch is possible (i.e. fisheries with federal logbook reporting and State of Hawaii commercial fisheries, including MHI bottomfish), tracking of catch landings towards the ACL would be initiated at the start of each fishing year. When the ACL is projected to be reached, the commercial and non-commercial fishery sectors will be closed in federal waters for the remainder of the fishing year. For fisheries that rely on non-federal creel survey programs conducted by local marine resource management agencies, in-season tracking of catch landings may not be fully possible because availability of catch data is dependent upon local agencies workload and priorities. For these fisheries, the Council may employ overage adjustments as an accountability measure. If the Council determines at the end of a fishing year that total catch has exceeded the specified ACL for any fishery, the Council may reduce the ACL for the subsequent fishing year by the percentage or absolute value of the overage. However, one crucial aspect of this is that overages are typically factored into the subsequent year's stock assessment, as are any underages. For this reason, the Council will need to decide whether to include an overage adjustment if the overage has already been considered in a stock assessment, although stock assessments are typically not performed annually. However, as a performance measure for all ACL managed fisheries, if landings exceed the ACL for any stock or stock complex more than once in a four year period, the Council will re-evaluate the system of ACLs and AMs for the fishery and may modify the system as necessary to improve its performance and effectiveness.

In Method 3 of ACL specification options, ACTs may also be utilized as an accountability measure to ensure a fishery does not exceed its ACL.

The first approach utilizes an ACT control rule based on a 3-year running average of overages of a specified catch limit (e.g. TAC, quota, ACL, or ACT). The percentage or absolute value of the

average of a catch limit over a three year period will be reduced from the ACL in the following year. With this approach, if an ACL is not exceeded, a zero (0) percentage or absolute value will be attributed for that year. For example, assuming a static ACL of 100,000 pounds has been set annually for three consecutive years, and total catch exceeded the ACL in year 1 by 2,000 pounds (or 2%), year 2 by 6000 pounds (6%), and in the third year was 3000 pounds short (or 97,000 pounds), the ACT reduction would be calculated as a percentage as follows $(2\% + 6\% + 0\%) \div 3 = 2.67\%$. In this example, ACT will be reduced by 2.67% (or 2,667 pounds) from the next 100,000 ACL, resulting in an ACT of 97,330 pounds in that following year.

Alternatively, absolute values instead of a percentage could also be utilized. For example, using the same 100,000 pound ACL, the ACT would be calculated as follows: $(2000 \text{ pounds} + 6000 \text{ pounds} + 0 \text{ pounds}) \div 3 = 2,667 \text{ pounds}$, which results in that amount being reduced from the 100,000 pound ACL in the following year, or an ACT of 97,330 pounds. It is important to note, however, that assuming a static ACL for a number of years sequentially is unrealistic. More likely the ACL will vary annually due to fishery dynamics; therefore, using the percentage approach would likely be employed in these situations because this method allows the value of any averages to be standardized.

The second approach for setting an ACT is based on a percentage reduction from ACL using the SEEM analysis. This approach could be used regardless of whether an ACL is set equal to or less than the ABC. Under this approach, instead of applying the 3-year running average approach, the Council could apply the full SEEM analysis described under Method 1 to set the ACT below the ACL when the ACL equals the ABC. If ACL is set lower than the ABC because the social, ecological, and economic factors have already been taken into account, then the ACT can be set by using the 3-year running average approach described above or based on factors related to management uncertainty (i.e. the M part of the SEEM analysis).

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Appendix F: EFH Species Descriptions



**WESTERN
PACIFIC
REGIONAL
FISHERY
MANAGEMENT
COUNCIL**

**Essential Fish Habitat Species Descriptions for Western Pacific
Archipelagic and Remote Island Areas Fishery Ecosystem Plan
Management Unit Species**

(Bottomfish, Precious Coral, Crustacean, Coral Reef Ecosystem Species)



Western Pacific Regional Fishery Management Council

1164 Bishop Street, Suite 1400

Honolulu, Hawaii 96813

December 21, 2015

**Essential Fish Habitat Source Document for Western Pacific Archipelagic, Remote Island
Areas, and Pelagic Fishery Ecosystem Plan Management Unit Species**

(Bottomfish, Precious Coral, Crustacean, Coral Reef Ecosystem Species)

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1 BOTTOMFISH SPECIES

1.1 Introduction

As noted in Amendment 3 of the Bottomfish Fishery Management Plan (FMP, bottom-associated fish resources of the western Pacific region can be divided into three broad classes relative to their vertical distribution on the islands' shelves and slopes: 1) the reef fish complex, inhabiting shallow reefs, bays and lagoons; 2) the bottomfish complex, inhabiting the outer shelves and deep slopes; and 3) the groundfish complex, inhabiting or associating with seamount summits. The bottomfish complex includes at least 65 species of four different families: jacks (Carangidae), emperor fishes (Lethrinidae), snappers (Lutjanidae), and groupers (Serranidae). These species are primarily caught by hook-and-line fishing gear, of which 19 are landed in quantities substantial enough to be classified as bottomfish management unit species (BMUS, Table 1).

BMUS in the western Pacific vary regionally with respect to species composition and relative abundance. For example, neither of the two lethrinid BMUS are found in Hawaii, nor are two of the three species of serranids. The third species, *Epinephelus quernus*, is an endemic to Johnston Atoll and Hawaii and is not found in American Samoa, Guam or the Commonwealth of the Northern Marianas Islands (CNMI). Table 2 provides the proportion of the total catch that each of the four families of bottomfish comprises in the different management areas (WPFMC, 2004, 2005). Lethrinids dominate the catch in the (CNMI) while snappers are the dominate component in the other three areas. Within the snapper group, Polovina et al. (1985) found that in Guam/CNMI, *Pristipomoides zonatus* made up 51.2% of the total catch followed by *Pristipomoides auricilla* and *Etelis carbunculus* that together accounted for 27.9%. More recent data (WPFMC, 2004, 2005) indicates that *Etelis coruscans* is now the dominant snapper in the catch from all 4 areas. The second and third most abundant species varied between areas and included *Aprion virescens*, *E. carbunculus*, *Pristipomoides filamentosus*, *P. zonatus*, and *P. auricilla*. *E. coruscans* may have been under-represented in the 1985 survey as a result of the fishing technique used. The three species that comprised over 79% of the catch in that survey are benthic whereas *E. coruscans* is primarily benthopelagic. Commercial fishers targeting the latter typically suspend their weights and hooks up to 40m above the bottom, which may not have been done in the earlier study.

Bottomfish production off western Pacific islands is inherently limited because only a narrow portion of the ocean bottom satisfies the depth requirements of most species. Since bottomfish are typically found concentrated in the steep drop-off zones at approximately 100-fathoms (183m), the length of the 100-fathom isobath has been used as an index of bottomfish habitat (Polovina, 1985). Polovina (1985) estimated the maximum sustainable yield (MSY) of bottomfish per year per nautical mile of 100-fathom isobath in the western Pacific to be 403

lb. This value was then used to estimate an annual MSY for American Samoa and Guam (Table 3). The results were then compared to similar calculations made for the Hawaiian archipelago, suggesting that MSY for Hawaii is 11-fold and 16-fold higher than that for American Samoa and CNMI, respectively.

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Table 1: Bottomfish Management Unit Species (BMUS)

Fishery	Family	Scientific Name	Common Name	American Samoa	Guam/ NMI	Hawaii
Bottomfish	Carangidae	<i>Caranx ignobilis</i>	giant trevally	sapoanae	tarakito	white ulua/pauu
		<i>Caranx lugubris</i>	black trevally	tafauli	trankiton attilong	black ulua
		<i>Pseudocaranx cheilio</i>	thicklip trevally		terakito	butaguchi/pig ulua
		<i>Seriola dumerili</i>	greater amberjack		guihan tatdong	kahala
Lethrinidae		<i>Lethrinus amboinensis</i>	ambon emperor		mafuti/lililok	
		<i>Lethrinus rubrioperculatus</i>	redgill emperor	filoa-paomumu	mafuti tatdong	
Lutjanidae		<i>Aphareus rutilans</i>	silvermouth snapper	palu-gutusiliva	maraap tatoong	lehi
		<i>Aprion virescens</i>	gray snapper	asoama	Tosan	uku
		<i>Etelis carbunculus</i>	ruby snapper	palu-malau	guihan boninas	ehu
		<i>Etelis coruscans</i>	flame snapper	palu-loa	onaga	onaga
		<i>Lutjanus kasmira</i>	blue-line snapper	savane	sas/funai	taape
		<i>Pristipomoides auricilla</i>	yellowtail snapper	palu-iusama	guihan boninas	yellowtail kalekale
		<i>Pristipomoides filamentosus</i>	pink snapper	palu-enaena	guihan boninas	opakapaka
		<i>Pristipomoides flavipinnis</i>	yelloweye snapper	palu-sina	guihan boninas	yelloweye opakapaka
		<i>Pristipomoides sieboldii</i>	lavender snapper		guihan boninas	kalekale
		<i>Pristipomoides zonatus</i>	oblique banded snapper	palu-sega	guihan boninas/gindai	gindai
Serranidae		<i>Epinephelus fasciatus</i>	blacktip grouper	fausi	gadao matai	

Epinephelus quernus

Hawaiian grouper

hapuupuu

Variola louti

lunartail grouper

papa

Bueli

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Table 2: Percent of the total catch that each of the four families of bottomfish comprises in the four management areas (Source: WPRFMC Seamount Groundfish and Bottomfish Annual Reports for 2004 and 2005)

Family	Common name	CNMI	AM Sam	Guam	Hawaii
Lethrinidae	emperors	52	18	6	0
Carangidae	jacks	7	7	3	5
Serranidae	groupers	7	9	11	9
Lutjanidae	snappers	34	69	80	86
Total		100	100	100	100

Table 3: Index of bottomfish habitat and yield for three of the four management areas. (Source: Amendment 1 of bottomfish FMP)

Management Area	Length of 100-fathom Isobath (nm)	Estimated MSY (403 lbs x length)
American Samoa	196	78,988
Guam	138	55,614
Hawaii (MHI)	997	401,791
Hawaii (NWHI)	1,231	496,093

The current bottomfish MSY values derived by Brodziak et al (2009) are 1,588,000 lbs and 1,964,000 lbs for the Main Hawaiian Islands (MHI) and Northwestern Hawaiian Islands (NWHI), respectively. These are approximately 4 times those estimated by Polovina (1985).

Multibeam sonar mapping has since provided a more precise estimate of the actual area of bottomfish habitat in the MHI (Table 4). Based on these data, the 0-400m MHI bottomfish Essential Fish Habitat (EFH) occupies a total of 10,614 square kilometers of seafloor from the big island of Hawaii to Middle Bank. This area divided into the estimate from Brodziak et al (2009) provides an average bottomfish MSY of 150 lbs per square kilometer of EFH for the MHI. EFH area can also be used as the basis to derive an estimated MSY for each bank/island (Table 4).

Table 4: The planimetric areas of bottomfish EFH (0-400m depths) and estimated MSY based on those areas for each “bank” in the MHI

Bank	EFH Area (km2)	MSY (lbs)
Hawaii	2,207	330,197
Maui	5,555	831,104
Oahu	1,430	213,948
Kauai	711	106,375

Niihau	427	63,885
Kaula	88	13,166
Middle	196	29,324
Total	10,614	1,588,000

These estimates assume no significant difference between banks in the proportion of actual preferred habitat (e.g. rocky with high relief) within the EFH areas. Maui County has the largest area of bottomfish EFH and consequently the largest MSY (831,104 lbs) while Kaula Rock has the smallest (88 km² and 13,166 lbs). In general, EFH area in the northwestern portion of the MHI is significantly smaller than in the southeastern portion.

Table 5 provides the EFH area in the MHI for each of the **three proposed complexes listed in the current amendment**: shallow (0-240m), intermediate (40-320m) and deep (80-400m). As a result of the depth overlap between these complex EFH definitions, their areas sum to approximately double the size of the 0-400m EFH for the entire fishery and deriving MSY for each complex is not possible. In general, the deep complex has the smallest amount of habitat in the MHI while the shallow complex has the largest. One noteworthy exception is the island of Hawaii. Maui has the largest amount of habitat available for all three complexes while Kaula Rock has the smallest, particularly for the deep species where there is only 40 km² available.

Table 5: The planimetric areas per MHI bank of the 3 proposed complex EFH definitions

Bank	Shallow Complex	Intermediate Complex	Deep Complex
	EFH Area (km ²)	EFH Area (km ²)	EFH Area (km ²)
Hawaii	1,188	1,203	1,725
Maui	4,155	4,166	3,392
Oahu	988	691	756
Kauai	578	329	280
Niihau	315	220	184
Kaula	72	75	40
Middle	133	157	97
Total	7429	6841	6474

1.2 General Life History

Bottomfish spawn pelagic eggs and once the pelagic larval stage is completed, settlement generally occurs below SCUBA depths. Obtaining field observations as well as collecting live individuals for captive studies is consequently quite difficult and expensive. Therefore the life histories of most species are not well known. For the purpose of EFH descriptions, their development from egg to sexually mature adult can be segregated into four general stages: egg, larval, juvenile and adult. In past EFH descriptions, the egg and larval stages were combined into one phase while juveniles and adults were combined into another. EFH descriptions were therefore only specific to two very broad life history phases: the pre-settlement pelagic phase and post-settlement benthic and/or benthopelagic phase. While the decision to do this was based on the lack of knowledge regarding bottomfish development, it yielded overly generalized descriptions that lost utility. For example, while the egg stages of all bottomfish species are presumed to be no longer than 36 hrs their larval stages through settlement can range from 30-180 days. Eggs are completely passive whereas larvae, of almost all species of fishes, are active swimmers and undoubtedly exhibit both positive and negative taxis that include rheotaxis and phototaxis, respectively (See Fishery Science: the unique contributions of early life stages, 2002). Similar larval behaviors are to be expected for the species evaluated here. The egg/larvae EFH is currently defined out to the 200 mile boundary of the Exclusive Economic Zone (EEZ), which larvae may reach but certainly not eggs. Nursery grounds that are completely isolated from adult habitat have been documented in at least one species of bottomfish (Parrish, 1989). The juveniles of onaga are benthic in comparison to their benthopelagic adults (Ikehara, 2006; Kelley, unpub. data). These are important differences that should be accommodated in EFH descriptions. For this reason, the pre-settlement and post-settlement phases have been separated back to egg, larval, juvenile, and adult stages.

1.2.1 Eggs

There have been very few taxonomic studies of the egg and larval stages of bottomfish and as a result, many species cannot be identified until after metamorphosis. Lutjanid and serranid eggs have a similar appearance to the eggs of many other fish species, leading Leis (1987) to conclude that their identification “from plankton samples is not likely to be possible in the foreseeable future”. However, recent advances in shipboard genetic identification have been made that may provide unprecedented opportunities to identify eggs and early stage larvae in the near future (Hyde et al 2005). All three families of bottomfish: serranids, carangids and lutjanids, are known to spawn spherical pelagic eggs with a single oil droplet (Heemstra & Randall, 1993; Leis, 1987; Leis & Trnski, 1989). Table 6 provides general information on egg diameter and time from fertilization to hatching.

Table 6: Ranges of egg diameters and incubation times for the three families of bottomfish.

Family	Egg Diameter (mm)	Incubation	Source
Serranidae	0.70-1.20	20-45 hrs	Heemstra & Randall 1993, Leis 1987

Carangidae	0.70-1.50	18-48 hrs	Leis & Trnski 1989, Honebrink 2000
Lutjanidae	0.65-1.02	17-36 hrs	Leis 1987

1.2.2 Larvae

Leis (1987) conducted a detailed review of the early life history of tropical groupers and snappers and found that eteline snapper larvae are generally more abundant in slope and oceanic waters than over the continental shelf. He also found evidence of a vertical migration pattern in which the larvae of both families avoided surface waters during the day. During the winter months larvae of most species are much less abundant. Very little is known about the natural food habits of serranid and lutjanid larvae and what little is known is based on limited laboratory data. More research is needed on all aspects of the early life history of snappers and groupers including feeding, growth and survival, ecology of early life history stages around oceanic islands, year-to-year variation in spatial and temporal patterns and return of young stages to adult habitat from the pelagic larval habitat. Table 7 provides general information on the size of the larvae at hatching, the duration of the yolk-sac phase and the age at “metamorphosis”, here defined as the age at which a transition occurs from either pelagic larva or pelagic juvenile to a benthic or benthopelagic juvenile at the time of “settlement”.

Table 7: Newly hatched larval length, completion of yolk sac absorption, and age at metamorphosis for the three families of bottomfish (Laroche et al., 1984; Leis & Trnski, 1989; Leis, 1987)

Family	Post-hatch (mm)	Yolk-sac (hrs)	Metamorphosis (days)
Serranidae	1.6-2.5	48-120	25-70
Carangidae	1.0-4.3	72	unknown
Lutjanidae	1.8-2.3	72-96	25-120

1.2.3 Juveniles

The juvenile stage in fishes begins at the completion of the larval stage. Even though similar in appearance, juveniles differ from adults by being physiologically underdeveloped and reproductively immature. Some authors consider the end of the juvenile stage to be sexual maturity when the fish becomes a fully functional adult. Others insert a “sub-adult” stage between juveniles and reproductive adults based in part on observed behavioral changes, such as migration from nursery habitat to adult habitat and the onset of interaction with adult conspecifics. These behaviors likely occur in at least two bottomfish species, *E. coruscans* and *P. filamentosus*, but may not in others such as *E. carbunculus* and *P. zonatus*. Sub-adults occupy the same habitat as adults and therefore, from a habitat prospective, are indistinguishable from functional adults. For that reason, a separate sub-adult stage is not included in this review. The duration of the juvenile phase for the various species in this

fishery ranges (as far as is presently known) from 1 year for *Lutjanus kasmira* to 6 years for *E. coruscans*. All of the eteline lutjanids require at least 2.4 years to reach sexual maturity based on present estimates of size-at-age and size-at-maturity.

Size at metamorphosis from larva to juvenile and whether settlement occurs as a post-flexion larva or a pelagic juvenile are generally unknown for most species of bottomfishes; although most eteline lutjanids probably settle as juveniles. After settlement, the juveniles of most bottomfish species are benthic, utilizing hard substrate features as shelter from predation. One exception to this pattern is *P. filamentosus*, whose juveniles have been observed in schools swimming up in the water column over soft substrate flats (Parrish, 1989). The juveniles of at least two other species, *P. sieboldii*, and *E. coruscans*, have also been observed in schools but the individuals swam much closer to the bottom. The adults of these three species are best considered benthopelagic. Juvenile *E. carbunculus* and *P. zonatus* have only been observed as solitary individuals. Juvenile behavior is therefore species specific and cannot be generalized for the fishery as a whole.

Juvenile diets are generally unknown for most bottomfish, *P. filamentosus* again being the one exception. Parrish (1989) and DeMartini et al. (1996) reported the diet of juvenile *P. filamentosus* off Kaneohe Bay, Oahu consisted of small crustaceans (crabs, shrimps and stomatopods), other juvenile fish, mollusks (octopods, squids, and micro-gastropods) gelatinous plankton (salps and heteropods) and echinoids. More recently, the stomachs of juveniles caught from a shallower location off the south shore of Oahu were found to contain pelagic crustaceans and salps (B. Schumacher, unpub data). These reports are consistent with juvenile *P. filamentosus* being observed in the water column where they are presumed to be feeding. It therefore follows that the more benthic juveniles of other bottomfish species may feed primarily on benthic prey. As was noted with juvenile behavior, the diets of juvenile bottomfish cannot be generalized for the fishery as a whole except to say that they are most likely carnivorous, feeding at multiple trophic levels.

1.2.4 Adults

Adult bottomfish share the fact that, by definition, they are all sexually mature individuals. However, aside from that, considerable differences exist between species in their size and age at sexual maturity, maximum size, behavior, reproductive biology and diet. Table 8 summarizes currently available information on sexual maturity and maximum size.

Bottomfish reach sexual maturity as soon as 1.3 years of age for *Seriola dumerili* to as late as 6 years of age for *E. coruscans* and *P. sieboldii*. *S. dumerili* also reaches maturity at the largest size of any species, which coupled with the age, is indicative of an extremely fast growth rate.

L. kasmira is the smallest species in the fishery and it is not surprising that it also reaches maturity at the smallest size. The maximum sizes of the various species ranged between 164 cm and 87 kg for *C. ignobilis* down to 32 cm and 0.9 kg for *L. kasmira*. With *E. quernus* being the only exception, the larger sized species are all generally found higher in the water column possibly due in part to their lower vulnerable to predation in comparison to the smaller species. Water column preferences permits the various species to be partitioned into either benthic or benthopelagic categories. There are also clear differences in social systems with some species forming large schools (e.g., *E. coruscans* and *P. filamentosus*) while others forming only small aggregations of a few individuals (e.g., *E. carbunculus* and *P. zonatus*). Schooling species are typically benthopelagic while non-schooling species are typically benthic. These relatively common patterns have also been observed in many other fish species.

Table 8: Summary of bottomfish age and size at sexual maturity and maximum sizes in Hawaii based on Hawaii state records obtained. Species are ordered from largest to smallest by weight. Maximum size data are from Randall (2007) and Hawaii state fishing records from the Hawaii Fishing News website (<http://www.hawaiifishingnews.com/records.cfm>). Most length data were in forklengths but in some cases, it wasn't clear and therefore is listed below as simply length. Various sources were used for the data on sexual maturity and are provided in the species accounts below.

Species	Sexual Maturity		Maximum Size	
	Years	Length (cm)	Length (cm)	Hawaii (kg)
<i>Caranx ignobilis</i>	3.5	55-60	164	87.0
<i>Seriola dumerili</i>	1.3	64-73	145	66.0
<i>Epinephelus quernus</i>	6*	58	106	22.7
<i>Pseudocaranx cheilio</i>	-	28-30	82	18.0
<i>Aprion virescens</i>	4-5	43-48	110	17.9
<i>Aphareus rutilans</i>	-	-	80	14.7
<i>Etelis coruscans</i>	5-6	66	81	12.7
<i>Pristipomoides filamentosus</i>	3-5	43	80	8.4
<i>Caranx lugubris</i>	-	-	80	7.6
<i>Etelis carbunculus</i>	2.8	24-30	90	5.2
<i>Pristipomoides zonatus</i>	3.3	-	45	1.9
<i>Pristipomoides sieboldii</i>	3-6	29	60	1.4
<i>Pristipomoides auricilla</i>	2.4	-	45	1.3
<i>Lutjanus kasmira</i>	-	12-25	32	0.9

* Age and length at 50% female maturity is for *E. quernus* in the NWHI only (DeMartini et al. 2010). Length-at-sex change (from adult female to adult male) in *E. quernus* is about 90 cm in the NWHI (DeMartini et al. (2010); fish of 90 cm are a poorly estimable 20-something years old (Nichols and DeMartini 2008).

1.2.4.1 Reproductive biology

Thirteen of the 14 species of bottomfish in Hawaii are either confirmed or believed to be gonochoristic. *E. quernus* is the only sex changing species, having recently been confirmed as a protogynous hermaphrodite (DeMartini et al. 2010). All 14 species are broadcast spawners that release pelagic eggs into the water column. Twelve of the species exhibit peak spawning activity during the summer or early fall with the other two, *E. quernus* and *S. dumerili* peaking during the spring (Table 9). Reproductive seasonality is a particularly important life history characteristic to understand for fisheries management since it has direct bearing on the potential success of seasonal closures that are currently part of bottomfish fishery management in Hawaii. During the last 4 years, the bottomfish closed fishing seasons have been:

May 15 to October 1, 2007	139 days
April 16 to September 1, 2008	138 days
July 6 to August 31, 2009	57 days
April 20 to August 31, 2010	134 days

An annual total allowable catch limit (TAC) has been implemented for this fishery and the point at which this is reached each year has been used to determine the lengths and dates of the closed seasons. Table 10 provides a graphical summary of the bottomfish seasonal closures in Hawaii for direct comparison to Table 9. Annually varying seasonal closures undoubtedly result in annually varying numbers of reproductive adults in the catch. Of potential concern is the fact that due to their offset spring reproductive season, *E. quernus* spawning adults received almost no protection from this management measure.

Grimes (1987) provided a detailed review of the reproductive biology of the Lutjanidae. In the lutjanids, spawning takes place at night, and may be timed to coincide with spring tides at new and full moons. Spawning likely takes place at night in both the serranids and carangids as well. As with many marine fish species, courtship behavior is believed to culminate in an upward spiral swim, with gametes released at the apex. Similarly, many features of the reproductive biology of lutjanids (e.g. spawning site preference, spawning seasonality, lunar periodicity and spawning behavior) appear to be a strategy to introduce gametes into an environment where predation is relatively less intense and that young juveniles are returned to suitable, but patchy habitat for settlement.

Table 9: Summary of bottomfish reproductive seasons. The question marks represent data obtained from non-Hawaii locations. Lighter shading is from questionable or incidental records. This table was created from the following sources: Sudekum et al 1991; Munro et al. 1973; Alfonso et al. 2008; Uchiyama & Tagami 1984; Kikkawa & Everson 1984; Current Line Fish Facts for Bottom Fishes of Hawaii; Allen 1985; Morales-Nin & Ralston, 1990; DeMartini & Lau 1999; Ralston & Williams 1988a, Harris et al., 2007.

Species	J	F	M	A	M	J	J	A	S	O	N	D
<i>E. quernus</i>												
<i>C. ignobilis</i>												
<i>C. lugubris</i>		?	?	?	?	?	?	?	?			
<i>P. cheilio</i>								?	?			
<i>S. dumerili</i>												
<i>A. rutilans</i>	?	?							?	?	?	?
<i>A. virescens</i>												
<i>E. carbunculus</i>												
<i>E. coruscans</i>												
<i>L. kasmira</i>												
<i>P. auricilla</i>												
<i>P. filamentosus</i>												
<i>P. sieboldii</i>												
<i>P. zonatus</i>				?	?	?	?		?			

Table 10: Summary of bottomfish seasonal closures from 2007 to 2010. Lightly hatched cells indicate the closure did not encompass the entire month. This table was created for comparison to table 9 above

Year	J	F	M	A	M	J	J	A	S	O	N	D
2007												
2008												
2009												
2010												

1.2.4.2 Feeding Habits and Prey

The feeding habits and prey preferences of all larval and most juvenile bottomfish are completely unknown at the present time. For adults, there have been very few studies of groupers and snappers that have documented the time and depth at which feeding occurs. Based on the review of the available literature, Parrish (1987) concluded that snappers engage in widespread, nocturnal foraging while groupers feed at all times of day, but particularly near dusk and dawn. Anecdotal information from fishers indicates that some species are caught more easily at night, while others are caught during the day or near sunrise and sunset. However, more recent unpublished fishing survey data collected by UH and NOAA researchers indicate that snappers will take bait at any time of the day (UH data, 2010, Parrish, unpub data), which is consistent with the belief that these fish are opportunistic carnivores. Both *P. filamentosus* and *E. carbunculus* will feed at any time of the day when

held in captivity (Moriwake et al, unpub data). Both fishing and captivity provide unnatural feeding opportunities for these fish and therefore should generally not be used to draw conclusions regarding their natural feeding behavior. However, these observations do suggest that the time of day “natural” feeding occurs may be closely related to prey availability. Snappers that feed in the water column on either the shallow or deep backscatter layers may have well defined feeding periods that coincide with the vertical migration of these layers. Benthic feeders may have either poorly defined feeding periods or forage primarily during the day or night depending on prey preference and availability.

Depth of foraging is also hard to evaluate in deep-water snappers and groupers. Our only source of information is fishing data however bait produces an unnatural odor plume that can draw these fish from a considerable distance. Along most island or bank slopes, the current will disperse a bait plume horizontally rather than vertically. However, caution should be exercised when using depths derived from catch data to draw conclusions about natural feeding depths. Without precise data on feeding times and depths it is difficult to identify a species feeding habitat. Feeding is a major daily activity for most species of fish and therefore it is assumed for now that the depth a species is caught or observed at is within its feeding depth range.

The adults of larger snapper species such as *E. coruscans*, *Aphareus rutilans*, and *P. filamentosus*, have been observed in schools relatively high in the water column while the adults of smaller species such as *E. carbunculus* and *P. zonatus* have only been observed as solitary individuals or in small groups close to the bottom. With one exception, juvenile snappers appear to stay, and presumably feed, close to the bottom. Smaller fish, whether they are adults or juveniles, are at greater risk of predation and the carbonate substrate where snappers are often found have ledges and cavities that offer shelter from attacks. Juvenile *P. filamentosus* are the exception, having been observed feeding in the water column, although generally not as high as adults. This is the only snapper species that has been found to have a distinctly different nursery area (sediment flats) and depth range (40-80 m) than adults. Larger predators have not been observed in these areas, which has led to the hypothesis that *P. filamentosus* juveniles may be “hiding in plain sight” (Parrish, 1989). Parrish (1987) reported that most species of groupers take their prey at, or very close to, the bottom. *E. quernus* is no exception and, regardless of size, is most often observed close to the substrate. This may be a shark avoidance strategy, but is more likely due to their reproductive strategy and social structure, which is described in more detail later.

Diet studies of deepwater snappers and groupers are difficult to conduct because gut contents are frequently lost from regurgitation when specimens are brought to the surface. The few found in the literature indicate that both groupers and snappers are omnivorous, opportunistic carnivores whose diets include a wide range of food items dominated by fish, crabs, shrimp

and other benthic crustaceans, especially stomatopods and lobsters (Haight et al, 1993a, Parrish et al, 2000). However, some diet preferences are evident among the species and are consistent with behavioral observations mentioned above. Some off-bottom schooling species consume large planktonic prey including pelagic urochordates (Pyrosomida, Salpidae, and Dolioda) and pelagic gastropods (pteropods and heteropods) while others principally consume pelagic fishes (Haight et al 1993a). Opportunistic collection of non-regurgitated prey from these same species during other surveys have yielded a pelagic salp as well as fishes, crustaceans and cephalopods typically found in backscatter layers (Kelley, unpub). Planktonic animals have not been reported in the diets of groupers which is consistent with their benthic lifestyle. Benthic species of snappers have been found to have diets consisting of benthic crustaceans and benthic fishes including eels and octopuses (Kelley, unpub).

1.3 General Habitat

Bottomfish Essential Fish Habitat (EFH) is presently defined as the 0-400m depth range on the slopes of each island, bank or seamount around Hawaii and other Pacific Islands. For benthic or benthopelagic juveniles and adults, the geographic extent of their habitat ends with the 400 m contour around each of these features because these stages are associated with the bottom. However, egg and larval stages are pelagic and therefore the geographic boundaries of their habitats are believed to extend well beyond 400m contours as a result of current flow.

1.3.1 Egg Habitat

While bottomfish egg habitat is presently unknown, several logical assumptions can be made based on available data. First, eggs are spawned no deeper than the lower extent of the adult ranges. Adults of pelagic spawning fish species typically spawn at the same depth as their feeding habitat or move into shallower waters. Secondly, bottomfish eggs hatch no more than 48 hrs after spawning and are completely passive with regard to their dispersal. The maximum distance bottomfish egg habitat can extend from shore can therefore be estimated using HYCOM, a hydrodynamic ocean circulation model of the flow around the Hawaiian Islands. Vaz (unpub data) obtained the 2008 output from HYCOM at www.hycom.org, and coupled it offline with the BOLTS biological model (Paris et al. 2007) depicting adult spawning strategy, larval development, displacement and mortality. Bottomfish spawning was assumed to take place no further than 10 km from each island. Therefore, the 10 km (i.e., 6 mi) buffer regions around the islands were subdivided in 183 polygons each representing a separate egg release area. Every 5 days 300 “eggs” were released from each of the polygons at a simulated depth of 50m and were then tracked for 1, 2 and 6 days. The mortality coefficient used in the model was 0.03 day⁻¹.

Figure 1 provides the results from this trial. Eggs reached a maximum of 30 km (i.e. 19 mi) from shore one day after release, which increased to only 50 km (i.e. 31 mi) from shore by day 2. At this point, the eggs of all bottomfish species should have hatched. Based on these

results, the recommendation was made to define bottomfish egg habitat as the 0-400m depth range extending no more than 30 mi from the 400m contour around each island and bank. In the MHI, this area is generally within the first 50 mi from shore in the EEZ. It is reasonable to assume the eggs of bottomfish species are no deeper than the maximum depth of adult habitat because of their positive buoyancy. Therefore, in this review, it was recommended that egg habitat definitions for the three complexes as well as the “deep seven” species in the MHI have the same lower depth limit as the adults. For example, the proposed shallow complex egg habitat definition is 0-240 m extending out 50 miles from each island and bank.

1.3.2 Larval Habitat

Bottomfish larvae are pelagic, but unlike eggs, are active swimmers during most of this stage which can last from 25 to 180 days post hatch. Their swimming proficiency improves dramatically from hatching to metamorphosis. In addition to diel vertical movements (Leis 1987), bottomfish larvae acquire the ability to move effectively in the horizontal plane in response to current flow, prey detection, and possibly to sound and magnetic fields, which have been documented in other species (See Fishery Science: the unique contributions of early life stages, 2002; Stobutzki & Bellwood 1997, Cowen et al 2006). These variable 3-dimensional movements are overlaying complex water circulation patterns, making it extremely difficult to precisely define their habitat extent. Using the same model described above, Vaz (unpub data) determined that, in the absence of any swimming activity, water circulation around the MHI could carry larvae spawned at either 50 or 100m depth out past the 200mi EEZ 4 in 6 days, or 4 days post-hatch. During the first 3 days post-hatch, the larvae are still within their yolk-sac absorption phase, during which their swimming ability is extremely limited. It is therefore likely that bottomfish larvae are being dispersed as far out as the EEZ boundary.

Relatively few bottomfish larvae have been collected in plankton tows (Leis 1987; Clarke, 1991) and therefore the depth range of their habitat is presently unknown. All of the species of bottomfish are physoclists, however the mechanism and timing of swim bladder inflation is unknown. Many, but not all, physoclists initially inflate their swim bladders by gulping air at the surface (Swartz, 1971). Assuming at least some bottomfish species need to do this, then the upper depth limit should conservatively be left at 0 m. It is also assumed that the larval habitat does not extend below the lower limit of the adult habitat. Coupled with the modeled trajectories, it is recommended that the bottomfish larval habitat definition remain the same at 0-400m depth extending out to the EEZ. Complex and species habitat definitions will only vary with regard to their lower depth limit, which is recommended to match that of the adults.

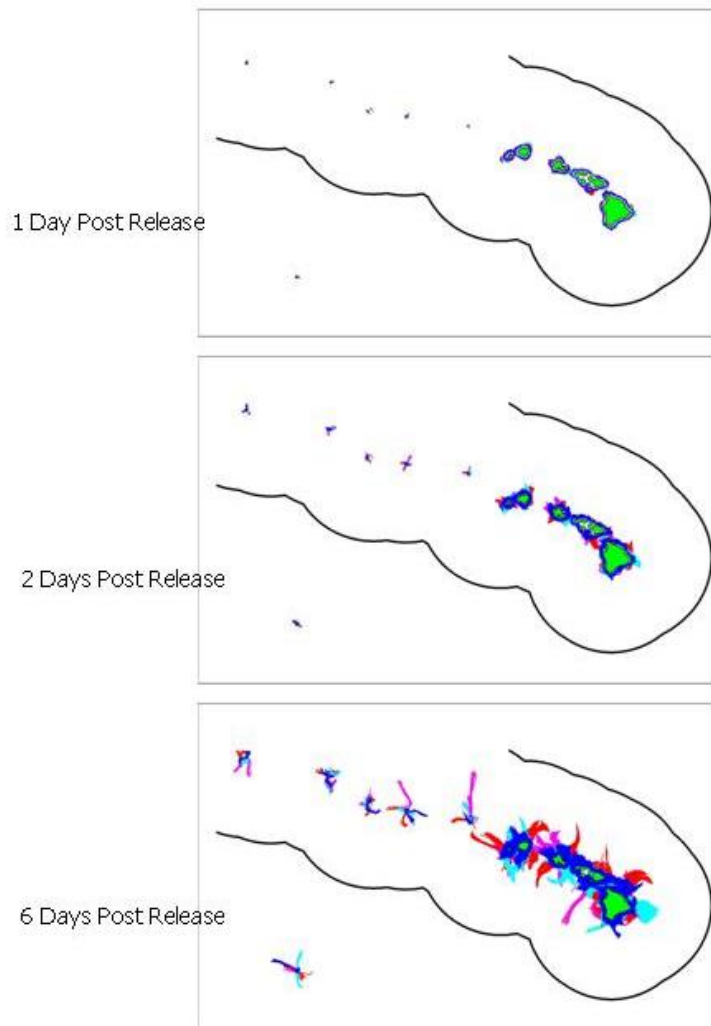


Figure 3: Simulated bottomfish egg trajectories released from 50m depth around the MHI and lower NWHI (Vaz, unpub data). The 200 mile boundary of the US EEZ is shown as a black boundary line. The colors of the trajectories in the plots represent the season of spawning as follows: a) magenta: January-March; b) red: April-June, c) light blue: July-September, d) blue: October-December.

1.3.3 Juvenile Habitat

Progress in identifying juvenile bottomfish habitat has clearly been made during the last 5-10 years. However, only *P. filamentosus* juveniles have been systematically studied and there are still a number of species whose juveniles have never been observed. Even with its importance for understanding recruitment patterns, identification of bottomfish juvenile habitat is one of the major gaps in our basic knowledge of this fishery.

In 1988, the NOAA Fisheries Honolulu Laboratory initiated an investigation to identify the habitat requirements of juvenile snappers in the Hawaiian Islands. This effort found a significant number of *P. filamentosus* juveniles and a modest number of *A. virescens*, and *A. rutilans* juveniles occupying a habitat quite different than their adults (Parrish, 1989; Haight, 1989; Moffitt & Parrish, 1996; Parrish et al., 1997). The “nursery areas” for these shallow and intermediate species were primarily flat, open soft substrate in depths ranging from 40 to 73 m, whereas adult habitat is typically steep rocky carbonate slopes in deeper water. Subsequent surveys have found additional *P. filamentosus* nursery areas of this same kind (UH data, 2010) but also one quite different off the Big Island that consisted of highly rugose volcanic basalt (Drazen, unpub). Juvenile carangids also seem to settle out in habitats shallower than those of adults (Longenecker & Langston, 2008). The presence of juvenile *S. dumerili* on one of the *P. filamentosus* nursery areas has been documented using a baited drop camera (Merritt, unpub). Major (1978) and Smith & Parrish (2002) found that back reefs, lagoons, and particularly estuaries were important nursery areas for carangids such as *Caranx ignobilis* and *Pseudocaranx cheilio*.

This pattern however, does not appear to be consistent for all of the species in this fishery. Juveniles of two deep species, *E. coruscans* and *E. carbunculus*, have been documented in habitat more similar and in closer proximity to that of their adults (Kelley et al, 1997, Ikehara, 2006). These deeper “nurseries” consisted of low sloping rocky carbonate terraces and ledges that were clearly providing the juveniles with shelter. A solitary juvenile *P. zonatus* swimming very close to the bottom has also been observed from the Pisces submersible at the same depth and habitat where adults were observed (Kelley, unpub data).

The various species in this fishery appear to be using one of two different strategies for avoiding predation after settlement: either settling in shallower areas that predators don't frequent (Parrish, 1989) or settling in or near adult habitat but close to the bottom. In the latter case, risk of predation is directly related to height off the bottom and inversely related to body size. The substrate in these areas has cavities that provide shelter, thereby reducing that risk. Table 11 summarizes what is presently known about juvenile habitat for bottomfish.

Within the snapper component of the bottomfish fishery, the adults of larger species are found higher off the bottom than the adults of smaller species as well as the juveniles of any species including their own. Behavioral observations recorded by submersibles and drop cameras indicate that large *S. dumerili* pose the most significant predation risk to small bottomfish species and juveniles (Kelley and Drazen in prep). *S. dumerili* are aggressive predators that often form large aggregations, making them a threat to many different species of fish and invertebrates. Unlike sharks, this species must swallow its prey whole. Thus there is a maximum size of prey that *S. dumerili* can consume and once potential prey exceed that size, their risk of predation drops significantly. Based on behavioral observations, *S. dumerili* are a

risk to all juvenile bottomfish as well as adult *E. carbunculus*, *P. zonatus*, *P. sieboldii*, and *P. auricilla*. This species does not pose a threat to adult *E. coruscans*, *P. filamentosus*, *A. rutilans*, and *E. quernus* due to their size.

Table 11: Summary of juvenile bottomfish habitats

Complex	Species	Juvenile habitat	Reference
Shallow (0 - 240m)	<i>Aprion virescens</i>	shallow sediment flats	Parrish 1989
	<i>Lutjanus kasmira</i>	sediment flats, fringe rubble piles	Friedlander et al 2002
	<i>Caranx ignobilis</i>	lagoons, estuaries, back reefs	Longenecker & Langston 2008
Intermediate (40 - 320m)	<i>Aphareus rutilans</i>	shallow sediment flats	Parrish 1989
	<i>Pristipomoides filamentosus</i>	shallow sediment flats, basalt	Parrish 1989, Drazen unpub data
	<i>Epinephelus quernus</i>	shallow bank flats	Moffitt 2003
	<i>Caranx lugubris</i>		
	<i>Pseudocaranx cheilio</i>	lagoons, estuaries, back reefs	Longenecker & Langston 2008
	<i>Seriola dumerili</i> <i>Seriola rivoliana</i>	shallow sediment flats	Merritt, unpub data
Deep (80 - 400m)	<i>Etelis carbunculus</i>	deep carbonate terraces	Kelley et al 1997
	<i>Etelis coruscans</i>	deep carbonate terraces	Kelley, unpub data
	<i>Pristipomoides auricilla</i>		
	<i>Pristipomoides sieboldii</i>	deep carbonate terraces, sediment flats	Kelley et al 1997
	<i>Pristipomoides zonatus</i>	deep carbonate terraces	Kelley (pers comm)

1.3.4 Adult Habitat

As part of this review, adult Hawaiian bottomfish depth data were obtained from recent University of Hawaii (UH) scientific fishing surveys, baited drop cameras, submersible transects and the Hawaii Undersea Research Laboratory's (HURL) database. A total of 18,125 records were extracted for 9 snappers, 1 grouper, and 5 jacks (Table 12). The number of records per species varied considerably, due to differences in abundance but also to non-uniform sampling across geographic areas as well as depth range. For example, the depth range for *P. auricilla* and *Caranx lugubris* was very well sampled in this analysis however these species are simply not as common in Hawaii as they are around other Pacific Islands. *A. virescens* is common in shallower waters around Hawaii, however, very few submersible and drop camera records were available for this depth range. Nevertheless, this dataset hereafter referenced as "UH data (2010)", combined with depth data found in the literature, provided the most up-to-date and thorough compilation of bottomfish depth ranges currently available. Table 13 provides the upper and lower depth limits for each species to the nearest 40 m interval.

Adult depth ranges for these 15 bottomfish species clearly overlap to one extent or another but depth record frequency distributions (Fig. 2) indicate the existence of depth preferences or potentially distinct species assemblages, or both. Two snappers and one jack (*L. kasmira*, *A. virescens*, and *C. ignobilis*) were rarely observed below 160 m whereas four species of snappers (*P. auricilla*, *P. zonatus*, *E. coruscans*, and *E. carbunculus*) were rarely observed

above that depth. With one exception, none of the shallow species were recorded together at the same time with any of the deeper species. The other 9 bottomfish species were recorded together at separate times with either shallow or deep species, although *P. sieboldii* was for the most part observed together with the deeper species. Based on these distributions, bottomfish species were classified as being either shallow (0-240m, 3 species), intermediate (40-320m, 7 species), or deep (80-400m, 5 species). Table 14 provides these classifications as proposed revisions to the currently accepted species complex definitions.

Table 12: The number of depth records obtained for each of 15 species of bottomfish in the main Hawaiian Islands from fishing surveys, baited drop cameras, submersible transects and the HURL database.

Family	Species	# Records
Lutjanidae (snappers)	<i>Aprion virescens</i>	81
	<i>Lutjanus kasmira</i>	1136
	<i>Aphareus rutilans</i>	93
	<i>Etelis carbunculus</i>	3007
	<i>Etelis coruscans</i>	2540
	<i>Pristipomoides auricilla</i>	63
	<i>Pristipomoides filamentosus</i>	1714
	<i>Pristipomoides sieboldii</i>	4809
	<i>Pristipomoides zonatus</i>	719
Serranidae (groupers)	<i>Epinephelus quernus</i>	859
Carangidae (jacks)	<i>Caranx ignobilis</i>	25
	<i>Caranx lugubris</i>	43
	<i>Pseudocaranx cheilio</i>	166
	<i>Seriola dumerili</i>	2512
	<i>Seriola rivoliana</i>	358
Total		18, 125

Table 13: Depth ranges for Hawaiian bottomfish rounded to the nearest 40m interval

Family	Species	Depth range (m)
Lutjanidae (snappers)	<i>Aprion virescens</i>	0 – 240
	<i>Lutjanus kasmira</i>	0 – 280
	<i>Aphareus rutilans</i>	40 – 360
	<i>Etelis carbunculus</i>	80 – 520
	<i>Etelis coruscans</i>	80 – 480
	<i>Pristipomoides auricilla</i>	80 – 360
	<i>Pristipomoides filamentosus</i>	40 – 400
	<i>Pristipomoides sieboldii</i>	40 – 360
	<i>Pristipomoides zonatus</i>	40 – 360
Serranidae (groupers)	<i>Epinephelus quernus</i>	0 – 360
Carangidae (jacks)	<i>Caranx ignobilis</i>	0 – 200
	<i>Caranx lugubris</i>	0 – 400

<i>Pseudocaranx cheilio</i>	40 – 360
<i>Seriola dumerili</i>	0 – 560
<i>Seriola rivoliana</i>	0 – 320

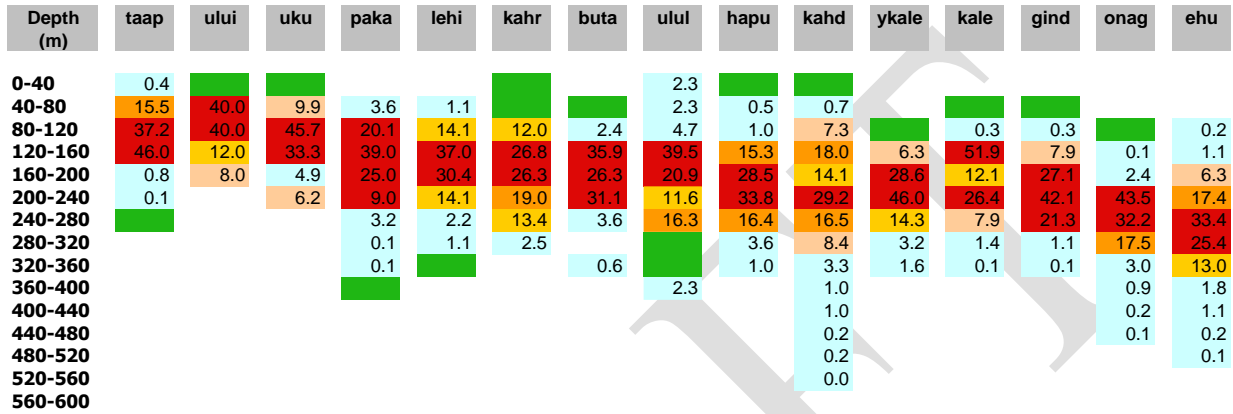


Figure 4: Forty meter binned depth frequency distributions for 15 species of bottomfish (red to blue colored bins with numbers) derived from the records shown in table 1. Frequencies greater than 20 are red, 15-20 dark orange, 10-15, beige 5-10, and light blue 0-5. Green bins represent extensions, or filling of gaps, in these depth ranges derived from the literature. Species abbreviations are the following: taap= *Lutjanus kasmira*, ului= *Caranx ignobilis*, uku= *Aprion virescens*, paka= *Pristipomoides filamentosus*, lehi= *Aphareus rutilans*, kahr= *Seriola rivoliana*, buta= *Pseudocaranx cheilio*, ulul= *Caranx lugubris*, hapu= *Epinephelus quernus*, kahd= *Seriola dumerili*, ykale= *Pristipomoides auricilla*, kale= *Pristipomoides sieboldii*, gind= *Pristipomoides zonatus*, onag= *Etelis coruscans*, ehu= *Etelis carbunculus*.blue

A study of the hooking depth of the six most important bottomfish species in the Northwestern Hawaiian Islands (NWHI) supports the existence of overlapping depth ranges as well as the fact that certain species are more common at shallow depths while others are more common at deeper depths. As noted in Amendment 2 of the bottomfish FMP, adult bottomfish in the NWHI are caught at depths of 40 to 145 fathoms (73-265m, Table 15). Hooking depth ranges for individual species show no overlap between the shallow *A. virescens* and the deeper *E. coruscans* and *E. carbunculus*, while the other three species fell into an intermediate group. These findings are the same as those from the analysis above.

In a five-year study of the bottomfish fishery resource of the Northern Mariana Islands and Guam, Polovina et al. (1985) found bottomfish species to be stratified by depth with three broad distributions located throughout the archipelago. Between 164 and 183 m, *C. lugubris*, *P. flavipinnis*, *P. filamentosus* and *A. rutilans* are common; between 183 to 201 m, *P. auricilla*, *S. dumerili* and *P. zonatus* are most abundant; and at depths of greater than 201 m, *P. sieboldii*, *E. coruscans*, *E. carbunculus* and *Epinephelus sp* were the most abundant (Table 16). Even though these findings were from a different region of the Pacific, the depth ranges are consistent with the data from Hawaii. The seven species that ranged between 164 and 201

m would fall into an intermediate complex while the 4 species caught below 201m would fall into a deep complex. No shallow complex species were caught during this particular study while the groupers (*Epinephelus sp*) were all caught in deeper water.

Table 14: Recommended adult bottomfish complexes based on observed depth preferences and species assemblages.

Fishery	Complex	Family	Species
Bottomfish	Shallow (0 – 240m)	snapper	<i>Aprion virescens</i>
		snapper	<i>Lutjanus kasmira</i>
		jack	<i>Caranx ignobilis</i>
	Intermediate (40 – 320m)	snapper	<i>Aphareus rutilans</i>
		snapper	<i>Pristipomoides filamentosus</i>
		grouper	<i>Epinephelus quernus</i>
		jack	<i>Caranx lugubris</i>
		jack	<i>Pseudocaranx cheilio</i>
		jack	<i>Seriola dumerili</i>
		jack	<i>Seriola rivoliana</i>
	Deep (80 – 400m)	snapper	<i>Etelis carbunculus</i>
		snapper	<i>Etelis coruscans</i>
		snapper	<i>Pristipomoides auricilla</i>
		snapper	<i>Pristipomoides sieboldii</i>
		snapper	<i>Pristipomoides zonatus</i>

Table 15: Hooking depth range for dominant Northwestern Hawaiian Islands Bottomfish. Source: (Amendment 2 of bottomfish FMP)

Species	Hooking Depth Range (m)	Average (m)
<i>Aprion virescens</i>	37-110	73
<i>Pristipomoides filamentosus</i>	54-201	128
<i>Pseudocaranx cheilio</i>	73-183	128
<i>Epinephelus quernus</i>	91-274	183
<i>Etelis coruscans</i>	183-274	229
<i>Etelis carbunculus</i>	201-329	265

Depth alone does not provide an adequate description of adult bottomfish habitat. As noted in Amendment 2 of the bottomfish FMP, variations in catch rates along the same depth contour indicate that the quantity and quality of benthic habitat are also both important. Within their depth ranges, bottomfish populations are found in non-random clumped distributions. Both topography and substrate type appear to be responsible for this pattern as well as the schooling behavior of some species. Unlike the US mainland with its continental shelf ecosystems, the Pacific islands are primarily volcanic seamounts with steep drop-offs and limited shelf ecosystems (Ralston 1979). Adult bottomfish in the NWHI are found in habitats characterized by a hard substrate of high structural complexity. Pinnacles, drop-offs and other high relief rocky substrate are prime fishing grounds (Ralston 1979). In the main Hawaiian Islands, bottomfish are generally concentrated on or above old carbonate terraces, which are remnants of coral reefs that developed on the slopes of these islands and subsequently drowned thousands of years ago. The top of the largest and most prominent drowned reef terrace above 400m is located between 110-150m (60-82 fathoms) around every island or bank. Off the Big Island, this reef is believed to have drowned approximately 14,000 yrs ago during the late Pleistocene in association with a major glacial melt water pulse (Webster et al. 2007). The tops and slopes of this, and similar smaller drowned reef structures, have ledges, promontories, canyons, ridges and pinnacles where upwelling, turbulence or other alterations to the vertical flow field that is likely to concentrate benthopelagic prey. This process has been documented on seamounts and banks elsewhere (Genin et al 1986, Genin 2004, Porteiro & Sutton 2007).

Table 16: Hooking depth range of various snappers, jacks and groupers caught off the Northern Marianas and Guam from Polovina et al, 1985.

Depth range	Scientific Name (common name)	Mean Depth		
		M	Fathoms	N
164 - 183 m				
	<i>Caranx lugubris</i> (black ulua)	166	91	270
	<i>Pristipomoides flavipinnis</i> (yelloweye opakapaka)	170	93	499
	<i>Pristipomoides filamentosus</i> (pink opakapaka)	170	93	191
	<i>Aphareus rutilans</i> (lehi)	174	95	81
183 - 201 m				
	<i>Pristipomoides auricilla</i> (yellowtail kalekale)	188	102	1,166
	<i>Seriola dumerili</i> (kahala)	196	107	47
	<i>Pristipomoides zonatus</i> (gindai)	199	109	3,890
>201 m				
	<i>Epinephelus</i> sp	214	117	38
	<i>Pristipomoides sieboldii</i> (pink kalekale)	214	117	200
	<i>Etelis coruscans</i> (onaga)	218	119	200
	<i>Etelis carbunculus</i> (ehu)	225	123	950

These sites also have cavities that provide shelter to benthic prey as well as smaller species of bottomfish. In his study of Penguin Bank in the Hawaiian Islands, Haight (1989) observed aggregations of up to 100 *P. filamentosus* and *A. rutilans* 2-10 m above high-relief coral bench substrate and in the vicinity of underwater headlands and promontories. These and other observations suggest that the distribution of at least some species of deepwater snappers appears to be closely related to current flow. Ralston et al (1986) found that the up-current side versus the down-current side of Johnston Atoll supported higher densities of *P. filamentosus*. It has been hypothesized that water flow may enhance food supplies (Haight 1989; Parrish et al. 1997). High relief forms localized zones of turbulent vertical water movement, which may increase the availability of prey (Haight et al. 1993a).

More recent submersible and ROV surveys in Hawaii indicate that large-scale topographic features (i.e. pinnacles, canyons, large outcrops and terraces) that potentially increase water flow are important to some species while substrate type and macro-scale characteristics, particularly hard substrate with cavities, are important to others (Kelley et al, 2006). Exposed basalt, not buried under old carbonate reef terraces is uncommon at depths above 400m. However this type of substrate is present off the big island of Hawaii where active volcanism is still occurring and as far west as Niihau, where it was recently found up as shallow as 200m (Kelley & Drazen, unpub data). Bottomfish and their prey were observed in these habitats indicating that the type of rock is less important than the vertical relief and cavities hard substrate of any type provides. This is furthermore supported by observations of juvenile and benthic species of bottomfish on or near man made metal wreckage that had holes where they and their prey could hide. (Kelley, unpub.data).

High slope hard substrate is attractive to many different species of bottomfish that, according to Ralston & Polovina (1982), co-exist with apparent negligible inter-specific interaction. Polovina (1987) found a weak predator-prey relationship among the species of the NWHI bottomfish complex. As noted in Amendment 2, the establishment of territorial strongholds by individual species may account for the low multi-species interaction. Amendment 2 also notes that variations are known to occur in the way different bottomfish utilize habitat. For example *P. filamentosus* are believed to migrate into shallower depths during the night hours; *E. coruscans* are caught in considerably deeper water than other species of snappers and in association with abrupt relief zones, such as outcroppings, pinnacles and drop-offs; and groupers are generally more benthic than these species of snappers. Haight (1989) found that niche overlap between species of deep-slope snappers on Penguin Bank, in terms of forage habitat and forage period, was reduced by the different depth and dietary preferences of individual species.

Ambient light bait stations, conducted from submersibles (Kelley & Ikehara, 2006) or using a remote drop camera (Drazen et al, in prep), clearly show differences in swimming height off the bottom between different species that are likely to contribute to minimizing interspecific interactions. Adult *E. coruscans*, *P. filamentosus*, *A. virescens* and *A. rutilans* are “high-column” benthopelagic, typically swimming from a few meters to over 50m above the bottom. Adult *P. sieboldii*, *P. auricilla*, *L. kasmira*, *P. cheilio*, *C. ignobilis*, *C. lugubris* and the two species of *Seriola* are generally “low or mid column” benthopelagic species that typically swim from a few to no more than 20 meters off the bottom. *E. carbunculus*, *P. zonatus* and *E. quernus* are benthic species typically found near the bottom, often in cavities or under ledges. Predation is at least one of the variables that may be responsible for this observed pattern while social structure and reproductive strategy are others, at least for *E. quernus*.

E. quernus are protogynous hermaphrodites (DeMartini et al. 2010) and like most fishes having this type of reproductive strategy, may have a harem social structure that requires territoriality. Since the sexes cannot be identified by external appearance, this contention will likely remain unproven for many years. However, assuming this is correct harem maintenance (i.e., control and competition for females) may be a more important factor than the risk of predation that is causing large adults to remain close to the bottom.

1.4 Life History and Habitat Descriptions for Each Species

1.4.1 Groupers (family Serranidae)

The groupers (family Serranidae) consist of at least 511 species in 68 genera organized into 3 subfamilies (Fishbase.org). All three species presently classified as BMUS in the Pacific are in the subfamily Epinephelinae and only one of these, *Epinephelus quernus*, is found in Hawaii. Most if not all epinepheline groupers are believed to be benthic protogynous hermaphrodites that according to Heemstra & Randall (1993) spawn small (0.70-1.20 mm) pelagic eggs that contain a single oil globule. The incubation period varies between 20-45 hrs after spawning with newly hatched larvae ranging between 1.6-2.5 mm (Leis, 1987). Yolk sac absorption is completed 48-120 hrs after hatching. Early stage serranid larvae are described as having “kite-shaped” bodies and highly developed head spination. The length of the pelagic larval stage is believed to range from 25-70 days, with settlement taking place when the fish reach 25-31 mm total length (TL). The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools while the adults of one species (*Epinephelus nigritus*) range in depth down to 525m (Heemstra & Randall 1993).

1.4.1.1 *Epinephelus quernus* (Hawaiian grouper, hapuupuu)

Life History

The Hawaiian grouper, *Epinephelus quernus*, is a member of the subfamily Epinephelinae and has recently been renamed to *Hyporthodus quernus*. In Hawaii adults of this species are known as hapu while juveniles are referred to as hapuupuu. According to Heemstra & Randall (1993) *E. quernus* is endemic to the Hawaiian Islands and Johnston Atoll and is the only grouper species native to the Hawaiian Islands. In the NWHI, this species reaches 50% sexual maturity at a length of 58 cm (Everson 1992; DeMartini et al. 2010) and at an age of about 6 years (Nichols & DeMartini 2008). Most individuals attain at least 80 cm total length and reach a weight of 10 kg or 22 lbs (Randall, 2007). In the NWHI, the species changes sex from adult female to adult male at a length of about 90 cm (DeMartini et al. 2010) and at an imprecisely estimable age of between 20 and 30 years (Nichols & DeMartini 2008). Its maximum length has been reported to be 106 cm or 41.7 in (Randall, 2007) and the Hawaii state record weight for this species is 22.7 kg (50 lbs)

(<http://www.hawaiifishingnews.com/records.cfm>).

A recent histological study of their gonads has confirmed that this species is a protogynous hermaphrodite, similar to most other epinepheline groupers (DeMartini et al. 2010). *E. quernus* is often observed in small groups of 3-5 individuals during submersible dives (Kelley, unpub data). In the NWHI, the adult sex ratio is about 6 females to 1 male (DeMartini et al. 2010). Protogyny is commonly associated with monandric, harem social systems and in these cases the sex ratio is typically skewed 2:1 to 5:1 females to males. Specimens captured during fishing surveys in the MHI were predominantly females (Kelley, unpub data) suggesting the possibility that *E. quernus* could have a harem social system.

Seki (1984a) reported the diet of *E. quernus* consists primarily of fish and to a lesser extent of cephalopods (mostly octopuses) and other invertebrates. Three of the 22 families of fish identified to be most important in the diet were Lutjanidae, Emmelichthyidae, and Congridae. Shrimp from the family Pandalidae accounted for 79% of all crustaceans. Prey regurgitated by *E. quernus* specimens after they were boated included two species of fish, *Symphysanodon maunaloae*, and *Bembradeum roseum*, as well as an unidentified octopus (Kelley, unpub data). These data are summarized in Table 17 and coupled with behavioral observations, suggests that *E. quernus* feeds primarily on benthic fish and invertebrates over a wide range of depths both day and night.

Table 17: *Epinephelus quernus* prey species combined from 67 stomachs (Seki, 1984a) and regurgitated specimens (Kelley, unpub data) ¹

Group	Category/Family	Subcategory/Species
Mollusks	Cephalopoda	unidentified
	Cephalopoda – octopods	<i>Octopus</i> sp. ¹
	Cephalopoda – octopods	unidentified
Crustaceans	Amphipoda	<i>Phronima sedentaria</i>
	Decapoda - crabs	Galatheidae
	Decapoda - crabs	Homolidae
	Decapoda - crabs	<i>Munida</i> sp.
	Decapoda - crabs	Raninidae
	Decapoda - shrimps	Caridae
	Decapoda - shrimps	Pandalidae
	Decapoda - shrimps	<i>Plesionika longirostris</i>
	Decapoda - shrimps	unidentified
	Isopoda	unidentified
Stomatopoda	<i>Odontodactylus brevirostris</i>	
Echinoderms	Echinoidea	unidentified
Urochordates	Pyrosomatidae	<i>Pyrosoma</i> sp.
Fishes	Anguilliformes	unidentified
	Apogonidae	unidentified
	Argentinidae	unidentified
	Brembridae	<i>Bembradium roseum</i> ¹
	Carangidae	<i>Decapterus</i> sp.
	Carangidae	<i>Seriola</i> sp.
	Congridae	unidentified
	Echeneidae	unidentified
	Emmelichthyidae	unidentified
	Gempylidae	unidentified
	Gonorhynchidae	<i>Gonorhynchus gonorhynchus</i>
	Holocentridae	unidentified

	Lutjanidae	<i>Etelis carbunculus</i>
	Monacanthidae	<i>Pervagor spilosoma</i>
	Monacanthidae	unidentified
	Mullidae	<i>Parupeneus</i> sp.
	Muraenidae	unidentified
	Myctophidae	unidentified
	Ophidiidae	<i>Brotula multibarbata</i>
Group	Category/Family	Subcategory/Species
Fishes cont.	Polymixiidae	<i>Polymixia berndti</i>
	Polymixiidae	unidentified
	Pomacentridae	unidentified
	Priacanthidae	<i>Priacanthus</i> sp.
	Scorpaenidae	unidentified
	Serranidae	unidentified
	Symphysanodontidae	<i>Symphysanondon maunaloae</i> ¹
	Symphysanodontidae	<i>Symphysanondon</i> sp.
	Tetraodontidae	unidentified
	Trachichthyidae	<i>Paratrachichthys</i> sp.
	Trachichthyidae	unidentified
	unidentified	unidentified

Egg and Larval Habitat

E. quernus eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 380m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Newly settled (i.e., 25mm long) *E. quernus*, still having pelagic coloration, have been found in NWHI lobster traps in early summer (Moffitt 2003). Age of settlement from these fish was estimated from otolith examination to be about 50 days (R. Nichols, NMFS, PIFSC, unpubl. data) The traps were set on bank flats at depths of 30–50 m, but with limited information, generalizations as to the bottom type these fish naturally settle on can not be made. *E. quernus* is generally more abundant and found in shallower water in the NWHI than in the MHI. Small juveniles (i.e., <4 in FL) have been collected off the west shore of Oahu in depths of 14 and 55m (Culp, pers comm.). The one shallow specimen was found in a discarded refrigerator while at least 5 deeper specimens were found hiding in an aggregation of *Diadema* sp urchins. Larger juveniles (i.e., 9-11 in FL) have been caught by hook and line off Oahu and depths between 73-121m (UH data, 2010). While both juveniles and adults have been observed relatively close to

shore, it is believed that settlement generally occurs at depths greater than 30 m. The lower limit of juvenile *E. quernus* habitat is not known and in the absence of additional information, is considered to be the same depth as that of adult habitat.

Adult Habitat

Adult *E. quernus* have been documented as shallow as 5 m at Midway and Kure (Hobson, 1980) and as deep as 350 m in the MHI (UH data, 2010). Heemstra & Randall (1993) listed its overall depth range at 20-380 m. Seki (1984a) trapped adult *E. quernus* at 18 m in the NWHI. With only one exception, adults caught during fishing surveys in the MHI were all below 100 m while > 90% of those observed in BotCam deployments ranged from 119 to 229 m (UH data, 2010). Adults were observed on carbonate or mixed carbonate/sediment substrate during submersible transects (Kelley unpub data). In some cases, the fish were clearly associating with ledges and other large cavities while in other cases they appeared on more open terrain. A habitat summary is provided in Table 18.

Table 18: Habitat summary for *Epinephelus quernus* (Hawaiian grouper, hapuupuu)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown <380m	Unknown <380m	14-121m	5-380m
Water Column Zone	Pelagic	Pelagic	Benthic	Benthic
Water Quality	Unknown	Unknown	Unknown	15-24 °C
Substrate Type	N/A	N/A	Unknown	Rocky bottom substrate.
Prey	N/A	Unknown	Unknown	Fishes, shrimps, octopods, and other invertebrates

Bottomfish Complex: Intermediate (40-320 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-320 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-320 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic zone, 40-320 m depth range

Adult: benthic zone, 40-320 m depth range

1.4.2 Jacks (family Carangidae)

Large carangids, or jacks, form an important component of shallow water reef and lagoon fish catches throughout the Pacific Islands. The species are found distributed throughout tropical and subtropical waters of the Indo-Pacific region in shallow coastal areas in estuaries and on reefs, on the deep reef slope and banks and seamounts (Sudekum et al., 1991). Despite their importance to fisheries, little is known about the basic biology and habitat requirements of these fish. Generally speaking, jacks are highly mobile, wide-ranging predators that travel throughout the water column from the surface to depths greater than 250 m, although they are more closely affiliated with demersal habitats and feeding on benthos (Seki 1986b, Sudekum et al. 1991).

Carangid eggs are planktonic, spherical (0.70-1.5 mm in diameter), and have one to several oil globules (Laroche et al., 1984; Leis & Trnski, 1989; Honebrink, 2000). Incubation generally takes 18 to 48 hours with newly hatched larvae ranging from 1.0 to 2.0 mm according to Laroche et al. (1984) and 2.0 to 4.3 mm according to Leis & Trnski (1989). Carangid larvae have a relatively large yolk sac and an oil globule at the anterior end of the sac (Laroche et al., 1984). Yolk sac absorption is completed in 72 hrs. Leis & Trnski (1989) provide a detailed description of larvae in the genus *Caranx*. According to Miller et al. (1979), carangid larvae are common in the near-shore waters of Hawaii. However, the identification of either eggs or larvae to even the level of family is frequently impossible because of their similarity in size and appearance to many other marine fishes (Laroche et al., 1984). No general information could be found on settlement and metamorphosis in this family.

1.4.2.1 *Caranx ignobilis* (giant trevally/white ulua)

Life History

Caranx ignobilis or white ulua is one of the most abundant species of jacks found in Hawaii. This species is the largest jack found in the Indo-Pacific region, obtaining a weight over 50 kg and living in excess of 15 years (Lewis et al. 1983). The Hawaii state record is 191 lbs or 87 kg (<http://www.hawaiiifishingnews.com/records.cfm>). The sex ratio of males to females in Hawaii was reported to be 1:1.39 (Sudekum et al. 1991) in contrast to Fiji where it was reported to be 2:1 (Lewis et al. 1983). This species reaches sexual maturity in 3.5 years at a size of 60 cm (Sudekum et al. 1991).

Gravid fish are found between April and November in the NWHI while in general, peak spawning in Hawaii occurs between May and August (Sudekum et al. 1991). Johannes (1981) reported that *C. ignobilis* spawns in pairs within larger aggregations during new and full moon events. Myers (1991) reports that *C. ignobilis* gather to spawn on offshore banks and shallow seaward reefs. No description of either eggs or larvae currently exists for this species.

C. ignobilis in the NWHI is predominantly piscivorous with fish comprising > 90% of its diet (Sudekum et al. 1991, Parrish et al. 1980). Stomach contents included parrotfish (Scaridae), mackerel scads (Carangidae), wrasses (Labridae), bigeyes (Priacanthidae) eels (Muraenidae and Congridae), and invertebrates including cephalopods, gastropods and crustaceans (crabs, shrimp and lobsters). The number of reef fishes in their diet suggests that shallow-water benthic habitats are important foraging areas, however, the occurrence of small pelagic fish and squids in their stomachs indicates that time is also spent foraging in the water column (Sudekum et al. 1991). In Kaneohe Bay in the MHI, Meyer et al. (2001) examined the stomach contents of 19 *C. ignobilis* and found only about 7.3% of the prey items were fish. Crustaceans, particular crabs (*Portunus sanguinolentus*, *Portunus japonicus*, and *Pachygrapsus* sp.), were the most abundant items, accounting for 90% of the prey volume. Table 19 summarizes the known types of prey for this species.

Smith (1992) found that juvenile *C. ignobilis* consumed primarily fish. Smith & Parrish (2002) subsequently examined the stomach contents of 106 juveniles collected from an estuary on Kauai and found that fish, including kuhliids, bothids, mugilids and gobioids, accounted for 95.1% of the total volume. Crustaceans, including amphipods, tanaids, isopods, shrimp, stomatopods, copepods and crabs, were also found in the majority of the stomachs but did not account for a high percentage of the volume. Based on both prey species found in their stomachs and tracking studies, *C. ignobilis* appears to be primarily a nocturnal feeder (Longenecker & Langston, 2008; Sudekum et al. 1991; Okamoto & Kawamoto 1980).

Egg and Larval Habitat

C. ignobilis eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 190m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Juvenile *C. ignobilis* are often found in near-shore and estuarine waters (Lewis et al. 1983; Smith, 1992) and in small schools over sandy inshore reef flats (Myers 1991). Smith & Parrish (2002) collected over 100 juveniles in an estuary on the island of Kauai. This species therefore appears to have near-shore nursery areas however, their presence in less surveyed deeper habitats, cannot be ruled out. The lower limit of juvenile *C. ignobilis* habitat is not known and in the absence of additional information, is considered to be the same depth as that of adult habitat.

Adult Habitat

In the NWHI, diver towboard surveys conducted among reefs, among habitats within atolls (fore reef, back reef, channel and lagoon), and banks (insular and exposed), found *C. ignobilis*

in greater abundance on fore reef habitats within atolls and in similar abundance on exposed and insular reefs within banks (Holzwarth et al., 2006). The deepest record of *C. ignobilis* in Hawaii is 190m (UH data, 2010). A habitat summary is provided in Table 20.

Table 19: *Caranx ignobilis* prey species combined from 81 stomachs (Sudekum et al. 1991) and 19 stomachs (Meyer et al., 2001).

Group	Category/Family	Subcategory/Species
Mollusks	Cephalopoda	unidentified
	Cephalopoda – octopus	unidentified
	Cephalopoda - squids	unidentified
	Gastropoda	<i>Bittium parcum</i>
Crustaceans	Decapoda - crabs	<i>Pachygrapsus</i> sp.
	Decapoda - crabs	Portunidae
	Decapoda - crabs	<i>Portunus japonicas</i>
	Decapoda - crabs	<i>Portunus sanguinolentus</i>
	Decapoda - lobsters	Palinuridae
	Decapoda - shrimps	unidentified
	Stomatopoda	unidentified
Fishes	unidentified	unidentified
	Acanthuridae	unidentified
	Anguilliformes	unidentified
	Blennidae	unidentified
	Carangidae	<i>Decapterus macarellus</i>
	Carangidae	unidentified
	Congridae	unidentified
	Holocentridae	unidentified
	Labridae	unidentified
	Monacanthidae	unidentified
	Mullidae	<i>Parupeneus cyclostomus</i>
	Mullidae	unidentified
	Muraenidae	unidentified
	Ophidiidae	<i>Brotula multiberbata</i>
	Ostraciidae	unidentified
	Pomacentridae	unidentified
	Priacanthidae	unidentified
Scaridae	unidentified	
unidentified	unidentified	

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Table 20: Habitat summary for *Caranx ignobilis* (giant trevally, white ulua)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	unknown < 190m	unknown < 190m	0-10m	10-190m
Water Column Zone	Pelagic	Pelagic	Benthic or benthopelagic	Benthopelagic
Water Quality	18-30°C	18-30°C	Unknown	21-24 °C
Substrate Type	N/A	N/A	Often found in near-shore and estuarine waters and in small schools over sandy inshore reef flats	Wide variety of substrates
Prey	N/A	Unknown	Predominantly fish, including kuhliids, bothids, mugilids, and gobioids. Also preys on crustaceans, including amphipods, tanaids, isopods, shrimp, stomatopods, copepods and crabs.	Habitat dependent. Predominantly fish in areas in the NWHI while predominantly crustaceans in Kaneohe Bay. Also preys on gastropods and cephalopods.

Bottomfish Complex: Shallow (0-240 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-200 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-200 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic or benthopelagic zone, 0-200 m depth range

Adult: benthic or benthopelagic zone, 0-200 m depth range

1.4.2.2 *Caranx lugubris* (black trevally/black ulua)

Life History

Caranx lugubris, known in Hawaii as the black ulua, has a world wide distribution although it is not particularly common in the Hawaiian Islands (Randall, 2007). *C. lugubris* is the most common carangid taken from offshore banks in the Marianas, despite concerns about ciguatera, which is a form of food poisoning caused by bioaccumulation of dinoflagellate toxins in the flesh. (Myers, 1991). This species is not a major component of the bottomfish catch in Hawaii, accounting for 0.2% of the annual catch and ranking 13th in importance (WPRFMC, 2005). *C. lugubris* reach lengths of up to 80 cm or 31.5 in, with the world angling record being 17.9 kg or 28.4 lbs (Randall, 2007). In Hawaii, the state record weight for this species is 16.75 lbs or 7.6 kg (<http://www.hawaiiifishingnews.com/records.cfm>). No information was available regarding its spawning season in Hawaii. However, in the Caribbean it reportedly spawns from February to September (Munro et al., 1973). This species has been reported to feed primarily on other fishes and, as a result, has been implicated in ciguatera poisoning (Randall, 2007).

Egg and Larval Habitat

The early life history of *C. lugubris* is poorly known. *C. lugubris* eggs and larvae are pelagic however their depth and geographic ranges are unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 367 m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

There is presently no information available on the juveniles of this species in Hawaii. However, it is assumed that juvenile habitat will be found at either the same or shallower depths as the adults.

Adult Habitat

Very little is known about the adult habitat of this species in Hawaii. Smith-Vaniz (1986) stated that this species appears to be confined to clear, offshore waters at depths of 25 to 65 m. Myers (1991) however, found these fish occurring singularly or in small groups on offshore banks and along the steep outer reef slopes at depths of 12 to 354 m. *C. lugubris* has been recorded to a depth of 367 m during submersible dives (UH data, 2010). A habitat summary is provided in Table 21.

Table 21: Habitat summary for *Caranx lugubris* (black trevally/black ulua)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown <367m	Unknown <367m	Unknown <367m	12-367m
Water Column Zone	Pelagic	Pelagic	Benthic or benthopelagic	Benthopelagic
Water Quality	18-30°C	18-30°C	Unknown	Unknown
Substrate Type	N/A	N/A	Unknown	Shallow coastal areas and in estuaries and on reefs, the deep reef slope, banks and seamounts
Prey	N/A	Unknown	Unknown	Predominantly piscivorous, fish comprising >90% of its diets. Also preys on crustaceans, gastropods and cephalopods, eels. Shallow-water reef habitats are of prime importance as foraging habitat for large jacks. Time is also spent foraging in the water column.

Bottomfish Complex: Intermediate (0-320 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-320 m depth range depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-320 m depth range depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic or benthopelagic zone, 40-320 m depth range

Adult: benthic or benthopelagic zone, 40-320 m depth range

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1.4.2.3 *Pseudocaranx cheilio* (thick-lipped trevally, butaguchi)

Life History

Pseudocaranx cheilio has been recently renamed from *Pseudocaranx dentex*, and is called butaguchi in Hawaii. Its taxonomy is still uncertain and as a result, its current distribution is considered to be only in the Hawaiian Islands (Randall, 2007). This species has accounted for roughly 15% of the annual bottomfish catch in the NWHI (WPRFMC 1997) and 10.4% of the annual catch throughout the archipelago since 1948 (WPRFMC, 2005). On that basis, it is ranked 5th in importance to the fishery in Hawaii. However, the number caught has been in decline for over 10 years and in 2004, the most recent year of data, it accounted for only 4.3% of the catch. Its maximum size has been reported to be 82 cm or 32 in (Randall, 2007), while the Hawaii state record is 40 lbs or 18 kg (<http://www.hawaiifishingnews.com/records.cfm>).

Based on the von Bertalanffy growth curves from Williams & Lowe (1997), this species can reach 80 cm FL in 4-6 years, depending on the method used.

In the Azores, *P. dentex* spawns from June to September (Afonso et al., 2008), however, in Hawaii, spawning has only been reported from June to July (Uchiyama & Tagami 1984).

Seki (1984b) examined the content of 64 *P. cheilio* stomachs and found them to be opportunistic carnivores (Table 22). Their diet was primarily piscivorous, but also included cephalopods and crustaceans. The types of prey and the observation of rubble in 31% of the stomachs suggest *P. cheilio* are bottom feeders. During submersible bait stations, adult *P. cheilio* appeared to “vacuum” bait right off the bottom with their large mouths.

Egg and Larval Habitat

P. cheilio eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 321m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Very little information is currently available on the juveniles of this species. Seki (1984b) reported trapping hundreds of *P. cheilio* juveniles in the NWHI at depths of 60-64m which is at the upper end of the adult depth range. As mentioned earlier, Major (1978) and Smith & Parrish (2002) found that back reefs, lagoons and particularly estuaries were important nursery areas for carangids such as *C. ignobilis* and *P. cheilio*. While no juveniles of this species have ever been recorded on deeper submersible dives and drop camera deployments their presence in deeper water cannot be ruled out.

Table 22: *Pseudocaranx cheilio* prey species collected from 64 stomachs (Seki, 1984b).

Group	Category/Family	Subcategory/Species
Mollusks	Bivalvia	<i>Nemocardium thaaumi</i>
	Bivalvia	<i>Pinna muricata</i>
	Cephalopoda	unidentified
	Cephalopoda – octopods	unidentified
	Gastropoda	unidentified
Annelids	Polychaeta	unidentified
Crustaceans	Amphipoda	unidentified
	Decapoda - crabs	Brachyura
	Decapoda - crabs	<i>Munida</i> sp.
	Decapoda - crabs	Paguridae
	Decapoda - lobsters	<i>Panulirus</i> sp.
	Decapoda - shrimps	Caridae
	Decapoda - shrimps	Crangonidae
	Decapoda - shrimps	Pandalidae
	Decapoda - shrimps	“shrimp remains”
	Decapoda - shrimps	unidentified
	Stomatopoda	<i>Lysiosquilla</i> sp.
	Stomatopoda	<i>Odontodactylus</i> sp.
	Stomatopoda	<i>Pseudosquilla</i> sp.
	Stomatopoda	unidentified
	unidentified	unidentified
Echinoderms	Cidaridae	<i>Prionocidaris hawaiiensis</i>
	Ophiuroidea	unidentified
Fishes	Ammodytidae	<i>Embolichthys</i> sp.
	Anguilliformes	unidentified
	Bothidae	<i>Bothus thompsoni</i>
	Bothidae	unidentified
	Callionymidae	unidentified
	Chlorophthalmidae	unidentified
	Congridae	<i>Congrina aequoria</i>
	Congridae	unidentified
	Dactyloperidae	<i>Dactyloptera orientalis</i>
	Lutjanidae	unidentified
	Monacanthidae	unidentified
	Moridae	unidentified
	Myctophidae	unidentified
	Ogocephalidae	<i>Halieutaea retifera</i>
	Ogocephalidae	<i>Malthopsis</i> sp.

	Ogocephalidae	unidentified
	Ophichthidae	“Leptocephalus larvae”
	Ophichthidae	<i>Muraenichthys cookei</i>
	Ophichthidae	unidentified
	Ophidiidae	unidentified
	Osteichthyes	unidentified
	Pegasidae	<i>Pegasus papilio</i>
	Percophidae	unidentified
	Priacanthidae	<i>Priacanthus</i> sp.
	Scorpaenidae	unidentified
Group	Category/Family	Subcategory/Species
Fishes cont.	Serranidae	<i>Anthias</i> sp.
	Serranidae	unidentified
	Symphysanodontidae	<i>Symphysanondon</i> sp.
	Synodontidae	unidentified
	Tetraodontidae	unidentified

Adult Habitat

Seki (1986a) noted that *P. cheilio* is rarely caught in the MHI, but is abundant in the NWHI where it is found at depths of 18-183 m. In addition to living on deeper reef slopes and banks, *P. cheilio* can also be found in near-shore areas in large schools of 200-300 fish. Adults of this species have been recorded to a maximum depth of 321 m on submersible dives (UH data, 2010). These fish were observed swimming closely and synchronously in small aggregations over carbonate or mixed carbonate/sediment substrate. Based on these observations, this species likely has a relatively large home range. Table 23 provides a habitat summary for this species.

Table 23: Habitat description for *Pseudocaranx cheilio* (thick-lipped trevally, butaguchi)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown <321m	Unknown <321m	0-64m	18-321m
Water Column Zone	Pelagic	Pelagic	Benthic or benthopelagic	Benthopelagic
Water Quality			Unknown	Unknown
Substrate Type	N/A	N/A		Carbonate and mixed carbonate/sediment
Prey	N/A	Unknown	Unknown	Fish, cephalopods, and crustaceans

Bottomfish Complex: Intermediate (0-320 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-280 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-280 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic or benthopelagic zone, 40-280 m depth range

Adult: benthic or benthopelagic zone, 40-280 m depth range

1.4.2.4 *Seriola dumerili* (greater amberjack, kahala)

Life History

Seriola dumerili is found throughout the Atlantic, Indian, and Pacific oceans occupying a wide range of habitats including shallow estuaries, reefs, the deep reef slope, banks and seamounts (Harris et al., 2007; Sudekum et al., 1991). This species was previously an important component of the commercial bottomfish fishery in Hawaii. For the last couple of decades, however, its landings have been insignificant due principally to its association with ciguatera and a resulting ban on commercial sales (Uchida & Uchiyama 1986). *S. dumerili* is a key member of the bottomfish community being both a predator and competitor to other bottomfish species. Attacks and consumption of juveniles and smaller snapper species have been recorded during Pisces submersible and ROV dives (Kelley, unpub data).

Despite their importance to the fishery, very little is known about their basic biology in Hawaii. *S. dumerili* reaches sexual maturity between 1 and 2 years of age at an approximate length of 54 cm (Kikkawa & Everson 1984, Uchida & Uchiyama 1986). The Hawaii state record for this species is 145.5 lbs or 66 kg (<http://www.hawaiiifishingnews.com/records.cfm>). Humphreys (1986a) reported that in the NWHI, *S. dumerili* spawn throughout the year with peak activity occurring in April. Elsewhere, Harris et al. (2007) conducted a comprehensive study on their life history off the Southeast Atlantic coast. From over 2,700 specimens, the maximum age was 13 years and maximum FL was 145 cm. Females reached 50% sexual maturity at 1.3 years at an average FL of 73 cm. Males attained sexual maturity at 64 cm. Spawning took place from February to May at 24-26 degrees of latitude with April and May being the peak months. Annual fecundity estimates ranged up to 59 million eggs. In the Canary Islands, *S. dumerili* underwent natural spawning in captivity from the month of April through October (Jerez et al, 2006). Thirty-eight spawns produced on average 368,431 pelagic eggs with mean diameter 1.121 ± 0.032 mm. The eggs hatched between 34-45 hrs, with newly hatched larvae averaging 3.639 ± 0.012 mm. Miller et al. (1979) described *Seriola* sp. larvae as moderately deep-bodied, large-headed and possessing well-developed pre-opercular spines. The length of the pelagic larval phase and age of settlement and metamorphosis are presently unknown.

S. dumerili is an opportunistic bottom feeder, with primary prey items comprising fishes such as eels, groupers, bigeyes, crustaceans (crabs and shrimps) and octopus (Seki, 1986b; Humphreys, 1980; Kelley, unpub data). Humphreys (1986a) found that their diet in the NWHI included bottom-associated prey and octopus while in the MHI the primary prey items are pelagic species, such as round scads. There is a significant shift in the diet of *S. dumerili* from cephalopods to fish as it increases in weight (Humphreys 1980). Humphreys & Kramer (1984) examined the stomach contents of 268 *S. dumerili* in the Hawaiian Islands and concluded that *S. dumerili* is primarily piscivorous, but also feeds on cephalopods and crustaceans. Known prey items are listed below in Table 24.

Table 24: *Seriola dumerili* prey species combined from 268 stomachs (Humphreys & Kramer, 1984) and regurgitated specimens (Kelley, unpub data¹).

Group	Category/Family	Subcategory/Species
Mollusks	Cephalopoda	unidentified
	Cephalopoda – octopods	unidentified
	Cephalopoda – squids	Teuthoidea
Crustaceans	Amphipoda	unidentified
	Decapoda - crabs	<i>Munida</i> sp.
	Decapoda - crabs	Paguridae
	Decapoda - crabs	Portunidae
	Decapoda – lobsters and crabs	unidentified
	Decapoda - shrimps	Caridae
	Decapoda - shrimps	<i>Heterocarpus ensifer</i>
	Decapoda - shrimps	Penaeidea
	Decapoda - shrimps	<i>Plesionika edwardsii</i>
	Decapoda - shrimps	<i>Plesionika</i> sp.
	Decapoda - shrimps	unidentified
	Euphausiacea	unidentified
	Stomatopoda	<i>Squilla</i> sp.
	unidentified	unidentified
	Fishes	Acanthuridae
Ammodytidae		<i>Ammodytoides pylei</i>
Ammodytidae		<i>Lepidammodytes macrophthalmus</i>
Ammodytidae		unidentified
Anguilliformes		unidentified
Argentinidae		unidentified
Ariommatidae		<i>Ariomma</i> sp.
Balistidae		unidentified
Balistidae		<i>Xanthichthys mento</i>
Bothidae		unidentified
Bramidae		unidentified
Callanthiidae		<i>Grammatonoyus</i> sp.
Caproidae		<i>Antigonia capros</i>
Caproidae		unidentified
Carangidae		<i>Decapterus macrosoma</i>
Carangidae		<i>Decapterus</i> spp.
Carangidae		<i>Decapterus tabl</i>
Carangidae		<i>Selar crumenophthalmus</i>
Carangidae		unidentified
Chaetodontidae		unidentified
Congridae	unidentified	
Dactylopteridae	unidentified	
Emmelichthyidae	unidentified	

	Engraulidae	unidentified
	Exocoetidae	unidentified
	Fistulariidae	unidentified
	Gobiidae	unidentified
	Gonostomatidae	unidentified
	Labridae	unidentified
Group	Category/Family	Subcategory/Species
Fishes cont.	Lutjanidae	<i>Etelis carbunculus</i> ¹
	Lutjanidae	<i>Etelis coruscans</i>
	Lutjanidae	<i>Lutjanus</i> sp.
	Lutjanidae	<i>Pristipomoides filamentosus</i> ¹
	Lutjanidae	<i>Pristipomoides sieboldii</i>
	Lutjanidae	<i>Pristipomoides</i> sp.
	Lutjanidae	unidentified
	Monacanthidae	<i>Thamnaconus garretti</i>
	Moridae	unidentified
	Mullidae	unidentified
	Muraenidae	unidentified
	Myctophidae	unidentified
	Nomeidae	<i>Psenes</i> sp.
	Nomeidae	unidentified
	Ostraciidae	<i>Kentrocarpros aculeatus</i>
	Ostraciidae	unidentified
	Paralepididae	unidentified
	Pegasidae	unidentified
	Percophidae	unidentified
	Pleuronectiformes	unidentified
	Polymixiidae	unidentified
	Pomacentridae	unidentified
	Priacanthidae	unidentified
	Scombridae	<i>Auxis rochei</i>
	Scombridae	<i>Auxis</i> sp.
	Scombridae	<i>Auxis thazard</i>
	Scombridae	<i>Scomber japonicus</i>
	Scombridae	unidentified
	Scorpaenidae	<i>Pontinus macrocephalus</i>
	Scorpaenidae	<i>Scorpaenopsis</i> sp.
	Scorpaenidae	unidentified
	Serranidae	<i>Anthias</i> sp.
	Serranidae	unidentified
	Sphyraenidae	unidentified
	Symphysanodontidae	<i>Symphysanodon typus</i>
	Symphysanodontidae	<i>Symphysanodon maunaloae</i>

Synodontidae	unidentified
Tetraodontidae	unidentified
Triglidae	unidentified
unidentified	unidentified
Zeidae	unidentified

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Egg and Larval Habitat

S. dumerili eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 555m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ, while the larval habitat extends all the way out to the 200 mi EEZ boundary.

In a survey of larval distribution in near-shore waters off Hawaii, *Seriola* sp. larvae were found to be relatively uncommon (Miller et al, 1979). Slightly more *Seriola* sp. larvae were taken in summer than in winter, although this was not significant. They also found that *Seriola* sp. larvae were more common in offshore, as opposed to near-shore, tows.

Juvenile Habitat

Juvenile *S. dumerili* have been documented at approximately 80 m on flat sediment outside of Kaneohe Bay, Oahu (Figure 6a, Merritt, unpub data) and swimming at the surface under a dead albatross (http://www.hawaiianatolls.org/research/June2006/underwater_village.php, Fig. 6b). Juveniles have been reported to associate with floating plants and debris (Fishbase.org).

Adult Habitat

In the NWHI, diver towboard surveys among reefs, among habitats within atolls (fore reef, back reef, channel, and lagoon) and banks (insular and exposed), found *S. dumerili* in greater abundance on fore reef habitats within atolls and similar in abundance on exposed and insular reefs within banks (Holzwarth et al., 2006). *S. dumerili* is commonly found inhabiting the inner reefs and outer slopes of island shelves to depths of 335 m (Humphreys 1986a; Myers 1991; Ralston et al. 1986). This species has been frequently recorded on submersible dives and drop camera deployments to a maximum depth of 555 m (UH data, 2010). These records include observations of solitary individuals, pairs, small aggregations and schools swimming very close to the bottom or very high in the water column over hard carbonate and or basalt substrates, mixed hard and sediment substrates and sediment flats. *S. dumerili* appears to be a widely ranging, versatile, opportunistic carnivore. Table 25 provides a habitat summary for this species.



Figure 6: a) Juvenile *S. dumerili* off Kaneohe Bay, Oahu (Merritt unpub data), and b) under a dead albatross in the NWHI (photo by E. Tong).

Table 25: Habitat description for *Seriola dumerili* (greater amberjack, kahala)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown <555m	Unknown <555m	0-80m	1-555m
Water Column Zone	Pelagic	Pelagic	Benthic or benthopelagic	Benthopelagic
Water Quality	18-30 °C	Unknown	Unknown	13-24 °C
Substrate Type	N/A	N/A	often found in near-shore and estuarine waters and in small schools over sandy inshore reef flats	shallow coastal areas and in estuaries and on reefs, the deep reef slope, banks and seamounts
Prey	N/A	Unknown	Unknown	Mostly piscivorous, with fish comprising >90% of its diets. Also preys on crustaceans, gastropods and cephalopods, eels. Shallow-water reef habitats are of prime importance as foraging habitat for large jacks. Time is also spent foraging in the water column.

Bottomfish Complex: Intermediate (0-320 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-320 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-320 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic or benthopelagic zone, 40-320 m depth range

Adult: benthic or benthopelagic zone, 40-320 m depth range

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1.4.3 Snappers (family Lutjanidae)

The snappers (family Lutjanidae) consist of at least 103 species in 17 genera (Fishbase.org). Ten species are presently classified as BMUS in the Pacific, nine of which are found in Hawaii. All but one of these (e.g. *Lutjanus kasmira*) are in the subfamily Etelinae. *L. kasmira* is the only one of the nine that is non-native, having been introduced to Hawaii in the later half of the last century.

Lutjanids are reported to have life spans of 4-21 years, with larger species generally ranging from 15 to 20 years. Lutjanids reach sexual maturity at 43-51% of their maximum total length and dioecious (separate sexes), displaying little or no sexual dimorphism (Allen 1985). Females are batch spawners, producing several clutches of pelagic eggs over the course of the spawning season. According to Leis (1987), lutjanids eggs are typically less than 0.85mm in size and hatch in 17-36 h depending on water temperature. Newly hatched lutjanids are similar in appearance to the pelagic larvae of many other species and have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. The duration of the pelagic phase has been estimated to range from 25 to 47 days for snappers of the subfamily Lutjaninae, with the larger members of the subfamily Etelinae (e.g. *A. rutilans*) taking longer to settle at a larger size of 50 mm or greater (Leis 1987). Leis (1987) also proposed that size may be a more important factor than age in determining when larval settlement occurs. However, the relatively low abundance of lutjanid larvae in plankton samples makes ecological studies difficult.

Ralston et al. (1986) found that the distribution of the larger deepwater snappers is non-random, with aggregations forming near areas of prominent relief features such as headlands and promontories. The adults of both large and small species clearly show a preference for habitats with hard substrates.

1.4.3.1 *Aphareus rutilans* (silvermouth snapper, lehi)

Life History

Aphareus rutilans is a member of the subfamily Etelinae and is one of two species in the genus *Aphareus* found in Hawaii. *A. rutilans* is widespread throughout the subtropical and tropical Pacific and Indian Oceans (Allen, 1985). This species has distinctive silver pigment lining the inside of its mouth which is responsible for its English common name of silvermouth snapper. *A. rutilans* is reported to reach a maximum length of 80 cm (Allen, 1985) with the Hawaii state record being 32.5 lbs (14.7 kg, <http://www.hawaiifishingnews.com/records.cfm>). This is an important commercial species in the island areas of the Indo-Pacific region and has been one of the principal target species in the Hawaiian bottomfish fishery, although it presently accounts for only 1% of the total bottomfish catch (WPRFMC, 2005). According to “Current Line Fish Facts: Bottomfishes of Hawaii” published by the state of Hawaii’s DLNR Division of Aquatic Resources, *A. rutilans* prey include pelagic tunicates, fish, squid and crustaceans.

Egg and Larval Habitat

A. rutilans eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 350 m (White & Sumpton 2002). The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

There is almost no information available concerning the life history and habitat requirements of the juveniles. Parrish (1989) reported the collection of a single juvenile at 40 m off Kaneohe Bay, Oahu.

Adult Habitat

Adult *A. rutilans* aggregate near areas of high bottom relief (Parrish 1987). Of the 28 records of *A. rutilans* found in the HURL database, 24 were over hard substrate of basalt or carbonate. This species was observed as either solitary individuals or small groups but not in large schools typical of *E. coruscans* or *P. filamentosus*. *A. rutilans* has been recorded at submersible bait stations with other species of snappers, but is generally seen moving only with conspecifics (Kelley, unpub data). *A. rutilans* adults are benthopelagic and may be feeding primarily on pelagic organisms similar to other large schooling snappers. White (2002) reported its depth range as 100-350 m. Submersible, drop camera, and fishing records from Hawaii range from 61 to 310m (UH data, 2010). Table 26 provides a habitat summary for this species.

Table 26: Habitat Summary for *Aphareus rutilans* (silvermouth snapper, lehi)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown <350m	Unknown <350m	40m	61-350m
Water Column Zone	Pelagic	Pelagic	Benthic or benthopelagic	Benthopelagic
Water Quality	Unknown	Unknown	Unknown	14-23 °C
Substrate Type	N/A	N/A	Unknown	Hard rocky bottoms, areas of high relief
Prey	N/A	Unknown	Unknown	Fish, squid, and crustaceans

Bottomfish Complex: Intermediate (0-320 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-280 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-280 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic or benthopelagic zone, 40-280 m depth range

Adult: benthopelagic zone, 40-280 m depth range

1.4.3.2 *Aprion virescens* (gray snapper, uku)Life History

Aprion virescens is in the subfamily Etelinae and is the only species in its genus. This species is widely distributed throughout the Indian and Pacific oceans from East Africa to Hawaii, where it is known as the uku (Druzhinin 1970, Tinker, 1978). *A. virescens* has been an important member of the bottomfish fishery in American Samoa, Guam, and Hawaii (1996 *Annual Report Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region*) but much less so in the Northern Mariana Islands (Polovina 1987). In the latest available annual report (WPRFMC, 2005), this species is second only to *E. coruscans* in number of pounds caught in Hawaii in 2004. This is one of only 3 species that include *E. coruscans* and *P. zonatus* caught in 2004 in significantly higher numbers than their annual average since 1948.

In the NWHI, Kramer (1986) reported that *A. virescens* were caught only at Nihoa Island, Brooks Banks, St. Rogatien Bank and Midway Islands. However, in a survey of the near shore fishery resources of the NWHI, uku were also observed at Necker Island, French Frigate Shoals and Pearl and Hermes Atolls (Okamoto & Kanenaka 1983). In addition to these sites, *A. virescens* has been caught and tagged on Maro Reef (Meyer et al. 2007) and during research cruises transiting across the top of Raita Bank (Kelley, pers comm). This species is likely present on the tops of most or all banks in the NWHI. In the MHI, *A. virescens* has been recorded at depths of 54-227 m (UH data, 2010). However, it is also known to frequent waters just below the surface. In this respect, *A. virescens* is quite different from the other species of bottomfish and consequently is caught on surface trolling lures (Haight et al. 1993a, b; Kelley & Ikehara 2006; Meyer et al. 2007). Landings are seasonal, the majority of which are made between June and December (Ralston 1979, Haight 1989, Haight et al. 1993a). *A. virescens* reach sexual maturity at an age of 4-5 years and approximately 42.5-47.5cm SL (Everson et al, 1989; Grimes, 1987) in Hawaii. Ralston (1979) reported it spawns during the summer months while its spawning season has been reported elsewhere as being from May to October (Everson et al, 1989). The maximum length is 110 cm (Randall, 2007) and the Hawaii state record is 39.5 lbs or 17.9 kg (<http://www.hawaiifishingnews.com/records.cfm>).

Egg and larval development in this species is poorly known. Leis & Lee (1994) described identifying characteristics of their larvae which appear to be more similar to *Etelis* than *Aphareus* or *Pristipomoides* larvae. This species lacks a melanophore cluster on the dorsal side of the tail but has a distal melanophore or several in series on the second dorsal spine. Larvae are confirmed to be pelagic to at least 18 mm NL and may in fact settle before it reaches 20 mm Leis & Lee (1994).

Haight (1989) reported that *A. virescens* feed during daytime hours and found the diet of specimens collected from Penguin Bank in the MHI to include fish (89%), larval fish (6%), planktonic crustaceans (1%), shrimp (3%) and crabs (1%). Talbot (1960) reported the diet of *A. virescens* on the coast of East Africa to consist of fish (49%), plankton (17%), cephalopods (14%), non-planktonic crustaceans (12%) and others (8%). Unlike the benthic species of deepwater lutjanids, *A. virescens* has feeding habits that do not seem to be constrained by substrate association (Parrish 1987). This species forages throughout the water column (Ralston 1979, Parrish 1987), from the surface down to almost 200 m. Table 27 summarizes the known prey of this species.

Table 27: Food items in 42 stomachs of *Aprion virescens* (Haight et al., 1993b).

Group	Category/Family	Subcategory/Species
Mollusks	Cephalopoda	unidentified
	Cephalopoda – octopods	unidentified
	Gastropoda - Pteropods	<i>Diacra</i> sp.
Crustaceans	Decapoda - crabs	megalopa larvae
	Decapoda - crabs	unidentified adults
	Decapoda - shrimps	unidentified
	Isopoda	unidentified
	Stomatopoda	<i>Odontodactylus henseni</i>
Urochordates	unidentified	unidentified
	Salpidae	unidentified
Fishes	Thaliacea	unidentified
	Acanthuridae	<i>Naso hexacanthus</i>
	Acanthuridae	<i>Naso</i> sp.
	Antennariidae	<i>Antennarius pictus</i>
	Balistidae	unidentified
	Dactylopteridae	<i>Dactyloptena orientalis</i>
	Larvae	unidentified
	Monacanthidae	unidentified
	Mullidae	<i>Parupeneus</i> sp.
	Pegasidae	<i>Pegasus papilio</i>
	Sphyraenidae	unidentified
	Synodontidae	larvae
	Tetraodontiformes	unidentified
unidentified	unidentified	

Eggs and Larval Habitat

A. virescens eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 194 m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

There is very little information available concerning the distribution and habitat requirements of the juvenile stage of this species. Parrish (1989) caught 5 juveniles off Kaneohe Bay in 40m of water where there the substrate was coarse sediment covered by a bed of *Halimeda* spp algae. They also caught one juvenile over a sediment bottom off West Oahu at a depth greater than 61 m. Parrish et al. (1997) suggested that this type of habitat is not attractive to many species which could provide the advantage of reduced predation pressure and lessened interspecific competition.

Adult Habitat

In the Hawaiian Archipelago, Ralston & Polovina (1982) reported that most bottomfish species are caught along the steep drop-offs and slopes that surround the islands and banks. *A. virescens*, however, is different that it is primarily caught on the tops, not the sides or slopes, of these banks. Furthermore *A. virescens* is the only bottomfish species that is regularly caught at or near the surface with a lure (Kramer 1986). Its adult habitat has been described as the open waters of deep lagoons, channels, or seaward reefs at depths of 0–180 m, where individuals or small aggregations are most often observed (Haight et al. 1993b; Lieske & Myers 1994). At several banks in the NWHI, *A. virescens* were tracked moving both along the slope as well as across the flat tops Meyer et al. (2007). In Guam, *A. virescens* are found along the outer reef slopes, in deep channels and in shallow lagoons at depths of 3-180 m (Amesbury and Myers 1982). Druzhinin (1970) reported *A. virescens* as deep as 150 fathoms (i.e., 274m). Talbot (1960) reported that *A. virescens* was more abundant in shallow water over coral reefs along the coast of East Africa. The deepest record found for Hawaiian waters was 227 m (UH data, 2010). Table 28 provides a habitat summary for this species.

Table 28: Habitat Description for *Aprons virescens* (gray snapper, uku)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown <227m	Unknown <227m	40-61m	0-227m
Water Column Zone	Pelagic	Pelagic	Benthic	Benthopelagic
Water Quality	Unknown	Unknown	Unknown	20-24 °C
Substrate Type	N/A	N/A	Hard, flat, coarse sand bottom	Top of banks, mixed sediment and rocks
Prey	N/A	Unknown	Unknown	Fish (89%), larval fish (6%), Planktonic crustaceans (1%), shrimp (3%) and crab (1%), (Haight 1989).

Bottomfish Complex: Shallow (0-240m depth range)

Species EFH descriptions:

Egg: pelagic zone, 0-240 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-240 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic or benthopelagic zone, 0-240 m depth range

Adult: benthopelagic zone, 0-240 m depth range

1.4.3.3 *Etelis carbunculus* (ruby snapper, ehu)Life History

Etelis carbunculus is in the subfamily Etelinae and is known in Hawaii as ehu. It is widely distributed throughout the Indo-Pacific region from East Africa to the Hawaiian Islands and from southern Japan to Australia (Allen 1985; Everson 1984). Like most bottomfish species, *E. carbunculus* is important in western Pacific fisheries but its life history is not well known (Ralston 1979). *E. carbunculus* is an important commercial species throughout its range and is taken primarily with deep-sea hand lines. This species ranks 7th in Hawaii in terms of average percent of the annual bottomfish catch since 1948 (WPRFMC, 2005).

In American Samoa, *E. carbunculus* is one of the most valuable species landed and comprised almost 9% of the total reported bottomfish landings in 1996 (WPRFMC 1997). However, a genetic analysis of this species found evidence for two genotypes in those islands, which indicates the presence of either two subspecies or completely separate species (Moriwake et al., 2000). These appear to have separate phenotypes as well, one growing to a much larger size than the other. This same study found only the smaller genotype present in Hawaii.

Polovina & Ralston (1986) reported that this species reaches sexual maturity in 2.75 yrs while Everson (1986a) reported it reached sexual maturity at approximately 30 cm FL in the NWHI. DeMartini & Lau (1999) more precisely identified the L50, or length at which 50% of the fish are mature, to be 27.9 cm FL for this species in the NWHI. More recent surveys in the MHI found one sexually mature female as small as 20.3 cm SL; however, with that exception aside, mature gonads were not observed in fish below 24 cm SL (UH data, 2010). Both Everson (1984) and DeMartini & Lau (1999) found that this species has a relatively short, well-defined spawning season of July to September in the NWHI. Closer to the equator at Vanuatu, spawning reportedly occurs throughout most of the year (Allen 1985). Both Everson (1984) and DeMartini & Lau (1999) reported that *E. carbunculus* are serial spawners, with females producing multiple batches of eggs during the spawning season. Everson (1984) reported that the sex ratio was skewed 2:1 in favor of females over males in the NWHI.

There have been very few taxonomic studies of the eggs and larval stages of lutjanids and as a result, very few larvae can be identified to species (Leis, 1987). Leis & Lee (1994) subsequently reported being able to distinguish differences between *E. carbunculus* and *E. coruscans* larvae larger than 13.7 mm. In 1999-2000, two *E. carbunculus* females were captured alive, one of which had completed final maturation at capture while the other was hormonally induced to undergo final maturation in a hatchery tank (Kelley et al., 2000, Kelley, 2004). The first female naturally completed ovulation and was “strip spawned” with several captured mature males to produce 129,000 eggs, 73% of which were fertilized. The eggs hatched 27 hrs after fertilization and the larvae survived for 10 days on no food since their larval diet was completely unknown. These were the first ever eggs and early larvae

observed for this species. Figure 7 provides images of the larval development through day 4. Images of 5-10 day old larvae were not included here since they appeared emaciated and therefore did not adequately represent natural development. Newly hatched larvae (D0) were characterized by an ellipsoidal yolk sac containing an oil droplet located at the anterior end.

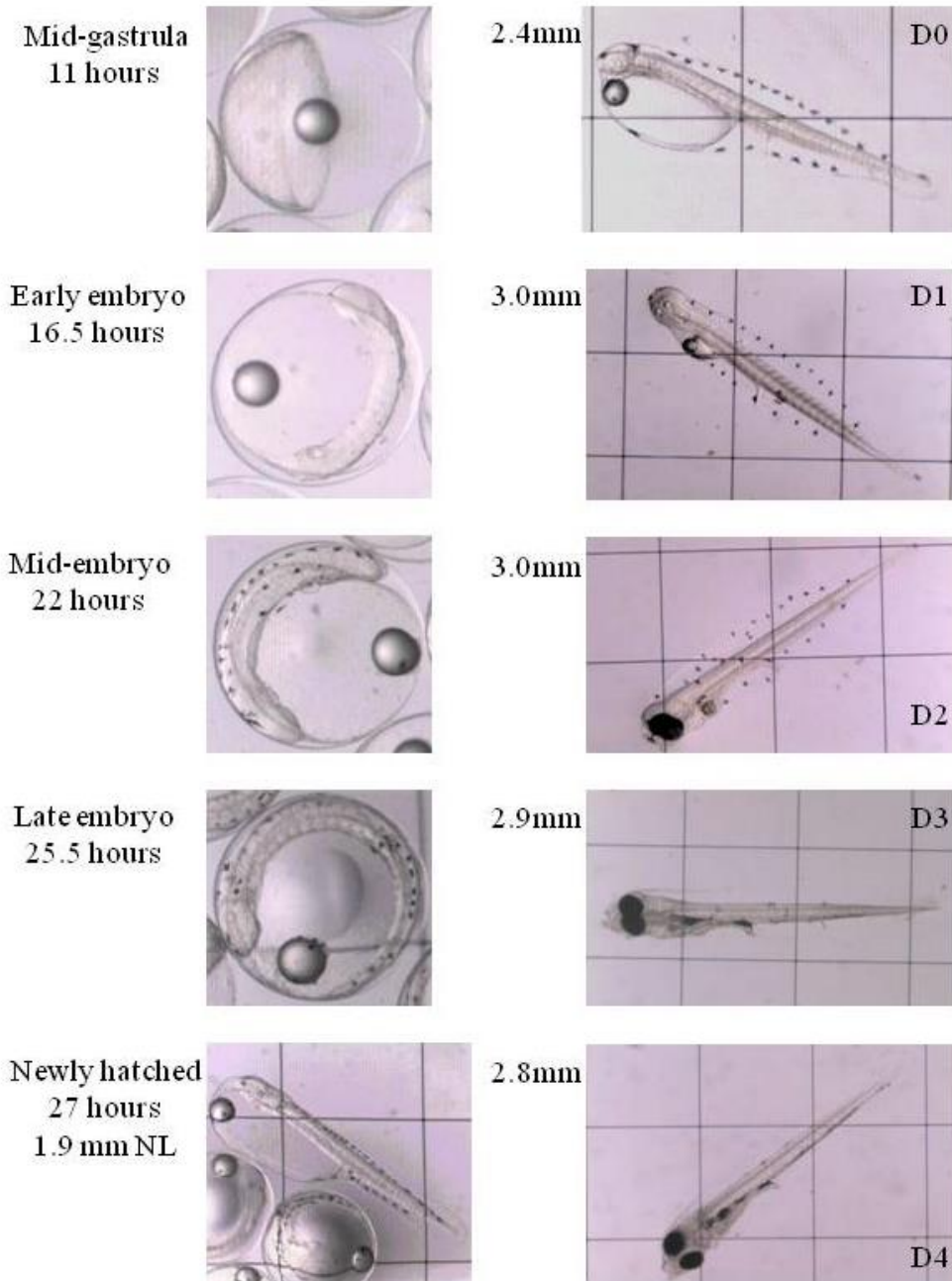


Figure 7: *Etelis carbunculus* egg and larval development at 25-27 °C. Spawning eggs were spherical and contained a single oil droplet. Gastrulation was well underway by 11 hours after fertilization (HAF) with

embryogenesis beginning 3 hours later. Hatching took place approximately 27 HAF. Yolk absorption was completed by day 2 post-hatch (PH). By days 3 and 4, the eyes were pigmented, pectoral fins were present, the mouth had opened and the larvae appeared to be able to ingest food if appropriate prey had been available (Kelley et al, unpub data).

The lenses in the eyes were present as were melanophores extending along the outer edges of the dorsal and ventral finfolds. By day 1 (D1) post-hatch, the yolk sac was greatly reduced, and by Day 2 (D2), was for the most part completely consumed. Melanophores were still present along the finfold edges and pigment was now visible in the eyes. Day 3 (D3) larvae had fully pigmented eyes, the mouth had opened and the finfold melanophores were almost completely absent. Day 4 (D4) larvae were similar in appearance to D3 larvae, perhaps due to the lack of feeding.

The second female was strip spawned, five days after capture and hormone injection, producing over 400,000 eggs, 80% of which were fertilized. The eggs from these two trials were used to conduct an incubation temperature experiment, the results from which suggest *E. carbunculus* eggs must reach shallow water in order to complete embryogenesis and hatching (Kelley et al., 2000, Kelley et al., unpub data). In both trials, eggs incubated in ambient surface temperatures (24 to 28°C) hatched, whereas eggs incubated at colder temperatures similar to what's found on adult habitats (15.0-19°C) arrested at the late multi-cell stage. Perhaps eggs spawned at adult depths, being buoyant, can reach the relatively warm mixed layer above 80 m before the late multi-cell stage.

Additional data obtained from studies on captive fish support the conclusion of Everson (1984) and DeMartini & Lau (1999) that this species spawns serially. One captive *E. carbunculus* female naturally spawned three times within a three week period, producing approximately 775,000 eggs (Kelley, 2004). In this and other cases, spawning took place at night.

E. carbunculus reportedly reach a maximum length of 90 cm (Randall, 2007). The Hawaii state record is 11.5 lbs or 5.2 kg (<http://www.hawaiifishingnews.com/records.cfm>). Parrish (1987) stated that, like most species of deepwater snappers, very little is known about the food habits of this species. In the Mariana Islands important prey items have been reported to include fish, benthic crustaceans and pelagic urochordates (Pyrosomida, Salpidae, and Dolioda). In Hawaii, Haight (1989) found that *E. carbunculus* mostly fed between 6:00pm and 8:00pm, with fish comprising almost 98% of the prey items followed by copepods, shrimp, crabs and octopuses. More recent submersible and fishing surveys (UH data, 2010) did not find any preference in feeding time for this species. *E. carbunculus* is a benthic species and the presence of pelagic prey in their stomach contents could be indicative of nocturnal feeding. Pelagic invertebrates and fishes such as pyrosomes and myctophids regularly come in close proximity to the substrate at night. Haight et al. (1993a) suggested

that the composition of the diet may be influenced by opportunistic feeding on temporarily abundant prey items. For example, the monacanthid, *Pervagor* sp., which accounted for 28.5% of the volume of gut contents, was one of the most abundant species seen in submersible observations of Penguin Bank during the time of the diet study. Table 29 provides a list of known prey for *E. carbunculus* showing the presence of both benthic and pelagic species in their diet.

Table 29: Combined *Etelis carbunculus* prey records: 33 stomachs (Haight et al., 1993b), 42 stomachs (Parrish et al., 2000), and regurgitated prey (Kelley, unpub data¹).

Group	Category/Family	Subcategory/Species
Mollusks	Bivalvia	unidentified
	Cephalopoda	unidentified
	Cephalopoda – octopods	unidentified
	Cephalopoda – squids	<i>Abralia trionura</i>
	Cephalopoda – squids	<i>Chiroteuthis</i> sp.
	Cephalopoda – squids	<i>Nototodarus hawaiiensis</i>
	Cephalopoda – squids	unidentified
	Gastropoda	unidentified
	Gastropoda - Heteropods	unidentified
	unidentified	unidentified
Annelids	Polychaeta	unidentified
Crustaceans	Benthic	unidentified
	Copepoda	Cyclopoida
	Copepoda	unidentified
	Decapoda - crabs	Anomura
	Decapoda - crabs	Brachyura
	Decapoda - crabs	<i>Munida plexaura</i> ¹
	Decapoda –crabs	unidentified
	Decapoda –crabs	xanthid crab
	Decapoda - shrimps	<i>Heterocarpus ensifer</i>
	Decapoda - shrimps	<i>Plesionika</i> sp? ¹
	Decapoda - shrimps	unidentified
	Ostracoda	unidentified
	Planktonic	unidentified
	unidentified	unidentified
Urochordates	Salpida	unidentified

	Thaliacea	unidentified	
Fishes	Callanthiidae	<i>Grammatonotus laysanus</i>	
	Engraulidae?	<i>Encrasicholina punctifer?</i> ¹	
	Epigonidae	<i>Epigonus occidentalis</i>	
	Nettastomatidae	unidentified	
	Serranidae	<i>Pseudanthias fucinus</i>	
	Monacanthidae	<i>Pervagor</i> sp.	
	Monacanthidae	unidentified	
	Myctophidae	<i>Benthoosema fibulatum</i>	
	Ogcocephalida	<i>Malthopsis</i> sp. ¹	
	Sternoptychidae	<i>Argyripnus brocki</i>	
	Symphysanodontidae	<i>Symphysanodon maunaloae</i>	
		unidentified	unidentified

Egg and Larval Habitat

E. carbunculus eggs and larvae are pelagic, the latter to at least 51 mm SL (Leis & Lee, 1994), however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 515m. Based on the incubation experiments described above, the eggs of this species need to reach a minimum of 120-180 m depth prior to hatching (note: depth range based on submersible temperature and depth data from bottomfish habitats in the MHI and NWHI).

The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

There is very little information available concerning the preferred juvenile habitat for this species. Parrish (1989) reported that the habitat requirements of the juveniles of several species of deepwater snappers are markedly different than those of adults. However, juvenile *E. carbunculus* have been observed from a submersible at the same depth and rocky habitat preferred by adults (Kelley et al., 1997). Immature ehu, less than 22 cm SL and presumed to be juveniles, were caught during fishing surveys in depths between 183-313 m while juveniles with 6 in (15 cm) FL were observed during submersible dives off North Oahu (Figure 8) and East Oahu at depths of 274-290 m and 300 m, respectively (UH data, 2010). Juvenile behavior is very similar to adults in that both stages have been observed as solitary individuals or in very small groups that associate very closely with the bottom. Cavities that provide shelter appear to be particularly important to this species in comparison to other species of bottomfish (Kelley et al., 2006).



Figure 8: *E. carbunculus* juvenile 6 in FL observed during dive P5-323 off north Oahu at a depth of 284 m.

Adult Habitat

E. carbunculus are found on the deepwater slopes of Pacific Islands in habitats having hard substrate of high structural complexity. Individuals are found solitarily or in small groups at depths of 90 to 350 m (Allen 1985, Everson 1984, Ralston & Polovina 1982). Haight (1989) found the catch rate for *E. carbunculus* was highest between 200-250 m on Penguin Bank in the MHI. *E. carbunculus* were recorded during 90 BotCam drop camera deployments in the MHI at depths of 192 to 325 m and in temperatures ranging from 10.70 °C to 19.11 °C and averaging 14.58 °C (Drazen, unpub data). This species has been recorded as deep as 515 m from the Pisces submersible (UH data, 2010). *E. carbunculus* is a benthic species in Hawaii, always being observed in very close association with natural hard bottom features such as ledges and holes as well as man made features such as shipwrecks and discarded large metal objects (Figure 9). This is one of the smallest species of bottomfish and even as adults, appears to be vulnerable to predation from other species of fish. Successful predatory attacks on this species by kahala (*S. dumerili*) have been recorded during submersible dives (Kelley unpub data). *E. carbunculus* has also been found in the stomach contents of *E. quernus* (Seki, 1984a). Unlike most other species of bottomfish, the adults of *E. carbunculus* require shelter and therefore are rarely observed venturing up into the water column. Table 30 provides a habitat summary for this species.



Figure 9: Adult *E. carbunculus* off east Oahu at 300m depth. This photo was taken during dive P5-433 (R. Moffitt, PI).

Table 30: Habitat Description for *Etelis carbunculus* (ruby snapper, ehu)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown <515m	Unknown <515m	183-313m	89-515m
Water Column Zone	Pelagic	Pelagic	Benthic	Benthic
Water Quality	>20 °C?	>20 °C?	10-15 °C	10.2-19.1 °C
Substrate Type	N/A	N/A	Hard substrate that has cavities for shelter and may include carbonate, basalt, or manmade objects. Slope and relief are of secondary importance.	Hard substrate that has cavities for shelter and may include carbonate, basalt, or manmade objects. Slope and relief are of secondary importance.
Prey	N/A	Unknown	Unknown	Include fish, benthic crustaceans and pelagic urochordates

Bottomfish Complex: Deep (0-400 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-400 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-400 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic zone, 80-400 m depth range

Adult: benthic zone, 80-400 m depth range

1.4.3.4 *Etelis coruscans* (flame snapper, onaga)

Life History

Etelis coruscans is in the subfamily Etelinae and has numerous common names around the world. In Hawaii it's known as the long-tailed red snapper (English) or by its more often used local name onaga. This species is widely distributed throughout the Indian and Pacific oceans from Hawaii to the east to Samoa, the Mariana Islands, the Cook Islands, Tuvalu and Vanuatu (Ralston, 1979). *E. coruscans* is the most highly prized of the bottomfish species and is one of only 3 species, including *A. virescens* and *P. zonatus*, caught in 2004 in significantly higher numbers than their annual average since 1948 (WPRFMC, 2005). It commands the highest price per pound of any bottomfish species landed in Hawaii (WPRFMC, 1997) and is presently the most important species in terms of the number of pounds caught and percentage of the total catch (WPRFMC, 2005). *E. coruscans* also accounted for 11% of the total reported BMUS landings in American Samoa and commanded the second highest price per lb of any species landed in the territory (WPRFMC, 1997). In the Northern Mariana Islands, *E. coruscans* was the single most abundant bottomfish species landed in 1996, accounting for almost 29% of the total catch, and commanded the highest price per pound of any bottomfish species. In Guam, this species comprised only about 3% of the total reported bottomfish landings yet is still considered a highly prized species. In the MHI, landings of *E. coruscans* are seasonal, increasing in or around the month of December when prices are highest, and decreasing during the early summer months.

Ralston (1979) reported the maximum size *E. coruscans* attains is 80 lb (36 kg) while Amesbury and Myers (1982) reported this species can reach 81 cm FL and weights of up to 20 kg. Most of those landed in Hawaii weigh less than 15 lbs (6.8 kg), with the mean in the NWHI being 4.28 and 5.45 kg for males and females, respectively (Everson, 1986b). The state record for this species is 28 lbs or 12.7 kg (<http://www.hawaiifishingnews.com/records.cfm>).

While little is known about the reproduction of *E. coruscans*, Everson (1986b) speculated that it is probably similar to its congener *E. carbunculus*. Polovina & Ralston (1986) estimated sexual maturity was reached at two years of age however, it has since been determined to take a minimum of 5-6 years when they reach 66.3 cm (Everson et al., 1989). In the NWHI, ripe ovaries were collected from *E. coruscans* in August and September however the study only took place during the summer months (Everson 1986b). Hydrating females have been caught August-October around the full moon (Holzman, pers comm) while vitellogenic females have been caught as early as April (UH data, 2010). In general, *E. coruscans* does appear to be a summer spawner similar to *E. carbunculus*.

As with other bottomfish species, there are almost no ecological or taxonomic studies of the eggs and larvae of *E. coruscans*. Recently a commercial bottomfisher (Greg Holzman)

obtained the first and only fertilized eggs of this species ever collected. In 2001, Mr. Holzman was trained in “strip spawning techniques and in September of that year, caught a ripe, adult *E. coruscans* female and two males that he was able to successfully strip and fertilize on his boat. This took place at 5 pm and the following day he sent 59,000 eggs to the Hawaii Institute of Marine Biology (HIMB) where they hatched at approximately 4:40 pm. Mr. Holzman again succeeded in strip-spawning *E. coruscans* in October, 2003, this time sending hatched larvae to HIMB. As a result of his efforts, detailed in Hawaii Fishing News, the first 46 days of *E. coruscans* larval development were documented and are summarized in Figures 10a-c (Kelley et al, unpub data). *E. coruscans* eggs and larvae were clearly shown to be pelagic. Furthermore, it was established that the larvae can be differentiated from *P. filamentosus* larvae as early as day 15 post-hatch.

Similar to *E. carbunculus* and *P. filamentosus*, embryonic development in *E. coruscans* occurs rapidly with hatching taking place approximately 24 hrs after fertilization (Figure 10a) at ambient surface temperatures. The large, ellipsoidal yolk sac of newly-hatched day 0 (D0) larvae containing an anterior oil droplet extended slightly beyond the head. The lenses in the eyes were present as were melanophores extending along the outer edges of the dorsal and ventral finfolds. By day 1 (D1) post-hatch, the yolk sac was greatly reduced. Developing pectoral fins and pigment in the eyes were visible and by day 3 (D3), the larvae had fully pigmented eyes, open mouths, and actively fed on copepods. Melanophores were fewer and were now located along the base of the finfolds, having for the most part disappeared from the edges.

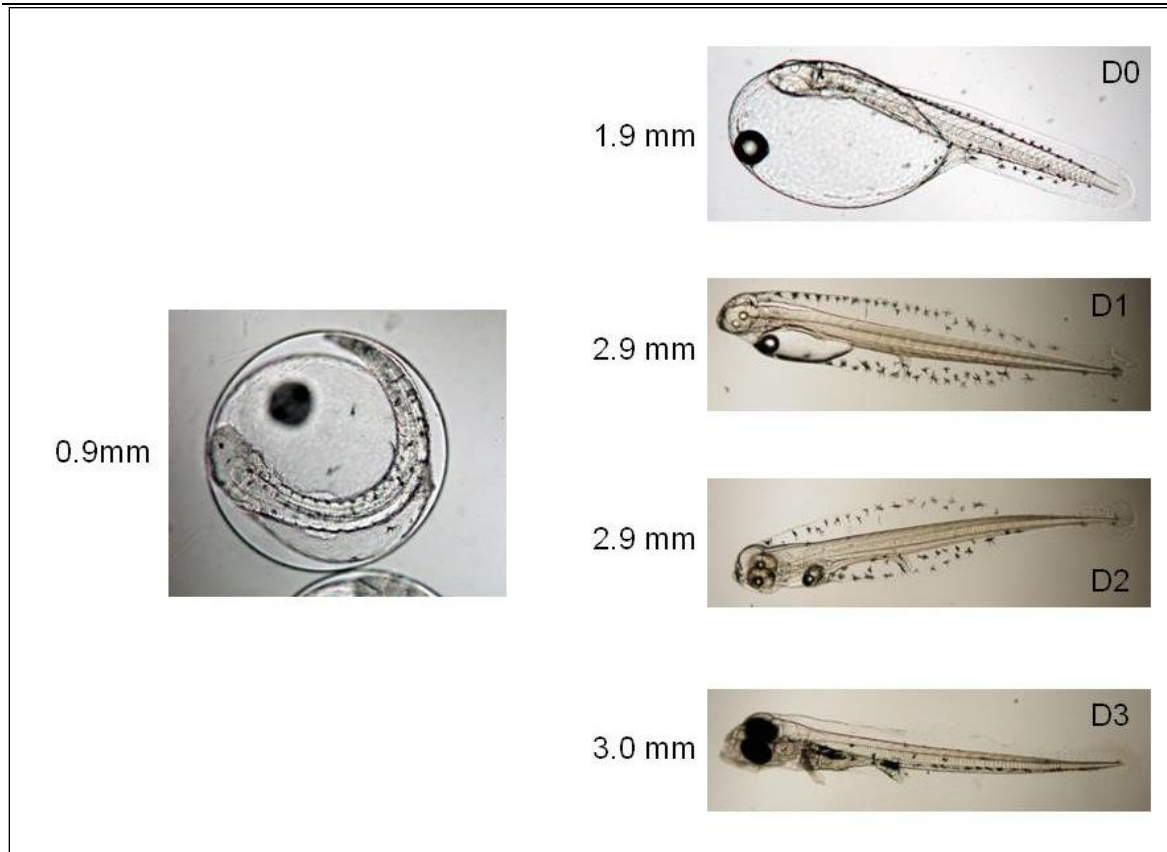


Figure 10a: Early development of *E. coruscans* from un-hatched late embryo (left) to three days (D3) post hatching (Kelley et al, unpub data).

Dorsal and pelvic fin spines were present in D15 larvae (Figure 10b). Melanophores were concentrated along the entire length of these spines in contrast to *P. filamentosus*, where they appeared only at the distal ends. This observation is consistent with Leis & Lee (1994) who reported for the genus *Etelis* the presence of “many dash-like closely-spaced melanophores in chevron groove of D_{sp2} and P_{2sp}” which were not present in *Pristipomoides* or *Aphareus*, and only present in D_{sp2} of *Aprion*. This difference in fin spine pigmentation appears to be the first easily observed character useful in differentiating the larvae of this species. Day 20 larvae showed continued dorsal fin development with spines both longer and in greater numbers. Melanophores were absent on the dorsal side of the tail in both D15 and D20 larvae, which is consistent with Leis & Lee (1994).

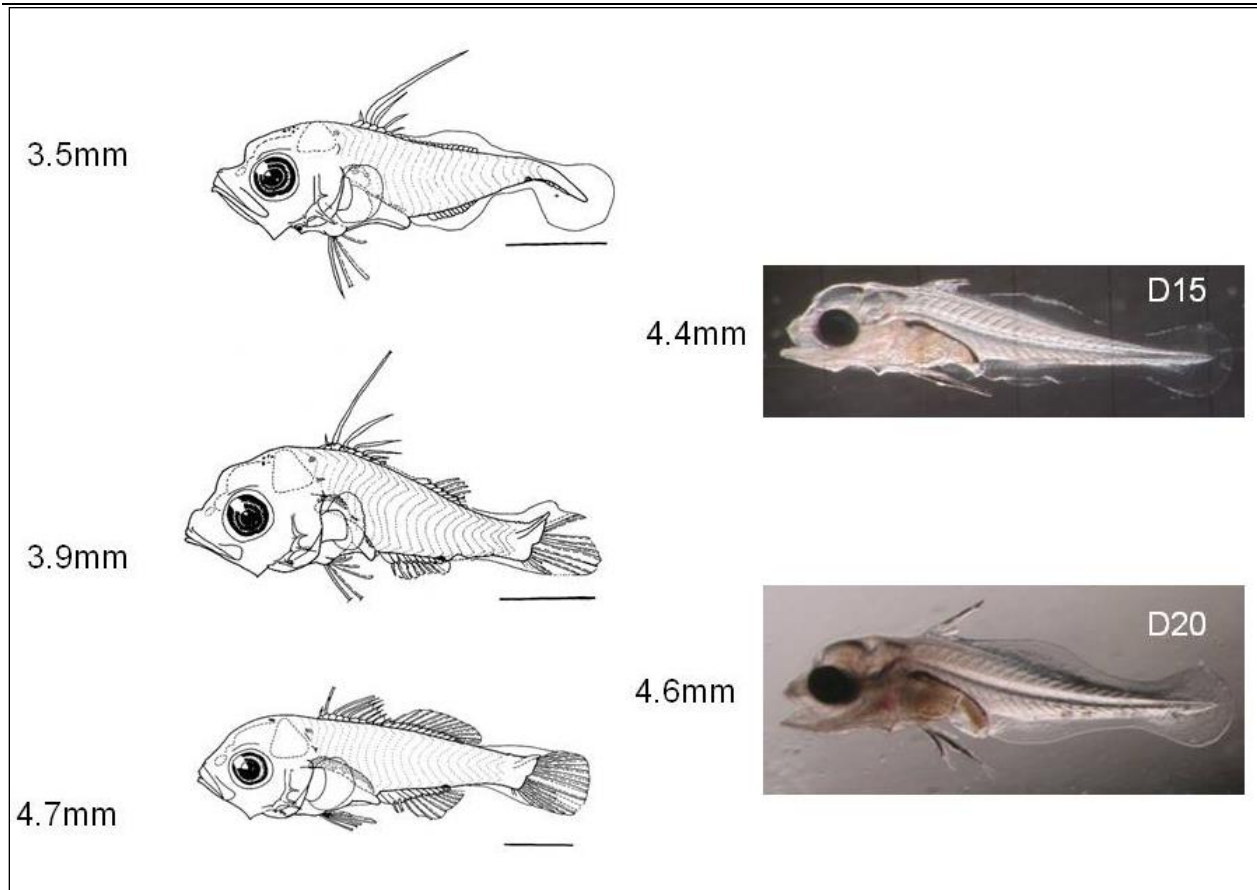


Figure 10b: Drawings of trawled wild *E. coruscans* larvae (left) ranging between 3.5-4.7 mm NL (notochord length) reproduced with permission from Leis & Lee (1994) adjacent to photographs of day 15 and day 20 hatchery reared *E. coruscans* larvae of roughly the same size (right, Kelley et al, unpub data).

Fins were relatively well developed and transparent scales were present by day 38 (Figure 10c). The melanophore series in P_{2sp} and Dsp₂ were still present however, the latter but not the former had spread out to other dorsal fin spines as was reported to occur in individuals larger than 8.7 mm NL by Leis & Lee (1994). Not noted in the previous study was the presence of red chromatophores, particularly along the base of the dorsal and anal fins extending down to the caudal peduncle. Red chromatophores were also present in a cluster over the urostyle as well as along the dorsal edge of the caudal fin where at the tip, a small number of melanophores were observed. This same pigmentation pattern was present in the day 46 larvae that had reached 14.0 mm SL.

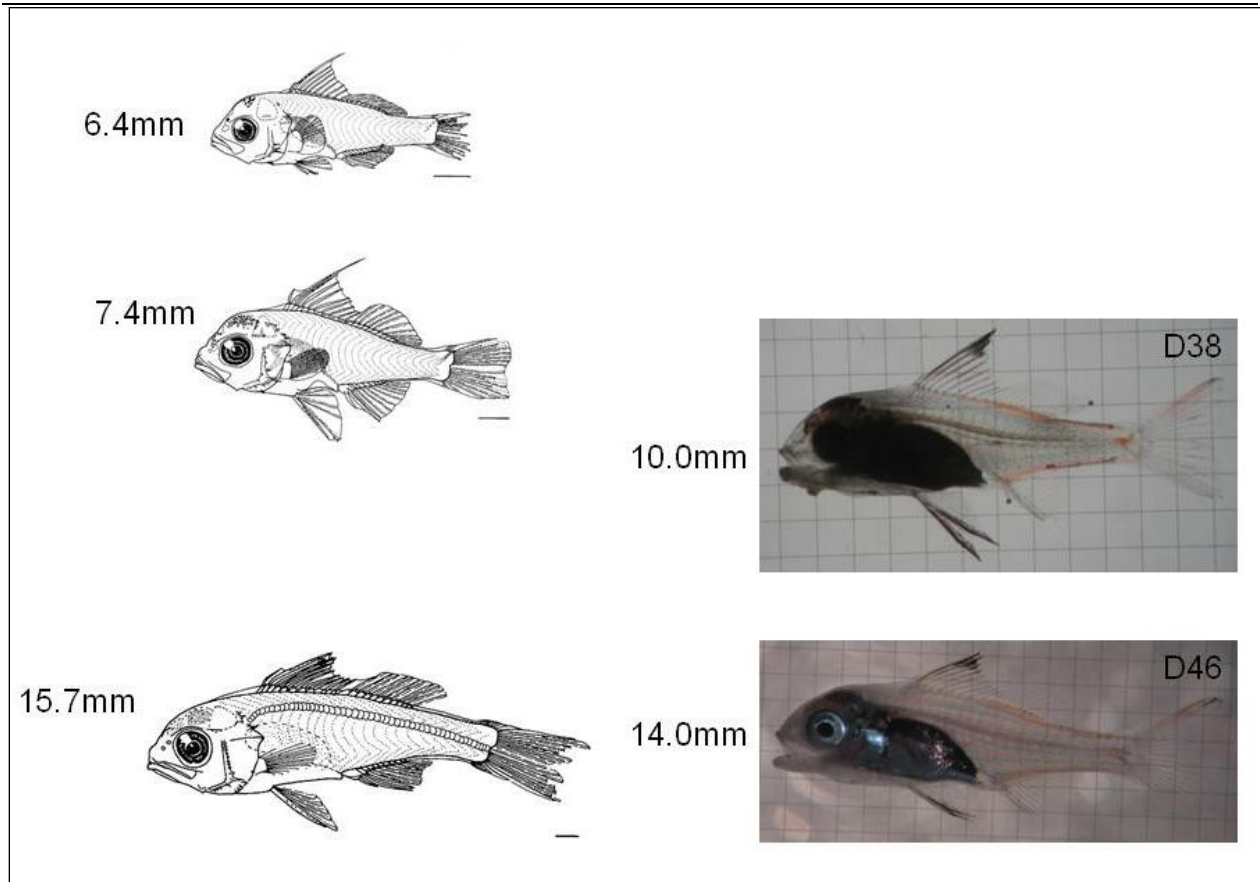


Figure 10c: Drawings of trawled wild *E. coruscans* larvae (left) ranging between 6.4-15.7 mm NL (notochord length) reproduced with permission from Leis & Lee (1994) adjacent to photographs of cultured *E. coruscans* larvae measuring 10.4 and 14.0 mm SL (Kelley et al, unpub data).

Haight (1989) found that peak feeding times for adult *E. coruscans* occurred during daylight hours, with the highest catch rates between 0600-0800 hours. Their diet included fish (76.4%), shrimp (16.4%), planktonic crustaceans (3.4%), cephalopods (2%), urochordates (1.5%) and crabs (.2%). Haight et al. (1993b) noted that some prey fish species have diel migration patterns, which depending on the time of feeding could be consumed near the bottom or in the water column. More recently, opportunistic collection of regurgitated prey yielded mostly pelagic prey species that included fish, shrimp, squids, the pelagic phase of an octopus and salps (Kelley et al., unpub data). Additionally, Kubodera et al (2009) reported a new species of bobtail squid, *Heteroteuthis ryukyuensis* n. sp. regurgitated by *E. coruscans* off Japan. A summary of all known *E. coruscans* prey from Hawaiian waters is provided in Table 31.

Table 31: Combined records of *Etelis coruscans*: 24 stomachs (Haight et al., 1993b), 9 stomachs (Parrish et al., 2000) and regurgitated prey (Kelley, unpub data¹).

Group	Category/Family	Subcategory/Species
Mollusks	Bivalvia	unidentified
	Cephalopoda – octopods	<i>Octopus</i> sp. ¹
	Cephalopoda – squids	<i>Abralia trigonura</i> ¹
	Cephalopoda – squids	<i>Abraliopsis</i> sp. ¹
	Cephalopoda – squids	<i>Enoploteuthis</i> sp. ¹
	Cephalopoda – squids	<i>Nototodarus hawaiiensis</i>
	Cephalopoda – squids	unidentified
	Cephalopoda	unidentified
	Gastropoda - Pteropods	<i>Diacra</i> sp.
	unidentified	unidentified
Crustaceans	Amphipoda	unidentified
	Benthic	unidentified
	Copepoda	Cyclopoida
	Decapoda - crabs	Brachyura
	Decapoda - crabs	Hippoidea
	Decapoda - crabs	Megalops larvae
	Decapoda - lobsters	slipper lobster parts ¹
	Decapoda - shrimps	<i>Heterocarpus ensifer</i>
	Decapoda - shrimps	<i>Oplophorus</i> sp. ¹
	Decapoda - shrimps	unidentified
	Euphausiacea	unidentified
	Ostracoda	Myodocopa
	Ostracoda	unidentified
	Stomatopoda	<i>Pseudosquilla oculata</i> ¹
	Planktonic	unidentified
	unidentified	unidentified
Urochordates	Larvacea	unidentified
	Pyrosomatidae	<i>Pyrosoma</i> sp.
	Salpida	unidentified
Fishes	Acanthuridae	<i>Naso</i> sp. ? pelagic phase ¹
	Bramidae	<i>Pterycombus petersii</i> ¹
	Epigonidae	<i>Epigonus</i> sp.
	Idiacanthidae	<i>Idiacanthus fasciola</i> ¹
	Myctophidae	<i>Diaphus</i> sp.
	Myctophidae	<i>Benthoosema fibulatum</i> ¹
	Myctophidae	<i>Lampadena urophaos</i> ¹
	Myctophidae	<i>Lampanyctus</i> sp. ¹
	Pomacanthidae	unidentified pelagic phase ¹
	Priacanthidae	unidentified ¹
	Stomiidae	<i>Astronesthes spendidus</i> ¹

	Trichiuridae	<i>Aphanopus</i> sp. ¹
	Trichiuridae	<i>Benthodesmus</i> sp. ¹
	unidentified	unidentified
Other	Algae	unidentified

DRAFT

Eggs and Larval Habitat

E. coruscans eggs and larvae are pelagic, the latter to at least 51 mm SL (Leis & Lee 1994). However, their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 457 m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Juvenile *E. coruscans* have been recorded during submersible dives at 222 m south of Lanai and 282-300 m off Oahu (Kelley et al, 1997; Ikehara, 2006; Figures 11a,b). In both cases, the substrate was hard carbonate. The juveniles were stationary and close to the bottom or hiding in cavities, and their locations were close to or part of known adult habitats. Additional observations of juveniles have been made on manmade wreckage at 350 m off the south coast of Oahu (Kelley, unpub data). Based on these observations, it appears that juvenile habitat for *E. coruscans* is natural or manmade hard substrate that provides shelter. Unlike *P. filamentosus*, juvenile habitat appears to be located at the same depth as adult habitat. In contrast to adults, juveniles are found in very close association with the bottom near cavities, presumably due to their greater vulnerability to predation.

Adult Habitat

Similar to its congener, *E. carbunculus*, *E. coruscans* is typically found at the deeper portion of the bottomfish depth range in association with areas of abrupt relief, such as steep drop-offs, ledges, outcrops and pinnacles (Everson 1986b, Moffitt 1993). A cluster analysis of bank catch composition in the Mariana archipelago determined that the banks can be grouped into three catch profiles: southern, northern and seamount clusters. The seamount cluster was characterized throughout the resource assessment by its higher proportion of *Etelis* species (*Etelis coruscans* and *E. carbunculus*), almost twice the amount of the other clusters (Polovina, 1985). In Hawaii, adults have been recorded on seamounts, pinnacles, canyons and promontories (UH data, 2010). In almost all cases, the fish have been swimming in schools from a few to tens of meters off the bottom. Unlike the benthic juveniles, adults are benthopelagic, which is consistent with the high proportion of pelagic prey in their diets.

Analyzing the overall CPUE distribution in Hawaii by depth intervals for all species landed, Haight (1989) found that *E. coruscans* are caught at the highest rate between depths of 250 and 300 m. The average hooking depth is slightly shallower than the 229 m found for the NWHI, and 218 m in the Northern Mariana Islands (Polovina et al., 1985). *E. coruscans* has been recorded on sixty-six BotCam deployments in Hawaii at depths of 208 to 308 m and in temperatures ranging from 11.65 °C to 18.98 °C (Drazen, unpublished data). This species has

been recorded down to a depth of 457 m on Pisces submersible dives (UH data, 2010). Table 32 provides a habitat summary for this species.

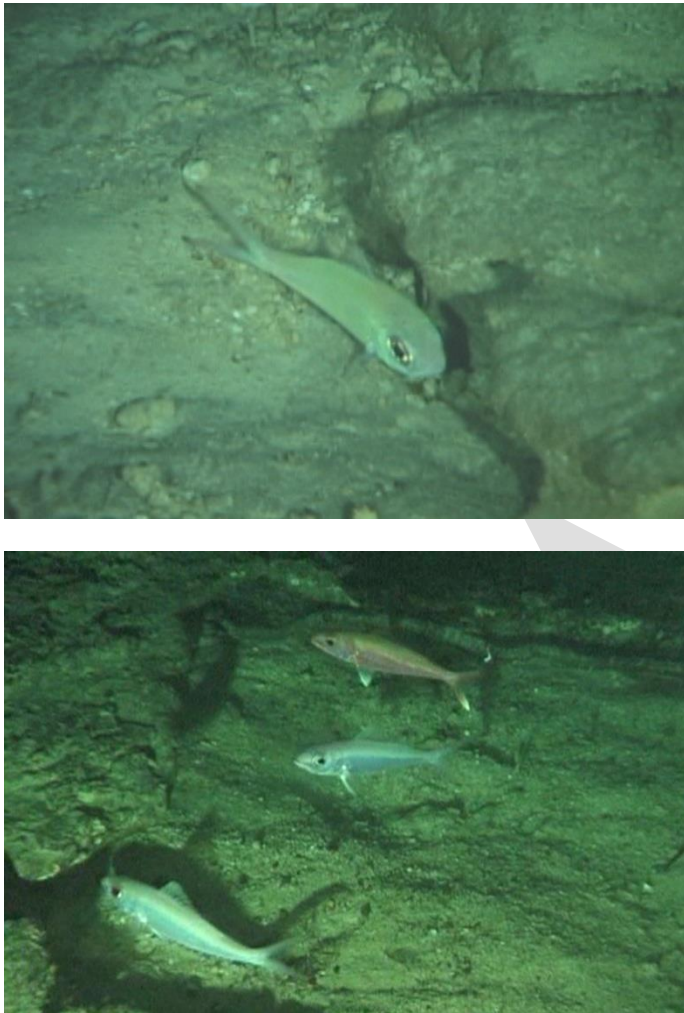


Figure 11: a) *E. coruscans* juvenile 6 in FL observed on dive P5-323 off north Oahu at 282 m (Kelley et al, 1997). b) *E. coruscans* juveniles 6-8 in FL (bottom and middle fishes) observed during a Pisces submersible dive 373 at 300 m depth off east Oahu (Ikehara, 2006). The fish on top is a small *E. carbunculus*.

Table 32: Habitat Description for *Etelis coruscans* (flame snapper, onaga)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	unknown <410m	unknown <410m	known between 222-350m	90-457m
Water Column Zone	Pelagic	Pelagic	Benthic	Benthopelagic
Water Quality	Unknown	Unknown	Unknown	11.65-18.98 °C
Substrate Type	N/A	N/A	Hard natural or manmade substrate with cavities	Areas of high relief, (e.g., steep slopes, pinnacles, headlands, rocky outcrops)
Prey	N/A	Unknown	Unknown	Fish (76.4%), shrimp (16.4%), planktonic crustaceans (3.4%), cephalopods (2%), urochordates (1.5%), crabs (0.2%) (Haight 1989).

Bottomfish Complex: Deep (0-400 m depth range)

Species EFH descriptions:

Egg: pelagic zone, 0-400 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-400 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic zone, 80-400 m depth range

Adult: benthic zone, 80-400 m depth range

1.4.3.5 *Lutjanus kasmira* (blue-lined snapper, taape)

Life History

Lutjanus kasmira is in the subfamily Lutjaninae and is the only non-eteline lutjanid in the bottomfish fishery. The native range of this species covers nearly the entire tropical and subtropical Indo-Pacific region; it is found from East Africa to the Line and Marquesas Islands and from Australia to Japan (Allen 1985, Druzhinin 1970). It also occurs in waters around Hawaii where it was introduced between 1955 and 1961 by the Hawaii Department of Land and Natural Resources (Oda & Parrish 1981). There are concerns among fishermen that *L. kasmira* may compete with commercially important native fish such as bottomfish, but available data from multiple studies do not support this claim (Oda & Parrish 1981; Parrish et al. 2000; DeFelice & Parrish 2003; Schumacher 2011). *L. kasmira* is one of the shallow members of the bottomfish fishery and most are landed in state waters (Ralston 1979) by hand lines, gill nets and traps (Allen 1985).

Very little is known about this species' life history in Hawaii, and currently most information comes from general reports (e.g. Allen 1985) or those from other locations (e.g. Rangjaran 1979). As with other lutjanids, *L. kasmira* is dioecious (Allen 1985). It generally reaches sexual maturity at 20-25 cm (Rangjaran 1979; Allen 1985). In an aquarium study in Japan, Suzuki & Hioka (1979) reported group spawning taking place in the evening and at night. Mizenko (1984) found in Samoa that spawning events occur with a lunar periodicity coinciding with the full and new moon over an extended spawning period during autumn and winter months. Rangjaran (1979) reported a peak spawning period from November to March in the Andaman Sea. Suzuki & Hioka (1979) describe fertilized eggs as being spherical and 0.78-0.85 mm in diameter. They also note that these eggs contain a single oil droplet and are buoyant. Hatching occurs approximately 18 hours after fertilization at 22 to 25°C under controlled conditions. Newly hatched *L. kasmira* larvae measure 1.83 mm in total length, possess a large ellipsoid yolk sac and are otherwise typical of the pelagic larvae of other fish species. The Hawaii state record for this species is just under 2 lbs or 0.9 kg (<http://www.hawaiifishingnews.com/records.cfm>), making it the smallest of all the species in this fishery. This species can attain a length of 32 cm (Randall 2007).

While some pelagic prey are found in their diets, *L. kasmira* would best be described as an opportunistic benthic carnivore. Studies in shallow water indicate this species is a nocturnal predator that preys primarily on small benthic fish and crustaceans such as portunid crabs, megalops and alpheid shrimp (Oda & Parrish 1981, Parrish 1987; DeFelice & Parrish 2003; Schumacher 2011). Similarly, a study of deepwater native eteline snappers and *L. kasmira* in the MHI found that benthic invertebrates were the predominant prey of *L. kasmira* (Parrish et al. 2000). In general existing data do not indicate that there are dramatic difference in the diets of young and adult fish of this species in Hawaii or elsewhere (Rangaran 1972; Oda & Parrish 1981; Schumacher 2011), though more focused study would be needed to fully understand

ontogenetic patterns in diets. Table 33 provides a summary of prey items identified in at least one fish by Parrish et al. (2000). Note that some fish identifications were listed as tentative by the authors.

DRAFT

Table 33: Food items in 180 stomachs of *Lutjanus kasmira* (Parrish et al., 2000).

Group	Category/Family	Subcategory/Species
Cnidarians/Ctenophores	unidentified	unidentified
Mollusks	Bivalvia	unidentified
	Cephalopoda	unidentified
	Cephalopoda – octopods	<i>Haliphron atlanticus</i>
	Cephalopoda – squids	<i>Abralia trigonura</i>
	Cephalopoda – squids	<i>Heteroteuthis hawaiiensis</i>
	Gastropoda	unidentified
	Gastropoda - Heteropods	unidentified
	Gastropoda - Pteropods	<i>Cavolinia</i> sp.
	Gastropoda - Pteropods	<i>Clio</i> sp.
	Gastropoda - Pteropods	<i>Creseis</i> sp.
	Gastropoda - Pteropods	<i>Diacra</i> sp.
	unidentified	unidentified
Annelids	Polychaeta	unidentified
Crustaceans	Amphipoda	Caprellidea
	Benthic	unidentified
	Copepoda	Calanoida
	Copepoda	Cyclopoida
	Copepoda	unidentified
	Decapoda - crabs	Anomura
	Decapoda - crabs	Brachyura
	Decapoda - crabs	Galitheidae
	Decapoda - crabs	Megalops larvae
	Decapoda - crabs	Portunidae
	Decapoda - shrimps	unidentified
	Euphausiacea	unidentified
	Ostracoda	Myodocopa
	Ostracoda	unidentified
	Planktonic	unidentified
	Stomatopoda	unidentified
	unidentified	unidentified
Urochordates	Larvacea	unidentified
	Salpida	unidentified
Fishes	Apogonidae	<i>Apogon kallopterus</i>
	Apogonidae	<i>Apogon maculiferus</i>
	Callanthiidae	<i>Grammatonotus laysanus</i>
	Carangidae	<i>Gnathanodon speciosus</i>
	Elopidae	<i>Elops hawaiiensis</i>
	Emmelichthyidae	<i>Emmelichthys struhsakeri</i>

Gempylidae	Species 2
Lutjanidae	<i>Aphareus furca</i>
Lutjanidae	<i>Aphareus rutilans</i>
Lutjanidae	<i>Lutjanus kasmira</i>
Lutjanidae	<i>Pristipomoides filamentosus</i>
Moridae	<i>Physiculus jordani</i>
Mullidae	<i>Parupeneus cyclostomus</i>
Myctophidae	Species 2

Group	Category/Family	Subcategory/Species
Fishes cont.	Myctophidae	Species 3
	Serranidae	<i>Luzonichthys</i> sp.
	Serranidae	<i>Plectranthisa helenae</i>
	Serranidae	<i>Pseudanthias fucinus</i>
	Soleidae	<i>Aseraggodes</i> sp.
	unidentified	unidentified
Other	Algae	unidentified

Egg and Larval Habitat

Leis (1987) estimated the pelagic larval phase of lutjanids in general to be 25-47 days, with species in the genus *Lutjanus* being shorter than that of the etelines. The depth and geographic ranges of their eggs and larvae are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 265 m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Juveniles of this species are known to utilize shallow water habitats such as seaward reefs and small patch reefs as nursery habitat (Myers 1991; Amesbury & Myers 1982; Frederick 1997). Friedlander et al. (2002) found most of the juveniles on their surveys “hiding in the interstitial spaces in small rubble piles on the talus slope below the reef slope”.

Adult Habitat

L. kasmira is found in a variety of habitat types and depths. *L. kasmira* is found from shallow inshore waters and lagoons to outer reef slopes down to a maximum depth of 265 m (Amesbury & Myers 1982; Myers 1991; Parrish et al. 2000; Friedlander et al 2002). Mizenko (1984) found in Samoa that except during spawning events *L. kasmira* was segregated by sex, with males dominating the deeper part of its range. It is not known whether this pattern occurs in Hawaii, though there are some indications that larger fish are found in deeper water (Morales-Nin & Ralston 1990). During the day, *L. kasmira* commonly forms large

aggregations near high relief bottom features such as prominent coral heads, ledges, caves, wrecks and patch reefs, and disperses at dusk to forage on benthic organisms—primarily crustaceans and fish—over surrounding sand or rubble (Myers 1991; Friedlander et al. 2002; DeFelice & Parrish 2003; Schumacher 2011). Schumacher (2011) found that in shallow waters (< 70 m) some fish move up to several hundred meters during these nocturnal feeding migrations, though Friedlander et al. (2002) found that larger fish may forage closer to daytime habitat. The extent of daily feeding migrations is not known for *L. kasmira* in deeper waters. This species has been recorded in the shallower extent of *P. filamentosus* depth range (UH data 2010; Parrish et al. 2000), but does not appear to co-occur frequently with other species of deepwater lutjanids in Hawaii. *L. kasmira* has been recorded during recent drop-camera deployments, submersible dives, and fishing surveys to a maximum depth of 200 m (UH data 2010). This species has been reported to reach a depth of 265 m (Randall 2007), though it is found at these depths relatively rarely. It is most common in water less than 150 m deep (Parrish et al 2000). Table 34 provides a habitat summary for this species.

Table 34: Habitat Description for *Lutjanus kasmira* (blue-lined snapper, taape)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown < 265m	Unknown < 265m	0-20m	3-265m
Water Column Zone	Pelagic	Pelagic	Benthic	Benthopelagic
Water Quality	Unknown	Unknown	Unknown	20.8-24.1 °C
Substrate Type	N/A	N/A	Unknown	Mixed rock and sediment
Prey	N/A	Unknown	Unknown	Primarily fish and crustaceans

Bottomfish Complex: Shallow (0-240m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-240 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-240 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic zone, 0-240 m depth range

Adult: benthic zone, 0-240 m depth range

1.4.3.6 *Pristipomoides auricilla* (yellowtail snapper, yellowtail kalekale)Life History

Pristipomoides auricilla is in the subfamily Etelinae and is called yellowtail kalekale in Hawaii.

This species is found in both the Indian and Pacific oceans, from Mauritius and Maldives Islands to the Hawaiian Islands and from New Caledonia to Japan (Randall, 2007). This species accounts for approximately 20% of commercial bottomfish catches in Guam, and was the second most common fish caught on a survey in the Mariana Islands (Randall, 2007). However, it comprises the smallest fraction of the bottomfish catch in Hawaii. On average, only 22 lbs have been reported per year since 1996, the first year it showed up in the catch (WPRFMC, 2005). In 2004, the annual reported catch was 54 lbs. *P. auricilla* attains a length of about 45 cm (Randall, 2007) with the Hawaii state record for this species being 2.9 lbs or 1.3 kg (<http://www.hawaii-fishing-news.com/records.cfm>). *P. auricilla* has been reported to reach sexual maturity in 2.4 yrs (Polovina & Ralston, 1986). However, its spawning season in Hawaii is presently unknown.

Seki & Callahan (1988) found *P. auricilla* in the Mariana Archipelago feed primarily on large pelagic plankton. Table 35 provides a summary of the prey species found in their study.

Table 35: Food items in 72 stomachs of *Pristipomoides auricilla* in the Mariana Archipelago (Seki & Callahan, 1988).

Group	Category/Family	Subcategory/Species
Mollusks	Cephalopoda	unidentified
	Cephalopoda – squids	Teuthoidea
	Gastropoda	unidentified
	Gastropoda - Heteropods	Atlantidae
	Gastropoda - Pteropods	Cavolinidae
Annelids	Polychaeta	unidentified
Crustaceans	Decapoda - crabs	Brachyura
	Decapoda - lobsters	Palinura
	Decapoda - shrimps	Caridea
	Euphausiidae	unidentified
	Stomatopoda	unidentified
	unidentified	unidentified
Urochordates	Pyrosomatidae	<i>Pyrosoma</i> sp.
Fishes	Gempylidae	unidentified
	Myctophiformes	unidentified
	unidentified	unidentified

Egg and Larval Habitat

P. auricilla eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 360 m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Nothing is known about the juvenile habitat for this species in Hawaii.

Adult Habitat

P. auricilla adult habitat has been described as rocky bottom between the depths of 90-360 m (Allen, 1985). This species has also been observed on rocky substrate in Hawaii between 124 and 352 m (UH data, 2010). Table 36 provides a habitat summary for this species. Only 63 records were found in a recent analysis of submersible, drop camera and fishing survey data (UH data, 2010). From these few observations, this species appears to be benthopelagic forming small to medium sized schools that swim relatively close to the bottom. This is a similar life style as that of the more common *P. sieboldii*.

Table 36: Habitat description for *Pristipomoides auricilla* (yellowtail snapper, yellowtail kalekale)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown, ≤360m	Unknown, ≤360m	Unknown, ≤360m	90-360m
Water Column Zone	Pelagic	Pelagic	Unknown but probably benthic	Benthopelagic
Water Quality	Unknown	Unknown	Unknown	18.5-22.3 °C
Substrate Type	N/A	N/A	Unknown	Rocky bottoms
Prey	N/A	Unknown	Unknown	Fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods

Bottomfish Complex: Deep (80-400 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-400 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-400 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic zone, 80-400 m depth range

Adult: benthic zone, 80-400 m depth range

1.4.3.7 *Pristipomoides filamentosus* (pink snapper, opakapaka)

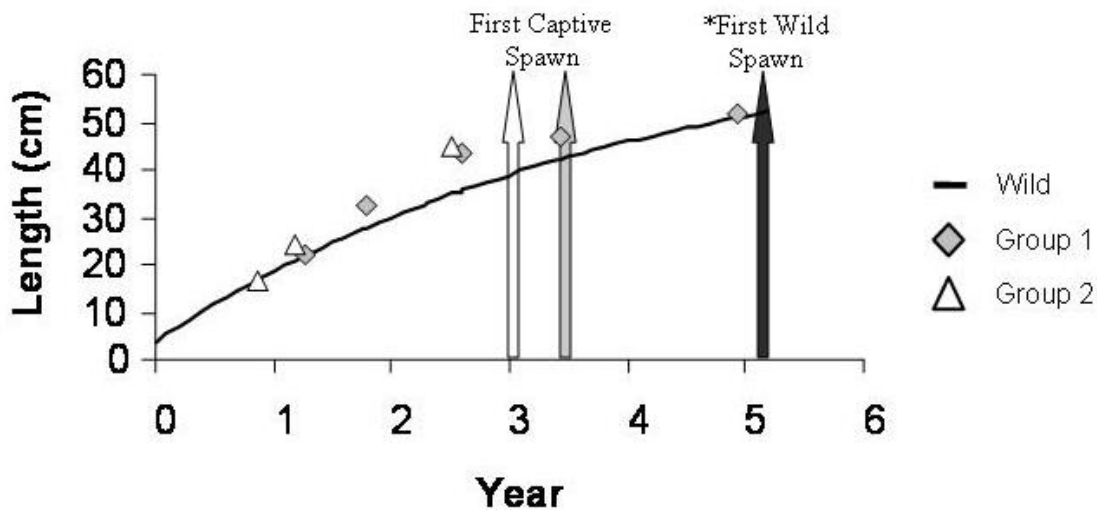
Life History

Pristipomoides filamentosus is in the subfamily Etelinae and is known in Hawaii as the opakapaka. This species is widely distributed from the Red Sea and East Africa to the Hawaiian Islands (Randall, 2007) and is common throughout the Indo-west Pacific region (Mees 1993, Druzhinin 1970). In Hawaii, *P. filamentosus* is the top ranked bottomfish species in terms of the average number of pounds caught per year since 1948 (WPRFMC, 2005). It has accounted for an average of 26.6% of the annual bottomfish catch, which is almost twice (i.e., 13.9%) that of the second ranked *A. virescens*. *P. filamentosus* comprises a smaller proportion of the catches (i.e., 1-10%) in American Samoa, Guam and the Northern Mariana Islands but is still considered one of the more important bottomfish species in these areas (WPRFMC, 1997).

P. filamentosus is a long-lived species capable of reaching an age of at least 40 years (A. Andrews, PIFSC, unpublished data). Previous research on the age and growth of opakapaka estimated a maximum age of 18 years (Ralston and Miyamoto, 1983). However, recent ageing research based on bomb radiocarbon and lead radium decay dating of archival otolith samples indicate that this species has a life span on the order of 40 years. (A. Andrews, PIFSC, unpublished data, in Brodziak et al., in prep). This suggests that the adult natural mortality rate of opakapaka, the most abundant and key Deep 7 bottomfish species, is on the order of $M=0.1$ (Brodziak et al. in prep). Growth rates for wild *P. filamentosus* have been estimated to range from 0.03 to 0.05 cm FL/day using the von Bertalanffy growth function (Ralston & Miyamoto, 1983, DeMartini et. al, 1994, Ralston & Williams, 1988b, and Hardman-Mountford et. al, 1997). Captive juveniles maintained in floating net pens in Hawaii have grown an average of 0.06 to 0.07 cm FL/day (Kelley et al, in prep). The latter however, should be considered a potential growth rate for this species since neither the temperature nor the feed were natural. This species can attain at least 80 cm in length (Randall, 2007) and the Hawaii state record is currently 18.5 lbs or 8.4 kg (<http://www.hawaiiifishingnews.com/records.cfm>).

Females of this species reach sexual maturity at a length of 42.7 cm (Kikkawa, 1984) which, based on the growth curve from DeMartini et al. (1994) is reached at just over 5 years of age (Figure 12). In captivity, *P. filamentosus* juveniles attained sexual maturity after two years when their age was estimated to be just over 3 years (Kelley et al., in prep). The results should be interpreted cautiously and with the understanding that the captive conditions did not mimic their natural environment. These fish were caught off Kaneohe Bay, Oahu, in 1999 and 2001 and held in floating net pens at the Hawaii Institute of Marine Biology (HIMB) under ambient surface seawater conditions. The “higher than natural” temperature and light conditions did not appear to negatively impact their reproductive cycles. Once the fish reached sexual maturity, they began spawning in the pens (Kelley et al., in prep). From 2001

though 2005, 568 natural spawns were documented from which approximately sixty million fertilized eggs were collected. In the first year, spawning occurred over a period of 5 months from June to October which is 2 months shorter than the 7 month, June to December spawning season reported from the wild (Kikkawa 1984). However, by 2005 the captive spawning season had expanded to 11 months (February to December) perhaps as a result of increased age or continued adaptation to warmer temperatures. Spawning took place during all lunar phases and up to 25 times in a single month. Individual *P. filamentosus* females spawned up to 31 times in a single year, releasing more than 3 million fertilized eggs (Moriwake et al 2004), which is an underestimate since an unknown number were lost out the sides of the pens.



*Based on age-length relationship (DeMartini et al, 1994) and size of spawning (Kikkawa, 1984).

Figure 12: Growth of *P. filamentosus* juveniles under captive conditions (Kelley et al., in prep) in comparison their published age-length curve from DeMartini et al. (1994). Also shown is their estimated age at first spawning in comparison to the predicted age of first spawning in the wild from Kikkawa (1984).

Captive *P. filamentosus* always spawned at night and the eggs were collected between 0730 and noon in mid-gastrula to mid-embryo stage. Spawning took place exactly between 9-10 pm on the one occasion the collector was monitored throughout the evening. Night time spawning has been reported in other lutjanids (Suzuki & Hioki, 1979, Hamamoto et al., 1992, Grimes, 1987). However, the only purported observation of wild *P. filamentosus* spawning

was in the mid-morning (Haight et al., 1993a). This was an anecdotal observation from a commercial fisherman in the NWHI and included a description of egg masses adhering to his fishing gear. Fertilized eggs of this and many other pelagic spawning species do not form masses and therefore this observation is suspect.

Little was known about embryonic development in *P. filamentosus* until captive spawning began in 2001. In the bottomfish hatchery at HIMB, the egg stage was documented from fertilization through hatching, which occurred 27 hours later in incubation temperatures between 24 and 26 °C (Figure 13a). Newly spawned eggs were spherical, ranged in size from 0.77 to 0.85 mm in diameter and typically contained a single, small (0.13 mm) oil droplet. Cell division began about an hour after fertilization and progressed to the 128 cell stage by 3 hours after fertilization (HAF). Blastulation was considered complete at the germ ring stage at 8 HAF. Gastrulation was well underway by 10.5 HAF and the embryo clearly began to form by 15.5 HAF. The mid-embryo stage was reached by 19 HAF when the embryo had optic vesicles and 15-17 somites. At this point, melanophores began to appear along the embryo's dorsal surface. Close to hatching (26 HAF) muscular contractions (i.e., embryonic twitching) began, their hearts had started beating and their tails detached from the yolk. One hour later the larvae hatched.

Newly hatched larvae measured 2.0 to 2.1 mm from the end of the head to the end of the notochord, which is referred to as the notochord length (NL). The large ellipsoidal yolk sac contained an oil droplet at the anterior end and extended slightly beyond the head (Figure 13a). The lenses in the eyes were present and rows of melanophores were visible along the dorsal and ventral finfolds, as well as a few scattered along the body and the yolk sac. One day later, the larvae had elongated to between 2.8 and 3.2 mm NL and had consumed the majority of the yolk. By two days post-hatch (D2), the mouth had opened, the eyes had pigmented, pectoral fins were present and very little remained of the yolk sac. At this point, the larvae began actively searching for food and those that had not fed by D5 did not survive. Similar to *E. coruscans* and *E. carbunculus*, the melanophores in D2-3 *P. filamentosus* larvae were fewer and were now located along the base of the finfolds, particularly on the ventral side.

Leis & Lee (1994) provided the best information available on post yolk sac larval stages of this and other eteline snappers, detailing the characteristics of variously sized trawled larvae that they had identified to species. Drawings of their *P. filamentosus* larvae are reproduced here in Figures 13b and 13c. To the right of these, are photos of similarly sized cultured larvae from rearing trials at the HIMB hatchery (Kelley et al. in prep). In cultured larvae, the swim bladder began to develop at D4 and the pelvic fins appeared at D10-14. The dorsal fin began forming shortly thereafter as the pelvic fins were elongating. Teeth and pre-opercular spines also appeared at this point.

Cultured *P. filamentosus* larvae developed at different rates within the same tanks, between tanks within the same trial and between trials. This variation was due to factors which are still largely unknown but undoubtedly included differences in temperature and feeding behavior (Kelley et al. in prep). Figure 13b shows two D15 larvae from two separate trials as an example. Larvae of this age ranged from 4.8 to 5.7 mm NL and some had completed flexion while others had not. Twenty day-old larvae, however, were generally all post-flexion and had clearly formed dorsal, anal and caudal fins. The ratio of pelvic fin length to body length reached its maximum between D15-20. At this point, the tip of the fins, when folded back, extended back to the ventral melanophore cluster before drawing back anteriorly after the larvae reached 30 days of age.

As mentioned earlier, the pigmentation patterns of *P. filamentosus* larvae were clearly different than those for *E. coruscans*, which was first apparent at D15. Melanophores were restricted to the tips of the dorsal and pectoral fin spines in *P. filamentosus* as opposed to extending along the extent of the spines in *E. coruscans*. A melanophore cluster also appeared at the base of the anal fin or at the bases of both the anal and dorsal fins in D15 larvae, which were not present in *E. coruscans* larvae. These pigmentation patterns were also shown in the 4.9bmm larvae provided by Leis & Lee (1994). A red chromatophore cluster was present over the urostyle in D15 larvae, as well as a modest row extending along the base of the anal fin and onto the caudal peduncle.

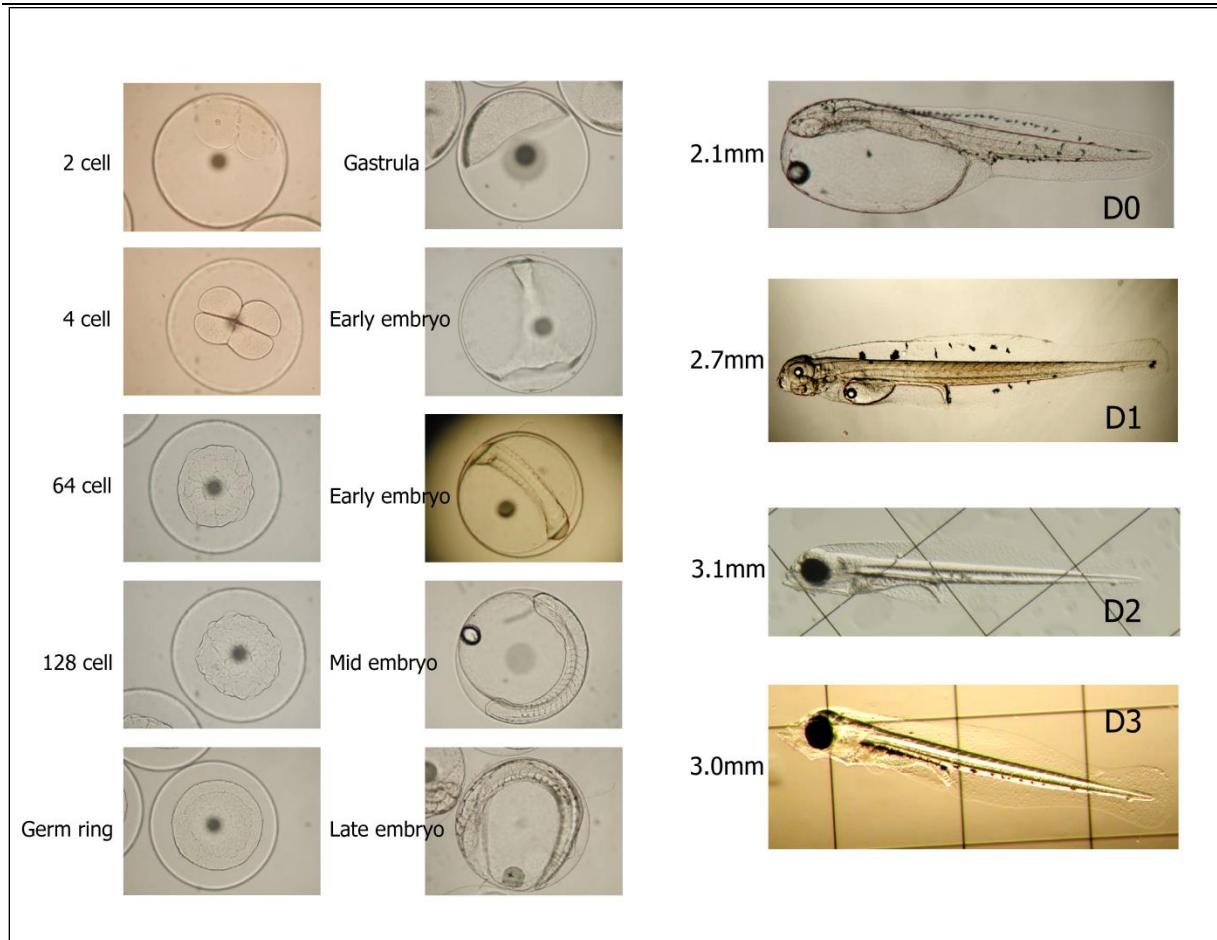


Figure 13a: Development of *P. filamentosus* eggs and larvae from 2 cell stage until three days after hatching.

By D27 (6.6mm NL), red chromatophores had also appeared at the base of the dorsal fin rays and were quite apparent over the urostyle (Figure 13c). Transparent scales had formed and the caudal fin had begun to fork by D30. By D33 the silvery lining of the abdominal cavity was obscuring the internal organs and a small number of red chromatophores had appeared on the front of the head. Melanophores persisted on the tips of the dorsal and pelvic fins spines through D39 but had disappeared from the caudal peduncle and the base of the anal and dorsal fins in the D39 larva shown in Figure 13c. The fork in the caudal fin became more pronounced and is mentioned here primarily because the caudal fins had been damaged in the specimens collected by Leis & Lee (1994). Also by D39, the pelvic fins appear noticeably shorter in relation to body length.

Figure 13d shows photos of cultured D52-120 larvae (right) next to a graph showing the growth rates of *P. filamentosus* larvae during hatchery rearing trials (left). At D52, the melanophores persisted at the tips of the dorsal and pelvic fins but had disappeared along the

anal fin and over the urostyle. Red chromatophores persisted over the urostyle and along the dorsal and anal fin posterior bases and the scales were still transparent. Moriwake (pers comm) that observed larvae around this age appeared to “settle” (i.e., began swimming much closer to the bottom) in the rearing tanks. In general, larvae of this size had not yet acquired scale pigmentation. Scale pigmentation generally appeared by D80, but this was variable and transparent larvae over 90 days old were sometimes observed (Figure 13d). By D120 metamorphosis was complete.

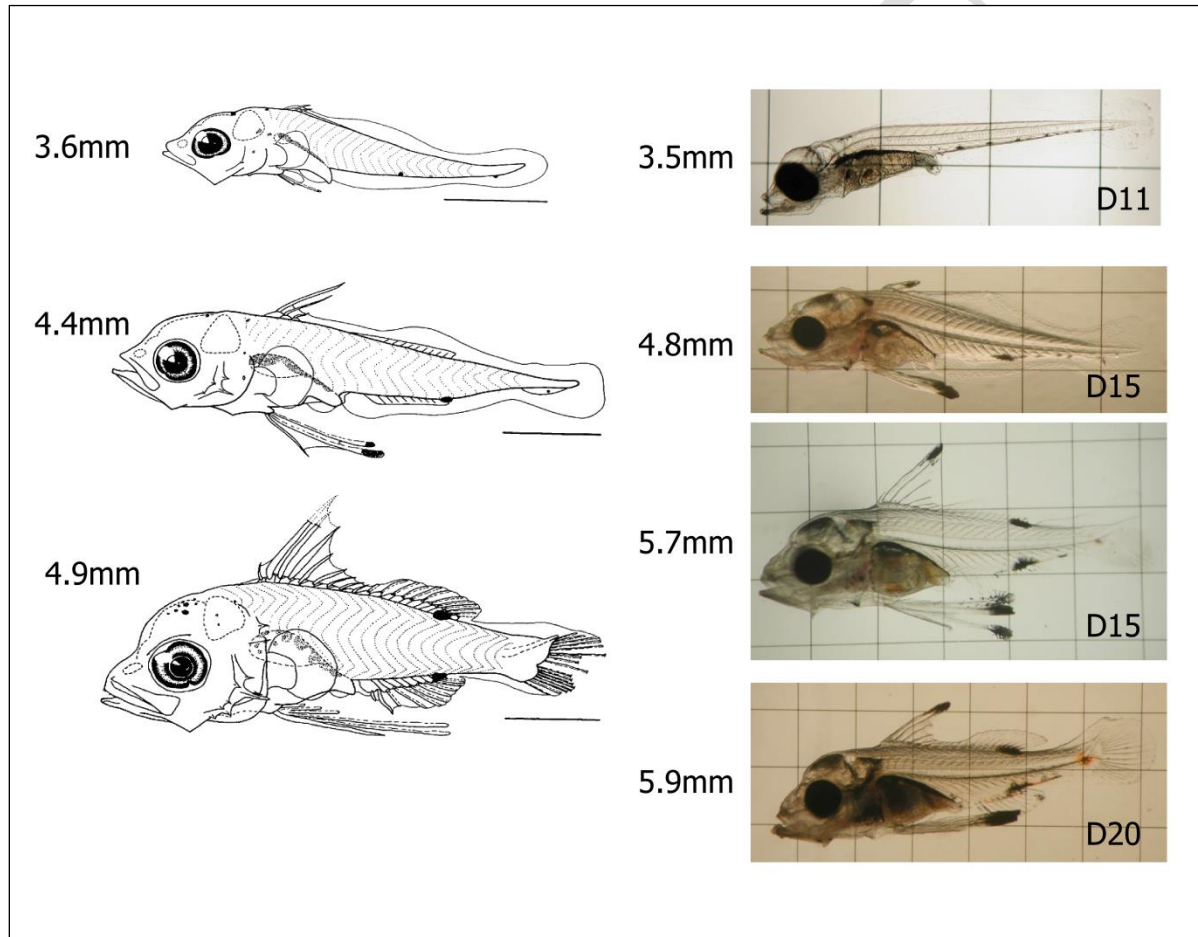


Figure 13b: Drawings of wild-caught larvae between 3.6-4.9mm NL reproduced with permission from Leis & Lee (1994) adjacent to photographs of cultured 11-20 day old *P. filamentosus* larvae from Kelley et al. (in prep).

The data on growth rates (Figure 13d on left) in captivity shows relatively low variability in lengths from D0 through D40. From D40 to D120, the variability increases significantly to the point where D120 larvae ranged in length from 40-110mm SL. This degree of variability is most

likely a reflection of our current ability to rear this species rather than the degree of variability that is occurring in the wild.

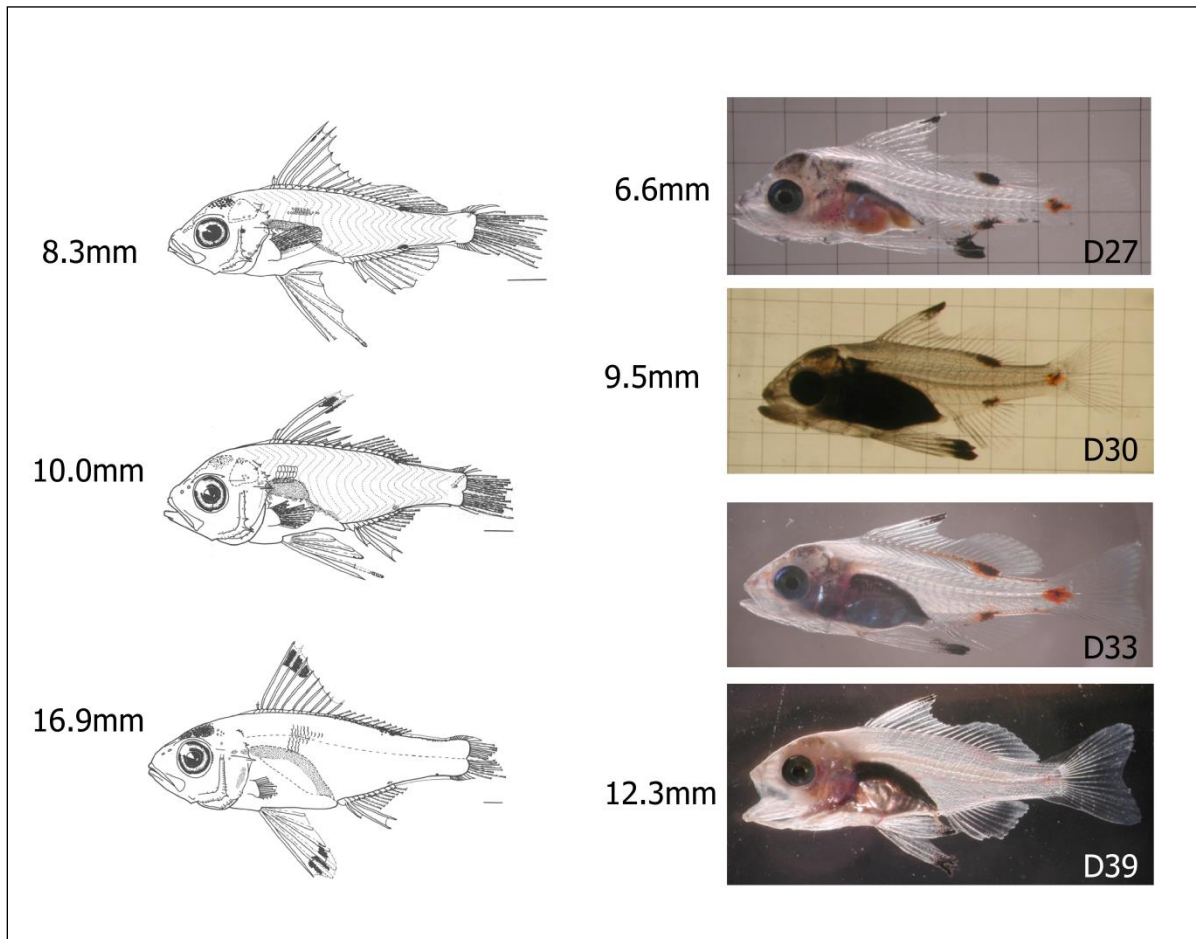


Figure 13c: Drawings of 8.3-16.9mm SL wild-caught *P. filamentosus* larvae reproduced with permission from Leis & Lee (1994) adjacent to cultured 27-39 day old *P. filamentosus* larvae measuring 6.6-12.3mm SL from Kelley et al. (in prep).

The natural diet of juvenile *P. filamentosus* off Kaneohe Bay, Oahu, comprises small crustaceans (crabs, shrimps and stomatopods), other juvenile fish, mollusks (octopods, squids, and micro gastropods) gelatinous plankton (salps and heteropods) and echinoids (Parrish, 1989, DeMartini et al., 1996). The diet of juveniles from a shallower location off the south shore of Oahu was pelagic crustaceans and salps (B. Schumacher, unpub data). Haight et al. (1993b) and Parrish (1987) included pelagic tunicates, fish, shrimp, cephalopods, gastropods, planktonic urochordates and crabs as prey items for this species in general.

It is of interest to note that in Malaysia, *P. filamentosus* are primarily piscivorous, feeding on ponyfish, *Leiognathus* spp. and purple-spot big-eye, *Priacanthus tayenus*, in addition to rabbitfish, *Siganus* spp., squids and crabs (Bachok et al, 2004).

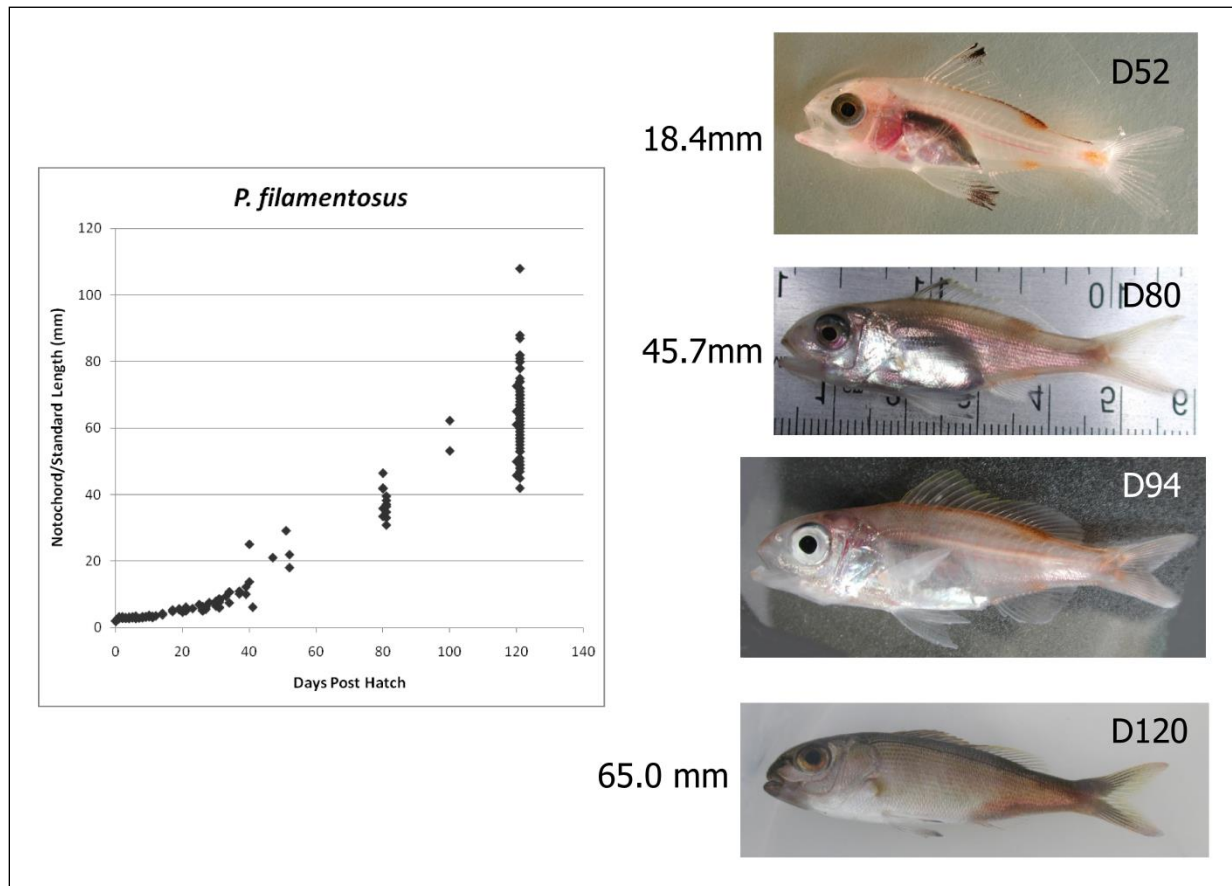


Figure 13d: Cultured 52-120 day old *P. filamentosus* larvae measuring 18.4-65mm SL (right) and left, a graph showing the growth rate of the larvae during hatchery rearing trials (Kelley et al., in prep.)

Parrish (1987) reported that this species forages over a wide area mostly at night while Haight (1989) characterized *P. filamentosus* as a crepuscular feeder, displaying two peak foraging periods, shortly before dawn and shortly after sunset. He also found this species to display a seasonal variation in its diet and later (Haight et al., 1993b) showed a diel variation in diet, feeding primarily on bioluminescent salps at night when they are easier to see. According to Parrish (1987), *P. filamentosus* feed primarily below 100 m and stay within several meters of the bottom, however its now known that this species comes up above 100 m at night (Ziemann & Kelley, 2004) where it appears to be foraging over sediment flats. Table 37 provides a summary of prey identified for this species.

Table 37: Combined records of *Pristipomoides filamentosus*: 54 stomachs (Haight et al., 1993b), 67 stomachs (Parrish et al., 2000), and regurgitated prey (Kelley, unpub data¹).

Group	Category/Family	Subcategory/Species
Cnidarians	Siphonophora unidentified	Diphyidae unidentified
Cnidarians/Ctenophores	unidentified	unidentified
Mollusks	Bivalvia Cephalopoda Cephalopoda – squids Cephalopoda – squids Gastropoda Gastropoda - Heteropods Gastropoda - Pteropods Gastropoda - Pteropods Gastropoda - Pteropods Gastropoda - Pteropods Gastropoda - Pteropods Gastropoda - Pteropods Gastropoda - Pteropods Micromollusks unidentified	unidentified unidentified <i>Abralia trigonura</i> <i>Sepioteuthis lessoniana</i> unidentified unidentified <i>Cavolinia</i> sp. <i>Clio</i> sp. <i>Creseis</i> sp. <i>Cuvierina</i> sp. <i>Diacra</i> sp. unidentified unidentified unidentified
Annelids	Polychaeta	unidentified
Crustaceans	Amphipoda Amphipoda Amphipoda Amphipoda Benthic Copepoda Copepoda Copepoda Decapoda - crabs Decapoda - crabs Decapoda - crabs Decapoda - shrimps Decapoda - shrimps Decapoda - Zoea Euphausiacea Isopoda Mysidacea Ostracoda Ostracoda Planktonic	Caprellidea Gammaridea Hyperidea unidentified unidentified Calanoida Cyclopoida unidentified Anomura Brachyura Megalops larvae Pandalidae unidentified unidentified unidentified unidentified Myodocopa unidentified unidentified

	Stomatopoda	<i>Lysiosquilla</i> sp. larvae
	Stomatopoda	<i>Odontodactylus</i> sp. larvae
	Stomatopoda	<i>Squilla</i> sp. larvae
	Stomatopoda	unidentified
	Stomatopoda	unidentified larvae
	unidentified	unidentified
Urochordates	Larvacea	unidentified
	Pyrosomatidae	<i>Pyrosoma</i> sp.
Group	Category/Family	Subcategory/Species
Urochordates cont.	Salpida	unidentified
	Thaliacea	unidentified
Fishes	Acanthuridae	<i>Zebrasoma</i> sp. pelagic phase ¹
	Gempylidae	Species 1
	Gempylidae	Species 2
	larvae	unidentified
	Malacosteidae	unidentified
	Melamphaidae	unidentified
	Monocanthidae	unidentified
	Myctophidae	Species 1
	Ostaciidae	unidentified
	unidentified	unidentified

Egg and Larval Habitat

Efforts are currently underway to model egg and larval dispersion patterns for this species in the main Hawaiian Islands. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 400 m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Juvenile *P. filamentosus* were first observed and documented in a featureless sediment flat (Figure 14) located offshore of Kaneohe Bay, Oahu at depths of 65-100 m (Parrish, 1989). This type of habitat is very different from the high relief rocky areas preferred by adults of the species. The Kaneohe site is now considered to be a nursery ground for this species based on repeated observations of juveniles over many years within its relatively narrow depth range and geographic extent. No juveniles were caught there in surveys below 100 m (Moffitt & Parrish, 1996). However, there have been unsubstantiated reports of catches by fishers at depths as shallow as 37 m (Kelley, pers comm). Parrish et al. (1997) found a significant correlation between the abundance of juvenile *P. filamentosus* and the presence of clay-silt

sediment suggesting this type of substrate is an important nursery habitat feature for this species. In contrast, significantly fewer juveniles were found in areas surrounded by small escarpments and exposed carbonate. Parrish (1989) posited the hypothesis that the lack of relief and hard substrate in this nursery ground made this area unattractive to predators thereby allowing the juveniles to “hide in plain sight”. The paucity of other species furthermore lessened inter-specific competition. The size range of juvenile *P. filamentosus* in the Kaneohe nursery ground was found to be approximately 7-20cm FL (Moffitt & Parrish 1996). DeMartini et al. (1994) conducted an age-length study and determined that 1 year old fish would be approximately 18 cm in FL. Parrish et al. (1997) concluded from these studies that juveniles remain in the nursery ground for less than a year before moving into deeper waters (e.g., 150-190m) where they presumably merge into schools of adult *P. filamentosus*.

Since 1989, other potential nursery grounds for *P. filamentosus* have been located in the MHI. From 1989 to 1994, Henry Okamoto of the state’s Division of Aquatic Resources (DAR) captured, tagged and released approximately 4,000 subadult/juveniles at locations off Oahu and in Maui County (Current Line, 2001). These fish were captured from 3 sites off Oahu and 8 sites from Maui County, specifically off Maui, Molokai and Lanai. Potential nursery grounds, where many juveniles were caught over time include both South Oahu and West Molokai. This study also provided clear evidence that this species was traversing channels between the islands which had previously been unknown. Parrish et al. (1997) found another nursery ground in 1993 off the southwest coast of Molokai. However, juvenile abundance at this site was not correlated with substrate type but rather sources of coastal drainage. Off Kaneohe, an internal, semi-diurnal tide was identified that provides an influx of cold water during high tide (Moffitt & Parrish 1996). Nutrients provided either by terrigenous material associated with outgoing tides or material carried from deeper water during incoming tides could be an important element of *P. filamentosus* nursery grounds. Parrish et al. (1997) suggested that the distribution of juvenile snappers within the nursery grounds may be more closely related to water flow and its enhancement of food supplies in these areas than sediment particle size. Finally, unpublished fishing surveys conducted for DAR between 1998 and 2007 identified more potential nursery grounds off the east and north coasts of Oahu outside Kailua, Kahana Bay and Haleiwa (UH data, 2010).



Figure 14: *P. filamentosus* juveniles recorded by the BotCam on the Kaneohe nursery ground (Merritt, unpub data).

All of these sites are shallow and have soft substrates similar to the Kaneohe nursery ground, which has led researchers to believe that juvenile *P. filamentosus* habitat is well understood. However, that is not the case. Recent BotCam deployments recorded juveniles at several locations off Hilo, Hawaii over very hard, rugose volcanic substrate (Figure 15, Drazen et al., unpub. data). These fish were at the larger end of the “juvenile size range” and therefore may have recently migrated from a more typical juvenile habitat. However, the possibility that settlement is occurring on hard substrate at some locations cannot be discounted.

Areas of flat featureless bottom have typically been thought of as providing low value fishery habitat. The discovery of dense juvenile snapper aggregations in areas of very low relief provides substantial evidence to the contrary. This fact has important management implications for the conservation and protection of this critical and limited habitat type. More research is clearly needed to identify and map nursery habitat for this particularly important species of bottomfish.



Figure 15: *P. filamentosus* juveniles recorded by the BotCam remote drop camera system over volcanic pillow lava formations off Hilo, Hawaii (Drazen et al., unpub data).

Adult Habitat

Adult *P. filamentosus* are typically found on the steep slopes and deepwater banks of Pacific Islands, aggregating near areas of high bottom relief (Parrish, 1987). Areas of high relief form localized zones of turbulent vertical water movement that increase the availability of prey items (Haight et al. 1993b). Ralston et al. (1986) found higher densities of *P. filamentosus* on the up-current side versus the down-current side of Johnston Atoll. Large mixed schools of snappers (50-100), including *P. filamentosus*, have been observed aggregating 2-10 m above high relief structures on Penguin Bank (Haight, 1989). However, more recent submersible surveys suggest that behaviorally these are not actual mixed schools but rather overlapping mono-specific schools (Kelley, pers comm) feeding in a common area. The presence of bait is an adequate stimulus to causes this type of overlap.

Moffitt (1993) reported that *P. filamentosus* adults are not restricted to high relief, deep-slope habitat. During the day, individuals are found in areas of high relief at depths of 100-200 m, however at night, they migrate into shallower flat, shelf areas, where they are found at depths of 30-80 m. This diel migration pattern is further supported by recent tracking studies conducted off the island of Kahoolawe (Ziemann & Kelley, 2004). Adults were tracked via surgically implanted VR2 transmitters that broadcast a signal detected by moored receivers.

Off Kahoolawe, adults repeatedly moved up into shallow sediment flats at night and returned to the rocky shelf drop-off during the day.

Haight (1989) found the greatest catch per unit effort (CPUE) for *P. filamentosus* on Penguin Bank at depths of between 100 and 150 m, but did not specify whether fishing took place during the day or night. Juvenile and adult *P. filamentosus* have recently been recorded during fishing, drop camera and submersible surveys between depths of 40-350 (UH data, 2010). Temperature data recorded from 127 BotCam deployments between 40-275 m, where this species was recorded, ranged from 11.74 °C to 24.37 °C (Drazen et al., unpub data). Finally, adult *P. filamentosus* occurs in progressively shallower waters (103 m) in the more northern reaches of the NWHI (Humphreys 1986b). Table 38 provides a habitat summary for this species.

Table 38: Habitat Description for *Pristipomoides filamentosus* (pink snapper, opakapaka)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown, ≤400m	Unknown, ≤400m	40-100m	55-400m
Water Column Zone	Pelagic	Pelagic	Benthopelagic	Benthopelagic
Water Quality	Unknown	Unknown	20.5 °C to 22.5 °C	11.7 °C to 24.4 °C
Substrate Type	N/A	N/A	Low relief, sediment, low slope	Generally high relief, rocky with steep slope
Prey	N/A	Unknown	Small crustaceans, juvenile fish, cephalopods gelatinous plankton, fish scale	Pelagic tunicates, fish, shrimp, cephalopods gastropods, planktonic urochordates, crabs

Bottomfish Complex: Intermediate (0-320 m depth range)

Species EFH Descriptions:

Egg: pelagic zone, 0-280 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-280 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic or benthopelagic zone, 40-100 m depth range

Adult: benthic or benthopelagic zone, 40-280 m depth range

:

1.4.3.8 *Pristipomoides sieboldii* (lavender snapper, kalekale)

Life History

The lavender snapper, *Pristipomoides sieboldii*, is a member of the subfamily Etelinae. This species ranged from East Africa to Hawaii and as far north as Japan (Randall, 2007). In Hawaii it is known as kalekale while in Guam and the Northern Mariana Islands it is called guihan boninas. *P. sieboldii* is common throughout the Hawaiian archipelago however, because of its relative small adult size it is not typically targeted by commercial fishers. This species is ranked 10th in terms of the average number of pounds landed per year in Hawaii since 1948 (WPRFMC, 2005). Based on the available landing data, *P. sieboldii* is also not a major contributor to the total catch in American Samoa, Guam and the Northern Mariana Islands. The maximum size of this species has been reported to be 60 cm or 24 in (Randall, 2007) although it doesn't often get larger than 40 cm (Allen 1985). The Hawaii state record for this species is 3.1 lbs or 1.4 kg (<http://www.hawaiifishingnews.com/records.cfm>).

DeMartini & Lau (1999) reported that *P. sieboldii* attained sexual maturity at a length of 29 cm FL, which based on estimated von Bertalanffy growth curves from Williams & Lowe (1997) is reached between 3-6 years of age depending on the method used. They found mature ovaries in females collected from June through September. Uchiyama & Tagami (1984) also reported that their spawning season ran from June through September, peaking in the last two months. Based on the presence of hydrated oocytes found in their ovaries, *P. sieboldii* eggs are pelagic and similar to the eggs of other eteline snappers. However, spawned eggs have not been documented to date. Leis & Lee (1994) provided descriptions of *P. sieboldii* larvae collected in Hawaii, noting that this species can possibly be distinguished from other eteline snappers by the presence of 69-72 lateral line scales and 17 pectoral rays. Its closest congener, *P. auricilla*, has a similar number of lateral line scales but generally only 15-16 pectoral fin rays. These two morphological characters are likely not present or distinguishable in larvae of either species younger than 20 days post hatch (PH).

Allen (1985) stated that *P. sieboldii* feeds primarily on fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods. Based on an examination of guts contents from 60 specimens, Haight et al. (1993b) described *P. sieboldii* as being primarily planktivorous. Table 39 provides a summary of known prey for this species.

Table 39: Combined prey records for *Pristipomoides sieboldii* from 60 stomachs (Haight et al., 1993b), and 32 stomachs (Parrish et al., 2000).

Group	Category/Family	Subcategory/Species
Cnidarians	Siphonophorae	Abylidae
	Siphonophorae	Diphyidae
Cnidarians/Ctenophores	unidentified	unidentified
Mollusks	Bivalvia	unidentified
	Cephalopoda	unidentified
	Cephalopoda - octopods	unidentified
	Cephalopoda – squids	<i>Onychoteuthis</i> sp.
	Cephalopoda – squids	<i>Pterygioteuthis giardi</i>
	Cephalopoda – squids	unidentified
	Gastropoda	<i>Cymatium/Bursa</i>
	Gastropoda	unidentified
	Gastropoda - Heteropods	unidentified
	Gastropoda - Pteropods	<i>Cavolinia</i> sp.
	Gastropoda - Pteropods	<i>Clio</i> sp.
	Gastropoda - Pteropods	<i>Creseis</i> sp.
	Gastropoda - Pteropods	<i>Cuvierina</i> sp.
	Gastropoda - Pteropods	<i>Diacra</i> sp.
	Gastropoda - Pteropods	unidentified
	Micromollusks	unidentified
	unidentified	unidentified
	Annelids	Polychaeta
Crustaceans	Amphipoda	Caprellidea
	Amphipoda	Gammaridea
	Amphipoda	Gammaroidea
	Amphipoda	Hyperidea
	Amphipoda	unidentified
	Benthic	unidentified
	Copepoda	Calanoida
	Copepoda	Cyclopoida
	Copepoda	unidentified
	Decapoda - crabs	Anomura
	Decapoda - crabs	Brachyura
	Decapoda - crabs	Megalops larvae
	Decapoda - crabs	unidentified
	Decapoda - lobsters	Palinuridae larvae
	Decapoda - shrimps	Alpheidae larvae
	Decapoda - shrimps	unidentified
	Decapoda - Zoea	unidentified
	Euphausiacea	unidentified
	Isopoda	unidentified

	Mysidacea	unidentified
	Ostracoda	Myodocopa
	Ostracoda	unidentified
	Planktonic	unidentified
	Stomatopoda	<i>Lysiosquilla</i> sp. larvae
	Stomatopoda	<i>Squilla</i> sp. larvae
	Stomatopoda	unidentified
	Stomatopoda	unidentified larvae
Group	Category/Family	Subcategory/Species
Crustaceans cont.	unidentified	unidentified
Chaetognaths	unidentified	unidentified
Urochordates	Doliolidea	<i>Doliolum</i> sp.
	Larvacea	unidentified
	Pyrosomatidae	<i>Pyrosoma</i> sp.
	Salpida	unidentified
	Thaliacea	unidentified
Fishes	Bothidae	<i>Engyprosopon</i> sp.
	Eel	unidentified ¹
	Larvae	unidentified
	Malacanthidae	<i>Malacanthus brevirostris</i>
	Melamphaidae	unidentified
	Monocanthidae	unidentified
	Myctophidae	<i>Diaphus</i> sp.
	Myctophidae	<i>Hygophum</i> sp.
	Myctophidae	unidentified
	Unidentified	unidentified

Egg and Larval Habitat

P. sieboldii eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 360 m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Juvenile *P. sieboldii* have been documented on two Pisces submersible dives, one in the MHI (Kelley et al., 1997) and the other in the NWHI (Kelley et al., unpub data). The first took place during dive P5-322 off the North shore of Oahu. A school of juveniles was encountered swimming very close to a bottom of low relief carbonate at a depth of 187 m (Figure 16). The second took place on dive P5-462 off Raita Bank. Juveniles along with subadults and adults were observed at 145 m over hard carbonate substrate. The former remained very close to the bottom and attempted to hide in holes as the submersible passed. A small number of juvenile

P. sieboldii have also been caught at 80 m on the *P. filamentosus* nursery ground off Kaneohe Bay, Oahu (UH data, 2010). Juvenile habitat for this species is therefore somewhat enigmatic, however, appears to be primarily on rocky substrate between 145-187m in the upper half of the adult depth range.

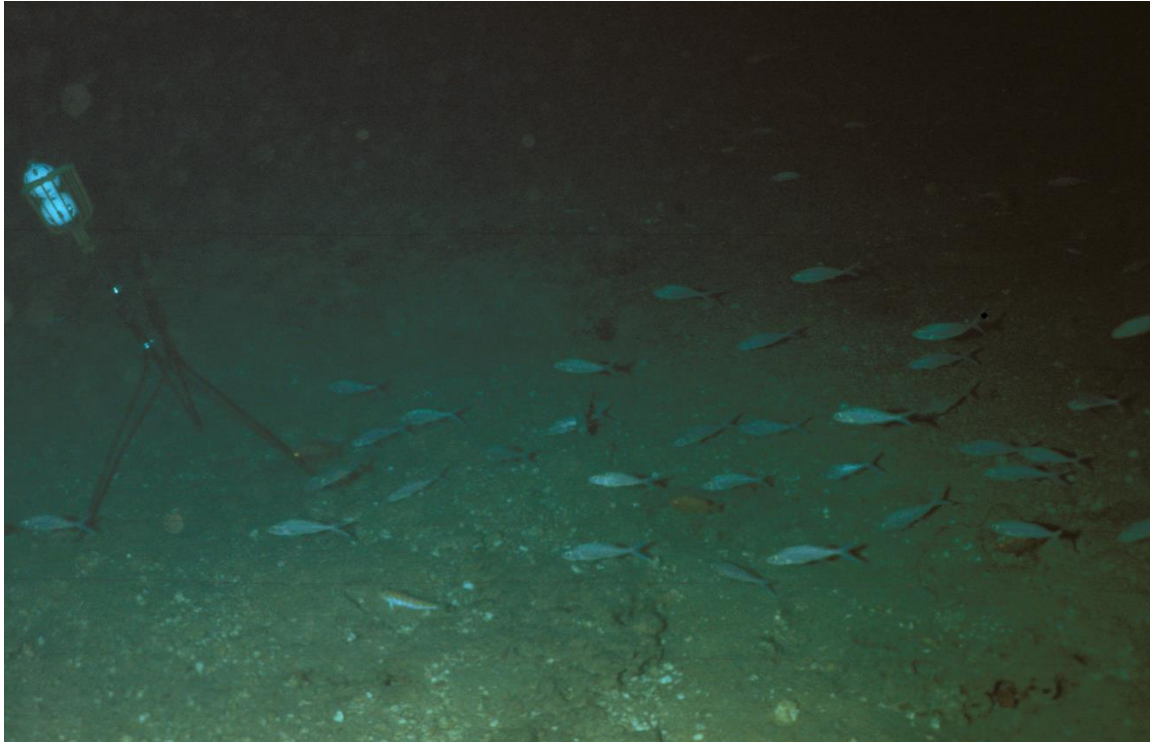


Fig. 16: Juvenile *P. sieboldii* recorded on Pisces dive P5-322 off the north shore of Oahu.

Adult Habitat

P. sieboldii adult habitat was previously described as rocky bottoms throughout the tropical Indo-Pacific region. More recent data supports their preference for hard substrate (UH data, 2010). Previous studies have reported their depth range as being 65-360 m (DeMartini & Lau, 1999; Randall, 2007). In Hawaii the majority of the observations have been made from 145-280 m (UH data, 2010) in temperatures typically ranging from 11.72 °C to 22.28 °C (Drazen et al., unpub data). This species is benthopelagic, forming schools that while coming up into the water column swim closer to the bottom than those of *P. filamentosus* and *E. coruscans*. Adults are smaller than either of those two species, and attacks by *S. dumerili* have been documented during submersible dives (Kelley et al., unpub data). Observations of their behavior are consistent with this species feeding primarily on planktonic prey. Based on its depth range, this species could be placed in either the intermediate or deep complexes. However, the adults are more often observed in the same area as *E. coruscans* and *E. carbunculus*. On that basis is considered to be part of the deep complex. Table 40 provides a habitat summary for this species.

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Table 40: Habitat description for *Pristipomoides sieboldii* (lavender snapper, kalekale)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown, ≤360	Unknown, ≤360	80-187m	65-360m
Water Column Zone	Pelagic	Pelagic	Benthic	Benthopelagic
Water Quality	Unknown	Unknown	Unknown	11.72 °C to 22.28 °C
Substrate Type	N/A	N/A	Primarily rocky	rocky bottom substrate
Prey	N/A	Unknown	Unknown	fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods

Bottomfish Complex: Deep (80-400 m depth range)

Species EFH descriptions:

Egg: pelagic zone, 0-400 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-400 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic zone, 80-400 m depth range

Adult: benthic zone, 80-400 m depth range

1.4.3.9 *Pristipomoides zonatus* (oblique-banded snapper, gindai)Life History and General Description

The oblique-banded snapper, *Pristipomoides zonatus*, is the final member of the subfamily Etelinae in Hawaii. This species is found from East Africa to Hawaii and is common in the IndoPacific from Japan to New Caledonia (Randall, 2007). Its local name in Hawaii is gindai. *P. zonatus* accounts for about 6% of the commercial bottomfish catch in Guam. However, it does not comprise a major fraction of the catch in Hawaii, ranking 12th in terms of the average number of pounds landed per year since 1948 (WPRFMC, 2005). Its maximum size has been reported to 45 cm or 18 in (Randall, 2007). The Hawaii state record for this species is 4.2 lbs or 1.9 kg (<http://www.hawaii-fishingnews.com/records.cfm>). *P. zonatus* has been reported to reach sexual maturity in 3.25 yrs (Polovina & Ralston, 1986). Its spawning season in the Marianas was reported to be April-September (Ralston & Williams 1988a), but is probably late summer in Hawaii, ("Current Line Fish Facts for Bottom Fishes of Hawaii"). In the NWHI, ripe ovaries have been collected in August (Uchiyama & Tagami 1984).

Haight et al. (1993b) reported that *P. zonatus* appeared to have a diet intermediate to the piscivorous (*Etelis sp.* and *Aprion virescens*) and the planktivorous (*P. filamentosus* and *P. sieboldii*) snappers. Seki & Callahan (1988) describe *P. zonatus* in the Mariana Archipelago as demersal carnivores. Prey specimens regurgitated by this species at capture in Hawaii were all benthic fish and invertebrates (Kelley, unpub data). The combined data from these sources and from Parrish et al. (2000) suggest that this species is primarily a benthic or demersal carnivore (Table 41). This is consistent with observations that *P. zonatus* is a benthic species, living either as solitary individuals or in small aggregations. Similar to *E. carbunculus*, this species has not been observed in schools.

Table 41: Combined prey records of *Pristipomoides zonatus*: 6 stomachs (Haight et al., 1993b), 23 stomachs (Parrish et al., 2000), 106 stomachs from the Mariana Archipelago (Seki & Callahan, 1988), and regurgitated prey (Kelley, unpub data¹).

Group	Category/Family	Subcategory/Species
Cnidarians/Ctenophores	unidentified	unidentified
Ctenophores	Ctenophora	unidentified
Mollusks	Cephalopoda	unidentified
	Cephalopoda - octopods	Octopoda
	Gastropoda	unidentified
	Gastropoda - Heteropods	unidentified
	Gastropoda - Pteropods	<i>Cavolinia sp.</i>
	Gastropoda - Pteropods	Cavolinidae
	Gastropoda - Pteropods	<i>Diacra sp.</i>

	unidentified	unidentified
Annelids	Polychaeta	unidentified
Crustaceans	Benthic	unidentified
	Copepoda	Cyclopoida
	Copepoda	unidentified
	Decapoda - crabs	Brachyura
	Decapoda - crabs	Galatheidae
	Decapoda - crabs	Megalops larvae
	Decapoda - crabs	<i>Munida</i> sp.
	Decapoda - crabs	Galatheidae ¹
	Decapoda - crabs	unidentified
	Decapoda - lobsters	<i>Scyllanus</i> sp. ¹
	Decapoda - shrimps	Caridea
	Decapoda - shrimps	Pandalidae
	Decapoda - shrimps	unidentified
	Ostracoda	unidentified
	Planktonic	unidentified
	Stomatopoda	unidentified
	unidentified	unidentified
Echinoderms	Ophiuroidea	unidentified
Urochordates	Larvacea	unidentified
	Pyrosomatidae	<i>Pyrosoma</i> sp.
	Salpida	unidentified
	Thaliacea	unidentified
Fishes	Anguilliformes	unidentified
	Ballistidae	unidentified
	Chaetodontidae	unidentified
	Congridae	unidentified
	Monocanthidae	<i>Pervagor</i> sp.
	Moridae	unidentified ¹
	Myctophidae	Species 2
	Ophichthidae	unidentified
	Ophidiidae	<i>Ophidion muraenolepis</i> ¹
	Ophidiidae	unidentified
	Serranidae	<i>Luzonichthys</i> sp.
	Serranidae	<i>Odontanthias elisabethae</i> ¹
	Serranidae	Anthiiae ¹
Group	Category/Family	Subcategory/Species
Fishes cont.	Serranidae	unidentified
	Symphysanodontidae	<i>Symphysanodon maualoae</i> ¹
	Symphysanodontidae	unidentified
	unidentified	unidentified

Egg and Larval Habitat

P. zonatus eggs and larvae are pelagic however their depth and geographic ranges are presently unknown. Based on the analyses described in sections 1.3.1 and 1.3.2, it is assumed that both the eggs and larvae range from the surface down to the lower limit of the adult depth range, which is 352m. The geographic extent of the egg habitat is estimated to be the first 50 mi of the EEZ while the larval habitat extends all the way out to the 200 mi EEZ boundary.

Juvenile Habitat

Very little is known about the distribution and habitat requirements for juveniles of this species. There have been only two observations of *P. zonatus* juveniles, both of which occurred during Pisces submersible dive P4-045 off the south coast of Kahoolawe in the MHI (Kelley, unpub data). Both juveniles were observed swimming very close to the bottom which was hard carbonate at a depth of 200m. One juvenile was accompanied by an adult (Fig. 17). The depth, substrate, and behavior of the juveniles were very similar to that of adults.



Fig. 17: Juvenile *P. zonatus* (right, top) with an adult (right, bottom) recorded during Pisces dive P4-045 at 200m off Kahoolawe. The juvenile was estimated to be 4 in SL.

Adult Habitat

P. zonatus adults are found in depths ranging from 70 to 352 m, and in Hawaii, it is most abundant from 160-280m in temperatures ranging from 13.65 °C to 19.75 °C (UH data, 2010). This species is benthic, found close to the bottom on rocky substrate as either solitary individuals or in small aggregations. It is often seen near ledges or other cavities that may serve as shelter. Attacks on this species from *S. dumerili* have been documented from the

Pisces submersible (Kelley, unpub data). Table 42 provides a habitat summary for this species.

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Table 42: Habitat Description for *Pristipomoides zonatus* (oblique-banded snapper, gindai)

	Egg	Larvae	Juvenile	Adult
Geographic Area	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago	Hawaiian Archipelago
Depth Range (m)	Unknown, ≤352m	Unknown, ≤352m	200m	70-352m
Water Column Zone	Pelagic	Pelagic	Benthic	Benthic
Water Quality	Unknown	Unknown	Unknown	13.7-19.8 °C
Substrate Type	N/A	N/A	rocky bottom	Rocky bottom
Prey	N/A	Unknown	Unknown	Benthic fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods

Bottomfish Complex: Deep (80-400 m depth range)

Species EFH description:

Egg: pelagic zone, 0-400 m depth range from shoreline out 50 mi

Post Hatch Pelagic: pelagic zone, 0-400 m depth range from shoreline to EEZ

Post Settlement and Sub Adult: benthic zone, 80-400 m depth range

Adult: benthic zone, 80-400 m depth range

1.5 Bibliography

1.5.1 Cited References

- Afonso, P., J. Fontes, T. Morato, K. Holland and R.S. Santos (2008). Reproduction and spawning habitat of white trevally, *Pseudocaranx dentex*, in the Azores, central north Atlantic. *Scientia Marina* 72(2): 373-381.
- Allen R. 1985. FAO species catalogue. Vol. 6. Snappers of the world. FAO. Fisheries synopsis no 125, volume 6. 208 p.
- Amesbury S. & R. Myers. 1982. Guide to the coastal resources of Guam. Vol. 1, The fishes. Univ. Guam Pr. University of Guam Marine Laboratory contribution nr 17.
- Bachok Z, Mansor MI, Noordin RM. 2004 Diet composition and food habits of demersal and pelagic marine fishes from Terengganu waters, east coast of Peninsular Malaysia. *Naga, WorldFish Center Q.* 27(3&4):41-47.
- Boland R. & F. Parrish. 2005. A description of fish assemblages in the black coral beds off Lahaina, Maui, Hawai'i. *Pac. Sci.* 59: 411-420.
- Brodziak J., R. Moffitt, & G. DiNardo. 2009. Hawaiian Bottomfish Assessment Update for 2008. Pacific Islands Fisheries Science Center Administrative Report H-09-02. 93p.
- Clarke, T. 1991. Larvae of Nearshore Fishes in Oceanic Waters near Oahu, Hawaii. NOAA. Technical report NMFS 101.
- Cowen R., C. Paris & A. Srinivasan. 2006. Scaling of Connectivity in Marine Populations. *Science.* 311:5760. 522-527.
- Current Line Fish Facts for Bottom fishes of Hawaii. DLNR Division of Aquatic Resources.
- DeFelice RC & Parrish JD (2003) Importance of benthic prey for fishes in coral reef-associated sediments. *Pacific Science* 57: 359-384.
- DeMartini E., K. Landgraf, & S. Ralston. 1994. A re-characterization of the age-length and growth relationships of the Hawaiian snapper *Pristipomoides filamentosus*. NOAA Technical Memorandum NMFS-SWFSC-199. 15pp.
- DeMartini E. & B. Lau. 1999. Morphometric Criteria for Estimating Sexual Maturity in Two Snappers, *Etelis carbunculus* and *Pristipomoides sieboldii*. *Fish Bull.* U.S. 97: 449-458.
- DeMartini E., Parrish F., and Ellis D. (1996) Barotrauma-associated regurgitation of food: implications for diet studies of Hawaiian pink snapper, *Pristipomoides filamentosus* (family Lutjanidae) *Fish Bull.* 94(2): 250-256.

- DeMartini E., A. Everson, & R. Nichols. 2010 Estimates of body sizes at maturation and at sex change, and the spawning seasonality and sex ratio of the endemic Hawaiian grouper (Hapuupuu, *Hyporthodus quernus*, F. Epinephelidae). *Fish Bull.* 109:123-134.
- Druzhinin A. 1970. The range and biology of snappers (family Lutjanidae). *J Ichth.* 10:717-36.
- Everson A. 1984. Spawning and gonadal maturation of the ehu, *Etelis carbunculus*, in the Northwestern Hawaiian Islands. In: Grigg RW, Tanoue KY, editors. Proceedings of the second symposium on resource investigations in the Northwestern Hawaiian Islands; 1983 May 25-27; Honolulu, HI. Honolulu: University of Hawaii. p 128-48. Report nr ANYHOW-SEAGRANT-MR-84-01 volume 2.
- Everson A. 1986a. Ehu. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwest Hawaiian Islands. p 106-7. NOAA. Technical report NMFS 38.
- Everson A. 1986b. Onaga. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwestern Hawaiian Islands. p 108-109. NOAA. Technical report NMFS 38.
- Everson A., H. Williams, & B. Ito. 1989. Maturation and reproduction in two Hawaiian eteline snappers, uku, *Aprion virescens*, and onaga, *Etelis coruscans*. *Fish. Bull.* 87(4):877-888.
- Everson A. 1992. Sexual maturity and seasonal spawning of Hapuupuu, *Epinephelus quernus*, in Hawaii. Southwest Fisheries Science Center Admin Report H-92-13. 14pp.
- Fishery Science: the unique contributions of early life stages. Edited by L. Fuiman & R. Werner. Blackwell Science LTD. 2002. 336p.
- Frederick JL (1997) Post-settlement movement of coral reef fishes and bias in survival estimates. *Marine Ecology Progress Series* 150: 65-74.
- Friedlander A., J. Parrish, & R. DeFelice. 2002. Ecology of the introduced *Lutjanus kasmira* (Forsskal) in the reef fish assemblage of a Hawaiian bay. *J. Fish Biol.* 60:28-48.
- Genin A., P. Dayton, P. Lonsdale, & F. Spiess. 1986. Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. *Nature* 322: 59-61.
- Genin A. 2004. Bio-physical coupling in the formation of zooplankton and fish aggregations over abrupt topographies. *Journal of Marine Systems* 50(1-2), 3-20.
- Grimes C. 1987. Reproductive biology of Lutjanidae: a review. In: Polovina J, Ralston S, editors. Tropical snappers and groupers: biology and fisheries management. Boulder, CO: Westview Pr. p 239-94.

- Haight W. 1989. Trophic relationships, density and habitat associations of deepwater snappers (Lutjanidae) from Penguin Bank, Hawaii [MS thesis]. Honolulu: University of Hawaii.
- Haight W, D. Kobayashi, K. Kawamoto. 1993a. Biology and management of deepwater snappers of the Hawaiian archipelago. *Mar Fish Rev* 55(2):20-7.
- Haight W., J. Parrish, & T. Hayes. 1993b. Feeding ecology of deepwater lutjanid snappers at Penguin Bank, Hawaii. *Trans. Am. Fish. Soc.* 122: 328-347.
- Hamamoto S., S. Kumagai, K. Nosaka, S. Manabe, A. Kasuga & Y. Iwatsuki, 1992. Reproductive behavior, eggs and larvae of lutjanid fish, *Lutjanus stellatus*, observed in an aquarium. *Jpn. J. Ichthyol.*, 39(3):219-228.
- Hardmann-Mountford, N., N. Polunin, & D. Boulle. 1997. Can the age of tropical species be determined by otolith measurement? A study using *Pristipomoides filamentosus* (Pisces: Lutjanidae) from the Mahe Plateau, Seychelles. *Naga*. 20 (2): 27-31.
- Harris P., D. Wyanski, B. White, P. Mikell, & P. Eyo. 2007. Age, growth, and reproduction of greater amberjack off the Southeastern U.S. Atlantic Coast. *Transactions of the American Fisheries Society*. 136:1534–1545.
- Heemstra P. & J. Randall. 1993. Groupers of the world (family Serranidae, subfamily Epinephelinae). Rome: FAO. 382 p. Fisheries synopsis nr 125, volume 16.
- Hobson E. 1980. The structure of reef fish communities in the Hawaiian Archipelago: Interim status report. Pages 57-70 in R. W. Grigg and R. Pfund, eds. Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands. UNIHISEAGRANT- MR-80-04
- Holzwarth S, E. DeMartini, R. Schroeder, B. Zgliczynski, & J. Laughlin. 2006. Sharks and jacks in the Northwestern Hawaiian Islands from towed-diver surveys 2000-2003. *Atoll Res Bull*. Vol. 543, pp. 257-279.
- Honebrink, R. 2000. A review of the biology of the family Carangidae, with emphasis on species found in Hawaiian waters. DAR Technical Report (Honolulu: Department of Land and Natural Resources) 20-01: 1–43.
- Humphreys R. 1980. Feeding habits of the kahala, *Seriola dumerili*, in the Hawaiian archipelago. In: Grigg RW, Tanoue KY, editors. Proceedings of the Symposium on Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 May 25-27; Honolulu, HI. Honolulu: University of Hawaii. p 233-40. Report nr UNIHISEAGRANT-MR-84-01.

- Humphreys R. 1986a. Greater amberjack. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.
- Humphreys R. 1986b. Opakapaka. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.
- Humphreys R. & S. Kramer. 1984. Ciguatera and the feeding habits of the greater amberjack, *Seriola dumerili*, in the Hawaiian Archipelago. In: Grigg, R.W. and K.Y. Tanoue (Eds.), Proceedings of the second symposium on resource investigations in the Northwestern Hawaiian Islands, vol. 2, p. 237-264. Univ. of Hawaii Sea Grant College Program, Honolulu.
- Hyde J., E. Lynn, R. Humphreys, M. Musyl, A. West, & R. Vetter. 2005. Shipboard identification of fish eggs and larvae by multiplex PCR, and description of fertilized eggs of blue marlin, shortbill spearfish, and wahoo. *Mar Ecol Prog Ser.* 286:269-277.
- Ikehara W. 2006. Bottomfish management and monitoring in the main Hawaiian Islands. Shotton R, editor. Rome (Italy): FAO. no. 3/2, p.289-300.
- Jerez, S.; M. Samper; F.J. Santamaría; J.E. Villamandos; J.R. Cejas; & B.C. Felipe. 2006. Natural spawning of greater amberjack (*Seriola dumerili*) kept in captivity in the Canary Islands. *Aquaculture.* 252:199-207.
- Johannes RE. 1981. Words of the lagoon. Berkeley: Univ California Pr. 245 p.
- Kahng S. & C. Kelley. 2007. Vertical zonation of mega-benthic taxa on a deep photosynthetic reef (50–140 m) in the Au’au Channel, Hawaii. *Coral Reefs* 26:679–687.
- Kelley C., B. Mundy & E.G. Grau. 1997. The use of the Pisces V submersible to locate nursery grounds of commercially important deepwater snappers, family Lutjanidae, in Hawaii. In: Programme and Abstracts, Marine Benthic Habitats Conference, Noumea, New Caledonia, November 10–16, 1997. 62pp
- Kelley C., V. Moriwake & A. Moriwake. 2000. Final report for the DLNR bottomfish project: phase I. Improvement of bottomfish stocks in the Hawaiian Islands: development of stock enhancement techniques for deepwater snappers. Submitted to the State of Hawaii Department of Land and Natural Resources.
- Kelley C. 2004. The bottomfish project phase II final report. Submitted to the State of Hawaii Department of Land and Natural Resources.
- Kelley C. & W. Ikehara. 2006. The impacts of bottomfishing on Raita and West St. Rogatien Banks in the Northwestern Hawaiian Islands. *Atoll Research Bulletin.* 543: 305-318.

Kelley C., R. Moffitt, & J.R. Smith. 2006. Description of bottomfish essential fish habitat on four banks in the Northwestern Hawaiian Islands. *Atoll Research Bulletin*. 543: 319-332.

Kikkawa B. 1980. Preliminary study on the spawning season of the opakapaka, *Pristipomoides filamentosus*. In: Grigg RW and Pfund RT (eds.). Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, April 24-25, 1980, University of Hawaii, Honolulu, Hawaii. Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-80-04, p. 226-232.

Kikkawa B. 1984. Maturation, spawning, and fecundity of opakapaka, *Pristipomoides filamentosus*, in the Northwestern Hawaiian Islands In: Grigg RW and Tanoue KY (eds.). Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands, Vol. 2, May 25-27, 1983, University of Hawaii, Honolulu, Hawaii, p. 149-160. UNIHI-SEAGRANT-MR-84-01.

Kikkawa B. & A. Everson. 1984. Gonadal maturation, fecundity and spawning of the greater amberjack (*Seriola dumerili*) in Hawaiian waters with reference to ciguatera incidences. In: Grigg RW, Tanoue KY, editors. Proceedings of the Symposium on Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 May 25-27; Honolulu, HI. Honolulu: University of Hawaii. p 161-178. Report nr UNIHI-SEAGRANT-MR-84-01.

Kramer S. 1986. Uku. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.

Kubodera, T., T. Okutani, & T. Kosuge. 2009. A new bobtail squid species from Yonaguni Island, southwestern Japan (Cephalopoda: Sepiolidae). *Malacol. Soc. Japan* Vol. 67, no. 3-4, pp. 173-179.

Laroche W., W. Smith-Vaniz, & S. Richardson. 1984. Carangidae: development.

In: Ontogeny and systematics of fishes, based on an international symposium dedicated to the memory of Elbert Halvor Ahlstrom, August 15-18, 1983, La Jolla, California. Special publication of the American Society of ichthyologists and herpetologists, no 1. pp. 510-522.

Leis J. 1987. Review of the early life history of tropical groupers (Serranidae) and snappers (Lutjanidae). In: Polovina J, Ralston S, editors. Tropical snappers and groupers: biology and fisheries management. Boulder, CO: Westview Pr. p 189-237.

Leis J. & K. Lee. 1994. Larval development in the lutjanid subfamily Etelinae (Pisces): the genera *Aphareus*, *Aprion*, *Etelis*, and *Pristipomoides*. *Bull. Mar. Sci.* 55(1): 46-125.

- Leis J. & T. Trnski. 1989. The Larvae of Indo-Pacific Shore fishes. Kensington: New South Wales University Press. 372.
- Lewis A., L. Chapman, & A. Sesewa. 1983. Biological notes on coastal pelagic fishes in Fiji. Fiji: Fisheries Division (MAF). Technical report nr 4.
- Lieske E. & R. Myers. 1994. Coral Reef Fishes. Harper Collins. Italy. pp. 50, 114.
- Longenecker K. & R. Langston. 2008. Life History Compendium of Exploited Hawaiian Fishes. Report prepared for Fisheries Local Action Strategy and the Division of Aquatic Resources. 61p.
- Major P. 1978. Predator-prey interactions in two schooling fishes, *Caranx ignobilis* and *Stolephorus purpureus*. *Animal Behaviour*. 26: p. 760-777.
- Mees C. 1993. Population biology and stock assessment of *Pristipomoides filamentosus* on the Mahe Plateau, Seychelles. *J Fish Biol* 43:695-708.
- Meyer C., K. Holland, B. Wetherbee, & C. Lowe. 2001. Diet, resource partitioning and capture vulnerability of Hawaiian jacks captured in fishing tournaments. *Fish. Res.* **53**, pp. 105–113.
- Meyer C., Y. Papastamatiou, & K. Holland. 2007. Seasonal, diel, and tidal movements of green jobfish (*Aprion virescens*, Lutjanidae) at remote Hawaiian atolls: implications for marine protected area design. *Mar. Biol.* 151:2133–2143.
- Miller J., W. Watson, & J. Leis. 1979. An atlas of common near shore marine fish larvae of the Hawaiian Islands. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report nr UNIH-SEAGRANT-MR-80-02.
- Mizenko D. 1984. The biology of Western Samoan reef-slope snapper (Pisces: Lutjanidae) populations of *Lutjanus kasmira*, *L. rufolineatus* and *Pristipomoides multidens* [MS thesis]. University of Rhode Island.
- Moffitt R. 1993. Deepwater demersal fish. In: Wright A, Hill L, editors. Near shore marine resources of the South Pacific, 73-95, FFA, Honiara. Suva: Institute of Pacific Studies; Honiara: Forum Fisheries Agency; Canada: International Centre for Ocean Development.
- Moffitt R. 2003. Biological data and stock assessment methodologies for deep-slope bottomfish resources in the Hawaiian archipelago. Paper presented at the Workshop on the Management of Deepwater Artisanal and Small Scale Fisheries.
- Moffitt R. & F. Parrish. 1996. Habitat and life history of juvenile Hawaiian pink snapper, *Pristipomoides filamentosus*. *Pac Sci* 50(4):371-81.

- Morales-Nin, B. & S. Ralston, 1990. Age and growth of *Lutjanus kasmira* (Forskål) in Hawaiian waters. *Journal Fish Biology UK* 36: 191–203.
- Moriwake, V., M. Chow, K. Ching, C. Kelley, E.G. Grau, D. Su'a & M. Bagley. 2000. Genetic evidence for two sibling species of deepwater snappers (genus *Etelis*) in Samoa. Abstract. 11th Western Groundfish Conference, April, 2000. P.102.
- Moriwake A., V. Moriwake, B. Alexander & C. Kelley. 2004. Spawning and larval rearing of the deepwater snapper, *Pristipomoides filamentosus* [abstract]. Aquaculture 2004, March 1-5, 2004, Honolulu, HI
- Morales-Nin B & Ralston S (1990) Age and growth of *Lutjanus kasmira* (Forskål) in Hawaiian waters. *Journal of Fish Biology* 36: 191-203.
- Munro J., V. Gaut, R. Thompson, & P. Reeson. 1973. The spawning seasons of Caribbean reef fishes. *J. Fish Biol.* 5:69-84.
- Nichols, R. & E. DeMartini. 2008. Preliminary estimates of age and growth for the endemic Hawaiian grouper (Hapuupuu, *Epinephelus quernus*, F. Serranidae). Pacific Islands Fisheries Science Center, NOAA Admin. Rep. NMFS-PIFSC H-08-06, 19 pp.
- Myers R. 1991. *Micronesian reef fishes*. Barrigada, Guam: Coral Graphics.
- Oda D., & J. Parrish. 1981. Ecology of commercial snappers and groupers introduced to Hawaiian reefs. In: Gomez ED , Birkeland CE, Buddemeier RW, Johannes RE, Marsh JA Jr, Suda RT, editors. Proceedings of the fourth international coral reef symposium; 18-22 May 1981; Manila, Philippines. 1:59-67.
- Okamoto, H. & P. Kawamoto. 1980. Progress report on the near shore fishery resource assessment of the Northwestern Hawaiian Islands: 1977 to 1979. In: Grigg, RW, Pfund RT, editors. Proceedings of the Symposium on the status of resource investigations in the Northwestern Hawaiian Islands; 1980 Apr 24-25; Honolulu, HI. p 71-80. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.
- Okamoto, H. & B. Kanenaka. 1983. Preliminary report on the near shore fishery resource assessment of the Northwestern Hawaiian Islands, 1977-1982. In: Grigg RW, Tanoue KY, editors. Proceedings of the second symposium on resource investigations in the Northwestern Hawaiian Islands; 1983 May 25-27; Honolulu, HI. Honolulu: University of Hawaii. p 123-43. Report nr ANYHOW-SEAGRANT-MR-84-01 volume 1.
- Paris CB, Cherubin, LM, Cowen, RK (2007) Surfing, spinning, or diving from reef to reef: effects on population connectivity. *Marine Ecology Progress Series*, 347:285-300.

- Parrish J. 1987. The trophic biology of snappers and groupers. In: Polovina J, Ralston S, editors. Tropical snappers and groupers: biology and fisheries management. Boulder, CO: Westview Pr. p 405-63.
- Parrish F. 1989. Identification of habitat of juvenile snappers in Hawaii. *Fish Bull* 87(4):1001-5.
- Parrish J, L. Taylor, M. DeCrosta, S. Feldkamp, L. Sanderson, C. Sorden. 1980. Trophic studies of shallow-water fish communities in the Northwestern Hawaiian Islands. In: Grigg RW, Pfund RT, editors. Proceedings of the Symposium on the status of resource investigations in the Northwestern Hawaiian Islands; 1980 Apr 24-25; Honolulu, HI. Honolulu: University of Hawaii Sea Grant College Program. p 175-88. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.
- Parrish F., E. DeMartini, & D. Ellis. 1997. Nursery habitat in relation to production of juvenile pink snapper, *Pristipomoides filamentosus*, in the Hawaiian archipelago. *Fish Bull* 95:137-48.
- Parrish J., G. Aeby, E. Conklin, & G. Ivey. 2000. Interactions of non-indigenous blue line snapper (taape) with native fishery species. Final Report submitted to the State of Hawaii Department of Land and Natural Resources Division of Aquatic Resources.
- Polovina J. 1985. Variation in catch rates and species composition in hand line catches of deepwater snappers and groupers in the Mariana archipelago. In: Proceedings of the Fifth International Coral Reef Congress; 1985; Tahiti. Volume 5.
- Polovina J., R. Moffitt, S. Ralston, P. Shiota, & H. Williams. 1985. Fisheries resource assessment of the Mariana archipelago, 1982-85. *Mar Fish Rev* 47(4):19-25.
- Polovina, J. & S. Ralston. 1986. An approach to yield assessment for unexploited resources with application to the deep slope fisheries of the Marianas. *US Fish Bull* 84(4):759-70.
- Polovina, J. 1987. Assessment and management of deepwater bottom fishes in Hawaii and the Marianas. In: Tropical snappers and groupers: biology and fisheries management, Polovina J, Ralston S (eds.), (1987): 505-532.
- Porteiro, F. & T. Sutton 2007. Chapter 6: Midwater fish assemblages and seamounts. In: T.J. Pitcher, T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan and R.S. Santos (eds), Seamounts: Ecology, Conservation and Management. *Fish and Aquatic Resources Series*, Blackwell, Oxford, UK. pp. 101-116.

- Ralston, S. 1979. A description of the bottomfish fisheries of Hawaii, American Samoa, Guam and the Northern Marianas. Honolulu: Western Pacific Regional Fisheries Management Council.
- Ralston, S & G. Miyamoto. 1983. Analyzing the width of daily otolith increments to age the Hawaiian snapper, *Pristipomoides filamentosus*. *Fish. Bull.* 81 (3): 523-535.
- Ralston, S., R. Gooding, & G. Ludwig. 1986. An ecological survey and comparison of bottomfish resource assessments (submersible versus hand line fishing) at Johnston Atoll. *US Fish Bull* (84):141-55.
- Ralston, S. & J. Polovina. 1982. A multispecies analysis of the commercial deep-sea hand line fishery in Hawaii. *Fish Bull.* 80(3):435-48.
- Ralston, S. & H. Williams. 1988a. Depth distributions, growth, and mortality of deep slope fishes from the Mariana archipelago. NOAA Technical Memorandum NMFS-SWFSC-113. 47pp.
- Ralston, S. & H. Williams. 1988b. Numerical integration of daily growth increments: an efficient means of ageing tropical fishes for stock assessment. *Fish Bull.* US. 87:1-16.
- Randall, J. 2007. Reef and shore fishes of the Hawaiian Islands. Sea Grant College Program, University of Hawaii, Honolulu, Hawaii. 546pp.
- Rangarajan K. 1972. Food and feeding habitats of the snapper, *Lutjanus kasmira* (Forsskal) from the Andaman Sea. *Indian J Fish* 17:43-52.
- Roark, B., T. Guilderson, R. Dunbar, & B. Ingram. 2006. Radiocarbon-based ages and growth rates of Hawaiian deep-sea corals. *Mar Ecol Prog Series.* 327: 1–14.
- Schumacher BD (2011) *Habitat use and trophic ecology of the introduced snapper Lutjanus kasmira and native goatfishes in Hawai‘i*. Doctoral Dissertation, University of Hawai‘i, Zoology: Honolulu, HI. 238 pp.
- Seki M. 1984a. The food and feeding habits of the grouper, *Epinephelus quernus* Seale, 1901, in the Northwestern Hawaiian Islands. In: Grigg RW, Tanoue KY, editors. Proceedings of the second symposium on resource investigations in the Northwestern Hawaiian Islands; 1983 May 25-27; Honolulu, HI. Honolulu: University of Hawaii. p 179-91. Report nr ANYHOW-SEAGRANT-MR-84-01 volume 2.
- Seki M. 1984b. The food and feeding habits of the white trevally, *Pseudocaranx cheilio* in the Northwestern Hawaiian Islands. In: RW Grigg, Pfund RT, editors. Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian

- Islands, volume 2; 1980 Apr 24-25; Honolulu, HI. Honolulu: University of Hawaii Sea Grant College Program. p 264-77. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.
- Seki M. 1986a. Butaguchi. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.
- Seki M. 1986b. Carangidae, ulua. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwestern Hawaiian Islands. NOAA Tech. Rep. NMFS 38. pp. 86-87.
- Seki M & M. Callahan. 1988. The feeding habits of two deep slope snappers, *Pristipomoides zonatus* and *P. auricilla*, at Pathfinder Reef, Mariana Archipelago. Fish. Bull. 86(4):807-811.
- Smith, G. 1992. Occurrence and Diets of Juvenile *Caranx ignobilis* and *Caranx melampygus* (Teleostei: Carangidae) in the Hanalei River Estuary, North Kauai, Hawaii. Pacific Science. vol. 46, no. 1: Abstract of Papers. Sixteenth Annual Albert L. Tester Memorial Symposium, 10-12 April 1991. p. 90-105.
- Smith G., & J. Parrish. 2002. Estuaries as nurseries for the jacks *Caranx ignobilis* and *Caranx melampygus* (Carangidae) in Hawaii. Estuarine Coastal and Shelf Science. 55: p. 347-359.
- Smith-Vaniz, W. 1986. Carangidae. In: Smith, M. & P. Heemstra, P. 1986. *Smith's Sea Fishes*. Berlin: Springer-Verlag. pp. 638-661.
- Stobutzki, I & D. Bellwood. 1997. Sustained swimming abilities of the late pelagic stages of coral reef fishes. *Marine Ecology Progress Series* 149: 35-41.
- Sudekum, A., J. Parrish, R. Radtke, & S. Ralston. 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. *Fish Bull* (89):492-513.
- Suzuki K & S. Hioka. 1979. Spawning behavior, eggs, and larvae of the Lutjanid fish, *Lutjanus kasmira*, in an aquarium. *Japanese J Ichthy*. 26(2):161-6.
- Schwarz, A. 1971. Swim bladder development and function in the haddock, *Melanogrammus aeglefinus* L. *Biol. Bull.*, 141: 176-188.
- Talbot F. 1960. Notes on the biology of the Lutjanidae (Pisces) of the East African Coast, with special reference to *L. bohar* (Forsskal). *Annals So Afri Museum* 45:549-74.
- Tinker S. 1978. Fishes of Hawaii. Honolulu: Hawaiian Service. 532 p.
- Uchiyama, J. & D. Tagami. 1984. Life history, distribution and abundance of bottomfishes in the Northwestern Hawaiian Islands. pp. 229-247 In: R. W. Grigg and K. Y. Tanoue (Eds.) Proceedings of the 2nd Symposium on Resource Investigations in the

Northwestern Hawaiian Islands Vol. 1. University of Hawaii Sea Grant Misc. Report
UNIHI-SEAGRANT-MR-84-01. Honolulu.

Uchida R. 1986. Taape. In: R.Uchida & J.Uchiyama, eds. Fishery atlas of the Northwest
Hawaiian Islands. NOAA. p 110-1. Technical report nr NMFS 38.

Uchida, R. & J. Uchiyama. 1986. Fishery Atlas of the Northwestern Hawaiian Islands. NOAA
Tech. Rep. NMFS 38,142 p.

Van der Elst R. 1981. A guide to common sea fishes of southern Africa. Cape Town, South
Africa: C. Struik. 367 p.

Webster, J.; L. Wallace; D. Clague; J. Braga. 2007. Numerical modeling of the growth and
drowning of Hawaiian coral reefs during the last two glacial cycles (0–250 kyr)
Geochem. Geophys. Geosys. vol 8: Q03011.

White, E & W. Sumpton. 2002. Assessment of the deep water line fishery in Queensland. The
State of Queensland, Department of Primary Industries. QI02081.

Williams, H. & M. Lowe. 1997. Growth rates of four Hawaiian deep slope fishes: a comparison
of methods for estimating age and growth from otolith micro-increment widths. *Can. J.
Fish. Aquat. Sci.* 54(1): 126–136

[WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Bottomfish and
seamount groundfish fisheries of the western Pacific region, 1996 annual report.
Western Pacific Regional Fishery Management Council. Honolulu.

[WPRFMC] Western Pacific Fishery Management Council. 2004. Bottomfish and seamount
groundfish fisheries of the western Pacific region, 2003 annual report. Western Pacific
Fishery Management Council. Honolulu.

[WPRFMC] Western Pacific Fishery Management Council. 2005. Bottomfish and seamount
groundfish fisheries of the western Pacific region, 2004 annual report. Western Pacific
Fishery Management Council. Honolulu.

Ziemann, D. & C. Kelley. 2004. Detection and Documentation of Bottomfish Spillover from the
Kahoolawe Island Reserve. Final Report submitted to the Kahoolawe Island Reserve
Commission.

1.5.2 Un-cited Additional References

Anderson W. 1987. Systematics of the fishes of the family Lutjanidae (Perciformes: Percidei),
the snappers. In: Polovina JJ, Ralston S, editors. Tropical snappers and groupers:
biology and fisheries management. Boulder, CO: Westview Pr. p 1-31.

- Barreiros, J., T. Morato, R. Santos & A. Borba 2003. Inter-annual changes in the diet of the almaco jack *Seriola rivoliana* (Perciformes: Carangidae) from the Azores. *Cybium* 27(1): 37-40.
- Brownell, C. 1979. Stages in the early development of 40 marine fish species with pelagic eggs from the Cape of Good Hope. *Ichthyol. Bull. J.L.B. Smith Inst. Ichthyol.* 40:1-84.
- Dalzell P & G. Preston 1992. Deep reef slope fishery resources of the South Pacific, a summary and analysis of the drop line fishing survey data generated by the activities of the SPC fisheries programme between 1974 and 1988. Noumea, New Caledonia: South Pacific Commission. Inshore fisheries research project Technical Document n 2.
- Ellis, D. & E. DeMartini 1994. Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes. *Fish. Bull.* 93:67-77.
- FAO. 2001. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 5. Bony fishes part 3 (Menidae to Pomacentridae). Rome Carpenter KE and Niem VH, editors. 589 p.
- Gooding, R. (1985). "Predation on Released Spiny Lobster, *Panulirus marginatus*, During Tests in the Northwestern Hawaiian Islands". *Marine Fishery Reviews* 47 (1): 27–35.
- Kami H. 1973. The *Pristipomoides* (Pisces: Lutjanidae) of Guam with notes on their biology. *Micronesica* 9(1):97-117.
- Kendall A. 1984. Serranidae: development and relationships. In: Moser HG, Richards WJ, Cohen DM, Fahay MP, Kendall AW Jr, Richardson SL, editors. Ontogeny and systematics of fishes. An international symposium dedicated to the memory of Elbert Halvor Ahlstrom; 1984 Aug 15-18; La Jolla, CA. Am Soc of Ichthyol and Herpetol. p. 499-510.
- Lau, B. & E. DeMartini 1994. An evaluation of oocyte size in multiple regressions predicting gonad weight from body weight: a test using Hawaiian ehu, *Etelis carbunculus*. NOAA Tech. Momo. NMFS-SWFSC-212, 17 p.
- Masuda, H., C. Araga, & T. Yoshino. 1975. Coastal fishes of southern Japan. Tokai University Press. 379 pp.
- Morgans J. 1982. Serranid fishes of Tanzania and Kenya. *Ichthyol Bull. JLB Smith Inst Ichthyol* 46:1-44, 6 pls.
- Munro J. 1987. Workshop synthesis and directions for future research. In: Polovina JJ, Ralston S, editors. Tropical snappers and groupers: biology and fisheries management. Boulder, CO: Westview Pr. p 639-59.

Pontekorvo, T. 1974. Certain peculiarities of distribution of hydrological and biological characteristics in the region of Hawaiian undercurrent mountain banks. *Izvestiya of the Pacific Scientific Research Institute for Fisheries and Oceanography (TINRO)* 92:32-37. (Partial English translation by W.G. Van Campen, 1983; available Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI).

Randall J. & A. Ben-Tuvia 1983. A review of the groupers (Pisces: Serranidae: Epinephelinae) of the Red Sea, with description of a new species of *Cephalopholis*. *Bull Mar Sci* 33(2):373-426.

Randall J., G. Allen, R. Steene. 1990. *Fishes of the Great Barrier Reef and Coral Sea*. Crawford House Press, Bathurst, Australia. 507pp.

[WPRFMC] Western Pacific Regional Fishery Management Council. 1988. Amendment 2 to the fishery management plan for the bottomfish and seamount groundfish fisheries of the Western Pacific Region. Western Pacific Regional Fishery Management Council. Honolulu.

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2 Hawai'i Seamount Groundfish

2.1 Introduction

2.2 General Life History

2.3 General Habitat

2.4 Life History and Habitat Descriptions for Each Species

2.4.1 Habitat description for *Beryx splendens* (alfonsin)

Management Plan and Area:

American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

The alfonsins (Berycidae), typically bright red in coloration, are fairly large fish. The family consists of two genera, *Beryx* and *Centroberyx* (Mundy, 1990).

Alfonsin inhabit rocky bottom habitats at depths of several hundred meters (Seki and Tagami, 1986; Masuda et al., 1975). The distribution of the alfonsin is widespread in the tropical and subtropical waters of the Pacific, Indian and Atlantic oceans (Busakhin, 1982). In the Pacific northern hemisphere, alfonsin are found primarily in two areas, over the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts in the central Pacific and from Japan to Palau in the western Pacific. In the central Pacific, alfonsin are found over seamounts while in the western Pacific region they are also found over continental shelf areas (Humphreys et al., 1984). Over the SE-NHR seamounts their distribution overlaps with that of the pelagic armorhead (*Pseudopentaceros wheeleri*). Most of the available information about the biology and life history of alfonsin come from studies done in the South Pacific and a few Russian studies from the Atlantic. Alfonsin occupies a wide depth range from 10 to 1240 m (Lehodey and Grandperrin, 1995; Massey and Horn, 1990).

Based on examination of otoliths, Lehodey and Grandperrin (1996) calculated a maximum age of 16.8 years for a female of 56.7 cm (FL). The average size of alfonsin captured at the Hancock seamounts in the SE-NHR region ranges from 15.3 to 35.3 cm (FL) (Uchida, 1986).

In the South Pacific, females reportedly grow faster than males, the difference increasing with age (Lehodey and Grandperrin, 1994). At the Hancock seamounts, the sex ratio is nearly equal (Humphreys et al., 1983). In the South Pacific, Alfonsin reaches sexual maturity at 6 years of age for females and at 7 to 8 years for males; approximately 33 to 34 cm respectively for females and males (Lehodey and Grandperrin, 1996; Mundy, 1990). In the western Pacific, alfonsin reportedly reach sexual maturity by age three (Ikenuye, 1969). Alfonsin spawns between August and October in the Hancock seamount region (Mundy, 1990). The pelagic eggs hatch approximately 1 day after spawning (Uchida, 1986)

Tagging studies conducted by Japanese researchers indicate that alfonsins migrate from coastal to offshore waters as they mature. Alfonsins become demersal at one year of age or less (Uchida, 1986)

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In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. A collapse of the seamount groundfish stocks has resulted in a greatly reduced yield in recent years. Alfonsin are taken primarily by means of bottom trawls. While it is the second most abundant species taken in the seamount groundfish fishery it comprises only a small portion of the total catch (Seki and Tagami, 1986). Much of the demersal habitat on the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts is too steep and rough for bottom trawling. In the past, the principal gear used in the harvest of alfonsin by the Japanese was bottom longlines and handlines (Seki and Tagami, 1986).

Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

Egg and larval distribution

Although alfonsin are commercially important species little is known about their early life history. As previously mentioned, the eggs of the alfonsin are pelagic and hatch in about 1 day after spawning. The larvae are planktonic for the first 2 to 3 days of existence after which time they begin to swim (Uchida, 1986). The dispersal of eggs and larvae is determined by the prevailing currents (Humphreys et al., 1983).

Larvae

At the Hancock seamount *Beryx* larvae have been found almost exclusively in the upper 50 m of the water column. Larvae are nearly twice as abundant in the upper 25 m than between the 25 to 50 m (Mundy, 1990).

Juvenile distribution

Juveniles undergo a pelagic development phase that lasts several months. Recruitment to benthic habitat takes place at approximately 1.5 years of age. (Lehodey and Grandperrin, 1994). Juveniles inhabit shallower water than do adults, moving into progressively deeper waters as they grow and mature (Seki and Tagami, 1986).

Galaktionov (1984) studied the schooling behavior of juvenile alfonsin. He found that during midday juveniles were concentrated on the bottom. Between 1700 and 1800 hours school formation occurs relatively rapidly. The schooled juveniles move into shallower water at depths as shallow as 75 m around sunset.

Adult distribution

The alfonsin is a benthopelagic species, migrating to the surface at night to feed returning to the bottom during the day (Lehodey and Grandperrin, 1994). Galaktionov (1984) reports that adult alfonsin form dense schools from 1000 to 1100 hours and from 1600 to 1700 hours. The fish school while at or near the bottom and slowly migrate upward through the water column.

Food habit studies indicates that small fish dominate this species diet. Other prey items include small crustaceans including decapods, euphausiids, krill and mysids (Uchida, 1986). Alfonsin are believed to prey primarily on bathypelagic organisms with benthic prey

contributing little to its diet (Lehodey and Grandperrin, 1994). In turn, alfonsin are preyed upon by large pelagic predators, including tuna.

In the western Pacific region, the abundance and distribution of alfonsin is dependent on the prevailing currents, particularly the Kuroshio (Uchida, 1986). Size increases with depth and latitude (Uchida, 1986). Sekli and Tagami (1986) report an optimum temperature range for this species of 6° to 18° C.

Essential Fish Habitat: Seamount groundfish complex

The EFH designation for the adult life stage of the seamount groundfish complex is all EEZ waters and bottom habitat bounded by latitude 29°-35°N and longitude 171°E-179°W between 80 to 600 m. EFH for eggs, larvae and juveniles is the epipelagic zone (~ 200 m) of all EEZ waters bounded by latitude 29°-35°N and Longitude 171°E-179°W.

Habitat description for *Beryx splendens* (alfonsin)

	Egg	Larvae	Juvenile	Adult
Duration	Eggs hatch approximately 1 day after spawning	The larvae are planktonic for the first 2 to 3 days of existence after which time they begin to swim.	Alfonsin reaches sexual maturity at 6 years of age for females and at 7 to 8 years for males; approximately 33 to 34 cm respectively for females and males	16.8 years for a female of 56.7 cm
Diet	N/A	No information available	No information available	Small fish dominate this species diet. Other prey items include small crustaceans including decapods, euphausiids, krill and mysids
Distribution: General and Seasonal	No information available	No information available	Alfonsins migrate from coastal to offshore waters as they mature	The distribution of the alfonsin is widespread in the tropical and subtropical waters of the Pacific. In the Pacific northern hemisphere, alfonsin are found

				primarily in two areas, over the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts in the central Pacific and from Japan to Palau in the western Pacific.
Water Column	Pelagic	Pelagic, At the Hancock seamount <i>Beryx</i> larvae have been found almost exclusively in the upper 50 m of the water column. Larvae are nearly twice as abundant in the upper 25 m than between the 25 to 50 m	Pelagic, Juveniles undergo a pelagic development phase that lasts several; months. Recruitment to benthic habitat takes place at approximately 1.5 years of age. Juveniles inhabit shallower water than do adults, moving into progressively deeper waters as they grow and mature	Demersal, <i>Alfonsin</i> occupies a wide depth range from 10 to 1240 m
Bottom Type	N/A	N/A	N/A	<i>Alfonsin</i> inhabit rocky bottom habitats at depths of several hundred meters. In the central Pacific, <i>alfonsin</i> are found over seamounts while in the western Pacific region they are also found over continental shelf areas

Oceanic Features	The dispersal of eggs is determined by the prevailing currents	The dispersal of larvae is determined by the prevailing currents	The abundance and distribution of alfoncin is dependent on the prevailing currents, particularly the Kuroshio	The abundance and distribution of alfoncin is dependent on the prevailing currents, particularly the Kuroshio
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Bibliography

- Busakhin, S. V. 1982. Systematics and distribution of the family Berycidae (Osteichthyes) in the world ocean. *Journal of ichthyology* 22(6): 1-21.
- Galaktionov, G.Z. 1984. Features of the schooling behavior of the Alfonsina, *Beryx splendens* (Berycidae), in the thalassobathyl depths of the Atlantic Ocean. *Journal of Ichthyology* 24(5):148-151.
- Humphreys, Robert L., Jr., Darryl T. Tagami, and Michael P. Seki. 1983. Seamount fishery resources within the southern Emperor-northern Hawaiian Ridge area. *in* R.W. Grigg and K.Y. Tanoue (eds.), *Proceedings of the second symposium on resource investigations in the northwestern Hawaiian Islands, May 25-27, 1983*, p. 283-327. University of Hawaii, Honolulu, HI, ANYHOW-SEAGRANT-MR-84-01 Vol. 1.
- Ikenuye, H. 1969. Age determination by otolith of a Japanese alfonsin, *Beryx splendens*, with special reference to growth. *Journal of Tokyo University of Fisheries* 55(2):91-98.
- Lehodey, P. and R. Grandperrin. 1996. Age and growth of the alfonsino *Beryx splendens* over the seamounts off New Caledonia. *Marine Biology* 125:249-258.
- Lehodey, P. and R. Grandperrin. 1994. A study of the fishery and biology of *Beryx splendens* (alfonsin) in New Caledonia. *Fisheries Newsletter* 71:30-34.
- Lehodey, P. Paul Marchal, and R. Grandperrin. 1994. Modelling the distribution of alfonsino, *Beryx splendens*, over the seamounts of New Caledonia. *U.S. Fishery Bulletin*. 92:748-759.
- Massey, B.R. and P.L. Horn. 1990. Growth and age structure of alfonsino (*Beryx splendens*) from the lower east coast, North Island, New Zealand. *New Zealand journal of marine and freshwater research*. 24:126-136.
- Masuda, Haime, Chuichi Araga, and Tetsuo Yoshino. 1975. *Coastal fishes of southern Japan*. Tokai University Press. 379 pp.
- Mundy, Bruce C. 1990. Development of larvae and juveniles of the alfonsins, *Beryx splendens* and *B. decadactylus* (Berycidae, Beryciformes). *Bulletin of Marine Sciences*. 46(2):257-273.
- Saski, Takashi. 1986. Development and present status of the Japanese trawl fisheries in the vicinity of seamounts. *in* *Environment and Resources of Seamounts in the North Pacific*, (Richard N. Uchida, Sigeiti Hayasi, and George W. Boehlert, eds). pp 21-30 . NOAA Technical Report NMFS 43.

Seki, Michael P., and Darryl T. Tagami. 1986. Review and present status of handline and bottom longline fisheries for alfonsoin. *in* Environment and Resources of Seamounts in the North Pacific, (Richard N. Uchida, Sigeiti Hayasi, and George W. Boehlert, eds). pp 31-35. NOAA Technical Report NMFS 43.

Uchida, Richard N. 1986. Berycidae. *in* Fishery Atlas of the Northwest Hawaiian Islands, (R.N. Uchida and J.H. Uchiyama, eds.), pp. 78-79. NOAA Technical Report. NMFS 38.

Vinnichenko, V.I. 1997. Vertical diurnal migrations of slender alfonsoin *Beryx splendens* (Berycidae) at underwater rises of the open North Atlantic. *Journal of Ichthyology*. 37(6):438-444.

2.4.2 Habitat description for *Hyperoglyphe japonica* (ratfish, butterfish)

Management Plan and Area

American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

There is no information available concerning the life history and basic biology of the ratfish. This species is infrequently taken as an incidental species in conjunction with the seamount groundfish fishery.

2.4.3 Habitat description for *Pseudopentaceros wheeleri* (armorhead)

Management Plan and Area

American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Boehlert and Sasaki (1988) and Humphreys et al. (1983) were the primary sources used in the preparation of this species profile.

The pelagic armorhead (*Pseudopentaceros wheeleri*) is widely distributed throughout the North Pacific Ocean (Boehlert and Sasaki, 1988). Electrophoretic and meristic work suggests that a single stock of pelagic armorhead exists (Humphreys et al., 1983). Oceanographic conditions seem to be the primary factor regulating the armorhead's distribution. Zones of upwelling, produced by the prevailing currents, result in high biological productivity over the Southern

Emperor-Northern Hawaiian Ridge (SE-NHR) seamounts (Pontekorvo, 1974 in Humphreys et al., 1983). The life histories and distributional patterns of the armorhead are poorly understood as is the effects of oceanographic variability on migration and recruitment of the armorhead.

The pelagic armorhead has two distinct life history phases that includes a pelagic juvenile phase and a demersal adult phase (Somerton and Kikkawa, 1992). Between 1.5 and 2.5 years of age, the pelagic armorhead inhabits the epipelagic zone of the subarctic-transitional waters of the North Pacific during a lengthy pre-recruit phase (Humphreys, 1995; Somerton and Kikkawa, 1992). During this time the fish remain nonreproductive. Subsequently, these fish recruit to demersal habitat on the SE-NHR seamounts. Humphreys et al. (1983) report that adults are found on the slopes of seamounts down to depths of 800 to 900 m. The commercial fishery for pelagic armorhead targets fish on the summits of seamounts at the 200 to 490 m depth range (Humphreys et al., 1983; Takahashi and Sasaki, 1977)

The smallest reported sizes for pelagic armorhead range from 5 to 20 mm and typically occurred south of 33 N° (Humphreys et al., 1984). Research indicates an age estimate of 3 years for 22 cm fork length (FL) and 6 years for 32 cm fork length (Humphreys et al., 1983). Based on length frequency data, it is believed that fish taken by the trawl fishery are typically 5 to 7 years of age (Chikuni, 1970 in Humphreys et al., 1983). Females are slightly larger than males.

Adult pelagic armorhead have three distinct morphological types: “lean type”, “intermediate type” and “fat type”. While all three types are found over the SE-NHR seamounts, the lean and intermediate types predominate. The epipelagic phase of the armorhead life history is characterized by the accumulation of fat reserves and continuous somatic growth (Humphreys et al., 1989). The bluish mottled coloration of the open ocean fat type is indicative of its epipelagic existence. The open ocean fat type is nonreproductive. After recruitment to the summits of the SE-NHR seamounts, newly settled adults rapidly lose their mottled bluish coloration, ultimately assuming a brownish coloration. This transformation is fairly rapid and explains the relatively low abundance of fat type on the seamounts. Somatic growth ceases and the fat reserves are depleted as the fish become reproductively active. These physiological changes result in the intermediate morphological type and ultimately the lean type as the fat reserves are further depleted (Humphreys et al., 1989). The existence of these distinct morphological types are absent in juveniles. (Humphreys et al., 1983).

The main reproductive population is found on SE-NHR seamounts between latitude 29° and 35° N. (Boehlert and Sasaki, 1988). Spawning activity is benthic and is restricted to December to February at the SE-NHR seamounts. (Humphreys, 1995). Peak spawning activity occurs between January and February (Humphreys et al., 1983). Research indicates that armorhead reach sexual maturity at 1.5 to 2.5 years in age, ranging in size from 23.0 to 28.5 standard length (Boehlert

and Sasaki, 1988). Spawning occurs at depths ranging from 200 to 500 m (Boehlert and Sasaki, 1988). It is thought that *P. wheeleri* is semelparous, spawning only once before dying.

Eggs, larvae and juveniles are pelagic and are found widely distributed in the North Pacific Ocean (Boehlert and Sasaki, 1988). Initially the larvae are found in the epipelagic waters in the vicinity of the SE-NHR seamounts (Humphreys et al., 1993). The larvae are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean (Humphreys et al., 1993). Boehlert and Sasaki (1973) report a 1.5 to 2.5 year time period between spawning and recruitment to the seamounts. The process by which these fish return and recruit to the seamounts is poorly understood (Humphreys et al., 1993). It is thought that recruitment occurs only during the late spring to midsummer months. The long pelagic phase combined with the variability of oceanic conditions play an important role in determining the strength of year-classes in this species (Boehlert and Sasaki, 1988). The size of individuals at recruitment is generally uniform, ranging from 25 to 33 cm (Humphreys et al., 1989).

In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. The seamount groundfish complex consists of three species (pelagic armorhead's, alfonsons, and ratfish). These species dwell at 200 to 600 m on the submarine slopes and summits of seamounts. A collapse of the seamount groundfish stocks has resulted in a greatly reduced yield in recent years. Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

Egg and larval distribution

The egg, larval and juvenile stages of the pelagic armorhead all occur in the surface layers where they are subject to advection by the prevailing currents (Humphrey et al., 1984; Borets, 1979).

Larval and juvenile stages prey on zooplankton. Interannual variability in environment conditions affecting the abundance and availability of zooplankton may play an important role in the survival of these early life stages and thus year class strength (Boehlert and Sasaki, 1988).

Larvae of *P. wheeleri* are neustonic and are carried eastward by the prevailing wind driven surface flow in the SE-NHR seamount region (Boehlert and Sasaki, 1988). Through some unknown mechanism, fish move northeastward ultimately entering the subarctic waters of the Alaska gyre (Boehlert and Sasaki, 1988). The two available studies of larval distribution of armorhead conflict but suggest that the distribution of larvae varies from year to year (Boehlert and Sasaki, 1988).

Juvenile distribution

As stated, during the first 1.5 to 2.5 years of life, juveniles lead a pelagic existence., inhabiting the epipelagic zone of the subarctic-transitional waters of the North Pacific Ocean (Somerton and Kikkawa, 1992). Subsequently, a shift occurs from pelagic to demersal habitat. During the

pelagic juvenile phase, armorhead acquire large reserves of fat before recruiting to SE-NHR seamounts. The largest influx of juvenile recruits to the Juveniles recruit to the SE-NHR seamounts occurs during spring between April and June (Humphreys, 1995). Recruits are characterized by their bluish to grey coloration and their fat reserves. After recruitment, the fish gradually assume a brownish coloration. The diet of juveniles is comprised primarily of small planktonic prey items, particularly copepods (Borets, 1979).

Adult distribution

As stated, adults are found on the slopes of seamounts. *P. wheeleri* display crepuscular migrations through the water column. During daylight hours, they are found in the upper water column at depths between 80 to 100 m. As dusk approaches they descend to the summits of the seamounts. It is thought that these movements are related to foraging activity (Humphreys et al., 1983). At night, dense aggregations of armorhead are found on the summits of the seamounts (Somerton and Kikkawa, 1992).

The pelagic armorhead feeds during daylight hours, especially between the hours of 0800 and 1000. (Humphreys et al., 1983; Sakiura, 1972). Prey items include epipelagic crustaceans, copepods, amphipods, tunicates, eupausiids, pteropods, sergestids, myctophids, macrura and mesopelagic fish. Organisms of the deep scattering layer also comprise a portion of this species diet (Humphreys et al., 1983; Sakiura, 1972).

It is believed that the horizontal and vertical distribution of *P. wheeleri* is controlled by water temperature. The lower tolerance limit is approximately 5 C° while the upper limit is roughly 20 C°. It is thought that the preferred temperature range of this species is 8 to 15 C° (Humphreys et al., 1983; Chikuni, 1971). Pelagic armorhead are found year-round on the southern Emperor-Northern Hawaiian Ridge seamounts.

The life expectancy of the armorhead once it has recruited to demersal habitat ranges from 4 to 5 years.

Essential Fish Habitat: Seamount groundfish complex

The EFH designation for the adult life stage of the seamount groundfish complex is all EEZ waters and bottom habitat bounded by latitude 29°-35°N and longitude 171°E-179°W between 80 to 600 m. EFH for eggs, larvae and juveniles is the epipelagic zone (~ 200 m) of all EEZ waters bounded by latitude 29°-35°N and Longitude 171°E-179°W.

Habitat description for *Pseudopentaceros wheeleri* (armorhead)

	Egg	Larvae	Juvenile	Adult
Duration	No information available	No information available	Fish recruit to demersal habitat Between 1.5 and 2.5 years of age	The life expectancy of the armorhead once it has recruited to demersal habitat ranges from 4 to 5 years
Diet	N/A	Larval stages prey on zooplankton	Juvenile stages prey on zooplankton	Prey items include epipelagic crustaceans, copepods, amphipods, tunicates, eupausiids, pteropods, sergestids, myctophids, macrura and mesopelagic fish.
Distribution: General and Seasonal	Eggs are found in the epipelagic waters in the vicinity of the SE-NHR seamounts	Initially the larvae are found in the epipelagic waters in the vicinity of the SE-NHR seamounts	The pelagic armorhead inhabits the epipelagic zone of the subarctic-transitional waters of the North Pacific during a lengthy	The pelagic armorhead (<i>Pseudopentaceros wheeleri</i>) is widely distributed throughout the North Pacific Ocean

			pre-recruit phase	
Water Column	pelagic	pelagic	pelagic	Demersal, During daylight hours, they are found in the upper water column at depths between 80 to 100 m. At night, dense aggregations of armorhead are found on the summits of the seamounts
Bottom Type	N/A	N/A	N/A	Adults are found on the slopes of seamounts down to depths of 800 to 900 m
Oceanic Features	The eggs are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean	The larvae are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean	Oceanographic conditions seem to be the primary factor regulating the armorhead's distribution.	Oceanographic conditions seem to be the primary factor regulating the armorhead's distribution.

Bibliography

Boehlert, George W., and Takashi Sasaki. 1988. Pelagic biogeography of the armorhead (*Pseudopentaceros wheeleri*), and recruitment to isolated seamounts in the North Pacific Ocean. U.S. Fishery Bulletin 86(3): 453-465.

Borets, L.A. 1979. The population structure of the boarfish, *Pentaceros richardsoni*, from the Emperor Seamounts and the Hawaiian Ridge. Journal of Ichthyology 19(3):15-20.

Chikuni, S. 1971. Groundfish on seamounts in the North Pacific. Bulletin of Japanese Society of Fisheries Oceanography. Fisheries Research Board of Canada, Translation No. 2130. 12 pp.

_____. 1970. The "Phantom fish," "kusakari tsubodai" --- an outline. Enyo (Far Seas) Fisheries Research Laboratory News 3:1-4. National Marine Fisheries Service, Terminal Island, CA.

Humphreys, Robert L., Jr. 1995. Recruitment variation in a seamount population of armorhead: an analysis of biological characters derived primarily from otolith analysis. Master's Thesis, University of Hawaii.

Humphreys, Robert L., Jr., Mark Crossler, and Craig M. Rowland. 1993. Use of a monogenean gill parasite and feasibility of condition for identifying new recruits to a seamount population of armorhead *Pseudopentaceros wheeleri* (Pentacerotidae). U.S. Fishery Bulletin 91:455-463.

Humphreys, Robert L., Jr., Gary A. Winans, and Darryl T. Tagami. 1989. Synonymy and life history of the north Pacific armorhead, *Pseudopentaceros wheeleri* Hardy (Pisces: Pentacerotidae). Copeia 1: 142-153.

Humphreys, Robert L., Jr., Darryl T. Tagami, and Michael Seki. 1983. Seamount fishery resources within the Southern Emperor-Northern Hawaiian Ridge area. in R.W. Grigg and K.Y. Tanoue (eds.), Proceedings of the second symposium on resource investigations in the northwestern Hawaiian Islands, May 25-27, 1983, p. 283-327. University of Hawaii, Honolulu, HI, ANYHOW-SEAGRANT-MR-84-01 Vol. 1.

Pontekorvo, T.B. 1974. Certain peculiarities of distribution of hydrological and biological characteristics in the region of Hawaiian undercurrent mountain banks. Izyestiya of the Pacific Scientific Research Institute for Fisheries and Oceanography (TINRO) 92:32-37. (Partial English translation by W.G. Van Campen, 1983; available Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI).

Sakiura, H. 1972. The pelagic armorhead *Pentaceros richardsoni*, fishing grounds off the Hawaiian Islands, as viewed by the Soviets. *The Fishing and Food Weekly* 658:28-31, June 15, 1972. Translation no. 16. Southwest Fisheries Science Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

Somerton, David A. and Bert S. Kikkawa. 1992. Population dynamics of pelagic armorhead *Pseudopentaceros wheeleri* on Southeast Hancock Seamount. *U.S. Fishery Bulletin* 90:756-769.

Takahashi, Y., and T. Sasaki. 1977. Trawl fishery in the central Pacific seamounts. Division of northern waters groundfish Resources, Far Seas Fisheries Research Laboratory. 49 pp. Translation no. 22. Southwest Fisheries Science Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

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3 PRECIOUS CORALS SPECIES

3.1 General Distribution of Precious Corals

Besides the references noted, the Council's 1979 environmental impact statement and FMP for the precious corals fisheries in the western Pacific region as well as Amendments 1 and 2 to the FMP and their accompanying environmental assessments were sources for the following sections.

Precious corals are known to exist in American Samoa, Guam, Hawaii and the Northern Mariana Islands, as well as other US possessions in the Pacific (Tables 1 and 2). However, very little is known about their distribution and abundance. A summary of the known distribution and abundance of precious corals in the western Pacific region follows.

American Samoa

There is little information available for the deepwater species of precious corals in American Samoa. Much of the information available comes from the personal accounts of fishermen. All known commercial quantities of *Corallium* sp. occur north of 19°N (Grigg 1984). In the South Pacific there are no known commercial beds of pink coral (Carleton and Philipson 1987). Survey work begun in 1975 by the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC) has identified three areas of *Corralium* off Western Samoa: off eastern Upolu, off Falealupo and at Tupuola Bank (Carleton and Philipson 1987). Pink coral has been reported off Cape Taputapu, but no information concerning the quality or quantity of these corals or the depths where they occur is available. Unidentified precious corals have also been reported in the past off Fanuatapu at depths of around 90 m. Precious corals are known to occur at an uncharted seamount, about three-fourths of a mile off the northwest tip of Falealupo Bank at depths of around 300 m.

Commercial quantities of one or more species of black coral are known to exist at depths of 40 m and deeper. However, these are found in the territorial waters of American Samoa and, therefore, are not subject to the Council's authority.

Guam and the Commonwealth of the Northern Marianas

There are no known commercial quantities of precious corals in the Northern Mariana Islands archipelago (Grigg and Eldredge 1975). In the past, Japanese fishermen claimed to have taken some *Corralium* north of Pagan Island and off Rota and Saipan.

Hawaii

In the Hawaiian Islands there are six known beds of pink, gold and bamboo corals (Grigg 1974). These six locations are as follows:

- In the MHI, precious coral beds have been found only in the deep inter-island channels and off promontories such as Keahole Point on the Big Island of Hawaii.

Species	Common name
<i>Corallium secundum</i>	Pink coral
<i>Corallium regale</i>	Red coral
<i>Corallium laauense(sp)</i>	Red coral
<i>Gerardia sp.</i>	Gold coral
<i>Narella sp.</i>	Gold coral
<i>Calyptrophora sp.</i>	Gold coral
<i>Callogorgia gilberti</i>	Gold coral
<i>Lepidisis olapa</i>	Bamboo coral
<i>Acanella sp.</i>	Bamboo coral
<i>Antipathes dichotoma</i>	Black coral
<i>Antipathes grandis</i>	Black coral

Species	Common name
<i>Antipathes ulex</i>	Black coral

Table 1: Precious corals covered under the FMP.

- Also in the MHI, the Makapuu bed is located off Makapuu, Oahu, at depths of between 350 and 450 m. Discovered in 1966, it the only precious coral bed that has been accurately surveyed in the Hawaiian chain. Its total area is about 4.5 km². Its substrate consists largely of hard limestone (Grigg 1988). Careful examination during numerous dives with a submersible has determined that about 20% of the total area of the Makapuu bed is comprised of irregular lenses of thin sand, sediments and barren patches (WPRFMC 1979). These sediment deposits are found primarily in low lying areas and depressions (Grigg 1988). Thus, the total area used for extrapolating coral density is 3.6 km², or 80% of 4.5 km² (WPRFMC 1979). The preliminary results of a recent resurvey of the Makupuu bed show that the bed may actually be as much as 15% larger then previously thought (Grigg 1998, pers. comm.).
- Also in the MHI is a bed off Kaena Point, Oahu.
- In the NWHI, a very small bed of deepwater precious corals have been found on WesPac bed, between Nihoa and Necker Islands and east of French Frigate Shoals. This bed is not large enough to sustain commercial harvests. However, large areas of potential habitat exist in the NWHI on seamounts and banks near 400 m depth. Based on the abundance of potential habitat it is thought that stocks of precious corals may be more abundant in the northwestern end of the island chain.

- A small precious coral bed has also been discovered at Brooks Banks, located near Cross Seamount southwest of the island of Hawaii. This bed is no large enough to sustain commercial harvests
- Precious corals have also been discovered at the 180 Fathom Bank, north of Kue Island, in EEZ waters surrounding Palmyra Island, a US possession in the western Pacific. The extent of this bed is not known. While little is known about the distribution and abundance of precious corals in the western Pacific region, it is almost certain that undiscovered beds of precious corals exist in the EEZ waters of the region covered by the Council.

Description	Lat. N	Long. W.	Area in km ²
Off Keahole Point, Hawaii	19°46.0'	156°06.0'	0.24
Off Makapuu, Oahu	21°18.0'	157°35.5'	4.2
Off Kaena Point, Oahu	21°35.4'	158°22.9'	0.24
WesPac Bed, between Nihoa and Necker Islands	23°18'	162°35'	0.8
Brooks Banks	24°06.0'	166°48'	1.6
180 Fathom Bank, north of Kue Island	28°50.2'	178°53.4'	0.8

Table 2: Location of known precious coral beds. Source: WPRFMC 1979

3.2 Systematics of the Deepwater Coral Species

Precious corals have a global distribution (Grigg 1993). The richest beds are found on seamounts in the western North Pacific Ocean and the western Mediterranean Sea. Precious corals are found principally in three orders of the class Anthozoa: Gorgonacea, Antipatharia, and Zoanthia (Grigg 1984). In the western Pacific region, pink coral (*Corallium secundum*), gold coral (*Gerardia sp.* and *Parazoanthus sp.*), black coral (*Antipathes sp.*) and bamboo coral (*Lepidistis olapa*) are the primary species/genera of commercial importance. Of these, the most valuable precious corals are species of the genus *Corallium*, the pink and red corals (Grigg 1984). Pink coral (*Corallium secundum*) and Midway deep-sea coral (*Corallium sp. nov.*) are two of the principal species of commercial importance in the Hawaiian and Emperor Seamount chain's (Grigg 1984). *C. secundum*, is found in the Hawaiian archipelago from Milwaukee Banks in the Emperor Seamounts (36°N) to the Island of Hawaii (18°N); *Corallium sp. nov.* is found between 28°–36°N, from Midway to the Emperor Seamounts (Grigg 1984). In addition to the pink corals, the bamboo corals, *Lepidistis olapa* and *Acanella sp.*, are commercially important precious corals in the western Pacific region (Grigg 1984). Pink coral and bamboo coral are found in the order Gorgonacea in the subclass Octocorallia of the class Anthozoa, in the Phylum Coelenterata (Grigg, 1984). The final two major groups of commercially important precious corals, gold coral and black coral, are found in separate orders, Zoanthidea and Antipatharia, in the subclass Hexacorallia in the class Anthozoa and the phylum Coelenterata. The gold coral, *Gerardia sp.*, is endemic to the Hawaiian and Emperor Seamount chain (Grigg 1984). It inhabits depths ranging from 300–400 m (Grigg 1974, 1984). In Hawaii, gold coral, *Gerardii sp.*, grows in association with *Acanella* as a parasitic overgrowth (Brown 1976, Grigg 1984). Gold coral is, therefore, only found growing in areas that were previously inhabited by colonies of *Acanella* (Grigg 1993).

Grigg (1984) classifies black corals in the order *Antipatharia*. Grigg says there are 200 known species of black coral that occur in the oceans of the world, and of this total, only about 10 species are of commercial importance, almost all of which are found in the genus *Antipathes*.

Many species of gorgonian corals are known to occur within the habitat of pink, gold and bamboo corals in the Hawaiian Islands. At least 37 species of precious corals in the order Gorgonacea have been identified from the Makapuu bed (Grigg and Bayer 1976). In addition, 14 species of black coral (order Antipatharia) have been reported to occur in Hawaiian waters (Grigg and Opresko 1977, Oishi 1990).

3.3 Biology and Life History

Precious corals may be divided into two groups of species based on the depths that they inhabit, the deepwater species and the shallow water species. In the EEZ waters of the western Pacific region, precious corals are found in two principal depth zones: 350–450 m and 1,000–1,500 m. In the Hawaiian Islands, these two zones comprise 1,700 nm² and 5,900 nm² of potential habitat, respectively, and range from 18° N to 35° S.

The deepwater precious coral species include pink coral (*Corallium secundum*), gold coral (*Gerardia sp.*, and *Parazoanthus sp.*) and bamboo coral (*Lepidistis olapa*). As previously discussed, the most valuable precious corals are in the genus *Corallium* (Grigg 1984). There are seven varieties of pink and red precious corals in the western Pacific region, six of which are recognized as distinct species of *Corallium* (Grigg 1981). As mentioned, the two species of *Corallium* of commercial importance in the EEZ around the Hawaiian Islands are *C. secundum* (pink coral) and *Corallium sp. Nov.* (Midway deep-sea). The Midway deep-sea coral (*Corallium sp. Nov.*), a previously undescribed species of *Corallium*, was discovered in 1980–1981 by Japanese vessels fishing for precious corals on the Emperor Seamounts northwest of Midway Island. The discovery of this rich, unexploited deepwater precious coral species resource underscores the potential of the coral fishery in the NWHI.

The second group of species is found in shallow water between 30 and 100 m (Grigg 1993). The shallow water fishery is comprised of three species of black coral, *Antipathes dichotoma*, *A. grandis* and *A. ulex*, which have historically been harvested in Hawaii (Oishi 1990). In Hawaii, *A. dichotoma* accounts for around 90% of the commercial harvest of black coral (Oishi 1990). *A. grandis* accounts for 9% and *A. ulex* 1% of the total black corals harvested. In Hawaii, roughly 85% of all black coral harvested are taken from within state waters. Black corals are managed jointly by the State of Hawaii and the Council. Within state waters (0–3 nmi), black corals are managed by the State of Hawaii (Grigg 1993).

Species and Common Name	Depth Range (m)
<i>Corallium secundum</i> Angle skin coral	350–475
<i>Corallium sp nov.</i> Midway deepsea coral	1,000–1,500
<i>Gerardia sp.</i> Hawaiian gold coral	300–400
<i>Lepidistis olapa</i> bamboo coral	350–400

Species and Common Name	Depth Range (m)
<i>Antipathes dichotoma</i> , black coral	30–100
<i>Antipathes grandis</i> , pine black coral	45–100
<i>Antipathes ulex</i> , fern black coral	40–100
<i>Antipathes anguina</i> , wire black coral	20–60

Table 3: Depth zonation of all species of precious coral in the Western Pacific. (Source: Grigg 1993)

While different species of precious corals inhabit distinct depth zones, their habitat requirements are strikingly similar. Grigg (1984) notes that these corals are non-reef building and inhabit depth zones below the euphotic zone. In an earlier study, Grigg (1974) determined that precious corals are found in deep water on solid substrate in areas that are swept relatively clean by moderate to strong bottom currents (>25 cm/sec). Strong currents help prevent the accumulation of sediments, which would smother young coral colonies and prevent settlement of new larvae. Grigg (1984) notes that, in Hawaii, large stands of *Corralium* are only found in areas where sediments almost never accumulate. He also notes that 1971–75, surveys of all potential sites for precious corals in the MHI conducted using a manned submersible show that most shelf areas in the MHI near 400 m are periodically covered with a thin layer of silt and sand. Grigg (1988) concludes that the concurrence of oceanographic features (strong currents, hard substrate, low sediments) necessary to create suitable precious coral habitat are rare in the MHI.

The habitat sustaining precious corals is generally in pristine condition. There are no known areas that have sustained damage due to resource exploitation, notwithstanding the alleged heavy foreign fishing for corals in the Hancock Seamounts area. Although unlikely, if future development projects are planned in the proximity of precious coral beds, care should be taken to prevent damage to the beds. Projects of particular concern would be those that suspend sediments or modify water-movement patterns.

There is a correlation between the location and abundance of *Corallium* beds and the Kuroshio Current in the western Pacific region (Grigg 1984). This relationship further illustrates the importance of suitable current regimes in determining suitable precious coral habitat. Currents also play an important ecological role in transporting food to and carrying wastes away from corals.

There has been very little research conducted concerning the food habits of precious corals. Precious corals are filter feeders (Grigg 1984, 1993). The sparse research available suggests that particulate organic matter and microzooplankton are important in the diets of pink and bamboo coral (Grigg 1970). Many species of pink coral (*Corallium*), gold coral (*Gerardia*) and black coral (*Antipathes*) form fan shaped colonies (Grigg 1984, 1993). This type of morphological adaption maximizes the total area of water that is filtered by the polyps (Grigg 1984, 1993). Bamboo coral (*Lepidisis olapa*), unlike other species of precious corals, is unbranched (Grigg 1984). Long coils that trail in the prevailing currents maximize the total amount of seawater that is filtered by the polyps (Grigg 1984). While clearly, the presence of strong currents is a vital factor determining habitat suitability for precious coral colonies, their role to date is not fully understood.

Precious corals are known to grow on a variety of bottom substrate types. Precious coral yields, however, tend to be higher in areas of shell sandstone, limestone and basaltic or metamorphic rock with a limestone veneer.

Light is one of the most important determining factors of the upper depth limit of many species of precious corals (Grigg 1984). The larvae of two species of black coral, *Antipathes grandis* and *A. dichotoma*, are negatively phototaxic.

Grigg (1984) states that temperature does not appear to be a significant factor in delimiting suitable habitat for precious corals. In the Pacific Ocean, species of *Corallium* are found in temperature ranges of 8° to 20°C, he observes. Temperature may determine the lower depth limits of some species of precious coral, including two species of black corals in the MHI, he suggests. In the MHI, the lower depth range of two species of black corals (*Antipathes dichotoma* and *A. grandis*) coincides with the top of the thermocline (about 100 m), Grigg observes.

In pink coral (*Corallium secundum*), the sexes are separate (Grigg 1993). Based on the best available data, it is believed that *C. secundum* becomes sexually mature at a height of approximately 12 cm (13 years) (Grigg 1976). Pink coral reproduce annually, with spawning occurring during the summer, during the months of June and July. Coral polyps produce eggs and sperm. Fertilization of the oocytes is completed externally in the water column (Grigg 1976, 1993). The resulting larvae, called planulae, drift with the prevailing currents until finding a suitable site for settlement.

Pink, bamboo and gold corals all have planktonic larval stages and sessile adult stages. Larvae settle on solid substrate where they form colonial branching colonies. Grigg (1993) notes that the length of the larval stage of all deepwater species of precious corals is not known. Clean swept areas exposed to strong currents provide important sites for settlement of the larvae, Grigg adds. The larvae of several species of black coral (*Antipathes*) are negatively photoactive, he notes. They are most abundant in dimly lit areas, such as beneath overhangs in waters deeper than 30

m, he observes. In an earlier study, Grigg (1976) found that “[w]ithin their depth ranges, both species are highly aggregated and are most frequently found under vertical dropoffs. Such features are commonly associated with terraces and undercut notches relict of ancient sea level still stands. Such features are common off Kauai and Maui in the MHI. Both species are particularly abundant off of Maui and Kauai, suggesting that their abundance is related to suitable habitat.” Off of Oahu, many submarine terraces that otherwise would be suitable habitat for black corals are covered with sediments, Grigg (1976) adds.

Grigg (1993) observes that precious corals have low recruitment and mortality. They are slow growing and long lived, believed to reach the age of 75 years and older, he notes. Common causes of mortality include smothering by sediments and toppling of colonies due to erosion of the substrate, he concludes. (Another cause is worms boring into the colony, weakening it and causing it to collapse.)

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. These species of fish include onaga (*Etelis coruscans*), kahala (*Seriola dumerallii*) and the shrimp (*Heterocarpus ensifer*). These species do not seem to depend on the coral for shelter or food.

Densities of pink, gold and bamboo coral have been determined for an unexploited section of the Makapuu bed (Grigg, 1976). As noted in the FMP for precious corals, the average density of pink coral in the Makapuu bed is 0.022 colonies/m². This figure was extrapolated to the entire bed (3.6 million m²), giving an estimated standing crop of 79,200 colonies. At the 95% confidence limit, the standing crop is 47,500 to 111,700 colonies. The standing crop of colonies was converted to biomass ($3N_iW_i$), resulting in an estimate of 43,500 kg of pink coral in the Makapuu bed.

In addition to coral densities, Grigg (1976) determined the age-frequency distribution of pink coral colonies in Makapuu bed. He applied annual growth rates to the size frequency to calculate the age structure of pink coral at Makapuu Bed (Table 4).

Age Group (years)	Number of Colonies
0–10	44
10–20	73

Age Group (years)	Number of Colonies
20–30	22
30–40	12
40–50	7
50–60	0

Table 4: Age-Frequency Distribution of *Corallium secundum* (Source: Grigg 1973)

Estimates of density were also made for bamboo (*Lepidisis olapa*) and gold coral (*Gerardia* sp.) for Makapuu bed. The distributions of both these species are patchy. As noted in the FMP, the area where they occur comprises only half of that occupied by pink coral (1.8 km²). Estimates of the unexploited abundance of bamboo and gold coral were 18,000 and 5,400 colonies, respectively. Estimates of density for the unexploited bamboo coral and gold coral in the Makapuu bed are 0.01 colonies/m² and 0.003 colonies/m². Using a rough estimate for the mean weights of gold and bamboo coral colonies (2.2 kg and 0.6 kg), a standing crop of about 11,880 kg of gold coral and 10,800 kg for bamboo for Makapuu bed was obtained.

Growth rates for several species of precious corals found in the western Pacific region have been calculated.

Grigg (1976) determines that the height of pink coral (*C. secundum*) colonies increases about 0.9 cm/yr up to about 30 years of age. As noted in the FMP for precious corals, the height of the largest colonies of *Corallium secundum* at Makapuu bed rarely exceed 60 cm. Colonies of gold coral are known to grow up to 250 cm tall while bamboo corals may reach 300 cm. The natural mortality rate of pink coral at Makapuu bed is believed to be 0.066, equivalent to an annual survival rate of about 93%.

Bibliography

Grigg RW, Bayer FM. 1976. Present knowledge of the systematics and zoogeography of the Order Gorgonacea in Hawaii. Pac Sci 30(2):167–75.

Grigg RW, Opreska D. 1977. Order Antipatharia: black corals. In: editor(s). Reef and shore fauna of Hawaii. Honolulu: Bishop Museum Pr. p 242–61. Special publication nr 64(1).

Grigg RW. 1974. Growth rings: annual periodicity in two gorgonian corals. *Ecology* 55:876–81.

Grigg RW. 1976. Fishery management of precious and stony corals in Hawaii. Honolulu: Univ Hawaii Pr. 48 p. Report nr SEAGRANT-TR-77-03...

Grigg RW. 1982. Status of the precious coral industry in 1982. Final report to the Western Pacific Regional Fishery Management Council. Honolulu: WPRFMC.

Grigg RW. 1988. Recruitment limitations of deep benthic hard-bottom octocoral populations in the Hawaiian Islands. *Mar Ecol Prog Ser* 45:121–6.

Grigg RW. 1993. Precious coral fisheries of Hawaii and the US Pacific Islands. *Mar Fish Rev* 55(2):50–60.

Oishi FG. 1990. Black coral harvesting and marketing activities in Hawaii—1990. Honolulu: DAR, Dept of Land and Natural Resources.

4 CRUSTACEAN SPECIES

This section is divided up between spiny lobster, slipper lobster, and Kona crab in Hawaii and spiny lobster in the other islands of the Western Pacific Region. This is because the only significant fisheries for crustaceans, primarily spiny lobsters and slipper lobsters, are found in Hawaii. Moreover, these fisheries use traps, which are not used extensively for crustaceans outside of Hawaii, and which are used in Hawaii to target other crustaceans such as Kona crab and white crabs. Moreover, while other spiny lobsters are widespread in the Pacific Islands and the US Western Pacific Region, the target of the lobster fishery in Hawaii, *Panulirus marginatus*, is found only in Hawaii, Johnson Island and Wake Island. Further, a major component of the Hawaii lobster fishery is the slipper lobster *Scyllarides squammosus*. Slipper lobsters, which are not targeted to any extent by other fisheries in the Western Pacific, may be taken opportunistically by divers.

Throughout the other Pacific Islands, including American Samoa, Mariana Islands and the Pacific Remote Islands, the most common spiny lobster found on rocky and coral reefs, apart from Hawaii, is *Panulirus penicillatus*, while other species such as *P. versicolor*, *P. ornatus* and *P. longipes* have also been observed, but are much less common.

4.1 Hawaiian Spiny Lobster

4.1.1 Habitat

Adult spiny lobsters are typically found on rocky substrate in well protected areas, in crevices and under rocks (Pitcher 1993, FAO 1991). Spiny lobsters found in Hawaii include both *Panulirus marginatus* and *P. penicillatus*. However, most fishing for lobsters in Hawaii is targeted at *P. marginatus* and the slipper lobster *Scyllarides squammosus*, and these species are the focus of this review. An extensive review of the EFH for *P. penicillatus* is included in the FEPs for Mariana Islands, American Samoa and the PRIAs.

Unlike many other species of *Panulirus*, the juveniles and adults of *P. marginatus* are not found in separate habitat apart from one another (MacDonald and Stimson 1980, Pitcher 1993, Parrish and Polovina 1994). Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters (MacDonald and Stimson 1980, Parrish and Polovina 1994). Juvenile and adult *P. marginatus* do utilize shelter differently from one another (MacDonald and Stimson 1980). Similarly, juvenile and adult *P. penicillatus* also share the same habitat (Pitcher 1993).

In the NWHI, *P. marginatus* is found seaward of the reefs and within the lagoons and atolls of the islands (WPRFMC 1983). Uchida (1986) reports that *P. penicillatus* rarely occurs in the commercial catches of the NWHI lobster fishery. In the NWHI, *P. penicillatus* is found inhabiting shallow waters (<18 m) (Uchida and Tagami 1984).

In the NWHI, the relative proportion of slipper lobsters to spiny lobsters varies between banks; several banks produce relatively higher catch rates of slipper lobster than total spiny lobster (Uchida 1986; *Clarke et al. 1987, WPRFMC 1986). The slipper lobster is taken in deeper waters than the spiny lobster (Clarke et al., 1987, WPRFMC 1986). Uchida (1986) reports that the highest catch rates for slipper lobster in the NWHI occur between the depths of 20-55 m.

Pitcher (1993) observes that, in the southwestern Pacific, spiny lobsters are typically found in association with coral reefs. Coral reefs provide shelter as well as a diverse and abundant supply of food items, he notes. Pitcher also states that in this region, *P. penicillatus* inhabits the rocky shelters in the windward surf zones of oceanic reefs, an observation also noted by Kanciruk (1980). Other species of *Panulirus* show more general patterns of habitat utilization, Pitcher continues. At night, *P. penicillatus* moves on to reef flat to forage, Pitcher continues. Spiny lobsters are nocturnal predators (FAO 1991).

4.1.2 Morphology

Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida 1986, FAO 1991). Spiny lobster have a large spiny carapace with two horns and antennae projecting forward of their eyes and a large abdomen terminating in a flexible tailfan (FAO 1991).

Uchida (1986) provides a detailed description of the morphology of the slipper lobster *Scyllarides squammosus* and *S. haanii*. He notes that the two species are very similar in appearance and are easily confused (Uchida 1986). The appearance of the slipper lobster is notably different than that of the spiny lobster.

4.1.3 Reproduction

Spiny lobsters (*Panulirus* sp.) are dioecious (Uchida 1986). Generally, the different species of the genus *Panulirus* have the same reproductive behavior and life cycle (Pitcher 1993). The male spiny lobster deposits a spermatophore or sperm packet on the female's abdomen (WPRFMC 1983, Uchida 1986). In *Panulirus* sp., the fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released for the female's oviduct and are then fertilized and attach to the setae of the female's pleopod (WPRFMC 1983, Pitcher 1993). At this point the female lobster is ovigerous, or berried (WPRFMC 1983). The fertilized eggs hatch into phyllosoma larvae after 30-40 days (MacDonald 1986, Uchida 1986). Spiny lobsters are very fecund (WPRFMC 1983). The release of the phyllosoma larvae appears to be timed to coincide with the full moon and dawn in some species (Pitcher 1993). In *Scyllarides* sp. fertilization is internal (Uchida 1986b).

4.1.4 Larval Stage

Very little is known about the planktonic phase of the phyllosoma larvae of *Panulirus marginatus* (Uchida et al. 1980). After hatching, the leaf-like larvae (or phyllosoma) enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies depending on the species and geographic region (WPRFMC 1983). The planktonic larval stage may last from 6 months to 1 year from the time of the hatching of the eggs (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar morphological stages of development that the phyllosoma larvae pass through before they transform into the postlarval puerulus phase (Johnson 1986, MacDonald 1986).

The pelagic phyllosoma stage of development is followed by the puerulus stage. The puerulus stage lasts 6 months or less (WPRFMC 1983). Spiny lobster pueruli are free-swimming and actively return to shallow, nearshore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). Johnston (1973) reports that the phyllosoma phase of some species of the genera *Scyllarides* is somewhat shorter. MacDonald and Stimson (1980) found pelagic, puerulus larvae settlement to occur at approximately 1 cm in length. MacDonald (1986) found puerulus settlement occurred primarily at the new moon and first quarter lunar phase in Hawaii. The settlement of puerulus is higher in the central portion of the Hawaiian Island chain than what, and it is higher in the NWHI than around the MHI (MacDonald 1986).

There is a lack of published data pertaining to the preferred depth distribution of phyllosoma larvae in Hawaii. However, the depth distribution of phyllosoma larvae of other species of *Panulirus* common in the Indo-Pacific region has been documented. Phillips and Sastry (1980) reports that the newly hatched larvae of the western rock lobster (*P. cygnus*) is typically found within 60 m of the surface. Later stages of the phyllosoma larvae are found at depths between 80-120 m. *P. cygnus* undergoes a diurnal vertical migration, ascending to the surface at night, descending to lower depths during the day, the authors add. The authors also note that research has shown that early phyllosoma larvae display a photopositive reaction to dim light. In the Gulf of Mexico, the depth to which *Panulirus* larvae descend is restricted by the depth of the thermocline, Phillips and Sastry note.

MacDonald (1986) state that after settlement the pueruli molt and transform into post-pueruli, a transitional phase between the pelagic phyllosoma phase and the juvenile stage. Yoshimura and Yamakawa (1988) note that very little is known about the habitat requirements of Palinurid pueruli after settlement occurs. However, Pitcher (1993) states that the post-pueruli of *Panulirus penicillatus* has been observed inhabiting the same high-energy reef-front habitat as adults of the species. Studying the benthic ecology and habitat utilization of newly settled pueruli and juveniles of the Japanese spiny lobster (*P.*

japonicus), Yoshimura and Yamakawa (1988) conclude that microhabitats, such as small holes in rocks and boulders and algae, provide important habitat for the newly settled pueruli and juvenile lobsters. The Japanese spiny lobster is found inhabiting shallow waters at depths of 1-15 m on rocky bottom (FAO 1991).

The oceanographic and physiographic features that result in the retention of lobster larvae within the Hawaiian archipelago are not understood (WPRFMC 1983). Johnston (1968) suggests that fine-scale oceanographic features, such as eddies and currents, serve to retain phyllosoma larvae within the Hawaiian Island chain. In the NWHI, puerulus settlement appears to be linked to the north and southward shifts of the North Pacific Central Water (NPCW) type (MacDonald 1986). The relatively long pelagic larval phase for palinurids results in very wide dispersal of spiny lobster larvae; palinurid larvae are transported up to 2,000 miles by prevailing ocean currents (Johnston 1973, MacDonald 1986).

4.1.5 Habitat Description for Hawaiian Spiny Lobster (*Panulirus marginatus* and *Scyllarides squammosus*)

Management Plan and Area:

American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

The Hawaiian spiny lobster, within the Council's jurisdiction is managed under the FEP for the Hawaiian Archipelago.

General Description and Life History

The Hawaiian spiny lobster (*Panulirus marginatus*) is endemic to the Hawaiian Islands and Johnston Atoll (Brock 1973, FAO 1991). The relative abundance of *P. marginatus* at Johnston Atoll is very low (Brock 1973). The spiny lobster is distributed throughout the entire NWHI, from Kure Atoll to Nihoa (Uchida 1986a). *P. marginatus* is the principal species landed in the NWHI spiny lobster fishery (WPRFMC.1983). The reported depth distribution of this species in the NWHI is 5-100 fm (WPRFMC 1983). While this species is found down to depths of 100 fm it usually inhabits shallower waters (FAO 1991). Uchida and Tagami (1984) report that *P. marginatus* is most abundant in waters of 90 m or less. Moffitt (1998, pers. comm.) states that spiny lobster are found in greatest abundance between the depths of 10-50 fm. At Maro Reef, in the NWHI, large adult spiny lobsters have been captured at depths as shallow as 10 feet (Moffitt 1998, pers comm.).

Uchida and Tagami (1984) note that within the NWHI, there is a dramatic shift between depth and relative abundance. They report that in the vicinity of the northern most islands

and banks relative abundance of spiny lobsters was highest at depths of 19-54 m and that at the lower end of the chain the highest abundance of spiny lobsters were observed between 55-73 m. North of Maro Reef the highest relative abundance of spiny lobsters is found at shallower depths, they continue. They suggest that this variability may be due to differences in the temperature regime in the NWHI.

P. marginatus is typically found on rocky substrate in well-protected areas such as crevices and under rocks (FAO 1991). During the day, spiny lobsters are found in dens or crevices in the company of one or more other lobsters (WPRFMC 1983). MacDonald and Stimson (1980), studying the population biology of spiny lobsters at Kure Atoll in the NWHI, found that 57% of the dens examined were inhabited by solitary lobsters. The remaining 43% were occupied by more than one lobster, with adult and juvenile lobsters of both sexes often found sharing the same dens. However, the authors note, adult and juvenile spiny lobsters exhibit distinctly different den occupancy patterns, with juveniles (less than 6 cm in carapace length) typically in multiple occupancy dens with other lobsters. Adult and juvenile spiny lobsters are not segregated by geographic area or habitat type at Kure Atoll, MacDonald and Stimson observe. They found that juvenile spiny lobsters do not utilize separate nursery habitats apart from the adult lobsters. The larval spiny lobster puerulus recruits directly to the adult habitat (Parrish and Polovina 1994). This is in contrast to the juveniles of other species of spiny lobsters that tend to reside in shallow water and migrate to deeper, offshore waters as they mature (MacDonald and Stimson 1980).

There are limited data available concerning growth rates, reproductive potentials and natural mortality rates at the various life history stages (WPRFMC 1983). The relationship between egg production, larval settlement, and stock recruitment are poorly understood (WPRFMC 1983).

Egg and larval distribution

The Hawaiian spiny lobster (*P. marginatus*) is dioecious (Uchida 1986a). The male spiny lobster deposits a spermatophore or sperm packet on the female's abdomen (WPRFMC 1983, Uchida 1986a). In *P. marginatus*, fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released for the female's oviduct, where they are then fertilized and attach to the setae of the female's pleopod (WPRFMC 1983). At this point the female lobster is ovigerous, or berried (WPRFMC 1983). The fertilized eggs hatch into phyllosoma larvae after 30-40 days (MacDonald 1986, Uchida 1986a).

The spawning season for *P. marginatus* varies throughout the Hawaiian Island chain (Uchida 1986a). In the northwestern end of the NWHI spawning occurs primarily during

the early summer months (Uchida et al. 1980, Uchida, 1986a). MacDonald and Stimson (1980) found ovigerous females at Kure Atoll between the months of May to September. Uchida et al (1980) found the peak abundance of ovigerous female lobsters at Nihoa, French Frigate Shoals between late summer and early winter. It is believed that reproduction is nearly continuous in the warmer waters south of Maro Reef in the NWHI (WPRFMC 1983). Around the island of Oahu spawning occurs year-round (Uchida 1986a). In the MHI, peak spawning activity occurs between the months of May and August with a minimal amount of activity from November to January (Uchida 1986a). Egg-bearing females are found year-round in the MHI (WPRFMC 1983).

Spiny lobsters are very fecund (WPRFMC 1983). Honda (1980) found that fecundity increased with size. Most female spiny lobsters reach sexually maturity at 2 years of age (WPRFMC 1983). Estimating size at maturity for male and female spiny lobsters at Necker Island and Oahu, Prescott (19 *) concludes the Necker Island females reach sexual maturity at 60.7 mm, males at 59.2 mm, while Oahu females reach sexual maturity at 58.6 mm, males at 63.6 mm. At Necker Island the smallest mated lobster observed was 48.3 mm; it is not conclusive that the ovaries of females are mature at this size (Uchida and Tagami 1984). Growth rates for male spiny lobsters at Necker Island have been calculated as follows: 3.7 cm CL at 1 year, 5.7 cm at 2 years, 7.3 cm at 3 years, 8.5 cm at 4 years, 9.4 cm at 5 years and 10.1 cm in 6 years (Uchida 1986a). Due to insufficient data the growth of females has not been calculated (Uchida 1986a).

Larvae

After hatching, the larvae (or phyllosoma) enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies depending on the species and geographic region (WPRFMC 1983). Very little is known about the planktonic phase of the phyllosoma larvae of *P. marginatus* (Uchida et al.1980). The planktonic larval stage may last from 6 months to 1 year from the time of the hatching of the eggs (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar stages of development that the phyllosoma larvae pass through before they transform into the postlarval puelurus phase (Johnson 1968, MacDonald 1986).

The pelagic phyllosoma stage of development is followed by the puerulus stage. Spiny lobster pueruli are free-swimming and actively migrate into shallow, near-shore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). The puelurus stage lasts 6 months or less (WPRFMC 1983). MacDonald and Stimson (1980) found pelagic, puerulus larvae settlement to occur at approximately 1 cm in length. After settlement the pueluri molt and transform into postpueruli, a transitional phase between the pelagic phyllosoma phase and the juvenile stage (MacDonald 1986).

It is believed, that because of the endemic nature of *P. marginatus* in the Hawaiian archipelago, the resident population is the source of larval recruits (Uchida et al. 1983). Shaklee (1962) found no genetic variation within the various spiny lobster populations at the different islands and banks in the NWHI chain. These data suggest that a single stock of spiny lobster exists in the NWHI (WPRFMC 1983). Recruitment of puerulus lobster larvae occurred at Kure Atoll beginning in the spring and lasting to October; no recruitment occurred from October to March (MacDonald and Stimson 1980). The distribution of lobster larvae in the waters surrounding the banks and islands of the NWHI is patchy (Parrish and Polovina 1994). Settlement of palinurid larvae tends to be higher in the middle of the Hawaiian Island chain and higher in the NWHI than in the MHI (MacDonald, 1986).

There is evidence that the recruitment of puerulus lobster larvae is tied to the lunar phase with maximum recruitment occurring during the new moon and first quarter phases (MacDonald and Stimson 1980).

Juvenile distribution

Parrish and Polovina (1994) found that banks with summits deeper than 30 m had consistently lower catches of spiny lobster; six of eight banks surveyed with summits at depths greater than 30 m did not provide commercial quantities of spiny lobster. They suggest a depth threshold may prevent the successful settlement and/or survival of pueruli of the spiny lobster in commercial quantities at these banks.

Parrish and Polovina (1994) studied the production rates of three banks in the NWHI; two commercially productive banks, Maro Reef and Necker Island, and one commercially unproductive bank, Lisianski. In this study the percent coverage of the different substrate types were measured and classified into four habitat types. The intermediate relief habitat (5-30 cm) was found to support the highest abundance of juvenile lobsters. Based on the results of their analysis, Parrish and Polovina conclude that the intermediate relief habitat provides optimal habitat for juvenile spiny lobster. This intermediate relief habitat rarely exceeded 10 cm in height and was comprised of macroalgae including *Dictyopterus* sp., *Sargassum* sp. and *Padina* sp. Parrish and Polovina determined that a much greater proportion of intermediate substrate exists at the two productive banks studied, Maro Reef and Necker Island, than at the unproductive bank, Lisianski Island. They conclude that the amount of suitable habitat may be a factor limiting the total abundance of adult lobster production. The intermediate relief habitat provides suitable habitat for the settlement, survival and growth of *P. marginatus* pueruli and post pueruli. It does not provide enough structural relief to support a community of predatory reef fish, Parrish and Polovina note. Furthermore, they add, the lack of structural relief provides little shelter or protection for fish that forage on juvenile lobster from large piscivores such as sharks and jacks.

Parrish and Polovina (1994) describe the substrate of Necker Island and Maro Reef as predominantly comprised of intermediate relief algal communities. However, prolonged changes in water temperature could greatly modify the algal abundance, they note. The effects of such changes might include increased predation, reduced recruitment and reduced availability of food, they conclude.

Annual exploratory trapping surveys at Maro Reef in the NWHI have been conducted by NMFS since 1994. Haight (1998) explains that the survey was designed to identify juvenile spiny lobster habitat and determine abundance. Preliminary results of this survey indicate that the northwestern portion of Maro Reef supports higher concentrations of juvenile *P. marginatus* than are found at other sample stations within the reef. The northwest portion of the reef extends outward from the lagoon and as a result is exposed to greater wave action and currents than other areas of Maro Reef, Haight observes. The benthic habitat at the northwestern site (site 1) is distinctly different from that of other sites sampled within Maro Reef, he continues. Of particular note was the predominance of live coral colonies of *Acropora* and *Pocillopora* corals, he observes. However, colonies of *Acropora* sp. coral were not found at any of the stations sampled within the reef and are rarely found outside the reef (F. Parrish, unpub. data. in Haight 1998). Three other sites comprised of coral heads interspersed with barren sand patches and coral rubble were sampled during the survey, and the majority of spiny lobsters found at them were adults (Haight 1998). The specific ecological and physical mechanisms that are responsible for higher abundance of juvenile spiny lobster at the northwestern portion of Maro Reef need further study.

MacDonald and Stimson (1980) found juvenile spiny lobsters to exhibit a restricted home range, while adult spiny lobsters displayed a much wider home. Uchida and Tagami (1984) observed that 90 percent of recaptured adult spiny lobsters showed movement of 5 nmi or less, while MacDonald and Stimson (1980) found spiny lobsters had a dispersal rate that rarely exceeded several hundred m.

Adult distribution

Spiny lobsters are distributed throughout the NWHI, from Nihoa to Kure Atoll (WPRFMC 1983). The distribution of adult spiny lobsters is uneven throughout the NWHI chain. Research conducted prior to advent of commercial exploitation of spiny lobsters found the greatest abundance of lobsters at Necker and Maro Reef in the NWHI (Uchida et al. 1980, WPRFMC 1983). Surprisingly, the benthic habitat of Maro Reef differs markedly from bottom conditions found at Necker Island (Uchida et al 1980, WPRFMC 1983). The substrate at Necker Island is largely composed of coral interspersed with sandy areas and sandstone outcroppings. The bottom at Maro Reef is primarily

composed of coral rubble and sand, lacking the type of habitat features normally thought to be lobster habitat (WPRFMC 1983).

Uchida et al (1980) found significant differences in the average sizes among spiny lobster populations at the various banks and islands they sampled. MacDonald and Stimson (1980) found there to be a seasonal variation in the size distribution of the spiny lobster population at Kure Atoll in the NWHI. Small lobsters were more abundant in the months of June to September while larger lobsters were found to be more abundant in January. These researchers found males to be more abundant than females throughout the year. Male spiny lobsters were also found to comprise the majority of individuals in the larger-sized class.

Spiny lobsters are nocturnal predators (FAO 1991). Spiny lobsters are regarded as omnivorous, opportunistic scavengers (Pitcher 1993). Food items reported from the diets of *Panulirus* sp. include echinoderms, crustaceans, molluscs (primarily gastropods) algae and seagrass (Pitcher 1993). The habitat description for *P. marginatus* is summarized in Table 1.

Table 17. Habitat Description for Hawaiian Spiny Lobster (*Panulirus marginatus*)

	Egg	Larvae	Juvenile	Adult
Duration	30-40 days.	Planktonic Phyllosoma stage (6-12 months), free-swimming pueruli stage (up to 6 months).	Not known	Not known
Diet	N/A	No information available	No information available	Diet of <i>Panulirus</i> sp. includes echinoderms, crustaceans, molluscs (primarily gastropods) algae and seagrass
Distribution	Release of phyllosoma larvae appears to be timed to coincide with the full moon and dawn (Pitcher 1993). In NWHI spawning takes place during summer months, in MHI spawning takes place year round.	In Hawaii, puerulus settlement occurs primarily at the new moon and first quarter lunar phase (MacDonald 1986)	Juvenile <i>P. marginatus</i> recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters.	
Location	female spiny lobster broods the eggs until they hatch	Puerulus larvae seem to have a low rate of settlement success and survival if summit of bank is deeper than 30 m.	Banks with summits deeper than 30 m support lower abundance of juvenile lobsters. The NW portion of Maro supports higher concentrations of juvenile lobsters.	NWHI, MHI, Johnston Atoll
Water Column	N/A	Pelagic - Palinurid larvae are transported great distances by the prevailing water currents, up to 2,000 miles	Benthic	Benthic

Bottom Type	N/A	N/A	Areas of intermediate relief habitat (5B30 cm) seems to provide optimal habitat for juveniles	Adults are typically found on rocky substrates in well protected areas, in crevices and under rocks.
Oceanic Features	female spiny lobster may move to areas of strong currents to release newly hatched larvae into the oceanic environment.	In the NWHI, settlement appears to be linked to the north and southward shifts of the North Pacific Central Water (NPCW) type.	No information available	No information available

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Bibliography

- Cooke WJ, MacDonald CD. 1981. The puerulus and post-puerulus of the Hawaiian spiny lobster, *Panulirus marginatus*. Proc Biol Soc Wash 94(4):1226-32.
- [FAO] Food and Agriculture Organization. 1991. Marine lobsters of the world. Rome: FAO. # p. FAO fisheries synopsis nr 125, volume 13
- [FAO] Food and Agriculture Organization. 1995. Fishery statistics, catches and landings. FAO yearbook, volume 80. Rome: FAO. # p.
- Haight WR. 1998. Maro Reef juvenile spiny lobster survey, 1993-1997. Honolulu: NMFS Southwest Fisheries Science Center, Honolulu Laboratory. # p. Administrative report nr H-98-01.
- Johnston MW. 1968. Palinurid phyllosoma larvae from the Hawaiian archipelago (Palinuridea). Crustaceana Supplemental II:59-79.
- Johnston MW. 1974. On the dispersal of lobster larvae into the eastern Pacific barrier (Decapoda, Palinuridea). Fish Bull 72(3):639-47.
- Kancirik P. 1980. Ecology of juvenile and adult Palinuridae (spiny lobsters). In: Cobb JS, Phillips BF, editors. The biology and management of lobsters. Vol. 2, Ecology and management. Sydney, Australia: Academic Pr. p 11-57.
- MacDonald CD. 1986. Recruitment of the puerulus of the spiny lobster *Panulirus marginatus*, in Hawaii. Can J Fish Aquatic Sci 43:2118-125.
- Parrish FA, Polovina JJ. 1994. Habitat threshold and bottlenecks in production of the spiny lobster (*Panulirus marginatus*) in the Northwestern Hawaiian Islands. Bull Mar Sci 54(1):151-61.
- Phillips BF, Sastry AN. 1980. Larval ecology. In: Cobb JS, Phillips BF, editors. The biology and management of lobsters. Volume 2, Ecology and management. Sydney: Academic Pr. p 11-57.
- Pitcher RC. 1993. Spiny lobster. In: Wright A, Hill L, editors. Nearshore marine resources of the South Pacific. Honiara: Forum Fisheries Agency. p 539-607.
- Polovina JJ. 1993. The lobster and shrimp fisheries in Hawaii. Mar Fish Rev 55(2):28-33.
- Uchida RN. 1986(a). Palinuridae. In: Fishery Atlas of the Northwest Hawaiian Islands, (R.N. Uchida and J.H. Uchiyama, eds.), pp. 70-71. NOAA Technical Report. NMFS 38. p 66-7
- Uchida RN. 1986(b). Scyllaridae. In: Fishery Atlas of the Northwest Hawaiian Islands, (R.N. Uchida and J.H. Uchiyama, eds.), pp. 70-71. NOAA Technical Report. NMFS 38. p 68B9.

- Uchida RN. Raninidae. In: Fishery Atlas of the Northwest Hawaiian Islands, (R.N. Uchida and J.H. Uchiyama, eds.), pp. 70-71. NOAA Technical Report. NMFS 38. p 70-1.
- Uchida, RN, Uchiyama JH, Humphreys RL Jr, Tagami DT. 1980. Biology, distribution, and estimates of apparent abundance of spiny lobster, *Panulirus marginatus* (Quoy and Gaimard), in waters of the Northwestern Hawaiian Islands. Part I, Distribution in relation to depth and geographical areas and estimates of apparent abundance. In: Grigg RW, Pfund RT, editors. Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands; 1980 Apr 24-25; Honolulu, HI. Honolulu: University of Hawaii. p 121-30. report nr UNIHI-SEAGRANT-MR-80-04.
- Uchida RN, Tagami DT. 1984. Biology, distribution and population structure and preexploitation abundance of spiny lobster, *Panulirus marginatus* (Quoy and Gaimard 1825), in the Northwest Hawaiian Islands. In: Grigg RW, Tanoue KY, editors. Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands; date; location. Honolulu: University of Hawaii.p 157-98. UNIHI-SEAGRANT-MR-84-01. 1.
- Uchida RN, Uchiyama JH, editors. 1986. Fishery atlas of the Northwestern Hawaiian Islands. Washington: NOAA. Technical report nr NMFS 38.
- [WPRFMC] Western Pacific Regional Fishery Management Council. 1986. Honolulu: WPRFMC.
- Yoshimura T, Yamakawa H. 1988. Microhabitat and behavior of settled pueruli and juveniles of Japanese spiny lobster *Panulirus japonicus* at Kominato, Japan. J Crust Biol 8(4):524-31.

4.2 Life Histories and Habitat Descriptions for Other Crustacean Species

4.2.1 Habitat Description for Kona Crab (*Ranina ranina*)

Management Plan and Area

American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland and Baker Islands and Wake Islands.

Very little is known about the life history of *Ranina ranina*. The kona crab is found in the northwestern Hawaiian Islands (NWHI) from Kure Atoll to Nihoa at depths of 24 to 115 m (Uchida, 1986; Edmonson, 1946). *R. ranina* is also found in the main Hawaiian Islands (MHI).

It is believed that female kona crabs obtain sexual maturity somewhere between 54.3 and 63 mm CL. Uchida (1986) reports that 60% of male kona crabs ≥ 60 mm were sexually mature.

Kona crabs are dioecious and display sexual dimorphism. The males tend to grow to a larger size (Uchida, 1986). The sex ratio of males to females has been found to be skewed in favor of males (Fielding and Haley, 1976; Onizuka, 1972).

This species spawns at least twice during the spawning season (Uchida, 1986). The female kona crab usually spawns a second time approximately nine days after the first batch of eggs hatch. Fertilization of the eggs occurs externally. The fertilized eggs adhere to the females numerous setae (Uchida, 1986). In the MHI, ovigerous females have been found to occur only from May to September (Uchida, 1986; Fielding and Haley, 1976). There are insufficient data available to define the exact spawning season in the NWHI (Uchida, 1986).

A small, directed fishery for kona crabs exists in the MHI. There is no directed fishery for kona crabs in the NWHI however it is taken incidentally in the spiny lobster fishery. The principal gear used in the fishery is the kona crab net. *R. ranaina* is also taken in lobster traps. In the MHI from 1961 to 1979 the average total landings for kona crab averaged 13,519 kg.

Egg and larval distribution

Kona crab eggs are spherical and orange. They hatch at approximately 29 days after fertilization (Uchida, 1986). About 5 days prior to hatching the eggs change from an orange to brown color at the onset of the eyed stage (Uchida, 1986).

Larvae

Little is known about the plankton larval stage of kona crabs. The first molt occurs at 7-8 after hatching, the second molt about seven days later (Uchida, 1986).

Juvenile distribution

There is no information available concerning the distribution or habitat utilization patterns of juvenile kona crabs.

Adult distribution

Adult kona crabs are found inhabiting sandy bottom habitat at depths between 24 to 115 m. Kona crabs are opportunistic carnivores that feed throughout the day. It buries itself in the sand where it lies in waits for prey or food particles (Uchida, 1986).

The Council has designated EFH for the juvenile and adult life stages of *Ranina ranina* as the shoreline to a depth of 100 m. EFH for this species larval stage is designated as the water column from the shoreline to the outer limit of the EEZ down to 150 m.

Habitat Description for Kona Crab (*Ranina ranina*)

	Egg	Larvae	Juvenile	Adult
Duration	Approximately 29 days after fertilization	Little is known about the duration of the plankton larval stage of kona crabs. The first molt occurs at 7-8 after hatching, the second molt about seven days later.	Not known	No information available
Diet	N/A	Not known	Not known	Kona crabs are opportunistic carnivores that feed throughout the day. It buries itself in the sand where it lies in wait for prey or food particles
Distribution: General	Fertilization of the eggs	Little is known about	There is no information	Adult kona crabs are

*FEP for the Hawaiian Archipelago**Appendix F*

and Seasonal	occurs externally. The fertilized eggs adhere to the females numerous setae.	the plankton larval stage of kona crabs	available concerning the distribution or habitat utilization patterns of juvenile kona crabs	found inhabiting sandy bottom habitat at depths between 24 to 115 m.
Water Column	demersal	pelagic?	Demersal	demersal
Bottom Type	N/A	N/A	N/A	sandy bottom
Oceanic Features	N/A	Larvae are subject to advection by prevailing currents.	N/A	N/A

Bibliography

Edmonson, C.H. 1946. Reef and shore fauna of Hawaii. Bishop Museum special publication 22, 381 pp.

Fielding, A., and S.R. Haley. 1976. Sex Ratio, size at reproductive maturity, and reproduction of the Hawaiian kona crab, *Ranina ranina* (Linnaeus)(Brachyura, Gymnopleura, Raninidae). Pacific Science 30:131-145.

Onizuka, E.W. 1972. Management and development investigations of the kona crab, *Ranina ranina* (Linnaeus). Final Report. DLNR, Division of Fish and Game, Hawaii. 28 pp.

Uchida, Richard N. 1986. Raninidae. In Fishery Atlas of the Northwest Hawaiian Islands, (R.N. Uchida and J.H. Uchiyama, eds.), pp. 70-71. NOAA Technical Report. NMFS 38.

4.2.2 Habitat description for *Panulirus penicillatus*, *P. versicolor*, *P. ornatus* and *P. longipes* in the Western Pacific Region

Management Plan and Area:

American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands. The spiny lobsters, within the Council's jurisdiction are managed under the FMP for the Crustaceans of the Western Pacific Region. Some information is also provided on the slipper lobsters of the genus *Parribacus*, which was also observed in recent surveys in American Samoa.

General Description and Life History

Scyllarids and palinurids are commonly considered to be opportunistic omnivorous i.e. they are able to feed on a wide range of food (Phillips et al., 1980). Chambers and Nunes (1975) indicated that the diet of *P. penicillatus* in American Samoa was "primarily, if not solely, algae". However, other studies showed that this species also feeds on Annelids Polychaetes, Mollusks (Gastropods and Bivalve), Crustaceans, and Echinoderms (George, 1972; Prescott in Pitcher, 1993). Whereas only a few studies have dealt with the slipper lobster diet, they showed similar patterns to that for spiny lobsters (Lau, 1987; Spanier, 1987). These organisms are able to select their food according to availability and density. Thus, individuals of the same species but which are living in different areas can have different diets implying important differences in growth rates (Morgan, 1980; McKoy & Esterman, 1981; Edgar, 1990).

Lobsters, as other Crustaceans, increase in size by molting, while the growth of tissues (and thus the weight) is continuous. The growth rate decreases with age, and the inter-molt duration increases. During the molt, most of the calcified components are replaced. *P. penicillatus* is sexually dimorphic for size, with males reaching larger sizes than

females. The largest males can weight 3 kg (6.5 Lb) for 16 cm (6 ¼ in) of Cephalothoracic (or Carapace) Length (CL: measured from the basis of the supraorbital spines to the end of the cephalothorax) (Richer de Forges & Laboute, 1995).

Reproduction

For crustaceans, the reproductive season is determined by photoperiod and luminosity (Lipcius & Cobb, 1994). As a result, lobsters from temperate and sub-tropical waters have only one spawning period (Chubb, 1994; Kittaka & MacDiarmid, 1994) whereas numerous tropical species are able to spawn nearly year-round, and some individuals are able to spawn several times in the same year (Berry, 1971; Moore & MacFarlane, 1984; Juinio, 1987). In Hawaii, 40 % of the *P. penicillatus* females are berried (with eggs under the abdomen) (McDonald, 1971, 1979) at any time, and some females spawn 2 or 3 times a year (Juinio, 1987; Plaut, 1993).

Fertilization is external (Lyons, 1970; Morgan, 1980); the male deposits a spermatophore, via paired penile projections at the base of the fifth walking legs, onto the female sternum. This spermatophoric mass becomes black and is butterfly-shaped for spiny lobsters and covers the two first pairs of pleopods in *Parribacus* spp. The female is then called ‘tarred’. After a few days, the female spawns several thousands of oocytes from the paired gonopores situated at the base of the third walking legs, into a ‘chamber’ formed by curving the abdomen under the sternum. The female scrapes the spermatophore with special chelae (claws or pincher) on the dactyl (last segment) of the fifth walking legs, to release the sperm which fertilizes the oocytes during the transit (Berry, 1970; Lipcius & Herrnkind, 1987; Pitcher, 1993). The fertilized eggs adhere to the ovigerous setae of the internal part of the biramous pleopods (Berry, 1970) (see Appendix I). In the literature, the smallest *P. penicillatus* berried females measured from 4.08 cm of CL (1.6 inches) in Philippines (Juinio, 1987) to 6.20 cm (2.45 inches) in the Marshall Islands (Ebert & Ford, 1986). No information on any *Parribacus* spp. reproduction is available in the literature.

Eggs

Following courtship, several hundred thousand eggs are extruded from the paired gonopores at the base of the third walking legs into a chamber formed by curving the abdomen over the sternum. The eggs are carried under the tail of females for about a month before the phyllosoma larvae are released.

Larvae

After 1 to 9 weeks of incubation [20 to 35 days for *P. penicillatus* (Juinio, 1987; Plaut, 1993)], larvae are released in the field (George, 1958; Chittleborough, 1974, 1976; Nair et al., 1981; Pitcher, 1993). Among spiny lobsters, hatching always occurs in an area allowing the larvae to quickly drift offshore (Phillips & Sastry, 1980; Coutures, 2000b),

which implies that sometimes there is migration from coastal to oceanic areas (Moore & MacFarlane, 1984; MacFarlane & Moore, 1986; Coutures, 2000b).

The larvae of Palinuroidea (spiny lobster or Palinuridae, slipper lobster or Scyllaridae, and Synaxidae or coral lobsters) is called phyllosoma (from Greek “phyllo” leaf, and “soma” body), a flat, transparent, leaf-like larva, which corresponds to the Crustacean zoea stage.

The outstanding feature in the life history of the Palinuroidea is the exceptional duration of their larval phase, which varies among spiny lobsters from 6 to 12 months according to the species (Phillips & Sastry, 1980; Booth & Phillips, 1994) and even 24 months for *Jasus edwardsii* (Lesser, 1978), a species occurring in New Zealand and South Australia, and from 1 to 9 months for slipper lobsters (Sims, 1965; Robertson, 1968a,b, 1969a,b; Takahashi & Saisho, 1978; Ito & Lucas, 1990; Marinovic et al., 1994; Mikami & Greenwood, 1997). During the larval phase, phyllosomata can travel great distances, e.g. Johnson (1974) caught one *Panulirus penicillatus* phyllosoma in the Pacific Ocean 3,700 km from the Galapagos Archipelago, which was the closest hatching site. Mechanisms allowing phyllosomata to come back to the coast have been shown only for a few species, especially for *Panulirus cygnus* in the southwest of Australia (see Pearce & Phillips, 1980; Phillips et al., 1991; Pearce et al., 1992). However, for species with a wide geographic distribution such as *P. penicillatus* and *P. parribacus*, the larval dispersion implies that recruits can come from adults living at great distances (Lyons, 1980, 1981; Menzies & Kerrigan, 1980). Oceanic currents and gyres seem important in the transport, and the dispersion, and thus, in the “oceanic routes” used by phyllosomata (Yeung & McGowan, 1991; Booth & Phillips, 1994).

During their larval development, phyllosomata increase in size and general shape through numerous molts. For the species studied, systematians have described 7 to 12 larval stages which characterize the growth by appearance of anatomic features (e.g.: Stage I, 3 pairs of pereopods, stage II: bud of the fourth one), and characteristic measurements (Phillips & Sastry, 1980).

The different larval stages of *P. penicillatus* have been described by Johnson (1968) and Michel (1969, 1971). The duration of the larval species has been estimated to be 7 - 8 months for this species (Johnson, 1971).

For *P. caledonicus*, stage I is the only stage to have been described so far with certainty (Coutures, 2001b). It must be noted that in the Pacific, *Parribacus* species form a complex including a widely distributed species – *P. antarcticus* – and 5 allopatric species (without overlap of their adult distributions). Larvae of this complex are very similar (Coutures,

2001b), and sometimes impossible to separate (Prasad & Tampi, 1960; Michel, 1971; Berry, 1974). Furthermore, some giant larvae – from 6.5 to 8 cm (2.55 to 3.14 inches) of total length, without pereopods - have been caught in the Pacific, Indian, and Atlantic Oceans, that would correspond to the late-stage of *P. antarcticus* (Johnson, 1951; Robertson, 1968c).

When phyllosomata have reached the last larval stage, have enough body reserves, and may be after stimulation from a coastal signal (Booth, 1986; Phillips & McWilliam, 1986a; Booth & Phillips, 1994; McWilliam & Phillips, 1997), they metamorphose into post-larvae called nisto for slipper lobsters and puerulus for spiny lobsters (Lyons, 1970).

Juvenile distribution

Puerulus and nistos differ from juveniles by the absence of calcification and lack of pigmentation, except for the eyes and a few streaks and points on the antennae (Phillips & Sastry, 1980) (Figure 6). The carapace is smoother, pleopods bear long setae (Phillips & Penrose, 1985), the body is longer, antennae are longer (only for spiny lobsters), and sometimes they terminate in a spatula (Serfling & Ford, 1975; Briones-Fourzan) (Fig. 5). According to numerous authors (Serfling & Ford, 1975; Sweat, 1968; Witham et al., 1968; Phillips, 1972; Phillips & Olsen, 1975; Serfling & Ford, 1975; Phillips et al., 1978; Lyons, 1980; Calinski & Lyons, 1983; McDonald, 1986; Hayakawa et al., 1990; Coutures, 2000a, 2001a; Coutures & Chauvet, 2002), the behavior of pueruli and nistos would be to actively swim to benthic coastal habitats (with the aid of their pleopods) before settling onto the benthos. For example, the puerulus of *Panulirus cygnus* can swim from 20 to 60 km (12.5 to 37.5 miles) (Phillips & Penrose, 1985), in 5 to 15 days (Lemmens, 1994).

The post-larvae begins to be colored as soon as it settles on the bottom. The first molt occurs 8 to 10 days after settlement (Phillips & Sastry, 1980). Although it is not the case for all species, *Panulirus penicillatus* and *Parribacus caledonicus* settle in the same habitat as the adults (McDonald, 1971; Nunes & Chambers, 1975; Pitcher, 1992, 1993; Coutures, 2000a; Coutures et al., 2002), i.e. just in front of the breakers.

The puerulus of *Panulirus penicillatus* has been described by Michel (1971): it measures about 1 cm (0.4 inch) of CL. The nisto of *Parribacus caledonicus* has not been described yet but it is likely to be similar to congeners which reach sizes varying from 5 to 5.82 cm (2-2.3 inches) (Rathbun, 1903; Coutures et al., 2002).

Small juvenile *P. penicillatus* of this species have not been observed but it is assumed that they occupy the same habitat as the adults on the windward exposures of fringing rock or coral reefs. *P. versicolor* juveniles inhabit inshore areas as well as the more typical adult

reef. Post larvae are often seen under floating moorings and rafts. It is not known whether these lobster move to the reef successfully or whether they die.

Adult distribution

Virtually all shallow water habitats in the tropical western Pacific are occupied by one or more species of spiny lobster. Each species has a preferred habitat, however, there is a

Great deal of overlap and it is not uncommon to find 2-4 species cohabiting on a single reef in locations such as the south coast of Papua New Guinea. Certain species are more specific in their habitat requirements than others. The greatest constrats is perhaps between *P. ornatus* and *P. penicillatus*. *P. ornatus* has been found from a depth of 100 fathoms on the outer slope of the Great Barrier Reef to areas with extremely high sediment load and reduced salinity near the mouth of the Fly River in Papua New Guinea. *P. penicillatus* is found across nearly a 60 degree range in latitude, from rocky shores to coral reefs, but with the common feature of clear oceanic waters and high energy wave action typical of windward exposures. This habitat is remarkably similar in terms of salinity, dissolved oxygen, and turbidity and the variability of these factors despite latitudinal changes.

The preferred habitat of *P. penicillatus* as discussed above is the windward exposures of fringing rock or coarl reefs. It shelters in deep recesses during the day at depths to ten meters and frequently much shallower than that. At night it forages over the reef face, crest and flats, thus exploiting a much larger habitat than where it shelters during the day. It is also common on leeward barrier reefs and in reef passages when there is sufficient water movement. The larvae likely settle in the adult habitat, settling in deep caves and crevices used by the adults to shelter in the day.

P. longipes is generally found in the lower energy zones behind the reef crest and at the lower boundary of the the distribution of *P. peniciullatus*, i.e. away from areas of intense wave action. *P. versicolor* dominates in still lower energy areas, frequently among live acropora and other reef building coral. It is less cryptic than either *P. penicillatus* or *P. longipes* and can frequently be seen during the day in coral bommies or under plate corals. *P. versicolor* appears to be more tolerant of terrestrial influences than either *P. longipes* or *P. penicillatus* and can be found on reefs exposed ro high turbidity and reduced salinity.

P. ornatus is the most common in areas with a strong terrestrial influence. It is frequently found on lagoon bottoms and deep channels emanating from mangrove communities. In Papua New Guinea it makes a 500 km breeding migration, passing through a variety of habitats in its life cycle, but elsewhere in its distribution large scale migrations have not been noted, and it is likely more resident in one habitat. Some larval settlement is known to take place in its reef habitat.

Bibliography

- Berry, P.F. 1970. Mating behaviour, oviposition and fertilisation in the spiny lobster *Panulirus homarus* (L.). South African Oceanographic Research Institute, Investigation Report. 24: 1-16
- Berry, P.F. 1971. The biology of the spiny lobster *Panulirus homarus* (Linnaeus) off the East coast of Southern Africa. South African Assessment Marine Biology Research, Investigation Report. 28: 74 p.
- Berry, P.F. 1974. Palinurid and Scyllarid lobster larvae of the Natal Coast, South Africa. South African Assessment Marine Biology Research, Investigation Report. 34: 44 p.
- Booth, J.D. 1986. Recruitment of packhorse rock lobster *Jasus verreauxi* in New Zealand. Canadian Journal of Fisheries and Aquatic Sciences. 43: 2212-2220
- Booth, J.D. And B.F. Phillips. 1994. Early life history of the spiny lobster. Crustaceana. 66(3): 271-294
- Briones-Fourzan, P. And P. Mcwilliam. 1997. Puerulus of the spiny lobster *Panulirus guttatus* (Latreille, 1804) (Palinuridae). Marine and Freshwater Research. 48: 699-705
- Calinski, M.D. And W.G. Lyons. 1983. Swimming behavior of the puerulus of the spiny lobster *Panulirus argus* (Latreille, 1804) (Crustacea: Palinuridae). Journal of Crustacean Biology. 3: 329-335
- Chambers Jr, J.R. And W.E. Nunes. 1975. The spiny lobster *Panulirus penicillatus* (Oliver) in American Samoa. California Polytechnic State University. San Luis Obispo, CA. 25 p.
- Chittleborough, R.G. 1974. Western rock lobster reared to maturity. Australian Journal of Marine and Freshwater Research. 25: 221-225
- Chubb, C.F. 1994. Reproductive biology. In 'Spiny lobster management', (Eds.: B.F. Phillips, J.S. Cobb & J. Kittaka), Blackwell Scientific, Oxford. 181-212
- Coutures, E. 2000a. Contributions to the history life study of the Palinuridae and Scyllaridae of the South-Western lagoon of New Caledonia". Thèse Doctorat. University of New Caledonia. Downloadable at <http://www.univ-nc.nc/~coutures> as .pdf (in French). 213 p.
- Coutures, E. 2000b. Distribution of phyllosomata (Decapoda: Palinuridea) in the South-West lagoon of New Caledonia. Marine and Freshwater Research. 51(4): 363-369

- Coutures, E. 2001b. On the first phyllosoma stage of *Parribacus caledonicus*, *Scyllarides squammosus* and *Arctides regalis* from New Caledonia. *Journal of Plankton Research*. 23(7): 745-751.
- Coutures, E. 2003. The shoreline fishery of American Samoa – Analysis of 1-yr data (April 02-March 03) and implementation of a new sampling protocol. DMWR Biological Report. 102: 1-23
- Coutures, E. And C. Chauvet. 2002. Growth and minimum suitable catch of spiny lobsters, *Panulirus penicillatus* and *P. longipes bispinosus* from Isle of Pines (New Caledonia). *Crustaceana*. 74(11): 1189-1199
- Coutures, E., P. Hebert, L. Wantiez & C. Chauvet. 2002. Lobster catches using crest nets in Uvea (Wallis and Futuna). *The Lobster Newsletter*. 15(1): 3-5
- Ebert, T.A. And R.F. Ford. 1986. Population ecology and fishery potential of the spiny lobster *Panulirus penicillatus* at Enewetak Atoll, Marshall Islands. *Bulletin of Marine Science*. 38: 56-67
- Edgar, G.J. 1990. Predator-prey interactions in seagrass beds. III. Impacts of the western rock lobster *Panulirus cygnus* George on epifaunal gastropod populations. *Journal of Experimental Marine Biology and Ecology*. 139: 33-42
- FAO. 1987. Fisheries statistics, catches and landings. FAO Year book. Vol. 64.
- George, R.W. 1972. Guide des langoustes du Pacifique Sud. Agence de développement des pêches dans les Îles du Pacifique Sud. *South Pacific Bulletin*. 22(2): 31-34
- Hayakawa, Y., Booth, J.D., Nishida, S., Sekiguchi, H., Saisho, T. And J. Kittaka. 1990. Daily settlement of the puerulus stage of the red rock lobster *Jasus edwardsii* at Castlepoint, New Zealand. *Nippon Suisan Gakkaishi*. 56(11): 1703-1716
- Ito, M. And J.S. Lucas. 1990. The complete larval development of the scyllarid lobster, *Scyllarus demani* Holthuis, 1946 (Decapoda, Scyllaridae), in the laboratory. *Crustaceana*. 58(2): 144-167
- Johnson, M.W. 1951. A giant phyllosoma larva of a loricate crustacean from the tropical Pacific. *Transactions of the American Microscopy Society*. 70(3): 274-278
- Johnson, M.W. 1968. Palinurid phyllosoma larvae from the Hawaiian archipelago (Palinuridae). *Crustaceana*. 2: 59-79

- Johnson, M.W. 1971. The palinurid and scyllarid lobsters of the tropical Eastern Pacific and their distribution as related to the prevailing hydrography. *Bulletin of the Scripps Institution of Oceanography, University of California*. 19: 1-36
- Johnson, M.W. 1974. On the dispersal of lobster larvae into East Pacific Barrier (Decapoda, Palinuridae). *Fishery Bulletin, U.S.* 72: 639-647
- Juinio, M.A.R. 1987. Some aspects of the reproduction of *Panulirus penicillatus* (Decapoda: Palinuridae). *Bulletin of Marine Science*. 41(2): 242-252
- Kittaka, J. And A.B. MacDiarmid. 1994. Breeding. In 'Spiny lobster management', (Eds.: B.F. Phillips, J.S. Cobb & J. Kittaka), Blackwell Scientific, Oxford. 384-401
- Lau, C. 1987. Feeding behavior of the hawaiian slipper lobster, *Scyllarides squammosus*, with a review of decapod crustacea feeding tactics on molluscan prey. *Bulletin of Marine Science*. 41(2): 378-391
- Lesser, J.H.R. 1978. Phyllosoma larvae of *Jasus edwardsii* (Hutton) (Crustacea: Decapoda: Palinuridae) and their distribution off the east coast of the North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research*. 12(4): 357-370
- Lipcius, R.N. And J.S. Cobb. 1994. Introduction: ecology and fishery biology of spiny lobsters. In 'Spiny lobster management', (Eds.: B.F. Phillips, J.S. Cobb & J. Kittaka), Blackwell Scientific, Oxford. 1-30
- Lipcius, R.N. And W.F. Herrnkind. 1987. Control and coordination of reproduction and molting in the spiny lobster *Panulirus argus*. *Marine Biology*. 96: 207-214
- Lyons, W.G. 1970. Scyllarid Lobsters (Crustacea, Decapoda). *Memoirs of the Hourglass Cruises*. 1(4): 1-74
- Lyons, W.G. 1980. The postlarval stage of scyllaridean lobsters. *Fisheries*. 5(4): 47-49
- MacDonald, C.D. 1971. Final report and recommendations to the U.S. Trust Territory Government on the spiny lobster resources of Micronesia. Marine Resources Division, Department of Resources and Development, Saipan, Mariana Islands. 82 p.
- MacDonald, C.D. 1979. Management aspects of the biology of the spiny lobsters, *Panulirus marginatus*, *P. penicillatus*, *P. versicolor*, and *P. longipes femoristriga* in Hawaii and the Western Pacific. Final Report to the Western Pacific Regional Fishery Management Council, Honolulu, HI. 46 p.

- MacDonald, C.D. 1982. Catch composition and reproduction of the spiny lobster *Panulirus versicolor* at Palau. Transactions of the American Fishery Society. 111: 694-699.
- MacDonald, C.D. 1986. Recruitment of the puerulus of the spiny lobster, *Panulirus marginatus*, in Hawaii. Canadian Journal of Fisheries and Aquatic Sciences. 43: 2118-2125
- MacDonald, C.D. 1988. Fecundity and reproductive rates in Indo-West Pacific spiny lobsters. Micronesica. 21: 103-114
- MacFarlane, J.W. And R. Moore. 1986. Reproduction of the ornate rock lobster, *Panulirus ornatus* (Fabricius), in Papua New Guinea. Australian Journal of Marine and Freshwater Research. 37: 55-65
- Marinovic, B., Lemmens, J.W.T.J. And B. Knott. 1994. Larval development of *Ibacus peronii* Leach (Decapoda: Scyllaridae) under laboratory conditions. Journal of Crustacean Biology. 14(1): 80-96
- Mckoy, J.L. And D.B. Esterman. 1981. Growth of rock lobsters (*Jasus edwardsii*) in the Gisborne region, New Zealand. New Zealand Journal of Marine and Freshwater Research. 15: 121-136
- McWilliam, P.S. And B.F. Phillips. 1997. Metamorphosis of the final phyllosoma and secondary lecithotrophy in the puerulus of *Panulirus cygnus* George: a review. Marine and Freshwater Research. 48: 783-790
- Michel, A. 1969. Les larves PHYLLOSOME du genre *Panulirus* - Palinuridae (Crustacés Décapodes) du Pacifique tropical Sud et Equatorial. Cahier ORSTOM, Série Océanographie. 7(4): 3-19
- Michel, A. 1971. Note sur les puerulus de Palinuridae et les larves PHYLLOSOME de *Panulirus homarus* (L.). Cahier ORSTOM, Série Océanographie. 9(4): 459-473
- Mikami, S. And J.G. Greenwood. 1997. Complete development and comparative morphology of larval *Thenus orientalis* and *Thenus* sp. (Decapoda: Scyllaridae) reared in the laboratory. Journal of Crustacean Biology. 17(2): 289-308
- Moore, R. And W. Macfarlane. 1984. Migration of the ornate rock lobster, *Panulirus ornatus* (Fabricius), in Papua New Guinea. Australian Journal of Marine and Freshwater Research. 35: 197-212

- Morgan, G.R. 1980. Population dynamics of spiny lobsters. In "The biology and management of lobsters" (Eds.: J.S. Cobb & B.F. Phillips), Academic Press, NY. Vol. II: 189-217
- Nair, R.V., Soundarajan, R. And G. Nandakumar. 1981. Observations on growth and moulting of spiny lobsters *Panulirus homarus* (Linnaeus), *P. ornatus* (Fabricius) and *P. penicillatus* (Olivier) in captivity. *Indian Journal of Fisheries*. 28(1-2): 25-35
- Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer*. 21: 1-35
- Pearce, A.F. And B.F. Phillips. 1980. Oceanic processes, puerulus settlement and recruitment of the western rock lobster *Panulirus cygnus*. In "The biology and management of lobsters" (Eds.: J.S. Cobb & B.F. Phillips), Academic Press, NY. Vol. II: 279-302
- Pearce, A.F., Phillips, B.F. And C.J. Crossland. 1992. Larval distributions across the Leeuwin Current: report on RV Franklin Cruise FR8/87 in August/September 1987. CSIRO Marine Laboratory Report. 217: 13 p.
- Phillips, B.F. 1972. A semi-quantitative collector of the puerulus larvae of the western rock lobster *Panulirus longipes cygnus* George (Decapoda, Palinuridae). *Crustaceana*. 22: 147-154
- Phillips, B.F. And J.D. Booth. 1994. Design, use, and effectiveness of collectors for catching the puerulus stage of spiny lobsters. *Review of Fisheries Science*. 2(3): 255-289
- Phillips, B.F., Cobb, J.S. And R.W. George. 1980. General biology. In "The biology and management of lobsters" (Eds: J.S. Cobb & B.F. Phillips), Academic Press, NY. Vol. I: 1-82
- Phillips, B.F. And L. Olsen. 1975. Swimming behaviour of the puerulus larvae in the western rock lobster. *Australian Journal of Marine and Freshwater Research*. 26: 415-417
- Phillips, B.F. And P.S. McWilliam. 1986. The pelagic phase of spiny lobster development. *Canadian Journal of Fisheries and Aquatic Sciences*. 43: 2153-2163

- Phillips, B.F., Pearce, A.F. And R.T. Litchfield. 1991. The Leeuwin current and larval recruitment to the rock (spiny) lobster fishery off western Australia. *Journal of the Royal Society of Western Australia*. 74: 93-100
- Phillips, B.F. And J.D. Penrose. 1985. The puerulus stage of the spiny (rock) lobster and its ability to locate the coast. Western Australia Institute, Technical Report. 50 p.
- Phillips, B.F., Rimmer, D.W. And D.D. Reid. 1978. Ecological investigations of the late-stage phyllosoma and puerulus larvae of the Western rock lobster *Panulirus longipes cygnus*. *Marine Biology*. 45: 347-357
- Phillips, B.F. And A.N. Sastry. 1980. Larval ecology. In "The biology and management of lobsters" (Eds.: J.S. Cobb & B.F. Phillips), Academic Press, NY. Vol. II: 11-57
- Pitcher, C.R. 1992. Biology ecology and fisheries for spiny lobsters in the tropical south-western Pacific. SPC, Inshore Fisheries Resources Report. 92 p.
- Pitcher, C.R. 1993. Spiny lobster. In "Nearshore Marine Resources of the South Pacific" (Eds. A. Wright & L. Hill) Singapore National Printers. Chapter 17: 541-581
- Plaut, I. 1993. Sexual maturity, reproductive season and fecundity of the spiny lobster *Panulirus penicillatus* from the Gulf of Eilat (Aqaba), Red Sea. *Australian Journal of Marine and Freshwater Research*. 44: 527-535
- Prasad, R.R. And P.R.S. Tampi. 1960. Phyllosomas of scyllarid lobsters from the Arabian sea. *J. Mar. Biol. Ass. India*. 2(2): 241-249
- Prescott, J. 1988. Tropical spiny lobster: an overview of their biology, the fisheries and the economics with particular reference to the double spined rock lobster *Panulirus penicillatus*. SPC, Inshore Fisheries Resources Report. 18: 36 p.
- Serfling, S.A. And R.F. Ford. 1975. Ecological studies of the puerulus larval stage of the california spiny lobster, *Panulirus argus*. *Fishery Bulletin, U. S.* 73(2): 360-377
- Sims Jr., H.W. 1965. The phyllosoma larvae of *Parribacus*. *Quarterly Journal of Florida Academic Sciences*. 28(2): 142-172
- Spanier, E. 1987. Mollusca as food for the slipper lobster *Scyllarides latus* in the coastal waters of Israel. *Levantina*. 68: 713-716
- Sweat, D.E. 1968. Growth and tagging studies on *Panulirus argus* (Latreille) in the Florida keys. Florida Board of Conservation Marine Research Laboratory Technical Series. 57: 1-30

Takahashi, H. And T. Saisho. 1978. The complete larval development of the scyllarid lobster, *Ibacus ciliatus* (von Siebold) and *Ibacus novemdentatus* Gibbes in the laboratory. *Memoirs of the Faculty of Fisheries, Kagoshima University*. 27(1): 305-353

Witham, R., Ingle, R.M. And E.A. Joyce Jr. 1968. Physiological and ecological studies of *Panulirus argus* from the St. Lucie estuary. Florida Board of Conservation Marine Research Laboratory Technical Series. 53: 1-31

Yeung, C. And M.F. McGowan. 1991. Differences in inshore-offshore and vertical distribution of phyllosoma larvae of *Panulirus*, *Scyllarus* and *Scyllarides* in the Florida keys in May-June 1989. *Bulletin of Marine Science*. 49(3): 699-714

4.2.3 Habitat Description for *Heterocarpus* spp.

Deepwater caridean shrimp species of the genus *Heterocarpus* have been reported throughout tropical waters of the Pacific including, Hawaii (Clark 1972, Struhsaker and Aasted; 1974, Daley and Ralston 1986; Gooding et al. 1988; Tagami and Barrows 1988; Moffit and Parrish 1992; Ralston and Tagami 1992;), Guam (Wilder 1977), Western Samoa (King 1980), and the Northern Mariana Islands (Moffit 1983, Ralston 1986).

Eight species of *Heterocarpus* (*Heterocarpus ensifer*, *H. laevigatus*, *H. sibogae*, *H. gibbosus*, *H. Lepidus*, *H. dorsalis*, *H. tricarinatus* and *H. longirostris*) have been reported from U.S. Pacific Islands although two species – *Heterocarpus ensifer* and *H. laevigatus* – have been the predominate focus of commercial harvesting operations and scientific research surveys to date.

Adult and Juvenile

Adult *Heterocarpus* are generally found in benthic deepwater habitats between 200-900 meters in depth, primarily on steep outer reef slopes surrounding islands and deepwater banks. Their distribution tends to be stratified by depth with each species occupying different but often overlapping depth ranges (King and Moffit, 1984; Ralston 1986). However, because *Heterocarpus* are found at such deep depths, accurate description and characterization of preferred habitat types are difficult to obtain and virtually non-existent for all but a few select locations in Hawaii.

Hawaii

Around Hawaii, *Heterocarpus laevigatus* and *H. ensifer* have been reported from both the Main Hawaiian Islands and the Northwestern Hawaiian Islands (Gooding 1984; Daley and Ralston 1986; Ralston and Tagami 1992; Moffit and Parrish 1992). Submersible surveys of shrimp densities on different habitats in the Main Hawaiian Islands reported *Heterocarpus*

ensifer tended to group around large anemones and other benthic relief over an otherwise flat, sandy bottom (Gooding et. al., 1988; Moffitt and Parrish, 1992). Conversely, *Heterocarpus laevigatus* were observed as solitary individuals and had greater densities on volcanic substrata compared to coralline substrata (Moffitt and Parrish, 1992). However, Moffitt and Parrish (1992) also suggest bottom slope, substrate complexity, stability, current patterns and other aspects may be of considerable importance to both *Heterocarpus ensifer* and *H. laevigatus*.

In terms of habitat related abundance, trapping surveys in the Main Hawaiian Islands report that the exploitable biomass of *H. laevigatus* was greatest at 460- 640 meters and negligible amounts occurred shallower than 350 meters or deeper than 830 meters (Ralston and Tagami, 1992). In the NWHI, highest catch rates for *H. laevigatus* were made between 500 and 800 meters while the highest catch rates for *H. ensifer* occurred between 350 and 600 meters (Gooding 1984).

Mariana Archipelago

In the Mariana Archipelago, shrimp trapping surveys conducted at 22 islands and banks between 1982 and 1984 reported the presence of all eight species of *Heterocarpus*. During these surveys, *Heterocarpus ensifer*, *H. laevigatus* and *H. longirostris* accounted for 99 percent of the catch while *H. tricarinatus*, *H. gibbosus* and *H. sibogae* were reportedly rare (Moffitt and Polovina 1987). Maximum catch rates for *H. ensifer* occurred at a depth of 366 meters, *H. laevigatus* – between 549 and 777 meters and *H. longirostris* at 777 meters. Wilder (1977) reported similar findings for *H. ensifer* and *H. laevigatus* in Guam. Specific descriptions on habitat types were not reported in these surveys.

American Samoa

Currently, there is no information on *Heterocarpus* for American Samoa. However, King (1980) reported that trapping surveys on steep slopes between 250 and 700 m in Western Samoa yielded six species of carid shrimp with *Heterocarpus ensifer* and *Heterocarpus laevigatus* possessing the greatest commercial potential. Because American Samoa and Western Samoa are distinct only by their political status, it can be inferred that *Heterocarpus* are present and distributed at similar depths on steep slopes surrounding the islands and banks of American Samoa.

U.S. Pacific Remote Island Areas

There have been no surveys of deepwater caridean shrimps conducted in any of the U.S. Pacific Remote Island Areas of Howland, Baker, and Jarvis Islands, Johnston and Palmyra Atoll or Kingman Reef. However, *Heterocarpus ensifer*, *H. laevigatus* and *H. gibbosus* have

been reported from the Northern Gilbert Islands, Kiribati, which is at the same latitude and roughly 800 miles west of Howland and Jarvis Islands (Crutz and Preston 1987). Due to their distribution throughout the tropical Pacific islands, it may be inferred that *Heterocarpus* resources are likely to be present at similar depth ranges throughout the U.S. Pacific Remote Island Areas.

Eggs and Larvae

The relationship between habitat and egg production, larval settlement and stock recruitment for *Heterocarpus* is extremely limited. Studies by King and Moffit (1984) and Moffit and Polovina (1987) have reported that deepwater caridean shrimps have separate sexes which can be determined by examining the shapes of the first endopods of the first pleopods or swimming legs. In the male sex, the endopod is broader and more leaf shape than in females. Additionally, on the second pleopod, males possess both an appendix interna and an appendix masculina whereas, the latter is absent in females. Like most shrimps, eggs of caridean deepwater shrimps are carried externally on the pleopods of ovigerous females. King (1983) estimates larger species of *Heterocarpus* may carry over 30,000 eggs.

In Hawaii, there is some evidence to suggest that mature male and female of *Heterocarpus laevigatus* move to deeper waters (between 550-700 meters) when females are ovigerous, indicating that deeper depths are of some importance during this life stage (Daley and Ralston, 1986). It is not known if eggs have a pelagic or epipelagic life cycle although, Daley and Ralston (1986) conclude that females apparently settle in deep water and migrate gradually to shallower depths as they grow.

Reproduction, Growth and Mortality (by island area if possible)

The available literature on the reproductive biology, growth and mortality of deepwater caridean shrimps in the Western Pacific Region is limited, and primarily restricted to *H. ensifer* and *H. laevigatus* and to an even lesser degree, *H. longirostris*.

Heterocarpus Laevigatus

Female *H. laevigatus* reaches sexual maturity between 40 and 43 cm (King, 1983; Daley and Ralston, 1986; Moffit and Polovina, 1987). In Hawaii, over 50% of *H. laevigatus* bear eggs from October to January suggesting that reproduction of this species occurs during the fall and winter seasons (Daley and Ralston, 1986). Moffit and Polovina (1987) reported the corresponding time periods in the Northern Mariana Islands was November – February, while similar, but more narrowly defined breeding seasons were reported by Wilder (1977) in Guam. King (1983) reports that in Fiji, egg bearing females were observed in the months of April, June and July. Based on this information, spawning season of *H. laevigatus* appears to be during the winter season of each hemisphere.

Heterocarpus ensifer

In Hawaii, *H. ensifer* is recruited into the fishery at 23 cm

In Mariana *H. ensifer* length at maturity is 20.2 mm (Moffitt and Polovina, 1987)

For *H. ensifer*, Moffitt and Polovina (1987) found that peak breeding season occur in both December and May

(Moffitt and Polovina, 1987) found that

- length at maturity is 20.2 mm
- females become sexually mature at 40 mm
- believe males become sexually mature at age 3 when they are 37-38 mm CL
- suggest spatial heterogeneity between sexes, with female abundance diminish as depth increases
- *H. longirostris* become sexually mature at 34 cm

Length at recruitment (info from all areas)

- Growth parameters
 - Size/length species is recruited into the fishery
 - Size at maturity

H. ensifer is recruited into the fishery at 23 cm (Moffitt and Polovina, 1987)

For female HL, length at recruitment into the fishery at 29 cm (Moffitt and Polovina, 1987) or 2 years of age

H. longirostris is recruited into the fishery at 34 cm (Moffitt and Polovina, 1987)

Length at maturity for *H. ensifer* is 20.2 mm (Moffitt and Polovina, 1987)

Length at mortality is 23.9 mm

Length at maturity for male *H. laevigatus* is 35.7; female 40 mm (Moffitt and Polovina, 1987)

Length at mortality 42.7mm

Length at maturity for *H. longstrosis* is 31 mm (Moffitt and Polovina, 1987)

Length at mortality is 37.4

Unlike shallow-water penaeid shrimps, pandalid shrimps have lifespans in excess of a year, and some species such as *H. laevigatus*, may have life spans of up to 8 years. King (1993) suggests that the natural mortality rates of *H. laevigatus* is about 50% per year. King (1993) reports that *H. laevigatus* matures at about 75% of its maximum size or between 4-5 years old.

Sub-arctic pandalid shrimps have been suggested to be protandrous hermaphrodites (Butler 1964), which means being male for the first few years of life and then changing to female for the last year or two of life. However, measuring the length of male appendage of several species of *Heterocarpus* in the Mariana Archipelago, Moffit and Polovina (1987) found that length of the male appendage increased with carapace length, which suggests that tropical deep water shrimp may not be protandrous hermaphrodites. Observations by Dailey & Ralston (1986) suggest that *Heterocarpus* shrimps may be semelparous, i.e. reproducing only once in their lifetime then dying thereafter. In the Mariana Archipelago, the length at maturity for *H. ensifer* was calculated at 22.2 mm, 35.7 mm for *H. laevigatus*, and 31 mm for *H. longirostris* (Moffit and Polovina 1987).

Description of male and female physiology

Studies on male and female caridean shrimps have shown that tropical deepwater species have separate sexes (King and Moffit 1984; Moffit and Polovina 1987). The sexes can be differentiated by the shape of the endopods and its first pleopods. Males have a broader endopod than females, and have an appendix masculine situated between the appendix interna and the endopod of the second pleopod. Females carry their eggs externally on their pleopods and the number of eggs that they carry can be greater than 30,000 in *Heterocarpus* species (King and Butler 1985).

Males grow faster while experiencing a greater total mortality and smaller size than females (Dailey and Ralston 1986). Young females may move from deep to shallow water as they mature. Mature *H. laevigatus* in Hawaii may migrate seasonally (Dailey and Ralston 1986).

Spawning seasons if known

In Hawaii, *Heterocarpus spp.* reproduce in the fall and winter months October to January, which is the opposite of other crustaceans in Hawaii that reproduce in the spring and summer seasons (Dailey and Ralston 1986). Similarly, *H. laevigatus* in Guam has an ovigerous peak in the winter months of November to February (Wilder 1977; Moffit and Polovina 1987). Incidences of ovigerous females have been reported in Fiji from April to July, concluding that there appears to be a spawning season coinciding with the winter season of each hemisphere (King 1983).

Estimates of natural mortality rates

In the Marianas archipelago, the natural mortality of *Heterocarpus* is estimated to be 0.75 yr⁻¹ (Moffit and Polovina 1987).

Trophic Relationships

King (1983) reported heterocarpus found in stomachs of tuna in Fiji, indicating some vertical migration.

[Add information from sources listed on pink reference paper]

In summary, available evidence suggests that *H. ensifer* is not a major prey item for either tuna or commercial bottomfish. Tuna feed in the surface and midwater zones and would encounter *Heterocarpus ensifer* only during its pelagic stage. Upon settlement, *H. ensifer* inhabits depths <300m while commercial bottomfish tends to occur >300 m.

Diet and trophic relationships.

King (1993) notes that *H. sibogae* feeds on other demersal crustaceans, fish, foraminiferans, and even small, midwater squid. Little is known of the trophic relationships of deepwater shrimps. Pandalid shrimps have been observed in fishes as diverse as obligate demersal deepslope snappers and even open ocean pelagic tunas, however available evidence suggests that *Heterocarpus ensifer* is not a major prey item for either tunas or commercial bottomfish. Research conducted on the stomach contents of the Hapuupuu, Seale's grouper, (*Epinephelus uernus*) and Butaguchi, or pig ulua, (*Pseudocarnax dentex*) found that pandalid shrimps may be of major importance to hapuupuu, but only *Plesionika longirostris* was identified to species (Seki 1984). A study by Kami (1973) lists shrimp as being present in the stomach contents of *Pristipomoides sieboldii* (Von sieboldi's snapper or Kalekale), though it was not identified to the family level. This study also found that shrimps were not present in the stomachs of *P. auricilla* (goldflag jobfish), *P. filamentosus* (pink snapper or Opakapaka) or *P. flavipinnis* (golden eye jobfish). A study on Kahala (*Seriola dumerili*) by Humpreys and Kramer (1984) found that crustaceans formed only 1-4% of the stomach contents, with only *Plesionika longirostris* and *Heterocarpus ensifer* identified. Pandalid shrimps have not been identified in yellowfin, bigeye, or albacore tuna in any of the studies, while only one individual pandalid (*Heterocarpus ensifer*) was identified in the stomach contents of a skipjack tuna out of 707 fish studied.

5 Coral Reef Ecosystem Management Unit Species

This report presents a compilation of information that will be used to help to define essential fish habitat (EFH) as part of a Coral Reef Ecosystem (CRE) Fisheries Management Plan (FMP) for the Western Pacific Region pursuant to Sections 303(a) and (b) of the Magnuson-Stevens Act. The development of a CRE FMP is also in keeping with the spirit and intent of Executive Order No. 13089 on Coral Reef Protection, issued by the President on June 11, 1998.

The report presents data for selected fish, invertebrate, and sessile taxa, termed Management Units Species (MUS), occurring within the geographical fishery management units (FMUs) under the jurisdiction of the Western Pacific Regional Fishery Management Council (WPRFMC). Information was gathered through review of available literature, and communication with authorities in the field. For each taxon, an effort was made to locate those data that will be helpful in defining EFHs, including descriptions of the habitat and ecological requirements for each life phase of the organisms under consideration.

For the purpose of this investigation, the taxa included were limited to those known or believed to occur on or in association with coral reefs, at least during some phase of the life cycle. In general therefore, pelagic taxa are excluded from this report. Similarly, those species occurring exclusively in zones deeper than the typical depth for coral reefs (as defined by the lower limits of the photic zone, i.e., 100 m depth), are not included.

5.1 EFH for Management Unit Species - Fish

5.1.1 Acanthuridae (surgeonfishes)

The acanthurids typically have ovate to elongate compressed bodies, a small terminal mouth with a single row of close-set teeth, eyes high on the head, continuous unnotched dorsal and anal fins, and a tough skin with very small ctenoid scales. The common name surgeonfish stems from the presence of one or more pairs of sharp spines on the caudal peduncle which may be used to slash other fish or unwary human handlers. In species of the genera *Acanthurus*, *Ctenochaetus*, and *Zebrasoma*, the single lancet-like spine folds into a groove, while species of *Naso* have 2 fixed, keel-like spines. Some *Naso* species have a horn-like projection on the forehead, and as a result all members of the genus are commonly called unicornfishes. Generally, acanthurids are diurnal herbivores or planktivores. Species of *Ctenochaetus* and some of *Acanthurus* have a thick-walled gizzard-like stomach and often ingest sand with their diet of benthic algae. Some species of *Acanthurus* and many *Naso* spp. feed mainly on zooplankton in the water column. All acanthurids shelter on the reef at night.

Reproduction typically occurs on a lunar cycle with greater activity in winter or early spring, but with some activity throughout the year. Spawning events are more frequent at dusk and involve groups, pairs, or both. The larval stage is long by reef fish standards, and size at settlement is larger than most. Surgeonfishes are important foodfishes on most Pacific islands. This description was composed from Myers (1991) and Randall (1996).

Habitat utilization

Jones (1968) divided the acanthurids from Hawaii and Johnston Island into 4 major habitat types: mid-water (*Acanthurus thompsoni*, *Naso hexacanthus*), sand patch (*A. dussumieri*, *A. mata*, *A. olivaceous*, *A. xanthopterus*), subsurge reef (*A. nigrofuscus*, *A. nigroris*, *A. sandvicensis*, *Ctenochaetus hawaiiensis*, *C. strigosus*, *Naso brevirostris*, *N. lituratus*, *N. unicornis*, *Zebrasoma flavescens*, *Z. veliferum*), and seaward reef or surge zone (*A. achilles*, *A. glaucopareius*, *A. guttatus*, *A. leucopareius*) dwellers. The same paper gives extensive descriptions of feeding habits and each species use of the habitat features.

Life history

The biology and life history of surgeonfish have been studied in a number of Western Pacific locations, including *Acanthurus triostegus* in Hawaii (Randall 1961), *Naso brevirostris* in French Polynesia (Caillart 1988), and *Acanthurus nigricauda* and *A. xanthopterus* in Papua New Guinea (Dalzell 1989). Age and growth has been described by a combination of observing captive specimens, otolith microstructure, length frequency data, and tagging. Lou and Moltschanowskyj (1992) validated daily growth increment formation on otoliths of several juvenile surgeonfish species, and Lou (1993) plotted growth curves for juvenile *Ctenochaetus binotatus* by measuring lapillus growth increments. Surgeonfishes have relatively long life spans. Randall (1961) reported *Naso unicornis* and *Acanthurus xanthopterus* living 15-20 years in captivity. Surgeonfish on the Great Barrier reef have shown an average maximum life span of over 20 years, and 40 years in one instance (Dalzell et al. 1996). Both of these situations involve no mortality from fishing. Hart & Russ (1996) measured *A. nigrofuscus* ages and found a mean age at different reefs on the Great Barrier reef ranging from 5.4 to 9.5 years, with the oldest specimen being 25 years old. Choat and Axe (1996) aged 10 species of acanthurids from the Great Barrier Reef through the use of otoliths and found life spans of 30-45 years in which growth was very rapid in the first 3-4 years of life. In American Samoa, Craig et al. (1997) found *A. lineatus* to grow very rapidly during the first year, 70-80% of total growth, followed by slower growth and a long life, up to 18 years.

Permanent sexual dimorphism is uncommon in the family. There are usually few differences between males and females, though in some species there are size differences, usually larger males. Males of the genus *Naso* frequently have a larger horn than females. Sexual dichromatism only exists during times of spawning, the rest of the time the sexes are

similarly colored. Spawning is frequently timed with the lunar cycle, either during a new moon, a full moon, or both. Many surgeonfishes spawn in large aggregations, and others spawn strictly in pairs. Pair spawners may spawn throughout the lunar month (Robertson et al. 1979). The act of reproduction for all surgeonfishes involves a quick upward rush of the participants and a release of gametes into the water column. Spawning rushes typically occur in low light conditions, usually at or near dusk.

Detailed descriptions of spawning behavior and spawning cycles of eight Indo-Pacific surgeonfish species are given in Robertson (1983).

Acanthurids appear to have a peak in spawning activity in late winter and early spring. Spawning of *Acanthurus triostegus* in Hawaii occurs primarily from December to June (Thresher 1984). Watson and Leis (1974) identified peak spawning from March to May, and another peak in October, for many reef fish in Hawaii, including acanthurids. There are instances of year-round spawning, and Randall (1961) suggested that seasonal variations in spawning may be less obvious in the deep tropics where variations in seawater temperature are less pronounced. Large aggregations of acanthurids do occur during spawning events, often near the mouths of channels in the reef and in areas with strong offshore currents (Randall 1961, Johannes 1981).

There are no species of surgeonfish endemic to any of the management areas in this plan, although *A. triostegus sandvicensis* in Hawaii is recognized as a subspecies. Also, *Zebrasoma flavescens* has a distribution from the North Pacific to southern Japan, but it is abundant only in Hawaii. Twenty three species of surgeonfish are found in Hawaii (Randall 1996), 39 species in Micronesia (Myers 1991), and 32 species in Samoa (Wass 1984).

Schooling behavior is common in acanthurids, particularly in association with spawning aggregations. Biologists have documented trains of surgeonfishes traveling along the reef to join thousands of other surgeonfish at spawning aggregation sites. Once there, the fish mingle near the substrate and slowly move upward as a group. Near dusk, small groups (6-15 individuals) of fish make spawning rushes to near the water surface and release gametes. Following spawning, fish return to the substrate, form trains, and return to their home reefs. Many species also form large single-species or mixed-species schools, apparently for overwhelming territorial reef fish to feed on the algal mats they are protecting.

Trophic ecology

Although acanthurids are predominantly herbivores, they are diverse and delicate feeders harvesting a variety of plants and organic materials which are processed in a gut environment characterized by a complex microflora (Choat 1991). Species of *Ctenochaetus* feed on

detritus and algal fragments by whisking them from the substrate with comb-like teeth.

Acanthurus thompsoni, *Naso annulatus*, *N. brevirostris*, *N. caesius*, *N. hexacanthus*, and *N. maculatus* feed primarily on zooplankton well above the bottom. *Naso lituratus* and *naso unicornis* browse mainly on leafy algae such as *Sargassum* (Randall 1996).

Surgeonfishes commonly defend territories that are primarily feeding territories (Robertson et al. 1979). In a study of the behavioral ecology of *Acanthurus lineatus*, *A. leucosternon*, and *Zebrasoma scopas*, Robertson et al. (1979) described the morphology, feeding strategies, and social and mating systems of three territorial species that occupied characteristic depth zones and habitat types.

Jones (1968) identified *Acanthurus thompsoni* and *Naso hexacanthus* as zooplankton feeders on copepods, crustacean larvae, and pelagic eggs; *A. dussumieri*, *A. mata*, *A. olivaceus*, *Ctenochaetus hawaiiensis*, and *C. strigosus* as grazers on a calcareous substratum rich in diatoms and detritus; and *A. achilles*, *A. glaucopareius*, *A. guttatus*, *A. leucopareius*, *A. nigrofuscus*, *A. nigroris*, *A. sandvicensis*, *Zebrasoma flavescens*, *Z. veliferum*, *Naso brevirostris*, *N. lituratus*, and *N. unicornis* as browsers on multicellular benthic algae.

Pacific fisheries

Surgeonfishes are important food fish on many Pacific islands, where they are typically caught by spearfishing or nets. Some species are also sought after for the aquarium trade.

Main Hawaiian Islands - Less than 12% of the catch of inshore fishes reported in DAR commercial statistics from 1991-1995 came from federal waters (Friedlander 1996). For catches reported to DAR between 0-200nm, six of the top 25 inshore species by weight are acanthurids: *A. dussumieri*-32,407 lbs, *A. triostegus*-11,705 lbs, *Naso* spp.-9969 lbs, *A. xanthopterus*-5,234 lbs, *A. olivaceous*-4,813 lbs, and *Ctenochaetus strigosus*-3,776 lbs (Friedlander 1996).

Northwestern Hawaiian Islands - No data is available on catches of surgeonfish in this area, where inshore fisheries are fairly unexploited (see Green 1997).

American Samoa - Craig et al. (1993) reported that no major commercial fishery operates in federal waters in American Samoa. Closer to shore, *Acanthuridae* compose 28% of the reef fish catch (Dalzell et al. 1996). Over 40% of the catch composition by weight in the 1994 artisanal fishery was surgeonfishes (in Craig et al. 1995). In 1994, *A. lineatus* ranked second among all species harvested in both the artisanal and subsistence fisheries, accounting for 10 % of the total catch of 295 metric tons (Craig et al. 1997). The artisanal fishery captured 28 t of *A. lineatus* by spearfishing. A much smaller amount of that species, only 1-3% of the catch, was taken in the subsistence fishery by use of gill nets, throw nets, rod-and-reels, and handlines.

Guam - At this time, much less than 20% of the total coral reef resources harvested in Guam are taken from federal waters (Myers 1997). Acanthuridae composed 9.12 % of the reef fish catch in Guam (Dalzell et al. 1996). Small-boat based spearfish landings from FY85-91 were 19.0% surgeonfishes by weight (Myers 1996). Further discussion of reef fish catches in Guam can be found in Green (1997).

CNMI - Most reef fish landed in the Northern Mariana Islands are reported as mixed reef fish. Only 1.11% of the catch was assigned to surgeonfishes (Dalzell et al. 1996).

Egg and larval distribution

Acanthurid eggs are pelagic, spherical, and small - 0.66-0.70 mm in diameter with a single oil droplet to 0.165 mm for *Acanthurus triostegus sandvicensis* (Randall 1961). For that species, hatching occurred in about 26 hours. Watson and Leis (1974) found an egg size of 0.575 to 0.625 mm in diameter for an unidentified acanthurid from Hawaii.

Acanthurid larvae are typically diamond-shaped and strongly laterally compressed, with a prominent serrated dorsal spine, two large and serrated pelvic fin spines, and a single smoother spine near the anal fin (Thresher 1984). Late larval stages, roughly 20-25 mm, are orbicular, transparent except for a silvery abdomen and gut, with small scales in narrow vertical ridges on the body (Randall 1996). Spines on the larvae serve to enhance protection from predation, and may be venomous. Lou (1993) reported that *Ctaenochaetus binotatus* larvae fed on various zooplankton for a larval period ranging from 47-74 days. Similarly, Randall (1961) reported a zooplankton diet and a larval duration of 2.5 months for *Acanthurus triostegus sandvicensis*.

Surgeonfish larvae are primarily found well offshore at depths from 0-100m. Like other common adult members of the coral reef fish community, surgeonfish larvae are typically less abundant in samples of the water column near the reef than they are in samples from offshore (Miller 1973).

Although surgeonfish generally settle at a larger size than most reef fish, acanthurids are one of the families with juveniles that settle with larval characters still present (Leis & Rennis 1983). Late phase larvae actively swim inshore at night, seek shelter in the reef, and begin growing scales and intestines to complete the transformation to juveniles (Clavijo 1974). Lengthening of the alimentary track to accommodate an herbivorous diet happens fairly quickly. Juvenile surgeonfish have been reported to shelter in tide pools in Hawaii (Randall 1961). Hart and Russ (1996) found an age-at-maturity for *Acanthurus nigrofuscus* of 2 years. Choat (1991) reported a range of 12-18 months to maturity for acanthurids. Juveniles frequently differ in coloration and behavior from adults.

Adult surgeonfish are found in many coral reef habitat types, including mid-water, sand patch, subsurge reef, and seaward or surge zone reef. The largest number of surgeonfish species are typically found in the subsurge reef habitat, which are defined by Jones (1968) to be areas of moderate to dense coral growth corresponding to the subsurge portions of fringing reefs, deepwater reef patches, reef filled bays, and coral-rich parts of lagoons inside of atolls. These species are typically found between 0-30m depth, although surgeonfish do live in depths from 0-150m. Some species of *Naso* have been seen below 200m (Chave & Mundy 1994).

Acanthurids were the dominant family of fishes in Hanalei Bay in both numbers and biomass (Friedlander 1997). There were high numbers of surgeonfish in shallow, complex backreef habitat. Biomass for the depth stratum 4.3-7.2m was dominated by three surgeonfish species, *A. tristegus*, *A. leucopareis*, and *Ctenochaetus strigosus*. *C. strigosus* and *A. nigrofuscus* were common in the shallow complex backreef as well as in the deep slope and spur and groove habitat types (Friedlander and Parrish 1998).

As an example for the family, *Acanthurus nigrofuscus* form schools that migrate 500 to 600m daily to intertidal feeding areas of algal turf communities. In the summer, the main food items are brown and red algae, while in the winter, it is green algae. Spawning occurs in large schools of 2000 to 2500 fish on selected sites at dusk (Fishelson et al. 1987).

Bibliography

- Chave, E.H. and B.C. Mundy. 1994. Deep-sea benthic fishes of the Hawaiian archipelago, Cross Seamount, and Johnson Atoll. *Pacific Science* 48: 367-409.
- Choat, J.H. 1991. The biology of herbivorous fishes on coral reefs. In: Sale, P.F. (Ed.), *The Ecology of Fishes on Coral Reefs*. Academic Press, Inc., San Diego, pp. 120-155.
- Choat, J.H. and L.M. Axe. 1996. Growth and longevity in acanthurid fishes; analysis of otolith increments. *Mar. Ecol. Prog. Ser.* 134: 15-26.
- Clavijo, I. 1974. A contribution on feeding habits of three species of Acanthurids from the West Indies. M.S. thesis, Florida Atlantic Univ., Boca Raton, FL.
- Craig, P.C., Choat, J.H., Axe, L.M., and S. Saucerman. 1997. Population biology and harvest of the coral reef surgeonfish *Acanthurus lineatus* in American Samoa. *Fish. Bull.* 95: 680-693.
- Dalzell, P. 1989. The biology of surgeonfishes (Family: *Acanthuridae*), with particular emphasis on *Acanthurus nigricauda* and *A. xanthopterus* from northern Papua New Guinea, M. Phil. thesis, University of Newcastle upon Tyne.

- Dalzell, P., Adams, T.J.H. and N.V.C. Polunin. 1996. Coastal fisheries in the Pacific islands. *Oceanography and Marine Biology: an Annual Review* 34: 395-531.
- Davis GW. 1985. Reproductive patterns of three economically important surgeonfish species on Guam. M.S. thesis, Univ. of Guam, Mangilau, 44p.
- Fishelson, L., Montgomery, L.W., and A.H. Myrberg, Jr. 1987. Biology of surgeonfish *Acanthurus nigrofuscus* with emphasis on changeover in diet and annual gonadal cycles. *Mar. Ecol. Prog. Ser.* 39: 37-47.
- Friedlander, A.M. 1996. Assessment of the coral reef resources of Hawaii with emphasis on waters of federal jurisdiction. Report prepared for the Western Pacific Regional Fishery Management Council. 62 pp.
- Friedlander, A.M., DeFelice, R.C., Parrish, J.D., and J.L. Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.
- Friedlander AM and JD Parrish. 1998. Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. *J. of Exp. Mar. Bio. and Ecol.* 224: 1-30.
- Green, A.L. 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the U.S. Pacific Islands. Report prepared for the Western Pacific Regional Fishery Management Council. 278 pp.
- Hart, A.M., and G.R. Russ. 1996. Response of herbivorous fishes to crown-of-thorns starfish *Acanthaster planci* outbreaks. III. Age, growth, mortality and maturity indices of *Acanthurus nigrofuscus*. *Mar. Ecol. Prog. Ser.* 136: 25-35.
- Johannes, R.E. 1978. Reproductive strategies of coastal marine fishes in the tropics. *Env.Biol. Fish.* 3(1): 65-84.
- Jones, R.S. 1968. Ecological relationships in Hawaiian and Johnston Island Acanthuridae (Surgeon fish). *Micronesica* 4: 309-361.
- Leis, J.M, and D.S. Rennis. 1983. *The Larvae of Indo-Pacific Coral Reef Fishes*. New South Wales Univ. Press, Sydney, Australia, and Univ. of Hawaii Press, Honolulu, Hawaii.
- Lou, D.C. 1993. Growth in juvenile *Scarus rivulatus* and *Ctenochaetus binotatus*: a comparison of families Scaridae and Acanthuridae. *J. of Fish Biol.* 42: 15-23.

- Lou, D.C. and N.A. Moltschanowskyj. 1992. Daily otolith increments in juvenile tropical parrotfishes and surgeonfishes. *Aust. J. of Mar. and Freshwater Research* 43: 973-981.
- Miller, J.M. 1973. Nearshore distribution of Hawaiian marine fish larvae: effects of water quality, turbidity and currents. In J.H.S. Baxter (ed.) *The early life history of fish*, Springer-Verlag. NY. 1973. 765 pp.
- Myers, R.F. 1991. *Micronesian reef fishes*. Coral Graphics, Guam.
- Myers, R.F. 1996. Assessment of coral reef resources of Guam with emphasis on waters of federal jurisdiction. Report prepared for the Western Pacific Regional Fishery Management Council.
- Randall, J.E. 1961. A contribution to the biology of the convict surgeonfish of the Hawaiian Islands, *Acanthurus triostegus sandvicensis*. *Pac. Sci.* 15: 215-272.
- Randall, J.E. 1996. *Shore fishes of Hawaii*. Natural World Press, Vida, O.R.
- Reeson PH. 1983. The biology, ecology and bionomics of the surgeonfishes, Acanthuridae. In *Caribbean Coral Reef Fishery Resources* (JL Munro, ed) *ICLARM Stud. Rev.* 7: 178-190.
- Robertson, D.R. 1983. On the spawning behavior and spawning cycles of eight surgeonfishes (Acanthuridae) from the Indo-Pacific. *Environ. Biol. Fishes* 9: 193-223.
- Robertson, D.R., Polunin, N.V., and K. Leighton. 1979. The behavioral ecology of three Indian Ocean surgeonfishes (Acanthuridae) from Indo-Pacific. *Envir. Biol. Fish.* 4: 125-170.
- Thresher, R.E. 1984. *Reproduction in reef fishes*. T.F.H. Pub., Neptune City, NJ.
- Watson, W. and J.M. Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: A one-year study of fish eggs and larvae. *Tech. Rep. - Univ. Hawaii Sea Grant Program TR-75-01*: 1-178.

Table 18. Management Unit Species: Acanthuridae (surgeonfishes)

	Egg	Larvae	Juvenile	Adult
Duration	26 hours for <i>A. triostegus sandvicensis</i>	47-74 days for <i>C. Binotatus</i> , 2.5 months for <i>A. triostegus sandvicensis</i>	1-2 years	25 yrs for <i>A. Nigrofuscus</i> (Hart & Russ 1996), over 40 yrs for <i>Naso</i> spp. (Choat & Axe 1996)
Diet	N/A	various zooplankters (Randall 1961)	mostly herbivorous although some may feed on zooplankton	<i>Acanthurus</i> & <i>Zebrasoma</i> - algal turfs, <i>Ctenochaetus</i> - detritus and sediment, <i>Naso</i> & <i>Paracanthurus</i> - mostly zooplankton
Distribution, general and seasonal	some species spawn year-round, but generally there appears to be a peak in spring and early summer; many species show lunar spawning periodicity	year-round distribution, with perhaps more settlement in late summer or fall	coral reef habitats throughout the Western Pacific	coral reef habitats throughout the Western Pacific, spawning aggregations at prominent outcroppings, some species are fairly stationary and territorial while others travel long distances for feeding
Location	water column from the surface to 100m	0-100m, larvae typically are more common in offshore waters than in water over reefs	tide pools, refugia on the reef	bottom and water-column; most between 0-100m but some deeper than 200m
Water column	N/A	pelagic	demersal and mid-water	demersal and mid-water

Bottom type	N/A	N/A	coral, rock, sand, mud, rubble, pavement	coral, rock, sand, rubble, pavement
Oceanic features	subject to ocean currents	subject to ocean currents		spawning aggregations may occur at channels just before or during outgoing tide

DRAFT

5.1.2 Carcharhinidae, Sphyrnidae, *Triaenodon obesus* (sharks)

Carcharhinidae is one of the largest and most important families of sharks, with many common and wide-ranging species found in all warm and temperate seas. They are the dominant sharks in tropical waters in variety, abundance and biomass. Most species inhabit tropical continental coastal and offshore waters, but several species prefer coral reefs and oceanic islands. All members of *Carcharhinidae* have a circular eye, nictitating eyelids, a first dorsal fin positioned well ahead of the pelvic fins, precaudal pits and well developed lower caudal lobe.

Sharks differ from bony fishes in their cartilaginous skeleton, 5 to 7 gill openings on each side of the head, the frequent presence of a spiracle behind or below the eye, a rough skin composed of small, close-set dermal denticles, the absence of a swimbladder and the presence of a very large liver with large amounts of oil. Many sharks are apex predators in the food chain, feeding on bony fishes, octopuses, squids, shrimps, sea birds, other sharks and rays, sea turtles and marine mammals. Many sharks, including members of *Carcharhinidae* and *Sphyrnidae*, make seasonal migrations to warmer waters in the winter and cooler waters in the summer.

DeCrosta et al. (1984) reported on age determination, growth and energetics of the gray reef shark, the Galapagos shark and the tiger shark in the Northwestern Hawaiian Islands (NWHI). They found maximum ages from a sample of 30B65 specimens of each species to be 10, 15 and 22 years, respectively. The gray reef shark was the most highly piscivorous species with 51% of its diet composed of perciform fish, as well as >12% eels and >22% cephalopods. The Galapagos shark ate primarily cephalopods (43%), tetraodontiform fish (21%), eels (14%) and parrotfish (7 %). The tiger shark was a very opportunistic feeder, with seabirds in 75% of the specimen stomachs, but also sea turtles (33%), lobsters (30%), cephalopods (22%) and tetraodontiform fish (15%).

Sphyrnidae is a small but common family of wide-ranging, warm-temperate and tropical sharks found in continental and insular waters. Depths range from the surface to at least 275 m depth. Hammerheads are very active swimmers, ranging from the surface to the bottom. They are versatile feeders on bony fishes, elasmobranchs, cephalopods, crustaceans and other prey, although some may specialize on other elasmobranchs (Compagno 1984). Sphyrnids are similar to carcharhinids with one obvious exception, a blade-like lateral extension of the head. The head shape serves to spread the eyes and olfactory organs farther apart and may increase electroreception, vision and smell; increases lift and maneuverability; and may be used to pin prey such as rays to the bottom.

Sharks reproduce by internal fertilization. Male sharks can be identified by the presence of a pair of claspers along the medial edge of the pelvic fin. The tiger shark, *Galeocerdo cuvier*,

and most sharks are ovoviviparous, developing eggs within the uterus. The sharks of *Sphyrnidae* and *Carcharinidae* except the tiger shark, are viviparous, nourishing embryos by a placenta-like organ in the female. Some species such as *Nebrius concolor* and *Sphyrna lewini* move into shallow water to give birth. Calm, protected bays such as Kaneohe Bay are important nursery areas for sharks such as *S. lewini*.

Forty species of sharks are known from Hawaiian waters, but 20 of them occur only in deep water. Sharks likely to be associated with coral reefs in Hawaii include the gray reef shark *Carcharhinus amblyrhynchos*, the Galapagos shark *C. galapagensis*, the tiger shark *Galeocordo cuvier*, the blacktip reef shark *Carcharhinus melanopterus*, the sandbar shark *C. plumbeus*, the whitetip reef shark *Triaenodon obesus* and the scalloped hammerhead *S. lewini*. Ten species of carcharhinid sharks and two sphyrnid species, *S. lewini* and *S. mokorran*, are described for Micronesia in Myers (1991). Twelve carcharhinid and two sphyrnids are recorded for American Samoa.

Schooling is well documented for many shark species, especially the hammerheads. These species make long migrations in large groups for the purpose of spawning.

Trophic ecology

Sharks are apex predators on many coral reefs, where their presence may be a good indication of large stocks of fishes upon which they feed. All sharks are carnivorous, feeding on a wide variety of fishes, elasmobranchs and invertebrates including eagle rays, other sharks, reef fish, cephalopods, crustaceans, tuna, baitfishes and mahimahi. Larger species such as tiger sharks and great white sharks feed on those animals as well as porpoises, whales, sea turtles, sea birds, domestic animals, humans occasionally and marine debris, such as tin cans and plastic cups. Many sharks are nocturnal feeders, as sensory organs such as ampullae of Lorenzini are used to detect electromagnetic fields of prey fishes. The same sensory systems, including exceptional smell and a highly developed lateralis system, allow sharks to detect injured prey from considerable distance and lead to opportunistic feeding during the day as well.

Reproductive ecology

Egg and larval distribution are not applicable to sharks because they develop eggs internally. Sharks typically have a gestation period within the female of about 12 months. The gestation period and number of offspring per litter of common Western Pacific Region reef-associated sharks are *Triaenodon obesus* - 13 mths, 1B5 pups; *Carcharhinus albimarginatus* - 12 mths, 1B11 pups; *C. amblyrhynchos* - about 12 mths, 1B6 pups; *C. falciformis* - 2B14 pups; *C. galapagensis* - 6B16 pups; *C. melanopterus* - 8B9 mths, 2B4 pups; *Galeocerdo cuvier* - 12B13 mths, 10B82 pups; *C. plumbeus* - 8B12 mths, 1B14 pups, *Negaprion acutidens* - 1B11 pups; *Sphyrna lewini* - 15B31 pups; and *S. mokorran* - 13B42 pups.

Juvenile sharks frequently inhabit inshore areas such as bays, seagrass beds and lagoon flats before moving into deeper water as they mature. For example, *S. lewini* has well-documented nursery areas in shallow, turbid coastal areas such as Guam's inner Apra Harbor and Kaneohe Bay and Keehi lagoon on Oahu in Hawaii. The southern part of Kaneohe Bay is a major breeding and pupping ground for this species. Pups tend to avoid light, preferring more turbid water. They school in a core refuge area during the day and then disperse at night, foraging along the base of patch reefs (Clarke 1971, Holland et al. 1993). Schools of young hammerheads forage near the bottom within these bays before moving to deeper outer reef waters as adults.

Size at maturity for reef-associated sharks within the management area are *T. obesus* - 101 cm for females and 82 cm for males, *C. galapagensis* - 205B239 cm for males and 215B245 cm for females, *C. melanopterus* - 131B178 cm for males and 144B183 cm for females, *G. cuvier* - 226B290 cm for males and 250B350 cm for females, *C. plumbeus* - 131B178 cm for males and 144B183 cm for females, *S. lewini* - 140B165 cm for males and about 212 cm for females, and *S. zygaena* - about 210B240 cm for males and females.

Adult sharks can be found in shallow inshore areas during mating or birthing events. Some species forage in these shallow areas as well. Reef-associated sharks are found in a wide variety of coral reef habitats, and because of their wide-ranging nature, no particular coral reef habitat except the inshore areas important for mating and birthing holds significantly higher numbers of sharks than other habitats. The larger species, such as *Galeocerdo cuvier*, are more often found on outer reef slopes near deep dropoffs. Randall et al. (1993) noted the presence of tiger sharks in lagoon waters of Midway Island during JuneBAugust when they prey upon fledgling Laysan albatross. Adult female gray reef sharks *C. amblyrhynchos* aggregate seasonally over shallow reef areas in the NHWI.

Bibliography

- Clarke TA. 1971. The ecology of the scalloped hammerhead shark, *Sphyrna lewini*, in Hawaii. Pac Sci 25:133B44.
- Compagno LJV. 1984. Sharks of the world. FAO Species Catalogue, FAO Fisheries Synopsis No. 125, vol. 4, part 1 and part 2. Rome: United Nations Development Programme, Food and Agriculture Organization of the United Nations, 655p.
- Crow GL, CG Lowe and BM Wetherbee. 1996. Shark records from longline fishing programs in Hawaii with comments on Pacific Ocean distributions. Pac Sci 50(4): 382B92.

- DeCrosta MA, LR Taylor and JD Parrish. 1984. Age determination, growth, and energetics of three species of carcharhinid sharks in Hawaii. Proc 2nd Symp Res Invest NWHI (2), UNIHI-SEAGRANT-MR-84-01:75B95.
- Holland KN, Wetherbee BM, JD Peterson and CG Lowe. 1993. Movements and distribution of hammerhead shark pups on their natal grounds. Copeia 1993 (2): 495B502.
- Kimley AP. 1980. Observations of courtship and copulation in the nurse shark, *Ginglymostoma cirratum*. Copeia, 1980:878B82.
- Kimley AP. 1981. Grouping behavior in the scalloped hammerhead. Oceanus 24:65B71.
- Kimley AP. 1985. Schooling in *Sphyrna lewini*, a species with low risk of predation: a non-egalitarian state. Z Tierpsychol 70:297B319.
- Lowe CG, Wetherbee BM, GL Crow and AL Tester. 1996. Ontogenetic dietary shifts and feeding behavior of the tiger shark, *Galeocerdo cuvier*, in Hawaiian waters. Env Biol of Fishes.
- Mckibben JN and DR Nelson. 1986. Patterns of movement and grouping of gray reef sharks, *Carcharhinus amblyrhynchos*, at Enewetak, Marshal Islands. Bull Mar Sci 38:89B110.
- Michael SW. 1993. Reef sharks and rays of the world: a guide to their identification, behavior, and ecology. Monterey, CA: Sea Challengers, 1993.
- Polovina JJ and BB Lau. 1993. Temporal and spatial distribution of catches of tiger sharks (*Galeocerdo cuvier*) in the pelagic longline fishery around the Hawaiian Islands. 209B5. JJP, Honolulu Laboratory, Southwest Fisheries Science Center, NMFS.
- Randall JE. 1977. Contribution to the biology of the whitetip reef shark. Pac Science 31:143B164.
- Randall JE, JL Earle, RL Pyle, JD Parrish and T Hayes. Annotated checklist of the fishes of Midway Atoll, Northwestern Hawaiian Islands. Pac Sci 47(4):356B400.
- Suzumoto A, RL Pyle and RB Reeve. 1991. Sharks Hawaii. Honolulu: Bishop Museum Pr. 44p.
- Taylor L. 1994. Sharks of Hawaii=i: their biology and cultural significance. Honolulu: Univ of Hawaii Pr.
- Tricas TC and EM LeFeuvre. 1985. Mating in the reef whitetip shark, *Triaenodon obesus*. Mar Biol 84:233B7.

Tricas TC. 1981. Diel behavior of the tiger shark, *Galeocerdo cuvier*, at French Frigate Shoals, Hawaiian Islands. *Copeia*, 1981:904B8.

Wass RC. 1971. A comparative study of the life history, distribution and ecology of the sandbar shark and the gray reef shark. PhD thesis. Univ of Hawaii, Honolulu.

Wetherbee B. 1990. Feeding biology of sharks. *Amer Littor. Soc Spec Publ* 14:74B6.

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Table 19. Management Unit Species: Carcharhinidae, Sphyrnidae (sharks)

	Gestation	Juvenile	Adult
Duration	about 12 months	to 5B10 years or more	to 20 years or more
Diet	N/A	carnivorous - fish, elasmobranchs, squid, crustaceans, molluscs, may feed more intensively on crustaceans in inshore nursery areas	carnivorous - fish, elasmobranchs, squid, crustaceans, molluscs
Distribution, general and seasonal	Sphyrnids and some Carcharhinids have inshore nursery grounds	variable among species, <i>S. lewini</i> and <i>Negaprion acutidens</i> inhabit inshore nursery grounds	Carcharhinidae: variable among the family from Indo-Pacific, circumglobal, and circumtropical Sphyrnidae: circumtropical
Location	variable	highly variable, <i>S. lewini</i> and <i>Negaprion acutidens</i> inhabit inshore nursery grounds	Carcharhinidae: highly variable among the family Sphyrnidae: primarily pelagic but use inshore areas for reproduction
Water column	N/A	inshore benthic, neritic to epipelagic, 1B275 m	inshore benthic, neritic to epipelagic, mesopelagic. 1B275 m
Bottom type	N/A	highly variable due to wide-ranging nature of most species	highly variable due to wide-ranging nature of most species

Oceanic features	N/A	unknown	unknown
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5.1.3 Dasyatididae, Myliobatidae, Mobulidae (rays)

The rays are characterized by a flattened form, a lack of dorsal fins, a distinct tail which has one or more venomous barbs in some families and a small mouth with close-set pavement-like teeth. Water is taken in through a spiracle behind the eye and expelled through gill slits on the underside of the ray. Rays often bury into the sand with only the eyes and spiracle showing. Most rays are carnivorous on shellfish, worms and small burrowing fishes, except the members of Mobulidae that feed on zooplankton in the water column. Rays are ovoviviparous, giving birth to fully developed young that are nourished from vascular filaments within the uterus during gestation.

Dasyatidae

There are 3 species in Hawaii - *Dasyatis violacea*, *D. brevis* and *D. latus*; 4 species in Micronesia - *D. kuhlii*, *Hymantura uarnak*, *Taeniura melanospilos* and *Urogymnus asperrimus*; and 2 species in Samoa - *D. kuhlii* and *Hymantura fai*. Sting rays feed on sand-dwelling and reef-dwelling invertebrates and fishes, often excavating large burrows in sand bottoms to capture subsurface mollusks and worms.

Myliobatidae

One species, the spotted eagle ray *Aetobatis narinari*, represents the family in Hawaiian, Micronesian and Samoan waters. Eagle rays feed mainly on hard-shelled mollusks and crustaceans, using their snout to probe through sand and powerful jaws to crush the shells. An average of 4 pups is born per litter after a gestation period of about 12 months. They have a depth range from the intertidal to 24 m. Groups move from reef channels and the reef face during flood tide to feed. Schools of up to 200 individuals have been observed.

Mobulidae

One species of manta ray, *Manta birostris* (which recently has come to include other synonyms, including *M. alfredi*) represents the family in Hawaiian and Micronesian waters. Mantas are the largest of all rays and may attain a width of 6.7 m and a weight of 1,400 kg. They occur singly or in small groups in surface or mid-waters of lagoons and seaward reefs, particularly near channels. They strain zooplankton from the water using cephalic flaps to direct the plankton into the mouth. They occur in all tropical and subtropical seas. Mating and birthing occur in shallow water, and juveniles often remain in these areas before heading into deeper water as adults. During winter, mantas may migrate to warmer areas or deeper water or disperse offshore.

Bibliography

Compagno LJV. 1990. Alternative life-history styles of cartilaginous fishes in time and space. *Env Biol Fish* 28:33-75.

Michael SW. 1993. Reef sharks and rays of the world: a guide to their identification, behavior, and ecology. Monterey, CA: Sea Challengers, 1993.

Tricas TC. 1980. Courtship and mating-related behaviors in myliobatid rays. *Copeia*, 1980:553-6.

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Table 20. Management Unit Species: *Dasyatididae*, *Myliobatidae*, *Mobulidae* (rays)

	Gestation	Juvenile	Adult
Duration	about 12 months for <i>Myliobatidae</i> , avg of 4 pups	little information	little information on longevity
Diet	N/A	small fish, crustaceans, mollusks, worms, zooplankton for <i>Mobulidae</i> , may be a greater emphasis on shellfish for juveniles in shallow water habitats	fish, crustaceans, mollusks, worms, zooplankton for <i>Mobulidae</i>
Distribution, general and seasonal	N/A	<i>Dasyatis latus</i> range includes Hawaii and Taiwan, <i>D. kuhlii</i> and <i>Hymantura uarnak</i> range through the Indo-west-Pacific, <i>Taeniura melanospilos</i> and <i>Urogymnus asperrimus</i> range the Indo-Pacific, the spotted eagle ray and manta ray are circumtropical	<i>Dasyatis latus</i> range includes Hawaii and Taiwan, <i>D. kuhlii</i> and <i>Hymantura uarnak</i> range through the Indo-west-Pacific, <i>Taeniura melanospilos</i> and <i>Urogymnus asperrimus</i> range the Indo-Pacific, the spotted eagle ray and manta ray are circumtropical
Location	variable	wide variety of habitats from shallow lagoons to outer reef slopes, nursery areas in seagrass beds, mangroves, and shallow flats are important for many species	wide variety of habitats from shallow lagoons to outer reef slopes, generally located from 0-100m but have been found much deeper
Water column	N/A	demersal and in the water column	demersal and in the water column

Bottom type	N/A	soft (sand and mud), coral reef, pavement	soft (sand and mud), coral reef, pavement
Oceanic features	N/A	unknown	unknown

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5.1.4 Chlopsidae, Congridae, Moringuidae, Ophichthidae (eels)

There are 15 families of true eels, and these are some of the important ones on Western Pacific Region coral reefs. The eels are characterized by very elongate bodies, lack of pelvic fins, very small gill openings and a caudal fin that, if present, is joined with the dorsal and anal fins.

Members of Muraenidae, the morays, lack pectoral fins and scales and have a large mouth. Most species have long, fang-like teeth, but some do not. Species with long canines feed mainly on reef fishes, occasionally on crustaceans and octopuses. Species of *Echidna* and *Gymnomuraena* with mainly nodular or molariform teeth feed more on crustaceans, especially crabs. Morays have a lengthy pelagic leptocephalus larval stage that has resulted in a very wide distribution. Morays are hunted for food in many locations, even though large individuals may be ciguatoxic. Morays typically remain hidden within the framework of the reef, and many are more active at night than during the day. There are 38 species of morays in Hawaii, second only to the wrasses for number of species. *Gymnothorax steindachneri* is endemic to Hawaii. At least 53 species are known from Micronesia. At least 47 species are known from Samoa.

Members of Chlopsidae, the false morays, resemble morays but have pectoral fins and posterior nostrils open to the margin of the upper lip. Males are typically smaller with larger teeth, which may be used for grasping females during courtship. They probably migrate off the reef to spawn but otherwise stay well hidden within the reef framework. Five species are recorded from Samoa.

Members of Congridae include the conger eels and garden eels. Conger eels have well-developed pectoral fins. Garden eels are smaller, extremely elongate burrowing forms with reduced or absent pectoral fins. They occur in large colonies on sand plains or slopes at depths of 7B53 m with strong currents. They are diurnal planktivores that extend from their burrows to feed on plankton in the current. The large-eye conger, *Ariosoma marginatum*, and the Hawaiian garden eel, *Gorgasia hawaiiensis*, are endemic to Hawaii. Five species are recorded in Samoan waters.

Members of Moringuidae, the spaghetti eels, have extremely elongate bodies with the anus located about two thirds of the way back. They change morphology radically as they mature. Immature spaghetti eels are orange-brown with small eyes and reduced fins. Mature eels have large eyes and a distinct caudal fin and are dark above and silvery below. Females burrow in shallow sandy areas but migrate to the surface to spawn with males, which are pelagic. Six species are recorded from Samoan waters.

Members of Ophichthidae, the snake eels, have elongate, nearly cylindrical bodies with median fins and small pectoral fins. Most species of snake eels are indwellers that stay buried in the sand but a few will occasionally come out and swim across sand, rubble or seagrass habitats. They appear to be nocturnal, and some species, if not all, come to the surface to spawn at night. Sixteen species are reported from the Hawaiian Islands. The freckled snake eel, *Callechelys lutea*, is endemic to Hawaii, and the magnificent snake eel, *Myrichthys magnificus*, is endemic to the Hawaiian Islands and Johnston Island. At least 26 species are known from Micronesia. Five species are recorded from Samoan waters.

Sexual characteristics of eels vary widely among the different families. Spawning migrations are a general, though not universal, characteristic of eel reproduction. Eel species that migrate for spawning, including members of the congrid, moringuid and ophichthid, tend to be sexually dimorphic, with moringuids displaying the greatest morphological difference between males and females. Nonmigratory eels such as morays and garden eels typically have no definitive external sexual dimorphism. Hermaphroditism has been documented for some species, including some morays, but is not a widespread characteristic of eels. Group spawning of eels has been documented, with large numbers of adults congregating at the water surface at night.

Eel eggs are pelagic and spherical with a wide perivitelline space, usually no oil droplets and in some species a densely reticulated yolk. The eggs are relatively large, ranging from 1.8 to 4.0 mm. Watson and Leis (1974) collected 145 eel eggs off Hawaii that ranged from 2.4 to 3.8 mm. Brock (1972) found 200,000 to 300,000 ripe eggs in each of four 5.0 to 6.8 kg *Gymnothorax javanicus*. Hatching of an unidentified 1.8 mm muraenid egg took approximately 100 hours (Bensam 1966).

Eels have a characteristic leptocephalus larval stage: a long, transparent, feather-shaped larva that starts out at 5-10 mm and grows up to 200 mm before settlement and metamorphosis. The duration of the planktonic stage is on the order of 3-5 months for moringuids (Castle 1979), 6-10 months for muraenids (Eldred 1969, Castle 1965) and about 10 months for some congrid (Castle and Robertson 1974).

Both juvenile and adult eels inhabit cryptic locations in the framework of the reef or in sand plains for some species. Some species remain so hidden within the reef that they have never been seen alive; their existence is known only from samples taken with the use of poisons.

Bibliography

Bensam P. 1966. The eggs and early development of a muraenid eel. J Mar Biol Assoc India, 8:181-187.

Brock RE. 1972. A contribution to the biology of *Gymnothorax javanicus* (Bleeker). MS thesis, Univ of Hawaii, Honolulu.

Castle PHJ. 1965. Muraenid leptocephali in Australian waters. *Trans Roy Soc NZ*, 7:125B133.

Castle PHJ. 1979. Early life history of the eel *Moringua edwardsi* (Pisces, Moringuidae) in the western north Atlantic. *Bull. Mar. Sci.* 29: 1B18.

Castle PHJ and DA Robertson. 1974. Early life history of the congrid eels *Gnathophis habenatus* and *G. incognitus* in New Zealand waters. *NZ J Mar Freshwater Res*, 8: 95B110

Eldred B. 1969. Embryology and larval development of the blackedge moray, *Gymnothorax nigromarginatus* (Girard, 1859). Fla Bd Conserv Mar Lab, Leaflet Ser, 4(13):16pp.

Gosline W and DW Strasburg. 1956. The Hawaiian fishes of the family Moringuidae: another eel problem. *Copeia*, 1956: 9B18.

Raju SN. 1974. Distribution, growth and metamorphosis of leptocephali of the garden eels, *Taenioconger* sp. and *Gorgasia* sp. *Copeia*, 1974: 494B500.

Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii. Sea Grant Tech Rept. TR-75-01.

Table 21. Muraenidae, Chlopsidae, Congridae, Moringuidae, Ophichthidae (eels)

	Egg	Larvae	Juvenile	Adult
Duration	100 hours or more	3B10 months		
Diet	N/A	zooplankton	most are benthic carnivores on fish, octopus, crustaceans; frequently nocturnal garden eels are diurnal planktivores	most are nocturnal benthic carnivores on fish, octopus, crustaceans; the morays of <i>Gymnomuraena</i> , <i>Enchelycore</i> and <i>Sideria</i> feed mainly on crustaceans; garden eels are diurnal planktivores
Distribution, general and seasonal	eggs frequently released near the surface; some are pelagic spawners, others spawn on reefs	predominantly offshore	worldwide in tropical and temperate seas; <i>Callechelys lutea</i> , <i>Ariosoma marginatum</i> , <i>Gorgasia hawaiiensis</i> and <i>Gymnothorax steindachneri</i> are endemic to the Hawaiian islands; <i>Myrichthys magnificus</i> is endemic to the Hawaiian Islands and Johnston Island	worldwide in tropical and temperate seas; <i>Callechelys lutea</i> , <i>Ariosoma marginatum</i> , <i>Gorgasia hawaiiensis</i> and <i>Gymnothorax steindachneri</i> are endemic to the Hawaiian Islands; <i>Myrichthys magnificus</i> is endemic to the Hawaiian Islands and Johnston Island
Location	near reefs and offshore	predominantly offshore	coral reefs and soft-bottom habitats	coral reefs and soft-bottom habitats
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef crevices, holes;	coral reef crevices, holes;

			sand, mud, rubble	sand, mud, rubble
Oceanic features				

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5.1.5 Engraulidae (anchovies)

The anchovies are a large family of small, silvery schooling fishes that are common baitfish for pole-and-line tuna fisheries. They share many of the characteristics of the clupeids but can be distinguished by their rounded overhanging snout and slender lower jaw. Most species also have a brilliant silver mid-lateral band. Anchovies typically inhabit estuaries and turbid coastal waters. However, but some occur over inner protected reefs, and, at least one, *Encrasicholina punctifer*, is found in the open sea. Anchovies occur in dense schools and feed by opening their mouths to strain plankton from the water with their numerous gill rakers. Two species are known from Hawaiian waters: the endemic Hawaiian anchovy *Encrasicholina purpurea* and the offshore species *E. punctifer*. Seven species are known from Micronesian waters. Four species are known from Samoan waters.

Anchovy eggs are pelagic. In *Coilia*, *Setipinna* and *Thryssa* they are spherical and of small to moderate size (0.8B1.6 mm). Eggs of *Encrasicholina*, *Engraulis* and *Stolephorus* are ovate to elliptical and vary from small to large (0.8B2.3 x 0.5B0.8 mm) (Zhang et al 1982, Fukuhara 1983, McGowan and Berry 1984, Ikeda and Mito 1988). Larvae hatch at 2.5B3.7 mm. The size of the largest pelagic specimen examined by Leis and Trnski (1989) was 23B27 mm.

Thryssa baelama occurs in large schools in turbid waters of river mouths and inner bays. The oceanic or buccaneer anchovy *E. punctifer* is mostly pelagic, but it can be found in large atoll lagoons or deep, clear bays. The blue anchovy *E. heterolobus* occurs primarily in deep bays under oceanic influence. Other anchovies occur in estuaries and coastal bays.

Bibliography

- Clarke TA. 1987. Fecundity and spawning frequency of the Hawaiian anchovy or nehu, *Encrasicholina purpurea*. Fish Bull 85:127B38.
- Clarke TA. 1992. Egg abundance and spawning biomass of the Hawaiian anchovy or nehu *Encrasicholina purpurea*, during 1984B1988 in Kaneohe Bay, Hawaii. Pac Sci 46:325B43.
- Fukuhara O. 1983. Development and growth of laboratory reared *Engraulis japonica* (Houttuyn) larvae. J Fish Biol 23(6):641B52
- Ikeda T and S Mito. 1988. Pelagic fish eggs. pp 999B1083 in Okiyama (ed) 1988.
- Leary DF, GI Murphy and M Miller. 1975. Fecundity and length at first spawning of the Hawaiian anchovy or nehu (*Stolephorus purpureus* Fowler) in Kaneohe Bay, Oahu. Pac Sci 29:171B80.

Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

McGowan MF and FH Berry. 1984. Clupeiformes: development and relationships. pp 108B26 in ASIH Spec Publ 1.

Nakamura E. 1970. Synopsis of biological data on Hawaiian species of *Stolephorus*. In The Kuroshio: a symposium on the Japan Current, JC Marr (ed). Honolulu: East-West Centre Pr. 425B46.

Struhsaker P and JH Uchiyama. 1976. Age and growth of the nehu, *Stolephorus purpureus* (Pisces: Engraulidae) from Hawaii Islands as indicated by daily growth increments of sagittae. Fish Bull 74:9B17.

Whitehead PJP, GJ Nelson and T Wongratana. 1987. FAO species catalog >Clupeoid fishes of the world= Part 2 - Engraulidae. FAO fisheries synopsis 125 (7B2):304B545. Rome: FAO.

Zhang X, Chen Z, Ruan J, He G and X Sha. 1982. On the development of the eggs and larvae of *Thrissa kammalensis* and *Thrissa mystax*. Acta Zoologica Sinica 28(2): 183B9 (in Chinese, English abstract).

Table 22. Management Unit Species: Engraulidae (anchovies)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	plankton	plankton	plankton
Distribution, general and seasonal			same as adults	Two species in Hawaiian waters: the endemic Hawaiian anchovy <i>Encrasicholina purpurea</i> and the offshore species <i>E. punctifer</i> . Seven Micronesian species. Four Samoan species.
Location			schools in inshore waters	estuaries and turbid coastal waters but some occur over inner protected reefs and at least one, <i>Encrasicholina punctifer</i> , is found in the open sea
Water column	pelagic	pelagic	frequently near the surface	frequently near the surface
Bottom type	N/A	N/A	same as adults	sand, coral reef, rock, mud
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.6 Clupeidae (herrings)

Herrings, sardines and sprats are small planktivorous silvery fishes with a single short dorsal fin near the middle of the body, no spines, no lateral line and a forked caudal tail. They are schooling fishes that are important for food and bait. Round herrings include several species that inhabit coral reefs as well as coastal waters. Sardines typically inhabit coastal waters of large land masses or high islands. In Hawaiian waters, 4 species occur. Two were introduced: the goldspot sardine *Herklotsichthys quadrimaculatus* unintentionally from the Marshall Islands in 1972 and the Marquesan sardine *Sardinella marquensis* intentionally from the Marquesas between 1955 and 1959, but it never became abundant. The other two Hawaiian species are the delicate roundherring *Spratelloides delicatulus*, which is an inshore species that occurs in small schools over coral reefs and the red-eye roundherring *Etrumeus teres*, although it is rare. In Micronesian waters, there are at least 6 species of Clupeidae. In Samoan waters, 9 species have been recorded.

Clupeid eggs are spherical and vary among species from small to large (0.8B2.1 mm). They are thought to be pelagic in all tropical taxa except *Spratelloides*, which has demersal eggs (McGowan and Berry 1984, Jiang and Lim 1986). Clupeid larvae range from 1.6 to 4.7 mm long at the time of hatching. The size of the largest pelagic specimens examined by Leis and Trnski (1989) ranged from 21 to 33 mm.

The gold spot sardine, or herring, is an important food fish in many areas. It schools near mangroves and above sandy shallows of coastal bays and lagoons during the day and moves into deeper water at night to feed. In Belau, it migrates to tidal creeks to spawn from November to April (Myers 1991). The blue sprat *Spratelloides delicatulus* generally schools near the surface of clear coastal waters, lagoons and reef margins where it feeds on plankton.

Bibliography

- Jiang S and L Lim. 1986. Studies on the eggs and larvae of *Sardinella aurita* (Cuv. and Val.) in the fishing grounds of southern Fujian and Tawan Bank. Chinese J. Oceanol. Limnol. 4(1):108B18.
- Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.
- McGowan MF and FH Berry. 1984. Clupeiformes: development and relationships. pp 108B26 in ASIH Spec Publ 1.
- Myers, RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Whitehead PJP. 1985. FAO species catalog >Clupeoid fishes of the world= Part 1 -

Chirocentridae, Clupeidae and Pristigasteridae. FAO fisheries synopsis 125(7B1): 1B303.

Rome: FAO.

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Table 23. Management Unit Species: Clupeidae (herrings, sprats and sardines)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	plankton	plankton	plankton
Distribution, general and seasonal			same as adults	Four species in Hawaiian waters; two introduced: <i>Herklotsichthys quadrimaculatus</i> and <i>Sardinella marquensis</i> , and two others: <i>Spratelloides delicatulus</i> and <i>Etrumeus teres</i> . At least 6 species occur in Micronesian waters, and at least 9 species occur in Samoa.
Location			schools in inshore waters	estuaries and turbid coastal waters but some occur over inner protected reefs
Water column	pelagic	pelagic	frequently near the surface	frequently near the surface; 0-20 m
Bottom type	N/A	N/A	same as adults	sand, coral reef, rock, mud
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		most species tend to accumulate in relatively clear coastal, lagoon, and seaward reef waters

5.1.7 Antennariidae (frogfishes)

Frogfishes have bulbous bodies, jointed elbow-like pectoral fins that are used like arms, small holes behind the pectorals for gill openings and large upturned mouths. The first dorsal spine is modified to a lure consisting of the slender ilicium tipped with the esca (bait), which is used to attract prey. The frogfishes are very well camouflaged piscivores with cryptically colored prickly skin and fleshy or filamentous appendages. They are able to lure prey by waving the esca above their head, then striking quickly with a large mouth. They are able to swallow prey longer than themselves because of a highly distensible body. At intervals of 3 to 4 days, reproductive females lay thousands of tiny eggs embedded in a large, sometimes scroll-shaped gelatinous mass. Habitats where frogfish are found include bottoms of seagrass, algae, sponge, rock or corals from tidepools to lagoon and seaward reefs. In Hawaiian waters, 6 species are found, with one endemic: the Hawaiian freckled frogfish *Antennarius drombus*. At least 12 species occur in Micronesia, and at least 7 species in Samoa. Frogfishes are rare on most coral reefs and are present only in low numbers if at all.

Spawning by anglerfishes involves the production of a large, jelly-like egg mass. Frogfishes appear to be sexually monomorphic, with the only difference between sexes being the expanded size of the female prior to releasing eggs. For those species that have been observed spawning *Histrio histrio* (Mosher 1954, Fujita and Uchida 1959), *Antennarius nummifer* (Ray 1961) and *A. zebrinus* (Burgess 1976) spawning occurred in pairs after a quick spawning rush to the surface. Egg masses, or rafts, or scrolls, vary in size from species to species but are usually quite large. That of *H. histrio* is about 9 cm long (Mosher 1954, Fujita and Uchida 1959); that of *A. multiocellatus*, *A. tigrinus* and *A. zebrinus* is slightly larger (Mosher 1954, Burgess 1976); and that of *A. nummifer* is about 5 cm across and about 7 cm high (Ray 1961). Some species have immense egg rafts, including a raft produced by *A. hispidus* in an aquarium that was 2.9 m by 15.9 cm (Hornell 1922). Since rafts can be produced at 3-to 4-day intervals for many species, fecundity is extremely high for the frogfishes. Eggs hatch within 2-5 days. For *H. histrio*, growth and development is extremely fast, and an entire generation can take as little as 21 days (Adams 1960). Other species likely have much longer development and life spans.

A different spawning mode has been documented for members of at least two genera, *Lophiocharon* and *Histiophryne*, which brood eggs attached to the body of the male. The eggs are much larger (3.2-4.2mm) and more advanced at hatching than for pelagic spawners (Pietsch and Grobecker 1987).

Bibliography

Adams JA. 1960. A contribution to the biology and postlarval development of the sargassum fish, *Histrio histrio* (Linnaeus), with a discussion of the Sargassum complex. Bull Mar Sci, 10:55-82.

Burgess WE. 1976. Salts from the seven seas. *Trop Fish Hobbyist* 25:57-64.

Fujita S and K Uchida. 1959. Spawning habits and early development of a sargassum fish, *Pterophryne histrio* (Linne.). *Sci Bull Fac Agric Kyushu Univ* 17:277-82.

Hornell J. 1922. The Madras marine aquarium. *Bull Madras Fish Bur* 5:57-96.

Mosher C. 1954. Observations on the spawning behavior and the early larval development of the sargassum fish, *Histrio histrio* (Linnaeus). *Zoologica* 39:141-52.

Pietsch TW and DB Grobecker. 1987. Parental care as an alternative reproductive mode in an antennariid Anglerfish. *Copeia*, 1980:551-3.

Ray C. 1961. Spawning behavior and egg raft morphology of the ocellated fringed frogfish, *Antennarius nummifer* (Cuvier). *Copeia*, 1961:230-1.

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Table 24. Management Unit Species: Antennariidae (frogfishes)

	Egg	Larvae	Juvenile	Adult
Duration	2-5 days	days for <i>H. histrio</i> , but likely weeks for other species		<i>H. histrio</i> may only live a month or so; little information on others but likely to live much longer
Diet	N/A	likely zooplankton	similar to adult	ambush small fish which they lure close by waving an esca that resembles food
Distribution, general and seasonal				shallow tropical and temperate seas worldwide; 6 species in Hawaii with one endemic: the Hawaiian freckled frogfish <i>Antennarius drombus</i> . At least 12 species in Micronesia, and at least 7 species in Samoa.
Location	large egg raft released at the surface after a fast spawning rush			from tidepools to lagoon and seaward reefs
Water column	pelagic	pelagic	demersal	demersal; 1B130 m, but most at less than 30 m
Bottom type	N/A	N/A	seagrass, algae, sponge, rock or corals	seagrass, algae, sponge, rock or corals
Oceanic features	subject to advection	subject to advection		

by ocean currents	by ocean currents	
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5.1.8 Anomalopidae (flashlightfish)

Flashlightfish are small, dark fishes with luminous organs under each eye, blunt snouts, large mouths and a forked tail. The lime-green light is produced biochemically by bacteria within the light organ. The light may be used to attract zooplankton prey, to communicate to other flashlightfish or to confuse predators. They are usually at depths from 30 to 400 m but may be found much shallower in some locations. They remain hidden during the day and venture out at night to feed, tending to occur shallower on dark, moonless nights. Flashlightfish do not occur in the Hawaiian Islands, but two species occur in Micronesian waters: *Anomalops katoptron* and *Photoblepheron palpebratus*. *A. katoptron* also occurs in Samoan waters.

The eggs of *A. katoptron* and *P. palpebratus* are of moderate size (1.0-1.3 mm) with a mucous sheath. They are positively buoyant (Meyer-Rochow 1976). The larvae of *A. katoptron* hatch at 2.6-3.3 mm.

Bibliography

- Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.
- McCosker JE and RH Rosenblatt. 1987. Notes on the biology, taxonomy and distribution of flashlightfishes (Beryciformes: Anomalopidae). Japan J Ichthyol 34(2):157B64.
- Meyer-Rochow VB. 1976. Some observations on spawning and fecundity in the luminescent fish *Photoblepharon palpebratus*. Mar Biol 37(3):325B8.
- Myers, RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Table 25. Management Unit Species: Anomalopidae (flashlightfishes)

	Egg	Larvae	Juvenile	Adult
Duration		hatch at a size of 2.6B3.3 mm		
Diet	N/A	zooplankton	zooplankton	zooplankton
Distribution, general and seasonal				none found in Hawaiian Islands; 2 species in Micronesia, <i>Anomalops katoptron</i> and <i>Photoblepheron palpebratus</i>
Location			same as adult	hidden in caves or crevices by day; active in the water column by night
Water column	pelagic	pelagic	same as adult	demersal by day, and in the water column by night; 5B400 m
Bottom type		N/A	coral reef	coral reef
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.9 Holocentridae (soldierfishes/squirrelfishes)

Holocentrids are spiny, deep bodied, usually red fishes with large eyes and mouth, small teeth, large coarse scales and stout dorsal and anal fin spines. The family is divided into two subfamilies: the Myripristinae (soldierfishes of the genus *Myripristis*, *Plectrypops*, *Pristelepis* and *Ostichthys* are found in the Indo-Pacific; the latter two occur in deep water) and the Holocentrinae (squirrelfishes of the genus *Neoniphon* and *Sargocentron*). Soldierfishes lack a well-developed preopercular spine and a pointed snout, both of which are present in squirrelfishes. The spine on the preopercle of squirrelfish may be venomous. Soldierfishes and squirrelfishes are both nocturnal predators, but soldierfish predominantly feed on large zooplankton in the water column while squirrelfish prey mainly on benthic crustaceans, worms and small fishes. During the day, most holocentrids hover in or near caves and crevices or among branching corals.

About 17 holocentrid species inhabit Hawaiian waters, some of them in very deep water. At least 13 species of soldierfishes and 16 species of squirrelfishes occur in Micronesia. At least 31 holocentrid species are found in Samoan waters.

Holocentrids are slow growing, late maturing and fairly long lived. A study (Dee and Parrish 1993) on the reproductive and trophic ecology of *Myripristis amaena* found that sexual maturity for both sexes was reached between 145 and 160 mm SL at about 6 years of age. Longevity was determined to be at least 14 years. Fecundity was relatively low, fewer than 70,000 eggs in the most fecund specimen, and increased sharply with body weight. Spawning peaked from early April to early May, with a secondary peak in September. The diet of *M. amaena* was mainly meroplankton, especially brachyuran crab megalops, hermit crab larvae and shrimps but also a variety of benthic invertebrates and fishes.

M. amaena is particularly important in the recreational fishery at Johnston Atoll where it is the species caught in greatest abundance (Irons et al. 1990). It is common in reef fish catches throughout the Hawaiian archipelago.

Bibliography

Brecknock EL. 1969. Some aspects of the ecology of *Myripristis murdjan* in the Hawaiian Islands. MS thesis, Univ of Hawaii, Honolulu, 22 p.

Dee AJ and RL Radtke. 1989. Age and growth of the brick soldierfish, *Myripristis amaena*. Coral Reefs 8:79B85.

Dee AJ and JD Parrish. 1994. Reproductive and trophic ecology of the soldierfish *Myripristis amaena* in tropical fisheries. Fish. Bull. 92:516B30.

Gladfelter WB and WS Johnson. 1983. Feeding niche separation in a guild of tropical reef fishes (Holocentridae). *Ecology* 64:552-63.

Irons DK, RK Kosaki and JD Parrish. 1990. Johnston Atoll resource survey. Final report of Phase Six (21 July 1989-20 July 1990). Project report to US Army Engineer District, Honolulu, HI, 150 pp.

Johannes RE. 1981. Words of the lagoon. Los Angeles: Univ Calif Pr, 320pp.

Jones S and M Kumaran. 1964. Notes on the eggs, larvae and juveniles of fishes from Indian waters XII. *Myripristis murdjan* (Forsk.) and XIII. *Holocentrus* sp. *Ind J Fish* 18:155-67.

Mckenny TW. 1959. A contribution to the life history of the squirrelfish *Holocentrus vexillarius* Poey. *Bull Mar Sci* 9:174-221.

Schroeder RE. 1985. Recruitment rate patterns of coral reef fishes at Midway lagoon, Northwestern Hawaiian Islands. In C Gabrie and B Salvat (eds.), *Proc Fifth Int Coral Reef Congress, Tahiti, 27 May-1 June 1985*, vol. 5, p. 379-84. Antenne Museum-EOHE, Moorea, French Polynesia.

Wyatt JR. 1983. The biology, ecology and bionomics of the squirrelfishes, Holocentridae. *ICLARM Stud Rev* 7:50-8.

Table 26. Management Unit Species: **Holocentridae (soldierfishes/squirrelfishes)**

	Egg	Larvae	Juvenile	Adult
Duration		probably several weeks, settle at large size (up to 30 mm or more)	6 years for <i>M. amaena</i>	at least 14 years (Dee and Radtke 1989)
Diet	N/A	zooplankton	diet similar to adults	Myopristis spp.: mostly meroplankton, especially brachyuran crab megalops, hermit crab larvae and shrimps, but also a variety of benthic invertebrates and fishes, Holocentrinae: feed mainly on benthic crustaceans
Distribution, general and seasonal	spawning peak in April-May and another in Sept. for <i>M. amaena</i> at Johnston Atoll	generally, a recruitment peak in June-July and another in Feb.-March, but a lot of variation	tropical Atlantic, Indian, and Pacific Oceans	tropical Atlantic, Indian, and Pacific Oceans
Location				
Water column	pelagic	pelagic	demersal in caves and crevices during the day; demersal and in the water column at night	demersal in caves and crevices during the day ; demersal and in the water column at night
Bottom type	N/A	settle in refugia on the reef	coral reef caves and	coral reef caves and crevices, also within

		crevices, also within the branches of branching corals	the branches of branching corals
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents	

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5.1.10 Aulostomidae (trumpetfishes)

Trumpetfishes are very elongate with a compressed body, a small mouth, a long tubular snout, small teeth and a small barbel on the chin. The one Indo-Pacific species occurs in three color patterns: uniformly brown to green, mottled brown to green and uniformly yellow. They feed on fishes and shrimps by slowly moving close to the prey, often in a vertical stance, and then darting forward to suck the prey in through its snout. Trumpetfishes inhabit rocky and coral habitats of protected and seaward reefs from below the surge zone to a depth of 122 m. They have an ability to blend in with a background of coral branches or seagrasses by hanging vertically in order to sneak up on unwary prey. They also camouflage themselves by traveling with schools of surgeonfishes or large individual fish to sneak up on prey. There are three species in the world, but only one in the Indo-Pacific, *Aulostomus chinensis*. It is found in Hawaii, Micronesia and Samoa.

Spawning by *A. chinensis* has been observed off One Tree Island, Great Barrier Reef. At dusk, a male and female made a spawning ascent of 5-8 m to release gametes before returning to the bottom (in Thresher 1984). The pelagic eggs of *A. chinensis* are spherical, smooth and 1.3 to 1.4 mm in diameter. Larvae are approximately 4.8 mm at hatching (Watson and Leis 1974).

Bibliography

Mito, S. 1966. Fish eggs and larvae: Illustrations of the marine plankton of Japan 7:74pp.

Thresher, RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: a one-year study of the fish eggs and larvae. Univ Hawaii Sea Grant Program Honolulu Tech Rept UNIH-SEAGRANT-TR-75-01 178 pp.

Table 27. Management Unit Species: Aulostomidae (trumpetfish)

	Egg	Larvae	Juvenile	Adult
Duration	approximately 4 days	4.8 mm at hatching		
Diet	N/A	likely small zooplankton	similar to adults	ambush predators of small fishes and crustaceans
Distribution, general and seasonal			similar to adults	one Indo-Pacific species, <i>Aulostomus chinensis</i>
Location	pelagic	pelagic	similar to adults	protected and seaward reefs from below the surge zone to 122 m
Water column	pelagic	pelagic	similar to adults	reef-associated; 1B122 m
Bottom type	N/A	N/A	similar to adults	coral reef and rock
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.11 Fistularidae (cornetfish)

Cornetfishes have a very elongate body like the trumpetfish but differ in the body being vertically flattened rather than laterally compressed and by having a forked caudal fin with a long median filament. Like the trumpetfish, cornetfish feed by sucking small fishes and crustaceans into their long tubular snout. They are seen in virtually all reef habitats except areas of heavy surge. They are usually seen in open sandy areas and may occur in schools of similarly sized individuals. One species, *Fistularia commersonii*, is seen on Hawaiian, Micronesian and Samoan coral reefs, and another species is seen only in deep water.

Fistularid eggs are pelagic and large, with a diameter of 1.5-2.1 mm (Mito 1961). The larvae hatch at 6-7 mm (Mito 1961). Hatching occurred in about 7 days for *Fistularia petimba* (Mito 1966). The size of the largest examined pelagic fistularid specimen examined by Leis and Rennis (1983) was 145 mm.

Bibliography

- Delsman HC. 1921. Fish eggs and larvae from the Java Sea. 1. *Fistularia serrata*. *Treubia* 2:97-108.
- Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Honolulu: Univ of Hawaii Pr.
- Mito S. 1961. Pelagic fish eggs from Japanese waters - I. Clupeina, Chanina, Stomiatina, Myctophida, Anguillida, Belonida, and Syngnathida. *Sci Bull Fac Agr Kyushu Univ* 18(3) pp 285-310 plus plates 20-34 (in Japanese, English summary).
- Mito, S. 1966. Fish eggs and larvae: Illustrations of the marine plankton of Japan 7: 74pp.
- Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: a one-year study of the fish eggs and larvae. Univ Hawaii Sea Grant Program Honolulu Tech Rept UNIH-SEAGRANT-TR-75-01 178 pp.

Table 28. Management Unit Species: *Fistularidae* (cornetfish)

	Egg	Larvae	Juvenile	Adult
Duration	4 B7 days	6 mm at hatching		
Diet	N/A	likely small zooplankton	similar to adults	ambush predators of small fishes and crustaceans
Distribution, general and seasonal			similar to adults	two Indo-Pacific species: <i>Fistularia commersonii</i> and one deepwater species
Location	pelagic	pelagic	similar to adults	virtually all coral reef habitats except areas of high surge; most common in sandy areas where it may form schools of similarly sized fish
Water column	pelagic	pelagic	similar to adults	reef-associated; 1B128 m
Bottom type	N/A	N/A	similar to adults	sand, coral reef, rock
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.12 Syngnathidae (pipefishes/seahorses)

Pipefishes and seahorses have a long tubular snout with a very small mouth, which they use to feed in a pipette-like manner on small free-living crustaceans such as copepods. Some species clean other fishes. Many species are small and generally inconspicuous bottom dwellers that feed on minute benthic and planktonic animals. The syngnathids have very unique parental care in which the female deposits eggs into a ventral pouch on the male, which carries the eggs until hatching. Most species are rarely seen on reefs in the management area, partly because of their small size and inconspicuous nature. They occur in a wide variety of shallow habitats from estuaries and shallow sheltered reefs to seaward reef slopes, though they are generally limited to water shallower than 50 m. There are 8 species reported from Hawaiian waters, where the redstripe pipefish *Dunckerocampus baldwini* is endemic. At least 37 species occur in Micronesian waters, and at least 17 species occur in Samoa.

Bibliography

Dawson CE. 1985. Indo-Pacific pipefishes (Red Sea to the Americas). The Gulf Coast Res Lab, Ocean Springs, MS.

Gronell A. 1984. Courtship, spawning and social organization of the pipefish, *Corythoichthys intestinalis* (Pisces, Syngnathidae) with notes on two congeneric species. *Z Tierpsychol* 65:1-24.

Strawn K. 1958. Life history of the pygmy sea horse *Hippocampus zosterae* at Cedar Key, FL. *Copeia* 1:16-22.

Vincent ACJ. 1996. The international trade in seahorses. Cambridge, UK: TRAFFIC Intl., 163 pp.

Table 29. Syngnathidae (pipefishes/seahorses)

	Egg	Larvae	Juvenile	Adult
Duration		likely weeks to months		
Diet	N/A		similar to adults	small free-living crustaceans such as copepods; minute benthic and planktonic invertebrates
Distribution, general and seasonal				circumtropical and temperate; 8 spp. reported from Hawaiian waters, where the redstripe pipefish <i>Dunckerocampus baldwini</i> is endemic. At least 37 species in Micronesian waters, and at least 17 in Samoa
Location	male carries eggs in a ventral pouch	offshore waters	occasionally found in the open sea in association with floating debris	wide variety of shallow habitats from estuaries and shallow sheltered reefs to seaward reef slopes
Water column	male carries eggs in a ventral pouch	pelagic	similar to adults	benthic and free-swimming
Bottom type	N/A	N/A	similar to adults	coral, rock, mud, seagrass, algae
Oceanic features		subject to advection by ocean currents		

5.1.13 Caracanthidae (coral crouchers)

The coral crouchers consist of one genus, *Caracanthus*, and 4 small species. They are small, deep-bodied, ovoid fishes with venomous dorsal spines and small tubercles covering the body. They are found exclusively among the branches of certain *Stylophora*, *Pocillopora* and *Acropora* corals, where they feed on alpheid shrimps and other small crustaceans. The name coral crouchers comes from their tendency to tightly wedge themselves into the coral branches when threatened. One species, the Hawaiian orbicular velvetfish *Caracanthus typicus*, is found in Hawaiian waters and is endemic. Two species are found in Micronesian and Samoan waters: the spotted coral croucher *C. maculatus* and the pigmy coral croucher *C. unipinna*. *C. maculatus* is common among the long branches of large pocilloporid corals such as *Pocillopora eydouxi*, *Stylophora mordax* and ramose species of *Acropora*. *C. unipinna* is found in *S. mordax* and ramose species of *Acropora*.

The spawning mode and development at hatching of coral crouchers is not known. Caracanthid larvae are very similar to Scorpaenid larvae. The size of the largest examined pelagic specimen was 16.5 mm (Leis and Trnski 1989).

Bibliography

- Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.
- Myers, R.F. 1991. Micronesian reef fishes. Guam: Coral Graphics.
- Smith MM and PC Heemstra (eds). 1986. Smith's sea fishes. Johannesburg, S Africa: Macmillan.

Table 30. Management Unit Species: Caracanthidae (coral crouchers)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	zooplankton		alpheid shrimps and other small crustaceans
Distribution, general and seasonal			same as adults	Indian and Pacific Ocean; one endemic species in Hawaii - <i>Caracanthus typicus</i> , two species in Micronesia
Location			same as adults	exclusively among the branches of certain <i>Stylophora</i> , <i>Pocillopora</i> , and <i>Acropora</i> corals
Water column	probably pelagic; gelatinous egg masses float	pelagic; 0B100m depth	demersal	demersal
Bottom type	N/A	N/A	<i>Stylophora</i> , <i>Pocillopora</i> , and <i>Acropora</i> corals	<i>Stylophora</i> , <i>Pocillopora</i> and <i>Acropora</i> corals
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.14 Tetrarogidae (waspfish)

Waspfishes are closely related to scorpionfishes but have dorsal fins that originate over or in front of the eyes, typically do not have scales and tend to be more compressed. They have extremely venomous spines. They feed on small fishes and crustaceans. No species are found in Hawaiian waters, and only one species is found in Micronesia: the mangrove waspfish *Tetraroge barbata*, which inhabits muddy inshore waters of mangrove swamps and may also move into freshwater rivers.

There is little information on waspfish reproduction, but it is likely to be very similar to that for Scorpaenidae. They likely produce small to medium eggs embedded in a large, pelagic, sac-like gelatinous matrix.

Bibliography

- Leis, JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Sydney: New South Wales Univ Pr and Honolulu: Univ of Hawaii Pr.
- Harmelin-Vivien ML and C Bouchon. 1983. Feeding behavior of some carnivorous fishes (Serranidae and Scorpaenidae) from Tulear (Madagascar). *Mar Biol* 37:329-40
- Miller JM, W Watson and JM Leis. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian Islands. Misc Rep 80-02. Univ of Hawaii Sea Grant, Honolulu.
- Mito S and K Uchida. 1958. On the egg development and hatched larvae of a scorpaenid fish, *Pterois lunulata*. *Sci Bull Fac Agric , Kyushu Univ* 16:381-85.
- Moyer JT and MJ Zaiser. 1981. Social organization and spawning behavior of the pteroine fish *Dendrochirus zebra* at Miyake-jima, Japan. *Japan J Ichthyol* 28:52-69 .
- Norris JE and JD Parrish. 1988. Predator-prey relationships among fishes in pristine coral reef communities. *Proc Int Coral Reef Symp* 6th (2):107-13.
- Takai T and T Fukunaga. 1971. The life history of a ovo-viviparous scorpaenoid fish, *Sesbastes longispinis* (Matsubara). I. Egg and larval stages. *J Shimonoseki Univ Fish.* 20:91-5.

Table 31. Management Unit Species: Tetrarogidae (waspsfishes)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	zooplankton	ambush small fishes and crustaceans	ambush small fishes and crustaceans
Distribution, general and seasonal	no information on spawning in the wild			Indo-West Pacific; little seasonal difference in distribution
Location				estuarine or freshwater habitats; mangroves or rivers
Water column	probably pelagic; gelatinous egg masses float	pelagic; 0-100m depth	demersal	demersal
Bottom type	N/A	N/A		mangroves, rock, rubble, mud
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.15 Scorpaenidae (scorpionfishes)

Scorpionfishes are so named for the venomous dorsal, anal and pelvic fins of many species. They are stout-bodied, benthic carnivores that typically have fleshy flaps, a mottled coloring and small tentacles on the head and body. These camouflage features help them to ambush small fishes and crustaceans. Scorpionfish lie on the reef and wait for unwary prey to come near, when they pounce on the prey with a large mouth full of small viliform teeth. Many feed mainly at dusk or during the night. Lionfishes and turkeyfishes of the subfamily Pteroinae have greatly enlarged pectoral fins, elongate dorsal fin spines and bright colorations. The lionfish and turkeyfish species may swim well above the bottom, whereas small cryptic species of the subfamily Scorpaeninae tend to remain on the bottom and may be quite common in shallow rubble areas. In Hawaiian waters, 13 species are known and 3 are endemic: *Dendrochirus barberi*, *Pterois sphex* and *Scorpaenopsis cacopsis*. At least 30 species are known from Micronesia. At least 22 species are recorded from Samoa.

Most reef scorpaenids (*Scorpaena*, *Pterois*, *Dendrochirus*) have 0.7-1.2 m spherical to slightly ovoid eggs embedded in a large, pelagic, sac-like gelatinous matrix (Leis and Rennis 1983). Eggs hatch in 58-72 hours. The duration of the planktonic larval stage is not known. Older larval stages are described by Miller, Watson and Leis (1979).

Harmelin-Vivien and Bouchon (1976), analyzing the stomach contents of 17 species of scorpionfish from Tuléar, Madagascar, find that crustaceans generally were a dominant component of their diet. Only one species, *S. gibbosa*, fed exclusively upon fishes, while others fed on a mixture of fish and crustaceans. Seven species fed mainly on crustaceans such as brachyurans, shrimps and polychaetes. Their diets were supplemented with small amounts of galatheids and amphipods. Feeding tended to be heavier at night than during the day, but feeding was apparent for both night and day for all species.

Several biologists and aquarium collectors have noted reduced numbers of the endemic Hawaiian turkeyfish, *Pterois sphex*. Sightings of this previously more abundant species have become very infrequent. Its numbers may have been reduced by collecting efforts driven by its popularity as an aquarium fish. Randall et al. (1993) lists it as occasional in caves or ledges inside and outside the lagoon at Midway Atoll, but it is now very rare in the main Hawaiian Islands.

Bibliography

Harmelin-Vivien ML and C Bouchon. 1983. Feeding behavior of some carnivorous fishes (Serranidae and Scorpaenidae) from Tulear (Madagascar). *Mar Biol* 37:329-40.

Leis, JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Sydney: New South Wales U Pr. and Honolulu: Univ of Hawaii Pr.

Miller JM, W Watson, and JM Leis. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian Islands. Misc Rep 80-02. Univ of Hawaii Sea Grant, Honolulu, HI.

Mito S and K Uchida. 1958. On the egg development and hatched larvae of a scorpaenid fish, *Pterois lunulata*. Sci Bull Fac Agric, Kyushu Univ 16:381-5.

Moyer JT and MJ Zaiser. 1981. Social organization and spawning behavior of the pteroine fish *Dendrochirus zebra* at Miyake-jima, Japan. Japan J Ichthyol 28:52-69.

Norris JE and JD Parrish. 1988. Predator-prey relationships among fishes in pristine coral reef communities. Proc Int Coral Reef Symp 6th (2):107-113.

Orton GL. 1955. Early developmental stages of the California scorpionfish *Scorpaena guttata*. Copeia, 1955:210-214.

Randall JE, Earle JL, Pyle RL, JD Parrish and Hayes. 1993. Annotated checklist of the fishes of Midway Atoll, Northwestern Hawaiian Islands. Pac Sci 47(4):356-400.

Takai T and T Fukunaga. 1971. The life history of a ovo-viviparous scorpaenoid fish, *Sesbastes longispinis* (Matsubara). I. Egg and larval stages. J Shimonoseki Univ Fish 20:91-5.

Table 32. Management Unit Species: Scorpaenidae (scorpionfishes)

	Egg	Larvae	Juvenile	Adult
Duration	little information, but 58-72 hrs for <i>Scorpaena guttata</i> (David 1939)		2B3 yrs for 2 Mediterranean species	
Diet	N/A	zooplankton	ambush small fishes and invertebrates	ambush fish and invertebrates; <i>Scorpaenopsis diabolus</i> feeds exclusively on fishes (Harmelin-Vivien et al. 1976)
Distribution, general and seasonal	little information on spawning in the wild		worldwide in tropical and temperate seas; little seasonal information, but probably recruitment peak in summer or fall	worldwide in tropical and temperate seas; small home ranges; little seasonal difference in distribution
Location			reef and hard-bottom associated	reef and hard-bottom associated
Water column	pelagic; gelatinous egg masses float	pelagic; 0B100m depth	demersal	demersal
Bottom type	N/A	N/A	coral reef, rock, rubble	coral reef, rock, rubble
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.16 Serranidae (groupers)

Egg and Larvae

Serranid fertilized eggs are spherical, transparent and range in size from 0.70 to 1.20 mm in diameter. Each egg contains a single oil globule 0.13 to 0.22 mm in diameter. Based on the available data, the length of the pelagic larval stage of groupers is 25-60 days (Kendall 1984, Leis 1987). The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase. Serranid larvae are distinguishable by their kite-shaped bodies and highly developed head spination (Heemstra and Randall 1993).

Juvenile

Very little is known about the distribution and habitat utilization patterns of juvenile serranids. Research has found that transformation of pelagic serranids into benthic larvae takes place between 25 mm to 31 mm TL (Heemstra and Randall, 1993). The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools.

Adult

Serranids inhabit coral reefs and rocky bottom substrates from the shore to depths of at least 400 m. Serranids typically are long-lived and have relatively slow growth rates. Based on the available data, groupers appear to be protogynous hermaphrodites. After spawning for one or more years the female undergoes sexual transformation, becoming male. Some species of serranids spawn in large aggregations, others in pairs. Individual males may spawn several times during the breeding season. Some species of groupers are known to undergo small, localized migrations, of several km to spawn. Except for occasional spawning aggregations, most species of groupers are solitary fishes with a limited home range (Heemstra and Randall, 1993). Based on the results of tagging studies, it has been found that serranids are resident to specific sites, often residing on a particular reef for years .

Groupers are typically ambush predators, hiding in crevices and among coral and rocks in wait for prey (Heemstra and Randall 1993). Adults reportedly feed during both the day and night. The diet of adult serranids includes brachyuran crabs, fishes, shrimps, galatheid crabs, octopus, stomatopods, fishes and ophiurids (Heemstra and Randall, 1993, Morgan 1982, Randall and Ben-Tuvia 1983, Harmelin-Vivien and Bouchon 1976)

Bibliography

Allen, G.R. 1985. Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fish. Synop. no. 125, volume 6 208 p..

Brock, V.E., and T.C. Chamberlain. 1968. A geological and ecological reconnaissance off western Oahu, Hawaii, principally by means of the research submarine *Asherah*. Pac. Sci. 22:373-394.

- Carpenter KE, Allen GR. 1989. FAO species catalogue. Volume 9, Emperor fishes and large-eye breams of the world (family Lethrinidae). FAO. Fisheries synopsis no 125, volume 9. Rome: FAO. 118p.
- Ellis, D. A., E. E. Demartini, and R. B. Moffitt. 1992. Bottom trawl catches of juvenile opakapaka, *Pristipomoides filamentosus* (F. Lutjanidae), and associated fishes, Townsend Cromwell cruise TC-90-10, 1990. U. S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. H-92-03. 33pp.
- Everson, A.R., H.A. Williams, and B.M. Ito. 1989. Maturation and reproduction in two Hawaiian Eteline snappers, Uku, *Aprion virescens*, and Onaga, *Etelis coruscans*. U.S. Fish. Bull. 87:877-888.
- Everson, A.R. 1984. Spawning and gonadal maturation of the ehu, *Etelis carbunculus*, in the Northwestern Hawaiian Islands. pp. 128-148 In: Grigg, R.W. and K.Y. Tanoue (Eds.). Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands. Vol. 2. University of Hawaii Sea Grant Miscellaneous Report UNIHI-SEAGRANT-MR-84-01. Honolulu, Hawaii.
- Grimes, C.B. 1987. Reproductive biology of the Lutjanidae: a review. *In* J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 239-294. Westview Press, Boulder, Colorado.
- Haight WR, Kobayashi D, Kawamoto KE. 1993a. Biology and management of deepwater snappers of the Hawaiian archipelago. *Mar Fish Rev* 55(2):20-27.
- Haight, W.R., J.D. Parrish, and T.A. Hayes. 1993b. Feeding ecology of Lutjanid snappers at Penguin Bank, Hawaii. *Trans. Am. Fish. Soc.* 122:328-347.
- Harliem-Vivien ML, Bouchon C. 1976. Feeding behavior of some carnivorous fishes (Serranidae and Scopaenidae) from Tulear (Madagascar). *Mar Biol* 37:329-40.
- Heemstra PC, Randall JE. 1993. Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper, and lyretail species known to date. Rome: FAO. 382 p. Fisheries synopsis no 125, volume 16.
- Johannes RE. 1981. *Words of the lagoon*. Berkeley: Univ California Pr. 245 p.
- Kendall AW Jr. 1984. Serranidae: development and relationships. *In*: Moser HG, Richards WJ, Cohen DM, Fahay MP, Kendall AW Jr, Richardson SL, editors. *Ontogeny and*

- systematics of fishes. An international symposium dedicated to the memory of Elbert Halvor Ahlstrom; 1984 Aug 15B18; La Jolla, CA. Am Soc of Ichthyol and Herpetol. p. 499-510.
- Kikkawa, B.S. 1984. Maturation, spawning, and fecundity of opakapaka, *Pristipomoides filamentosus*, in the Northwestern Hawaiian Islands. pp. 149-160 In: Grigg, R.W. and K.Y. Tanoue (Eds.). Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands. Vol. 2. University of Hawaii Sea Grant Miscellaneous Report UNIHI-SEAGRANT-MR-84-01. Honolulu, Hawaii.
- Laroche, W.A., W.F. Smith-Vaniz and S.L. Richardson. 1984. Carangidae: development. in Ontogeny and systematics of fishes, based on an international symposium dedicated to the memory of Elbert Halvor Ahlstrom, August 15-18, 1983, La Jolla, California. Special publication of the American Society of ichthyologists and herpetologists, no 1. pp. 510-522.
- Leis, J. M. 1987. Review of the early life history of tropical groupers (Serranidae) and snappers (Lutjanidae). In J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 329-373. Westview Press, Boulder, Colorado.
- Lewis AD, Chapman LB, Sesewa A. 1983. Biological notes on coastal pelagic fishes in Fiji. Fiji: Fisheries Division (MAF). Technical report no 4.
- Manooch, C. S. III. 1987. Age and growth of snappers and groupers. In J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 329-373. Westview Press, Boulder, Colorado.
- Morgan JFC. 1982. Serranid fishes of Tanzania and Kenya. Ichthyol Bull. JLB Smith Inst Ichthyol 46:1B44, 6 pls.
- Myers RF. 1991. *Micronesian reef fishes*. Barrigada, Guam: Coral Graphics.
- Miller JM, Watson W, Leis JM. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian Islands. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report no UNIHI-SEAGRANT-MR-80-02.
- Moffitt RB, Parrish FA. 1996. Habitat and life history of juvenile Hawaiian pink snapper, *Pristipomoides filamentosus*. Pac Sci 50(4):371-81.
- Moffitt, R. B., F. A. Parrish, and J. Polovina. 1989. Community structure, biomass and productivity of deepwater artificial reefs in Hawaii. Bull. Mar. Sci. 44(2):616-630.

- Munro, J.L. 1987. Workshop synthesis and directions for future research. In J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 329-373. Westview Press, Boulder, Colorado.
- Parrish, F. A. 1989. Identification of habitat of juvenile snappers in Hawaii. Fish. Bull. U.S. 87:1001-1005
- Parrish, J.D. 1987. Trophic biology of snappers and groupers. pp. 405-463 In: Polovina, J.J. and S.V. Ralston (Eds.). Tropical snappers and groupers: Biology and fishery management. Westview Press, Boulder, Colorado.
- Ralston, S. 1987. Mortality rates of snappers and groupers. In J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 375-404. Westview Press, Boulder, Colorado.
- Ralston, S. 1981. A study of the Hawaiian deepsea handline fishery with special reference to the population dynamics of opakapaka, *Pristipomoides filamentosus* (Pisces: Lutjanidae). Ph.D. Thesis, Univ. Wash., Seattle, Washington, 204 p.
- Ralston, S., R. M. Gooding, and G. M. Ludwig. 1986. An ecological survey and comparison of bottomfish resource assessments (submersible versus handline fishing) at Johnston Atoll. U. S. Fish. Bull. 84(1):141-155
- Ralston, S., and G. T. Miyamoto. 1983. Analyzing the width of daily otolith increments to age the Hawaiian snapper, *Pristipomoides filamentosus*. Fish. Bull. 81(3):423-535.
- Randall JE., Ben-Tuvia A. 1983. A review of the groupers (Pisces: Serranidae: Epinephelinae) of the Red Sea, with description of a new species of *Cephalopholis*. Bull Mar Sci 33(2):373-426.
- Sudekum AE, Parrish JD, Radtke RL, Ralston S. 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fish Bull (89):492-513.
- Uchida, R.N. and J.H. Uchiyama (Eds.). 1986. Fishery Atlas of the Northwestern Hawaiian Islands. NOAA Technical Report NMFS 38. 142 pp.
- Walker, M.H. 1978. Food and feeding habits of *Lethrinus chrysostomus* Richardson (Pisces: Perciformes) and other lethrinids on the Great Barrier Reef. Aust. J. Mar. Freshwater Res., 29:623-630
- Yamaguchi, Y. 1953. The fishery and the biology of the Hawaiian opelu, *Decapterus pinnulatus*. M.S. Thesis, Univ. of Hawaii, Honolulu, 125 p.

Young, P.C., and R.B. Martin. 1982. Evidence for protogynous hermaphroditism in some lethrinid fishes. *Fish. Biol.* 21:475-484.

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Table 33. Management Unit: Serranidae (groupers)

	Egg	Larvae	Juvenile	Adult
Duration	Incubate in 20-35 days	Pelagic duration : 25-60 days	Metamorphosis to demersal habitat at ~25-31 mm TL	Long-lived, slow growing
Diet	N/A	No information available	No information available	Primarily feed in demersal habitat. Diet includes crabs, shrimp, octopus and fish.
Distribution	Serranid eggs have a relatively long pelagic phase that results in wide distribution	Serranid larvae have a relatively long pelagic phase that results in wide distribution	Throughout Indo-Pacific. Juveniles of some species inhabit shallow reef areas (sea-grass beds and tide pools).	Throughout Indo-Pacific. Inhabit shallow coastal coral reef areas to deep slope rocky habitats (0-400 m)
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	Wide variety of shallow-water reef and estuarine habitats	Primary forage habitat is shallow to deep reef and rocky substrate.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

5.1.17 Grammistidae (soapfish)

The soapfishes are small, grouper-like fishes that emit a toxic slime to deter predation by larger fishes. They are secretive fish that occur on reef flats, shallow lagoon and seaward reefs, often in small caves, under ledges or in holes at depths up to 150 m. They are nocturnal predators on fishes, crustaceans and a variety of invertebrates. They are represented in Hawaii by three species of the genus *Liopropoma* and two species of *Pseudogramma*. At least one species, *L. aurora*, is endemic. There are 6 species of soapfishes in Micronesia and 4 species in Samoan waters. The taxonomy of the soapfish is frequently under debate, and it has been placed in at least 4 other families. Randall (1996) treats Grammistinae as a subfamily of the Serranidae.

The grammistids, like the serranids, are generally hermaphroditic, although Smith (1971) reported that members of *Liopropoma* appeared to be secondary gonochorists, with separate sexes but clearly derived from hermaphroditic ancestors. Smith and Atz (1966) reports that members of *Pseudogramma* are hermaphroditic. All are typically solitary and territorial. *Diploprion* and *Liopropoma* appear to have pelagic eggs, while *Pseudogramma* has large, bright red eggs that are probably demersal. The duration of the planktonic phase is not known, but the size of the largest examined pelagic specimen was 12.6B14.5 mm (Leis and Rennis 1983).

Bibliography

- Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Honolulu: Univ of Hawaii Pr.
- Randall, J.E. 1996. Shore fishes of Hawaii. Vida, OR: Natural World Pr.
- Smith, CL. 1971. Secondary gonochorism in the serranid genus *Liopropoma*. *Copeia*, 1971:316B9.
- Smith, CL and EH Atz. 1969. The sexual mechanism of the reef bass *Pseudogramma bermudensis* and its implications in the classification of the Pseudogrammidae (Pisces: Perciformes). *Zeit Morph Tiere* 65:315B26.

Table 34. Management Unit Species: Grammistidae (soapfishes)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	zooplankton	similar to adult	small fishes, crustaceans and other invertebrates
Distribution, general and seasonal			similar to adult	Atlantic, Pacific, and Indian Oceans; 5 species in Hawaii with at least one endemic; at least 6 species in Micronesia
Location	pelagic; possibly demersal for <i>Pseudogramma</i> spp.	predominantly offshore		outer reef slopes, reef flats, lagoons, wave-washed seaward reefs
Water column	pelagic; possibly demersal for <i>Pseudogramma</i> spp.	pelagic	demersal; 1-150 m	demersal; 1B150 m
Bottom type		N/A	similar to adults	secretive inhabitants of caves, crevices on coral reefs and rocky substrate
Oceanic features		subject to advection by ocean currents		

5.1.18 Plesiopidae (prettyfins)

Prettyfins, or longfins, are characterized by a disjunct lateral line, preopercle with a double border and long pelvic fins. They are nocturnal predators on small crustaceans, fishes and gastropods. They are secretive during the day. No species are recorded for the Hawaiian Islands and 3 species are recorded for Micronesian waters. Three species are recorded in Samoan waters. The comet *Calloplesiops altivelis* is a popular aquarium fish that is relatively uncommon in Micronesia. The red-tipped longfin *Plesiops caeruleolineatus* is a common, but seldom seen, fish on exposed outer reef flats and outer reef slopes to a depth of 23 m. The bluegill longfin *P. corallicola* is relatively common on reef flats under rocks or in crevices.

Prettyfin reproduction is similar to the closely related dottybacks. They are demersal spawners in which the male tends the egg mass. Mito (1955) reported that *P. semeion* eggs are 0.9 by 0.6 mm, and are deposited in a single layer on the underside of a rock.

Bibliography

- Mito, S. 1955. Breeding habits of a percoid fish, *Plesiops semeion*. Sci Bull Fac Agric, Kyushu Univ, 15:95B9.
- Myers, RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.
- Randall JE. 1986. Red Sea reef fishes. London: Immel Publ.
- Thresher, RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

Table 35. Management Unit Species: Plesiopidae (prettyfins)

	Egg	Larvae	Juvenile	Adult
Duration	15 days by a mouth-brooding species in an aquarium (Debelius and Baensch 1994)	3 months for a related basslet	3 years for a related basslet	
Diet	N/A	zooplankton	probably similar to adult	small crustaceans, fishes, and gastropods
Distribution, general and seasonal				3 species recorded for Micronesian waters; none in Hawaiian waters
Location	near adult territory; often in caves or crevices	primarily offshore	similar to adults	outer reef slopes and flats
Water column	demersal; or carried in the mouth of the male	pelagic	demersal; 3-45 m	demersal; 3B45 m
Bottom type	cleared patch of rock or coral	N/A	same as adults	holes and crevices on coral reefs; also sand and rock

Oceanic features		subject to advection by ocean currents		
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5.1.19 Pseudochromidae (dottybacks)

Dottybacks are small (<65mm) elongate fishes with a long continuous dorsal fin. Two genera are present in Micronesian waters: *Pseudochromis* has a disjunct lateral line, whereas *Pseudoplesiops* lacks one. Members of *Pseudoplesiops* typically remain hidden within the reef framework and are rarely seen except when an ichthyocide is used. Some members of *Pseudochromis* are brightly colored and are sought after for the aquarium trade. The dottybacks are carnivores of small crustaceans, polychaete worms and zooplankton. The dottybacks are demersal spawners, and some may brood eggs in the mouth of the male. Females of *Pseudochromis* produce a spherical mass of eggs that is guarded by the male. Dottybacks are not present in Hawaiian waters, while 10 species are present in Micronesian waters. Five species are recorded for Samoan waters.

Dottybacks are hermaphrodites. Males are typically larger than females. Some species are obviously sexually dichromatic, while others are not. Pseudochromoid egg balls range in diameter from 7 mm with about 60 eggs in *Assessor macneilli* (Thresher 1984) to 5.8 cm with 8,200 to 17,500 eggs for *Acanthoclinus quadridactylus* (Jillet 1968). Individual *Pseudochromis fuscus* eggs are 1.25 mm in diameter, slightly elongate spheroids attached by several adhesive threads. Incubation periods range from 3 to 5 days at approximately 29EC. Hatching typically occurs at night, shortly after sunset. Newly hatched larvae of *P. fuscus* are 2.5 mm, and feeding typically begins on the first day after hatching (Lubbock 1975). Jillett (1968) estimates a planktonic larval stage of 3 months for *A. quadridactylus*, which reaches sexual maturity in approximately 3 years.

Pseudochromis cyanotaenia is sexually dichromatic, relatively common near holes and crevices of exposed outer reef flats and reef margins to a depth of 4 m, often occurs in pairs and feeds on small crabs, isopods and copepods. *P. fuscus* is common near small patches of branching corals on shallow sandy subtidal reef flats and lagoons.

Bibliography

- Jillett JB. 1968. The biology of *Acanthoclinus quadridactylus* (Bloch and Schneider) (Teleostei-Blennioidea) II. Breeding and development. Aust J Mar Freshwater Res 19:1B8.
- Lubbock R. 1975. Fishes of the family Pseudochromidae (Perciformes) in the northwest Indian Ocean and Red Sea. J. Zool., London, 176: 115-157.
- Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.
- Randall JE. 1986. Red Sea reef fishes. London: Immel Publ.
- Thresher RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

Table 36. Management Unit Species: Pseudochromidae (dottybacks)

	Egg	Larvae	Juvenile	Adult
Duration	3B5 days for <i>Pseudochromis fuscus</i> (Thresher 1984)	3 months	3 years for an Australian species <i>Acanthoclinus quadridactylus</i>	
Diet	N/A	zooplankton	probably similar to adult	small crustaceans, polychaete worms, and zooplankton
Distribution, general and seasonal				10 species recorded for Micronesian waters; none in Hawaiian waters
Location	near adult territory; often in caves or crevices	primarily offshore	similar to adults	exposed outer reef flats and reef margins; also near small patches of branching corals on shallow sandy subtidal reef flats and lagoons
Water column	demersal; or carried in the mouth of the male	pelagic	demersal; 0B100m	demersal; 0B100m
Bottom type	cleared patch of rock or coral	N/A	same as adults	holes and crevices on coral reefs; also sand

Oceanic features		subject to advection by ocean currents		
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5.1.20 Acanthoclinidae (spiny basslets)

Acanthoclinids are closely related to the pseudochromids but differ in having more dorsal and anal fin spines and 1 or 2 instead of 3 to 5 pelvic rays. Basslets in general produce demersal eggs and have a tendency towards oral incubation. Eggs are typically tended by the male or brooded by them in the case of brooders. Other basslets have eggs that hatch within 3-16 days and larvae that have a planktonic stage of up to 3 months. The basslets are fairly secretive inhabitants of coral reefs, but some species are conspicuous as they hover near shelter. They are often collected for aquariums. There are 10 known species, but only 3 occur in the Indo-Pacific, with none in Hawaii and one species in Micronesia. Hiatt's basslet *Acanthoplesiops hiatti* is a tiny species (to 21 mm) that has been collected from shallow-washed seaward reefs in Micronesia.

Bibliography

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Randall JE. 1986. Red Sea reef fishes. London: Immel Publ..

Table 37. Management Unit Species: Acanthoclinidae (spiny basslets)

	Egg	Larvae	Juvenile	Adult
Duration	3B16 days	months		
Diet	N/A		similar to adults	small crustaceans, polychaete worms, and zooplankton
Distribution, general and seasonal				West-central Pacific; one species <i>Acanthoplesiops hiatti</i> found in Micronesia
Location		offshore waters	shallow wave-washed seaward reefs	shallow wave-washed seaward reefs
Water column	demersal	pelagic	reef-associated; 1B65 m	reef-associated; 1B65 m
Bottom type			coral or rock shelter	coral or rock shelter
Oceanic features		subject to advection by ocean currents		

5.1.21 Cirrhitidae (hawkfish)

Hawkfishes are small grouper-like fishes characterized by projecting cirri on the tips of the dorsal spines. The common name comes from their tendency to perch themselves on the outermost branches of coral heads or other prominences. They use enlarged lower pectoral rays to support their body or to wedge themselves in place. All are carnivores of small benthic crustaceans and fishes. The species thus far studied are protogynous hermaphrodites, and the males are territorial and defend a harem of females. Courtship and spawning occur at dusk or early night throughout the year in the tropics. Spawning occurs at the apex of a short, rapid paired ascent. The pelagic larval stage probably lasts a few to several weeks (Randall 1963). In Hawaii, there are 6 species recorded. At least 10 species occur in Micronesia, and at least 8 species occur in Samoa. The colorful species are popular aquarium fishes.

Hawkfishes range in size at maturity from less than 10 cm to almost a meter. Most species are sexually monomorphic. Pair spawning occurs with the male making quick ascents with each of the members of his harem in rapid succession. Eggs are pelagic, spherical and approximately 0.5 mm in diameter. The development at hatching is unknown. A lengthy pelagic stage is suggested by the widespread distribution and limited geographic variation of some species. The smallest specimen examined by Leis and Rennis (1983) was 2.7 mm, and the largest pelagic specimen examined was 33.0-37.9 mm. Juveniles of most species resemble the adults.

Adults typically inhabit rock, coral or rubble of the surge zone, seaward reefs, lagoons, channels, rocky shorelines and submarine terraces. Some are typically found on heads of small branching corals. The longnose hawkfish *Oxycirrhites typus* is a popular aquarium fish that feeds mainly on zooplankton and is usually seen perched on black coral or gorgonians at depths greater than 30 m.

Bibliography

- Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Honolulu: Univ of Hawaii Pr.
- Lobel PS. 1974. Sea spawnings-hawkfish. *Octopus* 1(7):23.
- Randall JE. 1963. Review of the hawkfishes (family Cirrhitidae). *Proc US Nat Mus* 113: 389-450.
- Suzuki K, Tanaka Y, Hioki S and Y Shiobara. 1980. Studies on reproduction and larval rearing of coastal marine fishes. pp. 53-82 in G Yamamoto (ed); *Research in large scale aquaculture of marine fisheries resources*. Inst of Oceanic Res and Dev Tokai Univ: Shimizu.

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Table 38. Management Unit Species: Cirrhitidae (hawkfishes)

	Egg	Larvae	Juvenile	Adult
Duration		weeks to months		
Diet	N/A		similar to adults	carnivores of small benthic crustaceans and fishes; the longnose hawkfish <i>Oxycirrhites typus</i> feeds heavily on zooplankton
Distribution, general and seasonal				most are Indo-West Pacific; 6 species in Hawaii, at least 10 species in Micronesia, and at least 8 species in Samoa
Location	near adult territory	generally offshore	similar to adults	the surge zone, seaward reefs, lagoons, channels, rocky shorelines and submarine terraces. Some are typically found on heads of small branching corals
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	rock, coral, or rubble	rock, coral, or rubble
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.22 Apogonidae (cardinalfishes)

The cardinalfishes are named for the red color of some of the species, although most are fairly drab and many are striped. They are characterized by two dorsal fins, large eyes, a large mouth and double-edged preopercles. Most species are small, less than 12 cm. They are typically nocturnal, remaining hidden under ledges or in holes in the reef during the day. Most prey mainly on large zooplankton, but some feed primarily on small benthic crustaceans. A few species form dense aggregations immediately above mounds of branching corals. As far as is known, all species are brood spawners in which the male carries the eggs in his mouth until they hatch. Ten species occur in Hawaii, and at least 58 species occur in Micronesia. *Apogon erythrinus*, *A. maculiferus*, and *A. menesemus* are endemic to the Hawaiian Islands. At least 36 species occur in Samoa.

External sexual dimorphism is slight or nonexistent in the cardinalfishes, except for females that are noticeably swollen with eggs prior to spawning. Temporary color differences during courtship and spawning occur in a few species. Apogonid species display a variety of different seasonal spawning patterns, from year-round spawning to spring and fall peaks. Spawning may also be tied to the phases of the moon.

Schooling behavior is important in some species of cardinalfishes. The fragile cardinalfish *A. fragilis* occurs in large aggregations above branching corals. Despite these aggregations, courtship and spawning in cardinalfishes are always paired rather than group activities. The female often initiates courtship, which involves prolonged tight side-by-side swimming until spawning occurs and the female releases a ball of eggs which the male quickly circles back to and inhales. The male broods the eggs in the mouth for anywhere from 2 to 8 days. The eggs, up to 22,000 of them, are bound together by threads that originate from one pole of the egg and, in some species, a fine mucous membrane. Upon hatching, the eggs become planktonic larvae ranging in size from 1.0-3.3 mm. The planktonic larval stage lasts approximately 60 days, until larvae settle out at a size ranging from 10 to 25 mm.

Cardinalfish are found in water depths from 1 to 80 m. Members of the genera *Apogonichthys*, *Foa* and *Fowleria* are typically secretive, cryptic inhabitants of seagrasses, algal beds or rubble of sheltered reefs and reef flats. The bay cardinalfish *Foa brachygramma* is usually found around dead coral, sponge or heavy plant growth in shallow bays such as Kaneohe Bay, Oahu, and Tumon Bay, Guam.

Chave (1978) detailed the ecology of 6 species of Hawaiian cardinalfishes, all of which remain in holes and caves in the daytime and emerge at night to feed on zooplankton and benthic invertebrates. The habitat requirements of each species were distinct. Some species remain near the substrate at night (*A. snyderi* and *A. erythrinus*), while others occur in midwater (*A. menesemus*, *A. maculiferus* and *A. waikiki*), and *Foa brachygramma* occurs in

both locations. *A. snyderi* eats mostly sand dwelling invertebrates in sandy, bright, flat substrate, *A. maculiferous* eats mostly midwater zooplankton near dawn, and *A. erythrinus* eats crustaceans only (Chave 1978).

Bibliography

- Charney P. 1976. Oral brooding in the cardinalfishes *Phaeoptyx conklini* and *Apogon maculatus* from the Bahamas. *Copeia*, 1976:198-200.
- Chave EH. 1978. General ecology of six species of Hawaiian cardinalfishes. *Pac Sci* 32: 245-69.
- Chave EH and DW Eckert. 1974. Ecological aspects of the distribution of fishes at Fanning Island. *Pac Sci* 28(3):279-319.
- Fraser TH. 1972. Comparative osteology of the shallow water cardinalfishes (Perciformes: Apogonidae) with reference to the systematics and evolution of the family. *Ichthyol Bull* 1-105.
- Hobson ES. 1972. Activity of Hawaiian reef fishes during the evening and morning transitions between daylight and darkness. *Fish Bull* 70:715-40.
- Hobson ES. 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. *Fish Bull* 72:915-1031.
- Hobson ES and R Chess. 1978. Trophic relationships among fishes and plankton in the lagoon at Enewetak Atoll, Marshall Islands. *Fish Bull* 76:133-53.
- Oppenheimer JR. 1970. Mouthbreeding in fishes. *Anim Behav* 18:493-503.

Table 39. Management Unit Species: Apogonidae (Cardinalfishes)

	Egg	Larvae	Juvenile	Adult
Duration	2B8 days	approximately 60 days		
Diet	N/A	zooplankton; tintinnids (Watson 1974)	feed on plankton at night; some species eat primarily small benthic crustaceans	feed on plankton at night; some species eat primarily small benthic crustaceans
Distribution, general and seasonal	throughout the year, spring and fall peaks for some species	throughout the year, spring and fall peaks for some species	Atlantic, Pacific, and Indian Ocean	Atlantic, Pacific, and Indian Ocean
Location	within the father's mouth	predominantly offshore	coral reefs	coral reefs
Water column	within the father's mouth	pelagic	demersal and mid-water at night for feeding on zooplankton; 1-80m depth	demersal and mid-water at night for feeding on zooplankton; 1B80 m depth
Bottom type	N/A	N/A	coral reef ledges, holes, flats, rubble, within the branches of branching corals	coral reef ledges, holes, flats, rubble, within the branches of branching corals
Oceanic features				

5.1.23 Priacanthidae (bigeyes)

Priacanthids have very large eyes, moderately deep compressed bodies, oblique mouths with a projecting lower jaw, small conical teeth in a narrow band in each jaw, an opercle with 2 flat spines and a serrate preopercle with a broad spine at the corner. They are usually red but are able to change quickly to silver or blotches of silver and red. They are nocturnal zooplanktivores on larger zooplankton, such as the larvae of crabs, fishes, polychaete worms and cephalopods. The family is distributed circumtropically and in temperate seas, but some species are limited to the Indo-Pacific or the Hawaiian Islands. In Hawaiian waters, 4 species have been recorded: *Heteropriacanthus cruentatus*, the endemic *Priacanthus meeki* and two deep-water species. In Micronesian waters, *H. cruentatus*, *P. hamrur* and a deep species from below 200 m depth have been recorded. The shallow-water species are limited to 100 m or less. Five species are recorded from Samoan waters.

The glass-eye *H. cruentatus* inhabits lagoon or seaward reefs from below the surge zone to a depth of at least 20 m. During the day it is usually solitary or in small groups but may gather in large numbers at dusk prior to ascending into the water column for feeding.

Spawning by priacanthids has not been observed, but Colin and Clavijo (1978) reports seeing an aggregation of more than 200 individuals at a reef where many other species were spawning. The eggs of *Pristigenys nipponium* and *Priacanthus macracanthus* are pelagic, spherical and 0.75 mm in diameter (Suzuki et al. 1980, Renzhai and Suifen 1982). The larvae hatch at 1.4 mm (Renzhai and Suifen 1982). The size of the largest examined pelagic larval specimen was 48 mm (Leis and Rennis 1983). Caldwell (1962) reports a size at settlement for the deep-water subtropical species *Pristigenys alta* of 65 mm.

Bibliography

Caldwell DK. 1962. Development and distribution of the short bigeye, *Pseudopriacanthus altus* (Gill) in the western North Atlantic. Fish Bull (US) 62:103-49.

Colin PL and I Clavijo. 1978. Mass spawning by the spotted goatfish, *Pseudupeneus maculatus*. Bull Mar Sci 28: 78-82.

Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Sydney: New South Wales Univ Pr. and Honolulu: Univ of Hawaii Pr.

Renzhai Z and L Suifen. 1982. The development of egg and larvae of *Priacanthus macracanthus* (Cuvier and Valenciennes). J Fisheries China 6(3):243-51.

Table 40. Management Unit Species: Priacanthidae (bigeyes)

	Egg	Larvae	Juvenile	Adult
Duration		from 10 mm to about 60 mm		
Diet	N/A	various zooplankton	similar to adults	larger zooplankton such as the larvae of crabs, fishes, polychaete worms and cephalopods; also crustaceans and soft-bodied invertebrates
Distribution, general and seasonal				worldwide in tropical and temperate seas, but 3 Indo-Pacific genera, 1 Hawaiian endemic
Location				lagoon or seaward reefs from below the surge zone to a depth of at least 80 m
Water column	pelagic	pelagic	demersal and mid-water column	demersal and mid-water column; some species very deep
Bottom type	N/A	N/A		coral reef crevices or overhangs during the day; may feed over soft substrate at night
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.24 Malacanthidae (tilefishes)

The tilefishes have elongate bodies with one sharp opercular spine and a long continuous dorsal fin. They have viliform and canine teeth for taking a variety of benthic animals along with substantial amounts of plankton. They usually occur in pairs on sandy and rubble areas of outer reef slopes. They frequently build a burrow into which they retreat when threatened, often piling rubble on top. They can be found in depths from 6 to 115 m in mud, sand, rubble or talus areas of barren seaward slopes. The family is distributed worldwide in tropical and temperate seas. The family is represented in Hawaiian waters by a single species, *Malacanthus brevirostris*, and in Micronesian waters by the same species plus four more: *Hoplolatilus cuniculus*, *H. fronticinctus*, *H. starcki* and *M. latovittatus*. Two species are present in Samoan waters: *M. brevirostris* and *M. latovittatus*.

Accounts of spawning are few, but pairs typically make a short spawning ascent to release pelagic, spheroid eggs, about 0.7 mm in diameter with a single oil globule. After a larval phase of undetermined duration, *Malacanthus* settle to the bottom at a size of about 6 cm and immediately construct burrows under rocks in shallow water (Araga 1969).

Bibliography

- Araga C. 1969. Young form of the rare coral fish, *Malacanthus latovittatus* from Tanabe Bay. Pub Seto Mar Biol Lab 16:405-10.
- Ikeda T and S Mito. 1988. Pelagic fish eggs. pp 999-1083 in Okiyama (ed). An atlas of the early stage fishes in Japan. Tokyo: Tokai Univ Pr.
- Johnson GD. 1984. Percoidei: development and relationships. pp 464-499 in ASIH Spec Publ 1.
- Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.
- Randall JE. 1981. A review of the Indo-Pacific sand tilefish genus *Hoplolatilus* (Perciformes: Malacanthidae). Freshw and Mar Aquar 4(12):39-46.
- Thresher RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

Table 41. Management Unit Species: Malacanthidae (Tilefishes)

	Egg	Larvae	Juvenile	Adult
Duration		weeks or months	settlement at a size of about 6 cm	
Diet	N/A		benthic invertebrates and plankton	benthic invertebrates and plankton
Distribution, general and seasonal				3 Indo-Pacific genera
Location			shallow sheltered habitats	outer reef slopes
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	sand, mud, rubble	sandy and rubbly areas
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.25 Echineididae (remoras)

Remoras have a broad flat head uniquely modified for suction that allows them to attach to other marine animals. Some species are host specific while others use a variety of hosts such as sharks, rays, large bony fishes, sea turtles or marine mammals. Some species are free swimming. The two species of *Echeneis* are not host-specific and are free-living part of the time. Remoras are circumglobal in their distribution. In Hawaii and in Micronesia, the sharksucker *E. naucrates* is the most common, although *Remora remora* may be found on large sharks and *Remorina albescens* on mantas. Five species are recorded from Samoan waters, including *E. naucrates*, *R. remora*, and *Phtheichthys lineatus*, which was attached to a hawksbill turtle. *Remoropsis pallidus* and *Rhombochirus osteochir* were found attached to marlin.

Johnson (1984) reports that eggs of *E. naucrates* and *R. remora* are large (1.4-2.6 mm), pelagic and spherical, although Nakajima et al. (1987) reports *E. naucrates* eggs are negatively buoyant. Newly hatched eggs are 4.7-7.5 mm long. The size of the largest examined pelagic larval stage was 14.5-22 mm (Leis and Trnski 1989).

Bibliography

- Johnson GD. 1984. Percoidei: development and relationships. pp 464-499 in ASIH Spec Publ 1.
- Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.
- Nakajima H, H Kawahara, and S Takamatsu. 1987. The breeding behavior and the behavior of larvae and juveniles of the Sharksucker, *Echeneis naucrates*. Japan J Ichthyol 34(1):66-70.

Table 42. Management Unit Species: Echineididae (remoras)

	Egg	Larvae	Juvenile	Adult
Duration		size at hatching ranges from 3.7 to 7.5 mm		
Diet	N/A	zooplankton	similar to adults	zooplankton such as copepods and isopods; zoobenthos such as small crustaceans; detritus, and small fishes (Randall 1967)
Distribution, general and seasonal	little information on seasonal patterns		circumglobal	circumglobal
Location			coastal and pelagic waters	coastal and pelagic waters; often attached to sharks, rays, large bony fishes, sea turtles, or marine mammals
Water column	pelagic	pelagic	same as adults	pelagic; either free swimming or attached to large reef-associated inhabitants
Bottom type	N/A	N/A	N/A	N/A
Oceanic features	subject to advection	subject to advection by		

	Egg	Larvae	Juvenile	Adult
	by ocean currents	ocean currents		

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5.1.26 Carangidae (jacks, *papio*, *ulua*)

Eggs and larvae

There are few extant studies of the distribution of carangid eggs and larvae. Carangid eggs are planktonic, spherical and 0.70-1.3mm in diameter (Laroche et al. 1984, Miller et al. 1979). The eggs usually contain one to several oil globules. The eggs hatch 24-48 hours after spawning in water temperatures from 18 to 30 CE (Laroche et al. 1984). The larvae are relatively small (1 - 2 mm) at hatching and contain a relatively large yolk sac. The larvae are moderately deep bodied and large headed with well developed preopercular spines (Miller et al. 1979). According to Miller et al. (1979) carangid larvae are common in nearshore waters surrounding the Hawaiian Archipelago.

Juvenile

Juvenile carangids are often found in nearshore and estuarine waters and may form small schools over sandy inshore reef flats (Lewis et al. 1983, Meyers 1991). Available diet studies suggest that juvenile carangids are planktivorous and feed on fish larvae and planktonic crustaceans

Adult

The carangids are distributed throughout tropical and subtropical waters in the Indo-Pacific. They are widely distributed in shallow coastal waters, estuaries, shallow reefs, deep reef slope, banks and seamounts (Sudekum et al. 1991). Juvenile and adult carangids are an important component of shallow reef and lagoon fish catches throughout the management area. Adult carangids are large highly-mobile predators that range widely through the reef and deep slope habitat from depths of 0- 250m. A single species (*Seriola dumerili*) has been documented to forage at depths of up to 355 m (Myers 1991, Ralston et al. 1986). Although most of the large jacks utilize the complete water column in their habitat range they are associated primarily with demersal habitat.

In general adult carangids are piscivorous, they also prey on crustaceans, gastropods, and cephalopods. *Caranx ignobilis*, one of the most abundant species of jacks found in Hawaii is primarily piscivorous, preying primarily on reef-associated fish. The most recent study of the feeding habits of *C. ignobilis* concludes that the predominance of reef fishes in its diet indicates that shallow-water reef areas are important foraging habitat for these fish. The occurrence of small pelagic fish and squid in the diet of *C. ignobilis* indicates that part of its foraging also occurs in the water-column (Sudekum et al. 1991).

Reproductive information is sparse for most species. In Hawaii the sex ratio for *C. ignobilis* is slightly skewed toward females 1:1.39 (Sudekum et al. 1991). Peak spawning occurs between May and August, although gravid fish are present in the Northwestern Hawaiian

Islands (NWHI) between April and November. Spawning occurs in pairs within larger aggregations during the new and full moon (Johannes 1981), on offshore banks and shallow nearshore reefs (Myers 1991).

Bibliography

- Humphreys RL Jr. 1986. Greater amberjack. In: Uchida RN, Uchiyama JH, editors. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.
- Humphreys RL Jr. 1980. Feeding habits of the kahala, *Seriola dumerili*, in the Hawaiian archipelago. In: Grigg RW, Tanoue KY, editors. Proceedings of the Symposium on Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 May 25-27; Honolulu, HI. Honolulu: University of Hawaii. p 233-40. Report nr UNIHI-SEAGRANT-MR-84-01.
- Johannes RE. 1981. Words of the lagoon. Berkeley: Univ California Pr. 245 p.
- Kikkawa BS, Everson AR . 1984. Gonadal maturation, fecundity and spawning of the greater amberjack (*Seriola dumerili*) in Hawaiian waters with reference to ciguatera incidences. In: Grigg RW , Tanoue KY, editors. Proceedings of the Symposium on Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 May 25-27; Honolulu, HI. Honolulu: University of Hawaii. p 149-160. Report nr UNIHI-SEAGRANT-MR-84-01.
- Laroche, W.A., W.F. Smith-Vaniz and S.L. Richardson. 1984. Carangidae: development. *in* Ontogeny and systematics of fishes, based on an international symposium dedicated to the memory of Elbert Halvor Ahlstrom, August 15-18, 1983, La Jolla, California. Special publication of the American Society of ichthyologists and herpetologists, no 1. pp. 510-522.
- Lewis AD, Chapman LB, Sesewa A. 1983. Biological notes on coastal pelagic fishes in Fiji. Fiji: Fisheries Division (MAF). Technical report nr 4.
- Miller JM, Watson W, Leis JM. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian Islands. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-02.
- Myers RF. 1991. *Micronesian reef fishes*. Barrigada, Guam: Coral Graphics.

- Okamoto H, Kawamoto P. 1980. Progress report on the nearshore fishery resource assessment of the Northwestern Hawaiian Islands: 1977 to 1979. In: Grigg, RW, Pfund RT, editors. Proceedings of the Symposium on the status of resource investigations in the Northwestern Hawaiian Islands; 1980 Apr 24-25; Honolulu, HI. p 71-80. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.
- Parrish J, Taylor L, DeCrosta M, Feldkamp S, Sanderson L, Sorden C. 1980. Trophic studies of shallow-water fish communities in the Northwestern Hawaiian Islands. In: Grigg RW, Pfund RT, editors. Proceedings of the Symposium on the status of resource investigations in the Northwestern Hawaiian Islands; 1980 Apr 24-25; Honolulu, HI. Honolulu: University of Hawaii Sea Grant College Program. p 175-88. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.
- Ralston S, Gooding RM, Ludwig GM. 1986. An ecological survey and comparison of bottom fish resource assessments (submersible versus handline fishing) at Johnston Atoll. US Fish Bull. 84:141-55.
- Randall, John E., Gerald R. Allen, and Roger C. Steene. 1990. Fishes of the Great Barrier Reef and Coral Sea. Crawford House Press, Bathurst, Australia. 507 pp.
- Seki MP. 1986. Butaguchi. In: Uchida RN, Uchiyama JH, editors. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.
- Seki MP. 1984. The food and feeding habits of the white trevally, *Pseudocaranx dentex* in the Northwestern Hawaiian Islands. In: RW Grigg, Pfund RT, editors. Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 Apr 24-25; Honolulu, HI. Honolulu: University of Hawaii Sea Grant College Program. p 264-77. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.
- Smith's Sea Fishes*. 1986. Smith, Margaret M., and Phillip C. Heemstra (eds). Springer-Verlag, Berlin.
- Sudekum AE, Parrish JD, Radtke RL, Ralston S. 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fish Bull (89):492-513.
- [WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Bottomfish and seamount groundfish fisheries of the western Pacific region, 1996 annual report. Honolulu: WPRFMC.

Table 43. Management Unit: Carangidae (jacks)

	Egg	Larvae	Juvenile	Adult
Duration	24 - 48 hours after spawning	Poorly known, larvae thought to be more common offshore than inshore	Sexual maturity attained at 1-3.5 years depending on species	One species (<i>C. ignobilis</i>) life span exceeds 15 years
Diet	N/A	No information available	Generally switch from planktivory to piscivory with increase in age	Predominantly piscivorous utilizing shallow-water reefs. The water-column is also utilized .
Distribution	Pelagic	Pelagic, more common in summer	Near-shore and estuarine waters	Throughout Indo-Pacific. Inhabit shallow coastal areas to deep slope (0-350m)
Water Column	Pelagic	Pelagic	Benthopelagic	Benthopelagic, utilize entire water-column but primarily associated with demersal habitat
Bottom Type	N/A	N/A	Wide variety of shallow-water reef and estuarine	Primary forage habitat is shallow to deep reef
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

5.1.27 Decapterus/Selar (scads, *opelu*, *akule*)Egg and Larvae

The spawning of scads occurs in the pelagic environment. Depending on the species the ovaries of the female may contain from 30,000 to 200,000 eggs. The spawned eggs are spherical with a single oil globule, non-adhesive, and free floating (Yamaguchi 1953).

Juvenile

After hatching the larvae and juvenile fish remain in the pelagic environment where they frequently form large aggregating schools. Reports from fishermen have identified aggregations of juvenile scads as far as 80 nmi. offshore (Yamaguchi 1953). Juveniles enter the nearshore coastal waters in late fall and winter, where they grow rapidly over the next few months, usually attaining sexual maturity during the first year of life.

Larval and juvenile fish remain in offshore pelagic waters for the first several months of their life, after which they migrate to the nearshore adult habitat (0-100m).

Adults

Adults spawn in pelagic waters usually in proximity to their coastal habitat. Spawning appears to be seasonal from March through August, reaching a peak from May to July. These species feed in the water column and are mainly planktivorous, preying on zooplankton. Their diet consists of amphipods, crab megalops, fish larvae, pteropods, and copepods, however some species also feed on small fishes such as anchovies and holocentrids (Yamaguchi 1953). Adult *opelu* and *akule* inhabit nearshore waters around islands from shoreline depths to 100m.

Table 44. Management Unit: Decapcturus/Selar (scads)

	Egg	Larvae	Juvenile	Adult
Duration	No information	No information	migrate to nearshore waters ~ Six months after hatching	Relatively fast growing and short lived. Sexual maturity usually in first year of life
Diet	N/A	planktivorous	zooplanktivorous	primarily zooplanktivorous, with some piscivory
Distribution	circumtropical pelagic	circumtropical pelagic	circumtropical nearshore	circumtropical nearshore
Water Column	pelagic	pelagic	pelagic and nearshore reef in water column	nearshore reef in water column (neritic)
Bottom Type	N/A	N/A	N/A	N/A
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	offshore pelagic, migrate to nearshore waters in first year	nearshore waters

5.1.28 Caesionidae (fusiliers)

Fusiliers are planktivorous, schooling fishes. They have an elongate, fusiform body, a small terminal mouth with a very protrusible upper jaw, small conical teeth and a deeply forked tail. During the day, fusiliers swim actively in midwater around or near reefs in synchronous formation, changing the formation to feed on zooplankton. They are particularly abundant along steep outer reef slopes and around deep lagoon pinnacles. They are often observed around cleaner stations, where some members of the aggregations pause to be cleaned by cleaner wrasses. They are not found in Hawaii. At least 10 species occur in Micronesia, and at least 5 species occur in Samoa.

The reproductive biology of caesionids has been examined in only a few species. They appear to be typified by early sexual maturity and high fecundity. They have a prolonged spawning season, but recruitment peaks once or twice a year. Fusiliers are dioecious and gonochoristic, with no significant difference in sex ratio. Spawning has been observed for *Caesio teres* (Bell and Colin 1986) and *Pterocaesio digramma* (Thresher 1984). These caesionids spawn in large groups around the full moon. They migrate to select areas on the reef at dusk and initiate spawning during slack water. In *C. teres*, spawning is preceded by periodic mass vertical ascents and descents to within about 1 m of the surface. During spawning they stay near the surface and subgroups within the mass swirl rapidly in circles and release gametes (Carpenter 1988).

During initial recruitment to a reef, juvenile caesionids generally remain close to the substrate and dart around coral heads and rocks to escape. At night, fusiliers shelter in crevices and under coral heads. Fusiliers often school in mixed species aggregations. They are primarily reef inhabitants, although they often range over soft bottoms in between reefs.

Bibliography

- Bell LJ and PL Colin. 1986. Mass spawning of *Caesio teres* at Enewetak Atoll, Marshall Islands. *Envir Biol Fish* 15(1):69-74.
- Cabanban AS. 1984. Some aspects of the biology of *Pterocaesio pisang* in the central Visayas. MS thesis. Coll of Sci, Univ of the Philippines: 69pp.
- Carpenter KE. 1988. Fusilier fishes of the world. FAO species catalogue No. 125, Vol. 8. Rome: United Nations Development Programme FAO of the United Nations.
- Hiatt RW and DW Strasburg. 1960. Ecological relationships of fish fauna on coral reefs of the Marshall Islands. *Ecol Monogr* 30:65-127.
- Hobson ES and JR Chess. 1978. Trophic relationships among fishes and plankton in the lagoon at Enewetak Atoll, Marshall Islands. *Fish Bull NOAA/NMFS* 76:133-53.

Table 45. Management Unit Species: Caesionidae (fusiliers)

	Egg	Larvae	Juvenile	Adult
Duration		weeks to months	reach maturity early	
Diet	N/A	various plankton	planktivores	planktivores
Distribution, general and seasonal	prolonged spawning season but tends to peak once or twice a year			tropical Indo-Pacific; None in Hawaii, at least 10 spp. in Micronesia, and 5 in Samoa
Location	spawning occurs at specific sites on a reef (Bell and Colin 1986)	offshore	similar to adults	abundant along steep outer reef slopes and around deep lagoon pinnacles
Water column	pelagic	pelagic	reef-associated; typically remain close to shelter	pelagic
Bottom type	N/A	N/A	coral or rock	coral, rock, but range over sand in travels from reef to reef
Oceanic features	subject to advection by	subject to advection		

	Egg	Larvae	Juvenile	Adult
	ocean currents	by ocean currents		

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5.1.29 Haemulidae (sweetlips)

Haemulids are very similar to lutjanids but differ by having smaller mouths a bit lower on the head with small conical teeth and thickened lips, by having pharyngeal teeth and by lacking canine and palatine teeth. Some members of the sweetlip family are commonly called grunts because of the sound they can make by grinding the pharyngeal teeth and amplifying the noise with their gas bladder. Haemulids are primarily nocturnal feeders on benthic invertebrates. During the day they typically school under or near overhangs or tabular corals. Their general lethargy during the day and their schooling tendencies makes them easy targets for spearfishers. As a result, they have become scarce in waters near population centers such as Guam. Most species of *Plectorhinchus* change color dramatically with group. The striped juveniles of many species are similar and difficult to distinguish from other haemulid juveniles. Eleven species are recorded from Micronesian waters. None are recorded for the Hawaiian Islands. Three species are recorded from Samoan waters.

There is little information on haemulid reproduction, particularly in Indo-Pacific locations. Given their similarity to other roving benthic predators, such as groupers or snappers, the haemulids probably migrate to spawning sites on the outer reef slope for group spawning at dusk. Eggs are pelagic with a single oil droplet, and hatching time is approximately 24 hours. Duration of the planktonic stage for *Haemulon flavolineatum* is approximately 15 days, when the larvae settle to the bottom at a length of approximately 6 mm (McFarland 1980, Brothers and McFarland 1981). Juvenile grunts are commonly found in small groups on grass flats, near mangroves and in other inshore areas. Cummings et al. (1966) report sexual maturity of *H. album* at approximately 37.5 cm. Gaut and Munro (1983) found mean lengths at maturity for the Caribbean species *H. plumieri*, *H. flavolineatum*, *H. sciurus* and *H. album* of 22 cm FL, 12 cm FL or less, 15.5 cm FL 22 cm FL and 24 cm FL respectively.

Bibliography

- Baillon N and M Kulbicki. 1988. Ageing of adult tropical fish by otoliths: A comparison of three methods on *Diagramma pictum*. Proc 6th Int Coral Reef Symp, Australia, 1988. Vol. 2:341-6.
- Brothers EB and WN McFarland. 1981. Correlations between otolith microstructure, growth and life history transitions in newly recruited french grunts. Rapp.P.-v. Reun Cons Int Explor Mer 178:369-74.
- Cummings WC, BD Brahy and JY Spires. 1966. Sound production, schooling and feeding habits of the margate, *Haemulon album* Cuvier, off North Bimini, Bahamas. Bull Mar Sci 16(3):626-40.
- Gaut VC and JL Munro. 1983. The biology, ecology and bionomics of the the grunts, Pomadasyidae. ICLARM Stud Rev 7:110-41.

McFarland WN. 1980. Observations on recruitment in haemulid fishes. Proc Gulf Caribb Fish Inst 32:132-238.

Munro JL, VC Gaut, R Thompson and PH Reeson. 1973. The spawning seasons of Caribbean reef fishes. J Fish Biol. 5:69-84.

Podosinnikov AY. 1977. Early ontogeny of the striped grunt, *Parapristipoma humile* (Pomadasyidae, Pisces). J Ichthy 17(4):683-4.

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Table 46. Management Unit Species: Haemulidae (sweetlips and grunts)

	Egg	Larvae	Juvenile	Adult
Duration	approximately 24 hrs	15 days to months	from 6 mm until 12B24 mm FL	
Diet	N/A	copepods, nauplii (Houde and Lovdal 1984)	similar to adult	nocturnal predators on benthic invertebrates, including crustaceans, mollusks, and fishes
Distribution, general and seasonal	likely spring spawning peak		similar to adult	no species recorded for Hawaii; tropical and temperate seas in marine and brackish waters worldwide; 11 Micronesian species
Location	probably outcroppings on outer reef slopes	offshore	sheltered inshore areas in lagoons, estuaries, mangroves as well as adult locations	close to patch reefs, lagoons, inshore and seaward reefs, channels, outer reef slopes
Water column	pelagic	pelagic	demersal and reef or mangrove-associated	demersal and reef-associated; 1B100m
Bottom type	N/A	N/A	sandy to muddy bottoms, coral, rocky ledges or table corals	sandy to muddy bottoms, coral, rocky ledges or table corals

	Egg	Larvae	Juvenile	Adult
Duration	approximately 24 hrs	15 days to months	from 6 mm until 12B24 mm FL	
Diet	N/A	copepods, nauplii (Houde and Lovdal 1984)	similar to adult	nocturnal predators on benthic invertebrates, including crustaceans, mollusks, and fishes
Distribution, general and seasonal	likely spring spawning peak		similar to adult	no species recorded for Hawaii; tropical and temperate seas in marine and brackish waters worldwide; 11 Micronesian species
Location	probably outcroppings on outer reef slopes	offshore	sheltered inshore areas in lagoons, estuaries, mangroves as well as adult locations	close to patch reefs, lagoons, inshore and seaward reefs, channels, outer reef slopes
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.30 Lethrinidae (emperors)Egg and Larvae

Lethrinid eggs are pelagic, spherical, colorless, and range in size from 0.63 to 0.83 mm. The eggs hatch within 21 to 40 hours after fertilization (Carpenter and Allen 1989). The larvae when hatched range in size from 1.3 to 1.7mm. Larval characteristics include unpigmented eyes, large yolk sac, variable body pigmentation and extensively developed head spination.

Juveniles and Adults

Juvenile and adult lethrinids are found throughout the Indo-Pacific in tropical and subtropical waters. They are fairly long-lived ranging 7-27 years (Carpenter and Allen 1989). Although little is known of the biology of these species, they are known to inhabit the deeper waters of coral reefs and adjacent sandy areas. Some species also occur in shallow water habitats around coral reefs, sand flats, sea-grass beds and mangrove swamps (Carpenter and Allen 1985). Lethrinids appear to be carnivorous bottom-feeders. Their diet includes: crabs, sea-urchins, bivalves, gastropods, and fish (Walker 1978).

Based on the available data, lethrinids appear to be protogynous hermaphrodites (Young and Martin 1982). Spawning occurs throughout the year, and is preceded by localized migrations during crepuscular periods. Peak spawning occurs on or near the new moon. Spawning may occur at near the surface as well as near the bottom of reef slopes. Lethrinids may reach a maximum length of 70 cm. Males tend to attain a larger size than females.

Table 47. Management Unit: Lethrinidae (emperors)

	Egg	Larvae	Juvenile	Adult
Duration	hatch 21 - 40 hours after spawning	No information	No information	7-27 Years
Diet	N/A	No information	No information	Carnivorous bottom-feeders
Distribution	Pelagic	Pelagic	Nearshore areas and shallow seamounts	Throughout Indo-Pacific. Inhabit shallow coastal areas to deep slope (0-350m)
Water Column	Pelagic	Pelagic	Benthic	Benthic
Bottom Type	N/A	N/A	Demersal Reef	Primary forage habitat shallow to deep reef feeding on the bottom
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

5.1.31 Lutjanidae (snappers)

Egg and Larvae

Lutjanid eggs are pelagic, spherical and 0.65-1.02 mm in diameter. Each egg contains a single oil globule which provides buoyancy during the pelagic phase. Incubation is between 17-27 hours depending on species and temperature. Newly hatched larvae of lutjanids in general are typical of those from fish with small pelagic eggs; the larvae have a large yolk sac, unpigmented eyes and no mouth. The yolk sac typically lasts 3-4 days, after which the mouth is fully formed and the eyes become pigmented (Leis 1987). The larvae are absent from surface waters during the day and migrate upward at night. Snapper larvae are thought to be planktonic and subject to advection by ocean current systems until benthic habitat suitable for metamorphosis is encountered (Munro 1987). The duration of the pelagic phase is thought to be at least 25 days (Leis 1987) and may be as long as 45 days.

Juveniles

Little information currently exists on larval development, settlement or early juvenile life history of deepwater snappers in Hawaii (Haight et al. 1993a). Little is known about the ecology of juveniles from time of settlement to their appearance in the adult fishery. Age at entry to the fishery for the principle fishery species in Hawaii is thought to be 2 to 3 years after settlement (Moffitt and Parrish 1996). In a three year study of fish settlement on artificial reefs adjacent to adult snapper habitat in Hawaii, no recruitment of juvenile snappers to the reefs was observed, although adults aggregated at times around the reef structures (Moffitt et al. 1989).

Studies on juveniles of one snapper species in Hawaii indicated juvenile *Pristipomoides filamentosus* first appear in the relatively shallow (60 - 100 m) nearshore areas at about 10 months of age (7 - 10 cm FL) during the fall and early winter months. The young fish remain in this habitat for the next 7 months until they reach 18 - 24 cm FL (Moffitt and Parrish 1996, Ellis et al 1992). *In situ* scuba observations of the juvenile habitat found it to be a relatively flat, soft sediment substrate devoid of relief (Parrish 1989).

Adults

Tropical snappers in general are slow growing, long lived and have low rates of natural mortality. Maximum ages exceed 10 years and von Bertalanffy growth coefficients (K) are usually in the range of 0.10 to 0.25 per year (Manooch 1987). Most ageing studies of tropical snappers have depended on the enumeration of regularly formed marks on calcareous structures. In Hawaii, Ralston and Miyamoto (1983) used daily growth increments deposited on the otoliths of immature *P. filamentosus* to determine its growth rate. The estimated

growth coefficient of opakapaka is 0.145 per year, and asymptotic upper boundary on growth (L_4) was 78 cm FL, which occurred at over 18 years of age.

Ralston (1987), in a comprehensive review of published reports on snapper growth and natural mortality, determined that for the 10 species studied, mortality and growth rates were highly correlated, with a mean M/K ratio of 2.0. Thus, if a value of K is available for a given species, its natural mortality rate can be estimated. Using an age-length probability matrix for opakapaka applied to length frequency samples, Ralston (1981) estimated the natural mortality rate for opakapaka in Hawaii to be 0.25, which when compared to the estimated K value for this species (0.145) is close to the value predicted by the M/K relationship derived for snappers in general.

Size at sexual maturity for lutjanids on average occurs at about 43 to 51% of L_4 (Allen 1985). Size at maturity has been estimated for only two species in the MHI and two species in the NWHI. In the MHI, uku reaches sexual maturity at 47 cm fork length (FL), which is 46% of maximum size (L_4). Onaga reaches sexual maturity at 61 cm FL (62% L_4) (Everson et al. 1989). In the NWHI, ehu reaches maturity at about 30 cm FL (46% L_4) and opakapaka reaches maturity at around 43 cm FL (48% L_4) (Everson 1984, Kikkawa 1984, Grimes 1987).

Gonadal studies on four of the species in Hawaii indicate that spawning may occur serially over a protracted period but is at a maximum during the summer months, and peaks from July to September (Everson et al. 1989, Uchida and Uchiyama 1986). Estimated annual fecundity is 0.5 to 1.5 million eggs. The eggs are released into the water column.

Although snappers throughout the world are generally thought of as top level carnivores, several snapper species in the Pacific are known to incorporate significant amounts of zooplankton, often gelatinous urochordates, in their diets (Parrish 1987). Haight et al. (1993b) found zooplankton to be an important prey item in four of the commercially important snappers in Hawaii. The same study found that the six snapper species studied were either primarily zooplanktivorous or primarily piscivorous, with little overlap in diet composition between trophic guilds. A contributing factor in the distribution pattern of zooplanktivores may be that currents striking deepwater areas of high relief form localized zones of turbulent vertical water movement, increasing the availability of planktonic prey items (e.g. Brock and Chamberlain 1968). In an ecological study of the bottomfish resources of Johnston Atoll, Ralston et al. (1986) found *P. filamentosus* in much higher densities on the upcurrent versus downcurrent side of the atoll, and postulated that this was related to increased availability of allochthonous planktonic prey in the neritic upcurrent areas due to oceanic currents impacting the atoll.

Table 48. Management Unit Lutjanidae (snappers)

	Egg	Larvae	Juvenile	Adult
Duration	Incubate 17-36 hours	Pelagic duration : 25-47 days	Reach sexual maturity in 2-3 years	Long-lived, slow growing. Age at entry to fishery at 2-3 years
Diet	N/A	No information available	Diet of one species includes crustaceans, cephalopods and small fish	Primarily demersal carnivores although some species are zooplanktivorous
Distribution	Widely distributed throughout management area	Widely distributed throughout management area	Throughout Indo-Pacific. Juveniles of some species inhabit shallow reef areas not utilized by adults	Throughout Indo-Pacific. Inhabit shallow coastal coral reef areas to deep slope rocky habitats (0-400 m)
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	Wide variety of shallow-water reef and estuarine habitats	Primary forage habitat is shallow to deep reef and rocky substrate.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

5.1.32 Mullidae (goatfishes)

Goatfish are important commercial fish that are highly esteemed as food. All have a characteristic pair of long barbels at the front of the chin, a moderately elongate body, two well-separated dorsal fins, a small mouth with a slightly protruding upper jaw and a forked tail. Goatfish use the barbels, which contain chemosensory organs, to probe sand or holes in the reef for benthic invertebrates or small fishes. The barbels are tucked between the lower portion of the gill covers when not in use. Some species are primarily nocturnal, others are diurnal and a few are active by day or night. Nocturnal species tend to hover in stationary aggregations or rest on coral ledges by day.

There are 10 native species of goatfish known from Hawaiian waters, and one accidental introduced species from the Marquesas, *Upeneus vittatus*. Two species, *Parupeneus porphyreus* and *P. chrysonemus*, are endemic to Hawaii. Fifteen species are recorded from Micronesia. Thirteen species are recorded from Samoa.

Goatfish have pelagic eggs, which are spherical, transparent and non-adhesive with a single oil droplet. Egg diameters range from 0.63 to 0.93 mm and hatch within 3 days. Goatfish in general have a long larval development. After settlement, juveniles take approximately 1 year to reach sexual maturity. Munro (1976) suggests that few live more than 3 years.

Schooling is common among the mullids. Group spawning and pair spawning have been documented for goatfishes. An aggregation of 300 to 400 individuals was observed spawning at 21 m depth off the coast of the US Virgin Islands (Colin and Clavijo 1978). Groups of fish made spawning rushes about 2 meters above the bottom before releasing gametes.

Holland et al. (1993) conducted a study of the movements, distribution and growth rates of *Mulloidichthys flavolineatus* by using tagging data. *M. flavolineatus* and *M. vanicolensis* were the most abundant mullids found in Hanalei Bay (Friedlander et al. 1997). *M. flavolineatus* ranked second in overall mean biomass at 211 g/100m², with an overall mean numerical density of 1.1 individuals/100m². *M. vanicolensis* had higher numbers in patch reef habitat, but the larger fish were present in reef slope habitat, indicating partitioning of habitat by size. *Parupeneus cyclostomus* was the rarest and most mobile of the mullids found in Hanalei Bay, with an overall mean density of 0.01 individuals/100m² or 2.02 g/100m². The largest individuals were seen in deeper reef slope habitat. *P. cyclostomus* has a diet strongly dominated by fish, particularly fish that are diurnally active over reef and other hard substrata. It also eats lesser quantities of crabs, shrimps and stomatopods and trace amounts of other invertebrates. It typically probes sand or reef crevices to flush out small fish with its barbels. *P. cyclostomus* is inactive at night.

The diet of the Hawaiian endemic *P. porphyreus* encompasses a wide variety of benthic invertebrates such as crabs, shrimps, isopods, amphipods, ostracods, stomatopods, planktonic crab megalops larvae and copepods, gastropods, foraminiferans and fish in order of decreasing importance. *P. porphyreus* shelters in areas of high relief and feeds over hard substrate and sandy areas nearby (Friedlander et al. 1997).

The breeding season for *P. porphyreus* shows peak spawning somewhere between December and July. Counts of nuclear rings on otoliths indicate a larval period of approximately 40-60 days. The juvenile phase involves rapid color changes, a lengthening of the gut and an external change in shape. Juveniles can sexually mature as early as 1.25 years. Fecundity was estimated as 11,000 to 26,000 eggs per spawn. Adults live 6 years or longer (Moffitt 1979).

Five goatfish species at Midway Island were generalized feeders, eating mostly small crustaceans, polychaetes and bivalve and opisthobranch molluscs (Sorden 1982). Sorden (1982) discusses similarities and differences among feeding preferences of the goatfish fauna at Midway.

Bibliography

- Colin PL and IE Clavijo. 1978. Mass spawning by the spotted goatfish, *Pseudopeneus maculatus* (Bloch). Bull Mar Sci 28:780-2.
- Friedlander AM, DeFelice RC, Parrish JD and JL Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.
- Holland KN, JD Peterson, CG Lowe and BM Wetherbee. 1993. Movements, distribution and growth rates of the white goatfish *Mulloides flavolineatus* in a fisheries conservation zone. Bull of Mar Sci 52:982-92.
- Mahi CA. 1969. The food and feeding habits of the kumu, *Parupeneus porphyreus*. MS thesis, Univ of Hawaii, Department of Zoology.
- Moffitt RB. 1979. Age, growth, and reproduction of the kumu, *Parupeneus porphyreus* (Jenkins). MS thesis, Univ of Hawaii, Department of Zoology.
- Munro JL. 1976. Aspects of the biology and ecology of Caribbean reef fishes: Mullidae (goat-fishes). J Fish Biol 9: 79-97.
- Munro JL. 1983. The biology, ecology and bionomics of the goatfishes, Mullidae. ICLARM Stud Rev 7:142-54.

Sorden CT. 1982. Trophic relationships of goatfishes (family Mullidae) in the Northwestern Hawaiian Islands. MS thesis, Univ of Hawaii, Department of Zoology.

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Table 49. Management Unit Species: Mullidae (goatfishes)

	Egg	Larvae	Juvenile	Adult
Duration	3 days	relatively long, months?	approximately one year	3 years (Munro 1976)
Diet	N/A	planktivorous	benthic invertebrates such as crabs, shrimps, isopods, amphipods, ostracods, stomatopods, planktonic crab megalops larvae and copepods, gastropods, and foraminiferans; some species eat small fish	benthic invertebrates such as crabs, shrimps, isopods, amphipods, ostracods, stomatopods, planktonic crab megalops larvae and copepods, gastropods, and foraminiferans; some species eat small fish
Distribution, general and seasonal	spawning peaks in late spring and fall	most abundant in the open ocean, though still <25km from reefs	Atlantic, Indian and Pacific oceans, rarely in brackish waters	Atlantic, Indian and Pacific oceans, rarely in brackish waters; may have seasonal spawning aggregations at prominent reef features
Location	released several meters from the bottom	most abundant in the open ocean, though still <25km from reefs	pelagic for some species (Caldwell 1962), but coral reef and sand flat otherwise	coral reef or soft-bottom habitat
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef, rock, sand, mud, crevices, ledges	coral reef, rock, sand, mud, crevices, ledges

	Egg	Larvae	Juvenile	Adult
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents	unknown	spawning aggregations near channels with heavy tidal flow

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5.1.33 Kyphosidae (rudderfishes)

Rudderfishes, or sea chubs, are shore fishes of rocky bottoms or coral reefs of exposed coasts. They have deep oval bodies, a continuous dorsal fin, a forked caudal fin and a small mouth with close-set incisiform teeth. They are benthic herbivores and the species of *Kyphosus* often occur in large groups that may overwhelm the defenses of territorial herbivorous fish, such as damselfishes and surgeonfishes. Juveniles often occur far out at sea beneath floating debris. Adults typically swim in schools several meters above the bottom, where they may feed on planktonic algae. Three species occur in Hawaii, Micronesia and Samoa: *Kyphosus bigibbus*, *K. cinerascens* and *K. vaigiensis*. Another species *Sectator ocyurus* has been reported in Hawaii but is rare and may be a waif from the tropical eastern Pacific.

Very little is known about reproduction in the kyphosids. The eggs are spherical, pelagic and 1.0-1.1 mm in diameter (Watson and Leis 1974). The larvae hatch at 2.4-2.9 mm. The largest pelagic specimen, a juvenile, examined by Leis and Rennis (1983) was 56 mm. Juvenile individuals may be carnivorous for a while before becoming herbivorous (Rimmer 1986).

Bibliography

- Rimmer DW. 1986. Changes in diet and the development of microbial digestion in juvenile buffalo bream *Kyphosus cornellii*. Mar Biol 93:443-8.
- Randall JE and HA Randall. 1960. Examples of mimicry and protective resemblance in tropical marine fishes. Bull Mar Sci 10:444-80.
- Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: A one-year study of fish eggs and larvae. Tech Rep, Univ Hawaii Sea Grant Program TR-75-01:1-178.

Table 50. Management Unit Species: Kyphosidae (rudderfishes)

	Egg	Larvae	Juvenile	Adult
Duration		prejuveniles commonly collected far out at sea under floating debris		
Diet	N/A	zooplankton	may be carnivorous for a while, such as <i>Kyphosus cornelii</i> (Rimmer 1986)	herbivorous on benthic and planktonic algae
Distribution, general and seasonal				circumtropical; 3 species in Hawaii, Micronesia, and Samoa: <i>Kyphosus bigibbus</i> , <i>K. cinerascens</i> , and <i>K. vaigiensis</i>
Location			exposed seaward reefs	exposed seaward reefs
Water column	pelagic	pelagic	same as adults	benthic and pelagic, may school in the water column
Bottom type	N/A	N/A	rocky bottoms or coral reefs	rocky bottoms or coral reefs
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.34 Monodactylidae (monos)

Monos are a small family of highly compressed silvery fishes with small oblique mouths, brush-like teeth in the jaws, viliform teeth on the vomer and palatines, vestigial pelvic fins and a continuous unnotched dorsal fin. They occur primarily in estuarine habitats and can live in freshwater. No monos are recorded for the Hawaiian Islands. The family occurs off West Africa and in the Indo-Pacific, and one species, *Monodactylus argenteus*, occurs in Micronesia and Samoa. It is an active schooling fish that occurs primarily in estuaries but may venture over silty coastal reefs. It is valued as an aquarium fish.

M. argenteus spawns demersal, adhesive eggs, at least in freshwater (Breder and Rosen 1966). The eggs of *Psettus sebae*, a tropical Atlantic species, are small (0.6-0.7 mm), spherical and pelagic in seawater but demersal in freshwater (Akatsu et al. 1977). Larvae of *P. sebae* hatch at 1.8 mm. The largest size of a pelagic larval specimen of *M. argenteus* was 14.5 mm (Leis and Trnski 1989).

Bibliography

- Akatsu S, Y Ogasawara and F Yasuda. 1977. Spawning behavior and development of eggs and larvae of the striped fingerfish, *Monodactylus sebae*. Japan J Ichthyol 23(4):208B14.
- Breder CM and DE Rosen. 1966. Modes of reproduction in fishes. Jersey City, NJ: TFH Pub.
- Heemstra PC. 1984. Monodactylidae. In: W Fischer and G Bianchi, eds. FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51). Vol. 3. Rome: FAO.
- Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

Table 51. Management Unit Species: Monodactylidae (monos)

	Egg	Larvae	Juvenile	Adult
Duration		from <1 mm to 14.5 mm		
Diet	N/A		probably similar to adults	small benthic and planktonic invertebrates
Distribution, general and seasonal	spring or summer spawning peak likely		similar to adults	West Africa and Indo-Pacific; not in Hawaii, <i>Monodactylus argenteus</i> only species in Micronesia
Location			similar to adults	primarily in estuaries, but may venture over silty coastal reefs
Water column	pelagic in seawater, demersal in freshwater	pelagic in seawater, demersal in freshwater	pelagic	pelagic
Bottom type			silt, mud, sand, coral	silt, mud, sand, coral
Oceanic features	pelagic larvae subject to dispersal by ocean currents	pelagic larvae subject to dispersal by ocean currents		

5.1.35 Ehippidae (batfishes, spadefishes)

Batfishes have deep, highly compressed bodies, a small terminal mouth with brushlike teeth, a continuous dorsal fin and small ctenoid scales extending to the basal portions of the median fins. They are schooling, semi-pelagic fishes often associated with reefs. Juveniles have very deep bodies and greatly elevated dorsal, anal and pelvic fins that shorten with age. Juveniles occur singly or in small groups among mangroves and in inner sheltered lagoons or reefs. Adults migrate to deeper channels and lagoons where they aggregate in small schools, although larger adults may be solitary. They are omnivores that feed on algae, invertebrates and small fishes. In Micronesian waters, 3 species occur: *Platax orbicularis*, *P. pinnatus* and *P. teira*. In Samoan waters, 2 species have been recorded.

There is little information on the spawning or egg characteristics of Indo-Pacific ehippidids, but there is some information for the Atlantic genus *Chaetodipterus*, which has pelagic eggs of about 1 mm diameter (Johnson 1984). Spawning for *C. faber* was observed near floating objects about 40 m offshore. Two small schools were present, but spawning occurred between pairs (Chapman 1978). This observation suggests that ehippidids migrate offshore to spawn. Spadefish larvae hatch in 24 hours and are about 2.5 mm long. By a length of 10 mm, the larvae are recognizable as spadefish and are ready to settle.

Bibliography

Chapman RW. 1978. Observations of spawning behavior in Atlantic spadefish, *Chaetodipterus faber*. *Copeia* 1978:336.

Johnson GD. 1984. Percoidae: Development and relationships. pp 464-99 in ASIH Spec Publ 1.

Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

Table 52. Management Unit Species: Ehippidae (batfishes, spadefishes)

	Egg	Larvae	Juvenile	Adult
Duration	24 hrs	hatch at 2.5 mm, ready to settle at 10 mm		
Diet	N/A		similar to adults	algae, invertebrates, small fishes
Distribution, general and seasonal	spring or summer spawning (Munro et al. 1973)		similar to adults	the family is found in tropical and temperate seas worldwide; the genus <i>Platax</i> is found in Micronesia, not in Hawaii
Location	offshore	offshore	mangroves, sheltered lagoons and reefs	deeper channels, lagoons, seaward reefs
Water column	pelagic	pelagic	semi-pelagic	semi-pelagic
Bottom type	N/A	N/A	sand, mud, silt, and coral reefs	reef-associated, but also mud and sand bottoms in mangroves and lagoons
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.36 Chaetodontidae (butterflyfishes)

Butterflyfishes are colorful, conspicuous fishes with deep, highly compressed, ovate bodies, small mouths and a band of brush-like teeth in the jaws. They have a single continuous dorsal fin with anterior interspinous membranes deeply incised and a caudal fin varying from slightly rounded to slightly emarginate. They are diurnal predators with diets that vary significantly between species. Many specialize on polyps of corals and other coelenterates. The corallivores tend to be territorial and limited to the shallower depth ranges of the corals, such as *Pocillopora meandrina*, upon which they feed. Others feed heavily on benthic algae and small benthic invertebrates. Some species, including those of *Hemitaurichthys*, are primarily zooplanktivores. The zooplankton feeders often occur in mid-water aggregations and range into relatively deep water. Most butterflyfishes are solitary or occur in pairs, but a few form aggregations. Butterflyfishes appear to be gonochorists, with sex remaining the same throughout life, and often form heterosexual pairs that stay together for many years and possibly their whole life.

Spawning generally occurs in pairs at the top of an ascent in which the male nudges the abdomen of the female. Eggs are planktonic and hatch within 2 days. The larval stage lasts from several weeks to a few months, with a distinctive late larval stage called the tholichthys larva when large bony plates cover the head and front of the body. Settlement occurs at night, and juveniles tend to occur in shallower, more sheltered habitats than adults. Coloration typically changes little with growth, although butterflyfish do exhibit slightly different, more subdued color patterns at night when they shelter in the reef. Because of their specialized feeding habits, butterflyfishes do not tend to do well in aquariums, although some of the generalists and planktivores are collected for the aquarium trade. The family is represented in Hawaiian waters by 24 species; *Chaetodon fremblii*, *C. miliaris*, and *C. multicinctus* are endemic to Hawaii; and *C. tinkeri* is found only in Hawaii and the Marshall Islands. The family is represented in Micronesian waters by at least 40 species. It is represented in Samoan waters by 30 species. The yellow-crowned butterflyfish *C. flavocoronatus* is listed as a vulnerable species in Guam on the 1996 IUCN Red List.

Chaetodontid eggs are buoyant, transparent and spherical. They typically range from 0.6 to 0.74 mm in diameter and contain a single oil droplet. The eggs hatch in 1-2 days. The larvae typically have a preopercular spine and a bony sheath around the head. The tholichthys stage of development is unique to the butterflyfishes and is characterized by a series of thin transparent bony plates that completely encase the head of the larva and extend dorsally and ventrally to form bony spines. The plates remain until after the fish have settled on the bottom. The duration of the planktonic stage is not well studied, but Burgess (1978) suggests it is likely to be at least several months.

The Hawaiian endemic *C. miliaris* reaches reproductive maturity at a size of about 90 mm SL, or about 1 year old (Ralston 1976). Spawning occurs between December and April but peaks around the end of February or the beginning of March.

Bibliography

- Aiken K. 1983. The biology, ecology and bionomics of the butterfly and angelfishes, Chaetodontidae. ICLARM Stud Rev 7:166-77.
- Allen GR, R Steene and M Allen. 1998. A guide to angelfishes & butterflyfishes. Perth, WA: Vanguard Pr.
- Burgess WE. 1978. Butterflyfishes of the world. Neptune City, NJ: TFH Pub..
- Colin PL. 1989. Aspects of the spawning of western Atlantic butterflyfishes (Pisces: Chaetodontidae). Env Biol Fishes 25:131-41.
- Cox EF. 1986. The effects of a selective corallivore on growth rates and competition for space between two species of Hawaiian corals. J Exp Mar Biol Ecol 101:161-74.
- Leis JM. 1989. Larval biology of butterflyfishes (Pisces, Chaetodontidae): What do we really know? Environ Biol 25(1-3):87-100.
- Motta PJ. 1989. The butterflyfishes: success on the coral reef. The Netherlands: Kluwer Acad Pub. 256 pp.
- Ralston S. 1976a. Age determination of a tropical reef butterflyfish utilising daily growth rings of otoliths. Fish Bull 74:990-4.
- Ralston S. 1976b. Anomalous growth and reproductive patterns in populations of *Chaetodon miliaris* (Pisces, Chaetodontidae) from Kaneohe Bay, Oahu, Hawaiian Islands. Pac Sci 30(4):395-403.
- Reese ES. 1973. Duration of residence by coral reef fishes on home reefs. Copeia, No. 1:145-9.
- Reese ES. 1977. Coevolution of corals and coral feeding fishes of the family Chaetodontidae. Proc Int Coral Reef Symp, 3rd 2:268-74.
- Reese ES. 1991. How behavior influences community structure of butterflyfishes (family Chaetodontidae) on Pacific coral reefs. Ecol Int Bull 19:29-41.

Sano M. 1989. Feeding habits of Japanese butterflyfishes (Chaetodontidae). *Env Biol Fish* 25(1-3):195-203.

Yabuta S. 1997. Spawning migrations in the monogamous butterflyfish, *Chaetodon trifasciatus*. *Ichthyol Res* 44(2):177-82.

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Table 53. Management Unit Species: Chaetodontidae (butterflyfishes)

	Egg	Larvae	Juvenile	Adult
Duration	2 days	several weeks to a few months	1B2 yrs; approximately one year for <i>C. miliaris</i> (Ralston 1976), two years for <i>C. rainfordi</i> (Fowler 1991); size at settlement for <i>Hemitaurichthys polylepis</i> is 60 mm (Burgess 1978)	10B25 yrs in captivity (Allen et al. 1998)
Diet	N/A	zooplankton	some are obligate corallivores (<i>C. trifascialis</i> and <i>C. trifasciatus</i>); some are planktivores; others consume a variety of benthic algae, small benthic invertebrates, fish eggs, coelenterate tentacles or polyps	some are obligate corallivores (<i>C. trifascialis</i> and <i>C. trifasciatus</i>); some are planktivores; others consume a variety of benthic algae, small benthic invertebrates, fish eggs, coelenterate tentacles or polyps
Distribution, general and seasonal	spawning peaks in late winter through early summer (January to March for <i>C. miliaris</i> in Hawaii (Ralston 1981), with another smaller peak in early fall for some species)	typically more abundant in offshore waters in the summer months in Hawaii	primarily Indo-West-Pacific, but also tropical to temperate Atlantic, Pacific, and Indian Oceans; settlement of juvenile <i>C. lunula</i> and <i>C. multinctus</i> peaked in Hawaii in May-July (Walsh 1987)	primarily Indo-West-Pacific, but also tropical to temperate Atlantic, Pacific, and Indian Oceans
Location	waters above coral reefs and nearshore waters	offshore waters	coral reef ecosystems	coral reef ecosystems
Water column	eggs released at the height of spawning rushes	pelagic	demersal and mid-water column; 1B100 m, as deep as 172 m	demersal and mid-water column; 1B100 m, as deep as 172 m
Bottom type	N/A	N/A	coral reef; obligate corallivores may be restricted to distributions of corals they feed upon- <i>C. trifascialis</i> and <i>Acropora</i> for example (Reese 1981)	coral reef; obligate corallivores may be restricted to distributions of corals they feed upon- <i>C. trifascialis</i> and <i>Acropora</i> , for example (Reese 1981)

Oceanic features	subject to dispersal by currents	subject to dispersal by currents		
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5.1.37 Pomacanthidae (angelfishes)

Angelfishes are similar to butterflyfishes and at one time were grouped in the same family. They differ mainly in having a strong spine on the cheek at the corner of the preopercle, in the presence of strongly ctenoid scales and in lacking the distinctive chaetodontid tholichthys larval stage. They are diurnal, spectacularly colored and territorial. Many of the large species, including those of *Pomacanthus*, are primarily spongivores with a small amount of feeding on other soft-bodied invertebrates, algae and fish eggs. Smaller species such as those of *Centropyge* feed on benthic algae and detritus. Species of *Genicanthus* feed primarily on zooplankton but also a little on benthic invertebrates and algae. Juveniles of some species are cleaners of external parasites from larger fishes.

Most, and possibly all, of the angelfishes are protogynous hermaphrodites that change from male to female and frequently have different color patterns depending on their sexual development. Males frequently maintain a harem of 2-5 females and defend a territory ranging from a few square meters for some species of *Centropyge* to well over 1 km for some *Pomacanthus* species. Angelfish spawn in pairs, typically near dusk, at the apex of a spawning rush after courtship and nuzzling by the male. Eggs hatch within 24 hours and undergo a pelagic larval stage of 3-4 weeks. They are popular aquarium fish. Six species are found in Hawaiian waters, and 4 of them are endemic: *Centropyge fisheri*, *C. potteri*, *Desmoholacanthus arcuatus* and *Genicanthus personatus*. At least 26 species occur in Micronesia. At least 11 species occur in Samoa.

Pomacanthid eggs are small, spherical and nearly transparent and contain from one to several oil droplets. Egg diameter ranges from 0.6 to 1.05 mm depending on the species. Hatching occurs from 15 to 23 hours after release (Thresher 1984). Feeding by the larva begins within 2-3 days and settlement to the bottom occurs between 17 and days (Moe 1977, Allen et al. 1998). Juveniles seek shelter in reef crevices. Juveniles frequently exhibit dramatically different color patterns from adults and may inhabit shallower habitats. Juveniles of *Pomacanthus* may maintain cleaning stations on or near the reef (Brockmann and Hailman 1976). There is little information on the age at sexual maturity, but most angelfishes probably become mature at between 1 and 2 years of age (Allen et al. 1998).

Adult angelfishes require suitable shelter in the form of boulders, caves and coral crevices. Most species occur from 2 to 30 m depth, but a few, such as *C. narcosis*, are found over 100 m deep. Adults forage throughout territories that vary in size with the size of the species. Generally *Pomacanthus* are spongivores; *Genicanthus* are zooplanktivores, especially on pelagic tunicates; and *Centropyge* are herbivores. Small amounts of zoantharians, tunicates, gorgonians, fish and invertebrate eggs, hydroids and seagrasses may supplement the diet of any of the angelfish species. Hybridization is common amongst the angelfish species (Pyle and Randall 1994).

Bibliography

- Allen GR, R Steene and M Allen. 1998. A guide to angelfishes and butterflyfishes. Perth, WA: Vanguard Pr.
- Aiken K. 1983. The biology, ecology and bionomics of the butterfly and angelfishes, Chaetodontidae. ICLARM Stud Rev 7:166-77.
- Hioki S, K Suzuki, and Y Tanaka. 1990. Development of eggs and larvae in the angelfish, *Centropyge ferrugatus*. Japan J Ichthyolo 37(1):34-8.
- Lobel PS. 1978. Diel, lunar and seasonal periodicity in the reproductive behavior of the pomacanthid fish, *Centropyge potteri*, and some other reef fishes in Hawaii. Pac. Sci 32:193-207.
- Moyer JT and A Nakazono. 1978. Population structure, reproductive behavior, and protogynous hermaphroditism in the angelfish *Centropyge interruptus* at Miyake-jima, Japan. Japan J Ichthyol 25(1):25-39.
- Neudecker S and PS Lobel. 1982. Mating systems of chaetodontid and pomacanthid fishes at St. Croix. Z Tierpsychol 59:299-318.
- Pyle RL and JE Randall. 1994. A review of hybridization in marine angelfishes (Perciformes: Pomacanthidae). Env Biol Fishes 41:127-45.
- Thresher RE. 1982. Courtship and spawning in the emperor angelfish *Pomacanthus imperator*, with comments on reproduction by other pomacanthid fishes. Mar Biol 70:149-56.
- Thresher RE and EB Brothers. 1985. Reproductive ecology and biogeography of Indo-West Pacific angelfishes (Pisces: Pomacanthidae). Evolution 39(4):878-87.

Table 54. Management Unit Species: Pomacanthidae (angelfishes)

	Egg	Larvae	Juvenile	Adult
Duration	12B24 hrs	17B39 days	1B2 yrs	10B26 yrs in captivity
Diet	N/A	plankton	diet similar to adults, although some species may be cleaners as juveniles	<i>Pomacanthus</i> -sponges; <i>Genicanthus</i> - zooplankton, especially pelagic tunicates; <i>Centropyge</i> - benthic algae; all may take small amounts of zoantharians, tunicates, gorgonians, fish and invertebrate eggs, hydroids, algae and seagrasses
Distribution, general and seasonal	spawning peak for <i>C. miliaris</i> in Hawaii from Jan. to Mar. (Ralston 1981)	more abundant in offshore samples	circumtropical, with greatest number of species in Indo-Pacific; seasonal peak of recruitment for Hawaii in the summer (Walsh 1987)	circumtropical, with greatest number of species in Indo-Pacific
Location	eggs released at apex of spawning rush of 3B9 m above the bottom	more abundant in offshore samples	coral reef ecosystems	coral reef ecosystems
Water column	pelagic	pelagic	demersal and mid-water column, mostly 2B30 m but some species over 100 m deep	demersal and mid-water column, mostly 2B30 m but some species over 100 m deep

	Egg	Larvae	Juvenile	Adult
Bottom type	N/A	N/A	refugia on the reef such as cracks, crevices, boulders	home ranges encompass a wide variety of bottom types on coral reefs and flats; rubble/coral
Oceanic features	subject to advection by currents	subject to advection by currents		

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5.1.38 *Genicanthus personatus* (masked angelfish)

The masked angelfish is endemic to the Hawaiian Islands and is highly valued for the aquarium trade, despite doing very poorly in captivity. They are typically found on seaward reef slopes below 23 m deep. In the main Hawaiian Islands, they are seldom seen within safe diving depth limits, but, in the Northwestern Hawaiian Islands, they are more common in shallower water. The population starts at Necker Island and increases in density toward Midway, where it is common at diveable depths and probably extends into undiveable depths (Pyle, pers. comm.). They are often found near ledges and dropoffs and on bottoms or walls of coral reef, rock or sand and rubble.

First collected in 1972, the females of the species were described in Randall (1975) from 3 specimens collected off Oahu and one off the Kona coast of Hawaii. Almost all the specimens from the main Hawaiian Islands have been females, including individuals seen from submersibles greater than 100 m deep (Chave and Mundy 1994). Soon after the original description, 2 males were trawled from a depth of 51 m near Nihoa Island and described by Randall (1976). The stomach of one of the males was full of the green alga *Codium*, as well as planktonic organisms and fish eggs. Though members of *Genicanthus* are generally zooplanktivores, the guts of several *G. personatus* contained a majority of algae but also copepods, diatoms, fish eggs and sponge spicules (Howe 1993). Howe (1993) notes that the presence of oesophageal papillae may allow for a different feeding mode from other pomacanthids.

Like other members of the genus, *G. personatus* is sexually dichromatic. It most likely forms harems and is hermaphroditic. Like other angelfish species, it releases pelagic eggs at the end of a short spawning ascent, with eggs hatching within 12-24 hours and larvae remaining adrift for 17-39 days before settlement (Allen et al. 1998). In a study of the reproductive behaviour of another endemic Hawaiian angelfish, *Centropyge potteri*, Lobel (1978) found a peak in spawning from January to April and a peak in juvenile recruitment from May to July. Juvenile and adult angelfishes are highly dependent on the availability of shelter in the form of boulders, caves and coral crevices.

Bibliography

Allen GR, R Steene and M Allen. 1998. A guide to angelfishes and butterflyfishes. Perth, WA: Vanguard Pr.

Carlson BA. 1982. The masked angelfish, *Genicanthus personatus* Randall 1974. Fresh and Mar Aquar 5:31-2.

Chave EH and BC Mundy. 1994. Deep-sea benthic fishes of the Hawaiian archipelago, Cross Seamount, and Johnson Atoll. Pac Sci 48:367-409.

- Howe JC. 1993. A comparative analysis of the feeding apparatus in pomacanthids, with special emphasis on oesophageal papillae in *Genicanthus personatus*. *J Fish Biol* 43:593-602.
- Lobel PS. 1978. Diel, lunar and seasonal periodicity in the reproductive behavior of the pomacanthid fish, *Centropyge potteri*, and some other reef fishes in Hawaii. *Pac. Sci* 32:193-207.
- Pyle RL. 1990. Rare and unusual marines: the masked angelfish *Genicanthus personatus* Randall. *Freshw and Mar Aquar* 13(10):112, 114, 116, 118.
- Randall JE. 1975. A revision of the Indo-Pacific angelfish genus *Genicanthus* with descriptions of three new species. *Bull Mar Sci* 25:393-421.
- Randall JE. 1976. Description of the male of the Hawaiian angelfish *Genicanthus personatus*. *Bull Mar Sci* 26:414-6.
- Severns M and PF Fiene-Severns. 1993. Molokini Island, Hawaii's premier marine preserve. Hawaii: Pac Isl Pub.
- Toyama D. 1988. The angelfish of Midway Island. *Freshw and Mar Aquar* 11(11):104-6.

Table 55. Management Unit Species: *Genicanthus personatus* (masked angelfish)

	Egg	Larvae	Juvenile	Adult
Duration	angelfish in general: 12-24 hrs (Allen et al. 1998)	angelfish in general: 17-39 days (Allen et al. 1998)	angelfish in general: likely 1-2 yrs (Allen et al. 1998)	
Diet	N/A	likely small zooplankton	no information that it is different from adult	the genus is considered zooplanktivorous, but gut samples of <i>G. personatus</i> show a majority of algae, with some copepods, diatoms, fish eggs, and sponge spicules (Howe 1993, Randall 1976)
Distribution, general and seasonal	Lobel (1978) found a spawning peak from Jan to April for another endemic Hawaiian angelfish, <i>Centropyge potteri</i>		Lobel (1978) found a recruitment peak from May through July for another endemic Hawaiian angelfish, <i>Centropyge potteri</i>	endemic to Hawaii; rare in main Hawaiian Islands within diving depths, but more common shallower in Northwestern Hawaiian Islands
Location	typically released 3-9 m from the bottom after a spawning ascent	offshore waters	no information that it is different from adult	seaward reef slope, often near vertical discontinuities
Water column	pelagic	pelagic	demersal	demersal

	Egg	Larvae	Juvenile	Adult
Bottom type	N/A	N/A	coral reef, rock, sand and rubble	coral reef, rock, sand and rubble
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents	N/A	N/A

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5.1.39 Pomacentridae (damselfishes)

The damselfishes are one of the most abundant fishes on coral reefs. They are seldom larger than 10-15 cm and are moderately deep-bodied, with a small mouth and conical or incisiform teeth. They have a continuous dorsal fin and a caudal fin that varies from truncate to lunate but is usually forked. Juveniles frequently have very different and brighter colors than adults. Males tend to have a distinct, darker color pattern during spawning times. Most damselfishes occur in shallow water on coral reefs or rocky substrata, wherever there is shelter. The species of *Chromis*, *Dascyllus*, *Lepidozygus*, *Amblyglyphidodon*, *Neopomacentrus* and *Pomachromis* are aggregating planktivores, which often form large schools in the water column.

Most members of *Abudefduf*, *Chrysiptera* and *Pomacentrus* are omnivores that feed on benthic algae, small invertebrates or zooplankton. *Plectroglyphidodon johnstonianus* feeds on coral polyps. Other members of *Plectroglyphidodon*, as well as members of *Stegastes*, are aggressively territorial herbivores. Algal feeders frequently cultivate algal mats, which they weed of undesirable algae and aggressively defend from other reef inhabitants. Spawning for damselfishes usually occurs in the morning. The eggs, are elliptical and demersal and are guarded by the male until hatching. Predators on the eggs such as wrasses and butterflyfishes, quickly consume the eggs if the male is removed from the nest. In Hawaiian waters, there are 17 species of pomacentrids; 6 are endemic: *Abudefduf abdominalis*, *Chromis hanui*, *C. ovalis*, *C. verater*, *Dascyllus albisella* and *Plectroglyphidodon sindonis*. At least 89 species occur in Micronesian waters. At least 47 species occur in Samoan waters.

The anemonefishes, subfamily Amphiprioninae, live in a symbiotic relationship with large sea anemones. They are protandrous hermaphrodites; all females start out as males before sex reversal. *Amphiprion* and *Premnas* are unique among the damselfishes in forming permanent pair bonds (Fautin and Allen 1992). Spawning typically occurs near the time of a full moon most often during morning hours and involves the laying of several hundred adhesive eggs on a hard surface near the base of the anemone. Within the tropics, spawning occurs throughout the year although there may be seasonal peaks of activity. The male guards the eggs until hatching after about a week. A short planktonic larval stage lasts from 8 to 16 days before settlement. New recruits must locate a suitable anemone, as anemonefish do not survive without a host. No anemonefish are found in Hawaii because of both the absence of host anemones and the short larval duration. Anemonefishes feed primarily on copepods, larval tunicates and filamentous algae. They have been recorded to live at least 6-10 years in nature (Fautin and Allen 1992).

Pomacentrid eggs are demersal, elliptical and adhesive by means of a cluster of fine threads at one end of the egg. Egg diameters range from 0.49 to 2.3 mm. Hatching occurs in 2-4 days for most species but up to 2 weeks for anemonefish eggs. The planktonic larval stage

typically lasts 2-3 weeks but may be longer. Thresher, Colin and Bell (1989) found larval durations for the following families: *Amphiprion* and *Premnas*: 7-14 days; *Chromis* and *Dascyllus*: 17-47 days with most between 20 and 30 days; and genera in the subfamily Pomacentrinae: 13-42 days. Size at settlement ranges from 7 to 15 mm, and several studies suggest that settlement occurs mainly at dusk and at night (Williams 1980, Nolan 1975).

Bibliography

- Allen GR. 1991. Damsel-fishes of the world. Hong Kong: Mergus Pr.
- Fautin DG and GR Allen. 1992. Field guide to anemonefishes and their host sea anemones. Perth, WA: Western Australian Museum. 160 pp.
- Hixon MA and WN Brostoff. 1983. Damsel-fish as keystone species in reverse: Intermediate disturbance and diversity of reef algae. *Science* 220:511-3.
- Nolan RS. 1975. The ecology of patch reef fishes. Unpub PhD dissertation, Univ of Cal. San Diego, CA.
- Ross RM. 1978. Territorial behavior and ecology of the anemonefish *Amphiprion melanopus* on Guam. *Z Tierpsychol* 46:71-83.
- Thresher RE, PL Colin and LJ Bell. 1989. Planktonic duration, distribution and population structure of western and central Pacific damselfishes (Pomacentridae). *Copeia* 1989 (2):420-34.
- Waldner RE and DR Robertson. 1980. Patterns of habitat partitioning by eight species of territorial Caribbean damselfishes (Pisces: Pomacentridae). *Bull Mar Sci* 30:171-86.
- Wellington GM and BC Victor. 1989. Planktonic larval duration of one hundred species of Pacific and Atlantic damselfish. *Mar Biol* 101:557-67.
- Williams DB. 1980. Dynamics of the pomacentrid community on small patch reefs in One Tree Lagoon (Great Barrier Reef). *Bull Mar Sci* 30:159-70.

Table 56. Management Unit Species: Pomacentridae (damselfishes)

	Egg	Larvae	Juvenile	Adult
Duration	2B4 days for most species, but up to 14 days for anemonefish	2B3 weeks for most species, but ranging from 7-47 days	1B2 years	6B8 years, but up to 10 years or more
Diet	N/A	zooplankton	planktivores: <i>Chromis</i> , <i>Dascyllus</i> , <i>Lepidozygus</i> , <i>Amblyglyphidodon</i> , <i>Neopomacentrus</i> and <i>Pomachromis</i> ; omnivores: <i>Abudefduf</i> , <i>Chrysiptera</i> and <i>Pomacentrus</i> ; herbivores: <i>Stegastes</i> and <i>Plectroglyphidodon</i> , except <i>P. johnstonianus</i> that feeds on corals	planktivores: <i>Chromis</i> , <i>Dascyllus</i> , <i>Lepidozygus</i> , <i>Amblyglyphidodon</i> , <i>Neopomacentrus</i> and <i>Pomachromis</i> ; omnivores: <i>Abudefduf</i> , <i>Chrysiptera</i> and <i>Pomacentrus</i> ; herbivores: <i>Stegastes</i> and <i>Plectroglyphidodon</i> , except <i>P. johnstonianus</i> that feeds on corals
Distribution, general and seasonal	peak spawning in Mar./Ap. and another in Sept./Oct. (Watson and Leis 1974)	more abundant in offshore waters	circumtropical and warm temperate with 84% of species in the Indo-West Pacific; peak in recruitment in spring or summer (Walsh 1987)	circumtropical and warm temperate with 84% of species in the Indo-West Pacific
Location	on hard substrate cleared and protected by the male	more abundant in offshore waters	coral reef-associated	coral reef-associated
Water column	demersal	pelagic	demersal and mid-water column, most within 0B20 m, but some deeper than 100 m	demersal and mid-water column, most within 0B20 m, but some deeper than 100 m

	Egg	Larvae	Juvenile	Adult
Duration	2B4 days for most species, but up to 14 days for anemonefish	2B3 weeks for most species, but ranging from 7-47 days	1B2 years	6B8 years, but up to 10 years or more
Diet	N/A	zooplankton	planktivores: <i>Chromis</i> , <i>Dascyllus</i> , <i>Lepidozygus</i> , <i>Amblyglyphidodon</i> , <i>Neopomacentrus</i> and <i>Pomachromis</i> ; omnivores: <i>Abudefduf</i> , <i>Chrysiptera</i> and <i>Pomacentrus</i> ; herbivores: <i>Stegastes</i> and <i>Plectroglyphidodon</i> , except <i>P. johnstonianus</i> that feeds on corals	planktivores: <i>Chromis</i> , <i>Dascyllus</i> , <i>Lepidozygus</i> , <i>Amblyglyphidodon</i> , <i>Neopomacentrus</i> and <i>Pomachromis</i> ; omnivores: <i>Abudefduf</i> , <i>Chrysiptera</i> and <i>Pomacentrus</i> ; herbivores: <i>Stegastes</i> and <i>Plectroglyphidodon</i> , except <i>P. johnstonianus</i> that feeds on corals
Distribution, general and seasonal	peak spawning in Mar./Ap. and another in Sept./Oct. (Watson and Leis 1974)	more abundant in offshore waters	circumtropical and warm temperate with 84% of species in the Indo-West Pacific; peak in recruitment in spring or summer (Walsh 1987)	circumtropical and warm temperate with 84% of species in the Indo-West Pacific
Bottom type	cleared surface of rock or coral	N/A	all hard substrate in coral reef habitats	all hard substrate in coral reef habitats
Oceanic features	N/A	subject to advection by ocean currents		

5.1.40 Labridae (wrasses)

Labridae is a large family, second only to Gobiidae for number of species in the Western Pacific. It is a very diverse family in size and body shape, with adult sizes ranging from less than 5 cm in *Wetmorella albofasciata* to greater than 229 cm in the humphead wrasse, *Cheilinus undulatus* (this species is rare and heavily fished in Guam and is treated as a separate management unit). Labrid body shapes vary from elongate and cigar-shaped in many species to deep and compressed in others (Myers 1991). Most wrasses are brilliantly and complexly colored, with juveniles frequently having a different color pattern from adults. Color changes may also be associated with protogynous hermaphroditism, sex reversal from female to male that has been described for many labrids and may be true for all species in the family (Randall 1996). Wrasses swim mainly with their pectoral fins, using their tail only when quick bursts are necessary. They have a terminal mouth usually with thick lips, protruding front canine teeth and nodular to molariform pharyngeal teeth. Scales are cycloid. Important summary documents are Randall (1996) and Myers (1991).

The wide variety of color phases in the labrids has created significant taxonomic confusion. Some new species have proven to be a different color phase of an existing species, resulting in a general shrinking of the number of species listed in the family. Still, the family has over 600 species (Hoover 1993). There are 96 known species of labrids in Micronesia (Myers 1991), 43 species in Hawaii (Randall 1996) and 68 species in American Samoa (Wass 1984).

Labrids are shallow-water fishes closely associated with coral reefs or rocky substrate, though some species of *Bodianus* occur deeper than 200 m (Smith 1986, Chave and Mundy 1994), and the razorfishes *Xyrichtys* and *Cymolutes* spp. occur on sand flats. Labrids are diurnal, and at night many bury into the sand, seek refuge in holes and cracks of the reef or lie motionless on the bottom. During the day, labrids keep close to coral or rocky cover, darting into refugia in the reef or burying themselves in the sand when danger approaches. Labrids can be found in virtually all coral reef habitats from inner lagoons and subtidal reef flats to deep seaward reefs (Myers 1991, Green 1996).

Schooling behavior and excursions away from the reef into the water column are usually associated with reproduction (Thresher 1984). Many labrid species are solitary inhabitants of the reef, though many members of the family have large home ranges encompassing a wide variety of habitats (Green 1996). The geographic range of *Labridae* as a family is shallow, tropical and temperate seas of the Atlantic, Pacific and Indian Oceans. Labrids are found throughout shallow areas in the Western Pacific Region, including 96 known species in Micronesia (Myers 1991), and 43 species in Hawaii, 14 of them endemic (Randall 1996).

There is generally a dearth of information on the life history parameters of age, growth and mortality of many coral reef fishes, including labrids, and what information exists cannot realistically be applied to the whole family. Reef fish guides for Pacific coral reef fishes

(Myers 1991, Hoover 1993, Randall 1996) include maximum sizes in the species description. Few correlations have been made between size and age for wrasses.

Sexual dimorphism is a characteristic of all labrids. Every species studied thus far has proven to be a protogynous hermaphrodite (Myers 1991, Randall 1996). Most species have a drab initial phase consisting of all females or a combination of females and non-sex-reversing males and a gaudier terminal phase consisting of males that were formerly females. Species vary as to the ratio of initial phase and terminal phase fishes (Thresher 1984).

Spawning usually occurs along the outer edge of a patch reef or along the outer slope of more extensive reefs. Two types of spawning are characteristics of the labrids: aggregate spawning of large groups of a dozen to several hundred initial-phase males and females and pair spawning of a terminal-phase male and an initial-phase female (Thresher 1984). Both types of spawning involve a sudden upward rush of the participants 0.1 to 2 m into the water column, where milt and eggs are released before the fish return to the bottom. The entire sequence often takes less than a second (Thresher 1984). Colin and Bell (1991) described polygonous harem, lek-like and promiscuous mating systems for labrids in the Marshall Islands. Spawning season for many tropical wrasses is year-round, and some species perform spawning rituals daily. In Hawaii, the saddle wrasse *Thalassoma duperrey* had a peak in spawning from November to February (Ross 1983) and a peak in juvenile recruitment from January to March (Walsh 1987). Many species migrate to prominent coral or rock outcrops for spawning, including species of *Thalassoma*, *Halichoeres*, *Choereodon*, *Bodianus* and *Hemigymnus* (various references in Thresher 1984).

Fourteen species of wrasses are endemic to Hawaii: *Anampses chrysocephalus*, *A. cuvier*, *Bodianus sanguineus*, *Cirrhilabrus jordani*, *Coris ballieui*, *Coris flavovittata*, *Coris venusta*, *Cymolutes lecluse*, *Labroides phthirophagus*, *Macropharyngodon geoffroy*, *Stethojulis balteata*, *Thalassoma ballieui*, *T. duperrey* and *Xyrichtys umbrilatus* (Randall 1996). The Hawaiian population of another species, *Bodianus bilunulatus albotaeniatus*, is recognized as a subspecies (Randall 1996). No wrasse species are reported to be endemic to American Samoa (Wass 1984). There are no important species of introduced wrasses to the Western Pacific Region.

Schooling behavior is common among the wrasses, particularly group spawning aggregations and harem systems of certain wrasse species. Aggregations of spawning labrids sampled by Robertson and Choat (1974) consisted of mostly males, although initial-phase females typically outnumber initial-phase males in the general population (Thresher 1984).

The majority of labrids are benthic carnivores, feeding on a wide variety of invertebrates or fishes, although some are planktivores, corallivores or cleaners.

The following carnivores feed on benthic invertebrates, including molluscs,

crustaceans, polychaetes, sea urchins, brittle stars, tunicates and foraminiferans. Many species also feed on fishes or fish eggs.

Bodianus spp.

Choerodon anchorago

Pseudodax moluccanus

Cheilinus spp.

Wetmorella spp.

Epibulis insidiator

Cymolutes spp.

Novaculichthys spp.

Xyrichtys spp.

Pseudocheilinus spp.

Pterogogus spp.

Anampses spp.

Cheilio inermis

Coris spp.

Gomphosus varius

Halichoeres spp.

Hemigymnus spp.

Hologymnosus spp.

Macropharyngodon spp.

Pseudojuloides spp.

Stethojulis spp.

Thalassoma spp. (except *T. amblycephalum*)

The following small planktivore (usually < 100 mm) feed on zooplankton such as copepods, fish eggs, and larval fish and invertebrates in the water column.

Cirrhilabrus spp.

Paracheilinus spp.

Pseudocoris yamashiroi

Thalassoma amblycephalum

The following corallivores feed on live coral polyps.

Labropsis xanthonata (adults)

Labrichthys unilineatus

Diproctacanthus xanthurus (plus cleaning)

The following cleaners feed on external parasites or damaged tissue of other fishes. They are frequently territorial around a cleaning station, although some species roam larger areas to find fishes to clean. Larger fishes often travel long distances seeking the services of a cleaner, and removal of cleaners has led to abandonment of the area by larger fishes.

Labroides spp.

Labropsis micronesica

Labrids are found in large numbers in a wide variety of habitats associated with reefs in the Western Pacific Region. Green (1996) measured the density of the 10 most abundant fish families in each of 5 coral reef habitat types in American Samoa. Labridae were the third most abundant fish family in the reef flat, shallow lagoon, reef crest and reef front at 20 m depth, with densities ranging from 719 to 1,123 fish per hectare. Wrasses were the fourth most abundant family on the reef front at 10 m depth with 858 fish per hectare (Table 11 in Green 1997). The great majority of Labridae are found in depths from 1 to 100 m of water, in close association with coral or rocky substrate, although species of *Bodianus*, *Polylepion* and *Suezichthys* were seen well below 150 m during submersible cruises on seamounts near Hawaii (Chave and Mundy 1994). Prominent outcroppings of rock or coral are important as sites for spawning aggregation in some species (Thresher 1984). Sandy areas are necessary for the sand-dwelling labrids, *Xyrichtys* spp. and *Cymolutes* spp.

Migration patterns have not been documented for the labrids. Many of the smaller species stay confined to very small areas of the reef, while larger species have bigger home ranges (Green 1996). Even very large species, such as *Cheilinus undulatus*, return to a favored hole or crevice to spend the night or to escape danger (Myers 1991).

In the main Hawaiian Islands, wrasses are a minor portion of the commercial catch, according to Division of Aquatic Resources catch statistics from 1991 to 1995. Two species are present in the top 25 inshore fish species by weight 4,159 lbs of *Bodianus bilunulatus* and 3,955 lbs of *Xyrichtys pavo* (Table 15 in Friedlander 1996). Some wrasse species are caught for the aquarium trade, including *Pseudocheilinus octotaenia*, *Cirrhilabrus jordani*, *Thalassoma* spp., *Anampses chrysocephalus*, *Macropharyngodon geoffroy* and *Novaculichthys taeniourus*, but wrasses are a small portion of the trade in numbers and value (Pyle, pers. comm). A report on commercial collection of aquarium fish by Forum Fisheries Agency countries which did not include Hawaii, Guam or the Philippines but did include exporters from Belau, Christmas Island, Fiji, Kwajalein, Majuro, Pohnpei, Rarotonga, Tarawa and Australia indicate that wrasses made up 7% of the catch by number of fish and 12% by value of catch, with an approximate selling price between US \$3 and \$15 per fish (Pyle 1993).

No fisheries target wrasses in the Northwestern Hawaiian Islands. Labrids do form a substantial component of coral reef systems in these areas (Hobson 1983, Parrish 1989, Randall et al. 1993, Demartini et al. 1994).

The coral reef fishery in American Samoa has two components: the shoreline subsistence and the boat-based artisanal fishery (Green 1997). Labrids comprise less than 3% of the reef fish catch throughout American Samoa (Dalzell et al. 1996) and were not listed in the catch

composition of the shoreline fishery on Tutuila Island in 1991 (from Craig et al. 1993 in Green 1997). Green (1997) reports no commercial aquarium trade in American Samoa.

There is little information on the biological resources of the coral reefs in the federal waters surrounding Guam. Fisheries data is limited to unprocessed catch reports and anecdotal collection data (Myers 1996). Inshore, Labridae made up 7.3% of total landings by weight of the small-boat based spearfishing landings on Guam between 1985 and 1991 (Table 63 in Green 1997). In a study by Katnik (1982), wrasses composed 4.4% of the total catch weight on heavily fished reefs and 4.0% of total catch weight on lightly fished reefs. Similarly, Dalzell et al. (1996) reported that labrids composed 4.31% of the reef fish catch in Guam. Studies detailing overfishing of reefs near Guam are discussed in Green (1997).

There is very little information on the catch of wrasses in the Northern Marianas. For example, data collection in Saipan from 1992 to 1994 assigned 87-91% of annual landings to an unidentified reef fish category (Gourley 1997). Hamm et al. (1994, 1995, 1996) reported catches of 44, 346 and 206 lbs of wrasses in NMI reef-associated commercial fisheries in 1992, 1993 and 1994, respectively. As of 1997, NMI Division of Fish and Wildlife regulations prohibited the commercial export of live fish for the aquarium trade (Gourley 1997).

Labrid eggs are pelagic, spherical, 0.45 to 1.2 mm in diameter and lightly pigmented if at all and usually contain a single oil droplet (Leis and Rennis 1983, Thresher 1984, Colin and Bell 1991). Colin and Bell (1991) measured oil globule diameter for 21 species of labrids in Enewetak Atoll and found a range of 0.10 to 0.24 mm. Colin and Bell documented spawning mostly on a reef bisecting a main channel with strong tidal currents but also on lagoon reefs and in *Halimeda* beds. Most labrids spawned at or slightly after high tide (Colins and Bell 1991), which is in agreement with similar findings for Indo-Pacific labrids (Ross 1983).

Larvae hatch at 1.5-2.7 mm and have a large yolk sac, unformed mouth and unpigmented eyes (Leis and Rennis 1983). Victor (1986) measured the duration of the larval phase of 24 species of wrasses in Hawaii and found a range of 29.5 days (*Anampses chrysocephalus*) to 89.2 days (*Thalassoma duperrey*), although he noted substantial variability within species, up to a standard deviation of 11 days for some wrasses. Victor (1986) and other authors (Miller 1973, Leis and Miller 1976) have noted that despite their abundance as adults in the nearshore fauna of coral reef habitats, labrid larvae are conspicuously absent from nearshore samples and common in offshore samples. Some labrid larvae are routinely found in the open ocean (Leis and Rennis 1983).

Like adult wrasses, juvenile labrids inhabit a wide variety of habitats from shallow lagoon flats to deep reef slopes. Green (1996) reported that *Labroides dimidiatus* and *Thalassoma lunare* use deeper reef slope and reef base habitats as recruits and shallower habitats as

adults. Examples of ontogenetic shifts in habitat use are not widely reported for the family, although relatively few studies have examined the topic.

Labrids are found in most any habitat associated with a coral reef, including rubble, sand, algae, seaweeds, rocks, flats, tidepools, crevices, caves, fringing reefs, patch reefs, lagoons and reef slopes (Myers 1991, Randall 1993). Most species of Labridae show similar patterns of habitat use as adults and recruits, aside from 2 species reported by Green (1996). Spatial and temporal patterns of habitat use by labrids, including descriptions of labrid assemblages distinct to each depth zone, are further reported in Green (1996).

A study of the fish population of Hanalei Bay, Kauai, found *Thalassoma duperrey* was the most numerous species in all habitat types except the deep slope (Friedlander et al. 1997). In the same study, 3 labrid species, *Bodianus biulunulatus*, *Coris flavovittata* and *Thalassoma ballieui*, were present in a creel survey of fishers in the bay. Sand-dwelling species, such as the razorfish *Xyrichtys pavo*, live in and forage over open sandy areas on crabs, shrimp and benthic molluscs (Friedlander et al. 1997). Their densities tend to decline with distance from the reef (Friedlander et al. 1997).

Bibliography

- Chave EH and BC Mundy. 1994. Deep-sea benthic fishes of the Hawaiian archipelago, Cross Seamount, and Johnson Atoll. *Pac Sci* 48:367-409.
- Colin PL and LJ Bell. 1991. Aspects of the spawning of labrid and scarid fishes (Pisces: Labroidei) at Enewetak Atoll, Marshall Islands with notes on other families. *Env Biol of Fishes* 31:229-60.
- Dalzell P, TJH Adams and NVC Polunin. 1996. Coastal fisheries in the Pacific islands. *Ocean and Mar Biol: Ann Rev* 34:395-531.
- Demartini EE, FA Parrish and JD Parrish. 1994. Temporal comparisons of reef fish populations at Midway Atoll, Northwestern Hawaiian Islands. Southwest Fisheries Science Center administrative report H-94-05.
- Friedlander AM, RC DeFelice, JD Parrish and JL Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.
- Green AL 1996. Spatial, temporal and ontogenetic patterns of habitat use by coral reef fishes (Family Labridae). *Mar Ecol Prog Series* 133:1-11.

- Green AL 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the US Pacific Islands. Report prepared for the Western Pacific Regional Fishery Management Council. 278 pp.
- Hobson EH 1984. The structure of reef fish communities in the Hawaiian archipelago. In Proceedings of the second symposium on resource investigations in the Northwestern Hawaiian Islands, volume 1, UNIHI-SEAGRANT-MR-84-01. pp. 101-22.
- Hoover JP 1993. Hawaii's fishes. Honolulu: Mutual Pub.
- Johannes RE 1978. Reproductive strategies of coastal marine fishes in the tropics. *Env Biol Fish* 3(1):65-84.
- Leis JM and JM Miller. 1976. Offshore distributional patterns of Hawaiian fish larvae. *Mar Biol* 36:359-67.
- Miller JM. 1973. Nearshore distribution of Hawaiian marine fish larvae: Effects of water quality, turbidity and currents. In J.H.S. Baxter (ed.) *The early life history of fish*, NY: Springer-Verlag. 765 pp.
- Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.
- Myers RF. 1996. Assessment of coral reef resources of Guam with emphasis on waters of federal jurisdiction. Report prepared for the Western Pacific Regional Fishery Management Council.
- Parrish JD. 1989. Fish communities of interacting shallow-water habitats in tropical oceanic regions. *Mar Ecol Prog Ser* 58(1-2):143-60.
- Randall JE. 1996. *Shore fishes of Hawaii*. Vida, OR: Natural World Pr.
- Randall JE, JL Earle, RL Pyle, JD Parrish and T Hayes. 1993. Annotated checklist of the fishes of Midway Atoll, Northwestern Hawaiian Islands. *Pac Sci* 47(4):356-400.
- Ross RM. 1983. Annual, semilunar, and diel reproductive rhythms in the Hawaiian labrid *Thalassoma duperrey*. *Mar Biol* 72:311-8.
- Thresher RE. 1984. *Reproduction in reef fishes*. Neptune City, NJ: TFH Pub.
- Victor BC. 1986. Duration of the planktonic larval stage of one hundred species of Pacific and Atlantic wrasses (family Labridae). *Mar Biol* 90:317-26.
- Walsh WJ. 1987. Patterns of recruitment and spawning in Hawaiian reef fishes. *Env Biol of Fishes* 18(4):257-76.

Westneat MW. 1997. Labridae. Wrasses, hogfishes, razorfishes, corises, tuskfishes. In: KE Carpenter and V Niem, eds. *FAO identification guide for fishery purposes: The Western Central Pacific*.

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Table 57. Management Unit Species: Labridae (wrasses)

	Egg	Larvae	Juvenile	Adult
Duration	approximately 24 hours	29.5 to 89.2 days for 24 species in Hawaii (Victor 1986)		
Diet	N/A	likely small zooplankton	some species have ontogenetic shifts <i>Labropsis xanthonata</i> from cleaner to corallivore, for example but most have similar diets as adults	1) most are carnivores of benthic invertebrates and fishes; some are 2)corallivores, 3)planktivores, and 4)cleanersCsee text for species list
Distribution, general and seasonal	year-round spawning common, although Miller (1973) and others have documented spring and fall peaks in spawning; <i>Thalassoma duperrey</i> has a winter spawning peak (Ross 1983)	more abundant in offshore samples	coral reef habitats throughout the Western Pacific; seasonal peak in recruitment for <i>T. duperrey</i> from January to May (Walsh 1987)	coral reef habitats throughout the Western Pacific
Location	released from <1 up to 5 m from the bottom	more abundant in offshore samples (Miller 1973, Leis and Miller 1976)	closely associated with reef substrate or sand flats; 1-200m	closely associated with reef substrate or sand flats; 1B200 m
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	wide variety from shallow lagoon sand flats to deep reef slopes (Green 1996)	wide variety from shallow lagoon sand flats to deep reef slopes (Green 1996)

Oceanic features	subject to ocean currents	subject to ocean currents		prominent points or outcroppings are important for spawning aggregations; gyres associated with these points may serve to take larvae temporarily away from reef predators (Johannes 1978)
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5.1.41 *Cheilinus undulatus* (humphead wrasse)

Cheilinus undulatus is treated as a separate management unit because spear fishing has brought the species to very low population levels, particularly around Guam (Dalzell et al. 1996). Because the species is not present in Hawaii, a description follows from Micronesia (Myers 1991).

The humphead wrasse is among the largest of reef fishes. Adults develop a prominent bulbous hump on the forehead and amazingly thick fleshy lips. Adults occur along steep outer reef slopes, channel slopes, and occasionally on lagoon reefs, at depths of 2 to at least 60 m. They often have a home cave or crevice within which they sleep or enter when pursued. Juveniles occur in coral-rich areas of lagoon reefs, particularly among thickets of staghorn *Acropora* corals. The humphead wrasse is usually solitary, but occasionally occurs in pairs. It feeds primarily on mollusks and a wide variety of other well-armed invertebrates including crustaceans, echinoids, brittle stars, and starfish, as well as on fishes. It is one of the few predators of toxic animals such as the crown-of-thorns starfish, boxfishes, and sea hares. The thick fleshy lips appear to absorb sea urchin spines, and the pharyngeal teeth easily crush heavy-shelled gastropods like *Trochus* and *Turbo*. Much of its prey comes from sand or rubble.

The range of *Cheilinus undulatus* is Indo-Pacific: Red Sea to the Tuamotus, north to the Ryukyus, south to New Caledonia. Though rare, they can be found throughout Micronesia and also in American Samoa.

Humphead, or Napoleon, wrasse reach sizes of 229 cm TL and weights of 191 kg. Kitalong and Dalzell (1994) estimate growth and mortality parameters from length frequency data for humpheads in Belau. Studies of humphead wrasse otoliths from the Great Barrier Reef indicate an expected life span of about 25 years (in Dalzell et al. 1996). New research on the life history of *C. undulatus* indicates that it may grow and mature much faster than previously thought (C. Birkeland, pers. comm.).

Once an economically important species in Guam, *C. undulatus* is now rarely seen on the reefs, much less reported on the inshore survey catch results (Hensley and Sherwood 1993). Similar declines in the number of sightings are reported from Saipan (Green 1997). Spearfishing, particularly at night when wrasses are inactive near the reef surface or in caves, has significantly decreased the numbers of this very large reef fish. They are sought after despite accounts of ciguatera poisoning (Myers 1991).

Bibliography

Dalzell P, TJH Adams and NVC Polunin. 1996. Coastal fisheries in the Pacific islands. *Ocean and Mar Biol: Ann Rev* 34:395-531.

Green A. 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the US Pacific Islands. Report prepared for the Western Pacific Regional Fisheries Management Council, Honolulu, HI.

Hensley RA and TS Sherwood. 1993. An overview of Guam's Inshore Fisheries. *Mar Fish Rev* 55(2):129-38.

Kitalong A and P Dalzell. 1994. A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fisheries Research Technical Document, No. 6, South Pacific Commission, Noumea, New Caledonia.

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

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Table 58. Management Unit Species: *Cheilinus undulatus* (humphead wrasse)

	Egg	Larvae	Juvenile	Adult
Duration			research underway by Dr. Howard Choat	at least 25 years (in Dalzell et al. 1996)
Diet	N/A		likely to be similar to adult	carnivore; primarily on mollusks and a wide variety of well-armored invertebrates including crustaceans, echinoids, brittle stars, and starfish, as well as on fishes; also eats toxic animals such as crown-of-thorns starfish, boxfishes, and sea hares
Distribution, general and seasonal				Indo-Pacific, though not found in Hawaii
Location			coral-rich areas of lagoon reefs; among thickets of staghorn <i>Acropora</i> corals	steep outer reef slopes, channel slopes, and occasionally on lagoon reefs
Water column	pelagic	pelagic	demersal	demersal; 2 to at least 60 m depth
Bottom type	N/A	N/A	coral, sand, rubble	coral, sand, rubble
Oceanic features	subject to ocean currents	subject to ocean currents		

5.1.42 Scaridae (parrotfishes)

Parrotfishes get their name from the beak-like dentition and brightly colored appearance of mature adults. Like the wrasses from which they evolved, scarids are protogynous hermaphrodites that change color in relation to changes in growth and sex. Unlike wrasses, parrotfishes have a characteristic pharyngeal dentition, a digestive system lacking a true stomach but with a very long intestine, and a diet of mostly algae with some ingestion of live coral. Most scarids feed by scraping algae and bits of coral from the surface of coral rock, grinding the material with their pharyngeal mill into a slurry of calcium carbonate and algae, digesting the slurry and excreting grains of calcium carbonate sand that make up a large portion of the sediment on most coral reefs. A few species feed heavily on live coral, on large leafy algae or seagrasses or on sand to extract algae from between the grains.

Parrotfishes are diurnal, sleeping under ledges or wedged against coral or rock at night, often surrounded by a mucus cocoon that may serve to mask their scent from detection by nocturnal predators. Small juveniles are frequently drab with white stripes. Some species are diandric, with both male and female juveniles, while others are monandric, with only females in the initial phase. Terminal males, usually formed from sex-reversal of a female, frequently maintain a harem of females, though they perform pair-spawning with each female individually. Initial phase males spawn in groups. Parrotfishes often occur in large, mixed-species schools which rove long distances while feeding on reefs. Some species are territorial and occur in small groups. Important summary documents are Myers (1991) and Randall (1996).

Scarids inhabit a wide variety of coral reef habitats including seagrass beds, coral-rich areas, sand patches, rubble or pavement fields, lagoons, reef flats and upper reef slopes (Myers 1991). They are prominent members in numbers and biomass of shallow reef environments. Scarids are chiefly distributed in tropical regions of the Indian, Atlantic and Pacific Oceans.

Among scarid species, adult sizes range from 110 to 1,000 mm SL, but most are between 200 to 500 mm. Warner and Downs (1977) suggested a maximum age of 6 years for *Scarus iserti*. Choat et al. (1996) found life spans ranging from 5 years (*S. psittacus*) to 20 years (*S. frenatus*). Coutures (1994) used annular marks on scales to age *Bolbometopon muricatum* and found a life span of about 25 years.

Parrotfishes generally have complex socio-sexual systems based on protogynous hermaphroditism, drab initial phase coloration, gaudy terminal phase color patterns and dualistic reproduction. Males can either be primary, in which they are born male, or secondarily derived from females. Most species of *Scarus* are diandric. The relative proportion of primary males, terminal males and females vary widely between and within species.

Scarids spawn in both pairs and groups. Group spawning frequently occurs on the outer slope of the reef in areas with high current speeds. Pair spawnings are frequently observed at the reef crest or reef slope at peak or falling tide. Scarids have been observed to undergo spawning migrations within lagoons and to the outer reef slope (Randall and Randall 1963, Yogo et al. 1980, Johannes 1981, Choat and Randall 1986, Colin and Bell 1991). Some species are diandric, forming schools and spawning in groups often after migration to specific sites, while others are monandric, at times being strongly site-attached with harem, pair-spawning (Choat and Randall 1986).

A few species are territorial, but the most are roving herbivores, with the size of the home range increasing with the size of the fish. Choat and Robertson (1975) found that smaller, less mobile scarids are usually associated with cover such as *Acropora* growth. Open areas with large amounts of grazing surface harbour larger, more mobile and school-forming scarids. Schooling behavior is common among the scarids, both for feeding and spawning.

Species endemic to Hawaii are *Calotomus zonarchus*, *Chlorurus perspicillatus*, *Scarus dubius*. Seven species of scarids can typically be found in Hawaii, 33 species in Micronesia, and 23 species in Samoa.

Most scarids are herbivores, although a few feed on live coral (most notably *Bolbometopon muricatum*) and a few have been reported to feed on newly exposed cryptic sponges (Bakus 1964, Dunlap and Pawlik 1996). The majority graze turf algae from hard substrata, some ingest algal filaments with sand grains, and some feed on seagrasses and leafy algae, such as *Padina*. Friedlander et al. (1997) found high counts of scarids in back reef and reef slope habitats of Hanalei Bay.

Bibliography

- Bakus GJ. 1964. The effects of fish-grazing on invertebrate evolution in shallow tropical waters. *Allan Hancock Found Pub* 27:1-29.
- Bellwood DR. 1997. Scaridae. Parrotfishes. In: KE Carpenter and V Niem, eds. *FAO Identification guide for fishery purposes: The Western Central Pacific*.
- Brock RE. 1979. An experimental study on the effects of grazing by parrotfishes and role of refuges in benthic community structure. *Mar Biol* 51:381-8.
- Choat JH, LM Axe and DC Lou. 1996. Growth and longevity in fishes of the family Scaridae. *Mar Ecol Prog Ser* 145:33-41.
- Choat JH and JE Randall. 1986. A review of the parrotfishes (Family Scaridae) of the Great Barrier Reef of Australia with description of a new species. *Rec Aust Mus* 38:175-228.

- Choat JH and DR Robertson. 1975. Protogynous hermaphroditism in fishes of the family scaridae. pp. 263-283. In: R Reinboth, ed. *Intersexuality in the Animal Kingdom*. Heidelberg, Germany: Springer Verlag.
- Colin PL and LJ Bell. 1991. Aspects of the spawning of labrid and scarid fishes (Pisces:Labroidei) at Enewetak Atoll, Marshall Islands with notes on other families. *Env Biol of Fishes* 31:229-60.
- Coutures E. 1994. La pêche néo-calédonienne de Perroquet à bosse (*Bolbometopon muricatum*, Valenciennes 1840): préliminaires à l'étude de la biologie de pêches. Nouméa: Université Française du Pacifique.
- Dunlap MJ and JR Pawlik. 1996. Video-monitored predation by Caribbean reef fishes on an array of mangrove and reef sponges. *Mar Biol* 126:117-23.
- Friedlander AM, RC DeFelice, JD Parrish and JL Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.
- Johannes RE. 1978. Reproductive strategies of coastal marine fishes in the tropics. *Env Biol Fishes* 3:65-84.
- Johannes RE. 1981. Words of the lagoon. Fishing and marine law in the Palau district of Micronesia. Berkeley: Univ of Calif Pr. 245 pp.
- Lou DC 1993. Growth in juvenile *Scarus rivulatus* and *Ctenochaetus binotatus*: a comparison of families Scaridae and Acanthuridae. *J of Fish Biol* 42:15-23.
- Lou DC and NA Moltschanowskyj. 1992. Daily otolith increments in juvenile tropical parrotfishes and surgeonfishes. *Aust J of Mar and Freshw Research* 43:973-81.
- Randall JE and HA Randall. 1963. The spawning and early development of the Atlantic parrotfish, *Sparisoma rubripinna*, with notes on other scarid and labrid fishes. *Zoologica* 48:49-60.
- Reeson PH. 1983. The biology, ecology and bionomics of the parrotfishes, Scaridae. In: JL Munro, ed. *Caribbean Coral Reef Fishery Resources*. ICLARM Stud Rev 7:166-77.
- Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii. Sea Grant Tech Rept TR-75-01.
- Yogo Y, A Nakazono and H Tsukahara. 1980. Ecological studies on the spawning of the parrotfish, *Scarus sordidus* Forsskal. *Sci Bull Fac Agric, Kyushu Univ* 34:105-14.

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Table 59. Management Unit Species: Scaridae (parrotfishes)

	Egg	Larvae	Juvenile	Adult
Duration	25 hours	30-50 days	3-5 years (Sale 1991)	average as a family is 8B12 years, medium size-6B9 years, large size-20B25+years
Diet	N/A	copepods, nauplii, bivalve larvae (Houde and Lovdal 1984)	carniverous for 1 month, gradually becoming herbivorous (Horn 1989, Bellwood 1988)	algaeCusually thin algal film on coral or rock, but some feed on seagrasses, macroalgae, or graze over sand; a few species feed on live coral
Distribution, general and seasonal	year round, but peak spawning may occur in the summer	higher concentrations in offshore water samples	abundant year round in many coral reef systems	abundant year round in many coral reef systems
Location	spawning aggregation sites frequently on the outer edge of the reef	0-100 m; peak density between 40-80 m in the Caribbean (Hess et al. 1986)	all coral reef habitats, plus seagrass beds, mangroves, lagoons	all coral reef habitats, plus seagrass beds, mangroves, lagoons
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef, sand patches, rubble, pavement	coral reef, sand patches, rubble, pavement

	Egg	Larvae	Juvenile	Adult
Oceanic features	advection by ocean currents	advection by ocean currents	seagrass beds and mangroves may be important nursery areas	channels with high relief habitat nearby are important spawning aggregation sites

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5.1.43 *Bolbometopon muricatum* (bumphead parrotfish)

The bumphead is a very large parrotfish (to 120 cm and 75 kg) with a vertical head profile, a uniform dark green color except for the front of the head which is often light green to pink and a nodular outer surface to its beak. It typically occurs in schools on clear outer lagoon and seaward reefs at depths from 1 to 30 m. They are often located on reef crests and fronts. In unfished areas it may enter outer reef flats at low tide. In addition to algae, it feeds substantially on live coral, using its large foreheads to ram coral and break it into smaller pieces for ingestion. It is very wary in the daytime but sleeps in groups on the reef surface at night, making it an easy target for spearfishers. As a result, it has nearly disappeared from most of Guam's reefs and is rapidly declining in Belau. Johannes (1981) cites an example of bumpheads changing the location of their sleeping site away from the shallow reef flat to the deeper reef slope in Belau in response to increasing nighttime spearfishing. Its range is Indo-Pacific, although it is not found in the Hawaiian Islands.

B. muricatum on the Great Barrier Reef exhibits a gradual approach to the asymptotic length. On the Northern Great Barrier Reef, most schools are composed of fish 12-20 years old. The oldest bumphead *maximum age* identified is a 3-year-old fish with a standard length of 770 mm (Howard Choat, pers. comm.). Younger fishes appear to have different habitat requirements, as fish of SL less than 400 mm are not seen on outer reefs.

Bibliography

- Couture E and C Chauvet. 1994. Croissance du perroquet à bosse (*Bolbometopon muricatum*) et son exploitation en Nouvelle-Calédonie. Information paper No. 4, 25th Regional Technical Meeting on Fisheries, South Pacific Commission, Noumea, New Caledonia. 4 pp.
- Dalzell P, TJH Adams and NVC Polunin. 1996. Coastal fisheries in the Pacific islands. *Ocean and Mar Biol: Ann Rev* 34:395-531.
- Green A. 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the U.S. Pacific Islands. Report prepared for the Western Pacific Regional Fisheries Management Council; Honolulu, HI.
- Hensley RA and TS Sherwood. 1993. An overview of Guam's Inshore Fisheries. *Mar Fish Rev* 55(2):129-38.
- Johannes RE. 1981. Words of the lagoon: fishing and marine lore in the Palau district of Micronesia. Berkeley, CA: Univ of Cal Pr.
- Kitalong A and P Dalzell. 1994. A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fisheries Research Technical Document, No. 6, South Pacific Commission, Noumea, New Caledonia.

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Table 60. Management Unit Species: *Bolbometopon muricatum* (bumphead parrotfish)

	Egg	Larvae	Juvenile	Adult
Duration	25 hours	30B50 days		20B25+years, up to 34 years
Diet	N/A		herbivore/coralivore	herbivore/ coralivore; eats a substantial amount of live coral; in Palau, stomachs were often full of sea urchins (Johannes 1981)
Distribution, general and seasonal	Spawning aggregations reported in barrier reef channels of Palau on the 8th and 9th days of the lunar month (Johannes 1981)			Indo-Pacific; not found in Hawaii
Location			fish < 400 mm not seen on outer reefs of the Great Barrier Reef	typically occurs in schools on clear outer lagoon and seaward reefs at depths of 1 to at least 30 m; may enter outer reef flats at low tide in unfished areas
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef, rubble, pavement	coral reef, rubble, pavement

	Egg	Larvae	Juvenile	Adult
Oceanic features	advection by ocean currents	advection by ocean currents		

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5.1.44 Polynemidae (threadfins)

Threadfins are relatives of the mullets with silvery bodies, an inferior mouth with villiform teeth, two widely-spaced dorsal fins, a deeply forked caudal fin and moderately large scales. Thread-like lower pectoral rays are used as feelers and become relatively shorter with growth. Threadfins typically occur over shallow sandy to muddy bottoms, occasionally in fresh or brackish water. One species, *Polydactylus sexfilis*, occurs in Hawaii where it is highly valued as a food fish. The species, called *moi* in Hawaii, was historically reserved for royal people, or *alii*. It has become rare as a result of intense fishing pressure, and is currently being propagated in hatcheries for use in stock enhancement projects. The same species occurs in Micronesia. Two species occur in Samoa, *P. sexfilis* and *P. plebeius*. The family Polynemidae is distributed throughout the tropical Atlantic and Indo-Pacific Ocean.

P. sexfilis is a fast-growing species that inhabits turbid waters and can be found in large schools in sandy holes along rocky shoals and high energy surf zones. Spawning takes place for 3-6 days per month and has been observed in Hawaii from June to September, with a peak in July and August (Ostrowski and Molnar 1997). Spawning may be year-round in very warm locations. Spawning occurs inshore and eggs hatch offshore within 14-24 hours depending on water temperature (May 1979). Eggs are small, averaging 0.75 mm in diameter with a large oil globule.

Larvae are pelagic, but after metamorphosis they enter nearshore habitats such as surf zones, reefs and stream entrances (Ostrowski and Molnar 1997). Larvae and pre-settlement juveniles feed on zooplankton in the water column, mainly mysids, euphausiids, crab zoeae and amphipods.

Inshore juveniles have distinct dark vertical bars and feed on benthic crustaceans, mostly penaeid and caridean shrimps, as well as zooplankton. Young *moi*, from 150 to 250 mm long, are found from shoreline breakers to 100 m depth (Lowell 1971). Fishing for juvenile *P. sexfilis*, or *moilii*, has historically been an important recreational and subsistence seasonal fishery in Hawaii.

P. sexfilis is a protandrous hermaphrodite, with individuals first maturing as males within 5-7 months at a fork length of 20-29 cm. After mating at least once as a male, fish have a hermaphroditic stage of about 8 months when they have both male and female characteristics. By an age of about 1.5 years and a fork length of 30-40 cm, fish become mature females. The sexes are monomorphic.

Adults feed throughout the day on benthic crustaceans as well as fish. In Kaneohe Bay, adults could be found on reef faces, in the depths of the inner bay and in shallow (2-4 m) areas with muddy sand bottoms (Lowell 1971). When *moi* were more abundant in Hawaii, airplane spotters used to locate large schools and direct net fishers to the catch.

Bibliography

- Kanayama RK. 1973. Life history aspects of the moi *Polydactylus sexfilis* (Cuvier and Valenciennes) in Hawaii. Report to the State of Hawaii, DLNR, Div. Fish and Game, Honolulu, HI. IV +50 pp.
- Lowell NE. 1971. Some aspects of the life history and spawning of the moi (*Polydactylus sexfilis*). MS thesis, Univ. Hawaii. V +45 pp.
- May RC, ed. 1979. Papers on culture of the moi, *Polydactylus sexfilis*. UNIHI-Seagrant-TP-79-03.
- Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.
- Ostrowski AC and A Molnar. 1997. Pacific threadfin, *Polydactylus sexfilis* (moi), hatchery manual. Ctr for Trop and Subtrop Aquacult Pub. #132.

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Table 61. Management Unit Species: Polynemidae (threadfins)

	Egg	Larvae	Juvenile	Adult
Duration	14-24 hours depending on the temperature	weeks to months	5-7 months	
Diet	N/A	zooplankton, mainly mysids, uphausiids, crab zoeae, and amphipods	benthic crustaceans (mainly penaeid and caridean shrimps) and zooplankton	benthic crustaceans (mainly penaeid and caridean shrimps) and fish
Distribution, general and seasonal	spawning 3-6 days per month from June to September in Hawaii, with a peak in July/August; may be year-round in very warm locations	largest numbers in late summer	largest numbers in late summer and fall in Hawaii	<i>Polydactylus sexfilis</i> only species in Hawaii, also found in Micronesia and Samoa; <i>P. plebeius</i> recorded in Samoa
Location	inshore	offshore	from shoreline breakers to offshore reefs; also near stream entrances in sheltered bays	sandy holes along rocky shoals and high energy surf zones
Water column	pelagic	pelagic	0-100 m depth	0B100 m depth
Bottom type	N/A	N/A	sand, mud, rock, coral reef	sand, mud, rock, coral reef
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.45 Sphyraenidae (barracudas)

The barracudas are a single genus of top-level carnivorous fishes that feed mainly on other fishes. They have a very elongate body, a large mouth with protruding pointed lower jaw, very large compressed teeth and two widely separated dorsal fins. They have small cycloid scales and a well-developed lateral line. Some species are primarily diurnal, while others are nocturnal. Species such as *Sphyraena helleri* school in large groups during the day but disperse at night to feed. *S. barracuda* is typically a solitary diurnal predator. In Hawaiian waters, these are the only 2 species positively recorded. In Micronesian waters, at least 6 species occur. In Samoan waters, at least 5 species occur.

Juvenile *S. barracuda* occur among mangroves and in shallow sheltered inner reef areas. Adults occur in a wide range of habitats ranging from murky inner harbors to the open sea. Ciguatera is widely reported for large *S. barracuda*, and has caused deaths in the West Indies where it is now banned from sale. *S. forsteri*, *S. acutipinnis*, *S. novaehollandiae* and *S. obtusata* are all schooling barracudas that occur over lagoon and seaward reefs. *S. genie* is a larger schooling barracuda that frequently schools at the same sites on submarine terraces and is most often caught at night by trollers in Micronesia.

There is no evident external sexual dimorphism among sphyraenids, although males reach sexual maturity at a smaller size than females. Male *S. barracuda* reach maturity in 2 years, but females take about 4 years. Barracudas migrate to specific spawning areas, often in very large numbers at reef edges or in deeper water. Spawning typically takes place in warmer months, and may last extended periods of time in which individual females spawn repeatedly.

The eggs are pelagic, spherical, and range in diameter from 0.7-1.5 mm with a single clear or yellow oil droplet. Eggs hatch within 24-30 hours. Larvae begin to feed within 3 days on small copepods. Larger larvae voraciously feed on zooplankton and other fish larvae. Settlement typically occurs at a length of 18 mm but may be larger. *S. barracuda* larvae occasionally drift in the ocean for an indefinite period of time, usually associated with floating debris or algae, developing all the characteristics of juveniles and sometimes attaining large sizes before being delivered inshore. Newly settled juveniles are piscivorous.

Bibliography

- Abe T. 1974. Sphyraenidae. In: W Fischer and PJP Whitehead, eds. FAO species identification sheets for fishery purposes: Eastern Indian Ocean and Western Central Pacific, vol. 4. Rome: FAO.
- Au KC. 1979. Systematic study on the barracudas (Pisces: Sphyraenidae) from a northern sector of the South China Sea. J Nat Hist 13:619-49.

de Silva DP. 1963. Systematics and life history of the Great Barracuda, *Sphyræna barracuda* (Walbaum). *Stud Trop Oceanog* 1:179.

Edwards RRC, A Bakhader and S Shafer. 1985. Growth, mortality, age composition and fishery yields of fish from the Gulf of Aden. *J Fish Biol* 27:13-21.

Senou H. 1997. Sphyrænidae. Barricudas. In: KE Carpenter and V Niem, eds. *FAO identification guide for fishery purposes: The Western Central Pacific*.

Schultz LP. 1953. In: Schultz et al. *Fishes of the Marshall and Marianas Islands*. *Bull US Nat Mus* 202:279-87.

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Table 62. Management Unit Species: Sphyraenidae (barracudas)

	Egg	Larvae	Juvenile	Adult
Duration	24-30 hours for <i>S. pinguis</i>	the time it takes to grow from 1-2 mm to 18 mm	2 years for male <i>S. barracuda</i> , 4 years for females	
Diet	N/A	zooplankton, copepods, fish eggs	mostly fish	mostly fish
Distribution, general and seasonal	spring spawning aggregation sites may be important for some species	typically more abundant in offshore waters	circumtropical and subtropical	circumtropical and subtropical; seasonal spawning aggregations may be important for some species
Location	reef edge or interface of pelagic and coastal currents	coastal offshore waters	mangroves, shallow lagoons, estuaries	from shallow turbid inner harbors to reefs, as well as coastal offshore waters
Water column	pelagic	pelagic; within 0-100 m depth	from reef-associated to surface	from reef-associated to surface
Bottom type	N/A	N/A	mud, sand, reef	all bottom types
Oceanic features	subject to advection by currents	subject to advection by currents		

5.1.46 Pinguipedidae (sandperches)

The sandperches are represented in the Indo-Pacific by only one genus, *Parapercis*. The genus is characterized by an elongate, nearly cylindrical body, eyes on the top of the head and oriented upwards and a terminal protractile mouth. All are benthic carnivores of small invertebrates and fishes. They are usually found on rubble or sand bottoms near reefs, where they typically rest on the bottom by propping on well-separated pectoral fins. Adults are typically found in depths from 1 to 50 m, but some occur deeper. Most species are sexually dichromatic. Hermaphroditism has been demonstrated for some species and may be true for all. Males are territorial and harem. Spawning occurs year round in the tropics, typically just before sunset. Eggs are pelagic and the larval period lasts for 1-2 months. In Hawaiian waters, 2 species occur. In Micronesia, 4 shallow water species occur. In Samoan waters, 3 species are recorded.

P. cylindrica males defend an area that includes 2-5 females who are defending smaller territories from each other. The male initiates courtship with one of the females about 40 minutes prior to sunset, and eventually the pair makes a short spawning ascent of 60-70 cm before releasing gametes. The eggs are spherical and pelagic, with a diameter ranging from 0.63 to 0.99 mm. Hatching occurs in 22-24 hours. Duration of the planktonic larval stage is estimated to be 1-2 months (Stroud 1981).

Bibliography

Marshall NB. 1950. Fishes from the Cocos-Keeling Islands. Bull Raffles Mus 22:166-205.

Mito S. 1965. On the development of the eggs and hatched larvae of a trachinoid fish, *Neopercis sexfasciata* (Temminck et Schlegel). Sci Bull Fac Agric, Kyushu Univ 15:507-12.

Stroud G. 1981. Aspects of the biology and ecology of weever-fishes (Mugiloididae) in northern Great Barrier Reef waters. PhD diss., James Cook Univ, Townsville, Australia.

Table 63. Management Unit Species: Pinguipedidae (sandperches)

	Egg	Larvae	Juvenile	Adult
Duration	22-24 hours	1-2 months		
Diet	N/A	zooplankton	small invertebrates and fishes	small invertebrates and fishes
Distribution, general and seasonal	year-round spawning, but late spring/summer peak	year-round, with summer peak	one Indo-Pacific genus <i>Parapercis</i>	one Indo-Pacific genus <i>Parapercis</i>
Location	released near parents home; no evidence of spawning migrations	offshore of reefs and soft-bottom habitats	coral reefs and associated soft-bottom communities	coral reefs and associated soft-bottom communities
Water column	pelagic	pelagic, although Leis (1989) found them concentrated in the epibenthos over soft bottoms on the GBR	demersal; most within 1B50 m, but some deeper	demersal; most within 1B50 m, but some deeper
Bottom type	N/A	N/A	sand, mud, rubble and occasionally coral	sand, mud, rubble and occasionally coral
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

5.1.47 Blenniidae (blennies)

Blennies are small, elongate, agile, scaleless fishes with blunt heads and a long continuous dorsal fin. They are a large family of more than 300 species, most of which are bottom-dwelling territorial fishes that lay adhesive demersal eggs that are guarded by the male. The family may be divided into two subfamilies primarily based on dentition and diet. The sabretooth blennies, subfamily Salariinae, typically have small mouths and large fangs. They are carnivores and some feed on the scales, skin or mucus of larger fishes. Some species are mimics of cleaner wrasses or other blennies. They are active swimmers that rapidly approach larger fish, while other members of Salariinae are sedentary.

The combtooth blennies, subfamily Blenniinae, typically have wide mouths, feeble teeth and feed on benthic algae. An exception is the leopard blenny *Exalias brevis*, which feeds primarily on coral polyps of *Acropora*, *Pocillopora*, *Seriatopora*, *Porites* and *Millepora*. Most combtooth blennies are sedentary inhabitants of rocky shorelines, reef flats or shallow seaward reefs. In Hawaiian waters, 14 species of blennies have been recorded; 7 are endemic: *Cirripectes obscurus*, *C. vanderbilti*, *Entomacrodus marmoratus*, *E. strasburgi*, *Istiblennius zebra*, *Plagiotremus ewaensis* and *P. goslinei*. The mangrove blenny *Omobranchus rotundiceps obliquus* was introduced to the Hawaiian and Line Islands, and the tasseled blenny *Pablennius thysanius* was probably introduced to Hawaii by ballast water. At least 59 species occur in Micronesia. At least 47 species occur in Samoa.

The blennies have very complex color patterns and are often well camouflaged to the surrounding habitat. Blennies tend to shelter in small holes in the reef or sand by backing into them tail-first. Some blennies, including those of the genera *Istiblennius* and *Entomacrodus*, live inshore on rocky bottom exposed to surge. They are called rockskippers for their ability to leap from pool to pool.

In addition to their unique feeding strategy, *Exalias brevis* has unusual reproductive characteristics. Males prepare a nesting site by clearing a patch of coral near a crevice. Females make the rounds of up to 10 different male's nests, depositing bright yellow eggs in each of them. Nests may contain more than one female's eggs, and both males and females occasionally cannibalize eggs. Spawning occurs throughout the year with a peak from January to April.

The reproductive biology of blennies has been studied extensively. There are many variations, but all appear to produce relatively large demersal eggs which are deposited in or near a shelter hole and defended by the male. Eggs are characteristically flattened ovals, usually brightly colored, and about 1.0 mm in the longest dimension. Hatching typically occurs in 9-11 days. In the Red Sea species *M. nigrolineatus*, the larvae develop juvenile colors in 20 days and settle to the bottom by 30 days.

Bibliography

Carlson BA. 1978. A contribution to the biology of the spotted blenny, *Exallias brevis* (Pisces; Blenniidae). Pac Sci 32:96.

Dotsu Y and T Oota. 1973. The life history of the blenniid fish, *Omobranchus loxozonus*. Bull Fac Fish Nagasaki Univ 36:13-22.

Randall JE and HA Randall. 1960. Examples of mimicry and protective resemblance in tropical marine fishes. Bull Mar Sci 10:444-80.

Smith-Vaniz WF. 1976. The sabre-toothed blennies, tribe Nemophini (Pisces: Blenniidae). Acad Natur Sci, Phila, Monogr 19:1-196.

Thresher RE. 1984. Reproduction in reef fishes. Neptune, NJ: TFH Pub.

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Table 64. Management Unit Species: Blenniidae (blennies)

	Egg	Larvae	Juvenile	Adult
Duration	9-11 days	20-30 days		
Diet	N/A	copepods, nauplii, bivalve larvae (Watson 1974, Houde and Lovdal 1984)	most graze on benthic algae; some feed on zooplankton; some prey on minute invertebrates such as foraminiferans, ostracods, copepods and gastropods; fangblennies of <i>Plagiotremus</i> eat mucus and skin tissue from fishes; at least one species, <i>Exallias brevis</i> , feeds on coral polyps	most graze on benthic algae; some feed on zooplankton; some prey on minute invertebrates such as foraminiferans, ostracods, copepods and gastropods; fangblennies of <i>Plagiotremus</i> eat mucus and skin tissue from fishes; at least one species, <i>Exallias brevis</i> , feeds on coral polyps
Distribution, general and seasonal			worldwide in tropical and temperate seas	worldwide in tropical and temperate seas
Location	near the adults shelter hole		rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons	rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons
Water column	demersal	pelagic	demersal; a few feed on zooplankton in the water column, and many of the fangtooths are active swimmers that pursue larger fish; many found in very shallow depths, and some rockskippers found above sealevel	demersal; a few feed on zooplankton in the water column, and many of the fangtooths are active swimmers that pursue larger fish; many found in very shallow depths, and some rockskippers found above sealevel

	Egg	Larvae	Juvenile	Adult
Bottom type	coral or rock	N/A	rock, coral reef, sand	rock, coral reef, sand
Oceanic features		subject to advection by ocean currents		

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5.1.48 Gobiidae (gobies)

The gobies are the largest family of marine fishes, with about 1000 Indo-Pacific species and at least 1900 marine and freshwater species worldwide. They are typically small, elongate, blunt-headed fishes with a relatively large mouth with conical teeth, pelvic fins close together and usually fused to form a sucking disk, and two dorsal fins. Gobies are primarily shallow-water species. All are carnivorous and bottom-dwelling, although a few swim a short distance above the bottom to feed on plankton (*Ioglossus*, *Nemateleotris*). They inhabit a variety of habitats such as coral reef, sand, mud, rubble or seagrass. The majority of gobies occur on coral reefs, where they typically have unsurpassed diversity and abundance, but many occur in adjacent coastal and estuarine waters.

Many live in close association with other animals such as sponges, gorgonians, and snapping shrimps. Several species have a symbiotic relationship with one or more species of Alpheid snapping shrimp in which the gobies share a burrow. The shrimp digs the burrow while one or more gobies keeps watch for predators. Nearly all gobies are gonochorists that lay a small mass of demersal eggs which are guarded by the male. A few have been shown to be protogynous hermaphrodites. There are 31 marine species of gobies in Hawaiian waters. Five of them are endemic to Hawaii: the noble goby *Priolepis eugenius*, the rimmed-scale goby *Priolepis limbatosquamis*, the Hawaiian shrimp goby *Psilogobius mainlandi*, plus two new species described recently in *Copeia*. In Micronesian waters, at least 159 species occur. At least 100 species are recorded for Samoan waters.

Most reef-associated gobies are sexually monomorphic, although gobies in other habitats do have color and size differences between the sexes. Protogynous hermaphroditism was documented for gobies of the genus *Paragobiodon*, in which the largest individual present was always male, the second largest was the functional female, and the smaller individuals were non-spawning females (Lassig 1977). In most cases gobies appear to spawn promiscuously with many individuals loosely organized into a social hierarchy or with individuals maintaining small contiguous territories, although pairing and apparent monogamy have been documented for a number of gobies, including *Ioglossus* spp. (Colin 1972), *Gobiodon* spp. (Tyler 1971), and *Valencienna* spp. (Hiatt & Strasburg 1960), among others.

Gobies lay demersal adhesive eggs in a burrow, on the underside of a rock or shell, or in cavities within the body of a sponge. Males tend and guard the eggs, which are attached to the substrate by a tuft of adhesive filaments at one end. Most goby eggs are elongate, smoothly round-ended and range in length from 1.1 to 3.3 mm and in diameter from 0.5 to 1.0 mm, although the eggs of fresh water and anadromous species may be as large as 8 mm. Some species, such as those of *Elacatinus*, have distinctive protuberances from the eggs. Incubation typically lasts 5-6 days depending on temperature. The size at hatching ranges

from less than 2 mm to 4mm. The majority of the gobies leave the plankton at a size less than 10 mm. The planktonic larval duration is known for a few species. Lassig (1976) estimated a duration of about 6 weeks for *Paragobiodon* spp. at Heron Island. Moe (1975) reported a planktonic larval duration of from 18-40 days for *Gobiosoma oceanops*. Colin (1975) reported metamorphosis at 26 days for neon gobies, which grew quickly to subadult size in 3 months and spawned as soon as 5 months. He suggested neon gobies were annual fishes that mature quickly and may only live one or two years.

Species of *Amblyeleotris*, *Cryptocentroides*, *Cryptocentrus*, *Ctenogobiops*, *Vanderhorstia*, *Lotilia*, and *Mahidolia* live in burrows constructed by alpheid prawns. At least 20 species of gobies share burrows with at least 7 species of prawns in Micronesia. The gobies, either singly or in pairs, act as sentinels for the alpheid shrimps who maintain the burrows. The gobies benefit from the use of the burrow, and also from feeding on the invertebrates excavated by the shrimp. The shrimps benefit from having a wary sentinel with better eyesight to warn them of approaching danger.

Some gobies have specific habitat requirements. The gorgonian goby *Bryaninops amplus* is usually found on gorgonians. The whip coral goby *Bryaninops yongei* is usually found on the antipatharian seawhip *Cirripathes anguina*. The Hawaiian shrimp goby *Psilogobius mainlandi* lives in burrows built and maintained by the snapping shrimp *Alpheus rapax*. The translucent coral goby *Bryaninops erythroptus* lives on certain branching forms of fire corals *Millepora* spp. and other branching or massive corals such as *Porites cylindrica* and *P. lutea*. The hovering goby *Bryaninops natans* occurs in groups that hover just above or within the branches of *Acropora* corals. Members of *Paragobiodon* and *Gobiodon* are obligate coral-dwellers. Mudskippers of the genus *Periophthalmus* are essentially amphibious and are typically found resting on mud, rocks, or mangrove roots.

Bibliography

- Böhlke JE and CR Robins. 1969. Western Atlantic sponge-dwelling gobies of the genus *Evermannichthys*: their taxonomy, habits, and relationships. Proc. Acad. Nat. Sci. 121(1): 1-24.
- Colin PL. 1972. Daily activity patterns and effects of environmental conditions on the behavior of the yellowhead jawfish, *Opistognathus aurifrons*, with notes on its ecology. Zoologica 57: 137-169.
- Colin PL. 1975. Neon gobies. T.F.H. Publ., Neptune City, New Jersey. 304 pp.
- Davis WP, JE Randall and DO French. 1977. The systematics, biology, and zoogeography of *Ptereleotris heteropterus*, pisces:Gobiidae. Proc. Third Internat. Coral Reef Symp., 1:261-266.

Hiatt RW and DW Strasburg. 1960. Ecological relationships of the fish fauna on coral reefs of the Marshall Islands. *Ecol. Monogr.* 30: 65-127.

Houde ED and JA Lovdal. 1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. *Estuarine, Coastal Shelf Sci.* 18: 403-419.

Lassig B. 1977. Socioecological strategies adopted by obligate coral-dwelling fishes. *Proc. Thir Internat. Coral Reef Symp.* 1:56-570.

Randall JE. 1968. *Ioglossus helenae*, a new gobiid fish from the West Indies. *Ichthyologica* 39(3&4): 107-116.

Tyler JC. 1971. Habitat preferences of the fishes that dwell in shrub corals on the Great Barrier Reef. *Proc. Acad. Nat. Sci.* 123: 1-26.

Watson W. 1974. Diel changes in the vertical distributions of some common fish larvae in southern Kaneohe Bay, Oahu, Hawaii. Unpublished M.S. thesis, University of Hawaii, Honolulu, Hawaii.

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Table 65. Management Unit Species: Gobiidae (gobies)

	Egg	Larvae	Juvenile	Adult
Duration	5-6 days	18-42 days	as soon as 5 months for neon gobies (Colin 1975)	smaller gobies may only live 1-2 years; others much longer
Diet	N/A	copepods, nauplii, tintinnids, mollusc larvae (Watson 1974, Houde and Lovdal 1984)	similar to adults	most are carnivorous on a wide variety of benthic invertebrates (copepods, amphipods, ostracods, nematodes, foraminiferans), fishes, and fish eggs; some semi-pelagic species are planktivorous
Distribution, general and seasonal				worldwide in tropical and temperate seas; 28 marine species of gobies in Hawaiian waters, with 3 endemic; at least 159 Micronesian species and at least 100 species in Samoa
Location			rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons	rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons
Water column	demersal	pelagic	same as adults	demersal; species of <i>Ioglossus</i> and <i>Nemateleotris</i> are semi-pelagic, hovering a short distance above the reef
Bottom type	coral, rock, sponge	N/A	coral reef, sand,	coral reef, sand, mud, rubble or seagrass

	Egg	Larvae	Juvenile	Adult
			mud, rubble or seagrass	
Oceanic features		subject to advection by ocean currents		

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5.1.49 *Zebrasoma flavescens* (yellow tang)

The yellow tang is a popular aquarium fish that is the top marine fish export from Hawaii, representing more than 75% of all animals caught statewide (Clark and Gulko 1999). They occur singly or in loose groups on coral-rich areas of lagoon and seaward reefs from below the surge zone to at least 46 m. Juveniles tend to hide among branches of finger coral, while adults graze near the shore in calm areas. They are diurnal herbivores of filamentous algae from hard surfaces. The genus is characterized by an unusually deep body with tall dorsal and anal fins and an elongate tubular snout. The yellow tang is moderately common at some locations in the Marianas, but is most abundant in Hawaii.

Group spawning (Lobel 1978) as well as pair spawning by territorial males that court passing females (in Thresher 1984) has been observed. Spawning occurs a few meters above the bottom or the depth of the spawning aggregation, usually at dusk. Pelagic eggs likely hatch within 1 to 2 days, and a pelagic larval stage lasts for up to a few months.

Z. flavescens tends to prefer the leeward sides of islands (Brock 1954), particularly areas of dense coral growth of *Pocillopora damicornis* and *Porites compressa*. It feeds on algae growing exposed on basalt and dead coral heads, as well as in crevices and interstices of the reef that it can reach with its long, thin snout (Jones 1968). The majority of yellow tang in Hawaii are collected off West Hawaii, Kawaihae, Kona and Milolii (Clark and Gulko 1999).

Bibliography

- Brock VE. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildlife Mngmt. 18: 289-308.
- Clark AM. and D Gulko. 1999. Hawaii's state of the reef report, 1998. Dept. of Land and Nat. Res., Honolulu, HI. 41pp.
- Jones RS. 1968. Ecological relationships in Hawaiian and Johnston Island Acanthuridae (Surgeonfishes). Micronesica 4: 309-361.
- Lobel PS. 1978. Diel, lunar, and seasonal periodicity in the reproductive behavior of the pomacanthid fish, *Centropyge potteri*, and some other reef fishes in Hawaii. Pac. Sci. 32: 193-207.
- Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.
- Walsh WJ. 1987. Patterns of recruitment and spawning in Hawaiian reef fishes. Env. Biol. of Fishes 18(4): 257-276.

Table 66. Management Unit Species: *Zebrasoma flavescens* (yellow tang)

	Egg	Larvae	Juvenile	Adult
Duration	approximately 24 hours	up to a few months		
Diet	N/A	various zooplankters	similar to adults	herbivores on filamentous algae
Distribution, general and seasonal	late winter, spring peak in spawning		highest recruitment in the summer, May to August, in Hawaii (Walsh 1987)	Pacific Plate; abundant only in Hawaii, found uncommonly at some locations in the Marianas; not recorded from Samoa
Location	eggs released after short spawning ascent from the bottom or the depth of a spawning aggregation	0-100m, larvae typically are more common in offshore waters than in water over reefs	often hide within the branches of finger coral	coral-rich areas of lagoon and seaward reefs from below the surge zone to at least 46 m; adults may feed very near the shore in calm areas
Water column	pelagic	pelagic	demersal and mid-water	demersal and mid-water
Bottom type	N/A	N/A	coral, rock, rubble, pavement	coral, rock, rubble, pavement
Oceanic features	subject to ocean currents	subject to ocean currents		

5.1.50 Zanclidae (Moorish idol)

This family consists of one species, *Zanclus cornutus*. It has a strongly compressed discoid body, tubular snout with a small mouth and many bristle-like teeth, and dorsal spines elongated into a whip-like filament. Moorish idols have a long larval stage and settle at a large size, >6cm SL for some individuals. As a result, they are ubiquitous in areas of hard substrate from turbid inner harbors to clear seaward reefs. They feed mainly on sponges, but will also take other invertebrates and algae. They usually are found in small groups of 2-5 individuals but may occur in large schools of well over 100 individuals. Their range is Indo-Pacific and tropical eastern Pacific, and they are found throughout the management area. They are a popular aquarium fish.

There is little information on Moorish idol reproduction, but they have been observed to spawn in pairs at dusk on outer reef slopes, producing pelagic eggs that are capable of long planktonic existence. Their wide distribution and length at settlement as large as 7.5cm are good indicators of long larval stages. The larval phase is similar to acanthuroid larval phases.

Moorish idols inhabit all types of hard substrate in the tropical Pacific. They are present in very shallow habitats < 1m deep and have also been sighted as deep as 180m. They are diurnal predators that feed mainly on sponges, but also on small benthic crustaceans and algal film on rocks and coral.

Bibliography

Debelius H and HA Baensch. 1994. Baensch Marine Atlas. Tetra Press: Blacksburg, VA.

Johnson GD and BB Washington. 1987. Larvae of the Moorish idol, *Zanclus cornutus*, including a comparison with other larval acanthuroids. Bull. Mar. Sci. 40(3): 494-511.

Strasburg DW. 1962. Pelagic stages of *Zanclus canescens* from Hawaii. Copeia, 1962: 844-845.

Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.

Table 67. Management Unit Species: Zanclidae (Moorish idol)

	Egg	Larvae	Juvenile	Adult
Duration	unknown	relatively long; several months, ranging in size from a few millimeters to 7.5 cm		
Diet	N/A	zooplankton	mostly sponges, some small benthic crustaceans and algae	mostly sponges, some small benthic crustaceans and algae
Distribution, general and seasonal	little known	predominantly offshore	Indo-Pacific and tropical Eastern Pacific	Indo-Pacific and tropical Eastern Pacific
Location	released near the surface on outer reef slope	predominantly offshore	from turbid inshore harbors to clear outer reef slopes	from turbid inshore harbors to clear outer reef slopes
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	all hard substrates, including coral reef, rocks, rubble, reef flats, wrecks	all hard substrates including coral reef, rocks, rubble, reef flats, wrecks
Oceanic features				

5.1.51 Siganidae (rabbitfishes)

Siganids are small (from 20 -50 cm), essentially marine tropical Indo-West Pacific fishes. They have venomous dorsal, anal and pelvic spines. With a single row of flattened, close-set teeth, rabbitfishes feed primarily on algae and seagrasses, although some may occasionally feed on tunicates or sponges. Because of their herbivorous diet, most species live at depths less than 15 m, but some are trawled from as deep as 50m. Half the species live as pairs on coral reefs, the others usually gather in small schools. One species, *Siganus vermiculatus*, is almost exclusively estuarine; the rest move between estuaries, coral reefs, rocky shores, and other habitats. Rabbitfishes generally spawn on a lunar cycle with peak activity during the spring and early summer. Spawning occurs in pairs or groups on outgoing tides either at night or early in the morning. Juveniles of some species are estuarine. Rabbitfishes are highly esteemed foodfishes. Some of the colorful ones are popular aquarium fishes. None are found in Hawaii. Approximately 16 species are found in Micronesia, and at least 4 species in Samoa.

Spawning by rabbitfishes is typically preceded by a migration to specific and traditional spawning sites. The location varies from near mangrove stands (*S. lineatus*, Drew 1971), to shallow reef flats (*S. canaliculatus*, Manacop 1937, Johannes 1981), the outer reef crest (several spp. at Palau, Mcvey 1972; Johannes 1978), and even the deeper reef (*S. lineatus*, Johannes 1981). Sites are usually characterized by easy access to the ocean via channels, and large areas of sea grass flats nearby.

Reproduction in the schooling species has been studied in some detail, and in general the eggs are adhesive and demersal (with a few exceptions such as the pelagic eggs of *S. argenteus*); hatching occurs within 1-3 days and yolk sac absorption is completed in about 3 or 4 days (Lam 1974). Fecundity is high: 250,000-500,000 eggs per spawning season (Lam 1974, Gunderman et al. 1983). Larvae are pelagic and feed on phytoplankton and zooplankton. The duration of the larval stage is about 3 weeks in *S. fuscescens* (Hasse et al. 1977) and 3-4 weeks in *S. vermiculatus* (Gunderman et al. 1983). Popper et al. (1976) reported that siganid larvae follow a lunar rhythm in appearing on the reef, typically arriving inshore 3-5 days after a new moon. Fish are 15-20 cm long and sexually mature after one year. Judging by maximum size, some species survive from 2-4 years. *S. argenteus* is unique amongst the Siganidae in having a prejuvenile stage which is distinct from the larval and juvenile stages and is specially adapted for a pelagic life (Hubbs 1958). They can reach sizes of 6-8 cm SL before settling. Not surprisingly, *S. argenteus* has the widest distribution of all rabbitfishes.

The rabbitfishes vary widely in their habitat uses. The schooling species typically move between a wide range of habitats, whereas the pairing species tend to lead a sedentary existence among the branches of hard corals. Rabbitfishes are common on reef flats, around

scattered small coral heads, and near grass flats. Gundermann et al. (1983) divided the siganids into two groups on the basis of habitat, behavioral characteristics and coloration. One group includes species (*S. corallinus*, *S. puellus*, and *Lo vulpinnus*) that live in pairs, have limited home-ranges on reefs and are brightly colored. The remaining group, including *S. rivulatus* and *S. canaliculatus*, form schools at some stage of their life cycle, may undertake substantial migrations, and assume coloration similar to their preferred habitat.

Schools of juvenile *S. rostratus* and *S. spinus* swarm on the reef flats of Guam each year during April and May, and occasionally during June and October. Tsuda et al. (1976) studied the feeding and habitat requirements for these fish to determine the likelihood of mariculture of the rabbitfishes, which are highly esteemed for gastronomic and cultural reasons in Guam.

Bibliography

- Drew AW. 1971. Preliminary report on ksebuul and meyas, two fish of Palau Islands. 20 pp. (unpublished report, Micronesian Mariculture Demonstration Center, Belau).
- Gunderman N, DM Popper and T Lichatowich. 1983. Biology and life cycle of *Siganus vermiculatus* (Siganidae, Pisces). Pac. Sci. 37: 165-180.
- Hasse JJ, BB Madraisau and JP McVey. 1977. Some aspects of the life history of *Siganus canaliculatus* in Palau. Micronesica 13(2): 297-312.
- Hubbs CL. 1958. Dikellorhynchus and kanazawichthys: nominal fish genera interpreted as based on juveniles of Malacanthus and Antennarius, respectively. Copeia 4: 282-285.
- Johannes RE. 1978. Reproductive strategies of coastal marine fishes in the tropics. Env. Biol. Fishes 3: 65-84.
- Johannes RE. 1981. Words of the lagoon. Univ. Calif. Press, Los Angeles, CA: 320pp.
- Kami HT and II Ikehar. 1976. Notes on the annual juvenile siganid harvest in Guam. Micronesica 12(2): 323-325.
- Lam TJ. 1974. Siganids: their biology and mariculture potential. Aquacult. 3: 325-354.
- Manacop PR. 1937. The artificial fertilization of dangit, *Amphacanthus oramin* (Bloch and Schneider). Philippine J. Sci. 62: 229-237.
- Mcvey JP. 1972. Observations on the early-stage formation of rabbit fish, *Siganus fuscescens*, at Palau Mariculture Demonstration Centre. South Pacific Isl. Fish. Newsletter 6: 11-12.

Popper D, RC May and T Lichatowich. 1976. An experiment in rearing larval *Siganus vermiculatus* (Valenciennes) and some observations on its spawning cycle. *Aquacult.* 7: 281-290.

Tsuda RT, Tobias WJ, Bryan PG, Fitzgerald WJ, Kami HT, and II Ikehara. 1976. Studies on the genus *Siganus* (rabbitfish) in Guam waters. Sea Grant Publ. UGSG-76-05. University of Guam Mar. Lab., tech. rept. #29.

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Table 68. Management Unit Species: Siganidae (rabbitfishes)

	Egg	Larvae	Juvenile	Adult
Duration	1-3 days	3-4 weeks	1 year	2-4 years
Diet	N/A	phytoplankton and zooplankton	herbivores	herbivores, though some may feed on tunicates and sponges; they will assume a carnivorous diet in captivity
Distribution, general and seasonal	spawning in Guam in April and May, and occasionally in June and October		some species estuarine as juveniles before moving offshore	throughout the shelf waters of the Indo-West Pacific, except for the Hawaiian and Easter Island provinces
Location	mangrove stands (<i>S. lineatus</i> , Drew 1971), to shallow reef flats (<i>S. canaliculatus</i> , Manacop 1937, Johannes 1981), the outer reef crest (several spp. at Palau, Mcvey 1972; Johannes 1978), and even the deeper reef (<i>S. lineatus</i> , Johannes 1981). Sites are usually characterized by easy access to the ocean via channels, and large areas of sea grass flats nearby	more abundant offshore	estuaries for some species	most wide-ranging over many habitats. <i>Siganus vermiculatus</i> , is almost exclusively estuarine; the rest tend to move between estuaries, seagrass beds, coral reefs, rocky shores
Water column	pelagic	pelagic	demersal or reef-associated	demersal or reef associated
Bottom type	N/A	N/A	silt, sand, and mud for estuarine species	some pair-forming species are sedentary in the branches of Acropora corals; most range over many bottom types

	Egg	Larvae	Juvenile	Adult
Oceanic features	ocean currents	ocean currents		

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5.1.52 *Gymnosarda unicolor* (dogtooth tuna)

Very little is known about the biology of the dogtooth tuna (*Gymnosarda unicolor*), although it is widely distributed throughout much of the Indo-Pacific faunal region, from the Red Sea eastward to French Polynesia (Collette and Nauen 1983). This species is not found in the Hawaiian Islands, although fishermen do refer to catches of the meso-pelagic snake mackerel (Gempylidae) as dogtooths.

G. unicolor is an epipelagic species, usually found individually or in small schools of 6 or less (Lewis et al. 1983). Dogtooth tuna are found in deep lagoons and passes, shallow pinnacles and off outer reef slopes (Collette and Nauen 1983). It occurs in mid-water, from the surface to depths of approximately 100m, and has a preference for water temperatures ranging from 20-28 degrees Celsius.

G. unicolor is one of the few tuna species found primarily in association with coral reefs (Amesbury and Myers 1982) and probably occupies a niche similar to other reef-associated pelagic predators such as Spanish mackerel (*Scomberomorus* spp.) and queenfish (*Scomberoides* spp). Like the Spanish mackerels, large dogtooths can become ciguatoxic from preying on coral reef herbivores, which themselves have become toxic through ingestion of the dinoflagellate, *Gambierdiscus toxicus* (Myers 1991).

A positive correlation between size and depth has been observed in the distribution of this species based on limited information from Tuvalu, with larger individuals being found at greater depths (Haight 1998). This species reportedly reaches a maximum size of 150cm FL and 80kg (Lewis et al. 1983).

Observations from Fiji suggest that dogtooth tuna obtain sexual maturity at approximately 65 cm (Lewis et al. 1983), while Silas (1963) reported a partially spent 68.5 cm male dogtooth tuna from the Andaman Islands. Females outnumbered males by nearly 2:1 in Fiji, and all fish larger than 100cm were females, suggesting sexual dimorphism in this species (Lewis et al. 1983). Lewis et al. (1983) suggest that the vulnerability of female dogtooth tuna to trolling declines as the fish approach spawning condition.

In Fiji, spawning reportedly occurs during the summer months - between October and March (Lewis et al. 1983). Dunstan (1961) observed spawning dogtooth tuna in Papua New Guinea during March, August and December, and various other authors (Silas 1963) have provided some evidence of summer spawning for this species. Okiyama and Ueyangi (1977) note that the larvae of dogtooth tuna occur over a wide area of the tropical and subtropical Pacific Ocean, between 10EN and 20ES, with concentrations along the shallow coastal waters of islands, such as the Caroline Islands, Solomon Islands and Vanuatu. Dogtooth larvae were collected in surface and subsurface tows, with greater numbers in the sub-surface tows at depths between 20-30m. Older larvae appear to make diurnal vertical migrations, rising to

the surface during the night. On the basis of larval occurrence throughout the year, Okiyama and Ueyangi (1977) postulate year round spawning in tropical areas.

There are no fisheries specifically directed at dogtooth tuna in the western Pacific region. The primary means of capture include pole and line, handlines and surface trolling (Severance 1998, pers. comm; Collette and Nauen 1983). Dogtooth tuna have been sold in local markets in American Samoa and the Northern Mariana Islands, but currently have little market value (Severance 1998, pers. comm.).

Dogtooth tuna are voracious predators, feeding on a variety of squids, reef herbivores such as tangs and unicorn fish (Acanthuridae), and small schooling pelagic species including fusiliers (*Caesio* spp) and roundscads (*Decapterus*) (Myers 1989).

Dogtooth tuna are unique among the family Scombridae in having such a close association with coral reefs, although they are also found around rocky reefs in higher latitudes such as in Korea and Japan (Myers 1989). Within the western Pacific region, waters on and adjacent to coral reefs down to a depth of about 100m should be designated EFH for this species.

Bibliography

- Amesbury SS, Myers RF. 1982. Guide to the Coastal Resources of Guam. Volume 1, The fishes. University of Guam Marine Laboratory. Contribution # 173.
- Collette BB, Nauen CE. 1983. An annotated and illustrated catalogue of tunas, mackerels, bonitos, and related species known to date. FAO Species Catalogue. Vol. 2, Scombrids of the world. Rome: Food and Agriculture Organization. 118pp.
- Dunstan DJ. 1961. Trolling results of F/RV *Tagula* in Papua waters. Papua New Guin Agric J 13(4):148-156.
- Haight WR. 1998. NMFS/JIMAR, Honolulu Laboratory. Unpublished data.
- Lewis AD, Chapman LB, Sesewa A. 1983. Biological notes on coastal pelagic fishes in Fiji. Suva, Fiji: Fisheries Division (MAF). Technical report #4.
- Myers RF. 1989. Micronesian reef fishes. Coral Graphics. 298pp.
- Okiyama M, Ueyangi S. 1977. Larvae and juvenile of the Indo-Pacific dogtooth tuna, *Gymnodarda unicolor* (Ruppell). Bull Far Seas Fish Lab 15:35-49.

Table 69. Management Unit Species: *Gymnosarda unicolor* (dogtooth tuna)

	Egg	Larvae	Juvenile	Adult
Duration			sexually mature at approximately 65cm	unknown
Diet	N/A	unknown	unlikely to be different from adult	a variety of squids, reef herbivores such as tangs and unicornfish (Acanthuridae), and small schooling pelagic species such as fusiliers (<i>Caesio</i> spp) and roundscads (<i>Decapterus</i>)
Distribution, general and seasonal	unknown	tropical and subtropical Pacific Ocean between 10EN and 20ES, with greater concentrations along shallow coastal waters of islands such as the Caroline Isl., Solomon Isl. and Vanuatu	unlikely to be different from adult	widely distributed throughout much of Indo-Pacific, from the Red Sea eastward to French Polynesia. Not found in the Hawaiian islands
Location			unlikely to be different from adults	deep lagoons and passes, shallow pinnacles and off outer reef slopes
Water column	epipelagic	epipelagic; greater numbers in subsurface tows at depths between 20-30m	epipelagic	epipelagic; occurs in mid-water, from the surface to approximately 100m

	Egg	Larvae	Juvenile	Adult
Bottom type	N/A	N/A	N/A	N/A
Oceanic features	subject to advection by prevailing currents	subject to advection by prevailing currents	unknown	unknown

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5.1.53 Bothidae/Soleidae/Pleuronectidae (flounder and soles)

Flatfishes have both eyes on one side of the body and a greatly compressed body suited for lying flat on the bottom. The eyes are situated on both sides of the head in the larvae, but migrate to one side as the larvae transforms into a benthic juvenile. The eyes migrate onto the left side for members of the family Bothidae, and onto the right side for members of the family Pleuronectidae and Soleidae. The side with no eyes settles on the bottom and remains unpigmented, while the top side can change color patterns to match the surrounding bottom.

They are ambush carnivores of small fishes and crustaceans that live on silt, sand or gravel bottoms. They are important foodfishes worldwide, where they inhabit continental shelves of tropical and temperate seas. A few species are found on shallow coral reefs: in Hawaiian waters, there are 13 species of Bothidae but only 2 common shallow species, 2 species of the genus *Samariscus* that formerly were considered a part of Pleuronectidae but now are in their own family Samaridae, and 2 species of Soleidae. In Micronesian waters, there are at least 3 species of Bothidae, one species of Pleuronectidae, and at least 5 species of Soleidae found on shallow reefs. Two sole species, *Aseraggodes borehami* and *Aseraggodes theres*, are recently described species found only in the Hawaiian Islands. Three species are recorded from Samoan waters.

Bothid eggs are pelagic, spherical, and small, with a diameter of 0.6-0.9mm. The larvae hatch at 1.6-2.6mm. Soleid eggs are pelagic, spherical and moderate in size, with a diameter of 0.9-1.8mm. The larvae range from 1.7 to 4.1mm at hatching. Larval pleuronectiform fish have symmetrical eyes, but many remain pelagic for some time after the eyes migrate. Some become quite large before settling, and often possess highly ornamented spines, elongate fin rays, or protruding guts as larval specializations (Leis & Trnski 1989). Larvae are found in the upper 100m of the water column.

Habitat for most flatfishes is soft bottoms such as sand, mud, or silt that are often found in association with coral reef habitats. Some species are found directly on the reef or within the reef framework. Many species are found in water deeper than 100m, but some are common in shallow habitats.

Bibliography

Ahlstrom EH, Amaoka K, Hensley DA, HG Moser and BY Sumida. 1984.

Pleuronectiformes: development. pp 640-670 in ASIH Spec Publ 1.

Boehlert GW. 1986. An approach to recruitment research in insular ecosystems. In IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities (D Pauly and A Yanez-Arancibia, eds), IOC Workshop rep. 40: 15-32. UNESCO, Paris.

Brownell CL. 1979. Stages in the early development of 40 marine fish species with pelagic eggs from the Cape of Good Hope. Ichthyol Bull JLB Smith Inst No. 40. 84 pp.

Hensley DA and EH Ahlstrom. 1984. Pleuronectiformes: relationships. pp. 670-68 in ASIH Spec. Publ. 1.

Houde ED and JA Lovdal. 1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. *Estuarine, Coastal Shelf Sci.* 18: 403-419.

Houde ED and RC Schekter. 1981. Growth rates, rations, and cohort consumption of marine fish larvae in relation to prey concentrations. *Rapp. P.-V. Reun., Cons. Int. Explor. Mer* 178: 441-453.

Leis JM and T Trnski. 1989. *The larvae of Indo-Pacific shorefishes.* U. of Hawaii Press: Honolulu, HI.

Liew HC. 1983. *Studies on flatfish larvae (Fam. Psettodidae, and Bothidae, Pleuronectiformes) in the shelf waters of the central Great Barrier Reef, Australia.* Unpublished M.S. thesis, James Cook University, Townsville, Australia.

Ozawa T and A Fukui. 1986. *Studies on the development and distribution of the bothid larvae in the western north Pacific.* pp 322-420 plus 23 plates in Ozawa T (ed) *Studies on the oceanic ichthyoplankton in the Western North Pacific.* Kyushu Univ Press: Fukuoka.

Table 70. Management Unit Species: Bothidae/Soleidae/Pleurnectidae (flounder and soles)

	Egg	Larvae	Juvenile	Adult
Duration		1.6 to 4.1mm at hatching		
Diet	N/A	the sole <i>Achirus lineatus</i> eats copepods, mollusc larvae, rotifers, dinoflagellates (Houde & Lovdal 1984); other species eat larvaceans, chaetognaths and copepods (Liew 1983)	similar to adult	ambush carnivores of fishes and invertebrates
Distribution, general and seasonal			similar to adult	tropical and temperate continental shelves worldwide; some species associated with coral reefs in the Indo-Pacific
Location	spawning aggregations not recorded	offshore waters	lagoons, caves, flats, reefs	lagoons, caves, flats, reefs
Water column	pelagic	pelagic; from 0-100m depth	demersal	demersal
Bottom type	N/A	N/A	similar to adult	soft bottoms such as sand, gravel, mud, and silt; some species found on reef surface or within reef framework
Oceanic features				

5.1.54 Balistidae/Monacanthidae (triggerfishes/filefishes)

The triggerfishes are named for an ability to lock their large, thickened first dorsal spine in an upright position, which can be released only by pressing down on the second dorsal spine (the trigger). They are deep-bodied fish with eyes high on the head, a long snout, a small terminal mouth, and tough skin with armor-like non-overlapping scales. Triggerfishes are usually solitary except when they form pairs at spawning time, although the black durgon *Melichthys niger* may form large aggregations. When alarmed, or at night, they wedge themselves into a hole in the reef or rocks by erecting the first dorsal spine and pelvic girdle.

During the day, most are carnivores of a wide variety of benthic animals including crustaceans, mollusks, sea urchins, other echinoderms, coral, tunicates, and fishes. Some feed largely on benthic algae and zooplankton, including *M. niger* and *M. vidua*, while *Xanthichthys auromarginatus* and *X. mento* feed mainly on zooplankton. Eleven species are known from the Hawaiian Islands. At least 20 species occur in Micronesia. At least 16 species occur in Samoa. Many species are collected for aquariums. The clown triggerfish *Balistoides conspicillum* is among the most highly prized aquarium fishes, although like most triggerfishes it is very aggressive to other fish in a tank and tends to eat all the invertebrates.

The filefishes are closely related to the triggerfishes, differing by having more compressed bodies, a longer and thinner first dorsal spine, a more pointed snout, a very small or absent second dorsal spine, and no third dorsal spine. Unlike the triggerfishes, many filefish are able to change their coloration to match their surroundings, and are frequently secretive. Some filefishes are sexually dimorphic, not in coloration so much as the size of the spines or setae posteriorly on the body. Filefishes are mostly omnivorous, feeding on a wide variety of benthic plant and animal life. Some species eat noxious sponges and stinging coelenterates that most fish avoid. Eight species occur in Hawaii, at least 17 in Micronesia, and at least 7 species occur in Samoa. Three species are endemic to Hawaii: the squaretail filefish *Cantherhines sandwichiensis*, the shy filefish *C. verecundus*, and the fantail filefish *Pervagor pilosoma*.

Sexual dimorphism is widespread, though not universal, in the triggerfishes. The male is typically more brightly colored and larger, as in *X. auromarginatus*, *X. mento*, *B. undulatus*, *B. vetula*, *Odonus niger*, *Pseudobalistes fuscus*, *Hemibalistes chrysopterus*, and *M. niger* (Berry & Baldwin 1966, Randall et al. 1978, Matsuura 1976, Breder & Rosen 1966, Aiken 1975, Fricke 1980). Sexual dimorphism is less common in the filefishes, in which males and females tend to be drabber. There is some evidence of lunar spawning periodicity for balistids. At Belau, the yellowmargin triggerfish *Pseudobalistes flavimarginatus* spawns in nests in sand-bottom channels within a few days before both new and full moons during the months of November, December, March, April, and May, if not throughout the year (Myers 1989). Balistids produce demersal eggs that may or may not be tended by a parent, usually

the female. They are one of the, if not the only, reef fish families that have extensive maternal care. This could be related to a harem-based social structure that requires the male to vigorously defend his territory from other males. Balistid eggs are spherical, slightly over 0.5 mm in diameter, and translucent. Eggs are typically deposited in shallow pits excavated by the parents as an adhesive egg mass containing bits of sand and rubble. Triggerfish eggs hatch in as little as 12 hours and no more than 24 hours. Filefish eggs may take longer to hatch, up to 58 hours. The pelagic larval stage can last for quite a while, and some species reach a large size before settling to the bottom. Several species of *Melichthys* can reach as much as 144 mm before settling (Randall 1971, Randall & Klauswitz 1973). Prejuveniles are often associated with floating algae, and may be cryptically colored. Berry and Baldwin (1966) suggested that sexual maturity of *Sufflamen verres* and *Melichthys niger* occurs at approximately half maximum size, at an age of a year or more. Smaller filefishes may mature within a few months after hatching.

Bibliography

- Aiken KA. 1983. The biology, ecology, and bionomics of the triggerfishes, Balistidae. ICLARM Stud. Rev. 7: 191-205.
- Baldwin. 1966. Triggerfishes of the eastern Pacific. Proc. Calif. Acad. Sci., 4th Ser. 34: 429-474.
- Breder CM and DE Rosen. 1966. Modes of reproduction in fishes. Natural History Press, Garden City, NY. 941 pp.
- Fricke HW. 1980. Mating systems, maternal and biparental care in triggerfish. Z. Tierpsychol. 53: 105-122.
- Matsuura K. 1976. Sexual dimorphism in a triggerfish, *Balistipus undulatus*. Japan J. Ichthyol. 23: 171-174.
- Myers, R.F. 1989. Micronesian reef fishes. Coral Graphics, Guam.
- Randall JE. 1971. The nominal triggerfishes *Pachynatus nycteris* and *Oncobalistes erythropterus*, junior synonyms of *Melichthys vidua*. Copeia, 1971: 462-469.
- Randall JE, K Matsuura and A Zama. 1978. A revision of the triggerfish genus *Xanthichthys*, with description of a new species. Bull. Mar. Sci. 28: 688-706.
- Randall JE and W Klauswitz. 1973. A review of the triggerfish genus *Melichthys*, with description of a new species from the Indian Ocean. Senckenberg. biol. 54: 57-69.

Table 71. Management Unit Species: Balistidae/Monacanthidae (triggerfishes/filefishes)

	Egg	Larvae	Juvenile	Adult
Duration	12-24 hours for triggerfish, up to 58 hours for filefish	several months, can grow up to 144 mm before settling (Randall & Klausewitz 1973)	one or more years	
Diet	N/A	various plankton	similar to adult	carnivores of a wide variety of benthic animals including crustaceans, mollusks, sea urchins, other echinoderms, coral, tunicates, and fishes. Some feed largely on benthic algae and zooplankton
Distribution, general and seasonal	At Belau, the yellowmargin triggerfish <i>Pseudobalistes flavimarginatus</i> spawns within a few days before both new and full moons during the months of November, December, March, April, and May, if not throughout the year (Myers 1989)		similar to adult	tropical and temperate seas worldwide; 11 species are known from the Hawaiian Islands. At least 20 species occur in Micronesia. At least 16 species occur in Samoa.
Location	many spawn on sand or other soft-bottom habitats		Juvenile <i>B. conspicillum</i> usually occur in or near ledges and caves of steep dropoffs below 20m (Myers 1989)	lagoon and seaward reefs; many prefer steeply sloping areas with high coral cover and a lot of caves and crevices; zooplanktivores spend day in the water column
Water column	demersal	pelagic	demersal and pelagic	some species in very shallow water, 2-

	Egg	Larvae	Juvenile	Adult
				20m while others as deeper than 100m
Bottom type	sand, mud, rubble	N/A	similar to adults	coral reef, rock, sand
Oceanic features		subject to advection by ocean currents		

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5.1.55 Ostraciidae (trunkfish)

The trunkfishes, or boxfishes, possess a bony carapace of polygonal plates that encase the head and body. The bony shell may be triangular, quadrangular, pentagonal, hexagonal, or nearly round in cross-section. Some species have stout spines projecting from the rough surface of the plates. The mouth is small and low with thick lips and a row of conical to incisiform teeth with rounded tips. Trunkfishes are slow swimming diurnal predators that feed on a wide variety of small sessile invertebrates, especially tunicates and sponges, and algae. Some species, and perhaps all, secrete a skin toxin when under stress. Some species, and perhaps all, are protogynous hermaphrodites. Sexual dichromatism is common in the family. The species studied thus far are harem with males defending a large territory with non-territorial females and subordinate males. Spawning in pairs occurs at dusk, usually above a conspicuous outcrop. In Hawaiian waters, 6 species are recorded and the spotted boxfish *Ostracion meleagris camurum* is recognized as a subspecies. In Micronesian waters, 6 species are recorded. In Samoan waters, 3 species are recorded.

Leis (1978) described the eggs of Hawaiian ostraciids as slightly oblong, with less than 10 oil droplets, and a patch of bumps at one end. However, Mito (1962) described eggs from Japanese waters as 1.62-1.96mm in diameter with a single oil droplet. A western Atlantic species *Acanthostracion quadricornis* had spherical eggs, 1.4 to 1.6mm in diameter that hatched in about 48 hours at 27.5EC. About 114 hours after hatching, it reaches a distinctive square armor-plated postlarval stage. Postlarvae and juveniles are commonly collected in grassbeds and other shallow areas and are rarely seen on the reef (Thresher 1984). Juveniles of *Ostracion*, on the other hand, are commonly seen on shallow reefs, especially in late summer.

The longhorn cowfish, *Lactoria cornuta*, occurs over sand and rubble bottoms of subtidal reef flats, lagoons, and bays to a depth of 50m. It feeds on polychaetes and other benthic invertebrates, often blowing sand off the bottom to expose the prey. The thornback cowfish *Lactoria fornasini* inhabits sandy areas with rubble, algae, or corals of clear outer lagoon and seaward reefs. The spotted trunkfish *Ostracion meleagris* occurs on clear lagoon and seaward reefs from the lower surge zone to 30m, where it feeds on didemnid tunicates as well as smaller amounts of polychaetes, algae, sponges, mollusks, and copepods. They are sexually dimorphic, with males taking a bright blue and yellow form upon sex-reversal from a female to male.

Bibliography

Leis JM. 1978. Systematics and zoogeography of the porcupinefishes (Diodon, Diodontidae, Tetraodontiformes) with comments on egg and larval development. Fish. Bull. 76: 535-567.

Leis JM and JT Moyer. 1985. Development of eggs, larvae and pelagic juveniles of three Indo-Pacific ostraciid fishes (Tetraodontiformes): *Ostracion meleagris*, *Lactoria fornasini*, and *L. diaphana*. Japan. J. Ichthyol. 32(2): 189-202.

Mito S. 1962. Pelagic fish eggs from Japanese waters. 8. Chaetodontina, Balistina and Ostraciotina. Sci. Bull., Fac. Agric. Kyushu U. 19: 503-506.

Moyer JT. 1979. Mating strategies and reproductive behavior of ostraciid fishes at Miyakejima, Japan. Japan. J. Ichthyol. 26: 148-160.

Randall JE. 1972. The Hawaiian trunkfishes of the genus *Ostracion*. Copeia, 1972: 756-768.

Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.

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Table 72. Management Unit Species: Ostraciidae (trunkfishes)

	Egg	Larvae	Juvenile	Adult
Duration	48 hrs for <i>A. quadricornis</i> (Thresher 1984)	fairly short in general; 114 hrs in <i>A. quadricornis</i> in the Caribbean (Thresher 1984), but Moyer (1980) reported much older pelagic larvae, up to 90mm long		
Diet	N/A		similar to adults	small sessile invertebrates, especially didemnid tunicates and sponges, but also polychaetes, algae, sponges, mollusks, and copepods; also algae
Distribution, general and seasonal				
Location		offshore	grassbeds and other shallow areas	coral reefs, lagoon and seaward reefs
Water column	pelagic	pelagic	demersal and mid-water column	demersal and mid-water column, well defended from predators
Bottom type	N/A	N/A	similar to adults;	sandy areas with rubble, algae, or corals

	Egg	Larvae	Juvenile	Adult
Oceanic features	subject to advection by prevailing currents	subject to advection by prevailing currents		

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5.1.56 Tetradontidae/Diodontidae (puffers/porcupinefishes)

Puffers are named for their ability to enlarge their bodies by drawing water into a highly distensible ventral diverticulum of the stomach. That feature, prickly skin, and a powerful toxin concentrated in their viscera, gonads, and skin helps them deter predators. Toxicity varies greatly with species, area, and season. Puffers have the teeth in their jaws fused to beak-like dental plates with a median suture. Most are slow swimmers that feed on a wide variety of algae and benthic invertebrates, including fleshy, calcareous or coralline algae and detritus, sponges, mollusks, tunicates, corals, zoanthid anemones, crabs, hermit crabs, tube worms, sea urchins, brittle stars, starfishes, hydroids, bryozoans and foraminifera. All species known to date lay demersal eggs. At least one species of *Canthigaster*, *C. valentini*, is harem with males controlling a territory containing 1-7 females. The males spawn at mid-morning with a different female each day, and the eggs are deposited in a tuft of algae. Most puffers are solitary but a few form small aggregations. In Hawaiian waters, there are 14 species recorded, with 2 endemics: *Canthigaster jactator* and *Torquigener randalli*. In Micronesian waters, there are at least 17 species. In Samoan waters, 18 species are recorded.

Much of the information on puffer reproduction has been completed in temperate locations, but some reasonable assumptions can be made about tropical species. Puffers lay demersal adhesive eggs, although courtship is often observed near the surface. The eggs are typically on their own after being deposited, and take approximately 4 days to hatch in *C. valentini* (Gladstone 1985). Newly hatched larvae range in size from 1.9 to 2.4mm. Settlement to the bottom can occur in a little over 30 days, but some species have a much longer pelagic existence.

Porcupinefishes are similar to puffers in many ways, but differ primarily in having prominent spines on the head and body. They also have larger eyes, broader pectoral fins, and lack a median suture on the dental plates. Hard, beak-like jaws allow them to crush the hard shells of mollusks or crustaceans, or tests of sea urchins. They appear to be nocturnal. Spawning has been observed in *Diodon holacanthus*, which spawns at the surface at dawn or dusk as pairs or groups of males with a single female. In Hawaiian waters, 3 species have been recorded. In Micronesian waters, 3 species are known, although one, *Diodon eydouxi*, is entirely pelagic. The juveniles of *D. hystrix* and *D. liturosus* are pelagic as well.

Porcupinefish in Hawaii have a peak in spawning in the late spring, with some spawning from January to September (Leis 1978). Courtship and spawning by *Diodon holacanthus* has been observed in a large public aquarium (Sakamoto & Suzuki 1978) and in the Gulf of California (Thresher 1984). Diodontid eggs are spherical, 1.62 to 2.1 mm in diameter, and may be demersal or pelagic. Hatching occurs in 4-5 days. Leis (1987) reported metamorphosis at a length of 3 mm and an age of 3 weeks to a postlarval stage similar in appearance to the adult. The duration of the larval stage may be several months. Very large

prejuveniles (up to 86 mm for *D. holacanthus* and 180 mm for *D. hystrix*) are common in plankton tows.

Bibliography

- Allen GR and JE Randall. 1977. Review of the sharpnose pufferfishes (subfamily Canthigasterinae) of the Indo-Pacific. *Rec. Aust. Mus* 30: 475-517.
- Fujita S. 1956. On the development of the egg and prelarval stages of the puffer, *Fugu* (Shosaifugu) *stictonotus* (Temminck et Schlegel). *Sci. Bull. Fac. Agri., Kyushu Univ.* 15: 525-530.
- Gladstone W. 1985. Behavioral ecology of the sharpnose pufferfish, *Canthigaster valentini* (Bleeker), at Lizard Island, Great Barrier Reef. Unpub. PhD thesis, Macquarie U., North Ryde, Australia.
- Kuthalingham MDK, G Luther and JJ Joel. 1973. On some growth stages and food of *Arothron stellatus* (Bloch)(Tetraodontidae:Pisces). *Indian J. Zool.* 20: 240-243.
- Leis JM. 1978. Systematics and zoogeography of the porcupinefishes (*Diodon*, Diodontidae, Tetraodontiformes) with comments on egg and larval development. *Fish. Bull.* 76: 535-567.
- Sakamoto T and K Suzuki. 1978. Spawning behavior and early life history of the porcupine puffer, *Diodon holacanthus*, in aquaria. *Japan. J. Ichthyol.* 24: 261-270.
- Thresher, R.E. 1984. *Reproduction in reef fishes*. T.F.H. Pub., Neptune City, NJ.

Table 73. Management Unit Species: *Tetradontidae/Diodontidae* (Puffers/Porcupinefishes)

	Egg	Larvae	Juvenile	Adult
Duration	4-5 days	several months or longer	size at settlement of 180-191mm (Leis 1987)	
Diet	N/A	various zooplankton	similar to adult	wide variety of algae and benthic invertebrates, including fleshy, calcareous or coralline algae and detritus, sponges, mollusks, tunicates, corals, zoanthid anemones, crabs, hermit crabs, tube worms, sea urchins, brittle stars, starfishes, hydroids, bryozoans and foraminifera
Distribution, general and seasonal			same as adults	worldwide throughout tropical and temperate seas
Location	pelagic or demersal depending on species	pelagic	estuaries, mangroves, lagoons, coral reefs	estuaries, mangroves, lagoons, coral reefs
Water column	puffers are demersal spawners, porcupinefish may spawn pelagic or demersal eggs	pelagic; 0-100m	reef-associated and pelagic	reef-associated and pelagic

	Egg	Larvae	Juvenile	Adult
Bottom type	reef, sand, or algae tufts	N/A	sand, silt, coral, rock	sand, silt, coral, rock
Oceanic features		subject to advection by ocean currents		

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5.2 EFH for Management Unit Species - Invertebrates

5.2.1 Cephalopods

General Description of the Taxonⁱ

The cephalopods (Class Cephalopoda of the Phylum Mollusca) comprise a relatively small group of organisms that includes squid, octopods, cuttlefish, and nautilus. Although certain members of the class (e.g., the octopods) are for the most part bottom-dwellers, the majority are adapted for a free-swimming lifestyle. The head projects into a circle of large prehensile tentacles or arms, which are homologous to the anterior of the foot of other mollusks. The tentacles are used for various functions, including seizing prey, grasping the substrate, and for copulation and fertilization. Most cephalopods swim by jet propulsion, rapidly expelling water from the mantle cavity through a ventral tubular funnel. The funnel is highly mobile and can be directed either anteriorly or posteriorly. The force of water leaving the funnel propels the animal in the opposite direction, enabling both backward and forward swimming.

Certain species of squid have attained the highest speed of movement through water observed for any marine invertebrate (up to 40 km per hour). (Barnes 1987; Nesis 1987). Within the class, only members of the genus *Nautilus* (in Subclass Nautiloidea) have a true external shell. All other cephalopods belong to the subclass Coleoidea, in which the shell is reduced and internal, or lacking altogether. In squids, for example, the shell is reduced to a long, flattened chitinous Apen@ or gladius, while in cuttlefish the internal shell, the sepion, is thicker and calcareous. In certain generaC*Nautilus*, *Spirula*, and *Sepia*Cthe gas-filled chambers of their shells allow for maintenance of neutral buoyancy within the water column. Many species exhibit diurnal vertical migration, moving upward to feed during the night and into deeper water during the day (Barnes 1987; Nesis 1987).

Reproduction and Life History

Cephalopods are dioecious, with a single gonad positioned at the posterior end of the body. Sperm are conducted through the vas deferens to a ciliated seminal vesicle, where the sperm are rolled together and encased in spermatophores. The spermatophores are then transported to a storage sac which opens into the mantle cavity. In females, the oviduct terminates in an oviductal gland. Octopods and some squid may have two oviducts.

Fertilization may occur within the mantle cavity or outside. One of the arms of the male is highly modified into a copulatory organ, the hectocotylus. During copulation, while the male grasps the female with the regular arms, the hectocotylus receives spermatophores from the funnel (opening of the vas deferens), or plucks them from the storage sac. The hectocotylus may be inserted into the mantle cavity, and spermatophores are deposited on the mantle wall of the female, near the openings of the oviducts. In *Octopus*, the hectocotylus is inserted into the genital duct. In some squid, the hectocotylus may be inserted into a seminal receptacle located in a fold beneath the mouth for deposition of spermatophores.

Eggs are discharged from the oviduct, then surrounded by a paired membrane or capsule. In some genera eggs may be surrounded by a gelatinous mass. In most cases, eggs are either attached by the female to a stable substrate, or shed into the seawater. Sepioids may attach the single eggs by means of a flexible threadlike stalk, which the female wraps around the blades of seagrasses or seaweeds (Pearse et al. 1987).

Embryonic development is considered direct, that is, there is no trochophore or larval phase. However, newly-hatched cephalopods may remain planktonic for a time. In the octopods, those species in which hatchlings are less-developed may first go through a planktonic phase and then settle down to a benthic existence, while those species in which the newly-hatched offspring are well-developed may immediately take up a benthic lifestyle (Pearse et al. 1987). The degree of development at hatching may be related to the size of the egg, since Young and Harman (1989) noted that species with small eggs include a paralarval (planktonic) phase, while those with larger eggs, do not.

Most cephalopods are relatively short-lived (typically one- to two-year lifespan), dying after a single spawning, while certain members such as *Nautilus*, may live longer (up to twenty years; Barnes 1987).

Habitat and Ecological Requirements for Various Life History Stages

Substrate and Depth Preferences

Nautilus occur in waters down to 500 m depth, but generally occur at depths from 200-300m. The few observations made of nautilus in the ocean suggest that they spend the day resting in coral crevices on deep reefs, attached by their tentacles, and swim out at night to feed (Pearse et al. 1987). They may rise to within 60-100m during nighttime (B. Carlson, Waikiki Aquarium, pers. comm., 27 Aug 99).

Cuttlefishes are generally found in shallow waters of seagrass beds and nearby reefs. Some species may bury themselves in the sand during the day, and emerge at night to hunt for the small fishes and crustaceans that are their preferred prey.

Octopods generally inhabit crevices in rocks or coral areas. In sandy areas, they may dig burrows or construct shelters built from scattered rocks.

Substrates utilized for the deposition of eggs may vary for different taxa, but it appears that there is some correlation with the habitats utilized for shelter by the species in question. Thus octopods may attach egg clusters within rocky recesses on the reef, while cuttlefish may attach their eggs to seaweeds or seagrasses.

The reef squid, *Sepioteuthis lessoniana*, uses corals and rocks of reef areas for egg-laying, and swims over the reef in shallow areas to feed. The reef cuttlefish, *Sepia latimanus*,

deposits its eggs deep among the branches of heads of finger coral (B. Carlson, pers. comm. 27 Aug 99).

Feeding

Within the cephalopod group are found a range of feeding habits and food preferences. Free-swimming squids typically hunt for fish, crustaceans, and other squids in open water. Cuttlefish swim near the bottom in shallow water, stir up sand with jets from their siphons, and feed on benthic and infaunal invertebrates, including crustaceans such as shrimps and crabs. Octopods venture out of their dens in search of food, and may swim and crawl more than 100m from their holes. Octopods often hunt by jumping to ambush their prey, which include principally crabs and shrimps. In Hawaii, one of the most common species, *Octopus cyanea*, forages during the day (hence the name day squid), while another *O. ornatus* (the night squid), forages after dark (Kay 1979). Squid bite and tear prey organisms with their jaws; cuttlefish first immobilize prey by injecting salivary toxins, and then chew their prey; while octopods, which also first paralyze their prey with salivary toxins, release enzymes that start to digest the tissue of the target prey prior to ingestion. It is thought that nautilus scavenge on such food items as crab and lobster molts; it is not known whether they also prey on live organisms (B. Carlson, pers. comm. 27 Aug 99).

Economic Importance and Utilization of the Resource

Within the region, cephalopods, especially squid, cuttlefish, and octopus, have some economic importance as food items in the subsistence fishery. Octopus are a component of the incidental catch of the lobster-trap fishery in the Northwest Hawaiian Islands (NWHI; WPRFMC 25 May 99). In addition, shells of *Nautilus* may be used for ornamental purposes on a small scale, either by utilizing the whole or cut shell, or processing for production of mother-of-pearl. The meat is also occasionally sold in markets (Roper et al. 1984). The internal shells (cuttlebones) of sepioids may also have limited commercial value for use in the pet supply industry.

Occurrence of the Taxon Within WPRFMC Fishery Management Units (FMUs)

The following is an account of those cephalopod species reported in the literature that may occur on reef areas within the jurisdictional waters of WPRFMC.

American Samoa

On Tutuila Island, it was reported that octopus accounted for approximately five percent of the catch composition for the shoreline subsistence fishery (Craig et al. 1993).

Nautilus pompilius is known to occur in American Samoa. This may represent the easternmost extension of its range (B. Carlson, pers. comm. 27 Aug 99).

Commonwealth of Northern Mariana Islands (CNMI)

Octopus (*Octopus cyanea* and *O. ornatus*), squid (*Sepioteuthis lessoniana*), and cuttlefish (*Sepia latimanus*) are reef-associated species² commonly taken as food in the Marianas (Myers 1997 in Green October 1997). *Octopus cyanea* was identified as a species found on the reef slope at Rota, and targeted for capture in the local fishery (Smith et al 1989).

Guam

It is reported that on Guam, the octopus is the most sought-after unshelled mollusk, while squid and cuttlefish form a part of the incidental catch of the inshore fisheries (Hensley and Sherwood 1993). Octopus and squid are reported to contribute to the importance of mollusks as a food source (Amesbury et al. 1986 in Green October 1997). *Sepia latimanus* is reported from Guam (B. Carlson, pers. comm. 27 Aug 99). Presumably, other cephalopod species reported in the Northern Marianas (i.e., *Octopus cyanea*, *O. ornatus*, *Sepioteuthis lessoniana*) would be expected to occur in Guam, as well.

Hawaii (MHI and NWHI)

The following octopod species are known from Hawaiian waters: *Octopus cyanea*, *O. ornatus*, *Beryia hoylei* and *Scaevurgus patagiatus*. An additional three unnamed species are believed present (Young and Harman 1989). Octopus are a component of the incidental catch of the lobster-trap fishery in the Northwest Hawaiian Islands (WPRFMC 25 May 99). An unnamed species of octopus is known from Waianae, Oahu. It occupies burrows in sandy areas. The burrows have openings about the diameter of a thumb. It is not known whether the octopus digs the burrow, or simply occupies a burrow already dug by another animal (e.g., mantis shrimp). This octopus emerges from its burrow and mimics a flatfish (B. Carlson, pers. comm. 27 Aug 99).

While more than a dozen species of squids and cuttlefishes are recorded from Hawaiian waters (Matsumoto and Suzuki October 1988), most of these are pelagic. *Euprymna scolopes*, an endemic cuttlefish, is typically associated with a benthic existence in shallow-water areas. The species is common in the sand and mud flats of Kaneohe Bay, where it forages to feed on shrimp (*Leander debilis*) at depths of less than 0.5m (Kay 1979).

In Hawaii, *Sepioteuthis lessoniana*, the bigfin reef squid, was previously common, but may now be nearly extirpated. It had been known from Waianae, Oahu. A recent sighting of the species was made on Molokini Island, Maui (B. Carlson, pers. comm. 27 Aug 99).

¹ The octopods are well-known reef-dwellers. The common names for *Sepioteuthis lessoniana* and *Sepia latimanus*, bigfin reef squid and reef cuttlefish, respectively, reflect their association with reef areas (Allen and Steene 1996).

Other Sites

No reports.

5.2.2 TunicatesGeneral Description of the Taxon

The tunicates, or sea squirts, are an unusual group of sessile marine organisms within the Phylum Chordata. While vertebrates comprise the most conspicuous and well-known species in the phylum, species in two subphyla (the Urochordata and Cephalochordata) lack backbones. Nonetheless, they possess the three traits diagnostic for chordates--presence of a notochord, a dorsal hollow nerve cord, and pharyngeal clefts at some point in the life cycle. The Urochordata, which comprise the tunicates, are further divided into three classes, the Ascidiacea, the Larvacea, and the Thaliacea, the latter two being specialized planktonic forms (Abbott et al. 1977). The discussion in this section therefore refers to members of the Class Ascidiacea.

The ascidians are common marine invertebrates worldwide. Most inhabit shallow waters, where they attach to rocks, shells, pilings, or ship bottoms, or grow epizoidally on other sessile organisms. Some forms anchor in sand or mud, though the species inhabiting sediments occur more generally in deeper waters.

The tunicate animal is sheathed in an outer covering, the tunic that is distinctive for the group. The tunic in most cases contains cellulose, a rare instance of the substance being produced by an animal. Calcareous spicules may also be present. The consistency of the tunic varies from soft and gelatinous to fleshy, tough, leathery, cartilaginous, or fibrous. Tunicates are attached to the substrate at their proximal end, and have two openings at the opposite pole, the buccal and atrial siphons. The organisms filter plankton by drawing water into a pharyngeal basket through the buccal siphon (ICLARM 1998).

The pharyngeal basket is the most prominent internal organ in most tunicates. Rows of perforations in the basket, the stigmata, are fringed with beating cilia that circulate water through the basket, with plankton filtered out in the process. A single tunicate a few centimeters long can filter about 173 liters of seawater in a 24-hour period (Barnes 1987). The filtered water is ultimately discharged through the atrial siphon. In addition to obtaining nutrition through filter-feeding, some tunicates possess within their tissues (in the tunic or cloacal region) endosymbiotic algae of the genus *Prochloron*. In certain ascidians, another algal endosymbiont, *Synechocystis*, occurs. This alga imparts a pink or red color to the appearance of the tunicate Monniot et al. 1991). Presumably, excess photosynthate produced by *Prochloron* or *Synechocystis* cells provides an accessory food source for the tunicate host.

While some of the largest species are solitary (or simple) ascidians, many are colonial. Colonies may be organized along several different lines. In the simplest colonies (e.g.,

Perophora), the bodies of individual zooids are almost completely separated but are connected by a stolon. In other types, the stolons are short, and the individuals form tuftlike groups (e.g., *Clavelina*). In the most specialized colonial types (e.g., *Botryllus*), individual animals are minute, and completely embedded in a common tunic. The buccal siphons of each zooid open separately to the environment. The atrial siphons may also, but in many cases the apertures of the atrial siphons open into a common cloacal chamber, which has one large opening in the middle of the colony (Barnes 1987; Abbott et al. 1977).

Reproduction and Life History

Patterns of sexual reproduction vary from one family to another, and sometimes from one genus to another, within the class. For the most part, solitary and colonial ascidians are simultaneous hermaphrodites (Abbott et al. 1977). The degree to which self-fertilization occurs is not well known. Typically, solitary ascidians release both eggs and sperm into open water, where fertilization occurs. The embryo develops into a non-feeding, swimming larva, or tadpole. It is in the tadpole phase (which superficially resembles a typical frog tadpole) that the notochord and dorsal nerve cord, which characterize these organisms as chordates, are present. However, these features are lost during metamorphosis, and are absent in the adult phase. Colonial forms are ovoviviparous: sperm are shed to the sea, but not eggs. Fertilization in these types occurs within the oviduct or peribranchial cavity of the female parent, and the tadpole larvae emerge swimming, following development inside the parent body (Monniot et al. 1991). The larvae are completely encased in a tunic, and the buccal and atrial siphons are not functional. Thus the larvae are unable to feed; their prime function is to quickly find a suitable substrate to settle on. Therefore, tadpole larvae may only swim for a few minutes to a few days (Pearse et al. 1987). Following settlement, metamorphosis to the adult phase generally entails resorption of the tail and other larval structures, 180-degree rotation of the body to its adult posture, opening of the siphons, development of the brancial sac, and formation of the adult nervous system (Monniot et al. 1991).

In addition to sexual reproduction, the tunicates can reproduce asexually by budding. Budding individuals, or blastozooids, originate in different parts of the ascidian body, depending on the species. Individuals produced by primary buds are eventually freed from the parent colony (Barnes 1987). In addition to budding, colonial forms may undergo continuous divisions into smaller units termed cormomeres. The division entails rapid and dynamic movement of the colonies over the substrate. In addition to accomplishing the actual physical separation of the colony fragments, it is thought that this form of division may serve some other purposes as well, including maximizing periphery to area (which may improve efficiency of feeding or growth), excluding competitors by the dynamic movement involved; and mingling clones to facilitate cross-fertilization (Ryland et al., 1984).

Typically, tunicates may live for 1-3 years, but some colonies may have a somewhat longer life span (Barnes 1987).

Habitat and Ecological Factors

Finding a stable substrate is critical for the survival of settling tunicates. Thus, inert surfaces of rocks, corals or pilings may be preferable to the less durable surfaces of seaweeds, mangrove roots, or other sessile invertebrates (soft corals, sponges, other tunicates), though all of these may provide surfaces for tunicates to grow on. Many tunicates (especially the more delicate soft-bodied forms) also show a marked preference for growth in protected pockets or crevices, as opposed to exposed areas of the reef crest or face, where they would be subject to extreme variations in water movement, and possibly, greater predation by grazing animals. When they do occur in such places, tunicates are often covered by epibionts that may afford some camouflage and physical protection (Monniot et al. 1991).

Light and color of the substrate may be physical cues that influence larval settling, with darker, less illuminated surfaces being the preferred substrates. However, some forms, especially didemnids containing the endosymbiotic alga, *Prochloron*, can grow as high up as the intertidal zone, where light is most intense (Ryland et al. 1984). In addition, it is believed that certain chemicals may trigger initiation of various processes, including spawning, metamorphosis, larval attraction, and repulsion of predators or epibionts. For example, chemicals exuded by parent zooids may cause larvae to settle nearby, increasing the likelihood that larvae will find a suitable settlement substrate (Monniot et al. 1991).

As filter-feeders, tunicates are dependent upon the availability of adequate suspended food particles in the water column. Tunicate growth on outer reef slopes may be relatively more limited than within enclosed bays or lagoons, since phytoplankton may be less abundant there. Ovoviviparous colonial types are better suited to growth on outer slopes than are solitary forms, since larvae are protected during development and the free-swimming stage is very brief. By contrast, within lagoons, both solitary and colonial types are fairly abundant. Solitary forms seem to dominate in colonizing newly-available surfaces in disturbed areas (for example, in harbors), but typically species diversity in such settings is low (Monniot et al. 1991). Dominance of the solitary forms may be due to the fact that their larvae are released in greater numbers, and spend a longer time in the free-swimming phase, than larvae of colonial types.

Tunicates are not selective about the types of particles that are ingested in filter-feeding, and in waters with a high sediment load, silt and other mineral particles may accumulate in the pharyngeal basket and the digestive tract. If excessive, the silt may clog the pharynx and suffocate the animal.

Economic Importance

With minor exceptions,³ ascidians are not presently utilized for any economic purposes. However, over the last twenty years or so, considerable research efforts have been directed at isolating and identifying compounds from tunicates that may have some cytotoxic activity, and thus some future medical value. For example, didemnins extracted from *Trididemnum solidum* are effective anti-cancer agents and may also have anti-viral properties (Monniot et al. 1991). Alkaloids and peptides, derivatives of amino acids, have also been isolated from tunicates. Some of these have antimicrobial properties (Lee et al., 1997; Zhao et al., 1997). Other proteinaceous compounds derived from tunicates may play a role in mediating responses in the immune system (Pancer et al., 1997; Pancer et al., 1993). *Lissoclinum bistratum*, a tunicate from New Caledonia that contains within its tissues endosymbiotic *Prochloron* algae, has been the source of polyethers that have strong effects on the nervous system. It remains to be determined whether the embedded *Prochloron* algal cells, rather than the tissues of the tunicate animal itself, are the source of these compounds (Monniot et al., 1991). It is speculated that in life, tunicates may utilize cytotoxic compounds to ward off predators or repel epibionts (Muller et al., 1994).

The ascidians are important members of the community of marine fouling organisms. The solitary tunicates seem to be especially opportunistic in colonizing freshly-exposed surfaces of pilings, docks, other harbor structures, and boat hulls. Ascidians and other fouling organisms interfere with boat operations and normal function such equipment as cooling water intakes. On hulls, fouling organisms cause additional drag of vessels as they move through the water. Significant effort and money are spent in developing effective means for deterring the growth of fouling organisms, and for eliminating them from boat hulls and other structures. Recently, great concern has developed about the transoceanic transport of tunicate species to areas where they are not indigenous, typically by attachment to boat hulls or being carried in bilge water. Introduction of exotic species transported in this manner can be disruptive of the balance of species in natural communities.⁴ Among the Hawaiian species discussed by Abbott (1977), many are potential fouling organisms, with *Polyclinum constellatum*, *Diplosoma listerianum*, *Ciona intestinalis*, *Corella minuta*, *Ascidia sydneiensis*, *Phallusia nigra*, *Symplegma oceania*, *Polyandrocarpa zorritensis*, *Styela canopus*, *Herdmania momus* being the most prevalent.

³ In some countries, certain larger species are consumed as a food item.

⁴ Biological Resources Division, US Geological Service, Nonindigenous Tunicate Information Website.

While ascidians typically will settle only on dead parts of coral, once established they may overgrow and smother adjacent living coral tissue (Monniot et al. 1991). The encrusting colonial tunicate, *Diplosoma similis*, has an extremely wide range in the tropical Western Pacific, and is known to overgrow large areas of living *Acropora* coral and the coralline alga, *Hydrolithon* (Littler and Littler 1995). This can cause indirect economic consequences, since such overgrowth of living coral areas can reduce the productivity of the reef, reducing the potential for fisheries.

Occurrence of the Taxon Within WPRFMC Fishery Management Units (FMUs)

Little information is available on occurrence of ascidians in the Pacific Islands. Data from the few citations located are presented here.

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

Abbott et al. (1977) mention that *Polyclinum vasculosum*, has been reported widely in the Pacific, including from the Marianas.

Guam

The ascidian fauna of Guam is not well-known. As the result of some recent surveys, work is in progress to more accurately assess and describe the fauna (pers. comm. Gretchen Lambert, California State University, Fullerton 19 Aug 99).

Hawaii (MHI and NWHI)

Eldredge and Miller (1995) report a total of 45 species from Hawaii, but give no firm indications about how many might be endemic or introduced species. Abbott et al. (1977) report species from Hawaii in the following families: Polyclinidae (4 species); Polycitoridae (4); Didemnidae (11); Cionidae (1); Perophoridae (4); Corellidae (1); Ascidiidae (6); Styelidae (10); Pyuridae (3). All the growth forms discussed above are represented, and these taxa occupy a corresponding range of substrates. *Diplosoma similis*, the species that overgrows live reefs, is among the tunicates reported from Hawaii.

Other Sites

No reports.

5.2.3 Bryozoans

General Description of the Taxon

The Phylum Bryozoa is a taxonomically problematic group. While authorities have variously regarded them as including (Ehrenberg [1831]) or excluding (Hyman [1959]) the Entoprocta (a group of sessile organisms that superficially resemble hydroids), the Bryozoa

as considered here refer only to the Ectoprocta. This group is comprised of colonial, sessile animals, with the vast majority occurring in marine environments. They have formed an important component of the fossil record since the Ordovician period. Though widespread on tropical reefs, bryozoans are often not recognized because they occur in mixed associations with algae, hydroids, sponges, and tunicates, especially on older portions of coral reefs (Soule et al. 1987).

The Bryozoa comprise the largest of four phyla of invertebrates that possess a lophophore. The lophophore is a fold of the body wall that encircles the mouth and bears numerous ciliated tentacles. Through the movement of the cilia, a water current is generated that drives plankton into the mouth of the bryozoan animal. The individual animals of the colony, or zooids, have a large coelom and a U-shaped digestive tract, with the anus opening to the outside of the lophophore tentacle circle (hence, Ectoprocta). Organs for gas exchange, circulation, and excretion are absent, probably owing mostly to the small size of the animals, which would allow for direct exchange of nutrients and wastes.

The phylum is divided into three classes, with Class Gymnolaemata containing most of the living marine species. Other marine types are contained within the order Cyclostomata in Class Stenolaemata (Ryland 1970). While some Bryozoa occur at great depths, the majority are found in shallower coastal waters, where they grow attached to rocks, corals, shells, other animals, wood (e.g., mangrove roots), or algae. Growth habit may be stoloniferous, foliose, branching, or encrusting. Large colonies may consist of more than two million individual zooids, and may reach up to 24 cm in height for erect species, and up to 50 cm diameter for encrusting forms (Barnes 1987). While various species are recognized on a gross level by their growth habit, to some degree, growth form is mediated by environmental conditions, so that within any given taxon, a range of variation in the form of the colony may occur (Soule et al. 1987).

The Gymnolaemata are divided into two distinct orders. The Ctenostomata, or ctenostomes, contain stoloniferous or compact colonies in which the exoskeleton is membranous, chitinous, or gelatinous. Usually, the terminal aperture of the zooid is open (i.e., lacks an operculum). In contrast, the Cheilostomata, or cheilostomes, have boxlike calcareous walls. A hinged, moveable operculum covers the aperture of the zooid in most cheilostome species. The operculum opens when the lophophore is extended for feeding, and shuts when the animal withdraws into the calcareous chamber of the zooecium (the colonial skeleton). Specially modified zooids are the avicularia, with movable jaw-like parts that serve to repel predators, and vibracula, with setae or bristles that are used to prevent accumulations of silt. The marine Stenolaemata, the cyclostomes, are considered more primitive in organization than the Gymnolaemata (Ryland 1970). In the cyclostomes, the zooids are tubular and

calcified, and the orifice is distally or anteriorly located, without an operculum (Barnes 1987).

Reproduction and Life History

The reproductive process in the Gymnolaemata is representative for the majority of marine species. Most marine bryozoans are hermaphroditic. However, the details of this arrangement may vary, with individual bryozoans being sequentially or simultaneously hermaphroditic, or unisexual. In some cases, permanently unisexual colonies may form (Soule et al. 1987). Sperm are shed through terminal pores of two or more tentacles of the lophophore, and released into seawater. Sperm are captured in the currents generated by the action of the lophophores of other nearby zooids. Fertilization between zooids of the same colony is probably common, but sufficient cross-fertilization likely occurs between colonies to assure outbreeding. In certain non-brooding species, fertilized eggs are shed directly into the seawater. Eggs of other species may be brooded in the coelomic cavity, or outside it. One specialized structure for brooding is a hood-like outgrowth of the body wall and coelom called the ovicell. In many species, the developing embryo receives its nutrition from a contained yolk, but in others, placenta-like connections to the ovicell from the mother zooid may provide food material.

For the Cyclostomata, specialized individuals, the gonozooids, may be modified for reproduction, or the colony may form a centralized chamber as a brooding structure (Soule 1987).

Bilateral cleavage leads to the development of a larva that has a locomotory ciliated girdle, or corona, an anterior tuft of long cilia, and a posterior adhesive sac. In certain genera of non-brooding bryozoans (e.g., *Membranipora*) a specialized feeding larva, the cyphonautes larva, develops. These are the only larvae that possess a functional digestive tract, and feed during the larval stage, a phase which may last several months. In brooding species, larvae are non-feeding, and the larval phase lasts only for a brief period before settlement.

During settling, the vibratile plume, a sensory tuft of cilia, is used in selecting a suitable site for attachment. The adhesive sac is everted and attaches the larva to the selected site. After settlement, the larva undergoes a marked metamorphosis to form the ancestrula, the first zooid. Subsequent zooids in the colony are formed by asexual budding. The zooids formed by budding can themselves bud in various arrangements, giving rise to the form that characterizes each species (Meglitsch and Schram 1991).

Habitat and Ecological Requirements for Various Life History Stages **Preferences and Other Physical Parameters**

Rather than being a primary structural reef-builder, bryozoans generally function as hidden encrusters that grow on the undersides of coral heads, rock ledges, and rubble, and may also

partially fill cavities deep within the reef (Cuffey 1972). In this capacity, to a limited degree, bryozoans may reinforce the structural strength and stability of the reef.

A correlation has been noted between growth form and the depth at which various types occur (Ryland 1970). Generally, encrusting forms may be associated with intertidal areas or other sites subject to strong waves. Such forms would also be more resistant to grazing by predators. Less sturdy types, including erect branching and foliose forms, are found in areas not subject to strong surge or heavy pressure from grazing predators. For example, reticulate to fenestrate reteporids are typically confined to deeper, more stable marine habitats (Dade and Honkalehto 1986).

On modern tropical reefs, encrusting cheilostomes are the most abundant and diversified bryozoans. Encrusting cheilostomes comprise from 50 to 70 percent of the colonies observed in various reef environments in Kaneohe Bay (Dade and Honkalehto 1986). It appears that in depths below 5 to 7 m, bryozoans become more abundant and more diverse than in shallower areas (Cuffey 1972). In surveys conducted to depths of approximately 20 m in Kaneohe Bay (Dade and Honkalehto 1986), a similar trend was observed toward conditions that appear to favor more abundant and diverse growth in deeper water. Among the possible contributing factors cited were environmental stability (e.g., less water movement, fewer grazers); availability of substrate (as competition with corals and encrusting algae decreases); and decrease in ambient light.

It is known that bryozoan larvae actively search for suitable substrates for settlement. It has been observed that bryozoan larvae are able to persist in the plankton for many days longer than expected when conditions are not favorable for settling (Soule et al. 1987). Different species settle variously on rocks, shells, corals, or algae. The length of time over which larvae settle for a given species within a given area is thought to be dependent on a number of environmental factors, including day length and temperature. Day length may be both a direct influencing factor, and an indirect influence, since phytoplankton, presumed to be the preferred food source for many bryozoans, would be available in larger quantities during days with longer daylight hours. In Hawaii, larvae of *Bugula neritina* settled almost year-round (March to December). This also may indicate that *B. neritina* has an extended spawning season in Hawaii (Ryland 1970).

In many species, larvae first exhibit a positive phototropic reaction, but then become negatively phototropic before metamorphosis, eventually settling in dark places on the reef, such as the undersides of stones or flat coral plates (Soule et al. 1987). Generally, high light intensity environments do not support the growth of bryozoans (Soule et al. 1987). Empirical observation suggests that heavily-silted environments generally deter successful settlement; few bryozoans are found growing in areas where rapid deposition of fine sediments occurs, or where water is frequently muddy or turbid (Soule et al. 1987).

Strong correlations were observed between various growth form groups and their position on the reef. So-called lagoon reef areas (fringing and patch reefs, 1-8m depth) were dominated by encrusting cheilostomes (*Celleporaria vagans*, *Rynchozoon* sp., *Coscinopsis fusca*, *Cleidochasma* sp.) and mat-like, tuft-like, and disk-like cheilostomes, as well as lichenoporida and tubuliporida cyclostomes. The barrier reef coral-algal flat breaker zone (1-2.5m depth) portion of the study site was dominated by the encrusting cheilostomes, *Thalamoporella stapifera* and *Rynchozoon* sp. The ocean slope bench (15-20m depth) provided habitat for a wider variety of species, including encrusting cheilostomes (especially *Steginoporella magnilabris*, *Parasmittina parsevaliformis*, and *Schizoporella decorata*), as well as an assortment of reteporid cheilostomes, tuft-like cheilostomes, and lichenoporida and tubuliporida cyclostomes.

Idmidronea, a genus of highly-branched cyclostomatous bryozoans, is reported to occur on the surface of living corals and sponges in Hawaii (Gossliner et al. 1996).

Reteporellina and *Reteporella* sp. occur in areas with fairly strong currents at 10-20m depth (Gossliner et al. 1996).

Another interesting occurrence is the association of bryozoans with black corals (*Antipathes dichotoma*) growing at around 50m depth in the Auau Channel off Maui. About thirty species were found attached to the bases of the corals, and to mollusks attached to the lower coral branches. *Haloporella vagans* and *Reteporellina denticulata* were the most common members of these assemblages (Soule et al. 1986).

In another study, encrusting and erect cheilostome bryozoans were found to grow on an artificial reef positioned in 20m of water in Kaneohe Bay, Oahu. Bryozoans grew rapidly on introduced substrates after two months. Two encrusting species, *Celloporaria vagans* and *Thalamoporella* spp., competed vigorously for space on an artificial substrate (Bailey-Brock 1987). In a similar manner, fouling organisms also appear to opportunistically colonize available surfaces. Thirteen species⁵ were found to occur regularly on harbor and bay structures and boat hulls around Oahu (Soule et al. 1987).

Feeding

Bryozoans are suspension-feeders that capture plankton from the water. Gut contents show the presence of diatoms, detritus, bacteria, silicoflagellates, peridinians, coccolithophores, algal cysts, and flagellates. Unicellular algal cultures (*Dunaliella tertiolecta* and

⁵ *Aetea recta*, *Bowerbankia gracilis*, *B. imbricata*, *Bugula stolonifera*, *B. neritina*, *Hippopodina feegeensis*, *Savignyella lafonti*, *Schizoporella unicornis*, *Zoobotryon verticillatum*, *Scrupocellaria sinuosa*, *Cryptosula pallasiana*, *Tryptostega venusta*, and *Watersipora edmondsoni*.

Gymnodinium simplex) have been used to successfully rear bryozoans in the laboratory (Soule et al. 1987).

While not an obvious food source for other animals, bryozoans are utilized by a variety of grazers, including echinoids, labrid fishes, and nudibranchs (Soule et al. 1987).

Economic Significance

Despite their widespread occurrence, bryozoans are generally not directly utilized for any applied purposes. However, they are being thoroughly investigated for the presence of biochemically active compounds that may ultimately prove useful for treatment of disease. Bryostatin 1, a compound isolated from a common marine bryozoan, is currently being tested as an anti-cancer drug.⁶ Bryozoans are recognized for producing a range of other compounds, particularly alkaloids that may ultimately be shown to have pharmaceutical applications (Van Alstyne and Paul 1988).

Many bryozoan species also have economic importance because of their action as fouling organisms. Bryozoa, along with other common sessile invertebrates and algae, attach to boat hulls, making their movement in the water less efficient. Among the common bryozoan fouling species in warm-water areas are *Bugula neritina*, *Schizoporella errata*, *Watersipora subovoidea*, and *Zoobotryon verticillatum* (Ryland 1970). These and other species can also clog industrial water intakes and conduits. Significant effort and money are spent in developing effective means for deterring the growth of fouling organisms, and for eliminating them from boat hulls and other structures. The growth of fouling organisms, besides being of economic significance, also has ecological implications--species growing on ship hulls are readily transported great distances beyond their natural range, and may be introduced into new areas, thus having an impact on the natural balance of species in established ecosystems.

Occurrence of the Taxon Within WPRFMC Fishery Management Units (FMUs)

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

No reports.

Guam

No reports.

⁶ U. of California, Berkeley: Bryozoan Internet website.

Hawaii (MHI and NWHI)

Surveys in Kaneohe Bay (Dade and Honkalehto 1986) yielded a total of 57 species of ectoproct bryozoans, including 45 cheilostomes, 13 cyclostomes, and 1 ctenostome. Many of these are cosmopolitan, capable of being dispersed over great distances, often by rafting on algae, logs, or artificial substrates. However, owing to the isolation of the archipelago, significant speciation has occurred, with the result that of the species recorded in Kaneohe Bay, 23 percent were believed to be endemic to Hawaii. It is estimated that over 150 species of bryozoans occur in Hawaii; however the total number of endemic species for Hawaii is not known (Eldredge and Miller 1985).

Other Sites

With the exception of Hawaii, little published information is available for the other U.S. Pacific Islands. Because the shallow sublittoral bryozoan fauna for the Indo-Pacific is not well known, it is difficult at present to establish with any certainty the degree of endemism of specific taxa within any given island or archipelago (Soule et al. 1987).

5.2.4 Crustaceans

5.2.4.1 Introduction

The arthropod subphylum Crustacea is one of the most diverse and widespread groups of invertebrates. Within the subphylum, the Class Malacostraca contains such familiar types as mantis shrimps, lobsters, crabs, and shrimp, as well as less conspicuous, but ecologically important organisms, the isopods and amphipods.

Crustaceans cannot grow as many other animals do, because the hard exoskeleton does not stretch. Therefore, they periodically shed the outer skeleton, grow rapidly for a period of time, then re-grow a new exoskeleton. The molting process involves many complex physiological changes, including reduction of the lime content in the exoskeleton to weaken it prior to molting; rapid absorption of water after molting to expand the body size; and redeposition of lime to again strengthen the exoskeleton (Tinker 1965). During molting, the animal is in a weakened and vulnerable condition, and must seek shelter to avoid being preyed upon by other animals. Thus the molting process strongly influences the habitat requirements of these animals.

The malacostracan body is typically composed of 14 segments, plus the telson, with the first 8 segments forming the thorax and the last 6, the abdomen. The thorax may or may not be covered by a carapace. All segments bear appendages, with the first antennae usually being biramous, the exopodite (outer branch) of the second antennae often in the form of a flattened scale, and the mandibles usually bearing palps. In the primitive condition, the thoracic appendages are similar, with the endopodite (inner branch) being more developed for use in crawling or grasping. In most species, the first one, two, or three pairs of thoracic legs have

been turned forward and modified to form maxillipeds. The anterior abdominal legs are similar, and are called pleopods. They are used for swimming, burrowing, ventilating, gas exchange, and carrying eggs in females. In males, the first one or two pleopods are modified to form copulatory organs. The sixth abdominal appendages, or uropods, are flattened, and together with the telson, form a tail fan used in escape swimming.

The present discussion is confined to those larger forms that are of concern from a management standpoint. These belong to the order Stomatopoda (mantis shrimps), and order Decapoda (shrimps, lobsters, and crabs). As part of Amendment 10 to the *Crustacean Fisheries Management Plan*, (WPRFMC September 1998) background information has been presented, and EFH has already been defined, for certain economically-important decapod taxa (i.e., spiny lobsters, *Panulirus marginatus* and *P. penicillatus*, and kona crab, *Ranina ranina*) (Table 88). The present discussion will provide further information on other decapod taxa, and summarize the information contained in Amendment 10 on lobsters and Kona crab.

5.2.4.2 Stomatopoda (Mantis Shrimps)

Description

Several hundred marine species constitute the order Stomatopoda, the mantis shrimps. These organisms live in rock or coral crevices or in burrows excavated in sand. They are dorsoventrally flattened with a small, shield-like carapace and a large segmented abdomen that widens toward the posterior end. Characteristic of the group is the possession of a highly developed, powerful pair of second-segment raptorial appendages that are used either for spearing or smashing prey.

Reproduction and Life History

In stomatopods, as many as 50,000 eggs (e.g., genus *Squilla*) are joined together by an adhesive secretion to form a globular mass. The mass is held by the female in small subchelate appendages and constantly turned and cleaned. The female does not feed while brooding. Depending on the species, the egg mass may be left in the burrow, or the female may carry the egg mass with the thoracic legs (Meglitsch and Schram 1991). The eggs hatch into zoea larvae that have carapaces that are much larger than in the adult, relative to total body size. The larvae may appear in very large numbers in the plankton community in tropical waters. Two types of larvae are recognized, an erichthus and an alima. The larvae pass through a prolonged phase during which the last three thoracic somites have no appendages, a feature also observed in zoea larvae of decapods (Meglitsch and Schram 1991). The planktonic larval phase lasts for up to three months (Barnes 1987).

Habitat and Ecological Requirements for Various Life History Stages

Most stomatopods live in pockets or crevices on the reef, or in burrows in sand. They may dig their own burrows or occupy burrows excavated by other animals. A variety of mechanisms are used to close the burrow entrance for protection; the animal may plug the

hole with its telson, or gather shells and other debris to close the entrance at night, and block it during the day with the raptorial appendages.

Mantis shrimps may leave the burrows to feed, either crawling or swimming over the bottom. Some types (speakers, e.g., *Lysiosquilla maculata*) are equipped with raptorial appendages that have sharp barbs that pierce soft-bodied prey animals, such as shrimps or fishes. In others (smashers such as *Gonodactylus* spp.) the raptorial appendages have a sharp, heavy heel that can crack the shells of crabs, snails, and clams.

Economic Importance

Mantis shrimps are part of the incidental catch of subsistence fisheries, and may be captured in crab nets that are placed near their burrows (Tinker 1965). Their use as a food source is generally limited. Some species, especially brightly-colored ones (e.g., *Gonodactylus* sp.), may have some minor value in the aquarium trade (?-confirm). Limited use is made of the ivory-like raptorial appendages of some species in the small-scale manufacture of jewelry (Tinker 1965).

Occurrence of the Taxon Within WPRFMC Fishery Management Units

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

Two stomatopods found in the Northern Marianas, *Mesacturus dicrurus* and *Gonodactylus* sp., were reported by Hamano (1994). Both species, in the Gonodactylidae, occur in rocky intertidal areas.

Guam

Lysiosquilla spp. (Green October 1997) and *Mesacturus dicrurus* (Gonodactylidae; Hamano 1994) are known from Guam. *Mesacturus dicrurus* is associated with rocky intertidal environments (Hamano 1994).

Gossliner et al. (1996) report on the following species:

Gonodactylellus affinis (Stomatopodidae), a species that is highly polymorphic in color, occurs here, usually below 20m depth. By contrast, *Gonodactylus chiragra* is an inhabitant of shallow intertidal reef flats and rocky outcrops, and forages in low tide in a few centimeters of water. *Gonodactylaceus mutatus* occurs on reef flats to 5m depth, and also forages at extreme low tide. *Mesacturoides spinosocarinatus* may be found at depths ranging from 5 to 50 m. The animals stay close to their burrows, but dart about nearby.

Pseudosquilla ciliata burrows in sand and gravel on reefs and sand flats, to 30m depth.

Hawaii (MHI and NWHI)

Eldredge and Miller (1995) list a total of approximately 17 stomatopods from Hawaii. Of these, 11 are considered endemic.

Lysiosquilla maculata and *Squilla (Oratosquilla) oratoria* are reported to occur in Hawaii. Both are found in mud-bottom areas suitable for burrows (Tinker 1965).

Gossliner et al. (1996) report the occurrence of the following Hawaiian species:

Odontodactylus brevis is found in burrows of small rubble pieces at 10-50m depth. *O. scyallarus* is a night-feeding carnivore that preys on crustaceans, worms, mollusks, fish. It is found on sand and rubble bottoms to 70m. *Oratosquilla oratoria*, another nocturnal species, is reported in muddy estuaries and on reefs, in U-shaped burrows up to 1m long.

Pseudosquilla ciliata burrows in sand and gravel on reefs and sand flats, and is found to 30m depth.

Other Sites

A single specimen of *Pseudosquilla ciliata* was encountered at Palmyra Island (Edmondson 1923).

5.2.4.3 Decapoda: Shrimps, Lobsters, and Crabs**Introduction**

With approximately 10,000 species, decapods represent about one fourth of all known crustaceans (Barnes 1987). They are among the most diverse and successful crustacean groups, having exploited virtually all available niches in the marine habitat, as well as having developed specialized strategies for nutrition and reproduction.

The generalized decapod life cycle is characterized by the nauplius and protozoa stages being passed inside the egg. However, some primitive forms (e.g., penaeids) pass the earlier developmental stages outside of the egg. Transition from protozoa to the next stage (zoea) involves the addition of thoracic limbs and dependence on the thoracic appendages for locomotion. The carapace fuses to the thorax, and pleopods and stalked eyes appear. The zoea is typically the stage at which the larva emerges from the egg. From the zoea phase, further transformations occur, making the postlarval or juvenile phase more closely resemble the adult (Meglitsch and Schram 1991).

In the adult phase, decapods are distinguished by having the first three pairs of thoracic appendages modified into maxillipeds. The remaining five pairs are the legs. The first or second pair of legs may be chelipeds (pincer-like claws) that are used for seizing prey or for defense (Barnes 1987).

Decapods exhibit a wide range of feeding behaviors, but most combine predation with scavenging, with large invertebrates being typical prey items (Barnes 1987). Others may be detritus or filter feeders. The form of the body, especially the appendages, is often modified for more effective functioning in acquiring food. Thus, box crabs such as *Calappa calappa* have powerful chelae used to crush mollusks; sand-burrowing mole crabs (e.g., *Emerita pacifica*) use long fringed antennae to filter plankton and detritus; and banded coral shrimp (*Stenopus hispidus*) use thin pincers to delicately pick ectoparasites from the scales of fishes= bodies (Gossliner et al. 1996).

Shrimps: Infraorders Penaeidea, Stenopodidea, Caridea

General Description and Morphology

The shrimps are found in several different decapod infraorders, and this taxonomic disunity reflects the wide range of forms and lifestyles that are represented in this large but artificial grouping. The penaeids are considered the most primitive decapods, while other types, such as the alpheidids and palaemonids, represent more advanced forms. The features that generally characterize shrimps are bodies that are laterally compressed or more or less cylindrical, with well-developed abdomens, and a cephalothorax that often has a keel-shaped, serrated rostrum. Legs are usually slender, and chelipeds may be present or absent. The exoskeleton is usually relatively thin and flexible (Barnes 1987).

Reproduction and Life History

In most shrimps, copulation takes place with the adults pair oriented at right angles to each other. The male uses the modified first and second pair of pleopods to transfer a spermatophore to a median receptacle between the thoracic legs of the female. The penaeids are the only decapod group in which eggs are shed directly into the water and hatch as naupliar or metanaupliar larvae. In all other decapods, females carry the eggs on the pleopods, and hatching takes place at the protozoa or zoea stage (Barnes 1987). The various larval schemes in decapods are summarized in Table 83.

Habitat and Ecological Requirements for Various Life History Stages

Most shrimps are bottom-dwellers. Thoracic appendages are used for crawling, while pleopods are used for swimming, and also to fan sediments during excavation of burrows. Many penaeids construct burrows in sand or other soft-bottom material, or simply bury themselves in sediment during daytime, emerging at night to feed (Gossliner et al. 1996). Other types, such as snapping or pistol shrimp (Alpheidae), live in holes and crevices beneath rocks and coral rubble, or may construct burrows. Certain alpheidids are also closely associated with corals, especially in the genus *Pocillopora* (Hayashi et al. 1994; see notes in section IV.C.4.e, below) Other genera also may live inside or in close association with a variety of other living organisms, including sponges, tunicates, mollusks, corals, echinoderms, or anemones (Tables 84-87).

Many of the commensal associations between shrimps and other organisms are quite specialized. The cleaner shrimps, an artificial grouping of species distributed among several families, play an important role in reef ecology by reducing ectoparasites on reef fishes. Through complex behavioral cues and signals, the fishes approach well-defined cleaning stations on the reef and allow the shrimps to climb over their bodies and even insert their chelipeds into the gill region to pick off parasites. Anemone shrimps in the genus *Periclimenes* may also clean fish, and spend most of their time living among the stinging tentacles of sea anemones. Many snapping shrimps of the family Alpheidae typically share their burrows in a close relationship with fish of the family Gobiidae, presumably to the mutual benefit of both partners.

Occurrence of the Taxon Within WPRFMC Fishery Management Units

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

Hayashi et al (1994) surveyed the crustacean fauna on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug (East, West and North), and Uracas. Their collections were made at depths ranging from 3-14 meters. The findings included reports of the following species of shrimps:

Stenopodidae:

Stenopus hispidus (found in the rocky subtidal zone; known from a wide geographic range where it occurs from the intertidal to depths of 210m); Rhyncocinetidae: *Rhyncocinetes* sp.; Palaemonidae: *Brachycarpus biunguiculatus*, *Harpiliopsis beaupresii* (on coral), *H.depressa*, *Ichnopontonia lophos*, *Jocaste japonica*, *Onycocaris quadratophthalma* (on *Pocillopora* coral), *Palaemonella spinulata*; Alpheidae: *Alpheopsis* sp., *Alpheus bidens*, *A. cf. crinitus*, *A. frontalis* (under boulders), *A. lottini* (in somewhat deeper water [14 m] on *Pocillopora*), *A. obesomanus*, *A. pacificus*, *A. pearcyi*, *Athanas areteformis* (on *Pocillopora*), *Automate dolicognatha*, *Metalpheus rostratipes* (on *Pocillopora*), *Racilius compressus*, *Syalpheus charon* (on *Pocillopora*), *S. paraneomeris* (on *Pocillopora*), *S. tumidomanus* (on *Pocillopora*); Hippolytidae: *Hippolyte edmondsoni* (on algae; known otherwise only from Oahu, Hawaii)

Guam

Several species of snapping shrimp (Alpheidae) were found in Guam. One species, *Alpheus obesomanus*, occupied extensive tunnels in *Millepora platyphylla* colonies; up to 95 percent of the colonies surveyed had shrimp tunnels. Another species, *A. idiocheles*, occupied sub-hemispherical pockets, called Agalleries, in an intertidal erosion bench. Each gallery typically was inhabited by a male-female pair (Kropp 1987).

Hawaii (MHI and NWHI)

Eldredge and Miller (1995) indicate that there are approximately 200 species of marine shrimps in Hawaii; of these, 4 stenopodids are believed to be endemic. Endemism of other types has not been established with certainty.

Tinker (1965) reports the following species of interest: *Stenopus hispidus* (Stenopodidae), the banded cleaner shrimp, is of pan-tropical distribution. It is typically found in holes in the reef. The harlequin shrimp, *Hymenocera picta* (Gnathophyllidae), is found from Hawaii eastward to the Red Sea. This species, relatively uncommon in Hawaii, is occasionally found in quiet inshore waters on the reef.

Gossliner et al. (1996) report the following shrimps from Hawaii:

Stenopodidae:

Stenopus hispidus, *S. pyrosonotus* (cleaner shrimp found in crevices to 15 m depth; eggs are light blue color); Pontoniidae: *Periclimenes soror* (on sea stars), *P. imperator* (on nudibranch [*Hexabranhus*]), holothurians [*Stichopus*, *Bohadschia*, *Synapta*], and sea star [*Gomophia*]), *Pontonides unciger* (mimics polyps of black coral [*Cirripathes*] on which it lives), *Stegopontonia commensalis* (on sea urchin spines); *Lysmata amboinensis* (cleaner shrimp); Hippolytidae: *Parhippolyte uveae* (in anchialine ponds), *Saron marmoratus* (nocturnal in protected lagoons); Gnathophyllidae: *Gnathophylloides mineri* (on sea urchins), *Gnathophyllum americanum* (associated with echinoderms), *Hymenocera picta* (preys on sea stars); Rhynchocinetidae: *Rhynchocinetes rugulosus*.

Hayashi et al (1994) indicate that the following species are known from Hawaii:

Palaemonidae:

Brachycarpus biunguiculatus; Alpheidae: *Alpheus pearcyi*, *Metalpheus rostratipes*, *Syalpheus paraneomeris*; Hippolytidae: *Hippolyte edmondsoni* (on algae; known only from, Oahu, Hawaii and CNMI).

Other Sites

For each of the following families of shrimps, Edmondson (1923) lists the following number of species (in parentheses) represented at Palmyra Atoll and/or Fanning Island:⁷ Alpheidae (10); Hippolytidae (1); Gnathophyllidae (2); Palaemonidae (5); Stenopodidae (1); Sergestidae (1).

Lobsters, Spiny Lobsters, Slipper Lobsters: Infraorders Astacidea, Palinura
General Description and Morphology

Lobsters are heavy-bodied decapods that generally inhabit holes and crevices of rocky and coralline bottoms. They have extended abdomens that bear a full complement of appendages, and the carapace is always longer than it is broad. The infraorder Astacidea includes large-clawed lobsters, while the Palinura include the spiny lobsters (Palinuridae), slipper lobsters (Scyllaridae), and coral lobsters (Synaxidae) (Barnes 1987; Pitcher 1993). Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida 1986, FAO 1991). In spiny lobsters, the carapace is large and spiny. Two horns and antennae project forward of the eyes and the abdomen terminates in a flexible tailfan (FAO 1991). The slipper lobster, while in many respects quite similar to the spiny lobster, has its second antennae modified into broad, platelike structures (Pearse et al. 1987). The body is more flattened dorsiventrally than the body of spiny lobsters. Large-clawed, or true lobsters are more widespread and abundant in temperate areas, but of limited occurrence in the tropical and sub-tropical Western Pacific. They differ from palinurids in having large, heavy chelipeds.

Reproduction and Life History

The developmental history of the spiny lobster is covered at length in Amendment 10 of the *Crustacean Fisheries Management Plan*, (WPRFMC September 1998). Key points are excerpted here.

Spiny lobsters (*Panulirus* sp.) are dioecious (Uchida 1986). Generally, the different species within the genus have the same reproductive behavior and life cycle (Pitcher 1993). The male spiny lobster deposits a spermatophore or sperm packet on the female's abdomen (WPRFMC 1983, Uchida 1986). The fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released from the female's oviduct and are then fertilized and attached to the setae of the female's pleopods (WPRFMC 1983, Pitcher 1993). At this point the female lobster is ovigerous, or berried (WPRFMC 1983).

⁷ Family name nomenclature is updated.

The fertilized eggs hatch into leaf-like zoea larvae (the phyllosoma larvae) after 30-40 days (MacDonald 1986, Uchida 1986), and enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies, depending on the species and geographic region, and may last from 6 months to 1 year from the time of hatching (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar morphological stages of development that the phyllosoma larvae pass through before they transform into the postlarval puelurus phase (Johnson 1986, MacDonald 1986). The relatively long pelagic phase for palinurid larvae results in very wide dispersal; palinurid larvae are transported up to 2,000 miles by prevailing ocean currents (Johnston 1973, MacDonald 1986).

There is a lack of published data pertaining to the preferred depth distribution of phyllosoma larvae in Hawaii. However, the depth distribution of phyllosoma larvae of other species of *Panulirus* common in the Indo-Pacific region has been documented. Newly hatched larvae of the western rock lobster (*P. cygnus*) are typically found within 60 m of the surface. Later stages of the phyllosoma larvae are found at depths between 80-120 m. *P. cygnus* undergoes a diurnal vertical migration, ascending to the surface at night, descending to lower depths during the day, the authors add. Research has shown that early phyllosoma larvae display a photopositive reaction to dim light. In the Gulf of Mexico, the depth to which *Panulirus* larvae descend is restricted by the depth of the thermocline (Phillips and Sastry 1980).

The puelurus stage for spiny lobster lasts 6 months or less (WPRFMC 1983). The pueruli are free-swimming and actively return to shallow, nearshore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). MacDonald and Stimson (1980) found pueruli settlement to occur at approximately 1 cm in length.

MacDonald (1986) states that after settlement the pueruli molt and transform into post-pueruli, a transitional phase between the pelagic phyllosoma phase and the juvenile stage. Pitcher (1993) states that the post-pueruli of *Panulirus penicillatus* have been observed inhabiting the same high-energy reef-front habitat as adults of the species. Yoshimura and Yamakawa (1988) conclude that small holes in rocks, boulders and algae provide important habitat for the newly settled pueruli and juvenile lobsters.

The other palinuroids (coral and slipper lobsters) also have the unique phyllosoma larval phase (Pitcher 1993). Johnston (1973) reports that the phyllosoma phase of some species of slipper lobster (genus *Scyllarides*) is somewhat shorter than that of the spiny lobster.

Habitat and Ecological Requirements

Adult spiny lobsters are typically found on rocky substrate in well-protected areas, in crevices and under rocks (Pitcher 1993, FAO 1991), down to a depth of around 110m (Brock

1973). Unlike many other species of *Panulirus*, the juveniles and adults of *P. marginatus* are not found in separate habitat apart from one another (MacDonald and Stimson 1980, Pitcher 1993, Parrish and Polovina 1994). Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters (MacDonald and Stimson 1980, Parrish and Polovina 1994). Juvenile and adult *P. marginatus* do utilize shelter differently from one another (MacDonald and Stimson 1980). Similarly, juvenile and adult *P. pencillatus* also share the same habitat (Pitcher 1993).

In the NWHI, *P. marginatus* is found seaward of the reefs and within the lagoons and atolls of the islands (WPRFMC 1983). Uchida (1986) reports that *P. penicillatus* rarely occur in the commercial catches of the NWHI lobster fishery. In the NWHI, *P. pencillatus* is found inhabiting shallow waters (<18 m) (Uchida and Tagami 1984).

In the NWHI, the relative proportion of slipper lobsters to spiny lobsters varies between banks; several banks produce relatively higher catch rates of slipper lobster than total spiny lobster (Uchida 1986; Clarke et al. 1987, WPRFMC 1986). The slipper lobster is taken in deeper waters than the spiny lobster (Clarke et al., 1987, WPRFMC 1986). Uchida (1986) reports that the highest catch rates for slipper lobster in the NWHI occur between the depths of 20-55 m.

Pitcher (1993) observes that, in the southwestern Pacific, spiny lobsters are typically found in association with coral reefs. Coral reefs provide shelter as well as a diverse and abundant supply of food items, he notes. Pitcher also states that in this region, *P. pencillatus* inhabits the rocky shelters in the windward surf zones of oceanic reefs, an observation also noted by Kanciruk (1980). Other species of *Panulirus* show more general patterns of habitat utilization, Pitcher continues. At night, *P. penicillatus* moves on to reef flat to forage, Pitcher continues. Spiny lobsters are nocturnal predators (FAO 1991).

P. marginatus is typically found on rocky substrate in well-protected areas such as crevices and under rocks (FAO 1991). During the day, spiny lobsters are found in dens or crevices in the company of one or more other lobsters (WPRFMC 1983). MacDonald and Stimson (1980), studying the population biology of spiny lobsters at Kure Atoll in the NWHI, found that 57% of the dens examined were inhabited by solitary lobsters. The remaining 43% were occupied by more than one lobster, with adult and juvenile lobsters of both sexes often found sharing the same dens. However, the authors note, adult and juvenile spiny lobsters exhibit distinctly different den occupancy patterns, with juveniles (less than 6 cm in carapace length) typically in multiple occupancy dens with other lobsters. Adult and juvenile spiny lobsters are not segregated by geographic area or habitat type at Kure Atoll, MacDonald and Stimson observe. They found that juvenile spiny lobsters do not utilize separate nursery habitats apart from the adult lobsters. The larval spiny lobster puerulus recruits directly to the adult habitat

(Parrish and Polovina 1994). This is in contrast to the juveniles of other species of spiny lobsters that tend to reside in shallow water and migrate to deeper, offshore waters as they mature (MacDonald and Stimson 1980).

There are limited data available concerning growth rates, reproductive potentials and natural mortality rates at the various life history stages (WPRFMC 1983). The relationships between egg production, larval settlement, and stock recruitment are poorly understood (WPRFMC 1983).

Occurrence of the Taxon Within WPRFMC Fishery Management Units

American Samoa

The only species of *Panulirus* reported from American Samoa is *P. penicillatus* (Pitcher 1993).

Commonwealth of Northern Mariana Islands (CNMI)

P. penicillatus is the most common species of the genus encountered in the CNMI. *P.*

longipes and *P. versicolor* are also found in significant numbers. Regulations prohibit capture of individuals less than 76 mm carapace length and of egg-bearing females (Pitcher 1993).

Guam

P. penicillatus is the most common species of spiny lobster on Guam, and is caught by islanders spearfishing at night. *P. longipes* and *P. ornatus* are also caught occasionally. Regulations are in effect that protect small (<0.45 kg) lobsters (Pitcher 1993).

Of the several hundred species of crustaceans that likely occur on Guam, lobsters of various types are among the most sought-after by local fishermen. They include spiny lobsters (*Panulirus longipes*, *P. ornatus*, *P. penicillatus*, and *P. versicolor*); a homarid; and a slipper lobster (*Scyllarus squamosus*)(Green October 1997).

Crabs (True Crabs and Hermit Crabs): Infraorders Brachyura and Anomura

Description

The Brachyura, the so-called true crabs, are one of the largest and most successful groups of decapods. The body form is short and wide, and the abdomen is flexed to fit tightly beneath the cephalothorax. Uropods are generally lacking. Pleopods are retained in females for brooding of eggs, and in males only the anterior two pairs of copulatory pleopods are present. The carapace is typically wider than long. The broad body form, while allowing for crawling in the forward direction, is better suited for sideways movement. Most crabs are poor

swimmers, but in the Portunidae (swimming crabs), the last pair of legs are modified into broad paddles, enabling them to swim rapidly (Barnes 1987).

The Anomura contain the hermit crabs and several other interesting groups, such as the Porcellanidae (porcelain crabs). In the Anomura, the fifth pair of legs is reduced. However, the abdomen is not reduced (as in brachyurans) and uropods are generally present. The anomuran superfamily Pagurolidea, the hermit crabs, have adapted to living the majority of their adult life with their abdomens protected in abandoned shells of gastropods. In these types, the abdomen is modified to fit inside the spiral chamber of the gastropod shell. The porcelain crabs, often found in commensal relationships with sea anemones, resemble true crabs in having symmetrical, flexed abdomens, but the abdomens are longer than in typical brachyurans (Barnes 1987).

Reproduction and Life History

When brachyurans copulate, the female lies under the male facing in the same position or with ventral surfaces opposed. The male inserts the first pair of pleopods into the openings on the female's abdomen. Fertilization is internal. The abdomen, which is normally in a tightly flexed position, is lifted to a considerable degree to permit brooding. The egg mass, often orange in color is called a sponge. Eggs hatch out into a zoea larval stage, easily recognized by the presence of a long rostral spine, and sometimes a pair of lateral spines that project from the posterior of the carapace. The postlarval megalops is also quite distinctive, already possessing the flexed abdomen and the full complement of appendages found in the adult (Barnes 1987).

Hermit crabs partially emerge from their gastropod shell shelters to mate. The mating pair appress their ventral surfaces, and eggs and spermatophores are released simultaneously. Eggs hatch into a zoea larval phase, and metamorphose into glaucothoë postlarvae (Barnes 1987).

Habitat and Ecological Requirements

Crabs exhibit an astonishing array of structural and behavioral adaptations that enable them to occupy a wide range of niches within the coral reef habitat and associated environs. They may bury themselves in high littoral sands, occupy crevices or burrows among subtidal rocks and coral heads, or live on the surfaces of marine plants or other invertebrates. Their commensal associations include living in the mantle cavities of bivalves (pea crabs, Pinnotheridae); living among the tentacles of sea cucumbers (sea cucumber crab, Portunidae), attaching varied invertebrates to their carapaces for camouflage (sponge crabs, Dromiidae; decorator crabs, Majidae); or holding anemones in their chelipeds for defense (boxer crabs, genus *Lybia*). Additional ecological and habitat notes, where available, are provided in Section IV.C.4.e., below.

Occurrence of the Taxon Within WPRFMC Fishery Management Units**Commonwealth of Northern Mariana Islands (CNMI)**

Asakura et al. (1994) collected 27 species of anomurans in the Northern Marianas. Among these was the coconut crab, *Birgus latro* (Coenobitidae). Its distribution includes most islands of the Marianas, including Guam, Saipan and Tinian.

Takeda et al. (1994) reported on the results of collections of crustaceans made during a survey of the remote islands of the Northern Marianas in 1992. The majority of the collections were from the rocky intertidal and high subtidal zones. Subtidal collections were from the 3m depth zone, usually on coral. The following families and genera of crabs, and number of species (in parentheses) were recorded:

Dromiidae: *Cryptodromia* (1); Dynomenidae: *Dynomene* (1); Majidae: *Menaethius* (1), *Perinea* (1), *Tiarinia* (1); Parthenopidae: *Daira* (1); Atelecyclidae: *Kraussia* (1); Portunidae: *Charybdis* (1), *Thalamita* (2); Xanthidae: *Chlorodiaella* (1), *Forestia* (1), *Lachnopus* (1), *Leptodius* (1), *Liomera* (1), *Lophozozymus* (1), *Lybia* (1), *Macromedaeus* (1), *Paraxanthias* (1), *Phymodius* (1), *Pilodius* (2), *Pseudoliomera* (4), *Xanthias* (2); Menippidae: *Dacryopilumnus* (1), *Epixanthus* (1), *Eriphia* (1), *Lydia* (1), *Ozius* (1), *Pseudozius* (1); Pilumnidae: *Nanopilumnus* (1), *Parapilumnus* (1); Trapeziidae: *Domacia* (2), *Tetralia* (2), *Trapezia* (9); Ocypodidae: *Ocypode* (2); Grapsidae: *Grapsus* (2), *Geograpsus* (3), *Pachygrapsus* (2), *Cyclograpsus* (1), *Plagusia* (1), *Percnon* (1); Gecarcinidae: *Cardisoma* (1).

Guam

Several crabs (*Carpilius maculatus*, *Etisus dentatus*, *E. utilis*, *Calappa calappa* and *C. hepatica*) are among the species of shellfish sought by local fishermen (Green October 1997).

Table 74. Summary of post-embryonic development and larval types in Decapoda.⁸

Group	Postembryonic Development	Larvae
Suborder Dendrobranchiata		
Family Penaeidae	slightly metamorphic	nauplius > protozoa > mysis (zoea) > mastigopus (postlarva)
Family Sergestidae	metamorphic	nauplius > elaphocaris (protozoa) > acanthosoma (zoea) > mastigopus (postlarva)
Suborder Pleocyemata		
Infraorder Caridea	metamorphic	protozoa > zoea > parva (postlarva)
Infraorder Stenopodidea	metamorphic	protozoa > zoea > parva (postlarva)
Infraorder Palinura	metamorphic	phyllosoma (zoea) > puerulus, nisto, or pseudibaccus (postlarva)
Infraorder Astacidea	slightly metamorphic	mysis (zoea) > postlarva
Infraorder Anomura	metamorphic	zoea > glaucothoë [in pagurids], or grimothea (postlarva)

⁸ After Waterman and Chace (T. H. Waterman [ed.]: Physiology of Crustacea, Vol. 1) in Barnes 1987.

Infraorder Brachyura	metamorphic	zoea > megalopa (postlarva)
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Table 75. Habitat description for Cephalopods (Class Cephalopoda).

	Egg	Larvae	Juvenile	Adult
Duration		N/A (no larval phase)	unknown	in many cases, cephalopods die shortly after spawning; 1-2 year life span is typical (e.g., 12-15 months after settling from planktonic juvenile phase in <i>Octopus cyanea</i>); <i>Nautilus</i> may live up to 10 years
Diet	yolk	N/A	in <i>Nautilus</i> , eggs hatch directly to juvenile phase; juveniles believed to start immediately scavenging and grazing	generally predators on fishes, shrimps, crabs and mollusks; <i>Nautilus</i> may scavenge upon crab and lobster molts
Distribution	<p><i>!Nautilus</i> may have a single annual egg laying season, peaking around October; a few (10-15) large (mean 29mm) eggs are produced by each female</p> <p><i>!Euprymna scolopes</i> may have two reproductive periods per year</p> <p><i>!in other taxa (e.g., Octopus cyanea) no seasonality noted</i></p>	N/A	<i>Euprymna scolopes</i> goes through a short (<1 week) planktonic juvenile phase	nautiloids may migrate into deeper waters in daytime, rise to shallower reef flats at night to feed
Location	<p>octopods attach eggs to rocky recesses on the reef</p> <p>reef cuttlefish deposits eggs among branches of finger coral; other cuttlefish may attach eggs to seagrasses; <i>Euprymna scolopes</i> attaches eggs to dead coral</p> <p>reef squid attach eggs to rocks and coral</p> <p><i>Nautilus</i> attaches egg capsules to hard substrate</p>	N/A		<p><i>Octopus</i> spp. in American Samoa, CNMI, Guam, NWHL, MHI <i>Nautilus pompilius</i> is found in American Samoa, perhaps the easternmost extension of its range</p> <p>reef squid and cuttlefish in CNMI, Guam</p> <p><i>Euprymna scolopes</i> cuttlefish endemic to Hawaii</p> <p><i>Sepioteuthis lessoniana</i> believed nearly extirpated in Hawaii</p>
Water Column		N/A	in octopod species with smaller, less developed eggs, juveniles may be planktonic and then settle to benthic	intertidal, high subtidal (e.g., octopods, <i>Euprymna</i>); mesopelagic (squids, cuttlefishes);

	Egg	Larvae	Juvenile	Adult
			existence; other octopod species may not have planktonic phase juveniles of other cephalopods generally have a planktonic phase	60-500m (nautiloids) nautiloids may migrate into deeper waters in daytime, rise to shallower reef flats at night to feed
Bottom Type		N/A		octopods mostly in holes and crevices in rocky or coral areas, but some types in burrows in sand; squid and cuttlefish over reefs or seagrass areas; <i>Euprymna scolopes</i> burrows in sand on shallow sand and mud flats
Oceanic Features	N/A	N/A		some reef-associated squids semi-pelagic

Table 76. Habitat description for Tunicates (Class Ascideacea).

	Egg	Larvae	Juvenile	Adult
Duration	solitary forms release eggs to the water; in colonial forms, fertilization is internal and larvae, not eggs are released	Atadpole@ larvae are non-feeding, and thus short-lived; larval phase may last from several minutes to a few days	rapid transition from larval to adult zooid phase, with no marked juvenile phase	typically 1-3 year life span
Diet	N/A	nutrition derived from yolk sac; some forms have endosymbionts that may contribute photosynthate product to the ascidian host as a	N/A	adults filter-feed non-selectively on phytoplankton and other suspended food particles and nutrients

	Egg	Larvae	Juvenile	Adult
		food source		
Distribution	egg production occurs year-round	in some species studied (e.g., <i>Diplosoma similis</i>), larvae are released year-round		wide range of species known from most locations in the region; many species dispersed as fouling organisms transported on boat hulls
Location	eggs may be found in peribranchial cavity during embryonic development; in solitary forms, fertilization and subsequent development occurs outside the parent body	in colonial forms, larvae are typically held in the peribranchial cavity, or may be in a brood pouch or the basal test	N/A	range from high-light and high-energy environments (especially those forms with photosynthetic endosymbionts), to protected deeper-water areas
Water Column	N/A	larvae generally in same depth range as adults, approx. 0-100 m (or deeper); larvae in <i>Diplosoma similis</i> first swim up to enter layers with faster current, then swim down to settle on substrate	N/A	intertidal to 120 m depth or greater
Bottom Type	N/A	attach to dead corals, seaweeds, mangrove roots, other sessile invertebrates; favor attachment to darker surfaces with lower illumination	N/A	dead corals, seaweeds, mangrove roots, other sessile invertebrates; may also overgrow live coral
Oceanic Features	N/A	larvae in <i>Diplosoma similis</i> first swim up to enter layers with faster current, then swim down to settle on substrate	N/A	N/A (sessile attached organisms)

Table 77. Habitat description for Bryozoans (Phylum Bryozoa or Ectoprocta).

	Egg	Larvae	Juvenile	Adult
Duration	approximately two weeks from fertilization to development and release of larva	two types: ! non-feeding coronate larvae: planktonic for a few hours ! feeding (cyphonautes) larvae develop in those forms that shed eggs directly to the sea (e.g., in <i>Membranipora</i>): cyphonautes may last several months	no distinct juvenile phase; following adhesion of larva to substrate, all larval organs undergo histolysis within approx. one hour from the onset of metamorphosis, forming ancestrula (first zooid of colony)	large colonies may add 2-4 cm growth annually and believed to live for ten years or more
Diet	in some species, developing embryo receives its nutrition from a contained yolk, but in others, placenta-like connections to the ovicell from the mother zooid may provide food material	cyphonautes larvae are planktotrophic; Non-feeding types may take up dissolved organic nutrients (e.g., amino acids)		selective suspension-feeders that consume diatoms, bacteria, flagellates, and phytoplankton
Distribution				adult colonies may be transported as fouling organisms on ships= hulls; various species found throughout all sites in the region
Location	eggs may variously be: ! small sized, fertilized at the time of discharge into seawater (e.g., <i>Membranipora</i>); ! larger, brooded internally in coelomic cavity during embryonic development; ! brooded in specialized ovicells	may develop internal or external to parent zooid		usually found on shaded surfaces (e.g., undersides of coral tables)

Water Column	larvae are initially positively phototropic, and move upward in water column; later become negatively phototropic and move toward shaded areas (e.g., under stones or coral plates) prior to settlement	benthic sessile organisms occurring from intertidal to abyssal depths, but majority associated with substrates at 20-80m depth; preference for clear water free of suspended silt and sediment
Bottom Type	larvae highly selective in choosing attachment site; usually settle on rock, dead coral, seaweeds or wood	adults attached to rock, dead coral, seaweeds or wood
Oceanic Features	January thermal boundaries (e.g. 27 degree C isotherm may act as filtering mechanisms that determine larval distribution	steady water currents essential for successful filter-feeding function; however, waves may be destructive of delicate erect, branching or foliose colonies

Table 78. Habitat description for Crustaceans (Class Malacostraca [in part]).⁹

	Egg	Larvae	Juvenile	Adult
Duration	30-40 days in lobster; 29 days in kona crab	! zoea larvae last up to 3 months in stomatopods ! in penaeids, eggs hatch to the nauplius or metanauplius stage, last for a few weeks ! in spiny lobster phyllosomae may last approx. 6 months to 1 year (shorter in other lobsters), metamorphose into pueruli which last 6 months, and after settling, post pueruli	up to six years (in coconut crab)	most species several years; up to 50 years in coconut crab

	Egg	Larvae	Juvenile	Adult
Diet	N/A	!brachyurans and anomurans hatch to zoea phase, develop into megalops and glaucothoe postlarvae, respectively generally planktivorous		various, but typically carnivorous or omnivorous predators or scavengers, with preferred food items being mollusks, other crustaceans, and small fish; some taxa are specialized cleaners that feed on ectoparasites, while others are filter feeders
Distribution	in spiny lobster spawning continuous throughout the year, with individual females spawning up to 4 times each year, producing up to 0.5 million eggs each spawning; other species may have more defined spawning seasons			all major groups known or assumed to be well-represented at all locations in the region (e.g., around 2,000 species of crabs are known from the region)
Location	in penaeid shrimps, eggs are shed directly to the water; in other decapod groups and in stomatopods eggs carried on the pleopods of the female			
Water Column		in lobsters, newly-hatched larvae may occur in upper 60m, but later larval stages may occur in deeper water (80-120m)		!stomatopods are generally subtidal from 5-70m depth !coral associated shrimps generally found in depths from 3-15m but may be found much deeper !lobsters generally occur in depths between 20-55m, but may occur to at least 110m !crabs may be terrestrial, intertidal, or subtidal to depths of at least 115m

	Egg	Larvae	Juvenile	Adult
Bottom Type			juvenile spiny lobsters occupy habitat similar to that of adults	! stomatopods typically in burrows, either in sand or rubble ! shrimp may stay buried in sand or live in pockets in coral or among rubble ! lobsters typically in subtidal holes or crevices on reefs ! crabs may occupy mud or sand bottom, corals, or rocky areas
Oceanic Features		palinurid larvae may be transported up to 2,000 miles by prevailing ocean currents		while some taxa are pelagic, these are generally not reef-associated

⁸ The MUS as defined here includes mantis shrimp (Order Stomatopoda), as well as shrimps, lobsters, and crabs (various taxa within the Order Decapoda). The taxa not already addressed under Amendment 10 of the *Crustacean Fisheries Management Plan* (which covers spiny lobsters and kona crab) are the primary emphasis here.

Table 79. Economic importance of invertebrates.

FMU	Economic Importance				Distribution					
	Food	Ornamental	Bio-prospecting	Fouling Organism	AS	CNMI	GU	MHI	NWHI	Other
CEPHALOPODS:										
octopus	!	L			!	!	!	! R	! R	A
squid and cuttlefish	!				A	!	!	!	A	A
nautilus	L	!			!					
TUNICATES			!	!	A	!	!	!	!	!
BRYOZOANS			!	!	A	A	A	!	A	A
CRUSTACEANS:										

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Appendix F

stomatopods	L	L			A	! R ¹⁰	!	!	A	!
shrimps	!	!			A	! R ¹	!	!	!	!
lobsters	!	L			!	! R	!R	!R	!R	!
crabs	!	L			!	! R ¹	! R ¹¹	! R ¹²	! R	!

L = Limited Use

A = Assumed to be Present; R = Regulated

¹⁰ all invertebrates regulated (for export)

¹¹ coconut crab

¹² blue crab, Samoan crab

5.2.5 Bibliography

- Abbott, Donald P. et al. 1997. In L. G. Eldredge (ed.). Phylum Chordata, Subphylum Urochordata (Tunicata) Class Ascideacea. *Reef and Shore Fauna of Hawaii (Section 6B)*. Bishop Museum Press.
- Allen, Gerald R. and Roger Steene 1996. *Indo-Pacific Coral Reef Field Guide*. Tropical Reef Research, Singapore.
- Amerson, Jr., A. Binion, and Philip C. Shelton. 1976. The natural history of Johnston Atoll, Central Pacific Ocean. *Atoll Res. Bull.* 192.
- Amesbury, et al 1986 in USFWS 1996. *Pacific Islands Ecoregion Coastal Ecosystems Program Proposal*. Pacific Islands Ecoregion, USFWS, Honolulu, HI.
- Asakura et al. 1994. Anomura (Crustacea: Decapoda) collected from the Northern Mariana Islands, Micronesia, *Nat. Hist. Res. (Special Issue 1)*:275-283.
- Bailey-Brock, J. H. 1987. Epifaunal colonization and community development on an artificial reef in Hawaiian waters. *Bull. Mar. Sci.*41 (2): p.633.
- Barnes, Robert D. 1987. *Invertebrate Zoology*. Saunders College Publishing, Philadelphia.
- Brock, Richard E. 1973. A new distributional record for *Panulirus marginatus* (Quoy & Gaimard, 1825). *Crustaceana* 25:111-112.
- Coles, S. L., et al. 1999. Nonindigenous marine species introductions in the harbors of the south and west shores of Oahu, Hawaii. *Bishop Museum Technical Report 15*: 210pp.
- Craig et al. 1993. The commercial, subsistence, and recreational fisheries of American Samoa. *Marine Fisheries Review*. 55 (2): 109-116.
- Cuffey, R. J. 1972. The roles of bryozoans in modern coral reefs. *Geol. Rundschau* 61:542-550.
- Dade, W. Brian, and Taina Honkalehto May 1986. Bryozoan assemblages in modern coral reefs of Kaneohe Bay, Oahu. In Jokiel, Paul L. et al. (eds.). *Coral Reef Population Biology*. *Hawaii Institute of Marine Biology Technical Report No. 37*. Sea Grant Cooperative Report UNIHI-SEAGRANT-CR-86-01.
- Edmondson, Charles H. 1923. Crustacea from Fanning and Palmyra Islands. *Bernice P. Bishop Museum Bulletin* 5.
- Eldredge, L. G. 1995. Status of crustacean systematics. In Maragos, J., et al. (eds.). *Marine and coastal biodiversity in the tropical island Pacific region. Volume 1. Species*

- systematics and information management priorities*. East-West Center, Honolulu, Hawaii: pp.161-169.
- Eldredge, L. G. 1966. A taxonomic review of Indo-Pacific didemnid ascidians. *Micronesica* 2(2):161-261.
- Eldredge, Lucius G., and Scott E. Miller 1995. How many species are there in Hawaii? *Bishop Museum Occasional Papers*. 41:1-18.
- FAO 1991. Marine Lobsters of the World. *FAO Fish. Synop.* 125 (13).
- Fletcher, Warwick J. 1993. Coconut crabs. In: Wright, A. and L. Hill. (eds.) *Nearshore marine resources of the South Pacific*. Forum Fisheries Agency (Honiara): 643-681.
- Friedlander, Alan M., September 1996. *Assessment of the coral reef resources of Hawaii with emphasis on waters of federal jurisdiction*. Prepared for Western Pacific Regional Fishery Management Council.
- Gossliner, Terrence M., et al. 1996. *Coral Reef Animals of the Indo-Pacific: Animal Life from Africa to Hawaii—i Exclusive of the Vertebrates*. Sea Challengers, Monterey (Cal.).
- Green, Allison, October 1997. *An Assessment of the Coral Reef Resources, and Their Patterns of Use, in the U.S. Pacific Islands*. Western Pacific Regional Fishery Management Council. (draft).
- Green, James 1961. *A biology of 425rustacean*. Quadrangle Books, Chicago: xv+180pp.
- Hamano, T. 1994. Stomatopod crustaceans from the Northern Mariana Islands, Micronesia. *Nat. Hist. Res. (Special Issue 1)*: 291-292.
- Hayashi, K., et al. 1994. Macrura (Crustacea: Decapoda: Stenopodidea, Caridea, and Palinulidea) collected from the Northern Mariana Islands, Micronesia. *Nat. Hist. Res. (Special Issue 1)*: 267-273.
- Hensley, R. A., and T. S. Sherwood 1993. An overview of Guam's inshore fisheries. *Marine Fisheries Review*.55(2):129-138.
- Hoover, John P. 1998. *Hawaii's sea creatures: a guide to Hawaii's marine invertebrates*. Mutual Publishing, Honolulu: xviii+366 pp.
- ICLARM 1998. *ReefBase: A Global Database on Coral Reefs and Their Resources*. Version 3.0 (CD-ROM). Manila, Philippines.

- Johnston, M. W. 1974. On the dispersal of lobster larvae into the eastern Pacific barrier (Decapoda, Palinuridea). *Fish. Bull.* 72(3): 639-647.
- Kancirik, P. 1980. Ecology of juvenile and adult Palinuridae (spiny lobsters). In: Cobb, J. S., and B. F. Phillips (eds.). *The biology and management of lobsters. Vol. 2, Ecology and management.* Academic Press, Sydney: p.11-57.
- Kay, E Alison 1979. Hawaiian Marine Shells. *Reef and Shore Fauna of Hawaii, Section 4: Mollusca.* Bishop Museum Press.
- Kott, Patricia 1981. The ascidians of the reef flats of Fiji. *Proc. Linn. Soc. N.S.W.* 105: 147-212.
- Kropp, Roy K. 1987. Descriptions of some endolithic habitats for snapping shrimp (Alpheidae) in Micronesia. *Bull. Mar. Sci.* 41(2):204-213.
- Lee, I.H., et al. 1997. Clavanins, alpha-helical antimicrobial peptides from tunicate hemocytes. *FEBS Lett.* 400 (2): 158-162.
- Littler, M. M., and D. S. Littler 1995. A colonial tunicate smothers corals and coralline algae on the Great Astrolabe Reef, Fiji. *Coral Reefs* 14: 148-149.
- MacDonald, C.D. 1986. Recruitment of the puerulus of the spiny lobster *Panulirus marginatus*, I Hawaii. *Can. J. Fish. Aquatic Sci.* 43: 2118-2125.
- MacDonald, C. D., and S. Stimson 1980. Population biology of spiny lobsters in the lagoon at Kure Atoll-preliminary findings and progress to date. In: Grigg, R. W., and R. T. Pfund (eds.). *Proceedings of the symposium on status of resource investigations in the Northwestern Hawaiian Islands. April 24-25, 1980, University of Hawaii, Honolulu. UNIHI-SEAGRANT-MR-80-04:* pp. 161-184.
- Matsumoto, Walter M., and Tsuneyoshi Suzuki, October 1988. Cooperative squid surveys in Hawaiian waters, 1981-83. *NOAA Technical Memorandum NMFS.*
- Meglitsch, Paul A., and Frederick R. Schram. 1991. *Invertebrate Zoology.* Oxford University Press, New York.
- Micronesian Environmental Services, March 1997. *The Commonwealth of the Northern Mariana Islands: an assessment of the coral reef resources under local and federal jurisdiction.* Prepared for Western Pacific Regional Fishery Management Council.
- Monniot, C., et al. 1991. *Coral Reef Ascidians of New Caledonia.* ORSTOM (Noumea).

- Muller, W. E. , et al. 1994. Molecular cloning and localization of a novel serine protease form the colonial tunicate *Botryllus schlosseri*. *Mol. Mar. Biol. Biotechnol.* 3 (2): 70-77.
- Myers, R. F. 1997. Assessment of coral reef resources of Guam with emphasis on waters of federal jurisdiction. Report prepared for Western Pacific Regional Fisheries Management Council. 21pp.
- Nesis, Kir N. 1987. *Cephalopods of the World: Squids, Cuttlefishes, Octopuses, and Allies*. T.F.H. Publications, Inc., Neptune, N.J.
- Onizuka, E. W. 1972. Management and development investigations of the Kona crab, *Ranina ranina* (Linnaeus). Final report to Div. Aquatic Resources, Dep. Land and Natl. Resources, State of Hawaii. 28pp.
- Pancer, Z., et al. 1997. A novel tunicate (*Botryllus schlosseri*) putative C-type lectin features an immunoglobulin domain. *DNA Cell Biol* 16 (6): 801-806.
- Pancer, Z., et al. 1993. cDNA cloning of a putative protochordate FK506-binding protein. *Biochem. Biophys. Res. Commun.* 197 (2): 973-977.
- Parrish, F. A., and J. J. Polovina 1994. Habitat threshold and bottlenecks in production of the spiny lobster (*Panulirus marginatus*) in the Northwestern Hawaiian Islands. *Bull. Mar. Sci.* 54 (1):151-161.
- Pearse, Vicki, et al. 1987. *Living Invertebrates*. Blackwell Scientific Publications (Boston, Mass.)/Boxwood Press (Pacific Grove, Cal.).
- Pitcher, R. C. 1993. Spiny lobster. In: Wright, A. and L. Hill. (eds.) *Nearshore marine resources of the South Pacific*. Forum Fisheries Agency (Honiara): 539-607.
- Polovina, J. J. 1993. The lobster and shrimp fisheries in Hawaii. *Mar. Fish. Rev.* 55(2):28-33.
- Roper, Clyde F. E., et al. 1984. FAO species catalogue, vol. 3. Cephalopods of the world. An annotated and illustrated catalogue of species of interest to fisheries. *FAO Fish. Synop.* 125 (3):1-277.
- Ryland, J. S. 1970. *Bryozoans*. Hutchinson & Co., London: 175pp.

- Ryland, J. S. et al. 1984. Ecology and colonial dynamics of some Pacific reef flat Didemnidae (Ascidiacea). *Zool. J. Linnean Soc.* 80:261-282.
- Saunders, W. B., et al. 1989. On the distribution of *Nautilus pompilius* in the Samoas, Fiji and Tonga. *The Nautilus* 103(3):99-104.
- Singley, C. T. 1983. *Euprymna scolopes*. In Boyle, P. R. (ed.) *Cephalopod Life Cycles. Volume I: Special Accounts*. Academic Press, London: 69-74.
- Smith, B. D., et al. 1989. A marine survey of the Apanon coastal environment, Talakhaya Area, Rota, Mariana Islands. *University of Guam Marine Laboratory, Environmental Survey Report No. 22*.
- Soule, John D., et al. 1987. In Devaney, D. M., and L. G. Eldredge (eds.). Phyla Entoprocta and Bryozoa (Ectoprocta). *Reef and Shore Fauna of Hawaii (Section 2)*:83-166. Bishop Museum Press.
- Stoner, Douglas S. May 1989. *Life History and Population Biology of the Colonial Ascidian Diplosoma 428rustac*. Ph. D. Dissertation, University of Hawaii.
- Takeda, M., et al 1994. Brachyura (Crustacea: Decapoda) from the Northern Mariana Islands, Micronesia. *Nat. Hist. Res. (Special Issue 1)*: 285-290.
- Tinker, Spencer W. 1965. *Pacific Crustacea: An illustrated handbook on the reef-dwelling 428rustacean of Hawaii and the South Seas*. Charles E. Tuttle Co., Rutland, Vermont: 134pp.
- Tokioka, Takasi 1967. Pacific Tunicata of the United States National Museum. *U.S. Natl. Museum Bull.* 251:1-242.
- Uchida, R. N. 1986(a). Palinuridae. In: Uchida, R. N., and J. H. Uchiyama (eds.). Fishery atlas of the Northwest Hawaiian Islands. *NOAA Technical Report, NMFS 38*:p. 66-67.
- Uchida, R. N. 1986(b). Scyllaridae. In: Uchida, R. N., and J. H. Uchiyama (eds.). Fishery atlas of the Northwest Hawaiian Islands. *NOAA Technical Report, NMFS 38*:p. 68-69.
- Uchida, R. N. and D. T. Tagami 1984. Biology, distribution and population structure and preexploitation abundance of spiny lobster, *Panulirus marginatus* (Quoy and Gaimard 1825), in the Northwest Hawaiian Islands. In: Grigg, R. W., and K. Y. Tanoue (eds.). Proceedings of the second symposium on resource investigations in the Northwestern Hawaiian Islands. *UNIHI-SEAGRANT-MR-84-01.1*: pp. 157-198.

- Van Alstyne, K. L., and V. J. Paul 1988. The role of secondary metabolites in marine ecological interactions. In: Choat, J. H., et al (eds.). *Proceedings of the Sixth International Coral Reef Symposium, Australia 1*:175-186.
- Van Heukelem, W. F. 1983. *Octopus cyanea*. In Boyle, P. R. (ed.) *Cephalopod Lif Cycles. Volume I: Special Accounts*. Academic Press, London: 267-276.
- Ward, P. D. 1983. *Nautilus macromphalus*. In Boyle, P. R. (ed.) *Cephalopod Lif Cycles. Volume I: Special Accounts*. Academic Press, London: 11-28.
- Western Pacific Regional Fishery Management Council 1983.
- Western Pacific Regional Fishery Management Council. September 1998. *Magnuson-Stevens Act Definitions and Required Provisions: Amendment 6 to the Bottomfish and Seamount Groundfish Fisheries Management Plan; Amendment 8 to the Pelagic Fisheries Management Plan; Amendment 10 to the Crustaceans Fisheries Management Plan; Amendment 4 to the Precious Corals Fisheries Management Plan*.
- Western Pacific Regional Fishery Management Council. 25 May 1999. *Draft Fishery Management Plan for Coral Reef Ecosystems of the Western Pacific Region*. (working draft by CRE Plan team).
- Williamson, D. I. 1982. Larval morphology and diversity. In Abele, Lawrence G. (ed.) *The biology of Crustacea. Vol. 2: Embryology, Morphology, and Genetics*. Academic Press, New York: 43-110.
- Yoshimura T., and H. Yamakawa 1988. Microhabitat and behavior of settled pueruli and juveniles of Japanese spiny lobster *Panulirus japonicus* at Kominato, Japan. *J. Crust. Biol.* 8(4):524-531.
- Young, Richard Edward, and Robert F. Harman 1989. Octopodid paralarvae from Hawaiian waters. *The Veliger* 32(2):152-165.
- Zhao, C., et al. 1997. cDNA cloning of three cecropin-like antimicrobial peptides (Styelins) from the tunicate, *Styela clava*. *FEBS Lett.* 412 (1): 144-148.

5.3 EFH for Management Unit Species - Sessile Benthos

The concept of essential fish habitat (EFH) is of obvious value when used as a tool to protect individual fisheries. It is defined as that habitat necessary for their various stages of managed species life histories to perpetuate. To consider the sessile benthos (SB) as required by the Interim Final Rule (IFR) for EFH, the concept must be qualified. This is because it is applied to broad groups of organisms, many of which form the habitat upon which all other species depend. Due to the large numbers of species of coral, algae and other sessile benthos (450 spp algae; 99 Scleractinia and 150 spp. of the other groups considered in Hawaii (Eldredge and Miller, 1995) and a total of approximately 1200 spp of the combined groups in the total AFPI), the concept loses definition and becomes too generalized to be of value. The vast numbers of SB do not represent a managed fishery. This is particularly the case when considering the benthos of coral and algae. Tables 89 to 92 summarize the various aspects of EFH for algae in the Western Pacific Region.

The fauna and flora, generally, lack mobility in the adult stages with the intermediate stages are transported in the water column until settlement. Once they have settled they largely become habitat. They are instrumental in the ecosystems primary production and are largely responsible for supporting the higher trophic levels, many with predator-prey relationships. The high degree of symbiosis begins with the zooxanthellate associations and encompasses a wide degree of associations involving all groups of the fauna and flora. Much of the physical relief of the reef is the result of the living environment as is the deposition of the coral reef itself. An overly simplistic assessment of the habitat requirements for the sessile benthos includes suitable substrate, water quality and light. This, however, negates the history of the substrate development and the myriad of biological interactions, which qualify as a coral reef. Due to these considerations, the species and their fundamental roles in the ecosystem define the EFH as the coral reefs themselves. As such, all coral reefs in the AFPI should be designated EFH for the sessile benthos. This is because all of the coral reef associated fisheries for which the Magnuson-Stevens Fisheries Conservation and Management Act was designed to protect and conserve depend on the coral reef ecosystem.

As there is no fisheries extraction of the sessile benthos in the AFPI, the objective of the concept discussion shifts to the life history characteristics of the fauna and flora of the coral reef environment. It is the life history stages of the selected benthic groups that comprise the discussion of their importance in the EFH description. It is important in the consideration of the management unit species (MUS).

Life histories and habitat requirements rely on an understanding that the coral reef is a variable and dynamic entity. The composition of the reefs responds to environmental parameters such as temperature, dilution and sedimentation. Regionally, their composition varies in response to temperature by virtue of latitude, current regimes and events brought on

by unique climatic events such as El Niño hot spots. Such major discontinuities in taxa occurrence such as the absence of the genus *Acropora* in Hawaii or reef cementing coralline alga in extra-tropical areas, require that we consider reefs on a regional basis, as well as, locally. The history of a particular area is as important as short-term community cycles and is often seen to be decadal in time frame, and most probably represents longer cycles. The fossil record of reefs shows a process of progressive change in the nature of reefs. Current concern for global warming and the effects of some of the hotspots may require this to be added to the equation, when human induced impacts are considered.

The interconnectivity of the coral reef, in terms of potential recruitment, provide us with an understanding of the reef environment that is at once very robust and able to restore itself after the most destructive natural events. The coral reef is fragile, in that, if the composition of a reef is changed then the effect is likely to be manifest down current as well. A chronic change in the environmental parameters of an area is likely to result in a permanent change in the community composition. In summary, EFHs are not a useful concept for the numerous sessile benthos at the species level but rather a conformation of the importance of the many non-commercial species that comprise the coral reef ecosystem. In developing this as an operational framework, Conservation of these broad groups may be accomplished in two ways. 1) It may be appropriate to establish criteria for the amount of reef that is allowed to be affected by development, fishing practices or tourism. This quantity would be established in relation to the amount of area of unaffected reef, within the range of the ocean currents that would allow restoration or maintenance of this area through recruitment. 2) Equally useful is the concept of the *management unit species (MUS)* in making the description of the ecosystem more manageable with better resolution in its definition. Here generic assemblages or their interactions are considered entities, which allow a more categorical method of management.

The Management Unit Species (MUS): An Ecosystem Approach

The concept of the management unit species (MUS) is a useful concept when considering a resource composed of species or higher taxa who share the same habitat, have the same trophic ecology or respond to changing environmental variables in a predictable way. Coral reef zonation, as the result of an environmental regime, reflects a natural MUS organization. Whether through tolerance or requirement, benthos is sorted into a zonation with respect to the proximity to land, depth or wave action. Impacts which add nutrients, as the result of some human activity, to a naturally low-nutrient coral reef and the community changes from being micro-algal and coral dominated, to being macro-algal and with a great reduction in the hard coral component. In the case of increases in sediments and freshwater, there is a reduction in species numbers in both groups to those which are resistant to such effects. Tidal influences of periodic exposure, ponded waters or exposure to wave action have a dramatic effect in conditioning species complements.

The MUS may be defined in relation to the environmental variables, be it natural or induced. With respect to this, taxonomic classification does not conform to groupings by environmental tolerances. As a result, a wide range of taxonomic groups is considered depending on the type of organism. This section describes these groups as general taxonomic entities. Depending on the availability of information or scale of consideration, in an operational sense, the appropriate taxonomic level should be used. As an example, *Porites/Favid* assemblages are characteristic of areas of periodic flooding. *Acropora* assemblages and a micro-algal assemblage are characteristic of normal seawater salinity with clear, flowing aerated water. Add wave action to this and the coral assemblages become reduced in diversity and morphology characterized by robust or encrusting forms. Coralline alga dominated. The dynamic potential inherent in coral reef communities becomes apparent with a change in the environment as the result of some change in a natural parameter resulting from development or terrestrial activity.

In conforming to the MUS approach, using the general taxonomic groupings of sessile benthos was considered for designations of the MUS. Within these groups species can be clumped based on selection by environmental parameters. Suggested divisions are the hard and soft coral and the micro and macro-alga. Other benthic groups of reef associated organisms (*Porifera*, *Actinaria*, *Hydroidea*, *Gorgonacea* and *Zooanthidea*), generally, are less dominant in reef communities and more liable to conform, in terms of abundance, to the dominance exhibited by the primary groupings. In terms of the reef community composition, these more minor groups are largely coral or algal associated with the type and abundance of coral or alga conditioning their occurrence. It is useful to consider the light limited environments of depth or caves where the groups such as the *Gorgonacea* and *Porifera* may be dominant.

It would be in error not to emphasize considering the regionality of such a framework. The Caribbean and Florida seaboard are very different than the Indo-Pacific. Within the Indo-Pacific, species occurrence, generally, winnows from west to east and is limited when approaching the temperate boundaries. As a result, geographic locations may vary in terms of their species complements. This gives rise to variability in dominance but does not change the relationship within the four major groupings. The species within the groupings become less consequential, varying in dominance depending on the region.

Habitat Areas of Particular Concern (HAPC)

Habitat areas of particular concern for the benthos of coral reefs may include a variety of situations. These may be the same as those which give rise to marine protected areas or where a conservation area has been set aside to protect organisms which may have been depleted through fishery harvest. Particular concern may be for an area where coastal development has adversely impacted near shore areas. With respect to this, it may be that

areas within ocean current range should be protected to conserve areas which are unprotectable due to a requirement for subsistence fishing, recreational usage, damage done by circumstances of coastal development or activities inland such as agriculture. It may be that an area is of concern due to the long history of research at a particular site or area and the encroachment of development (e.g. Pago Pago Harbor, American Samoa). Reserves, national parks, wildlife refuges and other protected areas are existing operational areas of particular concern.

5.3.1 Algae

5.3.1.1 Algal Life Cycles

Both sexual and asexual reproduction are widespread in algae, and the predominance of one or the other is mainly linked to the class of algae in question (Cyanobacteria, Chlorophyta, Phaeophyta or Rhodophyta) and the predominant geographical and environmental conditions affecting the algal populations (Bold and Wynne, 1985). Unicellular algae reproduce mainly asexually, while multicellular algae have asexual or sexual life cycles of varying complexity. Sexual life cycles are classified into four basic types, according to the site of meiosis or reduction-division of the algal genome (table I). By far the most common type is the sporic life cycle, in which a usually diploid sporophyte stage alternates with a usually haploid gametophyte stage. The recurring sequence of these two stages is called alternation of generations, which can be either isomorphic (when both generations are morphologically similar) or heteromorphic (where one generation can differ markedly in morphology from the other).

Table 80. Classification of sexual algal life cycles (after South and Whittick, 1987)

Life cycle type	Site of meiosis	Main algal groups concerned
Zygotic	zygote	Unicellular algae (Chrysophyceae)
Sporic	sporangia	Rhodophyta, Phaeophyta, Chlorophyta
Gametic	gametangia	Chlorophyta
Somatic	thallus cells	Chlorophyta, Rhodophyta

Cyanophyta

In the Cyanophyta, reproduction is primarily by the production of asexual spores, which are released into the environment and grow into new individuals. These spores can be produced by budding from the free ends of the filaments, or by the fission of large vegetative cells within the thallus.

Phaeophyta

In most members of the Phaeophyta, sexual reproduction is sporic, with the alternation of a haploid gametophyte generation with a diploid sporophyte generation; both generations may or may not be morphologically similar. Spores are usually numerous and motile, being produced in unilocular sporangia.

Chlorophyta

The Chlorophyta life cycle is variable, but a typical case can be demonstrated in the common genera *Ulva*, where zoospores are produced in the thallus which are released and fuse to produce a new individual.

Rhodophyta

Most members of the Rhodophyta exhibit a sporic life cycle, a majority of which are of the triphasic *Polysiphonia*-type. The gametophytes and the tetrasporophyte are often isomorphic (although in some algae the tetrasporophyte can be crustose and alternate with large fleshy gametophytes). The Carposporophyte is reduced, and attached to the female gametophyte. The gametes are non-motile.

5.3.1.2 Distribution patterns of algae amongst the American Flag Pacific Islands (AFPI) (with nomenclature updated (following taxonomy in Silva *et al.* 1996), from available literature; excludes varietal status of species). The attached AFPI algae distribution table lists 815 taxa of marine algae, statistically broken down as follows:

Table 81. Algae distribution in the American Affiliated Pacific Islands (AFPI)

AFPI locality	Cyanophyta	Chlorophyta	Phaeophyta	Rhodophyta	Total
American Samoa	15	31	14	68	128
Baker Is.	1	6	3	6	16
Howland Is.	0	5	1	3	9
Jarvis Is. ¹	-	-	-	-	-
Palmyra Is.	19	39	11	64	133
Kingman Reef ¹	-	-	-	-	-
Johnston Atoll	19	24	9	40	92
Hawaii ²	3	48	29	343	423
NWHI	0	43	32	121	196
Wake Island	2	8	10	3	23
CNMI	5	55	20	57	137
Guam	16	58	29	98	201
Total	52	142	70	333	

¹ no data available at this time

² Abbott (1995) estimates the total Hawaiian flora at about 400 species

Comments

Because the reported distribution is related to the sampling effort in each particular locality, the comparisons are largely artificial at this stage. For instance, the Guam and North West Hawaiian floras are fairly well-known, while the Jarvis Is., Kingman Reef, Wake Is, Baker and Howland Islands floras are seriously under-collected or unknown. For the Hawaiian

flora, there is a large amount of as yet unpublished material which will drastically increase the number of known species in the near future (Abbott 1995).

The most comparable groups of algae are the Phaeophyta and Chlorophyta, because they are mostly intertidal in habitat and thus most easily collected and inventoried, and there is a relatively constant number of common species across the AFPI islands for the better investigated localities.

Distribution Among Islands

From an examination of the species distribution table, the most commonly reported species (those which occur in 50% or more of the localities under study) for the islands of the AFPI are as follows, according to class:

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Table 82. Most commonly reported algal species for the islands of the AFPI

Class	Most common species	Typical reef habitat
Cyanophyta	<i>Lyngbya majuscula</i>	inner reef flat
	<i>Schizothrix calcicola</i>	inner reef flat
Chlorophyta	<i>Boodlea</i> spp.	inner / outer reef flat
	<i>Bryopsis pennata</i>	inner reef flat / lagoon
	<i>Caulerpa racemosa</i>	inner / outer reef flat
	<i>Caulerpa serrulata</i>	inner reef flat / lagoon
	<i>Dictyosphaeria</i> spp.	inner reef flat / lagoon
	<i>Halimeda discoidea</i>	inner reef flat
	<i>Halimeda opuntia</i>	inner reef flat
	<i>Neomeris annulata</i>	inner reef flat
Phaeophyta	<i>Ventricaria ventricosa</i>	reef flat / outer reef slope
	<i>Dictyota friabilis</i>	reef flat
	<i>Feldmannia indica</i>	reef flat
	<i>Hincksia breviarticulata</i>	reef crest / exposed shoreline
	<i>Lobophora variegata</i>	reef flat / lagoon
	<i>Sphacelaria</i> spp.	reef flat / epiphytic
	<i>Turbinaria ornata</i>	reef flat / bommies in lagoon
Rhodophyta	<i>Amphiroa fragilissima</i>	inner reef flat
	<i>Asparagopsis taxiformis</i>	reef crest / outer reef slope
	<i>Centroceras clavulatum</i>	reef flat / epiphytic
	<i>Gelidiopsis intricata</i>	inner reef flat / lagoon

Class	Most common species	Typical reef habitat
	<i>Gelidium pusillum</i>	inner reef flat
	<i>Hydrolithon reinboldii</i>	reef crest
	<i>Hypnea esperi</i>	inner reef flat
	<i>Jania capillacea</i>	reef flat
	<i>Martensia fragilis</i>	outer reef slope
	<i>Neogoniolithon brassica-florida</i>	reef crest
	<i>Polysiphonia spp.</i>	reef flat
	<i>Porolithon onkodes</i>	reef crest
	<i>Portieria hornemanni</i>	outer reef slope

Habitat distribution of the common algal species in the AFPI (After N' Yeurt, 1999)

The Flora of Fringing Reefs

In shallow, calm fringing areas where sediment accumulations are predominant, green and brown algae are most abundant with the most characteristic species being *Caulerpa spp.*, *Chlorodesmis fastigiata*, *Halimeda spp.*, *Neomeris spp.*, *Ventricaria ventricosa* and *Boodlea spp.* for the greens, and *Padina spp.* and *Dictyota spp.* for the browns. Common red algae include *Galaxaura spp.* and *Laurencia spp.* When water depth and movement are more important, hard substrata (coral colonies and rubble) are more numerous and ubiquitous species such as *Turbinaria spp.* and *Sargassum spp.* thrive. In very exposed places, the marine scenery is generally rocky or limited to small shelves below the border road. The violent wave action increases sea spray and enables the rise of certain species notably the two brown algae *Chnoospora minima* and *Hincksia breviarticulata*. On this type of shelf we generally find the flora of external reef shelves described later, confined to a few square meters owing to the intensity of the hydrodynamic factors such as wave action.

The Flora of the Barrier Reef

On barrier reefs, coral bommies are generally dominant, between which are spread out well sorted-out sediments. The pavement of the lagoon floor is visible in areas of strong hydrodynamism. Water level rarely exceeds 2.5 m. The flora is essentially one of hard substrata, and species exist in close link with the coral colonies, resulting in a mosaic pattern of species distribution. The summit of coral bommies skimming the water surface are

generally colonised by the large brown algae *Turbinaria ornata* and *Sargassum spp.*, that form an elevated layer under which grow species such as *Amansia sp.*, and coralline algae. In areas where grazing by herbivores is more important, the bommies are covered by a fine tuft where a great number of discrete species belonging to the Ceramiaceae and Rhodomelaceae intermingle. In areas where hydrodynamism is more important, the encrusting coralline algae form pinkish, yellowish and bluish blotches on the upper parts of the substratum.

At the base of bommies, it is common to see large bunches of brown algae such as *Dictyota bartayresiana*, intermingled to the spread-out thalli of *Halimeda opuntia* and tufts of the red algae *Galaxaura fasciculata* and *G. filamentosa*. Most crevices are colonised by *Ventricaria ventricosa*, *Valonia fastigiata*, and *Dictyosphaeria spp.* Finally, where direct sunlight does not reach, live a range of encrusting coralline algae whose pink, violet and purple hues mingle with the soft green colours of *Halimeda spp.* and *Caulerpa spp.*

The Flora of the Outer Reef Flats

It is probably the richest and most diversified flora of the reef complex. On high islands, it is represented by a belt of the brown algae *Turbinaria ornata* and *Sargassum spp.*. We find in particular the erect and stiff tufts of *Laurencia spp.* and *Gelidiella spp.*, to which are attached the little bright green balls of *Chlorodesmis fastigiata*, or the light pink hemispherical cushions of the articulated Corallinaceae *Amphiroa spp.* and the opportunistic *Jania spp.* It is here that the encrusting calcified algae form the most important growths, with notably *Hydrolithon spp.* However, it is on the reef flats of atolls that Corallinaceae formations are the most exuberant. They form a compact pad of a beautiful brick-red colour, and in very exposed places even construct spectacular corbellings several tens of centimetres thick. The dominant species is *Hydrolithon onkodes* with a rather smooth texture. On atolls, large brown algae are absent and the fleshy species are limited to yellowish-brown rosettes of *Lobophora variegata* and *Turbinaria spp.*

The Flora of the Lagoons of Atolls

The sandy bottoms of the lagoons are often in deeper parts, covered with a mucous film rich in bacteria or of a carpet of Cyanobacteria where mingle tufts of filamentous red algae such as *Polysiphonia*, *Ceramium*. The hard substrata are always much richer in various green algae such as *Caulerpa* and *Halimeda*. Bommies in the lagoon offer a habitat for green genera such as *Cladophoropsis spp.* and very large varieties of *Dictyosphaeria cavernosa*.

The Flora of the Outer Reef Slope

It extends beyond 10 meters depth. The red algae are most abundant and diversified. It is the main area of encrusting coralline algae (mainly in the atolls), but also of elegant and fleshy

forms such as *Gibsmithia hawaiiensis* and *Asparagopsis taxiformis*. As one goes deeper, coralline algae become the dominant species, although occasionally species of the green algal genus *Halimeda* and the brown algal genus *Lobophora* have been found up to depths of 130 metres (Littler *et al.* 1985) while the green alga *Caulerpa bikiensis* has been reported beyond depths of 70 metres (Meinesz *et al.* 1981).

5.3.1.3 The Ecological Role of Algae in the Coral Reef Ecosystem

Benthic algae are a very important, yet often overlooked component of any reef biome. Marine plants are responsible for the primary productivity of the reef ecosystem, owing to their photosynthetic ability which inputs solar-derived energy into the reef community. This energy is made available to other reef organisms in a variety of forms, ranging from direct input (grazing by herbivores; symbiotic relationships with invertebrates and fungi) or indirectly by the breaking down of plant products and detrital residues after death.

Algae play an important role in organic and inorganic material cycles within the reef community, by being able to retain and uptake key elements such as nitrogen and carbon. The primary role of marine algae in the carbon and nutrient cycles of coral reef ecosystems cannot be underestimated and has been the focus of much research (Dahl 1974; Wanders 1976; Hillis-Colinvaux 1980; Payri 1988; Charpy and Charpy-Roubaud 1990; Charpy-Roubaud and Sournia 1990; Charpy-Roubaud *et al.* 1990, Charpy *et al.* 1992; Gattuso *et al.* 1996).

Calcified (*Halimeda* and *Amphiroa spp.*) and crustose coralline algae play a major but easily overlooked role in coral reef construction and consolidation, and contribute a major part of reef carbonate sediments (Payri 1988). These organisms lay down calcium carbonate as calcite, which is much stronger than the brittle aragonite produced by corals, thus cementing and consolidating the reef structure. In particular, coralline algae are of primary importance in constructing the algal ridge that is characteristic of exposed Indo-Pacific reefs, which prevent oceanic waves from striking and eroding coastal areas (Nunn 1993; Keats 1996). At the other extreme, penetrating or boring algae such as Cyanophyta are important contributors to bioerosion and breakdown of dead reef structures (Littler and Littler 1994).

Marine macroalgae contribute significantly to organism interrelationships in reef ecosystems, either by the production of chemical or structural by-products on which other organisms depend, the providing of protective micro-habitats for other species of algae or marine invertebrates, or by offering surfaces promoting the settlement and growth of other algal species or the larvae of some herbivorous invertebrates such as abalone (Dahl 1974; Keats 1996). Symbiosis is also an important aspect of algal interrelationships in reef communities, with hermatypic corals relying on photosynthetic zooxanthellae for food. Marine plants thus offer a remarkable potential as experimenting organisms in the elucidation of the complex

chemical and biological interactions that make up the fragile, closed ecosystems of tropical coral reefs (Littler and Littler 1994).

5.3.1.4 The Effects of Human Activities on Coral Reefs, in Relation to Algae

The impact of human habitation, and activities linked to industries and waste processing and disposal have proven negative impacts on coral reef ecology. An "healthy ecosystem" is a self-regulating unit where ecological productivity and capacity is maintained, with a diversity of flora and fauna present (Federal Register 1997: 66551). Some reef organisms are very sensitive to disruptions, and can act as timely indicators of changes in the natural balance of the ecosystem. For instance, the absence of *Acropora* coral on the backreef areas could indicate polluted waters with high levels of siltation, a situation reported from the stressed Aua Reef on Tutuila Island, American Samoa (Dahl and Lamberts 1977). The green algae *Enteromorpha* spp. and *Ulva* spp. thrive in high-nutrient areas, acting as bio-indicators of organic pollution linked to sewage outfalls, and also accumulate heavy metals present in industrial effluents (Tabudravu 1996). Dredging and increasing reclamation of coastal mangrove for industrial and urban use further contribute to siltation of the lagoon and the destruction of algal habitats and marine nursery areas. In this respect, algae can be classified as essential fish habitats (EFH) as they are direct contributors to the well-being and protection of fish species, both as a source of food and offering protection to larvae and small fish species. Overfishing in the lagoon reduces the number of herbivorous fishes, destroying the fragile equilibrium between reef organisms, while the input of excess nutrients via sewage and domestic effluents into the lagoon contributes to algal blooms. This can lead to the ecosystem shifting from coral dominance to algal dominance, and abnormal blooms of turf algae have been known to overgrow and kill healthy coral (Dahl 1974; Littler and Littler 1994) while >red tide= dinoflagellate blooms lead to anoxic conditions killing a wide range of marine organisms (Horiguchi and Sotto 1994). Increased chemical pollution of the lagoon could also lead to a bloom of reef-destroying organisms such as the crown-of-thorn starfish (Randall 1972).

Coral reefs have been known to recover relatively well if the stressing factors are removed soon enough before permanent damage is done (Dahl and Lamberts 1977). A strong and healthy barrier reef, in particular the *Porolithon* algal ridge of atolls, acts as a natural breakwater offering protection to coastal areas in the event of cyclones and such natural disasters, which are frequent in the region (Nunn 1993). However, the coral structure can be severely damaged and weakened as a result of siltation, eutrophication and the overgrowing of coral colonies by opportunistic filamentous algae (such as for instance happened in Kaneohe Bay, Hawaii; see Smith 1981), necessitating the construction of artificial barriers.

5.3.1.5 Bibliography

- Abbott, I. A. (1988). Food and food products from seaweeds. In: *Algae and Human Affairs*, edited by Lembi, C. A. and Waaland, J. R. Cambridge: Cambridge University Press, pp. 136-147.
- Abbott, I. A. (1989). Marine Algae of the Northwest Hawaiian Islands. *Pacific Science* 43(3): 223-233.
- Abbott, I. A. (1999). *Marine Red Algae of the Hawaiian Islands*. Bishop Museum Press, Honolulu. xvi + 477 + [1] p.
- Abbott, I. A. (1995). The state of systematics of marine algae in tropical island Pacific. In: *Marine and Coastal Biodiversity in the Tropical Island Pacific Region. Volume 1. Species Systematics and Information Management Priorities*, edited by Maragos, J. E.; Peterson, M. N. A.; Eldredge, L. G.; Bardach, J. E. and Takeuchi, H. F., pp. 25-38. East-West Center, Honolulu.
- Anon. (1997). Rules and regulations. *Federal Register* 62(244): 66551.
- Anon. (1999). *Baseline Marine Biological Survey, Peacock Point Outfall and other Point- Source Discharges, Wake Atoll, Pacific Ocean*. Report to the Department of Army by the Department of Interior, Fisheries and Wildlife Service (FWS) and the Department of Commerce, National Marine Fisheries Service (NMFS). Honolulu, Hawaii. 23 p.
- Bailey, J. W. and Harvey, W. H. (1862). Algae. In: *United States Exploring Expedition During the Years 1838-1842, Under the Command of Charles Wilkes, U. S. N.* edited by Bailey, J. W. and Harvey, W. H. Philadelphia: C. Sherman, pp. 155-192.
- Birkland, C.; Randall, R. and Amesbury, S. (1994). Coral and reef fish assessment of Fagatele Bay National Marine Sanctuary. *Report to NOAA, Technical Memoranda Series NOS / MEM 3*. 127 p.
- Bold, H. C. and Wynne, M. J. (1985). *Introduction to the Algae. Structure and Reproduction*. Prentice-Hall, Englewood Cliffs. xvi + 720 p.
- Brock, V. E.; Van Heukelem, W. and Helfrich, P. (1966). An ecological reconnaissance of Johnston Island and the effects of dredging. Second annual report submitted to the United States Atomic Energy Commission. *Hawaii Institute of Marine Biology Technical Report* 11: 68 p.
- Buggeln, R. G. and Tsuda, R. T. (1969). A record of benthic marine algae from Johnston Atoll. *Atoll Research Bulletin* (120): 1-20.

- Charpy-Roubaud, C., and Sournia, A. (1990). The comparative estimation of phytoplanktonic, microphytobenthic and macrophytobenthic primary production in the oceans. *Marine Microbial Food Webs* 4(1): 31-57.
- Charpy-Roubaud, C. J., Charpy, L. and Cremoux, J. L. (1990). Nutrient budget of the lagoonal waters in an open central South Pacific atoll (Tikehau, Tuamotu, French Polynesia). *Marine Biology* 107: 67-73.
- Charpy, L., and Charpy-Roubaud, C. J. (1990). A model of the relationship between light and primary production in an atoll lagoon. *Journal of the marine biology Association of the United Kingdom* 70: 357-369.
- Charpy, L., Blanchot, J. and Lo, L. (1992). Contribution des cyanobactéries (*Synechococcus* spp.) à la production phytoplanktonique dans un lagon d'atoll fermé (Takapoto, Tuamotu, Polynésie Française). *Cahiers de Recherche de l'Académie des Sciences de Paris* 314(3): 395- 401.
- Dahl, A. L. (1974). The structure and dynamics of benthic algae in the coral reef ecosystem. *Proceedings of the Second International Coral Reef Symposium* 1: 21-25. Great Barrier Reef Committee, Brisbane.
- Dahl, A. L., and A. E. Lamberts. (1977). Environmental impact on a Samoan coral reef: a resurvey of Mayor's 1917 transect. *Pacific Science* 31(3): 309-319.
- Dawson, E. Y. (1959). Changes in Palmyra Atoll and its vegetation through the activities of man, 1913-1958. *Pacific Naturalist* 1(2): 1-51.
- Dawson, E. Y.; Aleem, A. A. and Halstead, B. W. (1955). Marine algae from Palmyra Island with special reference to the feeding habits and toxicology of reef fishes. *Allan Hancock Foundation Publications, Occasional Paper* 17: 1-39.
- Egerod, L. E. (1952). An analysis of the siphonous Chlorophycophyta with special reference to the Siphonocladales, Siphonales and Dasycladales of Hawaii. *University of California Publications in Botany* 25(5): 325-454.
- Eldredge, L. G. and Paulay, G. (1996). *Baseline biodiversity assessment of natural harbors at Guam and Hawaii*. Report to the Insular Pacific Regional Marine Research Program, Honolulu.
- Eldredge, L. G.; Tsuda, R. T.; Moore, P.; Chernin, M. and Neudecker, S. (1977). A natural history of Maug, Northern Mariana Islands. *University of Guam Marine Laboratory Technical Report* 43: 83 p.

- Gattuso, J.-P.; Pichon, M.; Delesalle, B.; Canon, C. and Frankignoulle, M. (1996). Carbon fluxes in coral reefs. I. Lagrangian measurement of community metabolism and resulting air-sea CO₂ disequilibrium. *Marine Ecology - Progress Series* 145: 109-121.
- Gilbert, W. J. (1978). *Rhipilia sinuosa* sp. nov. (Chlorophyta, Siphonales) from Micronesia. *Phycologia* 17(3): 311-313.
- Hillis-Colinvaux, L. (1959). A Revision of the Genus *Halimeda* (Order Siphonales). *Publications of the Institute of Marine Sciences, University of Texas* (6): 321-403.
- Hillis-Colinvaux, L. (1980). Ecology and taxonomy of *Halimeda* primary producers of coral reefs. *Advances in Marine Biology* 17: 1-327.
- Horiguchi, T. and F. B. Sotto. (1994). On the identity of a red-tide Dinoflagellate in Maribago Bay, Philippines. *Bulletin of Plankton Society of Japan* 41(2): 166-169.
- Itono, H. and Tsuda, R. T. (1980). *Titanophora marianensis* sp. nov. (Nemastomataceae, Rhodophyta) from Guam. *Pacific Science* 34(1): 21-24.
- Keats, D. W. (1996). *Practical Taxonomy of Indo-Pacific Non-geniculate Coralline Algae. Course Manual*. Marine Studies Programme, The University of the South Pacific and The International Ocean Institute, Suva. 27 p.
- King, R. J. and Puttock, C. F. (1989). Morphology and taxonomy of *Bostrychia* and *Stictosiphonia* (Rhodomelaceae / Rhodophyta). *Australian Systematic Botany* 2: 1-73.
- Lee, R. E. (1980). *Phycology*. Cambridge University Press, New York. xi + 478 p.
- Littler, M. M. and Littler, D. S. (1994). Essay: Tropical reefs as complex habitats for diverse macroalgae. In: *Seaweed Ecology and Physiology*, edited by Lobban, C. S. and Harrison P. J., pp. 72-75. Cambridge: Cambridge University Press.
- Littler, M. M., Littler, D. S., Blair, S. M., and Norris, J. N. (1985). Deepest known plant life discovered on an uncharted seamount. *Science* 227: 57-59.
- Magruder, W. H. and J. W. Hunt. (1979). *Seaweeds of Hawaii. A photographic identification guide*. Oriental Publishing Company, Honolulu. 116 p.
- Meinesz, A., Jaubert, J., and Denizot, M. (1981). Distribution of the algae belonging to the genus *Caulerpa* in French Polynesia (atoll of Takapoto and island of Moorea). *Proceedings of the Fourth International Coral Reef Symposium, Manila* 2: 431-437.
- Nam, K. W. and Saito, Y. (1991). Anatomical characteristics of *Laurencia papillosa* (Rhodomelaceae, Rhodophyta) from Guam and Palau. *Micronesica* 24(1): 87-94.

- Nunn, P. D. (1993). Role of *Porolithon* algal-ridge growth in the development of the windward coast of Tongatapu Island, Tonga, South Pacific. *Earth Surface Processes and Landforms* 18: 427-439.
- N'Yeurt, A. D. R. (1999). *A Preliminary Illustrated Field Guide to the Common Marine Algae of the Cook Islands (Rarotonga and Aitutaki)*. World Wide Fund for Nature, Rarotonga. 74 p.
- Payri, C. E. (1988). *Halimeda* contribution to organic and inorganic production in a Tahitian reef system. *Coral Reefs* 6: 251-262.
- Randall, J. E. (1972). Chemical pollution in the sea and the crown-of-thorns starfish (*Acanthaster planci*). *Biotropica* 4(3): 132-144.
- Setchell, W. A. (1924). American Samoa, Part I: Vegetation of Tutuila Island. *Carnegie Institution of Washington, Publications* 341: 1-188, plates 18-20, 36-37.
- Silva, P. C., Basson, P. W., and Moe, R. L. (1996). Catalogue of the Benthic Marine Algae of the Indian Ocean. *University of California Publications in Botany* 79: 1-1259.
- Smith, S. V. (1981). Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbations. *Pacific Science* 35: 279-395.
- South, G. R. and Whittick, A. (1987). *Introduction to Phycology*. Blackwell Scientific Publications, Oxford. viii + 341 p.
- Tabudravu, J. N. (1996). *Experimental and field evaluation of Enteromorpha flexuosa as an indicator of heavy metal pollution by zinc, lead and copper in coastal water of Lami, Fiji*. M.Sc., The University of the South Pacific, Suva. xi + 146 p. + Appendix.
- Trainor, F. R. (1978). *Introductory Phycology*. John Wiley and Sons, New York. vii + 525 p.
- Tsuda, R. T. (1981). Bibliography of marine benthic algae of Micronesia: addendum. *Micronesica* 17(1-2): 213-218.
- Tsuda, R. T. and Wray, F. O. (1977). Bibliography of marine benthic algae in Micronesia. *Micronesica* 13(1): 85-120.
- Tsuda, R. T. and Trono, G. (1968). Marine benthic algae from Howland Island and Baker Island, Central Pacific. *Pacific Science* 22(2): 194-197.
- Wanders, J. B. W. (1976). The role of benthic algae in the shallow reef of Curaçao (Netherlands Antilles). I.: primary productivity in the coral reef. *Aquatic Botany* 2: 235-270.

Table 83. Algal species occurrence in the AFPI.

AS: American Samoa; PA: Palmyra Atoll; JA: Johnston Atoll; MHI: Main Hawaiian Islands; NWHI: Northwestern Hawaiian Islands; WA: Wake Atoll; CNMI: Commonwealth of Northern Mariana Islands; GU: Guam

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Division Cyanophyta (Blue-green)												
<i>Anacystis dimidiata</i>								X				
<i>Aphanocapsa grevillei</i>	X											
<i>Arthrospira brevis</i>												X
<i>Arthrospira laxissima</i>	X											
<i>Calothrix aeruginosa</i>					X							
<i>Calothrix confervicola</i>												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Calothrix crustacea</i>							X				X	X
<i>Calothrix pilosa</i>												X
<i>Calothrix scopulorum</i>							X					
<i>Chroococcus turgidus</i>					X							
<i>Entophysalis conferta</i>					X							X
<i>Entophysalis deusta</i>							X					X
<i>Hormothamnion enteromorphoides</i>							X	X				X
<i>Hormothamnion solutum</i>					X							X
<i>Hydrocoleum lyngbyaceum</i>							X					
<i>Hyella caespitosa</i>	X											
<i>Isactis plana</i>							X					
<i>Lyngbya aestuarii</i>					X		X					

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Lyngbya confervoides</i>					X		X					
<i>Lyngbya gracilis</i>					X							
<i>Lyngbya infixa</i>					X							
<i>Lyngbya lutea</i>							X					
<i>Lyngbya majuscula</i>	X				X		X	X		X	X	
<i>Lyngbya pygmaea</i>	X											
<i>Lyngbya rivulariarum</i>					X							
<i>Lyngbya semiplana</i>					X							
<i>Lyngbya sordida</i>					X							
<i>Microchaete vitiensis</i>	X											
<i>Microcoleus chthonoplastes</i>					X		X					

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Microcoleus lyngbyaceus</i>	X										X	X
<i>Microcoleus tenerrimus</i>							X					
<i>Microcoleus vaginatus</i>							X					
<i>Oscillatoria bonnemaisonii</i>					X							
<i>Oscillatoria lutea</i>												X
<i>Oscillatoria nigro-viridis</i>							X					
<i>Oscillatoria submembranacea</i>												X
<i>Phormidium corium</i>					X							
<i>Phormidium crosbyanum</i>										X		
<i>Phormidium penicillatum</i>					X							
<i>Phormidium submembranaceum</i>					X		X					
<i>Porphyrosiphon notarisii</i>												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Radaisia sp.</i>	X											
<i>Schizothrix calcicola</i>	X	X					X				X	X
<i>Schizothrix mexicana</i>	X										X	X
<i>Scytonema figuratum</i>	X											
<i>Scytonema hofmannii</i>	X											X
<i>Scytonema stuposum</i>	X											
<i>Spirulina major</i>					X							
<i>Spirulina subsalsa</i>												X
<i>Spirulina tenerrima</i>							X					
<i>Symploca atlantica</i>							X					
<i>Symploca hydroides</i>	X				X			X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Symploca muscorum</i>	X											
Division Chlorophyta (Green)												
<i>Acetabularia clavata</i>							X	X				
<i>Acetabularia exigua</i>											X	
<i>Acetabularia moebii</i>							X	X	X		X	
<i>Acetabularia tsengiana</i>							X					
<i>Acetabularia sp.</i>							X					
<i>Anadyomene wrightii</i>					X						X	X
<i>Avrainvillea erecta</i>												X
<i>Avrainvillea lacerata</i>					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Avrainvillea obscura</i>											X	X
<i>Avrainvillea pacifica</i>												X
<i>Boergesenia forbesii</i>											X	X
<i>Boodlea coacta</i>											X	X
<i>Boodlea composita</i>					X		X	X	X			X
<i>Boodlea vanbosseae</i>	X				X				X		X	X
<i>Bornetella oligospora</i>											X	
<i>Bornetella sphaerica</i>								X	X			
<i>Bryopsis harveyana</i>	X											
<i>Bryopsis hypnoides</i>									X			
<i>Bryopsis pennata</i>	X				X		X	X	X		X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Bryopsis plumosa</i>											X	X
<i>Bryopsis pottsii</i>	X											
<i>Bryopsis sp.</i>								X				
<i>Caulerpa ambigua</i>					X		X	X	X		X	
<i>Caulerpa cupressoides</i>										X	X	X
<i>Caulerpa elongata</i>											X	
<i>Caulerpa fastigiata</i>											X	
<i>Caulerpa filicoides</i>											X	X
<i>Caulerpa lentillifera</i>								X				X
<i>Caulerpa lessonii</i>												X
<i>Caulerpa okamurai</i>											X	X
<i>Caulerpa peltata</i>	X								X	X	X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Caulerpa plumaris</i>												X
<i>Caulerpa racemosa</i>	X						X	X	X		X	X
<i>Caulerpa serrulata</i>			X		X			X	X	X	X	X
<i>Caulerpa sertularioides</i>								X			X	X
<i>Caulerpa taxifolia</i>								X	X		X	X
<i>Caulerpa urvilliana</i>					X		X				X	X
<i>Caulerpa vickersiae</i>					X						X	
<i>Caulerpa verticillata</i>								X				X
<i>Caulerpa webbiana</i>								X	X		X	X
<i>Chaetomorpha antennina</i>	X							X	X			
<i>Chaetomorpha indica</i>								X				X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Chaetomorpha restricta</i>	X											
<i>Chamaedoris orientalis</i>												X
<i>Chlorodesmis fastigiata</i>	X											X
<i>Chlorodesmis hildebrandtii</i>					X			X	X		X	X
<i>Cladophora crystallina</i>					X		X					
<i>Cladophora fascicularis</i>								X				
<i>Cladophora glomerata</i>	X											
<i>Cladophora inserta</i>					X							
<i>Cladophora patentiramea</i>					X							X
<i>Cladophora patula</i>								X				
<i>Cladophora pinniger</i>	X											
<i>Cladophora socialis</i>					X				X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Cladophora vagabunda</i>									X			
<i>Cladophora sp.</i>		X			X			X	X	X		
<i>Cladophoropsis fascicularis</i>											X	
<i>Cladophoropsis gracillima</i>		X	X		X							
<i>Cladophoropsis infestans</i>	X											
<i>Cladophoropsis limicola</i>	X											
<i>Cladophoropsis luxurians</i>								X				
<i>Cladophoropsis membranacea</i>								X			X	X
<i>Cladophoropsis sundanensis</i>					X			X				
<i>Cladophoropsis sp.</i>							X					
<i>Codium arabicum</i>							X	X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Codium dichotomum</i>								X				
<i>Codium edule</i>								X	X		X	
<i>Codium geppiorum</i>	X				X							
<i>Codium mamillosum</i>								X	X			
<i>Codium ovale</i>												
<i>Codium phasmaticum</i>								X				
<i>Codium reediae</i>								X	X			
<i>Codium spongiosum</i>								X				
<i>Codium tomentosa</i>												X
<i>Codium sp.</i>							X		X			
<i>Derbesia attenuata</i>					X							
<i>Derbesia marina</i>					X		X					

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Derbesia ryukiuensis</i>					X							
<i>Derbesia sp.</i>							X					
<i>Dictyosphaeria cavernosa</i>		X	X		X			X	X	X	X	
<i>Dictyosphaeria versluysii</i>	X	X			X		X	X	X		X	X
<i>Enteromorpha clathrata</i>	X				X							X
<i>Enteromorpha compressa</i>												X
<i>Enteromorpha flexuosa</i>	X											
<i>Enteromorpha intestinalis</i>	X				X			X	X			
<i>Enteromorpha kylinii</i>		X			X		X					
<i>Enteromorpha prolifera</i>	X											
<i>Enteromorpha tubulosa</i>					X				X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Enteromorpha sp. 1</i>									X			
<i>Enteromorpha sp. 2</i>									X			
<i>Enteromorpha sp. 3</i>									X			
<i>Enteromorpha sp.</i>								X				
<i>Halimeda copiosa</i>									X		X	
<i>Halimeda cuneata</i>											X	X
<i>Halimeda cylindracea</i>											X	
<i>Halimeda discoidea</i>	X				X		X	X	X		X	X
<i>Halimeda fragilis</i>					X							
<i>Halimeda gigas</i>												X
<i>Halimeda gracilis</i>					X						X	X
<i>Halimeda incrassata</i>	X										X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Halimeda lacunalis</i>											X	
<i>Halimeda macroloba</i>	X										X	X
<i>Halimeda macrophysa</i>											X	
<i>Halimeda opuntia</i>	X				X				X	X	X	X
<i>Halimeda tuna</i>							X		X		X	X
<i>Halimeda velasquezii</i>									X			
<i>Halimeda spp.</i>			X									
<i>Microdictyon japonicum</i>								X	X			
<i>Microdictyon pseudohaptera</i>					X						X	X
<i>Microdictyon setchellianum</i>							X	X	X			
<i>Neomeris annulata</i>	X							X	X	X	X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Neomeris bilimbata</i>					X							
<i>Neomeris dumetosa</i>											X	X
<i>Neomeris vanbosseae</i>								X				
<i>Ostreobium quekettii</i>	X						X					X
<i>Palmogloea protuberans</i>							X					
<i>Phaeophila dendroides</i>					X							
<i>Phaeophila engleri</i>					X							
<i>Phyllodictyon anastomosans</i>								X	X			X
<i>Pseudobryopsis oahuensis</i>								X				
<i>Pseudochlorodesmis furcellata</i>											X	X
<i>Pseudochlorodesmis parva</i>							X					
<i>Rhipidosiphon javensis</i>								X	X		X	

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Rhipilia geppii</i>					X							
<i>Rhipilia orientalis</i>										X		
<i>Rhipilia sinuosa</i>												X
<i>Rhizoclonium hieroglyphicum</i>	X											
<i>Rhizoclonium implexum</i>	X				X							
<i>Rhizoclonium samoense</i>	X											
<i>Rhizoclonium tortuosum</i>												X
<i>Siphonocladus tropicus</i>								X				
<i>Spongocladia vaucheriaeformis</i>											X	X
<i>Struvea delicatula</i>											X	
<i>Struvea tenuis</i>											X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Tydemannia expeditionis</i>	X										X	X
<i>Udotea argentea</i>											X	X
<i>Udotea indica</i>											X	
<i>Ulva fasciata</i>		X	X					X	X			
<i>Ulva reticulata</i>								X				
<i>Ulva rigida</i>									X			
<i>Ulva sp.</i>									X			
<i>Valonia aegagropila</i>								X	X		X	X
<i>Valonia fastigiata</i>	X											X
<i>Valonia trabeculata</i>								X				
<i>Valonia utricularis</i>					X						X	X
<i>Ventricaria ventricosa</i>	X						X	X	X		X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Zygomitis</i> sp.					X							
Division Phaeophyta (Brown)												
<i>Chnoospora implexa</i>								X				X
<i>Chnoospora minima</i>	X							X	X			X
<i>Colpomenia sinuosa</i>								X	X			X
<i>Dictyopteris australis</i>								X	X			
<i>Dictyopteris plagiogramma</i>								X	X	X		
<i>Dictyopteris repens</i>	X								X	X	X	X
<i>Dictyota acutiloba</i>								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Dictyota bartayresiana</i>								X			X	X
<i>Dictyota cervicornis</i>												X
<i>Dictyota crenulata</i>									X			
<i>Dictyota divaricata</i>					X			X	X	X	X	X
<i>Dictyota friabilis</i>	X		X		X			X	X			
<i>Dictyota hamifera</i>											X	
<i>Dictyota lata</i>	X											
<i>Dictyota patens</i>											X	X
<i>Dictyota sandvicensis</i>								X				
<i>Dictyota sp.</i>							X		X			
<i>Dictyota sp. 1</i>										X		
<i>Dictyota sp. 2</i>										X		

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Dilophus radicans</i>												X
<i>Ectocarpus vanbosseae</i>	X											
<i>Ectocarpus sp.</i>					X		X					
<i>Endarachne binghamiae</i>								X				
<i>Feldmannia indica</i>	X	X			X		X		X		X	X
<i>Feldmannia irregularis</i>					X		X					
<i>Hapalospongidion pangoense</i>	X							X				X
<i>Hincksia breviarticulata</i>	X						X	X	X	X	X	
<i>Hincksia conifera</i>									X			
<i>Hincksia mitchelliae</i>									X			
<i>Homoeostrichus flabellatus</i>											X	

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Hormophysa triquetra</i>											X	
<i>Hydroclathrus clathratus</i>								X	X		X	X
<i>Lobophora papenfussii</i>					X							
<i>Lobophora variegata</i>					X		X	X	X	X	X	X
<i>Nemacystus decipiens</i>									X			
<i>Padina australis</i>								X				
<i>Padina boergesenii</i>									X			
<i>Padina crassa</i>									X			
<i>Padina gymnospora</i>												X
<i>Padina japonica</i>								X	X			
<i>Padina jonesii</i>											X	X
<i>Padina pavonia</i>								X		X		X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Padina tenuis</i>											X	X
<i>Padina thiyi</i>								X				
<i>Padina sp.</i>										X		
<i>Ralfsia occidentalis</i>								X				
<i>Rosenvingea intricata</i>								X			X	X
<i>Sargassum anapense</i>	X											
<i>Sargassum crassifolium</i>												X
<i>Sargassum cristaeifolium</i>											X	X
<i>Sargassum echinocarpum</i>								X	X			
<i>Sargassum fonanonense</i>	X											
<i>Sargassum hawaiiensis</i>									X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Sargassum microphyllum</i>											X	
<i>Sargassum obtusifolium</i>								X	X			
<i>Sargassum piluliferum</i>									X			
<i>Sargassum polycystum</i>												X
<i>Sargassum polyphyllum</i>								X	X			
<i>Sargassum tenerrimum</i>												X
<i>Sargassum sp.</i>									X			
<i>Spatoglossum solierii</i>								X				
<i>Sphacelaria ceylanica</i>	X											
<i>Sphacelaria cornuta</i>	X											
<i>Sphacelaria furcigera</i>	X				X		X	X				X
<i>Sphacelaria novae-hollandiae</i>					X		X	X	X			X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Sphacelaria rigidula</i>									X			
<i>Sphacelaria tribuloides</i>							X		X			X
<i>Sphacelaria sp.</i>		X			X						X	
<i>Sporochnus dotyi</i>									X			
<i>Stypopodium hawaiiensis</i>								X	X		X	
<i>Turbinaria condensata</i>												X
<i>Turbinaria ornata</i>	X	X						X	X	X	X	X
<i>Turbinaria trialata</i>					X						X	X
<i>Zonaria hawaiiensis</i>												X
Division Rhodophyta (Red)												

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Acanthophora pacifica</i>								X				
<i>Acanthophora spicifera</i>								X			X	X
<i>Acrochaetium actinocladium</i>								X				
<i>Acrochaetium barbadense</i>								X				
<i>Acrochaetium butleriae</i>								X				
<i>Acrochaetium corymbifera</i>								X				
<i>Acrochaetium dotyi</i>								X				
<i>Acrochaetium gracile</i>					X							
<i>Acrochaetium imitator</i>								X				
<i>Acrochaetium liagorae</i>								X				
<i>Acrochaetium microscopicum</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Acrochaetium nemalionis</i>								X				
<i>Acrochaetium robustum</i>					X			X				
<i>Acrochaetium seriatum</i>								X				
<i>Acrochaetium trichoglocae</i>								X				
<i>Acrochaetium sp.</i>									X			
<i>Acrosymphyton taylorii</i>								X				
<i>Actinotrichia fragilis</i>	X							X			X	X
<i>Actinotrichia robusta</i>											X	
<i>Aglaothamnion boergesenii</i>								X		X		
<i>Aglaothamnion cordatum</i>								X	X			
<i>Ahnfeltiopsis concinna</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Ahnfeltiopsis divaricata</i>												
<i>Ahnfeltiopsis flabelliformis</i>												
<i>Ahnfeltiopsis pygmaea</i>												
<i>Alsidium cymatophilum</i>								X				
<i>Alsidium pacificum</i>					X							
<i>Amansia glomerata</i>									X			X
<i>Amphiroa anceps</i>	X											
<i>Amphiroa beauvoisii</i>								X	X			
<i>Amphiroa crassa</i>	X											
<i>Amphiroa foliacea</i>	X							X				X
<i>Amphiroa fragilissima</i>	X							X	X		X	X
<i>Amphiroa rigida</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Amphiroa valonioides</i>								X				
<i>Amphiroa sp.</i>							X					
<i>Anotrichum secundum</i>	X							X				
<i>Anotrichum tenue</i>								X				
<i>Antithamnion antillanum</i>					X		X	X				
<i>Antithamnion decipiens</i>								X	X			
<i>Antithamnion erucacladellum</i>								X				
<i>Antithamnion nipponicum</i>								X				
<i>Antithamnion palmyrense</i>					X							
<i>Antithamnion percurrans</i>								X				
<i>Antithamnion sp.</i>										X		

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Antithamnionella breviramosa</i>								X	X			
<i>Antithamnionella graeffei</i>								X				
<i>Apoglossum gregarium</i>								X				
<i>Ardreanema seriospora</i>								X				
<i>Arthrocardia sp.</i>								X				
<i>Asparagopsis taxiformis</i>	X				X			X	X		X	X
<i>Asterocystis ornata</i>					X		X					
<i>Balliella repens</i>								X				
<i>Bangia atropurpurea</i>								X	X			
<i>Bostrychia tenella</i>	X											
<i>Botryocladia skottsbergii</i>								X			X	
<i>Botryocladia tenuissima</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Branchioglossum prostratum</i>								X				
<i>Callidictyon abyssorum</i>								X				
<i>Callithamniella pacifica</i>								X				
<i>Callithamnion marshallensis</i>							X					
<i>Callithamnion sp.</i>							X		X			
<i>Calloglossa leprieurii</i>					X		X					
<i>Calloglossa viellardii</i>	X											
<i>Caulacanthus ustulatus</i>								X				
<i>Carpopeltis bushiae</i>												
<i>Centroceras clavulatum</i>	X				X		X	X	X		X	X
<i>Centroceras corallophilloides</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Centroceras minutum</i>					X			X				X
<i>Ceramium aduncum</i>								X				
<i>Ceramium affine</i>							X		X			
<i>Ceramium borneense</i>								X				
<i>Ceramium byssoideum</i>	X											
<i>Ceramium cingulum</i>								X				
<i>Ceramium clarionense</i>					X			X	X			
<i>Ceramium codii</i>					X			X				
<i>Ceramium dumosertum</i>								X				
<i>Ceramium fimbriatum</i>							X	X				
<i>Ceramium flaccidum</i>								X	X			
<i>Ceramium gracillimum</i>		X			X		X					

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Ceramium hamatispinum</i>								X	X			
<i>Ceramium hanaense</i>								X				
<i>Ceramium jolyi</i>								X				
<i>Ceramium masonii</i>					X							
<i>Ceramium maryae</i>							X					
<i>Ceramium mazatlanense</i>	X							X	X		X	
<i>Ceramium paniculatum</i>								X				
<i>Ceramium punctiforme</i>	X							X				
<i>Ceramium serpens</i>					X			X				
<i>Ceramium taylori</i>					X							
<i>Ceramium tenuissimum</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Ceramium tranquillum</i>								X				
<i>Ceramium vagans</i>					X		X	X				X
<i>Ceramium womersleyi</i>								X				
<i>Ceramium zacaе</i>							X					
<i>Ceramium sp.</i>		X			X		X		X			
<i>Ceratodictyon spongiosum</i>											X	
<i>Chamaebotrys boergesenii</i>								X				
<i>Champia compressa</i>	X											X
<i>Champia parvula</i>							X	X	X			X
<i>Champia vieillardii</i>								X				
<i>Cheilosporum acutilobum</i>	X											
<i>Cheilosporum spectabile</i>	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Chondracanthus acicularis</i>								X				
<i>Chondracanthus tenellus</i>								X				
<i>Chondria arcuata</i>								X				
<i>Chondria dangeardii</i>								X				
<i>Chondria minutula</i>								X				
<i>Chondria polyrhiza</i>								X				
<i>Chondria simpliciuscula</i>								X				
<i>Chondria repens</i>					X		X		X			
<i>Chondria sp.</i>									X			
<i>Chondria sp. 1</i>									X			
<i>Chondria sp. 2</i>									X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Chondrus ocellatus</i>								X				
<i>Chroodactylon ornatum</i>								X				
<i>Chrysymenia kairnbachii</i>								X				
<i>Chrysymenia okamurae</i>								X				
<i>Chrysymenia procumbens</i>								X				
<i>Coelarthrum albertisii</i>									X			
<i>Coelarthrum boergesenii</i>									X			
<i>Coelothrix irregularis</i>								X				
<i>Corallina elongata</i>								X				
<i>Corallophila apiculata</i>					X		X	X	X			
<i>Corallophila huysmansii</i>							X	X				X
<i>Corallophila itonoi</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Corallophila ptilocladoides</i>								X				
<i>Crouania mageshimensis</i>								X	X			
<i>Crouania minutissima</i>							X	X	X			
<i>Crouania sp.</i>								X				
<i>Cruoriella dubyi</i>					X							
<i>Cruoriopsis mexicana</i>					X							
<i>Cryptonemia decumbens</i>	X											
<i>Cryptonemia umbraticola</i>					X			X				
<i>Cryptonemia yendoii</i>												
<i>Cryptopleura corallinara</i>								X				
<i>Cubiculosporum koronicarpus</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Dasya adhaerens</i>							X					
<i>Dasya bailouvianna</i>										X		
<i>Dasya corymbifera</i>										X		
<i>Dasya kristeniae</i>								X				
<i>Dasya murrayana</i>								X				
<i>Dasya pilosa</i>								X				
<i>Dasya sinicola</i>							X					
<i>Dasya villosa</i>										X		
<i>Dasya sp.</i>							X	X				
<i>Dasyopsis sp.</i>								X				
<i>Dasyphila plumarioides</i>												X
<i>Delesseriopsis elegans</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Dermocorynus occidentalis</i>								X				
<i>Dermonema virens</i>											X	
<i>Dermonema pulvinatum</i>								X				
<i>Diplothamnion jolyi</i>								X				
<i>Ditria reptans</i>								X	X			
<i>Dotyophycus pacificum</i>								X				
<i>Dotyophycus yamadae</i>								X				
<i>Dotyella hawaiiensis</i>								X	X			
<i>Dotyella irregularis</i>								X				
<i>Dudresnaya hawaiiensis</i>								X				
<i>Dudresnaya littleri</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Dudresnaya</i> sp.									X			
<i>Erythrocladia irregularis</i>					X							
<i>Erythrocolon podagricum</i>								X				
<i>Erythrotrichia carnea</i>					X			X				
<i>Erythrotrichia parietalis</i>					X							
<i>Erythrotrichia</i> sp.							X					
<i>Eucheuma denticulatum</i>							X					
<i>Eupogodon</i> sp.									X			
<i>Euptilocladia magruderii</i>								X				
<i>Exophyllum wentii</i>								X				
<i>Fernandosiphonia ecorticata</i>								X				
<i>Fernandosiphonia nana</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Fosliella farinosa</i>												X
<i>Galaxaura elongata</i>											X	
<i>Galaxaura fasciculata</i>								X				
<i>Galaxaura fastigiata</i>								X				
<i>Galaxaura filamentosa</i>	X							X			X	X
<i>Galaxaura glabriuscula</i>												X
<i>Galaxaura marginata</i>	X							X			X	X
<i>Galaxaura obtusata</i>								X			X	
<i>Galaxaura pacifica</i>									X		X	
<i>Galaxaura rugosa</i>	X							X	X		X	
<i>Galaxaura subfructiculosa</i>											X	

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Galaxaura subverticillata</i>								X				
<i>Galaxaura sp.</i>									X			
<i>Ganonema farinosum</i>								X				
<i>Gelidiella acerosa</i>								X				X
<i>Gelidiella antipai</i>								X				
<i>Gelidiella bornetii</i>					X							
<i>Gelidiella machrisiana</i>								X				
<i>Gelidiella myrioclada</i>								X				X
<i>Gelidiella stichidiospora</i>					X							
<i>Gelidiella womersleyana</i>												
<i>Gelidiella sp.</i>	X											
<i>Gelidiocolax mammillata</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Gelidiopsis acrocarpa</i>												X
<i>Gelidiopsis intricata</i>	X				X			X	X		X	X
<i>Gelidiopsis pannosa</i>											X	X
<i>Gelidiopsis repens</i>	X											
<i>Gelidiopsis rigida</i>												X
<i>Gelidiopsis scoparia</i>								X				
<i>Gelidiopsis variabilis</i>								X				
<i>Gelidiopsis sp.</i>			X									
<i>Gelidium abbotiorum</i>	X											
<i>Gelidium crinale</i>					X		X	X				
<i>Gelidium delicatulum</i>	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Gelidium pluma</i>								X				
<i>Gelidium pusillum</i>	X				X		X	X	X		X	X
<i>Gelidium reediae</i>								X				
<i>Gelidium samoense</i>	X											
<i>Gibsmithia dotyi</i>								X				
<i>Gibsmithia hawaiiensis</i>	X							X				
<i>Gloiocladia iyoensis</i>								X				
<i>Goniolithon frutescens</i>					X							
<i>Goniotrichum alsidii</i>							X					
<i>Goniotrichum elegans</i>					X							
<i>Gracilaria abbottiana</i>								X				
<i>Gracilaria arcuata</i>												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Gracilaria bursapastoris</i>								X				
<i>Gracilaria cacalia</i>												X
<i>Gracilaria coronopifolia</i>								X	X			
<i>Gracilaria dawsonii</i>								X				
<i>Gracilaria dotyi</i>								X				
<i>Gracilaria edulis</i>											X	
<i>Gracilaria epihippisor</i>								X				
<i>Gracilaria filiformis</i>								X				
<i>Gracilaria lemaneiformis</i>								X				
<i>Gracilaria lichenoides</i>								X				X
<i>Gracilaria minor</i>											X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Gracilaria radicans</i>												X
<i>Gracilaria parvispora</i>								X				
<i>Gracilaria salicornia</i>								X				X
<i>Gracilaria tikvahiae</i>								X				
<i>Gracilaria verrucosa</i>												X
<i>Grateloupia filicina</i>								X				
<i>Grateloupia hawaiiiana</i>								X				
<i>Grateloupia phuquocensis</i>								X				
<i>Griffithsia heteromorpha</i>								X				
<i>Griffithsia metcalfii</i>							X	X				
<i>Griffithsia ovalis</i>							X					
<i>Griffithsia schousboei</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Griffithsia subcylindrica</i>								X				
<i>Griffithsia tenuis</i>							X					X
<i>Griffithsia sp.</i>					X		X					
<i>Gymnogongrus sp.</i>								X				
<i>Gymnothamnion elegans</i>								X				
<i>Halarachnion calcareum</i>												X
<i>Halichrysis coalescens</i>								X				
<i>Haliptilon subulatum</i>								X	X			
<i>Haloplegma duperreyi</i>	X							X	X			
<i>Halymenia actinophysa</i>								X				
<i>Halymenia chiangiana</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Halymenia cromwellii</i>								X				
<i>Halymenia durvillaei</i>												X
<i>Halymenia formosa</i>								X				
<i>Halymenia lacerata</i>											X	X
<i>Halymenia stipitata</i>								X				
<i>Hawaiia trichia</i>								X				
<i>Helminthocladia rhizoidea</i>								X				
<i>Helminthocladia simplex</i>								X				
<i>Herposiphonia arcuata</i>								X				X
<i>Herposiphonia crassa</i>								X				
<i>Herposiphonia delicatula</i>								X	X			
<i>Herposiphonia dendroidea</i>									X			X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Herposiphonia dubia</i>								X	X			
<i>Herposiphonia nuda</i>								X	X			
<i>Herposiphonia obscura</i>								X				X
<i>Herposiphonia pacifica</i>								X	X			X
<i>Herposiphonia parca</i>								X	X			
<i>Herposiphonia secunda</i>	X				X			X	X			X
<i>Herposiphonia variabilis</i>								X				X
<i>Herposiphonia sp.</i>							X		X			
<i>Heterosiphonia crispella</i>					X		X	X	X			
<i>Heteroderma subtilissima</i>					X							
<i>Heteroderma sp.</i>					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Hydrolithon breviclavium</i>								X				
<i>Hydrolithon reinboldii</i>	X							X	X			X
<i>Hypnea cervicornis</i>								X	X			
<i>Hypnea chloroides</i>								X				
<i>Hypnea chordacea</i>								X				
<i>Hypnea esperi</i>					X		X		X		X	X
<i>Hypnea musciformis</i>								X				
<i>Hypnea nidulans</i>	X				X							
<i>Hypnea pannosa</i>	X							X	X			X
<i>Hypnea rugulosa</i>								X				
<i>Hypnea spinella</i>					X			X	X			
<i>Hypnea valentiae</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Hypnea sp.</i>		X										
<i>Hypnea sp. 1</i>										X		
<i>Hypnea sp. 2</i>									X			
<i>Hypneocolax stellaris</i>								X				
<i>Hypoglossum attenuatum</i>	X										X	
<i>Hypoglossum barbatum</i>								X				
<i>Hypoglossum caloglossoides</i>								X				
<i>Hypoglossum minimum</i>								X				
<i>Hypoglossum rhizophorum</i>								X				
<i>Hypoglossum simulans</i>								X				
<i>Hypoglossum sp.</i>									X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Janczewska hawaiiiana</i>								X				
<i>Jania adhaerens</i>	X							X				
<i>Jania capillacea</i>	X	X			X		X		X		X	X
<i>Jania decussato-dichotoma</i>					X		X		X		X	
<i>Jania mexicana</i>									X			
<i>Jania microarthrodia</i>			X					X	X	X		
<i>Jania natalensis</i>									X			
<i>Jania pumila</i>								X				
<i>Jania radiata</i>												X
<i>Jania tenella</i>					X						X	X
<i>Jania unguolata</i>									X			
<i>Jania verrucosa</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Jania sp.</i>								X				
<i>Kallymenia sessilis</i>								X				
<i>Kappaphycus alvarezii</i>								X				
<i>Kappaphycus striatum</i>								X				
<i>Laurencia brachyclados</i>								X				
<i>Laurencia cartilaginea</i>								X				
<i>Laurencia ceylanica</i>	X										X	X
<i>Laurencia corymbosa</i>									X			
<i>Laurencia crustiformans</i>								X				
<i>Laurencia decumbens</i>								X				
<i>Laurencia dotyi</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Laurencia forsteri</i>								X				
<i>Laurencia galtsoffii</i>								X	X			
<i>Laurencia glandulifera</i>								X				
<i>Laurencia intricata</i>											X	X
<i>Laurencia majuscula</i>								X	X			X
<i>Laurencia mariannensis</i>								X				
<i>Laurencia mcdermidiae</i>								X				
<i>Laurencia nana</i>		X	X									
<i>Laurencia nidifica</i>	X							X	X			
<i>Laurencia obtusa</i>								X	X		X	X
<i>Laurencia papillosa</i>	X											
<i>Laurencia parvipapillata</i>								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Laurencia perforata</i>									X		X	
<i>Laurencia pygmaea</i>									X			
<i>Laurencia rigida</i>											X	X
<i>Laurencia succisa</i>								X			X	
<i>Laurencia surculigera</i>											X	
<i>Laurencia tenera</i>								X				
<i>Laurencia tropica</i>											X	
<i>Laurencia undulata</i>								X				
<i>Laurencia yamadana</i>								X				
<i>Laurencia sp.</i>					X		X		X			X
<i>Laurencia sp. 1</i>									X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Laurencia sp. 2</i>									X			
<i>Laurencia sp. 3</i>									X			
<i>Laurencia sp. 4</i>									X			
<i>Laurencia sp. 5</i>									X			
<i>Lejolisia colombiana</i>					X							
<i>Lejolisea pacifica</i>								X				
<i>Leveillea jungermannioides</i>								X			X	X
<i>Liagora albicans</i>								X				
<i>Liagora boergesenii</i>								X				
<i>Liagora ceranoides</i>								X	X			
<i>Liagora coarctata</i>									X			
<i>Liagora divaricata</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Liagora farinosa</i>										X		
<i>Liagora hawaiiiana</i>								X	X			
<i>Liagora hirta</i>	X											
<i>Liagora kahukuana</i>										X		
<i>Liagora orientalis</i>								X	X			
<i>Liagora papenfussii</i>								X	X			
<i>Liagora perennis</i>												
<i>Liagora pinnata</i>								X				
<i>Liagora samaensis</i>								X				
<i>Liagora robusta</i>										X		
<i>Liagora setchellii</i>								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Liagora tetrasporifera</i>								X				
<i>Liagora valida</i>								X	X			
<i>Liagora sp.</i>	X									X	X	
<i>Liagorophyla endophytica</i>								X				
<i>Lithophyllum kaiserii</i>	X											
<i>Lithophyllum kotschyianum</i>								X			X	X
<i>Lithophyllum moluccense</i>	X										X	X
<i>Lithophyllum sp.</i>								X				
<i>Lithoporella melobesioides</i>											X	X
<i>Lithoporella pacifica</i>												X
<i>Lithoporella sp.</i>	X											
<i>Lithothamnion asperulum</i>												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Lithothamnion byssoides</i>								X				
<i>Lithothamnion funafutiense</i>												X
<i>Lithothamnion philippii</i>												X
<i>Lithothamnion spp.</i>					X				X			
<i>Lomentaria hakodatensis</i>					X		X	X				
<i>Lomentaria sp.</i>		X										
<i>Lophocladia kipukaia</i>								X				
<i>Lophocladia trichocladus</i>										X		
<i>Lophosiphonia bermudensis</i>					X							
<i>Lophosiphonia cristata</i>								X	X			
<i>Lophosiphonia obscura</i>	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Lophosiphonia prostrata</i>								X				
<i>Lophosiphonia scopulorum</i>					X							
<i>Lophosiphonia sp.</i>					X							
<i>Martensia fragilis</i>	X							X	X		X	X
<i>Mastophora lamourouxii</i>												X
<i>Mastophora macrocarpa</i>												X
<i>Mastophora melobesoides</i>	X											
<i>Mastophora plana</i>												X
<i>Mastophora rosea</i>												X
<i>Mazzaella volans</i>								X				
<i>Malaconema minimum</i>								X				
<i>Melanamansia daemeli</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Melanamansia fimbriifolia</i>								X				
<i>Melanamansia glomerata</i>								X				
<i>Mesophyllum erubescens</i>	X											X
<i>Mesophyllum mesomorphum</i>	X							X				X
<i>Mesophyllum simulans</i>	X											X
<i>Micropeuce setosus</i>								X				
<i>Monosporus indicus</i>								X				
<i>Murrayella pericladus</i>												X
<i>Myriogramme bombayensis</i>								X				
<i>Naccaria hawaiiiana</i>								X				
<i>Neogoniolithon brasica-florida</i>	X				X			X			X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Neogoniolithon fosliei</i>												X
<i>Neogoniolithon medioramus</i>												
<i>Neogoniolithon pacificum</i>												X
<i>Neogoniolithon reinboldii</i>											X	
<i>Neomartensia flabelliformis</i>								X				
<i>Nitophyllum adhaerens</i>								X				
<i>Osmundaria obtusiloba</i>								X				
<i>Ossiella pacifica</i>								X				
<i>Peleophycus multiprocarpium</i>								X				
<i>Peyssonelia conchicola</i>								X				
<i>Peyssonelia corallis</i>											X	X
<i>Peyssonelia delicata</i>	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Peyssonelia foveolata</i>	X											
<i>Peyssonelia inamoena</i>								X				
<i>Peyssonelia mariti</i>	X											
<i>Peyssonelia rubra</i>	X				X			X				
<i>Peyssonelia sp.</i>									X			
<i>Phaeocolax kajimurai</i>								X				
<i>Platoma ardreanum</i>								X				
<i>Pleonosporium caribaeum</i>								X				
<i>Peonosporium intricatum</i>								X				
<i>Plocamium sandwicense</i>								X	X			
<i>Polyopes hakalauensis</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Polysiphonia anomala</i>								X				
<i>Polysiphonia apiculata</i>								X				X
<i>Polysiphonia beaudettei</i>								X				
<i>Polysiphonia delicatula</i>								X				X
<i>Polysiphonia exilis</i>								X	X			
<i>Polysiphonia flaccidissima</i>								X				X
<i>Polysiphonia hancockii</i>								X				
<i>Polysiphonia hawaiiensis</i>								X				
<i>Polysiphonia herpa</i>								X				X
<i>Polysiphonia homoia</i>								X				
<i>Polysiphonia howei</i>								X				
<i>Polysiphonia pentamera</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Polysiphonia poko</i>								X				X
<i>Polysiphonia polyphysa</i>									X			
<i>Polysiphonia poko</i>								X				
<i>Polysiphonia profunda</i>								X				
<i>Polysiphonia pseudovillum</i>								X				
<i>Polysiphonia rubrorhiza</i>								X	X			
<i>Polysiphonia saccorhiza</i>								X	X		X	
<i>Polysiphonia savatieri</i>								X	X			X
<i>Polysiphonia scopulorum</i>	X				X			X	X			X
<i>Polysiphonia setacea</i>								X				X
<i>Polysiphonia simplex</i>								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Polysiphonia sparsa</i>								X				X
<i>Polysiphonia sphaerocarpa</i>								X	X			X
<i>Polysiphonia subtilissima</i>								X				
<i>Polysiphonia tepida</i>								X				
<i>Polysiphonia tongatensis</i>	X							X				
<i>Polysiphonia triton</i>								X				
<i>Polysiphonia tsudana</i>								X				
<i>Polysiphonia tuberosa</i>												
<i>Polysiphonia upolensis</i>								X	X			X
<i>Polysiphonia sp.</i>	X				X		X		X		X	X
<i>Polystrata dura</i>	X											
<i>Porolithon craspedium</i>					X						X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Porolithon gardineri</i>					X			X				
<i>Porolithon marshallense</i>					X							
<i>Porolithon onkodes</i>	X				X			X			X	X
<i>Porolithon sp.</i>									X			
<i>Porphyra vietnamensis</i>								X				
<i>Portieria hornemanni</i>	X							X	X		X	X
<i>Predaea laciniosa</i>								X				
<i>Predaea weldii</i>								X				
<i>Prionitis corymbifera</i>								X				
<i>Prionitis obtusa</i>	X											
<i>Pterocladia capillacea</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Pterocladia musiformis</i>					X							
<i>Pterocladia parva</i>									X			X
<i>Pterocladia tropica</i>					X							
<i>Pterocladia sp.</i>					X							
<i>Pterocradiella bulbosa</i>								X				
<i>Pterocradiella caerulescens</i>								X				
<i>Pterocradiella caloglossoides</i>								X				
<i>Pterocradiella capillacea</i>								X				
<i>Pterosiphonia pennata</i>								X				
<i>Ptilocladia yuenii</i>								X				
<i>Ptilothamnion cladophorae</i>								X				
<i>Pugetia sp.</i>									X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Reticulocaulis mucosissimus</i>								X				
<i>Rhodolachne decussata</i>								X				
<i>Rhodymenia sp.</i>	X											
<i>Rhodymenia leptophylla</i>								X				
<i>Scinaia furcata</i>								X				
<i>Scinaia hormoides</i>								X				
<i>Spermothamnion sp.</i>					X				X			
<i>Spirocladia barodensis</i>								X				
<i>Spirocladia hodgsoniae</i>								X				
<i>Sporolithon erythraeum</i>	X							X			X	
<i>Sporolithon schmidtii</i>												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Sporolithon sibogae</i>	X											
<i>Spyridia filamentosa</i>	X							X	X			X
<i>Stenopeltis gracilis</i>								X			X	
<i>Stenopeltis liagoroides</i>								X				
<i>Stenopeltis setchelliae</i>								X				
<i>Stictosiphonia kelanensis</i>												X
<i>Stylonema alsidii</i>	X							X				
<i>Stylonema cornu-cervi</i>								X				
<i>Symphycladia marchantioides</i>								X			X	
<i>Taenioma macrourum</i>							X					
<i>Taenioma perpusillum</i>								X	X			
<i>Tayloriella dictyurus</i>								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Tenarea tessellatum</i>								X				
<i>Tiffaniella codicola</i>									X			
<i>Tiffaniella saccorhiza</i>								X	X			
<i>Titanophora marianensis</i>												X
<i>Titanophora pikeana</i>								X				
<i>Tolypocladia glomerulata</i>	X							X			X	X
<i>Trichogloea lubrica</i>								X				
<i>Trichogloea requienii</i>								X	X			
<i>Trichogloeopsis hawaiiiana</i>								X	X			
<i>Trichogloeopsis mucosissima</i>								X				
<i>Tricleocarpa cylindrica</i>								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Tricleocarpa fragilis</i>								X	X		X	X
<i>Ululania stellata</i>								X				
<i>Vanvoorstia coccinea</i>								X				
<i>Vanvoorstia spectabilis</i>								X				
<i>Womersleyella pacifica</i>								X				
<i>Wrangelia anastomosans</i>											X	
<i>Wrangelia dumontii</i>								X				
<i>Wrangelia elegantissima</i>								X				
<i>Wrangelia penicillata</i>								X				
<i>Wrangelia tenuis</i>									X			
<i>Wurdemannia miniata</i>					X			X			X	X
<i>Wurdemannia sp.</i>							X					

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
<i>Yamadaella coenomyce</i>								X				

***References Used:** Birkland *et al.* 1994; Setchell 1924; Tsuda and Trono 1968; Dawson 1959; Dawson *et al.* 1955; Hillis- Colinvaux 1959; Buggeln and Tsuda 1969; Vernon *et al.* 1966; Abbott 1988; 1999; Bailey and Harvey 1862; Egerod 1952; Eldredge and Paulay 1996; Magruder and Hunt 1979; Abbott 1989; Anon 1999; Bailey and Harvey 1862; Eldredge *et al.* 1977; Tsuda 1981; Tsuda and Wray 1977; Eldredge and Paulay 1996; Gilbert 1978; Gordon 1976; Itono and Tsuda 1980; King and Puttock 1989; Nam and Saito 1991; Tsuda 1981; Tsuda and Wray 1977

5.3.2 Porifera (sponges)

Important Summary Documents

Moore (1955) described the paleosponges and their dominance in ancient reefs.

Early records of Pacific sponges Bowerbank (1873) and Agassiz (1906). Bergquist (1965, 1967, and 1977) catalogued sponges in Micronesia and Hawaii. Kelly-Borges and Valentine (1995) have reviewed the status of the sponges of Hawaii.

Taxonomic Issues

No overall classification of the *Porifera* exists. Calcarea: Burton (1963); Vacelet (1970). Demospongiae Levi (1973) and Bergquist (1978). Sclerospongiae: Hartman & Goreau (1970, 1975) Hexactinellida: Ijima (1927). De Laubenfels (1950a,b 1951, 1954; 1957) recorded the sponges from Hawaii. Species numbers: 84 species in Hawaii Bergquist (1977); Chave and Jones (1991); 5000-9000 spp. (Colin and Arneson, 1991) and 10,000 spp. George and George (1979) world-wide.

Habitat Utilization

Use of chemical agents in competing for substrate. Often found at depth, in caves, and vertical areas where not colonized by hard coral. Rutzler and Rieger (1973) described the burrowing sponge *Cliona* into a calcareous substrate.

Life History

Adult: Appearance and Physical Characteristics

Vary greatly in size. Most are irregular and exhibit massive, erect, encrusting, or branching growth pattern. Many are brightly colored. The body of the sponge is a system of water canals, where with incurrent pores allow water to flow into the atrium and out through the osculum (asconoid, syconoid, and leuconoid plans). The skeleton may be composed of calcareous and siliceous spicules, protein spongin fibers. The spicules exist in a variety of forms and are important in the identification and classification of species.

Of pharmaceutical interest due to the biologically active compounds, most probably used in defense. Some compounds affective against certain tumors and potential effective in treating other diseases.

Reproductive Strategies

Sexual (viviparous and oviparous), asexual and hermaphroditic. Synchronous release of gametes triggered by lunar or daily cycles. Eggs develop into larvae which swim or creep along the bottom. Asexual reproduction is through budding, fragmentation and gemmules (Barnes, 1987, Fromont, 1994). Recruitment may occur by fragmentation from predation (Kelly-Borges and Bergquist, 1988).

Distribution

Table 93 shows the distribution of the sponges in some of the AFPI. In Guam and Mariana Islands Bryan(1973). Briggs (1974) provided information on broad distributions as did Hooper and Levi, 1994. In Hawaii, biological interactions affect the occurrence of the sponge *Damiriana hawaiiiana* Casper (1981). Encrusting sponges may kill corals (Plucer-Rosario, 1987).

Feeding and Food

Particle feeding and ingestion of plankton and bacteria (Reiswig 1971,1975a)

Utilization of DOM, directly or indirectly, by symbiotic cyanobacteria (Barnes 1987; Wilkinson, 1979, 1983).

Behavior

Symbiosis common which includes shrimps, crabs, barnacles, worms, brittlestars, holothurians, and other sponges (Colin and Arneson, 1991). *Tethya sp.* produces filamentous extensions for mobility. *Placospongia* rapidly closes its plate-like surface when touched. *Tedania* (fire sponge) causes burning due to spicules and chemicals. *Hippospongia* and *Spongia* are used as bath sponges.

Diurnal rhythm in the active flow of water (Reiswig, 1971)

Spawning: Spatial and Temporal Distribution

Lunar and diurnal periodicity

Appearance and Physical Characteristics of Eggs (size, shape, color, etc) and Duration of Phase

During mass spawning events (Reiswig, 1971), sperm appears as clouds of smoke. In some cases, release of eggs causes appearance of opaque mucous covering sponge (Colin and Arneson, 1995).

Larvae: Appearance and Physical Characteristics of Larvae

The larval metamorphosis is described by Simpson (1986).

Bibliography

Agassiz, A. 1906. General Report of the Expedition. Report on the scientific results of the expedition to the Eastern Tropical Pacific, in charge of A. Agassiz, by the U.S. Fisheries Commission Steamer Albatross, 1904-1905 and 1888-1904. 21:Memoirs of the Museum of Comparative Zoology, Harvard Collection 41:261-323.

Barnes, R. D. 1987: *Invertebrate Zoology, Fifth Edition*. Saunders College Publ., International Edition.

- Bergquist, P. R. 1965. The Sponges of Micronesia. I. The Palau Archipelago. *Pacific Science* 3(2): 123-204.
- Bergquist, P. R. 1967. Additions to the sponge fauna of the Hawaiian Islands. *Micronesica* 3:159-173.
- Bergquist, P.R. 1978. *Sponges*. 268 pp. London: Hutchinson.
- Bergquist, P.R. 1979. Porifera. In Reef and Shore Fauna of Hawaii. Section 1. Protozoa through Ctenophora, ed. D. M. Devaney and L. G. Eldredge. Bernice P. Bishop Museum Special Publications 64(1): 53-70.
- Bowerbank, J. S. 1873. Contributions to a general history of the Spongidae. Part IV. *Proceedings of the Zoological Society of London*. 4:3-25.
- Briggs, J. C. 1974. *Marine Zoogeography*. New York: McGraw Hill.
- Bryan, P. G. 1973. Growth rate, toxicity and distribution of the encrusting sponge *Terpios* sp. (Hadromerida, Suberitidae) in Guam, Mariana Islands. *Micronesica* 9(2): 237-242.
- Burton, M. 1963. *A revision of the classification of the calcareous sponges*. 693 pp. London: British Museum (Natural History).
- Chave, E. H., & A. T. Jones. 1991. Deep-water megafauna of the Kohala and Haleakala slopes, Alenuihaha Channel, Hawaii. *Deep-Sea Research* 38, no. 7:781-803.
- Colin, P. L. & Arneson, C., 1995: A Field Guide to the Marine Invertebrates Occurring on Tropical Pacific Coral Reefs, Seagrass Beds and Mangroves. *Tropical Pacific Invertebrates*.
- Colin, P. L., and C. Arneson. In press. *Tropical Pacific Invertebrates*. San Diego: Coral Reef Press.
- de Laubenfels, M. W. 1950a. The sponges of Kaneohe Bay. *Pacific Science* 4(1): 3-36.
- de Laubenfels, M. W. 1950b. Sponges in Hawaii. *Cooperative Fishery Investigations Circular* 9 (June):1-2.
- de Laubenfels, M. W. 1951. The sponges of the islands of Hawaii. *Pacific Science* 5(3): 256-271.
- de Laubenfels, M. W. 1954. The sponges of the West Central Pacific. *Oregon State Monographs in Zoology* 7:1-306.

- de Laubenfels, M. W. 1957. New species and records of Hawaiian sponges. *Pacific Science* 11:236-251.
- Fromont, P. J. 1994. Reproductive development and timing of tropical sponges (Order Haplosclerida) from the Great Barrier Reef. *Coral Reefs* 13:127-133.
- George, D. & J. George, 1979: *An Illustrated Encyclopedia of Invertebrates in the Sea, Marine Life*.
- Hartman, W. D., & Goreau, T. F. 1970. Jamaican coralline sponges: their morphology, ecology, and fossil relatives. *Symp. Zool. Soc. Lond.*, No. 25, 205-43.
- Hartman, W. D., & Goreau, T. F. 1975. A Pacific tabulate sponge, living representative of a new order of sclerosponges. *Postilla*, **167**, 1-14.
- Hooper, J. N. A., and C. Levi. 1994. Biogeography of Indo-Pacific Sponges: Microcionidae, Raspailiidae, Axinellidae. In *Sponges in Time and Space*, ed. R. W. M. van Soest, Th. M. G. van Kempen, and J. C. Braekman, 191-212. Rotterdam: Balkema.
- Ijima, I. 1927. The Hexactinellida of the Siboga expedition. *Siboga Exped.*, **6**, 1-383.
- Kelly-Borges, M. and C. Valentine 1995 The sponges of the tropical island region of Oceania: a taxonomic status review. In: Maragos, J.E. Peterson, M.N.A., Eldredge, L.G., Bardach, J.E. and H.F. Takeuchi (eds.) *Proceedings of the Workshop on Marine/Coastal Biodiversity in the Tropical Island Pacific Region (November 2-4, 1994)*, Volume I, pp. 83-120. East-West Center and Pacific Science Association, Honolulu, Hawaii.
- Kelly-Borges, M., and P. R. Bergquist. 1988. Success in a shallow reef environment, sponge recruitment by fragmentation through predation. *Proceedings of the 6th International Coral Reef Symposium*, Townsville, Australia, 2:757-762.
- Levi, C. 1973. Systematique de la Classe des Demospongiaria (Demosponges), 37-631. In: Grasse P.-P. (ed.). *Traite de Zoologie, III, Spongiaires*. Paris: Masson.
- Moore, R. D. (Ed.), 1955: *Treatise on Invertebrate Paleontology. Arcaeocyatha, Polifera*. Vol. E. Geological Society of America and University of Kansas Press, Lawrence, Kans. No. 25., 189-203.
- Plucer-Rosario, G. 1987. The effect of substratum on the growth of *Terpios*, an encrusting sponge which kills coral. *Coral Reefs* 5(4): 197-200.
- Reiswig, H. M., 1971: *In Situ* pumping activities of tropical Damospongiae. *Mar. Biol.*, 9(1): 38-50.

Reiswig, H. M., 1971: Particle feeding in natural populations of three marine demosponges. *Biol. Bull.*, 141(3): 568-591.

Reiswig, H. M., 1975a: Bacteria as food for temperate-water marine sponges. *Can. J. Zool.*, 53(5): 582-589.

Rutzler, K., and Reiger, G., 1973: Sponge burrowing: fine structure of *Cliona lampa* penetrating calcareous substrata. *Mar. Biol.*, 21:144-162.

Simpson, T. L., 1968: The biology of the marine sponge *Microciona prolifera*. Temperature related, annual changes in functional and reproductive elements with a description of larval metamorphosis. *J. Exp. Mar. Biol. Ecol.*, 2:252-277.

Vacelet, J. 1970. Les sponges Pharetronides actuelles. *Symp. Zool. Soc. Lond.*,

Wilkinson, C. R., 1979: Nutrient translocation from symbiotic cyanobacteria to coral reef sponges. See Levi and Boury-Esnault, pp. 373-380.

Wilkinson, C. R., 1983: Net primary productivity in coral reef sponges. *Science*, 219:410-411.

Table 84. Distribution of sponges within the American Affiliated Pacific Islands (AFPI) (after Kelly-Borges and Valentine, 1995)

AS: American Samoa; HI: Hawaiian Islands; NMI: Commonwealth of Northern Mariana Islands; GU: Guam

Taxonomy/occurrence	AS	HI	CNMI	GU
DEMOSPONGIAE				
Homosclerophorida				
<i>Oscarella tenuis</i>		X		
<i>Plakina monolopha</i>		X		
<i>Plakortis simplex</i>		X		
Astrophorida				
<i>Ancorina acervus</i>			X	
<i>Asteropus kaena</i>		X		
<i>Dorypleres splendens</i>			X	
<i>Erylus caliculatus</i>		X		
<i>Erylus proximus</i>		X		
<i>Erylus rotundus</i>		X		
<i>Erylus sollasi</i>		X		
<i>Geodia gibberella</i>		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Jaspis stellifera</i>			X	
<i>Meloplus sarasinorum</i>				X
<i>Rhabdastrella pleopora</i>		X		
<i>Stelletta debilis</i>		X		
<i>Zaplethes digonoxea</i>		X		
Lithistida				
<i>Aciculites papillata</i>			X	
<i>Leidermatium sp</i>		X		
Spirophorida				
<i>Cinachyra porosa</i>			X	
<i>Paratetilla bacca</i>			X	
Hadromerida				
<i>Anthosigmella valentis</i>		X		
<i>Chondrosia chucalla</i>		X		
<i>Chondrosia corticata</i>			X	
<i>Chondrosia sp</i>		X		
<i>Cliona vastifica</i>		X		
<i>Diplastrella spiniglobata</i>		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Kotimea tethva</i>		X		
<i>Placospongia carinata</i>			X	
<i>Prosuberites oleteira</i>		X		
<i>Sphaciospongia aurivilla</i>			X	
<i>Sphaciospongia purpurea</i>			X	
<i>Sphaciospongia vagabunda</i>		X	X	
<i>Spirastrella coccinea</i>		X		
<i>Spirastrella keaukaha</i>		X		
<i>Terpios aploos</i>				X
<i>Terpios granulosa</i>		X		
<i>Terpios hoshinoto</i>				X
<i>Terpios sp</i>				X
<i>Terpios zeteki</i>		X		
<i>Tethya coccinea</i>			X	
<i>Tethya diploderma</i>		X		
<i>Tethya robusta</i>			X	
<i>Timea xena</i>		X		
Halichondrida				

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Axechina lissa</i>		X		
<i>Axinella solenoides</i>		X		
<i>Axinyssa aplysinoides</i>				X
<i>Axinyssa pitys</i>			X	
<i>Axinyssa terpnis</i>			X	
<i>Axinyssa xutha</i>			X	
<i>Ciocalypta pencillus</i>		X		
<i>Cymbastella cantherella</i>			X	
<i>Densa mollis</i>			X	
<i>Eurypon distincta</i>		X		
<i>Eurypon nigra</i>		X		
<i>Halichondria coerulea</i>		X		
<i>Halichondria dura</i>		X		
<i>Halichondria melanadocia</i>		X		
<i>Higginsia anfractuosa</i>			X	
<i>Higginsia mixta</i>			X	
<i>Homaxinella anamesa</i>		X		
<i>Hymeniacidon chloris</i>		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Myrmekioderma granulata</i>			X	
<i>Myrmekioderma sp.</i>				X
<i>Phycopsis aculeata</i>		X		
<i>Pseudaxinella australis</i>			X	
<i>Raphisia myxa</i>		X		
<i>Rhabderemia sorokiniae</i>			X	
<i>Stylotella aldis</i>			X	
<i>Stylotella aurantium</i>			X	X
<i>Ulosa rhoda</i>		X		
<i>Adocia gellindra</i>		X		
<i>Adocia turquosia</i>			X	
<i>Adocia viola</i>				X
<i>Aka mucosa</i>			X	
<i>Amphimedon sp</i>				X
<i>Callyspongia aerizusa</i>			X	
<i>Callyspongia diffusa</i>		X		X
<i>Callyspongia parva</i>			X	

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Gellius gracilis</i>			X	
<i>Haliclona acoroides</i>			X	
<i>Haliclona aquaeducta</i>		X		
<i>Haliclona flabellodigitata</i>		X		
<i>Haliclona koremella</i>			X	
<i>Haliclona lingulata</i>				X
<i>Haliclona pellasarca</i>			X	
<i>Haliclona permollis</i>		X		
<i>Haliclona streble</i>			X	
<i>Haliclona viridis</i>			X	
<i>Niphates cavernosa</i>			X	
<i>Niphates spinosella</i>			X	
<i>Sigmatocia amboinensis</i>			X	
<i>Sigmatocia symbiotica</i>			X	
<i>Toxadocia violacea</i>		X		
Petrosida				
<i>Pellina eusiphonia</i>		X	X	
<i>Pellina pulvilla</i>				X

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Dallia nitens</i>		✓		
<i>Petrosia puna</i>		X		
<i>Vestimentaria sp.</i>				✓
Poecilosclerida				
<i>Acamas caledoniensis</i>			X	
<i>Amphinomia sulphurea</i>			X	
<i>Axociella kilauea</i>		X		
<i>Biemna fortis</i>			X	
<i>Clathria frondifera</i>				X
<i>Clathria procera</i>		X		
<i>Clathria vulpina</i>			X	
<i>Coelocartaria singaporense</i>			X	
<i>Crella spinulata</i>			X	
<i>Damiriana hawaiiiana</i>		X		
<i>Desmacella lampra</i>			X	
<i>Echinodictyum antrodes</i>				X
<i>Esperiopsis anomala</i>		X		
<i>Iotrochota baculifera</i>			X	

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Iotrochota protea</i>		X		
<i>Kaneohea poni</i>		X		
<i>Lissodendoryx calypta</i>		X		
<i>Lissodendoryx oxytes</i>			X	
<i>Microciona eurypa</i>			X	
<i>Microciona cecile</i>			X	
<i>Microciona haematodes</i>		X		
<i>Microciona maunaloa</i>		X		
<i>Mycale cecilia</i>		X		
<i>Mycale contarenii</i>		X		
<i>Mycale maunakea</i>		X		
<i>Myxilla rosacea</i>		X		
<i>Naniupi ula</i>		X		
<i>Prianos phlox</i>			X	
<i>Strongylacidon sp.</i>		X		
<i>Tedania ignis</i>		X		
<i>Tedania macrodactyla</i>		X		
<i>Xytopsiphum kaneohe</i>		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Xytopsiphum meganese</i>		X	X	
<i>Xytopsues zuckerani</i>		X		
<i>Zygomycale parishii</i>		X		
Dictyoceratida				
<i>Coscinoderma denticulatum</i>		X		
<i>Fasciospongia chondrodes</i>				X
<i>Hippospongia densa</i>		X		
<i>Hippospongia metachromia</i>			X	
<i>Hyrtios erecta</i>				X
<i>Lendenfeldia dendyi</i>			X	
<i>Lufferiella sp</i>		X		
<i>Lufferiella variabilis</i>				X
<i>Spongia irregularis dura</i>		X		
<i>Spongia irregularis lutea</i>		X		
<i>Spongia irregularis mollior</i>		X		
<i>Spongia irregularis tenuis</i>		X		
<i>Spongia denticulata</i>		X		
<i>Spongia oecania</i>		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Stelospongia lordii</i>		X		
<i>Strepsichordaia lendenfeldi</i>			X	
Verongida				
<i>Aplysinella strongylata</i>			X	
<i>Aplysinella tyroeis</i>			X	
<i>Ianthella basta</i>				X
<i>Psammaplysilla purpurea</i>		X		
<i>Psammaplysilla verongiformis</i>			X	
Dendroceratida				
<i>Aplysilla rosea</i>		X		X
<i>Aplysilla sulphurea</i>		X		
<i>Aplysilla violacea</i>		X		
<i>Dendrilla cactus</i>		X		
<i>Dendrilla nigra</i>			X	
<i>Dysidea avara</i>		X	X	X
<i>Dysidea fragilis</i>			X	
<i>Dysidea herbacea</i>		X		
<i>Dysidea sp</i>		X		X

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Euryspongia lobata</i>			X	
<i>Pleraplysilla hyalina</i>		X		
Slerosponges				
<i>Acanthochaetetes wellsi</i>			X	
<i>Astrosclera willeyana</i>			X	X
<i>Stromatospongia micronesica</i>			X	X
CALCAREA				
<i>Clathrina sp</i>		X		
<i>Leucetta avacado</i>				X
<i>Leucetta solida</i>		X		
<i>Leuconia kaiana</i>		X		
<i>Leucosolenia eleanor</i>		X		
<i>Leucosolenia vesicula</i>		X		
<i>Murrayona phanolepis</i>			X	
<i>Sycandra coronata</i>		X		
<i>Sycandra parvula</i>		X		
<i>Sycandra staurifera</i>		X		
HEXACTINELLIDA				

Taxonomy/occurrence	AS	HI	CNMI	GU
<i>Euplectella sp</i>		X		
<i>Stylocalyx elegans</i>		X		

DRAFT

5.3.3 *Millepora* sp. (Linnaeus, 1758) (stinging or fire coral)

Important Summary Documents

Lewis (1989) discussed the ecology of *Millepora*. Growth and age were investigated (Lewis, 1991).

Taxonomic Issues

Class Hydrozoa: Order Milleporina (Hydroidea): Family Milleporidae: 48 species

The history of *Millepora* taxonomy has been the opposite of scleractinian taxonomy where each minor growth form was often described as a new species (Veron, 1986).

Habitat Utilization

Found on projecting parts of the reef where tidal currents are strong. They are also abundant on upper reef slopes and in lagoons and may be a dominant component of some coral communities (Veron, 1986).

Life History

Adult: Appearance and Physical Characteristics

Colonial and hermatypic. Arborescent, plate-like, columnar or encrusting with a smooth surface perforated by near-microscopic pores. These are of two sizes: the larger are the gastropores, with each surrounded by five to seven smaller dactylopores. Fine straight hairs, visible under water, project from the colony surface. The growth variation is often based on environmental influences. Colors are green, cream or yellow. May be tan-coloured antler-like sheets with branch ends whitish.

Distribution

Globally, the genus is distributed from as far south as South Africa and southern Western Australia to the Kyushu Islands. From the African coast of western Indian Ocean and the Red Sea and the Marquesas in the east. The genus also occurs in the Central and Eastern Pacific and the Caribbean Sea.

Table 94 summarizes some Indo-Pacific species (adapted from Lewis 1989): their morphology, depth and reef zone and water circulation requirements.

Table 85. Species summary of the genus *Millepora* (Lewis 1989).

Species	Form	Location on reef	Habitat type
<i>Millepora dichotoma</i>	Fan, branches, vertical sheets and walls	0-5m, reef edge	Turbulent, area of the surf
<i>M. exaesa</i>	Robust branches or solid and round	0-10m, reef edge, outer reef slope	Moderate to turbulent
<i>M. platyphylla</i>	Sheets, leaves fans branches	0-10m, reef edge, reef flat	Strong to powerful, turbulent
<i>M. tenella</i>	Fans, branches, sheets	0-10m, reef edge, outer reef slope	medium to strong

Feeding and Food

Gastrozooids consume food and are the colony polyps have tentacles and a gastrovascular cavity. The dactylozooids are used for prey capture and have numerous tentacles, which convey a fuzzy appearance. They have a potent sting. Autotrophic due to zooxanthellae but may rely on small plankton and dissolved nutrients.

Reproductive Strategies

Alternation of generations: a sessile, asexual polyp stage and a free-living, sexual medusa stage. Medusa are reproduced by asexual division or budding. The medusa has separate sexes and produce eggs or sperm, which unite and develop into free-swimming planula larvae. Planula larvae are able to swim freely, though largely planktonic.

Bibliography

Lewis J.B. (1989). The ecology of *Millepora*. *Coral Reefs* 8 (3): 99-107.

Lewis J.B. (1991). Banding age and growth in the calcareous hydrozoan *Millepora complanata* Lamark. *Coral Reefs* 9 (4): 209-214

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 15116 4.

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5.3.4 Stylasteridae (Gray, 1847) (Stylasterines; lace corals)

Important Summary Documents

Veron (1986) Colin and Arneson (1995) and Fossa and Nilsen (1998) provide description of the family.

Taxonomic Issues

Class Hydrozoa; Class Stylasterina; Family Stylasteridae

Approximately 15 genera. Two are common reef genera: *Stylaster* Gray 1831 (48 species); *Distichopora* Lamarck 1816 (34 species) (Veron, 1986).

Taxonomy at the species level poorly known.

Habitat Utilization

With in the reef, sciaphilic or low light, often abundant under overhangs or on the roof of caves. Also found in deep reef conditions particularly if swept by tidal currents (Colin and Arneson, 1995)

Life History

Adult: Appearance and Physical Characteristics

Colonial, ahermatypic, usually arborescent, with tubular gastropores surrounded by smaller dactylopores and usually forming cyclo systems (Veron, 1986). Colour is bright and may be red, pink, orange, purple or white.

Stylaster spp.: Colonies are arborescent with fine branches, growing in one plane, which seldom anastomose. Cyclo systems alternate left and right side of branches.

Distichopora spp.: Colonies are arborescent with flattened, blunt-ended, non-anastomosing branches of uniform width, growing in one plane. There are no cyclo systems: gastropores are aligned along the lateral margins of branches with rows of dactylopores on either side (Veron, 1986; Sheer and Obrist, 1986).

Distribution

Stylaster spp.: Worldwide, extending to the Arctic and Antarctic.

Distichopora spp.: Circum-Australia, Central and the Indo-Pacific.

Feeding and Food

No zooxanthellae so heterotrophic, feeding presumably on small plankton. Dissolved nutrient absorption must be important.

Reproductive Strategies

Sexual individuals, the gonophores, develop in ampullae between the gastropores and release planula larvae.

Bibliography

Colin, P. L., and C. Arneson. 1995. Tropical Pacific Invertebrates. San Diego: Coral Reef Press, California, USA.

Fossa and Nilsen 1998. The Modern Coral Reef Aquarium, Vol. 2. Birget Schmettkamp Verlag, Bornheim, Germany.

Sheer, G. and Obrist K. 1986. *Distichopora nitida* Verrill (Cnidaria, Hydrozoa) from the Maldives, a new record from the Indian Ocean. *Coral Reefs* 5: 151-154.

Veron J. E. N. 1986. *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 15116 4.

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5.3.5 Solanderidae (Gray) (hydroid fans)

Important Summary Documents

Cooke (1977) described Hawaiian fauna all, of which, have a wider distribution.

Taxonomic Issues

Class Hydrozoa; Order Hydroida; Suborder Athecata (=Anthomedusa; Gymnoblastea); Family Solanderiidae (George and George, 1977; Barnes, 1987).

Habitat Utilization

Shallow water to 100 metres (Colin and Arneson, 1995).

Often found in deeper water ore cave or overhang environment (Cooke, 1977).

Life History

Adult: Appearance and Physical Characteristics

Similar in appearance to gorgonians and other sea fans. May be branching, ramose or encrusting. Branching in one plane, perpendicular to the current or wave action. Commonly found in exposed areas on wave swept shallow outer reefs (Colin and Arneson, 1995). *Solanderia spp.* is branching and may be 30cm high. Family is characterized by the presence of a perisarc composed of anastomosing chitinous fibers with scattered capitate tentacles (Cooke, 1977).

Defense is accomplished by the specialized tentacle the dactylozooids.

Colour species dependent: dark brown to yellow brown, red with white tentacle.

Distribution

Occur from western Africa through the central Indo-Pacific. Northerly limit Japan and Hawaii.

From Cooke (1977):

Solanderia minima: Zanzibar, Africa; *Hawaii*.

S. secunda: Central Pacific

S. misakinensis: Japan; *Hawaii*

S. sp.: New Guinea (Colin and Arneson 1995)

Feeding and Food

Gastrozooids capture and ingest zooplankton that is small enough to be handled. Extra-cellular digestion takes place in the gastrozoid. The partially digested broth the passes into the common gastrovascular cavity where intracellular digestion occurs.

Reproductive Strategies

Reproduction is by means of fixed gonophores or gonozooids. Applying generalized hydroid reproduction, the gonophores bud off both male and female, mobile medusae, which develop gonads and reproduce. The fertilized egg divides and develops into free-swimming larvae that attach to substrate to form a new hydroid.

Bibliography

Barnes, R. D. 1987. Invertebrate zoology. Saunders College, Philadelphia.

Colin, P. L., and C. Arneson. 1995. Tropical Pacific Invertebrates. San Diego: Coral Reef Press.

Cooke, J. 1977. Order Hydroida. In Devany D. M. & L. G. Eldredge (eds.) 1977. Reef and Shore Fauna of Hawaii. Bernice P. Bishop Museum Special Publication **64** (1).

George, D. & J. George, 1979. An Illustrated Encyclopedia of Invertebrates in the Sea *Marine Life*.

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5.3.5.1 Scleractinia (stony corals)

Important Summary Documents

Veron (1986) provides a popular taxonomic guide for stony corals and their biology. Birkeland (1997) is a modern synthesis of coral reef dynamics.

Fadlallah, (1983), Harrison and Wallace (1990) reviewed coral reproduction. Richmond and Hunter (1990) compared coral reproduction geographically. Table 96 summarizes the Scleractinia in the US Flag Pacific Islands, while Table 97 includes a summary of the likely zooxanthellate corals to be found in the Western Pacific Region. .

Taxonomic Issues

Veron and Pichon (1976); Veron, Pichon and Wijsman-Best (1977); Veron and Pichon (1979); Veron and Pichon (1982); Veron and Wallace (1984) have revised the taxonomy of the order Scleractinia in the AIMS Monograph series. Many of the earlier checklists require revision for comparison. References for description and checklists of the AFPI are: Hawaii -Maragos (1977, 1992,1995); Guam - Jones and Randall (1973); CNMI - Randall (1995); American Samoa - Birkeland,, Randall and Amesbury (1994); Lamberts (1980); Wake I. - Anon. (1999); Midway Atoll, Northern Hawaiian Islands - DeFelice, Coles, Muir, Eldredge (1998); Johnston Atoll - Maragos and Jokiel (1986); Jokiel and Tyler (1992); Palmyra Atoll - Maragos (1979, 1988, in prep.)

Habitat Utilization

Stony coral attach to the reef substrate creating a variety of biological habitats on which many other groups rely for shelter and symbiosis. Coral skeletons with the aid of coralline algae create the reef structure.

The distribution of hard coral over the reef is the result of fortuitous settlement and environmental sorting. The history of disturbance in an area plays a large role in the nature of the coral assemblage. Generally, there is a near shore assemblage which is dominated by genera resistant to the influence of the terrestrial factors and tidal variation. (eg. siltation, flooding, and variation in temperature). The genus *Porites*, *Montipora* and *Pavona*, in that order to dominate the reef scleractinians in Hawaii. In Hawaii, the predominantly branching coral genus *Acropora* is rare and generally confined to several areas in the NWHI. Elsewhere in the region, *Acropora*, *faviids* and *Millepora* are dominant or very common along with the other genera mentioned above. In permanently sub-tidal areas and further offshore the *Acropora* dominate but often in association by substantial growths of a variety of other species. In Hawaii, this dominance is replaced by *Montipora* and *Pocillopora*. Stony coral are limited by light (depth), wave action and disturbance.

The AFPI span a broad biogeographic realm from Guam (144° 45' E long.) to Hawaii (155° W. Long) and from American Samoa (15° S latitude) to the northern Hawaii Islands (28° 40' N. Lat). In terms of coral development, the tropical/temperature gradient gives rise to a range of reef types and species assemblages. The luxuriance of the high island reefs of American Samoa, Guam are in contrast to the variety of reefs which occur in Hawaii. The Jarvis, Baker, Howland, Palmyra Johnston and Wake reefs are atolls as are some of the reefs northern Hawaiian Islands. For most of these areas, varying degrees of information is available, though being generally scant.

Life History

Adult: Appearance and Physical Characteristics

Corals are similar to anemones in having a polyp form which may be colonial or solitary. They are characterized by a hard skeleton of aragonite (calcium carbonate). The colonial form may manifest a variety of forms: branching, tabulate, massive or encrusting. Some forms are species specific while some species respond to environmental influences which condition the colonial morphology. Polyps have tentacle though these are absent in some genera. They are often a crown, in multiples of six, (Hexacorallia) encircling the mouth though these may be manifest in furrows or over the surface as in the solitary *Fungia*. They possess nematocysts. Internally, the mouth opens into a gastrovascular cavity with mesenteries and mesenterial filaments. The mesenteries extend from the scleroseptum. The skeleton has a thecal wall, sclerosepta and a basal plate (Barnes, 1987).

The colony expands by budding of new polyps from the bases of old polyps or from the oral discs of old polyps through intra-tentacular or extra-tentacular budding. Polyps of meandroid colonies share a common oral disc bearing many mouths (Barnes, 1987).

Age, Growth, Longevity

Corals can be very long lived for massive species. An estimated 1000 years has been estimated for some massive *Porites*, colonial sizes representing 300 is reasonably common. Growth rates have been recorded by Buddemeir and Kinzie (1976).

Corals as a group have a wide range of growth rates. The rate variable between 0.4 and 22.5 cm per year. The massive corals grow more slowly with a range of 0.4 to 1.8cm. (DeVantier, 1993). Growth also includes fusion of colonies (Table 95).

Table 86. Growth rates among some scleractinian coral.

Species	Growth (cm/yr)
<u>Faviidae</u>	0-1.38
<i>Favia, Favites</i>	Mean range
<i>Goniastrea,</i>	0.07-1.25
<i>Montastrea</i>	
<i>Platygyra</i>	
<u>Poritidae</u>	0-1.88
<i>Porites</i>	Mean range
<i>Goniopora</i>	0.13-0.97
<u>Mussidae</u>	0-1.65
<i>Lobophyllia</i>	Mean range
<i>Symphyllia</i>	0.38-0.94
<i>Acanthastrea</i>	
<u>Oculinidae</u>	0.67-1.18
<i>Galaxea</i>	Mean range
	0.54-0.93
<u>Merulinidae</u>	.56-1.15
<i>Hydnophora</i>	Mean 0.86
<u>Caryophylliidae</u>	0.5-0.75
<i>Physogyra</i>	Mean range
<i>Euphyllia</i>	0.5-0.75

Species	Growth (cm/yr)
<i>Plerogyra</i>	
<i>Acroporiidae</i>	10.17-22.58
<i>Acropora</i>	
<i>Pocilloporiidae</i>	0.4-3.59
<i>Pocillopora</i>	

Reproductive Strategies

Corals reproduce by both sexual (external fertilization and development and brooded planulae) and asexual development (brooded planulae, polyp-balls, polyp bail-out, fission, fragmentation and re-cementation). May be bisexual or hermaphroditic (protandric, protogynous or synchronous) (Chorneski and Peters, 1987). Self fertilisation occurs (Heyward and Babcock, 1986).

Asexual modes of reproduction:

brooded planulae

polyp-balls: *Goniopora* spp. (Sammarco 1986)

polyp bail-out: *Seriatopora* spp. (Sammarco 1981,1982)

reversible metamorphosis: *Pocillopora damicornis* (Richmond 1985)

fission: *Fungiidae*

fragmentation and re-cementation: *Acropora* spp and others (Tunncliffe, 1981)

Corals may be free spawners or brooders depending on their geographic distribution. In Hawaii , *Tubastrea* is a brooder but in Australia is a brooder and free spawner.(Harrison and Wallace, 1990)

Sexual maturity depends, on growth as well as colony age (Kojis and Quinn, 1985)

Brooders reach maturity a few years earlier than free spawners. Ahermatypic corals reach sexual maturity earlier than hermatypic corals (Harriot, 1983). Fecundity increases with age. (Soong and Lang, 1992). Availability of light influences fecundity whether through depth or

an increase in suspended particles in the water (Kojis and Quinn, 1984) or the reduction of UV light (Jokiel and York, 1982).

Distribution

Table 96 details the occurrence of Scleractinia in the AFPI. Veron (1993b) detailed the global distribution of coral genera and regionally with species. Regional variation in generic occurrence has been documented with latitudinal gradients (Wells 1956).

Zonation within reefs due to environmental influences is well known.(In American Samoa: Birkeland et al. 1994, 1996; In Hawaii: Palmyra Atoll: Maragos 1977, 1988, 1992; In Guam: Jones and Randall).

Discrete coral populations may result from asexual reproduction and possess the same genotype (Hunter, 1985; Willis and Ayre, 1985; Ayre and Resing, 1986) though many appear heterogenous.

Feeding and Food

Stony corals feed on planktonic organisms or dissolved organic matter (DOM). Capture of prey is by tentacles, suspension feeding occurs and some use mesenterial filaments. Most prey capture at night though some feed during the day.

The presence of symbiotic zooxanthellae makes some corals functional autotrophs (Muscatine et al. 1981) and contribute to all hermatypes nutrition. Muscatine and Porter (1977) determined plankton comprise approx. 20% of coral required nutrition. Franzisket (1970) showed coral could live without plankton, but additional nutrition was required from this source (Johannes et al. 1970). The relative dependence on heterotrophy varies with species and with environment. Sorokin (1973, 1995) described the relative dependence on predation, bacteria and DOM. The zooxanthellae receive elements from predation (i.e. nitrogen, iron, and vitamine B₁₂). Recycling of nutrients between corals and zooxanthellae is well known (Johannes 1974; Muscatine 1973; Porter, 1976).

Behavior

Competition for space is achieved by direct tentacular competition; mesenterial filaments, sweeper tentacles, allopathy, over-growth, shading.

Spawning: Spatial and Temporal Distribution

Mass spawning has been described by Babcock et al. (1986) and follows a lunar periodicity (Richmond and Hunter, 1990). Geographic variation introduces the effects of temperature

and other climatic factors. In Australia, (GBR), *A. palifera* spawns only once per year at 23°S latitude and through out the year at 14°S lat. (Kojis and Quinn, 1984, 1986a).

Appearance and Physical Characteristics of Eggs (size, shape, color, etc) and Duration of Phase

Eggs are round and may be pink, orange, blue, purple or white. Pigmentation may be UV protection. White eggs are non-fertile in *Galaxea fascicularis*. Maturation of eggs and ejection may be controlled by the hormone Estradiol-17 β (Atkinson and Atkinson, 1992). Form into egg sperm bundles. Some eggs contain zooxanthellae. Eggs range in size from 1.5 x 1.00mm (*Flabellum rubrum*) to Acroporidae and Mussidae 0.4-0.8mm; Faviidae and Pectiniidae 0.3- 0.5mm, Portitidae, Agariciidae, Fungiidae and Pocilloporidae 0.05-0.25mm. The total length of sperm is <0.005mm. Eggs and sperm production is cyclic and maturity is reached at the same time for most corals. For *Stylophora pistillata* (Rinkevich and Loya, 1979), the time is different for different colonies. *Acropora palifera* spawning may take place in several stages in synchrony with moon phases with six reproductive cycles per year (Kojis, 1986a, b). Free spawners have a 12 month maturation cycle but brooders have several cycles per year.

Spawning is in synchrony with the lunar cycle beginning on the 15th to the 24th night of the lunar cycle. Spawning starts at dusk and continues until midnight. It may vary geographically. A slick is often observed as the gametes are brought together by currents. Likelihood of fertilization is increased and the abundance of material means predation is decreased through satiation.

Duration of gamete development after spawning is 30 minutes until the ability to fertilise, first cell division 1-2 hours, to planula stage 6-24 hours (Szmant-Froelich et al. 1980; Kojis and Quinn 1982, Bull 1986, Heyward 1986)

Larvae: Appearance and Physical Characteristics of Larvae

It is covered with cilia which provide locomotion. In *Porites porites*, 200 planula may be released from a section of colony (2cm²) (Fadallah, 1983). They are ciliated, spherical initially and oval or pear-like when mobile.

Age, Growth and Duration of Larval Phase

Initially, they move to the surface of the water and drift as a ciliated ball. In 3-7 days they elongate into a conical shape. They have a cavity and mouth and are 1.5mm long with mesenteries developed. They then move to deeper water and seek substrate (Babcock and Heyward, 1986).

Coral with long lived larvae are: *Galaxea aspera* 49 days; *Cyphastrea ocellina* (Hawaii) 60 days; *Acropora* spp. 91 days; *Pocillopora damicornis* (Hawaii) 103 days (Gulko, 1999).

Larval Feeding and Food

Nutrition in planulae is achieved as the result of energy reserves transferred from the embryonic cells. Zooxanthellae, most probably, provide nutrition through nutrient translocation. Some planula feed actively.

Habitat Utilization

Some planula have zooxanthallae and may exist for longer in the plankton and disperse further. Most settle with the proximity of the parent <1km. Discussion of factors in dispersal have been reviewed by Harrison and Wallace (1990). Currents must play a major role in the transport of the larvae. Longevity in the plankton will determine the potential distance of dispersal (Richmond, 1987).

Settlement sites are often cryptic. Clumping of planula may give rise to fusion into a single colony.

Habitat Features Affecting the Abundance and Density of Eggs and Larvae

Currents affect the abundance of eggs and larvae, often concentrating them into a dense mass and dispersing them with the flow. Rain storms may cause mass mortality at this stage as does grounding of the slick at low tide or along the shore. After settlement, the planulae develop primary polyps. The settlement site is important. If inshore, large amounts of organic particular matter and sediment will increase mortality. Wave action may destroy the primary polyps. Young polyps may abandon primary calyx, and relocate planktonically (Richmond, 1985) or through bailout responses.

There is the potential for rafting of coral polyps on driftwood or other current borne objects which would allow for the settlement by larvae and polyp growth (Jokiel, 1984).

Abundance and distribution of coral planulae was investigated in Kaneohe Bay, Oahu (Hodgson, 1985) and Bull (1986) for Australia.

Settlement occurs by finding a suitable location. The size of the new polyp is <2mm. Mortality at this stage is high. Both the environmental and biological environment affect the potential for coral development (Goreau, et al. 1981).

In Western Australia, large numbers of fish and coral died as the result of a coral spawn slick being embayed and using up the oxygen and then decaying (Simson 1993).

Bibliography

Anon. (1999). *Baseline Marine Biological Survey, Peacock Point Outfall and other Point Source Discharges, Wake Atoll, Pacific Ocean*. Report to the Department of Army by the Department of Interior, Fisheries and Wildlife Service (FWS) and the Department of Commerce, National Marine Fisheries Service (NMFS). Honolulu, Hawaii. 23 p.

- Atkinson, S. and Atkinson, M.J. 1992. Detection of estradiol 17 β during a mass coral spawn. *Coral Reefs* 11 (1): 33-36.
- Ayre, F.J. and Resing J.M. 1986. Sexual and asexual production of planula in reef corals. *Mar. Biol.* (90): 187-190.
- Babcock, R.C., G. D. Bull, P. L. Harrison, A. J. Heyward, J. K. Oliver, C. C. Wallace & B. L. Willis (1986): Synchronous spawnings of 105 scleractinian coral species on the Great Barrier Reef. *Mar. Biol.* (90): 379-394
- Babcock, R.C. and Heyward A.J. (1986). Larval development of certain gamete-spawning scleractinian corals. *Coral Reefs* 5: 111-116.
- Barnes, R. D. (1987): *Invertebrate zoology*. Saunders Colledge, Philadelphia.
- Birkeland, C. 1997a Introduction. In: C. Birkeland (ed.) *Life and death of coral reefs*. Chapman and Hall, Melbourne.
- Birkeland, C., Randall, R. and S. Amesbury 1994 Coral and reef-fish assessment of the Fagatele Bay National Marine Sanctuary. Report to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 126 pp.
- Birkeland, C., Randall, R., Green, A.L. Smith, B. and S. Wilkens 1996 A re-survey of the marine resources of Fagatele Bay National Marine Sanctuary, American Samoa. A report to be submitted to the NOAA Technical Report Series. 223 pp.
- Buddemeir, R.W. and Kinzie, R.A. 1976. Coral Growth. *Oceanogr. Mar. Biol. Ann. Rev.* 14: 183-225.
- Bull, G. 1986. Distribution and abundance of coral plankton. *Coral Reefs* (4): 197-200.
- Chorneski E.A. and Peters E.C., 1987. Sexual reproduction and colony growth in the scleractinian coral *Porites asteroides*. *Biol. Bull.* (172): 161-177.
- DeFelice R.C., Coles, S.L., Muir D., Eldredge L.G. 1998. Investigations of the marine communities of Midway Harbour and adjacent lagoon, Northwestern Hawaiian Islands. Report to U.S. Fish and Wildlife Service, Pacific Islands Area Office, Honolulu, Hawaii.
- DeVantier, L.M. 1993. The Coral Communities of the Brook Islands, 1987 - 1992. Rpt. Qld. Dept. Environment and Heritage, Coastal Protection Unit.
- Fadlallah, Y. H., 1983: Sexual reproduction, development and larval biology in scleractinian corals. A review. *Coral Reefs*, 2(3):129-150.

- Franzisket, L., 1970. The atrophy of hermatypic reef corals maintained in darkness and their subsequent regeneration in light. *Inter. Rev. Gesamten Hydrobiol.*, 55(1): 1-12.
- Goreau, N.I., Goreau, T.J. and Hayes R.L. (1981) Settling, survivorship and spatial aggregation in planulae and juveniles of *Porites porites* (Pallas) *Bull. Mar. Sci.* 31: 424-435.
- Grigg, R.W. 1981. *Acropora* in Hawaii. Part2 Zoogeography. *Pac..Sci.* 35: 15-24.
- Grigg, R.W., Wells, J. and Wallace, C. 1981. *Acropora* in Hawaii PartI. History of the scientific record , systematica and ecology *Pac. Sci.* 35: 1-13.
- Gulko, D. Hawaiian Coral Reef Ecology. Mutual Publishing. pp. 245.
- Harriott, V. J. 1983: Reproductive ecology of scleractinian species at Lizard Island, Great Barrier Reef. *Coral Reefs* 2 (1): 9-18
- Harrison, P. L. & C. C. Wallace 1990: Reproduction, dispersal and Recruitment of Scleractinian Corals. In: Dubinsky, Z. (ed.) *Ecosystems of the World*, vol. 25 Coral Reefs. Elsevier, N.Y. pp 133-208.
- Heyward, A. J. 1986: Sexual reproduction in the five species of the coral *Montipora*. In: P. L. Jokiel, R. H. Richmond & R. A. Rogers (Eds.) *Coral Reef Population Biology*. Hawaii Inst. Mar. Biol. Tech. Rep. No.37: 170-178.
- Heyward, A. J. & R. C. Babcock 1986: Self- and crossfertilisation in scleractinian corals. *Mar. Biol.* (90): 191-195.
- Johannes, R. E., S. L. Coles & N. T. Kuenzel (1970): The role of zooplankton in the nutrition of some corals. *Limnol. Oceanogr.* (15): 579-586.
- Jokiel, P. L. & R. H. York Jr. 1982: Solar ultraviolet photobiology of the reef coral *Pocillopora damicornis* and symbiotic zooxanthellae. *Bull. Mar. Sci.* 32: 301-315.
- Jokiel, P. L. 1984: Long Distance Dispersal of Reef Coral by Rafting. *Coral Reefs* 3 (2): 113- 116.
- Jokiel, P. L. 1985: Lunar periodicity of planula release in the reef coral *Pocillopora damicornis* in relation to various environmental factors. *Proc. 5th.Int. Coral Reef Congress, Tahiti, 1985.* (4): 307-312.
- Jokiel, P.L. and Tyler W.A. 1992. Distribution of Stony Corals in Johnston Atoll Lagoon, *Proceedings of the 7th International Coral Reef Symposium, Guam, 1992, Vol.2.*

- Jones, R.S. and R.H. Randall 1973 A study of biological impact caused by natural and man-induced changes on a tropical reef. U.S. Environmental Protection Agency. University of Guam, Marine Laboratory Technical Report No.7.
- Hodgson, G, 1985. Abundance and distribution of planktonic coral larvae in Kaneohe Bay, Oahu, Hawaii. Mar. Ecol. Progr. Ser. 26:61-71.
- Hunter, C.L. 1985 Assessment of clonal diversity and population structure of *Porites compressa* (Cnidaria; Scleractinia) Proc. 5th Int. Coral Reef Congress, Tahiti, 1985. (6): 69-74.
- Kojis, B. L. & N. J. Quinn 1984: Seasonal and depth variation in fecundity of *Acropora palifera* at two reefs in Papua New Guinea. Coral Reefs 3 (3): 165-172.
- Kojis, B. L. & N. J. Quinn 1985: Puberty in *Goniastrea favulus*. Age or size limited ? Proc. 5th. Int. Coral Reef Congress., Tahiti, 1985 (4): 289-293.
- Kojis, B. L. 1986a: Sexual reproduction in *Acropora* (Isopora) species (Coelenterata: Scleractinia). I: *A. cuenata* and *A. palifera* on Heron Island reef , Great Barrier Reef. Mar. Biol. (91): 291-309.
- Kojis, B. L. 1986b: Sexual reproduction in *Acropora* (Isopora) species (Coelenterata: Scleractinia). II: Latitude variation in *A. palifera* from the Great Barrier Reef and Papua New Guinea. Mar. Biol. (91): 311-318.
- Lamberts, A. 1980. Checklist of Samoan Coral Genera and Species. In: American Samoa Coral Reef Inventory, U.S. Army Corps of Engineers for Development Plan Office, American Samoan Govt..
- Maragos, J.E. 1977 Order Scleractinia: stony corals. In: Devaney, D. and L. Eldredge (eds.) Reef and shore fauna of Hawaii. Section 1: Protozoa through Ctenophora. Bishop Museum Press, Honolulu, Hawaii. 278 pp.
- Maragos, J.E. 1995 Revised checklist of extant Shallow-water stony coral species from Hawaii (Cnidaria: Anthozoa: Scleractinia). Bishop Museum Occasional Papers 42: 54-55.
- Maragos, J.E. 1979a. Palmyra Atoll: Preliminary environmental survey and assessment. U.S. Army Corp of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii. 31pp+62pls.
- Maragos, J.E. 1988. Notes on the abundance and distribution of reef coral and reef features at Palmyra Atoll, Line Islands. US Army Corps of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii, 18pp+13pls.

- Maragos, J.E. 1992. Status of coral reefs off the southeast coast of Molokai, Hawaii 1990-91. Lacayo Planning Report.
- Maragos, J.E. and P. Jokiel 1986 Reef corals of Johnston Atoll: one of the world's most isolated reefs. *Coral Reefs* 4: 141-150.
- Muscantine, L. (1973): Nutrition of corals, In: O. A. Jones & R. Endean (ed.): *Biology and Geology of Coral Reefs* (2): 77-115.
- Muscantine, L., L. R. McCloskey & R. E. Marian (1981): Estimating the daily contribution of carbon from zooxanthellae to coral animal respiration. *Limnol. Oceanogr.* **26**: 601-611.
- Muscantine, L. & J. W. Porter (1977): Reef corals: mutualistic symbiosis adapted to nutrient-poor environments. *Bioscience* (27): 454-459.
- Porter, J.W., 1976: Autotrophy, heterotrophy, and resource partitioning in Caribbean reef-building corals. *Am. Nat.*, *110*:731-742.
- Randall, R.H. 1995 Biogeography of reef-building corals in the Mariana and Palau Islands in relation to back-arc rifting and the formation of the Eastern Philippine Sea. *Nat. Hist. Res.* 3(2): 193-210.
- Richmond, R.H. 1985. Reversible metamorphosis in coral planula larvae. *Mar. Ecol. Prog. Ser.* 22: 181-185.
- Richmond, R. H. 1987. Energetic, competency and long distance dispersal of planula larvae of the coral *Pocillopora damicornis*. *Mar. Biol.* 93: 527-533.
- Richmond, R. H. & C. L. Hunter 1990: Review B Reproduction and recruitment of corals: comparison among the Caribbean, the Tropical Pacific, and the Red Sea. *Mar. Ecol. Prog. Ser.* 1: 145-152.
- Rinkevich, B. & Y. Loya 1979: The reproduction of the Red Sea coral *Stylophora pistillata*. II. Synchronisation in the breeding and seasonality of planula shedding. *Mar. Ecol. Progr. Ser.* 1: 145-152.
- Sammarco, P. W. 1981: A new mode of reproduction in corals under stress: is there a life after death in *Seriatopora*? *Aust. Mar. Sci. Biol. Ecol.* (75): 20 (Abstract).
- Sammarco, P. W. 1982: Polyp bail-out: An escape response to environmental stress and a new means of reproduction in corals. *Mar. Ecol. Progr. Ser.* 10: 57-65.
- Sammarco, P. W. 1986: Coral Reproduction, Dispersal, and Survival. *Oceanus* **29** (2): 28-19.

- Simson, C.J., Cary, J.L. and Masini, R.J. (1993). Destruction of corals and other reef animals by coral spawn slicks on Ningaloo Reef, Western Australia. *Coral Reefs*: 12: 185-192.
- Szmant, A. M. 1986: Reproductive ecology of Caribbean reef corals. *Coral Reefs* **5** (1): 43-53.
- Szmant-Froehlich, A.M., Yepich, M. P., Pilson, M.E.Q. 1980: Gametogenesis and early development of the temperate coral *Astrangia danae* (*Anthosxoa:Scleractinia*). *Biol Bull.* (158): 257-269.
- Soong, K. & J. C. Lang 1992: Reproductive integration in reef corals. *Biol. Bull.* (183): 418-431.
- Sorokin, Y.I. 1973. On the feeding of some scleractinian corals with bacteria and dissolved organic matter. *Limnol. Oceanogr.* (18) 380-385.
- Sorokin, Y.I. 1995. *Coral Reef Ecology*, 2nd ed. Springer Verlag, New York, USA.
- Szmant, A. M. 1986: Reproductive ecology of Caribbean reef corals. *Coral Reefs* **5** (1): 43-53.
- Szmant-Froehlich, A.M., Yepich, M. P., Pilson, M.E.Q. 1980: Gametogenesis and early development of the temperate coral *Astrangia danae* (*Anthosxoa:Scleractinia*). *Biol Bull.* (158): 257-269.
- Tunncliffe, V. (1981) Breakage and propagation of the stony coral *Acropora cervicornis*. *Proc. Natl Acad. Sci* 78(9): 2427-2431.
- Vaughan, T.W. 1907. *Recent madreporaria of the Hawaiian Islands and Laysan*. U.S. National Mus. Bull. 59. Washington D.C.
- Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 1511
- Veron, J. E. N. 1993b: A Biogeographic Database of Hermatypic Corals. Species of the Central Indo-Pacific. Genera of the World. AIMS Monograph Series Volume 10, Australian Institute of Marine Science (AIMS), Townsville, Australia.
- Veron J. E. N. & Pichon, M. 1976: Scleractinia of eastern Australia, Part 1: Families Thamnasteriidae, Astrocoenidae, Pocilloporidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 1, 86pp.

- Veron J. E. N., Pichon M. & Wijsman-Best M. 1977: Scleractinia of eastern Australia, Part 2: Families Faviidae, Trachyphyllidae. *Aust. Ins. Mar. Sci., Monogr. Ser. 3*, 232pp.
- Veron J. E. N. & Pichon M. 1979: Scleractinia of eastern Australia, Part 3 Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectinidae, Caryophyllidae, Dendrophylliidae. *Aust. Inst. Mar. Sci., Monogr. Ser. 4*, 422pp.
- Veron J. E. N. & Pichon M. 1982: Scleractinia of eastern Australia, Part 4: Family Poritidae, *Aust. Ins. Mar. Sci., Monogr. Ser. 5*, 159pp.
- Veron J. E. N. & Wallace C. C. 1984: Scleractinia of eastern Australia, Part 5: Families Acroporidae. *Aust. Ins. Mar. Sci., Monogr. Ser. 6*, 485pp.
- Wells, J.W. 1956. A survey of the distribution of reef coral genera in the Great Barrier Reef region. Rep. Gt. Barrier Reef Comm. No. 6(2).
- Willis, B.L. and Ayre D.J. 1985. Asexual reproduction and generic determination of growth form in the coral *Pavona cactus*: biochemical genetic and immunogenetic evidence. *Oecologia* (65); 516-525.

5.3.6 Fungiidae (Dana, 1846) (mushroom corals)

Important Summary Documents

Veron (1986) provides a species summary of the systematics, anatomy and distribution in Australia and the Indo-Pacific. Veron (1993b) the family Fungiidae is discussed with respect to its global distribution.

Taxonomic Issues

Veron & Pichon (1979) revised the taxonomy of the family Fungiidae.

Has 11 extant genera: *Cycloseris* (7 spp.), *Diaseris* (4 nominal spp.), *Heliofungia*, *Fungia* (25 spp.), *Herpolitha* (2 spp.), *Polyphyllia* (3 spp.), *Halomitra* (1 spp.), *Sandalolitha* (2 spp.), *Lithophyllum* (2 spp.), *Podabacia* (1 spp.) and *Zoopilus* (1 spp.).

Habitat Utilization

Begin life as anthocauli attached to a hard substrate. Detach to continue life as a free-living colony inhabiting reef areas unsuitable for permanently attached corals such as sand or rubble.

Life History

Adult: Appearance and Physical Characteristics

All shallow water with the exception of the *Fungiacyathus* (not occur AFPI). The majority are hermatypic, solitary, and free living (not *Lithophyllum* or *Podabacia*) with attached juvenile stage. They may be individual with one mouth or colonial with many mouths and other anatomy characteristic of a colonial form.

From Veron (1986):

Cycloseris (Edwards & Haime, 1849): Solitary, free-living, flat or dome-shaped, circular or slightly oval in outline with a central mouth. Fine tentacles cover the upper surface of the disc. Pale brown to cream with a darker margin.

Diaseris (Edwards & Haime, 1849): Circular though with an irregular margin and segments. Colour is brown to green.

Heliofungia (Wells, 1966): Solitary, free-living, flat with central mouth. Septa have large lobed teeth. Polyps are extended day and night, and as a single polyp are the largest of all corals. Tentacles are longest of the stony corals and dark purple or green tentacle with pale tips. The oral disc is striped and the single mouth is 30mm wide.

Fungia (Lamarck, 1801): Free-living, circular or elongate

Herpolitha (Eschscholtz, 1825): Free-living, elongate with an axial furrow that may extend to the corallum ends. Several centers or mouths occur in the furrow. Colonies may be heavily calcified and >1m in length. Tentacles are short and widely spaced.

Polyphyllia (Quoy and Gaimard, 1833): Free-living, elongate with many mouths and tentacles over the upper surface. Larger mouths are down the axial furrow. Long tentacles, which are always extended.

Halomitra (Dana, 1846): Colonies are large and free-living, circular and dome or bell shaped, thin and delicate and without an axial furrow. Corallites widely spaced. Tentacles are small and widely spaced and extended at night.

Sandalolitha (Quoy and Gaimard, 1833): Colonies are large, free-living, and circular to oval, dome-shaped, heavily constructed and without an axial furrow. Corallites are compacted.

Pale or dark brown, sometimes with purple margins and white centers.

Lithophyllon (Rehberg, 1892): Colonies are attached, encrusting or laminar, unifacial. Colonies may be large, up to several metres. Polyps extended at night. Dull green, grey or brown with white margins or white centers.

Podabacia (Edwards and Haime, 1849): Colonies are attached, encrusting or laminar, unifacial and up to 1.5m in diameter.

Their coloration may be brown, green, red or pink. They may have contrasting striped design.

Distribution

Cycloseris: Extends from southern Africa to the Red Sea and Arabian Gulf through the Indo-Pacific ranging from south Western Australia, Lord Howe I. and Easter I. in the south to southern Japan in the north. It occurs in the Hawaiian Islands, though not in Midway. It is present in the eastern Pacific from Baja California, northern Mexico to Columbia. The recorded occurrence in the AFPI is Johnston Atoll, Hawaii and Guam

Diaseris: Similar to *Cycloseris* though narrower, extending from southern Madagascar and the Red Sea. Across the Pacific at varying latitude in the north to include Japan and in the south of New Caledonia and the Tuamotus Is. The recorded occurrence in the AFPI is Hawaii.

Heliofungia: Indonesia, Australia, Philippines, Ryukyu Is. east to the Caroline and Solomon Is and south to New Caledonia. The genus does not occur in the AFPI.

Fungia: South of Madagascar, to the Red Sea, Northern Australia, the Great Barrier Reef, south to Lord Howe I. and across to Pitcairn I. Its northerly extent is southern India, Southeast Asia, southern Japan, Midway I., Hawaiian Is. Its easterly extent is the Marquesas Is. The recorded occurrence by virtue of *Fungia scutaria* is present in all AFPI where checklists have been made. Considering the other species of the genus, occurrence is limited to American Samoa, Palmyra Atoll, and Guam.

Herpolitha: South of Madagascar to the Red Sea, Northern Australia, the Great Barrier Reef, south to New Caledonia and across to Pitcairn I. Its northerly extent is southern India, Philippines, and Ryukyu Is., Japan. Its easterly extent is the Tuamotus Is. The AFPI that this species is found in is American Samoa, Palmyra Atoll and Guam.

Polyphyllia: Central Indo-Pacific: Northern Madagascar and the Seychelles Is in the west. Northern Australia, New Caledonia and Tonga in the south. American Samoa (only AFPI occurrence) in the east and Ryukyu Is, Japan in the north.

Halomitra: West Africa Madagascar in the west through Indonesia to the Line Is in the east. South to New Caledonia and Tonga and north to the Ryukyu I in the north. Present in the AFPI in American Samoa and Palmyra.

Sandalolitha: Occurs in Indonesia and Southeast Asia in the west to the Kyushu Is. in the north. Extends to Northern Australia and New Caledonia and Tubuai Is in the south. Also extends to the Tubuai Is and Line Is in the east. AFPI occurrence limited to American Samoa and Palmyra Atoll.

Lithophyllon: Similar to *Sandalolitha*, occurring to Indonesia in the west and the Malay Peninsula. Its southerly extent is northern Australia, New Caledonia, and Fiji to the east. It is confined to the western Pacific to include the Philippines and north to southern Japan. There are no occurrences in the AFPI.

Podobacia: Indo-Pacific: Occurs from west Africa and the Red Sea south to Madagascar, Northern Australia, New Caledonia to Tahiti. Range extends to the Fiji in the east. In the north, it extends along Southeast Asia to Japan. There are no occurrences in the AFPI.

Feeding and Food

Heterotrophic: prominent tentacles indicate prey capture. Autotrophic: abundant zooxanthellae.

Behavior

Are partially mobile. May free themselves if buried and some are capable of lateral movement, ability to right themselves, and able to climb over obstacles by using their tentacles and inflating their body cavities.

Mobility in *Cycloseris* by ciliary hairs, by inflation of the body cavity or use of tentacles. Tentacle extended at night.

Fungia and *Herpolitha*: Polyps are extended only at night.

Reproductive Strategies

Asexual: Fragmentation or natural regeneration through fracture. Many develop attached daughter polyps (acanthocauli) from the parent colony.

Sexual: Dioecious or hermaphroditic. Planula larvae settle to form the attached acanthocauli, which may grow to several centimeters before detaching due to degeneration of the stalk. *Heliofungia* has been reported as hermaphroditic while *Fungia* has separate sexes. It is likely the family has separate sexes, the females either brood planulae or release gametes (Veron, 1986).

Bibliography

- Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 15116 4.
- Veron, J. E. N. (1993b): A Biogeographic Database of Hermatypic Corals. Species of the Central Indo-Pacific. Genera of the World. AIMS Monograph Series Volume 10, Australian Institute of Marine Science (AIMS), Townsville, Australia.
- Veron J. E. N. & Pichon M. 1979: Scleractinia of eastern Australia, Part 3: Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectinidae, Caryophyllidae, Dendrophylliidae. *Aust. Inst. Mar. Sci., Monogr. Ser.* 4, 422pp.

Table 87. Distribution of Scleractinia (hard coral) in the American Flag Pacific Islands (AFPI).

AS: American Samoa; PA: Palmyra Atoll; JA: Johnston Atoll; MHI: Main Hawaiian Islands; NWHI: Northwestern Hawaiian Islands; WA: Wake Atoll; CNMI: Commonwealth of Northern Mariana Islands; GU: Guam

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Order SCLERACTINIA									
Family ASTROCOENIIDAE									
<i>Stylocoeniella armata</i> (Ehrenberg, 1834)	X						X	X	3
<i>Stylocoeniella guentheri</i> (Bassett-Smith, 1890)							X	X	2
Family THAMNASTERIIDAE									
<i>Psammocora contigua</i> (Esper, 1797)	X							X	2
<i>Psammocora digitata</i> Edward & Haime, 1851							X	X	2
<i>Psammocora explanulata</i> van der Horst, 1922				X					1
<i>Psammocora folium</i> (Syn)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Psammocora (P.) haimeana</i> Edwards and Haime, 1851	X	X						X	3
<i>Psammocora nierstraszi</i> van der Horst, 1921	X		X	X			X	X	5
<i>Psammocora profundacella</i> Gardiner, 1898		X						X	2
<i>Psammocora stellata</i> (Verrill, 1866)		X	X	X	X			X	5
<i>Psammocora superficiales</i> Gardiner, 1898	X								1
<i>Psammocora (V.) tutuilensis</i> (Syn)	X								1
<i>Psammocora verrilli</i> Vaughan				X				X	2
Family POCILLOPORIDAE									
<i>Pocillopora ankei</i> Sheer & Pillai, 1974	X								1
<i>Pocillopora damicornis</i> (Linnaeus, 1758)	X	X	X	X	X			X	6
<i>Pocillopora eydouxi</i> Edwards & Haime, 1860	X	X	X	X		X		X	6

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Pocillopora ligulata</i> Dana, 1846	X			X				X	3
<i>Pocillopora molokensis</i> Vaughan, 1907				X					1
<i>Pocillopora setchelli</i> Hoffmeister, 1929	X						X	X	3
<i>Pocillopora verrucosa</i> (Ellis & Solander, 1786)	X	X	X	X	X	X	X	X	8
<i>Pocillopora woodjonesi</i> Vaughan, 1918	X							X	2
<i>Seriatopora crassa</i> Quelch, 1886	X								1
<i>Seriatopora hystrix</i> Dana, 1846	X							X	2
<i>Stylophora pistillata</i> Esper, 1797	X	X					X	X	4
Family ACROPORIDAE									
<i>Acropora</i> (A.) <i>aculeus</i> (Dana, 1846)	X					X			2
<i>Acropora</i> (A.) <i>acuminata</i> (Verrill, 1864)	X	X						X	3
<i>Acropora</i> (A.) <i>aspera</i> (Dana, 1846)	X	X						X	3

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Acropora (A.) azurea</i> Veron & Wallace, 1984	X								1
<i>Acropora (A.) bushyensis</i> Veron & Wallace, 1984								X	1
<i>Acropora (A.) carduus</i> (Dana, 1846)		X						X	2
<i>Acropora (A.) cerealis</i> (Dana, 1846)	X	X	X				X	X	5
<i>Acropora (A.) clathrata</i> (Brook, 1891)	X								1
<i>Acropora (A.) cuspidata</i> Dana	X								1
<i>Acropora (A.) cytherea</i> (Dana, 1846)	X	X	X	X				X	5
<i>Acropora (A.) danai</i> (Milne-Edwards & Haime, 1860)	X	X					X	X	4
<i>Acropora (A.) digitifera</i> (Dana, 1846)	X	X					X	X	4
<i>Acropora (A.) divaricata</i> (Dana, 1846)	X								1
<i>Acropora (A.) echinata</i> (Dana, 1846)								X	1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Acropora (A.) elseyi</i> (Brook, 1892)		X	X						2
<i>Acropora (A.) florida</i> (Dana, 1846)		X							1
<i>Acropora (A.) formosa</i> (Dana, 1846)	X	X						X	2
<i>Acropora (A.) gemmifera</i> (Brook, 1892)	X	X							2
<i>Acropora (A.) granulosa</i> (Edwards & Haime, 1860)	X						X	X	3
<i>Acropora (A.) horrida</i> (Dana, 1846)	X								1
<i>Acropora (A.) humilis</i> (Dana, 1846)	X	X	X	X			X	X	6
<i>Acropora (A.) hyacinthus</i> (Dana, 1846)	X	X					X	X	4
<i>Acropora (A.) latistella</i> (Brook, 1892)	X								1
<i>Acropora (A.) listeri</i> (Brook, 1893)	X								1
<i>Acropora (A.) longicyathus</i> (Edwards & Haime, 1860)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Acropora (A.) millepora</i> (Ehrenberg, 1834)	X							X	2
<i>Acropora (A.) monticulosa</i> (Bruggemanni, 1879)	X	X						X	3
<i>Acropora (A.) multiacuta</i> Nemenzo, 1967		X							1
<i>Acropora (A.) loripes</i> (Brook, 1892)	X	X					X	X	4
<i>Acropora (A.) nana</i> (Studer, 1878)	X	X						X	3
<i>Acropora (A.) nasuta</i> (Dana, 1846)	X	X				X	X	X	5
<i>Acropora (A.) nobilis</i> (Dana, 1846)	X	X						X	3
<i>Acropora (A.) ocellata</i> (Klunzinger, 1897)	X							X	2
<i>Acropora (A.) pagoensis</i> Hoffmeister	X								1
<i>Acropora (A.) palmerae</i> Wells, 1954	X							X	2
<i>Acropora (A.) paniculata</i> Verrill, 1902	X		X	X					3

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Acropora</i> (A.) <i>paxilligera</i> (Dana, 1846)	X								1
<i>Acropora</i> (A.) <i>polystoma</i> (Brook, 1891)	X	X							2
<i>Acropora</i> (A.) <i>pulchra</i> (Brook, 1891)	X								1
<i>Acropora</i> (A.) <i>rambleri</i> (Bassett-Smith, 1890)	X							X	2
<i>Acropora</i> (A.) <i>robusta</i> (Dana, 1846)	X							X	2
<i>Acropora</i> (A.) <i>samoensis</i> (Brook, 1891)	X	X							2
<i>Acropora</i> (A.) <i>schmitti</i>	X								1
<i>Acropora</i> (A.) <i>secale</i> (Studer, 1878)	X								1
<i>Acropora</i> (A.) <i>selago</i> (Studer, 1878)	X	X	X					X	4
<i>Acropora</i> (A.) <i>studer</i> (Brook, 1893)								X	1
<i>Acropora</i> (A.) <i>tenuis</i> (Dana, 1846)	X						X	X	3

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Acropora (A.) teres</i> (Verrill, 1866)	X							X	2
<i>Acropora (A.) valenciennesi</i> (Edwards & Haime, 1860)	X								1
<i>Acropora (A.) valida</i> (Dana, 1846)	X	X	X	X		X		X	6
<i>Acropora (A.) vaughani</i> Wells, 1954		X							1
<i>Acropora (A.) yongei</i> Veron & Wallace, 1984	X		X						2
<i>Acropora (A.)</i> sp.1	X				X			X	3
<i>Acropora (A.)</i> sp.2	X								1
<i>Acropora (A.)</i> sp.3	X								1
<i>Acropora (I.) brueggemanni</i> (Brook, 1893)	X	X						X	3
<i>Acropora (I.) cuneata</i> (Dana, 1846)	X	X							2
<i>Acropora (I.) palifera</i> (Lamarck, 1816)	X	X					X	X	4

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Astreopora cucullata</i> Lamberts, 1980	X								1
<i>Astreopora explanata</i>		X							1
<i>Astreopora gracilis</i> Bernard, 1896		X						X	2
<i>Astreopora listeri</i> Bernard, 1896	X							X	2
<i>Astreopora myriophthalma</i> (Lamarck, 1816)	X	X				X	X	X	5
<i>Astreopora randalli</i> Lamberts, 1890	X								1
<i>Astreopora</i> sp. 1	X						X		2
<i>Montipora aequituberculata</i> Bernard, 1897	X			X				X	3
<i>Montipora berryi</i> Hoffmeister, 1925	X								1
<i>Montipora bilaminata</i>	X								1
<i>Montipora caliculata</i> (Dana, 1846)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Montipora conicula</i> Wells								X	1
<i>Montipora danae</i> Edwards & Haime, 1851						X		X	2
<i>Montipora dilatata</i> Struder, 1901				X					1
<i>Montipora efflorescens</i> Bernard, 1897	X								1
<i>Montipora ehrenbergii</i> Verrill, 1875	X							X	2
<i>Montipora elschneri</i> Vaughan, 1918	X							X	2
<i>Montipora eydouxi</i>	X								1
<i>Montipora flabellata</i> Struder, 1901				X					1
<i>Montipora floweri</i> Wells, 1954								X	1
<i>Montipora foliosa</i> (Pallas, 1766)	X	X						X	3
<i>Montipora foveolata</i> (Dana, 1846)	X	X				X		X	4
<i>Montipora granulosa</i> Bernard, 1897	X							X	2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Montipora hispida</i> (Dana, 1846)	X	X	X						3
<i>Montipora hoffmeisteri</i> Wells, 1954	X	X				X		X	4
<i>Montipora incrassata</i> Dana, 1846			X	X					2
<i>Montipora informis</i> Bernard, 1897	X					X			2
<i>Montipora lobulata</i> Bernard, 1897	X							X	2
<i>Montipora marshallensis</i>	X								1
<i>Montipora millepora</i> Crossland, 1952								X	1
<i>Montipora monasteriata</i> (Forskal, 1775)		X	X	X	X	X		X	6
<i>Montipora peltiformis</i> Bernard, 1897				X				X	2
<i>Montipora spumosa</i> (Lamarck, 1816)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Montipora tuberculosa</i> (Lamarck, 1816)	X	X	X	X				X	5
<i>Montipora turgescens</i> Bernard, 1897					X				1
<i>Montipora undata</i> Bernard, 1897	X								1
<i>Montipora venosa</i> (Ehrenberg, 1834)	X								1
<i>Montipora verrucosa</i> (Lamarck, 1816)				X		X		X	3
<i>Montipora</i> sp.1 (green spine)	X				X		X	X	4
<i>Montipora</i> sp.2 (ramose tuber.)	X						X	X	3
<i>Montipora</i> sp.3 (Pago)	X						X	X	3
<i>Montipora</i> sp.4 (Ramose pap.)							X	X	2
<i>Montipora</i> sp.5 (thick branch)							X	X	2
Family AGARICIIDAE									
<i>Gardineroseris planulata</i> (Dana, 1846)	X			X				X	3

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Leptoseris hawaiiensis</i> Vaughan, 1907			X	X				X	3
<i>Leptoseris incrustans</i> (Quelch, 1886)	X		X	X				X	4
<i>Leptoseris mycetoseroides</i> Wells, 1954	X	X		X		X		X	5
<i>Leptoseris papyracea</i> (Dana, 1846)				X					1
<i>Leptoseris scabra</i> Vaughan, 1907			X	X					2
<i>Pachyseris levicollis</i>	X								1
<i>Pachyseris speciosa</i> (Dana, 1846)	X							X	2
<i>Pachyseris rugosa</i> (Lamarck, 1801)	X								1
<i>Pavona clavus</i> (Dana, 1846)	X	X	X	X	X		X	X	7

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Pavona decussata</i> (Dana, 1846)	X							X	2
<i>Pavona diffluens</i> (Lamarck, 1816)	X								1
<i>Pavona divaricata</i> (Lamarck, 1816)	X							X	2
<i>Pavona explanulata</i> (Lamarck, 1816)	X	X							2
<i>Pavona frondifera</i> (Lamarck, 1816)	X							X	2
<i>Pavona gigantea</i>	X								1
<i>Pavona maldivensis</i> (Gardiner, 1905)	X	X	X	X			X	X	6
<i>Pavona minuta</i> Wells, 1954	X							X	2
<i>Pavona gardineri</i> van der Horst								X	1
<i>Pavona varians</i> Verrill, 1864	X	X	X	X		X	X	X	7
<i>Pavona (P.) venosa</i> (Ehrenberg, 1834)	X							X	2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Family BALANOPHYLLIDAE									
<i>Balanophyllia</i> sp.cf. <i>affinis</i> (Semper, 1872)				X					1
<i>Balanophyllia hawaiiensis</i> Vaughan, 1907				X					1
Family SIDERASTREIDAE									
<i>Coscinaraea columna</i> (Dana, 1846)	X							X	2
<i>Coscinaraea wellsii</i> Veron & Pichon, 1879				X					1
Family FUNGIIDAE									
<i>Cycloseris hexagonalis</i> Edwards & Haime, 1848				X					1
<i>Cycloseris patelliformis</i> Boschma, 1923	X								1
<i>Cycloseris tenuis</i> Dana, 1846				X					1
<i>Cycloseris vaughani</i> (Boschma, 1923)			X	X					2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Diaseris distorta</i> Michelin, 1842				X					1
<i>Fungia (D.) danai</i> Edwards & Haime, 1851	X	X							2
<i>Fungia (D.) valida</i> Verrill, 1864		X							1
<i>Fungia (C.) echinata</i> (Pallas, 1766)	X								1
<i>Fungia (F.) fungites</i> (Linnaeus, 1758)	X	X						X	3
<i>Fungia (P.) paumotensis</i> Stutchbury, 1833	X	X						X	3
<i>Fungia (P.) scutaria</i> Lamarck, 1801	X	X	X	X	X	X	X	X	8
<i>Fungia (V.) concinna</i> Verrill, 1864	X	X						X	3
<i>Fungia (V.) granulosa</i> Klunzinger, 1879	X			X					1
<i>Fungia (V.) repanda</i> Dana, 1846	X	X							2
<i>Fungia (C.) simplex</i> (Gardiner, 1905)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Halomitra pileus</i> (Linnaeus, 1758)	X	X							2
<i>Herpolitha limax</i> (<i>Houttuyn, 1772</i>)	X	X						X	2
<i>Polyphyllia talpina</i> (Lamarck, 1801)	X								1
<i>Sandalolitha robusta</i> (Quelch, 1886)	X	X							2
Family PORITIDAE									
<i>Alveopora allingi</i> <i>Hoffmeister, 1925</i>	X								1
<i>Alveopora japonica</i>								X	1
<i>Alveopora superficialis</i> Sheer & Pillai, 1976	X								1
<i>Alveopora verrilliana</i> Dana, 1846	X	X						X	3
<i>Alveopora viridis</i> Quoy & Gaimard, 1833	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Goniopora arbuscula</i> Umbgrove								X	1
<i>Goniopora columna</i> Dana, 1846	X							X	2
<i>Goniopora parvistella</i> Ortmann, 1888	X								1
<i>Goniopora somaliensis</i> Vaughan, 1907	X								1
<i>Goniopora</i> sp.1	X						X	X	3
<i>Goniopora</i> sp.2							X	X	2
<i>Porites (P.) annae</i> Crossland, 1952	X							X	2
<i>Porites (P.) australiensis</i> Vaughan, 1918		X						X	2
<i>Porites (P.) cocosensis</i> Wells								X	1
<i>Porites (P.) compressa</i> Vaughan				X				X	2
<i>Porites (P.) cylindrica</i> Dana, 1846	X							X	2
<i>Porites (P.) duerdeni</i> Vaughan				X				X	2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Porites (P.)</i> cf. <i>Evermanni</i> Vaughan, 1907				X					1
<i>Porites (P.) latistella</i>	X								1
<i>Porites (P.) lichen</i> Dana, 1846	X			X				X	3
<i>Porites (P.) lobata</i> Dana, 1846	X	X	X	X	X		X	X	7
<i>Porites (P.) lutea</i> Edwards & Haime, 1860	X	X	X			X	X	X	6
<i>Porites (P.) matthaii</i> Wells	X							X	2
<i>Porites (P.) murrayensis</i> Vaughan, 1918	X			X				X	3
<i>Porites (P.) pukoensis</i> Vaughan, 1907	X			X					2
<i>Porites (P.) queenslandi septima</i>	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Porites (P.) solida</i> (Forskal, 1775)						X			1
<i>Porites (P.) stephensoni</i> Crossland, 1952	X								1
<i>Porites (P.) studeri</i> Vaughan, 1907				X					1
<i>Porites (P.)</i> sp.1(nodular)	X				X			X	3
<i>Porites (S.) horizontalata</i> Hoffmeister, 1925	X							X	2
<i>Porites (S.) rus</i> (Forskal, 1775)	X			X				X	3
<i>Porites (N.) vaughani</i> Crossland, 1952		X							1
<i>Stylaraea punctata</i> (Linnaeus, 1758)								X	1
<i>Synaraea horizontalata</i>	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Family FAVIIDAE									
<i>Caulastrea furcata</i> Dana, 1846	X								1
<i>Cyphastrea chalcidicum</i> (Forsk., 1775)			X	X	X			X	4
<i>Cyphastrea microphthalma</i> (Lamarck, 1816)	X					X			2
<i>Cyphastrea serailia</i> (Forsk., 1775)	X					X		X	3
<i>Diploastrea heliopora</i> (Lamarck, 1816)	X						X	X	3
<i>Echinopora hirsutissima</i> (Edwards & Haime, 1849)	X								1
<i>Echinopora lamellosa</i> (Esper, 1795)	X					X	X	X	4
<i>Favia fava</i> (Forsk., 1775)	X					X		X	3
<i>Favia helianthoides</i> Wells, 1954	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Favia laxa</i> (Klunzinger, 1879)	X								1
<i>Favia matthaii</i> Vaughan, 1918	X							X	2
<i>Favia pallida</i> (Dana, 1846)	X	X				X	X	X	5
<i>Favia rotumana</i> (Gardiner, 1899)	X							X	2
<i>Favia russelli</i> (Wells)								X	1
<i>Favia speciosa</i> (Dana)	X	X					X	X	4
<i>Favia stelligera</i> (Dana, 1846)	X	X				X		X	4
<i>Favia</i> sp.1 (small calice)	X	X					X		3
<i>Favia</i> sp.2							X		1
<i>Favites abdita</i> (Ellis & Solander, 1786)	X	X				X		X	4
<i>Favites chinensis</i> (Verrill, 1866)	X								1
<i>Favites complanata</i> (Ehrenberg, 1834)	X							X	2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Favites favosa</i> (Ellis & Solander)								X	1
<i>Favites flexuosa</i> (Dana, 1846)	X	X				X		X	4
<i>Favites halicora</i> (Ehrenberg, 1834)	X	X				X			3
<i>Favites pentagona</i> (Esper, 1794)		X							1
<i>Favites russelli</i> (Wells, 1954)	X								1
<i>Goniastrea australensis</i> (Edwards & Haime, 1857)	X								1
<i>Goniastrea edwardsi</i> Chevalier, 1971	X							X	2
<i>Goniastrea favulus</i> (Dana, 1846)	X					X			2
<i>Goniastrea palauensis</i> (Yabe, Sugiyama & Eguchi, 1936)	X								1
<i>Goniastrea pectinata</i> (Ehrenberg, 1834)	X	X				X		X	4
<i>Goniastrea retiformis</i> (Lamarck, 1816)	X					X	X	X	4

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Hydnophora exesa</i> (Pallas, 1766)	X	X						X	3
<i>Hydnophora microconos</i> (Lamarck, 1816)	X	X						X	3
<i>Hydnophora rigida</i> (Dana, 1846)	X								1
<i>Leptastrea bottae</i> (Edwards & Haime, 1849)				X				X	2
<i>Leptastrea</i> cf. <i>Immersa</i> Klunzinger, 1879	X								1
<i>Leptastrea purpurea</i> (Dana, 1846)	X	X	X	X	X	X	X	X	8
<i>Leptastrea transversa</i> Klunzinger, 1979	X	X						X	2
<i>Leptoria phrygia</i> (Ellis & Solander, 1786)	X					X	X	X	4
<i>Montastrea annuligera</i> (Edwards & Haime, 1849)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Montastrea curta</i> (Dana, 1846)	X	X				X	X		4
<i>Montastrea valenciennesi</i> (Edwards & Haime, 1848)						X			1
<i>Oulangia bradleyi</i> (Verrill, 1866)			X						1
<i>Oulophyllia crispa</i> (Lamarck, 1816)	X							X	2
<i>Platygyra daedalea</i> (Ellis & Solander, 1786)	X	X				X		X	4
<i>Platygyra lamellina</i> (Ehrenberg, 1834)	X	X					X	X	4
<i>Platygyra pini</i> Chevalier, 1975	X						X	X	3
<i>Platygyra sinensis</i> (Edwards & Haime, 1849)						X		X	2
<i>Plesiastrea versipora</i> (Lamarck, 1816)	X	X						X	3
Family RHIZANGIIDAE									
<i>Culicia rubeola</i> (Quoy & Gaimard)							X		1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Culicia</i> sp.cf. <i>tenella</i> Dana, 1846				X					1
Family OCULINIDAE									
<i>Acrhelia horrescens</i> (Dana, 1846)	X							X	2
<i>Galaxea</i> cf. <i>astreata</i> (Lamarck, 1816)	X							X	2
<i>Galaxea fascicularis</i> (Linnaeus, 1767)	X						X	X	3
Family MERULINIDAE									
<i>Clavarina triangularis</i> Veron & Pichon, 1979	X								1
<i>Merulina ampliata</i> (Ellis & Solander, 1786)	X	X				X		X	4
Family MUSSIDAE									
<i>Acanthastrea echinata</i> (Dana, 1846)	X					X	X	X	4

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Acanthastrea</i> sp.1								X	1
<i>Lobophyllia corymbosa</i> (Forskal, 1775)	X	X						X	3
<i>Lobophyllia hemprichii</i> (Ehrenberg, 1834)	X							X	2
<i>Symphyllia radians</i> (Edwards & Haime, 1849)						X			1
<i>Symphyllia recta</i> (Dana, 1846)	X					X			2
<i>Symphyllia valenciennesii</i> Edwards & Haime, 1849	X								1
Family PECTINIIDAE									
<i>Echinophyllia aspera</i> (Ellis & Solander, 1786)	X							X	2
<i>Mycedium elephantotos</i> (Pallas, 1766)	X								1
<i>Oxypora lacera</i> (Verrill, 1864)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Family CARYOPHYLLIIDAE									
<i>Euphyllia (E.) glabrescens</i> (Chamisso & Eysenhardt, 1821)	X						X	X	3
<i>Plerogyra simplex</i> Rehberg, 1892	X								1
<i>Plerogyra sinuosa</i> (Dana, 1846)							X	X	2
<i>Polycyathus verrilli</i> Duncan								X	1
Family DENDROPHYLLIIDAE									
<i>Tubastrea aurea</i> (Quoy & Gaimard)	X						X		2
<i>Tubastraea coccinea</i> Lesson, 1831	X	X		X	X				4

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Turbinaria frondens</i> (Dana, 1846)	X								1
<i>Turbinaria peltata</i> (Esper, 1794)	X								1
<i>Turbinaria reniformis</i> Bernard, 1896	X								1
Order COENOTHECALIA									1
Family HELIOPORIDAE									
<i>Heliopora coerulea</i> (Pallas, 1766)	X						X	X	3
Order STOLONIFERA									
Family TUBIPORIDAE									
<i>Tubipora musica</i> Linnaeus, 1758								X	1
Order MILLEPORINA									
Family MILLEPORIDAE									

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Millepora dichotoma</i> Forskal, 1775	X						X	X	3
<i>Millepora exaesa</i> Forskal, 1775						X	X	X	3
<i>Millepora platyphyllia</i> Hemprich & Ehrenberg, 1834	X						X	X	3
<i>Millepora tenera</i> Boschma, 1949	X		X						2
<i>Millepora tuberosa</i> Boschma, 1966	X								1
<i>Millepora</i> sp.1	X								1
Family STYLASTERIDAE									
<i>Distochopora gracilis</i> Dana, 1846	X								1
<i>Distochopora violacea</i> (Pallas, 1776)			X					X	2
<i>Distochopora</i> sp.1								X	1
<i>Stylaster gracilis</i> Dana, 1846	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Styaster</i> sp.			X						1
Order ALCYONACEA									
Family ALCYONIIDAE									
<i>Lobophytum</i> sp.1		X							1
<i>Sinularia abrupta</i> Tixier-Durivault, 1970				X					1
<i>Sinularia</i> sp.1		X							1
<i>Corallimorpharia</i> spp.	X								1
<i>Palythoa</i> sp.	X	X	X	X					4
<i>Tethya</i> sp.	X								1
<i>Zoanthus</i> sp.	X			X					2
<i>Number of: Scleractinians</i>	222	82	29	51	13	39	53	159	

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
<i>Acyonarians</i>	4	1		1					
<i>Hydrozoans</i>	7	1	3			1	3	5	
<i>Coelothecalia</i>	1							1	

DRAFT

Bibliography**American Samoa:**

Birkeland, C., Randall, R. and S. Amesbury 1994 Coral and reef-fish assessment of the Fagatele Bay National Marine Sanctuary. Report to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 126 pp.

Lamberts, A. 1980. Checklist of Samoan Coral Genera and Species. In: American Samoa Coral Reef Inventory, U.S. Army Corps of Engineers for Development Plan Office, American Samoan Govt..

Palmyra Atoll:

Maragos, J.E. 1979a. Palmyra Atoll: Preliminary environmental survey and assessment. U.S. Army Corp of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii. 31pp+62pls.

Maragos, J.E. 1988. Notes on the abundance and distribution of reef coral and reef features at Palmyra Atoll, Line Islands. US Army Corps of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii, 18pp+13pls.

Johnston Atoll:

Maragos, J.E. and P. Jokiel 1986 Reef corals of Johnston Atoll: one of the worlds most isolated reefs. *Coral Reefs* 4: 141-150.

Hawaii:

Maragos, J.E. 1977 Order Scleractinia: stony corals. In: Devaney, D. and L. Eldredge (eds.) Reef and shore fauna of Hawaii. Section 1: Protozoa through Ctenophora. Bishop Museum Press, Honolulu, Hawaii. 278 pp.

Maragos, J.E. 1995 Revised checklist of extant Shallow-water stony coral species from Hawaii (Cnidaria: Anthozoa: Scleractinia). *Bishop Museum Occasional Papers* 42: 54-55.

Northern Hawaiian Islands:

DeFelice R.C., Coles, S.L., Muir D., Eldredge L.G. 1998. Investigations of the marine communities of Midway Harbour and adjacent lagoon, Northwestern Hawaiian Islands. Report to U.S. Fish and Wildlife Service, Pacific Islands Area Office, Honolulu, Hawaii.

Wake Atoll:

Anon. (1999). *Baseline Marine Biological Survey, Peacock Point Outfall and other Point-Source Discharges, Wake Atoll, Pacific Ocean*. Report to the Department of Army by the Department of Interior, Fisheries and Wildlife Service (NMFS). Honolulu, Hawaii. 23 p.

Commonwealth of Northern Mariana Islands:

Randall, R.H. 1995 Biogeography of reef-building corals in the Mariana and Palau Islands in relation to back-arc rifting and the formation of the Eastern Philippine Sea. *Nat. Hist. Res.* 3(2): 193-210.

Guam:

Jones, R.S. and R.H. Randall 1973b. A study of Biological Impact Caused by Natural and Man-induced Changes on a Tropical Reef. University of Guam, Marine Laboratory Technical Report No. 7.

Taxonomy conforms to:

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 15116 4.

Veron J. E. N. & Pichon, M. 1976: Scleractinia of eastern Australia, Part 1: Families Thamnasteriidae, Astrocoenidae, Pocilloporidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 1, 86pp.

Veron J. E. N., Pichon M. & Wijsman-Best M. 1977: Scleractinia of eastern Australia, Part 2: Families Faviidae, Trachyphyllidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 3, 232pp.

Veron J. E. N. & Pichon M. 1979: Scleractinia of eastern Australia, Part 3 Families Agariciidae, Siderastreaeidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectinidae, Caryophyllidae, Dendrophylliidae. *Aust. Inst. Mar. Sci., Monogr. Ser.* 4, 422pp.

Veron J. E. N. & Pichon M. 1982: Scleractinia of eastern Australia, Part 4: Family Poritidae, *Aust. Ins. Mar. Sci., Monogr. Ser.* 5, 159pp.

Veron J. E. N. & Wallace C. C. 1984: Scleractinia of eastern Australia, Part 5: Families Acroporidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 6, 485pp.

Comment: *Oulangia bradleyi* (Verrill, 1866): *Johnston Atoll*. This record does not conform to the current taxonomy though is included subject to further clarification.

Table 88. Zooxanthellate corals likely to be found in the American Flag Pacific Islands. (Adapted from Veron 1995.)

Family and genus	Extant species {no.}	Present distribution	General abundance
Astrocoeniidae	At least 3	Red Sea to central Pacific	Uncommon, cryptic
Stylocoeniella			
Pocilloporidae	Approx. 10	Red Sea and western Indian Ocean to far eastern Pacific	Very common, very conspicuous
Pocillopora			
Stylophora	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Seriatopora	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Acroporidae	At least 80	Red Sea and western Indian	Extremely common
Acropora	At least 150	Cosmopolitan in Indo-Pacific reefs	Extremely common, very conspicuous, usually dominant
Astreopora	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Poritidae	Approx. 80	Cosmopolitan	Extremely common, conspicuous at generic level
Porites			
Stylaraea	1	Red Sea and western Indian Ocean to western Pacific	Rare, occurs only in shallow, wave-washed biotopes
Goniopora	Approx. 30	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous

Family and genus	Extant species {no.}	Present distribution	General abundance
Alveopora	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Sometimes common, very conspicuous
Siderastreidae Psammocora	Approx. 15	Red Sea and western Indian Ocean to far eastern Pacific	Generally common, sometimes cryptic
Coscinaraea	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Agariciidae Pavona	Approx. 22	Red Sea and western Indian Ocean to far eastern Pacific	Very common, conspicuous
Leptoseris	Approx. 14	Red Sea and western Indian Ocean to far eastern Pacific and Caribbean and Gulf of Mexico	Sometimes common, mostly conspicuous
Gardineroseris	At least 2	Red Sea and western Indian Ocean to southern Pacific	Generally uncommon, non-reefal
Pachyseris	Approx. 4	Red Sea and western Indian Ocean to far eastern Pacific	Very common, very conspicuous
Fungiidae Cycloseris	Approx. 16	Red Sea and western Indian Ocean to far eastern Pacific	Generally uncommon, non-reefal
Diaseris	At least 3	Red Sea and western Indian Ocean to far eastern Pacific	Generally uncommon, non-reefal
Fungia	Approx. 33	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Herpolitha	2	Red Sea and western Indian Ocean to western Pacific	Generally common, very conspicuous
Sandalolitha	2	Central Indian Ocean to southern Pacific	Sometimes common, very conspicuous

Family and genus	Extant species {no.}	Present distribution	General abundance
Halomitra	2	Western Indian Ocean to southern Pacific	Generally uncommon, very conspicuous
Oculinidae	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Galaxea			
Acrhelia	1	Eastern Indian Ocean to southern Pacific	Generally uncommon, conspicuous
Pectiniidae	Approx. 8	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Echinophyllia			
Oxypora	At least 3	Western Indian Ocean to southern Pacific	Generally common, conspicuous
Mycedium	At least 2	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Mussidae	Approx. 6	Red Sea and western Indian Ocean to southern Pacific	Generally uncommon, Favites-like
Acanthastrea			
Lobophyllia	Approx. 9	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Symphyllia	Approx. 6	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Merulinidae	Approx. 7	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Hydnophora			
Merulina	3	Red Sea and western Indian Ocean to southern Pacific	Sometimes common, conspicuous

Family and genus	Extant species {no.}	Present distribution	General abundance
Scaphophyllia	1	Eastern Indian Ocean to	Generally
Favidae	Approx. 4	Red Sea and western Indian	Generally common
Favia	At least thirty	Cosmopolitan	Extremely common, conspicuous
Favites	Approx. 15	Red Sea and western Indian	Very common
Goniastrea	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Very common, generally conspicuous
Platygyra	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Extremely common, conspicuous but may be confused with Goniastrea
Lecteria	2	Red Sea and western Indian	Sometimes common
Oulophyllia	Approx. 3	Red Sea and western Indian Ocean to western Pacific	Sometimes common, conspicuous
Montastrea	Approx. 13	Cosmopolitan	Generally common, conspicuous
Plesiastrea	At least 2	Red Sea and western Indian Ocean to far eastern Pacific	Sometimes common
Diploastrea	1	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Leptastrea	Approx. 8	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Cyphastrea	Approx. 9	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous

Family and genus	Extant species {no.}	Present distribution	General abundance
Echinopora	Approx. 7	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Caryophylliidae Euphyllia	9	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Plerogyra	3	Red Sea and western Indian Ocean to southern Pacific	Generally uncommon, very conspicuous
Dendrophylliidae Turbinaria	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Duncanopsammia	1	Central Indo-Pacific	Uncommon, very conspicuous

5.3.7 Ahermatypic Corals (Azooxanthellate)

Important Summary Documents

Veron (1986) describes the three genera with photos of living and skeletal examples. Table 98 summarizes the ahermatypic corals from Hawaii.

Taxonomic Issues

Order Scleractinia; Family Dendrophylliidae; Genera *Dendrophyllia* (de Blainville, 1830), *Tubastraea* (Lesson, 1829), *Balanophyllia* spp. (Wood, 1844). *Duncanopsammia axifuga* is of the same family and has a skeletal structure and growth form intermediate between hermatypic and ahermatypic forms. As it is zooxanthellate, it is not described here. Other zooxanthellate corals such as *Heteropsammia* and *Psammoseris* (both Dendrophyllidae), and *Heterocyathus* (Caryophyllidae) are they small, single polyp forms and appear as partial ahermatypes (Veron, 1986). Their contribution to reef growth is minor and they occur on sand and rubble substrates. *Heteropsammia* spp. doesn't occur in the AFPI.

Other genera occur in deep water or deep inter-reef areas and are listed with their recorded depth range (after Veron, 1986): *Letepsammia* (165-457m); *Fungiacyathus* (190-600m); *Madrepora* (55-450m); *Cyathelia* (40m); *Culicia* and *Astrangia* (inter-tidal to 128m, largely temperate); *Flabellum* (10-824m); *Placotrochus* (to 188m); *Monomyces* (3-40m); *Gardineria* (55m); *Anthemiphyllia* (to 210m); *Caryophyllia* (119-1006m); *Tethocyathus*; *Premocyathus* (20-230m); *Cythoceras* (86-766m); *Trochocyathus* (86-531m); *Deltocyathus* (16-531m); *Bouretrochus* (210-531m); *Sphenotrochus*; *Polycyathus* (>40m); *Aulocyathus* (163-190m); *Conotrochus* (210-365); *Stephanocyathus* (366-1006m); *Oryzotrochus* (9-15m); *Conocyathus* (8-22m); *Trematrochus* (>27m); *Dunocyathus* (100-531m); *Paracyathus* (>20m); *Patyrochus* (28-183m); *Cylindrophyllia*; *Peponocyathus* (339-365); *Holcotrochus* (11-183m); *Desmophyllum*; *Solenosmilia* (860m); *Stenocyathus* (455-531m); *Septosammia* (8-86m); *Endopachys*; *Notophyllia* (36-457m); *Thecopsammia* (270m).

Habitat Utilization

Not dependent on light so able to colonizes overhangs and caves. Competes best in areas of low scleractinian coral or algal occurrence. *T. micrantha* competes best due to its erect arborescent nature and may be dominant below 15m in areas of exposed currents.

Life History

Adult: Appearance and Physical Characteristics

Dendrophyllidae :

Solitary and colonial corals with more than two rings of tentacles on the polyps. Numerous skeletal element of the ridges form an almost continuous sheet and rods connect adjacent ridges. *Dendrophyllia* and *Tubastrea* spp. may appear similar superficially but are separated by differences in septal plans.

Dendrophyllia spp.: Often brightly colored (yellow or orange) resulting from the corals own pigment, as no zooxanthellae are present. Colonies are dendroid and proliferate through extra-tentacular budding. Generally nocturnal but also diurnal extension.

Tubastraea spp.: Tubular corallites forming hemispherical colonies. *Tubastrea aurea* forms domed clumps up to 10cm dia. Polyps protrude for a common encrusting base. Usually found in low-light conditions in caves and beneath rocky overhangs. Common species *T. faulkneri*, *T. coccinea*, *T. diphana* and *T. micrantha*.

Tubastrea micrantha forms tree-like branching colonies to 1m in height. Colour dark brown and green. Occurs in deeper reef environments.

Balanophyllia spp.: Solitary corals which bud to form closely packed clumps. Clumps may be 50cm diam. Thick walls. Polyps are oval and tapering towards the base, and the septa are fuse. Color black, bright-orange or yellow polyps.

Feeding and Food

Heterotrophic with dependence on the capture of zooplankton. Nocturnal and diurnal feeding.

Reproductive Strategies

Dioecious. Fertilization is internal and larvae are brooded. Asexual larval reported (Richmond and Hunter, 1990). The larvae are 1mm long and crawl or swim after release before settling. They may also be free-spawners (Harrison and Wallace, 1990). Planula takes four to seven days before they settle and form a primary polyp.

Bibliography

- Harrison, P. L. & C. C. Wallace (1990): Reproduction, dispersal and Recruitment of Scleractinian Corals. In: Dubinsky, Z. (ed.) Ecosystems of the World, vol. 25 Coral Reefs. Elsevier, N.Y. pp 133-208.
- Richmond, R. H. & C. L. Hunter (1990): Review B Reproduction and recruitment of corals: comparison among the Caribbean, the Tropical Pacific, and the Red Sea. Mar. Ecol. Prog. Ser. 1: 145-152.
- Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 15116 4.

Table 89. Deep-water Ahermatypes from Hawaii. (From Maragos 1977; data Vaughan (1907)).

Species	Shallowest Collection Record
<i>Anisopsammia amphelioides</i> (Alcock)	40 fm
<i>Anthemiphyllia pacifica</i> Vaughan	92 fm
<i>Balanophyllia desmophyllioides</i> Vaughan	78 fm
<i>Balanophyllia diomeseae</i> Vaughan	148 fm
<i>Balanophyllia hawaiiensis</i> Vaughan	190 fm
<i>Balanophyllia laysanensis</i> Vaughan	130 fm
<i>Bathyactis hawaiiensis</i> Vaughan	963 fm
<i>Caryophyllia alcocki</i> Vaughan	876 fm
<i>Caryophyllia hawaiiensis</i> Vaughan	92 fm
<i>Caryophyllia octopali</i> Vaughan	28 fm
<i>Ceratotrochus latus</i> Vaughan	319 fm
<i>Cyathoceras diomedeeae</i> Vaughan	169 fm
<i>Deltosyathus andamanicus</i> Alcock	147 fm
<i>Dendrophyllia oahensis</i> Vaughan	154 fm
<i>Dendrophyllia serpentina</i> Vaughan	147 fm
<i>Desmophyllum cristagalli</i> Milne- Edwards & Haine	
<i>Endopachys oahense</i> Vaughan	53 fm
<i>Flabellum deludens</i> v. Marenzeller	670 fm

Species	Shallowest Collection Record
<i>Flabellum parvoinum</i> Lesson	127 fm
<i>Gardineria hawaiiensis</i> Vaughan	272 fm
<i>Madracis kauaiensis</i> Vaughan	24 fm
<i>Madrepora kauaiensis</i> Vaughan	294 fm
<i>Paracyathus gardineri</i> Vaughan	
<i>Paracyathus mauiensis</i> Vaughan	95 fm
<i>Paracyathus molokensisx</i> Vaughan	88 fm
<i>Paracyathus tenuicalyx</i> Vaughan	252 fm
<i>Placotrochus fuscus</i> Vaughan	148 fm
<i>Stephanophyllia formosissima</i> Moseley	66 fm
<i>Trochocyathus oahensis</i> Vaughan	252 fm

5.3.8 Actiniaria (anemones)

Important Summary Documents

Symbiosis between anemones and fish was first noted by Collingwood (1868). Fishelson (1970, 1971) speculated on the ecological role of this association. The taxonomy of symbiotic anemones was revised by Dunn (1981). The taxonomy of the Hawaiian anemones was described in Eldredge and Devaney (1977). Chia (1976) has described reproduction in terms of patterns and adaptive radiation. Fautin and Allen (1992) describe the biology of anemonefish and their host anemones. Table 99 summarizes the Actinaria from Hawaii.

Taxonomic Issues

Ecotypes are common (e.g. *Entacmaea quadricolor*) which has given rise to taxonomic confusion. Allen (1975) described the deeper water as *Radianthus gelam* and the smaller individuals as *Physobranchia douglasi*. Their ability to adopt a varied coloration both in terms of background color and geographic variation has made taxonomy difficult.

Habitat Utilization

Anemones attach to hard substrate by their basal disc, burrow into soft substrate or attach as symbionts to sessile and mobile reef creatures.

Life History

Adult: Appearance and Physical Characteristic

Anemones have a body column and oral disc with tentacles with nematocysts and a central mouth. They are attached by a basal or pedal disc to the substrate (Barnes, 1980). They are often associated with symbiotic relationships such as with fish or shrimps (Fautin and Allen, 1992). *Heteractis magnifica* reaches a diameter of 30-50cm though may reach 1m.

Ten species are recognized as symbiotic anemones (Actiidae; Thalassianthidae; Stichodactylidae).

Both *Actinodendron plumosum* and *Phyllodiscus semoni* have severe stings if touched.

Some species of anemones can exhibit mimicry appearing like their background or other reef entities like hard coral or algae.

Age, Growth, Longevity

The growth of tropical anemones is variable being largely dependent on nutrition. Longevity among tropical anemones is poorly known. Anemones approaching a meter in diameter may exceed 100 years old (Fautin and Allen, 1992). *Actinia tenebrosa* requires 8 to 66 years to reach a column diameter of 40mm and has an average longevity of 50 years (Ottaway, 1980).

Reproductive Strategies

Asexual: Common: Pedal laceration and longitudinal or transverse fission

Asexual reproduction has been observed as budding (Vine, 1986). Devaney & Eldredge (1977) describe *Bolocerooides mcmurricchi* as reproducing sexually in spring and asexually in fall when the asexually young arise as buds on the outer tentacles and are shed when they have developed 10 to 30 tentacles.

Eggs and sperm are produced and host anemones appear to be characterised by separate sexes.

Absence of small individuals is indicative of low fertilization, larval survival or larval settlement or young have high mortality (Fautin and Allen, 1992).

Most are hermaphroditic but reproduce only one type of gamete per reproductive period. Groups of clones evident.

Distribution

Anemones are often widely distributed. The common anemone *Entacmaea quadricolor* is found from Samoa to East Africa and the Red Sea and from the surface down to 40 metres. Of nearly 1000 species, only 10 species are host to anemone fishes. In Hawaii, There is only one host species recorded from Hawaii though without commensal fish (Fautin and Allen, 1992).

Feeding and Food

Anemones are polyphagous opportunists (Ayre 1984). Prey is caught by the tentacles, paralyzed by nematocysts and carried to the mouth. The food consists of plankton borne crustacea but fish worms, and algal fragments are included. Sand dwelling anemones such as *Heteractis malu* ingest gastropods (Shick, 1990) as does *Catalophyllia sp.* Some anemones are suspension feeders (Barnes, 1980).

Specialized corallimorpharians such as *Rhodactis*, *Actinodiscus*, *Discosoma*, *Amplexidiscus* can capture large prey by enveloping them with the entire disk (Hamna and Dunn, 1980; Elliott and Cook, 1989).

Anemones which contain symbiotic zooxanthellae but also capture plankton and other detrital or water borne food. Those without zooxanthella are dependent on plankton and may capture other food such as crustaceans or smaller fish.

Absorption of dissolved organic material (DOM) by anemones occurs Schlichter (1980) and Schlichter et al. (1987). DOM is important in times of no solid food. (Shick, 1975)

Extracellular digestion is achieved by mesenterial filaments (Nicol, 1959)

Some species of anemones extend their tentacles at night and diminutive during the day (*Alicia sp.*). Others feed during daylight hours.

Behavior

The family Boloceriodidae contains anemones capable of swimming by beating their tentacles. The Hawaiian species *Bolocerooides mcmurricchi* has a large crown of tentacles compared to a relatively small body. They become capable of swimming at the 10 to 30 tentacle stage (Devaney and Eldredge, 1977).

Edwardsia spp. are found on sandy bottoms and dig themselves into the substrate.

Anemones are basically sedentary but are able to move over the substrate slowly, some can swim for short distances.

There commensal behavior with fish where it gains protection and food and in turn protects the anemone from some predators and removes sediment and other material by its swimming motion (Barnes, 1987).

Spawning: Spatial and Temporal Distribution

Spawning is synchronised with the full moon or low tide (Fautin and Allen, 1992).

Eggs are fertilized in the gastrovascular cavity or occur outside in the seawater (Fautin and Allen, 1992).

Free swimming planula

Larval Feeding and Food

Ingest copepods, chaetognaths, or larvae of other cnidarians. Unicellular algae and dinoflagellates has been observed (Widersten, 1968; Siebert, 1974)

The planula may be planktotrophic or lecithotrophic and has a variable larval life span. The young sea anemone lives as a ciliate ball, unattached and free swimming. The larvae settles, attaches and forms tentacles.

Habitat Utilization

Asexual of reproduction give rise to many individuals in close proximity, often forming a continuous surface by adjacent oral discs. Like other sessile benthos, settlement of larval stages colonizes available substrate.

Bibliography

Allen, G. R. (1975): *The Anemonefishes: their Classification and Biology*. 2nd edition TFH Publ. Inc. USA.

Ayre , D. J. (1984) The sea anemone *Actinia tenebrosa*: an opportunistic insectivore. *Ophelia*, 23, 149-153.

Barnes, R. D. (1980): *Invertebrate zoology*. Saunders Colledge, Philadelphia.

- Chia, F. S., 1976: Sea anemone reproduction: patterns and adaptive radiation. In Mackie, G. O. (Ed.): Coelenterate Ecology and Behaviour. Plenum Press, N. Y. pp. 261-270.
- Collingwood, C. (1868): Note on the existence of gigantic sea- anemones in the China Sea, containing within them quasiparasitic fish. Ann. Mag. Nat. His. Ser. 4, **1** (1): 31-33.
- Cutress, C. E. (1977): Order Corallimorpharia. In: Devany & Eldredge (eds.): Reef and Shore Fauna of Hawaii, section 1: Protozoa through Ctenophora. B. P Bishop Museum Special Publication 64 (1): I-XII, p.130.
- Devaney D. M. & L. G. Eldredge (eds.) 1977. Reef and Shore Fauna of Hawaii. Bernice P. Bishop Museum Special Publication **64** (1)
- Dunn, D. F. (1981): The Clownfish Sea Anemones: Stichodactylidae (Coelenterata: Actinaria) and Other Sea Anemones Symbiotic with Pomacentrid Fishes. Trans. Amer. Phil. Soc. **71** (1): 1-113.
- Elliot, J. and Cook, C. B. (1989) Diel variation in Prey Capture Behavior by the Corallimorpharian *Discosoma Sanctithomae*. Mechanical and Chemical Activation of Feeding. *Biol. Bull.*, 176, 218-228
- Fautin, D. G. & G. R. Allen (1992): Field Guide to Anemonefishes and their Host Sea Anemones. West Australian Museum, Perth.
- Fishelson, L. (1970): Littoral fauna of the Red Sea: the population of non scleractinian anthozoans of shallow waters of the Red Sea (Eilat). *Mar. Biol.* **6** (2): 106-116.
- Fishelson, L. (1971): Ecology and distribution of the benthic fauna in the shallow waters of the Red Sea. *Mar. Biol.* **10** (2): 113-133
- Grigg R.W. and Opresko D. (1977): Order Antipatharia In: Devany & Eldredge (eds.): Reef and Shore Fauna of Hawaii, section 1: Protozoa through Ctenophora. B. P Bishop Museum Special Publication 64 (1): I-XII, p.130.
- Hamner, W. M. & D. F. Dunn (1980): Tropical Corallimorpharia (Coelenterata:Anthozoa): Feeding by Envelopment. *Micronesia* **16** (1): 37-41.
- Nicol, J. A. C. (1959) Digestion in sea anemones. *J. Mar. Bio. Ass. UK*, 38, 469-476.
- Ottaway, J.R., 1980: Population ecology of the intertidal anemone, *Actinia tenebrosa*: 4. Growth rates and longevities. *Aust. J. Mar. Freshw. Res.*, 31(3): 385-396.
- Schlichter, D. (1980) Adaptations of cnidarians for itegumentary absorption of dissolved organic matter. *Rev. Can. Biol.*, 39, 259-282.

- Schlichter, D., Bajorat, K. H., Buck, M., Eckes, P., Gutknecht, D., Kraus, P., Krish, H., Schmitz, B. (1987) Epidermal nutrition of sea anemones by absorption of organic compounds dissolved in the oceans. *Zool. Beitr. N.F.*, 30, 29-47.
- Shick, J. M. (1975) Uptake and utilization of dissolved glycine by *Aurellia aurita* scyphistomae: Temperature effects on the uptake process: nutritional role of amino acids. *Biol. Bull.* 148, 117-140.
- Shick, J. M. (1990) Diffusion limitation hyperoxic enhancement of oxygen consumption in zooxanthellate sea anemones, zoanthids and corals. *Biol. Bull.* 179, 148-158.
- Siebert, A. E., Jr. (1974) A description of the embryology, larval development and feeding of the sea anemones *Anthopleura elegantissima* and *A. xanthogrammica*. *Can J. Zool.*, 52, 1383-1388.
- Vine, P. (1986): Red Sea Invertebrates. Immel Publ., London, UK.
- Walsh G. E. and Bowers R.L. (1977): Order Zonitiformia. In: Devany & Eldredge (eds.): Reef and Shore Fauna of Hawaii, section 1: Protozoa through Ctenophora. B. P Bishop Museum Special Publication 64 (1): I-XII, p.130.
- Widersten, B. (1968) On the morphology and development in some cnidarian larvae. *Zool. Bidr. Uppsala*, 37, 139-179 + 3 plates

Table 90. Actinaria from Hawaii (Cutress, 1977).

Order ACTINIARIA

Family BOLOCEROIDIDAE

Bolocerooides memurrici (Kwietniewski 1898)*Bunodeopsis medusoides* (Fowler 1888)

Family ALICIIDAE

Triactis producta Klunzinger 1877

Family ACTINIIDAE

Anemonia mutabilis Verrill 1928*Anthopleura nidrescens* (Verrill 1928)*Anthopleura* sp. A*Anthopleura* sp. B*Actiniogeton sesere* (Haddon & Shackleton 1893)*Cladactella manni* (Verrill 1899)

Family STOICHACTINIDAE

Antheopsis papillosa (Kwietniewski 1898)*Stoichactis* sp.

Family PHYMANTHIDAE

Heteranthus verruculatus Klunzinger 1877

Family ISOPHELLIDAE

Telmatactis decora (Hemprich and Ehrenberg 1834)*Epiphellia pusilla* (Verrill 1928)*Epiphellia humilis* (Verrill 1928)

Family HORMATHIIDAE

Calliactis polypus (Forskal 1775)

Family SAGARTIIDAE

Anthothoe sp.

Family AIPTASIIDAE

Aiptasia pulchella Carlgren 1943

Family DIADUMENIDAE

Diadumene leucolena (Verrill 1866)

Family EDWARDSIDAE

Edwardsia sp. A.

Edwardsia sp. B.

5.3.9 Zoanthidae (colonial anemones)Important Summary Documents

Hyman (1940) details systematics and anatomy. Mather and Bennett (1993) discuss the order Zoanthidae. Burnett et al. (1997) a good summary of systematics for some central Indo-Pacific species. Walsh (1967) produced an annotated bibliography for the family. Table 100 summarizes Zoanthinaria from Hawaii.

Taxonomic Issues

Class Anthozoa; subclass Zoantharia (=Hexacorallia); order Zoanthinaria (=Zoanthidea); suborder Brachnemina; family Zoanthidae; genera *Acrozoanthus*; *Zoanthus*; *Isaurus*; *Protopalycha*; *Palythoa*; *Sphenopus*. suborder Macrocnemina; family Epizoanthidae; genera *Epizoanthus*; family Epizoanthidae, *Thoracactis*; genus *Parazoanthus*, *Gerardia*, *Isozoanthus* (Barnes, 1987; Muirhead and Ryland, 1985).

Poorly known due to reliance on preserved specimens and a high degree of inter-population variability. Nominal species 300.

Differentiated from the Actinaria by the presence of a fifth cycle of mesenteries.

Zoanthinarian systematics is discussed by Herberts (1972a; 1987) and Mather and Bennett (1993).

Habitat Utilization

Often distinct zonation: back reef flats, lagoon floors, reef crests and shallow sublittoral zone.

Palythoa spp.: Growth in large numbers on reef flats immediately behind the reef crest, also found on lagoon floors and the spur and groove channels of reef slopes. Tide pools in Hawaii.

Parazoanthus ssp., *Epizoanthus ssp.*, *Acrozoanthus spp.*: May colonize worm tubes, hydroids, sponges and gorgonian skeletons. May be epizootic on sponges, or ascideans as ATuff Balls or providing as protection (Colin and Arneson, 1995).

Protopalythoa spp.: Shallow fore reefs, reef crests or outer reef flat areas. Shallow reef zones may be dominated by this genus and cover may be >90%. May occur as small assemblages of polyps or separate individuals.

Zoanthus spp.: They are found in back reef areas and the shallow sub-littoral zone.

Life History

Adult: Appearance and Physical Characteristics

Zoanthid anemones are solitary or colonial, zooxanthellate (except *Sphenopus*). Principal tropical genera are *Palythoa*, *Protopalythoa* and *Zoanthus*. Generally, discs are 1-2cm in diameter with tentacles 3-5mm long but may extend to 2-3cm. Coloration varies from red, orange, yellow, turquoise, green or brown. The stem (scapus), disc (capitulum), tentacles or coenenchyme vary in coloration. Zooanthids differ from other Zoantharia in that they don't produce skeleton but incorporate sediment into the body wall. As well, they don't have a pedal disc and a differing septal arrangement (this forms the basis for the two suborders).

Isaurus spp.: Loosely connected colonies without connecting stolons. Height varies 15- 160cm. Colonies with < 50 individuals. Taxonomically best known (Muirhead and Ryland, 1985). Often inconspicuous. Nocturnal tentacular extension.

Palythoa spp.: Growth in massive colonies. Sand particles are encrusted into the coenenchyme. Colonies are convex and 30cm. Coenenchyme is light brown to yellow.

Often buried in the sand to the level of the disc.

Protopalythoa spp.: Generally in loosely connected colonies. Often the polyps lack contact or have contact at the base through a stolon. Polyp height is 15-25 mm high and 7-11mm in diameter. Expanded discs may attain a diameter of 2-3cm. May occur as large areas of colonization, small assemblages or individual polyps. Polyps are encrusted with sand particles. For some, full retraction is not possible due to the size of the disc. Colour is uniform on the stem and disc; brown or green. It may be variable due to the intensity of light.

Zoanthus spp.: Sediments are not incorporated in their tissues but are tolerant of sediment environments. Most species are brightly coloured, often contrasting disc, tentacles and stem.

Growth

Growth morphology may depend on the environment. *Z. pacificus* has a lamellar coenenchyme with crowded polyps and separate bases. In surge pools, the bases are joined and crowding less.

In wave washed area the coenenchyme can be lamellar or stoloniferous with single polyps or groups of two or three (Walsh and Bowers, 1971).

In *Palythoa*, growth is by the spreading of the thickened coenenchyme. Yamazato et al. (1973), found 0.18 new polyps per day increase in *Palythoa tubercles*. Density of colonies may be 671 polyps/0.1m² (*Zoanthus sociatus*) and 302 polyps/ 0.1m² for *Z. solanderi*. (Karlson, 1981). 12,000/m² of *Palythoa vestitus* where found in Kaneohe Bay.

Distribution

Isaurus spp.: Widespread in all tropical seas; present in Hawaii.

Palythoa spp.: Pan-tropical; present in Hawaii.

Protopalythoa spp.: Pan tropical; occurs in Hawaii, American Samoa and Tahiti.

Zoanthus spp.: Pan-tropical; occurs in Hawaii, American Samoa and Tahiti.

Feeding and Food

Heterotrophic (zooplankton); autotrophic (zooxanthellae) (Reimer 1971b).

Muscatine et al. (1983) determined zooxanthellae could provide 48% of the carbon requirement for *Zoanthus sociatus*.

Palythoa, *Protopalythoa* and *Zoanthus* are diurnal in expansion. Others are nocturnal *Isaurus* and *Sphenopus*. Able to ingest a variety of live and dead crustacea and fish portions (Reimer, 1971a). Crustacean and detrital fragments were found in *Zoanthus Sociatus*, though few contained food items with only a greater frequency at night (Sebens, 1977). Azooxanthellate genera (*Epizoanthus* and *Parazoanthus*) rely greatly on feeding to obtain sufficient nutrition.

The uptake of dissolved organic matter may contribute to nutrition (Reimer, 1971; Trench, 1974). The common presence of *Zoanthus spp* and *Protopalythoa* in shore may be due to the higher organic levels. With the reduction in sewage contamination in Kaneohe Bay, zoanthid population declined.

Isaurus spp.: Autotrophic nutrition from the zooxanthellae but also feeds on plankton nocturnally. Polyps never open in the day.

Palythoa spp.: Generally autotrophic but tentacles and diurnal expansion indicate reliance on zooplankton.

Protopalythoa spp.: Heterotrophic; autotrophic

Zoanthus spp.: Heterotrophic; autotrophic

Reproductive Strategies

Asexual by the arising of new polyps from a spreading sheet of coenenchyma or stolons or budding from the parent polyp. Extensive monoclonal colonies occur.

Fragmentation is common.

Sexual reproduction: Both dioecious (gonochoristic) and sequential and simultaneous hermaphrodites.

Isaurus spp.: Unknown.

Palythoa spp.: Readily reproduces asexually. Yamazoto et al. (1973) studied the reproductive cycle of *Palythoa tuberculosa* in Okinawa. The oocytes grow from March/April, to a peak in the middle of the year, which followed by a second peak in October indicative of two spawnings per year. Mature eggs are rather large with a length of 300-500um.

Protopalythoa spp.: Asexual and sexual. Babcock and Ryland (1990) and Ryland and Babcock (1991) describe reproduction and larval development.

Zoanthus spp.: Asexual and sexual. Cooke (1976) describes reproduction for *Zoanthus pacificus* and for *Z. solanderi* and *Z. sociatus* by Fadlallah et al. (1989).

Spawning: Spatial and Temporal Distribution

Ovaries develop initially in the cycle along the margin of the mesenteries with the testis later in the cycle. Seasonal free spawning. Report of spawning synchronous with the mass spawning of the stony coral, on the 4th to 6th nights after full moon in November (Ryland and Babcock, 1991). In Hawaii, *P. versitis* was only active May to September while *Z. pacificus* was bound to be sexually active all year but greatest during the summer (Cooke, 1976).

Eggs and Larvae

Egg diameter range from 75um to 280 um. Sperm are bell shaped and 50 um long. Egg counts range from 800 to 2400 (Ryland and Babcock, 1991). Larvae settle in areas of coralline algae and crawl to find a site. Suitable sites are often shaded. Fecundity is high and settlement rates are low. Sexual reproduction is therefore thought to allow for dispersal and colonization over large distances (Karlson, 1981).

The larvae are oval in shape and have a girdle of cilia near the oral end. The Larvae of *Protopalythoa spp.* are referred to as zoanthea and are elongate with a ventral band of long cilia (Hyman, 1940).

Bibliography

Babcock, R. C. & J. S. Ryland (1990). Larval development of a tropical zoanthid (*Protopalythoa sp.*) Invert. Reprod. Develop. **17**: 229-236.

- Barnes, R. D. (1987). Invertebrate zoology. Saunders College, Philadelphia.
- Burnett, W. J., J. A. H. Benzie, J. A. Beardmore & J. S. Ryland (1997): Zoanthids (Anthozoa, Hexacorallia) from the Great Barrier Reef and Torres Street, Australia: systematics, evolution and a key to species. *Coral Reefs* **16**: 55-68.
- Colin, P. L., and C. Arneson. 1995. Tropical Pacific Invertebrates. San Diego: Coral Reef Press.
- Cooke, W.J. (1976). Reproduction, growth and some tolerances of *Zoanthus pacificus* and *Palythoa vestitus* in Kaneohe Bay, Hawaii. In G. O. Mackie (Red.): Coelenterate ecology and behavior. Plenum Press. N.Y., USA: 281-288.
- Fadlallah, Y. H., Karlson R. H., and Sebens K.P. (1984). A comparative study of sexual reproduction in three species of Panamanian zoanthids (Coelenterata: Anthozoa). *Bull. Mar. Sci.* (35): 80-89.
- Herberts, C (1972a): Etude Systematique de Quelques Zoanthaires Tempe et Reopicaux Tethys, Suppl. E 69-156.
- Herberts, C (1987). Orre des Zoanthaires. In: P.P. Grasse and D. Doumenci (Red.) *Traite de Zoologie, anatomie, systematique, biologie*. Tome 3: 170-178.
- Hyman, L.H. (1940). Chapter VII. Metazoa of the tissue grade of construction Bthe radiate phyla-Phylum Cnidaria. In: *The Invertebrates: Protozoa through Ctenophora* Vol. 1. McGraw-Hill, New York, pp. 365-696.
- Karlson, R.H. 1881. Reproductive patterns in *Zoanthus spp.* from Discovery Bay Jamaica. *Proc. 4th Int. Coral Reef Symp.* Vol. 2L 699-704.
- Mather, P. and Bennett I. (ed.) 1993. *A Coral Reef Handbook* 3rd.ed. Surry, Beatty and Sons PTY Ltd., Chipping Norton, NSW, Australia.
- Muirhead, A. and Ryland J. S. (1985). A review of the genus *Isaurus* Gray, 1828 (Zoanthidea), including new records from Fiji. *Jour. Nat. Hist.* (19): 323-335.
- Muscatine, L., Falkowski, P.G. and Dubinsky, Z. (1983). Carbon budgets in symbiotic associations. In E.A. Schenk and W. Schwemmler (eds.) *Endocytobiology*, Vol 2, Walter de Gruether, Berlin, pp. 649-658.
- Reimer, A. A. (1971a): Feeding Behaviour in the Hawaiian Zoanthids, *Palythoa* and *Zoanthus*. *Pacific Science* **25** (4): 512-520.
- Reimer, A. A. (1971b): Observations on the relationships between several species of tropical zoanthids (Zoanthidae, Coelenterata) and their zooxanthellae. *J. Exp. Mar. Biol. Ecol.* (7): 207-214.

- Ryland, J. S. & R. C. Babcock (1991): Annual cycle of gametogenesis and spawning in the tropical zoanthid, *Protopalythoa* sp. *Hydrobiologia* (216/217): 117-123.
- Sebens, K.P. 1977. Autotrophic and heterotrophic nutrition of coral reef zoanths. In: Proc. 3rd Int. Coral Reef Symp. 397-404.
- Trench R.K. (1974) Nutritional potentials in *Zoanthus sociatus* (Coelenterata, Anthozoa) *Helg. Wiss Meers.* 26:174-216.
- Walsh G.E. 1967. An Annotated Bibliography of the Families Zoanthidae, Epizoanthidae, and Parazoanthidae (Coelenterata, Zoantharia). Univ. Hawaii Hawaii Inst. Marine Biology Tech. Rep. 13. 77pp.
- Walsh G.E. and Bowers R.L. 1977. Order Zoanthinaria. In: Reef and Shore Fauna of Hawaii. Section 1. Protozoa through Ctenophora, ed. D. M. Devaney and L. G. Eldredge. Bernice P. Bishop Museum Special Publications 64(1): 148-157.
- Yamazato, K., F. Yoshimoto & N. Yoshihara (1973): Reproductive cycle in a zoanthid *Palythoa tuberculosa* Esper. *Publs. Seto mar. biol. Lab.* (20): 275-283.

Table 91. Zoanthinaria from Hawaii: (Walsh and Bowers 1971).

Order ZOANTHINIARIA

Family ZOANTHIDAE

Isaurus elongatus Verrill 1928

Palythoa vestitus (Verrill 1928)

Palythoa tuberculosa (Esper 1791)

Palythoa psammophilia Walsh and Bowers 1971

Palythoa toxica Walsh and Bowers 1971

Zoanthus pacificus Walsh and Bowers 1971

Zoanthus kealakekuaensis Walsh and Bowers 1971

5.3.10 Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Alcyoniina (soft corals)

Important Summary Documents

Bayer et al. (1983) and Bayer (1981) details anatomical terminology and taxonomy.

Hyman, (1940) describes the anatomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); order Alcyonacea; suborder Alcyoniina: families: Paralcyniidae; Alcyoniidae; Asterozoniidae; Nephtheidae; Nidaliidae; Xeniidae

The taxonomy of common intertidal and lagoon genera *Sarcophyton* and *Sinularia* are revised in Verseveldt (1980, 1982).

Habitat Utilization

Colonies characteristic of large size grow in shallow water areas in high light intensity and intertidally. Generally colonies are smaller on roofs of caves.

Life History

Adult: Appearance and Physical Characteristics

Alcyonaria: Colonial, tentacles and mesenteries 8 with tentacles pinnate attached.

Alcyonacea: Alcyoniina (Soft corals): Fleshy, stolon, membranous, encrusting or erect with tree-like branching. Monomorphic polyps (autozooids: function in food intake, water movement and bear the gonads). Some genera have dimorphic polyps (autozooids and tentacle-less siphonozooids) e.g. *Lobophytum spp.* and *Sarcophyton spp.* Dimorphism attributed to need for transport of water (Bayer, 1973). Skeleton has calcite spicules (sclerites). Coenenchyme is the general colonial mass filled with solenia that connect with the polyps and their anthocodium. Tentacular contraction possible in some and only partial in others.

Zooxanthellate with resulting colour of greens to brown or bright coloration in the sclerites.

Paralcyniidae: Lobed to arborescent upper portions and are able to retract this region into the lower stalk. Rigidly reinforced with large sclerites.

Alcyoniidae: Large, lobed colonial forms with considerable amounts of scleritic coenenchyme.

Nephtheridae: The coenenchyme between polyps is thin, arborescent with polyps grouped at the ends of branches. Hydrostatic pressure important to provide support.

Nidaliidae: Rigid, brittle, arborescent colonies with narrow stems and branches. Densely covered with spindle shaped sclerites. Similar in appearance to gorgonians Xeniidae: Fleshy with sclerite mass reduced. Characterized by tentacular oscillation.

Age, Growth, Longevity

Two main growth forms massive and arborescent.

Growth by vegetative budding from the system of solenial canals between confluent coenenchyme. Mucus production high in some and effective in cleaning of the surface of the colony. Colonies are often prolific with numerous colonies covering large areas. In Guam population density of up to 24 colonies per square meter of *Asterospicularia randalli* (Gawel, 1976).

Distribution

Occurring in all oceans at all latitudes, they are most abundant in the tropics.

Paralcyoniidae: *Studeiroides* spp.: Indo-Pacific

Alcyoniidae: *Sarcophyton* spp./ *Lobophytum* spp.: *Cladiella* spp.: Very common in the Indo-Pacific. *Sinularia* spp.: Indo-Pacific Philippines, Malayan Archipelago Great barrier Reef- Australia, Vietnam, Palau, New Caledonia and the Ryukyu Island, Japan.

Asterospiculariidae: *Asterospicularia* sp.: Guam

Nephtheidae: *Capnella* spp. / *Nephtea* spp. / *Dendronephtea* spp.: Very common in the Indo-Pacific.

Nidaliidae: *Chironephtya* spp./ *Nephtyigorgia* spp./ *Siphonogorgia* spp.: Very common in the Indo-Pacific.

Xeniidae: *Xenia* spp./ *Cespitularia* spp.: Indo-Pacific

Feeding and Food

Heterotrophic through zooplankton capture. Autotrophic through nutrient exchange with zooxanthellae, digestion of zooxanthellae and absorption of dissolved organic matter in the seawater (Fabricius, et al. 1995a,b).

Food is taken in through the mouth. Prey are immobilized by nematocysts and conveyed to the mouth by tentacles.

Behavior

Defensive

Chemical substances provide advantage over other organisms for protection by preventing feeding or securing space on the reef. Majority of species of soft corals contain toxic terpene

compounds which they release in to their surroundings (Coll et al. 1982; and Coll and Sammarco 1983; 1986; Sammarco et al. 1983; Webb and Coll 1983). These may influence the reproductive capability or survivorship of scleractinian corals (Aceret et al. 1995a,b).

Physical defenses involve the use of sweeper tentacles, sclerites, overtopping,

Reproductive Strategies

Asexual: Almost all increase colonial numbers through mechanisms such as fragmentation, budding, transverse fission and pedal laceration.

Fragmentation: Takes place in *Dendronephthya* in 5-10 days (Fabricius, 1995). Fragmentation can occur through constriction or through parting of the stolons.

Sexual: Dioecious and hermaphroditic. Gonads occur on the mesenteries and reproduction involves the release of gametes into the surrounding water. Fertilization may occur externally through broadcast spawning or within the polyp cavity. Internal fertilization gives rise to an internal brooded planula. Also internal fertilization may give rise to an externally brooded planulae. (Benayahu, and Loya 1983, 1984a, 1984b; Yamazato et al. 1981).

Alcyonium, *Heteroxenia*, *Lobophytum*, *Parerythropodium*, *Sarcophyton* and *Xenia* planulae were released between 11 and 13 days after the full moon in November. Egg size range from 625um (*Lobophytum*) to 810um (*Sarcophyton*) (Alino and Coll, 1989). Some are may be dioecious, external surface planula brooders (Benayahu, and Loya, 1983; 1984b; 1986). Presence of zooxanthellae is likely in planulae.

Bibliography

- Aceret T.L., Sammarco, P.W. and J.C. Coll. 1995a. Toxic effects of alcyonacean diterpenes on scleractinian corals. *J. Esp. Mar. Biol. Ecol.* 188:63-78.
- Aceret T.L., Sammarco, P.W. and J.C. Coll. 1995b. Effects of diterpenes derived from the soft coral *Sinularia flexibilis* on the eggs, sperm and embryos of the scleractinian corals *Montipora digitata* and *Acropora tenuis*. *Mar. Biol.* 122:317- 323.
- Alino, P.M. and Coll, J.C. 1989. Observations of the synchronized mass spawning and post-settlement activity of octocorals on the Great Barrier Reef, Australia: Biological aspects. *Bull. Mar. Sci.* 45:697-707.
- Bayer F. M. 1973. Colonial Organization in Octocorals, In: Boardman R.S., Cheetham A.H. and W.A. Oliver (eds.). *Animal Colonies: Development and Function Through Time*. Dowden, Hutchinson and Ross Stroudsburg, Pa. USA.

- Bayer, F. M. 1981. Key to the genera of Octocorallia exclusive Pennatulacea (Coelenterata: Anthozoa) with diagnoses of new taxa. Proc. Biol. Soc. Wash. **94** (3): 902-947.
- Bayer, F.M. Grasshoff, M. Verseveldt J., 1983. Illustrated trilingual glossary of morphological terms applied to Octocorallia. E.J. Brill/ Fr. W. Backhuys: Leiden.
- Benayahu, Y. and Loya Y. 1983. Surface brooding in the Red Sea soft coral *Parerythropodium fulvum fulvum* (Forksall, 1975). Biol Bull. 165: 353-369.
- Benayahu, Y. and Loya Y. 1984a. Life history studies on the Red Sea soft coral *Xenia macropiculata* Gohar, 1940. I. Annual dynamics of gonadal development. Bio. Bull. 166:32-43.
- Benayahu, Y. and Loya Y. 1984b. Life history studies on the Red Sea soft coral *Xenia macropiculata* Gohar, 1940. II. Planulae shedding and post larval development. Bio. Bull. 166:44-53.
- Benayahu, Y. and Loya Y. 1986. Sexual reproduction of a soft coral: synchronous and brief annual spawning of *Sarcophyton glaucum* (Quoy and Gaimard, 1833). Biol. Bull. 170:32-42.
- Coll, J. C., S. Barre, P. W. Sammarco, W.T. Williams & G. J. Bakus 1982: Chemical defenses in soft corals (Coelenterata: Octocorallia) of the Great Barrier Reef: a study of comparative toxicities. Mar. Ecol. Prog. Ser. 8: 271-278.
- Coll C. & P. W. Sammarco 1983: Terpenoid Toxins of soft coral (Coelenterata: Octocorallia): their nature, toxicity, and ecological significance. Toxicon, suppl. (3): 69.
- Coll C. & P. W. Sammarco 1986: Soft Corals: Chemistry and Ecology. Oceanus **29** (2): 33-37.
- Fabricius, K.E. 1995. Slow population turnover in the soft coral genera *Sinularia* and *Sarcophyton* on mid- and outer-shelf reefs to the Great Barrier Reef. Mar. Ecol. Progr. Ser. 126: 145-152.
- Fabricius, K.E., Benayahu, Y. and Genin. A. 1995a. Herbivory in asymbiotic soft corals. Science 268: 90-92.
- Fabricius, K.E., Genin. A. and Benayahu, Y. 1995b. Flow-dependent herbivory and growth in zooxanthellae-free soft corals. Limnol. Oceanogr. 40:1290-1301.
- Gawel, M.J. 1976: *Asterospicularia randalli*: A new species of Asterspicularidae (Octocorallia: Alcyonacea) from Guam. Micronesia 12 (2): 303-307.
- Hyman, L.H. (1940). Chapter VII. Metazoa of the tissue grade of construction Bthe radiate phyla-Phylum Cnidaria. In: The Invertebrates: Protozoa through Ctenophora Vol. 1. McGraw-Hill, New York, pp. 365-696.

- Sammarco, P. W., J. C. Coll, S. LaBarre & B. Willis 1982: Competitive strategies of soft corals (Coelenterata: Octocorallia): allelopathic effects on selected scleractinian corals. *Coral Reefs* **1**(3): 173-178.
- Verseveldt, J. (1980): A revision of the genus *Sinularia* May (Octocorallia, Alcyonacea). *Zool. Verhandlingen, Leiden* (179): 1-128, figs. 1-68, pls. 1-38.
- Verseveldt, J. (1982): A revision of the genus *Sarcophyton* Lesson (Octocorallia, Alcyonacea). *Zool. Verhandlingen, Leiden* (192): 1-91, 21 plates.
- Webb, L. & J. C. Coll 1983: Effects on Alcyonaria coral terpenes on scleractinian coral photosynthesis and respiration. *Toxicon suppl.* 3: 69.
- Yamazato, K., Sato, M. and Yamashiro H. 1981. Reproductive biology of an alcyonacean coral, *Lobophytum crassum* Marenzeller. *Proc, 4th Int. Coral Reef Symp.* Manila, vol. 2.

**5.3.11 Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Scleraxonia;
Holoaxonia (gorgonian corals, sea fans and sea whips)**

Important Summary Documents

Bayer (1956, 1973, and 1981) summarizes taxonomy and anatomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Scleraxonia; Families: Briareidae; Anthothelidae; Subergorgiidae; Coralliidae; Melithaeidae; Parisididae; Holoaxonia; Families: Acanthogorgiidae; Plexuridae; Gorgoniidae; Ellisellidae; Ifalukellidae; Chrysogorgiidae; Primmidae; Isididae.

Habitat Utilization

Strong current location; low light conditions such as depths and overhangs.

Life History

Adult: Appearance and Physical Characteristic

Generally arborescent in nature, some unbranched. Skeletal support by stiff axis utilizing the flexible gorgonin. Divided taxonomically on basis of a central supporting axis (gorgonin and fused sclerites) or core (cortex around chambered gorgonin). Polyps have pinnate tentacles, anthocodia sit in coenenchymal calyx and sheath is formed around the central axis.

The main stem is attached by to a plate or branchlets to the surface. Stem contains a central strengthening rod. The rod may be calcareous but is commonly of horny gorgonin. Short polyps occur all over the branches of the colony but not on the main stem. Colonies are often brightly colored and may reach 3m in height. Epizoidic life common (George and George, 1979).

From (George and George, 1979):

Suborder Scleraxonia

Briareidae: Erect, finger-like processes of spongy texture (20cm height) or massive and encrusting. Zooxanthellate. Polyps monomorphic

Anthothelidae: Thinly branched sea-fan. Fragments easily. Polyps monomorphic.

Subergorgiidae: Sea-fan with anastomosing branches (1m height), strong and flexible, polyps monomorphic.

Coralliidae: Calcareous skeleton with color from pink to red. Retractable white feathery polyps and branch in any plane. Polyps dimorphic.

Melithaeidae: Sea-fan with jointed axis and brittle (50cm height).

Suborder Holoaxonia

Plexuridae: Dichotomously branched species.

Gorgoniidae: Sea-fan with anastomosing box-section branches, flattened, bushy or feathery branches (1m height).

Ellisellidae: Whip-like (1m long).

Primnidae: Stems stiff and heavily calcified. Polyp bases composed of spicules are arranged in whorls around the stem.

Isididae: Parallel with upright branches

Age, Growth, Longevity

Photosynthetic gorgonians grow rapidly 15 cm (*Gorgonia ventalin*); 2.5 cm/mon./branch *Pseudoplexaura* spp and *Pseudopterogorgia acerosa* (Sprung and Delbeek 1997)

0.8-4.5cm/yr. found in Puerto Rico. (Yoshioka and Buchanan-Yoshioka 1991)

Small colonies grow vertically faster but not necessarily in area.

Distribution

Cosmopolitan though most abundant in warmer waters.

Indo-Pacific occurrence:

Suborder Scleraxonia

Briareidae: *Solenopodium* spp.; *Briareum* spp.

Anthothelidae: *Erythropodium* spp

Subergorgiidae: *Subergorgia* spp

Melithaeidae: *Melithaea* spp.; *Mopsella* spp.

Ellisellidae: *Ellisella* spp. / *Junceella* spp.

Suborder: Holoaxonia

Acanthogorgiidae: *Acanthogorgia* spp.; *Muricella* spp.

Plexuridae: *Bebryce* spp.

Gorgoniidae: *Lophogorgia* spp.

Chrysogorgiidae: *Stephanogorgia* sp.

Isididae: *Isis* spp.

Feeding and Food

Heterotrophic by the capture of zooplankton. Autotrophic through nutrient translocation from zooxanthellae. Relative few holoaxonic zooxanthellate genera in the Indo-Pacific. Particulate feeding described (Lasker, 1981)

Require strong current situations for effective feeding by fan-like colonies.

Behavior

Periodic shedding of the waxy cuticle as a means of surface cleaning.

Reproductive Strategies

Parthenogenetic planulae production possible with planulae internal brooders (Brazeau and Lasker, 1989) though most were produced through broadcast spawning (Lasker and Kim, 1996).

Clonal propagation occurs (Lasker 1990).

Bibliography

- Bayer, F.M. 1956: Octocorallia In Moore, R.C. (ed.): Treatise on Invertebrate Paleontology. Part F Coelenterata: 166-231, Geological Society of American University of Kansas Press.
- Bayer F. M. 1973. Colonial Organization in Octocorals, In: Boardman R.S., Cheetham A.H. and W.A. Oliver (eds.). *Animal Colonies: Development and Function Through Time*. Dowden, Hutchinson and Ross Stroudsburg, Pa. USA
- Bayer, F. M. 1981. Key to the genera of Octocorallia exclusive Pennatulacea (Coelenterata: Anthozoa) with diagnoses of new taxa. Proc. Biol. Soc. Wash. **94** (3): 902- 947
- Brazeau, F.A. and Lasker. H.R. 1989. The reproductive cycle and spawning in a Caribbean gorgonian. Biol Bull. 176:1-7.
- George, D. & J. George, 1979: An Illustrated Encyclopedia of Invertebrates in the Sea *Marine Life*.
- Lasker, H. R., 1981: A comparison of particulate feeding abilities of three species of gorgonian soft corals. Marine Ecol. Prog. Ser., 5:61-67.
- Lasker, H.R. 1990. Clonal propagation and population dynamic of a gorgonian coral. Ecology 71:1578-1589.
- Lasker, H.R. AND Kim K. 1996. Larval development and settlement behaviour of the gorgonian coral *Plexaura kuna* (Lasker, Kim and Coffroth). J. Exp. Mar. Biol. Ecol. 207: 161-175.
- Sprung, J. & J. C. Delbeek (1997): The Reef Aquarium, vol. 2. Ricordea Publishing, Miami, USA.

Yoshioka and Buchanan-Yoshioka 1991. A comparison of the survivorship and growth of shallow-water gorgonian species of Puerto Rico (West Indies.). *Mar. Ecol. Progr. Ser.* 69:253-260.

DRAFT

5.3.12 *Heliopora coerulea* (DeBlainville, 1830) (Alcyonaria, Coenothecalia) (blue coral)

Important Summary Documents

Zann and Boulton (1985) detail the distribution, abundance and ecology in the Pacific. Hyman (1940) and Bayer (1973, 1981) describe the anatomy and taxonomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia): Order Coenothecalia (=Helioporacea); monotypic, family Helioporidae with a single species. It is a soft coral with a hard, >stony coral-like= skeleton.

Habitat Utilization

High abundance of *Heliopora* is attributed to a reduction in competition from *Acropora*, *Pocillopora* and faviids in areas where these are mutually exclusive. *Heliopora* frequently co-existed with *Porites* and *Montipora*. In terms of interspecific aggression, *Heliopora* is a good competitor as both *Acropora* and *Pocillopora* are considered aggressive (Lang, 1973).

It is a warm-water generalist with a wide habitat range.

Life History

Adult: Appearance and Physical Characteristics

Zooxanthellate and colonial with a blue calcium carbonate skeleton which is the result of iron salts (Hill, 1960). Bouillon and Houvenaghel-Crevecœur (1970) conclude the blue pigmentation is composed primarily of biliverdin IX and secondary oxidation products. (Hyman, 1940) describes the skeleton as composed of crystalline slivers of aragonite fused into a layer. There are no sclero-proteinaceous structures as in the rest of the Octocorallia. The skeleton contains strontium but in smaller amounts in comparison to hermatypic scleractinia.

Colour and growth form is highly variable: corallum pale to deep blue; living coral is light brown-grey with extended polyps grey-white. Growth forms: encrusting, columnar and branching (coalescent compressed, flabellate fronds, fine branching). May form massive micro-atolls (Zann and Boulton, 1985). Appears like a species of *Millepora*. There is a clear correlation between colony shape and environmental conditions (Veron 1986).

Skeleton with blind tubes internally one for the polyps and one for the solenia (Hyman, 1940).

Reproductive Strategies

Dioecious with fertilization taking place internally and the eggs are brooded externally (Babcock, 1990). External brooding is where they fertilized eggs are shed from the polyp and adhere to the side in mucus pouches where they developed until they are released. Weingarten (1992) describes a synchronous annual of oocytic development following the general octocorallian reproductive strategy. The gametes are typically released in January, after the full moon, at the summer thermal maximum. Where its distribution is geographically marginal, it takes more than one year for the gametes to mature. It broods its larvae, which settle immediately after release.

Zann and Boulton (1985) suggest the limitation to its distribution to more isolated areas due to a relatively short larval life span. The short larval stage may be nutrient limited as the planula is azooxanthellate.

Distribution

Duration of larval life span, prevailing currents, and the geological and climatic history of isolated archipelagoes determine its distribution. Though widely distributed since the Cretaceous, now more abundant in the equatorial Central Pacific than in the Western Pacific. Comprises 16% of beach sediment in Tuvalu and 40% of substrate between 6m and 10m on Tarawa Atoll, Kirribati. Competition with Acroporidae and Faviidae influence its occurrence (Zann and Boulton, 1985). Globally, it occurs along West Africa, Red Sea, Indonesia and the Maldives, where it may be the dominant coral fauna. It occurs as far south as Madagascar and north to the Ryukyu Islands in Japan (Veron, 1986).

With regard to the AFPI, it is only present in Guam (Randall, 1977), Commonwealth of the Northern Marianas and American Samoa (rare) (U.S. Army Corps Engineers 1980).

Its habitat distribution is inter-tidal reef flats, reef front reef slope in Guam from < 1m to >30m. It is uncommon or rare (e.g. GBR; American Samoa) while it is abundant elsewhere. *Heliopora* zones have been described in the Marshall Islands and where it is considered as the most common coral (Emory et al. 1954; Wells, 1954a).

Feeding and Food

Heterotrophic and autotrophic by virtue of its zooxanthellae symbiosis. Prey capture is tentacular using nematocysts. Other sources of nutrition may be dissolved organic material and suspension feeding.

Bibliography

Babcock, R. C. (1990). Reproduction and development of the blue coral *Heliopora coerulea* (*Alcyonaria: Coenothecalia*). *Mar. Biol* 104:475-481.

Bayer F. 1973. Colonial Organization in Octocorals, In: Boardman R.S., Cheetham A.H. and W.A. Oliver (eds.). *Animal Colonies: Development and Function Through Time*. Dowden, Hutchinson and Ross Stroudsburg, Pa. USA

Bayer, F. M. 1981. Key to the genera of Octocorallia exclusive Pennatulacea (Coelenterata: Anthozoa) with diagnoses of new taxa. *Proc. Biol. Soc. Wash.* **94** (3): 902- 947.

Bouillon J. and Houvenaghel-Crevecœur N. 1970. Etude monographique du *Heliopora* de Blainville (*Coenothecalia-Alcyonaria-Coelenterata*). *Musee Royal De L'Afrique Central, Treuren. Annales Sciences Zoologiques* 178: 1-83.

- Emery L.O., Tracy J.I. Ladd H.S. 1954. Geology of Bikini and nearby atolls. Prof. Pap. US Geol. Survey 260A:1-265.
- Hyman, L.H. 1940. Chapter VII. Metazoa of the tissue grade of construction Bthe radiate phyla-Phylum Cnidaria. In: The Invertebrates: Protozoa through Ctenophora Vol. 1. McGraw-Hill, New York, pp. 365-696.
- Hill, D. 1960. Possible intermediates between Alcyonaria, Tabulata and Rugosa, and Rugosa and Hexacorallia. 21st Geol. Congr. 22:51-58.
- Lang, J., 1973. Interspecific aggression by scleractinian corals: 2. Why the race is not only to the swift. Bull. Mar. Sci., 23(2): 260-279.
- Randall, R.H. (1977). Corals. Univ. Guam Mar. Lab. Tech. Rep. 31:63-92.
- U.S. Army Corps Engineers. Pac. Ocean Div. (1980). American Samoa Coral Reef Inventory. Development Planning Office, Amer. Samoa Govt.
- Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 15116 4.
- Weingarten R.A. 1992. Notes on the reproduction and development of the *Heliopora coerulea*, the blue coral. FAMA 15 (1): 160-170.
- Wells J.W. (1954a). Recent corals of the Marshall Islands. US Geol. Surv. Prof. Pap. 260: 1-260: 285-486.
- Zann, L. P. & L. Boulton (1985). The distribution, abundance and ecology of the blue coral *Heliopora coerulea* (De Blainville) in the Pacific. Coral Reefs 4 (2): 125-134.

5.3.13 *Tubipora Musica* (Linnaeus, 1758) (organ-pipe coral or star polyps)

Important Summary Documents

Veron (1986) describe the species.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); Order Stolonifera; Family Tubiporidae; Genus *Tubipora* with one species *Tubipora musica*

Four nominal species, probably one true species (Veron, 1986).

Order Stolonifera may be considered a sub-order, with the Order Alcyonacea. Two genera present, *Tubipora* and *Pachyclavularia*, often confused with *Clavularia* spp. One form has tentacles which look like *Alveopora* though eight tentacles.

Habitat Utilization

Requires high illumination and strong circulation through wave action or currents. Abundant in shallow lagoons in turbid water. Also found on reef slopes and in deep water with clear or turbid water. In back reef locations, large heads form in sand or coral rubble. On the reef flat the colonies are smaller and encrusting (Sprung and Delbeek, 1997).

Life History

Adult: Appearance and Physical Characteristic

Colonies are massive, formed by long, parallel, calcareous tubes (stolons) of fused spicules connected by horizontal platforms. The tubes contain the polyps (zooids), each of which has eight pinnate or feather-like tentacles. The skeleton is a permanent dark-red colour. Polyp colour greenish-brown or grey polyps (Veron, 1986; Barnes 1987).

Age, Growth, Longevity

Asexual growth by budding from the solenial canals. Linking of polyps by outward growth from the body wall. The secondary stolon are platform-like and the sclerites fuse producing hard massive colonies.

Distribution

Extends from the Red Sea and west Africa, east to Fiji and the Marshall Is. Southerly distribution from south of Madagascar and south Western Australia, north to the Kyushu Is., Japan. Not present in Hawaii, though in Guam and the CNMI.

Feeding and Food

Heterotrophic, autotroph with zooxanthellae

Reproductive Strategies

Sexual and asexual. Sexual reproduction is unknown in *Tubipora musica*. An example of other genera within the family may provide an analogous understanding. Morphologically similar,

Briareum stechei, *Pachyclavularia violacea* was found to be dioecious external brooder with the developing planulae residing just beside the mouth. The reddish-brown planulae were released between 11 and 13 days after the full moon in November (Alino and Coll, 1989). The colour of the planulae suggests the presence of zooxanthellae.

Bibliography

Alino, P.M. and Coll, J.C. 1989. Observations of the synchronized mass spawning and post-settlement activity of octocorals on the Great Barrier Reef, Australia: Biological aspects. Bull. Mar. Sci. 45:697-707.

Barnes, R. D. (1987). Invertebrate zoology. Saunders Colledge, Philadelphia.

Sprung, J. & J. C. Delbeek 1997. The Reef Aquarium, vol. 2. Ricordea Publishing, Miami, USA.

Veron J. E. N. 1986. *Coral of Australia and the Indo-Pacific*. Angus and Robertson. ISBN 0 207 15116 4.

Appendix G: EFH Impacts Provisions

The EFH provisions of the Magnuson Stevens Act impose procedural requirements on both Councils and federal agencies related to marine planning. First, for each FMP, Councils must identify adverse impacts to EFH resulting from both fishing and non-fishing activities, and describe measures to minimize these impacts. Second, the provisions allow Councils to provide comments and make recommendations to federal or state agencies that propose actions that may affect the habitat, including EFH, of a managed species. NMFS is required to consult with federal agencies on actions that may adversely affect EFH, which usually occurs concurrently with the NEPA planning process.

None of the fisheries operating under the Hawaii Archipelago FEP are expected to have adverse impacts on EFH or HAPC for species managed under the different fisheries. Continued and future operations of fisheries under the Hawaii Archipelago FEP are not likely to lead to substantial physical, chemical, or biological alterations to the habitat, or result in loss of, or injury to, these species or their prey.

1. MSA and non-MSA fishing activities that may adversely affect EFH

The Council is required to act to prevent, mitigate, or minimize adverse effects from fishing on evidence that a fishing practice has identifiable adverse effects on EFH for any MUS covered by an FMP. Adverse fishing impacts may include physical, chemical, or biological alterations of the substrate and loss of, or injury to, benthic organisms, prey species, and their habitat or other components of the ecosystem.

The predominant fishing gear types—hook and line, longline, troll, traps—used in the fisheries managed by the Council cause few fishing-related impacts to the benthic habitat utilized by coral reef species, bottomfish, crustaceans, or precious corals. The current management regime prohibits the use of bottom trawls, bottom-set nets, explosives, and poisons. The use of non-selective gear to harvest precious corals is prohibited and only selective and non-destructive gear may be allowed to fish for Coral Reef Ecosystem MUS. Although lobster traps have a potential impact on the benthic habitat, the tropical lobster *Panulirus penicillatus* does not enter lobster traps. In the limited areas where harvesting does occur in the Hawaii Archipelago, lobsters are caught by hand. This technique causes limited damage or no fishing-related impacts to the benthic habitat, and its continued use is likely.

The Council has determined that current management measures to protect fishery habitat are adequate and that no additional measures are necessary at this time. However, the Council has identified the following potential sources of fishery-related impacts to benthic habitat that may occur during normal fishing operations:

- Anchor damage from vessels attempting to maintain position over productive fishing habitat.

- Heavy weights and line entanglement occurring during normal hook-and-line fishing operations.
- Lost gear from lobster fishing operations.
- Remotely operated vehicle (ROV) tether damage to precious coral during harvesting operations.

Trash and discarded and lost gear (leaders, hooks, weights) by fishing vessels operating in the EEZ, are a Council concern. A report on the first phase of a submersible-supported research project conducted in Hawaii in 2001 preliminarily determined that bottomfish gear exhibited minimal to no impact on the coral reef habitat (C. Kelley, personal communication). A November 2001 cruise in the Main Hawaiian Islands determined that precious corals harvesting has “negligible” impact on the habitat (R. Grigg, personal communication). The Council is concerned with habitat impacts of marine debris originating from fishing operations outside the Western Pacific Region. NMFS is currently investigating the source and impacts of this debris. International cooperation will be necessary to find solutions to this broader problem.

Because the habitat of pelagic species is the open ocean, and managed fisheries employ variants of hook-and-line gear, there are no direct impacts to EFH. Lost gear may be a hazard to some species due to entanglement, but it has no direct effect on habitat. A possible impact would be caused by fisheries that target and deplete key prey species, but currently there is no such fishery.

There is also a concern that invasive marine and terrestrial species may be introduced into sensitive environments by fishing vessels transiting from populated islands and grounding on shallow reef areas. Of most concern is the potential for unintentional introduction of rats (*Rattus* spp.) to the remote islands in the NWHI and PRIA that harbor endemic land birds. Although there are no restrictions that prohibit fishing vessels from transiting near these remote island areas, no invasive species introductions due to this activity have been documented. However, the Council is concerned that this could occur as fisheries expand and emerging fisheries develop in the future.

While the Council has determined that current management measures to protect fishery habitat are adequate, should future research demonstrate a need, the Council will act accordingly to protect habitat necessary to maintain a sustainable and productive fishery in the Western Pacific Region.

In modern times, some reefs have been degraded by a range of human activities. Comprehensive lists of human threats to coral reefs in the U.S. Pacific Islands are provided by Maragos et al. (1996), Birkeland (1997a), Grigg 2002, and Clark and Gulko (1999). (These findings are summarized in Table 27.) More recently, the U.S. Coral Reef Task Force identified six key

threats to coral reefs: (1) landbased sources of pollutions, (2) overfishing, (3) recreational overuse, (4) lack of awareness, (5) climate change, and (6) coral bleaching and disease. In general, reefs closest to human population centers are more heavily used and are in worse condition than those in remote locations (Green 1997). Nonetheless, it is difficult to generalize about the present condition of coral reefs in the U.S. Pacific Islands because of their broad geographic distribution and the lack of long-term monitoring to document environmental and biological baselines. Coral reef conditions and use patterns vary throughout the U.S. Pacific Islands.

A useful distinction is between coral reefs near inhabited islands of American Samoa, CNMI, Guam, and the main Hawaiian islands and coral reefs in the remote NWHI, PRIAs, and northern islands of the CNMI. Reefs near the inhabited islands are heavily used for small-scale artisanal, recreational, and subsistence fisheries, and those in Hawaii, CNMI and Guam are also the focus for extensive non-consumptive marine recreation. Rather than a relatively few large-scale mechanized operations, many fishermen each deploy more limited gear. The more accessible banks in the main Hawaiian Islands (Penguin Bank, Kaula Rock), Guam (southern banks), and the CNMI (Esmeralda Bank, 300 Reef, Marpi Reef, Dump Coke and Malakis Reef) are the most heavily fished offshore reefs in the Western Pacific Region management area.

The vast majority of the reefs in the Western Pacific Region are remote and, in some areas, they have protected status. Most of these are believed to be in good condition. Existing fisheries are limited. The major exception is in the NWHI, where there are commercial fisheries for spiny lobster and deep-slope bottomfish (Green 1997). Poaching by foreign fishing fleets is suspected at Guam's southern banks, in the PRIA, and possibly in other areas. Poachers usually target high-value and often rare or overfished coral reef resources. These activities are already illegal but difficult to detect.

2. Non-fishing related activities that may adversely affect EFH

On the basis of the guidelines established by the Secretary under Section 305 (b)(1)(A) of the MSA, NMFS has developed a set of guidelines to assist councils meet the requirement to describe adverse impacts to EFH from non-fishing activities in their FMPs (67 FR 2376). A wide range of non-fishing activities throughout the U.S. Pacific Islands contribute to EFH degradation. FEP implementation will not directly mitigate these activities. However, as already noted, it will allow NMFS and the Council to make recommendations to any federal or state agency about actions that may impact EFH. Not only could this be a mechanism to minimize the environmental impacts of agency action, it will help them focus their conservation and management efforts.

The Council is required to identify non-fishing activities that have the potential to adversely affect EFH quality and, for each activity, describe its known potential adverse impacts and the EFH most likely to be adversely affected. The descriptions should explain the mechanisms or

processes that may cause the adverse effects and how these may affect habitat function. The Council considered a wide range of non-fishing activities that may threaten important properties of the habitat used by managed species and their prey, including dredging, dredge material disposal, mineral exploration, water diversion, aquaculture, wastewater discharge, oil and hazardous substance discharge, construction of fish enhancement structures, coastal development, introduction of exotic species, and agricultural practices. These activities and impacts, along with mitigation measures, are detailed in the next section.

Table 92: Threats to Coral Reefs in the Hawaiian Archipelago

Activity	MHI	NWHI
Coastal construction	x	
Destructive fishing	x	
Flooding	x	
Industrial pollution		
Overuse/over harvesting	x	
Nutrient loading (sewage/eutrophication)	x	
Soil erosion/sedimentation	x	
Vessel groundings/oil spills		x
Military activity	x	x
Hazardous waste		x
Tourist impacts	x	
Urbanization	x	
Thermal pollution	x	
Marine debris	x	x
Introduced species	x	

Sources: Birkeland 1997a; Clark and Gulko 1999; Grigg 2002; Jokiel 1999; Maragos et al. 1996

3. Cumulative Impacts Assessment

A cumulative impacts analysis (CIA) is required by the NMFS EFH Final Rule (2002) to the extent feasible and practicable. The CIA “should analyze how the cumulative impacts of fishing and non-fishing activities influence the function of EFH on an ecosystem or watershed scale” (67

FR 2378, January 17, 2002). The assessment should include multiple threats, including natural stresses.

There are a variety of past, present, and future activities that have the potential to affect EFH in the Hawaiian Archipelago. In the Main Hawaiian Islands, there has been interest in aquaculture, inter-island electricity cables, and offshore energy development as the state moves toward self-sufficiency in energy and food production. Since many water column impacts are temporary in nature, benthic alteration associated with laying cables and anchoring are most likely to have an adverse impact and pose the greatest threat to EFH for juvenile and adult life stages. Nearshore impacts associated with development have the potential to impact shallow water species. Large-scale impacts such as global climate change that affect ocean temperatures, currents, and potentially food chain dynamics are most likely to threaten EFH for egg and larval pelagic stages.

The Northwestern Hawaiian Islands are very remote. All commercial fishing for bottomfish and seamount groundfish species is under moratorium in the Hancock Seamount Ecosystem Management Area; commercial fishing is banned within the Papahānaumokuākea Marine National Monument. Activity within the Monument is generally limited to scientific research. Similar to larval and egg life stages, global environmental problems pose the largest threat to EFH in the NWHI.

Future analyses will seek to analyze cumulative impact of habitat conversion and the impacts of discharges in order to evaluate the cumulative impacts on EFH. Information and techniques that are developed for this process will be used to supplement future revisions of these EFH provisions as the information becomes available.

4. Conservation and Enhancement Recommendations

According to NMFS guidelines, Councils should describe ways to avoid, minimize, or compensate for the adverse effects to EFH and promote the conservation and enhancement of EFH. Generally, non-water dependent actions that may have adverse impacts should not be located in EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. Disposal or spillage of any material (dredge material, sludge, industrial waste, or other potentially harmful materials) that would destroy or degrade EFH should be avoided. If

avoidance or minimization is not possible, or will not adequately protect EFH, compensatory mitigation to conserve and enhance EFH should be recommended. FEPs may recommend proactive measures to conserve or enhance EFH. When developing proactive measures, Councils may develop a priority ranking of the recommendations to assist federal and state agencies undertaking such measures. Councils should describe a variety of options to conserve or enhance EFH, which may include, but are not limited to the following:

Enhancement of rivers, streams, and coastal areas through new federal, state, or local government planning efforts to restore river, stream, or coastal area watersheds.

Improve water quality and quantity through the use of the best land management practices to ensure that water-quality standards at state and federal levels are met. The practices include improved sewage treatment, disposing of waste materials properly, and maintaining sufficient in-stream flow to prevent adverse effects to estuarine areas.

Restore or create habitat, or convert non-EFH to EFH, to replace lost or degraded EFH, if conditions merit such activities. However, habitat conversion at the expense of other naturally functioning systems must be justified within an ecosystem context.

Established policies and procedures of the Council and NMFS provide the framework for conserving and enhancing EFH. Components of this framework include adverse impact avoidance and minimization, provision of compensatory mitigation whenever the impact is significant and unavoidable, and incorporation of enhancement. New and expanded responsibilities contained in the MSA will be met through appropriate application of these policies and principles. In assessing the potential impacts of proposed projects, the Council and the NMFS are guided by the following general considerations:

- The extent to which the activity would directly and indirectly affect the occurrence, abundance, health, and continued existence of fishery resources.
- The extent to which the potential for cumulative impacts exists.
- The extent to which adverse impacts can be avoided through project modification, alternative site selection, or other safeguards.
- The extent to which the activity is water dependent if loss or degradation of EFH is involved.

- The extent to which mitigation may be used to offset unavoidable loss of habitat functions and values.

Seven non-fishing activities have been identified that directly or indirectly affect habitat used by MUS. Impacts and conservation measures are summarized below for each of these activities. Although not all inclusive, what follows is a good example of the kinds of measures that can help to minimize or avoid the adverse effects of identified non-fishing activities on EFH.

- Habitat Loss and Degradation

Impacts:

- Changes in abundance of infaunal and bottom-dwelling organisms
- Turbidity plumes
- Biological availability of toxic substances
- Damage to sensitive habitats
- Current patterns/water circulation modification
- Loss of habitat function
- Contaminant runoff
- Sediment runoff
- Shoreline stabilization projects

Conservation Measures:

1. To the extent possible, fill materials resulting from dredging operations should be placed on an upland site. Fills should not be allowed in areas with subaquatic vegetation, coral reefs, or other areas of high productivity.
2. The cumulative impacts of past and current fill operations on EFH should be addressed by federal, state, and local resource management and permitting agencies and should be considered in the permitting process.
3. The disposal of contaminated dredge material should not be allowed in EFH.

4. When reviewing open-water disposal permits for dredged material, state and federal agencies should identify the direct and indirect impacts such projects may have on EFH. When practicable, benthic productivity should be determined by sampling prior to any discharge of fill material. Sampling design should be developed with input from state and federal resource agencies.
5. The areal extent of the disposal site should be minimized. However, in some cases, thin layer disposal may be less deleterious. All non-avoidable impacts should be mitigated.
6. All spoil disposal permits should reference latitude–longitude coordinates of the site so that information can be incorporated into GIS systems. Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.
7. Further fills in estuaries and bays for development of commercial enterprises should be curtailed.
8. Prior to installation of any piers or docks, the presence or absence of coral reefs and submerged aquatic vegetation should be determined. These areas should be avoided. Benthic productivity should also be determined, and areas with high productivity avoided. Sampling design should be developed with input from state and federal resource agencies.
9. The use of dry stack storage is preferable to wet mooring of boats. If that method is not feasible, construction of piers, docks, and marinas should be designed to minimize impacts to the coral reef substrate and subaquatic vegetation.
10. Bioengineering should be used to protect altered shorelines. The alteration of natural, stable shorelines should be avoided.

○ Pollution and Contamination

Impacts:

- Introduction of chemicals
- Introduction of animal wastes
- Increased sedimentation
- Wastewater effluent with high contaminant levels
- High nutrient levels downcurrent of outfalls
- Biocides to prevent biofouling

- Thermal effects
- Turbidity plumes
- Affected submerged aquatic vegetation sites
- Stormwater runoff
- Direct physical contact
- Indirect exposure
- Cleanup

Conservation Measures:

1. Outfall structures should be placed sufficiently far offshore to prevent discharge water from affecting areas designated as EFH. Discharges should be treated using the best available technology, including implementation of up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances.
2. Benthic productivity should be determined by sampling prior to any construction activity. Areas of high productivity should be avoided to the maximum extent possible. Sampling design should be developed with input from state and federal resource agencies.
3. Mitigation should be provided for the degradation or loss of habitat from placement of the outfall structure and pipeline as well as the treated water plume.
4. Containment equipment and sufficient supplies to combat spills should be on-site at all facilities that handle oil or hazardous substances.
5. Each facility should have a Spill Contingency Plan, and all employees should be trained in how to respond to a spill.
6. To the maximum extent practicable, storage of oil and hazardous substances should be located in an area that would prevent spills from reaching the aquatic environment.
7. Construction of roads and facilities adjacent to aquatic environments should include a storm-water treatment component that would filter out oils and other petroleum products.
8. The use of pesticides, herbicides, and fertilizers in areas that would allow for their entry into the aquatic environment should be avoided.

9. The best land management practices should be used to control topsoil erosion and sedimentation.

- Dredging

Impacts:

- Changes in abundance of infaunal and bottom-dwelling organisms
- Turbidity plumes
- Bioavailability of toxic substances
- Damage to sensitive habitats
- Water circulation modification

Conservation Measures:

1. To the maximum extent practicable, dredging should be avoided. Activities that require dredging (such as placement of piers, docks, marinas, etc.) should be sited in deep-water areas or designed in such a way as to alleviate the need for maintenance dredging. Projects should be permitted only for water-dependent purposes, when no feasible alternatives are available.
2. Dredging in coastal and estuarine waters should be performed during the time frame when MUS and prey species are least likely to be entrained. Dredging should be avoided in areas with submerged aquatic vegetation and coral reefs.
3. All dredging permits should reference latitude–longitude coordinates of the site so that information can be incorporated into Geographic Information Systems (GIS). Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.
4. Sediments should be tested for contaminants as per the EPA and U.S. Army Corps of Engineers requirements.
5. The cumulative impacts of past and current dredging operations on EFH should be addressed by federal, state, and local resource management and permitting agencies and should be considered in the permitting process.
6. If dredging needs are caused by excessive sedimentation in the watershed, those causes should be identified and appropriate management agencies contacted to assure action is done to curtail those causes.

7. Pipelines and accessory equipment used in conjunction with dredging operations should, to the maximum extent possible, avoid coral reefs, seagrass beds, estuarine habitats, and areas of subaquatic vegetation.

- Marine Mining

Impacts:

- Loss of habitat function
- Turbidity plumes
- Resuspension of fine-grained mineral particles
- Composition of the substrate altered

Conservation Measures:

1. Mining in areas identified as a coral reef ecosystem should be avoided.
2. Mining in areas of high biological productivity should be avoided.
3. Mitigation should be provided for loss of habitat due to mining.

- Water Intake Structures

Impacts:

- Entrapment, impingement, and entrainment
- Loss of prey species

Conservation Measures:

1. New facilities that rely on surface waters for cooling should not be located in areas where coral reef organisms are concentrated. Discharge points should be located in areas that have low concentrations of living marine resources, or they should incorporate cooling towers that employ sufficient safeguards to ensure against release of blow-down pollutants into the aquatic environment.
2. Intake structures should be designed to prevent entrainment or impingement of MUS larvae and eggs.
3. Discharge temperatures (both heated and cooled effluent) should not exceed the thermal tolerance of the plant and animal species in the receiving body of water.

4. Mitigation should be provided for the loss of EFH from placement of the intake structure and delivery pipeline.

- Aquaculture Facilities

Impacts:

- Discharge of organic waste from the farms
- Impacts to the seafloor below the cages or pens

Conservation Measures:

1. Facilities should be located in upland areas as often as possible. Tidally influenced wetlands should not be enclosed or impounded for mariculture purposes. This includes hatchery and grow-out operations. Siting of facilities should also take into account the size of the facility, the presence or absence of submerged aquatic vegetation and coral reef ecosystems, proximity of wild fish stocks, migratory patterns, competing uses, hydrographic conditions, and upstream uses. Benthic productivity should be determined by sampling prior to any operations. Areas of high productivity should be avoided to the maximum extent possible. Sampling design should be developed with input from state and federal resource agencies.
2. To the extent practicable, water intakes should be designed to avoid entrainment and impingement of native fauna.
3. Water discharge should be treated to avoid contamination of the receiving water and should be located only in areas having good mixing characteristics.
4. Where cage mariculture operations are undertaken, water depths and circulation patterns should be investigated and should be adequate to preclude the buildup of waste products, excess feed, and chemical agents.
5. Non-native, ecologically undesirable species that are reared may pose a risk of escape or accidental release, which could adversely affect the ecological balance of an area. A thorough scientific review and risk assessment should be undertaken before any non-native species are allowed to be introduced.
6. Any net pen structure should have small enough webbing to prevent entanglement by prey species.
7. Mitigation should be provided for the EFH areas impacted by the facility.

○ Introduction of Exotic Species

Impacts:

- Habitat alteration
- Trophic alteration
- Gene pool alteration
- Spatial alteration
- Introduction of disease

Conservation Measures:

1. Vessels should discharge ballast water far enough out to sea to prevent introduction of nonnative species to bays and estuaries.
2. Vessels should conduct routine inspections for presence of exotic species in crew quarters and hull of the vessel prior to embarking to remote islands (PRIAs, NWHI, and northern islands of the CNMI).
3. Exotic species should not be introduced for aquaculture purposes unless a thorough scientific evaluation and risk assessment are performed (see section on aquaculture).
4. Effluent from public aquaria display laboratories and educational institutes using exotic species should be treated prior to discharge.

5. Essential Fish Habitat Research Needs

The Council conducted an initial inventory of available environmental and fisheries data sources relevant to the EFH of each managed fishery. Based on this inventory, a series of tables were created that indicated the existing level of data for individual MUS in each fishery. These tables are available in Supplements to Amendment 4, 6, and 10 to the Precious Corals, Bottomfish and Seamount Groundfish, and Crustaceans FMPs respectively (WPRFMC 2002), and the Coral Reef Ecosystems FMP (WPRFMC 2001) and are summarized below.

Additional research is needed to make available sufficient information to support a higher level of description and identification of EFH and HAPC. Additional research may also be necessary to identify and evaluate actual and potential adverse effects on EFH, including, but not limited to, direct physical alteration; impaired habitat quality/functions; cumulative impacts from fishing; or indirect adverse effects, such as sea level rise, climate change, and climate shifts.

The following scientific data are needed to more effectively address EFH provisions:

All Species

- Distribution of early life history stages (eggs and larvae) of MUS by habitat
- Juvenile habitat (including physical, chemical, and biological features that determine suitable juvenile habitat)
- Food habits (feeding depth, major prey species, etc.)
- Habitat-related densities for all MUS life history stages
- Habitat utilization patterns for different life history stages and species for BMUS
- Growth, reproduction, and survival rates for MUS within habitats

Bottomfish Species

- Inventory of marine habitats in the EEZ of the Western Pacific Region
- Data to obtain a better SPR estimate for American Samoa's bottomfish complex
- Baseline (virgin stock) parameters (CPUE, percent immature) for the Guam/NMI deep- and shallow-water bottomfish complexes
- High-resolution maps of bottom topography/currents/water masses/primary productivity

Crustaceans Species

- Identification of postlarval settlement habitat of all CMUS
- Identification of source–sink relationships in the NWHI and other regions (i.e., relationships between spawning sites settlement using circulation models, and genetic techniques)
- Establish baseline parameters (CPUE) for the Guam/Northern Marianas crustacean populations
- Research to determine habitat related densities for all CMUS life history stages in American Samoa, Guam, Hawaii, and NMI

- High-resolution mapping of bottom topography, bathymetry, currents, substrate types, algal beds, and habitat relief

Precious Corals Species

- Distribution, abundance, and status of precious corals in the Western Pacific Region

Coral Reef Ecosystem Species

- The distribution of early life history stages (eggs and larvae) of MUS by habitat
- Description of juvenile habitat (including physical, chemical, and biological features that determine suitable juvenile habitat)
- Food habits (feeding depth, major prey species, etc.)
- Habitat-related densities for all MUS life history stages
- Habitat utilization patterns for different life history stages and species
- Growth, reproduction, and survival rates for MUS within habitats.
- Inventory of coral reef ecosystem habitats in the EEZ of the Western Pacific Region
- Location of important spawning sites
- Identification of postlarval settlement habitat
- Establishment of baseline parameters for coral reef ecosystem resources
- High-resolution mapping of bottom topography, bathymetry, currents, substrate types, algal beds, and habitat relief

NMFS guidelines suggest that the Council and NMFS periodically review and update the EFH components of FMPs as new data become available. The Council recommends that new information be reviewed, as necessary, during preparation of the annual and SAFE reports by the Plan Teams, in accordance with the National Standards guidelines. EFH designations may be changed under the FEP amendment process if information presented in an annual review indicates that modifications are justified.

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Appendix H: Essential Fish Habitat and Habitat Areas of Particular Concern Maps

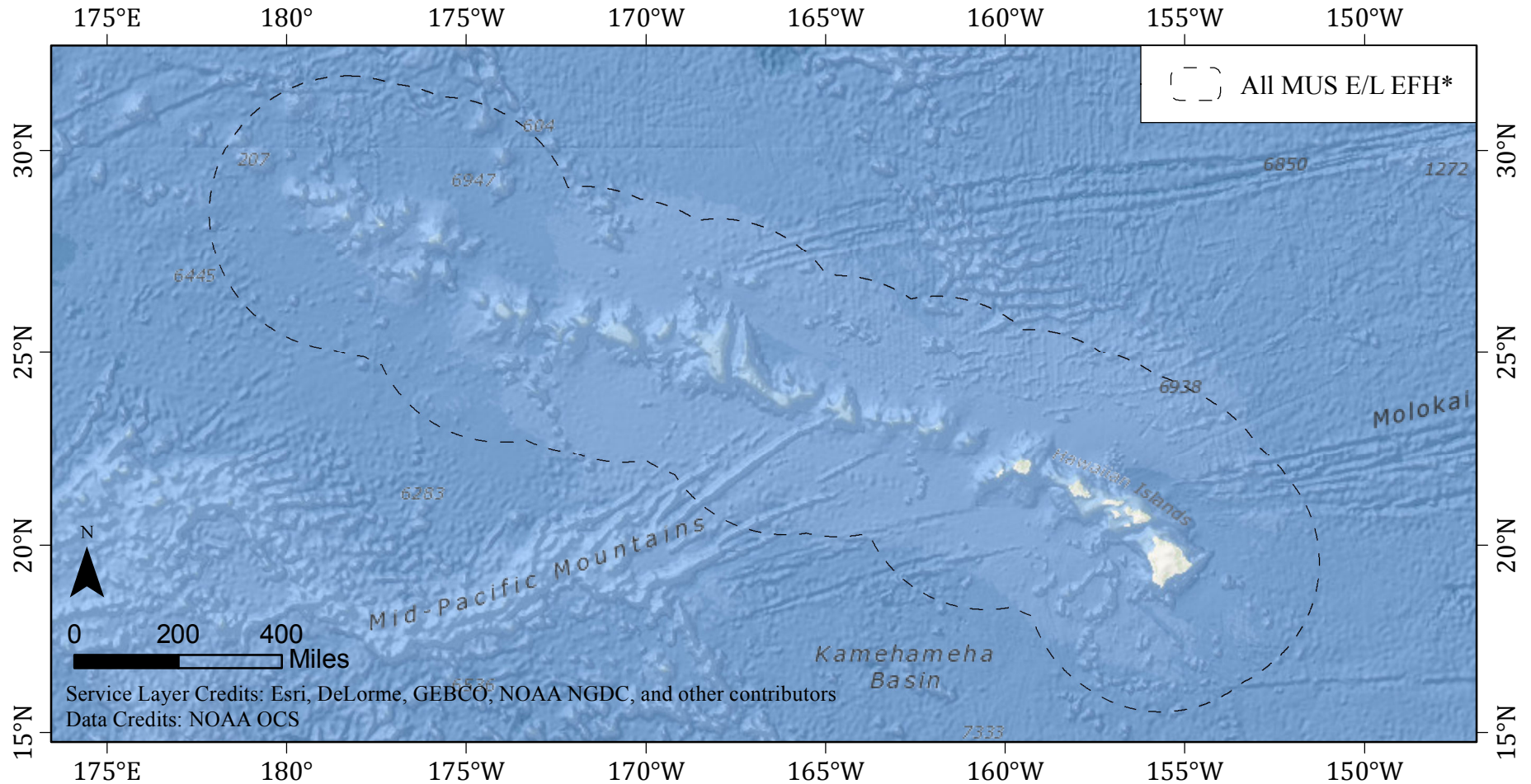
Management Unit Species	Extent	Page
All MUS, Egg and Larval Life Stages Bottomfish	Hawaiian Archipelago	H-3
Egg and Post-Hatch Pelagic	Main Hawaiian Islands	H-4
Post-Settlement, Sub-Adult, and Adult for Shallow Species	Main Hawaiian Islands	H-5
Post-Settlement, Sub-Adult, and Adult for Intermediate Species	Main Hawaiian Islands	H-6
Post-Settlement, Sub-Adult, and Adult for Deep Species	Main Hawaiian Islands	H-7
HAPC, All Species	Main Hawaiian Islands	H-8
Seamount Groundfish Coral Reef	Hancock Ecosystem Management Area	H-9
	Kure Atoll to Pearl and Hermes Reef	H-10
	Lisianski Island to Raita Bank	H-11
	Gardner Pinnacles to Necker Island	H-12
	Twin Banks to Middle Bank	H-13
	Ka'ula Rock to Kaua'i	H-14
	O'ahu	H-15
	Maui Nui	H-16
	Hawai'i Island	H-17
Crustaceans		
	Helsley Seamount to Pearl and Hermes Reef	H-18
	Lisianski Island to Raita Bank	H-19
	Gardner Pinnacles to French Frigate Shoals	H-20
	Necker Island to Middle Bank	H-21
	Ka'ula Rock to Kaua'i	H-22
	O'ahu to Maui Nui	H-23
	Hawai'i Island	H-24
Precious Corals		
	West Hawai'i Island	H-25
	Au'au Channel	H-26
	O'ahu	H-27
	Kaua'i	H-28
	WestPac Bed	H-29
	Brooks Bank	H-30
	180 Fathom Bank	H-31

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

Hawaiian Archipelago Fishery Ecosystem Plan

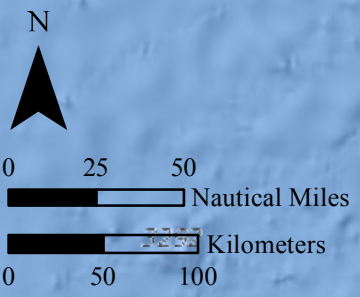
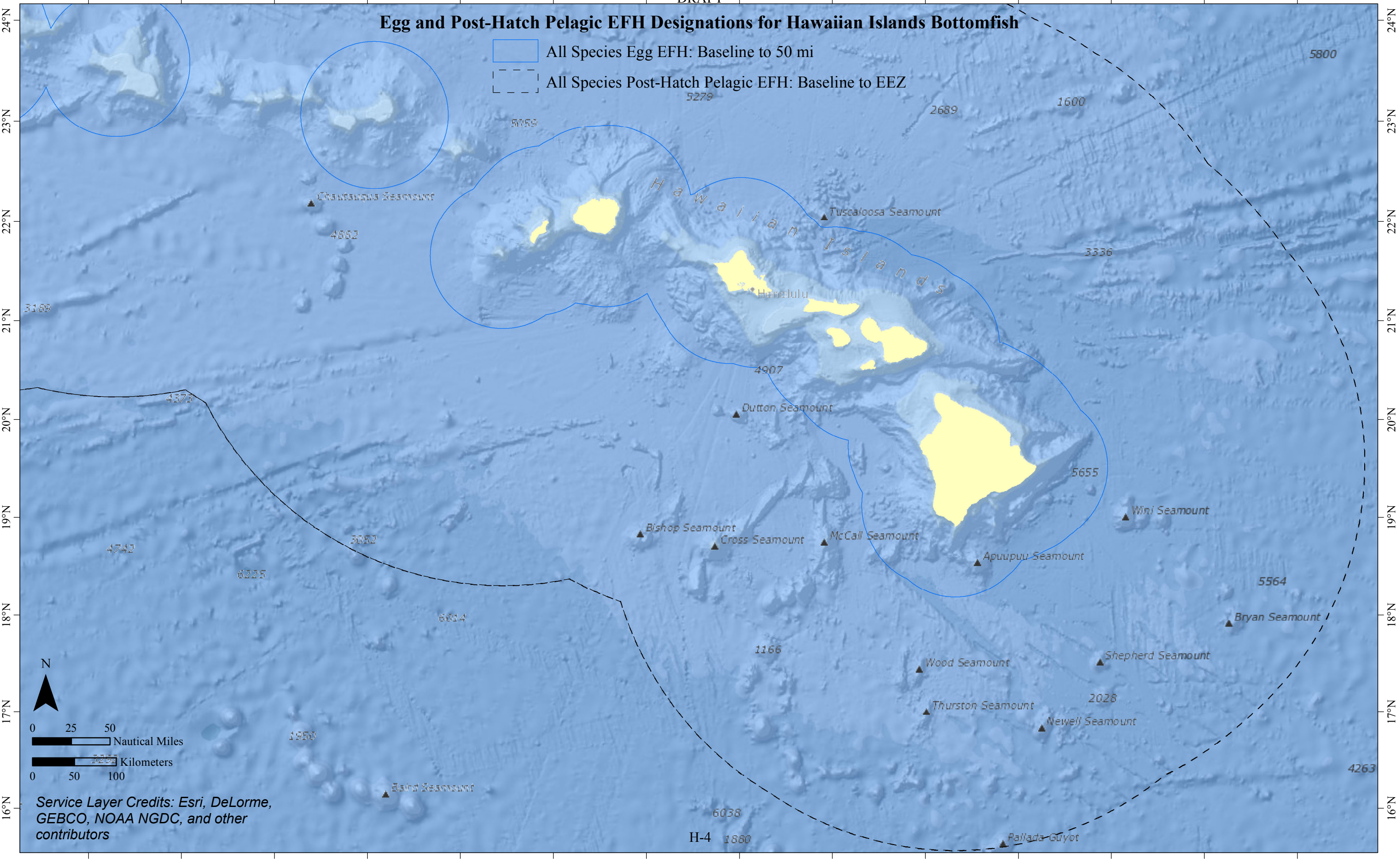
Egg and Larval EFH, All MUS: Hawaiian Archipelago



**The geographic extent of EFH is shown for the egg and larval (E/L) stages of all management unit species (MUS) except deepwater shrimp from the Crustaceans MUS. Other Crustacean E/L EFH is the water column to a depth of 150 m. Coral Reef E/L EFH is the water column to a depth of 100 m. Bottomfish E/L EFH is the water column to a depth of 400 m.*

Egg and Post-Hatch Pelagic EFH Designations for Hawaiian Islands Bottomfish

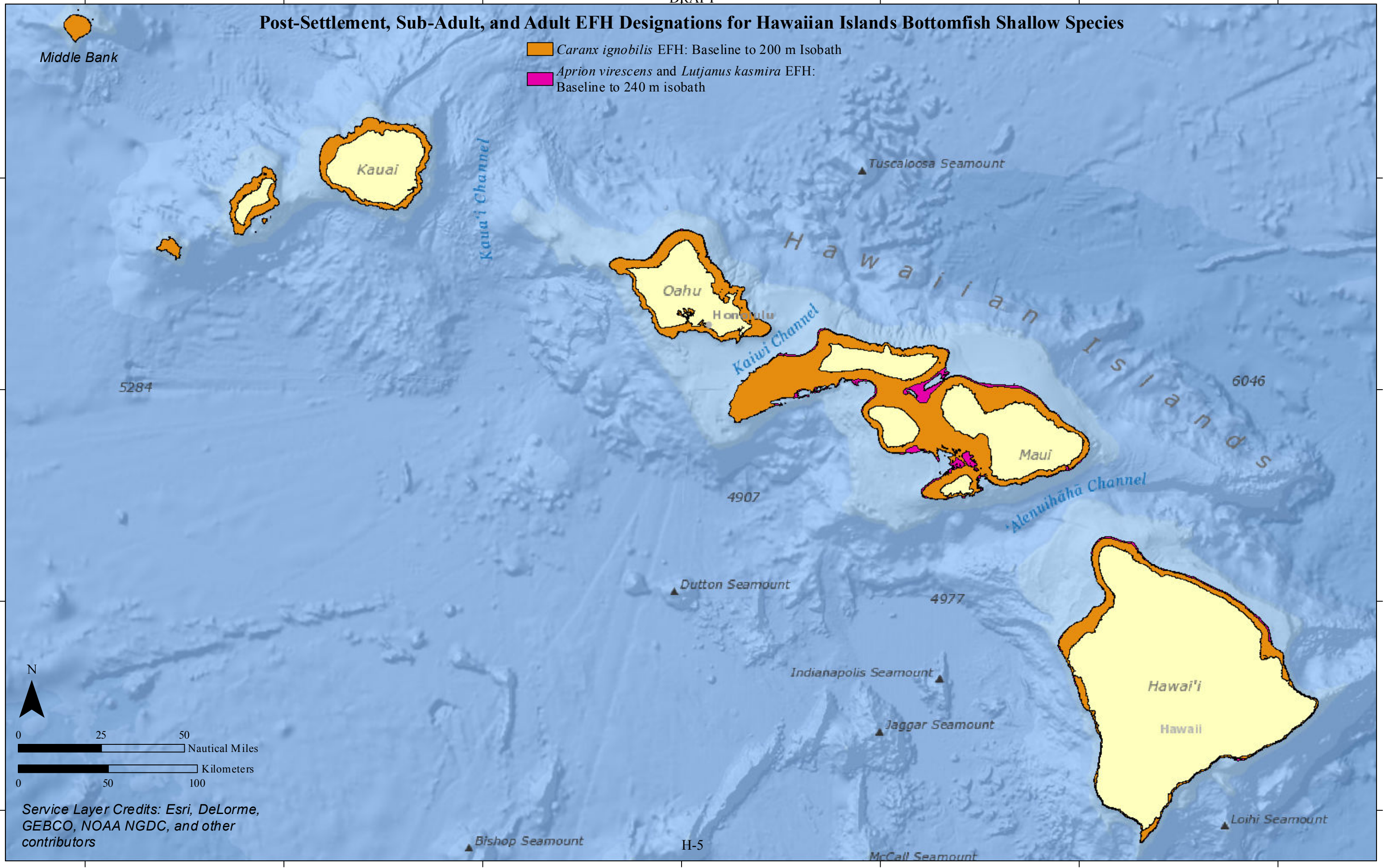
-  All Species Egg EFH: Baseline to 50 mi
-  All Species Post-Hatch Pelagic EFH: Baseline to EEZ



Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

Post-Settlement, Sub-Adult, and Adult EFH Designations for Hawaiian Islands Bottomfish Shallow Species

- *Caranx ignobilis* EFH: Baseline to 200 m Isobath
- *Aprion virescens* and *Lutjanus kasmira* EFH: Baseline to 240 m isobath



Middle Bank

Kauai

Oahu

Honolulu

Maui

Hawai'i

Hawaii

Kaua'i Channel

Kaiwi Channel

'Aleuihāhā Channel

Tuscaloosa Seamount

Dutton Seamount

Indianapolis Seamount

Jaggar Seamount

Loihi Seamount

Bishop Seamount

H-5

McCall Seamount

5284

4907

4977

6046

N

0 25 50 Nautical Miles

0 50 100 Kilometers

Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

161°W

160°W

159°W

158°W

157°W

156°W

155°W

22°N

21°N

20°N

19°N

22°N

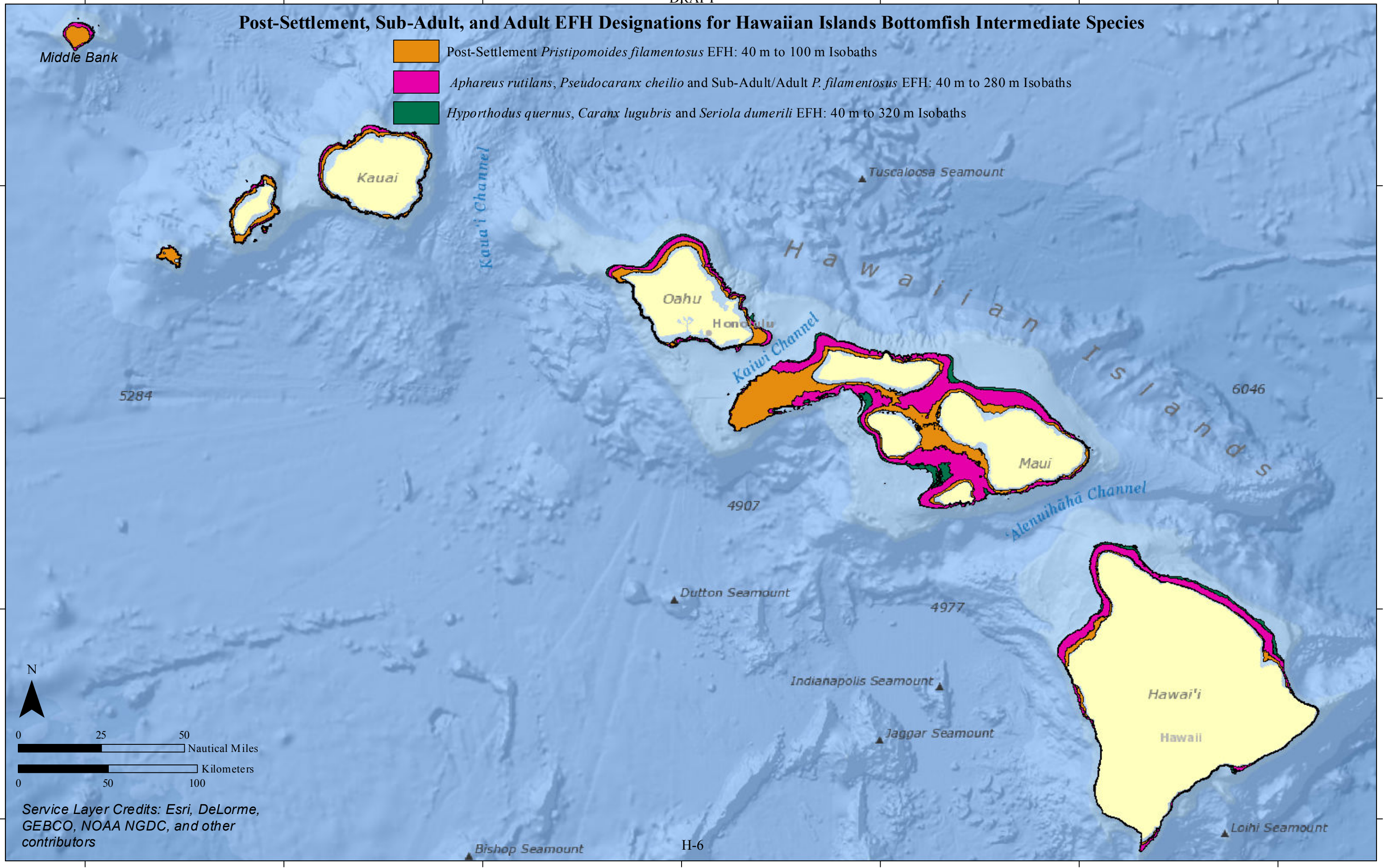
21°N

20°N

19°N

Post-Settlement, Sub-Adult, and Adult EFH Designations for Hawaiian Islands Bottomfish Intermediate Species

- Post-Settlement *Pristipomoides filamentosus* EFH: 40 m to 100 m Isobaths
- Aphareus rutilans*, *Pseudocaranx cheilio* and Sub-Adult/Adult *P. filamentosus* EFH: 40 m to 280 m Isobaths
- Hyporthodus quernus*, *Caranx lugubris* and *Seriola dumerili* EFH: 40 m to 320 m Isobaths



Middle Bank

Kauai

Oahu

Honolulu

Maui

Hawai'i

Hawaii

Kauai Channel

Kaiwi Channel

Alenuihaha Channel

Tuscaloosa Seamount

Dutton Seamount

Indianapolis Seamount

Jaggar Seamount

Loihi Seamount

Bishop Seamount

H-6

5284

4907

4977

6046



0 25 50 Nautical Miles

0 50 100 Kilometers

Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

161°W

160°W

159°W

158°W

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156°W

155°W

22°N

21°N

20°N

19°N

22°N

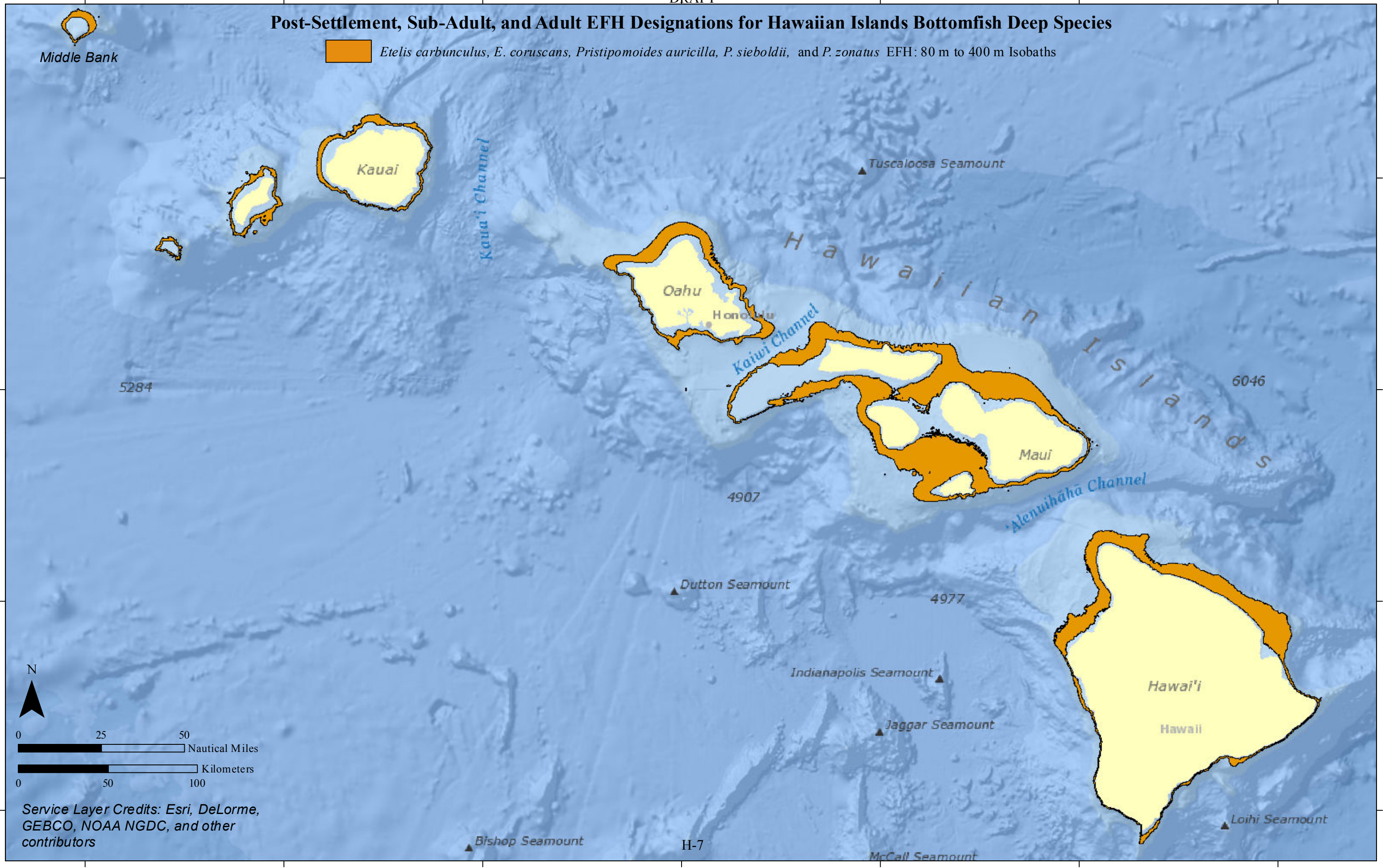
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Post-Settlement, Sub-Adult, and Adult EFH Designations for Hawaiian Islands Bottomfish Deep Species

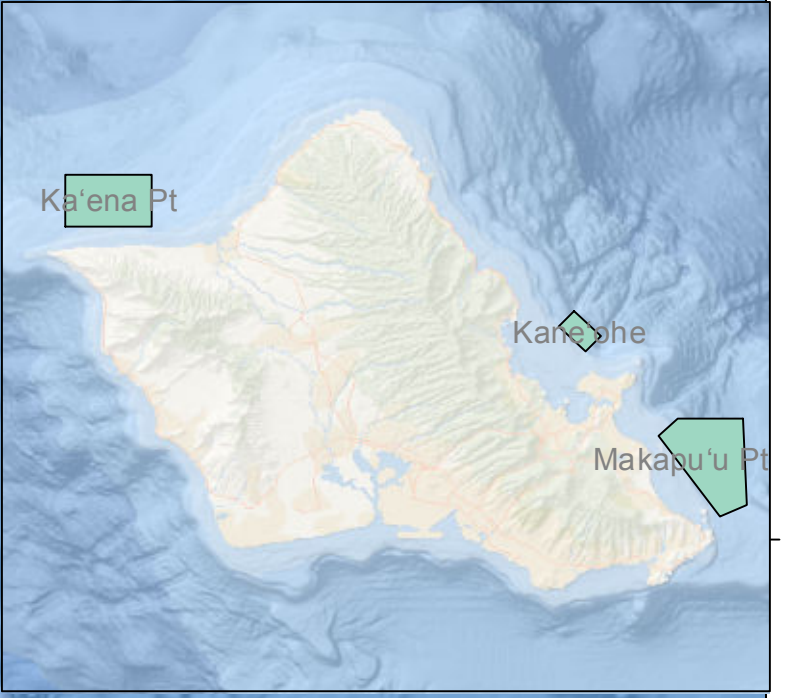
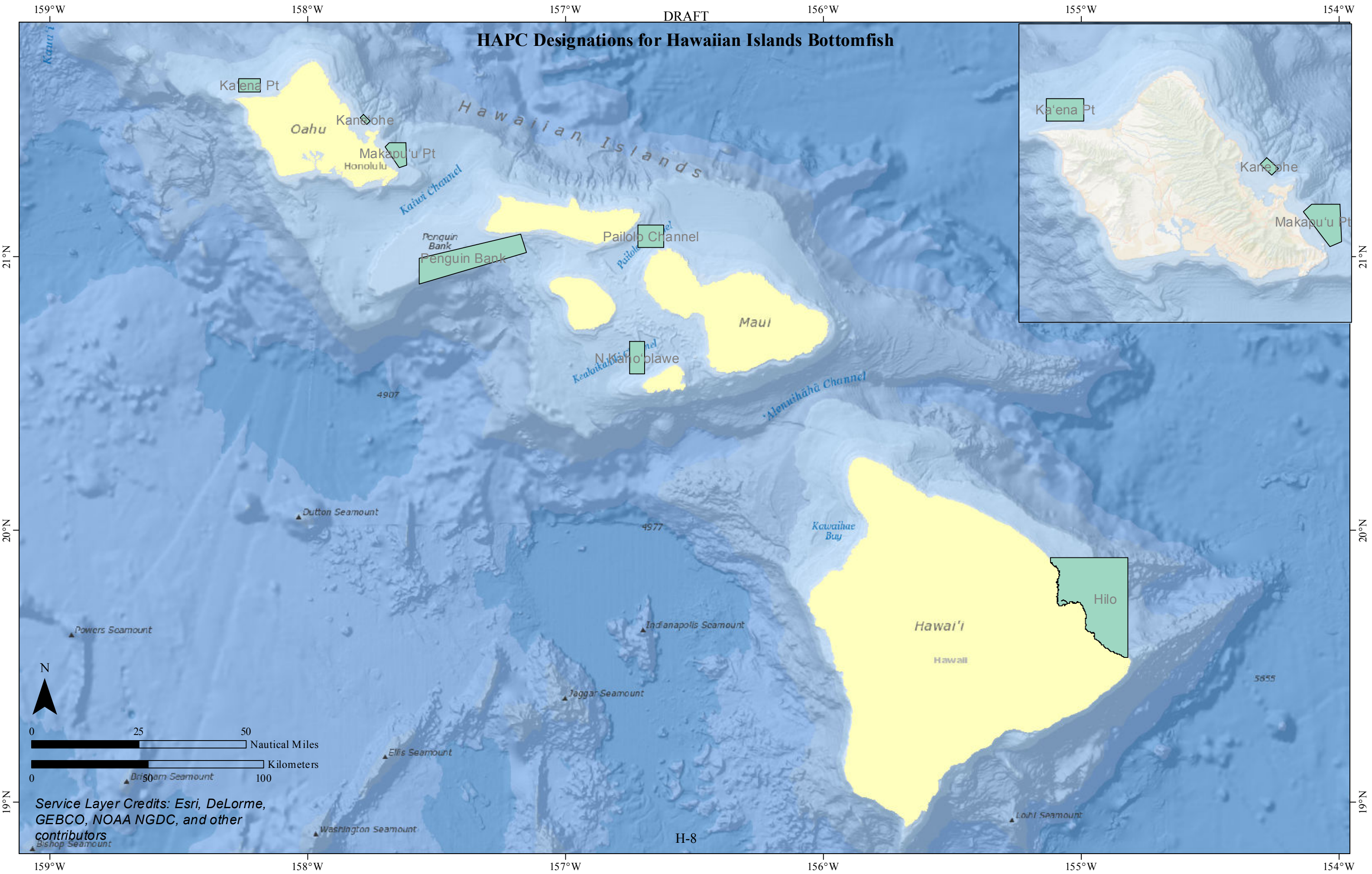
 *Etelis carbunculus*, *E. coruscans*, *Pristipomoides auricilla*, *P. sieboldii*, and *P. zonatus* EFH: 80 m to 400 m Isobaths



Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

HAPC Designations for Hawaiian Islands Bottomfish

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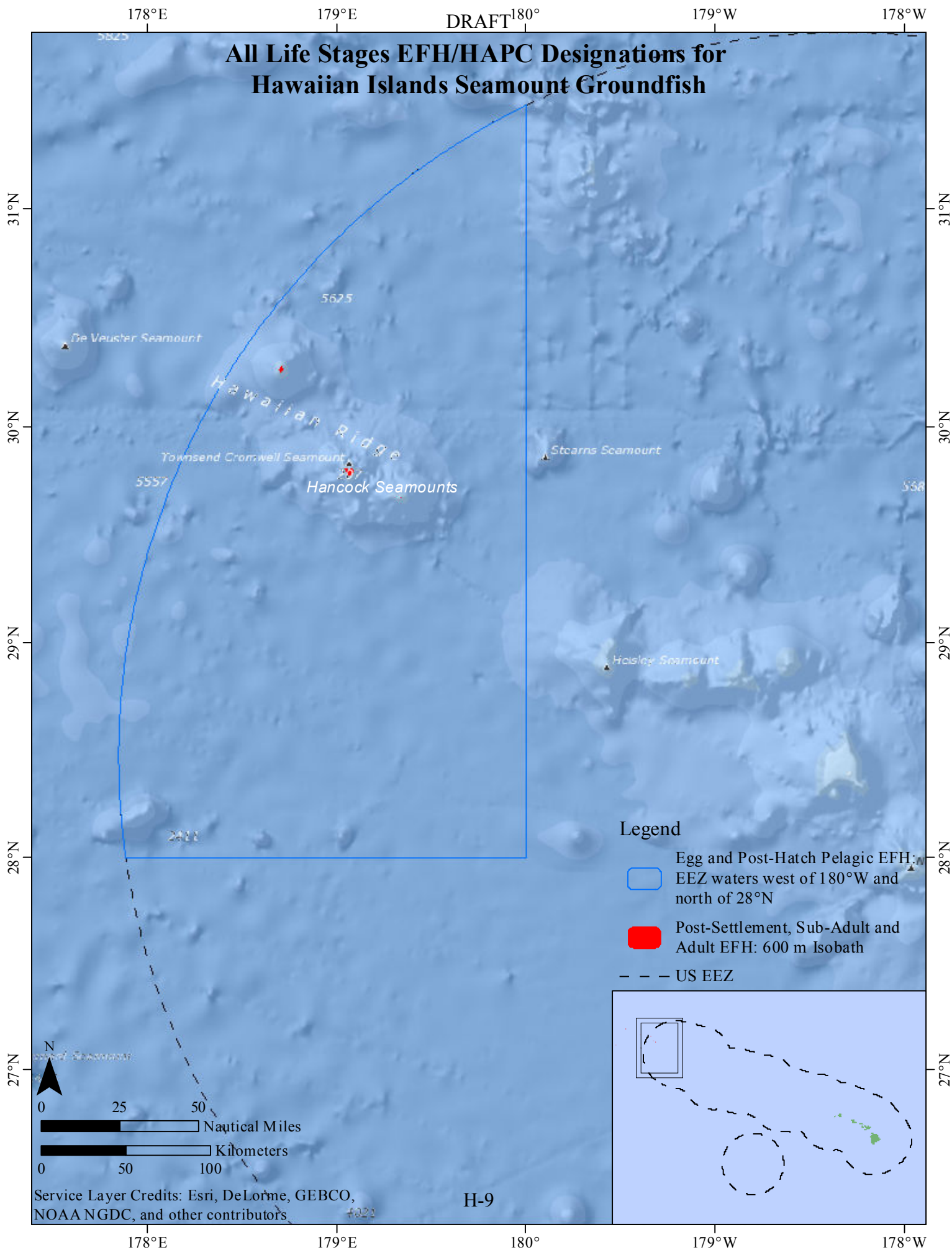


Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

H-8

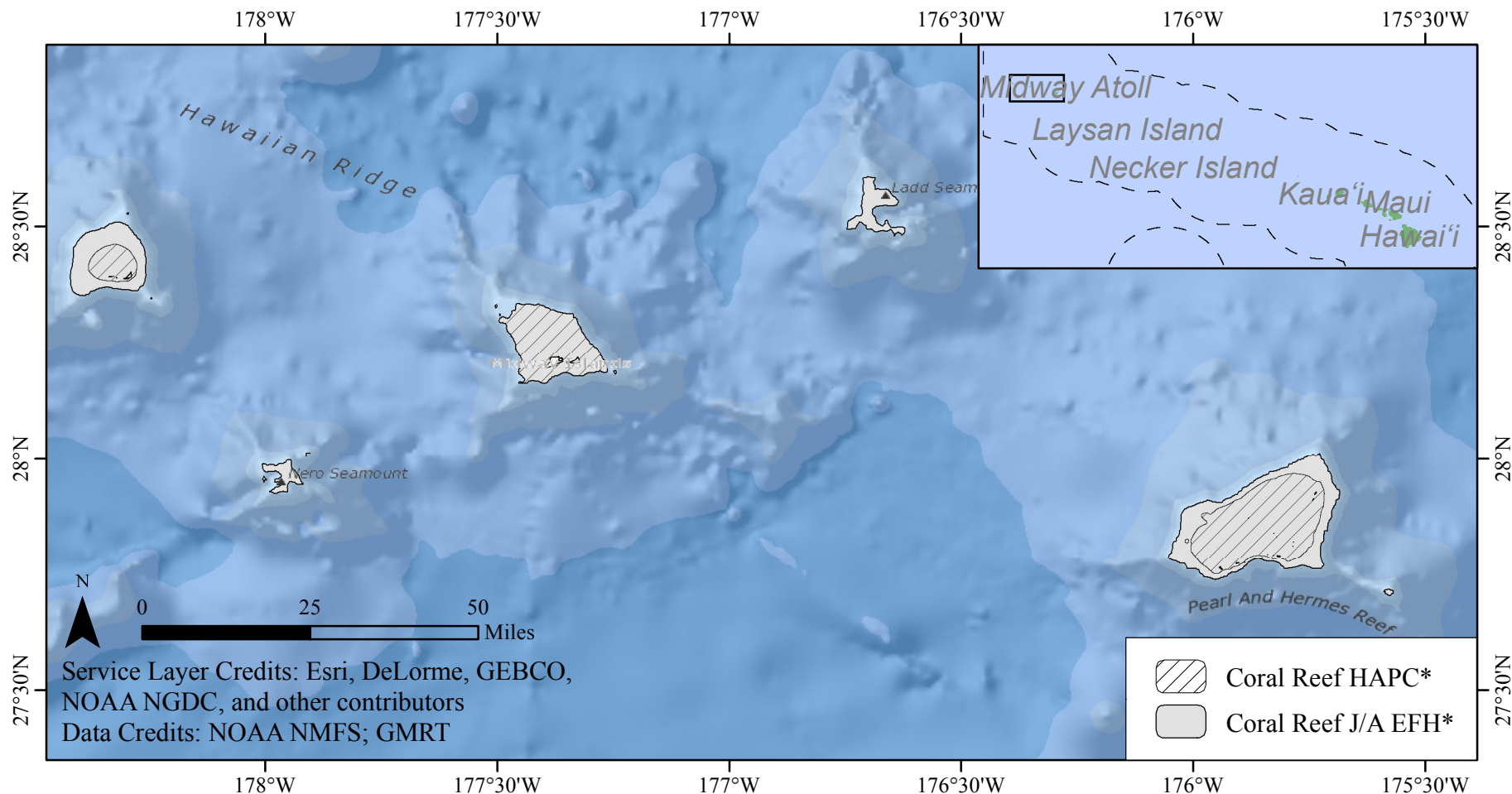
All Life Stages EFH/HAPC Designations for Hawaiian Islands Seamount Groundfish

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Hawaiian Archipelago Fishery Ecosystem Plan

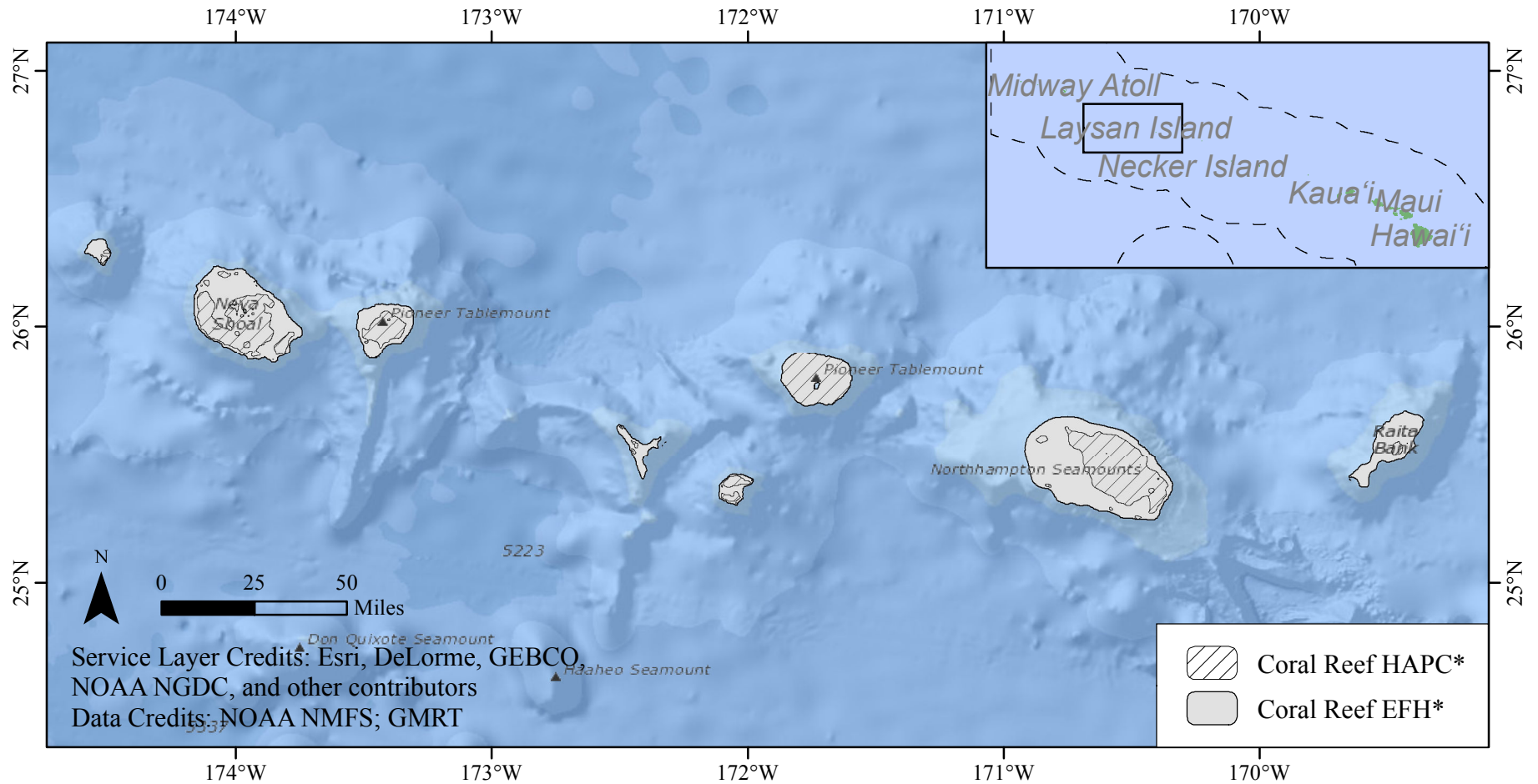
Coral Reef Essential Fish Habitat: Kure Atoll to Pearl and Hermes Reef



**The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the NWHI is all substrate 0-10 fathoms and all substrate at French Frigate Shoals, Midway, and Laysan 0-50 fathoms.*

Hawaiian Archipelago Fishery Ecosystem Plan

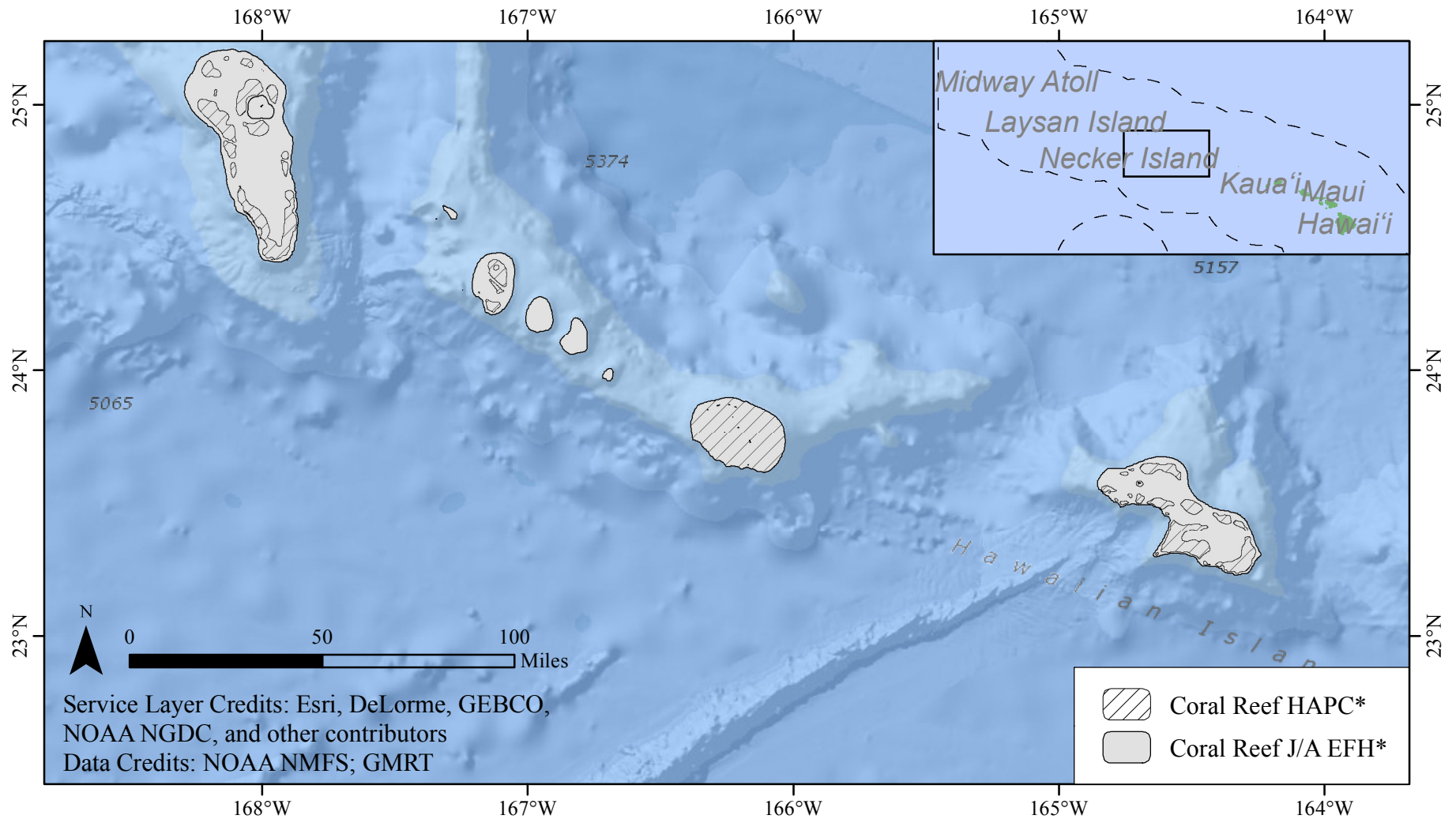
Coral Reef Essential Fish Habitat: Lisianski Island to Raita Bank



**The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the NWHI is all substrate 0-10 fathoms and all substrate at French Frigate Shoals, Midway, and Laysan 0-50 fathoms.*

Hawaiian Archipelago Fishery Ecosystem Plan

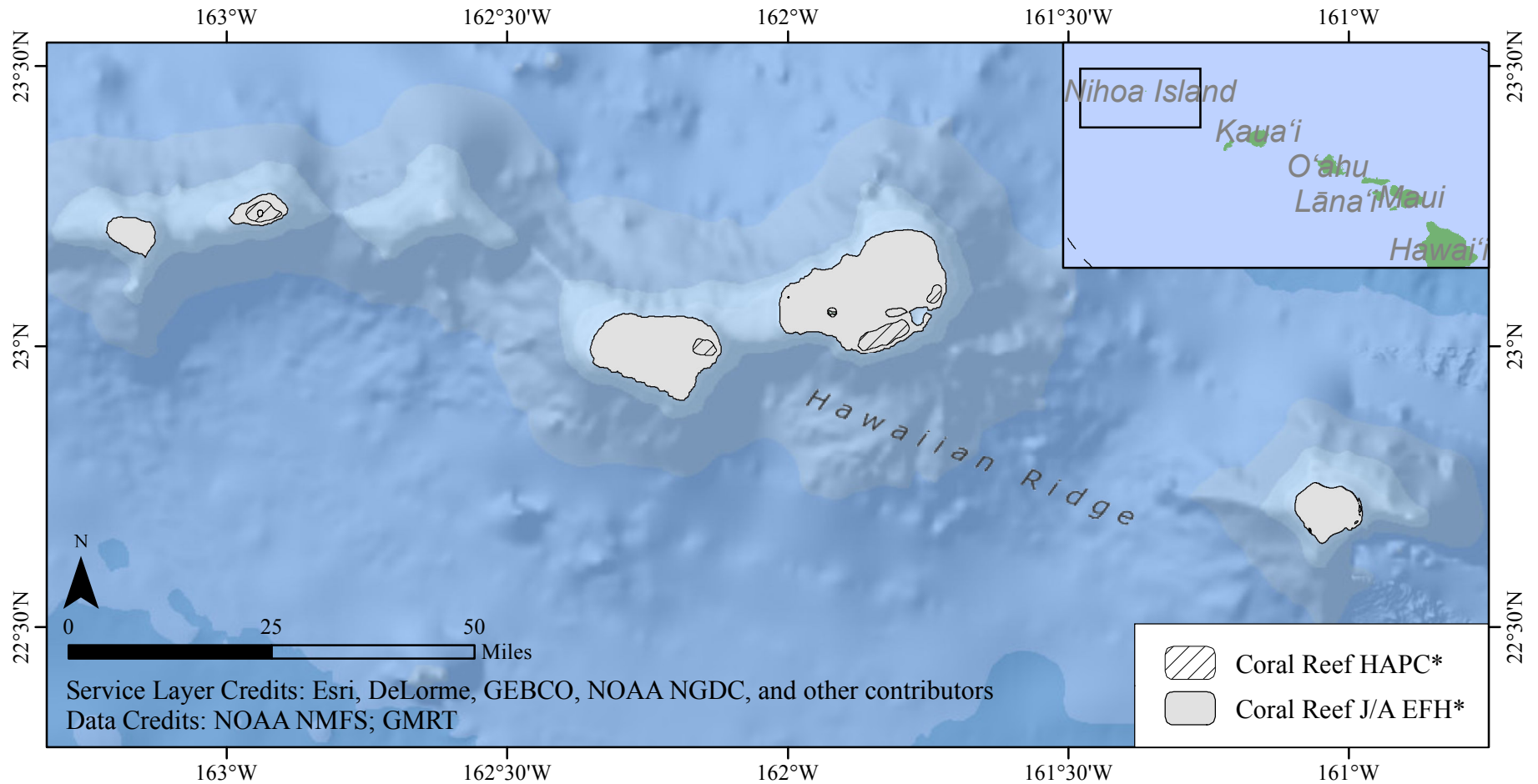
Coral Reef Essential Fish Habitat: Gardner Pinnacles to Necker Island



*The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the NWHI is all substrate 0-10 fathoms and all substrate at French Frigate Shoals, Midway, and Laysan 0-50 fathoms.

Hawaiian Archipelago Fishery Ecosystem Plan

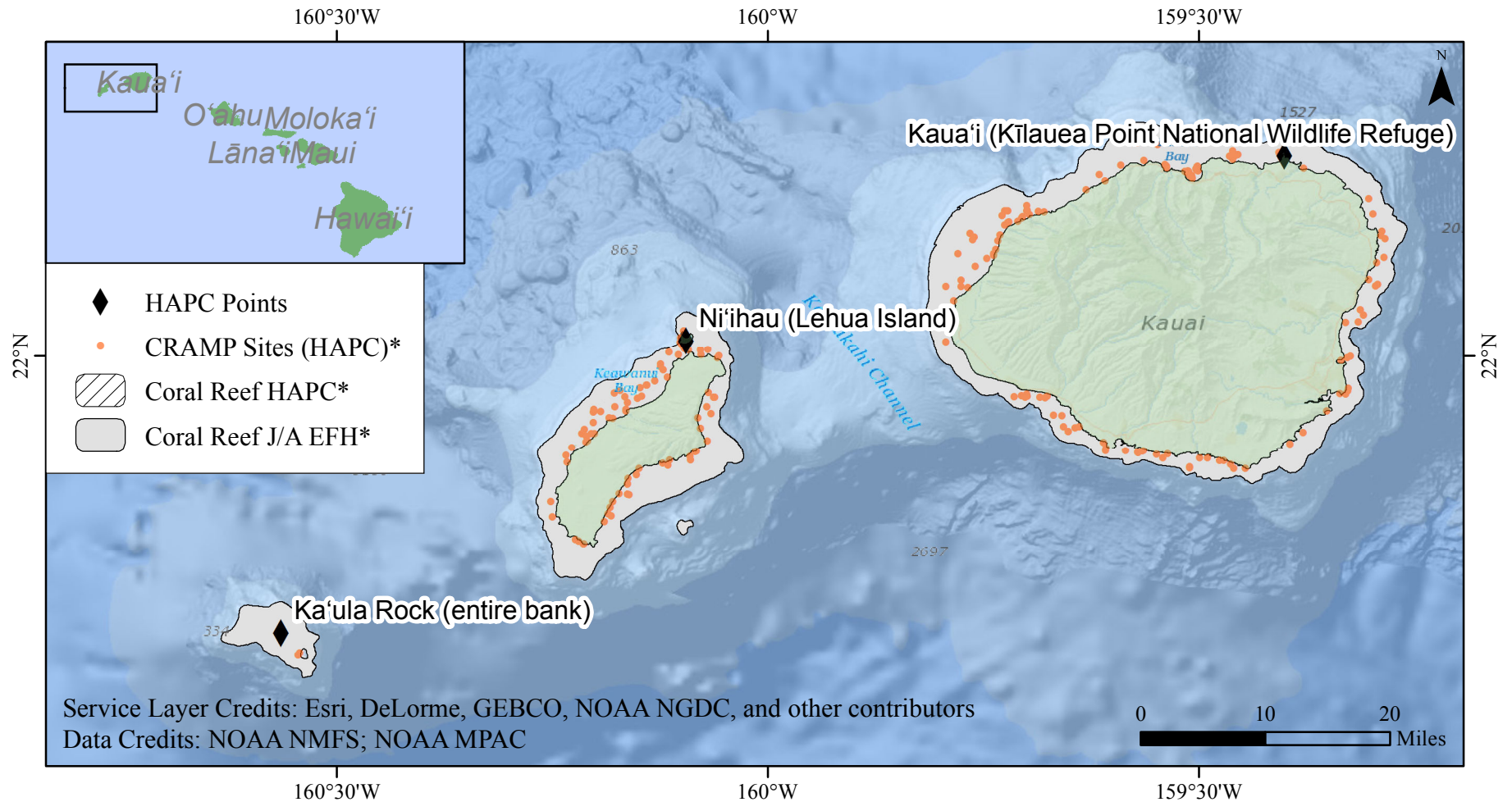
Coral Reef Essential Fish Habitat: Twin Banks to Middle Bank



**The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the NWHI is all substrate 0-10 fathoms and all substrate at French Frigate Shoals, Midway, and Laysan 0-50 fathoms.*

Hawaiian Archipelago Fishery Ecosystem Plan

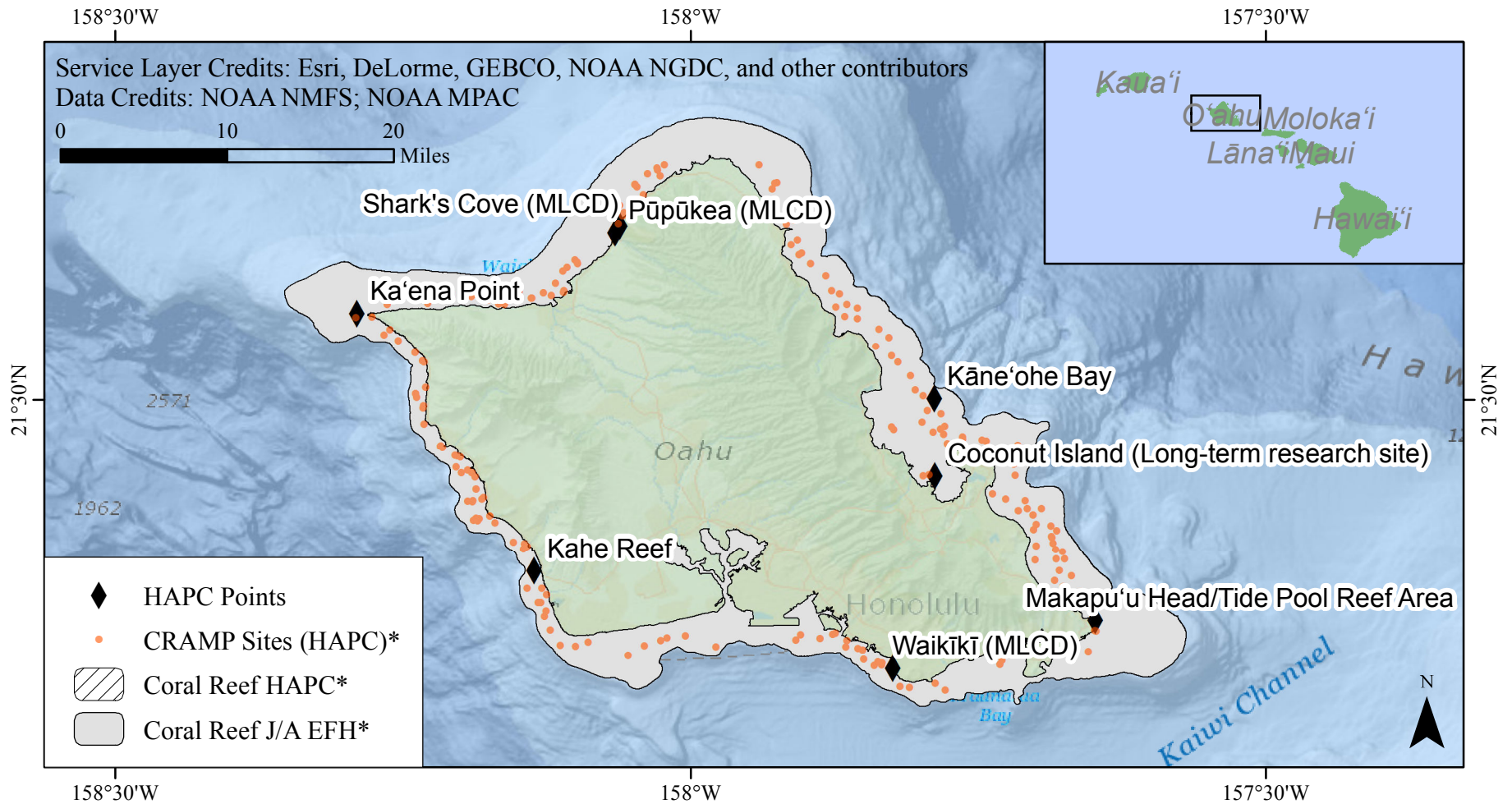
Coral Reef Essential Fish Habitat: Ka'ula Rock to Kaua'i



**The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the MHI includes all CRAMP sites.*

Hawaiian Archipelago Fishery Ecosystem Plan

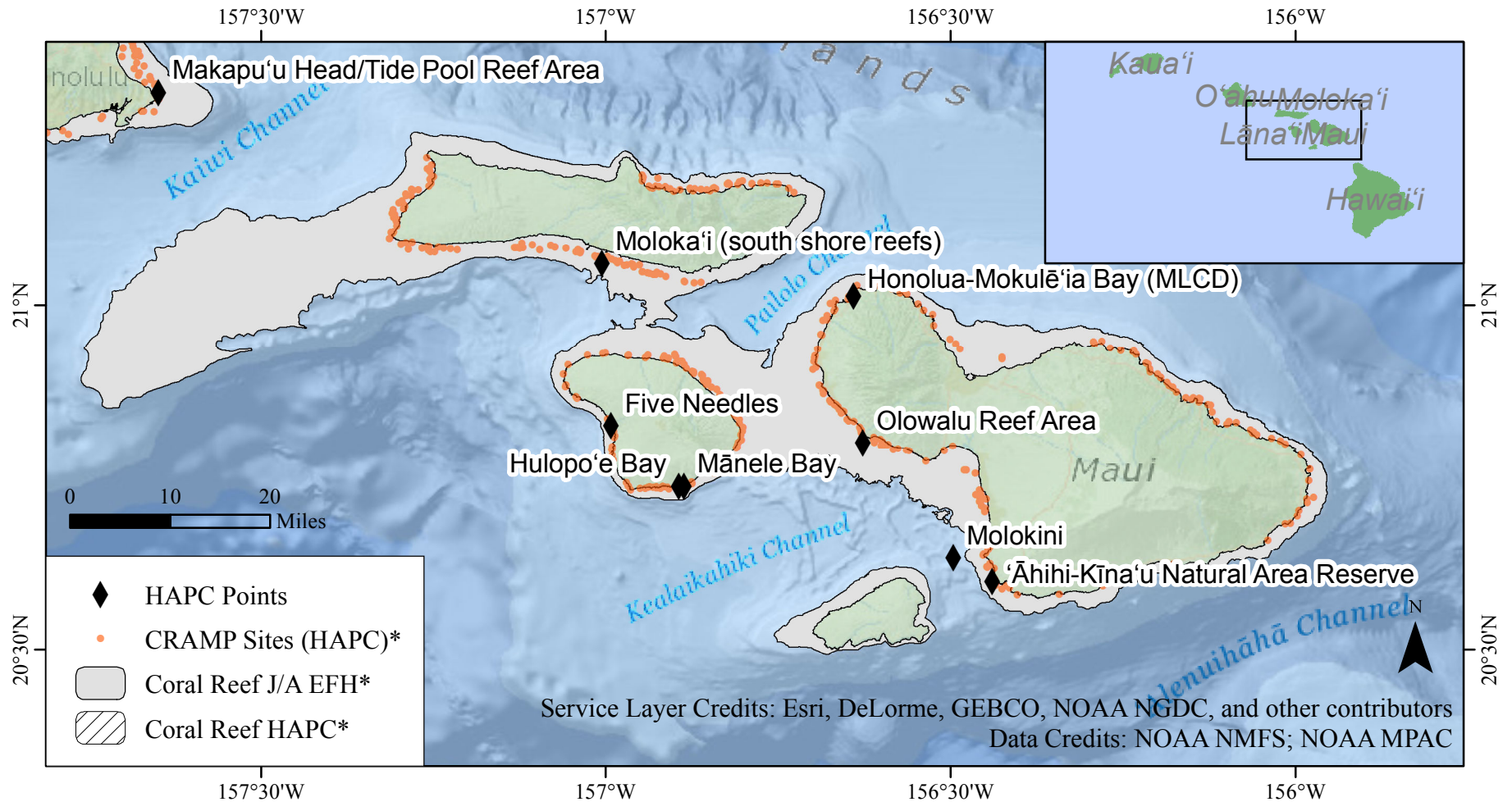
Coral Reef Essential Fish Habitat: O‘ahu



**The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the MHI includes all CRAMP sites.*

Hawaiian Archipelago Fishery Ecosystem Plan

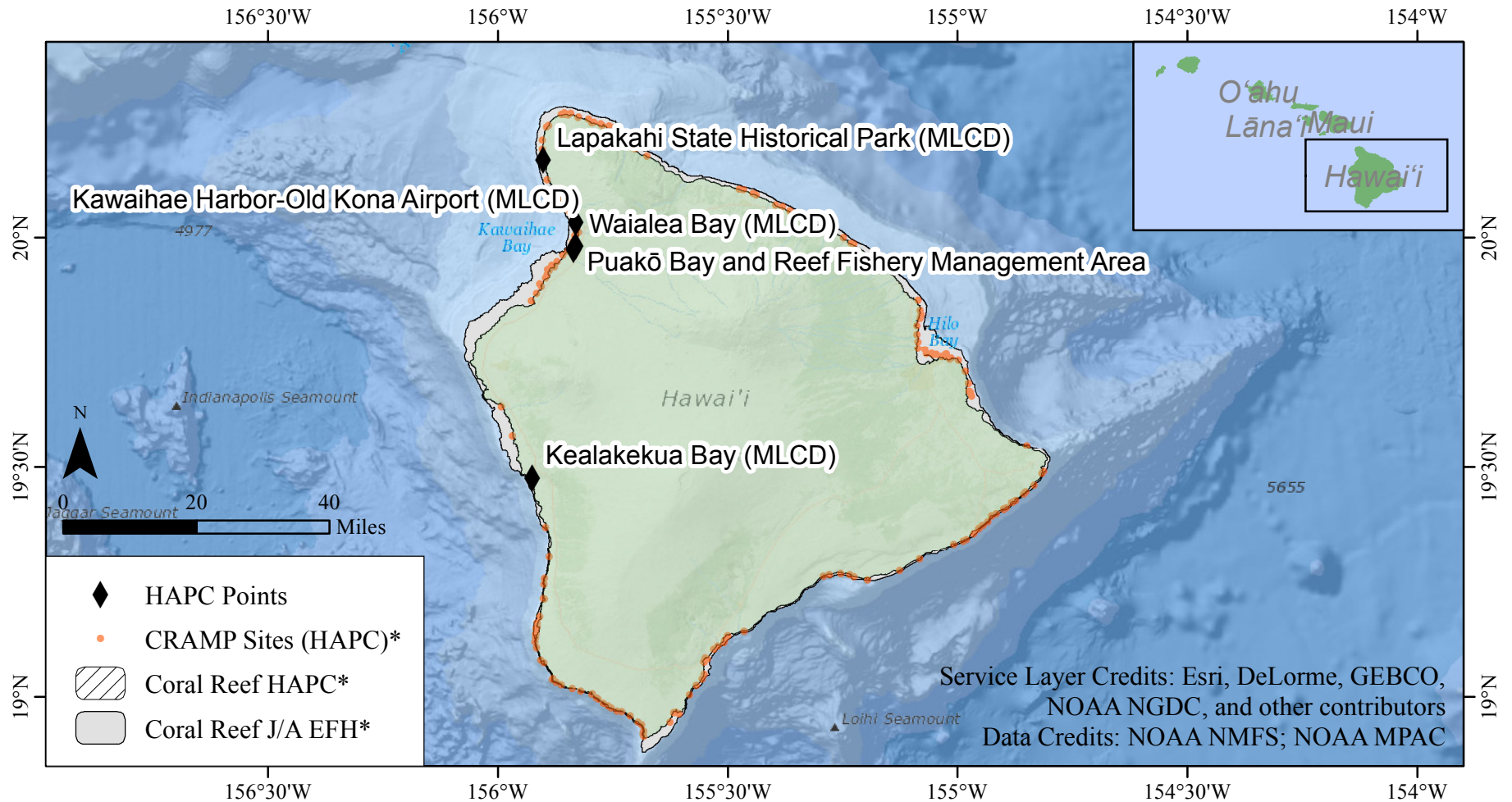
Coral Reef Essential Fish Habitat: Maui Nui



**The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the MHI includes all CRAMP sites.*

Hawaiian Archipelago Fishery Ecosystem Plan

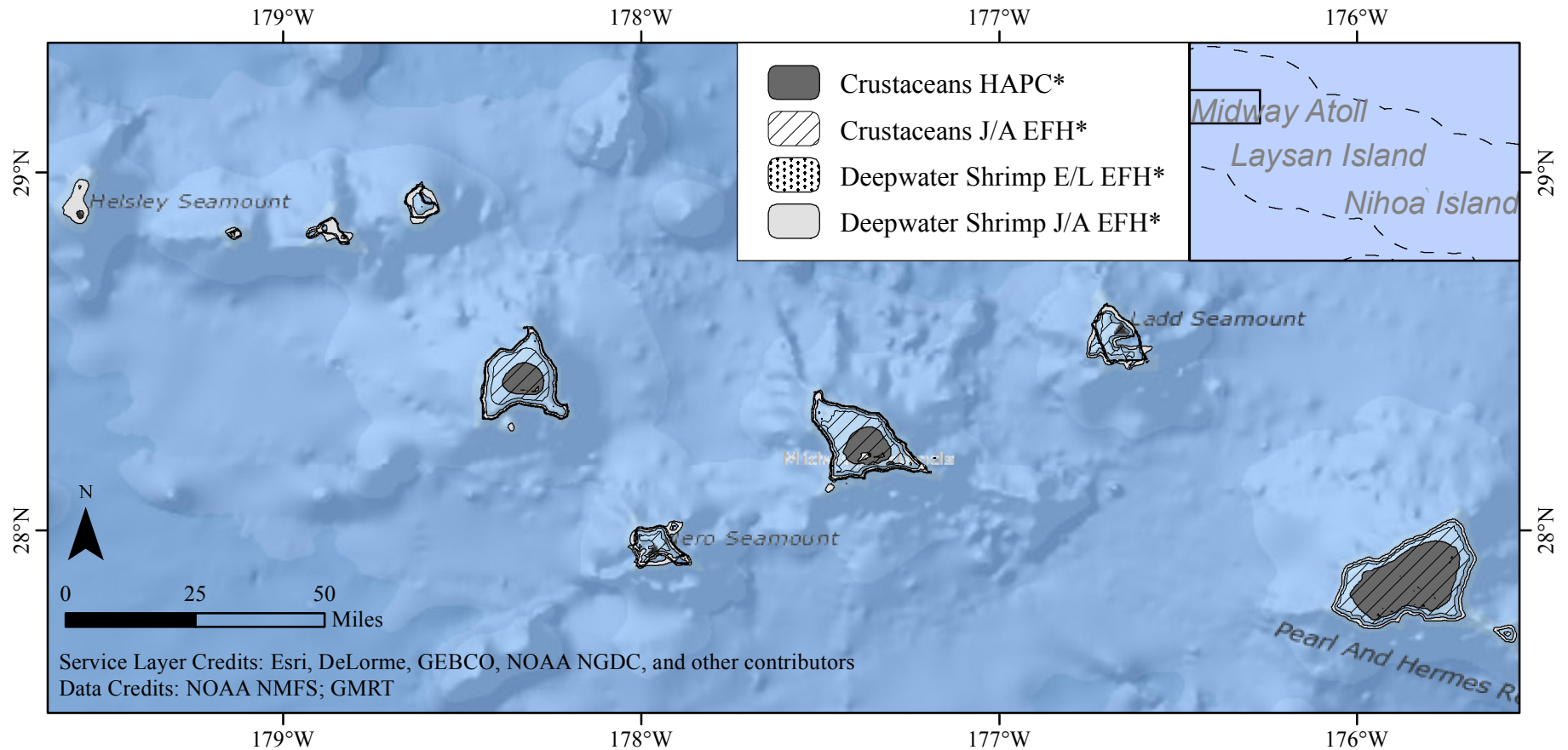
Coral Reef Essential Fish Habitat: Hawai‘i Island



**The geographic extent of juvenile/adult (J/A) EFH is shown. EFH for eggs and larvae is the water column to a depth of 100 m from the shoreline to the outer boundary of the EEZ, while J/A EFH is all bottom habitat and the adjacent water column to a depth of 100 m to the extent shown. The type of bottom habitat varies by family. HAPC in the MHI includes all CRAMP sites.*

Hawaiian Archipelago Fishery Ecosystem Plan

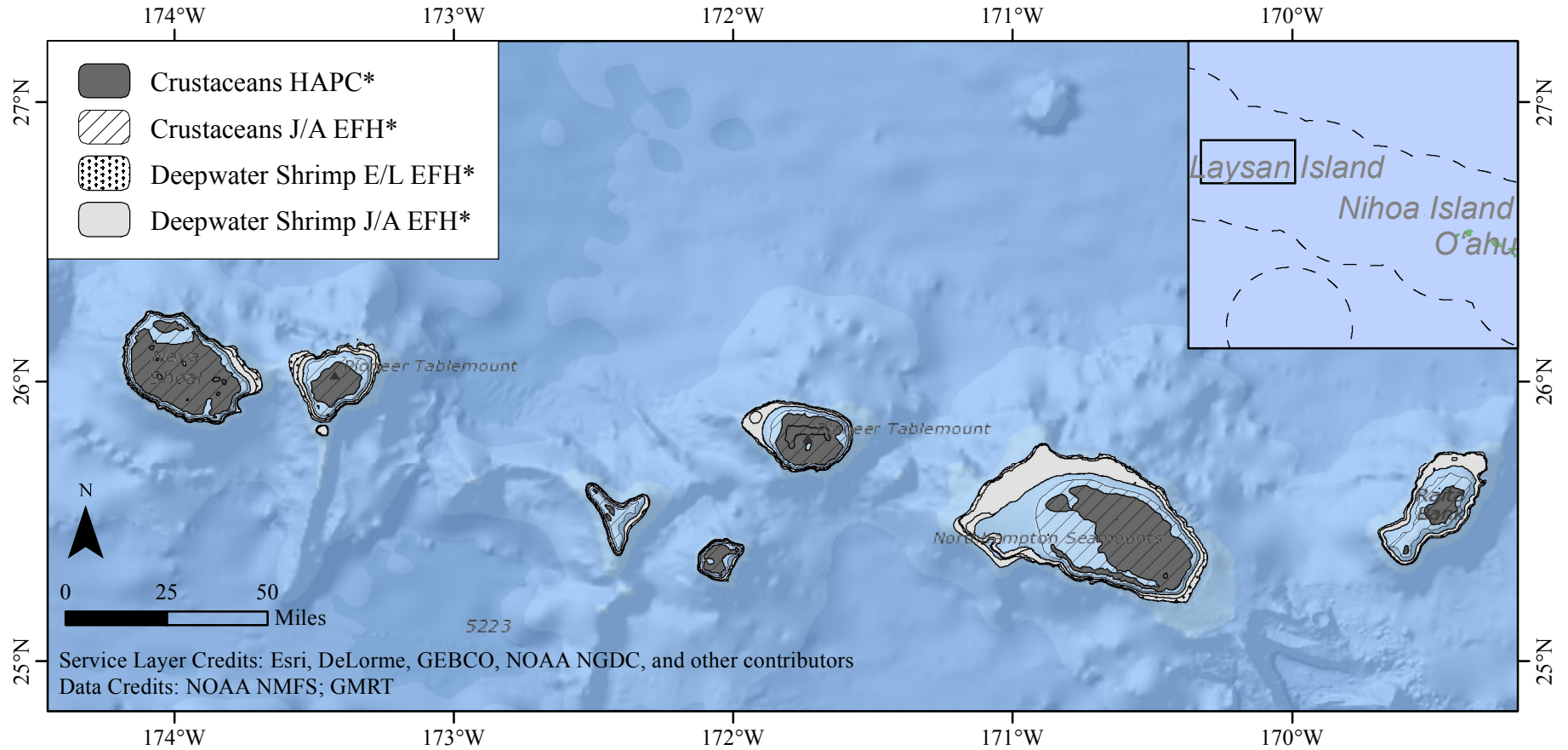
Crustaceans Essential Fish Habitat: Helsley Seamount to Pearl and Hermes Reef



**The geographic extent of EFH is shown. EFH for crustaceans eggs and larvae (E/L) is the water column to a depth of 150 m from the shoreline to the outer boundary of the EEZ, while juvenile/adult (J/A) EFH is all bottom habitat to a depth of 100 m to the extent shown.. HAPC is all banks in the NWHI with summits shallower than 30 m. Deepwater shrimp E/L EFH is the water column and outer reef slopes between 550 m and 700 m to the extent shown, while deepwater shrimp J/A EFH is the outer reef slopes between 300 and 700 meters to the extent shown.*

Hawaiian Archipelago Fishery Ecosystem Plan

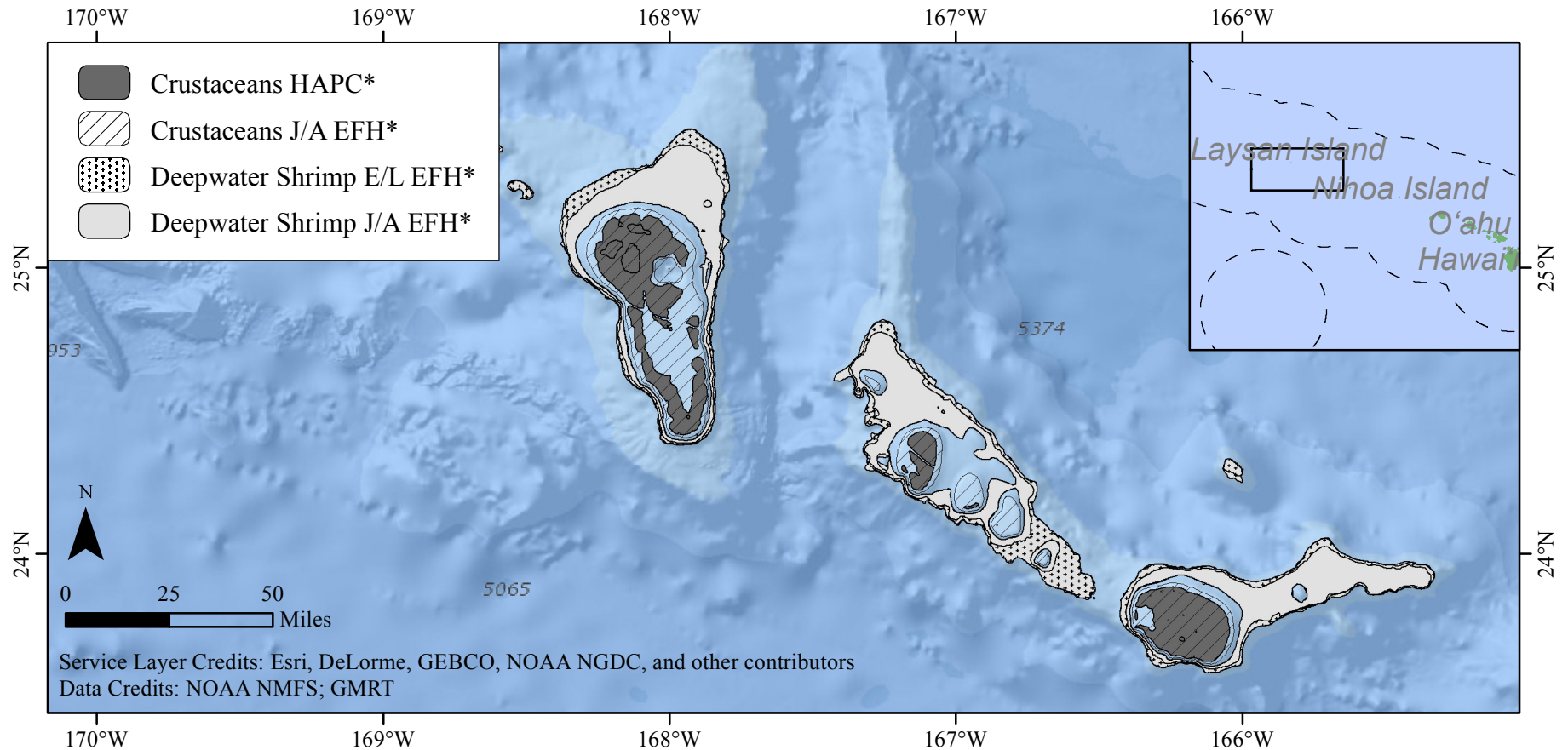
Crustaceans Essential Fish Habitat: Lisianski Island to Raita Bank



**The geographic extent of EFH is shown. EFH for crustaceans eggs and larvae (E/L) is the water column to a depth of 150 m from the shoreline to the outer boundary of the EEZ, while juvenile/adult (J/A) EFH is all bottom habitat to a depth of 100 m to the extent shown.. HAPC is all banks in the NWHI with summits shallower than 30 m. Deepwater shrimp E/L EFH is the water column and outer reef slopes between 550 m and 700 m to the extent shown, while deepwater shrimp J/A EFH is the outer reef slopes between 300 and 700 meters to the extent shown.*

Hawaiian Archipelago Fishery Ecosystem Plan

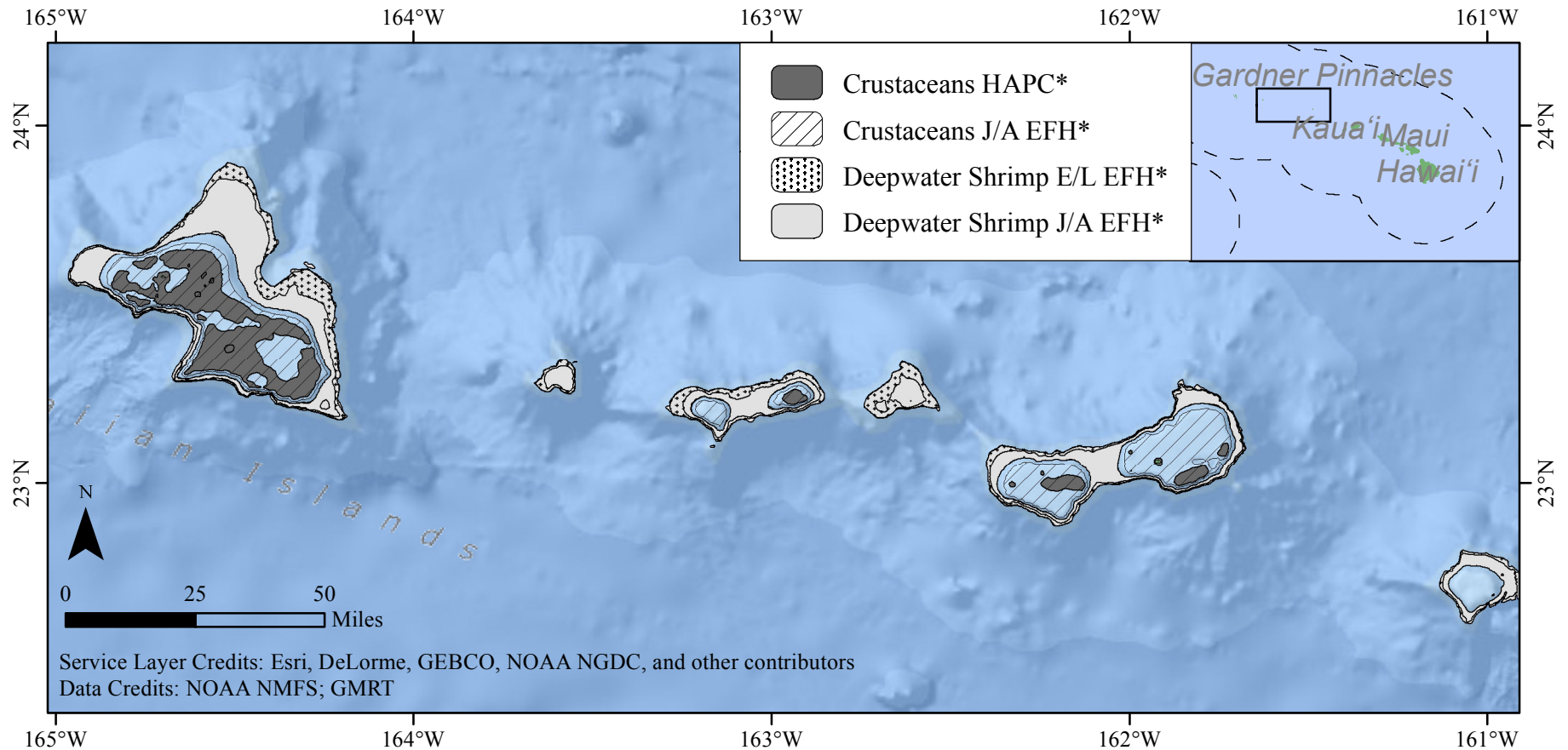
Crustaceans Essential Fish Habitat: Gardner Pinnacles to French Frigate Shoals



**The geographic extent of EFH is shown. EFH for crustaceans eggs and larvae (E/L) is the water column to a depth of 150 m from the shoreline to the outer boundary of the EEZ, while juvenile/adult (J/A) EFH is all bottom habitat to a depth of 100 m to the extent shown.. HAPC is all banks in the NWHI with summits shallower than 30 m. Deepwater shrimp E/L EFH is the water column and outer reef slopes between 550 m and 700 m to the extent shown, while deepwater shrimp J/A EFH is the outer reef slopes between 300 and 700 meters to the extent shown.*

Hawaiian Archipelago Fishery Ecosystem Plan

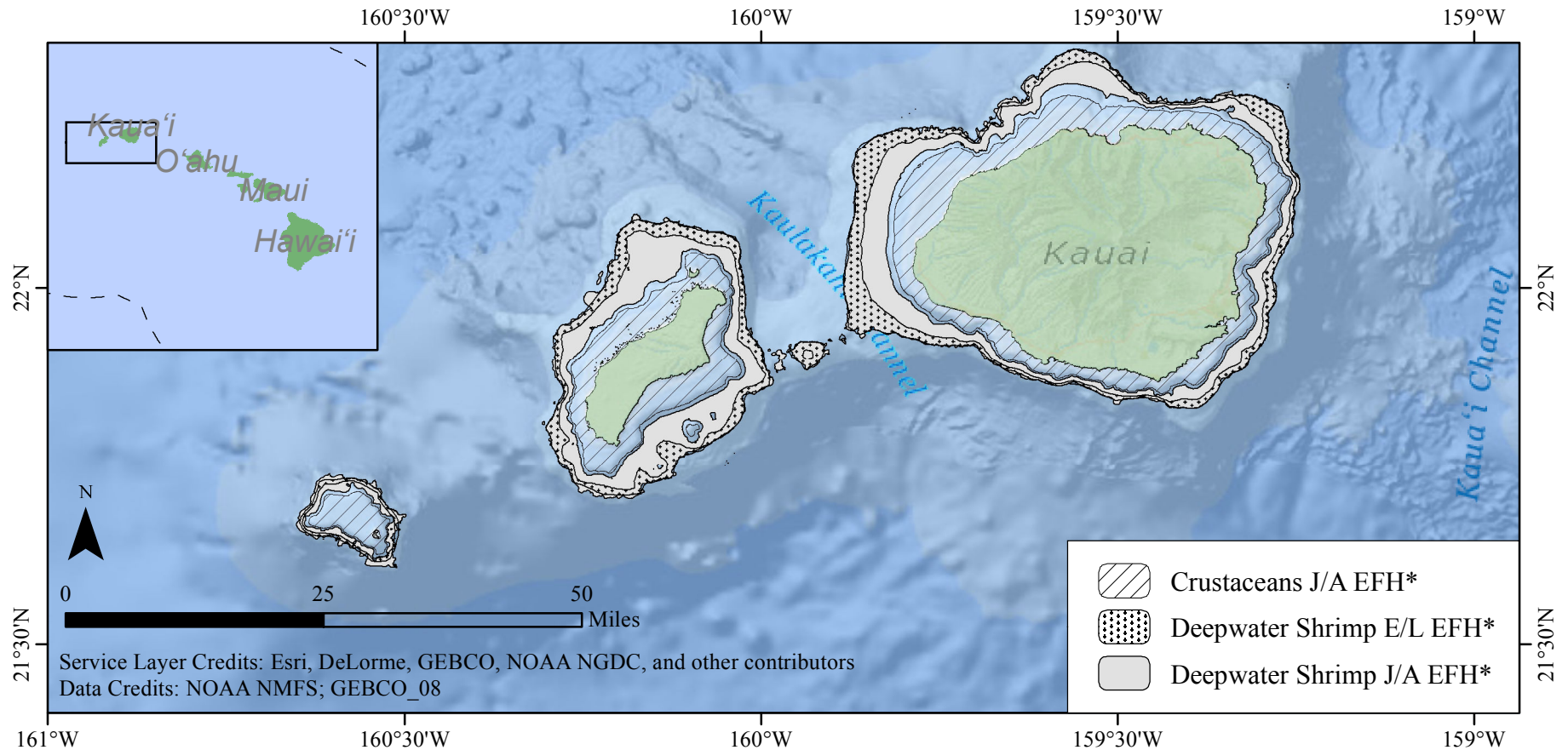
Crustaceans Essential Fish Habitat: Necker Island to Middle Bank



**The geographic extent of EFH is shown. EFH for crustaceans eggs and larvae (E/L) is the water column to a depth of 150 m from the shoreline to the outer boundary of the EEZ, while juvenile/adult (J/A) EFH is all bottom habitat to a depth of 100 m to the extent shown.. HAPC is all banks in the NWHI with summits shallower than 30 m. Deepwater shrimp E/L EFH is the water column and outer reef slopes between 550 m and 700 m to the extent shown, while deepwater shrimp J/A EFH is the outer reef slopes between 300 and 700 meters to the extent shown.*

Hawaiian Archipelago Fishery Ecosystem Plan

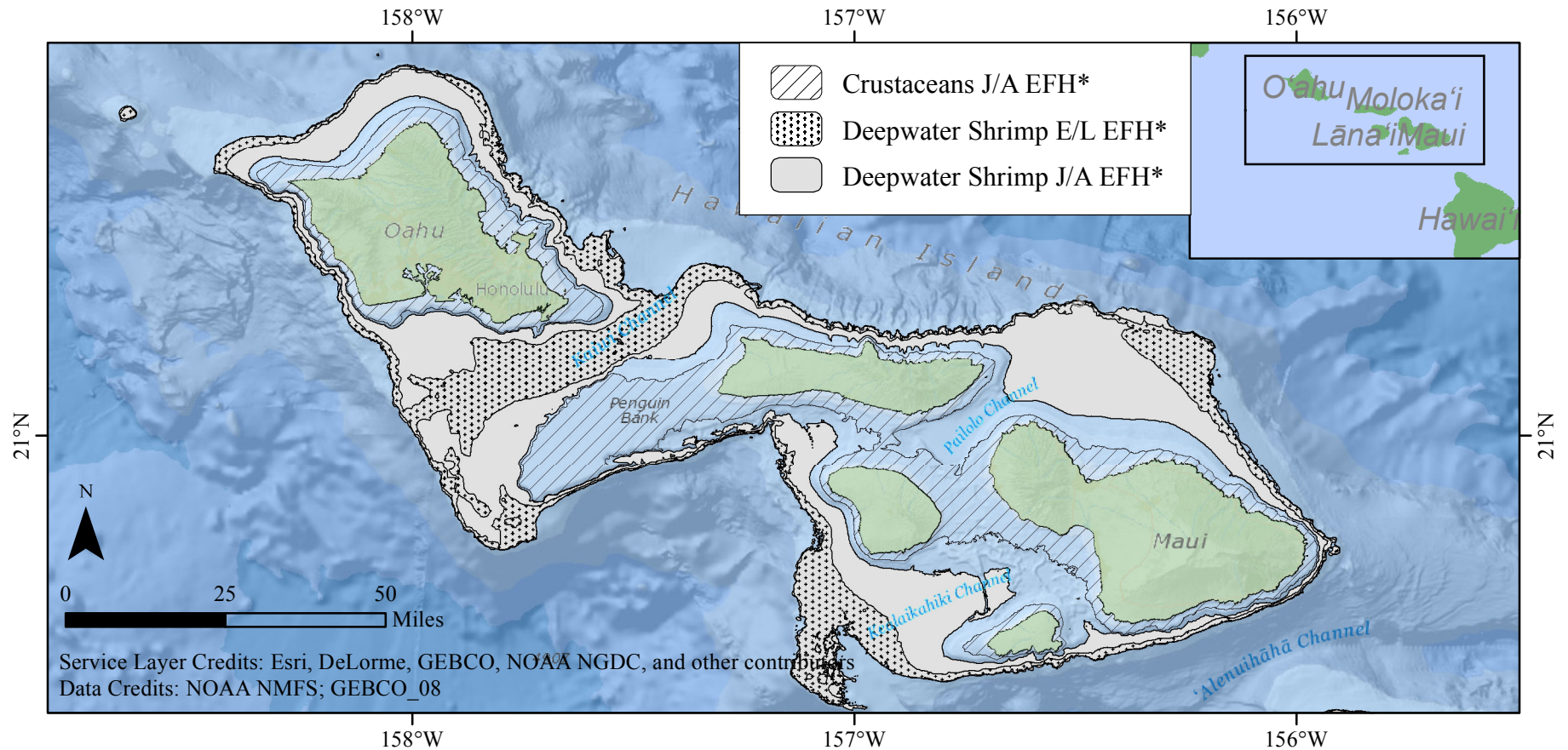
Crustaceans Essential Fish Habitat: Ka'ula Rock to Kaua'i



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Hawaiian Archipelago Fishery Ecosystem Plan

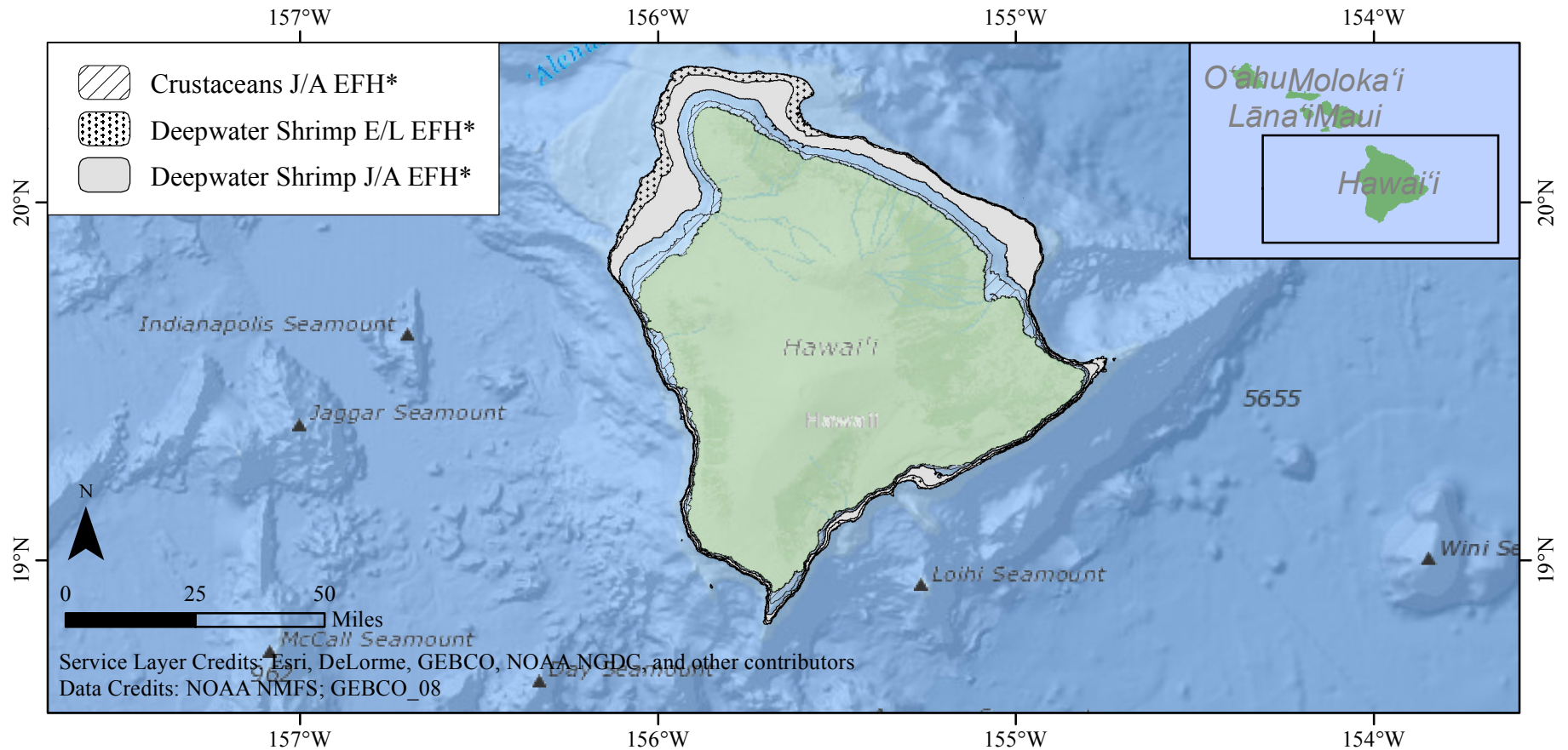
Crustaceans Essential Fish Habitat: O‘ahu to Maui Nui



**The geographic extent of EFH is shown. EFH for crustaceans eggs and larvae (E/L) is the water column to a depth of 150 m from the shoreline to the outer boundary of the EEZ, while juvenile/adult (J/A) EFH is all bottom habitat to a depth of 100 m to the extent shown.. HAPC is all banks in the NWHI with summits shallower than 30 m. Deepwater shrimp E/L EFH is the water column and outer reef slopes between 550 m and 700 m to the extent shown, while deepwater shrimp J/A EFH is the outer reef slopes between 300 and 700 meters to the extent shown.*

Hawaiian Archipelago Fishery Ecosystem Plan

Crustaceans Essential Fish Habitat: Hawai‘i Island

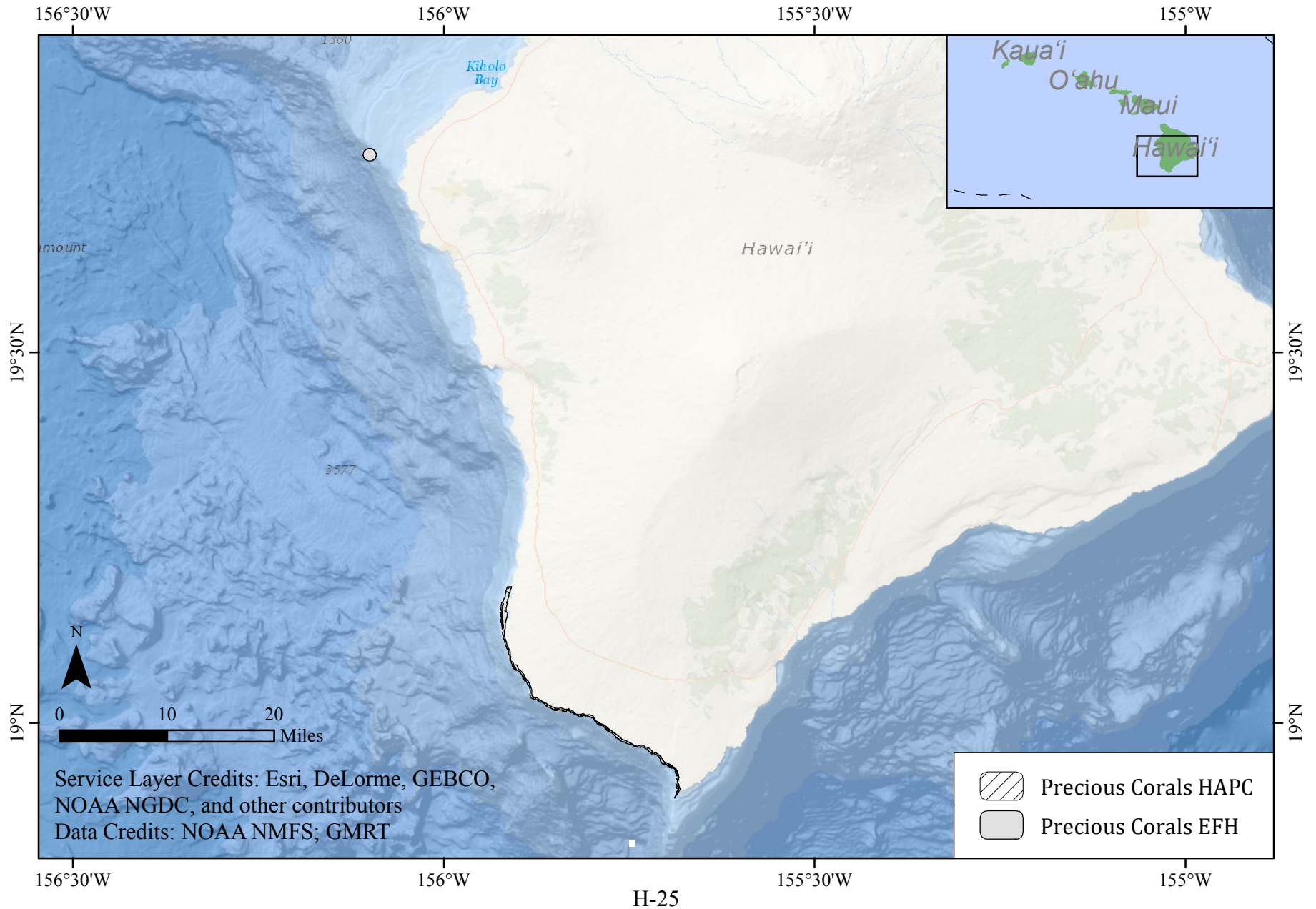


**The geographic extent of EFH is shown. EFH for crustaceans eggs and larvae (E/L) is the water column to a depth of 150 m from the shoreline to the outer boundary of the EEZ, while juvenile/adult (J/A) EFH is all bottom habitat to a depth of 100 m to the extent shown.. HAPC is all banks in the NWHI with summits shallower than 30 m. Deepwater shrimp E/L EFH is the water column and outer reef slopes between 550 m and 700 m to the extent shown, while deepwater shrimp J/A EFH is the outer reef slopes between 300 and 700 meters to the extent shown.*

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Hawaiian Archipelago Fishery Ecosystem Plan

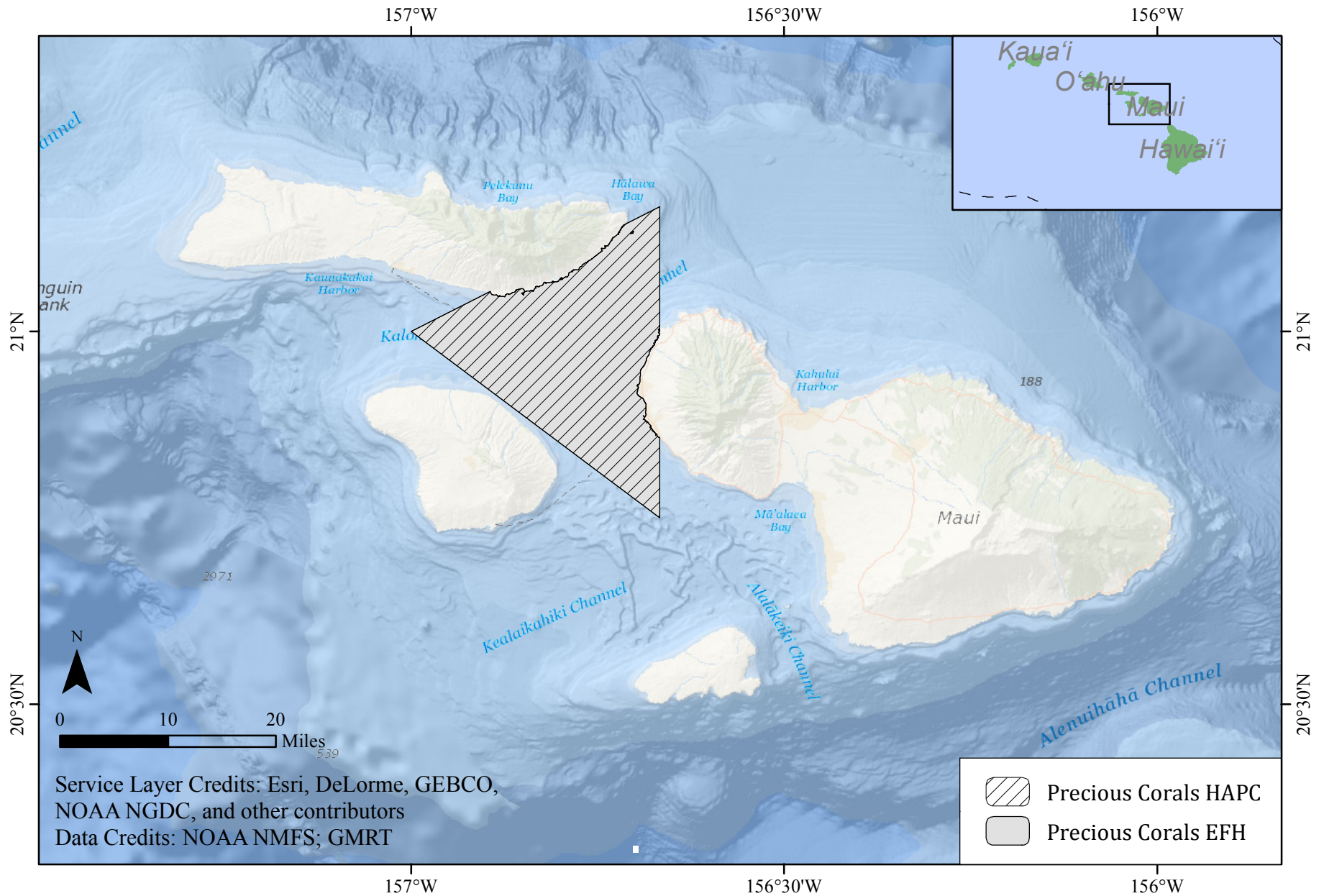
Precious Corals Essential Fish Habitat: West Hawaii Island



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Hawaiian Archipelago Fishery Ecosystem Plan

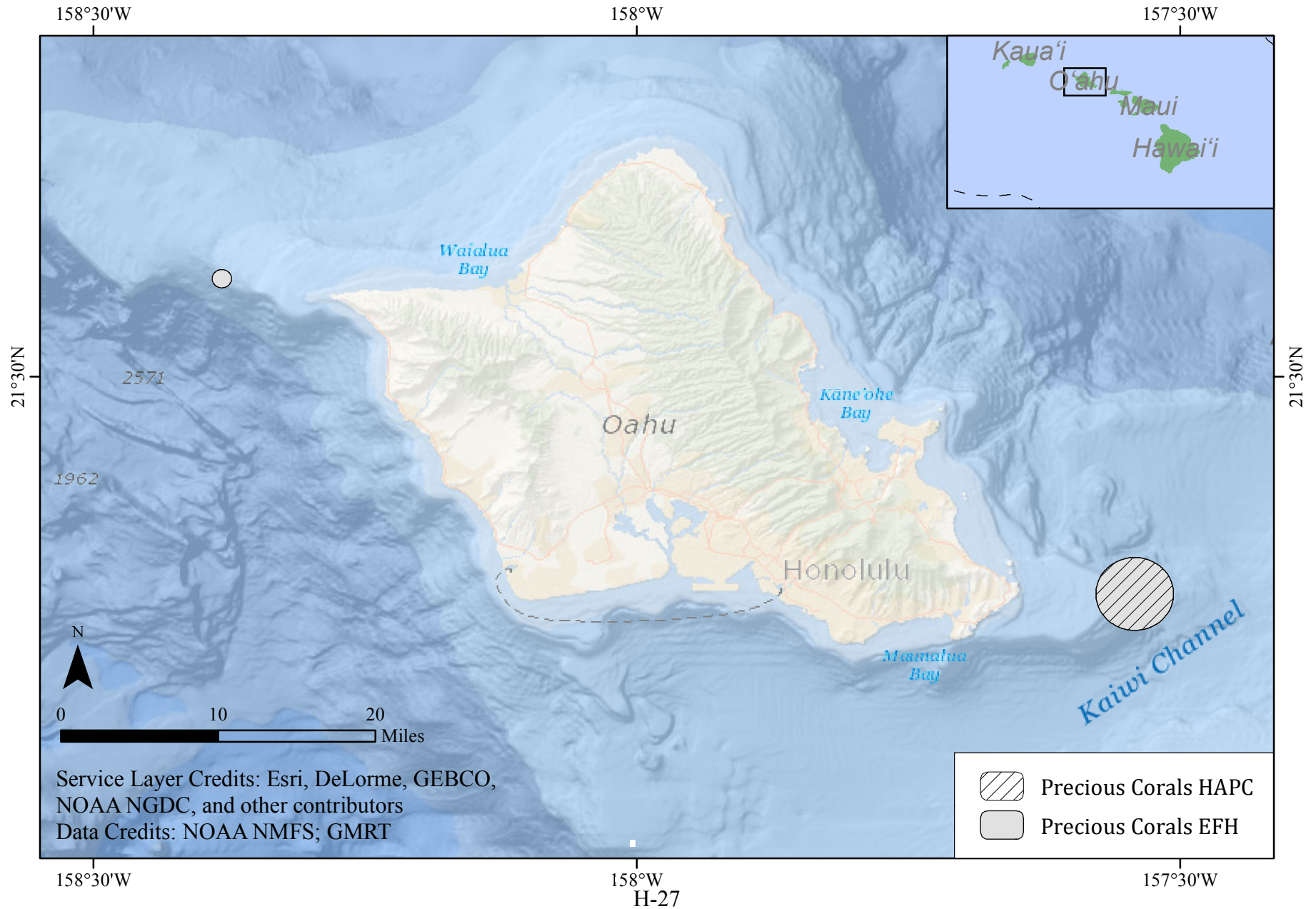
Precious Corals Essential Fish Habitat: Auau Channel



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Hawaiian Archipelago Fishery Ecosystem Plan

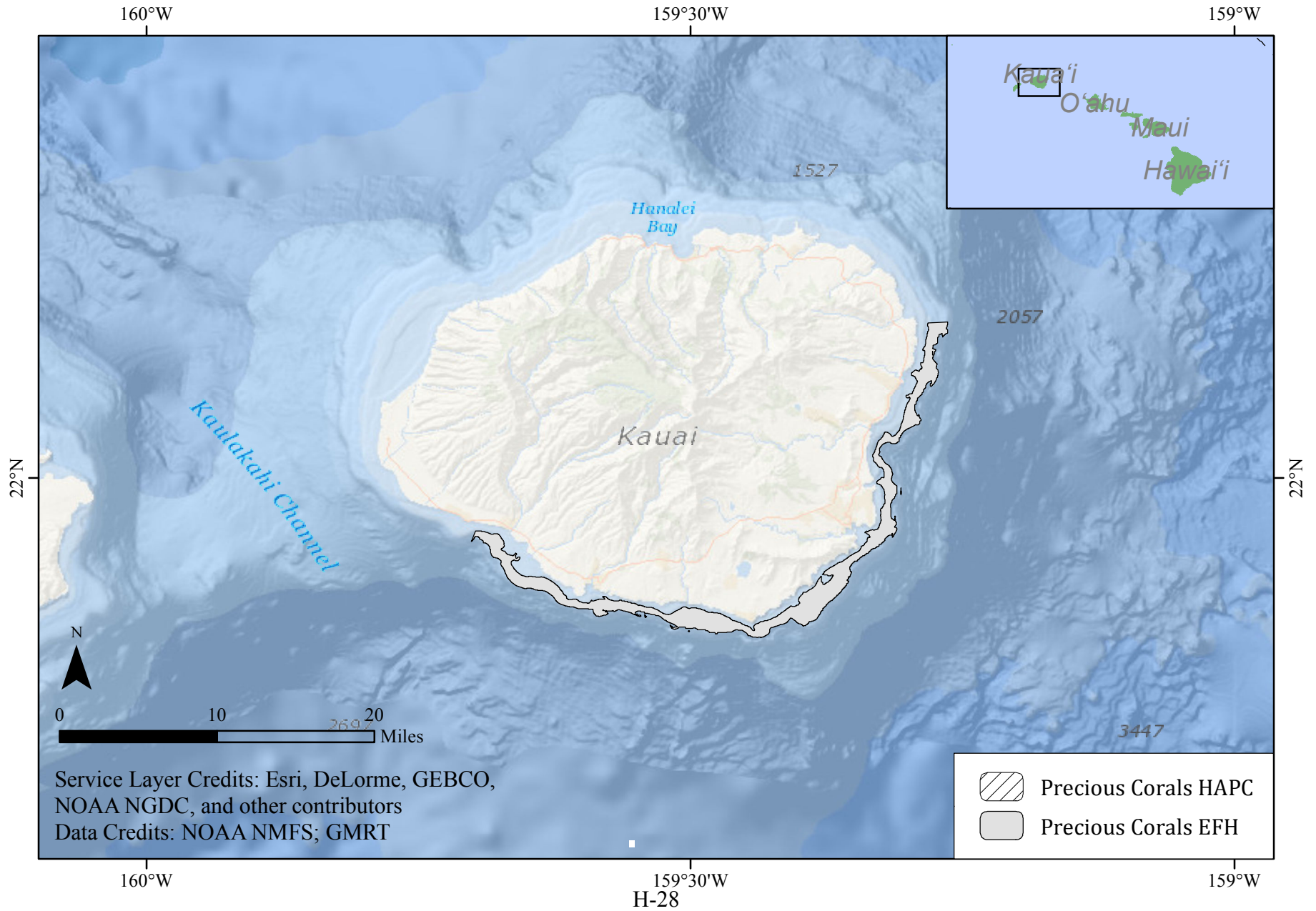
Precious Corals Essential Fish Habitat: Oahu



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Hawaiian Archipelago Fishery Ecosystem Plan

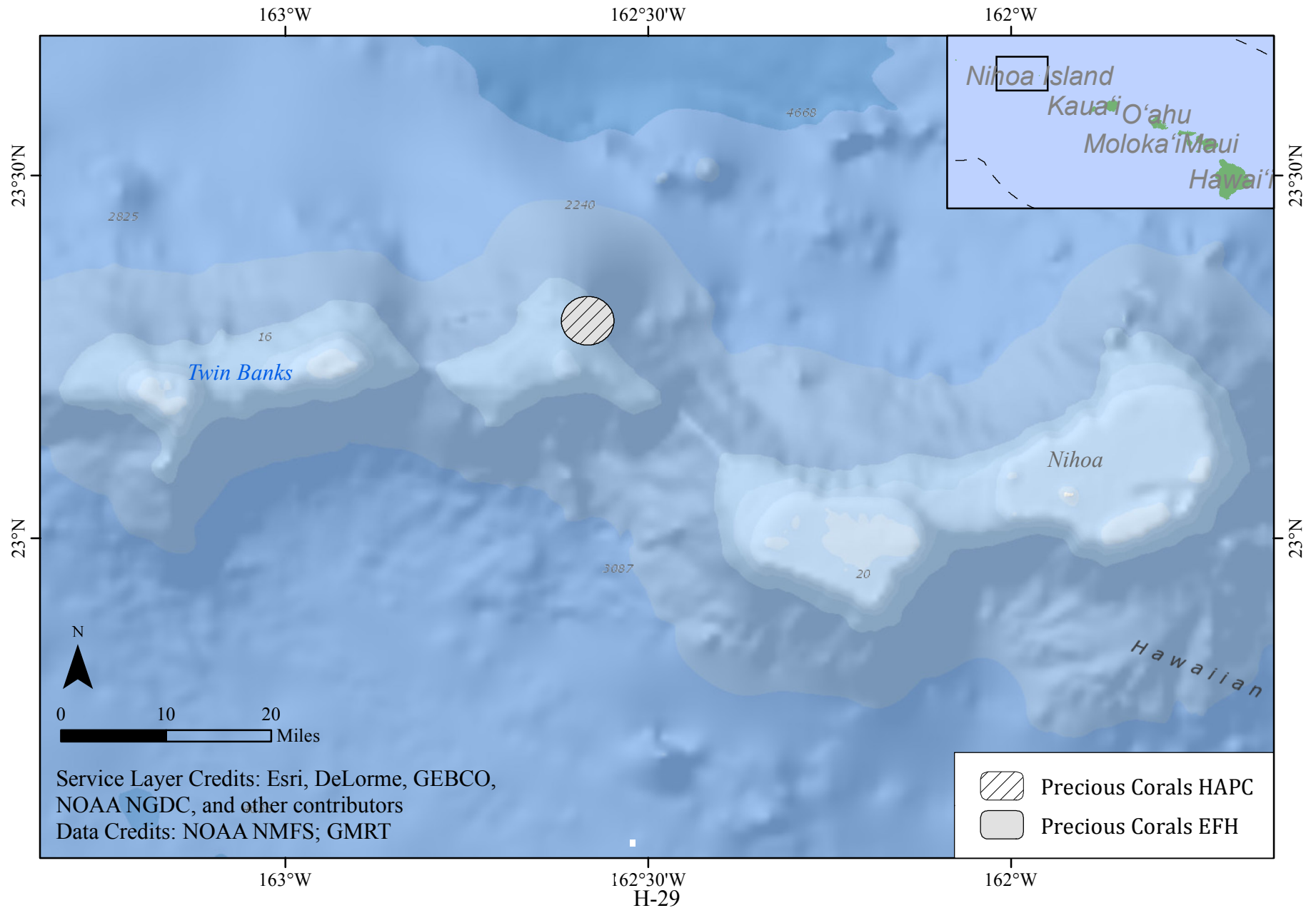
Precious Corals Essential Fish Habitat: Kauai



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Hawaiian Archipelago Fishery Ecosystem Plan

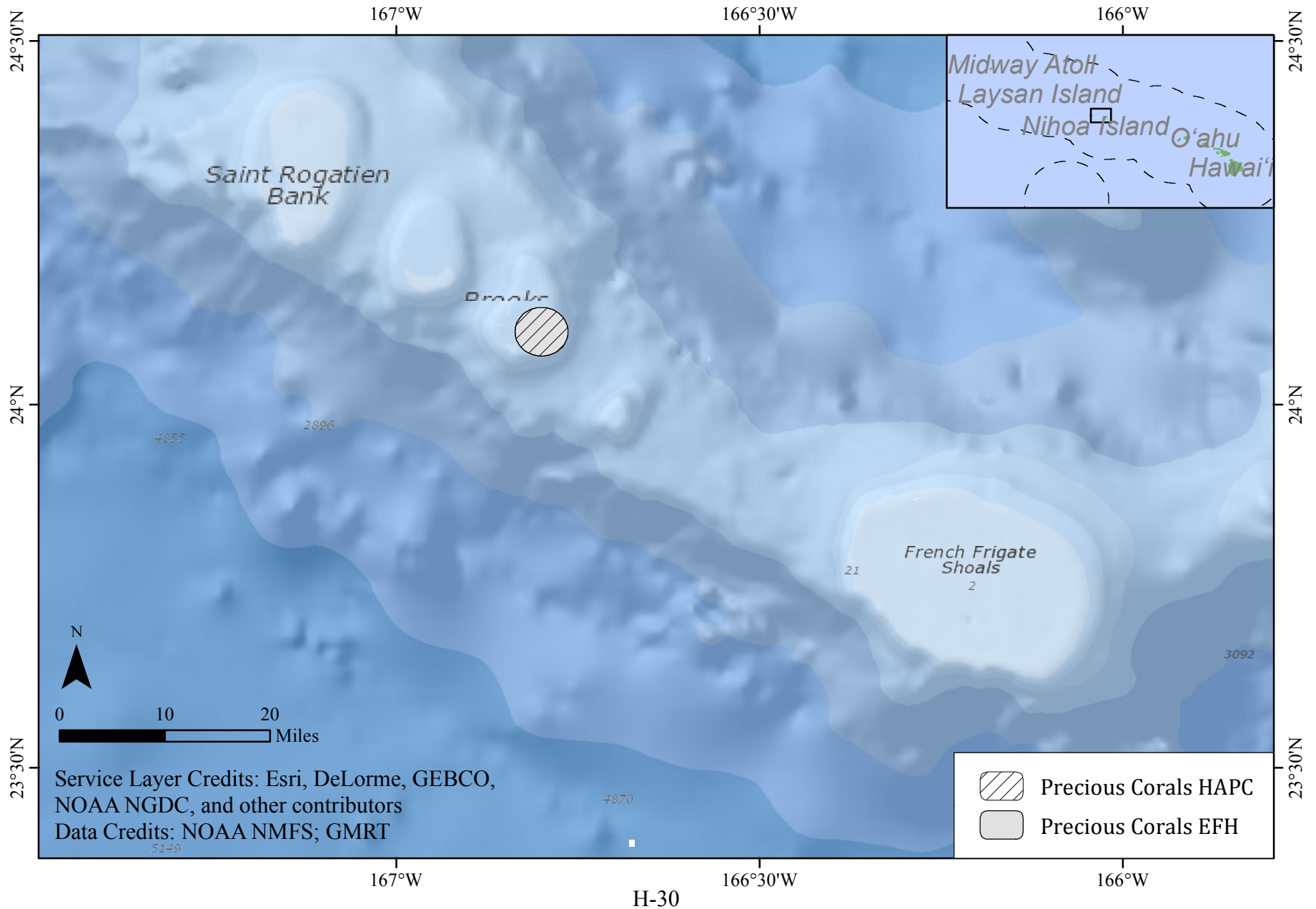
Precious Corals Essential Fish Habitat: Westpac Bed



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Hawaiian Archipelago Fishery Ecosystem Plan

Precious Corals Essential Fish Habitat: Brooks Bank



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Hawaiian Archipelago Fishery Ecosystem Plan

Precious Corals Essential Fish Habitat: 180 Fathom Bank

