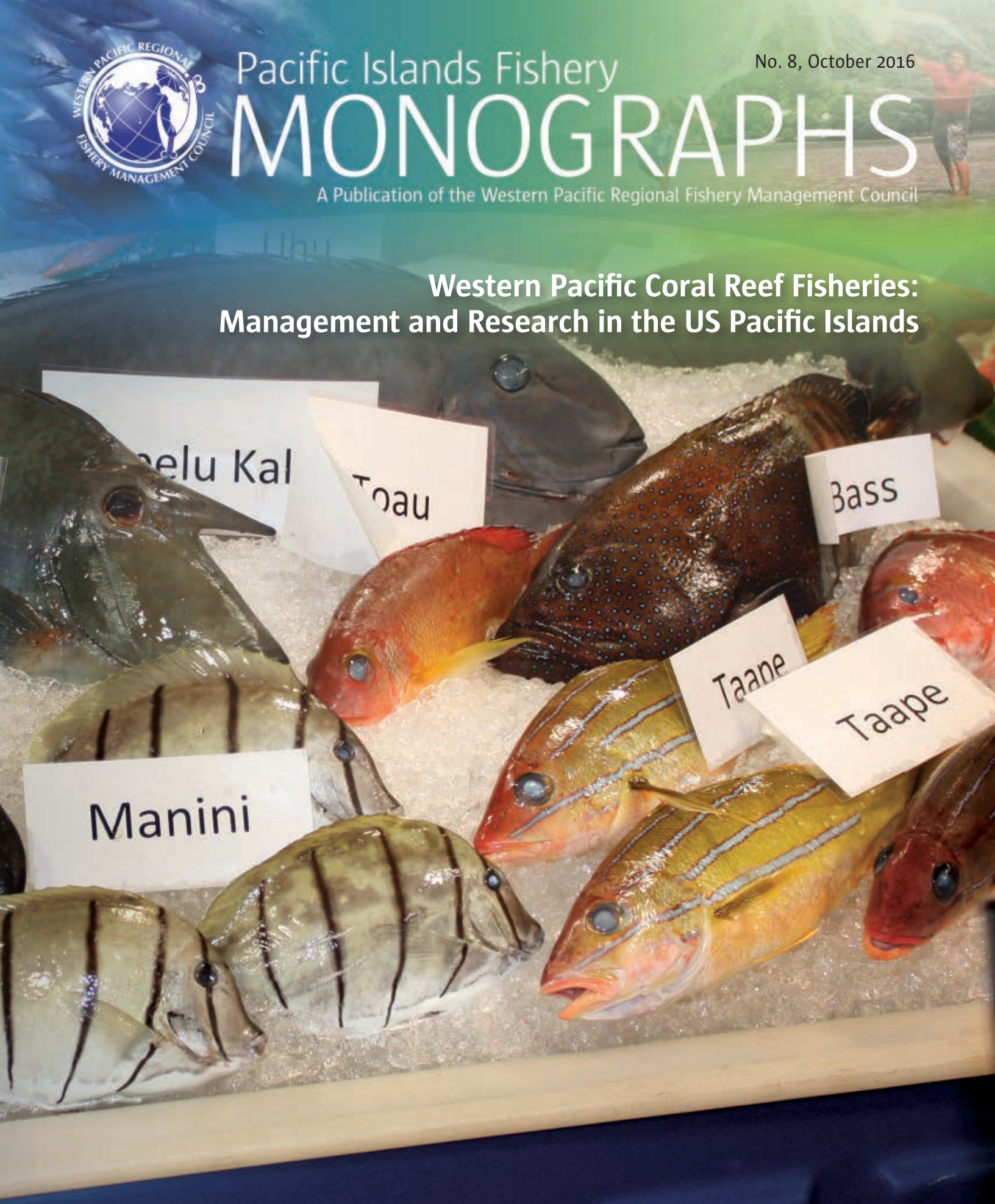
Pacific Islands Fishery
MONOGRAPHS
No. 8, October 2016
A Publication of the Western Pacific Regional Fishery Management Council

Western Pacific Coral Reef Fisheries: Management and Research in the US Pacific Islands



Joshua DeMello, Martha Maciasz, Jordan Kurokawa and Marlowe Sabater (Editors)

Acknowledgments

The Western Pacific Regional Fishery Management Council would like to acknowledge and thank all of the researchers and contractors who have worked on these Coral Reef Ecosystem Program (CREP) projects. Without their assistance and commitment, the CREP and coral reef ecosystem fishery management in the Western Pacific Region would lack the necessary data and information for the Council to make sound decisions.

We would also like to acknowledge the continued support from the NOAA Coral Reef Conservation Program and the funding provided through NOAA Award Numbers NA97FC0190, NA03NMF4410040, NA05NMF4410349, NA04NMF4410168, NA05NMF4411066, NA06NMF4410115, NA07NMF4410114, NA08NMF4410467, NA09NMF4410038 and NA10NMF4410061.

ISBN 978-1-937863-98-2

Contents

OBJECTIVES OF THE CORAL REEF ECOSYSTEM FMP

Objective 1

To foster sustainable use of multi-species resources in an ecologically and culturally sensitive manner and based on sound science and the principles of ecosystem-based resource management.

Objective 2

To engage and build capacity within island communities and local government agencies to assist in monitoring coral reef ecosystem resources to provide scientific, culturally relevant, community-based management measures for sustainable coral reef ecosystem fisheries.

Objective 3

To promote scientific fishery and ecological data, as necessary, through integrated data collection and permitting systems, as well as research and monitoring programs to make informed management decisions about coral reef ecosystems in the exclusive economic zone.

Objective 4

To provide a flexible and responsive management system for coral reef resources that can rapidly adapt to changes in resource abundance, new scientific information and changes in fishing patterns among user groups or by area.

Objective 5

To minimize adverse human impacts on coral reef ecosystem resources and habitats by establishing new and improving existing marine protected areas, managing fishing pressure, controlling wasteful harvest practices, reducing other anthropogenic stressors directly affecting coral reef resources and allowing the recovery of naturally balanced reef systems.

Objective 6

To provide for sustainable participation by fishing communities in coral reef fisheries and, to the extent practicable, through outreach and education on coral reef ecosystem fishery practices (modern and traditional), resources (stock status, identification, etc.) and management (e.g., regulations).

Objective 7

To encourage and promote improved surveillance and enforcement to support the Council's management measures.

PART 1: MANAGEMENT

INTRODUCTION

CORAL REEFS ARE ONE OF THE MOST PROMINENT ECOSYSTEMS in the Pacific Islands and the basis of the inshore reef fisheries in most locations. It is little wonder then that the native Hawaiian language contains more than two dozen names for coral.

Coral reefs in the US Pacific Islands that extend beyond state and territorial waters out into federal waters are the management responsibility of the Western Pacific Regional Fishery Management Council (Council), one of eight councils created by Congress through the Fishery Conservation and Management Act of 1976, now commonly known as the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The Council's jurisdiction includes waters seaward of state waters around Hawai'i, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands (CNMI) and eight US Pacific island possessions. Collectively known as the Pacific Remote Island Areas (PRIAs), these possessions include Howland, Baker and Jarvis Islands; Johnston, Midway, Palmyra and Wake Atolls; and Kingman Reef.

A New Way of Managing Fisheries

The early fishery management plans (FMPs) developed by the Council for crustaceans (1983), deep-water precious coral (1983), bottomfish (1986) and pelagic (1987) fisheries in the Western Pacific Region were species based. When the Council began looking at developing an FMP for coral reef fisheries, it considered a new ecosystem-based approach. Several factors contributed to the decision.

In 1984, Jeffrey Polovina at the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center's Honolulu Laboratory had introduced ECOPATH, the first simplified and versatile ecosystem-based model. He originally applied the model to a coral reef ecosystem at French Frigate Shoals in the Northwestern Hawaiian Islands (NWHI).

In 1986, the National Marine Fisheries Service (NMFS) held the first workshop on ecosystem approach to fisheries management. Council member Rufo Lujan of Guam and Council Executive Director Kitty Simonds participated in the workshop, where Simonds was a moderator.

In September 1987, NMFS released its Program Development Plan for Ecosystems Monitoring and Fisheries Management, laying the groundwork to move fisheries management from a focus on species or species complex towards one that also incorporated biological, oceanographic and economic factors. The aim was to maintain the quality of habitats that support fisheries, restore the productive capacity of habitats and create and develop habitats so as to increase fishery products for the benefit of society.

At the North Pacific Rim Fishermen's Conference on Marine Debris held Oct. 13 to 16, 1987, in Kailua-Kona, Hawai'i, the Council announced that it would be changing from a species-based fisheries management approach to an ecosystem-based approach.

In reality, the Council had from its inception managed with the ecosystem in mind, a reflection of its distinctive island perspective. Comprised of a dozen local members from the US Pacific Islands plus the National Marine Fisheries Service (NMFS) Pacific Islands Regional Administrator and other, non-voting federal members, the Council had in its early FMPs included measures that established a series of marine protected areas that safeguarded ecosystems.

In 1983, it classified the deep-water precious coral WesPac Bed, between Nihoa and Necker Islands in the NWHI, as a refugia. The objectives of the refugia were to a) preserve the coral bed as a natural area for purposes of research; b) to establish a control area that could be used in the future to measure environmental impacts of coral harvesting, and c) to establish possible reproductive reserve for enhancement of recruitment into adjacent years.

In 1986, NWHI spiny lobster were protected through establishment of a refugia encompassing 0 to 20 nautical miles around Laysan Island and a lobster fishery conservation zone comprised of waters landward of 10 fathoms in the remaining NWHI islands and atolls.

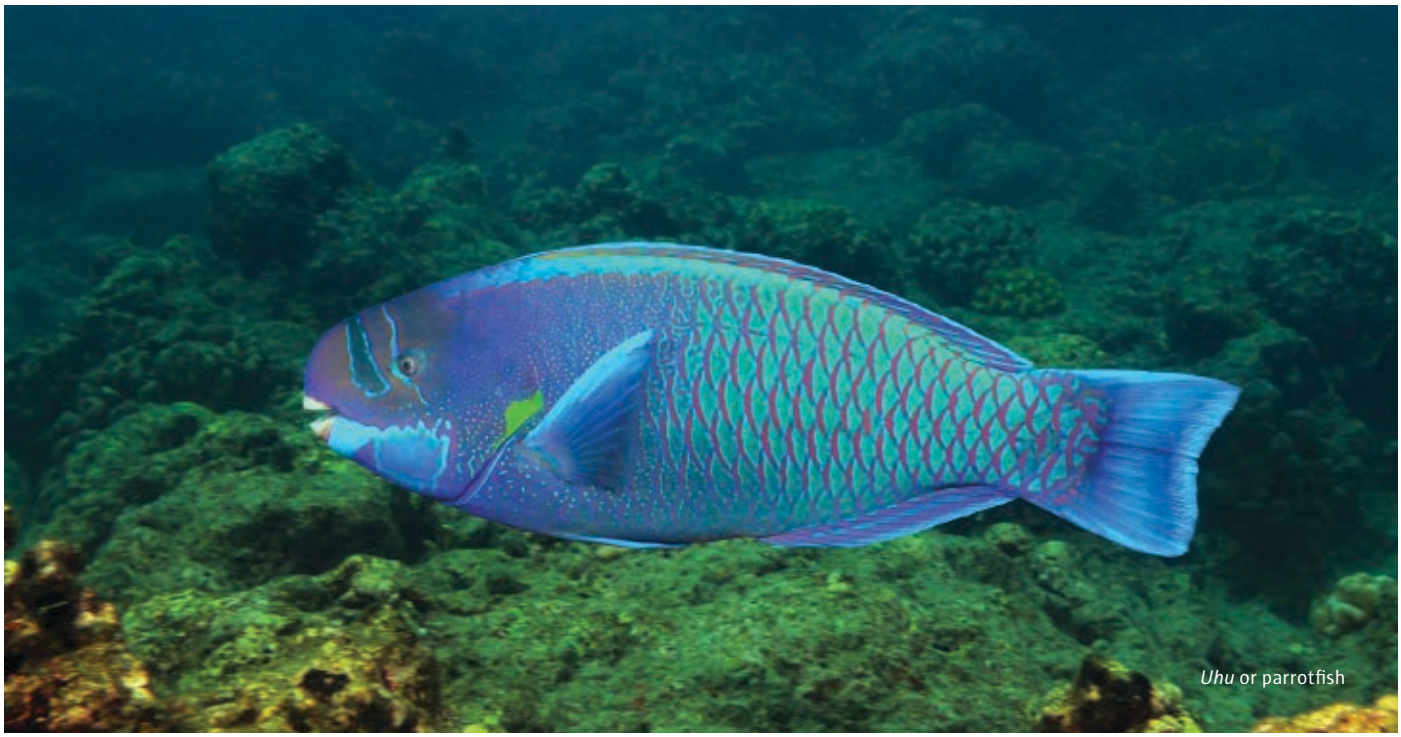
Also in 1986, potential destructive fishing techniques such as explosives, poisons, trawl nets and bottom-set gillnets were banned throughout the entire 1.4 million square nautical miles of the Western Pacific Region. In 1987, the Council prohibited drift gillnet fishing throughout the federal waters of the Western Pacific Region due to the bycatch and ecosystem harm of this practice. The United Nations would place a moratorium on drift net fishing two years later and, in 1992, ban the use of large drift nets in international waters.

And, in 1991, the Council created a longline fishing exclusion zone around the NWHI to protect endangered Hawaiian monk seals. The contiguous area of the Council's NWHI Protected Species Zone extended 50 nautical miles around the islands and atolls and included corridors to connect areas where the 50-nm-radius circles did not intersect. The Council's directed efforts at ecosystem-based management, however, began in earnest with the development of its Coral Reef Ecosystem FMP (CRE-FMP).

The Nation's First Ecosystem Fishery Management Plan

In the mid-1990s, the Council conducted two studies to determine the management needs for coral resources in the federal waters of the region. The first study published in 1995 reviewed the status of coral reefs around the American-flagged Pacific Islands to assess the need, value and feasibility of establishing the CRE-FMP. The second study, which was conducted with funding from NOAA and the National Fish and Wildlife Foundation and published in 1997, assessed the patterns of use of coral reef resources in the US Pacific Islands.

Around this same time, two national policies were instituted that had bearing on the developing CRE-FMP. First, Congress reauthorized of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), known as the Sustainable Fisheries Act (SFA) of 1996. The SFA was a landmark in the history of the nation's management of fisheries as it required the Regional Fishery Management Councils to designate essential fish habitat (EFH) for federally managed species in their FMPs.



Uhu or parrotfish

Second, on June 11, 1998, President Clinton issued Executive Order 13089 on Coral Reef Protection, establishing the US Coral Reef Task Force.

In 1998, the Council continued development of the CRE-FMP, conducting a series of public meetings on the proposed plan and incorporating the comments into a draft CRE-FMP. The original draft plan included such objectives as prevent destructive fishing methods to coral reef ecosystems; protect coral reef habitat areas of particular concern; establish fishing regulations in the exclusive economic zone (EEZ) complementary to existing state/territorial regulations concerning coral reefs; establish a permitting and reporting requirement for collection of non-food resources; require federal certification of marine tourism guides operating within habitats areas of particular concern; and require permits and plan reviews for research within habitats areas of particular concern. Ideas of a framework plan with provisions considered for appropriate gear restrictions, time/area closures, marking of gear and vessels, areas for special management, species/size restrictions, reporting systems, bag limits, catch restrictions, permits and state and federal coordination in monitoring and enforcement were also decided upon.

The Council and its advisory bodies, including the a newly formed CRE Plan Team, reviewed the early drafts and proposed the plan's goal: "to ensure that coral reef resources in the US Western Pacific EEZ are effectively managed to achieve a sustainable balance of economic productivity, ecological integrity, and social acceptability."

Work continued in late 1998 and throughout 1999 with drafting of the environmental impact statement (EIS) and holding public scoping meetings around the Western Pacific Region to gather additional information for the plan.

At its 102nd meeting in March 2000, the Council agreed to the preliminary preferred management measures: 1) permit and reporting requirements (general permit for harvested and special permit for non-harvested taxa); 2) allowable fishing gear with conditions for trap and net; 3) establishment of marine protected area (MPA), including no-take 0 to 50 fathoms around Laysan, French Frigate Shoals and half of Midway and 0 to 10 fathoms elsewhere in the Northwestern Hawaiian Islands (NWHI); low-use special permit zones at Wake, Johnston, half of Midway, Jarvis, Howland, Baker, Kingman Reef and Palmyra; and no anchoring at Guam's Southern Banks; 4) establishment of framework actions to designate mooring zones for anchoring, require vessel insurance and require vessel monitoring system (VMS); 5) establishment of non-regulatory actions, such as formal Plan Team coordination process, facilitate consistent state-federal management and create social, economic and political incentives for sustainable use; 6) SFA requirements on fishing sectors, communities, overfishing definitions, bycatch and EFH; and 7) ban the take of hard coral and live rock.

Protections Preempted

Then on May 26, 2000, work on the CRE-FMP was thrown a curve ball when, with the announcement by President Clinton of his intention to provide "strong and lasting protection for the coral reef ecosystem of the Northwestern Hawaiian Islands." He directed the Secretaries of the Department of the Interior and Commerce, working cooperatively with the State of Hawai'i and consulting with the Council, to develop recommendations within 90 days for a new, coordinated management regime to increase protection of the ecosystem and provide for sustainable use. The Departments were also directed to conduct "visioning" sessions, which would provide opportunities for public hearing comment to help shape the final recommendations. During July and August of 2000 seven public visioning sessions were conducted. At the first one, held in Washington, DC on July 21, 2000, the Council was prevented from presenting on the draft CRE-FMP by the White House's Council on Environmental Quality because the plan was not finalized. The other six visioning sessions were held in Hawai'i between July 24 and August 1, with displays created jointly by the Council, the US Fish and Wildlife Service and the State of Hawai'i.

Meanwhile, the Council continued work on the CRE-FMP. After multiple reviews between the Council and NMFS, staff from the North Pacific Fishery Management Council assisted with reorganization and revision of the CRE-FMP and the EIS in the fall of 2000. Then, on Dec. 4, 2000, the President through Executive Order 13178 designated the NWHI Coral Reef Ecosystem Reserve (CRER), essentially overlaying the NWHI Protected Species Zone established by the Council in 1991. The executive order directed the Secretary of Commerce to initiate the process to designate the Reserve as a national marine sanctuary. On January 18, 2001, the process and establishment of the Reserve was finalized by issuance of Executive Order 13196.

The CRE-FMP was transmitted to the Secretary of Commerce in the fall of 2001. A notice of availability of the EIS was published on May 10, 2002. On June 14, 2002, NMFS issued a record of decision that partially approved the CRE-FMP, disapproving the portion of the FMP that would have applied in the EEZ of the NWHI. The CRE-FMP's final rule was published two years later on Feb. 24, 2004, with an effective date of March 25, 2004. Seven years after the process began the CRE-FMP and its accompanying regulations were in place.

Understanding Coral Reef Ecosystems

Now that the CRE-FMP was implemented, the Council needed a way to continue to collect information to ensure that the plan held true to its adaptive management purpose and responded to the dynamic changes in the region's coral reef ecosystem fisheries. The Council, therefore, developed a Coral Reef Ecosystem Program (CREP) to improve the existing data-poor situation of these fisheries and to ensure proper management of coral reef fishery ecosystems in the region.

Funding for the Council's CREP has been provided through a cooperative agreement with the NOAA Coral Reef Conservation Program (CRCP), established by Congress through the Coral Reef Conservation Act of 2000. The CRCP Grant Program funds "projects to improve or amend coral reef fishery management plans" to the regional fishery management councils.

Projects initiated by the CREP have focused on gathering information on the coral reef fishery ecosystems and stocks for the purpose of amending the CRE-FMP. In 2009, the CRE-FMP and the four other species-based FMPs for the Western Pacific Region were restructured into placed-based Fishery Ecosystem Plans (FEPs). The CRE-FMP components are now found in the American Samoa Archipelago FEP, Hawai'i Archipelago FEP, Mariana Archipelago FEP (covering both Guam and the CNMI) and the PRIAs FEP.

Research projects for the numerous coral reef fishery ecosystem stocks under the Council's jurisdiction continue, even in the face of continually declining funds. Key priorities are stock assessments, traditional ecological knowledge, life history and habitat mapping.

This monograph provides a selection of summaries and complete bibliography of the projects funded under the Council's coral reef grant categorized in three parts. The entirety of these reports can be found on the Council's website at http://www.wpcouncil.org/fishery-plans-policies-reports/grey literature/.

PART 2: RESEARCH AND HISTORICAL DATA ON CORAL REEF FISHERIES

CORAL REEFS COVER LESS THAN 1 PERCENT of the entire Earth but are home to a quarter of its marine species.[1] Most of the coral reefs are found in the Pacific Ocean, which is also home to the majority of United States' coral reef jurisdiction. In the US Pacific, 90 percent of the coral reefs are found in remote areas, away from fishing communities.[2] With all that coral reef area, little was known about the coral reef fisheries as they had not been the focus of research in the past. This section provides summaries of some of the research that was done under the CREP to gather what was or is known about coral reef ecosystems and fisheries in the Council's jurisdiction, from a historical perspective, in order to better understand coral reef ecosystems and fisheries today.

Review of Archaeological and Historical Data Concerning Reef Fishing in the US Flag Islands of Micronesia: Guam and the Northern Mariana Islands

by Judith R Amesbury and Rosalind L. Hunter-Anderson

Summary

Archival and archaeological studies with information on prehistoric and historic populations and cultures in Guam and the Northern Mariana Islands are summarized by major time units: Prehistoric Period (c. 1500 BC–AD 1521), Spanish Period (1521–1898) and 20th Century. In prehistoric times, the Mariana Archipelago supported an aboriginal culture whose present-day descendants are called Chamorro (Chamoru). The late prehistoric culture, termed the Latte Phase (AD 1000–1521) by archaeologists, was based on horticulture, fishing and collecting. Settlements were dispersed and of different sizes, and people used sailing canoes for inter-island travel and deep-sea fishing. During the Spanish Period, animal introductions possibly encouraged the Chamorro to become less dependent upon seafood for animal protein.

Beginning in the 20th century, the historical trajectories of Guam and the Northern Mariana Islands diverged radically. Guam's government passed from Spain to the United States, while in the Northern Mariana Islands, the Germans took over from the Spanish. The Americans expelled the 100 or so Carolinians from Guam, whereupon they moved to the Northern Mariana Islands and continued to live as before on the beach and pursuing an oceanic way of life. In 1914, the Japanese replaced the Germans in the Northern Mariana Islands. By the 1930s, they had developed the islands for sugarcane production and export to Japan. Commercial deep-water fishing was also undertaken by the Japanese, some for local consumption and more for export. Documentation is poor regarding the use of marine resources at this time, but inshore fishing by throwing net and spears may have supplemented some families' diets. A lack of native-owned seagoing boats probably restricted access to pelagic fish.

Overall the 20th century picture for Guam and the Northern Mariana Islands is one of declining use of inshore marine resources as an important dietary component and markedly higher population densities after World War II. Wage economies replaced subsistence economies, most markedly before the war in the Northern Mariana Islands and after the war in Guam. Land shortages for farming and high population densities due to high rates of immigration have precluded a return to subsistence agriculture and fishing. Some families continue to supplement their diet by fishing and farming or by bartering for or purchasing local fish and garden produce.

An additional section of the background information reviews methodological problems with using the archaeological and paleo-environmental records when suggesting past cultural practices. It is argued that the main value of pollen and other microscopic studies of paleo-sediments cored from wetlands are as indicators of past environmental conditions. Such information can be used in models, which specify the dynamic contexts to which human groups were adapting through time in the Mariana Archipelago. It is suggested that there is great potential in the study of historical documents, archaeological data and oral histories to yield environmental information and to reveal past cultural responses to environmental changes.

Twenty-eight archaeological reports concerning 15 areas of Guam and 18 archaeological reports concerning 15 areas of Saipan, Tinian and Rota are reviewed for fish remains, fishing gear, turtle remains and invertebrate remains from the Prehistoric Period. Fish remains belonging to 24 families were identified from the Guam sites, while fish remains from 35 families were identified from the Northern Mariana Island sites. The larger number of families represented in the Northern Mariana Island sites may be due to the greater range of

[1] US Geological Service Pacific Coral Reefs Website (http://coralreefs.wr.usgs.gov/)

[2] WPRFMC. 2001. Final Fishery Management Plan for Coral Reef Ecosystems of the Western Pacific Region, Vol. 1. Honolulu, Hawai'i.

Photo: Marlowe Sabater

habitats in those islands, or it may instead be due to the quality of the reference collections used to identify the fishbone. More of the Northern Mariana Islands archaeological fishbone collections were analyzed by the University of Otago, New Zealand. Fishing gear recovered from archaeological excavations includes numerous shell hooks and gorges, points and shanks of two-piece or composite hooks, stone and shell weights and bone needles, which may have been used in making and repairing nets.

No clear trends with regard to fishing during the Prehistoric Period have been discovered. At Pagat, Guam, Pre-Latte deposits had a higher density of fish remains, although the Latte deposits yielded a greater quantity. The areal extent of the Pre-Latte deposits was much smaller than that of the Latte deposits. It was concluded that there were no major changes in density or diversity of fish remains from Pre-Latte versus Latte deposits in central Tinian, but that conclusion was reached after comparison of fish remains from less than one cubic meter of Pre-Latte deposits with those from just over one-half cubic meter of Latte deposits. In Rota, big game fishing for marlin and mahimahi, which took place early and through most of the sequence, was not evident in the late prehistoric deposits of the area investigated by the Rota Airport Project, but the researchers were unable to determine whether this was a change in fishing behavior or a change in patterns of midden deposition.

Turtle remains are infrequently reported from archaeological excavations. Only seven of the Guam reports and seven of the Northern Mariana Islands reports mention presence, number or weight of turtle bone. The three archaeological sites that yielded the greatest quantity of turtle bone (Pagat, Guam; Unai Chulu, Tinian; and Mochong, Rota) all show a decrease in abundance (number or weight) from the lower layers to the upper layers. Whether this represents a decrease in the harvesting of turtles during the Prehistoric Period is not known; the number of sites is too few to reach a conclusion.

Four kinds of invertebrates have been found to decrease in abundance during the Prehistoric Period in certain locations of Guam, Saipan, Tinian and Rota. The arc clam *Anadara antiquata* is preferentially associated with mangroves, and the decrease in abundance after the Pre-Latte Phase is thought to be related to the relative sea level decline that took place within the last 3,000 to 4,000 years. A decrease in the abundance of the limpets *Patelloida chamorrorum* and *Patellaflexuosa* after the Pre-Latte Phase has been variously attributed to human harvesting and to a combination of human harvesting and relative sea level decline. Corresponding to the decrease in limpets at Achugao, Saipan, is a decrease in chiton plates. Sea urchin spines have been found to decline in numbers after the Pre-Latte Phase at sites in Guam, Saipan, Tinian and Rota. Either a change in the environment or human harvesting pressure could have caused a decline in sea urchins. A third possibility with regard to the sea urchin spines is that a change in the culture meant that sea urchin spines were no longer needed as tools for manufacturing shell beads.

Writers of the Spanish Period left detailed descriptions of several reef fish and inshore fisheries including those for flying fishes (family Exocoetidae), mafiahak (juvenile rabbitfishes, *Siganus* spp.), ti‘ao (juvenile goatfishes, family Mullidae), atulai (bigeye scad, *Selar crumenophthalmus*), parrotfishes (family Scaridae) and hachuman (Decapterus sp., ‘opelu in Hawai‘i). The only one of these fisheries that declined markedly during the Spanish Period was the hachuman fishery. It was practiced only in Rota by the second half of the 1800s.

The Spanish Period writers documented a change in the use of turtle. During the 16th and 17th centuries, tortoise shell was an important valuable to the Chamorro. But by the late 18th century, turtles and tortoise shell had diminished in importance.

The invertebrates were only mentioned by the Spanish Period writers; there are no detailed descriptions of their use. During the 19th century, sea cucumbers were apparently exported to China but not eaten by the islanders. Governor de la Corte estimated that thousands of pounds per year could be harvested.

Recordkeeping during the 20th century has been uneven. The pre-war naval governors of Guam reported almost nothing about fisheries; post-war governors reported more. However, it is only within the last 25 years that the Division of Aquatic and Wildlife Resources (DAWR) of the Government of Guam's Department of Agriculture and NMFS's Western Pacific Fishery Information Network (WPacFIN) have compiled accurate data on reef fisheries.

In the Commonwealth of the Northern Mariana Islands (CNMI), the pre-war records pertain to the Japanese tuna fishery based in Saipan. This fishery employed mostly Japanese and Okinawans. Fishing for hachuman with the poio (a stone chumming device) continued on Rota into the late 1960s. An interview with the son of the last fisherman on Rota to use the poio is included. Currently the CNMI Division of Fish and Wildlife works cooperatively with the WPacFIN in collecting and disseminating fisheries data.

It appears that the technological changes in fishing since World War II and the indirect human impacts on the reefs have contributed to declines in the reef resources. The Guam DAWR recently reported a 70 percent decrease in catch per unit effort (CPUE) (kilograms per gear-hour) of important inshore food fishes over a 13-year period from 1985 to 1998. The WPacFIN data for Guam show an increase in commercial landings of reef fishes within the last few years, but the data cannot be interpreted as a turn-around in the decrease in CPUE reported by DAWR. The data are collected from different types of surveys and different fishermen. Two recent reports pertaining to the CNMI call for improved data collection and additional research to guide biologists in making fishery management decisions.

Review of Archaeological and Historical Data Concerning Reef Fishing in Hawai'i and Samoa

by Thomas S. Dye and Thomas R. Graham

Summary

The review of reef fishing in Hawai'i and American Samoa assesses the potential of archaeological and historical data to provide information on patterns of resource use from coral reefs. Sources reviewed are listed in an extensive bibliography, and their characteristics are summarized in a series of tables that are included as appendices. This review indicates that pre-1950 data in Hawai'i is much fuller and richer than in American Samoa. In Hawai'i, it should be possible to characterize patterns of fishery resource explanations and to chart at least some changes in these over time using a combination of extant archaeological and historical information. An investigation of long-term changes in inshore resources in Hawai'i will require new fieldwork, a re-examination of existing archaeological collections or application of a new analytic method whose utility is not yet established in the Pacific. None of these goals can be achieved with the scant archaeological and historical information available for the pre-1950 period in American Samoa. The post-1950 fisheries data for both Hawai'i and American Samoa are rich and detailed. They have revealed important aspects of and changes in exploitation patterns and the condition of inshore resources.

Reconstruction of Coral Reef and Bottom Fisheries Catches for US flag Island Areas in the Western Pacific, 1950 to 2002

by D. Zeller, S. Booth & D. Pauly

Summary

Fisheries play an important role in Pacific Island societies. While fisheries for pelagic species such as tuna and billfishes are generally of great commercial significance, near-shore fisheries targeting coral reef species, bottom species and species that are closely associated with coral reefs are of more fundamental importance, providing subsistence, recreational, cultural and food security functions. However, these fisheries, owing to their scattered nature, have often been underrepresented in accounts of catches in official statistics, due to difficulties in and cost of obtaining reliable "hard data" covering whole countries. Thus, such catches often remain unaccounted or underaccounted in official statistics.

Reconstructing historic catches in cases where time-series data are lacking requires assumptions and interpolations among often widely spaced data "anchor" points. These data points are usually based on local studies, fisheries-unrelated studies (e.g., human population,

diet or consumption studies) and unpublished grey literature. Consequently, estimates derived from such alternative and irregular (in time, space and sampling design) sources may be associated with higher data uncertainties than "hard" time-series data. Nevertheless, such approaches are required, as the alternative—i.e., continuing the established pattern of not reporting anything in situations where "no time-series data" exist—is not useful in light of increasing demands for accountability of marine resource use and calls for sustainability and ecosystem-based approaches to management. Without attempting to fully account for all fisheries catches (even if based on extrapolations), one would not be able to obtain any measure of the likely formal and informal economic as well as cultural value of marine resources to Pacific Island communities.

The purpose of this project was to assemble available information on catches for the coral reef and bottom fisheries of the US flag island areas of the Western Pacific Region, specifically American Samoa, Guam, the CNMI, Hawai'i and isolated islands and atolls under US jurisdiction for the 1950 to 2002 period. The aim was to derive estimates of total removal of marine resources over this time period, excluding large pelagic fisheries (e.g., tunas and billfishes). Thus, the focus was on coral reef fisheries, including the bottom fisheries, as well as catches of coastal, reef-associated small pelagic species such as scads and jacks.

This document attempts to reconstruct fish catches based on very limited data and thus required broad interpolation of disparate data and relied upon bold assumptions. The document does not consider other factors that affect per capita catches of marine resources such as extensive shoreline development and habitat alterations, environmental changes due to typhoons and El Niño–South Oscillation phenomena, changes in lifestyle and diets, the shift in preferences for Western food sources and increased availability of cheaper seafood imports from foreign sources.

Coral Reef Fishery Ecosystem Assessment in American Samoa

by Domingo Ochavillo

Summary

Factors that affect coral reef fishery ecosystems can be grouped into two categories: manmade and natural disturbances. Presumably these factors interact as well and their interactions probably compound their impacts. Sedimentation due to deforestation and poor agricultural practices, along with negative impacts of storms and tropical cyclones, has been speculated to cause a decline of coral reef fisheries due to habitat loss. Looking at the establish historical trends in CPUE and fish composition and correlating these trends with known events as a very general way of inferring their impacts on the fisheries was conducted to provide a quick assessment. Results of the assessment show some tenuous indications that CPUE declined in some cyclone years and during the year that a tsunami hit American Samoa. These correlations could not be explained by natural processes such as recruitment variability nor similar changes in fish abundance since such processes operate independently especially amongst disparate species groups. There was also evidence that catch composition varied between disturbance and non-disturbance years, which suggests disturbances affect some species groups differently. The impacts of severe natural disturbances on coral reef fisheries has never been clearly shown and will be difficult to show due to their timing and the background variability of processes affecting natural populations. However, this does not mean that they are not important factors. In contrast, the impacts of these disturbances should be studied as they have implications on what can be said of the status of exploited stocks.

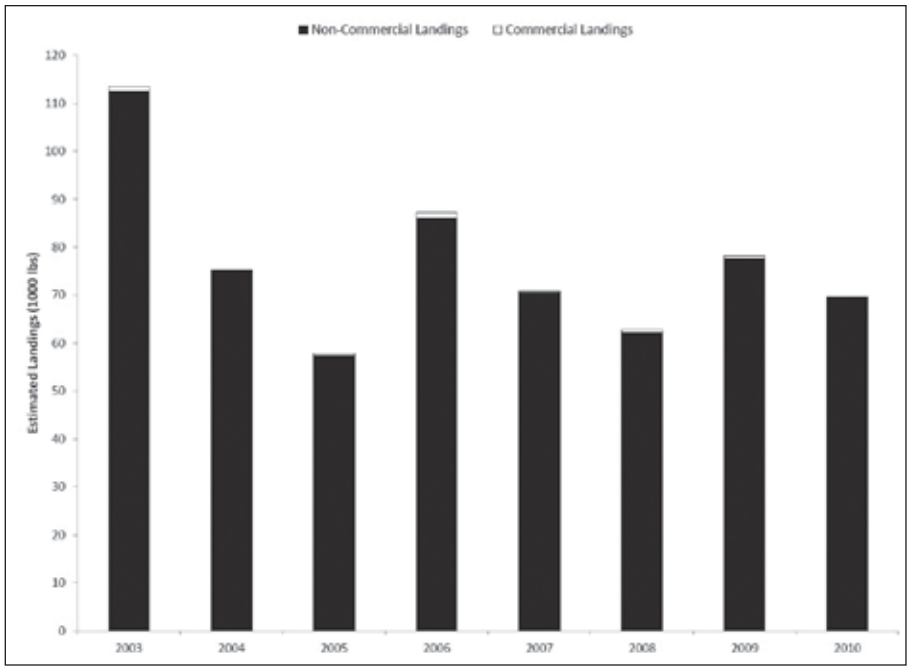
Hawai'i Coral Reef Dealer Study

by Nicole Milne

Summary

Hawai'i coral reef fisheries have great sociocultural and economic importance to island residents and the local economy. Coral reef fish are consumed seasonally at cultural events and are an important protein source for many local families. The coral reef fishery is defined by several common species including akule, 'ōpelu, parrotfish, surgeonfishes, goatfishes, jacks, unicornfishes and others, all which are harvested using a wide variety of methods including surround or fence nets, gillnets and hook-and-

line. Understanding the extent and importance of coral reef fish in local markets through a focus on coral reef fish dealers in the State of Hawai'i informs ecosystem-based approaches to management and conservation strategies, including the economic impacts of regulatory changes on the coral reef fish industry comprised of fishermen, dealers and end consumers. Interviews were conducted utilizing a semi-structured interview approach and the State of Hawai'i's Commercial Marine Dealer and Special Marine Product License databases. A total of 113 interviews from 98 primary fish dealers was conducted on Kaua'i, O'ahu, Maui and Hawai'i Island. Results show that the significance of coral reef fish varies considerably across islands with the largest markets for coral reef fish on O'ahu and Maui. Smaller stores that purchase directly from fishermen have developed close relationships, while larger grocery chains require coral reef fish purchasing to go through distributors. Dealers reported an overwhelming preference for hook-caught coral reef fish, citing concerns about product appearance and quality, but they were dependent upon the price and availability of hooked fish. The study also showed an ethnic preference for coral reef fish and a possible relationship between ethnicity and economic well-being. Certain ethnic groups' preference for coral reef fish may be tied to their longevity in the islands, as those with longer stays show more of a preference for pelagic and bottomfish species.



Annual relative contribution of estimated commercial and non-commercial landings of coral reef species in the Guam shore-based fishery.

Non-commercial Coral Reef Fishery Assessments for the Western Pacific Region

by Rebecca Walker, Lauren Ballou and Bryan Wolfford

Summary

Non-commercial coral reef fisheries of the Western Pacific Region were assessed using data from the creel survey programs of American Samoa, Guam and the CNMI and data from the Hawai'i Marine Recreational Fishing Survey (HMRFS) in Hawai'i. Because creel surveys were not originally designed to distinguish between commercial and non-commercial catch at the species level, data manipulations and estimating algorithms were required.

To determine the optimal assessment methods, interviews were conducted with NOAA Pacific Islands Fisheries Science Center staff and the HMRFS program director and program documentation was reviewed. Diagnostic analyses were performed to assess the quality of the data and quantify the level of estimating and "pooling" associated with the catch data. Interviews were conducted with local fisheries specialists to aid in interpreting the results. For American Samoa and Hawai'i, estimated catch data were analyzed directly; however, for Guam and the CNMI, an algorithm was developed and applied to estimate the non-commercial landings.

The results show that most shore-based fishing is non-commercial in American Samoa, Guam and the CNMI. Non-commercial fishing accounts for a much smaller proportion of the boat-based versus shore-based coral reef fishery catch. The shore-based fishing gear associated with the most catch in all regions is some form of hook and line. Bottomfish fishing is the most important method for catching coral reef species in the boat-based fisheries. Bigeye scad (*Selar crumenophthalmus*), jacks and surgeonfish are the top components of the catch in all regions.

In Hawai'i, the availability of weight data is too sparse to support weight-based analyses so only number of fish can be assessed. Bait fish species are caught in the highest numbers. Sampling and survey design limit the accuracy of the analysis of the non-commercial sector. Incomplete sampling frames of non-commercial fishing activity in all regions may introduce error and bias into the estimation procedure. Large changes in estimated catch across time suggest that sampling of pulse fisheries or rarely encountered methods can cause large variances.

In Guam and the CNMI, because the percent of catch kept versus sold (i.e., disposition) is available by method/gear type but not at a species level, estimates of species level non-commercial catch are subject to additional error and uncertainty. In American Samoa, the same holds true for the shore-based survey; however, the boat-based survey does capture disposition of the catch at the species level.

In the creel survey programs of the Western Pacific Region, estimation of catch occurs during the sampling of CPUE, the data expansion process (combining CPUE with estimated effort) and the development of the non-commercial algorithm. These three estimation components introduce potential error and uncertainty, which can be multiplicative. Based on the non-representative nature of sampling frames and feedback from local fishery specialists, the results must be interpreted with caution due to these limitations.

Review of Status of Coral Reefs Around American Flag Pacific Islands and Assessment of Need, Value, and Feasibility of Establishing a Coral Reef Fishery Management Plan for the Western Pacific Region

by Cynthia L. Hunter

Summary

Concern has been raised over the potential need for a Coral Reef Fishery Management Plan for the Western Pacific Region. On a global basis, coral reefs are valuable economic resources, although many reefs ecosystems have been degraded because of human-caused damage or overexploitation. The overall area of coral reef habitat in the Western Pacific Regional Fishery Management Council region is estimated at 15,852 km^2, the majority of which (10,762 km^2) is under the Council's fisheries management jurisdiction (generally 3-200 nm from shore). Major resource uses for most of the region are limited to areas close to shore (< 3 nm) and population centers. The general condition of reefs in the region varies from poor to excellent, again related to proximity to population centers and regions of coastal development.

Precious coral, lobster, bottom fish and pelagic fisheries are currently managed within the Council's region. Present and future potential uses of coral reef resources not currently managed within the region may include the collection of live corals and "live rock" for the aquarium trade. Live rock is an essentially non-renewable resource, although efforts are underway to investigate the potential for aquaculture production of live rock. Fishery Management Councils in Florida and the Gulf of Mexico have recently passed management plans that will limit and eventually ban (in 1997) the collection of live rock in the EEZs of those waters. These actions may be expected to cause live rock collectors in that industry to look elsewhere for resources.

Reef resources in most areas of the Council have not been adequately mapped or inventoried. There is a need for baseline information specific to these areas to provide information necessary for their conservation and management.

An Assessment of the Status of the Coral Reef Resources, and their Patterns of Use, in the US Pacific Islands

by Alison Green

Summary

The coral reef resources in the US Pacific Islands cover an estimated area of 15,852km^2, most of which (10,762 km^2) is located in the EEZ. The vast majority of the coral reef area in the EEZ is located in Hawai'i, with smaller areas present in the other parts of the region.

Coral reef condition and utilization patterns vary throughout the region. The majority of the reefs in the EEZ (88 percent by area) appear to be in good condition, largely because they are remote from major human population centers. Similarly, these reefs appear to be unfished or only lightly used, because of their remoteness, and in some cases, their protected status. Exceptions include the more accessible offshore banks in Hawai'i, Guam and CNMI (Penguin, Galvez and Esmeralda respectively) and the banks surrounding the island of Farallon de Medinilla in CNMI, which are heavily fished. However, much of the fishing in these areas is for bottomfish, with an unknown component of reef species included in the catch.

The relatively good condition of most reefs in federal waters is in stark contrast to many of the reefs in nearshore state or territorial waters, which appear to have been degraded by a combination of natural and anthropogenic effects, including habitat

degradation and overfishing. In general, nearshore reefs that are close to human population centers tend to be more heavily used and in worse condition than those in more remote areas.

The coral reef fisheries of the US Pacific Islands tend to be dominated by reef fishes (60 to 90 percent of catch), and the total "nominal" reef fish production is estimated to be 1,000 tons. Most of the catch comes from Hawai'i (700 tons), followed by American Samoa (176 tons), CNMI (84 tons) and Guam (39 tons). Minor catches have also been recorded in the Other US Pacific Islands. Invertebrates comprise most of the remainder of the catch (10 to 40 percent), although the taxa that are important vary among islands. For example, mollusks, echinoderms, and crustaceans are locally important in American Samoa, CNMI and Hawai'i respectively.

Corals and live rock comprise only an incidental part of the catch (mostly precious corals), since stony coral and live rock collecting is illegal in states throughout the region. Algal harvesting is also believed to be an important component of the fishery in some locations (especially Hawai'i), but the size of the harvest is unknown. The majority of the coral reef fisheries in the US Pacific Islands occur in nearshore waters (80 to 100 percent), with only a small component (<20 percent) occurring in the EEZ. The following is an overview of the results of the

assessment for each location. For the purposes of this report, coral reefs were defined as "substratum adjacent to coastlines (or on shoals) from depths of 1 to100 meters that is primarily composed of hard-bottom." This definition led to problems of overlap between coral reef fisheries and other fisheries. The main problem was the overlap with the bottomfish fishery, which is generally considered to include two components that can be separated on the basis of depth and species complex: the shallow-water (<150 meters) emperor based bottomfish fishery and the deep-water (150 to 250 meters) eteline snapper and grouper based bottomfish fishery. Therefore, many of the species in the shallow-water bottomfish fishery could also be considered "reef species" as defined in this report. Consequently, the shallow-water bottomfish fishery is also discussed in some locations (mostly CNMI).

State of Hawai'i

By far the largest coral reef area in federal waters is located in Hawai'i (10,004 km^2), of which most is situated in the (NWHI (9,124 km^2). Surveys of the NWHI show that they support healthy coral reefs with high standing stocks of many reef fishes. These resources receive little impact because of their protected status, remoteness and harsh seasonal weather conditions. However, some recreational fishing does occur by occasional visitors to the area, including federal government personnel and visitors to Midway Atoll. Data are not yet available for this fishery, although it is assumed to be minor.

The Main Hawaiian Islands (MHI) also comprise a reasonably large area of coral reef in federal waters (880 km^2), almost all of which is located on Penguin Bank off Moloka'i. Little is known about the condition of these reefs. In contrast, many of the reefs in near shore waters in the MHI are known to have been badly degraded as a result of overfishing, urbanization and development.

Commercial fisheries catch statistics for Hawai'i reveal that coral reef fisheries account for 10.2 percent of the weight (1,570,285 pounds) and 10.5 percent of the value ($3,392,645) of the total mean annual commercial catch. Less than 12 percent of all inshore fishes were caught in federal waters (32,018 pounds and $65,402). In contrast, approximately half (51 percent by weight) of the State's reported commercial landings of Kona crab were taken on Penguin Bank between 1990 and 1995 (14,191pounds and $57,436). However, the commercial crab landings on Penguin Bank are only a minor component of the total fisheries catch for the State (<1 percent by weight).

Recreational catch in Hawai'i is unknown, although it is assumed to be equal to or greater than the commercial catch for some important target species. Most of the recreational fishing for reef species occurs in state waters close to shore, although Penguin Bank is believed to support a substantial, but undocumented, recreational fishery for deep-water snappers and groupers.

Territory of American Samoa

The coral reef resources of American Samoa are limited in area (296 km^2), and only a small portion is located within federal waters (25 km^2). A recent resource assessment showed that the near shore reefs in territorial waters vary in condition throughout the archipelago. Reefs on the main island of Tutuila are in the worst condition because of a combination of natural and anthropogenic effects (hurricanes, coral bleaching, pollution, sedimentation, etc.), while the reefs on the more remote and less populated islands tend to be in good condition. Virtually nothing is known of the condition of the reefs in federal waters, because they are relatively inaccessible.

However, it is assumed that they are in better condition than the near shore reefs, because they are in deeper water and remote from most human activities.

Recent fisheries statistics from American Samoa show that coral reef fisheries have accounted for 62% percent of the catch (339,730 pounds) and 70 percent of the value ($619,009) of the value of the total mean landings in the Territory over the last few years. The actual total for coral reef fisheries is probably higher than this for two reasons. First, this estimate does not include the shoreline artisanal catch, which is assumed to be substantial. Second, the coral reef harvest will include an unknown proportion of the shallow-water bottomfish catch, because of overlap between the two fisheries. However, the mean annual harvest of the bottomfish fishery in American Samoa is small (23,754 pounds with a local market value of $45,722) and unlikely to contribute a substantial amount to this total.

Most of the landings in known coral reef fisheries in American Samoa are reef fishes (215,897 pounds), mollusks (73,112 pounds) and echinoderms (43,384 pounds). Small amounts of crustaceans (7,337 pounds) are also harvested. Recent fisheries statistics show that the shoreline coral reef fishery appears to be in decline, possibly because of habitat degradation.

All of the coral reef fisheries in American Samoa occur in near shore territorial waters. However, since most of the bottomfishing occurs in federal waters, and some of the species in this fishery can be considered reef fishes, then it is possible that a small proportion of the coral reef fishery also occurs in federal waters. However, this catch is assumed to be minor, since no major commercial fisheries operate in federal waters in American Samoa.

Territory of Guam

The total coral reef area in federal waters in Guam is small relative to the other states and territories (110 km^2). However, these reefs account for approximately 60 percent of the coral reef area in Guam. All of the reefs in the EEZ in Guam are offshore banks and shoals, which are relatively inaccessible. As such, they are much less heavily fished than the nearshore resources, and only account for <20 percent of the 235 to 335,000 pounds of coral reef resources harvested annually in the Territory in recent years. Most of these harvested resources (>90 percent) were finfish.

Virtually no information exists on the condition of the coral reef resources in federal waters in Guam, and a resource assessment of these reefs would be useful. On the basis of anecdotal information, it is appears that most of these reefs are in good condition because of their isolation. The exception may be Galvez Bank, which has been reported to be overfished in recent years. In contrast, many of the reefs in Guam's territorial waters appear to have been badly degraded by overfishing and other human impacts (especially sedimentation).

Commonwealth of the Northern Mariana Islands

CNMI accounts for the second largest coral reef area in the US Pacific Islands (579 km^2). At present, all coral reef resources in CNMI are under federal jurisdiction, 0 to 200 nautical miles (nm) from shore, although the local government currently manages these resources. The majority of the coral reef resources in CNMI (534 km^2) are located 3 to 200 nm from shore, most of which is accounted for by Farallon de Medinilla and submerged shoals, reefs and banks (311 km^2 and 204 km^2 respectively).

Limited information suggests that most of the near shore reefs in CNMI are in good condition, except in some locations on the southern islands, where there are major population centers and there has been extensive coastal development and over fishing (especially on Saipan). Some of the near shore reefs may have also suffered as a result of recent military (e.g., on Farallon de Medinilla and Rota) and volcanic activities (e.g., on Pagan). Virtually nothing is known of the condition of the banks and shoals in the EEZ in CNMI, although most are assumed to be in good condition because of their isolation.

Coral reef fisheries in CNMI appear to be mostly limited to near shore reefs, especially on the main islands of Saipan, Rota and Tinian. Unfortunately, it is difficult to assess the total harvest of these fisheries, because of shortcomings in the local fisheries statistics. These include limitations in geographic coverage (mostly limited to Saipan) and the poor quality of some of the data. For example, some of the data cannot be subdivided into strata that will allow for a detailed analysis of the catch by area, depth, and in some cases, taxa. In particular, coral reef fish are difficult to separate from bottomfish in some of the existing databases.

All of the recent statistics that are available for the coral reef fisheries in CNMI are for the commercial fisheries. Most of these fisheries take place in the nearshore waters on the southern islands of Saipan, Tinian, Aguijan and Rota. Data from the commercial purchase survey show that at least 136,653 to 177,377 pounds of coral reef fish and 2,240 to 3,425 pounds of spiny lobster were landed each year from 1992 to 1994. Commercial fisheries for trochus and sea cucumbers were also re-opened for the first time in recent history, and a total of 268,068 sea cucumbers (168,235 pounds live weight) were harvested over an 18 month period from 1995 to 1996. No harvest estimates are available for the trochus fishery.

Very little is known of the coral reef fisheries in the northern islands, although the catch is believed to minor in most years. The exception was in 1995, when the near shore fringing reefs of six of the northern islands (especially Anatahan and Sarigan) were fished commercially for seven months of the year. During that time, these islands yielded a harvest of 15, 335 kg of reef fish and 380 spiny lobsters.

An unknown proportion of the bottomfish landings in CNMI may also be classified as part of the coral reef fishery, based on species captured and depth fished. However, it is difficult to do so because much of the catch is unidentified (29 to 51 percent) and the depth at which the fish were captured is unknown. However, two of the commercial bottomfishing operations have recently started targeting shallow-water species (<100 meters deep) in the northern islands, and the proportion of "reef species" in the catch may have increased. Furthermore, since much of this fishery takes place on the extensive bank at Farallon de Medinilla, it is possible that a moderate fishery for "reef species" is taking place in the EEZ of the CNMI, which is currently classified as part of the shallow-water bottomfish fishery.

Virtually no information is available on the inshore subsistence and recreational catch of coral reef species in CNMI at present, since the data from the inshore and offshore creel surveys have not been properly analyzed because of data quality problems. However, this catch is assumed to be substantial, especially in the more heavily populated areas such as Saipan Lagoon. Coral reef species harvested in this fishery include reef fishes and invertebrates, as well as small quantities of marine algae.

Anecdotal information suggests that most of the reefs in the EEZ receive very little fishing pressure, since local fishermen do not like to venture far from shore. The exceptions are the banks that are relatively close to the main islands (e.g., Esmeralda) and the extensive bank at Farallon de Medinilla, which are heavily fished.

Other Unincorporated U.S. Pacific Islands

The total coral reef area on these remote islands and atolls is 620 km^2, of which 112 km^2 are currently under Council jurisdiction. Little is known about the status of most of these reefs, although the majority is assumed to be pristine because they are remote from human activities. The exceptions are reefs that are immediately adjacent to islands occupied by the military, where coastal construction and pollution and contamination have affected coral reef health.

The majority of these islands and atolls are unfished, because of their remoteness and protected status as National Wildlife Refuges. The main exceptions are Johnston and Wake, where fishing is a popular sport among the resident work forces.

PART 3: RESEARCH AND INFORMATION ON CORAL REEF ASSOCIATED SPECIES

THE COUNCIL'S LIST OF CRE-FMP management unit species includes hundreds of species from dozens of families across multiple island areas and archipelagoes. While numerous papers have been published on life history and other information regarding some specific species, as a whole, the coral reef fishery still has a great deal of information gaps. The Council's attempt at new and additional information on its CRE-FMP management unit species has led to discoveries of new species, diets of certain fish, where fish go and even preliminary insight on the status of these stocks.

Part 2 of this monograph provides a synopsis of research that looked into acquiring new information on different coral reef fishery species in the Western Pacific Region. Included in this is black coral, a shallow-water precious coral that can be found at coral reef fishery depths. Information provided by these studies gives managers a greater understanding of the species and helps to inform stock assessments and annual catch limits.

Main Hawaiian Island Lobsters: Commercial Catch and Dealer Data Analysis, 1984 to 2004

by Kevin E. Kelly and Andrea Messer

Summary

The State of Hawai'i, through its Department of Land and Natural Resources' Division of Aquatic Resources, manages marine resources for the people of Hawai'i. This study analyzes 21 years (1984 to 2004) of data from fishermen catch and dealer sales reports to provide a current assessment of the lobster resources of the main Hawaiian Islands (MHI) and its associated commercial fishery.

The study was conducted for several reasons. First, no one had done a thorough analysis of the commercial fishery data since 1968. Second, the information would give insight regarding the development and evolution of the fishery. Third, this study could provide some insight into the status of stocks. Fourth, there had been no effort to compare reported catch data with dealer data for correlations between reported landings and dealer sales, particularly after changes in catch report forms and a concurrent education and outreach initiative implemented by the Division of Aquatic Resources in 2002.

During the years this study covers, the fishery as a whole reported relatively stable landings but exhibited dramatic shifts in preferred gear type, market patterns and island-specific production. Statewide annual commercial landings ranged between

7,000 and 12,000 pounds with the exception of a three-year low of 2,000 to 3,000 pounds from 1993 to 1995. Maui fishers accounted for 61 percent of the 185,263 pounds of commercial catch reported from 1984 to 2004. O‘ahu and Hawai‘i fishers reported 16 percent and 17 percent, respectively, while Kaua‘i fishers accounted for only 6 percent of the total landings. Maui’s contribution increased to 85 percent of the landings during the last five years.

Spiny lobsters consist of almost 90 percent of the reported catch, while slipper lobsters account for just over 10 percent. Improved species identification in the catch and dealer data from the last two years of the study indicate that the green spiny lobster is the predominant catch from Maui and Kaua‘i (93 percent), while the red spiny lobster dominates the catch from Hawai‘i and O‘ahu (90 percent). A huge drop-off in reported slipper lobster landings was also observed in the last two years, totaling only 0.25 percent of the landings.

A dramatic shift in gear preference occurred around 1994. Between 1984 and 1993, trap harvest accounted for twice as many landings (59 percent) as the next most productive gear type, hand harvest (27 percent). Hand harvest represented 79 percent of the reported landings between 1994 and 2004 and accounted for 91 percent of landings between 2001 and 2004. Lobster nets were employed most frequently on O‘ahu, accounting for 23 percent of that island’s landings but only 5 to 10 percent of the landings from the other islands.

During the years of its greatest use (1984–1993), trap harvest CPUE averaged 20 to 40 pounds landed per day. Hand and net harvest displayed similar CPUE values during this same period. Catch rates for all three primary gear types were at 21-year lows in 1993, averaging less than 20 pounds per day. As hand harvest became the preferred gear type (1994–2004), its mean CPUE on Maui gradually improved from 10 pounds per day in 1993 to peak at 60 pounds per day in 2002. Hand harvest catch rates on O‘ahu and Hawai‘i remained relatively constant over the 21-year period, averaging 10 to 20 pounds per day and 20 to 30 pounds per day, respectively.

Mean weight for spiny lobsters remained fairly constant over the 21 years, fluctuating between 2.0 to 2.5 pounds on Hawai‘i and Maui and between 1.5 and 2.5 pounds on O‘ahu. There appears to be a gradual decrease in mean weight on Maui since 1995, while on O‘ahu mean weight has been steadily increasing since 1990. Based on limited data from 2002 to 2004, green and red spiny lobsters harvested in this fishery have a similar mean weight of 2.15 pounds in all island areas. Mean weight for slipper lobsters was slightly smaller than for spiny lobsters, fluctuating between 1.5 and 2.0 pounds over the time-series but exhibiting no upward or downward trend.

A few individuals dominated the fishery. Twenty fishers were responsible for 52 percent of the 185,263 pounds of reported landings, while more than 500 registered fishers harvested the remaining catch. The small-scale fishers earn only a few hundred dollars in a given year from their lobster sales. The 20 primary fishers, most active for about six years of the 21-year study, report between $5,000 and $10,000 each year in lobster income. The market exhibited even greater consolidation, with a single dealer from each island region dominating the market. At least for Maui and Kaua‘i, these virtual monopolies appeared to have a beneficial impact on their regional fishery by increasing the demand for lobsters and offering $2.50 to $5.00 more per pound than on Hawai‘i and O‘ahu. This, in turn, appeared to generate more participation and total landings. The 21-year statewide mean price per pound, adjusted to 2004 value, was $10.72.

Dealer data captured less of the commercial fishery activity, with fishers reporting selling 150,000 pounds of lobsters and dealers reporting only 100,000 in sales. The total value of dealer sales was lower by a comparable value, approximately $30,000 less annually. Dealer reports also captured fewer total active fishers, reporting sales from 340 different fishers in the 21-year period, whereas 537 fishers reported selling their

catch to licensed dealers. A much closer correlation between catch and dealer data sets began in 1999 and continued until 2002, with total annual reported pounds sold and value of sales within 8 percent for the two data sets. Catch reports were revised in 2002, no longer requiring fishers to report sales data, which eliminated the ability to cross-check future landings and sales figures.

In the early years of the time-series, data fields from both catch and dealer reports were not always completed. Catch reports did not specify the number of lobsters caught in 20 percent of the entries, which limited the ability to analyze mean weight in some instances. Catch reports improved to 100 percent completion in 2002 with the initiation of the revised report forms. Dealer reports only reported the number of lobsters in 40 percent of the entries. In addition, 23 percent of the dealers did not report the value of the sale, which limited determining price per pound. Prior to 1990, dealers almost never distinguished between spiny and slipper lobsters. Dealer reports improved gradually beginning in 1996 and were nearly 100 percent complete by 2002. In addition, both dealer and catch reports began identifying lobsters to species in 2002, with nearly 100 percent compliance by 2003.

Based on this 21-year summary of the available data, the MHI lobster fishery does not appear to be experiencing overfishing. The fishery has adapted to new harvest methods and responded to an expanding market with stable trends in total landings and mean weight and stable or increasing trends in CPUE for hand harvest, the currently preferred gear method. While analyses of these indicators were sometimes limited due to poor species identification or small data sets, revised reporting forms and increased reporting compliance by the fishery in the later years of this study should provide the type of data for better fishery analyses in the future.

Feeding Interactions of the Introduced Blue-Line Snapper with Important Native Fishery Species in Hawaiian Benthic Habitats

by James D. Parrish and Brett D. Schumacher

Summary

The blue-line snapper, or taʻape *(Lutjanus kasmira)*, was introduced to nearshore waters of Hawaiʻi in the 1950s with the goal of enhancing commercial and recreational fishing opportunities. Although the fish has adapted well to its new environment, spreading quickly throughout the archipelago and becoming highly abundant across a substantial depth range, it has not been well received as a food fish. It is not actively sought by recreational fishers and is among the lowest priced fish in local markets. At best it is considered a nuisance species, but many individuals in the state perceive taʻape as adversely affecting native species by competing with them for limited resources or by preying on them.

Detailed analysis of the guts of 91 taʻape, 99 moano, 39 weke ʻula and 40 white weke that contained food are presented in this report. Dietary data were summarized by "frequency of occurrence" and "percent numerical abundance," and these values were multiplied to give the "index of relative importance" (IRI) for each prey category. Dietary similarity was then assessed by several measures. The 25 most important prey for each fish species were determined based on IRI, and the correlation among these ranks was calculated for each species. Also, IRI ranks were used to cluster results and generate dendrograms representing the relative similarity of diets. Finally, two different overlap indices (Morisita's index and Horn's index) were calculated to compare dietary overlap. The results of these measures were generally consistent. Diets of moano were by all measures the most similar to taʻape, but the data used indicate that these species feed at different times of day. Diets of the two weke species were most similar to each other; there is some indication that the diet of weke ʻula may be more similar to the diets of moano and taʻape than to the diet of white weke.

It has frequently been suggested (without factual support) that taʻape prey on young goatfish or other fish or crustacean resource species. Neither suggestion was supported by our data. The two most piscivorous species formally analyzed in this study were taʻape and moano, but none of the remains of fish found in the guts of either of these species was from resource species. They were instead primarily small cryptic fishes such as gobies (family Gobiidae) and sand-burrowers (family Creediidae). Similarly, none of the invertebrate remains obtained in guts of any of the focal fish species was identified as being from resource species such as the Kona crab *(Ranina ranina)*.

Ecological Impacts of *Carijoa riisei* on Black Coral Habitat

by Samuel E. Kahng

Summary

In 2001, the invasive octocoral *Carijoa riisei* was discovered overgrowing commercial black coral species *Antipathes griggi* (formerly *A. dichotoma*) and *A. grandis* in the ʻAuʻau Channel between the islands of Maui and Lanaʻi. The unknown, long-term ecological impact of this biological invasion raised questions regarding the sustainable yield of the commercial black coral harvest in the ʻAuʻau Channel. In 2001, 2003, 2004 and 2006, deep-water surveys using the Hawaii Undersea Research Laboratory's *Pisces IV/V* manned submersibles and *RCV-150* remotely operated vehicle revealed that the overgrowth was widespread in the channel with a maximum impact between 70 and 110 meters, where more than 40 percent of the black corals had *C. riisei* overgrowth. The most recent data from 2006 suggested that the impact of the biological invasion was not worsening with time.

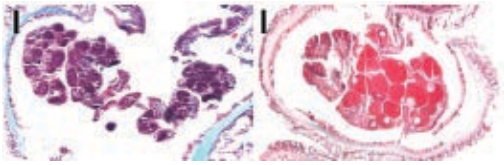
To confirm whether the ecological impact of *C. riisei* was worsening or stabilizing with time, a new survey was conducted in November of 2009 in the ʻAuʻau Channel and off the south coast of Kauaʻi. An effort was made to replicate areas previously surveyed in the Keyhole Pinnacle area in the northern ʻAuʻau Channel to enable a comparative analysis across time.

Results of the survey found that the biological invasion of *C. riisei* and its impact on black corals on the deep reef in the ʻAuʻau Channel, while widespread and serious, appeared

to be less severe than previously reported. Overgrowth on black corals had the most impact in the 70 to 105 meter depth range and was most abundant in areas of high current flow. *C. riisei* had not been observed overgrowing black corals in Kaua'i, where their upper depth range was slightly shallower due to lower optical water quality.

Reproductive Characteristics of the Hawai'i Black Coral Species *Antipathes griggi* with Implications for Future Management

by Daniel Wagner and Robert J. Toonen



Histological slides of mature polyps of the *Antipathes griggi* (Left: spermaries; Right: oocytes).

Summary

The Hawai'i species *Antipathes griggi* had previously been identified as *A. dichotoma*, a species from the Mediterranean. Until recently no taxonomic revision was made for this commercially valuable Hawai'i black coral species, and the name *A. dichotoma* was continuously used in the primary literature. In 2009, specimens collected as part of this study were compared to *A. dichotoma* specimens from the Mediterranean. As a result it was concluded that the Hawai'i species was different from *A. dichotoma*, and the new name of *A. griggi* was assigned.

A study was conducted to answer key questions about the sexual reproductive characteristics of *A. griggi*. An exhaustive review of the primary literature was performed covering more than 330 journal articles dealing with black corals, with special emphasis on black coral reproduction, taxonomy and ecology. Colonies of *A. griggi* were tagged south of Kaua'i and sampled monthly. Taxonomic samples were also collected in the 'Au'au Channel off of Maui, from Ni'ihau and Ka'ula, and from Laysan and Necker in the NWHI for the purpose of both reproductive and taxonomic studies.

The taxonomic study identified two additional black coral species: an *Aphanipthes* sp. from the 'Au'au Channel most closely resembling *A. verticillata* from the Southwest Indian Ocean and an unidentified *Antipathes* sp. from Ka'ula. It also revealed that identification of different black coral species in situ or from photographs is often problematic. Several species exhibit great morphological variation in colony branching pattern and coloration and cannot be readily differentiated in situ, resulting in incorrect identification by even trained personnel.

Reproductive study results showed that *A. griggi* is gonochoric with a 1:1 sex-ratio and that gametogenesis is highly synchronized both within and between colonies. It also showed that reproduction, while possible, does not occur frequently and/or successfully at depths between 75 and 100 meters. Results of these studies may have management implications as previously thought of deep refuges for black coral colonies may have been over estimated and harvest may be occurring on the more reproductive colonies.

Mapping and Assessing Critical Habitats for the Wrasse *(Cheilnus undulatus)*

by Marlowe Sabater

Summary

Underwater visual census is the most widely used method to determine fish abundance. However, this method ignores the basic assumptions of animal detectability. This study quantifies detectability in reef fishes and estimates population abundance as a function of species-specific detection probability. A double observer approach was applied to a roving snorkel survey to estimate detection probabilities and calculate population abundance of a rare coral reef fish, the Pacific humphead wrasse *(Cheilinus undulatus)*, on the reef flats of Tutuila Island in American Samoa. This approach allows for the calculation of observer-specific detection probabilities and the estimation of population abundance by incorporating detection probabilities. Factors that influence detection such as observer bias, species-specific detectability and species-group characteristics were incorporated in the model. Multiple regression was used to determine relationship of other factors such as distance of fish from observers, horizontal visibility and wideness of reef flats (as a function of sheltering from wave action) with the detection probability and population estimates.

A total of 58 surveys estimated a detection probability of around p = 0.61 for juvenile humphead wrasse. This suggests that on reef flat habitats an observer has a 61 percent chance of detecting the individual at any given survey. The "corrected" population size was 359 ± 25 individuals from counts of 218 individuals. Juvenile humphead wrasses were mostly observed in wide sheltered reef flats with small patches of sand bordered with branching corals. This juvenile habitat comprises only 1.6 percent of the shallow reef habitat and suggests that Tutuila Island coral reef system can potentially support only a small population size. These results suggest that the perceived low abundance of this coral reef fish species can be explained by the limited distribution of the juvenile stage's preferred habitat. Finally, this study provides a methodological perspective on the survey of a rare and threatened coral reef fish and provides a mechanism to correct estimates of its population abundance. More importantly, the results have implications on how the status of a naturally rare reef fish is viewed and the perceived impacts of threats such as overfishing.

Characterizing the Kona Crab *(Ranina ranina)* Fishery in the Main Hawaiian Islands

by Lennon Thomas

Summary

Using 1948 to 2009 commercial Kona crab landings data from the State of Hawai'i, Department of Aquatic Resources, an assessment of the Kona crab fishery in the main Hawaiian Islands was conducted to determine the status of the stock. Recreational catch data was not available and not incorporated into the assessment. Known life history characteristics of the Kona crab were summarized, and gaps in biological information were identified.

Data analyses revealed clear temporal and spatial trends in the fishery. CPUE varied significantly by statistical fishing area and by season. In the latter years, the commercial fishery was dominated by a few high volume fishers at Penguin Bank, which accounted for roughly half of the commercial landings. CPUE was standardized using a generalized linear model, which removed effects of potential spatial and temporal changes in the CPUE that are unrelated to stock abundance. The model produced a relative index of stock abundance (standardized CPUE) that showed a decline in the Kona crab stock of approximately 50 percent over the last 18 years. Changes in environmental conditions, changes in fishing effort and overexploitation of the stock are all likely factors contributing to the decline; however, the exact cause of the decline is unknown.

Assessment of Non-fishery Impacts on the Catch and Effort of the Kona Crab Fishery in Hawai'i

by Lennon R. Thomas

Summary

In 2011, a formal stock assessment was conducted on the Kona crab fishery in the MHI by standardizing commercial fishing data using a generalized linear model. The results of the assessment estimated a 50 percent decline in stock abundance over the last 18 years. While the model standardized CPUE for season and area fished, other potential factors were impacting CPUE for which the model did not account. The purpose of this project was to identify potential environmental and socioeconomic factors that could impact the MHI Kona crab fishery to gain a better understanding of interactions occurring in the ecosystem. Correlation analyses were run to examine the relationships between time series of Kona crab commercial data and non-fishery related factors.

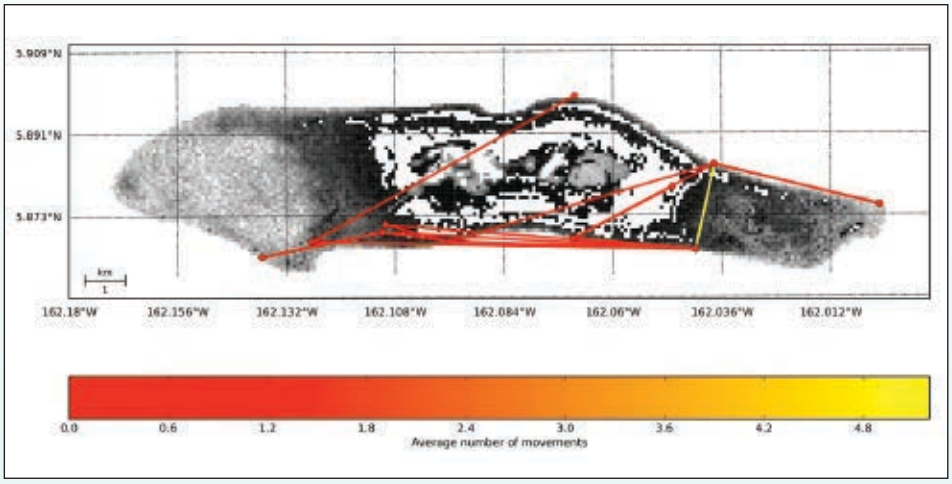
The results revealed significant relationships between Kona crab CPUE and average wind speed, population size, average market price for Kona crab and average cost of fuel. Rainfall and unemployment rates had a significant relationship with fishing effort. Both socioeconomic and environmental changes are believed to have a large impact on this small fishery, and stronger relationships may be present at smaller temporal and spatial scales. While no significant relationship was found between large scale environmental indices and CPUE, potential environmental relationships should continue to be investigated because of the potential large impact the environment may have on recruitment success of crustaceans.

Habitat Usage and Movement Behavior of Five Ubiquitous Mesopredators in Palmyra Atoll

by Gen Del Raye and Kevin Weng

Summary

Coral reef mesopredators are a relatively overlooked functional group that may play a large role in the functioning of human-impacted ecosystems. High resolution habitat maps coupled with long-term passive acoustic tracking were used to determine the habitat usage and movement behavior of five widely distributed mesopredators: the bluefin trevally *(Caranx melampygus)*, yellowlip emperor *(Lethrinus xanthochilus)*, long-face emperor *(L. olivaceus)*, Napoleon wrasse *(Cheilinus undulatus)* and wahoo *(Acanthocybium solandri)* in Palmyra Atoll. The results revealed significant relationships between habitat factors and frequency of detection and produced some of the first estimates of movement range for these species. In both movement behavior and habitat usage, the species studied can be broadly categorized into a more sedentary reef-associated group *(C. undulatus, L. olivaceus* and *L. xanthochilus)* and a highly mobile semi-pelagic group *(C. melampygus* and *A. solandri)*. These characterizations of preferred habitat and movement range hold strong implications for the management and ecology of these species, including the impact of habitat degradation and the design of marine reserves.



Movement summary for *Caranx melampygus*, showing all detected movements (lines) between receiver stations (nodes) where the color indicates the average number of movements between those receivers.

PART 4: RESEARCH ON THE CORAL REEF ECOSYSTEM

CORAL REEF ECOSYSTEMS ARE COMPOSED OF many species that extend across jurisdictional boundaries. Removal of species and changes in habitat may result in undesirable changes in ecosystem structure or function. Most island cultures recognize the importance of indirect impacts and have incorporated "ridge to reef" type of management concepts that take into account effects to the coral reef ecosystem beyond direct harvest.

Through the initial CRE-FMP and the consolidation of the Council's species-based Fishery Management Plans into place-based Fishery Ecosystem Plans, the first steps were taken to recognize the ecosystem-based approach to fishery management. As the Council works on the next phase, further research will be needed to determine and incorporate ecosystem concepts and indicators into the fishery ecosystem plans and fishery management process.

This last part of the monograph provides a glimpse at the Council's efforts to further implement an ecosystem-based approach to management through enhanced understanding of the ecosystem and the parts of the ecosystem that play an important role in in the lives of coral reef fish and impact the associated fisheries.

In Situ Acoustic Recording of Hawai'i Deep-Reef Slopes and Seamounts

Marc Lammers and Christopher Kelley

Summary

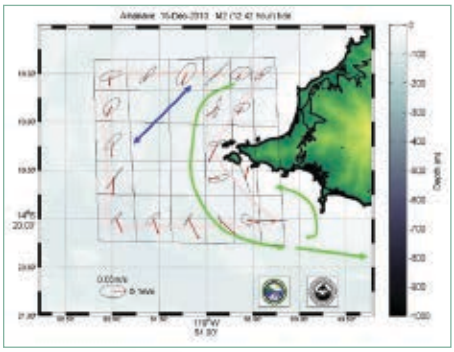
The sounds occurring on Hawai'i's deep reef slope and seamount habitats were investigated to determine the acoustic characteristics of these environments and to establish whether Hawai'i bottomfish produce sounds and could therefore be monitored acoustically. Three deep-water Ecological Acoustic Recorders were designed and built for this study. They were deployed at three sites near Penguin Bank, Moloka'i, for periods ranging from two weeks to two months between September 2006 and February 2007. A variety of sounds were recorded at each site, including sounds form fish, dolphins, whales, vessels and breaking surface waves. A strong evening chorus of presumably fish sounds was recorded daily at all three locations. This chorus began approximately a half hour after sunset and lasted for one hour at two of the sites and past midnight at the third site. A hypothesized source of the chorus is the mesopelagic boundary community, but more evidence is needed to confirm this. Other fish sounds

Ecological Acoustic Readers array.

were also common, particularly along the slope of Penguin Bank. It is unclear whether these sounds originated from Hawai'i bottomfish or other species. Cetacean sounds were also common, including the song produced by humpback whales *(Megaptera novaengliae)* and whistles and echolocation clicks produced by dolphins. Dolphins occurred consistently at two of the sites examined, particularly at night, suggesting that these might be important foraging areas. The ability of the recorders to detect nearby vessels was opportunistically tested, and it was determined that the system could automatically respond to vessels transiting within approximately 500 meters and could "hear" vessels as far as 5 kilometers. The findings presented reveal that Hawai'i's deep-water habitats are acoustically quite dynamic and that investigating the sounds present in these environments could lead to important new discoveries.

Current Surveys between Potential Marine Managed Areas in American Samoa

by Philip Wiles, Marlowe Sabater and Lucy Jacob



Component of the tide around the Western tip of Tutuila. The blue arrow indicates a tidal excursion. The green arrow is an approximate distance that the residual flow will carry drifters and indicates the position of the eddy in Amanave Bay.

Summary

Very little data exists describing the circulation of ocean currents around American Samoa, particularly on very local scales within bays and around headlands. The scarce amount of large scale current data that does exist suggests large scale currents generally flow from east to west around the American Samoan Archipelago. However, these currents meander, and it is not unusual for the flow to reverse in direction. To get a better understanding of these currents, a study was conducted to characterize some of the major currents (velocity, direction, persistence over time), the driving forces (e.g., tidal, seasonal, wind/wave driven) and the impact on larval transport and/or distribution around the island.

Utilizing an Acoustic Doppler Current Profiler affixed to a vessel, surveys were conducted in six sites of priority interest for larval dispersal, including channels, banks and marine protected areas. Cruise tracks were 5 to 8 nautical miles with the vessel operating at 4 to 6 knots and repeated every one to two hours. Survey results from Aunu'u, Taema and Amanave provided suitable tidal analysis.

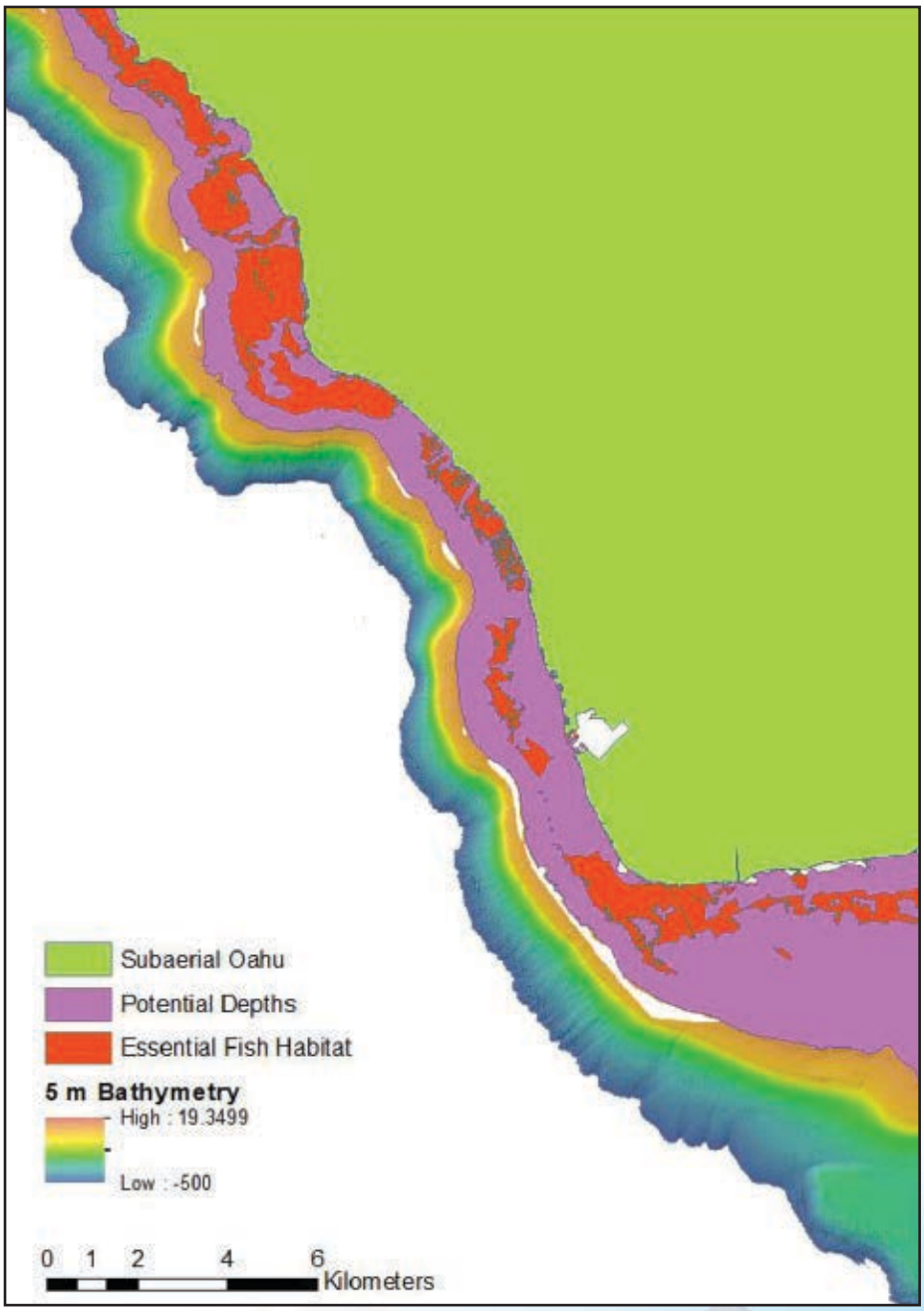
Survey results generally present the flow of currents around Tutuila from the southwest during high tides with eddies formed around bays and headlands. Currents are also particularly strong in the channel between Aunu'u and Tutuila. The presence of eddies and intense water movement have the potential to hold larvae close to the island, giving them a chance to settle locally before being lost to the open ocean. While continued surveys are needed to confirm the currents, the growing dataset indicates that enhancing spawning stocks in a location such as Fagamalo would be very beneficial to Maloata, Poloa and Amanave and of some benefit to the Aoloau coastline east of Fagamalo. However, enhanced spawning stocks in Amanave may have little benefit to Poloa, Maloata and Fagamalo.

An Approach for Assessing Essential Fish Habitat for Coral Reef Species in Hawai'i

by Daniel Luck

Summary

The Sustainable Fisheries Act of 1996 mandated that fishery management councils describe and identify EFH, defined therein as "those waters and substrate necessary for fish for spawning, breeding and growth to maturity" for all species managed



Selected habitats of the manini between Barabers Point and Nānākuli, O'ahu.

under a fisheries management plan. The lack of available data to do so, however, is something that most fishery management councils face, and solving that problem would require a large amount of resources. A cost-effective approach for designating EFH for coral reef fish species would offer fishery managers an option for improving EFH designations. One straightforward approach to determining EFH for a species of interest is to compare its relative abundance between available habitats.

A study was undertaken to determine how available fish survey data can be combined with remotely sensed benthic habitat data to provide a first-order approximation of habitat-specific relative abundance. In this context, the strengths and weaknesses of the available fish abundance and benthic habitat data for the MHI are discussed and habitat-specific density is combined with bathymetric data using ArcGIS to delineate EFH for a pilot species, manini *(Acanthurus triostegus sandvicensis)*. The approach used provides for an additional way for determining EFH; however, a ground-truth component is needed through cost-effective shallow-water visual fish surveys to validate the approach.

PART 5: CORAL REEF ECOSYSTEM REPORTS PREPARED FOR THE WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL (1995 TO 2016)

These reports can be found on the Council's website at www.wpcouncil.org/fishery-plans-policies-reports/grey literature/.

Research and Historical Data on Coral Reef Fisheries

Amesbury JR and Hunter-Anderson RL. 2003. Review of Archaeological and Historical Data Concerning Reef Fishing in the US Flag Islands of Micronesia: Guam and the Northern Mariana Islands.

Dye TS and Graham TR. 2003. Review of Archaeological and Historical Data Concerning Reef Fishing in Hawai'i and American Samoa.

Green A. 1997. An Assessment of the Status of the coral Reef Resources, and their Patterns of Use, in the US Pacific Islands.

Hunter C. 1995. Review of Status of Coral Reefs around American Flag Pacific Islands and Assessment of Need, Value and Feasibility of Establishing a Coral Reef Fishery Management Plan for the Western Pacific Region.

Munro JL. 2001. The Assessment of Exploited Stocks of Coral Reef Fishes.

Maciasz M. 2012. Analysis of Commercial Fish Trap Data in Hawai'i.

Milne N. 2012. Hawai'i Coral Reef Dealer Study.

Ochavillo D. 2012. Coral Reef Fishery Assessment in American Samoa.

Pylman K. 2012. Fish Traps as an Indicator of Fish Abundance.

Walker R, Ballou L and Wolfford B. 2012. Non-Commercial Coral Reef Fishery Assessments for the Western Pacific Region.

Zeller D, Booth S and Pauly D. 2005. Reconstruction of Coral Reef- and Bottom-Fisheries Catches for US Flag Island Areas in the Western Pacific, 1950–2002.

Research and Information on Coral Reef Associated Species

Del Raye G and Weng K. 2012. Habitat Usage and Movement Behavior of Five Ubiquitous Mesopredators in Palmyra Atoll.

Hawaii Cooperative Fishery Research Unit. 2008. Report on Biology of Parrotfish of Hawai'i.

Kahng SE. 2007. Ecological Impacts of Carijoa Riisei on Black Coral Habitat.

Kelly KE and Messer A. 2005. Main Hawaiian Island Lobsters: Commercial Catch and Dealer Data Analysis (1984–2004).

Parrish JD and Schumacher BD. 2005. Feeding Interactions of the Introduced Blue-line Snapper with Important Native Fishery Species in Hawaiian Benthic Habitats.

Sabater MS. 2010. Mapping and Assess-ing Critical Habitats for the Wrasse (Cheilnus undulates).

Thomas L. 2012. Assessment on Non-fishery Impacts on the Catch and Effort of the Kona Crab Fishery in Hawai'i.

Thomas L. 2015. Characterizing the Kona Crab (Ranina ranina) Fishery in the Main Hawaiian Islands.

Wagner D and Toonen RJ. 2010. Reproductive Characteristics of the Hawaiian Black Coral Species Antipathes Griggi with Implications for Future Management.

Research on the Coral Reef Ecosystem

Bartram P. 2012. Assessment of Freshwater Impacts on Coral Reef Fisheries of Hawai'i.

Fugro Pelagos, Inc. 2004. Bathymetry & Habitat Mapping: Farallon de Medinilla, Northern Mariana Islands Survey Report.

Hawhee JM. 2007. Western Pacific Coral Reef Ecosystem Report.

Lammers MO and Au WWL. 2011. Spatial and Temporal Patterns of a Deep-Water Acoustic Chorus Observed off O'ahu, Hawai'i.

Lammers MO and Kelley C. 2007. In Situ Acoustic Recordings of Hawaiian Deep-Reef Slopes and Seamounts.

Luck D. 2012. An Approach for Assess-ing Essential Fish Habitat for Coral Reef Species in Hawai'i.

Wiles P, Sabater MS and Jacob L. 2010. Current Surveys between Potential Marine Managed Areas in American Samoa.

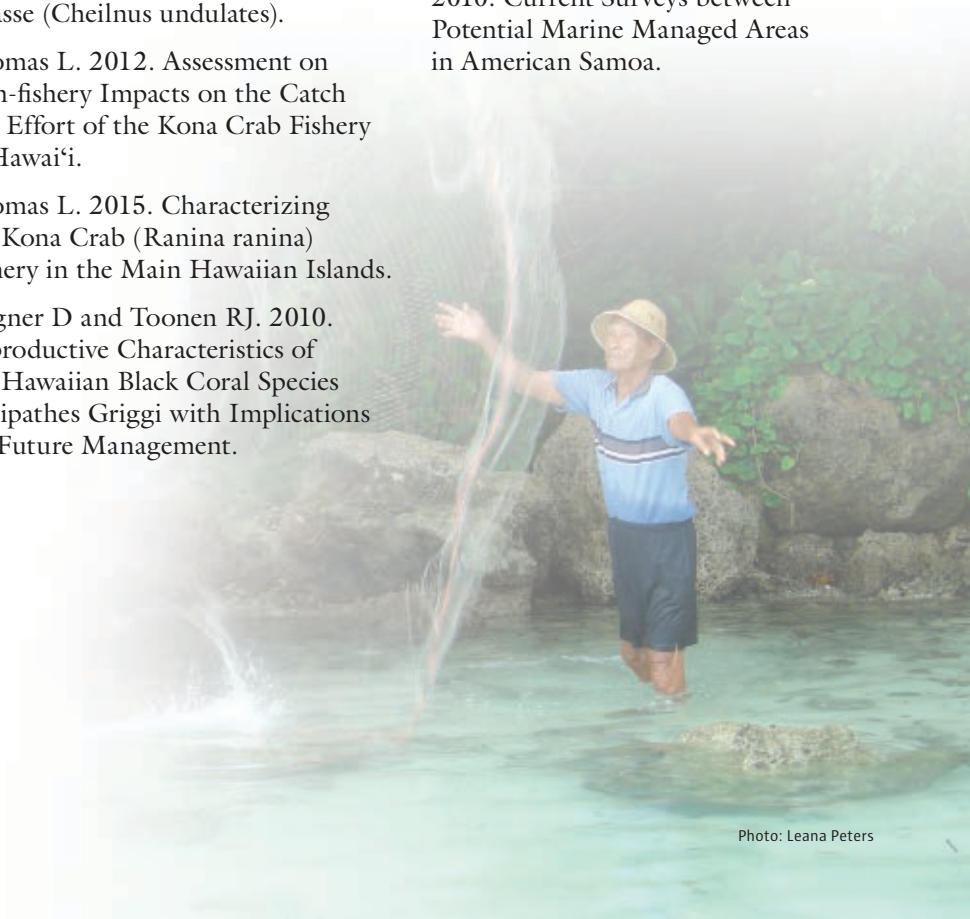


Photo: Leana Peters

Western Pacific Regional
Fishery Management Council
1164 Bishop Street, Suite 1400
Honolulu, Hawaii 96813
Tel: 808-522-8220
Fax: 808-522-8226
info.wpcouncil@noaa.gov
www.wpcouncil.org

Western Pacific Regional
Fishery Management Council
1164 Bishop Street, Suite 1400
Honolulu, Hawaii 96813
Tel: 808-522-8220
Fax: 808-522-8226
info.wpcouncil@noaa.gov
www.wpcouncil.org

ISBN 978-1-937863-98-2

Printed on Recycled Paper.

Cover photo: Eric Woo
Inside cover photo: Joshua DeMello/WPRFMC