ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT: MARIANA ARCHIPELAGO FISHERY ECOSYSTEM PLAN 2017

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The ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT for the MARIANA ARCHIPELAGO FISHERY ECOSYSTEM 2017 was drafted by the Fishery Ecosystem Plan Team. This is a collaborative effort primarily between the Western Pacific Regional Fishery Management Council, NMFS-Pacific Island Fisheries Science Center, Pacific Islands Regional Office, Division of Aquatic Resources (HI) Department of Marine and Wildlife Resources (AS), Division of Aquatic and Wildlife Resources (Guam), and Division of Fish and Wildlife (CNMI).

This report attempts to summarize annual fishery performance looking at trends in catch, effort and catch rates as well as provide a source document describing various projects and activities being undertaken on a local and federal level. The report also describes several ecosystem considerations including fish biomass estimates, biological indicators, protected species, habitat, climate change, and human dimensions. Information like marine spatial planning and best scientific information available for each fishery are described. This report provides a summary of annual catches relative to the Annual Catch Limits established by the Council in collaboration with the local fishery management agencies.

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Executive Summary

As part of its five-year fishery ecosystem plan (FEP) review, the Council identified the annual reports as a priority for improvement. The former annual reports have been revised to meet National Standard regulatory requirements for Stock Assessment and Fishery Evaluation (SAFE) reports. The purpose of the reports is twofold: to monitor the performance of the fishery and ecosystem to assess the effectiveness of the FEP in meeting its management objectives; and to maintain the structure of the FEP living document. The reports are comprised of three chapters: fishery performance, ecosystem considerations, and data integration. The Council will iteratively improve the annual SAFE report as resources allow.

The fishery performance section of this report first presents a general description of the local fishery within Commonwealth of Northern Mariana Islands (CNMI) and Guam, including both the bottomfish and coral reef management unit species (MUS). The fishery data collection system is then explained, encompassing shore-based and boat-based creel surveys, commercial receipt books, and boat inventories. Fishery meta-statistics for each MUS are organized into a summary dashboard table showcasing the values for the most recent fishing year and a comparison to short-term (10-year) and long-term (20-year) averages. Time series for catch and effort statistics are also provided alongside annual catch limit determinations. For 2017 catch in CNMI, only the slipper lobster MUS exceeded their overfishing limit (OFL), allowable biological catch (ABC), or annual catch limit (ACL). For 2017 catch in Guam, no MUS were identified that had a recent average catch below OFL, ABC, and ACL. ACLs were not specified by NMFS for the coral reef ecosystem MUS because NMFS has recently acquired new information that require additional environmental analyses to support the Council's ACL recommendations for these management unit species (50 CFR Part 665). For CNMI, the 2017 catch of slipper lobsters exceeded the ACL. Slipper lobsters had not appeared in the catch record until last year, and now have exceeded the ACL for two consecutive years. This can likely be attributed to the implementation of the Territory Science Initiative project that aimed to improve the reporting and compliance to the commercial receipt book data collection program by the Saipan fish vendors.

For the CNMI and Guam, the main fisheries monitored are the bottomfish, crustacean, and coral reef fisheries. The time series depicted for CNMI include the most recent decade, but do not extend far back to make a longer-term trend comparison. Catch with the bottomfishing gear showed a very slight increase in 2017 when considering all species or BMUS only. The bottomfishing CPUE, however, had a significant increase of 250% from the recent 10 year average in 2017. Fishing effort, fishery participation, and fishery bycatch decreased in the last year among a 10 year decline. For the coral reef fisheries, statistics for shore-based and boat-based fisheries are shown separately. The estimated 2017 CPUE measures for both shore- and boat-based reef fisheries in CNMI are generally higher than the 10 year average. The fishery participation (number of gear hours) in both shore- and boat-based coral reef fisheries showed a decrease in participation, but the number of fishing participants in 2017 for the boat-based reef fishery in CNMI had increased significantly for spearfishing and trolling. Coral reef bycatch in CNMI has been decreasing in both fisheries as well.

For Guam, the bottomfish fishery in 2017 exhibited a 10% decline in all species catch and an 11% decline for the BMUS catch. No commercial catch trends can be reported due to data

confidentiality (i.e. less than 3 vendors that reported). There were general decreases in 2017 CPUE considering both previous 10- and 20-year averages. The total estimated number of fishing trips for bottom fish decreased by over 20% for both short- and long-term averages, though the number of fishers in 2017 showed a very slight increase (1%). While bottomfish bycatch statistics increased in 2017 relative to short-term trends, there is a slight decrease apparent when compared to long-term statistics. The coral reef shore- and boat-based fisheries, in general, showed declines in catch and CPUE in 2017 relative to both short- and long-term trends. Only shore-based gill net and cast net showed increases in 2017 relative to 10- and 20-year measures. The fishing effort estimates in 2017 were generally down except for the boat-based trolling and shore-based cast net. Participation was mixed across fisheries and gear types, though the most notable changes included a large decrease in gear hours for boat-based SCUBA and snorkel spear and a large decrease in participants for boat-based gill netting. Coral reef fishery bycatch was down roughly 20% compared to short- and long-term averages, but was part of a gradual increasing trend over the past 10 years in Guam.

An Ecosystem Considerations chapter was added to the annual SAFE report following the Council's review of its fishery ecosystem plans and revised management objectives. Fishery independent ecosystem survey data, human dimensions, protected species, climate and oceanographic, essential fish habitat, and marine planning information are included in the ecosystem considerations section. Fishery independent ecosystem survey data was acquired through visual surveys conducted in CNMI, Pacific Remote Island Area, American Samoa, Guam, Main Hawaiian Islands, and Northwestern Hawaiian Islands. This report illustrates the mean fish biomass for the reef areas within these locations. Additionally, the mean reef fish biomass and mean size of fishes (>10 cm) for CNMI and Guam are presented by sampling year and reef area. Finally, the reef fish population estimates for each study site within CNMI and Guam are provided for hardbottom habitat (0-30 m).

For CNMI, life history parameters including maximum age, asymptotic length, growth coefficient, hypothetical age at length zero, natural mortality, age at 50% maturity, age at sex switching, length at which 50% of a fish species are capable of spawning, and length of sex switching are provided for 10 species of reef fish and 11 species of bottomfish. The same nine life history parameters are provided for 12 reef species and 11 bottomfish in Guam.

Summarized length derived parameters for coral reef fish and bottomfish in CNMI and Guam include: maximum fish length, mean length, sample size, sample size for L-W regression, and length-weight coefficients. Values for 25 coral reef fish species and 10 bottomfish species are presented for CNMI. Values for 22 coral reef fish species and three bottomfish species are presented for Guam.

The socioeconomics section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of the Fishery Ecosystem Plan for the Mariana Archipelago. It meets the objective "Support Fishing Communities" adopted at the 165th Council meeting; specifically, it identifies the various social and economic groups within the region's fishing communities and their interconnections. The section begins with an overview of the socioeconomic context for the region, and then provides a summary of relevant studies and data for Mariana Islands, followed by summaries of relevant studies and data for each fishery within the Mariana Archipelago. Socioeconomics data will be included in later versions of this report as resources allow.

There were no new data reported for the crustacean or precious coral fisheries in the CNMI or Guam. No data on commercial participation, landings, revenues, or prices were available for inclusion in this report at the time of publication. Considering the CNMI bottomfish fishery, the average cost of a bottomfish trip was nearly half of that in 2016 at $38 versus $65 in 2016; this is likely due to the steep drop in fuel coast from $57 per trip to $32 per trip over the past year. Note that data on the cost per spearfishing coral reef trips in the CNMI was considered confiendtial for 2017. Considering Guam's bottomfish fishery in 2017, average cost of a bottomfish trip was doubled compared to 2016 at $72; again, this is likely closely related to fuel cost per trip, which more than doubled over the same time period from $15 to $35.

The protected species section of this report summarizes information and monitors protected species interactions in fisheries managed under the Mariana Archipelago FEP. These fisheries generally have limited impacts to protected species, and do not have federal observer coverage. Consequently, this report tracks fishing effort and other characteristics to detect potential changes to the level of impacts to protected species. Fishery performance data contained in this report indicate that there have been no notable changes in the fisheries that would affect the potential for interactions with protected species, and there is no other information to indicate that impacts to protected species have changed in recent years in the Mariana Archipelago.

The climate change section of this report includes indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Western Pacific Regional Fishery Management Council has responsibility. In developing this section, the Council relied on a number of recent reports conducted in the context of the U.S. National Climate Assessment including, most notably, the 2012 Pacific Islands Regional Climate Assessment and the Ocean and Coasts chapter of the 2014 report on a Pilot Indicator System prepared by the National Climate Assessment and Development Advisory Committee. The primary goal for selecting the indicators used in this report is to provide fisheries-related communities, resource managers, and businesses with climate-related situational awareness. In this context, indicators were selected to be fisheries relevant and informative, build intuition about current conditions in light of changing climate, provide historical context and recognize patterns and trends. The atmospheric concentration of carbon dioxide (CO_2) trend is increasing exponentially with the tiem series maximum at 406.53 ppm. The oceanic pH at Station Aloha, in Hawaii has shown a significant linear decrease of -0.0386 pH units, or roughly a 9% increase in acidity ([H+]) since 1989. 2017 showed extreme high temperature anomalies, with values surpassing 12 degree heating week in both the CNMI and Guam. The NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2017, published online January 2018, notes that "The 2017 East Pacific hurricane season had 18 named storms, including nine hurricanes, four of which became major."

The Mariana Archipelago FEP and National Standard 2 guidelines require that this report include a report on the review of essential fish habitat (EFH) information. The 2017 annual report includes cumulative impacts on EFH as well as a review of relevant life history and habitat information for four common coral reef crustaceans. In 2016, descriptions of precious coral species and habitat were provided alongside the impacts of non-fishing. The guidelines also require a report on the condition of the habitat. In the 2017 annual report, mapping progress and benthic cover are included as indicators, pending development of habitat condition indicators for the Mariana Archipelago not otherwise represented in other sections of this report. The annual report addresses any Council directives toward its plan team. There were no directives in 2017.

The marine planning section of this report tracks activities with multi-year planning horizons and begins to track the cumulative impact of established facilities. Development of the report in later years will focus on identifying appropriate data streams. Military activities in the Marianas continue to impact fisheries and access. With the Records of Decision on the Mariana Islands Testing and Training and Guam and CNMI Military Relocation SEIS, access to fishing grounds will be impacted at Ritidian Point on Guam and at Farallon de Medinilla in CNMI during live-fire exercises. Nearshore water quality will be impacted in Northern Guam until the Northern District Wastewater Treatment Plant is upgraded. A re-release of the draft CNMI Joint Military Training EIS is not expected until the end of 2018. CNMI and the Department of Defense will establish a coordinating council to discuss issues associated with increased military activity in the CNMI.

The 2018 Archipelagic Plan Team had the following recommendations with respect to this report:

Regarding the monitoring of the management unit species, the Archipelagic Plan Team recommends the Council to direct staff to work with the Territory fishery agencies to identify and resolve issues with regards to real-time accurate reporting, such as regulatory gaps, and potential solutions, such as mandatory licensing and reporting (e.g. log books).

Regarding the development and improvement of data collection systems in the short-term, the Archipelagic Plan Team recommends the Council to support these processes by exploring the options of: a dedicated port sampler to conduct a full census of the bottomfish catch, the improvement and expansion of Commercial Receipt Books, and improvements in the timeliness of the data transcription.

Regarding the carry-over provision of the 2016 National Standard 1, the Archipelagic Plan Team recommends the Council direct staff to explore the application of the carry-over provision in the Council's control rules.

Regarding the evaluation 2017 catch relative to 2017 ACLs, the Archipelagic Plan Team recommends retaining the ACL at 60 lbs. for CNMI slipper lobster. The CNMI slipper lobsters recent three-year average catch of 130 lbs. exceeded its prescribed ACL of 60 lbs. The slipper lobster fishery is tracked through the Commercial Receipt Books in the CNMI. The increase in catch can likely be attributed to the implementation of the Territory Science Initiative, designed to improve the data submitted to the Commercial Receipt Book program. In 2017, seven invoices and five fishermen reported the sale of slipper lobsters, all of which were zeroes in years prior to 2016.

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TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
ABC	Acceptable Biological Catch
ACE	Accumulated Cyclone Energy
ACL	Annual Catch Limits
ACT	Annual Catch Target
AM	Accountability Measures
AVHRR	Advanced Very High Resolution Radiometer
BAC-MSY	Biomass Augmented Catch MSY
B_{FLAG}	warning reference point for biomass
BiOp	Biological Opinion
BMUS	Bottomfish Management Unit Species
BOEM	Bureau of Ocean Energy Management
BSIA	Best Scientific Information Available
CFR	Code of Federal Regulations
CMLS	Commercial Marine License System
CMS	coastal and marine spatial
CMUS	Crustacean Management Unit Species
CNMI	Commonwealth of the Northern Mariana Islands
CPUE	Catch per Unit Effort
CRED	Coral Reef Ecosystem Division
CREMUS	Coral Reef Ecosystem Management Unit Species
DAWR	Division of Aquatic and Wildlife Resources
DLNR-DAR	Department of Land and Natural Resources-Division of Aquatic Resources
DLNR-DFW	Department of Land and Natural Resources-Division of Fish and Wildlife
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EKE	Eddy kinetic energy
ENSO	El Niño Southern Oscillation
EO	Executive Order
ESA	Endangered Species Act
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FRS	Fishing Report System
GAC	Global Area Coverage
GFS	global forecast system
HAPC	Habitat Area of Particular Concern
HDAR	Hawaii Division of Aquatic Resources
IBTrACS	International Best Track Archive for Climate Stewardship
LOF	List of Fisheries

LVPA	Large Vessel Prohibited Area
MFMT	Maximum Fishing Mortality Threshold
MHI	Main Hawaiian Island
MMA	marine managed area
MMPA	Marine Mammal Protection Act
MPA	marine protected area
MPCC	Marine Planning and Climate Change
MPCCC	Council's MPCC Committee
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
MUS	management unit species
NCADAC	National Climate Assessment & Development Advisory Committee
NCDC	National Climatic Data Center
NEPA	National Environmental and Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service
NMFS	National Marine Fisheries Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWHI	Northwestern Hawaiian Islands
OFL	Overfishing Limits
OFR	Online Fishing Report
ONI	Ocean Niño Index
OR&R	Office of Response and Restoration
OY	Optimum Yield
PacIOOS	Pacific Integrated Ocean Observing System
PCMUS	Precious Coral Management Unit Species
Pelagic FEP	Fishery Ecosystem Plan for the Pacific Pelagic Fisheries
PI	Pacific Islands
PIBHMC	Pacific Island Benthic Habitat Mapping Center
PIFSC	Pacific Island Fisheries Science Center
PIRCA	Pacific Islands Regional Climate Assessment
PIRO	NOAA NMFS Pacific Islands Regional Office
PMUS	pelagic management unit species
POES	Polar Operational Environmental Satellite
PRIA	Pacific Remote Island Areas
RAMP	Reef Assessment and Monitoring Program
RPB	Regional Planning Body
SAFE	Stock Assessment and Fishery Evaluation
SBRM	Standardized Bycatch Reporting Methodologies
SDC	Status Determination Criteria
SEEM	Social, Economic, Ecological, Management uncertainties
SPC	Stationary Point Count
SST	Sea Surface Temperature

TAC	Total Allowable Catch
USACE	United States Army Corps of Engineers
WPacFIN	Western Pacific Fishery Information Network
WPRFMC	Western Pacific Regional Fishery Management Council
WPSAR	Western Pacific Stock Assessment Review
WW3	Wave Watch 3

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1 FISHERY PERFORMANCE

1.1 CNMI FISHERY DESCRIPTIONS

1.1.1 Background

The Commonwealth of the Northern Mariana Islands (CNMI) is a chain of islands in the Western Pacific Ocean. Along with the island of Guam, the chain is historically known as the Mariana Islands. The CNMI consists of 14 small islands situated in a north-south direction, stretching a distance of about 500 km. The surrounding waters of the CNMI play an integral role in the everyday lives of its citizens. The ocean is a major source of food and leisure activities for residents and tourists alike. Archeological research has also revealed evidence of fishing activities in the CNMI dating back 3,000 years. Although the composition of fishing activities in the Marianas has changed significantly since then, a common view of its importance remains.

Fisheries during the German occupation
During the German occupational period (1899-1914) a majority of the economic focus in the Northern Marianas was on the copra industry. Few commercial fisheries were noted during this period of time, as the German administration focused efforts on crop production and feral cattle trade (Russell, 1999). Chamorros and Carolinians utilized the protected lagoon and open waters with several fishing methods: talaya (cast net), chinchulu (surround net), gigao (fish weir), tokcha (spear), tupak (hook and line), and Carolinians additionally gleaned sea cucumbers for the Asian Markets. Most of these activities were for subsistence purposes, with the catch being distributed and bartered among relatives and acquaintances.

Fisheries during the Japanese occupation
Fisheries development prospered during the Japanese administration (1914-1945), becoming the nation's second largest industry. Small pelagic fishing operations were established and the Garapan port became the main area for drying fish. Large scale fishing activities occurred during the 1930s, shown as Saipan produced 11% of total tuna landed in Micronesia (Bowers, 2001). However, efforts to develop the tuna fishery shifted to Palau and FSM due to the availability of bait fish in the region. Subsistence fishing still persisted within the lagoon and fringing reefs, and was mainly conducted by the natives though a large extraction of sea cucumbers did occur. There were several main fishing methods used during this period: cast net, spear, gill net, surround net, hook and line, and gleaning. During this period, the topshell (*Trochus niloticus*) was also introduced into the Marianas.

Fisheries during the U.S. military occupation
The fishing industry was destroyed during WWII, but quickly rebuilt afterwardswith support from the U.S. military. Okinawans who operated the fishery prior to the war were hired to operate and train locals to fish commercially, targeting pelagic species. A company called Saipan Fishing Company operated during this time, which contributed to the early re-development of post-war commercial fisheries in the CNMI (Bowers, 2001). Most of the fishing activities were for *Katsuwanus pelamis* (bonito) and other tuna species. However, other resources such as big-eye scad, reef fish, and lobster were also harvested during calm weather. The Chamorros and Carolinians continued subsistence fishing within the lagoon after the war. Although limited quantities of monofilament nets were available during this period, they were used to capture

lagoon fish and along the reef lines. The use of modern fishing gear such as masks, rubber fins, and flash lights made it much easier to harvest coral reef resources during this time.

Fisheries activities within the past two decades
The CNMI has had numerous changes in fisheries within the past twenty years. In the mid-1990s, commercial fishery activities increased significantly. Commercial SCUBA fishing became a common method not only to support local demand for reef fish, but to bolster exports to Guam as well. Large-scale commercial bottomfishing activity in the Northern Islands of the CNMI peaked from the mid-1990's through 2002, with landings both being sold locally and being exported to Japan. Troll fishing continued to be the dominant fishing industry during this period. An exploratory, deepwater shrimp fishery also developed, but didn't last due to internal company issues and gear losses. During this time a sea cucumber fishery began on Rota before migrating to Saipan. Ultimately, this fishery was found to be unstable and was subsequently halted.

Several fishing companies entered the fisheries only to close down a few years later. The CNMI reached its highest population during the last two decades, most of whom have been migrant workers from Asia. The tourism industry has also been increasing, which contributes to high demand for fresh fish. Subsistence fishing within the nearshore waters of Saipan, Tinian, and Rota has also increased.

In the 2000's, small-scale troll, bottom and reef fish fisheries persisted, with landings sold locally. Federal and state support was provided multiple times to further develop fisheries in the CNMI with intermittent success. An exploratory longline fishery was funded and operated in the CNMI in the mid-2000 for about two years, but eventually closed down due to low productivity of high-value, pelagic fish, among other issues within the business. A few larger (40-80') bottomfishing vessels were also operational during this period, with a majority of them fishing the northern islands and offshore banks. A few of these vessels were recipients of financial assistance to improve their fishing capacities.

Fisheries in the CNMI have generally been relatively small and fluid, with 16-20' boats fishing within 20 miles from Saipan. Many of these small vessels conduct multiple fishing activities during a single trip. For example, a company that is supported mainly by troll fishing may also conduct bottomfishing and spearfishing to supplement their income. Fishing businesses tend to enter and exit the fishery when it is economically beneficial to do so, as they are highly sensitive to changes in the economy, development, population, and regulations. Subsistence fishing continues; however, fishing methods and target species have shifted in step with population demographics and fishery restrictions. Nearshore hook and line, cast net, and spear fishing are common activities, but fishing methods such as gill net, surround net, drag net, and SCUBA-spear have been restricted or outright banned in the CNMI since the early 2000s.

1.1.1.1 Bottomfish Fishery

The bottomfish fishery has not changed much from its early years in certain aspects. Relatively small (<25ft) fishing vessels are still being used to access bottom fishing grounds around Saipan and Tinian, while the larger (>25ft) vessels are used to access bottomfish resources in the Northern Islands. Only a handful of these larger bottom fishing vessels are operating within the CNMI. Most of the small bottomfishing vessels are owned by vendors; there are, however, a few subsistence bottomfishers that participate in the fishery intermittently. More recently, improved technologies, such as sophisticated electronics to locate fish and various types of reels replacing handlines, have entered the CNMI bottomfish fishery.

Two distinct types of bottomfish fisheries are identified in the CNMI: shallow-water bottom fishing, which targets fish at depths down to 150 m, and deep-water bottom fishing, which targets fish at depths greater than 150 m. Species targeted by the shallow-water fishery consist of the Redgill Emperor (*Lethrinus rubrioperculatus*), Black Jack (*Caranx lugubris*), Matai (*Epinephelus fasciatus*), Sas (*Lutjanus kasmira*), and Lunartail Grouper (*Variola louti*), among other fish residing at similar depths. Species targeted by the deep-water bottom fishing depths (>150m) include Onaga (*Etelis corsucans*), Ehu (*E. carbunculus*), Yellowtail Kalekale (*Pristipomiodes auricilla*), Amberjack (*Seriola dumerili*), Blueline Gindai (*P. argyrogrammicus)*, Gindai (*P. zonatus*)*,* Opakapaka (*P. filamentosus*), and Eightbanded Grouper (*Hyporthordus octofasciatus*), among other fish residing at similar depths.

Bottomfish Management Unit Species (BMUS) are not the only species being caught in the shallow-bottom fishery. Coral Reef Ecosystem Management Unit Species (CREMUS) are also caught in the shallow-bottom fishery because of the close proximity to reefs. These fish are caught with various hook and line gears including homemade hand lining gear, rod and reel, and electric reels. Deep-water bottomfishing requires more efficient fishing gears, such as hydraulic and electric reels. Bottomfishing trips generally occur during the day, but fishing trips to the Northern Islands can take two to four days depending on vessel size and refrigeration capacity. These trips are most productive during calm weather months. Successful fishermen targeting deep-water bottomfish tend to fish for one to four years before leaving the fishery, whereas the majority of fishermen targeting shallow-water bottomfish tend to leave the fishery after the first year.

The overall participation of fishermen in the bottomfish fishery tends to be very short-term (less than four years). The slight difference between the shallow-water fishermen and the deepwater fishermen likely reflects the greater skill and investment required to participate in the deepwater bottomfish fishery. In addition, deepwater bottomfishing tends to include larger ventures that are more buffered from the impulses of individual choice, and are usually dependent on a skilled captain and fishermen. Overall, the long-term commitment to hard work, maintenance and repairs, and staff retention appear to be challenging for CNMI bottom-fishermen to sustain more than a few years. A full list of BMUS species is provided in Appendix A.

1.1.1.2 Coral Reef Fishery

Coral reef fisheries have been generally steady in recent times relative to previous years. Small-scale nearshore fisheries in the CNMI continue to be important socially, culturally, recreationally, financially, and for subsistence. Most fishermen are subsistence fishers with a number of them selling a portion of their catch to roadside vendors, with some of these vendors employing the fishermen to maintain a constant supply of reef fish. Most of the fishing for coral reef species occurs within the Saipan lagoon and fringing reefs around the islands, targeting mainly finfish and invertebrates. All reef fish catches are sold to local markets or used for personal consumption with a minimal portion exported for off-island residents. Shoreline access is the most common way to harvest coral reef resources. Vessels are generally used during calm weather to fish areas not as accessible other times of the year, as fishing trips to other islands are made when the weather is favorable. Fishing methods have not changed significantly compared to previous years; hook and line, cast netting, spear fishing, and gleaning are methods still being used today. Some of the common families found in the CNMI reef fish markets are Acanthuridae (surgeonfish), Scarinae (parrotfish), Mullidae (goatfish), Serranidae (grouper), Labridae (wrasse), Holocentridae (soldier/squirrelfish), Carangidae (jacks), Scombridae (scad), Haemulidae (sweetlips), Gerridae (mojarra), Kyphosidae (rudderfish), and Mugilidae (mullet), as well as other non-finfish families. A full list of CREMUS species is provided in Appendix A.

1.1.2 Fishery Data Collection System

A majority of the information collected by the CNMI Division of Fish and Wildlife (DFW) is fishery-dependent. Since the early-1980s, attempts were made to establish a data collection program for the nearshore fisheries, but failed due to intergovernmental issues. Over the past 10 years, significant time and effort has been made to further develop nearshore fishery data collection. This effort has resulted in the re-establishment of the shore-based creel survey program by DFW in collaboration with other local and federal agencies.

1.1.2.1 Creel Surveys

Currently the CNMI maintains both a boat- and shore-based creel survey for the island of Saipan, with plans to expand it to the populated neighboring islands. The programs were established in 2000 and 2005 respectively, in order to strengthen the capacity of DFW in providing sufficient information to the public regarding local fisheries. Other programs, such as the invoicing system and importation monitoring, provide supplemental information on harvest and demand for the fishery.

Effective management of Saipan's marine fishery resources requires the collection of fishing effort, methods used, and harvest. The CNMI Boat- and Shore-based Creel Surveys are some of the major data collection systems used by DFW to estimate the total annual boat-based participation, effort, and harvest while surveying near-shore fishery resources. These surveys were formerly known as the “CNMI Offshore and Inshore Creel Survey”, but are now referred to as “boat- or shore-based” because they cover all fishing done from a boat or from shore. This is an important distinction because where the fishing activity is initiated (i.e. boat or shore) determines how that type of activity will be accounted for in the survey systems. For instance, very small boats launched from non-standard launching areas (e.g. from the back of a pickup truck on a beach) are not included in the Boat-based Creel Survey.

The objective of the Boat-based Creel Survey Program is to quantify fishing participation, effort, and catch done from on a vessel in CNMI’s waters. DFW had an early creel survey data collection program in 1984, and 1990 to 1994, however since the methods were not standardized, the data collected with that early program is not currently being used. The early program was eventually terminated due to a lack of resources. On April 2, 2000, the DFW fishery staff reinitiated the Boat-based Creel Survey program on the island's boat-based fishery following a three year hiatusThe fishery survey collects data on the island's boating activities and interviews returning commercial and noncommercial fishermen at the three most active launching ramps/docks on the island: Smiling Cove, Sugar Dock, and Fishing Base. Essential fishery information is collected and processed from both commercial and noncommercial vessels to help better inform management decisions. The two types of data collection programs utilized by Saipan’s Boat-based Creel Survey Program include: Boat-based Participation Count to collect participation data, and a Boat-based Access Point Survey to collect catch and effort data (through Survey Maps, Boat Logs and Interviews) at the three major boat ramp areas listed above. The data collected are then expanded at a stratum level (quarterly vs. annually, charter vs. non-charter, weekday vs. weekend, etc.) to create estimated landings by gear type for CNMI's Boat-based fishery. The Shore-based survey currently covers the Western Lagoon of Saipan. Some pilot surveys are being conducted on Saipan's Eastern beaches such as; Laolao Bay, Obyan Beach, and Ladder Beach. Other accessible areas are not covered at this time due to existing limited resource availability and logistical constraints. With the assistance of the Western Pacific Fisheries Information Network (WPacFIN) program at the Pacific Islands Fisheries Science Center (PIFSC), data processing software and a database were developed to process these survey data.

In May 2005, the DFW fishery staff reinitiated the shore-based creel survey program on the island's shore-based fishery following an 11-year hiatus. The Western Lagoon starts from the northwest (Wing Beach) and extends to the southwest (Agingan Point) of Saipan. This encompasses over twenty accessible and highly active shoreline access points. Saipan's Shore-based Creel Survey is also a stratified randomized data collection program. This program collects two types of data to estimate catch and effort information in the shore-based fishery: Participation Count (P) and Interview (I). The Participation Count involves counting the number of people fishing on randomly selected days and their method of fishing along the shoreline. Interview involves interviewing fishermen to determine catch, method used, length and weights of fish, species composition, catch disposition, and if any fish were not kept (bycatch). The data collected from this program have been used to expand and create annual estimated landings for this fishery.

From January to June in 2017, 36 boat-based surveys were scheduled. A total of 63 interviews were completed with an expanded catch estimate of 243,259 lbs. landed. The vessel/trailer participation survey is also ongoing and still includes all launching areas on the west coast of Saipan where all boat-based fishing occurs. For this reporting period, a total of 122 boat vessels/trailers were registered as "out fishing". During this progress period, the most common fishing methods encountered were trolling, bottomfishing, and hook-and-line fishing. The expanded harvest estimate for trolling was 151,270 lbs. Estimated catch for bottomfishing and hook-and-line were 83,246 lbs. and 8,743 lbs.

In the second half of the year from July to December in 2017, 37 boat-based surveys were scheduled. A total of 43 interviews were completed with an expanded catch estimate of 110,619 lbs. landed. The vessel/trailer participation survey is also ongoing and still includes all launching areas on the west coast of Saipan, where all boat-based fishing occurs. For this reporting period, a total of 86 boat vessels/trailers were registered as "out fishing". It should be noted that the same vessel may be out fishing on more than one day, so this count should not be used to estimate the total number of unique fishing vessels. During this progress period the most common fishing methods encountered were trolling, bottomfishing and hook-and-line fishing. The expanded harvest estimate for trolling was 106,525 lbs, while the estimated catch for bottomfishing was 989 lbs., and 3,105 lbs for hook-and-line.

Consistent collection and entry of offshore data have continued. Vehicle maintenance and repair issues pose to be the biggest problems faced for offshore surveys. In November, a new data technician was hired to help in collection efforts.

1.1.2.2 Vendor Invoice

The DFW has been collecting fishery statistics on Saipan's commercial fishing fleet since the mid-1970s. With the assistance of the NMFS WPacFIN program, the DFW also expanded its fisheries monitoring programs to include the other two major inhabited islands in the CNMI (Rota and Tinian). The DFW's principal method of collecting domestic commercial fisheries data is a dealer invoicing system, sometimes referred to as a "trip ticket" system. The DFW provides numbered two-part invoices to all purchasers of fresh fishery products (including hotels, restaurants, stores, fish markets, and roadside vendors). Dealers then complete an invoice each time they purchase fish directly from fishers; one copy goes to the DFW and one copy goes to their records. Some advantages of this data collection method are that it is relatively inexpensive to implement and maintain, and it is fairly easy to completely cover the commercial fisheries. Thr DFW can also provide feedback to dealers and fishers to ensure data accuracy and continued cooperation over time.

There are some disadvantages to the trip ticket system, including: (1) dependency on non-DFW personnel to identify the catch and record the data, (2) restrictions on the types of data that can be collected, (3) required education and cooperation of all fish purchasers, and (4) limited recordings of fish actually sold to dealers. Therefore, a potentially important portion of the total landings typically goes unrecorded. Since 1982, the DFW has tried to minimize these disadvantages in several ways by (1) maintaining a close working relationship with dealers, (2) adding new dealers to their list and educating them, and (3) implementing a creel survey to help estimate total catch (including recreational and subsistence portion). The current system collects data from dealers in Saipan, where the DFW estimates more than 90% of all CNMI commercial landings are made. The DFW also estimates that the proportion of total commercial landings that have been recorded in the Saipan database since 1983 is about 90%, however coverage has been relatively mottled over the years. Previous volumes of FSWP reported only recorded landings, but in recent volumes the data have been adjusted to represent 100% coverage and are referenced as "Estimated Commercial Landings" in the tables and figures.

These data elements are collected for all purchases of fishery products; however, species identification is frequently identified only to a group level, especially for reef fish.

For the period of January 1, 2017 to June 30, 2017, 135 invoices were collected from 5 vendors from the island of Saipan. A total of 7,552.85 lbs. of fish were recorded from the sales receipt program valued at $19,435.20. For the second half of the year over the period of July 1, 2017 to December 31, 2017, there were 689 invoices were collected from 20 vendors from the island of Saipan. A total of 39,643.95 lbs. of fish were recorded from the sales receipt program with a total valuation of $127,125.49. There were increased sampling efforts for the period of July to December 2017. More vendors, specifically hotels and restaurants, were targeted. Consistent, scheduled visits to collect purchase data helped increased vendor participation. A new hire for the data specialist position in November also assisted in collecting efforts.

1.1.2.3 Bio-Sampling

The bio-sampling data base contains general and specific bio-data obtained from individual commercial spearfish catches landed on Saipan from six different vendors during 2011. The following data was captured for each fishing trip sampled: date sampled, fishing gear type, time/hours fished, location fished, number/names of fishers, lengths/weights of individual fish, number/weight of octopus and squid, number/carapace size/weight/sex of lobster, and whether it was boat- or shore-based fishing trip.

Although sampling effort was intended to be spread evenly among all participating vendors, smaller vendors were inherently much more difficult to sample within the time constraints allowed. Therefore, a regular sampling schedule was implemented for the island's two largest vendors that included two weekdays and one weekend day each week starting in January/February 2011. Problems encountered in sampling the smaller vendors included: more days in any given month where no fish were purchased, the work area wasn't conducive for sampling, and communication problems. The bio-sampling database focuses on nighttime (non-SCUBA) spearfishing activities. Due to vendor-imposed limitations, other gear types that typically land their catch during normal business hours were not sampled.

1.1.2.4 Exemption Netting

In 2003, the use of gill nets was prohibited in the CNMI. In 2005, the DFW decided to allow gill netting under special circumstances. Gill netting is now allowed under strict conditions provided by the DFW with their permission such that all gill netting activities are to be monitored and recorded by DFW personnel.

In 2010, a law was passed allowing for the use of gill nets for the purpose of subsistence on the island of Rota. The following year, a regulation allowing for subsistence net fishing was passed for the island of Tinian.

For a majority of the permitted gillnet activities, length and weight measurements were taken at the fishing site. Fork lengths were measured in millimeters and weights were measured in grams. If time did not permit for individual measurements, then length measurements were taken for each fish and total weight was taken for each species. Length/weight ratios were used to estimate weights of sampled fish. Information has been collected for activities conducted on the island of Saipan, but no official collection of information has been collected for Rota or Tinian.

1.1.2.5 Life History

The CNMI DFW life history program began in 1996 with the redgill emperors (*Lethrinus rubrioperculatus*). Since then, sampling has been conducted on other species including: *A. lineatus*, Myriprestinae (*Myripristis violacea, M. kuntee, M. pralinea, M. bernti, M. murdjan), L. harak, Naso lituratus, Chlorurus sordidus*, and *C. undulatus*. Other life history programs have also developed over the past years. DFW personnel in collaboration with NMFS collect life history information on *Scarus rubroviolaceus, Lethrinus atkinsoni, Parupeneus barbarinus*, through funding provided by NOAA-NMFS and . The life history survey captures biological information inlcuding reproductive cycle, age at length, and age at maturity. The DFW is continually working to improve the understanding of reef fish life history in the CNMI through these types of programs.

1.1.2.6 Monitoring of Imported Fish

The DFW Fisheries Data Sections collect fisheries-related importation invoices from the Department of Commerce at the end of every month. The data is then entered into the ticket receipt system and reviewed prior to being sent out for compilation by the Pacific Islands Fisheries Science Center (PIFSC). A majority of the information entered in the system can only be identified to the family taxa.

1.1.2.7 Vessel Inventory

Little progress has been made under this project as staff time was focused on improving inshore, offshore and receipt data collection programs. This work is also affected by policies of the CNMI Department of Public Safety, which manages vessel licensing. Emphasis will be made on improving the vessel inventory project once the data technician and data manager positions have been filled.

1.1.3 Meta-data Dashboard Statistics

The meta-data dashboard statistics describe the amount of data used or available to calculate the fishery-dependent information. Creel surveys are sampling-based systems that require random-stratified design applied to pre-scheduled surveys. The number of sampling days, participation runs, and catch interviews would determine if there are sufficient samples to run the expansion algorithm. The trends of these parameters over time may infer survey performance. Monitoring the survey performance is critical for explaining the reliability of the expanded information.

Commercial receipt book information depends on the amount of invoices submitted and the number of vendors participating in the program. Variations in these meta-data affect the commercial landing and revenue estimates.

1.1.3.1 Creel surveys meta-data statistics

Calculations: Shore-based data

Interview Days: Count of the number of actual days that Creel Survey Data were collected. It's a count of the number of unique dates found in the interview sampling data (the actual sampling date data, include opportunistic interviews).

Participation Runs: Count of the number of unique occurrences of the combination of survey date and run number in the participation detail data.

Catch Interviews: Count of the number of unique occurrences of the combination of date and run number in the participation detail data/ count of unique surveyor initials and date in PAR. This is divided into two categories, interviews conducted during scheduled survey days (Regular), and opportunistic interviews (Opp.) which are collected on non-scheduled days.

Calculation: Boat-based data

Sample days: Count of the total number of unique dates found in the boat log data sampling date data.

Catch Interviews: Count of the total number of data records found in the interview header data (number of interview headers). This is divided into two categories, interviews conducted during scheduled survey days (Regular), and opportunistic interviews (Opportunistic) which are collected on non-scheduled days.

Table 1. Summary of creel survey meta-data describing survey performance parameters with potential influence on the creel survey expansion.

Year	Shore-based				Boat-based		
	# Interview Days	# Participation Runs	# Catch Interviews		# Sample Days	# Catch Interviews	
			Regular	Opportunistic		Regular	Opportunistic
1982					46	469	8
1983					47	431	34
1984	12	23	56	0	53	531	0
1985	51	78	367	0	66	812	0
1986	47	74	291	0	49	522	0
1987	45	62	245	0	48	612	0
1988	48	62	280	0	48	949	0
1989	49	63	297	0	48	931	2
1990	47	62	485	0	48	1028	0
1991	48	54	497	0	48	1019	1
1992	48	55	611	0	48	1110	0
1993	48	48	598	0	52	1119	0
1994	47	48	702	0	55	1168	0
1995	48	49	764	0	96	1613	4
1996	48	53	679	0	96	1608	0
1997	48	67	915	0	96	1358	0
1998	49	73	880	0	96	1581	0
1999	48	68	939	1	96	1367	3
2000	48	84	791	0	96	1246	1
2001	48	96	753	0	96	908	6
2002	47	94	439	4	84	610	1
2003	48	96	518	10	78	446	0
2004	47	93	337	35	95	530	1
2005	48	96	371	3	97	552	0
2006	49	96	300	0	96	556	0
2007	48	96	243	118	96	500	0
2008	46	96	282	0	96	571	2
2009	47	94	321	1	96	803	0
2010	48	94	299	0	96	902	0
2011	43	96	250	0	96	645	0
2012	47	92	272	0	74	371	0
2013	49	94	257	0	96	561	1
2014	48	92	227	0	90	635	9
2015	45	96	279	46	97	651	13
2016	48	96	281	9	93	900	2
2017	45	92	245	1	92	820	10
10 year avg.	**47**	**94**	**271**	**6**	**93**	**686**	**4**
10 year SD	**2**	**2**	**26**	**14**	**7**	**161**	**5**
20 year avg.	**47**	**92**	**414**	**11**	**93**	**758**	**2**
20 year SD	**1**	**8**	**226**	**27**	**6**	**311**	**4**

1.1.3.2 Commercial Receipt Book Statistics

Calculations:
Vendors: Count of the number of unique buyer codes found in the commercial purchase header data from the Commercial Receipt Book.

Invoices: Count of the number of unique invoice numbers found in the commercial header data from the Commercial Receipt Book.

Table 2. Summary of commercial receipt book meta-data describing reporting performance parameters with potential influence on total commercial landing estimates.

Year	Number of Vendors	Total Invoices Collected
1998	52	5369
1999	49	4649
2000	47	6030
2001	39	4914
2002	32	4759
2003	24	4261
2004	25	3507
2005	23	3945
2006	21	4002
2007	18	3387
2008	13	3054
2009	6	2513
2010	5	1612
2011	3	1198
2012	19	1565
2013	17	2161
2014	15	1665
2015	10	752
2016	16	2100
2017	27	892
10 year avg.	**13**	**1751**
10 year SD	**7**	**683**
20 year avg.	**23**	**3117**
20 year SD	**14**	**1552**

1.1.4 Fishery Summary Dashboard Statistics

The Fishery Summary Dashboard Statics section consolidates all fishery-dependent information comparing the most recent year with short-term (recent 10 years) and long-term (recent 20 years) average (shown bolded in [brackets]). Trend analysis of the past 10 years will dictate the trends (increasing, decreasing, or no trend). The right-most symbol indicates whether the mean of the short-term and long-term years were above, below, or within one standard deviation of the mean of the full time series.

Legend Key:

- *increasing trend in the time series*
- *decreasing trend in the time series*
- *no trend in the time series*
- *above 1 standard deviation*
- *below 1 standard deviation*
- *within 1 standard deviation*

10,000 [**1,000**] – *point estimate of fishery statistic* [***difference from short/long term average***]

Table 3. 2017 annual indicators for the coral reef and bottomfish fishery describing fishery performance comparing current year estimates with short-term (10-year) and long-term (20-year) averages.

Fishery	Fishery statistics	Short-term (recent 10 years)	Long-term (20 years)
Bottomfish	**Estimated catch (lbs.)**		
All species caught in the BF gear	Boat and shore creel data estimated (expanded) total lbs. (all BF trips)	**46,349[▲1%]**	**N/A**
	Estimated total lbs. (all species) commercial purchase data	**5,422[▼67%]**	**23,284[▼78%]**
Bottomfish management unit species only	Boat-based creel data Estimated (expanded) total lbs. (all BF trips)	**46,349[▲1%]**	**N/A**
	Estimated total lbs. (all species) commercial purchase data	**5,381[▼25%]**	**5,381[▼39%]**

Fishery	Fishery statistics	Short-term (recent 10 years)	Long-term (20 years)
	Catch-per-unit effort (lbs./gear hours)		
	CPUE (creel data only)	**0.6671[▲250%]**	**N/A**
	Fishing effort *(only available for creel data)*		
	Estimated (expanded) total bottomfish trips	**88[▼76%]**	**N/A**
	Estimated total bottomfishing gear hours	**1,568[▼99%]**	**N/A**
	Fishing participants		
	Estimated total # of fishers that went bottomfishing	**786[▼67%]**	**N/A**
	Bycatch		
	Total number of bycatch caught	**314[▼66%]**	**N/A**
	# bycatch released	**None**	**N/A**
	# bycatch kept	**314[▼66%]**	**N/A**
Coral Reef	**Estimated catch (lbs.)**		
	Boat-based creel data (expanded estimate all gears	**8,990[▼75%]**	**N/A**
	Shore-based creel (expanded estimate all gears)	**27,403[▼55%]**	**N/A**
	Commercial Purchase	**23,880[▼71%]**	**23,880[▼82%]**
	Catch-per-unit-effort (lbs./gear hours)		
	BB spear	**1.1333 [▼72%]**	**N/A**

Fishery	Fishery statistics	Short-term (recent 10 years)	Long-term (20 years)
	BB troll	**0.1184[▲18%]**	**N/A**
	BB atulai	**No CPUE estimate available**	**N/A**
	BB castnets	**No CPUE estimate available**	**N/A**
	SB hook and line	**0.0016[▲60%]**	**N/A**
	SB spear	**0.1911[▲82%]**	**N/A**
	SB castnets	**0.0404[▼49%]**	**N/A**
	Fishing effort (# of gear-hours by gear type)		
	BB spear	**81[▼83%]**	**N/A**
	BB troll	**124,845[▼23%]**	**N/A**
	BB atulai	**No effort estimate available**	**N/A**
	BB castnets	**No effort estimate available**	**N/A**
	SB hook and line	**67,801[▼83%]**	**N/A**
	SB spear	**429[▼68%]**	**N/A**
	SB castnets	**544[▼60%]**	**N/A**
	Fishing participants (# of gear)		
	BB spear	**117[▲255%]**	**N/A**
	BB troll	**2,646[▲96%]**	**N/A**

Fishery	Fishery statistics	Short-term (recent 10 years)	Long-term (20 years)
	BB atulai	**No participation estimate available**	**N/A**
	BB castnets	**No participation estimate available**	**N/A**
	SB hook and line	**13,594[▼44%]**	**N/A**
	SB spear	**1,327[▼42%]**	**N/A**
	SB castnets	**2,145[▼31%]**	**N/A**
	Boat-based Bycatch		
	# bycatch caught	**2,632[▼17%]**	**N/A**
	# bycatch released	**None**	**N/A**
	# bycatch kept	**2,632[▼17%]**	**N/A**
	Shore-based Bycatch		
	# bycatch caught	**1,450[▼37%]**	**N/A**
	# bycatch released	**3[▲50%]**	**N/A**
	# bycatch kept	**1,447[▼3%]**	**N/A**

1.1.5 Catch Statistics

The following section summarizes the catch statistics for the bottomfish and coral reef fisheries in CNMI. Estimates of catch are summarized from the creel survey and commercial receipt book data collection programs. Catch statistics provide estimates of annual harvest from the different fisheries. Estimates of fishery removals can provide proxies for the level of fishing mortality and a reference level relative to established quotas. This section also provides detailed levels of catch for fishing methods and the top species complexes harvested in the coral reef and bottomfish fisheries.

1.1.5.1 Catch by Data Stream

This section describes the estimated total catch from the shore- and boat-based creel survey programs as well as the commercial landings from the commercial receipt book system. The difference between the creel total and the commercial landings is assumed to be the non-commercial component. However, there are cases where the commercial landing may be higher than the estimated creel total of the commercial receipt book program. In this case, the commercial receipt books are able to capture the fishery better than the creel surveys.

Calculations: Estimated landings are based on all bottomfish species harvested, regardless of the gear used, for all data collection programs (e.g. shore-based creel, boat-based creel and the commercial purchase reports).

Table 4. Summary time series of catch (lbs.) for all species caught using the bottomfishing gear for from creel surveys and the commercial purchase system for 1983-2017.

Year	Creel Survey Estimates		Creel Total	Commercial landings
	Shore-based	Boat-based		
1983				16405
1984				24434
1985				24126
1986				18350
1987				32818
1988				44235
1989				19913
1990				8205
1991				5077
1992				6150
1993				8778
1994				18478
1995				28513
1996				40292
1997				26131
1998				34945
1999				41652
2000		78914	78914	28419
2001		29781	29781	42749
2002		26895	26895	30587
2003		13562	13562	24588
2004		33812	33812	33805
2005	428	38336	38764	42667
2006	158	39209	39367	19537
2007	1296	62430	63726	24904
2008	601	23033	23634	26333
2009	281	69460	69741	25221
2010	4	58608	58612	15157
2011	1112	29044	30156	17159
2012	168	137061	137229	11897
2013	2663	22873	25536	18601
2014	332	8284	8616	25001
2015	429	10906	11335	6260
2016	73	49534	49607	12455
2017	118	46231	46349	5422
10 year avg.	**578**	**45503**	**46082**	**16351**
10 year SD	**759**	**36077**	**35816**	**7187**
20 year avg.	**589**	**43221**	**43646**	**24368**
20 year SD	**706**	**29968**	**29862**	**10978**

Calculations: Estimated landings are based on a pre-determined list of species (Appendix 3) identified as the BMUS Complex regardless of the gear used, for each data collection (shore-based creel, boat-based creel and the commercial purchase reports).

Table 5. Summary of BMUS catch (lbs.) time series for from creel surveys and the commercial purchase system for 1983-2017.

Year	Creel survey Estimates		Creel Total	Commercial landings
	Shore-based	Boat-based		
1983				3407
1984				3463
1985				2222
1986				3822
1987				1889
1988				2412
1989				4022
1990				1274
1991				781
1992				607
1993				1723
1994				5476
1995				17735
1996				32446
1997				22133
1998				27594
1999				34648
2000		78914	78914	14968
2001		29781	29781	25264
2002		26895	26895	24869
2003		13481	13481	18062
2004		33812	33812	12974
2005	335	38266	38601	16539
2006	133	39200	39333	12238
2007	1296	62389	63685	18606
2008	138	23033	23171	18387
2009	281	69447	69728	20419
2010	4	58608	58612	14729
2011	1112	29044	30156	16931
2012	168	136769	136937	11747
2013	2663	22733	25396	17770
2014	332	8284	8616	19333
2015	429	10906	11335	4197
2016	73	49331	49404	12260
2017	118	46231	46349	5381
10 year avg.	**532**	**45439**	**45970**	**14115**
10 year SD	**771**	**36009**	**35776**	**5391**
20 year avg.	**545**	**43174**	**43567**	**17346**
20 year SD	**719**	**29924**	**29835**	**6972**

Calculations: Estimated landings are based on a pre-determined list of species (Appendix 3) identified as the CREMUS Complex regardless of the gear used, for each data collection (shore-based creel, boat-based creel and the commercial purchase reports). It is required to finalize the CREMUS list to use for Creel and commercial landings and verify non-overlap between Bottomfish Complex and CREMUS. It is also required to verify all shallow bottomfish are not included in CREMUS list.

Table 6. Summary of CREMUS catch (lbs.) from creel surveys and the commercial purchase system for 1983-2017.

Year	Creel survey Estimates		Creel Total	Commercial Landings
	Shore-based	Boat-based		
1983				167816
1984				215326
1985				191359
1986				206054
1987				190747
1988				224821
1989				345519
1990				259846
1991				143921
1992				188622
1993				193673
1994				253053
1995				210842
1996				218936
1997				244917
1998				274227
1999				227245
2000		84643	84643	236025
2001		33239	33239	235432
2002		34766	34766	223426
2003		38551	38551	147500
2004		27698	27698	127517
2005	104736	37204	141940	181261
2006	110573	42893	153466	176349
2007	84947	44556	129503	148110
2008	85945	64320	150265	160542
2009	74921	70087	145008	125404
2010	46710	49505	96215	89567
2011	40021	59218	99239	95087
2012	37437	49401	86838	68158
2013	154396	17306	171702	77120
2014	17078	15482	32560	75062
2015	40321	10723	51044	41832
2016	81067	17990	99057	56192
2017	27403	8990	36393	23880
10 year avg.	**60530**	**36302**	**96832**	**81284**
10 year SD	**38242**	**23081**	**45577**	**37679**
20 year avg.	**45278**	**35329**	**80606**	**139497**
20 year SD	**45096**	**22896**	**53287**	**71724**

1.1.5.2 Expanded catch estimates by fishing methods

Catch information is provided for the top shore-based and boat-based fishing methods that contributes 99% and 84% of the annual catch, respectively.

Calculations: The creel survey catch time series are the sum of the estimated weight for selected gear in all strata for all species (except for trolling, which exclude PMUS as well as any other pelagic species complex).

Table 7. Expanded CNMI creel survey catch estimates (lbs.) by gear for 2005-2017.

Year	Shore-based methods			Boat-based methods				
	H&L	Spear	Castnet	Bottomfish	Spear	Troll*	Atulai	Castnet
2005	130	259	50	3231	12	34575	520	2
2006	262	320	114	1802	91	29504	340	23
2007	203	74	110	2220	105	28464	482	0
2008	335	161	65	914	197	20080	263	48
2009	295	235	68	1974	113	13147	407	78
2010	105	102	93	1353	19	14592	74	13
2011	136	78	18	1521	6	10589	152	33
2012	93	40	36	2807	1	17921	128	0
2013	170	94	17	1324	53	19814	98	0
2014	55	0	9	299	16	16835	99	0
2015	27	123	10	470	81	15491	76	0
2016	25	370	10	1388	0	8202	0	0
2017	108	82	22	1046	153	14131	0	0
10 year avg.	**135**	**129**	**35**	**1310**	**64**	**15080**	**130**	**17**
10 year SD	**100**	**101**	**28**	**685**	**66**	**3621**	**117**	**26**
20 year avg.	**150**	**149**	**48**	**1565**	**65**	**18719**	**203**	**15**
20 year SD	**95**	**108**	**37**	**813**	**62**	**7474**	**173**	**24**

* Excluding pelagic species

1.1.5.3 Top species in the catch for the boat and shore-based fisheries

Catch time series can act as indicators of fishery performance. Variations in the catch can be attributed to various factors, and there is no single explanatory variable for the observed trends. The 10 species groups in the shore and boat-based catch records from the coral reef fishery make up 85% and 70% of the total annual catches, respectively.

Calculations: Catch by species complex is tallied directly from the boat-based expanded species composition data combining all gear types and species for all strata.

The averages for the table below were calculated from catch estimates for the entire time series across each of the CREMUS groupings. The average catch for each grouping is ranked from the highest to lowest. The dominant groups that make up more than half of the total annual catch are reported.

Table 8. Catch time series of 12 top species complexes from CNMI boat-based creel data from 2000-2017.

Year	Boat-based (estimated lbs.)											
	Bottomfish	BMUS	Emperors	Jacks	Atulai	Groupers	Snappers	Surgeonfish	Parrotfish	Mullet	Squirrelfish	Rudderfish
2000	82358	82358	34850	2035	967	1266	99	176	14242	2193	3648	0
2001	33938	33938	9774	1156	4456	1453	69	0	3094	623	5569	13
2002	41651	41651	9946	260	613	2032	879	818	5904	645	3831	0
2003	17319	17238	1339	883	13579	935	2030	0	10958	240	3924	265
2004	37792	37792	3675	1186	1008	1306	503	0	11215	1020	2153	600
2005	41410	41340	3242	1617	0	776	47	0	17733	2282	1722	925
2006	42118	42109	8086	1336	2932	1792	340	0	8700	590	4260	235
2007	77315	77274	9934	2424	7336	2778	4391	0	4280	2716	3948	985
2008	23633	23633	15785	1025	14039	4378	1104	0	6939	595	5572	520
2009	74883	74870	18669	3501	20622	3910	635	0	2197	548	7506	3189
2010	62529	62529	10980	745	6195	1364	780	0	12847	1430	3934	0
2011	32552	32552	15534	5160	7847	205	542	0	10238	178	4016	3715
2012	137118	136826	16418	4231	14438	1147	1150	0	974	123	974	88
2013	23068	22928	5221	1011	720	60	2	0	1400	64	955	175
2014	8284	8284	4638	8	330	695	236	0	5161	37	2063	0
2015	10906	10906	1436	2068	111	277	345	0	1037	325	4218	127
2016	49534	49330	1689	47	0	0	57	0	9467	194	0	0
2017	46231	46231	691	0	3122	17	4	0	2219	0	0	0
10 year avg.	**46809**	**46874**	**9106**	**1780**	**6742**	**1205**	**486**	**0**	**5248**	**349**	**2924**	**781**
10 year SD	**36371**	**36436**	**6738**	**1789**	**6975**	**1540**	**408**	**0**	**4155**	**409**	**2396**	**1349**
20 year avg.	**46766**	**46813**	**9550**	**1594**	**5462**	**1355**	**734**	**55**	**7145**	**767**	**3239**	**602**
20 year SD	**30386**	**30427**	**8301**	**1413**	**6115**	**1228**	**1024**	**189**	**4892**	**815**	**1970**	**1056**

Calculations: Catch by species complex is tallied directly from the boat-based expanded species composition data combining all gear types and species, for all strata.

The averages were for the table below was calculated from catch estimates from the entire time series for each of the CREMUS grouping. The average catch is ranked from the highest to lowest catch. The dominant groups that make up more than 60% of the catch are reported.

Table 9. Catch time series of 12 top species complexes from CNMI shore-based creel data from 2000-2017.

Year	Shore-based (estimated lbs.)										
	Jacks	Emperors	Rabbitfish	Surgeonfish	Goatfish	Atulai	Parrotfish	Mollusks	Mullet	Wrasse	Rudderfish
2005	15320	1181	42796	11678	6230	38455	19896	9511	8194	5247	18438
2006	30020	1317	32676	26864	7456	27203	7588	16234	13189	4532	28672
2007	31604	1483	36846	41781	8350	15863	10126	4838	10363	5210	10111
2008	45867	815	39556	57321	3878	39568	2233	6823	6412	7078	16039
2009	36928	7093	45064	47511	4419	20727	3237	9055	5608	3239	21732
2010	19068	804	20452	45172	2375	17778	813	3196	4077	1837	13846
2011	14813	4738	24464	33821	3020	23132	1393	5398	3547	1467	19700
2012	7987	251	21639	34309	2487	8937	4949	4566	11198	1375	3781
2013	30410	2935	16283	23233	1052	10880	524	39382	15120	4270	36083
2014	12009	2130	9977	2856	844	15367	581	3781	3161	472	6673
2015	12214	737	8943	739	887	3983	23	8221	8846	501	12596
2016	21449	2116	15811	2091	814	16743	1299	5070	7057	36	17585
2017	6011	2521	2891	4695	1519	15070	2463	2536	4593	291	8591
10 year avg.	**20676**	**2414**	**25175**	**20508**	**2130**	**17219**	**1752**	**8803**	**6962**	**2057**	**15663**
10 year SD	**12465**	**2010**	**20351**	**12561**	**1255**	**9161**	**1423**	**10387**	**3609**	**2110**	**8710**
20 year avg.	**21823**	**2163**	**25544**	**24415**	**3333**	**19516**	**4240**	**9124**	**7797**	**2735**	**16450**
20 year SD	**11676**	**1822**	**18812**	**13275**	**2493**	**10089**	**5358**	**9401**	**3648**	**2232**	**8586**

1.1.6 Catch-per-Unit-Effort (CPUE) Statistics

This section summarizes the estimates for CPUE in the boat- and shore-based fisheries. The boat-based fisheries include the bottomfishing (handline gear), spearfishing (snorkel), troll, atulai nets, and castnets, which comprise 84% of the total catch. Trolling is primarily a pelagic fishing method but also catches coral reef fishes like jacks and gray jobfish. The shore-based fisheries include the hook-and-line, spearfishing and cast nets, which comprise 99% of the total coral reef fish catch. CPUE is reported as pounds per gear-hour for the shore-based fishery, and pounds per fishing trip in the boat-based fishery.

Calculations: CPUE is calculated from interview data by gear type using ∑catch /∑ (hours fished*number of fishers) for boat based and ∑catch/∑ (hours fished*number of gears used) for shore based. If the value is blank (empty), then there was no interview collected for that method. Landings from interviews without fishing hours are excluded from the calculations.

Table 10. CPUE time series by dominant fishing methods in CNMI shore-based fisheries from 2005-2017.

Year	Gear CPUE (lbs./gear hour)		
	H&L	Spear	Castnet
2005	0.0009	0.0654	0.0321
2006	0.0002	0.0434	0.0158
2007	0.0003	0.0705	0.034
2008	0.0002	0.0658	0.0074
2009	0.0002	0.0623	0.028
2010	0.0004	0.0567	0.1771
2011	0.0005	0.0556	0.0557
2012	0.0004	0.0465	0.1
2013	0.0009	0.1302	0.0833
2014	0.0024	0	0.15
2015	0.0017	0.1538	0.1042
2016	0.002	0.2864	0.0526
2017	0.0016	0.1911	0.0404
10 year avg.	**0.001**	**0.1048**	**0.0799**
10 year SD	**0.0008**	**0.0812**	**0.0512**
20 year avg.	**0.0009**	**0.0944**	**0.0677**
20 year SD	**0.0007**	**0.0739**	**0.0502**

Table 11. CPUE time series by dominant fishing methods from CNMI boat-based fisheries from 2000-2017.

Year	Boat-based Gear CPUE (lbs./fishing hours)				
	Bottomfishing	Spear	Troll	Atulai	Castnet
2000	0.1102	2.3929	0.0837	0.1326	0
2001	0.0301	1.4844	0.0588	0.1067	0
2002	0.0485	3.9	0.0608	0.1079	0
2003	0.0345	0.1009	0.0371	0.2284	1.4
2004	0.0307	0.0839	0.0568	0.048	0
2005	0.0137	1	0.0372	0.0704	0.125
2006	0.0126	0.1071	0.0545	0.0437	1.15
2007	0.0289	0.3182	0.0726	0.0311	0
2008	0.0125	0.0533	0.0718	0.1927	0.6667
2009	0.0069	0.1495	0.0745	0.0755	5.5714
2010	0.0022	3.1667	0.1065	0.2284	1.4444
2011	0.0021	1	0.0855	0.6609	0.3929
2012	0.3558	0.25	0.1113	0.0914	0
2013	0.1445	0.3155	0.0982	0.2917	0
2014	0.1286	3.2	0.0866	0.5789	0
2015	0.2318	27	0.1594	0.7917	0
2016	0.3541	0	0.0893	0	0
2017	0.6671	1.1333	0.1184	0	0
10 year avg.	**0.1906**	**4.0298**	**0.1002**	**0.3639**	**1.6151**
10 year SD	**0.2062**	**8.2029**	**0.0245**	**0.2568**	**2.0339**
20 year avg.	**0.123**	**2.6856**	**0.0813**	**0.23**	**1.1945**
20 year SD	**0.1723**	**6.1996**	**0.0296**	**0.2296**	**1.6392**

1.1.7 Effort Statistics

This section summarizes the effort trends in the coral reef and bottomfish fishery. Fishing effort trends provide insights on the level of fishing pressure through time. Effort information is provided for the top shore-based and boat-based fishing methods that contributes 99% and 84% of the annual catch.

Calculations: Effort estimates (hours) are generated by summing the effort data collected from interviews by gear type. For shore-based estimates, data collection started in 2005.

Table 12. Time series of effort estimates from CNMI coral reef and bottomfish fisheries from 2000-2017.

Year	Estimated Effort by Gear or Fishing Method							
	Shore-based gear hours			Boat-based gear hours				
	H&L	Spear	Castnet	Bottom	Spear	Troll	Atulai	Castnet
2000				15194	21	131472	2379	0
2001				26076	16	475304	2400	0
2002				23547	10	286520	1888	0
2003				16492	3420	841750	918	5
2004				40633	666	462027	4620	0
2005	143992	3960	1560	230736	12	899028	7062	16
2006	1145508	7380	7216	145722	918	505362	7020	8
2007	677265	1050	3233	70168	352	359047	14602	6
2008	1464036	2448	8736	71463	3780	261960	1521	36
2009	1494570	3774	2432	305064	714	173600	5159	7
2010	238815	1800	525	658504	6	136413	297	9
2011	286144	1403	323	869240	6	117576	230	56
2012	216905	860	360	8211	4	169278	1200	0
2013	182684	722	204	9480	168	212346	392	0
2014	23023	2	60	2625	10	216425	171	3
2015	15624	800	96	2340	6	107514	96	0
2016	12402	1292	190	5376	0	99828	0	0
2017	67081	429	544	1568	81	124845	0	0
10 year avg.	**400128**	**1353**	**1347**	**193387**	**478**	**161979**	**907**	**11**
10 year SD	**547802**	**1044**	**2549**	**302257**	**1120**	**51497**	**1499**	**18**
20 year avg.	**459081**	**1994**	**1960**	**139024**	**566**	**310016**	**2775**	**8**
20 year SD	**530145**	**1937**	**2748**	**238335**	**1110**	**235557**	**3664**	**14**

1.1.8 Participants

This section summarizes the estimated number of participants in each fishery. The information presented here can be used in the impact analysis of potential amendments in the FEPs associated with the bottomfish and coral reef fisheries. The trend in the number of participants over time can also be used as an indicator for fishing pressure.

Calculations: Estimated number of participants is calculated by using and average number of fishers out fishing per day multiplied by the numbers of dates in the calendar year by gear type. The total is a combination of weekend and weekday stratum estimates.

Table 13. Number of fishermen participating in the CNMI bottomfish fishery and number of gears in the CNMI coral reef fishery from 2000-2017.

Year	Bottomfish		Coral Reef Boat-based				Coral Reef Shore-based		
	# fishers	# gears	Spear	Troll	Atulai	Castnet	H&L	Spear	Castnet
2000	1161	1119	1464	803	1577	0			
2001	993	898	1460	806	1095	0			
2002	1259	1287	730	851	1156	0			
2003	1374	1331	816	930	913	730			
2004	1319	1236	993	793	1313	0			
2005	1369	1342	1095	850	1007	730	43884	7058	4798
2006	1130	1155	830	870	973	1825	49116	8448	5251
2007	883	807	782	800	1186	1095	41127	6554	3521
2008	1888	1843	848	723	1423	976	58569	5270	4547
2009	3043	3224	821	671	1345	730	42908	4137	2771
2010	6375	6727	730	660	876	1095	17505	3039	2145
2011	6246	7581	730	758	913	730	24927	2049	3134
2012	690	718	366	738	1281	0	17198	2751	2075
2013	728	753	728	655	874	0	22960	2870	2728
2014	666	751	365	626	1095	730	13601	2452	1656
2015	678	782	365	641	730	0	8374	2769	817
2016	641	878	0	633	0	0	11804	3225	1544
2017	786	786	1369	650	0	0	13376	2108	1290
10 year avg.	**2404**	**2174**	**702**	**676**	**1067**	**852**	**23122**	**3067**	**2271**
10 year SD	**2497**	**2194**	**302**	**44**	**240**	**154**	**14997**	**927**	**1021**
20 year avg.	**1845**	**1735**	**852**	**748**	**1110**	**960**	**28104**	**4056**	**2791**
20 year SD	**1967**	**1711**	**332**	**92**	**225**	**341**	**16071**	**2017**	**1351**

Year	Bottomfish		Coral Reef Boat-based				Coral Reef Shore-based		
	# gears	# trips	Spear	Troll	Atulai	Castnet	H&L	Castnet	Spear
2000	366	441	10	903	133	0			
2001	365	425	6	1401	119	0			
2002	365	185	5	976	83	0			
2003	365	231	112	1913	53	3			
2004	366	390	37	934	112	0			
2005	365	824	2	531	53	2	45558	4715	7058
2006	365	843	30	553	73	2	52248	5160	8448
2007	365	695	33	793	200	4	42591	3479	6872
2008	366	592	57	377	50	5	60468	4482	5167
2009	365	587	7	101	27	0	44638	2744	4137
2010	365	421	0	35	2	1	18980	2086	3069
2011	365	452	0	27	1	1	26575	3054	2036
2012	366	320	14	1916	215	0	18388	2236	2751
2013	364	292	85	1711	85	0	24536	2649	2870
2014	365	211	21	2868	94	10	14062	1656	2410
2015	365	173	24	2409	97	0	8828	817	2769
2016	366	113	0	1433	0	0	12455	1733	3637
2017	365	88	117	2646	0	0	13594	1327	2145
10 year avg.	**325**	**365**	**33**	**1352**	**57**	**2**	**24252**	**2278**	**3099**
10 year SD	**174**	**1**	**39**	**1075**	**65**	**3**	**15458**	**979**	**919**
20 year avg.	**405**	**365**	**31**	**1196**	**78**	**2**	**29455**	**2780**	**4105**
20 year SD	**224**	**1**	**37**	**868**	**62**	**3**	**16667**	**1301**	**2034**

1.1.9 Bycatch Estimates

This section focuses on MSA § 303(a)(11), which requires that all FMPs establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures that, to the extent practicable, minimize bycatch and bycatch mortality. The MSA § 303(a)(11) standardized reporting methodology is commonly referred to as a ''Standardized Bycatch Reporting Methodology'' (SBRM) and was added to the MSA by the Sustainable Fisheries Act of 1996 (SFA). The Council implemented omnibus amendments to FMPs in 2003 to address MSA bycatch provisions and established SBRMs at that time.

Calculations: The number caught is the sum of the total number of individuals found in the raw data including bycatch. The number kept is the total number of individuals in the raw data that are not marked as bycatch. The number released is bycatch caught minus the number of bycatch kept. Percent bycatch is the sum of all bycatch divided by the total catch.

Table 14. Time series of bycatch estimates in CNMI non-bottomfishing boat-based fisheries from 2000-2017.

Year	Boat-based non-bottomfishing gear types			
	# caught	Kept	Released	% bycatch
2000	3089	3086	3	0.001
2001	5732	5731	1	0.0002
2002	4885	4885	0	0
2003	8785	8785	0	0
2004	5717	5717	0	0
2005	6772	6772	0	0
2006	6761	6759	2	0.0003
2007	6683	6683	0	0
2008	4463	4463	0	0
2009	3792	3792	0	0
2010	3462	3462	0	0
2011	2515	2515	0	0
2012	3963	3963	0	0
2013	3732	3732	0	0
2014	2600	2600	0	0
2015	2693	2693	0	0
2016	1812	1812	0	0
2017	2632	2632	0	0
10 year avg.	**3166**	**3166**	**0**	**0**
10 year SD	**788**	**788**	**0**	**0**
20 year avg.	**4449**	**4449**	**0**	**0.0001**
20 year SD	**1863**	**1863**	**1**	**0.0002**

Table 15. Time series of bycatch estimates in the CNMI bottomfish fishery from 2000-2017.

Year	Boat-based bottomfishing gear type			
	# caught	Kept	Released	% bycatch
2000	818	797	21	0.0257
2001	931	930	1	0.0011
2002	904	890	14	0.0155
2003	877	841	36	0.041
2004	1379	1359	20	0.0145
2005	3225	3221	4	0.0012
2006	1845	1842	3	0.0016
2007	2110	2110	0	0
2008	1158	1158	0	0
2009	1779	1779	0	0
2010	1474	1474	0	0
2011	1734	1734	0	0
2012	782	782	0	0
2013	857	857	0	0
2014	216	216	0	0
2015	196	196	0	0
2016	721	721	0	0
2017	314	314	0	0
10 year avg.	**923**	**923**	**0**	**0**
10 year SD	**567**	**567**	**0**	**0**
20 year avg.	**1184**	**1179**	**6**	**0.0056**
20 year SD	**736**	**737**	**10**	**0.0111**

Table 16. Time series of bycatch estimates in the CNMI shore-based fishery from 2000-2017.

Year	Shore-based (all gear types)			
	# caught	Kept	Released	% bycatch
2000				
2001				
2002				
2003				
2004				
2005	3170	3104	66	0.0208
2006	6015	5987	28	0.0047
2007	2670	2660	10	0.0037
2008	7142	7135	7	0.001
2009	4412	4411	1	0.0002
2010	1839	1839	0	0
2011	2601	2601	0	0
2012	1466	1465	1	0.0007
2013	2007	2001	6	0.003
2014	544	544	0	0
2015	687	687	0	0
2016	723	723	0	0
2017	1450	1447	3	0.0021
10 year avg.	**2287**	**2285**	**2**	**0.0007**
10 year SD	**1946**	**1945**	**3**	**0.001**
20 year avg.	**2671**	**2662**	**9**	**0.0028**
20 year SD	**1977**	**1971**	**18**	**0.0054**

1.1.10 Number of Federal Permit Holders

The Code of Federal Regulations (CFR), Title 50, Part 665 requires the following Federal permits for fishing in the exclusive economic zone (EEZ) under the Mariana FEP:

1.1.10.1 Northerthern Mariana Island Bottomfish Permit

Regulations require this permit for any vessel commercially fishing for, landing, or transshipping bottomfish management unit species (MUS) in the EEZ around the Commonwealth of the Northern Mariana Islands (CNMI). Commercial fishing is also prohibited within the boundaries of the Islands Unit of the Marianas Trench Marine National Monument.

1.1.10.2 Special Coral Reef Ecosystem Permit

Regulations require the coral reef ecosystem special permit for anyone fishing for coral reef ecosystem MUS in a low-use marine protected area (MPA), fishing for species on the list of Potentially Harvested Coral Reef Taxa, or using fishing gear not specifically allowed in the regulations. NMFS will make an exception to this permit requirement for any person issued a permit to fish under any fishery ecosystem plan who incidentally catches CNMI coral reef ecosystem MUS while fishing for bottomfish MUS, crustacean MUS, western Pacific pelagic MUS, precious coral, or seamount groundfish. Regulations require a transshipment permit for any receiving vessel used to land or transship potentially harvested coral reef taxa, or any coral reef ecosystem MUS caught in a low-use MPA.

1.1.10.3 Western Pacific Precious Corals Permit

Regulations require this permit for anyone harvesting or landing black, bamboo, pink, red, or gold corals in the EEZ in the western Pacific.

1.1.10.4 Western Pacific Crustaceans Permit (Lobster or Deepwater Shrimp)

Regulations require a permit by the owner of a U.S. fishing vessel used to fish for lobster or deepwater shrimp in the EEZ around American Samoa, Guam, Hawaii, and the Pacific Remote Islands Areas, and in the EEZ seaward of 3 nautical miles of the shoreline of the Northern Mariana Islands.

There is no record of special coral reef or precious coral fishery permits issued for the EEZ around Northern Mariana Islands since 2007. Table 17 provides the number of permits issued for CNMI fisheries between 2008 and 2018. Historical data are from the PIFSC accessed on February 9, 2017, and 2018 data are from the PIRO Sustainable Fisheries Division permits program as of January 3, 2018.

Table 17. Number of federal permits holders for the CNMI crustacean and bottomfish fisheries between 2008 and 2018.

CNMI Fisheries	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Lobster	6*	4*							1**		1**
Shrimp			2*	1*					1		

CNMI Fisheries	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bottomfish		2	13	10	13	5	6	7	17	20	13

* Permits apply to multiple areas and may include American Samoa, Guam, CNMI, and PRIA.
**Area 5 CNMI and Guam.

1.1.11 Status Determination Criteria

1.1.11.1 Bottomfish Fishery

Overfishing criteria and control rules are specified and 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 would be affected differently based on this type of control rule, and it is important that for any given species, fishing mortality does not currently exceed a level that would result in excessive depletion of that species. No indicator species are used for the bottomfish multi-species stock complexes and the coral reef species complex. Instead, the control rules are applied to each stock complex as a whole.

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 the recommendations of Restrepo *et al*. (1998) and both are dependent on the natural mortality rate (M). The value of M used to determine the reference point values are 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. 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 specified at some 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 18.

Table 18. Overfishing threshold specifications for the bottomfish management unit species in CNMI.

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY} B}{c\, B_{MSY}}$ for $B \leq c\, B_{MSY}$ $F(B) = F_{MSY}$ 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 would 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 $CPUE_{REF}$. E_{MSY} would 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.

Since the MSY control rule specified here applies to multi-species stock complexes, it is important to ensure that no particular species within the complex has a mortality rate that leads to excessive depletion. In order to accomplish this, a secondary set of reference points is specified to evaluate stock status with respect to recruitment overfishing. A secondary "recruitment overfishing" control rule is specified to control fishing mortality with respect to that status. The rule applies only to those component stocks (species) for which adequate data are available. The ratio of a current spawning stock biomass proxy ($SSBP_t$) to a given reference level ($SSBP_{REF}$) is used to determine if individual stocks are experiencing recruitment overfishing. SSBP is CPUE scaled by percent mature fish in the catch. When the ratio $SSBP_t/SSBP_{REF}$, or the "SSBP ratio" (SSBPR) for any species drops below a certain limit ($SSBPR_{MIN}$), that species is considered to be recruitment overfished and management measures will be implemented to reduce fishing mortality on that species. The rule applies only when the SSBP ratio drops below the $SSBPR_{MIN}$, but it will continue to apply until the ratio achieves the "SSBP ratio recovery target" ($SSBPR_{TARGET}$), which is set at a level no less than $SSBP_{RMIN}$. These two reference points and their associated recruitment overfishing control rule, which prescribe a target fishing mortality rate ($F_{RO-REBUILD}$) as a function of the SSBP ratio, are specified as indicated in Table 19. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 19. Rebuilding control rules for the bottomfish management unit species in CNMI.

$F_{RO-REBUILD}$	$SSBPR_{MIN}$	$SSBPR_{TARGET}$
$F(SSBPR) = 0$ for $SSBPR \le 0.10$ $F(SSBPR) = 0.2\ F_{MSY}$ for $0.10 < SSBPR \le SSBPR_{MIN}$ $F(SSBPR) = 0.4\ F_{MSY}$ for $SSBPR_{MIN} < SSBPR \le SSBPR_{TARGET}$	0.20	0.30

1.1.11.2 Coral Reef Fishery

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.

The MSY control rule should be applied to the individual species in a multi-species stock when possible. When this is not possible, MSY may be specified for one or more species; these values can 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.

For the coral reef fishery, the multi-species complex as a whole is used to establish limits and reference points for each area. Available data for a particular species are used to evaluate the status of individual MUS stocks in order to prevent recruitment overfishing when possible. 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 20.

Table 20. Status determination criteria for the coral reef management unit species using CPUE based proxies.

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 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 ($CPUE_{REF}$).

1.1.11.3 Current Stock Status

1.1.11.3.1 Bottomfish

Biological and other fishery data are poor for all bottomfish species in the Mariana Archipelago. 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. The most recent stock assessment update (Yau *et al*., 2015) for the CNMI bottomfish management unit species complex (comprised of 17 species of shallow and deep species of snapper, grouper, jacks, and emperors) was based on estimate of total catch, an abundance index derived from the nominal CPUE generated from the creel surveys, and a fishery independent point estimate of MSY from the Our Living Oceans Report (Humphreys and Moffitt, 1999; Moffitt and Humphreys, 2009). The assessment utilized a state-space surplus production model with explicit process and observation error terms (Meyer and Millar, 1999). Determinations of overfishing and overfished status can then be made by comparing current biomass and harvest rates to MSY level reference points. To date, the CNMI BMUS is not subject to overfishing and is not overfished (Table 21).

Table 21. Stock assessment parameters for the CNMI BMUS complex (Yau *et al*., 2015).

Parameter	Value	Notes	Status
MSY	173.1 ± 32.19	Expressed in 1000 lbs. (± std error)	
H_{2013}	0.022	Expressed in percentage	
H_{MSY}	0.261 ± 0.063	Expressed in percentage (± std error)	
H/H_{MSY}	0.088		No overfishing occurring
B_{2013}	1,262	Expressed in thousand pounds	
B_{MSY}	683.5 ± 126.7	Expressed in 1000 lbs. (± std error)	
B/ B_{MSY}	1.85		Not overfished

1.1.11.3.2 Coral reef

The application of the SDCs for the management unit species in the coral reef fisheries is limited due to various challenges. First, the thousands of species included in the coral reef MUS makes the SDC and status determination impractical. Second, the CPUE derived from the creel survey is based on the fishing method and there is no species-specific CPUE information available. In order to allocate the fishing method level CPUE to individual species, the catch data (the value of catch is derived from CPUE hence there is collinearity) will have to be identified to species level and CPUE will be parsed out by species composition. The third challenge is that there is very little species level identification applied to the creel surveys. There has been no attempt to estimate MSY for the coral reef MUS until the 2007 re-authorization of MSA that requires the Council to specify ACLs for species in the FEPs.

For ACL specification purposes, MSYs in the coral reef fisheries are determined by using the Biomass-Augmented Catch-MSY approach (Sabater and Kleiber, 2014). This method estimates MSY using plausible combination rates 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 was applied to species complexes grouped by taxonomic families. The most recent MSY estimates are found in Table 22. The SSC utilized the MSYs for the coral reef MUS complexes as the OFLs.

Table 22. Best available MSY estimates for the coral reef MUS in CNMI.

Coral Reef MUS Complex	MSY (lbs.)
Selar crumenophthalmus – atulai or bigeye scad	122,500
Acanthuridae – surgeonfish	361,200
Carangidae – jacks	55,300
Crustaceans – crabs	9,100
Holocentridae – squirrelfish	78,500
Kyphosidae – chubs/rudderfish	29,500
Labridae – wrasses[1]	73,500
Lethrinidae – emperors	69,700
Lutjanidae – snappers	225,800
Mollusks – turbo snail; octopus; giant clams	16,700
Mugilidae – mullets	7,700
Mullidae – goatfish	31,000
Scaridae – parrotfish[2]	189,900
Serranidae – groupers	110,300
Siganidae – rabbitfish	12,000
All Other CREMUS Combined - Other coral reef ecosystem finfish - Other invertebrates - Misc. bottomfish - Misc. reef fish - Misc. shallow bottomfish	14,500
Cheilinus undulatus – humphead (Napoleon) wrasse	N.A.
Bolbometopon muricatum – bumphead parrotfish	N.A.
Carcharhinidae – reef sharks	N.A.

1.1.12 Overfishing Limit, Acceptable Biological Catch, and Annual Catch Limits

1.1.12.1 Brief Description of the ACL Process

The Council developed a Tiered system of control rules to guide the specification of ACLs and Accountability Measures (AMs) (WPRFMC, 2011). The process starts with the use of the best scientific information available (BSIA) in the form of, but not limited to, stock assessments, published paper, reports, or available data. These information are classified to the different Tiers in the control rule ranging from Tier 1 (most information available typically an assessment) to Tier 5 (catch-only information). The control rules are applied to the BSIA. Tiers 1 to 3 would involve conducting a Risk of Overfishing Analysis (denoted by P*) to quantify the scientific uncertainties around the assessment to specify the Acceptable Biological Catch (ABC). This would lower the ABC from the OFL (MSY-based). A Social, Ecological, Economic, and Management (SEEM) Uncertainty Analysis is performed to quantify the uncertainties from the SEEM factors. The buffer is used to lower the ACL from the ABC. For Tier 4, which contains stocks with MSY estimates but no active fisheries, the control rule is 91% of MSY. For Tier 5, which contains catch only information, the control rule is a third reduction in the median catch depending on the qualitative evaluation on what the stock status is based on expert opinion. ACL specification can choose from a variety of method including the above mentioned SEEM analysis or a percentage buffer (percent reduction from ABC based on expert opinion) or the use of an Annual Catch Target. Specifications are done on an annual basis but the Council normally specifies a multi-year specification.

The Accountability Measure for the coral reef and bottomfish fisheries in CNMI is an overage adjustment. The ACL is downward adjusted with the amount of overage from the ACL based on a three year running average.

1.1.12.2 Current OFL, ABC, ACL, and Recent Catch

The most recent multiyear specification of OFL, ABC, and ACL for the coral reef fishery was completed in the 160th Council meeting on June 25 to 27, 2014. The specification covers fishing year 2015, 2016, 2017, and 2018 for the coral reef MUS complexes. A P* and SEEM analysis was performed for this multiyear specification (NMFS, 2015). For the bottomfish, it was a roll over from the previous specification since an assessment update was not available for fishing year 2015. ACLs were not specified by NMFS for the coral reef ecosystem MUS because NMFS has recently acquired new information that require additional environmental analyses to support the Council's ACL recommendations for these management unit species (50 CFR Part 665).

Table 23. CNMI ACL table with 2017 catch (lbs.). The MUS highlighted in red have a three-year recent average catch that exceeds the prescribed ACL.

Fishery	MUS	OFL	ABC	ACL	Catch
Bottomfish	Bottomfish multi-species complex	293,000	228,000	228,000	35,696
Crustacean	Deepwater shrimp	N.A.	275,570	275,570	N.A.F
	Spiny lobster	9,600	7,800	7,410	729
	Slipper lobster	**N.A.**	**60**	**60**	**130**
	Kona crab	N.A.	6,300	6,300	N.A.F
Precious Coral	Black coral	8,250	2,100	2,100	N.A.F
	Precious coral in CNMI expl. area	N.A.	2,205	2,205	N.A.F
Coral Reef	*Selar crumenophthalmus*	N.A.	N.A.	N.A.	2,745
	Acanthuridae-surgeonfish	N.A.	N.A.	N.A.	3,230
	Carangidae-jacks	N.A.	N.A.	N.A.	7,479
	Crustaceans-crabs	N.A.	N.A.	N.A.	0
	Holocentridae-squirrelfish	N.A.	N.A.	N.A.	291
	Kyphosidae-rudderfish	N.A.	N.A.	N.A.	333
	Labridae-wrasse	N.A.	N.A.	N.A.	60
	Lethrinidae-emperors	N.A.	N.A.	N.A.	6,302
	Lutjanidae-snappers	N.A.	N.A.	N.A.	509
	Mollusk-turbo snails; octopus; clams	N.A.	N.A.	N.A.	177
	Mugilidae-mullets	N.A.	N.A.	N.A.	289
	Mullidae-goatfish	N.A.	N.A.	N.A.	1,266
	Scaridae-parrotfish	N.A.	N.A.	N.A.	1,530
	Serranidae-groupers	N.A.	N.A.	N.A.	214

	Siganidae-rabbitfish	N.A.	N.A.	N.A.	1,771
	All other CREMUS combined	N.A.	N.A.	N.A.	788
	Cheilinus undulatus	N.A.	N.A.	N.A.	61
	Bolbometopon muricatum	N.A.	N.A.	N.A.	N.D.
	Carcharhinidae-reef sharks	N.A.	N.A.	N.A.	N.D.

The catch shown in Table 23 takes the average of the recent three years as recommended by the Council at its 160th meeting to avoid large fluctuations in catch due to data quality and outliers. "N.A.F." indicates no active fisheries to date. "N.D." indicates that there are no data available.

1.1.13 Best Scientific Information Available

1.1.13.1 Bottomfish Fishery

1.1.13.1.1 Stock Assessment Benchmark

The benchmark stock assessment for the Territory Bottomfish Management Unit Species complex was developed and finalized in October 2007 (Moffitt *et al*., 2007). This benchmark utilized a Bayesian statistical framework to estimate parameters of a Schaefer model fit to a time series of annual CPUE statistics. The surplus production model included process error in biomass production dynamics and observation error in the CPUE data. This was an improvement to the previous approach of using index-based proxies for B_{MSY} and F_{MSY}. Best available information for the bottomfish stock assessment is as follows:

Input data: The CPUE and catch data used were from the Guam off-shore creel survey. The catch and CPUE were expanded on annual level. CPUE was expressed in line-hours. The data was screened for trips that landed more than 50% BMUS species using the handline gear.

Model: state-space model with explicit process and observation error terms (see Meyer and Millar, 1999).

Fishery independent source for biomass: point estimate of MSY from the Our Living Oceans Report (Humphreys and Moffitt, 1999; Moffitt and Humphreys, 2009)

1.1.13.1.2 Stock Assessment Updates

Updates to the 2007 benchmark done in 2012 (Brodziak *et al*., 2012) and 2015 (Yau *et al*., 2015). These included a two-year stock projection table used for selecting the level of risk the fishery will be managed under ACLs. Yau *et al*. (2015) is considered the best scientific information available for the Territory bottomfish MUS complex after undergoing a WPSAR Tier 3 panel review (Franklin *et al*., 2015). This was the basis for the P* analysis and SEEM analysis the determined the risk levels to specify ABCs and ACLs.

1.1.13.1.3 Other Information Available

Approximately every five years PIFSC administers a socioeconomic survey to small boat fishermen in CNMI. This survey consists of about 60 questions regarding a variety of topics, including fishing experiences, market participation, vessels and gear, demographics and household income, and fishermen perspectives. The survey requests participants to identify which MUS they primarily targeted during the previous 12 months, by percentage of trips. Full reports of these surveys can be found at the PIFSC Socioeconomics webpage (Hospital and Beavers, 2011)

1.1.13.2 Coral Reef Fishery

1.1.13.2.1 Stock Assessment Benchmark

No stock assessment has been generated for the coral reef fisheries. The SDCs using index-based proxies were tested for its applicability in the different MUS in the coral reef fisheries (Hawhee, 2007). This analysis was done on a gear level. It paints a dire situation for the shore-based fishery with 43% of the gear/species combination fell below B_{flag} and 33% below MSST with most catch and CPUE trends showing a decline over time. The off-shore fisheries were shown to be less dire with 50% of the gear/species combination fell below B_{flag} and 38% below MSST but the catch and CPUE trends were increasing over time. The inconsistency in the CPUE and catch trends with the SDC results makes this type of assessment to be unreliable.

The first attempt to use a model based approach in assessing the coral reef MUS complexes was done in 2014 using a biomass-based population dynamics model (Sabater and Kleiber, 2014). This model was based on the original Martell and Froese (2012) model but was augmented with biomass information to relax the assumption behind carrying capacity. It estimates MSY based on a range of rate of population growth (*r*) and carrying capacity (*k*) values. The best available information for the coral reef stock assessment is as follows:

Input data: The catch data was derived from the inshore and off-shore creel surveys. Commercial receipt book information was also used in combination of the creel data. A downward adjustment was done to address for potential overlap due to double reporting.

Model: Biomass Augmented Catch MSY approach based on the original catch-MSY model (Martell and Froese, 2013; Sabater and Kleiber, 2014).

Fishery independent source for biomass: biomass density from the Rapid Assessment and Monitoring Program of NMFS-CRED was expanded to the hard bottom habitat from 0-30 m (Williams, 2010).

This model had undergone a CIE review in 2014 (Cook, 2014; Haddon, 2014; Jones, 2014). This was the basis for the P* analysis that determined the risk levels to specify ABCs

1.1.13.2.2 Stock Assessment Updates

No updates available for the coral reef MUS complex. However, NMFS-PIFSC is finalizing a length-based model for estimating sustainable yield levels and various biological reference points (Nadon *et al*. 2015). This can be used on a species level. The Council is also working with a contractor to enhance the BAC-MSY model to incorporate catch, biomass, CPUE, effort, length-based information in an integrated framework (Martell 2015)

1.1.13.2.3 Other Information Available

Approximately every five years PIFSC administers a socioeconomic survey to small boat fishermen in CNMI. This survey consists of about 60 questions regarding a variety of topics, including fishing experiences, market participation, vessels and gear, demographics and household income, and fishermen perspectives. The survey requests participants to identify which MUS they primarily targeted during the previous 12 months, by percentage of trips. Full reports of these surveys can be found at the PIFSC Socioeconomics webpage (Hospital and Beavers, 2011).

PIFSC and the Council conducted a workshop with various stakeholders in CNMI to identify factors and quantify uncertainties associated with the social, economic, ecological, and management of the coral reef fisheries (Sievanen and McCaskey 2014). This was the basis for the SEEM analysis that determined the risk levels to specify ACLs.

1.1.14 Harvest Capacity and Extent

The MSA defines the term "optimum," with respect to the yield from a fishery, as the amount of fish which:

- 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.
- Is prescribed on the basis of the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor.
- In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery [50 CFR §600.310(f)(1)(i)].

Optimum yield in the coral reef and bottomfish fisheries is prescribed based on the MSY from the stock assessment and the best available scientific information. In the process of specifying ACLs, social, economic, and ecological factors were considered and the uncertainties around those factors defined the management uncertainty buffer between the ABC and ACL. OY for the bottomfish and coral reef fish MUS complexes is defined to be the level of harvest equal to the ACL consistent with the goals and objectives of the Fishery Ecosystem Plans and used by the Council to manage the stock.

The Council recognizes that MSY and OY are long term values whereas the ACLs are yearly snapshots based on the level of fishing mortality at F_{MSY}. There are situations when the long-term means around MSY are going to be lower than ACLs especially if the stock is known to be productive or relatively pristine or lightly fished. One can have catch levels and catch rates exceeding that of MSY over short-term enough to lower the biomass to a level around the estimated MSY and still not jeopardize the stock. In this situation is true for the territory bottomfish multi-species complex.

The harvest extent, in this case, is defined as the level of catch harvested in a fishing year relative to the ACL or OY. The harvest capacity is the level of catch remaining in the annual catch limit that can potentially be used for the total allowable level of foreign fishing (TALFF).

Table 24 summarizes the harvest extent and harvest capacity information for CNMI in 2017.

Table 24. CNMI proportion of harvest capacity and extent for 2017.

Fishery	MUS	ACL	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	Bottomfish multi-species complex	228,000	35,696	15.7	84.3
Crustacean	Deepwater shrimp	275,570	N.A.F.	0.0	100.0
	Spiny lobster	7,410			
	Slipper lobster	60			
	Kona crab	6,300	N.A.F.	0.0	100.0
Precious coral	Black coral	2,100	N.A.F.	0.0	100.0
	Precious coral in CNMI expl. area	2,205	N.A.F.	0.0	100.0
Coral Reef	*Selar crumenophthalmus*	N.A.	2,745	N.A.	N.A.
	Acanthuridae-surgeonfish	N.A.	3,230	N.A.	N.A.
	Carangidae-jacks	N.A.	7,479	N.A.	N.A.
	Crustaceans-crabs	N.A.	0	N.A.	N.A.
	Holocentridae-squirrelfish	N.A.	291	N.A.	N.A.
	Kyphosidae-rudderfish	N.A.	333	N.A.	N.A.
	Labridae-wrasse	N.A.	60	N.A.	N.A.
	Lethrinidae-emperors	N.A.	6,302	N.A.	N.A.
	Lutjanidae-snappers	N.A.	509	N.A.	N.A.
	Mollusk-turbo snails; octopus; clams	N.A.	177	N.A.	N.A.
	Mugilidae-mullets	N.A.	289	N.A.	N.A.
	Mullidae-goatfish	N.A.	1,266	N.A.	N.A.
	Scaridae-parrotfish	N.A.	1,530	N.A.	N.A.
	Serranidae-groupers	N.A.	214	N.A.	N.A.
	Siganidae-rabbitfish	N.A.	1,771	N.A.	N.A.
	All other CREMUS combined	N.A.	788	N.A.	N.A.
	Cheilinus undulatus	N.A.	61	N.A.	N.A.
	Bolbometopon muricatum	N.A.	0	N.A.	N.A.
	Carcharhinidae-reef sharks	N.A.	0	N.A.	N.A.

1.1.15 Administrative and Regulatory Actions

This summary describes management actions NMFS has taken for CNMI fisheries since the April 2017 Joint FEP Plan Team meeting.

On April 21, 2017, NMFS specified final 2016 annual catch limits (ACLs) for Pacific Island bottomfish, crustacean, precious coral, and coral reef ecosystem fisheries and accountability measures (AMs) to correct or mitigate any overages of catch limits. The final specifications were applicable from January 1, 2016, through December 31, 2016, except for precious coral fisheries, which are applicable from July 1, 2016, through June 30, 2017. Although the 2016 fishing year ended for most stocks, NMFS evaluated 2016 catches against these final ACLs when data became available in mid-2017. The ACLs and AMs support the long-term sustainability of fishery resources of the U.S. Pacific Islands. This rule was effective on May 22, 2017.

On December 11, 2017, NMFS specified final 2017 ACLs for Pacific Island crustacean, precious coral, and territorial bottomfish fisheries, and AMs to correct or mitigate any overages of catch limits. The ACLs and AMs were effective for fishing year 2017. Although the 2017 fishing year had nearly ended for most stocks, NMFS will evaluate 2017 catches against these final ACLs when data become available in mid-2018. The ACLs and AMs support the long-term sustainability of fishery resources of the U.S. Pacific Islands. The final specifications were applicable from January 1, 2017, through December 31, 2017, except for precious coral fisheries, which are applicable from July 1, 2017, through June 30, 2018.

1.1.16 References

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1.2 GUAM FISHERY DESCRIPTIONS

1.2.1 Bottomfish Fishery

Bottomfishing on Guam is a combination of recreational, subsistence, and small-scale commercial fishing. It can be separated into two distinct fisheries separated by depth and species composition. The shallow water complex (<500 feet) comprises the largest portion of the total bottomfish harvest and effort, and primarily includes: reef-dwelling snappers of the genera *Lutjanus*, *Aphareus*, and *Aprion*; groupers of the genera *Epinephelus*, *Variola*, and *Cephalopholis*; jacks of the genera *Caranx* and *Carangoides*; Holocentrids (*Myripristis* spp. and *Sargocentron* spp.); emperors of the genera *Lethrinus* and *Gymnocranius*; and Dogtooth Tuna (*Gymnosarda unicolor*). The deep water complex (>500 feet) consists primarily of groupers of the genera *Hyporthodus* and *Cephalopholis*, jacks of the genera *Caranx* and *Seriola*, and snappers of the genera *Pristipomoides*, *Etelis*, and *Aphareus*. In recent years, deep water species have made up a significant portion of the total expanded bottomfishing catch.

The majority of people that participate in the bottomfish fishery are either subsistence or part-time commercial fishermen, operate boats less than 25 feet in length, and target primarily the shallow water bottomfish complex. It is not uncommon to intercept fishermen combining bottomfishing with other methods such as trolling, spearing, and jigging to maximize their catch. High demand has made it profitable to sell locally caught bottomfish, although overhead costs including fuel and gear may be significant factors for in determining a fisherman’s selection of fishing method. The demand for local bottomfish, when combined with environmental pressures, however, may cause stress to local bottomfish stocks.

The majority of bottomfishing around Guam takes place on offshore banks, though practically no information exists on the condition of the reefs on offshore banks. On the basis of anecdotal information, most of the offshore banks are in good condition due to their isolation. According to Myers (1997), less than 20 percent of the total coral reef resources harvested in Guam are taken from the EEZ, primarily because the reefs are often associated with less accessible offshore banks. As such, finfish make up most of the catch in the EEZ. Most offshore banks are deep, remote, and subject to strong currents. Generally, these banks are only accessible during calm weather in the summer months (May to August/September). Galvez Bank is the closest and most accessible and, consequently, fished most frequently. In contrast, other banks (White Tuna and Santa Rose, Rota) are remote and generally are fished only during exceptional weather conditions (Green, 1997). Local fishermen report that up to ten commercial boats, with two to three people per boat, and some recreational boats, make use of the banks when the weather is good (Green, 1997).

At present, the banks are fished using two methods: bottomfishing by hook and line, and jigging at night for bigeye scad (*Selar crumenophthalmus*; Myers, 1997). In recent years, the estimated annual catch in these fisheries has ranged from 14 to 22 metric tons of shallow bottomfish and 3 to 15 metric tons of bigeye scad (Green, 1997). The shallow water component accounted for nearly 68 percent (35,002 to 65,162 lbs.) of the aggregate bottomfish landings in fiscal years 1992–1994 (Myers, 1997). Catch composition of the shallow water bottomfish complex (and coral reef species) is dominated by lethrinids, with a single species (*Lethrinus rubrioperculatus*) alone accounting for 28 percent of the total catch. Other important components of the bottomfish catch include lutjanids, carangids, other lethrinids, and serranids. Holocentrids, mullids, labrids, scombrids, and balistids are minor components of the shallow water bottomfish complex. It should be noted that at least two of these species (*Aprion virescens* and *Caranx lugubris*) are also found in deeper waters, and as a result comprise a portion of the catch of the deep water fishery.

Species that are commonly taken in the shallow-bottom fishery of Guam are:

Aphareus furca
Aprion virescens
Lutjanus kasmira, *L. fulvus*
Carangoides orthogrammus
Caranx lugubris, *C. melampygus*, *C. ignobilis*
Selar crumenophthalmus
Cephalopholis argus, *C. spiloparaea*, *C. urodeta*
Epinephelus fasciatus
Gymnocranius spp.
Lethrinus atkinsoni, *L. erythracanthus*, *L. olivaceus*, *L. rubrioperculatus*,
L. xanthochilus
Gymnosarda unicolor
Sargocentron spp.
Myripristis spp.
Variola albimarginata, *V. louti*

Species that are commonly taken in the deep-bottom fishery of Guam are:

Aphareus rutilans
Aprion virescens
Caranx lugubris
Seriola dumerilii
Cephalopholis igarashiensis, *C. sonnerati*
Hyporthodus octofasciatus
Etelis carbunculus, *E. coruscans*
Pristipimoides spp.

1.2.2 Coral Reef Fishery

Shore-based fishing accounts for most of the fish and invertebrate harvest from coral reefs around Guam. The coral reef fishery harvests more than 100 species of fish, including members of the families Acanthuridae, Carangidae, Gerreidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mugilidae, Mullidae, Scaridae, and Siganidae (Hensley and Sherwood, 1993). There are several pulse fisheries for juvenile fish that can be major components of the coral reef fishery, but totals in these can vary year to year. These include juvenile rabbitfish (manahak and lesso'), juvenile jacks (i'e), and juvenile goatfish (ti'ao).

Species that are commonly taken in the coral reef fishery of Guam are:

Naso unicornis, N. lituratus
Acanthurus xanthopterus, *A. lineatus*, *A. triostegus*
Caranx melampygus, *C. papuensis*, i'e
Selar crumenophthalmus
Gerres acinaces
Myripristis spp.
Sargocentron spp.
Neoniphon spp.
Kyphosus cinerascens, *K. vaigiensis*
Cheilinus undulatus, *Cheilinus* spp., *Halichoeres* spp.
Lethrinus harak, *L. obseletus*, *L. atkinsoni*, *Gnathodentex aurolineatus*
Lutjanus fulvus, *L. monostigma*, *L. bohar*, *L. argentimaculatus*
Mulloidichthys flavolineatus, *M. vanicolensis*, ti'ao
Parupeneus multifasciatus, *P. barberinus*, *P. cyclostomus*
Ellechelon vaigiensis, *Moolgarda engeli*, *M. seheli*
Chlorurus spilurus, *C. frontalis,*
Scarus psittacus, *S. altipinnis*, *S. rubrioviolaceus*, *S. ghobban*, *S. schlegeli*
Siganus spinus, *S. argenteus,* manahak, lesso

Hook and line is the most common method of fishing for coral reef fish on Guam, accounting for around 70% of fishers and gear. Throw net (talaya) is the second most common method, accounting for about 15% of fishers and gear. Other methods include gill net, snorkel spearfishing, SCUBA spearfishing, surround net, drag net, hooks and gaffs, and gleaning.

1.2.3 Fishery Data Collection System

Guam currently has three fishery-dependent collection programs which can be described as long-term data collection programs with different approaches for gathering important information on fishery harvest methods performed by fishermen. The three programs are the offshore data program, the inshore data program, and the commercial fishery program. The Sportfish Restoration Grant from the U.S. Fish and Wildlife Service provides the significant portion of the funding for these programs. Training of the fishery staff to collect information is rigorous, and year-end totals are calculated by an expansion process done with in collaboration with NOAA's Pacific Islands Fishery Science Center (PIFSC). Identification of fish to the species level is the goal of Guam's fishery staff.

The offshore and inshore programs, boat- and shore-based creel surveys, respectively, are long-term programs that collect participation, effort, and catch data from fishermen. Collaboration with PIFSC has resulted in a reproducible computer database program that can analyze the data to produce various types of trends that describe status of both charter and non-charter fisheries in federal and local waters. The commercial receipt book program is an important source of information for fish that enter the commercial market; however, obtaining information from dealers has been sporadic, occasionally with less than three dealers providing data. In order to improve this situation, the Council, DAWR, and PIFSC partnered to increase vendor participation in the data collection program through the Territory Science Initiative.

Guam has continued to experience high levels of commercial activity targeting reef fish. This has primarily been performed by recent migrants from the Federated States of Micronesia. The fishers are generally hired by retail shops to fish six days per week; there have been as many as eight or nine of these stores open at a time. Gathering commercial sales data from these vendors has been difficult due to vendor anxiety surrounding the reason data is being collected and the lack of perceived benefit to the vendor for reporting sales. There have been several instances during data collection where the vendors were not able to comfortably communicate in English. Data collected from these vendors is of limited value, as fish are not identified to species level, and are frequently labeled simply as “reef fish”. In 2017, there were five vendors reporting sales. In order to improve this situation, the Council, DAWR, and PIFSC partnered to increase vendor participation in the data collection program through the Territory Science Initiative. Extensive training, follow-ups, education, and outreach efforts were conducted to vendors and fishermen to increase participation in data collection.

Oram *et al*. (in press) describes the fishery data collection process for the offshore and inshore programs. In general, DAWR staff collect fishery information through a series of random-stratified surveys for participation (i.e. accounting for fishing effort) and catch interviews (i.e. accounting for catch composition, size frequency, and catch-per-unit effort, CPUE). These data are transcribed into the WPacFIN database, and the annual catch estimates are expanded from the effort and CPUE information. Monthly commercial vendor reports are tallied at the end of the year and adjusted based on the coverage estimates provided by the vendor and/or the data collection program staff.

1.2.4 Meta-Data Dashboard Statistics

The meta-data dashboard statistics describe the amount of data used or available to calculate the fishery-dependent information. Creel surveys are sampling-based systems that require random-stratified design applied to pre-scheduled surveys. The number of sampling days, participation runs, and catch interviews would determine if there are sufficient samples to run the expansion algorithm. The trends of these parameters over time may infer survey performance. Monitoring the survey performance is critical for explaining the reliability of the expanded information.

Commercial receipt book information depends on the amount of invoices submitted and the number of vendors participating in the program. Variations in these meta-data affect the commercial landing and revenue estimates.

1.2.5 Creel Survey Meta-Data Statistics

Calculations: Shore-based data

Interview Days: Count of the number of actual days that Creel Survey Data were collected. It's a count of the number of unique dates found in the interview sampling data (the actual sampling date data, include opportunistic interviews).

Participation Runs: Count of the number of unique occurrences of the day/night shift combined with surveyor's initials (the person assigned to conduct the participation survey on a given date). This is compiled annually from the participation header data.

Catch Interviews: Count of the total number of data records found in the interview header data (number of interview headers). This is divided into two categories, interviews conducted during scheduled survey days (Regular), and opportunistic interviews (Opportunistic) which are collected on non-scheduled days.

Calculation: Boat-based data

Sample days: Count of the total number of unique dates found in the boat log data sampling date data.

Catch Interviews: Count of the total number of data records found in the interview header data (number of interview headers). This is divided into two categories, interviews conducted during scheduled survey days (Regular), and opportunistic interviews (Opportunistic) which are collected on non-scheduled days.

Table 25. Summary of Guam creel survey meta-data describing survey performance parameters with potential influence on the creel survey expansion from 1982-2017.

Year	Shore-based				Boat-based		
	# Interview Days	# Participation Runs	# Catch Interviews		# Sample Days	# Catch Interviews	
			Regular	Opportunistic		Regular	Opportunistic
1982					46	469	8
1983					47	431	34
1984	12	23	56	0	53	531	0
1985	51	78	367	0	66	812	0
1986	47	74	291	0	49	522	0
1987	45	62	245	0	48	612	0
1988	48	62	280	0	48	949	0
1989	49	63	297	0	48	931	2
1990	47	62	485	0	48	1028	0
1991	48	54	497	0	48	1019	1
1992	48	55	611	0	48	1110	0
1993	48	48	598	0	52	1119	0
1994	47	48	702	0	55	1168	0
1995	48	49	764	0	96	1613	4
1996	48	53	679	0	96	1608	0
1997	48	67	915	0	96	1358	0
1998	49	73	880	0	96	1581	0
1999	48	68	939	1	96	1367	3
2000	48	84	791	0	96	1246	1
2001	48	96	753	0	96	908	6
2002	47	94	439	4	84	610	1
2003	48	96	518	10	78	446	0
2004	47	93	337	35	95	530	1
2005	48	96	371	3	97	552	0
2006	49	96	300	0	96	556	0
2007	48	96	243	118	96	500	0
2008	46	96	282	0	96	571	2
2009	47	94	321	1	96	803	0
2010	48	94	299	0	96	902	0
2011	43	96	250	0	96	645	0
2012	47	92	272	0	74	371	0
2013	49	94	257	0	96	561	1
2014	48	92	227	0	90	635	9
2015	45	96	279	46	97	651	13
2016	48	96	281	9	93	900	2
2017	45	92	245	1	92	820	10
10 year avg.	**47**	**94**	**271**	**6**	**93**	**686**	**4**
10 year SD	**2**	**2**	**26**	**14**	**7**	**161**	**5**
20 year avg.	**47**	**92**	**414**	**11**	**93**	**758**	**2**
20 year SD	**1**	**8**	**226**	**27**	**6**	**311**	**4**

1.2.5.1 Commercial receipt book statistics

Calculations:

Vendors: Count of the number of unique buyer codes found in the commercial purchase header data from the Commercial Receipt Book.

Invoices: Count of the number of unique invoice numbers found in the commercial header data from the Commercial Receipt Book.

Table 26. Summary of Guam commercial receipt book meta-data describing reporting performance parameters with potential influence on total commercial landing estimates from 1980-2017.

Year	Number of Vendors	Total Invoices Collected
1980	*	*
1981	*	*
1982	*	*
1983	3	2311
1984	3	2587
1985	*	*
1986	*	*
1987	*	*
1988	*	*
1989	*	*
1990	4	2803
1991	3	2512
1992	3	2737
1993	3	2664
1994	*	*
1995	3	1565
1996	6	1965
1997	7	2923
1998	4	3591
1999	5	3410
2000	3	3868
2001	3	4155
2002	3	3494
2003	*	*
2004	3	3104
2005	3	2649
2006	4	2589
2007	*	*
2008	*	*
2009	*	*
2010	*	*
2011	*	*
2012	*	*
2013	*	*
2014	8	1353
2015	9	1335
2016	8	1661
2017	11	1969
10 year avg.	**4**	**1593**
10 year SD	**4**	**269**
20 year avg.	**4**	**2389**
20 year SD	**3**	**917**

* Less than three vendors.

1.2.6 Fishery Summary Dashboard Statistics

The Fishery Summary Dashboard Statics section consolidates all fishery-dependent information comparing the most recent year with short-term (recent 10-year) and long-term (recent 20-year) average (shown bolded in [brackets]). Trend analysis of the past 10 years will dictate the trends (increasing, decreasing, or no trend). The right-most symbol indicates whether the mean of the short-term and long-term years were above, below, or within one standard deviation of the mean of the full time series.

Legend Key:

- *increasing trend in the time series*
- *decreasing trend in the time series*
- *no trend in the time series*
- *above 1 standard deviation*
- *below 1 standard deviation*
- *within 1 standard deviation*

10,000 [**1,000**] – *point estimate of fishery statistic* [***difference from short/long term average***]

Table 27. Annual indicators for the coral reef and bottomfish fishery describing fishery performance comparing current estimates with short-term (10 year) and long-term (20 year) average values.

Fishery	Fishery statistics	Short-term (recent 10 years)	Long-term (20 years)
Bottomfish	**Estimated catch (lbs.)**		
All species caught in the BF gear	Boat and shore creel data estimated (expanded) total lbs. (all BF trips)	**22,962 [▼26%]**	**22,962 [▼37%]**
	Estimated total lbs. (all species) commercial purchase data	**No trends available due to confidentiality**	**No trends available due to confidentiality**
Bottomfish management unit species only	Total creel data Estimated (expanded) total lbs. (all BF trips)	**19,143[▼36%]**	**19,143 [▼46%]**
	Estimated total lbs. (all species) commercial purchase data	**No trends available due to confidentiality**	**No trends available due to confidentiality**
	Catch-per-unit effort (lbs./gear-hours)		
	CPUE (creel data only)	**0.0151[▼21%]**	**0.0151[▼3%]**

	Fishing effort ***(only available for creel data)***		
	Estimated (expanded) total bottomfish # of trips	**849[▼21%]**	**849[▼23%]**
	Fishing participants		
	Estimated total # of fishers	**841 [▼21%]**	**841 [▼23%]**
	Bycatch		
	# bycatch caught	**2,313[▲20%]**	**2,313 [▼5%]**
	# bycatch kept	**2,287[▲23%]**	**2,287[▼32%]**
	# bycatch released	**26[▼82]**	**N/A**
Coral Reef	**Estimated catch (lbs.)**		
	Boat-based creel data (expanded estimate all gears)	**75,373[▼36%]**	**86,033 [▼50%]**
	Shore-based creel (expanded estimate all gears)	**72,055 [▼41%]**	**72,055 [▼39%]**
	Commercial Purchase	**No trends available due to confidentiality**	**No trends available due to confidentiality**
	Catch-per-unit-effort (lbs./gear-hours)		
	BB spear	**0.0501[▼76%]**	**0.0501[▼69%]**
	BB SCUBA	**0.8095[▼35%]**	**0.8095[▼22%]**
	BB Gillnet	**0.3646[▼78%]**	**0.3646[▼69%]**
	BB Troll	**0.0065[▼38%]**	**0.0065[▼36%]**
	SB Hook and line	**0.0013[▼43%]**	**0.0013[▼13%]**
	SB Throw/cast	**0.0377[▲17%]**	**0.0377 [▲89%]**
	SB Gillnet	**0.2016[▲28%]**	**0.2016[▲106%]**
	SB Spear	**0.0806[▼66%]**	**0.0806[▼52%]**
	SB Hook and gaff	**0.0577[▼80%]**	**0.0577[▼78%]**
	Fishing effort (# of gear-hours by gear type)		

	BB spear	**8,051[▲81%]**	**8,051[▼5%]**
	BB SCUBA	**140 [▼658%]**	**140[▼2,355%]**+
	BB Gillnet	**64[▼76%]**	**64[▼93%]**
	BB Troll	**7,157,862[▲40%]**	**7,157,862[▲28%]**
	SB Hook and line	**3,320[▼45%]**	**3,320[▼63%]**
	SB Throw/cast	**191,438[▲25%]**	**191,438[▼42%]**
	SB Gillnet	**506 [▼64%]**	**506 [▼95%]**
	SB Spear	**484 [▼52%]**	**484 [▼86%]**
	SB Hook and gaff	**104[▼82%]**	**104[▼94%]**
	Fishing participants (# of gear)		
	BB spear	**977[▼9%]**	**977[▼2%]**
	BB SCUBA	**1,278[▲2%]**	**1,278[▲11%]**
	BB Gillnet	**356[▼172%]**	**365[▼179%]**
	BB Troll	**1,234[▲2%]**	**1,234[▼4%]**
	SB Hook and line	**63,367[▼18%]**	**63,367[▼34%]**
	SB Throw/cast	**11,283[▼15%]**	**11,283[▼30%]**
	SB Gillnet	**4,475[▼30%]**	**4,475[▼48%]**
	SB Spear	**9,760[▲6%]**	**9,760[▼18%]**
	SB Hook and gaff	**952[▼60%]**	**952[▼70%]**
	Bycatch		
	Total number of bycatch caught	**8,645 [▼23%]**	**8,645 [▼21%]**
	# bycatch kept	**8,643[▼23%]**	**8,643[▼21%]**
	# bycatch released	**N/A**	**N/A**

1.2.7 Catch statistics

The following section summarizes the catch statistics for the bottomfish and coral reef fisheries in Guam. Estimates of catch are summarized from the creel survey and commercial receipt book data collection programs. Catch statistics provide estimates of annual harvest from the different fisheries. Estimates of fishery removals can provide proxies for the level of fishing mortality and a reference level relative to established quotas. This section also provides detailed levels of catch for fishing methods and the top species complexes harvested in the coral reef and bottomfish fisheries.

1.2.7.1 Catch by Data Stream

This section describes the estimated total catch from the shore- and boat-based creel survey programs as well as the commercial landings from the commercial receipt book system. The difference between the creel total and the commercial landings is assumed to be the non-commercial component. However, there are cases where the commercial landing may be higher than the estimated creel total of the commercial receipt book program. In this case, the commercial receipt books are able to capture the fishery better than the creel surveys.

Calculations: Estimated landings are based on all bottomfish species harvested, regardless of the gear used, for all data collection programs (e.g. shore-based creel, boat-based creel and the commercial purchase reports).

Table 28. Summary of time series of catch (lbs.) for all species caught using the bottomfishing gear in Guam from 1980-2017.

Year	Creel Survey Estimates		Creel Total	Commercial landings
	Boat-based	Shore-based		
1980				*
1981				*
1982	24943	0	24943	*
1983	38823	NULL	38823	6255
1984	39146	NULL	39146	5329
1985	49399	333	49732	*
1986	19145	451	19596	*
1987	27937	12	27949	*
1988	44807	3100	47907	*
1989	57949	76	58025	*
1990	41846	3872	45718	5664
1991	38744	6957	45701	3061
1992	49231	4233	53464	2994
1993	53803	1348	55151	4621
1994	48822	545	49367	*
1995	40709	2108	42817	7695
1996	52667	2798	55465	2205
1997	30232	1946	32178	2687
1998	37391	812	38203	5277
1999	52795	1066	53861	22025
2000	66108	906	67014	13696
2001	50864	178	51042	11900
2002	23832	2573	26405	6245
2003	41677	439	42116	*
2004	37266	1040	38306	10453
2005	36477	223	36700	13552
2006	37713	1769	39482	9436
2007	26558	195	26753	*
2008	36847	168	37015	*
2009	38834	960	39794	*
2010	28320	224	28544	*
2011	58343	682	59025	*
2012	21718	466	22184	*
2013	29777	1137	30914	*
2014	26824	1491	28315	1714
2015	15142	499	15641	923
2016	27167	614	27781	1619
2017	22267	695	22962	5153
10 year avg.	**30524**	**694**	**31218**	**5205**
10 year SD	**11383**	**387**	**11403**	**3273**
20 year avg.	**35796**	**807**	**36603**	**7748**
20 year SD	**12807**	**594**	**12780**	**5008**

* Less than 3 vendors.

Calculations: Estimated landings are based on a pre-determined list of species (Appendix 3) identified as the BMUS Complex regardless of the gear used, for each data collection (shore-based creel, boat-based creel, and the commercial purchase reports).

Table 29. Summary of time series of BMUS catch (lbs.) in Guam from 1980-2017.

Year	Creel survey Estimates		Creel Total	Commercial landings
	Boat-based	Shore-based		
1980				*
1981				*
1982	24032		24032	*
1983	38794		38794	6255
1984	16205		16205	5329
1985	46574	4	46578	*
1986	19145	386	19531	*
1987	27831	12	27843	*
1988	43982	3092	47074	*
1989	57580	76	57656	*
1990	41653	3723	45376	5664
1991	38253	6849	45102	3061
1992	48960	4169	53129	2994
1993	53457	1184	54641	4621
1994	48621	396	49017	*
1995	40233	1900	42133	7657
1996	52484	2718	55202	2205
1997	29765	1467	31232	2687
1998	36966	409	37375	5267
1999	52531	117	52648	22025
2000	65682	768	66450	13534
2001	50370	175	50545	11900
2002	23803	2572	26375	6245
2003	41567	301	41868	*
2004	36008	865	36873	10453
2005	36431	129	36560	13552
2006	37704	1768	39472	9436
2007	26558	194	26752	*
2008	36847	168	37015	*
2009	38342	905	39247	*
2010	26821	223	27044	*
2011	58343	680	59023	*
2012	21718	464	22182	*
2013	29741	1128	30869	*
2014	23466	1399	24865	1651
2015	13532	305	13837	804
2016	26380	512	26892	1619
2017	18904	239	19143	5095
10 year avg.	**29409**	**602**	**30012**	**5082**
10 year SD	**12022**	**399**	**12095**	**3192**
20 year avg.	**35086**	**666**	**35752**	**7672**
20 year SD	**13222**	**624**	**13160**	**5005**

* Less than three vendors.

Calculations: Estimated landings are based on a pre-determined list of species (Appendix 3) identified as the CREMUS Complex regardless of the gear used, for each data collection (shore-based creel, boat-based creel, and the commercial purchase reports).

Table 30. Summary of time series of CREMUS catch (lbs.) in Guam from 1980-2017.

Year	Creel survey Estimates		Creel Total	Commercial Landings
	Boat-based	Shore-based		
1980				*
1981				*
1982	29248		29248	*
1983	53077		53077	80171
1984	95924		95924	118390
1985	131353	401187	532540	*
1986	69133	236498	305631	*
1987	62967	229383	292350	*
1988	111436	217126	328562	*
1989	156378	153837	310215	*
1990	121793	125914	247707	50769
1991	171220	261531	432751	38322
1992	123803	184287	308090	38793
1993	174809	100143	274952	33320
1994	154312	142562	296874	*
1995	267515	189515	457030	26304
1996	386366	101281	487647	50376
1997	219166	191563	410729	72762
1998	230905	231903	462808	169663
1999	374272	277098	651370	258789
2000	268191	68611	336802	262194
2001	256389	84594	340983	267622
2002	122999	54439	177438	197642
2003	152096	117200	269296	*
2004	166830	80487	247317	155223
2005	88942	72068	161010	179408
2006	86051	92737	178788	194229
2007	72870	69105	141975	*
2008	103971	67362	171333	*
2009	126473	411859	538332	*
2010	76133	80402	156535	*
2011	260962	77422	338384	*
2012	87746	149342	237088	*
2013	87812	181043	268855	*
2014	142326	48592	190918	87801
2015	122065	81157	203222	58762
2016	97872	56971	154843	73250
2017	75373	72055	147428	273375
10 year avg.	**118073**	**122621**	**240694**	**132330**
10 year SD	**52074**	**104274**	**114360**	**62742**
20 year avg.	**150014**	**118722**	**268736**	**166274**
20 year SD	**81922**	**89823**	**137319**	**65016**

* Less than three vendors.

1.2.7.2 Expanded catch estimates by fishing methods

Catch information is provided for the top shore-based and boat-based fishing methods that contribute 88% and 83% of the annual catch, respectively.

Calculations: The creel survey catch time series are the sum of the estimated weight for selected gear in all strata for all species (except for trolling, which exclude PMUS as well as any other pelagic species complex).

Table 31. Summary of expanded creel survey time series of catch (lbs.) by gear type in Guam for 1982-2017.

	Shore-based methods						Boat-based methods			
Year	Castnet	H&L	Gillnet	Spear	SCUBA	H&G	Bottom	Spear	SCUBA	Troll *
1982							41328	420	3135	14747
1983							50416	1355	4400	14586
1984							57412	14108	5460	6867
1985	83628	41488	59241	83182	3136	6900	88045	18737	12761	18692
1986	72685	34137	77319	35638	0	3582	34515	12545	5145	14918
1987	75312	31262	78088	31650	0	2076	44459	12448	7474	12440
1988	28197	44121	84778	44074	3862	6820	67037	24712	10649	24956
1989	38948	40012	40550	13435	1282	8267	79972	30930	20839	15349
1990	33648	43856	37089	10430	441	1883	61401	28871	22273	10895
1991	105524	52137	51556	18085	70	3748	60753	27898	37027	19522
1992	40493	41928	67799	26380	260	1484	78175	35162	25226	8533
1993	20711	14840	21458	30996	497	4053	107130	39434	22848	5611
1994	44410	33176	27242	25453	1247	3386	105283	37555	27244	12080
1995	81934	22492	25148	38939	14452	2207	101073	40554	74734	17045
1996	47587	19758	13423	14498	688	1953	129708	67447	91810	34810
1997	61155	34158	16456	20248	237	2159	109346	37363	41920	16396
1998	54412	27401	15276	88172	1844	20082	99600	56443	68197	17957
1999	100194	26485	33541	75345	320	15294	122930	45200	82024	30561
2000	21196	14780	14216	15265	117	763	115836	42403	116071	20367
2001	22304	7362	8934	21083	106	5670	123975	74369	65103	17581
2002	22352	12867	5913	13374	89	444	55448	21711	34766	10922
2003	40729	16174	10975	50456	157	177	82223	22649	42685	30524
2004	31462	11932	6530	27397	70	200	61874	33601	51237	52619
2005	23509	8286	22033	8073	394	7944	62651	15037	32375	13387
2006	33873	39707	6120	16550	552	765	89865	12796	6359	13755
2007	28815	6066	15867	12053	137	5131	57750	24704	29989	10567
2008	29866	13432	20403	3209	0	362	59639	31433	25449	6037
2009	44133	342402	6569	2329	0	13746	89997	22669	37424	12185
2010	6440	19873	50294	2063	0	706	56164	23635	32608	14026
2011	38331	33663	2607	1619	211	378	88694	26483	67431	6637
2012	95362	31598	15335	6361	30	6886	40214	23986	14087	1630
2013	44113	98377	26579	6675	148	4090	42601	20816	5390	26073
2014	37436	8796	576	1009	30	181	69300	28088	36140	21027
2015	49829	10332	8140	45819	0	1755	29395	22371	34607	19750
2016	11300	12603	8063	25645	0	712	51475	28985	21891	17619
2017	29163	33063	2873	4000	307	762	46715	17792	11201	12095
10 year avg.	**38597**	**60414**	**14144**	**9873**	**145**	**2958**	**57419**	**24626**	**28623**	**13708**
10 year SD	**23142**	**97243**	**14411**	**13809**	**107**	**4130**	**19073**	**3903**	**16738**	**7197**
20 year avg.	**38241**	**38760**	**14042**	**21325**	**301**	**4302**	**72317**	**29759**	**40752**	**17766**
20 year SD	**23055**	**72453**	**11719**	**24367**	**436**	**5692**	**27232**	**14450**	**26939**	**10874**

* Excluded Pelagic Species

1.2.7.3 Top Species in the Catch for the Boat- and Shore-Based Fisheries

The time series for catch is an indicator of fishery performance. Fluctuations in the catch can be attributed to various factors and there is no single explanatory variable for the trends. The 10 species group in the boat and shore-based catch for the coral reef fishery make up 67% and 76%, respectively, of the total annual catches.

Calculations: Catch by species complex is tallied directly from the boat-based expanded species composition data combining all gear types and species, for all strata.

The averages for the table below were calculated from catch estimates for the entire time series across each of the CREMUS groupings. The average catch for each grouping is ranked from the highest to lowest. The dominant groups that make up more than half of the total annual catch are reported.

Table 32. Catch time series of 11 top CREMUS from Guam boat-based creel survey expansion data from 2000-2017.

	Boat-based (Estimated Pounds)										
Year	**Bottomfish**	**BMUS**	**Atulai**	**Emperors**	**Surgeonfish**	**Jacks**	**Parrotfish**	**Groupers**	**Snappers**	**Goatfish**	**Rabbitfish**
1982	24944	24033	204	991	372	5034	4823	197	11	1710	55
1983	38824	38794	28099	929	805	804	3425	1049	0	2102	949
1984	39144	16203	37342	3774	377	1423	2869	1768	0	556	1023
1985	49401	46576	51625	5443	1810	4706	6237	9014	140	3975	3792
1986	19147	19147	22004	2719	274	1708	6585	4819	60	2693	2559
1987	27938	27832	14913	2152	612	2686	6170	6074	104	2697	1431
1988	44808	43983	33000	3094	1404	3559	15149	9479	267	3742	7510
1989	57946	57578	60347	5665	4611	1559	8790	9910	1769	4470	13994
1990	41846	41653	9602	15752	6482	8749	6537	12651	2890	4547	19415
1991	38744	38252	34101	10986	5325	5310	5693	24141	925	8319	12797
1992	49231	48961	10077	13306	2722	4789	6381	22345	662	7915	20403
1993	53805	53460	29291	10245	10341	11450	7467	15689	2535	6009	12141
1994	48822	48621	4063	18064	3782	9702	13499	17515	1247	6184	16635
1995	40706	40231	52171	22603	9210	8278	16533	24169	3736	5869	39683
1996	52669	52486	98881	27165	6257	6931	40254	22232	3950	9500	56172
1997	30233	29766	32958	26672	7808	9229	13975	19358	2867	4230	28141
1998	37390	36965	31118	19340	7459	6496	10501	22108	5079	5938	47571
1999	52795	52531	135337	19394	10098	7287	25812	25786	3925	6666	44710
2000	66109	65682	14008	29076	9056	12056	18161	30770	5147	8019	52732
2001	50866	50371	7974	34764	3775	9845	15731	27856	8545	5902	31109
2002	23835	23806	438	24871	5166	4151	15934	16497	3072	1934	20462
2003	41677	41567	502	18569	2990	5909	38377	18237	1553	3618	18640
2004	37266	36008	1768	13274	1009	6396	37328	19616	731	5593	35195
2005	36479	36432	160	9857	3656	6775	17195	8953	156	1462	18382
2006	37713	37705	1155	6321	4732	3917	19979	2222	204	4702	4258
2007	26558	26558	848	10572	1274	1417	10489	7968	19	2043	8695
2008	36844	36844	10335	7560	6599	7205	8460	7524	1486	5538	24395
2009	38834	38342	11337	16494	2355	10265	7155	7988	272	2946	24717
2010	28320	26821	5887	11940	1460	3884	7706	6788	485	3623	11518
2011	58342	58342	120766	12529	565	3192	6172	4394	304	3399	12235
2012	21718	21718	24936	7210	2470	1950	3083	5206	1349	2857	3313
2013	29778	29742	19864	11003	972	3856	12440	9458	1167	3951	9817
2014	26823	23465	4077	22347	8399	5136	13027	8856	3808	3741	10376
2015	15142	13531	28707	8053	3145	2090	14375	1440	782	5061	4966
2016	27165	26379	2523	9419	1615	3352	18661	10493	784	2561	7672
2017	22271	18908	6063	5506	704	9392	11707	1707	915	3317	3714
10 year avg.	**29409**	**30524**	**23450**	**11206**	**2828**	**5032**	**10279**	**6385**	**1135**	**3699**	**11272**
10 year SD	**12021**	**11382**	**33550**	**4789**	**2493**	**2796**	**4355**	**2969**	**973**	**901**	**7281**
20 year avg.	**35086**	**35796**	**21390**	**14905**	**3875**	**5729**	**15615**	**12193**	**1989**	**4144**	**19724**
20 year SD	**13222**	**12807**	**36847**	**7856**	**2913**	**2907**	**9079**	**8766**	**2195**	**1688**	**14945**

Calculations: Catch by species complex is tallied directly from the boat-based expanded species composition data combining all gear types and species, for all strata.

The averages for the table below were calculated from catch estimates from the entire time series for each of the CREMUS grouping. The average catch is ranked from the highest to lowest catch. The dominant groups that make up more than 60% of the catch are reported.

Table 33. Catch time series of 11 top CREMUS from Guam shore-based creel survey expansion data from 2000-2017.

Year	Shore-based Estimated Pounds									
	Surgeonfish	Rabbitfish	Mollusks	Atulai	Goatfish	Jacks	Mullet	Emperors	Rudderfish	Parrotfish
1980	4634	105	0	698	52	407	105	0	926	303
1981	5198	0	0	2820	249	96	0	0	70	451
1982	1588	1493	414	5449	0	484	513	25	177	179
1983	38314	2699	827	6219	0	1412	1808	187	1209	1937
1984	64893	9229	414	6387	57	3140	5588	448	2136	1955
1985	78837	35354	19836	19928	4659	24655	59114	7814	75189	96091
1986	26833	13640	37904	22320	12854	9047	9967	7470	63110	7455
1987	19243	8511	41539	25925	5906	7489	27334	7279	76214	5758
1988	35611	17526	28101	30118	13985	12939	24768	17216	72984	11776
1989	70707	15991	36147	16939	9683	10539	21535	11301	47436	10760
1990	11355	25240	22675	16943	12992	16081	23173	10630	47952	7534
1991	38440	19166	20970	53081	27946	40673	41552	22722	42754	44411
1992	11856	25745	17283	12545	16134	30319	33249	14010	70715	13826
1993	31738	16512	20545	15045	4885	19514	12598	7666	27744	21110
1994	5105	27486	11785	23947	14243	23909	32463	2013	46321	22190
1995	52713	35760	22066	25451	6281	32840	21012	8586	107982	18149
1996	99911	36618	12461	49005	3070	28748	22740	10834	88445	28173
1997	40087	37720	13458	29685	3972	26452	26835	8405	64979	11431
1998	36324	32097	15524	28123	3838	41052	21178	25804	102613	39709
1999	146877	30886	18393	66411	9965	49083	35416	9214	112339	38702
2000	22313	36192	13413	26927	1697	33184	19958	9600	65102	14888
2001	19553	47032	8662	30827	1422	29385	21488	2838	46204	19755
2002	5561	33757	7805	32972	2070	18427	17033	11813	39883	15805
2003	2034	26899	10959	54987	1702	27075	18008	5672	62021	30980
2004	3180	22321	4489	65951	689	23525	15293	8917	80557	16657
2005	1204	17533	10976	37910	3104	12121	8797	5572	55236	25036
2006	5595	11250	13890	33409	541	5851	16020	13204	69541	22781
2007	6146	19150	2773	31278	1287	9233	16614	3230	61201	16072
2008	14627	10465	7302	23536	4720	21291	16335	4850	66463	12588
2009	15850	23776	4566	37120	45336	58220	88390	8955	253839	21375
2010	9778	15940	3574	16459	2701	60439	9959	9123	75114	11402
2011	123038	19709	8801	40378	2195	44875	11779	720	54866	14553
2012	31196	15297	15877	87163	14455	19973	6293	1720	46194	16348
2013	23563	15034	35352	50947	4822	20471	29438	1308	77475	7615
2014	5639	33300	12932	34480	294	25317	11555	14998	35963	4914
2015	28739	12993	13543	25845	654	13866	8524	1642	34392	23892
2016	3942	13662	10088	25510	784	21074	14337	2722	36584	17520
2017	9047	21309	15725	30238	2981	54840	35850	2395	95703	10168
10 year avg.	**18149**	**26542**	**12776**	**37168**	**7894**	**34037**	**23246**	**4843**	**77659**	**14038**
10 year SD	**6341**	**33374**	**8565**	**19062**	**13072**	**17399**	**23488**	**4454**	**61890**	**5632**
20 year avg.	**22930**	**25710**	**11732**	**39024**	**5263**	**29465**	**21113**	**7215**	**73565**	**19038**
20 year SD	**9613**	**37981**	**6963**	**17117**	**9788**	**16124**	**17359**	**5958**	**46616**	**8990**

1.2.8 Catch-per-Unit-Effort (CPUE) Statistics

This section summarizes the estimates for catch-per-unit effort in the boat and shore-based fisheries. The boat-based fisheries include the bottomfishing (handline gear), spearfishing (SCUBA and snorkel), gillnets, and troll that comprise 83% of the total catch. Trolling methods are primarily a pelagic fishing method but also catches coral reef fishes like jacks and gray jobfish. The shore-based fisheries include the hook-and-line, throw or cast nets, gillnets, spear, and hook-and-gaff that comprise 88% of the total coral reef fish catch. CPUE is reported as pounds per gear-hours for the shore-based methods whereas in the boat-based methods it's pounds per trip.

Calculations: CPUE is calculated from interview data by gear type using ∑catch /∑ (hours fished*number of fishers) for boat based and ∑catch/∑ (hours fished*number of gears used) for shore based. If the value is blank (empty), then there was no interview collected for that method. Landings from interviews without fishing hours are excluded from the calculations.

Table 34. CPUE time series for dominant fishing methods in Guam shore-based fisheries CPUE from 1984-2017.

Year	Gear CPUE (Lbs/Gear-hr)				
	H&L	Castnet	Gill Net	Spear	Hooks and Gaffs
1984	0.0106	0.1339	0.3507	0.75	1.125
1985	0.0029	0.0224	0.0509	0.0773	0.0975
1986	0.004	0.0224	0.0441	0.0962	0.2393
1987	0.0074	0.0208	0.0515	0.0747	0.0354
1988	0.0027	0.0213	0.0764	0.0805	0.2444
1989	0.0022	0.0136	0.0548	0.0627	0.2545
1990	0.0011	0.0171	0.0309	0.059	0.0551
1991	0.0017	0.0128	0.0305	0.0918	0.069
1992	0.0005	0.0122	0.0255	0.0986	0.0327
1993	0.0003	0.006	0.0181	0.1621	0.0347
1994	0.0004	0.016	0.0208	0.037	0.0734
1995	0.0005	0.0064	0.0117	0.0734	0.0313
1996	0.0003	0.0158	0.022	0.0659	0.0938
1997	0.0004	0.006	0.0134	0.0415	0.0544
1998	0.0005	0.0082	0.0067	0.0544	0.1094
1999	0.0005	0.0076	0.0124	0.0316	0.1925
2000	0.0004	0.0083	0.0189	0.0476	0.0381
2001	0.0004	0.0045	0.0204	0.0575	0.2946
2002	0.0007	0.0152	0.0184	0.0906	0.45
2003	0.0007	0.0034	0.0359	0.1844	0.0256
2004	0.001	0.0051	0.029	0.1257	0.2222
2005	0.0005	0.0019	0.0781	0.1333	0.2593
2006	0.0015	0.0169	0.0373	0.1035	0.2889
2007	0.0007	0.0071	0.1264	0.1555	0.4286
2008	0.0009	0.0064	0.0738	0.0489	0.1333
2009	0.001	0.1468	0.1294	0.1222	0.3524
2010	0.0003	0.0138	0.2598	0.2708	0.2115
2011	0.0018	0.0203	0.1245	0.7429	0.52
2012	0.002	0.0188	0.1356	0.1527	0.2143
2013	0.0017	0.0438	0.1176	0.0988	0.2639
2014	0.003	0.0141	0.4388	0.4688	0.2857
2015	0.0102	0.0147	0.0673	0.3298	0.4231
2016	0.0006	0.0051	0.0269	0.029	0.4
2017	0.0013	0.0377	0.2016	0.0806	0.0577
10 year avg.	**0.0023**	**0.0322**	**0.1575**	**0.2345**	**0.2862**
10 year SD	**0.0027**	**0.04**	**0.113**	**0.2149**	**0.1333**
20 year avg.	**0.0015**	**0.02**	**0.0979**	**0.1664**	**0.2586**
20 year SD	**0.0021**	**0.031**	**0.1027**	**0.17**	**0.1385**

Table 35. CPUE time series for dominant fishing methods in Guam boat-based fisheries CPUE from 1984-2017.

Year	Boat-based Gear CPUE (Lbs./Fishing hrs)				
	Bottomfishing	Spear	SCUBA	Gill Net	Troll
1982	0.0293	0.48	0	0	0.0162
1983	0.0293	0.2198	0.3956	0	0.0154
1984	0.023	0.1159	0.3553	3	0.0135
1985	0.0099	0.2025	0.1598	0.5357	0.0098
1986	0.021	0.2915	0.4402	0.5	0.0092
1987	0.0223	0.2312	0.555	0.3195	0.0086
1988	0.0114	0.1518	0.2097	0.6465	0.0057
1989	0.0106	0.1194	0.2343	0.405	0.0048
1990	0.0116	0.1515	0.6306	0.3795	0.0037
1991	0.0116	0.1691	0.4482	0.311	0.0051
1992	0.0106	0.0794	0.1164	0.2381	0.0034
1993	0.0102	0.0637	0.4413	0.6389	0.0041
1994	0.0109	0.0766	0.3632	0.3262	0.0039
1995	0.0029	0.0568	0.2424	0.1213	0.0032
1996	0.0035	0.0586	0.2149	0.4762	0.0034
1997	0.0029	0.0706	0.446	0.2965	0.004
1998	0.0027	0.0252	0.3077	0.1199	0.0035
1999	0.0035	0.0334	0.2841	0.6192	0.0031
2000	0.0052	0.0532	0.2758	0.0661	0.0042
2001	0.0071	0.1912	0.3202	0.3005	0.0069
2002	0.0069	0.0857	0.5128	0.4275	0.0117
2003	0.0172	0.188	0.7129	1.8968	0.0176
2004	0.0143	0.2008	0.786	1.0195	0.0174
2005	0.0171	0.0848	0.7361	0.4407	0.0104
2006	0.023	0.1134	0.3905	1.75	0.0114
2007	0.0226	0.2217	4.0816	0.5214	0.0136
2008	0.0162	0.1087	0.6206	1.5606	0.01
2009	0.0164	0.0795	1.7182	0.2311	0.0083
2010	0.0081	0.0828	0.3333	0.3787	0.0067
2011	0.027	0.2714	2.6571	0.5	0.0095
2012	0.0341	0.8788	3	10.3504	0.0185
2013	0.0254	0.1598	0.9375	0.4643	0.0147
2014	0.0172	0.1629	1.5469	1.3313	0.0109
2015	0.0163	0.1729	0.5435	0.9467	0.0125
2016	0.0137	0.0961	0.2078	0.1993	0.0074
2017	0.0151	0.0501	0.8095	0.3646	0.0065
10 year avg.	**0.019**	**0.2063**	**1.2374**	**1.6327**	**0.0105**
10 year SD	**0.0072**	**0.2322**	**0.9199**	**2.9396**	**0.0036**
20 year avg.	**0.0155**	**0.163**	**1.0391**	**1.1744**	**0.0102**
20 year SD	**0.0081**	**0.177**	**1.0314**	**2.1717**	**0.0045**

1.2.9 Effort Statistics

This section summarizes the effort trends in the coral reef and bottomfish fishery. Fishing effort trends provide insights on the level of fishing pressure through time. Effort information is provided for the top shore-based and boat-based fishing methods that contribute 88% and 83% of the annual catch. Trolling method is included in this report because coral reef MUS is also caught using trolling method. Pelagic MUS caught using trolling method is reported in the Pelagic Annual/SAFE report module.

Calculations: Effort estimates (hours) are generated by summing the effort data collected from interviews by gear type. For shore-based estimates, data collection started in 1985.

Table 36. Time series of effort estimates (gear hours or no. trips for bottomfish) from Guam coral reef and bottomfish fisheries for 1982-2017.

Year	Shore-based gear-hours					Boat-based gear-hours				
	Castnet	H&L	Gillnet	Spear	H&G	Bottom	Spear	Scuba	Gillnet	Troll
1982	15	400	0	208	0	81620	65	1	0	3046932
1983	0	0	0	0	0	59512	143	527	0	2615565
1984	224	2914	345	24	8	131159	6156	630	15	2548752
1985	5673	82992	10658	15096	400	532350	4092	5304	21	4709880
1986	3430	52899	14378	3410	117	98112	1888	304	2	3019692
1987	4902	18204	8550	9964	4779	113442	2257	624	493	3946710
1988	8487	34662	9735	6264	225	295911	6375	1920	44	9291900
1989	15810	42120	6336	2184	224	331525	4416	2655	100	7495286
1990	13534	253492	20240	2679	272	249280	1794	1200	640	11182260
1991	13932	368466	17835	1862	1638	197964	2016	2142	918	9667476
1992	13900	739440	30000	1440	490	202400	5893	6820	414	11705316
1993	12604	796708	18040	1666	1701	270758	8961	2520	324	11355743
1994	6048	978945	21070	7520	722	383520	8827	3569	1300	11652024
1995	19840	673200	40608	7221	384	1258615	24497	16268	5520	17307210
1996	4875	939333	8601	2684	96	1351026	28310	13959	5244	20231220
1997	19760	1120575	31692	5328	294	1017597	13144	3713	3080	13812489
1998	21976	795960	73066	15006	448	1526630	62160	10126	3348	16974006
1999	14351	1234925	52116	26010	504	1230288	20574	12060	1122	12031104
2000	14157	838240	27930	9416	315	622364	15930	10856	8064	11211280
2001	15125	827519	16464	3968	224	483060	5940	4860	1008	6544218
2002	7614	227813	14691	2352	20	278604	5544	960	384	2681143
2003	18900	345598	2950	1394	195	148160	3596	1369	147	1405206
2004	7885	195202	4662	1050	36	168413	2295	1044	66	2336400
2005	9400	167334	1242	360	54	190400	4368	480	253	2290578
2006	6336	96074	2091	425	45	147125	3618	117	2	2796184
2007	2948	343952	546	418	70	92820	1550	49	154	2443480
2008	5976	164300	1720	266	15	127710	8393	289	264	2771390
2009	4026	185298	255	180	210	285891	6072	100	532	6262704
2010	7313	141860	408	144	156	370360	5250	6	168	7455312
2011	5184	103653	988	70	25	136284	1800	196	3	3945474
2012	6006	122850	1128	550	70	30084	504	65	45	1194173
2013	4221	81774	672	729	72	47061	1710	24	1120	3601465
2014	4544	130062	196	224	28	144690	3528	40	210	4490376
2015	5858	227766	3358	1980	156	65262	2842	391	65	5278731
2016	14040	183219	4717	5520	20	170159	6210	6732	189	9152541
2017	3320	191836	506	484	104	176253	8051	140	64	7157862
10-year avg.	**6049**	**153262**	**1395**	**1015**	**86**	**155375**	**4436**	**798**	**266**	**5131003**
10-year SD	**2888**	**42719**	**1423**	**1592**	**65**	**100350**	**2616**	**1981**	**319**	**2284900**
20-year avg.	**8959**	**330262**	**10485**	**3527**	**138**	**322081**	**8497**	**2495**	**860**	**5601181**
20-year SD	**5370**	**314856**	**18973**	**6332**	**139**	**382540**	**13193**	**3967**	**1812**	**4019059**

1.2.10 Participants

This section summarizes the estimated number of participants in each fishery. The information presented here can be used in the impact analysis of potential amendments in the FEPs associated with the bottomfish and coral reef fisheries. The trend in the number of participants over time can also be used as an indicator for fishing pressure.

Calculations: For boat-based data, the estimated number of participants is calculated by multiplying the average number of fishers per trip by the number of trips per day, and then by the number of dates in the calendar year by gear type. The total is a combination of weekend and weekday stratum estimates.

For shore-based data, the estimated number of participants is calculated by using an average number of fishers per day multiplied by the numbers of dates in the calendar year across gear types. The total is a combination of weekend, weekday, day, and night stratum estimates.

Table 37. Number of boats participating in the Guam bottomfish fishery and number of gears in the Guam boat- and shore-based coral reef fisheries from 1982-2017.

	Bottomfish		Coral Reef Boat-based				Coral Reef Shore-based				
Year	# fishers	# gears	Spear	SCUBA	Gillnet	Troll	H&L	Throw	Gill	Spear	H&G
1982	865	798	1095	365	0	920					
1983	820	709	852	533	0	955					
1984	977	847	1519	701	732	1022	101016	18141	18523	7065	2101
1985	971	883	1326	852	1460	952	120562	32345	37904	21282	3931
1986	918	794	913	1049	1095	975	90441	21308	46996	19236	2072
1987	874	829	712	830	1095	964	108511	25715	49381	18297	1978
1988	975	903	987	864	824	1151	98891	23518	42645	25360	5242
1989	931	869	1156	1065	730	1122	125421	26558	28505	10985	4310
1990	1002	883	1338	1116	1004	1247	101800	23666	32991	11233	2896
1991	1049	843	1241	1136	962	1287	215674	39177	64483	15087	6002
1992	1067	886	1330	1243	1098	1335	186939	38170	76740	18606	3673
1993	1028	910	1191	1359	776	1236	189891	41884	46720	19527	6296
1994	1103	947	1204	1278	791	1217	217996	33762	43891	18615	4015
1995	1327	1275	1062	1362	1137	1239	246531	37900	48269	21453	7956
1996	1609	1562	1074	1311	864	1253	252664	24115	32650	16408	7127
1997	1816	1581	1033	1406	1000	1215	210044	27784	29222	12944	2550
1998	1393	1305	1046	1396	960	1164	158460	37500	54300	22920	6780
1999	1441	1387	1181	1426	1121	1121	217454	24670	46892	37939	8116
2000	1391	1321	1075	1303	1236	1103	129407	18666	23163	17202	3712
2001	1043	1078	1178	1309	1235	1090	120039	18980	17839	12957	3513
2002	1197	1037	1019	1294	986	1030	90023	17893	12301	7688	1258
2003	924	1092	1344	1488	1095	1127	89197	21763	15239	11908	958
2004	1229	1121	990	1298	854	1011	80756	13365	17001	10720	708
2005	974	965	1019	1251	803	1114	75783	17109	11452	7574	3422
2006	918	956	1153	949	730	1068	71494	21033	14691	12729	3376
2007	1217	1034	1011	1278	730	1166	70126	15512	10631	8669	4152
2008	971	950	1168	1220	961	1141	76860	14365	9150	7961	2287
2009	915	1022	1173	1338	1049	954	89557	17194	10158	6477	4194
2010	964	1040	1081	1095	1773	1024	72969	14491	9133	8760	2609
2011	1008	1001	1363	1369	730	979	74916	14463	7026	6387	2601
2012	1001	953	1007	1708	952	992	98008	15277	14895	7877	2721
2013	1113	1150	1430	973	1209	925	73062	14538	15330	12814	1957
2014	1135	1262	1417	973	1399	947	63891	12664	8950	10617	1857
2015	1180	1095	1417	2281	1186	956	53746	11771	11406	11041	1962
2016	1146	1177	1127	1763	1412	908	53436	11575	10111	12215	3065
2017	841	1038	1189	1916	1095	905	58178	11664	6665	9712	952
10 year avg.	**1069**	**1027**	**1237**	**1464**	**1177**	**973**	**71462**	**13800**	**10282**	**9386**	**2421**
10 year SD	**96**	**106**	**148**	**415**	**279**	**66**	**13966**	**1744**	**2759**	**2151**	**815**
20 year avg.	**1099**	**1100**	**1169**	**1381**	**1076**	**1036**	**90868**	**17225**	**16317**	**12208**	**3010**
20 year SD	**127**	**169**	**145**	**320**	**257**	**86**	**38590**	**5800**	**12131**	**7019**	**1807**

Year	Bottomfish		Coral Reef BB				Coral Reef SB Fishery				
	# gear	# trips	Spear	SCUBA	Gill net	Troll	H&L	Castnet	Gill net	Spear	H&G
1982	798	40	949	365	0	1506					
1983	709	210	669	477	0	1428					
1984	847	242	1391	549	1098	1392	100252	16995	10503	7065	2864
1985	883	857	1191	791	365	1371	120562	24595	17408	20215	4661
1986	794	633	834	867	365	1423	91270	18289	21959	19236	3847
1987	829	852	675	863	1241	1489	108016	21759	25008	16672	3320
1988	903	1449	832	703	366	1479	99458	21535	19197	23943	9917
1989	869	1338	973	897	365	1459	128341	24681	13766	10707	6605
1990	883	943	933	1074	730	1466	102789	21335	14977	10950	3744
1991	843	1125	876	852	597	1392	221109	35446	28876	14600	5678
1992	886	945	866	839	471	1447	193008	33219	35056	18287	4073
1993	910	1495	836	906	411	1406	195366	35496	23816	19163	9034
1994	947	1520	898	947	791	1378	238436	29565	21809	18068	4015
1995	1275	2049	854	1082	501	1351	250643	32895	23598	21274	10995
1996	1562	1754	880	1075	673	1399	264597	21048	15331	15994	9944
1997	1581	1700	944	1068	595	1405	198473	24515	12356	10787	3073
1998	1305	2209	798	1113	487	1346	159600	33840	21840	22260	7260
1999	1387	2103	909	1137	574	1313	212623	22480	21836	36844	10564
2000	1321	1750	919	1053	712	1361	128937	16941	11085	15738	3817
2001	1078	1635	1095	1019	786	1365	121362	17702	9079	12501	3969
2002	1037	1230	793	995	584	1321	93984	16914	6337	7688	1258
2003	1092	1175	1029	1039	426	1306	95584	20896	8030	11954	958
2004	1121	1013	969	1198	366	1320	85809	13034	7839	10484	708
2005	965	896	791	1043	402	1391	83950	16288	6479	7528	3331
2006	956	863	1037	657	365	1365	75783	20349	8623	12182	3376
2007	1034	806	870	1278	803	1382	75144	11452	6251	8349	4243
2008	950	953	1084	1037	549	1340	75945	13679	4849	7869	2287
2009	1022	1110	899	1217	639	1284	96313	16868	6384	6384	4194
2010	1040	1316	946	1095	365	1201	78654	13326	5638	8294	2656
2011	1001	836	1095	1278	1095	1119	81121	13824	4517	6159	2327
2012	953	767	961	1586	366	1099	105408	14369	9548	7877	2721
2013	1150	741	1156	730	456	1205	85224	13839	8294	12721	1957
2014	1262	702	1353	608	608	1251	69461	12426	5523	10236	1857
2015	1095	598	1245	2099	456	1217	57807	11634	7391	10996	1871
2016	1177	783	1010	1647	471	1163	60344	11255	7686	12215	3065
2017	1038	849	977	1278	365	1234	63367	11283	4475	9760	952
10 year avg.	**866**	**1069**	**1073**	**1258**	**537**	**1211**	**77364**	**13250**	**6431**	**9251**	**2389**
10 year SD	**200**	**96**	**137**	**418**	**208**	**69**	**14682**	**1623**	**1647**	**2182**	**819**
20 year avg.	**1117**	**1099**	**997**	**1155**	**544**	**1279**	**95321**	**16120**	**8585**	**11902**	**3169**
20 year SD	**453**	**127**	**143**	**332**	**186**	**86**	**36118**	**5191**	**4728**	**6760**	**2248**

1.2.11 Bycatch Estimates

This section focuses on MSA § 303(a)(11), which requires that all FMPs establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures that, to the extent practicable, minimize bycatch and bycatch mortality. The MSA § 303(a)(11) standardized reporting methodology is commonly referred to as a ''Standardized Bycatch Reporting Methodology'' (SBRM) and was added to the MSA by the Sustainable Fisheries Act of 1996 (SFA). The Council implemented omnibus amendments to FMPs in 2003 to address MSA bycatch provisions and establish SBRMs.

The following are recent bycatch estimates for the boat-based non-bottomfishing gear (Table 38), bottomfish fishery (Table 39), and shore-based fisheries with all gears combined (Table 40).

Calculations: The number caught is the sum of the total number of individuals found in the raw data including bycatch. The number kept is the total number of individuals in the raw data that are not marked as bycatch. The number released is bycatch caught minus the number of bycatch kept. Percent bycatch is the sum of all bycatch divided by the total catch.

Table 38. Time series of bycatch estimates in Guam boat-based non-bottomfishing fisheries from 1982-2017.

Year	# caught	Kept	Released	% bycatch
1982	5388	5388	0	0
1983	3581	3581	0	0
1984	5584	5584	0	0
1985	8138	8138	0	0
1986	4829	4829	0	0
1987	4895	4895	0	0
1988	8113	8113	0	0
1989	12393	12393	0	0
1990	7645	7645	0	0
1991	9338	9338	0	0
1992	7352	7352	0	0
1993	9398	9398	0	0
1994	9843	9843	0	0
1995	17776	17776	0	0
1996	20931	20931	0	0
1997	19108	19108	0	0
1998	16428	16428	0	0
1999	19827	19827	0	0
2000	23373	23335	38	0.0016
2001	10409	10344	65	0.0062
2002	5560	5520	40	0.0072
2003	8543	8538	5	0.0006
2004	5851	5839	12	0.0021
2005	4012	4006	6	0.0015
2006	7176	7172	4	0.0006
2007	5611	5538	73	0.013
2008	9199	9198	1	0.0001
2009	11710	11707	3	0.0003
2010	8588	8588	0	0
2011	21232	21231	1	0
2012	12200	12200	0	0
2013	11834	11806	28	0.0024
2014	8814	8789	25	0.0028
2015	8995	8995	0	0
2016	11031	11025	6	0.0005
2017	8645	8643	2	0.0002
10 year avg.	**11225**	**11218**	**7**	**0.0006**
10 year SD	**3609**	**3610**	**10**	**0.001**
20 year avg.	**10952**	**10936**	**15**	**0.002**
20 year SD	**5226**	**5229**	**22**	**0.0032**

Table 39. Time series of bycatch estimates in the Guam bottomfish fishery from 1982-2017.

Year	# caught	Kept	Released	% bycatch
1982	1597	1597	0	0
1983	1507	1507	0	0
1984	3347	3347	0	0
1985	4840	4840	0	0
1986	1624	1624	0	0
1987	2519	2519	0	0
1988	3002	3002	0	0
1989	3562	3562	0	0
1990	2870	2870	0	0
1991	2783	2783	0	0
1992	2527	2527	0	0
1993	2893	2893	0	0
1994	3730	3730	0	0
1995	4985	4985	0	0
1996	5244	5244	0	0
1997	4342	4342	0	0
1998	5138	5138	0	0
1999	4938	4938	0	0
2000	3905	3373	532	0.1362
2001	3896	3273	623	0.1599
2002	2504	2151	353	0.141
2003	1888	1697	191	0.1012
2004	1804	1682	122	0.0676
2005	1706	1640	66	0.0387
2006	2188	2043	145	0.0663
2007	1372	1233	139	0.1013
2008	1657	1536	121	0.073
2009	2851	2774	77	0.027
2010	2588	2559	29	0.0112
2011	2128	2083	45	0.0211
2012	924	887	37	0.04
2013	1222	1178	44	0.036
2014	2452	2283	169	0.0689
2015	1420	1350	70	0.0493
2016	1674	1627	47	0.0281
2017	2313	2287	26	0.0112
10 year avg.	**1923**	**1856**	**67**	**0.0366**
10 year SD	**604**	**597**	**43**	**0.0206**
20 year avg.	**2428**	**2287**	**142**	**0.0589**
20 year SD	**1153**	**1119**	**166**	**0.0465**

Table 40. Time series of bycatch estimates in the Guam shore-based fishery from 1984-2017 for all gear types.

Year	# caught	Kept	Released	% bycatch
1984	1845	1845	0	0
1985	10200	10200	0	0
1986	9172	9169	3	0.0003
1987	9860	9860	0	0
1988	16199	16199	0	0
1989	8802	8802	0	0
1990	8817	8817	0	0
1991	9880	9880	0	0
1992	6753	6753	0	0
1993	30916	30916	0	0
1994	6013	6013	0	0
1995	8360	8360	0	0
1996	3385	3385	0	0
1997	9233	9216	17	0.0018
1998	11589	11580	9	0.0008
1999	12592	12530	62	0.0049
2000	7861	7831	30	0.0038
2001	8653	8593	60	0.0069
2002	3122	3114	8	0.0026
2003	5364	5345	19	0.0035
2004	2655	2611	44	0.0166
2005	2684	2654	30	0.0112
2006	3928	3851	77	0.0196
2007	3361	3238	123	0.0366
2008	5359	5282	77	0.0144
2009	3254	3160	94	0.0289
2010	4321	4222	99	0.0229
2011	5262	5187	75	0.0143
2012	5590	5559	31	0.0055
2013	3300	2893	407	0.1233
2014	4732	4622	110	0.0232
2015	4823	4775	48	0.01
2016	3907	3785	122	0.0312
2017	7804	7798	6	0.0008
10 year avg.	**4835**	**4728**	**107**	**0.0275**
10 year SD	**1258**	**1327**	**106**	**0.0333**
20 year avg.	**5508**	**5432**	**77**	**0.0191**
20 year SD	**2756**	**2783**	**84**	**0.0261**

1.2.12 Number of Federal Permit Holders

In Guam, the following Federal permits are required for fishing in the EEZ:

1.2.12.1 Guam Large Vessel Bottomfish Permit

The Code of Federal Regulations (CFR), Title 50, Part 665 requires the following Federal permits for Guam fisheries in the exclusive economic zone (EEZ) under the Mariana FEP:

1.2.12.2 Guam Large Vessel Bottomfish Permit

Regulations require this permit for any large vessel (50 feet or longer in overall length) fishing for, landing, or transshipping bottomfish MUS in the EEZ seaward of Guam.

1.2.12.3 Special Coral Reef Ecosystem Permit

Regulations require the coral reef ecosystem special permit for anyone fishing for coral reef ecosystem MUS in a low-use marine protected area (MPA), fishing for species on the list of Potentially Harvested Coral Reef Taxa, or using fishing gear not specifically allowed in the regulations. NMFS will make an exception to this permit requirement for any person issued a permit to fish under any fishery ecosystem plan who incidentally catches Guam coral reef ecosystem MUS while fishing for bottomfish MUS, crustacean MUS, western Pacific pelagic MUS, precious coral, or seamount groundfish. Regulations require a transshipment permit for any receiving vessel used to land or transship potentially harvested coral reef taxa, or any coral reef ecosystem MUS caught in a low-use MPA.

1.2.13 Western Pacific Precious Corals Permit

Regulations require this permit for anyone harvesting or landing black, bamboo, pink, red, or gold corals in the EEZ in the Western Pacific.

1.2.13.1 Western Pacific Crustaceans Permit (Lobster or Deepwater Shrimp)

Regulations require a permit by the owner of a U.S. fishing vessel used to fish for lobster or deepwater shrimp in the EEZ around American Samoa, Guam, Commonwealth of the Northern Mariana Islands (CNMI), Hawaii, and the Pacific Remote Islands Areas (PRIA).

There is no record of special coral reef or precious coral fishery permits issued for the EEZ around Guam since 2007. Table 41 provides the number of permits issued for Guam fisheries between 2008 and 2018. Historical data are from the PIFSC accessed on February 9, 2017 and 2018 data are from the PIRO Sustainable Fisheries Division permits program as of 1/3/2018.

Table 41. Number of federal permits holders between 2008 and 2018 for the crustacean and bottomfish fisheries of Guam.

Guam Fisheries	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Lobster	6*	4*							1**		1**

Guam Fisheries	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Shrimp			2*	1*					1		
Bottomfish	2	2	1	1	4	2	2	1	1	1	1

*Permits apply to multiple areas and may include American Samoa, Guam, CNMI, and PRIA.
**Area 5 CNMI and Guam.

1.2.14 Status Determination Criteria

1.2.14.1 Bottomfish Fishery

Overfishing criteria and control rules are specified and 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 would be affected differently based on this type of control rule, and it is important that for any given species fishing, mortality does not currently exceed a level that would result in excessive depletion of that species. No indicator species are being used for the bottomfish multi-species stock complexes and the coral reef species complex. Instead, the control rules are applied to each stock complex as a whole.

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) (Table 42). The value of M used to determine the reference point values are 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. 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 specified at some 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 44.

Table 42. Overfishing threshold specifications for Guam BMUS.

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY} B}{c\, B_{MSY}}$ for $B \leq c\, B_{MSY}$ $F(B) = F_{MSY}$ 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 $CPUE_{REF}$. E_{MSY} would 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.

Since the MSY control rule specified here applies to multi-species stock complexes, it is important to ensure that no particular species within the complex has a mortality rate that leads to excessive depletion. In order to accomplish this, a secondary set of reference points is specified to evaluate stock status with respect to recruitment overfishing. A secondary "recruitment overfishing" control rule is specified to control fishing mortality with respect to that status. The rule applies only to those component stocks (species) for which adequate data are available. The ratio of a current spawning stock biomass proxy (SSB_{Pt}) to a given reference level (SSB_{PREF}) is used to determine if individual stocks are experiencing recruitment overfishing. SSBP is CPUE scaled by percent mature fish in the catch. When the ratio SSB_{Pt}/SSB_{PREF}, or the "SSBP ratio" (SSBPR) for any species drops below a certain limit ($SSBPR_{MIN}$), that species is considered to be recruitment overfished and management measures will be implemented to reduce fishing mortality on that species. The rule applies only when the SSBP ratio drops below the $SSBPR_{MIN}$, but it will continue to apply until the ratio achieves the "SSBP ratio recovery target" ($SSBPR_{TARGET}$), which is set at a level no less than SSB_{PRMIN}. These two reference points and their associated recruitment overfishing control rule, which prescribe a target fishing mortality rate ($F_{RO-REBUILD}$) as a function of the SSBP ratio, are specified as indicated in Table 43. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 43. Rebuilding control rules for Guam BMUS.

$F_{RO-REBUILD}$	$SSBPR_{MIN}$	$SSBPR_{TARGET}$
$F(SSBPR) = 0 \quad \text{for } SSBPR \le 0.10$ $F(SSBPR) = 0.2\, F_{MSY} \quad \text{for } 0.10 < SSBPR \le SSBPR_{MIN}$ $F(SSBPR) = 0.5\, F_{MSY} \quad \text{for } SSBPR_{MIN} < SSBPR \le SSBPR_{TARGET}$	0.20	0.30

1.2.14.2 Coral Reef Fishery

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 should be 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.

For the coral reef fishery, the multi-species complex as a whole is used to establish limits and reference points for each area. 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.

1.2.14.2.1 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 44.

Table 44. Status determination criteria for the coral reef management unit species using CPUE based proxies.

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 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 ($CPUE_{REF}$).

1.2.14.3 Current Stock Status

1.2.14.3.1 Bottomfish

Biological and other fishery data are poor for all bottomfish species in the Mariana Archipelago. 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. The most recent stock assessment update (Yau *et al*., 2015) for the Guam bottomfish management unit species complex (comprised of 17 species of shallow and deep species of snapper, grouper, jacks, and emperors) was based on estimate of total catch, an abundance index derived from the nominal CPUE generated from the creel surveys, and a fishery-independent point estimate of MSY from the Our Living Oceans Report (Humphreys and Moffitt, 1999, Moffitt and Humphreys, 2009). The assessment utilized a state-space surplus production model with explicit process and observation error terms (Meyer and Millar, 1999). Determinations of overfishing and overfished status can then be made by comparing current biomass and harvest rates to MSY level reference points. To date, the Guam BMUS is not subject to overfishing and is not overfished (Table 45).

Table 45. Stock assessment parameters for the Guam BMUS complex (Yau *et al*., 2015).

Parameter	Value	Notes	Status
MSY	56.13 ± 7.79	Expressed in 1000 lbs. (± std. error)	
H_{2013}	0.123	Expressed in percentage	
H_{MSY}	0.352 ± 0.059	Expressed in percentage (± std. error)	
H/H_{MSY}	0.356		No overfishing occurring
B_{2013}	264.7	Expressed in thousand pounds	
B_{MSY}	162.3 ± 23.8	Expressed in 1000 lbs. (± std. error)	
B/ B_{MSY}	1.63		Not overfished

1.2.14.3.2 Coral reef

The application of the SDCs for the management unit species in the coral reef fisheries is limited due to various challenges. First, the thousands of species included in the coral reef MUS makes the SDC and status determination impractical. Second, the CPUE derived from the creel survey is based on the fishing method and there is no species-specific CPUE information available. In order to allocate the fishing method level CPUE to individual species, the catch data (the value of catch is derived from CPUE hence there is collinearity) will have to be identified to species level and CPUE will be parsed out by species composition. The third challenge is that there is very little species-level identification applied to the creel surveys. There has been no attempt to estimate MSY for the coral reef MUS until the 2007 re-authorization of MSA that requires the Council to specify ACLs for species in the FEPs.

For ACL specification purposes, MSYs in the coral reef fisheries are determined by using the Biomass-Augmented Catch-MSY approach (Sabater and Kleiber, 2014). This method estimates MSY using plausible combination rates 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 was applied to species complexes grouped by taxonomic families. The most recent MSY estimates are found in Table 46. The SSC utilized the MSYs for the coral reef MUS complexes as the OFLs.

Table 46. Best available MSY estimates for the coral reef MUS in Guam.

Coral Reef MUS Complex	MSY (lbs.)
Selar crumenophthalmus – atulai or bigeye scad	61,300
Acanthuridae – surgeonfish	118,000
Carangidae – jacks	31,700
Crustaceans – crabs	8,600
Holocentridae – squirrelfish	13,900
Kyphosidae – chubs/rudderfish	10,300
Labridae – wrasses[1]	28,500
Lethrinidae – emperors	78,000
Lutjanidae – snappers	21,800
Mollusks – turbo snail; octopus; giant clams	29,000
Mugilidae – mullets	26,200
Mullidae – goatfish	16,400
Scaridae – parrotfish[2]	87,100
Serranidae – groupers	28,600
Siganidae – rabbitfish	19,700
All Other CREMUS Combined - Other CRE-finfish - Other invertebrates - Misc. bottomfish - Misc. reef fish - Misc. shallow bottomfish	211,300
Cheilinus undulatus – humphead (Napoleon) wrasse	N.A.
Bolbometopon muricatum – bumphead parrotfish	N.A.
Carcharhinidae – reef sharks	2,900

1.2.15 Overfishing Limit, Acceptable Biological Catch, and Annual Catch Limits

1.2.15.1 Brief Description of the ACL Process

The Council developed a Tiered system of control rules to guide the specification of ACLs and Accountability Measures (AMs) (WPRFMC, 2011). The process starts with the use of the best scientific information available (BSIA) in the form of, but not limited to, stock assessments, published paper, reports, or available data. These information are classified to the different Tiers in the control rule ranging from Tier 1 (most information available typically an assessment) to Tier 5 (catch-only information). The control rules are applied to the BSIA. Tiers 1 to 3 would involve conducting a Risk of Overfishing Analysis (denoted by P*) to quantify the scientific uncertainties around the assessment to specify the Acceptable Biological Catch (ABC). This would lower the ABC from the OFL (MSY-based). A Social, Ecological, Economic, and Management (SEEM) Uncertainty Analysis is performed to quantify the uncertainties from the SEEM factors. The buffer is used to lower the ACL from the ABC. For Tier 4, which is comprised of stocks with MSY estimates but no active fisheries, the control rule is 91% of MSY. For Tier 5 which has catch-only information, the control rule is a third reduction in the median catch depending on the qualitative evaluation on what the stock status is based on expert opinion. ACL specification can choose from a variety of method including the above-mentioned SEEM analysis or a percentage buffer (% reduction from ABC based on expert opinion) or the use of an Annual Catch Target. Specifications are done on an annual basis but the Council normally specifies a multi-year specification.

The Accountability Measure for the coral reef and bottomfish fisheries in Guam is an overage adjustment. The ACL is downward adjusted with the amount of overage from the ACL based on a three-year running average.

1.2.15.2 Current OFL, ABC, ACL, and Recent Catch

The most recent multiyear specification of OFL, ABC, and ACL for the coral reef fishery was completed in the 160th Council meeting on June 25 to 27, 2014. The specification covers fishing year 2015, 2016, 2017, and 2018 for the coral reef MUS complexes. A P* and SEEM analysis was performed for this multiyear specification (NMFS 2015). For the bottomfish, it was a roll over from the previous specification since an assessment update was not available for fishing year 2015. ACLs were not specified by NMFS for the coral reef ecosystem MUS because NMFS has recently acquired new information that require additional environmental analyses to support the Council's ACL recommendations for these management unit species (50 CFR Part 665).

Table 47. Guam ACL table with 2017 catch (lbs.).

Fishery	MUS	OFL	ABC	ACL	Catch
Bottomfish	Bottomfish multi-species complex	71,000	66,000	66,000	22,777
Crustacean	Deepwater shrimp	N.A.F.	48,488	48,488	N.A.F.
	Spiny lobster	4,600	3,300	3,135	277
	Slipper lobster	N.A.F.	20	20	N.D.
	Kona crab	N.A.F.	1,900	1,900	N.A.F.
Precious coral	Black coral	8,250	700	700	N.A.F.
	Precious coral in CNMI expl. area	N.A.F.	2,205	2,205	N.A.F.
Coral Reef	*Selar crumenophthalmus*	N.A.	N.A.	N.A.	16,520
	Acanthuridae-surgeonfish	N.A.	N.A.	N.A.	21,309
	Carangidae-jacks	N.A.	N.A.	N.A.	25,680
	Crustaceans-crabs	N.A.	N.A.	N.A.	820
	Holocentridae-squirrelfish	N.A.	N.A.	N.A.	2,124
	Kyphosidae-rudderfish	N.A.	N.A.	N.A.	1,885
	Labridae-wrasse	N.A.	N.A.	N.A.	2,032
	Lethrinidae-emperors	N.A.	N.A.	N.A.	12,696
	Lutjanidae-snappers	N.A.	N.A.	N.A.	4,601
	Mollusk-turbo snails; octopus; clams	N.A.	N.A.	N.A.	11,215

	Mugilidae-mullets	N.A.	N.A.	N.A.	1,090
	Mullidae-goatfish	N.A.	N.A.	N.A.	14,916
	Scaridae-parrotfish	N.A.	N.A.	N.A.	6,001
	Serranidae-groupers	N.A.	N.A.	N.A.	7,407
	Siganidae-rabbitfish	N.A.	N.A.	N.A.	5,644
	All other CREMUS combined	N.A.	N.A.	N.A.	27,280
	Cheilinus undulatus	N.A.	N.A.	N.A.	74
	Bolbometopon muricatum	N.A.	N.A.	N.A.	0
	Carcharhinidae-reef sharks	N.A.	N.A.	N.A.	897

The catch shown in Table 47 takes the average of the recent three years as recommended by the Council at its 160th meeting to avoid large fluctuations in catch due to data quality and outliers. "N.A.F." indicates no active fisheries as of date. "N.D." indicates no data.

The ACL for jacks was reduced from 29,300 lbs. in 2015 to 21,201 lbs. for 2016 due to the overage in 2015 of 8,099 lbs. because of the spike in catch in 2013 of 59,468 lbs. NMFS applied the reduction to the ACL by the amount of the overage (82 FR 5517 2017-01-18) based on the Council's accountability measure for this data poor stock.

1.2.16 Best Scientific Information Available

1.2.16.1 Bottomfish fishery

1.2.16.1.1 Stock assessment benchmark

The benchmark stock assessment for the Territory Bottomfish Management Unit Species complex was developed and finalized in October 2007 (Moffitt *et al*., 2007). This benchmark utilized a Bayesian statistical framework to estimate parameters of a Schaefer model fit to a time series of annual CPUE statistics. The surplus production model included process error in biomass production dynamics and observation error in the CPUE data. This was an improvement to the previous approach of using index-based proxies for B_{MSY} and F_{MSY}. Best available information for the bottomfish stock assessment is as follows:

Input data: The CPUE and catch data used were from the Guam off-shore creel survey. The catch and CPUE were expanded on an annual level. CPUE was expressed in line-hours. The data was screened for trips that landed more than 50% BMUS species using the handline gear.

Model: state-space model with explicit process and observation error terms (see Meyer and Millar, 1999).

Fishery independent source for biomass: point estimate of MSY from the Our Living Oceans Report (Humphreys and Moffitt, 1999; Moffitt and Humphreys, 2009).

1.2.16.1.2 Stock Assessment Updates

Updates to the 2007 benchmark done in 2012 (Brodziak *et al*., 2012) and 2015 (Yau *et al*., 2015). These included a three-year stock projection table used for selecting the level of risk the fishery will be managed under ACLs. Yau *et al*. (2015) is considered the best scientific information available for the Territory bottomfish MUS complex after undergoing a WPSAR

Tier 3 panel review (Franklin *et al*. 2015). This was the basis for the P* analysis and SEEM analysis that determined the risk levels to specify ABCs and ACLs.

1.2.16.1.3 Other Information Available

Approximately every five years PIFSC administers a socioeconomic survey to small boat fishermen in Guam. This survey consists of about 60 questions regarding a variety of topics, including fishing experiences, market participation, vessels and gear, demographics and household income, and fishermen perspectives. The survey requests participants to identify which MUS they primarily targeted during the previous 12 months, by percentage of trips. Full reports of these surveys can be found at the PIFSC Socioeconomics webpage (Hospital and Beavers, 2011).

1.2.16.2 Coral Reef Fishery

1.2.16.2.1 Stock Assessment Benchmark

No stock assessment has been generated for the coral reef fisheries. The SDCs using index-based proxies were tested for its applicability in the different MUS in the coral reef fisheries (Hawhee, 2007). This analysis was done on a gear level. It paints a dire situation for the shore-based fishery with 43% of the gear/species combination falling below B_{flag} and 33% below MSST with most catch and CPUE trends showing a decline over time. The off-shore fisheries were shown to be less dire with 50% of the gear/species combination falling below B_{flag} and 38% below MSST - but the catch and CPUE trends were increasing over time. The inconsistency in the CPUE and catch trends with the SDC results makes this type of assessment to be unreliable.

The first attempt to use a model-based approach in assessing the coral reef MUS complexes was done in 2014 using a biomass-based population dynamics model (Sabater and Kleiber, 2014). This model was based on the original Martell and Froese (2012) model but was augmented with biomass information to relax the assumption behind carrying capacity. It estimates MSY based on a range of rate of population growth (*r*) and carrying capacity (*k*) values. The best available information for the coral reef stock assessment is as follows:

Input data: The catch data was derived from the inshore and off-shore creel surveys. Commercial receipt book information was also used in combination with the creel data. A downward adjustment was done to address for potential overlap due to double reporting.

Model: Biomass Augmented Catch MSY approach based on the original catch-MSY model (Martell and Froese, 2012; Sabater and Kleiber, 2014).

Fishery independent source for biomass: biomass density from the Rapid Assessment and Monitoring Program of NMFS-CREP was expanded to the hard bottom habitat from 0-30 m (Williams, 2010).

This model had undergone a CIE review in 2014 (Cook, 2014; Haddon, 2014; Jones, 2014). This was the basis for the P* analysis that determined the risk levels to specify ABCs.

1.2.16.2.2 Stock Assessment Updates

No updates available for the coral reef MUS complex. However, NMFS-PIFSC is finalizing a length-based model for estimating sustainable yield levels and various biological reference points (Nadon *et al*., 2015). This can be used on a species level. The Council is also working with a contractor to enhance the BAC-MSY model to incorporate catch, biomass, CPUE, effort, and length-based information in an integrated framework (Martell, 2015).

1.2.16.2.3 Other Information Available

Approximately every five years PIFSC administers a socioeconomic survey to small boat fishermen in Guam. This survey consists of about 60 questions regarding a variety of topics, including fishing experiences, market participation, vessels and gear, demographics and household income, and fishermen perspectives. The survey requests participants to identify which MUS they primarily targeted during the previous 12 months, by percentage of trips. Full reports of these surveys can be found at the PIFSC Socioeconomics webpage (Hospital and Beavers, 2011).

PIFSC and the Council conducted a workshop with various stakeholders in CNMI to identify factors and quantify uncertainties associated with the social, economic, ecological, and management of the coral reef fisheries (Sievanen and McCaskey, 2014). This was the basis for the SEEM analysis that determined the risk levels to specify ACLs.

1.2.17 Harvest Capacity and Extent

The MSA defines the term “optimum,” with respect to the yield from a fishery, 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.
- Is prescribed on the basis of the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor.
- In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such a fishery [50 CFR §600.310(f)(1)(i)].

Optimum yield in the coral reef and bottomfish fisheries is prescribed based on the MSY from the stock assessment and the best available scientific information. In the process of specifying ACLs, social, economic, and ecological factors were considered and the uncertainties around those factors defined the management uncertainty buffer between the ABC and ACL. OY for the bottomfish and coral reef fish MUS complexes is defined to be the level of harvest equal to the ACL consistent with the goals and objectives of the Fishery Ecosystem Plans and used by the Council to manage the stock.

The Council recognizes that MSY and OY are long-term values whereas the ACLs are yearly snapshots based on the level of fishing mortality at F_{MSY}. There are situations when the long-term means around MSY are going to be lower than ACLs especially if the stock is known to be productive or relatively pristine or lightly fished. One can have catch levels and catch rates exceeding that of MSY over short-term enough to lower the biomass to a level around the estimated MSY and still not jeopardize the stock. This situation is true for the territory bottomfish multi-species complex.

The harvest extent, in this case, is defined as the level of catch harvested in a fishing year relative to the ACL or OY. The harvest capacity is the level of catch remaining in the annual catch limit that can potentially be used for TALLF. Table 48 summarizes the harvest extent and harvest capacity information for Guam in 2017.

Table 48. Guam proportion of harvest extent and the harvest capacity.

Fishery	MUS	ACL	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	Bottomfish multi-species complex	66,000	22,777	34.5	65.6
Crustacean	Deepwater shrimp	48,488	N.A.F.	0	100
	Spiny lobster	3,135	277	8.9	91.1
	Slipper lobster	20	0	0	100
	Kona crab	1,900	N.A.F.	0	100
Precious coral	Black coral	700	N.A.F.	0	100
	Precious coral in CNMI expl. area	2,205	N.A.F.	0	100
Coral Reef	*Selar crumenophthalmus*	N.A.	16,520	N.A.	N.A.
	Acanthuridae-surgeonfish	N.A.	21,309	N.A.	N.A.
	Carangidae-jacks	N.A.	25,680	N.A.	N.A.
	Crustaceans-crabs	N.A.	820	N.A.	N.A.
	Holocentridae-squirrelfish	N.A.	2,124	N.A.	N.A.
	Kyphosidae-rudderfish	N.A.	1,885	N.A.	N.A.
	Labridae-wrasse	N.A.	2,032	N.A.	N.A.
	Lethrinidae-emperors	N.A.	12,696	N.A.	N.A.
	Lutjanidae-snappers	N.A.	4,601	N.A.	N.A.
	Mollusk-turbo snails; octopus; clams	N.A.	11,215	N.A.	N.A.
	Mugilidae-mullets	N.A.	1,090	N.A.	N.A.
	Mullidae-goatfish	N.A.	14,916	N.A.	N.A.
	Scaridae-parrotfish	N.A.	6,001	N.A.	N.A.
	Serranidae-groupers	N.A.	7,407	N.A.	N.A.
	Siganidae-rabbitfish	N.A.	5,644	N.A.	N.A.
	All other CREMUS combined	N.A.	27,280	N.A.	N.A.
	Cheilinus undulatus	N.A.	74	N.A.	N.A.
	Bolbometopon muricatum	N.A.	0	N.A.	N.A.
	Carcharhinidae-reef sharks	N.A.	897	N.A.	N.A.

1.2.18 Other Relevant Ocean-Uses and Fishery-Related Information

1.2.18.1 Marine Preserves

Guam has five locally managed Marine Preserves (MPAs): Achang Reef Flat in Merizo, Sasa Bay in Piti, Piti Bombholes in Piti, Tumon Bay in Tumon, and Pati Point in Yigo. A total of 11.8% of Guam's coastline is located within the MPAs.

1.2.18.2 Local Environmental Co-Variates

In early 2010, the U.S. military began exercises in an area south and southeast of Guam designated W-517. W-517 is a special use airspace (SUA) (approximately 14,000 nm^2) that overlays deep open ocean approximately 50 miles south-southwest of Guam. Exercises in W-517 generally involve live fire and/or pyrotechnics When W-517 is in use, a notice to mariners (NTM) is issued, and vessels attempting to use the area are advised to be cautious of objects in the water and other small vessels. This discourages access to virtually all banks south of Guam, including Galvez, Santa Rosa, White Tuna, and other popular fishing areas. From 1982-2015, DAWR surveys recorded more than 2930 trolling and bottom fishing trips to these southern banks, an average of more than 83 trips per year. The number of NTM in 2016 was 64, equaling 123 closure days. There were 109 closure days in 2015, certainly impacted the number of available fishing days south of Guam.

1.2.19 Administrative and Regulatory Actions

This summary describes management actions NMFS has taken for Guam fisheries since the April 2017 Joint FEP Plan Team meeting.

On April 21, 2017, NMFS specified final 2016 annual catch limits (ACLs) for Pacific Island bottomfish, crustacean, precious coral, and coral reef ecosystem fisheries and accountability measures (AMs) to correct or mitigate any overages of catch limits. The final specifications were applicable from January 1, 2016, through December 31, 2016, except for precious coral fisheries, which are applicable from July 1, 2016, through June 30, 2017. Although the 2016 fishing year ended for most stocks, NMFS evaluated 2016 catches against these final ACLs when data became available in mid-2017. The ACLs and AMs support the long-term sustainability of fishery resources of the U.S. Pacific Islands. This rule was effective on May 22, 2017.

On December 11, 2017, NMFS specified final 2017 ACLs for Pacific Island crustacean, precious coral, and territorial bottomfish fisheries, and AMs to correct or mitigate any overages of catch limits. The ACLs and AMs were effective for fishing year 2017. Although the 2017 fishing year had nearly ended for most stocks, NMFS will evaluate 2017 catches against these final ACLs when data become available in mid-2018. The ACLs and AMs support the long-term sustainability of fishery resources of the U.S. Pacific Islands. The final specifications were applicable from January 1, 2017, through December 31, 2017, except for precious coral fisheries, which are applicable from July 1, 2017, through June 30, 2018.

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Oram, R., TuiSamoa, N., Tomanogi, J., Sabater, M., Quach, M., Hamm, D., Graham, C., (in press). American Samoa Boat-Based Creel Survey Documentation. NOAA, National Marine Fishery Service, Pacific Island Fishery Science Center, Administrative Report x-xx-xx.

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2 ECOSYSTEM CONSIDERATIONS

2.1 CORAL REEF ECOSYSTEM PARAMETERS

2.1.1 Regional Reef Fish Biomass

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ✓ American Samoa
- ✓ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ✓ Main Hawaiian Islands
- ✓ Northwest Hawaiian Islands
- ✓ Pacific Remote Island Areas

Spatial Scale:
- ✓ Regional
- ☐ Archipelagic
- ☐ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods are described in detail elsewhere (http://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_15-07.pdf), but in brief involve teams of divers conducting stationary point count cylinder (SPC) surveys within a target domain of <30 meter hard-bottom habitat at each island, stratified by depth zone and, for larger islands, by section of coastline. For consistency among islands, only data from forereef habitats are used. At each SPC, divers record the number, size, and species of all fishes within or passing through paired 15 meter-diameter cylinders over the course of a standard count procedure. Fish sizes and abundance are converted to biomass using standard length-to-weight conversion parameters, taken largely from FishBase (http://www.fishbase.org), and converted to biomass per unit area by dividing by the area sampled per survey. Site-level data were pooled into island-scale values by first calculating mean and variance within strata, and then calculating weighted island-scale mean and variance using the formulas given in Smith *et al*., (2011), with strata weighted by their respective sizes.

<u>Rationale</u>: Reef fish biomass (i.e. the weight of fish per unit area) has been widely used as an indicator of relative ecosystem status, and has repeatedly been shown to be sensitive to changes in fishing pressure, habitat quality, and oceanographic regime.

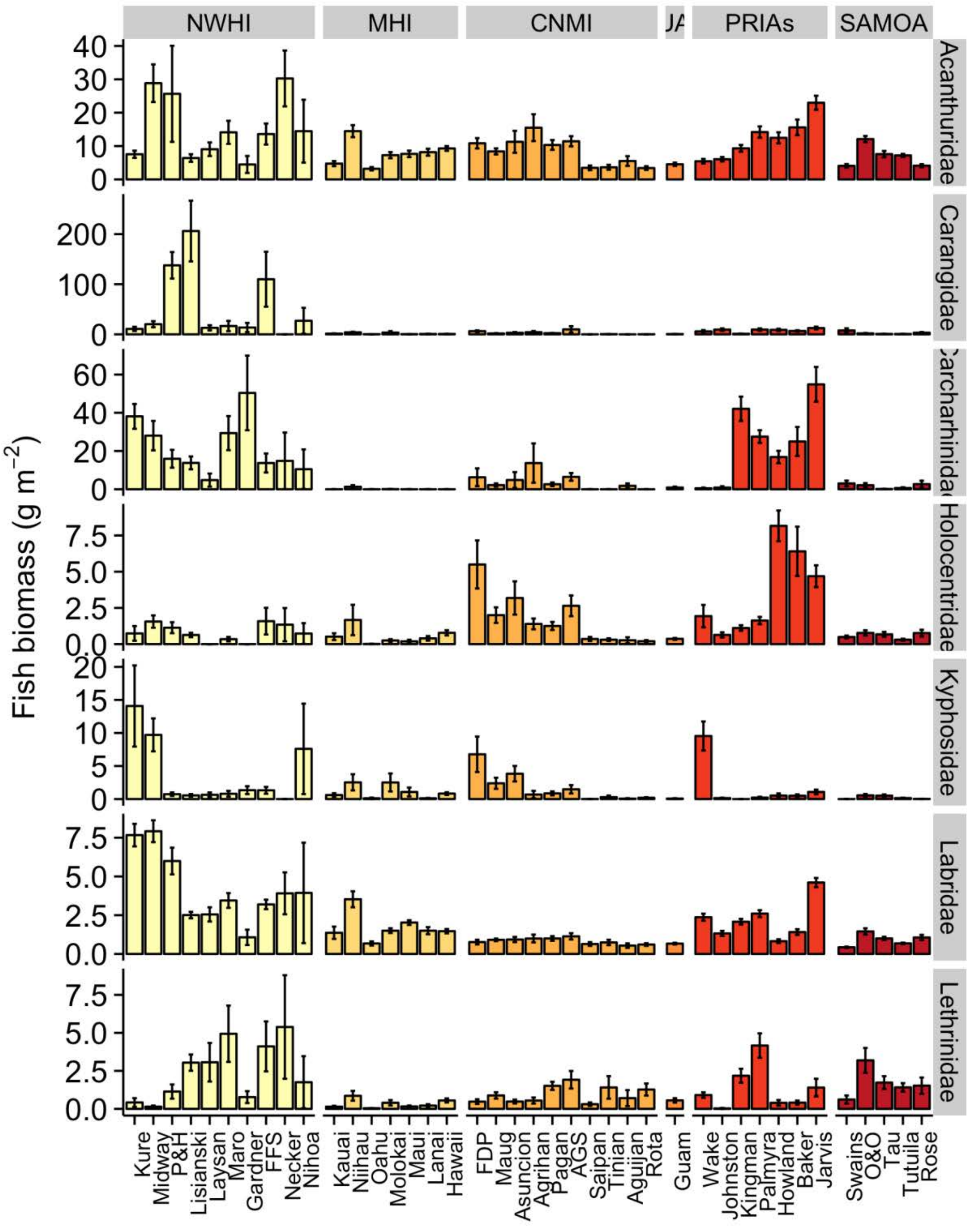
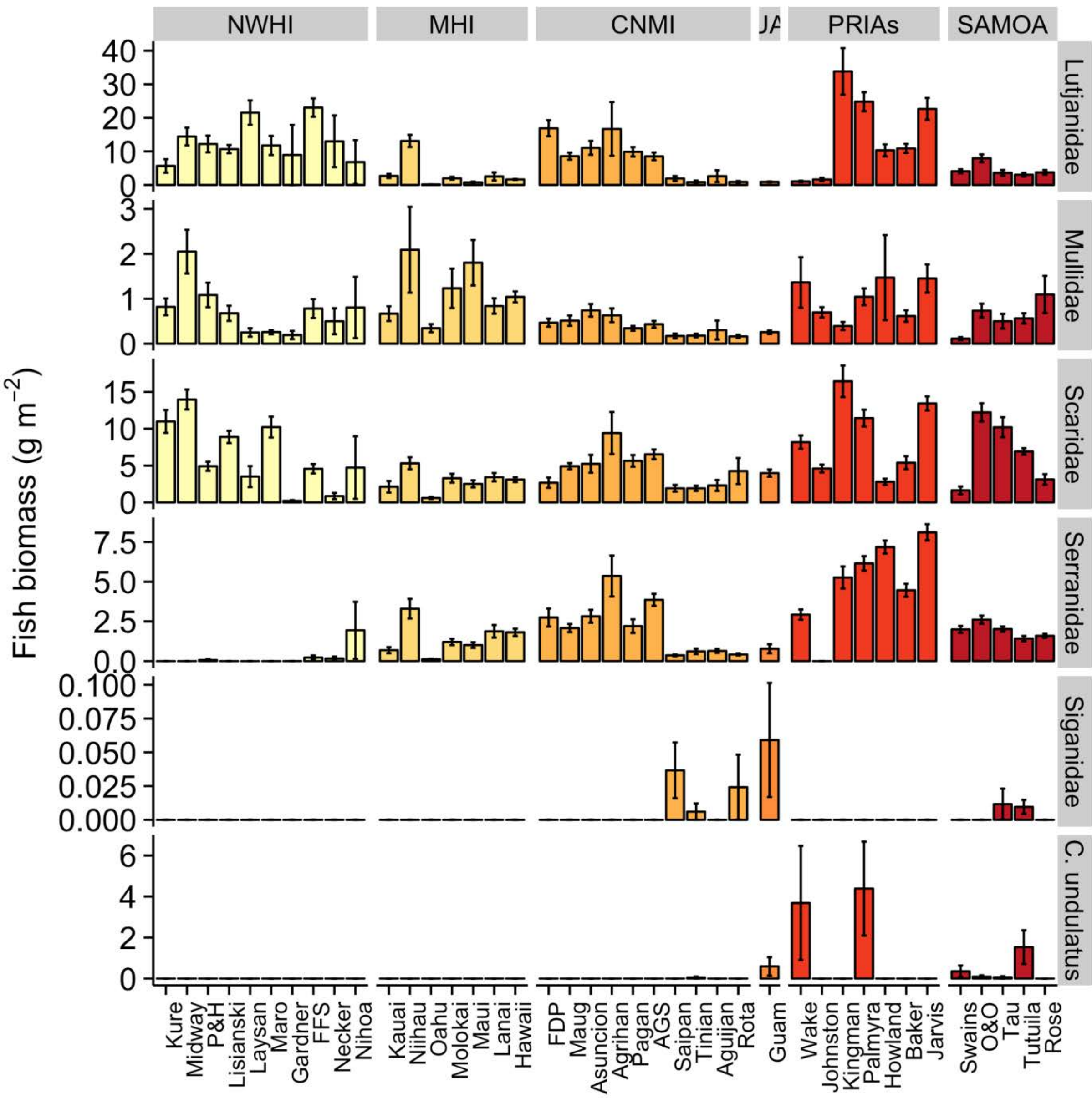


Figure 1. Mean fish biomass (g/m^2 ± standard error) of CREMUS grouped by U.S. Pacific reef area from the years 2009-2015. Islands are ordered within region by latitude. Figure continued on next page.


NWHI
MHI
CNMI
JA
PRIAs
SAMOA
Lutjanidae
Mullidae
Scaridae
Serranidae
Siganidae
C. undulatus
Fish biomass (g m^{-2})
Kure
Midway
P&H
Lisianski
Laysan
Maro
Gardner
FFS
Necker
Nihoa
Kauai
Niihau
Oahu
Molokai
Maui
Lanai
Hawaii
FDP
Maug
Asuncion
Agrihan
Pagan
AGS
Saipan
Tinian
Aguijan
Rota
Guam
Wake
Johnston
Kingman
Palmyra
Howland
Baker
Jarvis
Swains
O&O
Tau
Tutuila
Rose

2.1.2 CNMI Reef Fish Biomass

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ American Samoa
- ☐ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1).

Rationale: Reef fish biomass (i.e. the weight of fish per unit area) has been widely used as an indicator of relative ecosystem status, and has repeatedly been shown to be sensitive to changes in fishing pressure, habitat quality, and oceanographic regime.

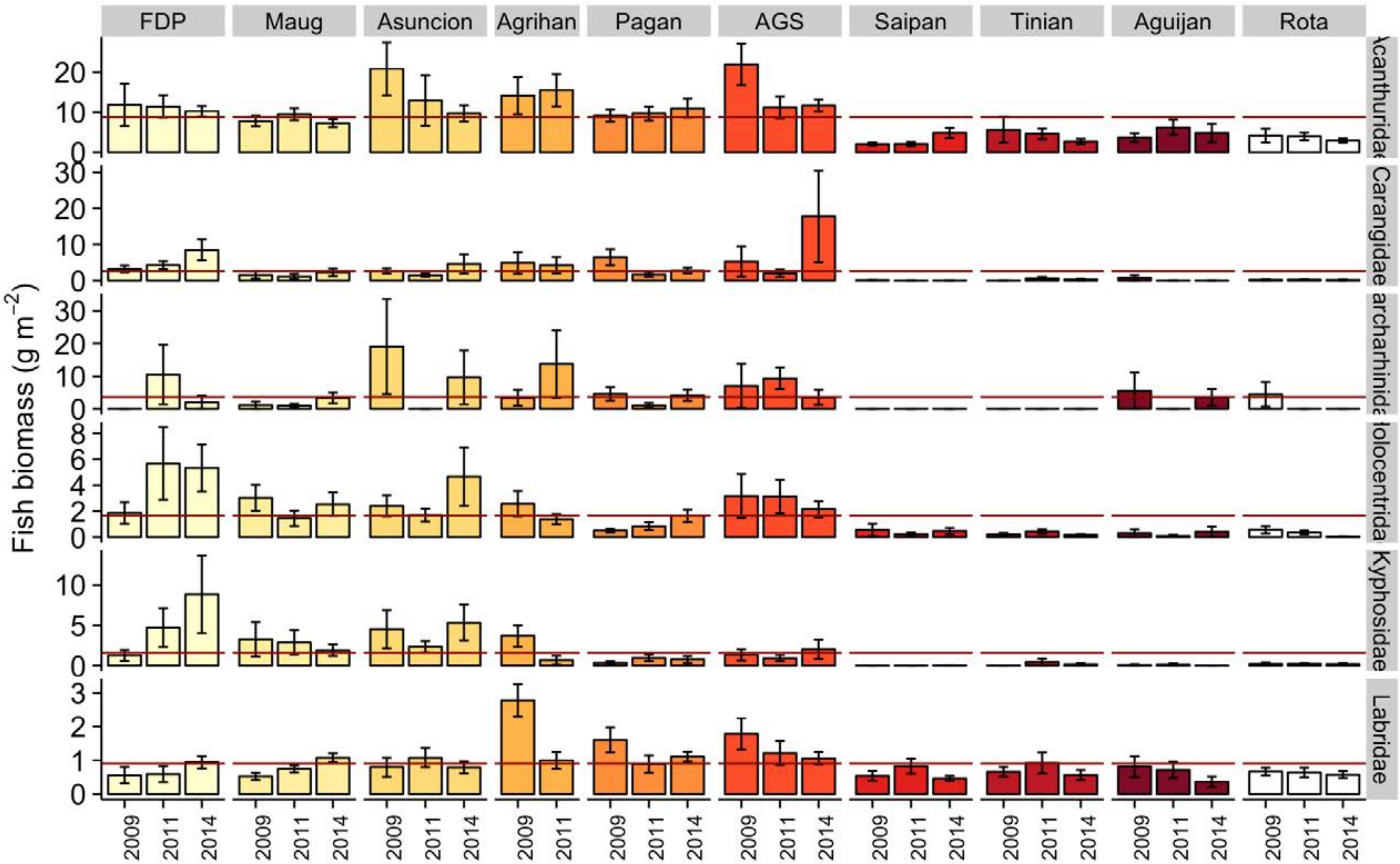
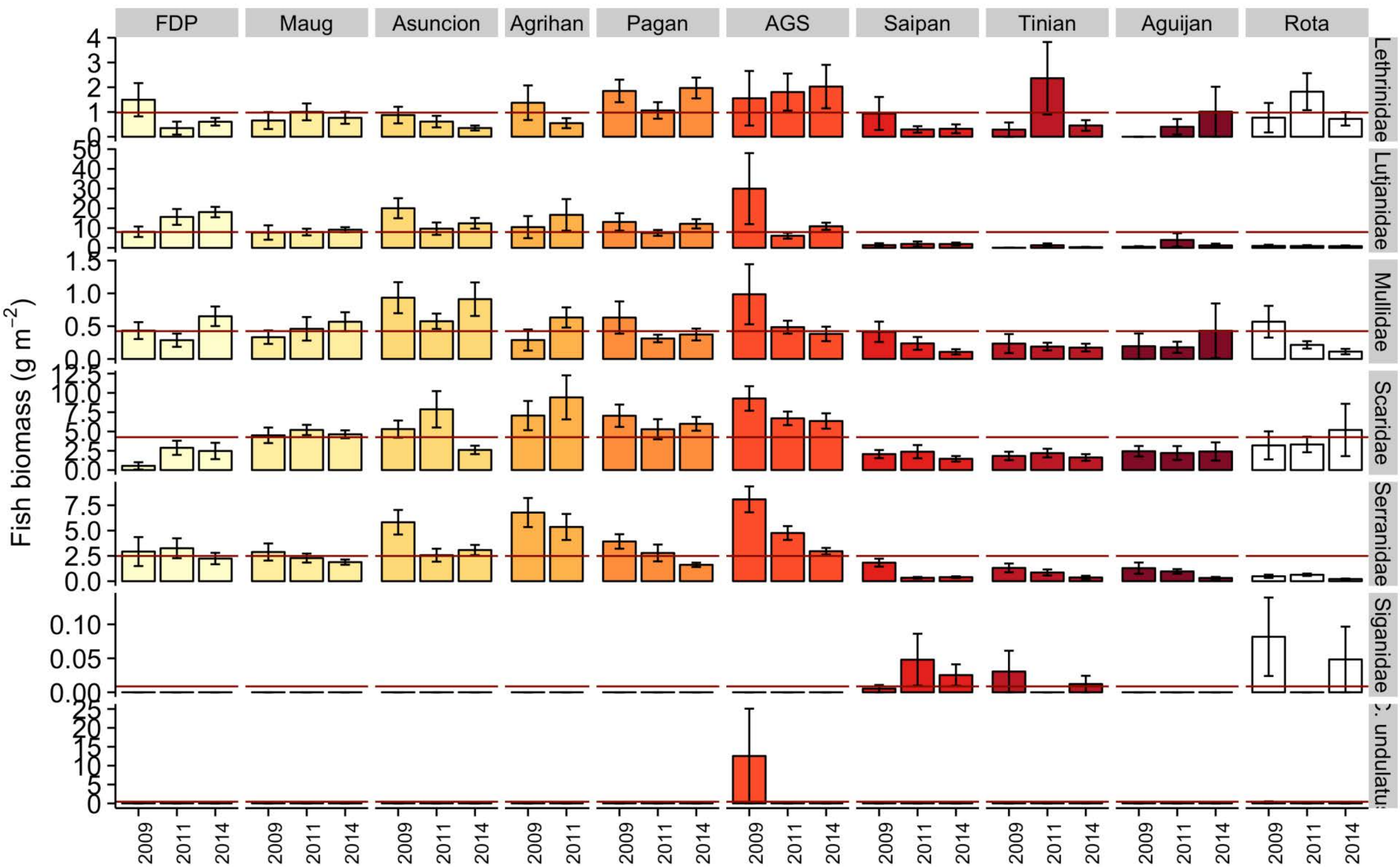


Figure 2. Mean fish biomass (g/m^2 ± standard error) of CNMI CREMUS from the years 2009-2015. The CNMI archipelago mean estimates are represented by the red line. Anatahan, Guguan, and Sarigan have been grouped. Figure continued on next page.


FDP
Maug
Asuncion
Agrihan
Pagan
AGS
Saipan
Tinian
Aguijan
Rota
Lethrinidae
Lutjanidae
Mullidae
Scaridae
Serranidae
Siganidae
Fish biomass (g m−2)
2009
2011
2014

2.1.3 CNMI Archipelagic Mean Fish Size

Description: 'Mean fish size' is mean size of reef fishes > 10 cm TL (i.e. excluding small fishes) derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:

- ☐ Regional
- ☐ American Samoa
- ☐ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:

- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1). Fishes smaller than 10 cm TL are excluded so that the fish assemblage measured more closely reflects fishes that are potentially fished, and so that mean sizes are not overly influenced by variability in space and time of recent recruitment.

Rationale: Mean size is important as it is widely used as an indicator of fishing pressure. A fishery can sometimes preferentially target large individuals, and can also the number of fishes reaching older (and larger) size classes. Large fishes contribute disproportionately to community fecundity and can have important ecological roles; for example, excavating bites by large parrotfishes probably have a longer lasting impact on reef benthos than bites by smaller fishes.

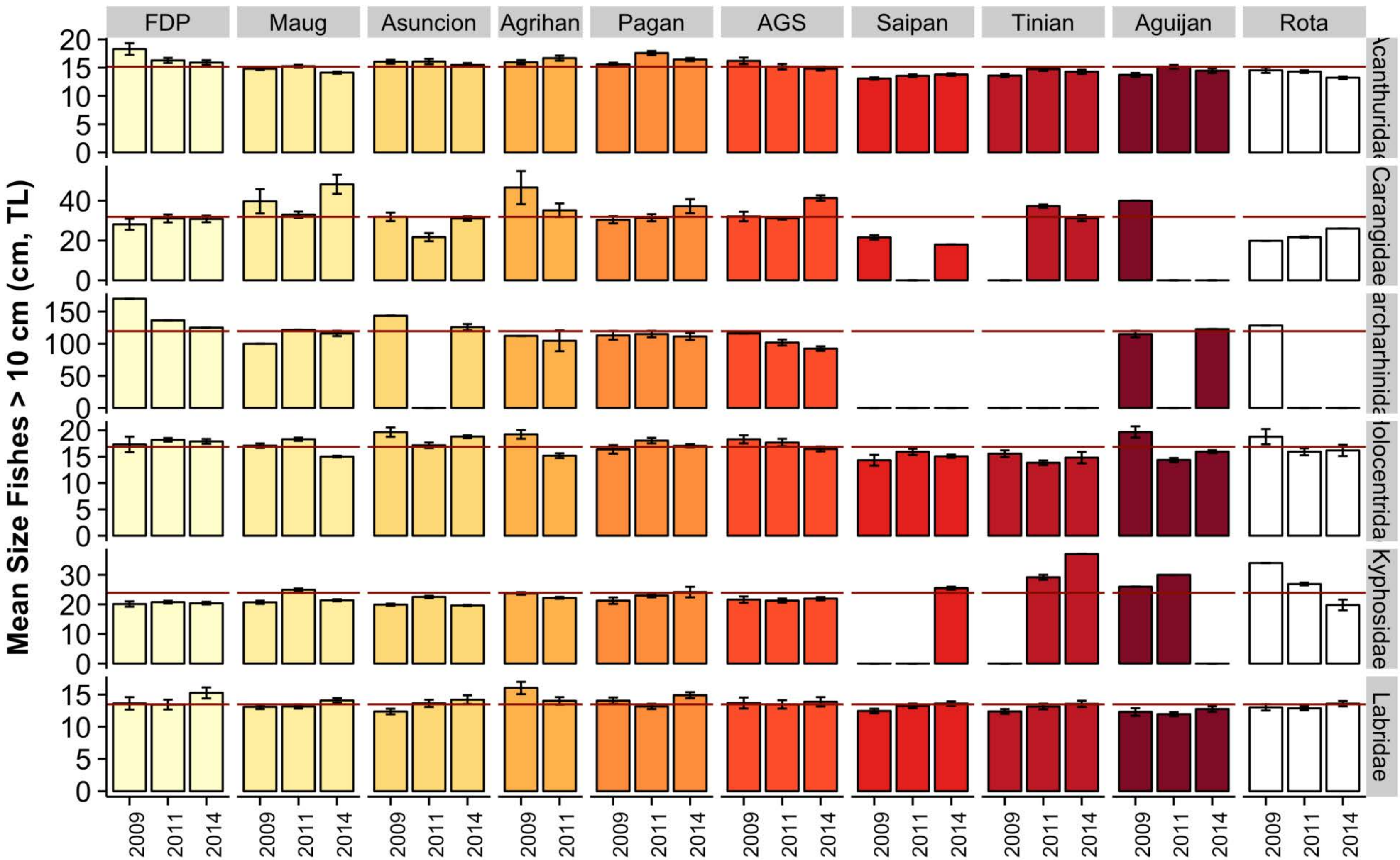
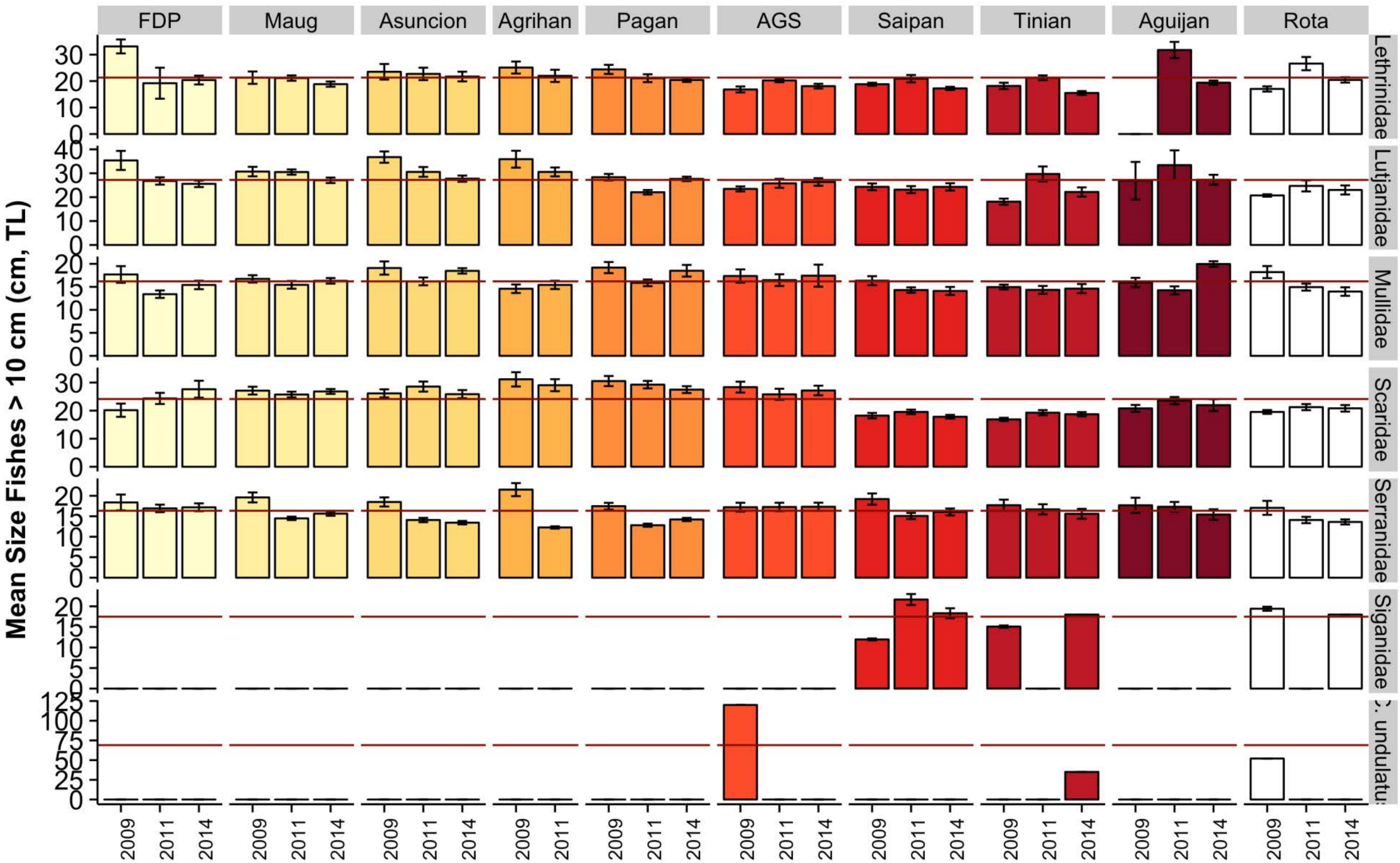


Figure 3. Mean fish size (cm, TL ± standard error) of CNMI CREMUS from the years 2009-2015. The CNMI mean estimates are plotted for reference (red line). Anatahan, Guguan, and Sarigan have been grouped. Figure continued on next page.


FDP
Maug
Asuncion
Agrihan
Pagan
AGS
Saipan
Tinian
Aguijan
Rota
Lethrinidae
Lutjanidae
Mullidae
Scaridae
Serranidae
Siganidae
C. undulatus
Mean Size Fishes > 10 cm (cm, TL)
2009
2011
2014

2.1.4 CNMI Reef Fish Population Estimates

Description: 'Reef fish population estimates' are calculated by multiplying mean biomass per unit area by estimated hardbottom area in a consistent habitat across all islands (specifically, the area of hardbottom forereef habitat in < 30 meters of water).

Category:

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:

- ☐ Regional
- ☐ American Samoa
- ☐ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:

- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate mean size estimates come from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1). Those estimates are converted to population estimates by multiplying biomass (g/m^2) per island by the estimated area of hardbottom habitat <30 meters deep at the island, which is the survey domain for the monitoring program that biomass data comes from. Measures of estimated habitat area per island are derived from GIS bathymetry and NOAA Coral Reef Ecosystems Program habitat maps. Many reef fish taxa are present in other habitats than is surveyed by the program, and some taxa likely have the majority of their populations in deeper water. Additionally, fish counts have the potential to be biased by the nature of fish response to divers. Curious fishes, particularly in locations where divers are not perceived as a threat, will tend to be overestimated by visual survey, while skittish fishes will tend to be undercounted. It is also likely that numbers of jacks and sharks in some locations, such as the NWHI are overestimated by visual survey. Nevertheless, the data shown here are consistently gathered across space and time.

Rationale: These data have utility in understanding the size of populations from which fishery harvests are extracted.

Table 49. Reef fish population estimates for CNMI CREMUS in 0-30 m hardbottom habitat only. *N* is number of sites surveyed per island. 'AGS' is a combined value for Alamagan, Guguan, and Sarigan.

Island	Total area of reef (Ha)	*N*	Estimated population biomass (metric tons) in survey domain of < 30 m hardbottom					
			Acanthuridae	Carangidae	Carcharhinids	Holocentridae	Kyphosidae	Labridae
Farallon de Pajaros	138.5	23	15.0	8.8	8.7	7.6	9.4	1.1
Maug	313.9	70	26.4	5.4	6.8	6.3	7.5	2.9
Asuncion	248.6	41	28.0	7.7	12.0	7.9	9.5	2.3
Agrihan	850.6	20	131.9	36.0	116.4	11.9	5.8	8.5
Pagan	1,512.9	72	156.3	34.2	39.6	19.0	13.0	15.1
AGS	743.9	57	85.0	73.6	48.0	19.7	11.0	8.5
Saipan	4,846.6	78	168.5	0.3	-	17.3	0.7	31.2
Tinian	1,414.2	38	51.4	5.9	-	4.4	4.2	10.5
Aguijan	405.6	23	22.4	-	7.2	1.1	0.3	2.2
Rota	1,331.4	52	45.4	2.1	-	2.7	2.5	8.1
TOTAL	**11,806.1**	**474**	**689.4**	**164.1**	**186.0**	**95.5**	**63.5**	**88.8**

Island	Total Area of reef (Ha)	*N*	Lethrinidae	Lutjanidae	Mullidae	Scaridae	Serranidae	Siganidae
Farallon de Pajaros	138.5	23	0.7	23.4	0.6	3.7	3.8	-
Maug	313.9	70	2.8	27.0	1.6	15.4	6.5	-
Asuncion	248.6	41	1.2	27.5	1.8	13.0	7.0	-
Agrihan	850.6	20	4.7	142.1	5.4	80.1	45.6	-
Pagan	1,512.9	72	22.9	149.6	5.2	85.3	33.3	-
AGS	743.9	57	14.3	63.5	3.2	48.6	28.7	-
Saipan	4,846.6	78	14.9	94.4	8.4	93.1	17.8	1.8
Tinian	1,414.2	38	19.9	11.7	2.6	27.1	8.7	0.1
Aguijan	405.6	23	2.9	10.7	1.2	9.4	2.6	-
Rota	1,331.4	52	16.9	11.9	2.2	56.6	5.6	0.3
TOTAL	**11,806.1**	**474**	**102.1**	**508.8**	**30.5**	**405.3**	**140.4**	**2.3**

Notes: (1) No *Bolbometopon muricatum* were observed during these surveys in CNMI.
(2) *Cheilinus undulatus* were recorded at Tinian (0.7 t).

2.1.5 Guam Reef Fish Biomass

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1).

Rationale: Reef fish biomass (i.e. the weight of fish per unit area) has been widely used as an indicator of relative ecosystem status, and has repeatedly been shown to be sensitive to changes in fishing pressure, habitat quality, and oceanographic regime.

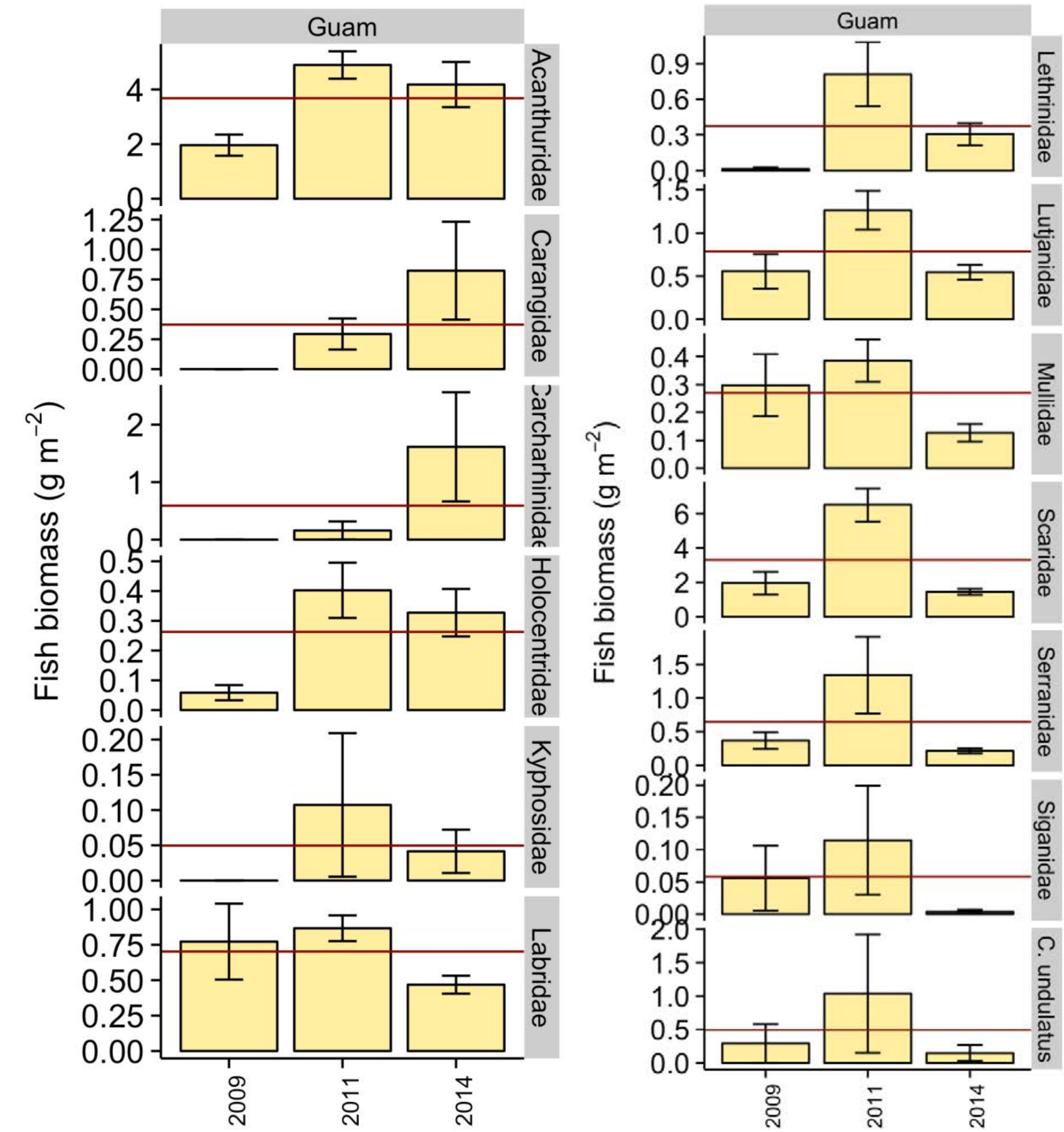


Figure 4. Mean fish biomass (g/m^2 ± standard error) of Guam CREMUS from the years 2009-2015. The Guam archipelago mean estimates are represented by the red line.

2.1.6 Guam Archipelagic Mean Size

Description: 'Mean fish size' is mean size of reef fishes > 10 cm TL (i.e. excluding small fishes) derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ Regional
- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1). Fishes smaller than 10 cm TL are excluded so that the fish assemblage measured more closely reflects fishes that are potentially fished, and so that mean sizes are not overly influenced by variability in space and time of recent recruitment.

Rationale: Mean size is important as it is widely used as an indicator of fishing pressure. A fishery can sometimes preferentially target large individuals, and can also the number of fishes reaching older (and larger) size classes. Large fishes contribute disproportionately to community fecundity and can have important ecological roles; for example, excavating bites by large parrotfishes probably have a longer lasting impact on reef benthos than bites by smaller fishes.

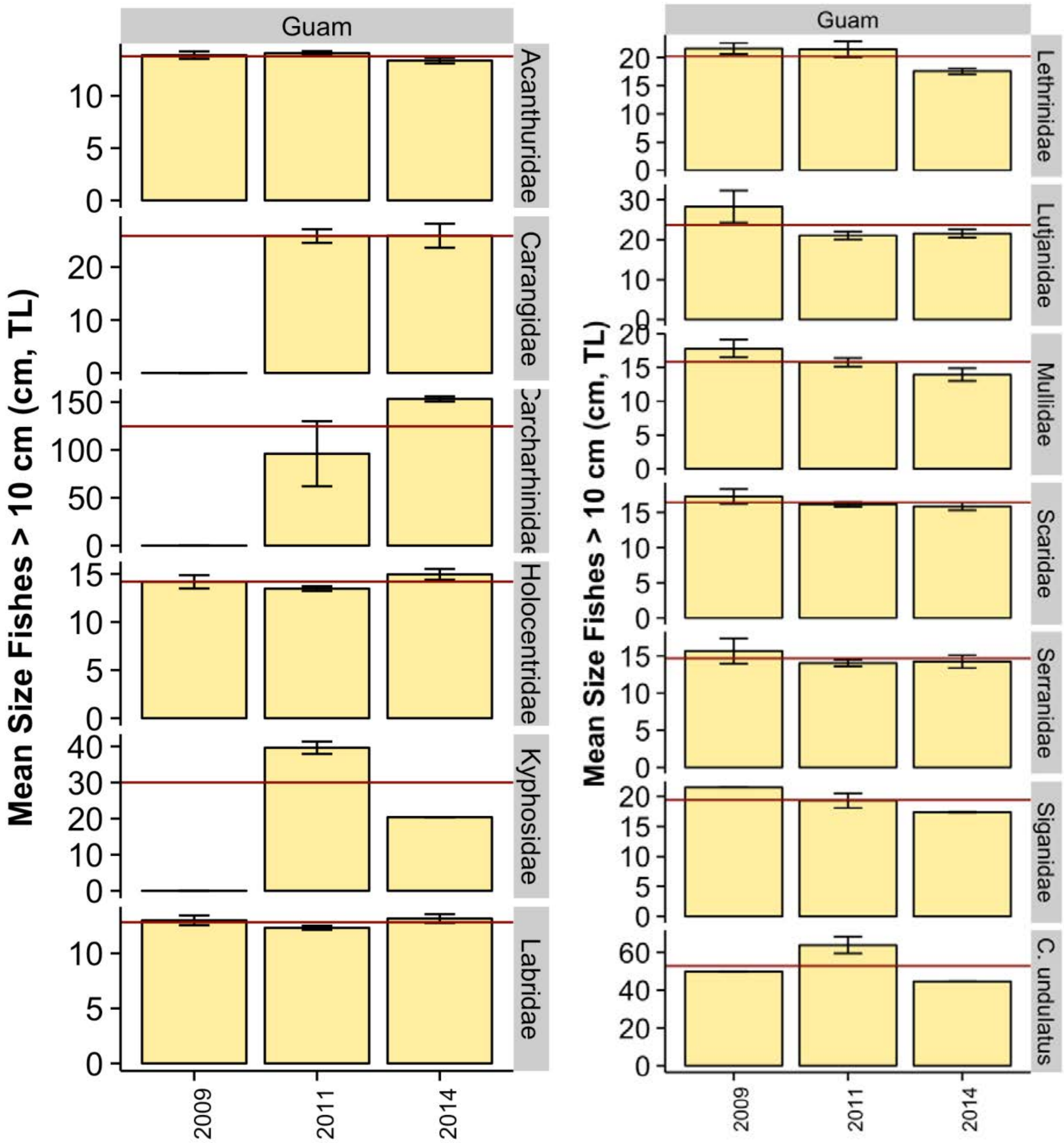


Figure 5. Mean fish size (cm, TL ± standard error) of Guam CREMUS from the years 2009-2015. The Guam mean estimates are plotted for reference (red line).

2.1.7 Guam Reef Fish Population Estimates

Description: 'Reef fish population estimates' are calculated by multiplying mean biomass per unit area by estimated hardbottom area in a consistent habitat across all islands (specifically, the area of hardbottom forereef habitat in < 30 meters of water).

Category:

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:

- ☐ Regional
- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:

- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate mean size estimates come from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1). Those estimates are converted to population estimates by multiplying biomass (g/m^2) per island by the estimated area of hardbottom habitat <30 meters deep at the island, which is the survey domain for the monitoring program that biomass data comes from. Measures of estimated habitat area per island are derived from GIS bathymetry and NOAA Coral Reef Ecosystems Program habitat maps. Many reef fish taxa are present in other habitats than is surveyed by the program, and some taxa likely have the majority of their populations in deeper water. Additionally, fish counts have the potential to be biased by the nature of fish response to divers. Curious fishes, particularly in locations where divers are not perceived as a threat, will tend to be overestimated by visual survey, while skittish fishes will tend to be undercounted. It is also likely that numbers of jacks and sharks in some locations, such as the NWHI are overestimated by visual survey. Nevertheless, the data shown here are consistently gathered across space and time. Nevertheless, in spite of these issues, the data shown here are consistently gathered across space and time.

Rationale: These data have utility in understanding the size of populations from which fishery harvests are extracted.

Table 50. Reef fish population estimates for Guam CREMUS in 0-30 meters depth of hardbottom habitat only. *N* is number of sites surveyed per island.

Island	Total area of reef (Ha)	*N*	Estimated population biomass (metric tons) in survey domain of < 30 m hardbottom					
			Acanthuridae	**Carangidae**	**Carcharhinids**	**Holocentridae**	**Kyphosidae**	**Labridae**
Guam	7,295.7	238	331.1	40.7	64.6	26.6	5.4	48.7
			Lethrinidae	**Lutjanidae**	**Mullidae**	**Scaridae**	**Serranidae**	**Siganidae**
Guam			40.8	66.0	18.7	290.6	56.7	4.3

Notes:
(1) No *Bolbometopon muricatum* were observed during these surveys in Guam.
(2) *Cheilinus undulatus* were recorded in Guam (43.2 t).

2.2 LIFE HISTORY AND LENGTH-DERIVED PARAMETERS

The SAFE Report will serve as the repository of available life history information for the Western Pacific region. Life history data, particularly age and growth data, inform stock assessments on fish productivity and population dynamics. Some assessments, such as those for data-poor stocks like coral reefs, utilize information from other areas that introduce errors and uncertainties in the population estimates. An archipelago-specific life history parameter ensures accuracy in the input parameters used in the assessment. The NMFS BioSampling Program allows for significant collection of life history samples like otoliths and gonads from priority species in the bottomfish and coral reef fisheries. These life history samples, once processed and data extracted, will contribute to the body of scientific information for the two data-poor fisheries in the region. The life history information available from the region will be monitored by the Fishery Ecosystem Plan Team and will be tracked through this section of the report.

This section will be divided into two fisheries: 1) coral reef; and 2) bottomfish. Within each fishery, the available life history information will be described under the age, growth, and reproductive maturity section. The section labelled fish length-derived parameters summarizes available information derived from sampling the fish catch or the market. Monitoring length information provides insight on the state of the fish stock where the change in length can be used as an indicator of population level mortality. Length-weight conversion coefficients provide area-specific values to convert length from fishery dependent and fishery independent data collection to weight or biomass.

2.2.1 CNMI Coral Reef Ecosystem – Reef Fish Life History

2.2.1.1 Age & Growth and Reproductive Maturity

Description: Age determination is based on counts of yearly growth marks (annuli) and/or daily growth increments (DGIs) internally visible within transversely-cut, thin sections of sagittal otoliths. Validated age determination, particularly for long-lived (≥30 years) fish, is based on an environmental signal (bomb radiocarbon ^{14}C) produced during previous atmospheric thermonuclear testing in the Pacific and incorporated into the core regions of sagittal otolith and other aragonite-based calcified structures such as hermatypic corals. This technique relies on developing a regionally-based aged coral core reference series for which the rise, peak, and decline of ^{14}C values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the ^{14}C otolith core values back in time from its capture date to where it intersects with the known age ^{14}C coral reference series. The relation between age and fish length is evaluated by fitting this data to a von Bertalanffy growth function based on statistical analyses. The resulting von Bertalanffy growth function predicts the pattern of growth over time for that particular species. This function typically uses three coefficients (L_∞, k, and t_0) which together characterize the shape of the length-at-age growth relationship.

Length at reproductive maturity is based on the histological analyses of small tissue samples of gonad material that are typically collected along with otoliths when a fish is processed for life history studies. The gonad tissue sample is preserved then subsequently cut into five micron sections, stained, and sealed onto a glass slide for subsequent examination. Based on standard cell structure features and developmental stages within ovaries and testes, the gender, developmental stage, and maturity status (immature or mature) is determined via microscopic evaluation. The percent of mature samples for a given length interval are assembled for each sex and these data are fitted to a three- or four-parameter logistic function to determine the best fit of these data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish have achieved reproductive maturity (L_{50}). For species that undergo sex reversal (primarily female to male in the tropical Pacific region) - such as groupers and deeper-water emperors among the bottomfishes, and for parrotfish, shallow-water emperors, and wrasses among the coral reef fishes - standard histological criteria are used to determine gender and reproductive developmental stages that indicate the transitioning or completed transition from one sex to another. These data are similarly analyzed using a three or four-parameter logistic function to determine the best fit of the data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish of a particular species have or are undergoing sex reversal ($L\Delta_{50}$).

Age at 50% maturity (A_{50}) and 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the von Bertalanffy growth function for that species and using the corresponding L_{50} and $L\Delta_{50}$ values to obtain the corresponding age value from this growth function. In studies where both age & growth and reproductive maturity are concurrently determined, estimates of A_{50} and $A\Delta_{50}$ are derived directly by fitting the percent of mature samples for each age (one-year) interval to a three- or four-parameter logistic function using statistical analyses. The mid-point of this fitted logistic function provides a direct estimate of the age at which 50% of fish of a particular species have achieved reproductive maturity (A_{50}) and sex reversal ($A\Delta_{50}$).

Category:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:

- ☐ American Samoa
- ☐ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:

- ☐ Regional
- ✓ Archipelagic
- ☐ Island
- ☐ Site

Data Source: Sources of data are directly derived from research cruises sampling and market samples collected by the CNMI contracted bio-sampling team which samples the catch of fishermen and local fish vendors. Laboratory analyses and data generated from these analyses reside with the PIFSC Life History Program. Refer to the "Reference" column in Table 49 for specific details on data sources by species.

<u>Parameter definitions</u>:

***T_{max}* (maximum age)** – The maximum observed age revealed from an otolith-based age determination study. T_{max} values can be derived from ages determined by annuli counts of sagittal otolith sections and/or bomb radiocarbon (^{14}C) analysis of otolith core material.

***L_∞* (asymptotic length)** – One of three coefficients of the von Bertalanffy growth function (VBGF) that measures the mean maximum length at which the growth curve plateaus and no longer increases in length with increasing age. This coefficient reflects the mean maximum length and not the observed maximum length.

***k* (growth coefficient)** – One of three coefficients of the VBGF that measures the shape and steepness by which the initial portion of the growth function approaches its mean maximum length (L_∞).

***t_0* (hypothetical age at length zero)** – One of three coefficients of the VBGF whose measure is highly influenced by the other two VBGF coefficients (k and L_∞) and typically assumes a negative value when specimens representing early growth phases (0+ to 1+ ages) are not available for age determination.

***M* (natural mortality)** – This is a measure of mortality rate for a fish stock not under the influence of fishing pressure and is considered to be directly related to stock productivity (i.e., high M indicates high productivity and low M indicates low stock productivity). M can be derived through use of various equations that link M to T_{max} and two VBGF coefficients (k and L_∞) or by calculating the value of the slope from a regression fit to a declining catch curve (regression of the natural logarithm of abundance versus age class) derived from fishing an unfished or lightly fished population.

***A_{50}* (age at 50% maturity)** – Age at which 50% of the sampled stock under study has attained reproductive maturity. This parameter is best determined based on studies that concurrently determine both age (otolith-based age data) and reproductive maturity status (logistic function fitted to percent mature by age class with maturity determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating A_{50} is to use an existing L_{50} estimate to find the corresponding age (A_{50}) from an existing VBGF curve.

***$A\Delta_{50}$* (age of sex switching)** – Age at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal. This parameter is best determined based on studies that concurrently determines both age (otolith-based age data) and reproductive sex reversal status (logistic function fitted to percent sex reversal by age class with sex reversal determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating $A\Delta_{50}$ is to use an existing $L\Delta_{50}$ estimate to find the corresponding age ($A\Delta_{50}$) from the VBGF curve.

***L_{50}* (length at which 50% of a fish species are capable of spawning)** – Length (usually in terms of fork length) at which 50% of the females of a sampled stock under study has attained reproductive maturity; this is the length associated with A_{50} estimates. This parameter is derived using a logistic function to fit the percent mature data by length class with maturity status best determined via microscopic analyses of gonad histology preparations). L_{50} information is typically more available than A_{50} since L_{50} estimates do not require knowledge of age & growth.

$L\Delta_{50}$ (length of sex switching) – Length (usually in terms of fork length) at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal; this is the length associated with $A\Delta_{50}$ estimates. This parameter is derived using a logistic function to fit the percent sex reversal data by length class with sex reversal status best determined via microscopic analyses of gonad histology preparations). $L\Delta_{50}$ information is typically more available than $A\Delta_{50}$ since $L\Delta_{50}$ estimates do not require knowledge of age & growth.

Rationale: These nine life-history parameters provide basic biological information at the species level to evaluate the productivity of a stock - an indication of the capacity of a stock to recover once it has been depleted. Currently, the assessment of coral reef fish resources in the CNMI is data-limited. Knowledge of these life-history parameters support current efforts to characterize the resilience of these resources, provide important biological inputs for future stock assessment efforts, and enhance our understanding of the species' likely role and status as a component of the overall ecosystem. Furthermore, knowledge of life histories across species at the taxonomic level of families or among different species that are ecologically or functionally similar can provide important information on the diversity of life histories and the extent to which species can be grouped (based on similar life histories) for future multi-species assessments.

Table 51. Available age, growth, and reproductive maturity information for coral reef species targeted for life history sampling (otoliths and gonads) in CNMI.

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Calotomus carolinus										
Chlorurus spilurus										
Lethrinus atkinsoni								213[b]	X[a]	
Lethrinus obsoletus	13[d]	25.1[d]	0.6[d]	3.0 (L_0)[d]	0.3 2[d]	3.8 (f), 2.8 (m)[d]	X[a]	22.9 (f), 19.9 (m)[d]	X[a]	[d]Taylor et. al. (2016)
Mulloidichthys flavolineatus	X[a]	X[a]	X[a]	X[a]	X[a]	X[a]		X[a]		Reed *et al.*, in prep.
Naso unicornis							NA	238[b]	NA	

Parupeneus barberinus	X[a]	X[a]	X[a]	X[a]	X[a]	X[a]	NA	X[a]		Reed *et al.*, in prep.
Sargocentron tiere							NA		NA	
Siganus argenteus	7[d]	274[d]	0.9[d]	-0.3[d]	0.56[d]	1.3[d]	NA	218[d]	NA	[d]Taylor et. al. (2016)

[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (including in press).

Parameter estimates are for females unless otherwise noted (F=females, M=males). Parameters T_{max}, t_0, A_{50}, and $A\Delta_{50}$ are in units of years; L_∞, L_{50}, and $L\Delta_{50}$ are in units of mm fork length (FL); k in units of year^{-1}; X=parameter estimate too preliminary or Y=published age and growth parameter estimates based on DGI numerical integration technique and likely to be inaccurate; NA=not applicable. Superscript letters indicate status of parameter estimate (see footnotes below table). Published or in press publications ([d]) are denoted in "Reference" column.

2.2.1.2 Fish Length Derived Parameters

Description: The NMFS Commercial Fishery BioSampling Program started in 2009. This program has two components: first is the Field/Market Sampling Program, and the second is the Life History Program, details of which are described in a separate section of this report. The goals of the Field/Market Sampling Program are:

- Broad scale look at commercial landings (by fisher/trip, gear & area fished)
- Length and weight frequencies of whole commercial landings per fisher-trip (with an effort to also sample landings not sold commercially)
- Accurate species identification
- Develop accurate local length-weight curves

In CNMI, the BioSampling is focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the northern islands. Sampling is conducted in partnership with the fish vendors. The Market Sampling information includes (but not limited to): 1) fish length; 2) fish weight; 3) species identification; and 4) basic effort information. Specific for CNMI, the program collects Daily Vendor Logs for reef fish that includes basic catch and effort information.

Category:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:
- ☐ American Samoa
- ☐ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: NMFS BioSampling Program

Parameter definitions:
***L_{max}* – maximum fish length** is the longest fish per species recorded in the BioSampling Program from the commercial spear fishery. This value is derived from measuring the fork length of individual samples for species occurring in the spear fishery.

***L_{bar}* – mean length** is the average value of all lengths recorded from the commercial spear fishery. This can be influenced by gear selectivity since the commercial spear fishery has a typical size target based on customer demand. This can also be influenced by size regulations.

***n* – sample size** is the total number of samples accumulated for each species recorded in the commercial spear fishery.

***$N_{L\text{-}W}$* – sample size for L-W regression** is the number of samples used to generate the *a* & *b* coefficients.

***a* & *b* – length-weight coefficients** are the coefficients derived from the regression line fitted to all length- and weight-measured per species in the commercial spear fishery. These values are used to convert length information to weight. Values are influenced by the life history characteristics of the species, geographic location, population status, and nature of the fisheries from which the species are harvested.

Rationale: Length-derived information is being used as an indicator of population status particularly for data poor stocks like coral reef fish. Average length (L_{bar}) was used as a principal stock assessment indicator variable for exploited reef fish population (Nadon *et al*., 2015). Average length was also shown to be correlated with population size (Kerr and Dickle, 2001). Maximum length (L_{max}), typically coupled with maximum age, is typically used as a proxy for fish longevity which has implications on the productivity and susceptibility of a species to fishing pressure. The length-weight coefficients (*a* & *b* values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length are typically recorded but weight is the factor being used for management. This section of the report presents the best available information for the length-derived variables for the CNMI coral reef and bottomfish fisheries.

Table 52. Available length-derived information for various coral reef species in CNMI.

Species	Length-derived parameters						Reference
	L_{max}	L_{bar}	*N*	*L-W*	*a*	*b*	
Naso lituratus	30.1	20.26	17,478	3,813	0.0167	3.1022	
Acanthurus lineatus	23.5	18.33	15,772	4,901	0.0383	2.8718	
Siganus argenteus	34.1	20.82	11,867	3,662	0.0133	3.1007	
Mulloidichthys flavolineatus	31.4	18.08	9,596	2,357	0.0137	3.0547	
Naso unicornis	53.6	29.62	8,323	4,349	0.0266	2.9115	
Siganus spinus	25.6	16.64	7,685	1,078	0.0118	3.1459	
Parupeneus barberinus	37.3	21.73	7,597	2,706	0.0175	3.0119	
Selar crumenophthalmus	26.5	19.08	4922	2654	0.0051	3.3958	
Scarus ghobban	38.1	24.07	4,964	1,502	0.0124	3.1271	
Lethrinus atkinsoni	35.1	21.06	4,306	2,095	0.0163	3.0971	
Lethrinus obsoletus	29.0	21.10	3,673	1,472	0.0171	3.0313	
Mulloidichthys vanicolensis	28.0	18.94	3233	701	0.0103	3.1948	
Scarus rubroviolaceus	52.6	34.49	3141	1,791	0.0087	3.2447	
Chlorurus sordidus	30.8	22.33	3346	956	0.0173	3.0795	
Siganus punctatus	34.8	20.82	2798	833	0.0129	3.1911	
Sargocentron spiniferum	34.6	20.31	2589	684	0.0245	2.9780	
Myripristis murdjan	22.3	16.84	2488	823	0.1699	2.3426	
Scarus psittacus	28.9	21.24	2466	771	0.0212	2.9928	
Acanthurus nigricauda	26.3	20.07	2354	799	0.0217	3.0583	
Cheilinus trilobatus	35.2	24.06	2223	1,196	0.0470	2.7156	
Hipposcarus longiceps	52.0	29.10	2194	615	0.0149	3.0624	
Panulirus penicillatus	17.0	9.05	2043	1,119	1.4849	2.6925	
Leptoscarus vaigiensis	35.2	26.31	1982	807	0.0234	2.8648	
Calotomus carolinus	31.0	24.21	1734	662	0.0156	3.1012	
Myripristis violacea	20.6	15.54	1796	514	0.1361	2.4356	

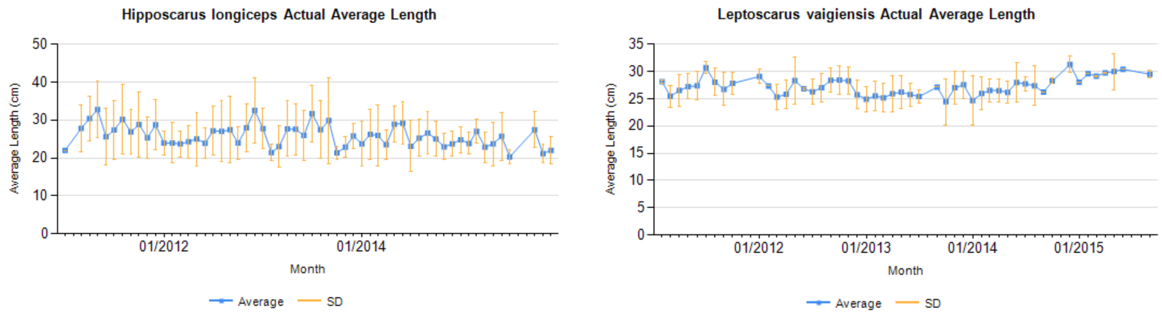
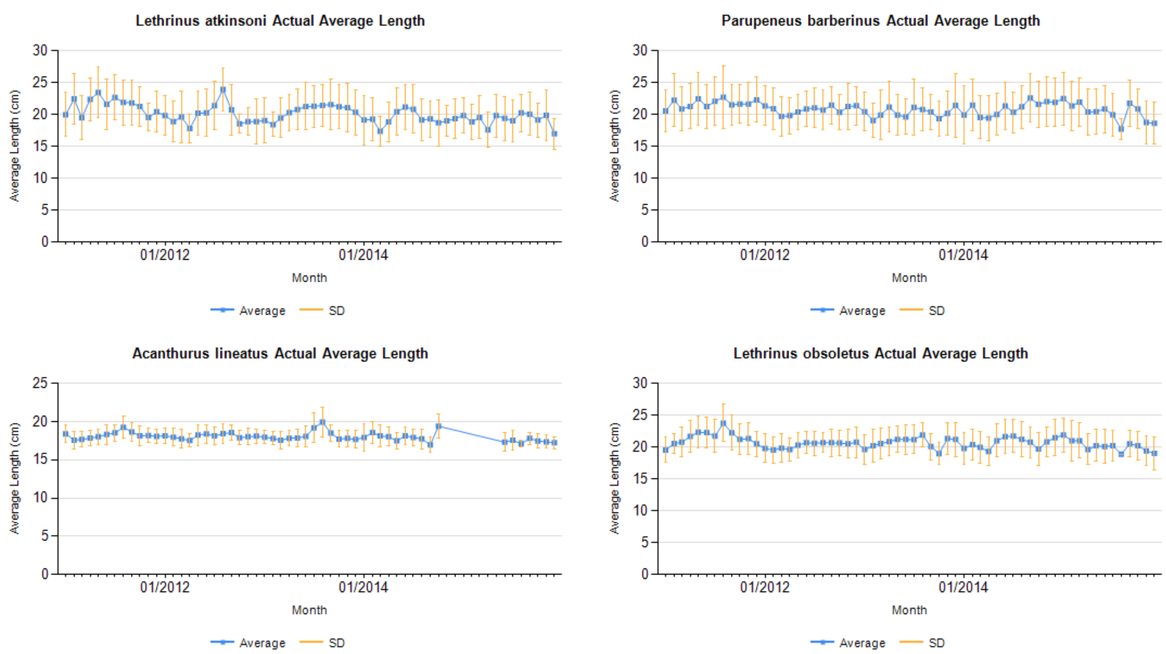
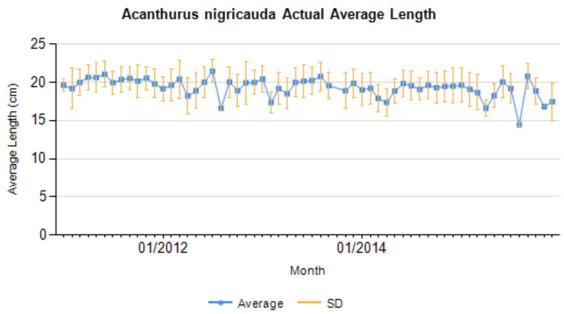
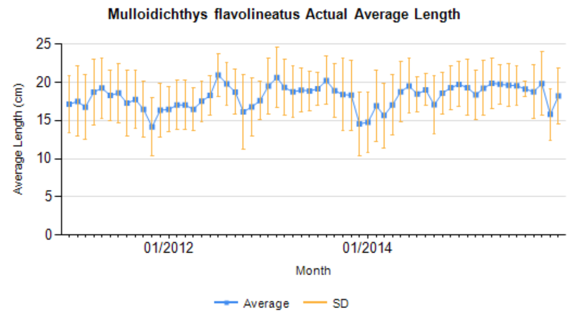
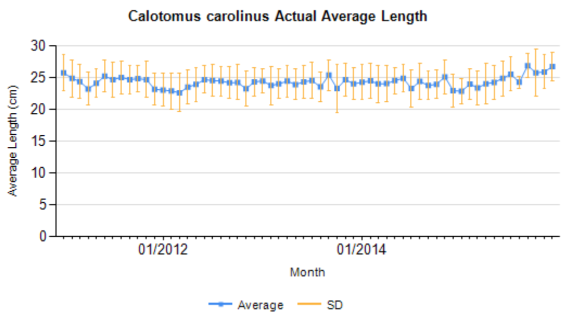


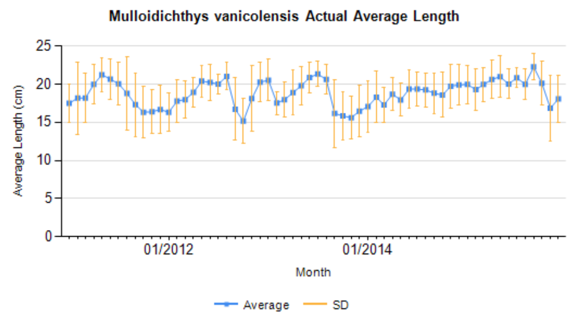
Figure 6. Average length over time of representative CNMI coral reef fish management unit species derived from the BioSampling Program. Figure continues for various species onto the next two pages.

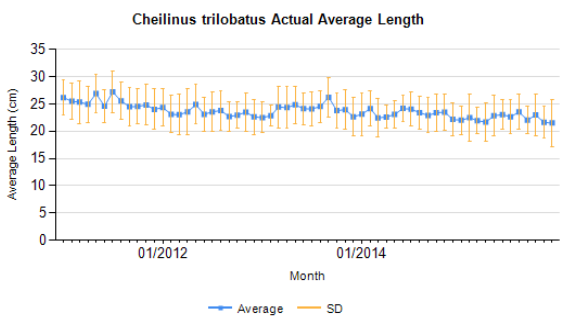


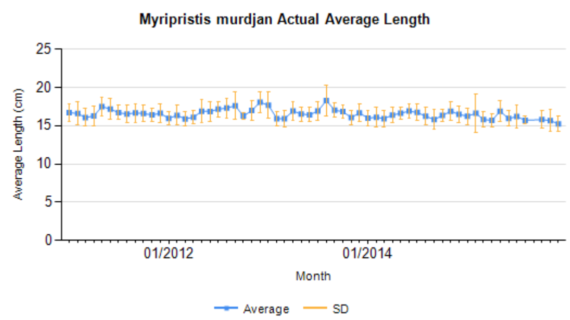

Acanthurus nigricauda Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

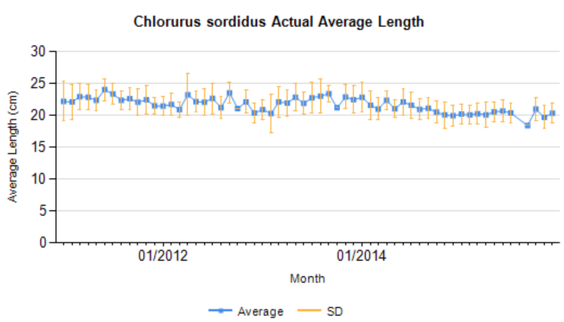

Mulloidichthys flavolineatus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

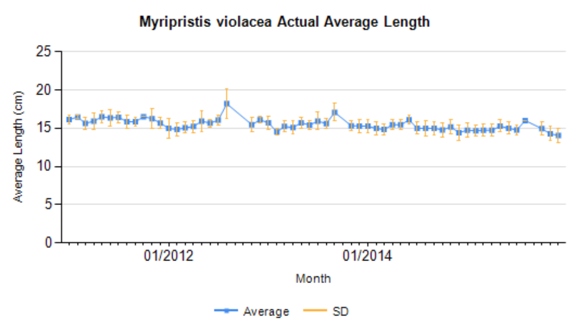

Calotomus carolinus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

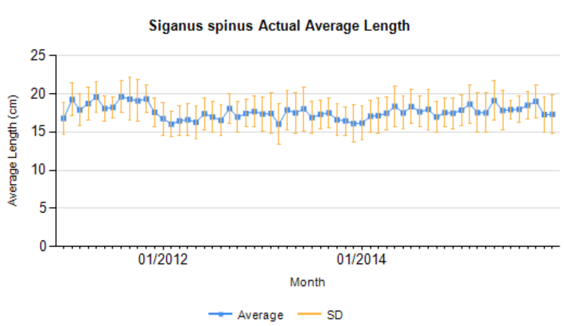

Mulloidichthys vanicolensis Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

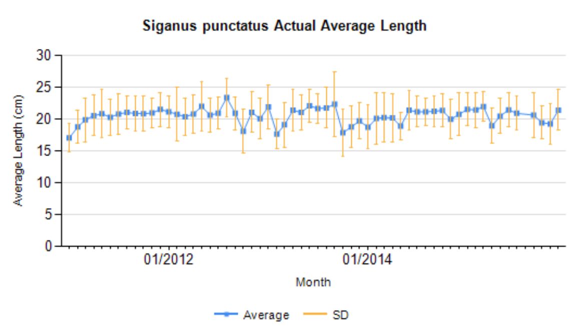

Cheilinus trilobatus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

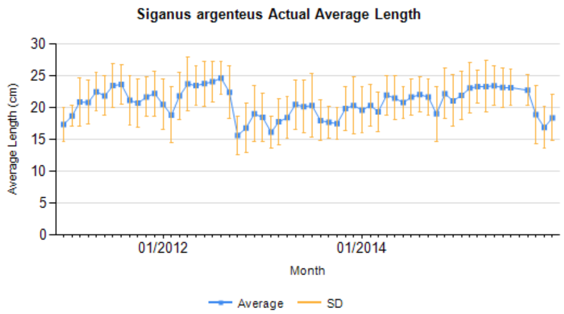

Myripristis murdjan Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

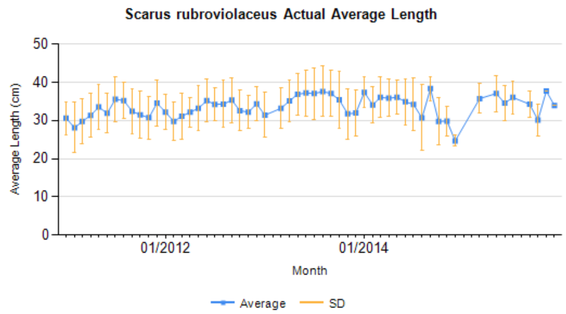

Chlorurus sordidus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

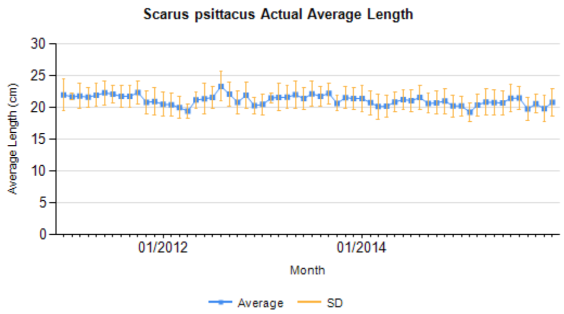

Myripristis violacea Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

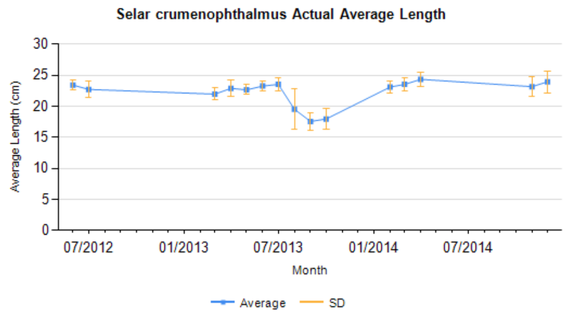

Siganus spinus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

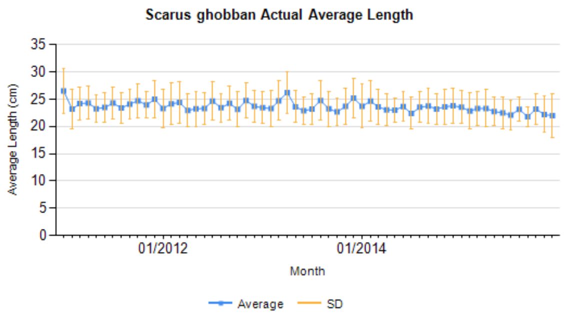

Siganus punctatus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

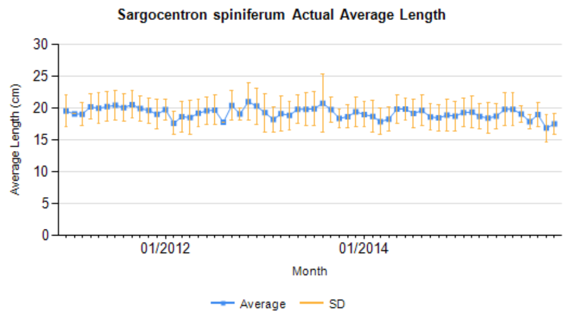

Siganus argenteus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD


Scarus rubroviolaceus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD


Scarus psittacus Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD


Selar crumenophthalmus Actual Average Length
Average Length (cm)
07/2012
01/2013
07/2013
01/2014
07/2014
Month
Average
SD


Scarus ghobban Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD


Sargocentron spiniferum Actual Average Length
Average Length (cm)
01/2012
01/2014
Month
Average
SD

2.2.2 CNMI Bottomfish Ecosystem – Bottomfish Life History

2.2.2.1 Age & Growth and Reproductive Maturity

Description: Age determination is based on counts of yearly growth marks (annuli) and/or daily growth increments (DGIs) internally visible within transversely-cut, thin sections of sagittal otoliths. Validated age determination, particularly for long-lived (≥30 years) fish, is based on an environmental signal (bomb radiocarbon ^{14}C) produced during previous atmospheric thermonuclear testing in the Pacific and incorporated into the core regions of sagittal otolith and other aragonite-based calcified structures such as hermatypic corals. This technique relies on developing a regionally-based aged coral core reference series for which the rise, peak, and decline of ^{14}C values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the ^{14}C otolith core values back in time from its capture date to where it intersects with the known age ^{14}C coral reference series. The relation between age and fish length is evaluated by fitting this data to a von Bertalanffy growth function based on statistical analyses. The resulting von Bertalanffy growth function predicts the pattern of growth over time for that particular species. This function typically uses three coefficients (L_∞, k, and t_0) which together characterize the shape of the length-at-age growth relationship.

Length at reproductive maturity is based on the histological analyses of small tissue samples of gonad material that are typically collected along with otoliths when a fish is processed for life history studies. The gonad tissue sample is preserved then subsequently cut into five micron sections, stained, and sealed onto a glass slide for subsequent examination. Based on standard cell structure features and developmental stages within ovaries and testes, the gender, developmental stage, and maturity status (immature or mature) is determined via microscopic evaluation. The percent of mature samples for a given length interval are assembled for each sex and these data are fitted to a three- or four-parameter logistic function to determine the best fit of these data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish have achieved reproductive maturity (L_{50}). For species that undergo sex reversal (primarily female to male in the tropical Pacific region), such as groupers and deeper-water emperors among the bottomfishes, and for parrotfish, shallow-water emperors, and wrasses among the coral reef fishes, standard histological criteria are used to determine gender and reproductive developmental stages that indicate the transitioning or completed transition from one sex to another. These data are similarly analyzed using a three or four-parameter logistic function to determine the best fit of the data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish of a particular species have or are undergoing sex reversal ($L\Delta_{50}$).

Age at 50% maturity (A_{50}) and 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the von Bertalanffy growth function for that species and using the corresponding L_{50} and $L\Delta_{50}$ values to obtain the corresponding age value from this growth function. In studies where both age & growth and reproductive maturity are concurrently determined, estimates of A_{50} and $A\Delta_{50}$ are derived directly by fitting the percent of mature samples for each age (one-year) interval to a three- or four-parameter logistic function using statistical analyses. The mid-point of this fitted logistic function provides a direct estimate of the age at which 50% of fish of a particular species have achieved reproductive maturity (A_{50}) and sex reversal ($A\Delta_{50}$).

<u>Category</u>:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

<u>Timeframe</u>: N/A

<u>Jurisdiction</u>:

- ☐ American Samoa
- ☐ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Area

<u>Spatial Scale</u>:

- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

<u>Data Source</u>: Sources of data are directly derived from research cruises sampling and market samples collected by the CNMI contracted bio-sampling team which samples the catch of fishermen and local fish vendors. Laboratory analyses and data generated from these analyses reside with the PIFSC Life History Program. Refer to the "Reference" column in Table 49 for specific details on data sources by species.

<u>Parameter definitions</u>:

T_{max} (maximum age) – The maximum observed age revealed from an otolith-based age determination study. T_{max} values can be derived from ages determined by annuli counts of sagittal otolith sections and/or bomb radiocarbon (^{14}C) analysis of otolith core material.

L_∞ (asymptotic length) – One of three coefficients of the von Bertalanffy growth function (VBGF) that measures the mean maximum length at which the growth curve plateaus and no longer increases in length with increasing age. This coefficient reflects the mean maximum length and not the observed maximum length.

***k* (growth coefficient)** – One of three coefficients of the VBGF that measures the shape and steepness by which the initial portion of the growth function approaches its mean maximum length (L_∞).

t_0 (hypothetical age at length zero) – One of three coefficients of the VBGF whose measure is highly influenced by the other two VBGF coefficients (*k* and L_∞) and typically assumes a negative value when specimens representing early growth phases (0+ to 1+ ages) are not available for age determination.

***M* (natural mortality)** – this is a measure of mortality rate for a fish stock not under the influence of fishing pressure and is considered to be directly related to stock productivity (i.e., high *M* indicates high productivity and low *M* indicates low stock productivity). *M* can be derived through use of various equations that link *M* to T_{max} and two VBGF coefficients (*k* and L_∞) or by calculating the value of the slope from a regression fit to a declining catch curve (regression of the natural logarithm of abundance versus age class) derived from fishing an unfished or lightly fished population.

A_{50} (age at 50% maturity) – Age at which 50% of the sampled stock under study has attained reproductive maturity. This parameter is best determined based on studies that concurrently determine both age (otolith-based age data) and reproductive maturity status (logistic function fitted to percent mature by age class with maturity determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating A_{50} is to use an existing L_{50} estimate to find the corresponding age (A_{50}) from an existing VBGF curve.

$A\Delta_{50}$ (age of sex switching) – Age at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal. This parameter is best determined based on studies that concurrently determines both age (otolith-based age data) and reproductive sex reversal status (logistic function fitted to percent sex reversal by age class with sex reversal determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating $A\Delta_{50}$ is to use an existing $L\Delta_{50}$ estimate to find the corresponding age ($A\Delta_{50}$) from the VBGF curve.

L_{50} (length at which 50% of a fish species are capable of spawning) – Length (usually in terms of fork length) at which 50% of the females of a sampled stock under study has attained reproductive maturity; this is the length associated with A_{50} estimates. This parameter is derived using a logistic function to fit the percent mature data by length class with maturity status best determined via microscopic analyses of gonad histology preparations). L_{50} information is typically more available than A_{50} since L_{50} estimates do not require knowledge of age & growth.

$L\Delta_{50}$ (length of sex switching) – Length (usually in terms of fork length) at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal; this is the length associated with $A\Delta_{50}$ estimates. This parameter is derived using a logistic function to fit the percent sex reversal data by length class with sex reversal status best determined via microscopic analyses of gonad histology preparations). $L\Delta_{50}$ information is typically more available than $A\Delta_{50}$ since $L\Delta_{50}$ estimates do not require knowledge of age & growth.

<u>Rationale</u>: These nine life-history parameters provide basic biological information at the species level to evaluate the productivity of a stock - an indication of the capacity of a stock to recover once it has been depleted. Currently, the assessment of coral reef fish resources in CNMI is data-limited. Knowledge of these life-history parameters support current efforts to characterize the resilience of these resources, provide important biological inputs for future stock assessment efforts, and enhance our understanding of the species' likely role and status as a component of the overall ecosystem. Furthermore, knowledge of life histories across species at the taxonomic level of families or among different species that are ecologically or functionally similar can provide important information on the diversity of life histories and the extent to which species can be grouped (based on similar life histories) for future multi-species assessments.

Table 53. Available age, growth, and reproductive maturity information for bottomfish species targeted for life history sampling (otoliths and gonads) in CNMI.

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Aphareus rutilans	Y	Y	Y	Y			NA		NA	Y-Ralston & Williams (1988)
Aprion virescens							NA		NA	
Etelis carbunculus							NA		NA	
Etelis coruscans	Y	Y	Y	Y			NA		NA	Y-Ralston & Williams (1988)
Monotaxis grandoculis										
Pristipomoides auricilla	X[a]	X[a]	X[a]	X[a]	X[a]		NA		NA	O'Malley *et al.*, in prep
Pristipomoides filamentosus							NA		NA	
Pristipomoides flavipinnis	X[a]	X[a]	X[a]	X[a]	X[a]		NA		NA	O'Malley *et al.*, in prep
Pristipomoides sieboldii	Y	Y	Y	Y			NA		NA	Y-Ralston & Williams (1988)
Pristpomoides zonatus	Y	Y	Y	Y			NA		NA	Y-Ralston & Williams (1989)
Variola louti										

[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (including in press).

Parameter estimates are for females unless otherwise noted (F=females, M=males). Parameters T_{max}, t_0, A_{50}, and $A\Delta_{50}$ are in units of years; L_∞, L_{50}, and $L\Delta_{50}$ are in units of mm fork length (FL); k in units of year^{-1}; X=parameter estimate too preliminary or Y=published age and growth parameter estimates based on DGI numerical integration technique and likely to be inaccurate; NA=not applicable. Superscript letters indicate status of parameter estimate (see footnotes below table). Published or in press publications ([d]) are denoted in "Reference" column.

2.2.2.2 Fish Length Derived Parameters

<u>Description</u>: The NMFS Commercial Fishery BioSampling Program started in 2009. This program has two components: first is the Field/Market Sampling Program and the second is the

Life History Program, details of which are described in a separate section of this report. The goals of the Field/Market Sampling Program are:

- Broad scale look at commercial landings (by fisher/trip, gear & area fished)
- Length and weight frequencies of whole commercial landings per fisher-trip (with an effort to also sample landings not sold commercially)
- Accurate species identification
- Develop accurate local length-weight curves

In CNMI, the BioSampling is focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the northern islands. Sampling is conducted in partnership with the fish vendors. The Market Sampling information includes (but not limited to): 1) fish length; 2) fish weight; 3) species identification; and 4) basic effort information. Specific for CNMI, the program collects Daily Vendor Logs for bottomfish that includes basic catch and effort information.

Category:
- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:
- ☐ American Samoa
- ☐ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: NMFS BioSampling Program

Parameter definitions:
L_{max} – maximum fish length is the longest fish per species recorded in the BioSampling Program from the commercial bottomfish fishery. This value is derived from measuring the fork length of individual samples for species occurring in the spear fishery.

***L_{bar}* – mean length** is the average value of all lengths recorded from the commercial spear fishery. This can be influenced by gear selectivity since the commercial bottomfish fishery has a typical size target based on customer demand. This can also be influenced by size regulations.

***n* – sample size** is the total number of samples accumulated for each species recorded in the commercial bottomfish fishery.

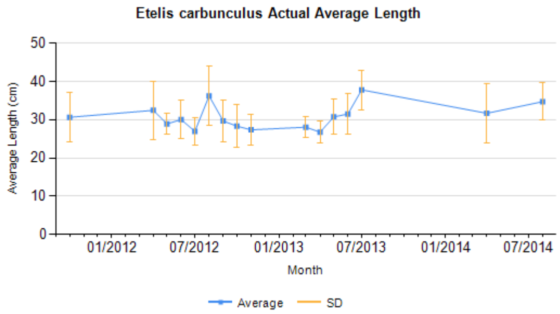
***N_{L-W}* – sample size for L-W regression** is the number of samples used to generate the *a* & *b* coefficients.

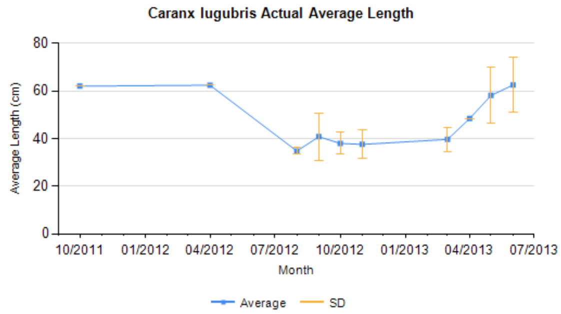
***a* & *b* – length-weight coefficients** are the coefficients derived from the regression line fitted to all length and weight measured per species in the commercial bottomfish fishery. These values are used to convert length information to weight. Values are influenced by the life history characteristics of the species, geographic location, population status, and nature of the fisheries from which the species are harvested from.

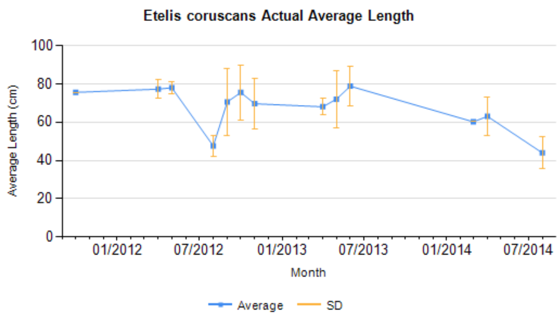
Rationale: Length-derived information is being used as an indicator of population status particularly for data poor stocks like coral reef fish. Average length (L_{bar}) was used as a principal stock assessment indicator variable for exploited reef fish population (Nadon *et al*., 2015). Average length was also shown to be correlated with population size (Kerr and Dickle, 2001). Maximum length (L_{max}), typically coupled with maximum age, is typically used as a proxy for fish longevity which has implications on the productivity and susceptibility of a species to fishing pressure. The length-weight coefficients (*a* & *b* values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length are typically recorded but weight is the factor being used for management. This section of the report presents the best available information for the length-derived variables for the bottomfish fisheries.

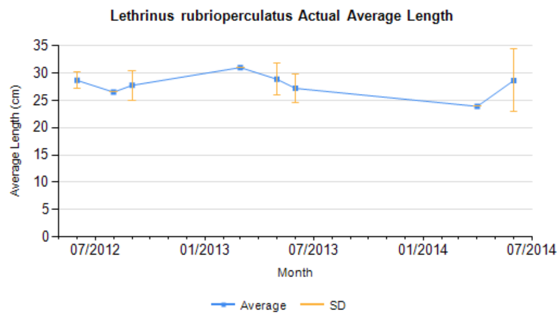
Table 54. Available length-derived information for various bottomfish species in CNMI.

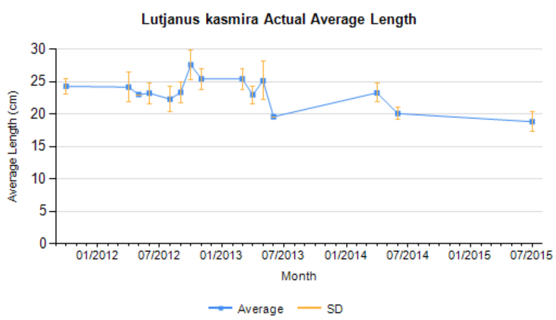
Species	Length-derived parameters						Reference
	L_{max}	L_{bar}	*N*	*L-W*	*a*	*b*	
Lethrinus rubrioperculatus	38.0	28.01	1,353	1,021	0.0185	2.9897	
Etelis carbunculus	53.5	30.18	685	685	0.0150	3.0430	
Pristipomoides auricilla	39.5	28.59	465	465	0.0189	3.0060	
Pristipomoides zonatus	45.4	32.99	371	370	0.0180	3.0411	
Etelis coruscans	96.4	72.50	325	325	0.0716	2.6147	
Lutjanus kasmira	32.5	24.84	258	258	0.0087	3.2307	
Pristipomoides flavipinnis	51.5	37.05	168	168	0.0133	3.0762	
Pristipomoides argyrogrammicus	31.6	24.44	150	150	0.0174	3.0464	
Pristipomoides filamentosus	58.5	39.97	123	123	0.0773	2.5914	
Caranx lugubris	82.5	46.07	122	122	0.0309	2.8768	

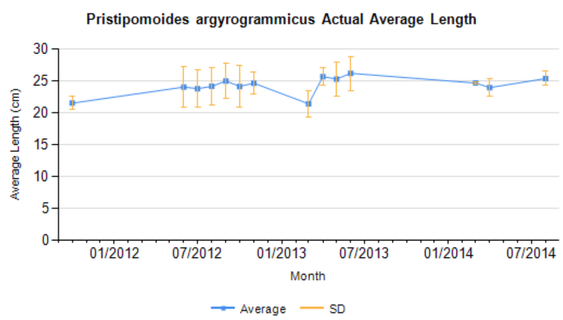

Etelis carbunculus Actual Average Length
Average Length (cm)
0
10
20
30
40
50
01/2012
07/2012
01/2013
07/2013
01/2014
07/2014
Month
Average
SD


Caranx lugubris Actual Average Length
Average Length (cm)
0
20
40
60
80
10/2011
01/2012
04/2012
07/2012
10/2012
01/2013
04/2013
07/2013
Month
Average
SD


Etelis coruscans Actual Average Length
Average Length (cm)
0
20
40
60
80
100
01/2012
07/2012
01/2013
07/2013
01/2014
07/2014
Month
Average
SD


Lethrinus rubrioperculatus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
35
07/2012
01/2013
07/2013
01/2014
07/2014
Month
Average
SD


Lutjanus kasmira Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
01/2012
07/2012
01/2013
07/2013
01/2014
07/2014
01/2015
07/2015
Month
Average
SD


Pristipomoides argyrogrammicus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
01/2012
07/2012
01/2013
07/2013
01/2014
07/2014
Month
Average
SD

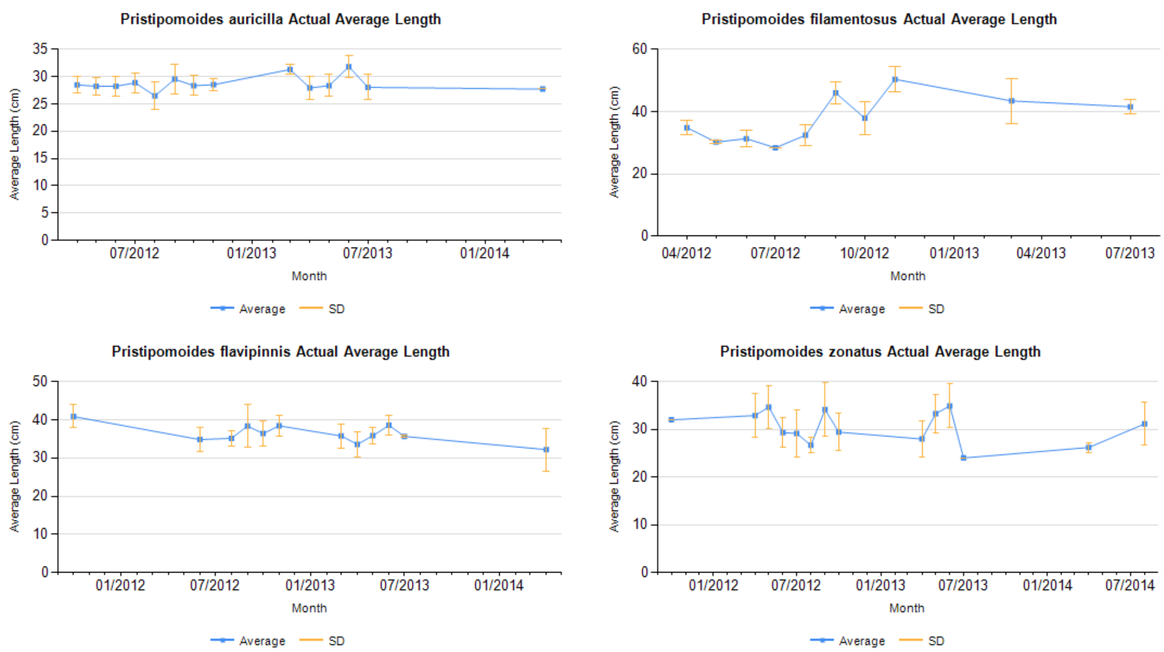


Figure 7. Average length over time of representative CNMI bottomfish management unit species derived from the BioSampling Program. Continued from previous page.

2.2.3 Guam Coral Reef Ecosystem – Reef Fish Life History

2.2.3.1 Age & Growth and Reproductive Maturity

<u>Description</u>: Age determination is based on counts of yearly growth marks (annuli) and/or daily growth increments (DGIs) internally visible within transversely-cut, thin sections of sagittal otoliths. Validated age determination, particularly for long-lived (≥30 years) fish, is based on an environmental signal (bomb radiocarbon ^{14}C) produced during previous atmospheric thermonuclear testing in the Pacific and incorporated into the core regions of sagittal otolith and other aragonite-based calcified structures such as hermatypic corals. This technique relies on developing a regionally-based aged coral core reference series for which the rise, peak, and decline of ^{14}C values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the ^{14}C otolith core values back in time from its capture date to where it intersects with the known age ^{14}C coral reference series. The relation between age and fish length is evaluated by fitting this data to a von Bertalanffy growth function based on statistical analyses. The resulting von Bertalanffy growth function predicts the pattern of growth over time for that particular species. This function typically uses three coefficients (L_{∞}, k, and t_0) which together characterize the shape of the length-at-age growth relationship.

Length at reproductive maturity is based on the histological analyses of small tissue samples of gonad material that are typically collected along with otoliths when a fish is processed for life history studies. The gonad tissue sample is preserved then subsequently cut into five-micron sections, stained, and sealed onto a glass slide for subsequent examination. Based on standard cell structure features and developmental stages within ovaries and testes, the gender, developmental stage, and maturity status (immature or mature) is determined via microscopic evaluation. The percent of mature samples for a given length interval are assembled for each sex and these data are fitted to a three- or four-parameter logistic function to determine the best fit of these data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish have achieved reproductive maturity (L_{50}). For species that undergo sex reversal (primarily female to male in the tropical Pacific region), such as groupers and deeper-water emperors among the bottomfishes, and for parrotfish, shallow-water emperors, and wrasses among the coral reef fishes, standard histological criteria are used to determine gender and reproductive developmental stages that indicate the transitioning or completed transition from one sex to another. These data are similarly analyzed using a 3- or 4-parameter logistic function to determine the best fit of the data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish of a particular species have or are undergoing sex reversal ($L\Delta_{50}$).

Age at 50% maturity (A_{50}) and 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the von Bertalanffy growth function for that species and using the corresponding L_{50} and $L\Delta_{50}$ values to obtain the corresponding age value from this growth function. In studies where both age & growth and reproductive maturity are concurrently determined, estimates of A_{50} and $A\Delta_{50}$ are derived directly by fitting the percent of mature samples for each age (one-year) interval to a three- or four-parameter logistic function using statistical analyses. The mid-point of this fitted logistic function provides a direct estimate of the age at which 50% of fish of a particular species have achieved reproductive maturity (A_{50}) and sex reversal ($A\Delta_{50}$).

Category:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:

- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:

- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Sources of data are directly derived from research cruises sampling and market samples collected by the Guam-contracted bio-sampling team which samples the catch of fishermen and local fish vendors. Laboratory analyses and data generated from these analyses reside with the PIFSC Life History Program. Refer to the "Reference" column in Table 1 for specific details on data sources by species.

Parameter definitions:

T_{max} **(maximum age)** – The maximum observed age revealed from an otolith-based age determination study. T_{max} values can be derived from ages determined by annuli counts of sagittal otolith sections and/or bomb radiocarbon (^{14}C) analysis of otolith core material.

L_∞ **(asymptotic length)** – One of three coefficients of the von Bertalanffy growth function (VBGF) that measures the mean maximum length at which the growth curve plateaus and no longer increases in length with increasing age. This coefficient reflects the mean maximum length and not the observed maximum length.

k **(growth coefficient)** – One of three coefficients of the VBGF that measures the shape and steepness by which the initial portion of the growth function approaches its mean maximum length (L_∞).

t_0 **(hypothetical age at length zero)** – One of three coefficients of the VBGF whose measure is highly influenced by the other two VBGF coefficients (k and L_∞) and typically assumes a negative value when specimens representing early growth phases (0+ to 1+ ages) are not available for age determination.

M **(natural mortality)** – This is a measure of mortality rate for a fish stock not under the influence of fishing pressure and is considered to be directly related to stock productivity (i.e., high M indicates high productivity and low M indicates low stock productivity). M can be derived through use of various equations that link M to T_{max} and k, or in some instances, by calculating the value of the slope from a regression fit to a declining catch curve (regression of the natural logarithm of abundance versus age class) derived from fishing an unfished or lightly fished population.

A_{50} **(age at 50% maturity)** – Age at which 50% of the sampled stock under study has attained reproductive maturity. This parameter is best determined based on studies that concurrently determine both age (otolith-based age data) and reproductive maturity status (logistic function fitted to percent mature by age class with maturity determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating A_{50} is to use an existing L_{50} estimate to find the corresponding age (A_{50}) from an existing VBGF curve.

$A\Delta_{50}$ **(age of sex switching)** – Age at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal. This parameter is best determined based on studies that concurrently determines both age (otolith-based age data) and reproductive sex reversal status (logistic function fitted to percent sex reversal by age class with sex reversal determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating $A\Delta_{50}$ is to use an existing $L\Delta_{50}$ estimate to find the corresponding age ($A\Delta_{50}$) from the VBGF curve.

L_{50} (length at which 50% of a fish species are capable of spawning) – Length (usually in terms of fork length) at which 50% of the females of a sampled stock under study has attained reproductive maturity; this is the length associated with A_{50} estimates. This parameter is derived using a logistic function to fit the percent mature data by length class with maturity status best determined via microscopic analyses of gonad histology preparations). L_{50} information is typically more available than A_{50} since L_{50} estimates do not require knowledge of age & growth.

$L\Delta_{50}$ (length of sex switching) – Length (usually in terms of fork length) at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal; this is the length associated with $A\Delta_{50}$ estimates. This parameter is derived using a logistic function to fit the percent sex reversal data by length class with sex reversal status best determined via microscopic analyses of gonad histology preparations. $L\Delta_{50}$ information is typically more available than $A\Delta_{50}$ since $L\Delta_{50}$ estimates do not require knowledge of age & growth.

Rationale: These nine life history parameters provide basic biological information at the species level to evaluate the productivity of a stock - an indication of the capacity of a stock to recover once it has been depleted. Currently, the assessment of coral reef fish resources in Guam is data-limited. Knowledge of these life history parameters support current efforts to characterize the resilience of these resources and also provide important biological inputs for future stock assessment efforts and enhance our understanding of the species' likely role and status as a component of the overall ecosystem. Furthermore, knowledge of life histories across species at the taxonomic level of families or among different species that are ecologically or functionally similar can provide important information on the diversity of life histories and the extent to which species can be grouped (based on similar life histories) for future multi-species assessments.

Table 55. Available age, growth, and reproductive maturity information for coral reef species targeted for life history sampling (otoliths and gonads) in Guam.

Species	Age, growth, and reproductive maturity parameters							Reference
	T_{max}	L_∞	k	t_0	A_{50}	L_{50}	$L\Delta_{50}$	
Calatomus carolinus	3[d]	263[d]	0.91[d]	-0.065[d]	1.14[d]	168[d]	213[d]	[d]Taylor & Choat (2014)
Oxycheilinus unifasciatus								
Chlorurus frontalis	11[d]	372[d]	0.71[d]	-0.058[d]	1.55[d]	240[d]	343[d]	[d]Taylor & Choat (2014)
Chlorurus microrhinos	11[d]	457[d]	0.34[d]	-0.097[d]	3.7[d]	308[d]	378[d]	[d]Taylor & Choat (2014)
Chlorurus spilurus	9[d]	218[d]	0.95[d]	-0.075[d]	1.3[d]	144[d]	207[d]	[d]Taylor & Choat (2014)
Hipposcarus longiceps	10[d]	396 (f), 466 (m)[d]	0.97 (f), 0.67	-0.04 (f), -0.05 (m)[d]		401[d]		Taylor and Cruz (2017)

			(m)[d]					
Naso lituratus	13d	204[d]	0.93[d]	-0.30[d]	2.4 (m)[d]	145 (f), 178 (m)[d]		[d]Taylor et. al. (2014)
Naso unicornis	23[d]	493d	0.22[d]	-0.48[d]	4.0 (f), 3.2 (m)[d]	292 (f), 271 (m)[d]		[d]Taylor et. al. (2014)
Scarus altipinnis	14[d]	339[d]	0.66[d]	-0.069[d]	2.89[d]	251[d]	337[d]	[d]Taylor & Choat (2014)
Scarus forsteni	12[d]	281[d]	0.88[d]	-0.062[d]	1.79[d]	216[d]	271[d]	[d]Taylor & Choat (2014)
Scarus psittacus	6[d]	207[d]	0.91[d]	-0.083[d]	1.36[d]	103[d]	193[d]	[d]Taylor & Choat (2014)
Scarus rubroviolaceus	6[d]	376[d]	0.66[d]	-0.062[d]	1.91[d]	271[d]	329[d]	[d]Taylor & Choat (2014)
Scarus schlegeli	8[d]	252[d]	1.03[d]	-0.06[d]	1.99[d]	197[d]	220[d]	[d]Taylor & Choat (2014)

[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (including in press).

Parameter estimates are for females unless otherwise noted (F=females, M=males). Parameters T_{max}, t_0, A_{50}, and $A\Delta_{50}$ are in units of years; L_∞, L_{50}, and $L\Delta_{50}$ are in units of mm fork length (FL); k in units of year^{-1}; X=parameter estimate too preliminary or Y=published age and growth parameter estimates based on DGI numerical integration technique and likely to be inaccurate; NA=not applicable. Superscript letters indicate status of parameter estimate (see footnotes below table). Published or in press publications ([d]) are denoted in "Reference" column.

2.2.3.2 Fish Length Derived Parameters

Description: The NMFS Commercial Fishery BioSampling Program started in 2009. This program has two components: first is the Field/Market Sampling Program and the second is the Life History Program, details of which are described in a separate section of this report. The goals of the Field/Market Sampling Program are:

- Broad scale look at commercial landings (by fisher/trip, gear & area fished)
- Length and weight frequencies of whole commercial landings per fisher-trip (with an effort to also sample landings not sold commercially)
- Accurate species identification
- Develop accurate local length-weight curves

In the Guam, the BioSampling is focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the banks. Sampling is conducted in direct partnership with the spear fisherman. The Market Sampling information includes (but not limited to): 1) fish length; 2) fish weight; 3) species identification; and 4) basic effort information.

Category:
- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:
- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: NMFS BioSampling Program

Parameter definition:

L_{max} – ***maximum fish length*** is the longest fish per species recorded in the BioSampling Program from the commercial spear fishery. This value is derived from measuring the fork length of individual samples for species occurring in the spear fishery.

L_{bar} – ***mean length*** is the average value of all lengths recorded from the commercial spear fishery. This can be influenced by gear selectivity since the commercial spear fishery has a typical size target based on customer demand. This can also be influenced by size regulations.

n – sample size is the total number of samples accumulated for each species recorded in the commercial spear fishery.

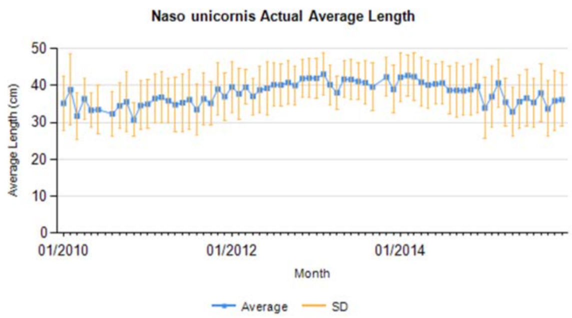
N_{L-W} – ***sample size for L-W regression*** is the number of samples used to generate the *a* & *b* coefficients.

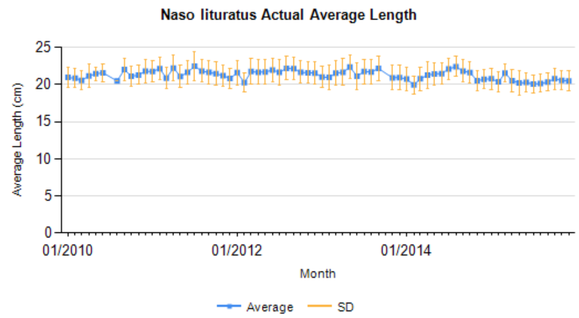
a & b – length-weight coefficients are the coefficients derived from the regression line fitted to all length and weight measured per species in the commercial spear fishery. These values are used to convert length information to weight. Values are influenced by the life history characteristics of the species, geographic location, population status, and nature of the fisheries from which the species are harvested

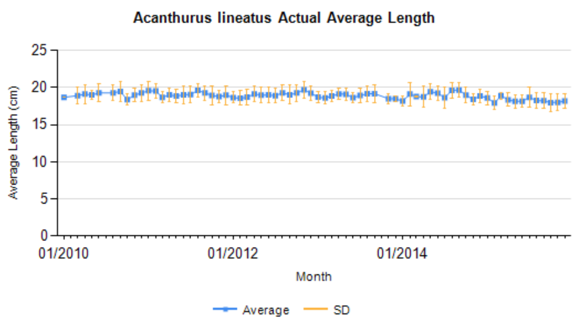
Rationale: Length-derived information is being used as an indicator of population status particularly for data-poor stocks like coral reef fish. Average length (L_{bar}) was used as a principal stock assessment indicator variable for exploited reef fish population (Nadon *et al*., 2015). Average length was also shown to be correlated with population size (Kerr and Dickle, 2001). Maximum length (L_{max}), typically coupled with maximum age, is typically used as a proxy for fish longevity which has implications on the productivity and susceptibility of a species to fishing pressure. The length-weight coefficients (*a* & *b* values) are used to convert length to weight for fishery dependent and fishery independent data collection where length are typically recorded but weight is the factor being used for management. This section of the report presents the best available information for the length-derived variables for the CNMI coral reef and bottomfish fisheries.

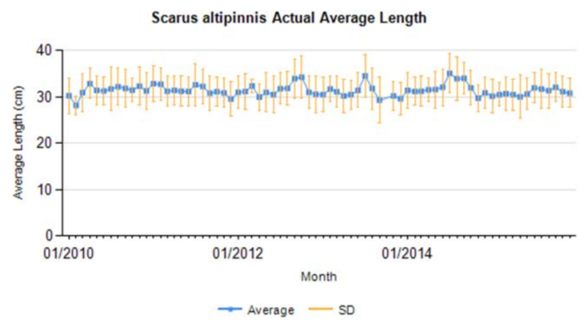
Table 56. Available length derived information for various coral reef species in Guam.

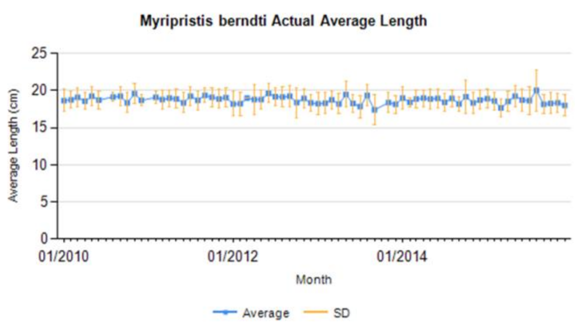
Species	Length-derived parameters					Reference
	L_{max}	L_{bar}	*n*	*a*	*b*	
Naso unicornis	57.2	38.02	15461	0.0278	2.9135	2010-2015 Guam Bio-Sampling Database
Naso lituratus	29.6	21.35	16702	0.0223	3.0264	
Acanthurus lineatus	28.9	19.04	4325	0.0473	2.8110	
Scarus altipinnis	46.4	31.16	3913	0.0207	3.0040	
Myripristis bendti	29.4	18.63	3903	0.0858	2.5911	
Siganus argenteus	34.5	21.71	3653	0.0163	3.0428	
Acanthurus nigricauda	29.1	21.40	3500	0.0511	2.7811	
Hipposcarus longiceps	51.4	37.30	3149	0.0172	3.0320	
Scarus schlegeli	36.2	25.19	2787	0.0205	3.0033	
Siganus punctatus	32.0	23.97	2619	0.0199	3.0690	
Monotaxis grandoculis	48.9	29.17	2388	0.0440	2.8384	
Scarus rubroviolaceus	47.8	31.91	2192	0.0114	3.1812	
Lethrinus obsoletus	34.7	22.15	2273	0.0169	3.0471	
Scarus forsteni	39.1	28.13	1801	0.0149	3.1169	
Lutjanus gibbus	43.5	29.99	1687	0.0195	3.0274	
Parupeneus insularis	28.5	21.89	1560	0.0178	3.0865	
Siganus spinus	27.5	16.53	1670	0.0353	2.7886	
Lethrinus atkinsoni	33.7	21.93	1644	0.0215	3.0217	
Chlorurus microrhinus	50.5	32.54	1527	0.0187	3.0520	
Chlorurus sordidus	33.1	22.39	1234	0.0208	3.0293	
Kyphosus cinerascens	50.7	29.94	1146	0.0323	2.9267	

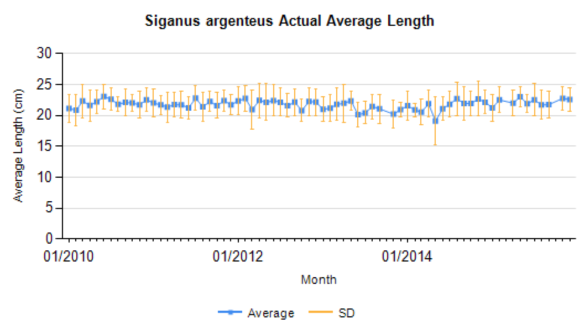

Naso unicornis Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

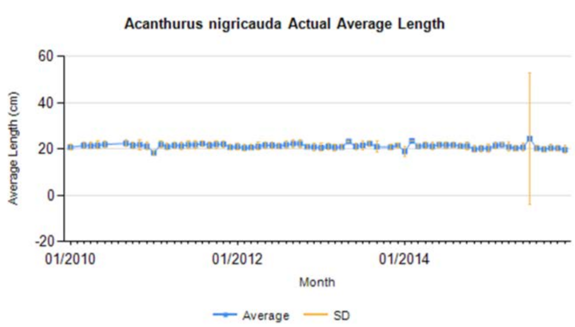

Naso lituratus Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

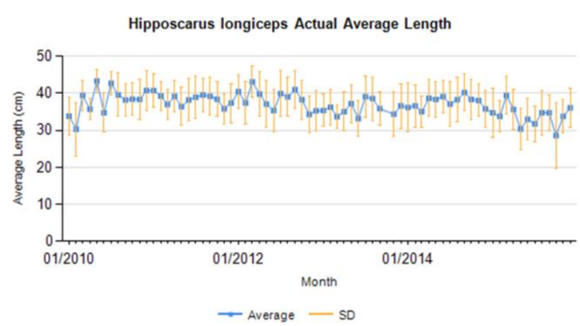

Acanthurus lineatus Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

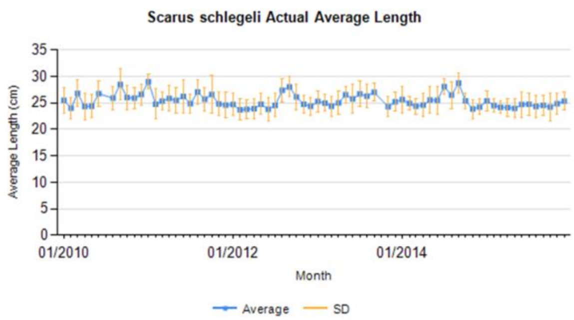

Scarus altipinnis Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

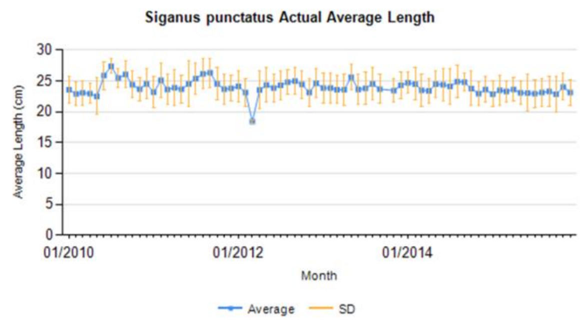

Myripristis berndti Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

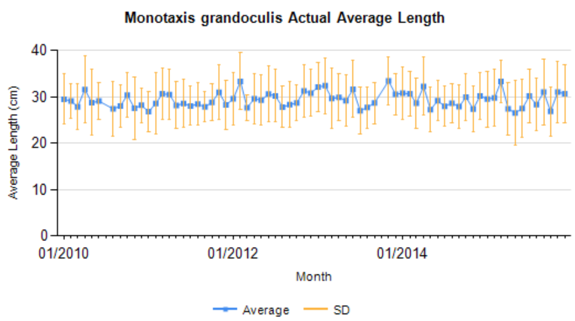

Siganus argenteus Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

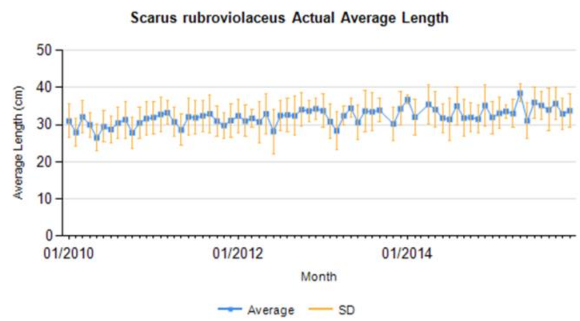

Acanthurus nigricauda Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

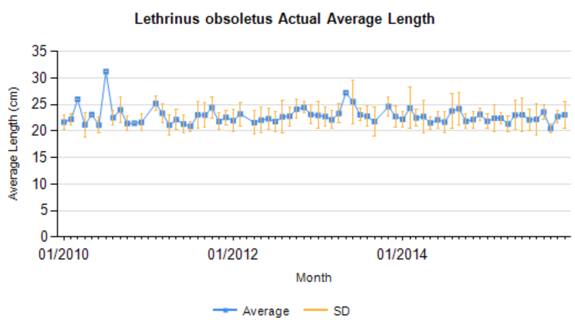

Hipposcarus longiceps Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

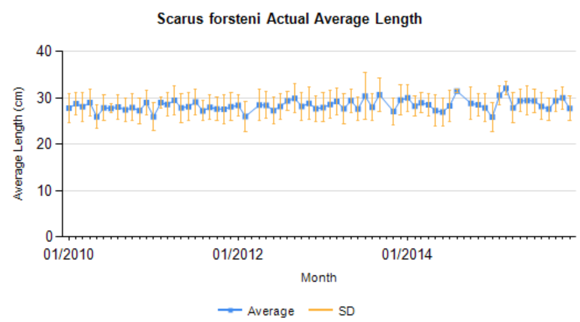

Scarus schlegeli Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
35
01/2010
01/2012
01/2014
Month
Average
SD

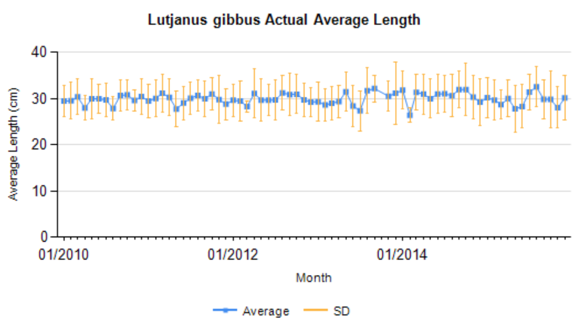

Siganus punctatus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
01/2010
01/2012
01/2014
Month
Average
SD


Monotaxis grandoculis Actual Average Length
Average Length (cm)
0
10
20
30
40
01/2010
01/2012
01/2014
Month
Average
SD


Scarus rubroviolaceus Actual Average Length
Average Length (cm)
0
10
20
30
40
50
01/2010
01/2012
01/2014
Month
Average
SD


Lethrinus obsoletus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
35
01/2010
01/2012
01/2014
Month
Average
SD


Scarus forsteni Actual Average Length
Average Length (cm)
0
10
20
30
40
01/2010
01/2012
01/2014
Month
Average
SD


Lutjanus gibbus Actual Average Length
Average Length (cm)
0
10
20
30
40
01/2010
01/2012
01/2014
Month
Average
SD

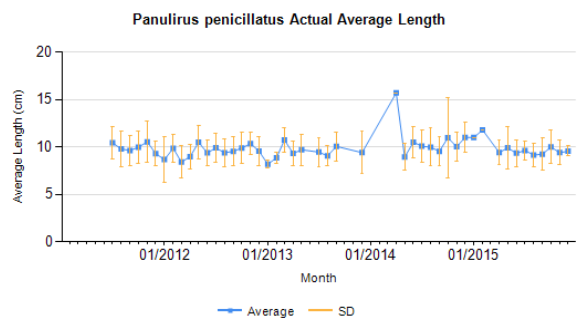

Panulirus penicillatus Actual Average Length
Average Length (cm)
0
5
10
15
20
01/2012
01/2013
01/2014
01/2015
Month
Average
SD

Figure 8. Average length over time of representative Guam CREMUS derived from the BioSampling Program. Continued from previous two pages.

2.2.4 Guam Bottomfish Ecosystem – Bottomfish Life History

2.2.4.1 Age & Growth and Reproductive Maturity

Description: Age determination is based on counts of yearly growth marks (annuli) and/or daily growth increments (DGIs) internally visible within transversely-cut thin sections of sagittal otoliths. Validated age determination, particularly for long-lived (≥30 years) fish, is based on an environmental signal (bomb radiocarbon ^{14}C) produced during previous atmospheric thermonuclear testing in the Pacific and incorporated into the core regions of sagittal otolith and other aragonite-based calcified structures such as hermatypic corals. This technique relies on developing a regionally-based aged coral core reference series for which the rise, peak, and decline of ^{14}C values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the ^{14}C otolith core values back in time from its capture date to where it intersects with the known age ^{14}C coral reference series. The relation between age and fish length is evaluated by fitting this data to a von Bertalanffy growth function based on statistical analyses. The resulting von Bertalanffy growth function predicts the pattern of growth over time for that particular species. This function typically uses three coefficients (L_∞, k, and t_0) which together characterize the shape of the length-at-age growth relationship.

Length at reproductive maturity is based on the histological analyses of small tissue samples of gonad material that are typically collected along with otoliths when a fish is processed for life history studies. The gonad tissue sample is preserved then subsequently cut into five micron sections, stained, and sealed onto a glass slide for subsequent examination. Based on standard cell structure features and developmental stages within ovaries and testes, the gender, developmental stage, and maturity status (immature or mature) is determined via microscopic evaluation. The percent of mature samples for a given length interval are assembled for each sex and these data are fitted to a three- or four-parameter logistic function to determine the best fit of these data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish have achieved reproductive maturity (L_{50}). For species that undergo sex reversal (primarily female to male in the tropical Pacific region), such as groupers and deeper-water emperors among the bottomfishes, and for parrotfish, shallow-water emperors, and wrasses among the coral reef fishes, standard histological criteria are used to determine gender and reproductive developmental stages that indicate the transitioning or completed transition from one sex to another. These data are similarly analyzed using a three- or four-parameter logistic function to determine the best fit of the data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish of a particular species have or are undergoing sex reversal ($L\Delta_{50}$).

Age at 50% maturity (A_{50}) and 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the von Bertalanffy growth function for that species and using the corresponding L_{50} and $L\Delta_{50}$ values to obtain the corresponding age value from this growth function. In studies where both age & growth and reproductive maturity are concurrently determined, estimates of A_{50} and $A\Delta_{50}$ are derived directly by fitting the percent of mature samples for each age (one-year) interval to a three- or four-parameter logistic function using statistical analyses. The mid-point of this fitted logistic function provides a direct estimate of the age at which 50% of fish of a particular species have achieved reproductive maturity (A_{50}) and sex reversal ($A\Delta_{50}$).

<u>Category</u>:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

<u>Timeframe</u>: N/A

<u>Jurisdiction</u>:

- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands

- ☐ Northwest Hawaiian Islands:
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Sources of data are directly derived from research cruises sampling and market samples collected by the Guam-contracted bio-sampling team which samples the catch of fishermen and local fish vendors. Laboratory analyses and data generated from these analyses reside with the PIFSC Life History Program. Refer to the "Reference" column in Table 1 for specific details on data sources by species.

Parameter definitions:

***T_{max}* (maximum age)** – The maximum observed age revealed from an otolith-based age determination study. T_{max} values can be derived from ages determined by annuli counts of sagittal otolith sections and/or bomb radiocarbon (^{14}C) analysis of otolith core material.

***L_∞* (asymptotic length)** – One of three coefficients of the von Bertalanffy growth function (VBGF) that measures the mean maximum length at which the growth curve plateaus and no longer increases in length with increasing age. This coefficient reflects the mean maximum length and not the observed maximum length.

***k* (growth coefficient)** – One of three coefficients of the VBGF that measures the shape and steepness by which the initial portion of the growth function approaches its mean maximum length (L_∞).

***t_0* (hypothetical age at length zero)** – One of three coefficients of the VBGF whose measure is highly influenced by the other two VBGF coefficients (k and L_∞) and typically assumes a negative value when specimens representing early growth phases (0+ to 1+ ages) are not available for age determination.

***M* (natural mortality)** – this is a measure of mortality rate for a fish stock not under the influence of fishing pressure and is considered to be directly related to stock productivity (i.e., high M indicates high productivity and low M indicates low stock productivity). M can be derived through use of various equations that link M to T_{max} and two VBGF coefficients (k and L_∞) or by calculating the value of the slope from a regression fit to a declining catch curve (regression of the natural logarithm of abundance versus age class) derived from fishing an unfished or lightly fished population.

***A_{50}* (age at 50% maturity)** – Age at which 50% of the sampled stock under study has attained reproductive maturity. This parameter is best determined based on studies that concurrently determine both age (otolith-based age data) and reproductive maturity status (logistic function fitted to percent mature by age class with maturity determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating A_{50} is to use an existing L_{50} estimate to find the corresponding age (A_{50}) from an existing VBGF curve.

$A\Delta_{50}$ (age of sex switching) – Age at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal. This parameter is best determined based on studies that concurrently determines both age (otolith-based age data) and reproductive sex reversal status (logistic function fitted to percent sex reversal by age class with sex reversal determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating $A\Delta_{50}$ is to use an existing $L\Delta_{50}$ estimate to find the corresponding age ($A\Delta_{50}$) from the VBGF curve.

L_{50} (length at which 50% of a fish species are capable of spawning) – Length (usually in terms of fork length) at which 50% of the females of a sampled stock under study has attained reproductive maturity; this is the length associated with A_{50} estimates. This parameter is derived using a logistic function to fit the percent mature data by length class with maturity status best determined via microscopic analyses of gonad histology preparations). L_{50} information is typically more available than A_{50} since L_{50} estimates do not require knowledge of age & growth.

$L\Delta_{50}$ (length of sex switching) – Length (usually in terms of fork length) at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal; this is the length associated with $A\Delta_{50}$ estimates. This parameter is derived using a logistic function to fit the percent sex reversal data by length class with sex reversal status best determined via microscopic analyses of gonad histology preparations. $L\Delta_{50}$ information is typically more available than $A\Delta_{50}$ since $L\Delta_{50}$ estimates do not require knowledge of age & growth.

Rationale: These nine life history parameters provide basic biological information at the species level to evaluate the productivity of a stock - an indication of the capacity of a stock to recover once it has been depleted. Currently, the assessment of coral reef fish resources in Guam is data-limited. Knowledge of these life history parameters support current efforts to characterize the resilience of these resources and also provide important biological inputs for future stock assessment efforts and enhance our understanding of the species' likely role and status as a component of the overall ecosystem. Furthermore, knowledge of life histories across species at the taxonomic level of families or among different species that are ecologically or functionally similar can provide important information on the diversity of life histories and the extent to which species can be grouped (based on similar life histories) for future multi-species assessments.

Table 57. Available age, growth, and reproductive maturity information for bottomfish species targeted for life history sampling (otoliths and gonads) in Guam.

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_{∞}	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Aphareus rutilans							NA		NA	
Aprion virescens							NA		NA	
Etelis carbunculus							NA		NA	
Etelis coruscans							NA		NA	
Monotaxis grandoculis								228[b]	X[a]	
Pristipomoides auricilla	X[a]	X[a]	X[a]	X[a]	X[a]		NA		NA	O'Malley *et al*., in prep.
Pristipomoides filamentosus							NA		NA	
Pristipomoides flavipinnis	X[a]	X[a]	X[a]	X[a]	X[a]		NA		NA	O'Malley *et al*., in prep.
Pristipomoides sieboldii							NA		NA	
Pristpomoides zonatus							NA		NA	
Variola louti								220[b]	X[a]	

[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (+ in press).

Parameter estimates are for females unless otherwise noted (F=females, M=males). Parameters T_{max}, t_0, A_{50}, and $A\Delta_{50}$ are in units of years; L_{∞}, L_{50}, and $L\Delta_{50}$ are in units of mm fork length (FL); k in units of year^{-1}; X=parameter estimate too preliminary or Y=published age and growth parameter estimates based on DGI numerical integration technique and likely to be inaccurate; NA=not applicable. Superscript letters indicate status of parameter estimate (see footnotes below table). Published or in press publications ([d]) are denoted in "Reference" column.

2.2.4.2 Fish Length Derived Parameters

Description: The NMFS Commercial Fishery BioSampling Program started in 2009. This program has two components: first is the Field/Market Sampling Program and the second is the Life History Program, details of which are described in a separate section of this report. The goals of the Field/Market Sampling Program are:

- Broad scale look at commercial landings (by fisher/trip, gear & area fished)
- Length and weight frequencies of whole commercial landings per fisher-trip (with an effort to also sample landings not sold commercially)

- Accurate species identification
- Develop accurate local length-weight curves

In Guam, the BioSampling is focused on the commercial fishery. Sampling is conducted in partnership with the Guam Fisherman's Cooperative Association (GFCA). The Market Sampling information includes (but not limited to): 1) fish length; 2) fish weight; 3) species identification; and 4) basic effort information. More specific fishery information such as gear information, species composition and total catch information is recorded through the log book system implemented by GFCA and transcribed into the database maintained by the Western Pacific Fishery Information Network.

Category:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:

- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:

- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: NMFS BioSampling Program

Parameter definition:

***L_{max}* – maximum fish length** is the longest fish per species recorded in the BioSampling Program from the commercial spear fishery. This value is derived from measuring the fork length of individual samples for species occurring in the spear fishery.

***L_{bar}* – mean length** is the average value of all lengths recorded from the commercial spear fishery. This can be influenced by gear selectivity since the commercial spear fishery has a typical size target based on customer demand. This can also be influenced by size regulations.

***n* – sample size** is the total number of samples accumulated for each species recorded in the commercial spear fishery.

N_{L-W} – sample size for L-W regression is the number of samples used to generate the a & b coefficients

a & b – length-weight coefficients are the coefficients derived from the regression line fitted to all length and weight measured per species in the commercial spear fishery. These values are used to convert length information to weight. Values are influenced by the life history characteristics of the species, geographic location, population status, and nature of the fisheries from which the species are harvested from.

Rationale: Length-derived information is being used as an indicator of population status particularly for data-poor stocks like coral reef fish. Average length (L_{bar}) was used as a principal stock assessment indicator variable for exploited reef fish population (Nadon *et al*., 2015). Average length was also shown to be correlated with population size (Kerr and Dickle, 2001). Maximum length (L_{max}), typically coupled with maximum age, is typically used as a proxy for fish longevity which has implications on the productivity and susceptibility of a species to fishing pressure. The length-weight coefficients (*a* & *b* values) are used to convert length to weight for fishery dependent and fishery independent data collection where length are typically recorded but weight is the factor being used for management. This section of the report presents the best available information for the length-derived variables for the CNMI coral reef and bottomfish fisheries.

Table 58. Available length derived information for various bottomfish species in Guam.

Species	Length-derived parameters					Reference
	L_{max}	L_{bar}	*n*	*a*	*b*	
Lethrinus rubrioperculatus	46.6	27.10	3374	0.0248	2.9158	2010-2015 Guam Biosampling Database
Epinephelus fasciatus	35.8	24.01	3033	0.0141	3.0303	
Pristipomoides auricilla	39.0	28.18	1732	0.0152	3.0742	

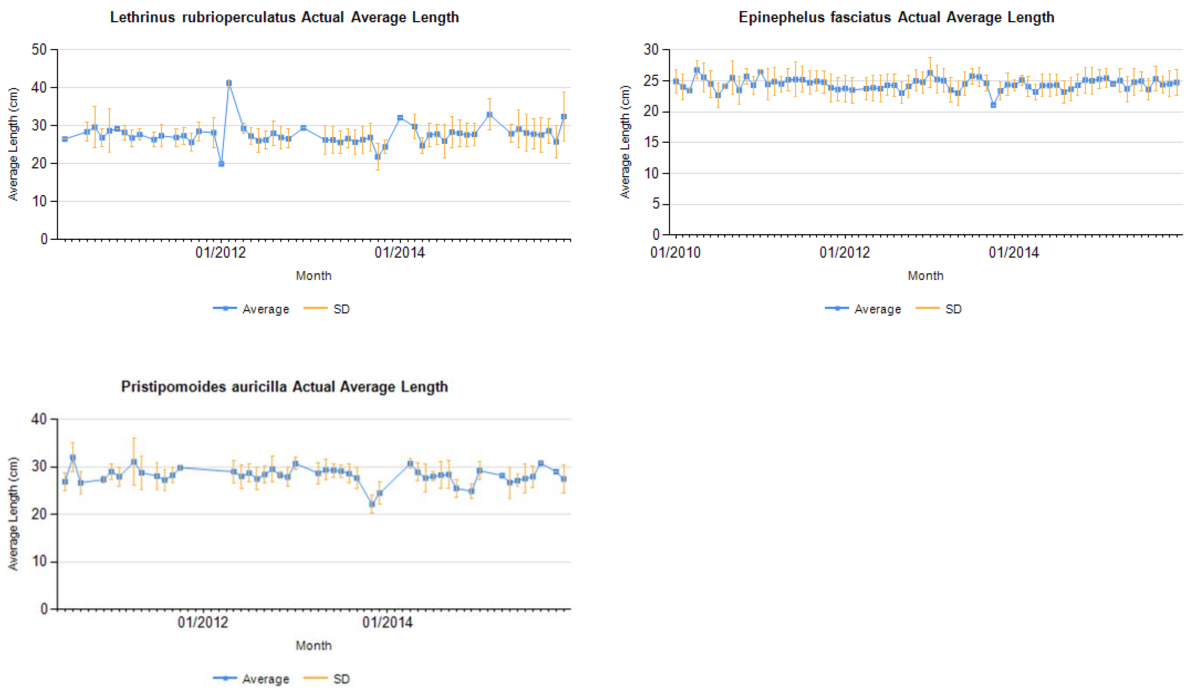


Figure 9. Average length over time of representative Guam BMUS derived from the BioSampling Program.

2.2.5 References

Nadon, M.O., Ault, J.S., Williams, I.D., Smith, S.G., and DiNardo, G.T., 2015. Length-based assessment of coral reef fish populations in the Main and Northwestern Hawaiian Islands. *PLoS One*, *10*(8), p.e0133960.

Kerr, S.R. and Dickie, L.M., 2001. *The biomass spectrum: a predator-prey theory of aquatic production*. Columbia University Press.

2.3 SOCIOECONOMICS

This section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of the Fishery Ecosystem Plan for the Marianas Archipelago (Western Pacific Regional Fishery Management Council, 2016). It meets the objective "Support Fishing Communities" adopted at the 165th Council meeting; specifically, it identifies the various social and economic groups within the region's fishing communities and their interconnections. The section begins with an overview of the socioeconomic context for the region, and then provides a summary of relevant studies and data for CNMI and Guam, followed by summaries of relevant studies and data for each fishery in CNMI and Guam.

In 1996, the Magnuson-Stevens Fishery Conservation and Management Act's National Standard 8 (NS8) specified that conservation and management measures take into account the importance of fishery resources to fishing communities, to provide for their sustained participation in fisheries and to minimize adverse economic impacts, provided that these considerations do not compromise the achievement of conservation. Unlike other regions of the U.S., the settlement of the Western Pacific region was intimately tied to the sea (Figure 10), which is reflected in local culture, customs, and traditions.

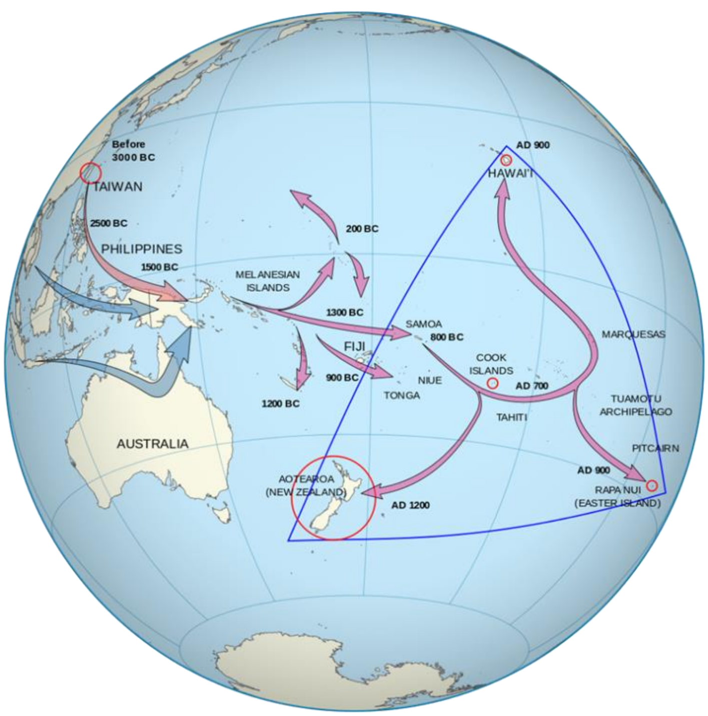


Figure 10. Settlement of the Pacific Islands, courtesy of Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg.

Polynesian voyagers relied on the ocean and marine resources on their long voyages in search of new islands, as well as in sustaining established island communities. Today, the population of the region also represents many Asian cultures from Pacific Rim countries, which reflect similar importance of marine resources. Thus, fishing and seafood are integral local community ways of life. This is reflected in the amount of seafood eaten in the region relative to the rest of the United States, as well as the language, customs, ceremonies, and community events. Because fishing is such an integral part of the culture, it is difficult to discern commercial from non-commercial fishing as most trips involving multiple motivations and multiple uses of the fish caught. While economics are an important consideration, fishermen report other motivations, such as customary exchange, as being equally important. Due to changing economies and westernization, recruitment of younger fishermen has become a concern for the sustainability of fishing and fishing traditions in the region.

The Marianas Archipelago consists of the Commonwealth of the Northern Mariana Islands (CNMI) at the northern end and Guam, the southernmost island. These are typically treated as two jurisdictions, which will be presented separately in the rest of this section despite being grouped under one FEP.

2.3.1 Response to Previous Council Recommendations

At its 165th meeting held in Honolulu, Hawaii, the Council approved modifications to the FEP objectives, one of which was to identify the various social and economic connectivity within the U.S. Western Pacific region's fishing communities; this objective is met in this section.

At its 166th meeting held in Tumon, Guam, the Council recommended that the NMFS Pacific Islands Fisheries Science Center (PIFSC) conduct an economic survey in the CNMI to determine differences in expense and expenditure in fisheries of the Mariana Archipelago (e.g. between Saipan, Tinian, Rota, and Guam) to determine if differences between the islands and their fisheries are apparent. The Council also recommended that NMFS PIFSC design and implement a socioeconomic survey to determine impacts of increased recent development in the CNMI in the form of new hotels and casinos in Saipan. A small-boat cost-earnings survey is scheduled for the Marianas in 2018 and 2019 that will look to address both of these recommendations.

In addition, the Council directed staff to develop a brief report identifying data sources, quality, and coverage for each required socioeconomic parameter in the annual/SAFE reports, as resources permit. This report should also identify the quality and coverage of this data, as well as any gaps. This data synthesis was conducted and used to guide the development of this chapter.

The Council also directed the Plan Team for future Annual SAFE Reports:

- To include the human perspective, the importance of the community, and the extended cultural and social values of fishing in the dashboard summary format. This section is the first effort at including the importance of community and the extended cultural and social values of fishing into an annual SAFE report in this region.
- To break out trip costs by island for the CNMI, as trip costs vary across islands. This chapter provides a reference to existing data on island-specific trip costs.
- To explore partnering with the CNMI Department of Commerce on efforts to address socioeconomic data gaps in the CNMI SAFE/annual report. The CNMI Department of

Commerce Statistical Yearbook data is displayed in this section. Information on fishing as an occupation is only reported in aggregate with farming and forestry. In addition, fishing in CNMI is a continuum of commercial to non-commercial activities that many do not consider a profession. For these reasons, occupational information was not included in this section. The other section relevant to fishing summarizes the amounts and values of commercial fish landings, which is already reported by PIFSC. In addition, the yearbook has not directly received new data on fish and fisheries since 2004.

- To include enhanced information on social, economic, and cultural impacts of a changing climate and increased pressure on the ocean and its resources, PIFSC developed a Regional Action Plan and Climate Science Strategy as a first step in providing this information (Polovina *et al*., 2016).

2.3.2 CNMI

2.3.2.1 Introduction

An overview of CNMI history, culture, geography, and relationship with the U.S. is described in the Fishery Ecosystem Plan for the Mariana Archipelago (Western Pacific Regional Fishery Management Council, 2016). Over the past decade, a number of studies have synthesized more specifics about the role of fishing and marine resources across CNMI, as well as information about the people who engage in the fisheries or use fishery resources.

The ancestors of the indigenous Chamorros first arrived in the Marianas around 3,500 years ago and relied on seafood as their principal source of protein (Allen and Amesbury, 2012, and Grace McCaskey, 2014). Similar to other archipelagos in the Western Pacific, fish and marine resources have played a central role in shaping the social, cultural, and economic fabric of the CNMI that continues today. They fished for both reef and pelagic species, collected mollusks and other invertebrates, and caught sea turtles. The occupation of CNMI by foreign nations dramatically changed the island's ecosystems, reshaped communities, and disrupted fishing traditions. In the 17^{th} and 18^{th} centuries, Spanish colonizers destroyed the Chamorros' seagoing canoes, suppressed offshore fishing practices, and relocated populations from their traditional home. The CNMI was briefly occupied by Germany from 1899 to the beginning of WWII. During WWII, the CNMI was occupied by the Japanese military, and then was captured by the United States. Throughout this time, fishing has remained an important activity. Later immigrants to the islands from East and Southeast Asia also possessed a strong fishing tradition. Today, only Saipan, Rota, and Tinian are permanently inhabited, with 90% of the population living on the island of Saipan.

2.3.2.2 People who Fish

Allen and Amesbury (2012) summarized results of studies that demonstrated the sociocultural importance of fishing to Saipan residents. In a 2005 study, most of the active or commercial fishermen who responded to the survey had fished for more than 10 years. They most often participated in snorkel spearfishing at night (participated in by 73% of the fishermen) and snorkel spear fishing during daytime (58% of the fishermen), followed by hook-and-line less than 100 ft. deep (36%), trolling (21%), cast net (talaya; 14%), hook-and-line more than 100 ft. deep (9%), trapping (octopus, crabs, etc.; 19%), and foraging the reef (8%); 18% said they participated in one or more other techniques. Less than a third (~30%) said they owned a boat.

The primary reasons for fishing were social, cultural, and nutrition; in addition to reporting that they enjoy the activity itself (32%), many said they needed the fish to feed their family (23%), give to family and friends to strengthen social bonds (13%), that their family has always fished (12%), and that it strengthens bonds with their children/family (6%). Only 4% said they needed the money from the fish they sold. Other motivations included strengthening the bond with their fellow fishermen, fishing to catch fish for festivals and parties, and seasonal fishing for manahak, ti'ao, and i'e (2% each).

The fishermen reported fishing an average of 71 days per year, with 26% going once every two to three days, and 24% fishing once every two weeks. Those surveyed also reported a decrease in the amount of time they have spent fishing in the past decade, fishing 93 days per year on average. Saipan reef fish were the most frequently harvested species (caught by 54% of the fishermen), followed by shallow-water bottomfish (23%) and reef invertebrates such as octopus, shellfish and crabs (14%).

As in other parts of the region, much of the fisher's catch in the CNMI was consumed by themselves and their immediate family (70%), with another 20% consumed by extended family and friends. Only 8% of the catch was sold. There were 18 respondents that identified themselves as commercial fishermen. They reported a median monthly income of $200 from fishing, with average montly income of just over $1,000. Costs exceeded sales for almost every income category for fishermen, suggesting that fishing is not a business for most, but that catch is simply sold to cover some of the cost.

While fish remain an important part of the local diet and an integral part of the people's history and culture, adaptation to and integration with a more westernized lifestyle appears to have changed people's dietary preferences on Saipan. Nearly half (45%) of the survey respondents reported eating "somewhat less fish" than they did a decade ago, although the majority still ate fish between one and three times a week. The majority also purchased their fish from a store or restaurant (40%), while 31% purchased fish from roadside vendors. Less common was acquiring fish from an extended relative/friend (13%) or their own catch (11%). Most of the fish consumed came from the U.S. mainland (41%), with other important sources coming from Saipan's coral reefs (31%), deepwater or pelagic fish caught off of Saipan (23%), or fish imported from other Pacific islands (e.g. chuuk ; 10%).

Few other surveys have been conducted on fishing in the CNMI. A household survey conducted in 2012 found that 37% of households had at least one individual that self-identified as a fisherman (Kotowicz and Allen, 2015). Respondents from fishing households tended to be younger, possess lower education levels, and have a higher rate of unemployment than respondents from non-fishing households.

While proportionally few residents own a boat, more than 400 vessels were registered in the CNMI small boat fleet between 2010 and 2011 (Allen and Amesbury, 2012). More than 200 of the vessels were active and operating in CNMI waters at that time, and more than 100 of the vessels were involved in fishing activities. The active small boat fleet targeted tunas, other small pelagics (through trolling), and bottomfish; with the increase in gas prices, however, pelagic fishing has waned. When caught, these fish are marketed locally, given away to family and friends, or used for ceremonial purposes such as parties, culturally significant fiestas, and the patron saint's days for each village.

On Saipan, fisheries managers estimated the active small boat fleet at approximately 100 vessels from 2010 to 2011. Full-time commercial fishing is primarily conducted by ethnic nonindigenous minorities, namely Filipino residents that fish primarily as independent owners and/or operators and recent immigrants from the Federated States of Micronesia that fish for income. Chamorro and Carolinians, in contrast, primarily fish for recreational and subsistence purposes, typically only selling catch to recoup costs. A few vessel owner operators are considered "pescadors", a term used to refer to fishermen who provide fish for important community and familial events. Pescadors customarily provide 100-200 lbs. of reef fish for cooked dishes and pelagic species for kelaguen (a raw fish dish) used in community and family celebrations. The system of seafood distribution underwent significant changes from approximately the turn of the century with the establishment of large seafood vendors. In contrast to individual fishermen/vendors who only market their own catch, large vendors typically own and operate a number of vessels and purchase catch from independent fishermen to sell. This trend has reportedly caused prices to decline. In addition, increases in fuel prices, low market prices for fish, and downturns in the domestic economy have led to a general decline in participation in this fishery since 2000 in numbers of fishermen, trips, landings, and seafood purchasers. The Saipan Fishermen's Association (SFA) is a nonprofit organization established in 1985 that holds annual fishing derbies and participated in community involvement projects, such as beach cleanup.

On Tinian, estimates of fleet size range from 15 to 20 vessels in 2010-2011. An estimated one to three fishermen fished consistently with the primary intent of selling fish. Respondents suggested that fishing and eating of fish was more habitual, rather than geared toward a particular event. Increasing fuel prices have reportedly led to the decline in number of active fishermen, and fishermen frequently have sold fish to cover fuel costs. Three restaurants and two stores in Tinian purchase fish, although fishermen have also resorted to selling house-to-house; the fishmen commonly have an established clientele. A few charter boats serve tourist clientele, however they do not land much catch, and even trolling trips serve more as photo opportunities. Charter boats are reportedly owned by non-local residents and target tourists by their country of origin (e.g. Japan, China, or Korea).

On Rota, fishermen target pelagic species when in season and bottomfish the rest of the year. Like on the other islands, the number and activity of fishermen have declined as a result of increased fuel prices. Family members will often make requests for certain kinds of fish, but they will also contribute money to purchase fuel for a fishing trip. In addition, fishermen will often check demand with local restaurants. In 2010 and 2011, fishermen sold catch to three separate restaurants or to neighbors and friends within the community (door-to-door or from a cooler on the roadside). One general store sold fish caught by a family member, who fished specifically to sell to that store. Rota holds one fishing derby in celebration of San Francisco, the saint of the island.

A survey of the small boat fleet was also conducted in 2011 (Hospital and Beavers, 2014). Respondents were 41 years old and had been boat fishing for 15 years on average, providing evidence of a deep tradition of boat fishing in the CNMI. They were more likely to identify themselves as Chamorro relative to the general population of the CNMI, although they were equally likely to have been born in the CNMI. In general, fishermen were more educated then the general population and of comparable affluence. Pelagic trolling was the most popular gear type, followed by deepwater bottomfising, shallow-water bottomfishing, and spearfishing. Most fishermen (71%) reported fishing adjacent to a Fish Aggregating Device (FAD) at some point in the past 12 months, and did so on nearly 22% of their fishing trips. A high degree of seasonal fishing effort was reported across most fishing fleet subgroups, though fishermen on Tinian and Rota were more likely to fish year-round than those on Saipan.

A majority of fishermen (74%) reported selling at least a portion of their catch in the past year. However, less than half of survey respondents (43%) indicated that they could always sell any fish that they wanted. A significant percentage of fish caught was consumed at home (28%) or given away to relatives, friends, or for cultural events (38%); this reflects the strong family and social connections associated with fishing in the CNMI. Approximately 29% of fish catch was sold, with the remaining catch either released (2%) or exchanged for goods and services (3%). Even fishermen who regularly sold fish still retained approximately 22% of their catch for home consumption, participation in traditional fish-sharing networks, and customary exchange. Additionally, 91% of survey respondents considered the bottomfish they catch to be an important source of food, and 93% considered the reef fish to be similarly importnat. These findings validate the significance of fishing in building and maintaining social networks, perpetuating fishing traditions, and providing fish to local communities as a source of food security.

Fishing in the CNMI is a social activity; only 3% of fishermen reported to fish alone, but 70% reported that their boat is used without them on occasion. In addition, the majority of fishermen (57%) agreed that, as a fisherman, they are respected by the greater community. Nearly a third of respondents were neutral (27%) regarding this sentiment, while some were hesitant to express an opinion or simply did not know (13%). The study found that very few fishers (3%) felt that they were not respected by the community.

The designation of the Marianas Trench Marine National Monument (the Monument) in 2009 has resulted in concerns about loss of fishing access (Richmond and Kotowicz, 2015; Kotowicz and Richmond, 2013; Kotowicz and Allen, 2015; and Kotowicz *et al*., 2017). Despite long distance, high cost, and inconvenience, travel to the areas now protected by the Monument were rare but culturally significant events, and fishing was an essential component. While CNMI residents generally supported designation of the monument, awareness was low regarding specific impacts (Kotowicz *et al*., 2017). In addition, fishing households showed higher awareness of the Monument, but were less likely to strongly support it.

Overall, the CNMI small boat fisheries are a mix of subsistence, cultural, recreational, and quasi-commercial fishermen whose fishing behaviors provide evidence of the importance of fishing to the people of the CNMI. For nearly all fishery participants, the social and cultural motivations for fishing far outweigh economic prospects. Nearly all fishermen supplement their income with other jobs and are predominantly subsistence fishermen.

2.3.2.3 CNMI Bottomfish

Bottomfish was one of the gear types included in the 2011 Small Boat Survey (Hospital and Beavers, 2014). Overall fisher demographics and catch disposition were summarized in the previous section. Approximately 68% of respondents reported fishing for deepwater bottomfish and 65% for shallow-water bottomfish; additionally, 41% identified deepwater bottomfish as their primary target, and 49% identified shallow-water bottomfish as their primary target. Approximately 37% of trips included some form of bottomfishing. In general, deepwater bottomfishing appeared to be associated with more commercially-motivated fishermen. Fishers who primarily targeted bottomfish sold over half of their catch (52%) to friends, neighbors, and co-workers. Some self-identified primarily as subsistence fishers (58% selected this category) and recreational expense fishers (41%), although respondents spanned all response categories (full-time commercial, part-time commercial, recreational expense, purely recreational, subsistence, and cultural). Nearly half identified multiple motivations (49%).

2.3.2.3.1 Commercial Participation, Landings, Revenue, Prices

This section will describe trends in commercial pounds sold, revenue, and prices, as data allows, for the CNMI bottomfish fishery. Supporting figures and tables will be added in future reports.

2.3.2.3.2 Costs of Fishing

Since 2009, PIFSC economists have maintained a continuous economic data collection program on Saipan through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). The economic data collection program gathers fishing expenditure data for boat-based reef fish, bottomfish, and pelagic fishing trips on an ongoing basis. Data for fishing trip expenses include; gallons of fuel used, price per gallon of fuel, cost of ice used, cost of bait & chum used, cost of fishing gear lost, and the engine type of the boat. These economic data are collected from same subset of fishing trips as the boat-based creel survey carried out by the local fisheries management agencies and WPacFIN. These data are currently under PIFSC editorial review and future versions of this report will include a time-series of Saipan boat-based trip costs by target species and/or gear. Metadata for these data are available online (PIFSC Socioeconomics Program, 2016). Island-specific (Saipan, Tinian, and Rota) trip cost estimates for bottomfish fishing trips are available only for 2011 in Hospital and Beavers (2014). Other relevant cost information in Hospital and Beavers (2014) include estimates of annual fishing expenditures (fixed costs) and levels of investment in the fishery.

The trip cost data presented in this section were collected through the continuous economic data collection program on Saipan through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). Figure 11 shows the trend of average trip costs for CNMI bottomfish trips during 2009–2017 (adjusted to 2017 dollars). Supporting data of Figure 11 are presented in Table 59. **Error! Reference source not found.**The trip costs seem to have substantial interannual variability. The average costs for a bottomfish trip was $38 in 2017.

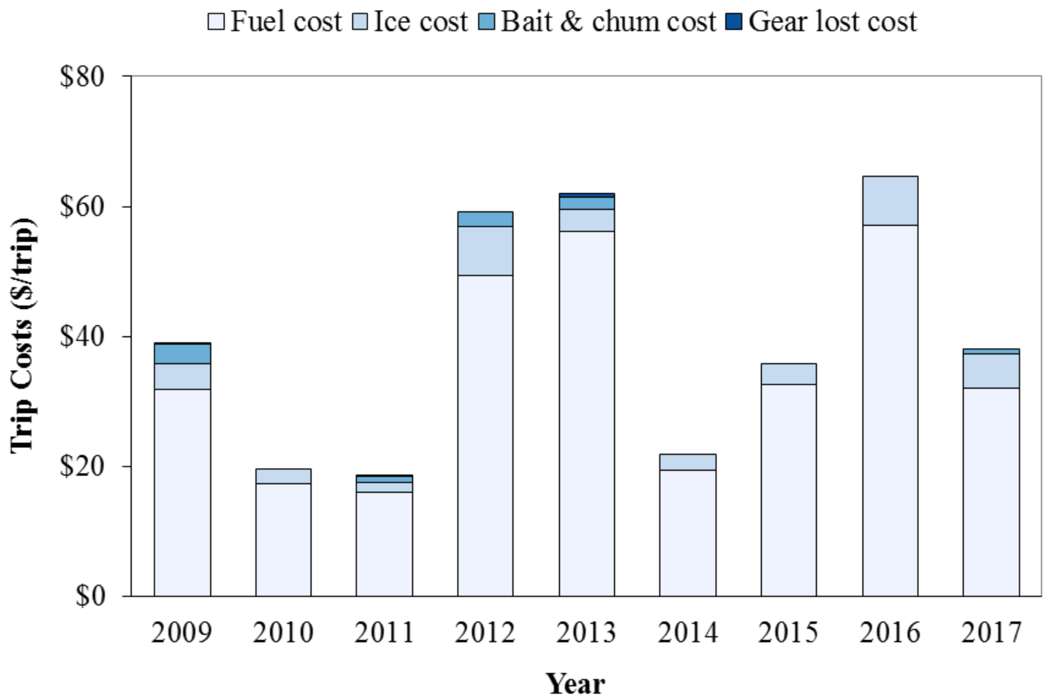


Figure 11. Average costs for CNMI bottomfish trips, 2009–2017, adjusted to 2017 dollars.

Table 59. Average costs for CNMI bottomfish trips, 2009–2017, adjusted to 2017 dollars.

Year	Total trip costs ($)	Total trip costs ($ adjusted)	Fuel cost ($)	Fuel cost ($ adjusted)	Ice cost ($)	Ice cost ($ adjusted)	Gear losted cost ($)	Gear losted cost ($ adjusted)	Bait & chum cost ($)	Bait & chum cost ($ adjusted)	CPI adjustor
2009	37	39	30	32	4	4	0.13	0.1	3	3	1.053
2010	20	20	17	17	2	2	0.00	0.0	0	0	0.998
2011	19	19	16	16	2	2	0.10	0.1	1	1	0.976
2012	61	59	51	49	8	8	0.00	0.0	2	2	0.965
2013	63	62	57	56	3	3	0.59	0.6	2	2	0.990
2014	22	22	20	19	3	3	0.00	0.0	0	0	0.979
2015	35	36	32	33	3	3	0.00	0.0	0	0	1.021
2016	65	65	57	57	8	8	0.00	0.0	0	0	1.000
2017	38	38	32	32	5	5	0.00	0.0	1	1	1.000

Data source: Chan and Pan (2018, *in review*).

2.3.2.4 CNMI Crustaceans

There are currently no socioeconomics data specific to the crustacean fishery. Future reports will include new information as resources allow.

2.3.2.5 CNMI Reef Fish

Coral reef fish were also included in the 2011 small boat survey (Hospital and Beavers, 2014). Unsurprisingly, fishermen targeting reef fish, on average, were slightly younger than others, likely due to the physical requirements of reef fishing. Approximately 54% of respondents reported atulai fishing, 50% reported spearfishing, and 12% reported net fishing. Atulai was identified as the primary choice by 46% of fishermen, while 38% indicated spearfishing was preferable, and 14% net fishing as their primary gear type. Fishers who primarily targeted reef fish sold almost half of their catch (45%) to friends, neighbors, and co-workers. They self-identified primarily as subsistence fishers (44%) and cultural fishers (38%), although respondents spanned all response categories (full-time commercial, part-time commercial, recreational expense, purely recreational, subsistence, and cultural). Over one-third identified multiple motivations (38%).

In addition to playing an important role in subsistence and cultural fishing, coral reef ecosystems of Saipan only have been estimated at a value of $61 million, 70% of which is accounted for by tourism (Grace McCaskey, 2014).

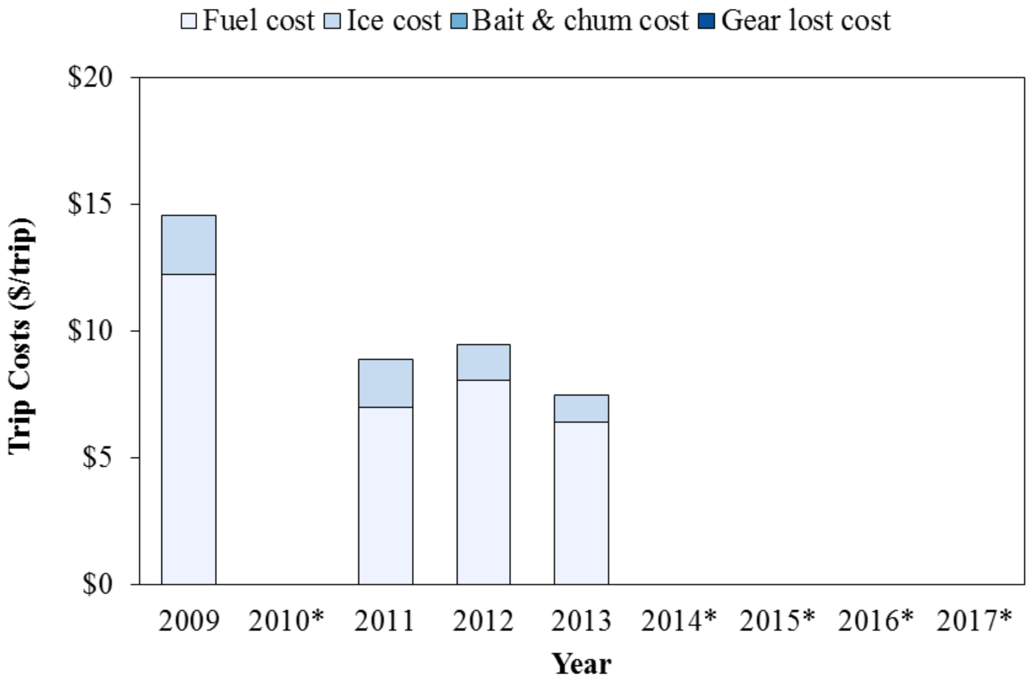
2.3.2.5.1 Commercial Participation, Landings, Revenue, Prices

This section will describe trends in commercial pounds sold, revenue, and prices, as data allows, for the CNMI bottomfish fishery. Supporting figures and tables will be added in future report.s

2.3.2.5.2 Costs of Fishing

Since 2009, the PIFSC Socioeconomics Program has maintained a continuous economic data collection program on Saipan through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). The economic data collection program gathers fishing expenditure data for boat-based reef fish, bottomfish, and pelagic fishing trips on an ongoing basis. Data for fishing trip expenses include: gallons of fuel used, price per gallon of fuel, cost of ice used, cost of bait and chum used, cost of fishing gear lost, and the engine type of the boat. These economic data are collected from same subset of fishing trips as the boat-based creel survey carried out by the local fisheries management agencies and WPacFIN. These data are currently under PIFSC editorial review and future versions of this report will include time-series of Saipan boat-based trip costs by target species and/or gear. Meta-data for these time series are available online (PIFSC Socioeconomics Program, 2016). Island-specific trip cost estimates for reef fishing trips are available only in 2011 from Hospital and Beavers (2014). Other relevant cost information from Hospital and Beavers (2014) includes estimates of annual fishing expenditures (fixed costs) and levels of investment in the fishery.

The trip cost data presented in this section were collected through the continuous economic data collection program on Saipan in collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). Figure 12**Error! Reference source not found.** shows the trend of average trip costs for CNMI coral reef fish fishing trips during 2009–2017 (adjusted to 2017 dollars). Only four years are available with data over the past decade due to limited observations in fishing cost data collections. Supporting data for Figure 12 are listed in Table 60.



*Trip cost data are not presented since the observations for those years were less than 3.

Figure 12. Average cost for CNMI spearfishing trips, 2009–2017, adjusted to 2017 dollars.

Table 60. Average costs for CNMI bottomfish trips, 2009–2017, adjusted to 2017 dollars.

Year	Total trip costs ($)	Total trip costs ($ adjusted)	Fuel cost ($)	Fuel cost ($ adjusted)	Ice cost ($)	Ice cost ($ adjusted)	Gear losted cost ($)	Gear losted cost ($ adjusted)	Bait & chum cost ($)	Bait & chum cost ($ adjusted)	CPI adjustor
2009	14	15	12	12	2	2	0	0	0	0	1.053
2010*	-	-	-	-	-	-	-	-	-	-	0.998
2011	9	9	7	7	2	2	0	0	0	0	0.976
2012	10	9	8	8	1	1	0	0	0	0	0.965
2013	8	7	6	6	1	1	0	0	0	0	0.990
2014*	-	-	-	-	-	-	-	-	-	-	0.979
2015*	-	-	-	-	-	-	-	-		-	1.021
2016*	-	-	-	-	-	-	-	-	-	-	1.000
2017*	-	-	-	-	-	-	-	-	-	-	1.000

*Trip cost data are not presented since the observations for those years were less than 3.
Data source: Chan and Pan (2018, *in review*).

2.3.2.6 CNMI Precious Corals

There are currently no socioeconomic data specific to this fishery. Future reports will include new information as resources allow.

2.3.3 Guam

2.3.3.1 Introduction

An overview of Guam's history, culture, geography, and relationship with the U.S. is described in the Fishery Ecosystem Plan for the Mariana Archipelago (Western Pacific Regional Fishery Management Council, 2016b). Guam is the largest and southernmost island of the Mariana Archipelago, and is also the largest and most heavily populated island in Micronesia. Over the past decade, a number of studies have synthesized more details about the role of fishing and marine resources for residents of Guam, as well as information about the people who engage in the fisheries and/or utilize fishery resources.

The ancestors of the indigenous Chamorros first arrived in the Marianas around 3,500 years ago, and were expert fishermen and seafarers, relying on seafood as their principal source of protein (Allen and Bartram, 2008; Grace McCaskey, 2014; Hospital and Beavers, 2012). They fished on the high seas in large sailing canoes (proas) and used numerous methods to catch reef and bottomfish from boats. Similar to other archipelagos in the Western Pacific, fish and marine resources have played a central role in shaping the social, cultural, and economic fabric of Guam that continues today. Chamorros fished for both reef and pelagic species, collected mollusks and other invertebrates, and caught sea turtles.

The occupation of Guam by foreign nations dramatically changed the island's ecosystems, reshaped communities, and disrupted fishing traditions. In the 17th and 18th centuries, Spanish colonizers destroyed the Chamorros' seagoing canoes, suppressed offshore fishing practices, and relocated populations from their traditional home. Following the Spanish-American War in 1898, the U.S. Navy took control of Guam until it was occupied by Japan from 1941-1944. Guam became a U.S. territory in 1950, and the U.S. military is currently in the process of building up an even greater presence on the island. Throughout this time, fishing has remained an important activity, although by the time Guam became and American territory, the indigenous inhabitants had lost many of their seafaring skills, fishing skills, and even the native names of many of the offshore species. Later immigrants to the islands from East and Southeast Asia also possessed a strong fishing tradition. In 2000, 37% of Guam's population that identified as a single ethnicity were Chamorro, followed by 32% Asian (about 80% of whom were Filipino), 17% other Pacific Islander, 7% white, and 1% black. Despite rapid socioeconomic change, households still reflect the traditional pattern of extended families with multigenerational clustering of relatives, especially in Guam's southern villages. Social occasions such as neighborhood parties, wedding and baptismal parties, wakes and funerals, and especially village fiestas that follow the religious celebrations of village patron saints all require large quantities of fish and other traditional foods, reflecting the role of fish in maintaining social ties and cultural identities. Sometimes fish are also sold to earn money to buy gifts for friends and relatives on important Catholic religious occasions such as novenas, births and christenings, and other holidays.

Since the late 1970s, Guam's most important role in commercial fisheries activity has been as a major regional fish transshipment center and resupply base for domestic and foreign tuna fishing fleets. Services provided include fueling, provisioning, unloading, air and sea transshipment, net and vessel repair, crew repatriation, medical care, and warehousing. Among Guam's advantages as a home port are: well-developed and highly efficient port facilities in Apra Harbor, an availability of relatively low-cost vessel fuel, a well-established marine supply/repair industry, and recreational amenities for crew shore leave. In addition, the territory is exempt from the Nicholson Act, which prohibits foreign ships from landing their catches in U.S. ports. Initially, the majority of vessels calling in Apra Harbor to discharge frozen tuna for transshipment were Japanese purse seine boats and carrier vessels. In the late 1980s, Guam became an important port for Japanese and Taiwanese longline fleets, but port calls have steadily declined and the transshipment volume has declined accordingly. By the early 1990s, an air transshipment operation had also been established on Guam. Fresh tuna was flown into Guam from the Federated States of Micronesia and elsewhere on air cargo planes and out of Guam to the Japanese market on wide-body passenger planes. Further, vessels from Japan and Taiwan also landed directly into Guam, where their fish were packed and transshipped by air to Japan. A second air transshipment operation began in the mid-1990s that was transporting fish to Europe that did not meet Japanese sashimi market standards, but this has since ceased. Moreover, the entire transshipment industry has contracted markedly with only a few operators still making transshipments to Japan. Annual volumes of tuna transshipped of between 2007 and 2011 averaged about 3,400 mt, with a 2012 estimate of 2,222 mt, compared to over 12,000 mt at the peak of operations between 1995 and 2001. As early as 2006, it was noted that the Port of Guam had lost much of its competitive advantage compared to alternative transshipment locations in the western Pacific and elsewhere, a trend that may not be reversible.

Otherwise, commercial fisheries have a relatively minor contribution to Guam's economy; the social and cultural importance of fisheries in Guam dwarfs their commercial value. Nearly all Guam domestic fishermen hold jobs outside the fishery, with fishing typically supplementing family subsistence. High value is placed on sharing one's fish catch with relatives and friends, and this social obligation extends to part-time and full-time commercial fishermen alike. A survey of Guam households in 2005 found that nearly one-quarter (24%) of fish consumed were caught by the respondent or an immediate family member, and an additional 14% were caught by a friend or extended family member (Allen and Bartram, 2008). However, a little more than half (51%) of the fish consumed were purchased at a store or restaurant, and 9% were purchased at a flea market or from a roadside stand. The same study found that annual seafood consumption in Guam is estimated to be about 60 lbs. per capita, with approximately 43% imported from the U.S.

The westernization of Guam, particularly since World War II, has not only resulted in a transition from a subsistence to wage-based economy, but has also contributed to dramatic changes in eating patterns, including lower seafood consumption. Indeed, recent years have seen steady declines in the market demand for fresh local fish across Guam (Hospital and Beavers, 2012). While some families continue to supplement their diet by fishing and farming, no existing communities are completely dependent on local fishing as a source of food. A household survey conducted in 2016 found that only 29% of respondents participate in fishing (National Coral Reef Monitoring Program, 2016a).

Allen and Bartram (2008) reviewed the history of shoreline and inshore fishing on Guam. They noted that the number of people engaged in shore fishing in the 1970s was surprisingly large, given that about 90% of the food consumed on the island was imported. A study conducted in 1975 found that 65% of households reported some participation in fishing, which was presumably shore-fishing as a result of the low level of boat ownership at the time. Creel surveys conducted by the Guam DAWR indicated that CPUE in Guam's shore-based fisheries for reef fish (pole, spear, cast net, surround net, and gill net) declined sharply in the 1980s and had not recovered by 2008. Offshore (boat-based) catches of reef-associated fish were relatively constant between1992 and 2008, whereas inshore catches that accounted for the majority of the reef fish harvest during the 1990s comprised a minority of the total harvest by 2008. Much of the traditional harvest targets seasonal runs of juvenile rabbitfish, goatfish, bigeye scad (atulai, *Selar crumenophthalmus*), and jacks (i'e, family Carangidae). A study in 2007 estimated that Guam's coral reef resources were valued at close to $127 million annually, primarily driven by the island's important tourism industry (Grace McCaskey, 2014). Nearly 1.2 million people visited Guam in 2010, many of them attracted by reef-related activities, such as snorkeling and scuba diving.

As recently as the early 1970s, relatively few people from Guam fished offshore because boats and deep-sea fishing equipment were prohibitively expensive (Allen and Bartram, 2008). During the economic boom from the late-1980s through most of the 1990s, Guam developed a small boat fishery that conducted trolling and bottomfishing mostly within 30 miles of shore.

The Guam Fishermen's Cooperative Association (GFCA) plays an important role in preserving important fishing traditions. It began operations in 1976 and was incorporated in 1977. In 2006, its membership included 164 full- and part-time fishermen from every district on Guam, and it processed and marketed approximately 80% of the local commercial catch. In addition, it plays a role in fisheries data collection, marine education and training, and fisheries conservation and management. The GFCA strives to provide benefits not just to fishermen but to residents throughout Guam, benefitting the broader Guam community. It utilizes a Hazard Analysis and Critical Control Point (HACCP) system to ensure safe seafood, and tests fish for potential toxins or whenever requested by the Guam Department of Health and Sanitation. It has also become a focal point for community activities, such as the Guam Marianas International Fishing Derby, cooking competitions, the Guam Fishermen's Festival, dissemination of educational materials on marine resources, vessel safety, seafood preparation, public meetings on resource management issues, and communications via radio base to relay information and coordinate rescues. It also has adopted a policy of purchasing local origin products that benefits 40 small businesses on Guam, regularly donates seafood for village functions and charitable activities, and provides assistance to victims of periodic typhoons with emergency supplies of ice and fuel. In addition, the GFCA has become a voice for Guam fishermen in the policy arena to ensure that concerns of fishermen are incorporated into relevant issues, including the military buildup and loss of fishing grounds due to establishment of Marine Preserve Areas.

Fishing in Guam continues to be important not only in contributing to the subsistence needs of the Chamorro and other residents, but also in preserving their histories and identities. Knowledge of how fish are distributed and consumed locally is crucial to understanding the social and cultural significance of fishing on Guam.

2.3.3.2 People who Fish

Few studies have been conducted on fishing in Guam in general. A household survey conducted in 2012 found that 35% of respondents said that they or someone else in their household was a fisherman (Kotowicz and Allen, 2015). Respondents from fishing households tended to have lower education levels and have a higher rate of unemployment than respondents from non-fishing households.

As described in Allen and Bartram (2008), in 1999, a detailed study of the inshore fishing behaviors and spatial patterns was conducted for the three largest resident fishing cultures on Guam: Chamorro, Micronesian, and Filipino. At that time, Chamorros comprised about 75% of the fishing parties encountered, while Micronesians constituted about 17% and Filipinos about 7%. A number of contemporary reef fishing methods on Guam were observed, including gleaning, hand line, rod and reel, talaya (cast net), tekken (gill net), chenchulu (surround net), and spearfishing. Explicit rules governing permanent marine ownership were not observed, but Chamorro fishermen maintained a strong identification with village and municipal space. This village relationship included the reef during the early part of the 20th century but that has since largely disappeared. Instead, a system of “pliant tenure” (a vestige of traditional marine tenure) was recognized; while any reef area is publicly accessible, fishermen act according to a system of temporary ownership or pliant tenure of reef area. These rules were understood and incorporated by Chamorro and immigrant fishers alike. Respondents voiced concern about the loss of fishing grounds through designation of marine reserves and tourist watercraft activities. They viewed reduced coastal access as threatening the perpetuation of cultural identity and practice by reducing ability to teach and practice traditions such as communal harvests and distribution of the catches, which reinforce family cohesion and communal identity. These practices have been further jeopardized by the build-up of U.S. military personnel and families in recent years.

In the mid-1980s Guam fisheries were characterized as including (1) a small number of true commercial fishermen, (2) subsistence/recreational fishermen who regularly sell part of their catch, (3) a large number of subsistence fishermen who rarely sell any of their catch, and (4) a substantial number of recreational fishermen. Approximately 60% of catch was non-commercial, with fish sales primarily used to generate revenue to pay for fuel costs. A similar pattern continues in recent years.

In 2011, a survey was conducted of the small boat fleet, which included questions about trolling, bottomfishing, and reef fishing. On average, fishermen responding to the survey were 44 years old and reported to have been boat fishing for an average of 20 years. Respondents were also more educated and more affluent than the general population. The majority of respondents described themselves as Chamorro (72%), followed by white (23%) with relatively small proportions of Filipinos (6%), Micronesians (6%), other ethnicities (5%), and Carolinians (1%) represented. There was considerable evidence of co-ownership and sharing of fishing vessels. In addition, fishermen reported the use of multiple gear types, with pelagic trolling as the most popular gear type followed by shallow-water bottomfish fishing and deepwater bottomfish fishing. Almost all (96%) fishermen reported fishing at a Fish Aggregating Device (FAD) during the past year and on nearly half (53%) of their fishing trips. Fishing for bottomfish and reef fish was highly seasonal compared to pelagics. Whereas over half of the survey respondents (54%) fished all year for pelagics, only 16% fished year-round for bottomfish and reef fish.

Approximately 70% of fishermen reported selling at least a portion of their catch, and 82% could always sell all the fish that they wanted to sell. However, nearly 30% reported that they had not sold any fish in the past year, and nobody reported selling all the fish they caught. Instead, cost recovery was cited as the primary motivation for the sale of fish, with fish sales contributing very little to personal income for the majority of respondents (59%). In fact, 64% of fishermen reporting the sale of fish earned fishing revenues of less than $1,000, which would not cover overall trip expenditures for a year. Sale of pelagic fish contributes to nearly 67% of fishing income, with 20% from bottomfish revenues and the rest from reef fish.

While respondents sold approximately 24% of their total catch, 29% was consumed at home, while 42% was given away. The remaining catch was either released (2%) or exchanged for goods and services (3%). This diversity of catch disposition extends to fishermen who regularly sell fish, as they still retain approximately 30% of their catch for home consumption and participation in traditional fish-sharing networks and customary exchange. Additionally, 78% consider the pelagic fish they catch to be an important source of food, 79% for bottomfish, and 85% for reef fish. These findings validate the importance of fishing in terms of building and maintaining social and community networks, perpetuating fishing traditions, and providing food security to local communities.

Like with CNMI, fishing on Guam is a social activity. Only 7% of fishermen reported fishing alone, and 45% reported that their boat is used without them on occasion. In addition, 61% reported to be a member of a fishing club, association, or group. The majority of fishermen (60%) also agreed that as a fisherman, they are respected by the Guam community. Very few felt that they were not respected by the community.

There was also an open-ended portion of the survey that asked for comments. The two most prevalent themes were that of a rising population and rising fuel costs. Many believed that the expanding population would increase the demand for fish and number of fishermen, yet at the same time, others noted that fuel costs and economic considerations could restrict fishing. In addition, there was concern about the designation of Marianas Trench Marine National Monument, especially since respondents felt that the Marine Preserve Areas established in 1997 had already displaced them from their traditional fishing grounds. Military exercises also affected fishing trips. Other studies have also documented concerns about fishing access related to the designation of the Monument (Richmond and Kotowicz, 2015; Kotowicz and Richmond 2013; and Kotowicz and Allen, 2015). Despite long distance, high cost, and inconvenience, travel to the areas now protected by the Monument were rare but culturally significant events of which fishing was an essemtial component.

Similar to CNMI, Guam's small boat fisheries are a complex mix of subsistence, cultural, recreational, and quasi-commercial fishermen whose fishing behaviors provide evidence of the importance of fishing to the island of the Guam. For nearly all fishery participants, the social and cultural motivations for fishing far outweigh any economic prospects. Nearly all fishermen supplement their income with other jobs and are predominantly subsistence fishermen, selling occasionally to recover trip expenses.

2.3.3.3 Guam Bottomfish

Allen and Bartram (2008) reviewed the history of the bottomfish fishery on Guam, which consists of both shallow- and deep water aspects. They noted that during the 1980s and 1990s, bottomfish fishing was a highly seasonal, small-scale, commercial, subsistence, and recreational fishery. The majority of the participants operated vessels less than 25 ft. long and targeted the shallow-water bottomfish complex because of the lower expenditure and relative ease of fishing close to shore. The commercially-oriented vessels tended to be longer than 25 ft., concentrating effort on the deepwater bottomfish complex. Both deepwater and shallow-water bottomfish are also important target species of the charter fishing fleet, and charter trips accounted for about 15–20% of all Guam bottomfishing trips from 1995 through 2000. In 1998, the charter fleet attracted approximately 3% of visitors to Guam and consisted of a dozen core boats.

Bottomfish was one of the gear types included in the 2011 small boat survey (Hospital and Beavers, 2014). Overall fisher demographics and catch disposition were summarized in the previous section. Approximately 57% of respondents reported fishing for deepwater bottomfish and 59% for shallow-water bottomfish, with 52% identifying deepwater bottomfish as their primary target and 49% identifying shallow-water bottomfish as their primary target. Fishers who primarily targeted bottomfish allocated their catch mainly through the Guam Fisherman's Cooperative Association (55%), or to friends, neighbors, and co-workers (41%). For the most part, they self-identified as recreational expense fishers (40%), cultural fishers (35%), subsistence fishers (35%), purely recreational fishers (30%), though respondents spanned all response categories except full-time commercial (i.e., part-time commercial, recreational expense, purely recreational, subsistence, and cultural). Over half of the respondents identified multiple motivations (54%).

2.3.3.3.1 Commercial Participation, Landings, Revenue, Prices

This section will describe trends in commercial pounds sold, revenue, and prices, as data allows, for the CNMI bottomfish fishery. Supporting figures and tables will be added in future reports.

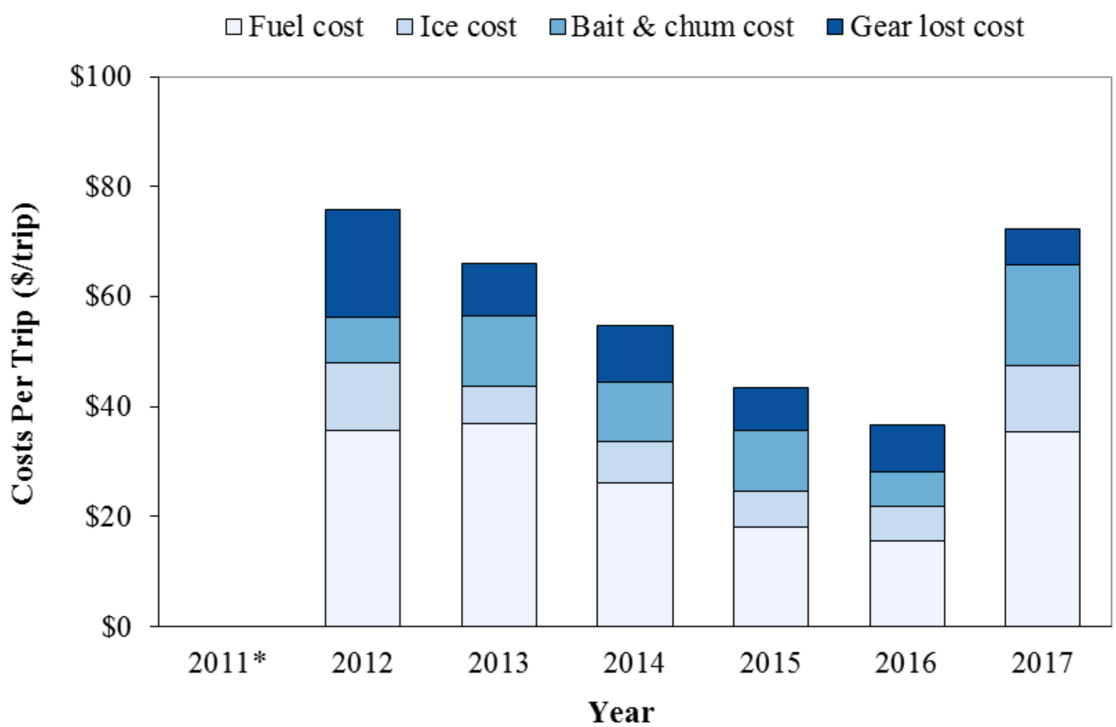
2.3.3.3.2 Costs of Fishing

Since 2011, PIFSC economists have maintained a continuous economic data collection program on Guam through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). The economic data collection gathers fishing expenditure data for boat-based reef fish, bottomfish, and pelagic fishing trips on an ongoing basis. Data for fishing trip expenses include; gallons of fuel used, price per gallon of fuel, cost of ice used, cost of bait & chum used, cost of fishing gear lost, and the engine type of the boat. These economic data are collected from same subset of fishing trips as the boat-based creel survey carried out by the local fisheries management agencies and WPacFIN.

These data are currently under PIFSC editorial review and future versions of this report will include a time-series of Guam boat-based trip costs by target species and/or gear. Metadata for these data are available online (PIFSC Socioeconomics Program, 2016).

Guam trip cost estimates from 2011 for bottomfish fishing trips are also available in Hospital and Beavers (2012). Other relevant cost information in Hospital and Beavers (2012) include estimates of annual fishing expenditures (fixed costs) and levels of investment in the fishery.

The trip costs presented in Figure 13 **Error! Reference source not found.** are based on a continuous economic data collection program maintained by the PIFSC Socioeconomics Program on Guam through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). The fishing costs of bottomfish were in a declining trend from 2012-2016, and it went up substantially in 2017. Supporting data for Figure 13**Error! Reference source not found.** are presented in Table 61**Error! Reference source not found.**.



* The number of boats (respondents) was fewer than 3; due to confidentiality concerns, responses are not presented.

Figure 13. Average trip costs for Guam bottomfish fishing trips from 2009–2017 (adjusted to 2017 dollars).

Table 61. Average trip costs for Guam bottomfish fishing trips from 2009–2017.

Year	Total trip costs ($)	Total trip costs ($) (adjusted)	Fuel cost ($)	Fuel cost ($) (adjusted)	Ice cost ($)	Ice cost ($) (adjusted)	Gear losted cost ($)	Gear losted cost ($) (adjusted)	Bait & chum cost ($)	Bait & chum cost ($) (adjusted)	CPI adjustor
2011*	-	-	-	-	-	-	-	-	-	-	1.120
2012	70	76	33	36	11	12	18	20	8	8	1.086
2013	61	66	34	37	6	7	9	9	12	13	1.085
2014	51	55	24	26	7	7	9	10	10	11	1.077
2015	40	43	17	18	6	7	7	8	10	11	1.087
2016	36	37	15	16	6	6	8	8	6	6	1.025
2017	72	72	35	35	12	12	7	7	18	18	1.000

* The number of boats (respondents) was fewer than 3; due to confidentiality concerns, responses are not presented.
Data source: Chan and Pan, (2018, *in review*).

2.3.3.4 Guam Crustaceans

There are currently no socioeconomic data specific to this fishery. Future reports will include new infromation as resources allow.

2.3.3.5 Guam Reef Fish

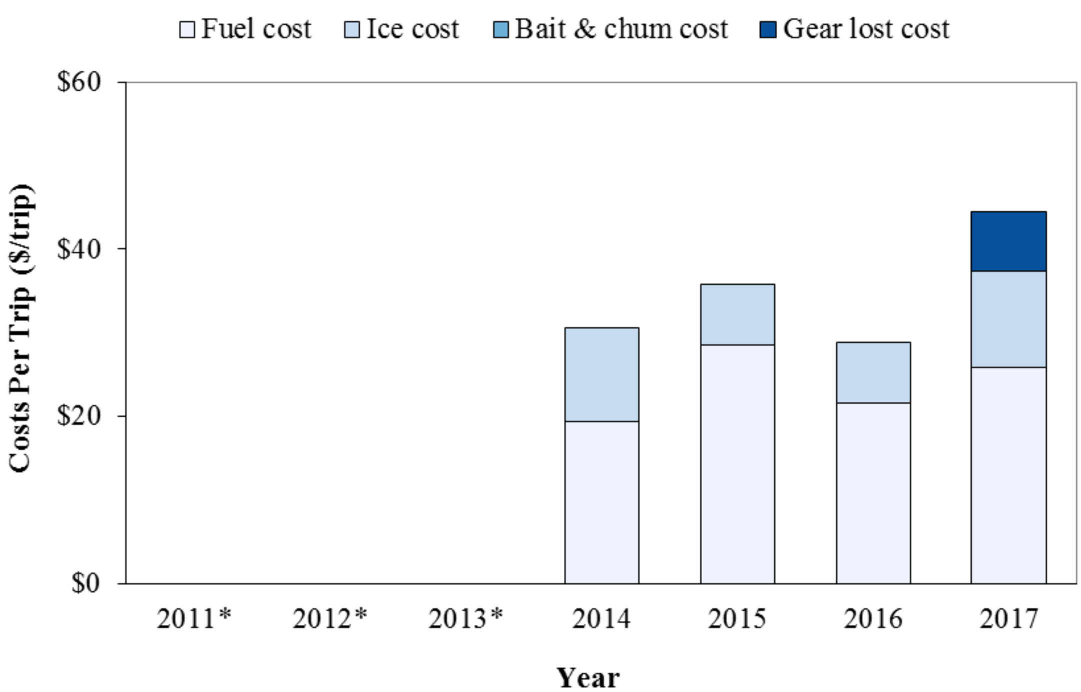
Coral reef fish were also included in the 2011 small boat survey (Hospital and Beavers, 2014). Approximately 33% of respondents reported atulai fishing, 32% spearfishing, and 8% net fishing. Atulai was identified as the primary target by 31%, 20% indicated spearfishing, and 4% indicated net fishing as their primary gear type. Fishers who primarily targeted reef fish sold their catch mainly through the Guam Fisherman's Cooperative Association (37%) or to friends, neighbors, and co-workers (51%). For the most part, respondents self-identified as subsistence fishers (46%), purely recreational fishers (46%), cultural fishers (38.5%), and recreational expense fishers (31%) although respondents spanned all response categories except full-time commercial (i.e., part-time commercial, recreational expense, purely recreational, subsistence, and cultural). Over half of respondents identified multiple motivations (54%).

2.3.3.5.1 Commercial Participation, Landings, Revenue, Prices

This section will describe trends in commercial pounds sold, revenue, and prices, as data allows, for the CNMI bottomfish fishery. Supporting figures and tables will be added in future reports.

2.3.3.5.2 Costs of Fishing

The trip costs presented in Figure 14**Error! Reference source not found.** are based on a continuous economic data collection program maintained by the PIFSC Socioeconomics Program on Guam through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). The fishing costs of coral reef fish fishing trips were in an increasing trend since 2014 to 2017. Supporting data for Figure 14**Error! Reference source not found.** are presented in Table 62**Error! Reference source not found.**.



* The number of boats (respondents) was fewer than 3; due to confidentiality concerns, responses are not presented.

Figure 14. Average trip costs for Guam spear/snorkel trips from 2011–2017 (adjusted to 2017 dollars).

Table 62. Average trip costs for Guam spear/snorkel fish trips from 2011–2017.

Year	Total trip costs ($)	Total trip costs ($) (adjusted)	Fuel cost ($)	Fuel cost ($) (adjusted)	Ice cost ($)	Ice cost ($) (adjusted)	Gear losted cost ($)	Gear losted cost ($) (adjusted)	Bait & chum cost ($)	Bait & chum cost ($) (adjusted)	CPI adjustor
2011*	-	-	-	-	-	-	-	-	-	-	1.120
2012*	-	-	-	-	-	-	-	-	-	-	1.086
2013*	-	-	-	-	-	-	-	-	-	-	1.085
2014	28	31	18	19	10	11	-	-	-	-	1.077
2015	33	36	26	29	7	7	-	-	-	-	1.087
2016	28	29	21	22	7	7	-	-	-	-	1.025
2017	45	45	26	26	12	12	7	7	-	-	1.000

* The number of boats (respondents) was fewer than 3; due to confidentiality concerns, responses are not presented.
Data source: Chan and Pan (2018, *in review*).

2.3.3.6 Guam Precious Corals

There are currently no socioeconomic data specific to this fishery. Future reports will include new information as resources allow.

2.3.4 Ongoing Research and Information Collection

Social indicators are being compiled for the CNMI and Guam in accordance with a national project to describe and evaluate community well-being measured through social, economic, and psychological welfare (https://www.st.nmfs.noaa.gov/humandimensions/social-indicators/index). In addition, a web-based tool is being developed to compile relevant socioeconomic data into a "Community Snapshot" by the Census County Division or equivalent. An update to the CNMI Fishing Community Profile is also in preparation. Efforts are underway to update the 2011 Marianas Archipelago Small Boat Cost-Earnings Survey, and PIFSC hopes to field a new survey in the coming years.

In 2017, an external review of the Economics and Human Dimensions Program was undertaken (PIFSC, 2017). Recommendations will help focus and prioritize a strategic research agenda.

2.3.5 Relevant PIFSC Economics and Human Dimensions Publications: 2017

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Hospital, J. and Beavers, C., 2014. Economic and Social Characteristics of Small Boat Fishing in the Commonwealth of the Northern Mariana Islands. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96818-5007. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-14-02, 58 p.+ Appendices. https://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_14-02.pdf.

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2.4 PROTECTED SPECIES

This section of the report summarizes information on protected species interactions in fisheries managed under the Mariana FEP. Protected species covered in this report include sea turtles, seabirds, marine mammals, sharks, and corals. Most of these species are protected under the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), and/or the Migratory Bird Treaty Act (MBTA). A list of protected species found in or near Mariana Archipelago waters and a list of critical habitat designations in the Pacific Ocean are included in Appendix B.

2.4.1 Indicators for Monitoring Protected Species Interaction

This report monitors the status of protected species interactions in the Marianas FEP fisheries using proxy indicators such as fishing effort, and changes in gear types as these fisheries do not have observer coverage. Creel surveys and logbook programs are not expected to provide reliable data about protected species interactions. Discussion of protected species interactions is focused on fishing operations in federal waters and associated transit through territorial waters.

2.4.2 FEP Conservation Measures

Bottomfish, precious coral, coral reef and crustacean fisheries managed under this FEP have 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 prohibitions benefit protected species by preventing potential interactions with non-selective fishing gear.

2.4.2.1 ESA Consultations

ESA consultations were conducted by NMFS and the U.S. Fish and Wildlife Service (USFWS; for species under their jurisdiction) to ensure ongoing fisheries operations managed under the Marianas FEP are not jeopardizing the continued existence of any listed species or adversely modifying critical habitat. The results of these consultations conducted under section 7 of the ESA are briefly described below and summarized in Table 63.

NMFS concluded in an informal consultation dated April 29, 2015 that all fisheries managed under the Mariana Archipelago FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark or ESA-listed reef-building corals.

In January 2018, oceanic whitetip sharks and giant manta rays were listed under the ESA (83 FR 4153 and 83 FR 2916, respectively). NMFS will reinitiate consultation for those two species for the applicable fisheries if NMFS determines that effects are likely. There is no record of giant manta ray incidental catches in Mariana fisheries, and NMFS is reviewing catch data on oceanic white tip shark incidental catch in these fisheries.

Table 63. Summary of ESA consultations for Mariana Archipelago FEP Fisheries.

Fishery	Consultation date	Consultation type[a]	Outcome[b]	Species
Bottomfish	3/8/2008	BiOp	NLAA	Loggerhead sea turtle

Fishery	Consultation date	Consultation type[a]	Outcome[b]	Species
(CNMI & Guam)	6/3/2008	LOC	NLAA	Green sea turtle, olive ridley sea turtle, hawksbill sea turtle, leatherback sea turtle, blue whale, fin whale, humpback whale, sei whale sperm whale
Coral reef ecosystem (CNMI & Guam)	3/7/2002	LOC	NLAA	Loggerhead sea turtle, leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, sei whale, sperm whale
	5/22/2002	LOC (USFWS)	NLAA	Green, hawksbill, leatherback, loggerhead and olive ridley turtles, Newell's shearwater, short-tailed albatross, Laysan duck, Laysan finch, Nihoa finch, Nihoa millerbird, Micronesian megapode, 6 terrestrial plants
	6/3/2008	LOC	NLAA	Green sea turtle, olive ridley sea turtle, hawksbill sea turtle, leatherback sea turtle, blue whale, fin whale, humpback whale, sei whale, sperm whale
Crustaceans (CNMI & Guam)	9/28/2007	LOC	NLAA	Green sea turtle, loggerhead sea turtle, olive ridley sea turtle, hawksbill sea turtle, leatherback sea turtle, blue whale, humpback whale, sei whale, sperm whale
Precious corals (CNMI & Guam)	10/4/1978	BiOp	Does not constitute threat	Sperm whale, leatherback sea turtle
Precious corals (Guam)	12/20/2000	LOC	NLAA	Humpback whale, green sea turtle, hawksbill sea turtle
All fisheries	4/29/2015	BE & LOC	NLAA	Reef-building corals, scalloped hammerhead shark (Indo-west Pacific DPS)

[a] BiOp = Biological Opinion; LOC = Letter of Concurrence; BE = Biological Evaluation

[b] LAA = likely to adversely affect; NLAA = not likely to adversely affect.

2.4.2.1.1 Bottomfish Fishery

In a Biological Opinion issued on March 8, 2002, NMFS concluded that the ongoing operation of the Western Pacific Region's bottomfish and seamount fisheries was not likely to jeopardize the continued existence of any threatened or endangered species under NMFS's jurisdiction or destroy or adversely modify any critical habitat. In an informal consultation on June 3, 2008, NMFS concluded that Mariana Archipelago bottomfish fisheries are not likely to adversely affects four sea turtle species (leatherback, olive ridley, green, and hawksbill turtles) and five marine mammal species (humpback, blue, fin, sei, and sperm whales).

2.4.2.1.2 Crustacean Fishery

In an informal consultation completed on September 28, 2007, NMFS concluded that Mariana Archipelago crustacean fisheries are not likely to adversely affect five sea turtle species (loggerhead, leatherback, olive ridley, green, and hawksbill turtles) and five marine mammal species (humpback, blue, fin, sei, and sperm whales).

2.4.2.1.3 Coral Reef Fishery

In an informal consultation completed by NMFS on March 7, 2002, NMFS concluded that fishing activities conducted under the Coral Reef Ecosystems FMP are not likely to adversely affect endangered or threatened species or critical habitat under NMFS's jurisdiction. On May 22, 2002, the USFWS concurred with the determination of NMFS that the activities conducted under the Coral Reef Ecosystems FMP are not likely to adversely affect listed species under USFWS's exclusive jurisdiction (i.e., seabirds) and listed species shared with NMFS (i.e., sea turtles).

In an informal consultation completed in June 3, 2008, NMFS concluded that the Mariana Archipelago coral reef fisheries are not likely to adversely affect adversely affects four sea turtle species (leatherback, olive ridley, green, and hawksbill turtles) and five marine mammal species (humpback, blue, fin, sei, and sperm whales).

2.4.2.1.4 Precious Coral Fishery

In a Biological Opinion issued on October 4, 1978, NMFS concluded that the ongoing operation of the Western Pacific Region's precious coral fisheries was not likely to jeopardize the continued existence of any threatened or endangered species under NMFS's jurisdiction or destroy or adversely modify critical habitat. In an informal consultation completed on December 20, 2000, NMFS concluded that Mariana Archipelago precious coral fisheries are not likely to adversely affect humpback whales, green turtles, or hawksbill turtles.

2.4.2.2 Non-ESA Marine Mammals

The MMPA requires NMFS to annually publish a List of Fisheries (LOF) that classifies commercial fisheries in one of three categories based on the level of mortality and serious injury of marine mammals associated with that fishery. According to the 2018 LOF (83 FR 5349, February 7, 2018), the Guam and CNMI bottomfish fisheries operating under the Marianas FEP are classified as Category III fisheries (i.e. a remote likelihood of or no known incidental mortality and serious injury of marine mammals).

2.4.3 Status of Protected Species Interactions in the Marianas FEP Fisheries

2.4.3.1 Bottomfish and Coral Reef Fisheries

There are no observer data available for the Guam and CNMI bottomfish or coral reef fisheries. However based on current ESA consultations, these fisheries are not expected to interact with any ESA-listed species in federal waters around Guam or CNMI. NMFS has also concluded that the Mariana Archipelago bottomfish and coral reef commercial fisheries will not affect marine mammals in any manner not considered or authorized under the Marine Mammal Protection Act.

Based on fishing effort and other characteristics described in Chapter 1 of this report, no notable changes have been observed in the fishery. There is no other information to indicate that impacts to protected species from this fishery have changed in recent years.

2.4.3.2 Crustacean and Precious Coral Fisheries

There are currently no crustacean or precious coral fisheries operating in federal waters around Guam or CNMI. However based on current ESA consultations, crustacean fisheries are not expected to interact with any ESA-listed species in federal waters around Guam or CNMI. NMFS has also concluded that the Mariana Archipelago crustacean and precious coral commercial fisheries will not affect marine mammals in any manner not considered or authorized under the Marine Mammal Protection Act.

2.4.4 Identification of Emerging Issues

Several ESA-listed species are being evaluated for critical habitat designation (Table 64). If critical habitats are designated, they will be included in this SAFE report and impacts from FEP-managed fisheries will be evaluated under applicable mandates.

Table 64. Candidate ESA species, and ESA-listed species being evaluated for critical habitat designation.

Species		Listing process			Post-listing activity	
Common name	Scientific name	90-day finding	12-month finding / Proposed rule	Final rule	Critical Habitat	Recovery Plan
Oceanic whitetip shark	*Carcharhinus longimanus*	Positive (81 FR 1376, 1/12/2016)	Positive, threatened (81 FR 96304, 12/29/2016)	Listed as Threatened (83 FR 4153, 1/30/18)	Not determinable because of insufficient data (83 FR 4153, 1/30/18)	TBA
Pacific bluefin tuna	*Thunnus orientalis*	Positive (81 FR 70074, 10/11/2016)	Not warranted (82 FR 37060, 8/8/17)	N/A	N/A	N/A
Giant manta ray	*Manta birostris*	Positive (81 FR 8874, 2/23/2016)	Positive, threatened (82 FRN 3694, 1/12/2017)	Listed as Threatened (83 FR 2916, 1/22/18)	Not determinable because of insufficient data (83 FR 2916, 1/22/18)	TBA
Reef manta ray	*Manta alfredi*	Positive (81 FR 8874, 2/23/2016)	Not warranted (82 FRN 3694, 1/12/2017)	N/A	N/A	N/A

Species		Listing process			Post-listing activity	
Common name	Scientific name	90-day finding	12-month finding / Proposed rule	Final rule	Critical Habitat	Recovery Plan
Corals	N/A	Positive for 82 species (75 FR 6616, 2/10/2010)	Positive for 66 species (77 FR 73219, 12/7/2012)	20 species listed as threatened (79 FR 53851, 9/10/2014)	In development, proposal expected TBA	In development, expected TBA, interim recovery outline in place
Green sea turtle	*Chelonia mydas*	Positive (77 FR 45571, 8/1/2012)	Identification of 11 DPSs, endangered and threatened (80 FR 15271, 3/23/2015)	11 DPSs listed as endangered and threatened (81 FR 20057, 4/6/2016)	In development, proposal expected TBA[a]	TBA

[a] NMFS and USFWS have been tasked with higher priorities regarding sea turtle listings under the ESA, and do not anticipate proposing green turtle critical habitat designations in the immediate future.

2.4.5 Identification of Research, Data, and Assessment Needs

The following research, data, and assessment needs for insular fisheries were identified by the Council's Protected Species Advisory Committee and Plan Team:

- Improve the precision of commercial and non-commercial fisheries data to improve understanding of potential protected species impacts.
- Define and evaluate innovative approaches to derive robust estimates of protected species interactions in insular fisheries.

2.5 CLIMATE AND OCEANIC INDICATORS

2.5.1 Introduction

Beginning with the 2015 Annual Report, there has been a section on indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Western Pacific Regional Fishery Management Council has responsibility. There are a number of reasons for the Council's decision to provide and maintain an evolving discussion of climate conditions as an integral and continuous consideration in their deliberations, decisions, and reports:

- Emerging scientific and community understanding of the impacts of changing climate conditions on fishery resources, the ecosystems that sustain those resources and the communities that depend upon them;
- Recent Federal Directives including the 2010 implementation of a National Ocean Policy that identified Resiliency and Adaptation to Climate Change and Ocean Acidification as one of nine National priorities; the development of a Climate Science Strategy by the National Marine Fisheries Service (NMFS) in 2015 and the ongoing development of Pacific Regional Climate Science program
- The Council's own engagement with the National Oceanic and Atmospheric Administration (NOAA) as well as jurisdictional fishery management agencies in American Samoa, the Commonwealth of the Northern Mariana Islands, Guam and Hawaii as well as fishing industry representatives and local communities in those jurisdictions; and
- Deliberations of the Council's Marine Planning and Climate Change Committee.

Starting with the 2015 Report, the Council and its partners have provided continuing descriptions of changes in a series of climate and oceanic indicators that will grow and evolve over time as they become available and their relevance to Western Pacific fishery resources becomes clear.

2.5.2 Conceptual Model

In developing this chapter, the Council relied on a number of recent reports conducted in the context of the U.S. National Climate Assessment including, most notably, the 2012 Pacific Islands Regional Climate Assessment (PIRCA) and the Ocean and Coasts chapter of the 2014 report on a Pilot Indicator System prepared by the National Climate Assessment and Development Advisory Committee (NCADAC).

The Advisory Committee Report presented a possible conceptual framework designed to illustrate how climate factors can connect to and interact with other ecosystem components to ocean and coastal ecosystems and human communities. The Council adapted this model with considerations relevant to the fishery resources of the Western Pacific Region:

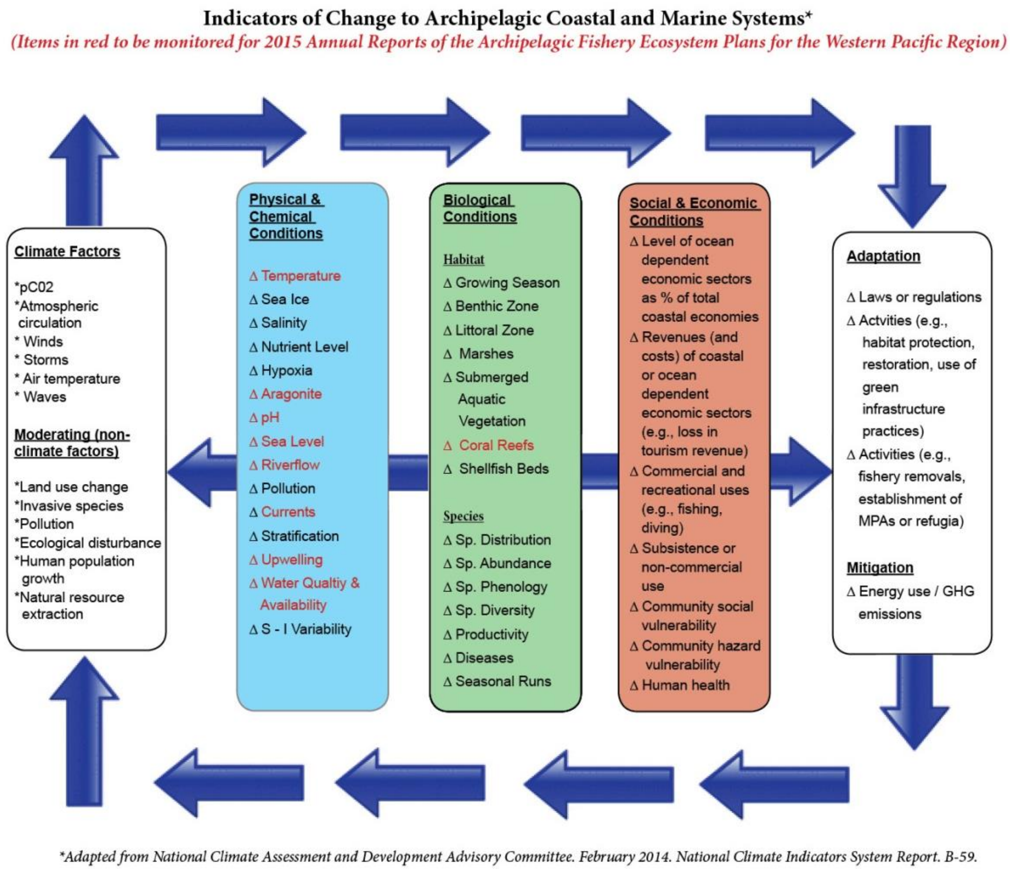


Figure 15. Simplified representation of the climate and non-climate stressors in the coastal and marine ecosystems.

As described in the 2014 NCADAC report, the conceptual model represents a "simplified representation of climate and non-climate stressors in coastal and marine ecosystems." For the purposes of this Annual Report, the modified Conceptual Model allows the Council and its partners to identify indicators of interest to be monitored on a continuing basis in coming years. The indicators shown in red were considered for inclusion in the 2015 Annual Report; the specific indicators used in the Report are listed in Section 2.4. Other indicators will be added over time as datasets become available and understanding of the nature of the causal chain from stressors to impacts emerges.

The Council also hopes that this Conceptual Model can provide a guide for future monitoring and research that will enable the Council and its partners to move from observations and correlations to understanding the specific nature of interactions and developing capabilities to predict future changes of importance in developing, evaluating, and adapting ecosystem-fishery plans in the Western Pacific Region.

2.5.3 Selected Indicators

The primary goal for selecting the Indicators used in this (and future reports) is to provide fisheries-related communities, resource managers, and businesses with climate-related situational awareness. In this context, Indicators were selected to:

- Be fisheries relevant and informative
- Build intuition about current conditions in light of changing climate
- Provide historical context and
- Recognize patterns and trends.

Beginning with the 2015 report on Western Pacific Pelagic resources, the Council has included the following climate and oceanic indicators:

Atmospheric Carbon Dioxide (at Mauna Loa Observatory) – Increasing atmospheric CO_2 is a primary measure of anthropogenic climate change.

Ocean pH (at Station ALOHA) – Ocean pH provides a measure of ocean acidification. Increasing ocean acidification limits the ability of marine organisms to build shells and other hard structures.

Oceanic Niño Index (ONI) – Sea surface temperature anomaly from Niño 3.4 region (5°N - 5°S, 120° - 170°W). This index is used to determine the phase of the El Niño – Southern Oscillation (ENSO), which has implications across the region affecting migratory patterns of key commercial fish stocks which, in turn, affect the location, safety and costs of commercial fishing.

Pacific Decadal Oscillation (PDO) – Like ENSO, the PDO reflects changes between periods of persistently warm or persistently cool ocean temperatures, but over a period of 20 – 30 years versus 6 – 18 months for ENSO event. The climatic finger prints of the PDO are most visible in the Northeastern Pacific, but secondary signatures exist in the tropics.

Sea Surface Temperature –Monthly sea surface temperature and anomaly blended from three data sources covering 1985-2017: Pathfinder v 5.0, the Global Area Coverage, and the GOES-POES dataset from both the AVHRR instrument aboard the NOAA Polar Operational Environmental Satellite (POES) and the Geostationary Operational Environmental Satellite (GOES). Sea surface temperature is one of the most directly observable measures we have for tracking increasing ocean temperature.

Sea Surface Temperature Anomaly – Sea surface temperature anomaly highlights long term trends. Filtering out seasonal cycle, and showing the current year relative to past years, sea surface temperature anomaly provides context on one of the most directly observable measures we have for tracking increasing ocean temperature.

Coral Thermal Stress Exposure – In tropical coastal habitats, one tangible impact of high temperature anomalies is the possibility of mass coral bleaching. To help gauge the history and impact of thermal stress on coastal corals, we present a satellite-derived metric called Degree Heating Weeks.

Chlorophyll-A – Monthly chlorophyll-a spanning 2002-2017 from the MODIS sensor aboard the NASA Aqua satellite. Chlorophyll-A is derived from ocean color, and is a proxy for the amount of phytoplankton in the seawater. Combined with temperature, it can give an index of primary production.

Chlorophyll-Anomaly – Deviation from seasonal and inter-annual chlorophyll-a (chl-A) patterns can provide a means of assessing the relative distinctiveness of 2017, as well as how chl-A varies over time.

Heavy Weather (Tropical Cyclones & Storm Force Winds) -- Measures of tropical cyclone occurrence, strength, and energy. Percentage occurrence of winds > 34 knots. Tropical cyclones and high winds may have the potential to significantly impact fishing operations.

Rainfall – Rainfall has been proposed as a potentially important correlate for the catch of some nearshore species, especially nearshore pelagics.

Sea Level (Sea Surface Height) and Anomaly – Rising sea levels can result in a number of coastal impacts, including inundation of infrastructure, increased damage resulting from storm-driven waves and flooding, and saltwater intrusion into freshwater supplies. NOTE that no water level gauges are available in PRIA so only regional information on this Indicator is included.

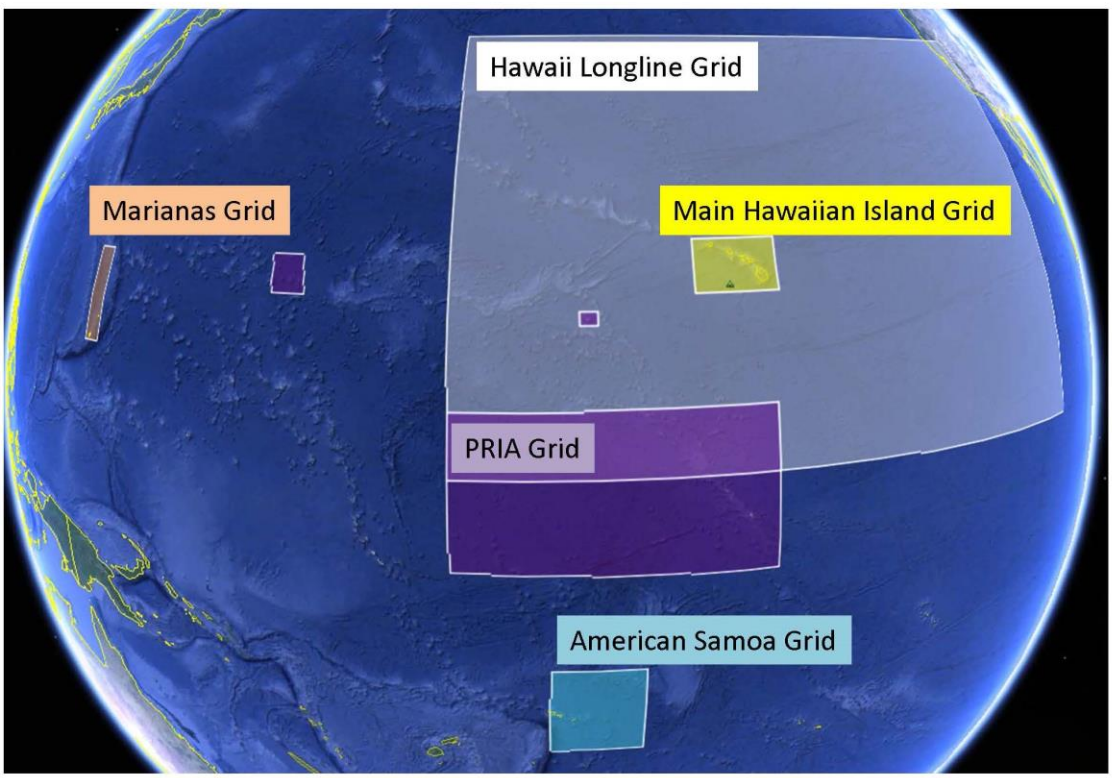


Figure 16. Regional spatial grids representing the scale of the climate change indicators being monitored.

Table 65. Climate and Ocean Indicator Summary

Indicator	Definition and Rationale	Indicator Status
Atmospheric Concentration of Carbon Dioxide (CO_2)	Atmospheric concentration CO_2 at Mauna Loa Observatory. Increasing atmospheric CO_2 is a primary measure of anthropogenic climate change.	Trend: increasing exponentially 2017: time series mean 406.53 ppm
Oceanic pH	Ocean surface pH at Station ALOHA. Ocean pH provides a measure of ocean acidification. Increasing ocean acidification limits the ability of marine organisms to build shells and other hard structures.	Trend: pH is decreasing at a rate of 0.039 pH units per year, equivalent to 0.4% increase in acidity per year
Oceanic Niño Index (ONI)	Sea surface temperature anomaly from Niño 3.4 region (5°N - 5°S, 120° - 170°W). This index is used to determine the phase of the El Niño – Southern Oscillation (ENSO), which has implications across the region, affecting migratory patterns of key commercial fish stocks which in turn affect the location, safety, and costs of commercial fishing.	2017: ENSO Neutral
Pacific Decadal Oscillation (PDO)	PDO can be thought of as a long-lived, multi-decadal ENSO cycle that has well-documented fishery implications related to ocean temperature and productivity.	2017: positive (warm) from Jan – June, negative (cool) from Jul – Dec
Sea Surface Temperature* (SST)	Satellite remotely-sensed sea surface temperature. SST is projected to rise, and impacts phenomena ranging from winds to fish distribution.	SST in waters surrounding most of PRIA ranged between 27-30° C with 2017 showing anomalies dependent on latitude: along the equator, 2017 showed a negative anomaly, while at ~4 deg N, the 2017 anomaly moves positive.
Coral Thermal Bleaching	Satellite remotely-sensed metric of time and	The equatorial PRIA showed

Exposure (DHW)	temperature above thresholds relevant for coral bleaching. Metric used is Degree Heating Weeks (DHW).	prolonged, substantial DHW stress in 2015-2016, in which DHW values exceeded the range in which mass mortality is expected (DHW>8). Wake Atoll showed more regular, but less prolonged heating events (’14, ’15, ’17).
Chlorophyll-A (Chl-A)	Satellite remotely-sensed chlorophyll-a. Chl-A is projected to drop over much of the central Pacific, and is directly linked ecosystem productivity.	The Chl-A around the PRIA ranges from 0.08 to 0.35 mg/m^3, with 2017 showing a near-zero and spatially variable anomaly.
Tropical Cyclones	Measures of tropical cyclone occurrence, strength, and energy. Tropical cyclones have the potential to significantly impact fishing operations.	Eastern Pacific, 2017: 31 storms, a level slightly lower than average.
		South Pacific, 2017: 6 storms, low – lowest since 2012.
		Central Pacific, 2017: 0 storms. Very low.
Rainfall/Precipitation	CMAP re-analysis of CPC Precipitation Data	2017 showed negative anomalies in rainfall.
Sea Level/Sea Surface Height	Monthly mean sea level time series, including extremes. Data from satellite altimetry & in situ tide gauges. Rising sea levels can result in a number of coastal impacts, including inundation of infrastructure, increased damage resulting from storm-driven waves and flooding, and saltwater intrusion into freshwater supplies.	Although varying over time the monthly mean sea level trend is increasing.

2.5.3.1 Atmospheric Concentration of Carbon Dioxide (CO_2) at Mauna Loa

Rationale: Atmospheric carbon dioxide is a measure of what human activity has already done to affect the climate system through greenhouse gas emissions. It provides quantitative information in a simplified, standardized format that decision makers can easily understand. This indicator demonstrates that the concentration (and, in turn, warming influence) of greenhouse gases in the atmosphere has increased substantially over the last several decades.

Status: Atmospheric CO_2 is increasing exponentially. In 2017, the annual mean concentration of CO_2 was 406.53 ppm. In 1959, the first year of the time series, it was 315.97 ppm. The annual mean passed 350 ppm in 1988 and 400 ppm in 2015.

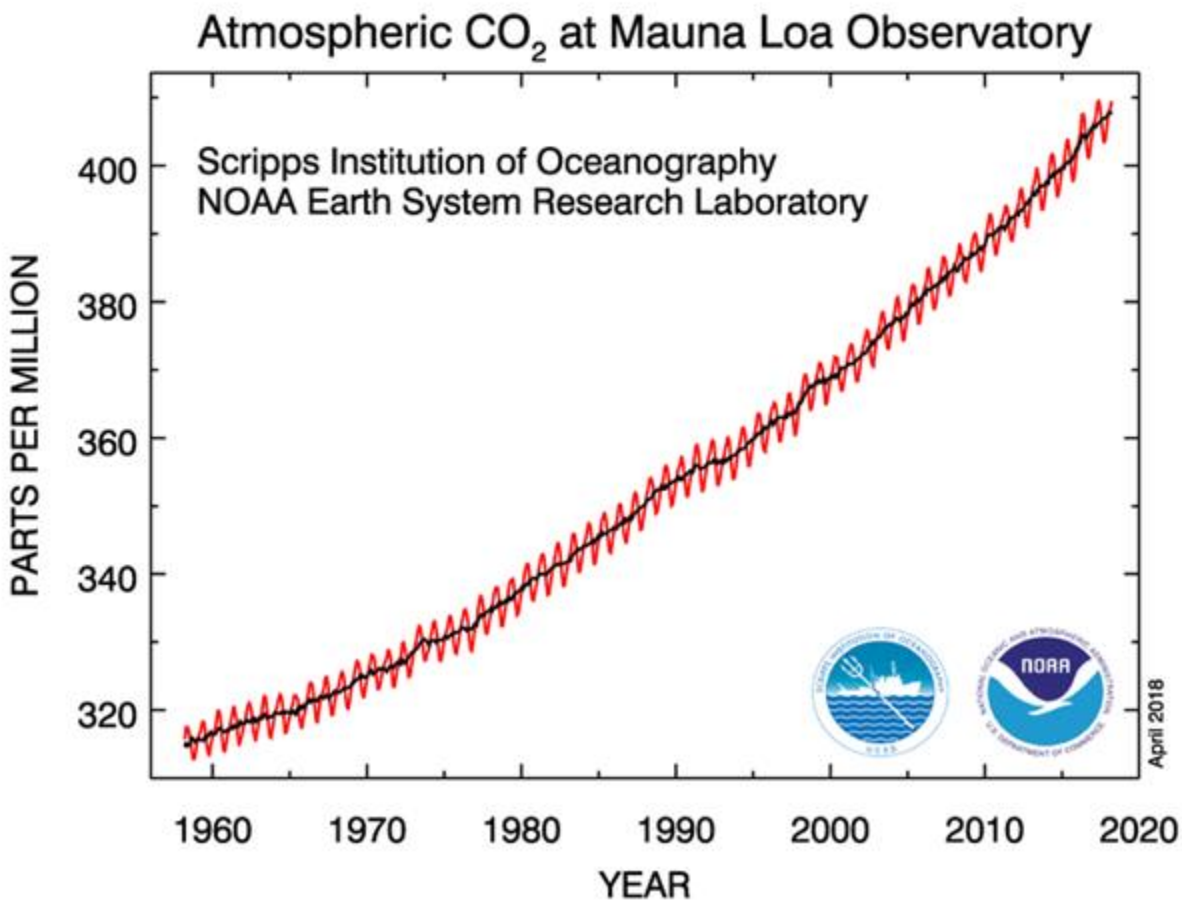


Figure 17. Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory Hawai`i (red) alongside seasonally-corrected data (black).

Description: Monthly mean atmospheric carbon dioxide (CO_2) at Mauna Loa Observatory, Hawai`i in parts per million (ppm) from March 1958 to present.

The observed increase in monthly average carbon dioxide concentration is primarily due to CO_2 emissions from fossil fuel burning. Carbon dioxide remains in the atmosphere for a very long time, and emissions from any location mix throughout the atmosphere in about one year. The annual oscillations at Mauna Loa, Hawai`i are due to the seasonal imbalance between the photosynthesis and respiration of plants on land. During the summer growing season photosynthesis exceeds respiration and CO_2 is removed from the atmosphere, whereas outside the growing season respiration exceeds photosynthesis and CO_2 is returned to the atmosphere. The seasonal cycle is strongest in the northern hemisphere because of this hemisphere's larger land mass.

Timeframe: Annual, monthly.

Region/Location: Mauna Loa, Hawai`i but representative of global atmospheric carbon dioxide concentration.

Data Source: "Full Mauna Loa CO_2 record" available at https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html. Data from additional monitoring stations, including the Tutuila, American Samoa station are available at https://www.esrl.noaa.gov/gmd/dv/iadv/.

Measurement Platform: *In-situ* station.

2.5.3.1.1 References

Keeling, C.D., Bacastow, R.B., Bainbridge, A.E., Ekdahl, C.A., Guenther, P.R., Waterman, L.S., 1976. Atmospheric carbon dioxice variations at Mauna Loa Observator, Hawaii. *Tellus*, *28*, pp. 538-551.

Thoning, K.W., Tans, P.P., Komhyr, W.D., 1989. Atmospheric carbon dioxide at Mauna Loa Observatory 2. Analysis of the NOAA GMCC data, 1974-1985. *Journal of Geophysical Research*, *94*, pp. 8549-8565.

2.5.3.2 Oceanic pH

Rationale: Ocean pH is a measure of how greenhouse gas emissions have already impacted the ocean. This indicator demonstrates that oceanic pH has decreased significantly over the past several decades (i.e., the ocean has become more acidic). Increasing ocean acidification (indicated by lower oceanic pH) limits the ability of marine organisms to build shells and other hard structures. Recent research has shown that pelagic organisms such pteropods and other prey for commercially-valuable fish species are already being negatively impacted by increasing acidification (Feely *et al.,* 2016). The full impact of ocean acidification on the pelagic food web is an area of active research (Fabry *et al.,* 2008).

Status: Oceanic pH has shown a significant linear decrease of 0.0369 pH units, or roughly an 8.9% increase in acidity, over the nearly 30 years spanned by this time series. Additionally, the highest pH value reported for the most recent year (8.0846) is roughly equal to the lowest pH value reported in the first year of the time series (8.0845).

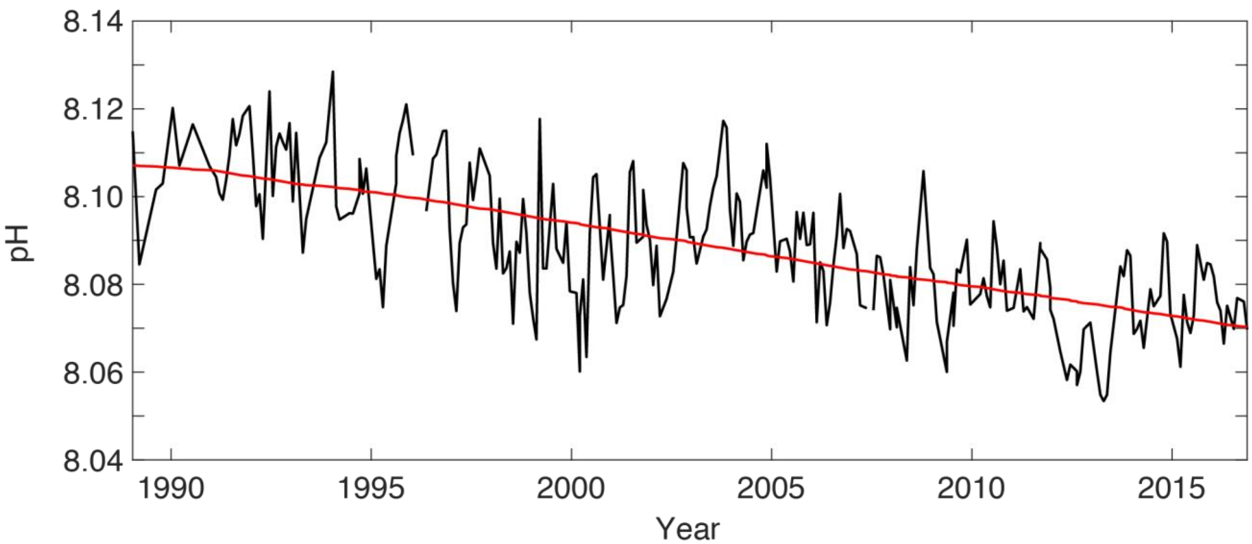


Figure 18. pH Trend at Station ALOHA, 1989-2016.

Description: Trends in surface (5 m) pH at Station ALOHA, north of Oahu (22.75°N, 158°W), collected by the Hawai`i Ocean Time-series (HOT) from October 1988 to 2016 (2017 data are not yet available). Oceanic pH is a measure of ocean acidity, which increases as the ocean absorbs carbon dioxide from the atmosphere. Lower pH values represent greater acidity. The multi-decadal time series at Station ALOHA represents the best available documentation of the significant downward trend in oceanic pH since the time series began in 1988. Oceanic pH varies over both time and space, though the conditions at Station ALOHA are considered broadly representative of those across the Western and Central Pacific's pelagic fishing grounds.

Timeframe: Monthly.

Region/Location: Station ALOHA: 22.75°N, 158°W.

Data Source: Hawai`i Ocean Time-series at http://hahana.soest.hawaii.edu/hot/. The Hawai`i Ocean Time-series is maintained by the University of Hawai`i's School for Ocean and Earth Science and Technology.

Measurement Platform: *In-situ* station .

2.5.3.2.1 References

An overview of the relationship between acidity and pH can be found at: http://www.pmel.noaa.gov/co2/story/A+primer+on+pH

A detailed description of how HOT determines pH can be found at: http://hahana.soest.hawaii.edu/hot/methods/ph.html

Methods for calculating pH from TA and DIC can be found at: https://www.soest.hawaii.edu/oceanography/faculty/zeebe_files/CO2_System_in_Seawater/csys.html

Fabry, V.J., Seibel, B.A., Feely, R.A., Orr, J.C., 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science*, *65*, pp. 414-432.

Feely, R.A., Alin, S.R., Carter, B., Bednarsek, N., Hales, B., Chan, F., Hill, T.M., Gaylord, B., Sanford, E., Byrne, R.H., Sabine, C.L., Greeley, D., Juranek, L., 2016. Chemical and biological impacts of ocean acidification along the west coast of North America. *Estuarine, Coastal and Shelf Science*, *183*, pp. 260-270. doi: 10.1016/j.ecss.2016.08.043

2.5.3.3 Oceanic Niño Index

Rationale: The ENSO cycle is known to have impacts on Pacific fisheries targeting species including but not limited to tuna. The ONI focuses on ocean temperature, which has the most direct effect on these fisheries.

Status: The ONI was neutral in 2017.

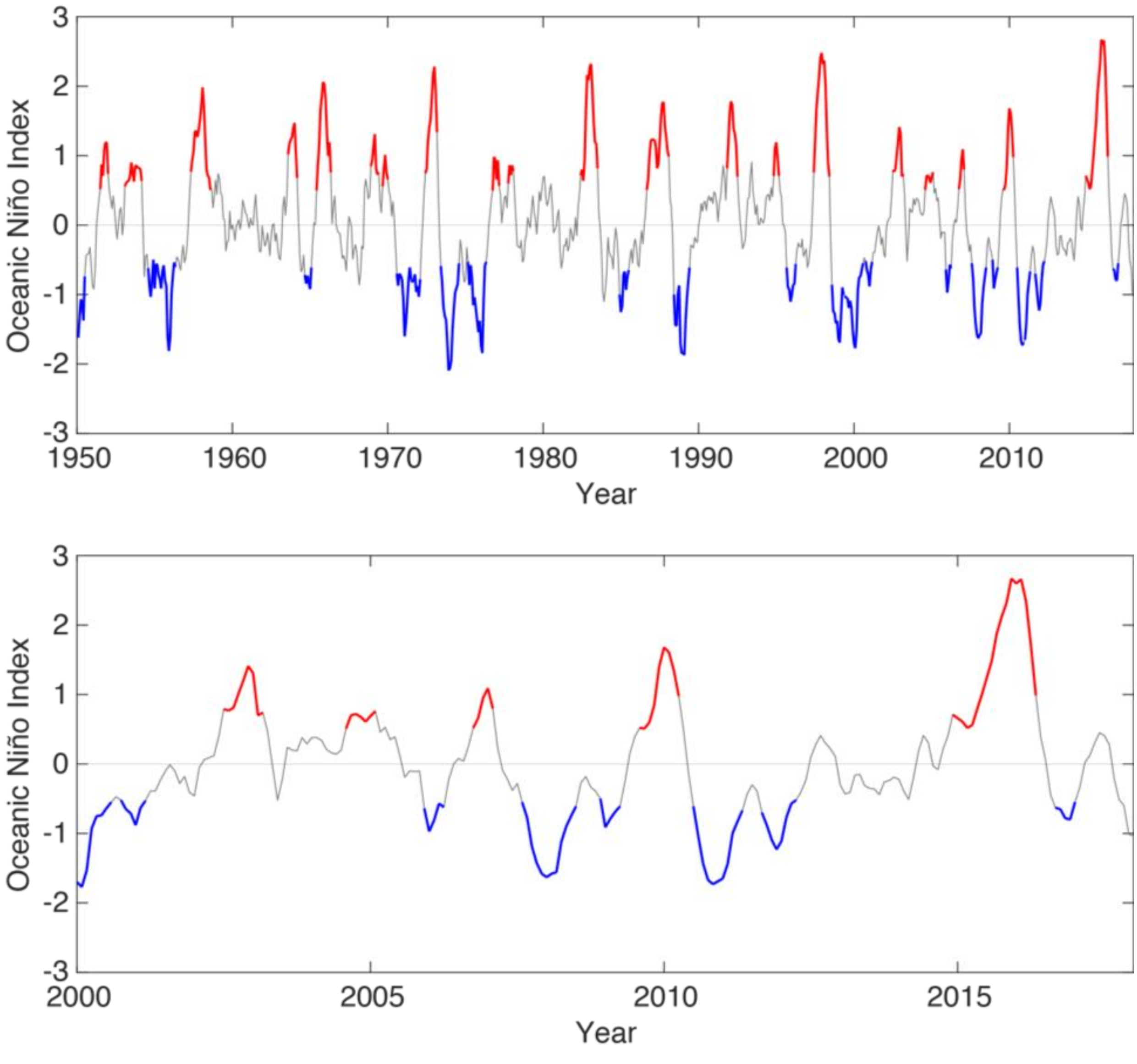


Figure 19. Oceanic Niño Index, 1950-2017 and 2000–2017. Note: Monthly time series of the Oceanic Niño Index for 1950 – 2017 (top) and 2000 – 2017 (bottom). El Niño periods are highlighted in red. La Niña periods are highlighted in blue.

Description: The three-month running mean of ERSST .v4 sea surface temperature (SST) anomalies in the Niño 3.4 region (5°S – 5°N, 120° – 170°W). The Oceanic Niño Index (ONI) is a measure of the El Niño – Southern Oscillation (ENSO) phase. Warm and cool phases, termed El Niño and La Niña respectively, are based in part on an ONI threshold of ± 0.5 °C being met for a minimum of five consecutive overlapping seasons. Additional atmospheric indices are needed to confirm an El Niño or La Niña event, as the ENSO is a coupled ocean-atmosphere phenomenon. The atmospheric half of this Pacific basin oscillation is measured using the Southern Oscillation Index.

Timeframe: Every three months.

Region/Location: Niño3.4 region: 5°S – 5°N, 120° – 170°W.

Data Source: NOAA NCEI at https://www.ncdc.noaa.gov/teleconnections/enso/indicators/sst.php.

Measurement Platform: *In-situ* station, satellite, model.

2.5.3.3.1 References

A full description of ENSO and its global impacts can be found at: https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-and-la-ni%C3%B1a-frequently-asked-questions.

2.5.3.4 Pacific Decadal Oscillation

Rationale: The Pacific Decadal Oscillation (PDO) was initially named by a fisheries scientist, Steven Hare, in 1996 while researching connections between Alaska salmon production cycles and Pacific climate. Like ENSO, the PDO reflects changes between periods of persistently warm or persistently cool ocean temperatures, but over a period of 20 – 30 years versus 6 – 18 months for ENSO event. The climatic finger prints of the PDO are most visible in the Northeastern Pacific, but secondary signatures exist in the tropics.

Status: The PDO was positive, or warm, from January through June of 2017. For the remainder of the year, the PDO was negative, or cool. It remains to be seen whether the negative conditions during the second half of the year represent a short-term fluctuation or a true phase change.

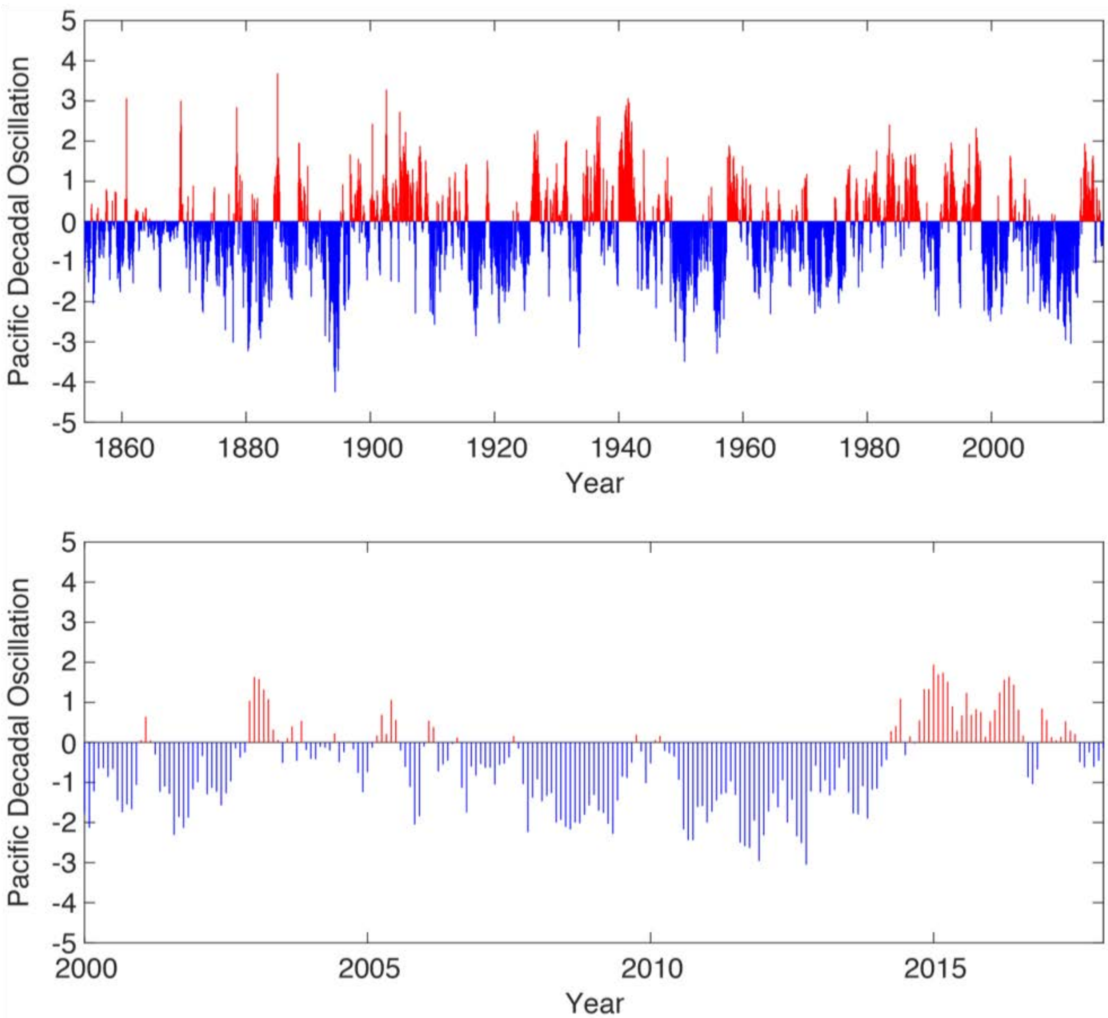


Figure 20. Pacific Decadal Oscillation, 1854–2017 (top) and 2000–2017 (bottom). Positive, or warm, phases are plotted in red; negative, or cool, phases are plotted in blue.

Description: The Pacific Decadal Oscillation (PDO) is often described as a long-lived El Niño-like pattern of Pacific climate variability. As seen with the better-known El Niño – Southern Oscillation (ENSO), extremes in the PDO pattern are marked by widespread variations in the Pacific Basin and the North American climate. In parallel with the ENSO phenomenon, the extreme cases of the PDO have been classified as either warm or cool, as defined by ocean temperature anomalies in the northeast and tropical Pacific Ocean. When sea surface temperatures (SSTs) are anomalously cool in the interior North Pacific and warm along the North American coast, and when sea level pressures are below average in the North Pacific, the PDO has a positive value. When the climate anomaly patterns are reversed, with warm SST anomalies in the interior and cool SST anomalies along the North American coast, or above average sea level pressures over the North Pacific, the PDO has a negative value.

The National Centers for Environmental Information (NCEI) PDO index is based on NOAA's extended reconstruction of SST (ERSST .v4).

Description inserted from https://www.ncdc.noaa.gov/teleconnections/pdo/.

Timeframe: Annual, monthly.

Region/Location: Pacific Basin north of 20°N.

Data Source: NOAA NCEI at https://www.ncdc.noaa.gov/teleconnections/pdo/. NCEI is responsible for hosting and providing access to one of the most significant archives on Earth, with comprehensive oceanic, atmospheric, and geophysical data.

Measurement Platform: *In-situ* station, satellite, model.

2.5.3.4.1 References

Mantua, N., 2000: The Pacific Decadal Oscillation. Available at http://research.jisao.washington.edu/pdo/. Accessed Feb 2017.

2.5.3.5 Sea Surface Temperature & Anomaly

Description: Monthly sea surface temperature from 1982-2017, stitched together from three sources: (1) for 1982-2009 we use the Pathfinder v 5.0 dataset – a reanalysis of historical data from the Advanced Very High Resolution Radiometer (AVHRR); (2) to span 2010-2012 we use the AVHRR Global Area Coverage (GAC) dataset, and (3) data from 2013 to present we use the GOES-POES dataset, (see below for details). Both Pathfinder and GOES-POES provide 0.05º spatial resolution, while GAC provides 0.1º. A monthly climatology was generated across the entire period (1982-2017) to provide both a 2017 spatial anomaly, and an anomaly time series.

Short Descriptions:

(1) The NOAA/NASA AVHRR Pathfinder v5 and v5.1 sea-surface temperature dataset is a reanalysis of historical AVHRR data that have been improved using extensive calibration, validation and other information to yield a consistent research quality time series for global climate studies. At 0.05 degrees per pixel (approximately 4 km/pixel), this dataset provides a global spatial coverage ranging from October 1981 - 2009. Our data holdings include descending passes (nighttime).

(2) The Advanced Very High Resolution Radiometer (AVHRR) satellite sensors onboard the NOAA POES (Polar-orbiting Operational Environmental Satellites) satellite constellation have been collecting sea-surface temperature (SST) measurements since 1981. This dataset combines the NOAA/NASA AVHRR Pathfinder v4.1 dataset (January 1985 - January 2003) and the AVHRR Global Area Coverage (GAC) dataset (January 2003 - present) to provide a long time series of SST. These datasets are reduced-resolution legacy datasets and will be discontinued by NOAA in 2016. The dataset is composed of SST measurements from descending passes (nighttime). 3-day composites are only available for GAC, from 2003 - 2016.

(3) The GOES-POES dataset is a blended product, combining SST information from the Geostationary Operational Environmental Satellites (GOES) and the Polar-orbiting Operational Environmental Satellites (POES). This global SST analysis provides a daily gap-free map of the foundation sea surface temperature, generating high density SST data and improving the monitoring of small scale dynamic features in the coastal coral reef environment. (Text from the OceanWatch Central Pacific Node.)

Technical Summaries:

Pathfinder v5 & GAC datasets: The 4 km Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Version 5 sea surface temperature (SST) dataset is a reanalysis of historical AVHRR data that have been improved using extensive calibration, validation and other information to yield a consistent research quality time series for global climate studies. This SST time series represents the longest continual global ocean physical measurement from space. Development of the Pathfinder dataset is sponsored by the NOAA National Oceanographic Data Center (NODC) in collaboration with the University of Miami Rosensteil School of Marine and Atmospheric Science (RSMAS) while distribution is a collaborative effort between the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) and the NODC. From a historical perspective, the Pathfinder program was originally initiated in the 1990s as a joint NOAA/NASA research activity for reprocessing of satellite based data sets including SST.

AVHRR dataset: The AVHRR is a space-borne scanning sensor on the National Oceanic and Atmospheric Administration (NOAA) family of Polar Orbiting Environmental Satellites (POES) having an operational legacy that traces back to the Television Infrared Observation Satellite-N (TIROS-N) launched in 1978. AVHRR instruments measure the radiance of the Earth in 5 (or 6) relatively wide spectral bands. The first two are centered around the red (0.6 micrometer) and near-infrared (0.9 micrometer) regions, the third one is located around 3.5 micrometer, and the last two sample the emitted thermal radiation, around 11 and 12 micrometers, respectively. The legacy 5 band instrument is known as AVHRR/2 while the more recent version, the AVHRR/3 (first carried on the NOAA-15 platform), acquires data in a 6th channel located at 1.6 micrometer. Typically the 11 and 12 micron channels are used to derive SST sometimes in combination with the 3.5 micron channel. For the Pathfinder SST algorithm only the 11 and 12 micron channels are used. The NOAA platforms are sun synchronous generally viewing the same earth location twice a day (latitude dependent) due to the relatively large AVHRR swath of approximately 2400 km. The highest ground resolution that can be obtained from the current AVHRR instruments is 1.1 km at nadir.

This particular dataset is produced from Global Area Coverage (GAC) data that are derived from an on-board sample averaging of the full resolution global AVHRR data. Four out of every five samples along the scan line are used to compute on average value and the data from only every third scan line are processed, yielding an effective 4 km resolution at nadir. The collection of NOAA satellite platforms used in the AVHRR Pathfinder SST time series includes NOAA-7, NOAA-9, NOAA-11, NOAA-14, NOAA-16, NOAA-17, and NOAA-18. These platforms contain "afternoon" orbits having a daytime ascending node of between 13:30 and 14:30 local time (at time of launch) with the exception of NOAA-17 that has a daytime descending node of approximately 10:00 local time. SST AVHRR Pathfinder includes separate daytime and nighttime daily, 5 day, 8 day, monthly and yearly datasets. This particular dataset represent nighttime monthly averaged observations.

GOES-POES dataset: The National Oceanic and Atmospheric Administration's Office of Satellite Data Processing and Distribution are generating operational sea surface temperature (SST) retrievals from the Geostationary Operational Environmental Satellite (GOES) 11 and 12 satellite imagers. They are situated at longitude 135^{o}W and 75^{o}W, respectively, thus allowing the acquisition of high-temporal-resolution SST retrievals.

A new cloud masking methodology based on a probabilistic (Bayesian) approach has been implemented for improved retrieval accuracy. This new GOES SST Bayesian algorithm provides SST retrievals with an estimate of the probability of cloud contamination. This indicates the confidence level of the cloud detection for the retrieval, which can be related to retrieval accuracy.

The GOES-11 and 12 imagers observe both northern and southern hemisphere every half an hour. These 5-band (0.6, 3.9, 6.7, 10.7, 12 or 13.3 micron) and 4-band (0.6, 3.9, 6.7, 10.7. or 13.3 micron) images are processed to retrieve SST retrievals at 4-km resolution. The window infrared channels determine the SST, and all channels (except the 6.7 and 13.3 μm) determine the cloud contamination. These retrievals are remapped, averaged, and composited hourly and posted to a server for user access. The retrievals are available approximately 90 minutes after the nominal epoch of the SST determinations. Three-hour and 24-hour averages are also made available.

CoastWatch Regional Imagery is generated every three hours by combining the 1hourly SST images for these areas. (Text from: https://www.star.nesdis.noaa.gov/sod/mecb/blended_validation/background.php).

Timeframe: 1982-2017, Daily data available, Monthly means shown.

Region/Location: Global.

Data Sources:

(1) "AVHRR Pathfinder v. 5 (ERDDAP Monthly)"
(2) "AVHRR GAC v. 5 (ERDDAP Monthly)"
(3) "GOES-POES v. 5 (ERDDAP Monthly)"

http://oceanwatch.pifsc.noaa.gov/doc.html

Measurement Platform: *AVHRR, POES Satellite, GOES 12 and 12 Satellites.*

Rationale: Sea surface temperature is one of the most directly observable measures we have for tracking increasing ocean temperature.

2.5.3.5.1 References

Li, X., W. Pichel, E. Maturi, P. Clemente-Colón, and J. Sapper, 2001a. Deriving the operational nonlinear multi-channel sea surface temperature algorithm coefficients for NOAA-15 AVHRR/3, Int. J. Remote Sens., Volume 22, No. 4, 699 - 704.

Li, X, W. Pichel, P. Clemente-Colón, V. Krasnopolsky, and J. Sapper, 2001b. Validation of coastal sea and lake surface temperature measurements derived from NOAA/AVHRR Data, Int. J. Remote Sens., Vol. 22, No. 7, 1285-1303.

Stowe, L. L., P. A. Davis, and E. P. McClain, 1999. Scientific basis and initial evaluation of the CLAVR-1 global clear/cloud classification algorithm for the advanced very high resolution radiometer. J. Atmos. Oceanic Technol., 16, 656-681.

Walton C. C., W. G. Pichel, J. F. Sapper, D. A. May, 1998. The development and operational application of nonlinear algorithms for the measurement of sea surface temperatures with the NOAA polar-orbiting environmental satellites, J. Geophys. Res., 103: (C12) 27999-28012.

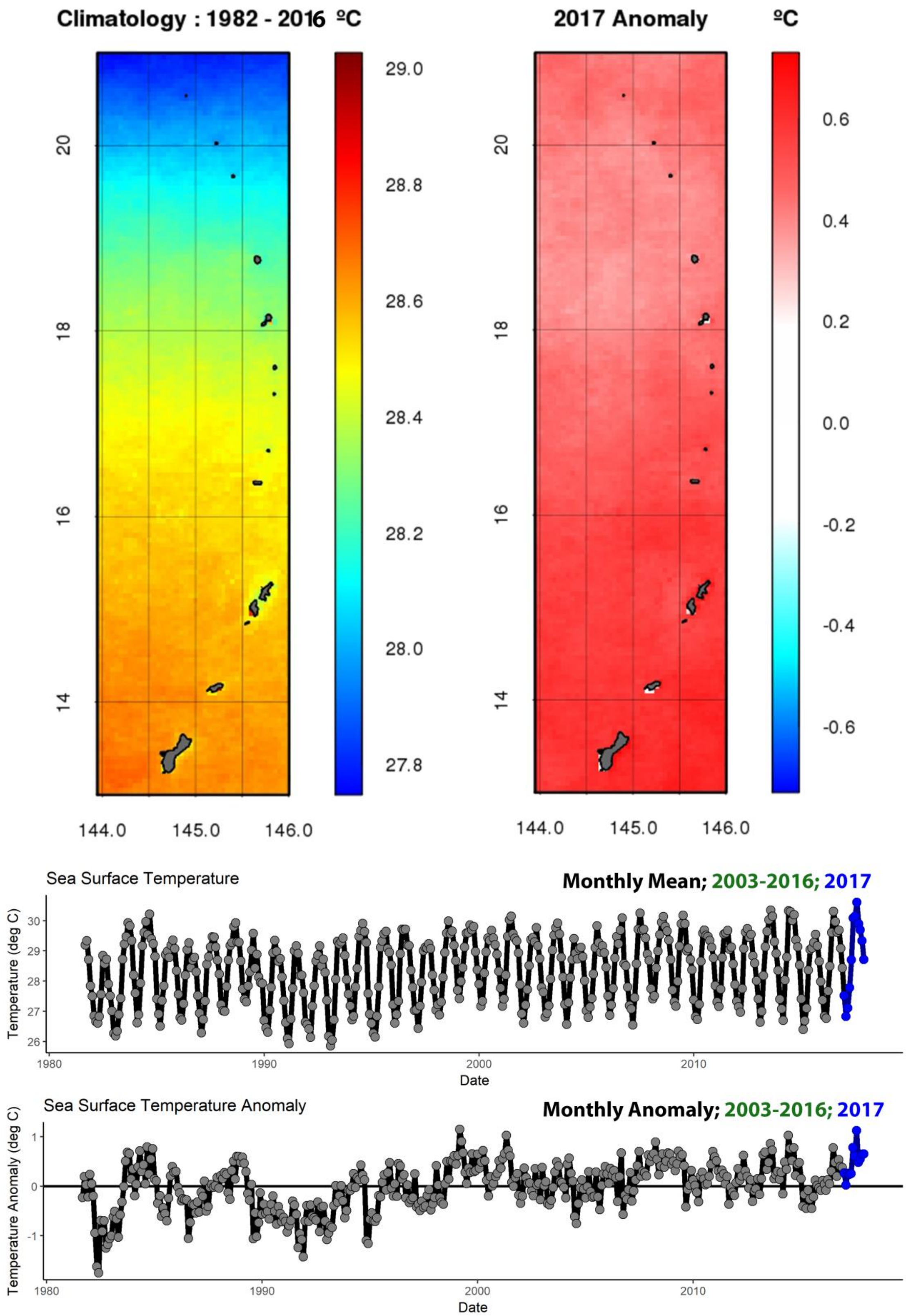


Figure 21. Sea surface temperature (SST) and SST Anomaly.

2.5.3.6 Coral Thermal Stress Exposure: Degree Heating Weeks

Description: Here we present a metric of exposure to thermal stress that is relevant to coral bleaching. Degree Heating Weeks (DHW) measure time and temperature above a reference 'summer maximum', presented as a rolling sum of weekly thermal anomalies over a 12-week window. Higher DHW measures imply a greater likelihood of mass coral bleaching or mortality from thermal stress.

Short Description: The NOAA Coral Reef Watch program uses satellite data to provide current reef environmental conditions to quickly identify areas at risk for coral bleaching. Bleaching is the process by which corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and death become likely. (Text inserted from the NOAA Coral Reef Watch website.)

The NOAA Coral Reef Watch (CRW) daily 5-km satellite coral bleaching Degree Heating Week (DHW) product presented here shows accumulated heat stress, which can lead to coral bleaching and death. The scale goes from 0 to 20 °C-weeks. The DHW product accumulates the instantaneous bleaching heat stress (measured by Coral Bleaching HotSpots) during the most-recent 12-week period. It is directly related to the timing and intensity of coral bleaching. Significant coral bleaching usually occurs when DHW values reach 4 °C-weeks. By the time DHW values reach 8 °C-weeks, widespread bleaching is likely and significant mortality can be expected.

Technical Summary: The NOAA Coral Reef Watch (CRW) experimental daily global 5km (0.05 degree) satellite coral bleaching heat stress monitoring product suite presented here is the third version (Version 3). The 5km suite is based on the NOAA/NESDIS operational daily global 5km geostationary-polar-orbiting (Geo-Polar) Blended Night-only SST Analysis. Current CRW 5km products include sea surface temperature (SST), SST Anomaly, Coral Bleaching HotSpot, Degree Heating Week (DHW), a 7-day maximum Bleaching Alert Area, and a 7-day SST Trend. CRW also has a 5km Regional Virtual Stations/Bleaching Heat Stress Gauges product and a free, automated 5km Bleaching Alert Email System that are based on this product suite. (Text inserted from: https://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php.)

A significantly improved climatology was introduced in the Version 3 products. It was derived from a combination of NOAA/NESDIS' 2002-2012 reprocessed daily global 5km Geo-Polar Blended Night-only SST Analysis and the 1985-2002 daily global 5km SST reanalysis, produced by the United Kingdom Met Office, on the Operational SST and Sea Ice Analysis (OSTIA) system. The near-real-time OSTIA SST was recently incorporated into the generation of NESDIS' operational daily 5km Blended SST that CRW's 5km coral bleaching heat stress monitoring product suite is based on. Hence, the 2002-2012 reprocessed 5km Geo-Polar Blended SST that has just become available, extended with the 1985-2002 portion of the 5km OSTIA SST re-analysis, is the best historical 1985-2012 global SST dataset for deriving a climatology that is internally consistent and compatible with CRW's near-real-time 5km satellite coral bleaching heat stress monitoring products. Although the reprocessed 5km Geo-Polar Blended SST dataset is available to the end of 2016, to be consistent with the time period (1985-2012) of the climatology used in our Version 2 5km product suite, the Version 3 climatology is based on the same time period. It was then re-centered to the center of the baseline time period of 1985-

1990 plus 1993, using the method described in Heron *et al.,* (2015)and Liu *et al.,* (2014), and was based on our monitoring algorithm (also described in these articles). More recent years may be incorporated in the climatology for future versions of CRW's 5 km products, but potential impacts on the products require further evaluation first.

This Version 3 suite was released on May 4, 2017, along with a new version of CRW's 5km Regional Virtual Stations/Bleaching Heat Stress Gauges product. Version 2 of the 5km product suite (that Version 3 replaces) was released on May 5, 2014, and Version 1 was released on July 5, 2012 (based on NESDIS' operational daily global 5 km Geo-Polar Blended Day-Night SST Analysis and an earlier version of the climatology derived from the PFV5.2).

Development of this next-generation 5 km product suite was accomplished through a collaboration of NOAA Coral Reef Watch, the University of South Florida, NASA-Ames, the UNEP World Conservation Monitoring Centre, and the Cooperative Institute for Research in Environmental Science, with funding support from the NASA Biodiversity and Ecological Forecasting program, the NOAA Coral Reef Conservation Program, and the NOAA/NESDIS Ocean Remote Sensing Program. Production of the Version 3 suite was made possible through funding from the NOAA Coral Reef Conservation Program. The 5km product suite, which was featured in the NASA Applied Sciences Program's 2013 Annual Report, will undergo continuous improvements.

Regional Virtual Stations Product Description: NOAA Coral Reef Watch (CRW) has developed a set of experimental 5 km Regional Virtual Stations (213 total).

NOAA CRW also expanded the geographic network of 5 km Virtual Stations to include all coral reefs around the world, based on available references. These included the Millennium Coral Reef project maps, the IUCN Coral Reefs of the World three-volume set, the UNEP/WCMC World Atlas of Coral Reefs, several country scale atlas publications, and a few other resources. These references were also used to develop the outline (in black) for each 5 km Regional Virtual Station. Each Virtual Station outline is based on a global 5 km reef pixel mask developed by NOAA CRW, with the addition of a 20 km buffer around each 5 km reef mask. If we have missed a coral reef that you know of, please let us know the name and coordinates of the missing reef.

Timeframe: 2013-2017, Daily data.

Region/Location: Global.

Data Source: "NOAA Coral Reef Watch" https://coralreefwatch.noaa.gov.

Measurement Platform: NOAA/NESDIS operational daily global 5km geostationary-polar-orbiting (Geo-Polar) Blended Night-only SST Analysis

Rationale: Degree heating weeks are one of the most widely used metrics for assessing exposure to coral bleaching-relevant thermal stress.

2.5.3.6.1 References

Liu, Gang, Scott F. Heron, C. Mark Eakin, Frank E. Muller-Karger, Maria Vega-Rodriguez, Liane S. Guild, Jacqueline L. De La Cour *et al*., 2014. "Reef-scale thermal stress monitoring of coral ecosystems: new 5-km global products from NOAA Coral Reef Watch." *Remote Sensing*, *6*(11), pp. 11579-11606.

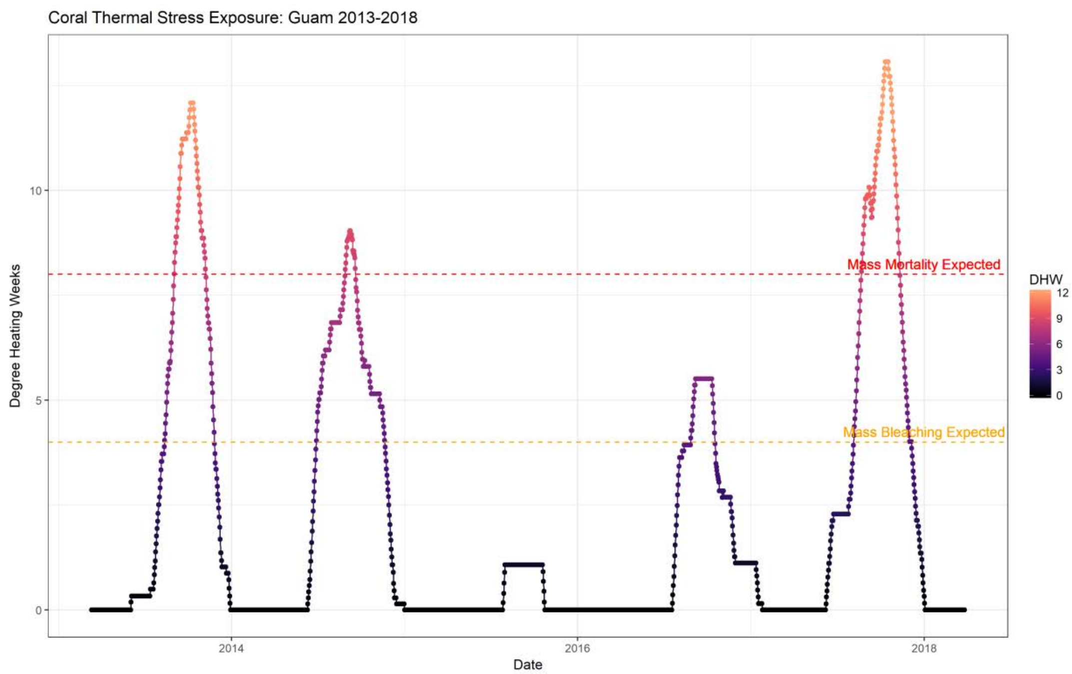


Figure 22. Coral Thermal Stress Exposure in degree heating weeks, Guam Virtual Station 2013-2017.

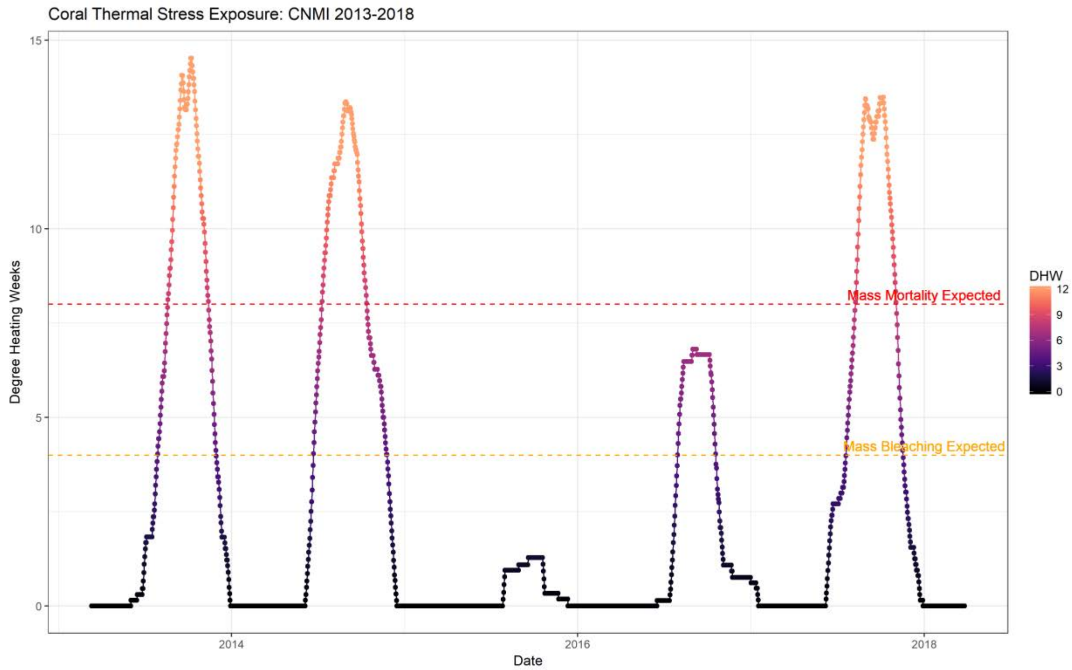


Figure 23. Coral Thermal Stress Exposure in Degree Heating Weeks, Northern Marianas Virtual Station 2013-2017.

2.5.3.7 Chlorophyll-A and Anomaly

Description: Chlorophyll-A Concentration from 2002-2017, derived from the MODIS Ocean Color sensor aboard the NASA Aqua Satellite. A monthly climatology was generated across the entire period (1982-2017) to provide both a 2017 spatial anomaly, and an anomaly time series.

Short Description: The MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor was deployed onboard the NASA Aqua satellite. It is a multi-disciplinary sensor providing data for the ocean, land, aerosol, and cloud research and is used for detecting chlorophyll-a concentrations in the world's oceans, among other applications. Aqua MODIS views the entire Earth's surface every 2 days, acquiring data in 36 spectral bands. The data available here is the latest reprocessing from June 2015, which NASA undertook to correct for some sensor drift issues. (Text inserted from the OceanWatch Central Pacific Node.)

Technical Summary: The Moderate-resolution Imaging Spectroradiometer (MODIS) is a scientific instrument (radiometer) launched by NASA in 2002 on board the Aqua satellite platform (a second series is on the Terra platform) to study global dynamics of the Earths atmosphere, land and oceans. MODIS captures data in 36 spectral bands ranging in wavelength from 0.4 um to 14.4 um and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). The Aqua platform is in a sun synchronous, near polar orbit at 705 km altitude and the MODIS instrument images the entire Earth every 1 to 2 days. The Level 3 standard mapped image (SMI) chlorophyll-a dataset has a monthly temporal resolution and 4.6 km (at the equator) spatial resolution. The SMI dataset is an image representation of binned MODIS data (more detailed information on the SMI format can be found at http://oceancolor.gsfc.nasa.gov). The MODIS Aqua instrument provides quantitative data on global ocean bio-optical properties to examine oceanic factors that affect global change and to assess the oceans' role in the global carbon cycle, as well as other biogeochemical cycles. Subtle changes in chlorophyll-a signify various types and quantities of marine phytoplankton (microscopic marine plants), the knowledge of which has both scientific and practical applications. This is a local dataset derived from the NASA Ocean Biology Processing Group (OBPG) meant to expose these data to tools and services at the PO.DAAC. **(**Text inserted from: https://podaac-www.jpl.nasa.gov/dataset/MODIS_Aqua_L3_CHLA_Monthly_4km_V2014.0_R.)

Timeframe: 2003-2017, Daily data available, Monthly means shown.

Region/Location: Global.

Data Source: “MODIS-Aqua (ERDDAP Monthly)” http://oceanwatch.pifsc.noaa.gov/doc.html.

Measurement Platform: *MODIS sensor on NASA Aqua Satellite*

Rationale: Chlorophyll-A is one of the most directly observable measures we have for tracking increasing ocean productivity.

2.5.3.7.1 References

Savtchenko, A., D. Ouzounov, S. Ahmad, J. Acker, G. Leptoukh, J. Koziana, and D. Nickless, 2004. Terra and Aqua MODIS products available from NASA GES DAAC. *Advances in Space Research* 34(4), pp. 710-714.

2.5.3.8 Heavy Weather (Tropical Cyclones & Storm-Force Winds)

Description: This indicator uses historical data from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) International Best Track Archive for Climate Stewardship (IBTrACS; Knapp *et al.,* 2010) to track the number of tropical cyclones in the western, central, and south Pacific basins. This indicator also monitors the Accumulated Cyclone Energy (ACE) Index, one way of monitoring the strength and duration of tropical cyclones based only on wind speed measurements.

The annual frequency of storms passing through the Pacific basin is tracked and a stacked time series plot shows the representative breakdown of the Saffir-Simpson hurricane categories. Three solid color groups in the graph represent a) the annual number of named storms, b) the annual number of typhoons, and c) the annual number of major typhoons (Cat 3 and above).

Every cyclone has an ACE Index value, which is a computed value based on the maximum wind speed measured at six-hourly intervals over the entire time that the cyclone is classified as at least a tropical storm (wind speed of at least 34 knot; 39 mph). Therefore, a storm's ACE Index value accounts for both strength and duration. This plot shows the historical ACE values for each typhoon season and has a solid line representing the 1981-2010 average ACE value.

In addition, we also plot the percentage occurrence of "storm-force" winds, wind occurrences greater than, or equal to, 34 knots since 1980 in the three sub-regions. The value of 34 knots represents "Gale, fresh gale" on the Beaufort scale, which corresponds to 5-8 m wave heights and boating becomes very challenging. Characterizing the percent occurrence of these gale-force winds gives an indication of storminess5 frequency within each sub-region. Indeed, slight increases in the frequency of gale-force winds are noted in both the South and Western Pacific basins, while a downward trend is evident in the Central Pacific. (Marra *et al.,* 2017)

Timeframe: Yearly.

Region/Location: Hawaii and U.S. Affiliated Pacific Islands.

Data Source/Responsible Party: NCEI's International Best Track Archive for Climate Stewardship (IBTrACS).

Measurement Platform: Satellite.

Rationale: The effects of tropical cyclones are numerous and well-known. At sea, storms disrupt and endanger shipping traffic as well as fishing effort and safety. The Hawaii longline fishery, for example, had serious problems between August and November 2015 with vessels dodging storms at sea, delayed departures and inability to make it safely back to Honolulu because of bad weather. When cyclones encounter land, their intense rains, and high winds can cause severe property damage, loss of life, soil erosion, and flooding. The associated storm surge, the large volume of ocean water pushed toward shore by the cyclone's strong winds, can cause severe flooding and destruction.

Neither the Pacific ENSO Applications Climate Center nor the Bulletin of the AMS has yet published their annual tropical cyclone report covering the central or south pacific in 2017.

While reports on activity during 2017 are not yet available for the south and central pacific, the NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2017, published online January 2018, notes that "The 2017 East Pacific hurricane season had 18 named storms, including nine hurricanes, four of which became major." The 1981-2010 average number of named storms in the East Pacific was 16.5, with 8.9 hurricanes, and 4.3 major hurricanes. Five Eastern Pacific tropical cyclones made landfall in 2017. Tropical Storm Selma made landfall in El Salvador and tropical storms Beatrix, Calvin, Lidia and Hurricane Max made landfall in Mexico. Tropical Storm Selma was the first named tropical cyclone on record to make landfall in El Salvador. Tropical Storm Adrian formed on May 9th, marking the earliest occurrence of a named storm in the East Pacific basin. The previous earliest occurrence was Tropical Storm Alma forming on May 12, 1990. For the first year since 2012 no tropical cyclones passed near the Hawaiian Islands. The ACE index for the East Pacific basin during 2016 was 98 (x10^4 knots^2), which is below the 1981-2010 average of 132 (x10^4 knots^2), and the lowest since 2013." Inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713.

Further, we present the occurrence of "storm-force" winds, i.e. wind speeds greater than 34 knots (Figure 26).

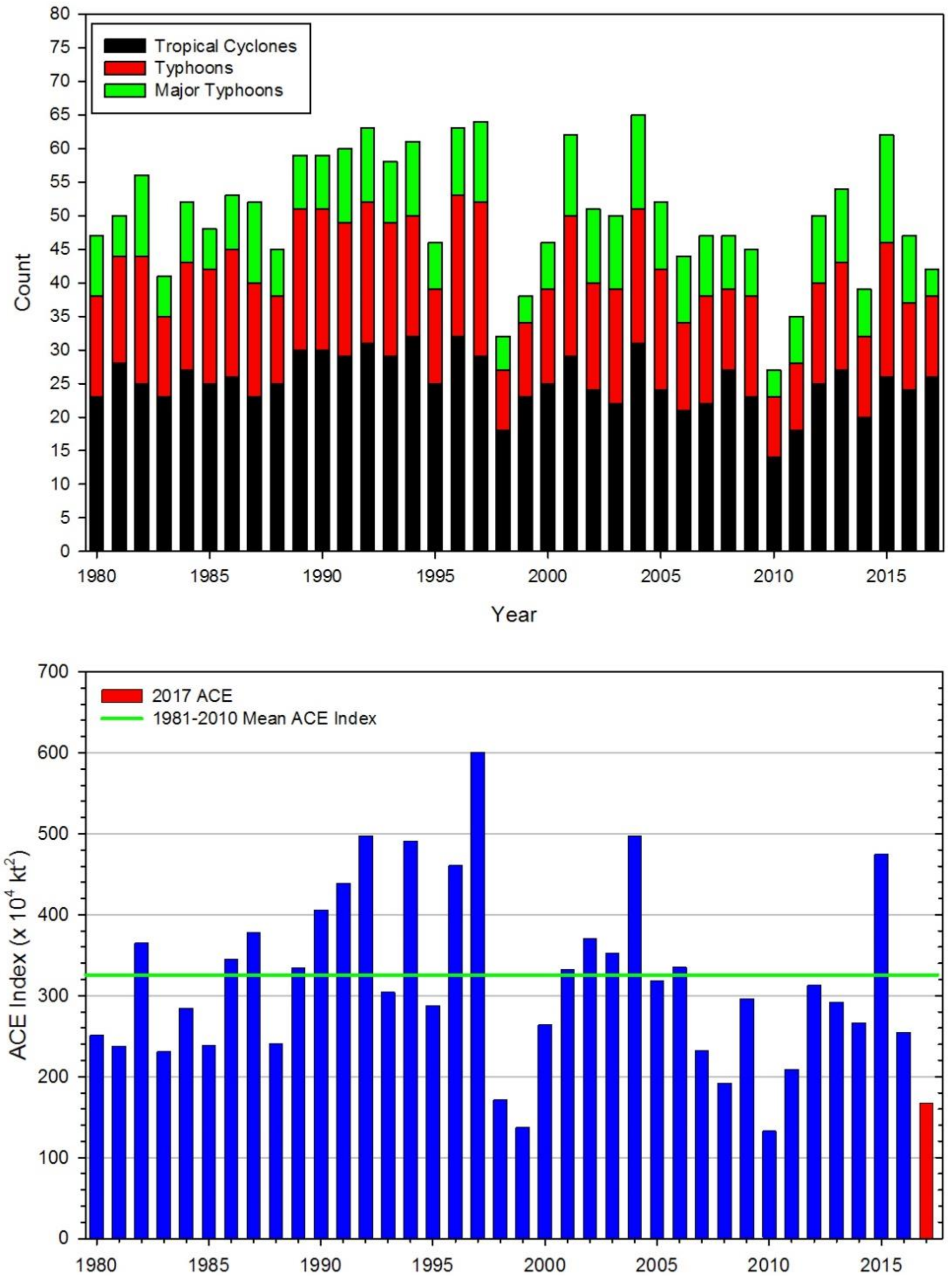


Figure 24. Annual Patterns of Tropical Cyclones in the Western North Pacific, 1980-2017, with 1981-2010 mean superimposed.

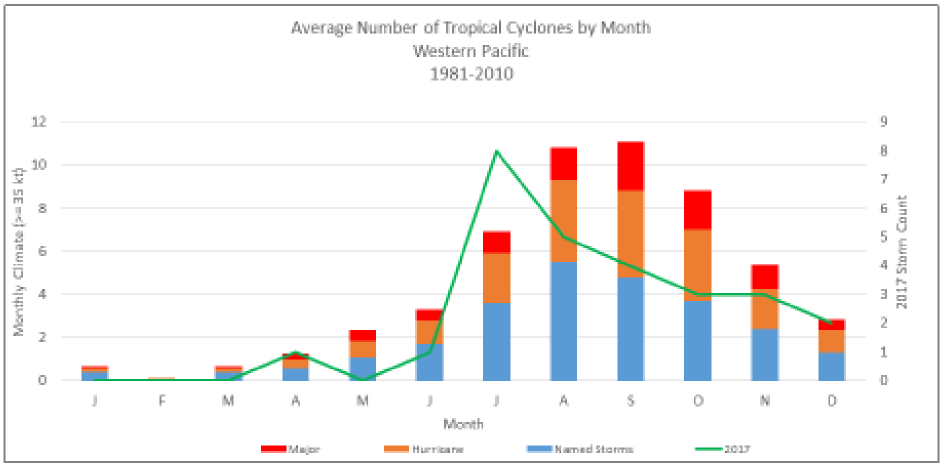


Figure 25. Seasonal Climatology of Tropical Cyclones in the Western Pacific, 1981-2010, with 2017 storms superimposed.

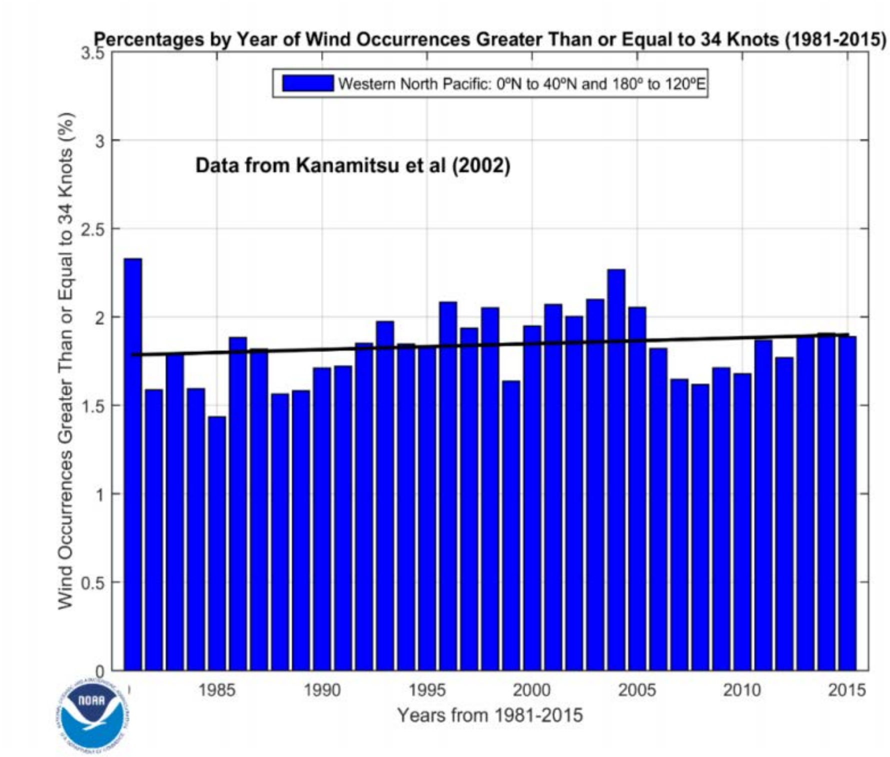


Figure 26. Storm-Force Wind in the Western North Pacific, 1981-2015.

2.5.3.8.1 References

NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2017, published online January 2018, retrieved on March 30, 2018 from http://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713.

Kanamitsu, M., W. Ebisuzaki, J. Woollen, S-K Yang, J.J. Hnilo, M. Fiorino, and G. L. Potter, 2002. NCEPDOE AMIP-II Reanalysis (R-2): Bull. Am. Met. Soc., 83, 1631-1643, https://doi.org/10.1175/BAMS-83- 11-1631

Knapp, K. R., M. C. Kruk, D. H. Levinson, H. J. Diamond, and C. J. Neumann, 2010: The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bulletin of the American Meteorological Society*, 91, 363-376. doi:10.1175/2009BAMS2755.1.

State of Environmental Conditions in Hawaii and the U.S. Affiliated Pacific Islands under a Changing Climate: 2017. Coordinating Authors: J.J. Marra and M.C. Kruk. Contributing Authors: M.Abecassis; H. Diamond; A. Genz; S.F. Heron; M. Lander; G. Liu; J. T. Potemra; W.V. Sweet; P. Thompson; M.W. Widlansky; and P. Woodworth-Jefcoats. September, 2017. NOAA NCEI.

2.5.3.9 Rainfall (CMAP Precipitation)

Rationale: Rainfall may have substantive effects on the nearshore environment and is a potentially important co-variate with the landings of particular stocks.

Description: The CPC Merged Analysis of Precipitation ("CMAP") is a technique which produces pentad and monthly analyses of global precipitation in which observations from raingauges are merged with precipitation estimates from several satellite-based algorithms (infrared and microwave). The analyses are are on a 2.5 x 2.5 degree latitude/longitude grid and extend back to 1979. These data are comparable (but should not be confused with) similarly combined analyses by the Project, which are described in Huffman *et al*. (1997).

It is important to note that the input data sources to make these analyses are not constant throughout the period of record. For example, SSM/I (passive microwave - scattering and emission) data became available in July of 1987; prior to that the only microwave-derived estimates available are from the MSU algorithm (Spencer, 1993) which is emission-based thus precipitation estimates are available only over oceanic areas. Furthermore, high temporal resolution IR data from geostationary satellites (every 3-hr) became available during 1986; prior to that, estimates from the OPI technique (Xie and Arkin, 1997) are used based on OLR from polar orbiting satellites.

The merging technique is thoroughly described in Xie and Arkin (1997). Briefly, the methodology is a two-step process. First, the random error is reduced by linearly combining the satellite estimates using the maximum likelihood method, in which case the linear combination coefficients are inversely proportional to the square of the local random error of the individual data sources. Over global land areas the random error is defined for each time period and grid location by comparing the data source with the rain gauge analysis over the surrounding area. Over oceans, the random error is defined by comparing the data sources with the rain gauge observations over the Pacific atolls. Bias is reduced when the data sources are blended in the second step using the blending technique of Reynolds (1988). Here the data output from step 1 is used to define the "shape" of the precipitation field and the rain gauge data are used to constrain the amplitude. (Text taken from: http://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.html.)

Monthly and pentad CMAP estimates back to the 1979 are available from CPC ftp server.

The monthly data set consists of two files containing monthly averaged precipitation rate values. Values are obtained from 5 kinds of satellite estimates (GPI,OPI,SSM/I scattering, SSM/I emission and MSU) and gauge data. The enhanced file also includes blended NCEP/NCAR Reanalysis Precipitation values. (Text taken from: https://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html#detail.)

Timeframe: Monthly.

Region/Location: Global.

Data Source: CMAP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at https://www.esrl.noaa.gov/psd/

Measurement Platform: *In-situ* station gauges and satellite data.

2.5.3.9.1 References

Xie, P., and P.A. Arkin, 1997: Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, 78, pp. 2539-2558.

Huffman, G. J. and co-authors, 1997: The Global Precipitation Climatology Project (GPCP) combined data set. *Bull. Amer. Meteor. Soc.*, *78*, pp. 5-20.

Reynolds, R. W., 1988: A real-time global sea surface temperature analysis. J. Climate, 1, 75-86.

Spencer, R. W., 1993: Global oceanic precipitation from the MSU during 1979-91 and comparisons to other climatologies. *J. Climate*, *6*, pp. 1301-1326.

Xie P., and P. A. Arkin, 1997: Global precipitation: a 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, *78*, pp. 2539-2558.

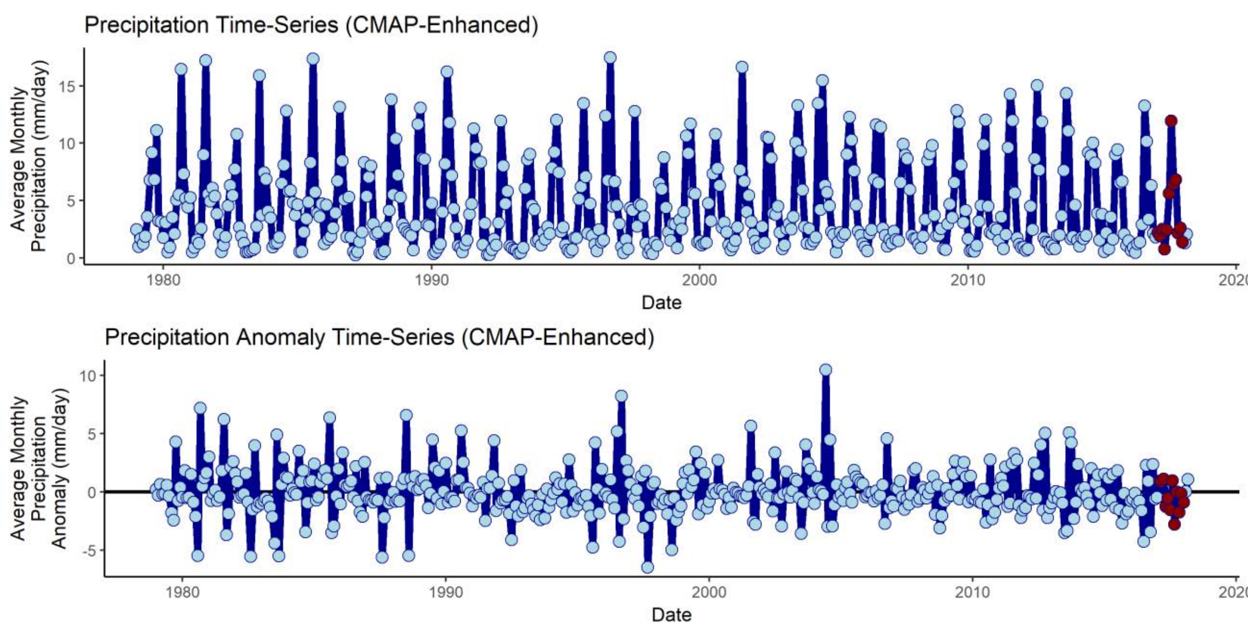


Figure 27. CMAP precipitation across the Mariana Grid with 2017 values in red.

2.5.3.9 Sea Level (Sea Surface Height and Anomaly)

Description: Monthly mean sea level time series, including extremes .

Timeframe: Monthly.

Region/Location: Observations from selected sites within the Samoan Archipelago.

Data Source/Responsible Party: Basin-wide context from satellite altimetry: http://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/el-nino-bulletin.html.

Quarterly time series of mean sea level anomalies from satellite altimetry: http://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2015.

Sea Surface Height and Anomaly from NOAA Ocean Service, Tides and Currents, Sea Level Trends: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1770000.

Measurement Platform: Satellite and *in situ* tide gauges.

Rationale: Coastal rising sea levels can result in a number of coastal impacts, including inundation of infrastructure, increased damage resulting from storm-driven waves and flooding, and saltwater intrusion into freshwater supplies.

2.5.3.9.1 Basin-Wide Perspective

This image of the mean sea level anomaly for February 2016 compared to 1993-2013 climatology from satellite altimetry provides a glimpse into how the 2015-2016 El Niño continues to affect sea level across the Pacific Basin. The image captures the fact that sea level continues to be lower in the Western Pacific and higher in the Central and Eastern Pacific (a standard pattern during El Niño events. This basin-wide perspective provides a context for the location-specific sea level/sea surface height images that follow.)

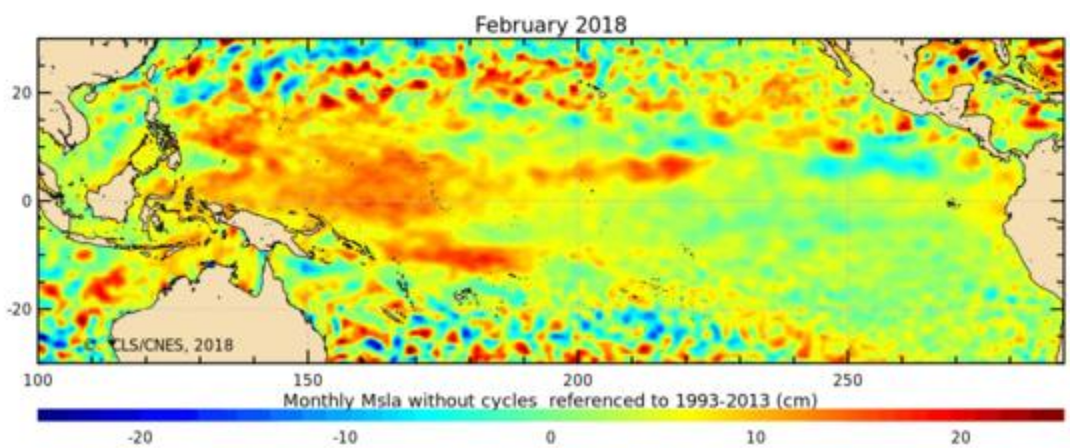


Figure 28a. Sea surface height anomalies across Pacific Ocean in February 2018.

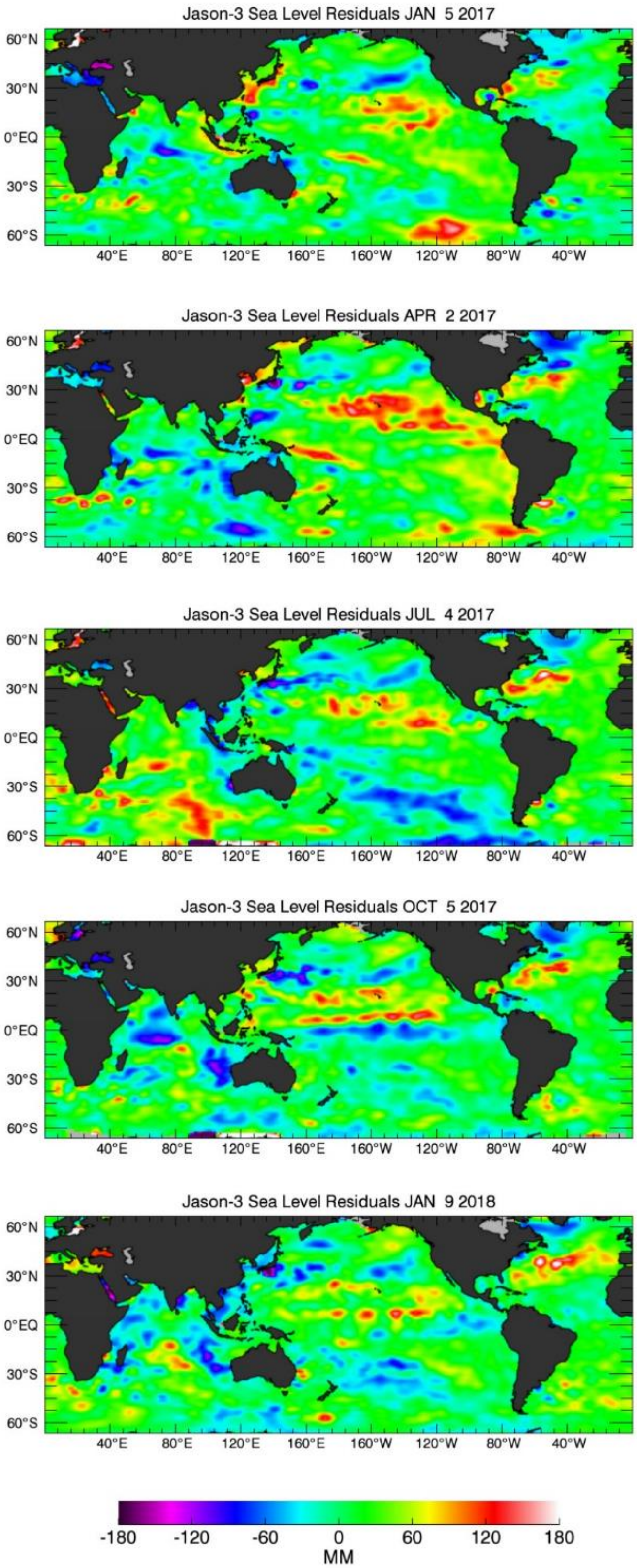
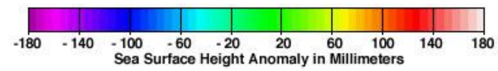


Figure 28b. Quarterly time series of mean sea level anomalies during 2017 show no pattern of El Niño throughout the year according to satellite altimetry measurements of sea level height (unlike 2015) from http://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2017.



2.5.3.9.2 Local Sea Level

These time-series from *in situ* tide gauges provide a perspective on sea level trends within each Archipelago (Tide Station Time Series from NOAA/COOPS).

The following figures and descriptive paragraphs were inserted from https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1630000.

Figure 29 shows the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea Level datum established by CO-OPS. The calculated trends for all stations are available as a table in millimeters/year and in feet/century (0.3 meters = 1 foot). If present, solid vertical lines indicate times of any major earthquakes in the vicinity of the station and dashed vertical lines bracket any periods of questionable data or datum shift.

The monthly extreme water levels include a Mean Sea Level (MSL) trend of 5.04 millimeters/year with a 95% confidence interval of +/- 4.15 millimeters/year based on monthly MSL data from 1993 to 2017 which is equivalent to a change of 1.65 feet in 100 years.

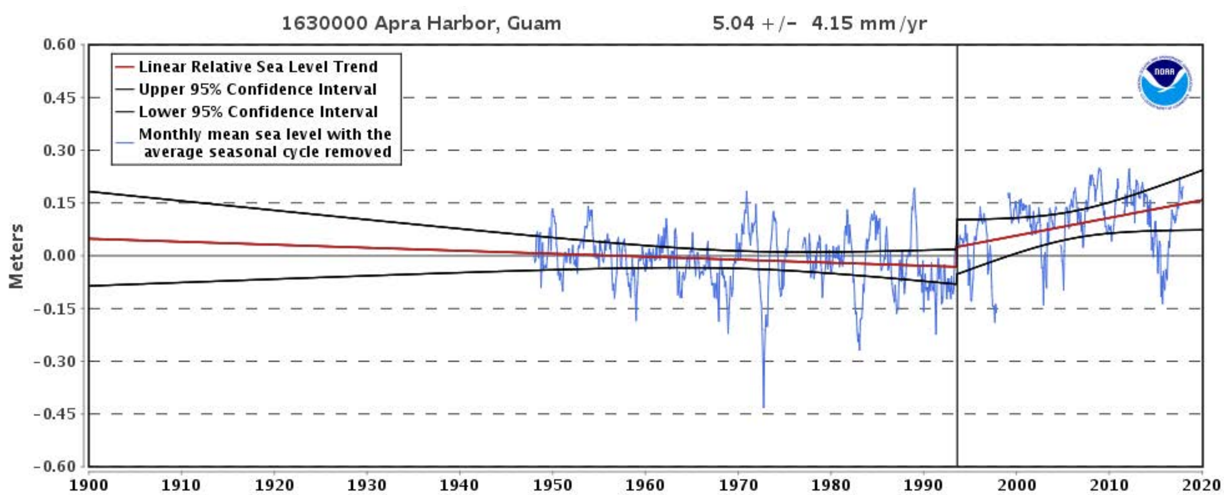


Figure 29. Monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents.

2.6 ESSENTIAL FISH HABITAT

2.6.1 Introduction

The Magnuson-Stevens Fishery Conservation and Management Act includes provisions concerning the identification and conservation of essential fish habitat (EFH), and under the EFH final rule, habitat areas of particular concern (HAPC) (50 Code of Federal Regulations [CFR] 600.815). The Magnuson-Stevens Act defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." HAPC are those areas of EFH identified pursuant to 50 CFR 600.815(a)(8), and meeting one or more of the following considerations: (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.

The National Marine Fisheries Service (NMFS) and regional Fishery Management Councils (Councils) must describe and identify EFH in fishery management plans (FMPs), minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. Federal agencies that authorize, fund, or undertake actions that may adversely affect EFH must consult with NMFS, and NMFS must provide conservation recommendations to federal and state agencies regarding actions that would adversely affect EFH. Councils also have the authority to comment on federal or state agency actions that would adversely affect the habitat, including EFH, of managed species.

The EFH Final Rule strongly recommends regional fisheries management councils and NMFS to conduct a review and revision of the EFH components of fisheries management plans every five years (600.815(a)(10)). The council's FEPs state that new EFH information should be reviewed, as necessary, during preparation of the annual reports by the Plan Teams. Additionally, the EFH Final Rule states: "Councils should report on their review of EFH information as part of the annual Stock Assessment and Fishery Evaluation (SAFE) report prepared pursuant to §600.315(e)." The habitat portion of the annual report is designed to meet the FEP requirements and EFH Final Rule guidelines regarding EFH reviews.

National Standard 2 guidelines recommend that the SAFE report summarize the best scientific information available concerning the past, present, and possible future condition of EFH described by the FEPs.

2.6.1.1 EFH Information

The EFH components of fisheries management plans include the description and identification of EFH, lists of prey species and locations for each managed species, and optionally, habitat areas of particular concern. Impact-oriented components of FMPs include federal fishing activities that may adversely affect EFH; non-federal fishing activities that may adversely affect EFH; non-fishing activities that may adversely affect EFH; conservation and enhancement recommendations; and a cumulative impacts analysis on EFH. The last two components include the research and information needs section, which feeds into the Council's Five Year Research Priorities, and the EFH update procedure, which are described in the FEP but implemented in the annual report.

The Council has described EFH for five management unit species (MUS) under its management authority: pelagic (PMUS), bottomfish (BMUS), crustaceans (CMUS), coral reef ecosystem (CREMUS), and precious corals (PCMUS). The Mariana FEP describes EFH for the BMUS, CMUS, CREMUS, and PCMUS.

EFH reviews of the biological components, including the description and identification of EFH, lists of prey species and locations, and HAPC, consist of three to four parts:

- Updated species descriptions, which can be found appended to the SAFE report. These can be used to directly update the FEP.
- Updated EFH levels of information tables, which can be found in Section 0.
- Updated research and information needs, which can be found in Section 2.6.5. These can be used to directly update the FEP.
- An analysis that distinguishes EFH from all potential habitats used by the species, which is the basis for an options paper for the Council. This part is developed if enough information exists to refine EFH.

2.6.1.2 Habitat Objectives of FEP

The habitat objective of the FEP is to refine EFH and minimize impacts to EFH, with the following sub-objectives:

a. Review EFH and HAPC designations every five years based on the best available scientific information and update such designations based on the best available scientific information, when available.

b. Identify and prioritize research to assess adverse impacts to EFH and HAPC from fishing (including aquaculture) and non-fishing activities, including, but not limited to, activities that introduce land-based pollution into the marine environment.

This annual report reviews the precious coral EFH components and non-fishing impacts components, resetting the five-year timeline for review. The Council's support of non-fishing activities research is monitored through the program plan and five year research priorities, not the annual report.

2.6.1.3 Response to Previous Council Recommendations

At its 170th meeting, the Council directed staff to develop options for refining precious corals essential fish habitat for the Council's consideration, based on the review in the 2016 SAFE report. The options paper is under development.

At its 170th meeting, the Council directed staff to scope the non-fishing impacts review, from the 2016 SAFE reports, through its advisory bodies. The CNMI Joint Advisory Group provided comments on the non-fishing impacts review at a meeting held November 15, 2017, in Garapan. The Guam Joint Advisory Group also reviewed the report at their meeting held on November 17, 2017, in Tumon.

2.6.2 Habitat Use by MUS and Trends in Habitat Condition

The Mariana Archipelago is a chain of islands in the western Pacific roughly oriented north-south. It is anchored at the southern end by the relatively large island of Guam at 13.5° north latitude. The Commonwealth of the Northern Mariana Islands (CNMI) stretch off to the north. The entire chain is approximately 425 miles long. The archipelago was named by Spanish explorers in the 16th Century in honor of Spanish Queen Mariana of Austria.

The total land area of Guam is approximately 212 square miles and its EEZ is just over 84,000 square miles. The CNMI consists of 14 main islands. From north to south these are: Farallon de Pajaros, Maug, Asuncion, Agrihan, Pagan, Alamagan, Guguan, Sarigan, Anatahan, Farallon de Medinilla, Saipan, Tinian, Aguijan, and Rota. Only Saipan, Rota, and Tinian are permanently inhabited, with 90% of the population residing on the island of Saipan. The total land area of the CNMI is 176.5 square miles and its EEZ is almost 300,000 square miles.

Guam and the southern islands of the CNMI are limestone, with level terraces and fringing coral reefs. The CNMI's northern islands are volcanic and sparsely inhabited, with active volcanoes on several islands, including Anatahan, Pagan, and Agrihan (the highest, at 3,166 feet). The archipelago has a tropical maritime climate moderated by seasonal northeast trade winds. While there is little seasonal temperature variation, there is a dry season (December to June) and a rainy season (July to November). The rainy season coincides with the northern hemisphere hurricane season, and the Mariana Archipelago is periodically impacted by powerful typhoons.

The Mariana Trench is located to the east of the chain. The trench includes the deepest point in the world's oceans. The vertical measurement from the seafloor to Saipan's highest point (Mount Tapotchau) is 37,752 ft.

Essential fish habitat in the Marianas for the four MUS comprises all substrate from the shoreline to the 700 m isobath. The entire water column is described as EFH from the shoreline to the 700 m isobath, and the water column to a depth of 400 m is described as EFH from the 700 m isobath to the limit or boundary of the exclusive economic zone (EEZ). While the coral reef ecosystems surrounding the islands in the Marianas have been the subject of a comprehensive monitoring program through the PIFSC Coral Reef Ecosystem Division (CRED) biennially since 2003, surveys are focused on the nearshore environments surrounding the islands, atolls, and reefs (PIFSC, 2011). Remote reefs and shoals were surveyed in some years.

The mission of the PIFSC Coral Reef Ecosystem Division (CRED) is to "provide high-quality, scientific information about the status of coral reef ecosystems of the U.S. Pacific islands to the public, resource managers, and policymakers on local, regional, national, and international levels" (PIFSC, 2011). CRED's Reef Assessment and Monitoring Program (RAMP) conducts comprehensive ecosystem monitoring surveys at about 50 island, atoll, and shallow bank sites in the Western Pacific Region on a one to three year schedule (PIFSC, 2008). CRED coral reef monitoring reports provide the most comprehensive description of nearshore habitat quality in the region. The benthic habitat mapping program provides information on the quantity of habitat.

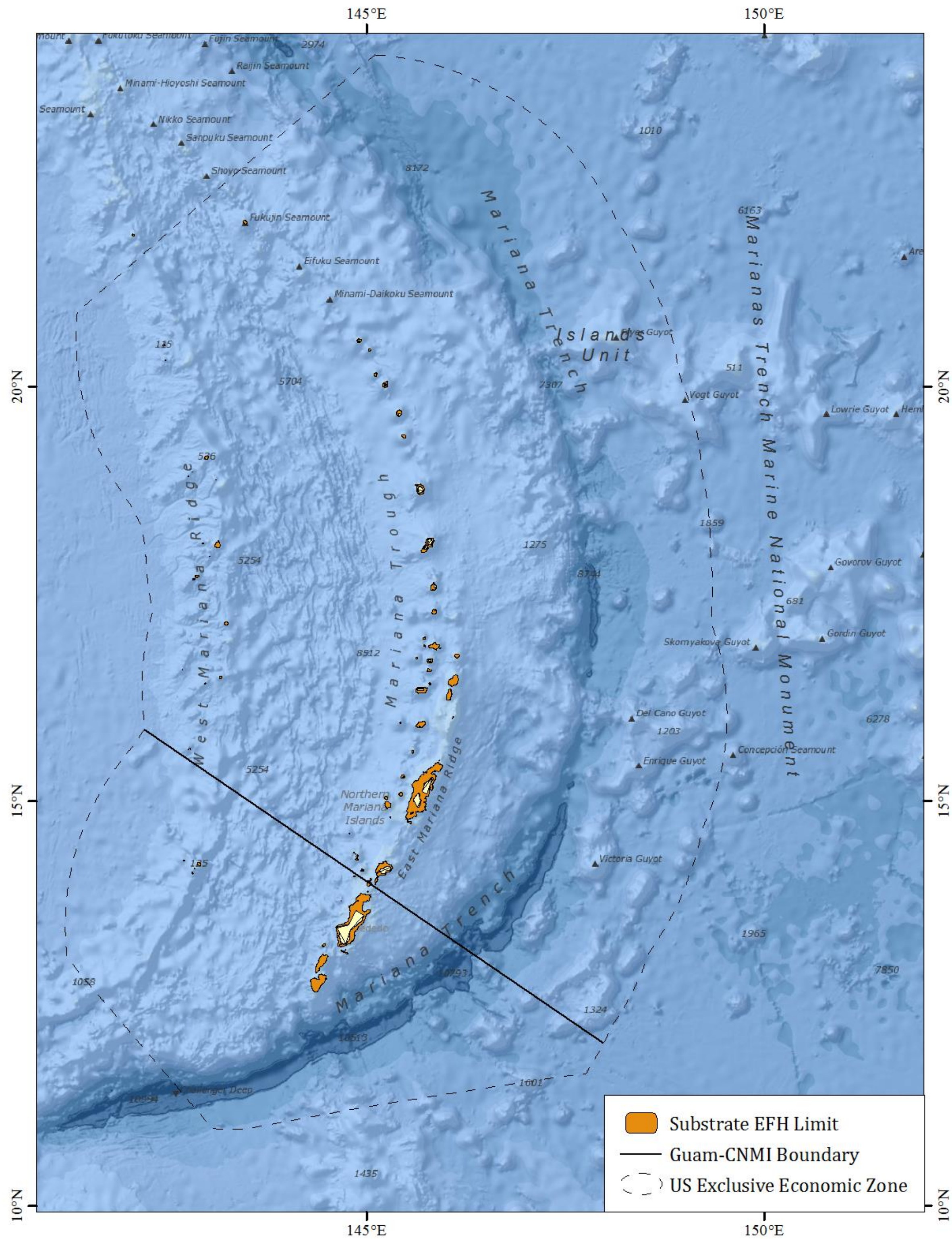


Figure 30. Substrate EFH Limit of 700 m isobath around the islands and surrounding banks of the Mariana Archipelago (from GRMT).

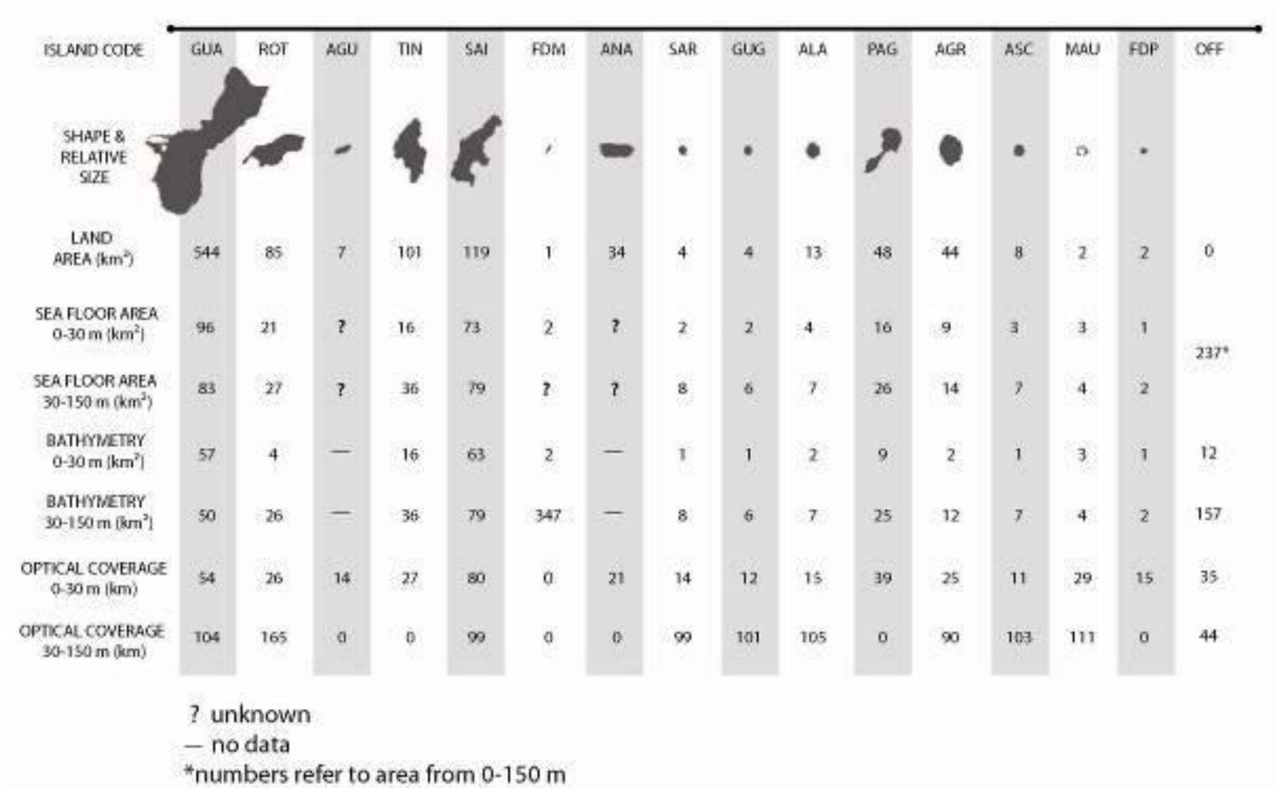
2.6.2.1 Habitat Mapping

Interpreted IKONOS benthic habitat maps in the 0 – 30 m depth range have been completed for all islands in the CNMI (CRCP, 2011). Mapping products for the Marianas are available from the Pacific Islands Benthic Habitat Mapping Center.

Table 66. Summary of habitat mapping in CNMI.

Depth Range	Timeline/Mapping Product	Progress	Source
0-30 m	IKONOS Benthic Habitat Maps	All Islands	CRCP 2011
	2000-2010 Bathymetry	70%	DesRochers 2016
	2011-2015 Multibeam Bathymetry	-	DesRochers 2016
	2011-2015, Satellite Worldview 2 Bathymetry	15%	DesRochers 2016
30-150 m	2000-2010 Bathymetry	85%	DesRochers 2016
	2011-2015 Multibeam Bathymetry	-	DesRochers 2016
15-2000 m	Multibeam Bathymetry	Complete around all islands except Guam, Rota, and Agrigan	Pacific Islands Benthic Habitat Mapping Center
	Derived Products	Backscatter available for all 60 m multibeam Geomorphology products – see website	Pacific Islands Benthic Habitat Mapping Center

The land and seafloor area surrounding the islands of the Marianas as well as primary data coverage are reproduced from CRCP (2011) in Figure 31.



ISLAND CODE	GUA	ROT	AGU	TIN	SAI	FDM	ANA	SAR	GUG	ALA	PAG	AGR	ASC	MAU	FDP	OFF
SHAPE & RELATIVE SIZE																
LAND AREA (km²)	544	85	7	101	119	1	34	4	4	13	48	44	8	2	2	0
SEA FLOOR AREA 0-30 m (km²)	96	21	?	16	73	2	?	2	2	4	16	9	3	3	1	237*
SEA FLOOR AREA 30-150 m (km²)	83	27	?	36	79	?	?	8	6	7	26	14	7	4	2	
BATHYMETRY 0-30 m (km²)	57	4	—	16	63	2	—	1	1	2	9	2	1	3	1	12
BATHYMETRY 30-150 m (km²)	50	26	—	36	79	347	—	8	6	7	25	12	7	4	2	157
OPTICAL COVERAGE 0-30 m (km)	54	26	14	27	80	0	21	14	12	15	39	25	11	29	15	35
OPTICAL COVERAGE 30-150 m (km)	104	165	0	0	99	0	0	99	101	105	0	90	103	111	0	44

? unknown
— no data
*numbers refer to area from 0-150 m

Figure 31. CNMI Land and Seafloor Area and Primary Data Coverage.

2.6.2.2 Benthic Habitat

Juvenile and adult life stages of coral reef MUS and crustaceans including spiny and slipper lobsters and Kona crab extends from the shoreline to the 100 m isobath (64 FR 19067, April 19, 1999). All benthic habitat is considered EFH for crustaceans species (64 FR 19067, April 19, 1999), while the type of bottom habitat varies by family for coral reef species (69 FR 8336, February 24, 2004). Juvenile and adult bottomfish EFH extends from the shoreline to the 400 m isobath (64 FR 19067, April 19, 1999), and juvenile and adult deepwater shrimp habitat extends from the 300 m isobath to the 700 m isobath (73 FR 70603, November 21, 2008).

2.6.2.2.1 RAMP Indicators

Benthic percent cover of coral, macroalgae, and crustose coralline algae from CRED are found in the following tables. CRED uses the benthic towed-diver survey method to monitor changes in benthic composition. In this method, "a pair of scuba divers (one collecting fish data, the other collecting benthic data) is towed about 1 m above the reef roughly 60 m behind a small boat at a constant speed of about 1.5 kt. Each diver maneuvers a towboard platform, which is connected to the boat by a bridle and towline and outfitted with a communications telegraph and various survey equipment, including a downward-facing digital SLR camera (Canon EOS 50D, Canon Inc., Tokyo). The benthic towed diver records general habitat complexity and type (e.g., spur and groove, pavement), percent cover by functional-group (hard corals, stressed corals, soft corals, macroalgae, crustose coralline algae, sand, and rubble), and for macroinvertebrates (crown-of-thorns seastars, sea cucumbers, free and boring urchins, and giant clams).

Towed-diver surveys are typically 50 minutes long and cover about two to three kilometers of habitat. Each survey is divided into five-minute segments, with data recorded separately per segment to allow for later location of observations within the ~200-300 meter length of each segment. Throughout each survey, latitude and longitude of the survey track are recorded on the small boat using a GPS; after the survey, diver tracks are generated with the GPS data and a layback algorithm that accounts for position of the diver relative to the boat. (PIFSC Website, 2016).

Table 67. Mean percent cover of live coral from RAMP sites collected from towed-diver surveys in the Mariana Archipelago.

Year	2003	2005	2007	2009	2011	2014
Agrihan	16.03	15.45	13.68	16.03	19.83	
Aguijan	17.88	17.25	11.68	15.61	21.88	33.46
Alamagan	18.23	17.39	22.21	23.34	30.28	27.58
Anatahan	7.93					
Arakane	24.06	11.83				
Asuncion	18.15	15.58	15.66	18.57	28	40.56
Farallon de Pajaros	10.13	4.82	4.94	11.28	11.69	16.45
Guam	19.58	23.3	11.72	13.71	19.06	17.58
Guguan	23	10.18	26.58	24.97	30.23	37.23
Maug	26.86	21.43	26.25	28.09	38	46.17
Pagan	18.51	9.84	12.04	13.09	16.23	27.87
Pathfinder	24.17	24.75				
Rota	8.98	6.04	4.36	4.45	9.94	17.39
Saipan	20.85	10.63	10.18	10.18	13.73	24.99
Santa Rosa	7.31	7.8				
Sarigan	18.02	12.88	14.21	23.37	18.01	31.98
Stingray	54.86					
Supply	38.75					
Tatsumi	7.92					
Tinian	12.46	8.99	8.08	9.33	12.02	17.37

Table 68. Mean percent cover of macroalgae from RAMP sites collected from towed-diver surveys in the Mariana Archipelago.

Year	2003	2005	2007	2009	2011	2014
Agrihan	48.25	22.65	8.55	3.2	4.63	
Aguijan	44.56	38.81	28.31	20.8	21.52	25.1
Alamagan	41.21	26.03	15.65	15.47	12.81	8.33
Anatahan	14.31					
Arakane	52.26	45.75				
Asuncion	51.1	5.37	19.11	7.54	7.47	3.86

Farallon de Pajaros	60.2	4.32	3.38	0.05	0.91	0.18
Guam	46.19	52.67	43.22	26.82	29.61	41.64
Guguan	45	10.18	19.5	17	12.59	8.66
Maug	45.91	27.2	8.17	3.26	4.37	12.01
Pagan	45.96	18.4	16.74	9.84	7.36	19.3
Pathfinder	37.29	29				
Rota	54.34	56.05	38.76	30.95	35.16	29.33
Saipan	48.57	30.75	31.87	20.39	15.26	25.18
Santa Rosa	42.5	70.54				
Sarigan	42.23	23.95	16.47	12.51	9.41	11.55
Stingray	33.89					
Supply	19.17					
Tatsumi	67.22					
Tinian	46.94	56.38	39.95	30.4	25.92	34.91

Table 69. Mean percent cover of crustose coralline algae from RAMP sites collected from towed-diver surveys in the Mariana Archipelago.

Year	2003	2005	2007	2009	2011	2014
Agrihan	8.64	5.7	9.94	5.57	3.91	
Aguijan	14.69	10.59	12.67	7.32	11.47	18.33
Alamagan	7.63	4.85	10.29	5.33	4.29	6.25
Anatahan	7.72					
Arakane	5.28	3.58				
Asuncion	7.96	8.99	9.53	3.67	4.62	2.19
Farallon de Pajaros	3.44	8.03	5.39	2.94	2.29	0.05
Guam	12.75	4.04	8.54	6.13	9.39	6.9
Guguan	17.13	15	12.95	14.59	7.35	9.91
Maug	10.22	7.53	12.32	7.73	5.38	8.23
Pagan	6.61	12.41	14.16	8.42	6.33	2.48
Pathfinder	5.56	10				
Rota	18.39	4.56	12.42	5.22	6.67	5.49
Saipan	10.04	8.74	15.03	8.27	6.31	5.61
Santa Rosa	7.13	0.55				
Sarigan	10.64	3.24	7.58	3.84	2.59	4.57
Stingray	1.54					
Supply	35					
Tatsumi	6.11					
Tinian	6.25	5.18	16.16	4.07	7.59	5.96

2.6.2.3 Oceanography and Water Quality

The water column is also designated as EFH for selected MUS life stages at various depths. For larval stages of all species except deepwater shrimp, the water column is EFH from the shoreline to the EEZ. Coral reef species egg and larval EFH is to a depth of 100 m; crustaceans, 150m; and bottomfish, 400 m. Please see the Ecosystem and Climate Change section for information related to oceanography and water quality.

2.6.3 Report on Review of EFH Information

One EFH review was drafted this year; the review of the biological components of crustaceans EFH can be found in Appendix C.

2.6.4 EFH Levels

NMFS guidelines codified at 50 C.F.R. § 600.815 recommend Councils organize data used to describe and identify EFH into the following four levels:

1. Level 1: Distribution data are available for some or all portions of the geographic range of the species.
2. Level 2: Habitat-related densities of the species are available.
3. Level 3: Growth, reproduction, or survival rates within habitats are available.
4. Level 4: Production rates by habitat are available.

The Council adopted a fifth level, denoted Level 0, for situations in which there is no information available about the geographic extent of a particular managed species' life stage. The existing level of data for individual MUS in each fishery are presented in tables per fishery. In subsequent SAFE reports, each fishery section will include the description of EFH method, method used to assess the value of the habitat to the species, description of data sources used if there was analysis; and description of method for analysis.

2.6.4.1 Precious Corals

Essential Fish Habitat for precious corals was originally designated in Amendment 4 to the Precious Corals Fishery Management Plan (64 FR 19067, April 19, 1999), using the level of data found in the table.

Table 70. Level of EFH information available for the Western Pacific precious corals management unit species complex. Note: all observations are from the Hawaiian Islands.

Species	Pelagic phase (larval stage)	Benthic phase	Source(s)
Pink Coral (*Corallium)*			
Pleurocorallium secundum (prev. *Corallium secundum)*	0	1	Figueroa & Baco, 2014 HURL Database
C. regale	0	1	HURL Database
Hemicorallium	0	1	HURL Database

Species	Pelagic phase (larval stage)	Benthic phase	Source(s)
laauense (prev. C. laauense)			
Gold Coral			
Kulamanamana haumeaae (prev.	0	1	Sinniger, *et al.* (2013) HURL Database
Callogorgia gilberti	0	1	HURL Database
Narella spp.	0	1	HURL Database
Bamboo Coral			
Lepidisis olapa	0	1	HURL Database
Acanella spp.	0	1	HURL Database
Black Coral			
Antipathes griggi (prev. *Antipathes dichotoma)*	0	2	Opresko, 2009 HURL Database
A. grandis	0	1	HURL Database
Myriopathes ulex (prev. *A. ulex)*	0	1	Opresko, 2009 HURL Database

2.6.4.2 Bottomfish and Seamount Groundfish

Essential Fish Habitat for bottomfish and seamount groundfish was originally designated in Amendment 6 to the Bottomfish and Seamount Groundfish FMP (64 FR 19067, April 19, 1999).

Table 71. Level of EFH information available for Western Pacific bottomfish and seamount groundfish MUS complexes.

Life History Stage	Eggs	Larvae	Juvenile	Adult
Bottomfish: (scientific/english common)				
Aphareus rutilans (red snapper/silvermouth)	0	0	0	2
Aprion virescens (gray snapper/jobfish)	0	0	1	2
Caranx ignoblis (giant trevally/jack)	0	0	1	2
C. lugubris (black trevally/jack)	0	0	0	2
Epinephelus faciatus (blacktip grouper)	0	0	0	1
E. quernus (sea bass)	0	0	1	2
Etelis carbunculus (red snapper)	0	0	1	2
E. coruscans (red snapper)	0	0	1	2
Lethrinus amboinensis (ambon emperor)	0	0	0	1
L. rubrioperculatus (redgill emperor)	0	0	0	1
Lutjanus kasmira (blueline snapper)	0	0	1	1
Pristipomoides auricilla (yellowtail snapper)	0	0	0	2

Life History Stage	Eggs	Larvae	Juvenile	Adult
P. filamentosus (pink snapper)	0	0	1	2
P. flavipinnis (yelloweye snapper)	0	0	0	2
P. seiboldi (pink snapper)	0	0	1	2
P. zonatus (snapper)	0	0	0	2
Pseudocaranx dentex (thicklip trevally)	0	0	1	2
Seriola dumerili (amberjack)	0	0	0	2
Variola louti (lunartail grouper)	0	0	0	2
Seamount Groundfish:				
Beryx splendens (alfonsin)	0	1	2	2
Hyperoglyphe japonica (ratfish/butterfish)	0	0	0	1
Pseudopentaceros richardsoni (armorhead)	0	1	1	3

2.6.4.3 Crustaceans

Essential Fish Habitat for crustaceans MUS was originally designated in Amendment 10 to the Crustaceans FMP (64 FR 19067, April 19, 1999). EFH definitions were also approved for deepwater shrimp through an amendment to the Crustaceans FMP in 2008 (73 FR 70603, November 21, 2008).

Table 72. Level of EFH information available for the Western Pacific crustacean MUS.

Life History Stage	Eggs	Larvae	Juvenile	Adult
Crustaceans: (english common\scientific)				
Spiny lobster (*Panulirus marginatus*)	2	1	1-2	2-3
Spiny lobster (*Panulirus pencillatus*)	1	1	1	2
Common slipper lobster (*Scyllarides squammosus*)	2	1	1	2-3
Ridgeback slipper lobster (*Scyllarides haanii*)	2	0	1	2-3
Chinese slipper lobster (*Parribacus antarcticus*)	2	0	1	2-3
Kona crab (*Ranina ranina*)	1	0	1	1-2

2.6.4.4 Coral Reef

Essential Fish Habitat for coral reef ecosystem species was originally designated in the Coral Reef Ecosystem FMP (69 FR 8336, February 24, 2004). An EFH review of CREMUS will not be undertaken until the Council completes its process of re-designating certain CREMUS into the ecosystem component classification. Ecosystem component species do not require EFH designations, as they are not a managed species.

2.6.5 Research and Information Needs

Based, in part, on the information provided in the tables above the Council identified the following scientific data which are needed to more effectively address the EFH provisions:

2.6.5.1 All FMP Fisheries

- Distribution of early life history stages (eggs and larvae) of management unit species 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.
- Growth, reproduction, and survival rates for MUS within habitats.

2.6.5.2 Bottomfish Fishery

- 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-water and shallow-water bottomfish complexes.
- High resolution maps of bottom topography/currents/water masses/primary productivity.
- Habitat utilization patterns for different life history stages and species.

2.6.5.3 Crustaceans Fishery

- Identification of post-larval 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, genetic techniques, etc.).
- Establish baseline parameters (CPUE) for the Guam/Northern Marinas crustacean populations.
- Research to determine habitat-related densities for all CMUS life history stages in American Samoa, Guam, Hawaii, and CNMI.
- High resolution mapping of bottom topography, bathymetry, currents, substrate types, algal beds, and habitat relief.

2.6.5.4 Precious Corals Fishery

- Distribution, abundance, and status of precious corals in the CNMI and Guam.

2.6.6 References

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2.7 MARINE PLANNING

2.7.1 Introduction

Marine planning is a science-based tool being utilized regionally, nationally and globally to identify and address issues of multiple human uses, ecosystem health and cumulative impacts in the coastal and ocean environment. The Council's efforts to formalize incorporation of marine planning in its actions began in response to Executive Order 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes. Executive Order 13158, Marine Protected Areas (MPAs), proposes that agencies strengthen the management, protection, and conservation of existing MPAs, develop a national system of MPAs representing diverse ecosystems, and avoid causing harm to MPAs through federal activities. MPAs, or marine managed areas (MMAs) are one tool used in fisheries management and marine planning.

At its 165th meeting in March 2016, in Honolulu, Hawai`i, the Council approved the following objective for the FEPs: Consider the Implications of Spatial Management Arrangements in Council Decision-making. The following sub-objectives apply:

a. Identify and prioritize research that examines the positive and negative consequences of areas that restrict or prohibit fishing to fisheries, fishery ecosystems, and fishermen, such as the Bottomfish Fishing Restricted Areas, military installations, NWHI restrictions, and Marine Life Conservation Districts.

b. Establish effective spatially-based fishing zones.

c. Consider modifying or removing spatial-based fishing restrictions that are no longer necessary or effective in meeting their management objectives.

d. As needed, periodically evaluate the management effectiveness of existing spatial-based fishing zones in Federal waters.

In order to monitor implementation of this objective, this annual report includes the Council's spatially-based fishing restrictions or marine managed areas (MMAs), the goals associated with those, and the most recent evaluation. Council research needs are identified and prioritized through the 5 Year Research Priorities and other processes, and are not tracked in this report.

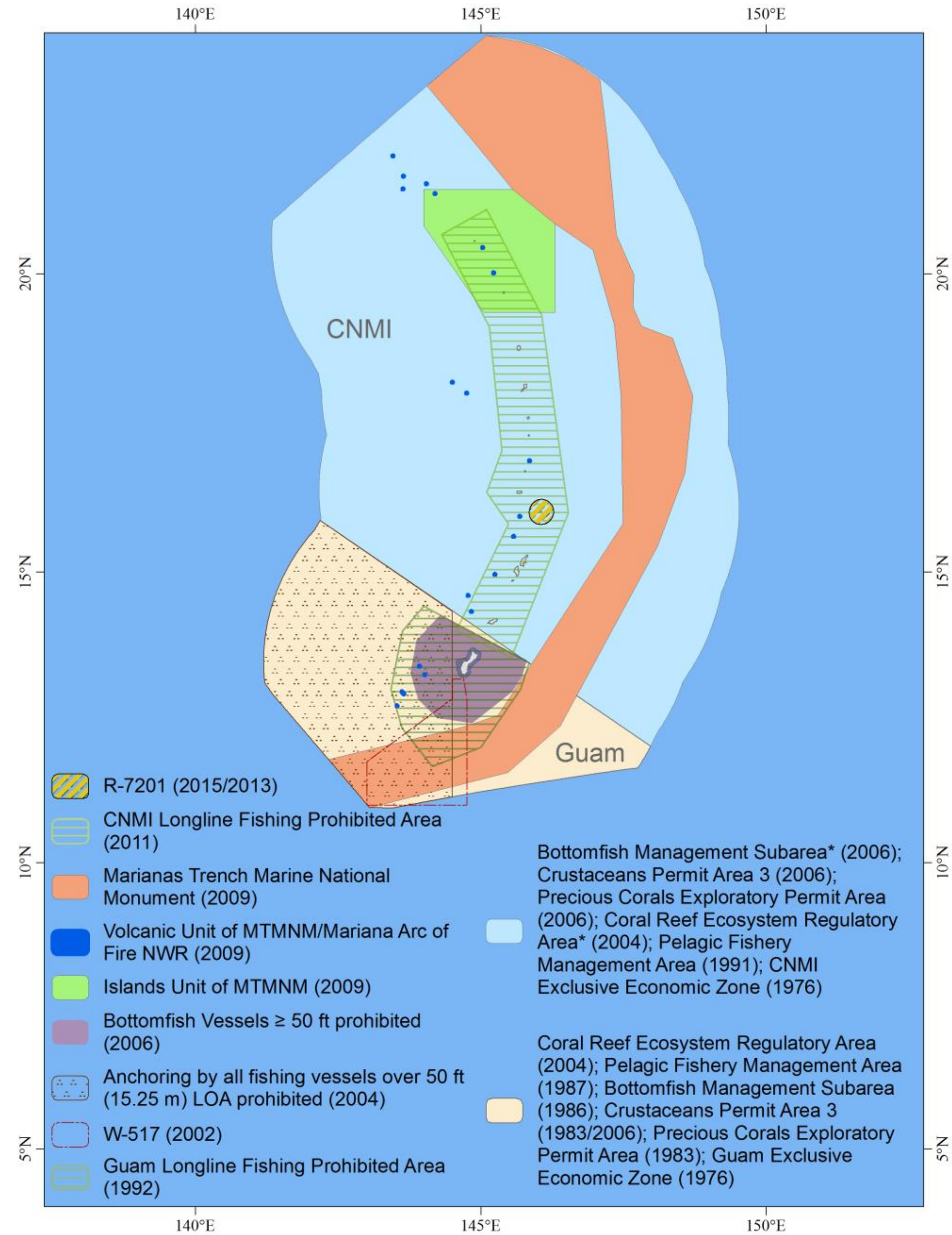
In order to meet the EFH and National Environmental Policy Act (NEPA) mandates, this annual report tracks activities that occur in the ocean that are of interest to the Council, and incidents or facilities that may contribute to cumulative impact. The National Marine Fisheries Service (NMFS) is responsible for NEPA compliance, and the Council must assess the environmental effects of ocean activities for the FEP's EFH cumulative impacts section. These are redundant efforts; therefore, this report can provide material or suggest resources to meet both mandates.

2.7.2 Response to Previous Council Recommendations

There are no standing Council recommendations indicating review deadlines for Marianas marine managed areas.

2.7.3 Marine Managed Areas established under FEPs

Council-established marine managed areas (MMAs) were compiled in Table 73 from 50 CFR § 665, Western Pacific Fisheries, the Federal Register, and Council amendment documents. Geodesic areas were calculated in square kilometers in ArcGIS 10.2. All regulated fishing areas and large scale access restrictions, including the Mariana Trench Marine National Monument, are shown in Figure 32.



* The Coral Reef Ecosystem Regulatory Area excluded the portion of EEZ waters 0-3 miles around the CNMI. The Bottomfish Management Subarea was divided in the CNMI Inshore Area, which was that portion of the EEZ shoreward of 3 nautical miles of the shoreline of CNMI, and the CNMI Offshore Area, which was that portion of the EEZ seaward of 3 nautical miles from the CNMI shoreline.

Figure 32. Regulated fishing areas of the Mariana Archipelago, including large access restrictions.

Table 73. MMAs established under FEPs from 50 CFR § 665.

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Pelagic Restrictions								
Guam Longline Prohibited Area	Pelagic	Guam	665.806(a)(3) 57 FR 7661 Pelagic FMP Am. 5	50,192.88	Longline fishing prohibited	Prevent gear conflicts between longline vessels and troll/handline vessels	1992	-
CNMI Longline Prohibited Area	Pelagic		665.806(a)(4) 76 FR 37287	88,112.68	Longline fishing prohibited	Reduce potential for nearshore localized fish depletion from longline fishing, and to limit catch competition and gear conflicts between the CNMI-based longline and trolling fleets	2011	-
Bottomfish Restrictions								
Guam Large Vessel Prohibited Area	Mariana Archipelago	Guam	665.403(a) 71 FR 64474 Bottomfish FMP Am. 9	29,384.06	Vessels ≥ 50 feet prohibited	To maintain viable participation and bottomfish catch rates by small vessels in the fishery	2006	-
Other Restrictions								
Guam No Anchor Zone	Mariana Archipelago	Guam	665.399 69 FR 8336 Coral Reef Ecosystem FEP	138,992.51	Anchoring by all fishing vessels ≥ 50 ft prohibited on the offshore southern banks located in the U.S. EEZ off Guam	Minimize adverse human impacts on coral reef resources	2004	-

2.7.4 Fishing Activities and Facilities

There are no offshore aquaculture projects in Federal waters, proposed or existing, in CNMI or Guam.

2.7.5 Non-Fishing Activities and Facilities

The following section includes activities or facilities associated with known uses and predicted future uses. The Plan Team will add to this section as new facilities are proposed and/or built. Due to the sheer volume of ocean activities and the annual frequency of this report, only major activities on multi-year planning cycles are tracked in this report. Activities which are no longer reasonably foreseeable or have been replaced with another planning activity are removed from the report, though may occur in previous reports.

2.7.5.1 Alternative energy facilities

There are no alternative energy facilities in Federal or local waters, proposed or existing, in Guam or CNMI.

2.7.5.2 Military training and testing activities and impacts

The Department of Defense major planning activities in the region are summarized below. Activities which are no longer reasonably foreseeable or have been replaced with another planning activity are removed from the report, though may occur in previous reports.

Table 74. Department of Defense major planning activities.

Action	Description	Phase	Impacts
Guam and CNMI Military Relocation SEIS	Relocate Marines to Guam and build a cantonment/family housing unit on Finegayan/AAFB, a live-fire individual training range complex at the Ritidian Unit of the Guam National Wildlife Refuge	ROD published August 29, 2015 Suit filed for segmentation and range of reasonable alternatives under NEPA, requesting that DON vacate the ROD. DOJ asked US District Court for the NMI to dismiss the plaintiff's complaint with prejudice to prevent refiling (http://www.saipantribune.com/index.php/doj-federal-court-lacks-jurisdiction/).	Surface danger zone established at Ritidian – access restricted during training. Access will be negotiated between the Navy and USFWS. Northern District Wastewater Treatment Plant is non-compliant with NPDES permit; until plant is upgraded, increased wastewater discharge associated with buildup will significantly impact nearshore water quality. DOD to fund plant upgrades – see Economic Adjustment Committee Implementation Plan.
Mariana Islands Training and Testing – Supplemental	The supplement to the 2015 Final EIS/OEIS is being prepared to support ongoing and future activities conducted at sea and on Farallon de Medinilla (FDM) beyond 2020. New information, including an updated acoustic effects model, updated marine mammal density data, and evolving and emergent BSIA, will be used to update the MITT.	Scoping August 1, 2017 to September 15, 2017. DoD representatives met with the Guam and CNMI APs and the Council submitted a scoping comment.	Likely access and habitat impacts similar to previous analysis
CNMI Joint Military Training	Establish unit and combined level training ranges on Tinian and Pagan	Supplemental Draft EIS expected in late 2018 or early 2019. Suit filed for segmentation and range of reasonable alternatives under NEPA. DOJ asked US District Court for the NMI to dismiss the plaintiff's complaint with prejudice to prevent refiling.	Significant access and habitat impacts
Divert Activities and Exercises, Air Force, Marianas	Improve airports in CNMI for expanding mission requirements in Western Pacific	ROD published December 8, 2016.	Adverse impacts to EFH minimal; access near Port of Tinian fuel transfer facility affected
Garapan Anchorage	Military Pre-Positioned Ships anchor and transit	Expired Memorandum of Understanding with the CNMI government. As of March 2018, MOU had not been signed.	Access, invasive species, unmitigated damage to reefs
Farallon de Medinilla	Restricted airspace covering the island to 12 nmi radius to conduct military training scenarios using air-to-ground ordnance delivery, naval gunfire, lasers and special operations training.	Final rule published March 13, 2017, effective June 22, 2017, designating a new area, R-2701A, that surrounds existing R-2701, encompassing airspace between a 3 nmi radius and 12 nmi radius of FDM (47 FR 13389). Proposed surface danger zone to 12 nmi. Damage to submerged lands and fisheries to be included within consultation establishing continued US interest in the island and compensation to the CNMI (Report to the President on 902 Consultations, 2017)	Access – to fishing grounds and transit to fishing grounds - and damage to submerged lands

2.7.6 Pacific Islands Regional Planning Body Report

The Council is a member of the Pacific Islands RPB and as such, the interests of the Council will be incorporated into the CMS plan. It is through the Council member that the Council may submit recommendations to the Pacific Islands RPB.

The Pacific Islands RPB met in Honolulu from February 14-15, 2018. The RPB's American Samoa Ocean Planning Team has completed its draft Regional Ocean Plan, on which the RPB provided comments and endorsement. CNMI and Guam Ocean Planning Teams have held their kick-off meetings. The RPB, by consensus, adopted the following goals for 2018: finalize the American Samoa Ocean Plan; continue planning in Guam and CNMI including conducting coastal and marine spatial planning training; transfer data portal prototype to permanent site and identify data gaps; and increase funding.

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3 DATA INTEGRATION

3.1 INTRODUCTION

3.1.1 Potential Indicators for Nearshore Fisheries

The purpose of this section ("Chapter 3") of the Stock Assessment and Fishery Evaluation (SAFE) annual report is to identify and evaluate potential fishery ecosystem relationships between fishery parameters and ecosystem variables to assess how changes in the ecosystem affect fisheries in the Main Hawaiian Islands (MHI) and across the Western Pacific region (WPR). "Fishery ecosystem relationships" are those associations between various fishery-dependent data measures (e.g. catch, effort, or catch-per-unit-effort), and other environmental attributes (e.g. precipitation, sea surface temperature, primary productivity) that may contribute to observed trends or act as potential indicators of the status of prominent stocks in the fishery. These analyses represent a first step in a sequence of exploratory analyses that will be utilized to inform new assessments of what factors may be useful going forward.

To support the development of Chapter 3 of the annual SAFE report, staff from the Council, National Marine Fisheries Service (NMFS), Pacific Islands Fisheries Science Center (PIFSC), Pacific Islands Regional Offices (PIRO), and Triton Aquatics (consultants), held a SAFE Report Data Integration Workshop (hereafter, "the Workshop") convened on November 30, 2016 to identify potential fishery ecosystem relationships relevant to local policy in the WPR and determine appropriate methods to analyze them. Participants are listed in Table 75.

Table 75. Participants of the Data Integration Workshop held in late 2016.

Name	Affiliation	Name	Affiliation
Keith Bigelow	PIFSC	Kevin Kelley	Consultant/PIRO
Chris Boggs	PIFSC	Eric Kingma	Council
Rusty Brainard	PIFSC	Don Kobayashi	PIFSC
Paul Dalzell	Council	Tom Oliver	PIFSC
Joshua DeMello	Council	Michael Parke	PIFSC
Stefanie Dukes	PIFSC	Frank Parrish	PIFSC
Sarah Ellgen	PIRO	Marlowe Sabater	Council
Jamison Gove	PIFSC	Sylvia Spalding	Council
Justin Hospital	PIFSC	Rebecca Walker	Council
Asuka Ishizaki	Council	Mariska Weijerman	PIFSC
Ariel Jacobs	PIRO	Ivor Williams	PIFSC

Following background presentations and discussions regarding ecosystem-based fishery management (EBFM) and previous attempts at data integration, participants were segregated into two smaller working groups to brainstorm island and pelagic fishery and environmental/ecological relationships that may be of use in the context of Chapter 3. Several guided questions were provided for every combination of variables:

- What can we reasonably expect to learn from or monitor with the results?
- How does it inform Council decision-making, consistent with the purposes of the FEP?
- Is it part of an ongoing research initiative?

The archipelagic fisheries group developed nearly 30 potential fishery ecosystem relationships (Table 76) to examine across bottomfish, coral reef, and crustacean fisheries based on data reliability, suitability of methodology, repeatability on an annual basis, and how well analyses could potentially inform management decisions.

Table 76. List of prioritized potential fishery ecosystem relationships in insular areas of Western Pacific island regions developed by the archipelagic fisheries group at the Data Integration Workshop.

Relationships	FEP	Score	Rank
Bottomfish catch/effort/CPUE/species composition and benthos/substrate (i.e. depth, structure)	All	22	3
Bottomfish catch/effort/ CPUE /species composition and Pacific Decadal Oscillation	All	20	3
Coral reef fish/fishery/biomass and temperature-derived variable	All	20	3
Akule/opelu and precipitation (MHI and Guam)	HI	20	3
Bottomfish catchability and wind speed	All	19	3
Coral reef fish/fishery/biomass and chlorophyll-*a* (with phase lag)	All	19	3
Bottomfish Catch /CPUE and lunar cycle/moon phase	All	19	3
Bottomfish catch/effort/ CPUE /species composition and sea-level height (eddy feature)	All	18	2
Coral reef fish/fishery/biomass and Pacific Decadal Oscillation	All	18	2
Green/red spiny lobster catch/CPUE and vertical relief	HI	18	2
Green/red spiny lobster catch/CPUE and Pacific Decadal Oscillation	HI	18	2
Bottomfish catchability and fishing conditions (i.e. surface, subsurface current, speed, and direction)	All	17	2
Coral reef fish/fishery/biomass and moon phase	All	17	2
Coral reef fish/fishery/biomass and Oceanic Niño Index	All	17	2
Coral reef fish/fishery/biomass and sea-level height	All	17	2

Coral reef fish/fishery/biomass and pH	All	17	2
Bottomfish catch/effort/ CPUE /species composition and temperature-derived variable (e.g. temperature at depth)	All	16	2
Bottomfish catch/effort/ CPUE /species composition and chlorophyll-*a* (with phase lag)	All	16	2
Bottomfish catch/effort/ CPUE /species composition and precipitation	All	16	2
Coral reef fish/fishery/biomass and structural complexity /benthic habitat	All	16	2
Bottomfish catch/effort/ CPUE /species composition and dissolved oxygen	All	15	2
Coral reef fish/fishery/biomass and precipitation	All	14	2
Bottomfish catch/effort/ CPUE /species composition and pH	All	13	2
Bottomfish catch/effort/ CPUE /species composition and predator abundance	All	12	2
Coral reef fish/fishery/biomass and salinity	All	12	2
Coral reef fish/fishery/biomass and dissolved oxygen	All	12	2
Bottomfish catch/effort/ CPUE /species composition and salinity	All	10	1

To begin, this chapter will include brief descriptions of past work on fishery ecosystem relationship assessment in the coral reefs of the U.S. Western Pacific, followed by initial evaluations of relationships previously recommended for evaluation by participants of the Workshop using current data streams in the Mariana Archipelago. The evaluations completed were exploratory in nature, being the first step of analyses to know which comparisons may be more useful to focus on going forward. Those relationships deemed potentially relevant will be emphasized and recommended for further analysis. In subsequent years, this chapter will be updated with these analyses through the SAFE report process as the strength of certain fishery ecosystem relationships relevant to advancing ecosystem-based fishery management are determined.

3.1.2 2018 Recommendations for Chapter Development

At the most recent FEP Plan Team Meeting held on April 30th – May 1st, 2018, participants were presented preliminary data integration results shown here, and provided detailed recommendations to support the ongoing development of the data integration section of the Archipelagic Annual SAFE Report. These suggestions, both general and specific, will be implemented in the coming year to ensure that more refined analyses comprise the data integration section. FEP Plan Team participants recommended that:

- CPUE data should be standardized and calculated in a more robust fashion, measuring the average catch per unit effort rate over the course of a year to analyze variance.
- Analyses of fishery performance data against environmental variables should focus on dominant gear types rather than the entirety of the fishery or other gear aggregates (e.g. purse seine harvest of *Selar crumenophthalmus* in the MHI).
- There should be additional phase lag implemented in the analyses

- Local knowledge of fishery dynamics, especially pertaining to shifting gear preferences, should be utilized. Changes in dynamics that may have impacted observed fishery trends over the course of available time series, both discreetly and long-term for taxa-specific and general changes should be emphasized.
- Spatial specificity and precision should be increased for analyses of environmental variables in relation to areas commonly fished.

At its 172nd Council meeting, the WPRFMC provided no formal recommendations. However, it was suggested by individual Council members that, in addition to implementing additional data streams when time series of sufficient length become available (e.g. bio-sampling data), that the results should be standardized in such that they can be presented as estimated potential percent change in the fishery in response to measured environmental variability.

At its 128th meeting, the Science and Statistical Committee (SSC) was also presented the preliminary data integration results shown here. Going forward, the SSC suggested the use of multivariate assessment in the form of Structural Equation Models to determine difference in parameters between years, but there existed disagreement as to whether these analyses should be used only as precedence for more thorough univariate assessments. Additionally, it was suggested that examining the potential fishery ecosystem relationships from an energetics perspective may emphasize changes in the fishery associated with ecological change. However, it was noted that such relationships between fishery and environmental parameters, if they exist, may already be (or should already be) represented in prevailing stock assessments.

Incorporating such recommendations into the 2018 version of the Annual SAFE Report will mark the beginning of a standardized process to implement current data integration analyses on an annual basis. Doing so will promote more proactive management action with respect to ecosystem-based fishery management objectives.

3.1.3 Past Work

Richards *et al.* (2012) performed a study on a range environmental factors that could potentially affect the distribution of large-bodied coral reef fish in Mariana Archipelago. Large-bodied reef fish were determined to typically be at the greatest risk of overfishing, and their distribution in the region was shown to be negatively associated with human population density. Additionally, depth, sea surface temperature (SST), and distance to deep water were identified as important environmental factors to large-bodied coral reef fish, whereas topographic complexity, benthic habitat structure, and benthic cover had little association with reef fish distribution in the Mariana Archipelago.

Kitiona *et al.* (2016) completed a study of the impacts climate and/or ecosystem change on coral reefs fish stocks of American Samoa using climate and oceanic indicators (see Section 2.5.3.5). The evaluation of environmental variables showed that certain climate parameters (e.g. SST anomaly, sea level height, precipitation, and tropical storm days) are likely linked to fishery performance. It was also noted that larger natural disturbances in recent decades, such as cyclones and tsunamis, negatively impacted reef fish assemblages and lowed reef fishery CPUE in American Samoa (Ochavillo *et al.*, 2012).

On a larger spatial scale, an analysis of various drivers on coral reef fish populations across 37 U.S.-affiliated islands in the Central and Western Pacific was performed by Williams *et al.* (2015), and evaluated relationships between fish biomass in these reefs with human and environmental factors. Again, reef fish assemblages were negatively associated with increasing human population density (even at relatively low levels) across the WRP, but were positively associated with elevated levels of ocean productivity across islands. The authors warned, however, that the ability of reefs surrounding uninhabited islands to maintain fish populations varies, and that high biomass observed in remote areas (e.g. the NWHI) may not necessarily be reflective of baselines or recovery response levels for all reef systems.

A common method of EBFM used in coral reef ecosystems is the implementation of biological reference points, statistical indicators of potential overfishing used to help determine how a fishery is performing relative to these points at a given time (McClanahan *et al.*, 2007). Hawhee (2007) adapted this idea, generating biological reference points in the form of CPUE-based proxies to be used as indicators for reef fish stocks in the WPR. However, the devised method was determined to be inappropriate for application in management of reef stocks in the U.S. Western Pacific due to the lack of a historical CPUE to use as a baseline for the reference points and their limit thresholds (Remington and Field, 2016).

3.2 PRECIPITATION

3.2.1 Guam

Participants of the Workshop determined that the potential fishery ecosystem relationships between precipitation levels and atulai and opelu (bigeye scad and mackerel scad, *Selar crumenophthalmus* and *Decapterus macarellus,* respectively) were among the highest priority of those involving coral reef fisheries in the Mariana Archipelago. It has been suggested that the recruitment of small tropical pelagic fish is related to annual rainfall and subsequent runoff enrichment (Longhurst and Pauly, 1987). The direct freshwater and nutrient input to reefs associated with increased precipitation can alter the physiochemical composition of the water, and it has been shown that reef assemblages are positively associated with this sort of increased ocean productivity (Williams *et al.*, 2015). Data for precipitation in the Mariana Archipelago was gathered from local databases maintained by the National Weather Service (NWS-G). The time series of total annual precipitation from showed a non-significant, slightly variable trend over the last 30 years ($R^2 = 0.05$, CV = 19.5; Figure 33).

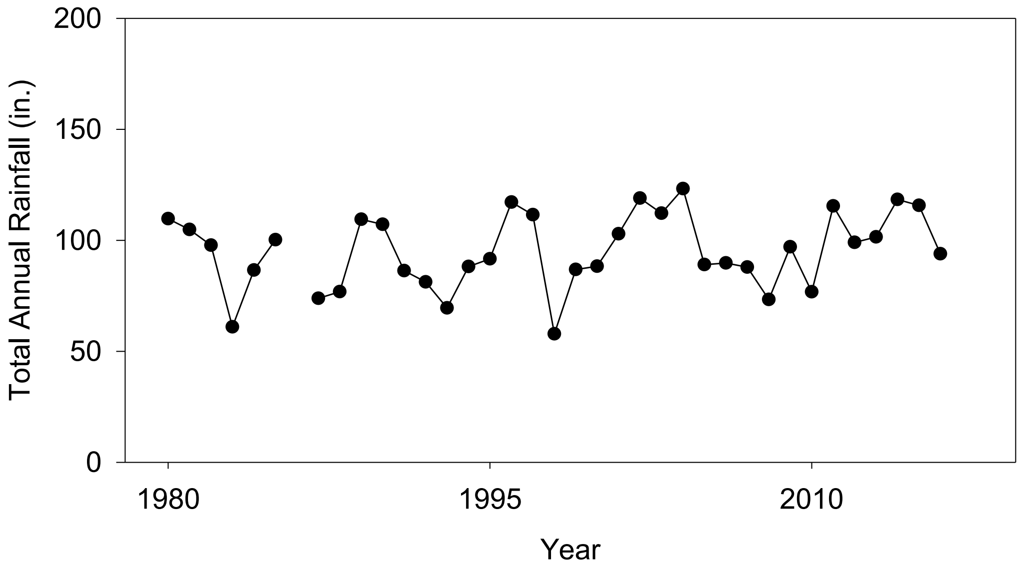

Figure 33. Total annual precipitation (in.) in Guam from 1980-2016.

3.2.1.1 Evaluating relationship with atulai

Total annual estimated atulai catch in the Guam recreational coral reef fishery according to shore- and boat-based creel surveys showed no general trend over the last thirty years, with relatively large variability likely due to several years of catch orders of magnitude greater than previous or subsequent years (e.g. 2009; $R^2 = 0.01$; CV = 119.5; Figure 34). Combined effort statistics between shore- and boat-based creel survey statistics could not be generated because the proxies used to measure effort in each survey are different (i.e. number of gear hours versus number of boat trips). Similarly, because effort could not be standardized across the data sets, CPUE could not be generated on the individual family level at which these evaluations are taking place.

Examining effort, Guam shore-based creel survey data show that there are considerable differences in the number of samples recorded across gear types. The most frequently sampled gear in the shore-based survey was hook and line by an order of magnitude, and had catch estimated to be several times greater than that in the expanded dataset (Figure 35a-b). Effort data also revealed that, despite catch statistics, the gill net had been sampled the least frequently among the top gears (Figure 35a-b). Boat-based effort data show that bottom fishing was sampled approximately twice as much than the other three top gears, but the difference in the expanded estimates between were at least an order of magnitude greater (Figure 35c-d). Generally, each of the time series for prominent gear types in Guam showed a slight shift but seemingly no net change over the course of available data despite interannual variability.

Total estimated atulai catch and rainfall in Guam showed no statistical association with one another such that would allow for assessment of the fishery ecosystem relationship between the two (R^2=0.02; Figure 36). However, there seemed to be a slight observable negative relationship between the two (r = -0.15), indicating that catch may have experienced a minor decrease in years with more rainfall. Additionally, there was no association between annual rainfall amounts and total estimated atulai catch in Guam when only considering shore-based data, boat-based data, or prominent gear types.

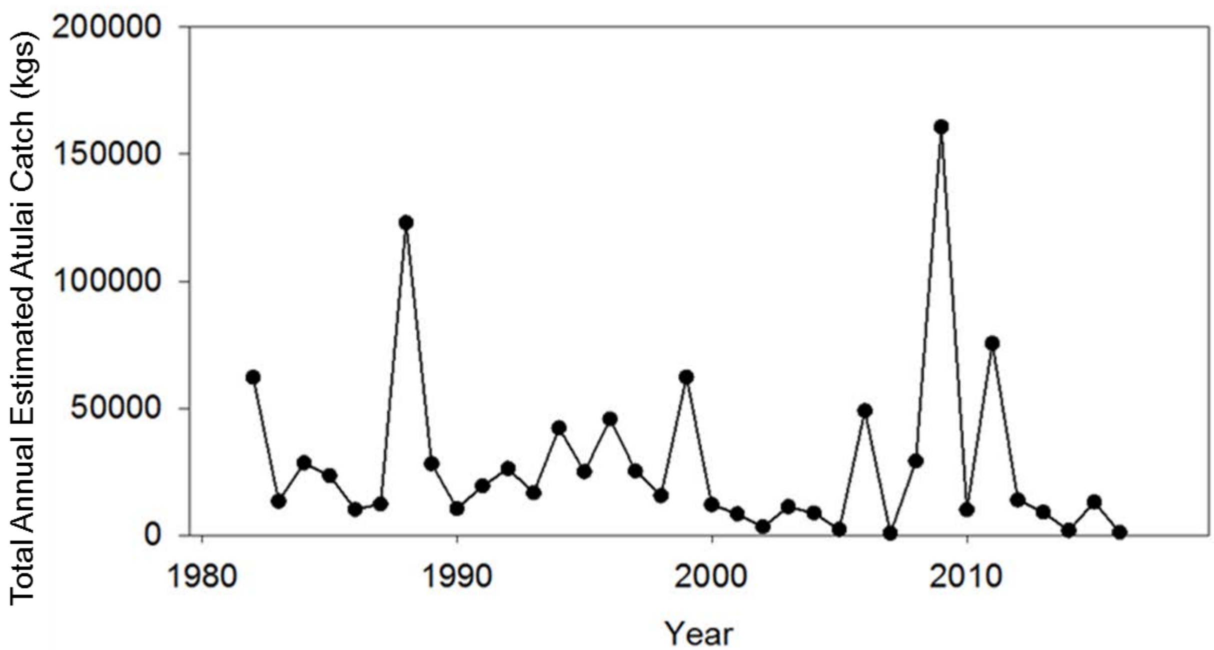

Figure 34. Time series of total annual estimated (i.e. expanded) landings of atulai in kilograms from Guam shore-and boat-based creel survey records from 1982-2016.

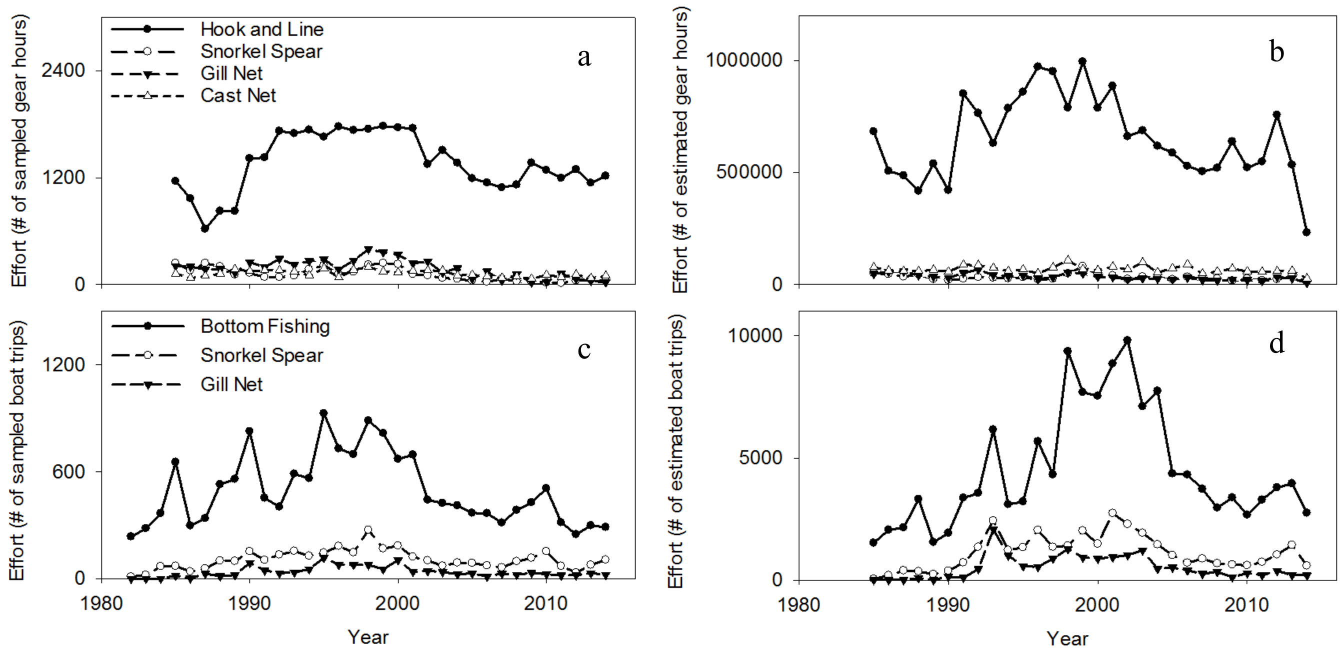

Figure 35. Time series of total sampled (left) and expanded (right) effort for top gear types in shore-based (top) and boat-based (bottom) creel surveys in Guam from 1982-2016.

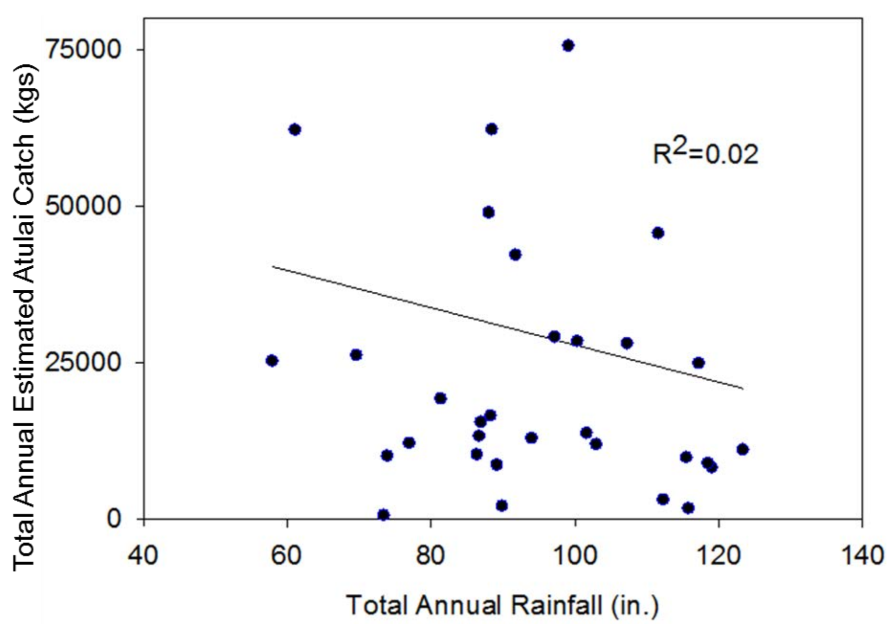

Figure 36. Linear regression between total atulai catch (kg) in the Guam shore-based and boat-based creel survey records and total annual rainfall (in.) from 1982-2016.

3.2.1.2 Evaluating relationship with *D. macarellus*

Decapterus macarellus (i.e. mackerel scad) records from creel surveys in Guam were scant and had high variability, with estimated catch for many years being close to zero while others had close to 8,000 kg ($R^2 = 0.01$; CV = 278.4; Figure 37). Several years where mackerel scad catch data were available, they indicated a total amount landed of just a few kilograms (e.g. 1999, 2001, 2013, etc.; Figure 37). Because there were 17 of 35 total years with available mackerel scad catch data across gear types for the entire territory since 1982, many with extremely low catch estimates, the time series were not able to be used for comparison to rainfall records in the same region over the last thirty years.

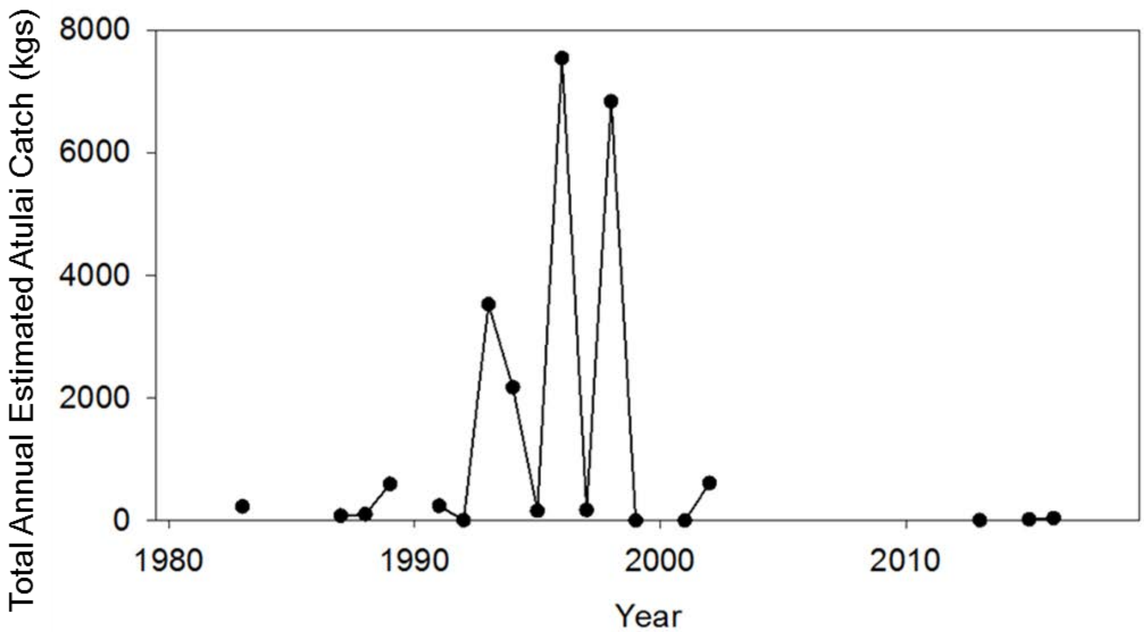

Figure 37. Time series of total annual expanded landings of *Decapterus macarellus* (kg) in Guam shore-and boat-based creel survey records from 1982-2016.

In summary, no fishery ecosystem relationship could be established between atulai or mackerel scad catch with precipitation in Guam from 1982 till present without the incorporation of phase lag, and no standardized index/threshold characteristic of the association between the parameters could be identified representative of an immediate population response. The general lack of recreational harvest data for mackerel scad in Guam hindered the ability to determine whether a relationship exists with rainfall in that portion of the fishery. Analyses including atulai data had similar comparisons with rainfall data completed in the MHI as well, though no notable relationship between atulai catch and annual precipitation was identified there.

3.3 SEA SURFACE TEMPERATURE

Sea surface temperature (SST) is a commonly used diagnostic tool in monitoring climate change and its affects both regionally and globally, as it is representative of changes in ocean temperatures over time that can affect coastal fisheries (see Section 2.5.3.5). The potential influence of temperature-derived variables in fishery ecosystem relationships for U.S. Western Pacific coral reef stocks was deemed to be among the highest priority by the participants of the Workshop. Data for SST was gathered from the NOAA's AVHRR Pathfinder v5.0 through the OceanWatch program in the Central Pacific (NOAA/NESDIS/OceanWatch).

A time series of SST for the CNMI from 1985-2016 is shown in Figure 38. SST here had slightly less variability over time than Guam (CV = 0.55), again indicating relative stability. Unlike Guam, the CNMI did not seem to be observably increasing or decreasing over the time series of available data. The hottest temperature in the last three decades was approximately 29°C, where preceding SST had largely been stable over time. The average SST over the course of evaluated data was 28.8°C, slightly warmer than observed in Guam. The lowest recorded SST over the course of the time series was just about 27.5°C in the year 1996 (Figure 38).

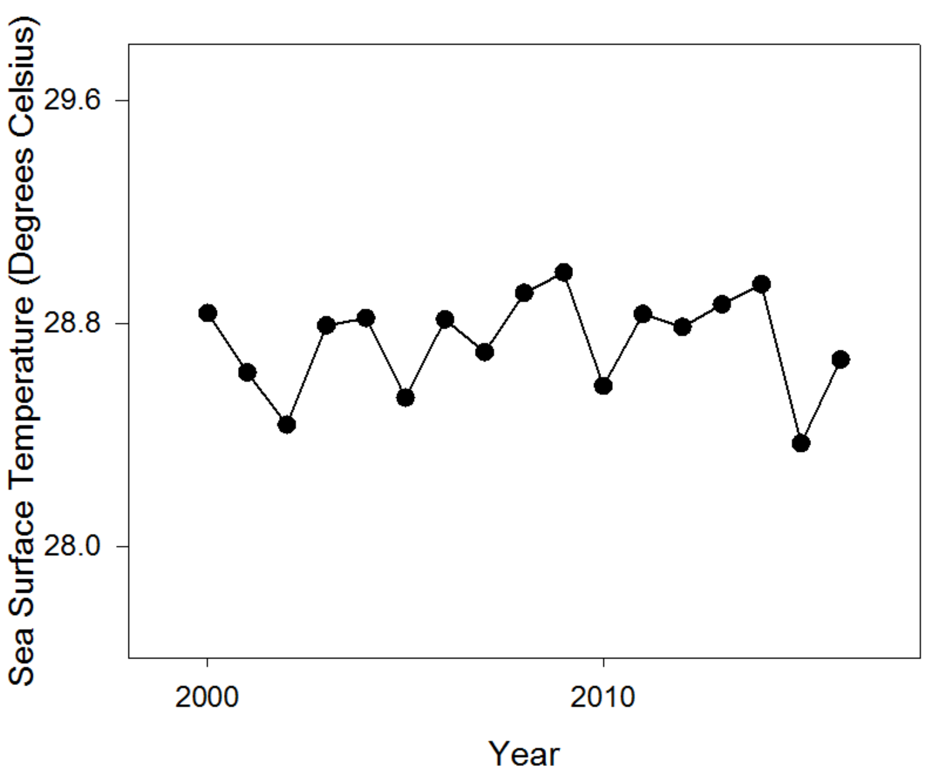

Figure 38. Time series of SST (°C) in the CNMI from 1985-2016 (CV = 0.55).

A time series of SST for Guam from 1985-2016 is shown in Figure 39. Temperature had low variability over time (CV = 1.38), suggesting relative stability. There was also a seeming increase in temperature over the last three decades, with some of the hottest temperatures recorded observed in the last five years. The average SST over the course of evaluated data was

28.6°C. The highest recorded SST over the course of the time series was just over 29°C in the year 1999, whereas the lowest was earlier in the 1990s (27.7°C; Figure 39).

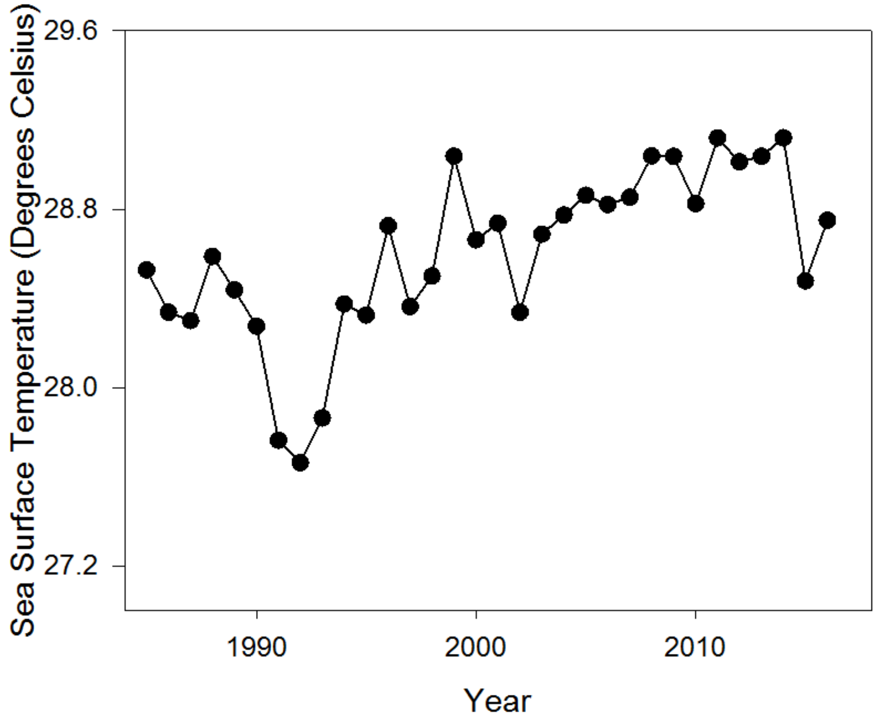

Figure 39. Time series of SST (°C) from 1985-2016 in Guam (CV = 1.38).

3.3.1 CNMI

3.3.1.1 Evaluating relationship for entire reef fishery

A plot showing the relationship between SST and catch time series from the recreational coral reef fishery in the CNMI from 2000-2016 is depicted in Figure 40. Landings were variable over the course of the time series (CV = 19.4), but less so than observed in catch time series in Guam. Total annual catch in the fishery has been observably decreasing over the last decade and a half despite an abrupt increase in 2013 resulting in the recorded maximum catch over this period (~338,000 kg). Recent recorded catch levels (i.e. for 2016) were the lowest for the fishery through the available time series of data (~165,000 kg; Figure 40).

In performing comparisons between fishery parameters and environmental variables such as SST, data were grouped in taxa categories based on family due to scarcity of data on the species level in many cases. Table 77 displays the different dominant family groups considered as well as their common names.

Linear regressions and correlation analyses performed on the time series of recreational coral reef fishery catch (kg) and annual mean SST from the CNMI are reported in Table 78. The comparisons between the two parameters showed a negatively significant relationship between 2000 and 2016 ($R^2 = 0.30$, $p = 0.02$; Table 78; Figure 41). The relationship between the total annual catch and average annual SST for the whole fishery were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 105,000 kg (Figure 41).

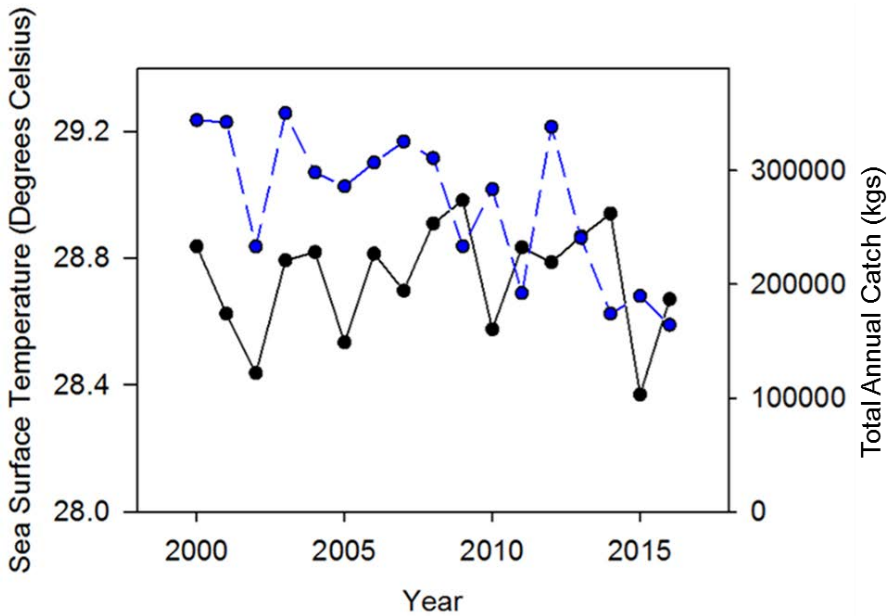

Figure 40. Time series of total annual catch (kg; blue) for the CNMI recreational coral reef fishery plotted alongside average annual SST (°C; black) from 2000-2016.

Table 77. Families in creel surveys from the U.S. Western Pacific analyzed in this report.

Four-letter code	Family	Common Name
LUTJ	Lutjanidae	snappers
LETH	Lethrinidae	emperors
CARA	Carangidae	jacks/mackerel/trevally
ACAN	Acanthuridae	unicornfish/tang
SERR	Serranidae	Sea bass/grouper
SIGA	Siganidae	rabbitfish
SCAR	Scaridae	parrotfish
MULL	Mullidae	goatfish
MUGI	Mugilidae	mullet
LABR	Labridae	wrasse
HOLO	Holocentridae	squirrelfish/soldierfish
BALI	Balistidae	triggerfish

Table 78. Correlation coefficients (*r*) between recreational coral reef fishery catch (kg) and SST (°C) in the CNMI for 12 top taxa harvested from 2000-2016.

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 17													
p	**0.02**	0.49	0.54	0.26	0.70	0.91	0.99	0.88	0.06	-	0.59	0.91	0.82
r	**-0.55**	0.18	-0.16	-0.29	-0.10	-0.03	0.00	-0.04	-0.47	-	0.14	0.03	-0.06
R^2	**0.30**	0.03	0.02	0.09	0.01	0.00	0.00	0.00	0.22	-	0.02	0.00	0.00

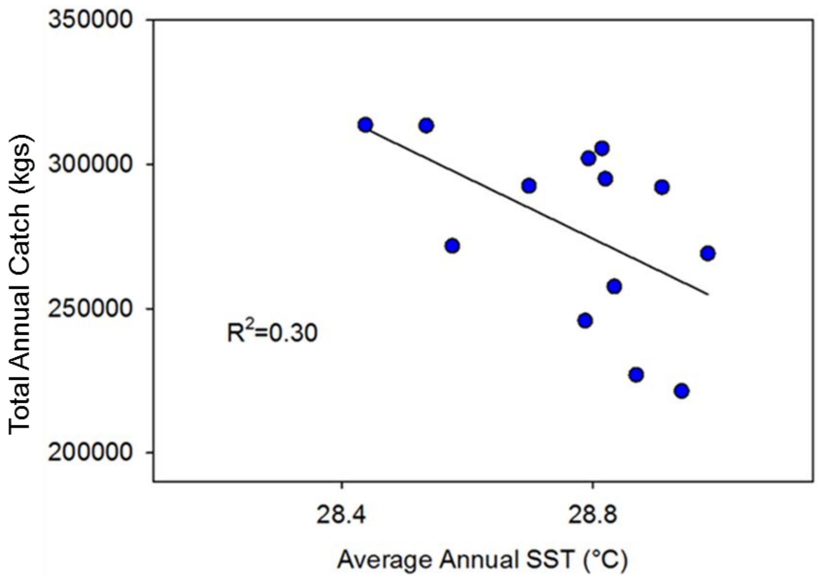

Figure 41. Linear regression showing the correlation between total annual catch (kg) in creel survey records and average annual SST (°C) in the CNMI from 2000-2016.

3.3.1.2 Evaluating relationship for dominant taxa

Correlation and regression analyses were performed on prominent taxa in the CNMI recreational coral reef fishery, and it was found that no individual taxa had significant relationships with SST data (Table 78). The strongest associations between fishery catch and SST were observed from the Mullids ($R^2 = 0.22$, $p = 0.06$; Figure 42a), Carangids ($R^2 = 0.09$, $p = 0.26$; Figure 42b), and Lutjanids ($R^2 = 0.03$, $p = 0.49$; Figure 42c). While the relationship between catch and temperature for families Mullidae and Carangidae were negative, the Lutjanidae family had a positive relationship (Table 78).

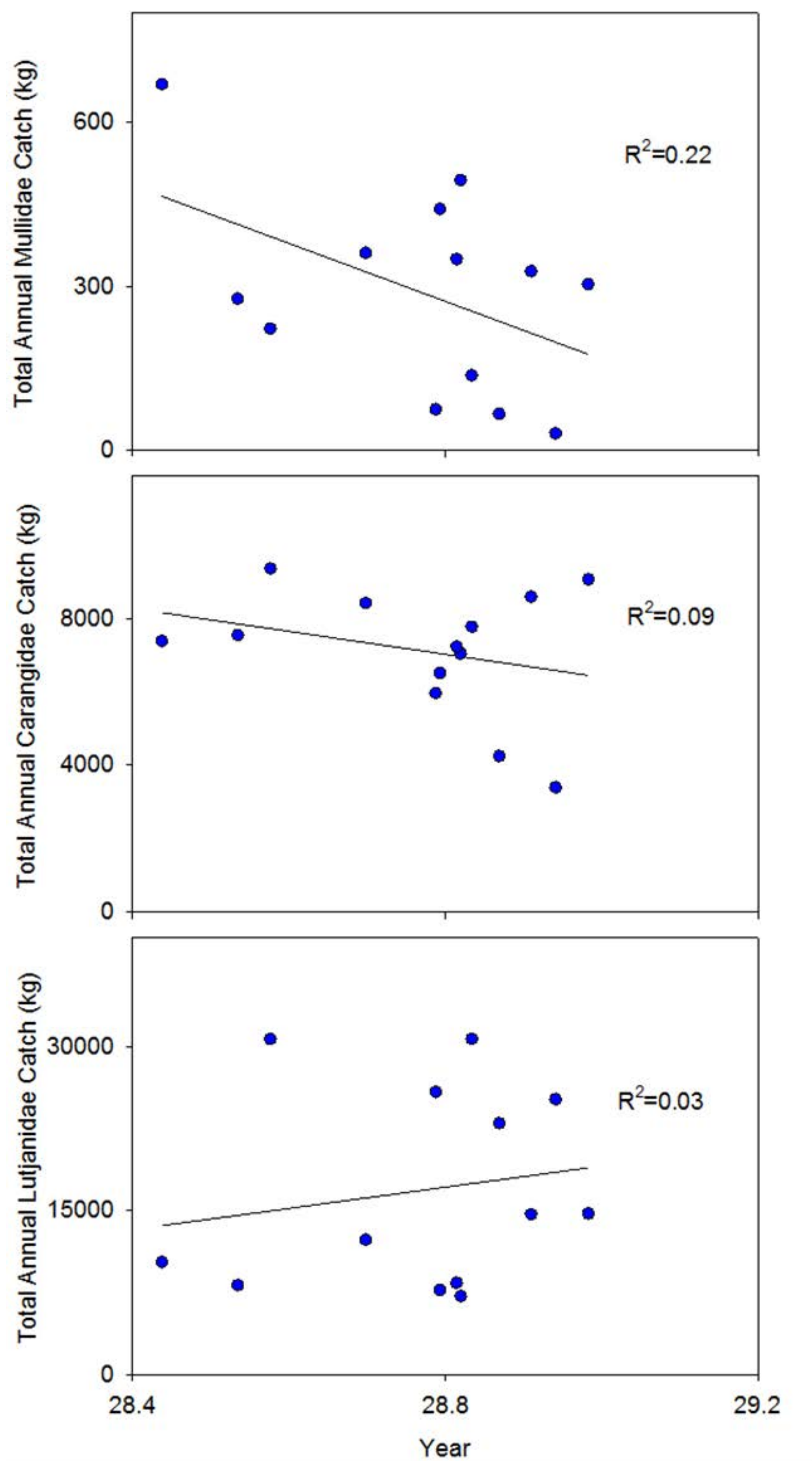

Figure 42. Linear regressions showing the three top correlations between total annual catch (kg) from creel survey records and average annual SST (°C) in the CNMI from for (a) Mullids, (b) Carangids, and (c) Lutjanids from 2000–2016.

3.3.2 Guam

3.3.2.1 Evaluating relationship for entire reef fishery

An individual plot depicting the comparisons of time series of SST and catch from the recreational coral reef fishery in Guam from 1985-2016 is shown in Figure 43. Landings were variable over the course of the time series (CV = 28.1) though relatively stable, especially before the year 2000. There was a relatively abrupt observed decrease in total annual catch from 1998 to 2005, where recorded landings went from over half a million kg to approximately 180,000 kg in less than a decade. Catch has slightly rebounded since that minimum, with landings reaching over 400,000 kg in six of the last seven years (Figure 43).

Multiple linear regressions and correlation analyses were performed on time series of recreational coral reef fishery catch and annual mean SST from Guam (Table 79). Evaluations measuring the association between SST and total catch for the entirety of the recreational coral reef fishery in Guam showed a negatively significant relationship between 1985 and 2016 (R^2 = 0.20, p = 0.02; Table 79; Figure 44). The relationship between the total annual catch and average annual SST were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 120,000 kg (Figure 44)

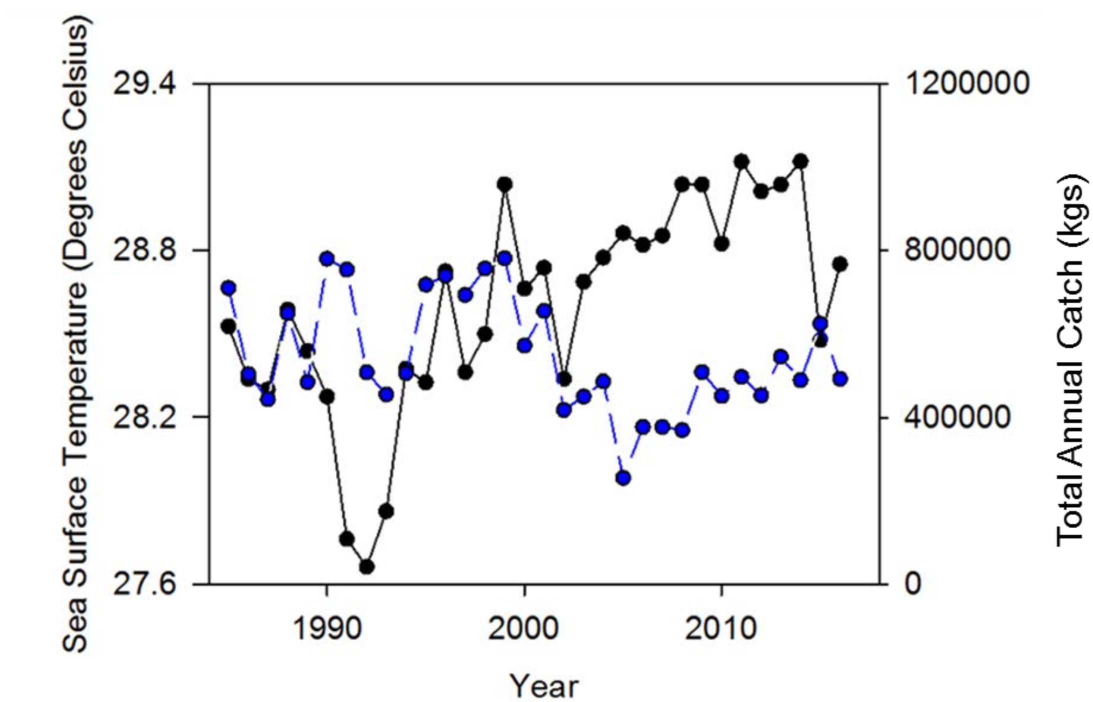

Figure 43. Time series of total annual catch (kg; blue) in the Guam shore-and boat-based creel survey records plotted with average annual SST (°C; black) from 1985-2016.

Table 79. Correlation coefficients (*r*) between recreational coral reef fishery catch (in kg) and SST (°C) in Guam for 12 top taxa harvested from 1985-2016.

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 28													
p	0.02	0.01	0.00	0.01	0.39	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00
r	-0.45	-0.80	-0.48	0.17	-0.50	-0.54	-0.71	-0.51	-0.56	-0.66	-0.60	-0.63	-0.43
R^2	0.20	0.64	0.23	0.03	0.25	0.30	0.50	0.26	0.31	0.43	0.35	0.39	0.18

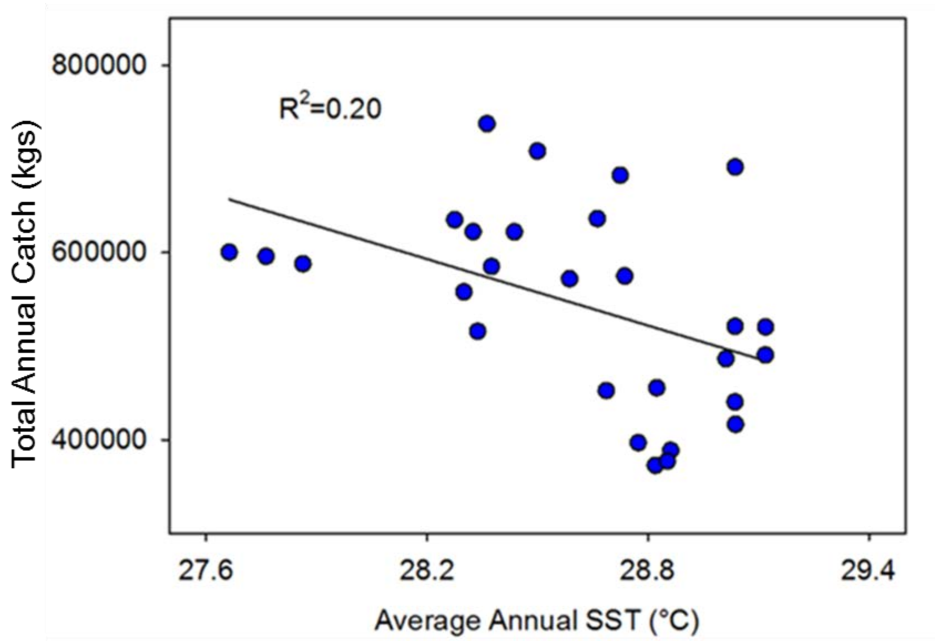

Figure 44. Linear regression between total annual catch (kg) for shore- and boat-based creel survey records and average annual SST (°C) in Guam from 1985-2016.

3.3.2.2 Evaluating relationship for dominant taxa

Comparisons were made for the time series of catch for prevalent taxa in Guam's recreational reef fishery as well, and it was found that all except for the Acanthuridae family showed negative statistically significant correlations with SST (Table 79). The strongest relationship observed was of that between SST and annual Lutjanidae catch, where the regression suggested that for every degree Celsius of temperature increase, catch would decrease by approximately 7,500 kg (R^2 = 0.64, p = 0.00; Table 79; Figure 45a). The next two strongest associations observed were for families Siganidae (R^2 = 0.50, p = 0.00; Figure 45b) and Mugilidae (R^2 = 0.43, p = 0.01; Figure 45c). The regressions performed with temperature for taxa, suggesting negative relationships with temperature, also showed that for every degree of temperature increase in degrees Celsius, Siganidae and Mugilidae recreational catch in Guam would decrease by approximately 10,000 kg and 7,500 kg, respectively.

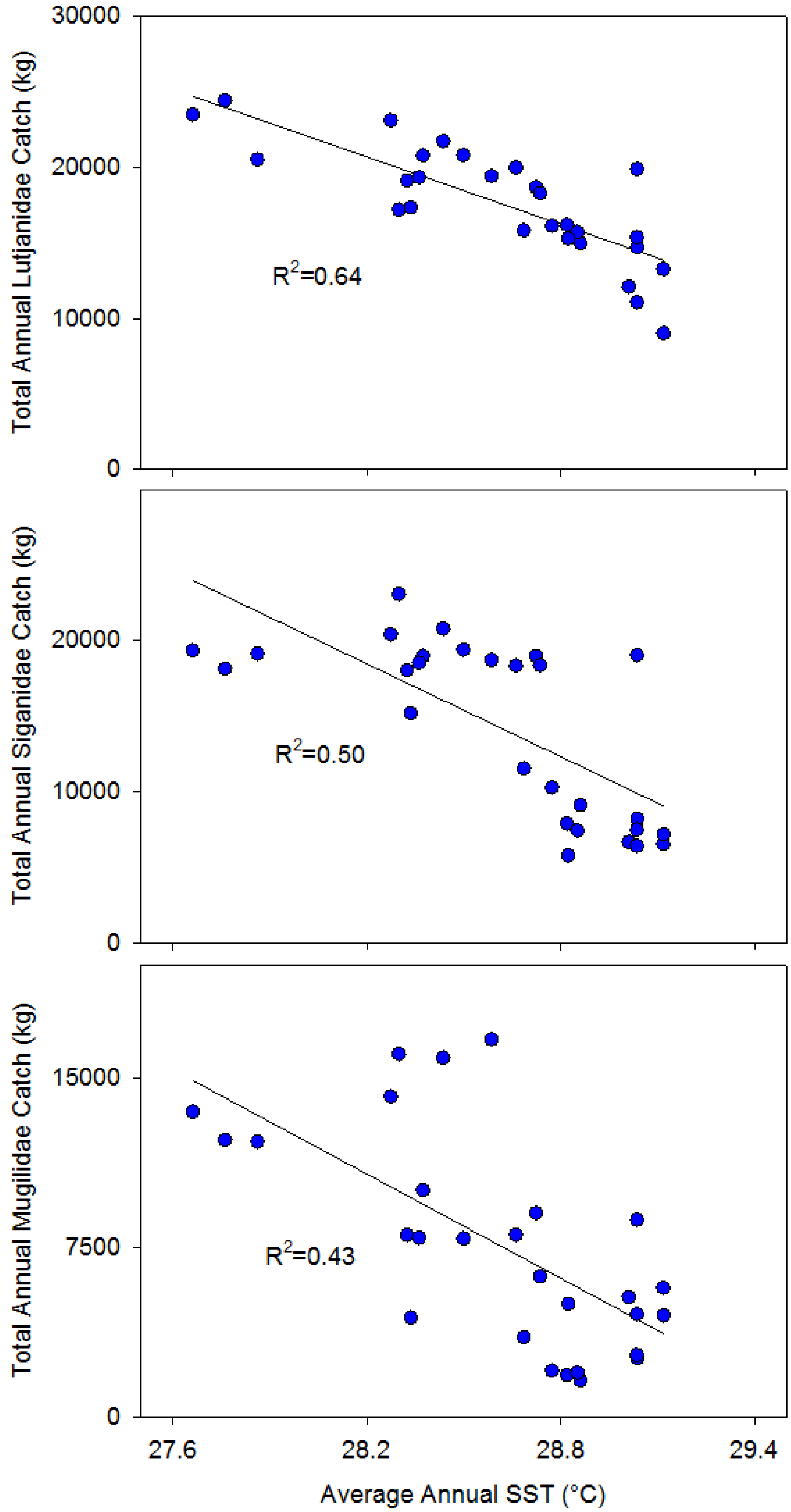

Figure 45. Linear regressions showing three top correlations between total annual catch (kg) for shore-and boat-based creel survey records and average annual SST (°C) in Guam for (a) Lutjanids, (b) Siganids, and (c) Mugilids from 1985–2016.

In summary, Guam and the CNMI had fishery ecosystem relationships that could be identified for the entirety of the recreational coral reef fishery. The relationship between the total annual catch and average annual SST in Guam were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 120,000 kg The relationship between the total annual catch and average annual SST in the CNMI were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 105,000 kg

In Guam, the linear regressions performed showed that all evaluated taxa except for the Acanthurids had a statistically significant negative relationship with average annual temperature. The three strongest associations with SST were with the Lutjanids, Siganids, and Mugilids, such that the total annual catch for each would decrease by approximately 7,500-10,000 kg for every increase in SST by one degree Celsius. In the CNMI, conversely, there were no individual family groups whose catch data had statistically significant associations with temperature, though the strongest associations observed were the Mullids (relatively close to the threshold of significance, $p = 0.06$), Carangids, and Lutjanids. The relationships for families Mullidae and Carangidae were negative, though the Lutjanidae family displayed a positive relationship with SST.

3.4 PRIMARY PRODUCTIVITY

3.4.1 CNMI

Concentrations of the pigment chlorophyll-*a* are commonly used as an index of phytoplankton biomass that represents primary production, a commonly utilized tool in identifying eutrophication also noted to be among the highest priority fishery ecosystem relationships in the WPR by participants of the Workshop (Islam and Tanaka, 2004). In Pacific regions where interannual precipitation and associated coastal runoff are relatively high, the physiochemistry of nearshore reefs is especially impacted from accompanying nutrient input resulting in increased primary production (Ansell *et al*., 1996).

Long-term changes in regional primary productivity have the potential to change reef fish population abundance due to the susceptibility of these assemblages in shallow areas of coastal reefs to variations in water chemistry, especially when combined with the variability of other environmental parameters like sea surface temperature (Kitiona *et al.*, 2016). For example, it has been suggested that warming ocean temperatures coupled with decreasing environmental productivity led to waning reef fish assemblages in the Southern California Bight, likely due to a reduction in upwelling that isolated nutrients at depth (Roemmich and McGowan, 1995). With recent progress in satellite and fluorometric measurements of oceanic surface waters, time series of global and regional primary production estimated using concentrations of chlorophyll-*a* have become increasingly available, and can be used for evaluating the impact of environmental productivity on reef fish population abundance and the marine food web in general (Behrenfed *et al*., 2006; Messié and Radenac, 2006). Data for the study at hand were gathered from the ESA Ocean Colour Climate Change Initiative dataset version 3.1.

Considering the Ocean Colour Climate Change Initiative dataset (v3.1) for CNMI, the time series of fluorometric chlorophyll-*a* concentrations (mg/m^3) for the years 1998-2016 in the region is shown in Figure 46. The chlorophyll concentrations had less variability than Guam (CV = 6.28), but was relatively higher in overall average concentration. Unlike Guam, however, pigment levels appeared to have been decreasing over the course of the time series despite the non-significant nature of the associated regression. Over the 15 years of evaluated data, the average chlorophyll-*a* concentration was 0.049 mg/m^3, though the lowest recorded level was seen in 2014 at 0.042 mg/m^3 Figure 46.

A time series of fluorometric chlorophyll-*a* concentrations (mg/m^3) for the years 1998-2016 in Guam is shown in Figure 47. Pigment concentration in the upper 200 meters had moderate variability over the course of the time series (CV=7.03). Also, there seemed to be a slight increase in pigment concentrations over the course of collected data despite the lack of a significant trend over the same time. The average chlorophyll-*a* concentration over this time was 0.048 mg/m^3, with the highest recorded levels being observed in 2005 at 0.055 mg/m^3 and the lowest occurring earlier in 2002 (0.042 mg/m^3; Figure 47).

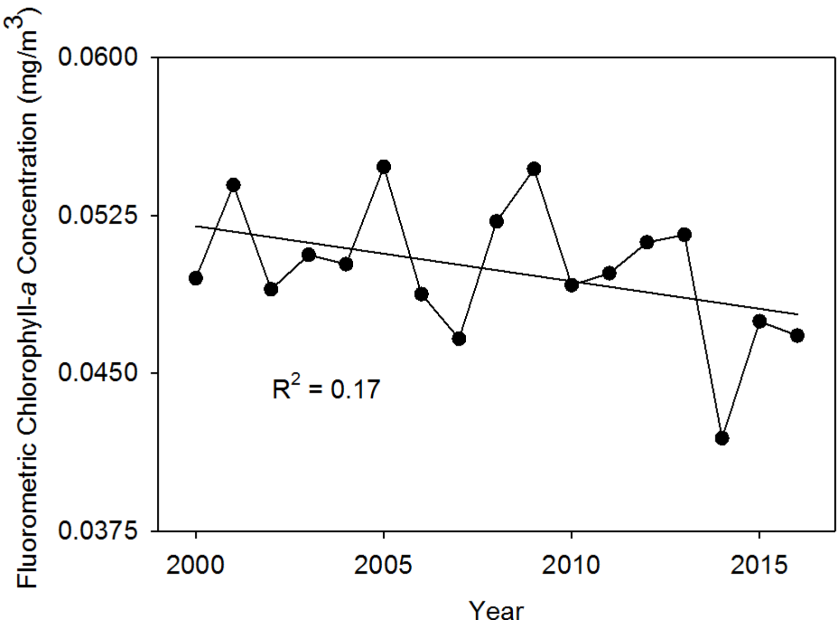

Figure 46. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around the CNMI from 1998-2016 (CV=6.28).

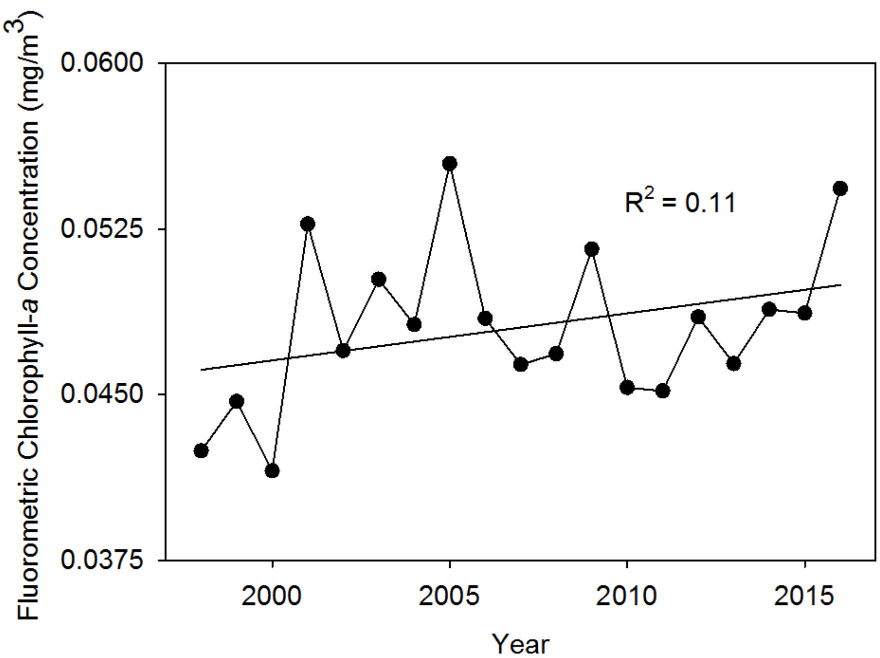

Figure 47. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around Guam from 1998-2016 (CV=7.03).

3.4.1.1 Evaluating relationship for entire reef fishery

A plot showing the relationship between these same chlorophyll levels and catch time series from the recreational coral reef fishery in the CNMI from 2000-2016 is depicted in Figure 48. Catch, again, was even more variable than the environmental data evaluated (CV=19.4), and was at about the same levels as Guam. Total annual catch in the fishery has been decreasing over the last decade and a half despite a spike in catch during 2013 that gave the maximum observed annual catch over this time series (~338,000 kg). The levels of current catch (i.e. for 2014-2016) are the lowest for the entirety of the recreational fishery over the past decade and a half (~165,000 kg; Figure 48).

In pattern with the analyses completed for Guam, linear regressions and correlation analyses were conducted for the time series of the CNMI recreational coral reef fishery catch (with phase lag) with fluorometric chlorophyll-*a* concentrations (mg/m^3) gathered for the 15 years between 2000-2014. The chlorophyll-*a* concentrations and total annual catch for the all harvested taxa had a positive relationship between 2000 and 2014, though the relationship was far from being considered statistically significant (r = 0.32, p = 0.25; Table 80; Figure 49). Though not significant, the regression was extrapolated to determine that, following this pattern, every increase of 0.01 mg/m^3 in chlorophyll-*a* concentration would cause increase by nearly 62,000 kg two years later for all the CNMI recreational reef fishery (R^2=0.11, p = 0.25; Figure 49).

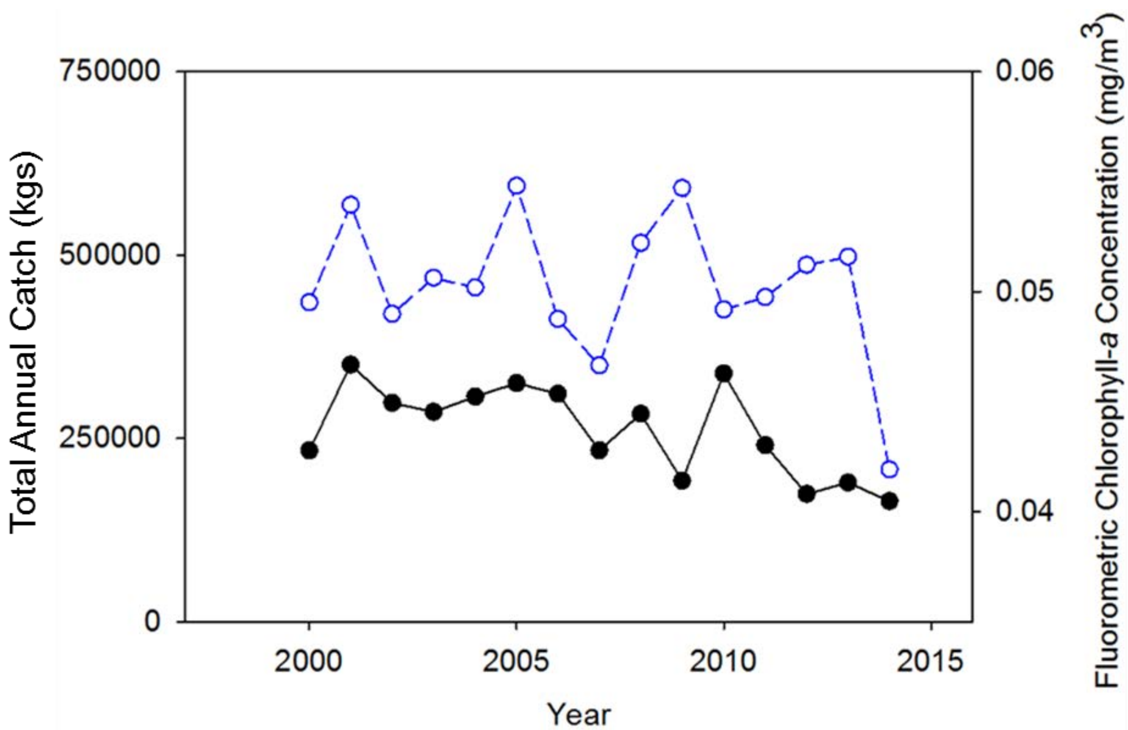

Figure 48. Comparison of the CNMI recreational reef fish catch (kg; black) from creel survey records with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 2000-2014 (r = 0.32).

Table 80. Correlation coefficients (*r*) from comparisons of time series of the CNMI recreational coral reef fishery annual catch (kg) and fluorometric chlorophyll-*a* concentrations (mg/m^3) from 2000-2014.

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 15													
p	0.25	0.47	0.14	0.67	0.37	0.09	0.72	0.80	0.99	0.83	0.83	0.10	0.72
r	0.32	-0.20	-0.04	0.12	0.25	0.45	-0.10	-0.07	0.00	-0.06	-0.06	0.44	0.10
R^2	0.11	0.04	0.00	0.02	0.06	0.20	0.01	0.01	0.00	0.00	0.00	0.20	0.01

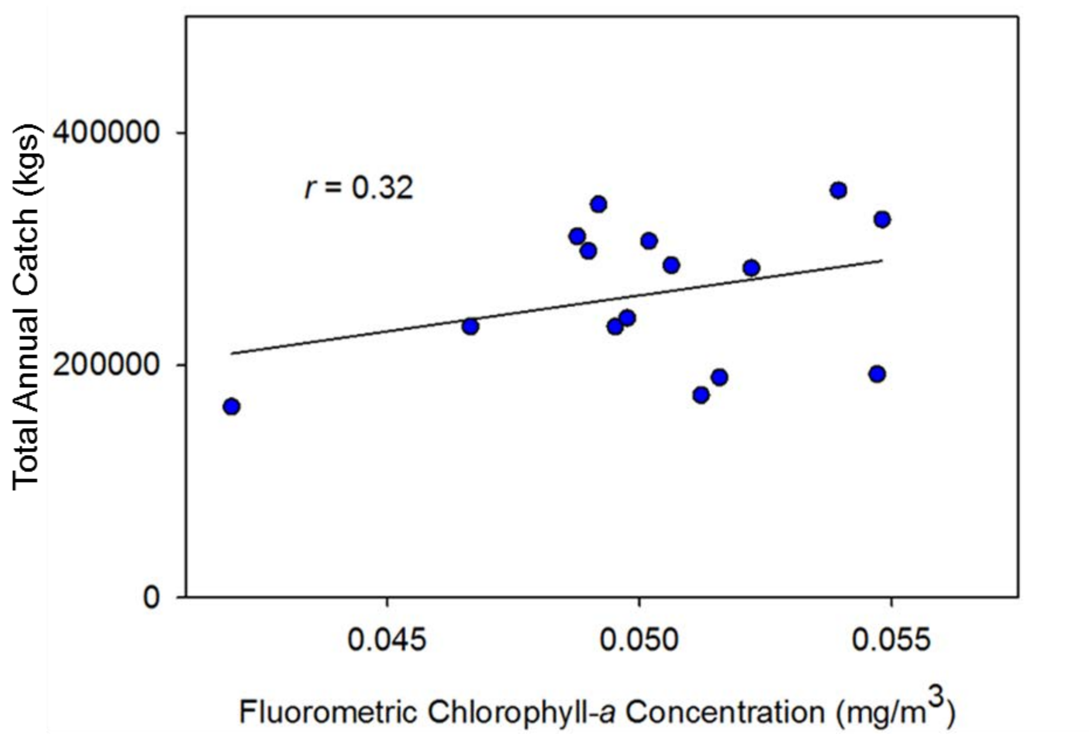

Figure 49. Linear regression between total annual catch (kg) phase lag (t+2 years) and fluorometric chlorophyll-a concentrations (mg/m^3) from CNMI (2000-2014).

3.4.1.2 Evaluating relationship for dominant taxa

Out of the many linear regressions completed for catch time series of dominant taxa in the CNMI's recreational coral reef fishery, none of them were determined to be significantly related to the recorded chlorophyll-*a* concentrations from the same area (Table 80). Of the 12 analyzed groups, the three with the strongest (non-significant) relationship with local chlorophyll concentrations were the Serranids, the Acanthurids, and the Holocentrids (R^2 = 0.20, 0.20, 0.06, respectively; Figure 50a-c). It is interesting to note that, unlike Guam, the overall relationship between pigment concentration and catch for the entirety of the reef fishery in the region was positive, though non-significant (*r* = 0.32, p = 0.25), and the strongest determined associations among the analyzed taxa were all positive as well (Table 80).

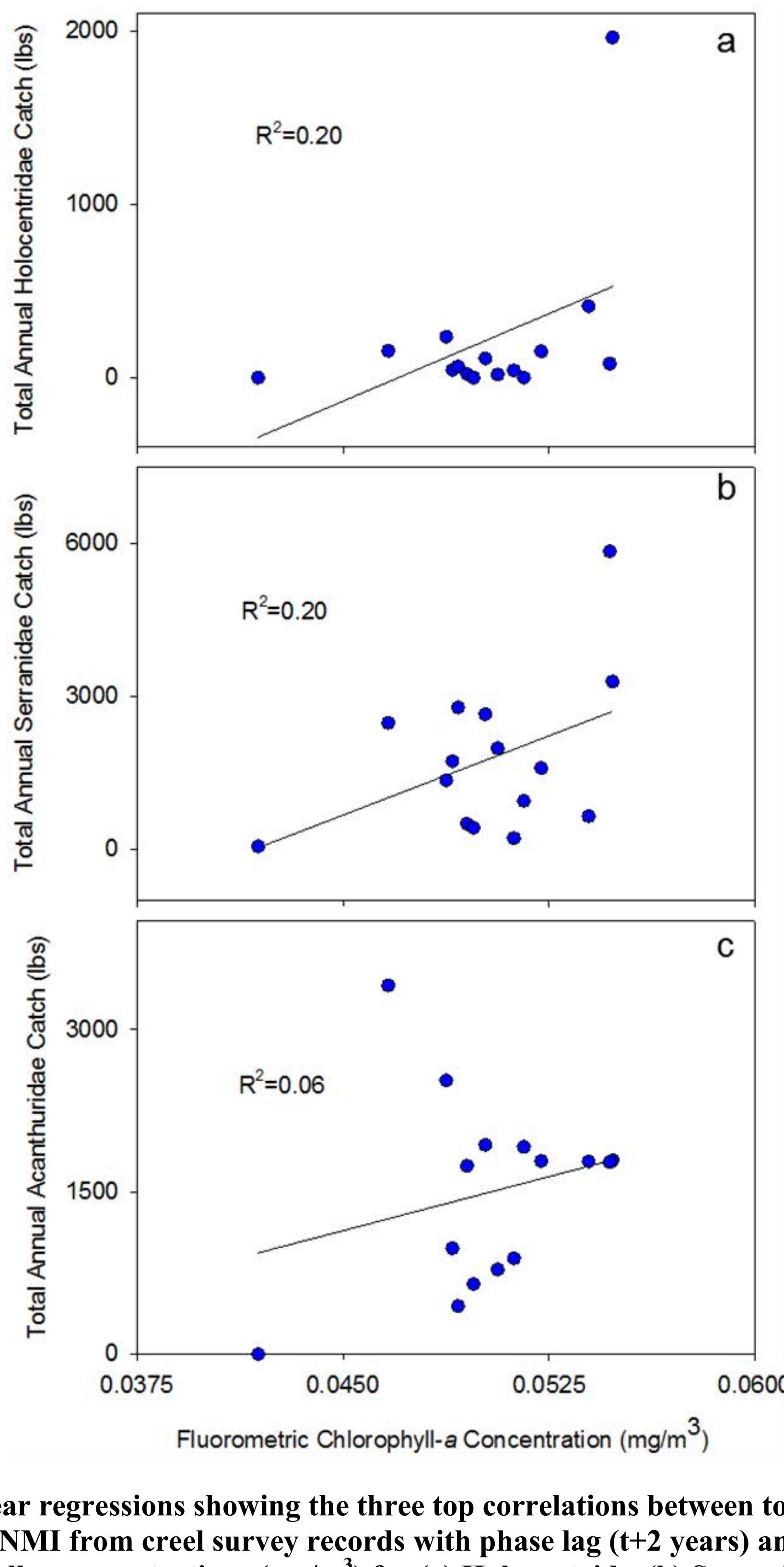

Figure 50. Linear regressions showing the three top correlations between total annual catch (kg) for the CNMI from creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) for (a) Holocentrids, (b) Serranids, and (c) Acanthurids from 2000–2014.

3.4.2 Guam

3.4.2.1 Evaluating relationship for entire reef fishery

A plot depicting the comparison of the fluorometric chlorophyll-*a* concentrations and recreational coral reef fishery catch time series from 1998 - 2014 in Guam is shown in Figure 51. Catch levels were relatively variable over the course of the time series when considering the variation in pigment levels (CV=26.2; Figure 51). A gradual drop in total annual catch was observed starting from 1998 before stabilizing in the late 2000s, where recorded catch decreased to approximately a quarter million. and rose back up to over half a million kilograms in more recent years; it is of note that the minimum catch and maximum chlorophyll concentration depicted in this plot both occurred in the year 2005 (Figure 51).

Linear regressions and correlation analyses were conducted for the time series of the Guam recreational coral reef fishery catch (with phase lag) with fluorometric chlorophyll-*a* concentrations (mg/m^3) gathered from the Ocean Colour Climate Change Initiative dataset (v3.1) for the 17 years between 1998 and 2014. It was found that the chlorophyll concentrations and total annual catch for the all harvested taxa had a negative relationship between 1989 and 2015, though it was slightly over the threshold of significance (r = -0.45, p = 0.02; Table 81; Figure 52). The association was statistically significant, and it was determined that for every increase of 0.01 mg/m^3 in chlorophyll-*a* concentration, catch would approximately decrease by 180,000 kg after two years all of the Guam recreational fishery (R^2 = 0.20, p = 0.02; Table 81; Figure 52).

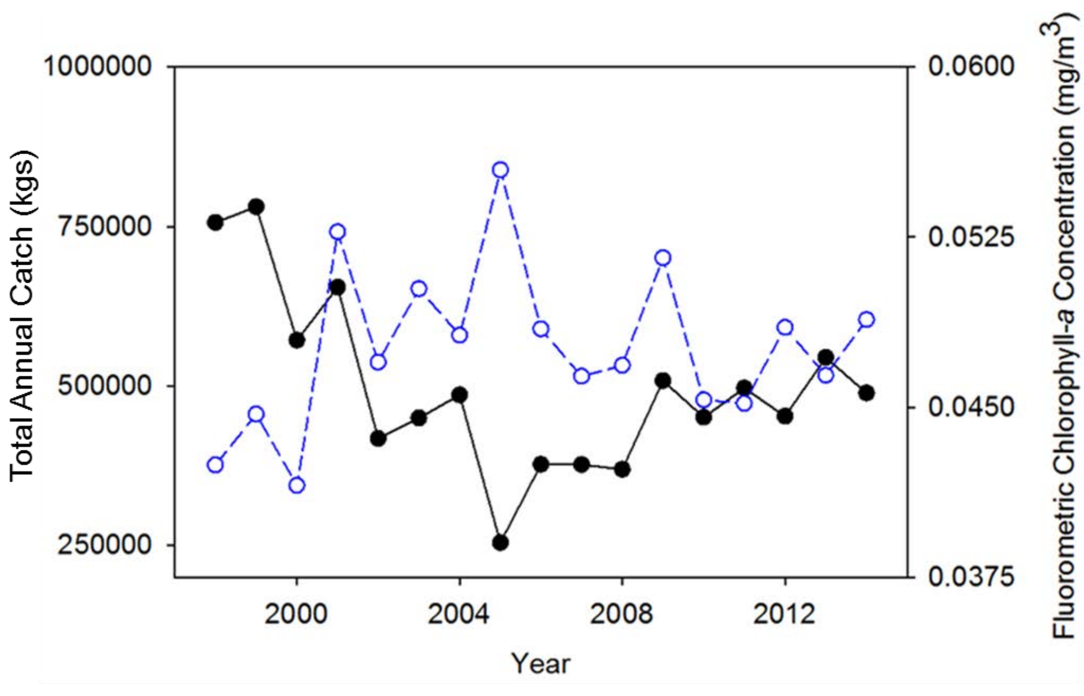

Figure 51. Comparison of Guam recreational reef fish catch for shore-and boat-based creel survey records (kg; black) with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 1998-2014.

Table 81. Correlation coefficients (*r*) from comparisons of time series of for shore-and boat-based creel survey records in Guam (kg) and fluorometric chlorophyll-*a* concentrations (mg/m^3) for 12 top taxa harvested from 1998 - 2014. Significant correlations are indicated in bold (α=0.05).

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 17													
p	0.07	0.62	0.16	0.73	0.44	0.51	0.17	0.42	0.08	**0.04**	0.47	0.21	**0.03**
r	-0.45	-0.13	-0.36	-0.09	-0.20	-0.17	-0.35	-0.21	-0.43	**-0.50**	-0.19	-0.32	**-0.53**
R^2	0.20	0.02	0.13	0.01	0.04	0.03	0.12	0.04	0.19	**0.25**	0.03	0.11	**0.28**

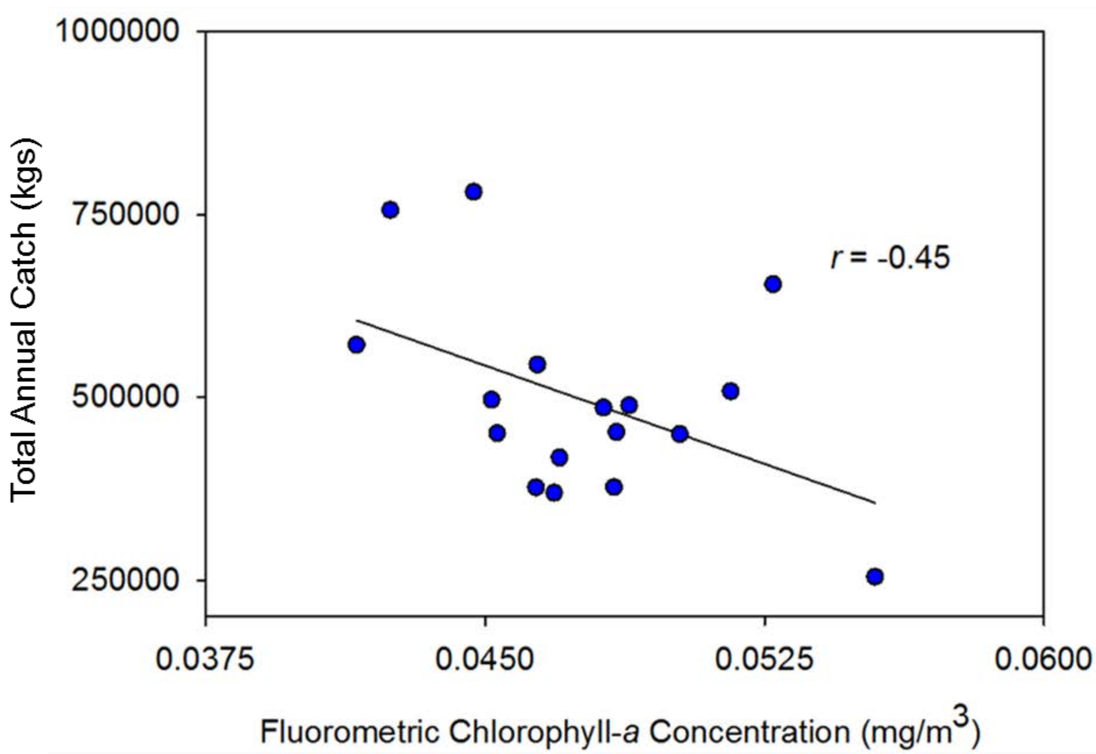

Figure 52. Linear regression between total annual catch (kg) for Guam shore-and boat-based creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) from 1998-2014.

3.4.2.2 Evaluating relationship for dominant taxa

The several linear regression and correlation analyses performed for time series of catch on the taxa level of Guam's recreational reef fishery showed that for dominant taxa in the fishery, and only two of the 12 analyzed groups had statistically significant relationships with local chlorophyll concentrations: the Balistids and the Mugilids (Table 81). The relationship between catch of species in the Balistidae group and chlorophyll concentration was shown to have negatively significant relationship such that for every increase of 0.01 mg/m^3 in chlorophyll-*a* concentration, catch would drop by more than 1,700 kg two years later when harvesting members of the Balistidae family (R^2=0.28, p = 0.03; Table 81; Figure 53a). The relationship between catch of members of the Mugilidae group and chlorophyll concentration was also shown to be negatively significant, but to a lesser degree. With a rise of 0.01 mg/m^3 in chlorophyll-*a* levels, recreational catch of the Mugilids would decrease by approximately over 4,600 kg after two years for the group (R^2=0.25, p = 0.04; Table 81; Figure 53b;). The next strongest relationship as determined by the regressions was not significant, but was similarly negative (Mullidae; R^2=0.19, p=0.08; Table 81; Figure 53c); all four of these potential fishery ecosystem relationships, however, were positive.

In the CNMI, there were no statistically significant relationships discovered between chlorophyll concentrations and any of the 12 prevalent taxa evaluated in this study, nor to the total fishery annual catch in its entirety. The lack of identifiable associations could have been attributed to the relatively short time series of data available for comparison at 15 years. While there were several families observed that had relationships on the cusp of being deemed significant according to resulting coefficients of determination, such as Serranidae and Holocentridae, they were positively associated.

In summary for Guam, it was determined that there existed a negatively significant relationship between reef recreational catch and fluorometric chlorophyll-*a* concentrations (mg/m^3) from the Ocean Colour Climate Change Initiative dataset (v3.1) for the entirety of the fishery. For every increase of 0.01 mg/m^3 in chlorophyll-*a* concentration, catch would approximately decrease by 180,000 kg across all harvested taxa two years later. Potential statistically significant fishery ecosystem relationships were also observed for the Balistidae and Mugilidae groups, where the catch of each group would decrease by approximately 1,700 and 4,600 kg, respectively, given two years of phase lag with a similar increase in fluorometric chlorophyll.

Uncertainty levels were relatively high in evaluations including chlorophyll-*a* concentrations due to the nature of incorporating phase lag and not smoothing the catch data. The largest issue in performing comparison analyses between catch from reef fisheries in the Mariana Archipelago and fluorometric chlorophyll-*a* concentrations was the relatively short time series (i.e. small sample size). Robust, homogenous time series highlighting interdecadal patterns in these regions were difficult to obtain due to time series merging several sources of chlorophyll concentration to elongate the range of continuous data. For example, the ESA’s OCC CCI dataset only permitted the use of less than two decades of data when evaluating the territories with the incorporation of phase lag. The length of the applied lag has a large impact in the patterns observed, so the relatively short extent of the available time series may obfuscate some of the identified relationships.

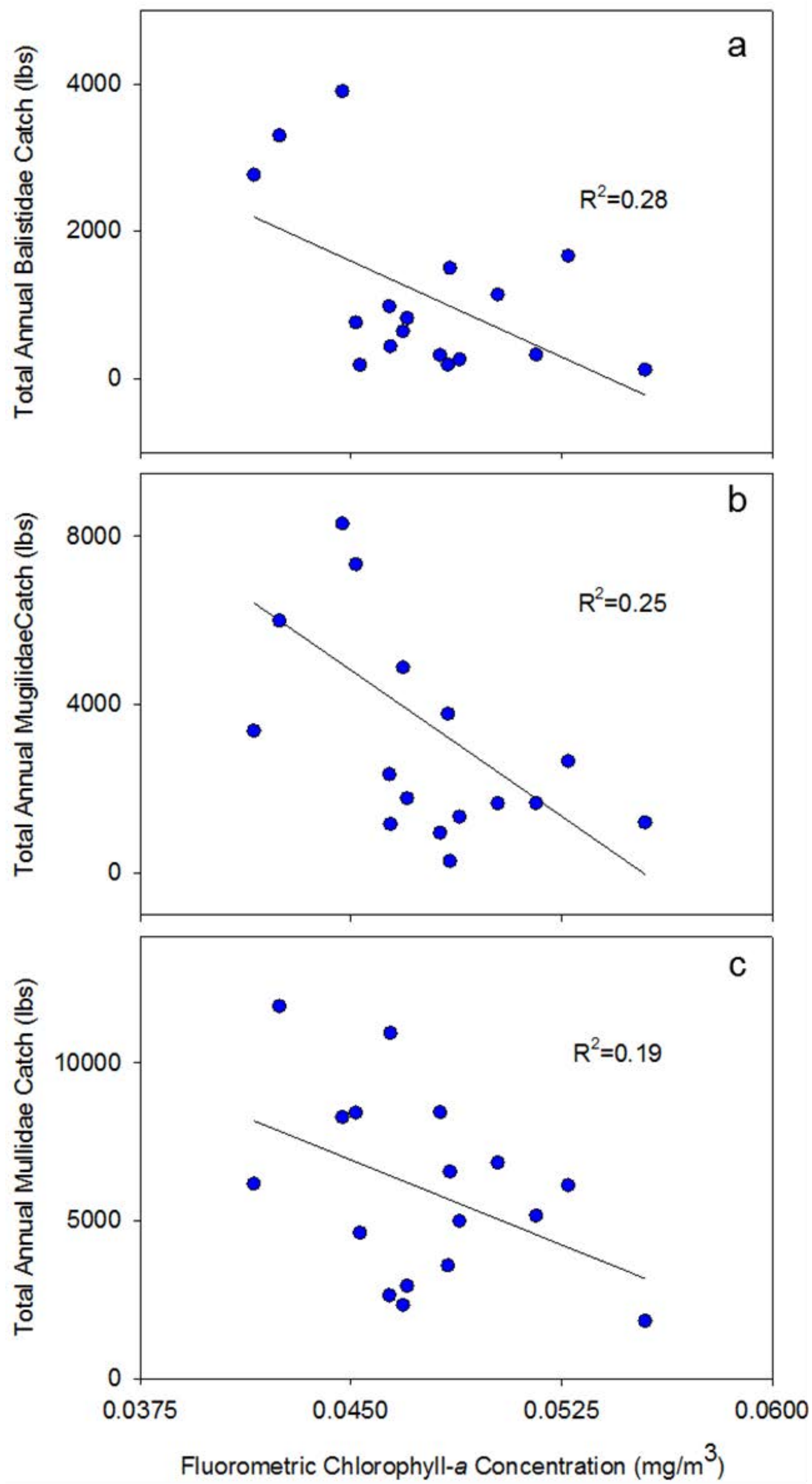

Figure 53. Linear regressions showing the three top correlations between total annual catch (kg) for Guam for shore-and boat-based creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) for (a) Balistidae, (b) Mugilidae, and (c) Mullidae from 1998–2014.

3.5 MULTIVARIATE ASSESSMENTS OF OTHER ECOSYSTEM VARIABLES

3.5.1 Non-metric Multidimensional Scaling

There were several other prioritized fishery ecosystem relationships for coral reefs in the Mariana Archipelago involving environmental parameters that were not to be addressed in this initial evaluation including: the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), sea level height, pH, dissolved oxygen, and salinity. Further descriptions of these climate and oceanic indicators are available in Section 2.5.3. Sea surface height data were aggregated from the Ocean Service, Tides, and Currents, and Sea Level database operated (NOAA/NOS/CO-OPS). Basin-wide data ONI were taken from NOAA's Nation Centers for Environmental Information- Equatorial Pacific Sea Surface Temperature Database (Climate Prediction Center Internet Team 2015). Similarly, PDO data were obtained from NOAA's Earth System Research Laboratory Physical Sciences Division originally derived from OI.v1 and OI.v2 SST parameters (NOAA PDO). Salinity data for American Samoa were gathered from Simple Ocean Data Assimilation (SODA) version 3.3.1 (Carton and Giese 2008). Rainfall estimates were obtained through the local National Weather Service in American Samoa (NWS-G).

Non-metric multidimensional scaling (NMS), a form of multivariate analysis that orders sample units along synthetic axes to reveal patterns of composition and relative abundance (Peck, 2016), is most commonly utilized when looking to identify patterns in heterogenous species response data (Peck, 2016). For this study, NMS was used to help identify associations between coral reef fishery parameters and environmental factors using the program PCORD 7. To ensure the same length of time series for all catch and environmental variables considered, data was analyzed from 1989-2015 to allow for the inclusion of more parameters (e.g. pH) for which longer-term time series were unavailable. The generated axes represent the best fit of patterns of redundancy in the catch data used as input, and the resulting ordination scores are a rank-order depiction of associations in the original dataset.

NMS produces robust results even in the presence of outliers by avoiding parametric and distributional assumptions (Peck, 2016). The only assumption to be met in NMS is that the relationship between the original rank ordered distances between sample units and the reduced distances in the final solution should be monotonic; that is, the slope of the association between the two is flat or positive, as determined by the stress statistic. In the most general terms, interpretable and reliable ordination axes have stress less than 10 up to 25 for datasets with large sample size, but large stress scores (i.e. greater than 30) may suggest that the final ordination results have little association with the original data matrix. Additionally, NMS ordination scores vary depending on the number of dimensions/axes designated to be solved (Peck, 2016). Dimensionality (i.e. number of axes for the final solution) for each test was identified though PCORD result recommendations based on final stress being lower than that for 95% of randomized runs (i.e. $p \leq 0.05$). Tau is a statistic that represents the rank correlations of the ordination scores to the original data matrices, and was used to identify explanatory variables with associations to the ordination axes. For the MHI test, data from 13 species/taxa groups from 1989 - 2015 (27 years) were included along with 10 variables of environmental data collected during the same time period (see Table F).

3.5.1.1 CNMI

The resulting ordination scores from the NMS analysis performed on boat-based expanded creel survey catch records and the previously mentioned environmental parameters recommended a one dimensional solution, which accounting for 87.2% of the cumulated variance observed in the CNMI boat-based creel survey data. The NMS final stress was morderate for the real runs (13.9), but low relative to stress from the randomization runs (31.0; Figure 54. NMS scree plot showing the stress test to determine dimensionality for the final solution for the CNMI multivariate analysis. A one-axis solution was recommended.). The final ordination scores for the families considered were scaled on a gradient relative to the individual ordination axis, the overlying environmnetal joint biplot is situated to the left of the final ordination points (Figure 54).

The only environmental parameter included in this analysis that displayed a significant relationship with the lone axis was PDO, though that assoication was negative. (tau = -0.47), Although this NMS run was not able to identify any other environmental parameters significanlty correlated to the ordination axis, additionaly relatively strong associations exist between sea level height (tau = 0.33) and pH (-0.31; Figure 55). Replicate NMS runs had similar stress levels for the final generated result.

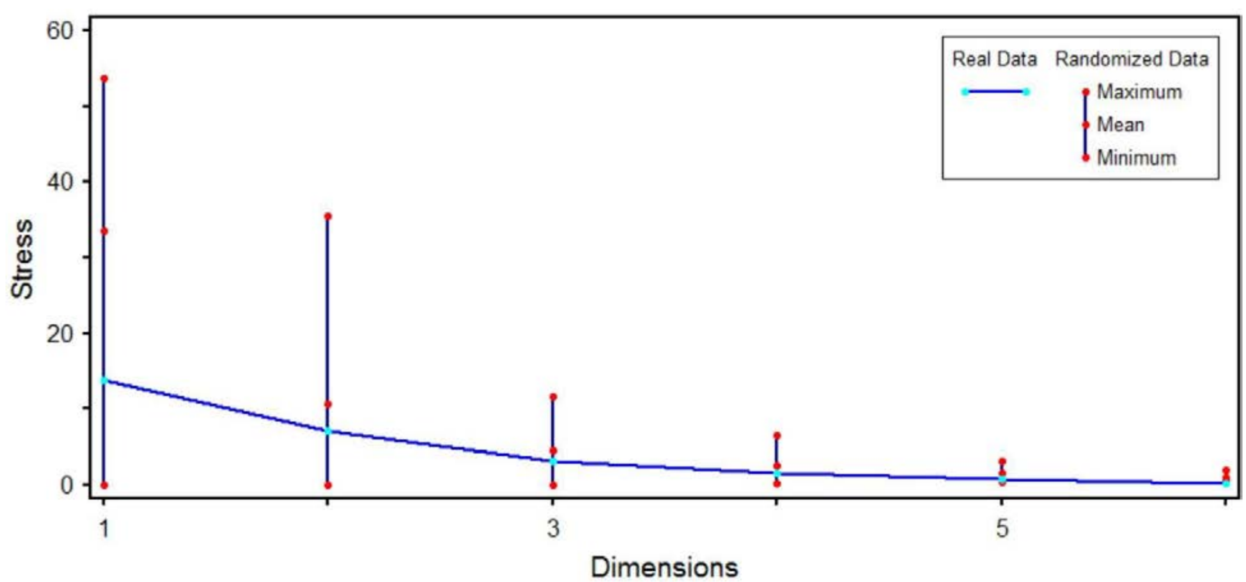

Figure 54. NMS scree plot showing the stress test to determine dimensionality for the final solution for the CNMI multivariate analysis. A one-axis solution was recommended.

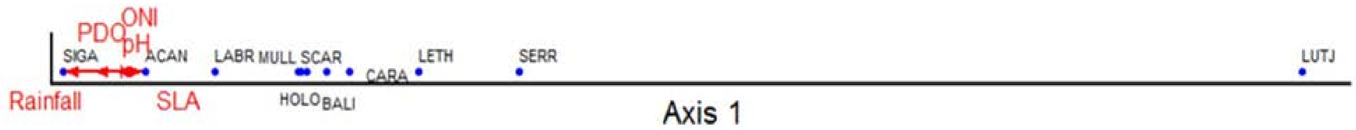

Figure 55. One-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters from the CNMI (2000 - 2014).

3.5.1.2 Guam

The Guam NMS identified two orthogonal axes for the final solution that accounted for 93.6% of the cumulative observed variance in shore- and boat-based creel survey data from Guam. The final stress for the Guam NMS barely less than 10, though it was notable lower than the average final stress from randomizations (14.2; Figure 56). A majority of the families were clustered in ordination space, with the notable exception of Carangidae (Figure 57).

The final ordination scores for the Guam NMS did not show any environmental parameters with a statistically significant correlation to the first axis (r^2 = 0.62; Figure 57). SST (tau = -0.50) and SSTA (tau = -0.50) were both negatively associated with the Axis 2 (r^2 = 0.32), and pH had a significantly positive relationship with the axis (tau = 0.56). Additionally, Axis 2 was shown to also be negatively associated with pH (tau = -0.37; Figure 57). Replicate NMS runs had similar stress levels for the final generated result.

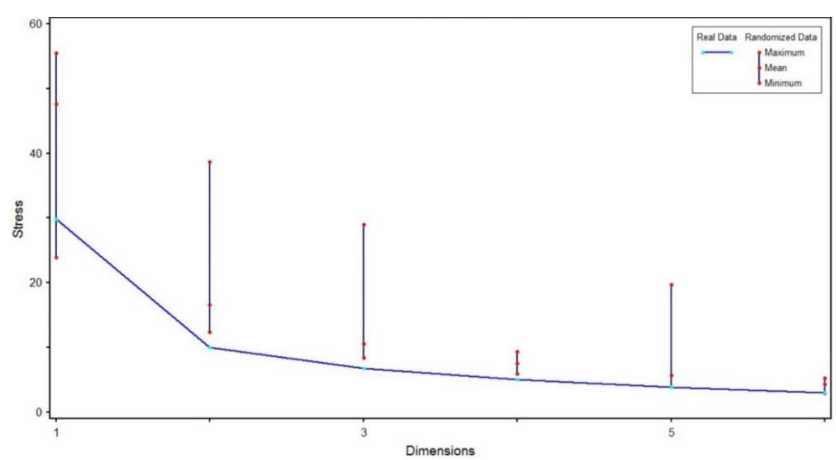

Figure 56. NMS scree plot showing the stress test to determine dimensionality for the final solution for the Guam multivariate analysis. A two-axis solution was recommended.

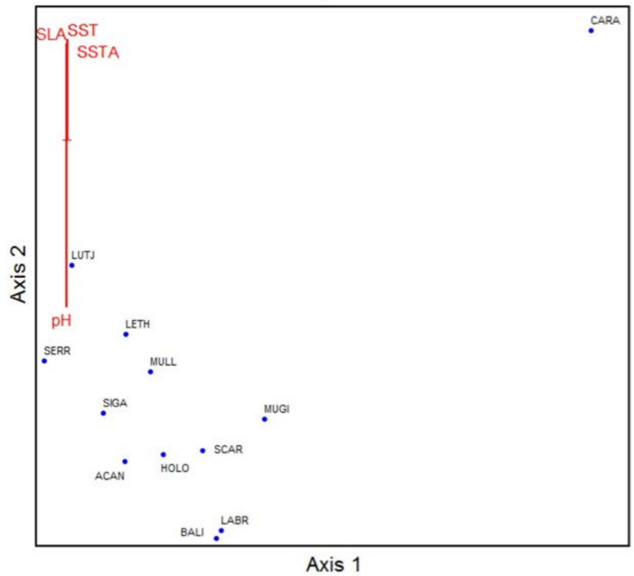

Figure 57. Two-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters from the Guam (1989-2014).

Ultimately, stress values for all analyses were relatively low, suggesting that the generated ordination scores were robust and useful for interpretation relative to the ordination axes. Nearly all included environmental parameters had a statistically significant relationship with at least one ordination axis in at least one of the final solutions, suggesting that these parameters likely intertwine in complicated processes to produce observed impacts on coral reef fisheries in the U.S. Western Pacific. Though a fishery ecosystem relationship may have not been explicitly identified in NMS runs of this preliminary evaluation, it does not preclude the possibility that an association may still exist.

3.6 REFERENCES

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APPENDIX A: LIST OF MANAGEMENT UNIT SPECIES

CNMI

1. Bottomfish Multi-species Stock Complex (FSSI)

DFW Creel Species Code	Species Name	Scientific Name
214	red snapper, silvermouth (lehi)	*Aphareus rutilans*
213	grey snapper, jobfish	*Aprion virescens*
112	giant trevally, jack	*Caranx ignoblis*
111	black trevally, jack	*Caranx lugubris*
231	blacktip grouper	*Epinephelus fasciatus*
241	lunartail grouper (lyretail grouper)	*Variola lauti*
203	red snapper (ehu)	*Etelis carbunculus*
210	red snapper (onaga)	*Etelis coruscans*
none	ambon emperor	*Lethrinus amboinenis*
350	redgill emperor	*Lethrinus rubrioperculatus*
253	blueline snapper	*Lutjanus kasmira*
none	yellowtail snapper	*Pristipomoides auricilla*
212	pink snapper (paka)	*Pristipomoides filamentosus*
209	yelloweye snapper	*Pristipomoides flavipinnis*
207	pink snapper (kalekale)	*Pristipomoides seiboldi*
204	flower snapper (gindai)	*Pristipomoides zonatus*
220	amberjack	*Seriola dumerili*

2. Crustacean deep-water shrimp complex (non-FSSI)

DFW Creel Species Code	Species Name	Scientific Name
508	deepwater shrimp	*Heterocarpus* spp.

3. Crustacean spiny lobster complex (non-FSSI)

DFW Creel Species Code	Species Name	Scientific Name
504	spiny lobster	*Panulirus marginatus*
504	spiny lobster	*Panulirus penicillatus*

4. Crustacean slipper lobster complex (non-FSSI)

DFW Creel Species Code	Species Name	Scientific Name
505	Slipper lobster	Scyllaridae

5. Crustacean Kona crab complex (non-FSSI)

DFW Creel Species Code	Species Name	Scientific Name
502	Kona crab	*Ranina ranina*

6. Precious coral black coral complex (non-FSSI)

DFW Creel Species Code	Species Name	Scientific Name
none	Black Coral	*Anitpathes dichotoma*
none	Black Coral	*Antipathes grandis*
none	Black Coral	*Antipathes ulex*

7. Exploratory area precious coral (except black coral; non-FSSI)

DFW Creel Species Code	Species Name	Scientific Name
none	Pink coral	*Corallium secundum*
none	Pink coral	*Corallium regale*
none	Pink coral	*Corallium laauense*
none	Bamboo coral	*Lepidisis olapa*
none	Bamboo coral	*Acanella* spp.
none	Gold Coral	*Gerardia* spp.
none	Gold Coral	*Callogorgia gilberti*
none	Gold Coral	*Narella* spp.
none	Gold Coral	*Calyptrophora* spp.

8. Coral reef ecosystem (non-FSSI)

DFW Creel Species Code	Species Name	Scientific Name	Grouping
357	Bigeye Emperor	*Monotaxis grandoculus*	Lethrinidae
353	Blackspot Emperor	*Lethrinus harak*	Lethrinidae
310	Emperor (mafute/misc.)	*Lethrinus* sp.	Lethrinidae
356	Flametail Emperor	*Lethrinus fulvus*	Lethrinidae
351	Longnose Emperor	*Lethrinus olivaceus*	Lethrinidae
352	Orangefin Emperor	*Lethrinus erythracanthus*	Lethrinidae
361	Ornate Emperor	*Lethrinus ornatus*	Lethrinidae
358	Stout Emperor	*Gymnocranius* sp.	Lethrinidae
355	Yellowlips Emperor	*Lethrinus xanthochilis*	Lethrinidae
359	Yellowspot emperor	*Gnathodentex aurolineatus*	Lethrinidae
354	Yellowstripe Emperor	*Lethrinus obsoletus*	Lethrinidae
362	Yellowtail Emperor	*Lethrinus atkinsoni*	Lethrinidae
115	Bigeye Trevally	*Caranx sexfasciatus*	Carangidae
113	Bluefin Trevally	*Caranx melampygus*	Carangidae
114	Brassy Trevally	*Caranx papuesis*	Carangidae
105	EE: Juvenile Jacks	*Canranx* sp.	Carangidae
104	Jacks (misc.)	*Caranx* sp.	Carangidae
101	Leatherback	*Scomberoides lysan*	Carangidae

103	Mackerel Scad	*Decapterus macarellus*	Carangidae
410	Rainbow Runner	*Elagatis bipinnulatus*	Carangidae
117	Small-spotted pompano	*Trachinotus bailloni*	Carangidae
116	Snubnose pompano	*Trachinotus blochii*	Carangidae
110	Yellow Spotted Trevally	*Carangoides orthogrammus*	Carangidae
380	Bluebanded Surgeonfish	*Acanthurus lineatus*	Acanthuridae
383	Bluelined Surgeon	*Acanthurus nigroris*	Acanthuridae
384	Bluespine Unicornfish	*Naso unicornis*	Acanthuridae
381	Convict Tang	*Acanthurus triostegus*	Acanthuridae
319	Orangespine Unicornfish	*Naso lituratus*	Acanthuridae
318	Surgeonfish (misc.)	*Acanthurus* sp.	Acanthuridae
320	Unicornfish (misc.)	*Naso* sp.	Acanthuridae
382	Yellowfin Surgeonfish	*Acanthurus xanthopterus*	Acanthuridae
102	Bigeye Scad	*Selar crumenopthalmus*	Atulai
239	Coral Grouper	*Epinephelus corallicola*	Serranidae
237	Flagtail Grouper	*Cephalopholis urodeta*	Serranidae
206	Grouper (misc.)	Serannidae	Serranidae
233	Highfin Grouper	*Epinephelus maculatus*	Serranidae
234	Honeycomb Grouper	*Epinephelus merra*	Serranidae
235	Marbled Grouper	*Epinephelus polyphekadion*	Serranidae
236	Peacock Grouper	*Cephalopholis argus*	Serranidae
244	Pink Grouper	*Saloptia powelli*	Serranidae
238	Saddleback Grouper	*Plectropomus laevis*	Serranidae
242	Tomato Grouper	*Cephanopholis sonnerati*	Serranidae
240	White Lyretail Grouper	*Variola albimarginata*	Serranidae
243	Yellow Banded Grouper	*Cephalopholis igarashiensis*	Serranidae
316	Snapper (misc. shallow)	Lutjanidae	Lutjanidae
250	Humpback Snapper	*Lutjanus gibbus*	Lutjanidae
251	Onespot Snapper	*Lutjanus monostigmus*	Lutjanidae
254	Red Snapper	*Lutjanus bohar*	Lutjanidae
208	Smalltooth Jobfish	*Aphareus furca*	Lutjanidae
371	Dash & Dot Goatfish	*Parupeneus barberrinus*	Mullidae
321	Goatfish (juvenile-misc)	Mullidae	Mullidae
322	Goatfish (misc.)	Mullidae	Mullidae
323	Sidespot Goatfish	*Parupeneus pleurostigma*	Mullidae
372	Two-barred Goatfish	*Parupeneus bifasciatus*	Mullidae
370	Yellowstripe Goatfish	*Mulloidichthys flavolineatus*	Mullidae
314	Parrotfish (misc.)	*Scarus* sp.	Scaridae
315	Seagrass Parrotfish	*Leptoscarus vaigiensis*	Scaridae

506	Octopus	*Octopus i.*	Mollusk
510	Squid	*Teuthida*	Mollusk
516	Trochus	*Trochus* sp.	Mollusk
522	Clam/bivalve	Bivalvia	Mollusk
106	Mullet	Mugilidae	Mugilidae
304	Rabbitfish (hitting)	*Siganus* sp.	Siganidae
306	Rabbitfish (h.feda)	*Siganus puntatus*	Siganidae
307	Rabbitfish (menahac)	*Siganus* sp.	Siganidae
308	Rabbitfish (sesjun)	*Siganus spinus*	Siganidae
	Bolbometopon muricatum	*Bumphead parrotfish*	
391	Cheilinus undulatus	*Napoleon wrasse*	
	Reef sharks (misc)	Carcharhinidae	Carcharhinidae
	Hammerhead shark	Sphyrnidae	Carcharhinidae
338	Angelfish	Pomacanthidae	Other CRE-Finfish
338	Butterflyfish	Chaetodontidae	Other CRE-Finfish
324	Bigeye/glasseye	*Heteropriacanthus cruentatus*	Other CRE-Finfish
396	Blue Razorfish	*Xyrichtys pavo*	Other CRE-Finfish
397	Bronzespot Razorfish	*Xyrichtys celebicus*	Other CRE-Finfish
260	Cardinal Misc.	Apogonidae	Other CRE-Finfish
162	Cornetfish	*Fistularia commersonii*	Other CRE-Finfish
332	Damselfish	Pomacentridae	Other CRE-Finfish
341	Filefish (misc)	Monacanthidae	Other CRE-Finfish
340	Flounder (misc)	*Bothus* sp.	Other CRE-Finfish
328	Fusilier (misc.)	Caesionidae	Other CRE-Finfish
325	Goggle-eye	*Priacanthus hamrur*	Other CRE-Finfish
195	Lizardfish misc.	Synodontidae	Other CRE-Finfish
180	Milkfish	*Chanos chanos*	Other CRE-Finfish
329	Mojarra	*Gerres* sp.	Other CRE-Finfish
140	Moray eel	Muraenidae	Other CRE-Finfish
170	Needlefish	Belonidae	Other CRE-Finfish
343	Picasso Trigger	*Rhinecanthus aculeatus*	Other CRE-Finfish
348	Pufferfish	Tetraodontidae	Other CRE-Finfish
395	Razorfish (misc)	*Tribe Novaculini*	Other CRE-Finfish
130	Scorpionfishes	Scorpaenidae	Other CRE-Finfish
330	Sweetlips	*Plectorhinchus picus*	Other CRE-Finfish
342	Triggerfish (misc.)	Balistidae	Other CRE-Finfish
163	Trumpetfish	*Aulostomus chinensis*	Other CRE-Finfish
344	Wedge Trigger	*Rhinecanthus rectangulus*	Other CRE-Finfish
312	Squirrelfish	Holocentridae	Squirrelfish

313	Soldierfish (misc.)	Holocentridae	Squirrelfish
302	Wrasse	Labridae	Wrasse
390	Tripletail Wrasse	*Cheilinus trilobatus*	Wrasse
309	Rudderfish (guilli)	*Kyphosus* sp.	Rudderfish
373	Highfin Rudderfish Silver	*Kyphosus cinerascens*	Rudderfish
374	Highfin Rudderfish Brown	*Kyphosus* sp.	Rudderfish
200	Bottomfish (misc)	n/a	Misc. Bottomfish
300	Reef fish (misc)	n/a	Misc. Reef Fish
	Shallow bottom	n/a	Misc. Shallow bottomfish
501	Crabs (misc)	n/a	Crustaceans
503	Coconut Crab	*Birgus latro*	Crustaceans
500	Invertebrates	n/a	Other Invertebrates
514	Sea Cucumber	Cucumariidae	Other Invertebrates
600	Seaweeds	n/a	Algae
602	Lemu	n/a	Algae

GUAM

1. Bottomfish Multi-species Stock Complex (FSSI)

DAWR Creel Species Code	Species Name	Scientific Name
32302	red snapper, silvermouth (lehi)	*Aphareus rutilans*
32303	grey snapper, jobfish	*Aprion virescens*
31404	giant trevally, jack	*Caranx ignoblis*
31405	black trevally, jack	*Caranx lugubris*
28919	blacktip grouper	*Epinephelus fasciatus*
28941	lunartail (lyretail) grouper	*Variola lauti*
32304	red snapper (ehu)	*Etelis carbunculus*
32305	red snapper (onaga)	*Etelis coruscans*
32818	ambon emperor	*Lethrinus amboinenis*
32809	redgill emperor	*Lethrinus rubrioperculatus*
32310	blueline snapper	*Lutjanus kasmira*
32317	yellowtail snapper	*Pristipomoides auricilla*
32318	pink snapper (paka)	*Pristipomoides filamentosus*
32319	yelloweye snapper	*Pristipomoides flavipinnis*
32320	pink snapper (kalekale)	*Pristipomoides seiboldi*
32321	snapper (gindai)	*Pristipomoides zonatus*
31414	amberjack	*Seriola dumerili*

2. Crustacean deep-water shrimp complex (non-FSSI)

DAWR Creel Species Code	Species Name	Scientific Name
67600	deepwater shrimp	*Heterocarpus* spp.
67601	deepwater shrimp	*Pandalus unid* sp.
67602	deepwater shrimp	Pandalidae
67603	deepwater shrimp	Pandalidae

3. Crustacean spiny lobster complex (non-FSSI)

DAWR Creel Species Code	Species Name	Scientific Name
67913	spiny lobster	*Panulirus marginatus*
67915	spiny lobster	*Panulirus penicillatus*

4. Crustacean slipper lobster complex (non-FSSI)

DAWR Creel Species Code	Species Name	Scientific Name
67954	slipper lobster	Scyllaridae
67955	slipper lobster	Scyllaridae

5. Crustacean Kona crab complex (non-FSSI)

DAWR Creel Species Code	Species Name	Scientific Name
69150	Kona crab	*Ranina ranina*

6. Precious coral black coral complex (non-FSSI)

DAWR Creel Species Code	Species Name	Scientific Name
none	Black Coral	*Anitpathes dichotoma*
none	Black Coral	*Antipathes grandis*
none	Black Coral	*Antipathes ulex*

7. Exploratory area precious coral (except black coral) (non-FSSI)

DAWR Creel Species Code	Species Name	Scientific Name
none	Pink coral	*Corallium secundum*
none	Pink coral	*Corallium regale*
none	Pink coral	*Corallium laauense*
none	Bamboo coral	*Lepidisis olapa*
none	Bamboo coral	*Acanella* spp.
none	Gold Coral	*Gerardia* spp.
none	Gold Coral	*Callogorgia gilberti*
none	Gold Coral	*Narella* spp.
none	Gold Coral	*Calyptrophora* spp.

8. Coral reef ecosystem (non-FSSI)

DAWR Creel Species Code	Species Name	Scientific Name	Species grouping
41201	Achilles tang	*Acanthurus achilles*	Acanthuridae
41232	Bariene's surgeonfish	*Acanthurus bariene*	Acanthuridae
41207	Ringtail surgeonfish	*Acanthurus blochii*	Acanthuridae
41234	Chronixis surgeonfish	*Acanthurus chronixis*	Acanthuridae
41202	Eye-striped surgeonfish	*Acanthurus dussumieri*	Acanthuridae
41204	Whitespotted surgeonfish	*Acanthurus guttatus*	Acanthuridae
41239	Whitebar surgeonfish	*Acanthurus leucocheilus*	Acanthuridae
41205	Palelipped surgeonfish	*Acanthurus leucopareius*	Acanthuridae
41206	Blue-banded surgeonfish	*Acanthurus lineatus*	Acanthuridae
41235	White-Freckled surgeonfish	*Acanthurus maculiceps*	Acanthuridae
41233	Elongate surgeonfish	*Acanthurus mata*	Acanthuridae
41203	Whitecheek surgeonfish	*Acanthurus nigricans*	Acanthuridae
41208	Blackstreak surgeonfish	*Acanthurus nigricauda*	Acanthuridae
41209	Brown surgeonfish	*Acanthurus nigrofuscus*	Acanthuridae
41210	Bluelined surgeonfish	*Acanthurus nigroris*	Acanthuridae
41240	Surgeonfish	*Acanthurus nubilus*	Acanthuridae
41211	Orangeband surgeonfish	*Acanthurus olivaceus*	Acanthuridae
41212	Mimic surgeonfish	*Acanthurus pyroferus*	Acanthuridae

41243	Surgeonfishes/tangs	Acanthuridae	Acanthuridae
41200	Surgeonfishes/tangs	Acanthuridae	Acanthuridae
41213	Thomson's surgeonfish	*Acanthurus thompsoni*	Acanthuridae
41214	Convict tang	*Acanthurus triostegus*	Acanthuridae
41215	Yellowfin surgeonfish	*Acanthurus xanthopterus*	Acanthuridae
41216	Twospot bristletooth	*Ctenochaetus binotatus*	Acanthuridae
41217	Black surgeonfish	*Ctenochaetus hawaiiensis*	Acanthuridae
41236	Blue-spotted Bristletooth	*Ctenochaetus marginatus*	Acanthuridae
41218	Striped bristletooth	*Ctenochaetus striatus*	Acanthuridae
41231	Yellow-eyed bristletooth	*Ctenochaetus strigosus*	Acanthuridae
41237	Tomini's surgeonfish	*Ctenochaetus tominiensis*	Acanthuridae
41219	Whitemargin unicornfish	*Naso annulatus*	Acanthuridae
41220	Humpback unicornfish	*Naso brachycentron*	Acanthuridae
41221	Spotted unicornfish	*Naso brevirostris*	Acanthuridae
41241	Gray unicornfish	*Naso caesius*	Acanthuridae
41222	Black tongue unicornfish	*Naso hexacanthus*	Acanthuridae
41223	Orangespine unicornfish	*Naso lituratus*	Acanthuridae
41238	Naso tang	*Naso lopezi*	Acanthuridae
41242	Barred unicornfish	*Naso thynnoides*	Acanthuridae
41224	Humpnose unicornish	*Naso tuberosus*	Acanthuridae
41225	Bluespine unicornfish	*Naso unicornis*	Acanthuridae
41226	Bignose unicornfish	*Naso vlamingii*	Acanthuridae
41227	Hepatus tang	*Paracanthurus hepatus*	Acanthuridae
41228	Yellow tang	*Zebrasoma flavescens*	Acanthuridae
41229	Brown tang	*Zebrasoma scopas*	Acanthuridae
41230	Pacific sailfin tang	*Zebrasoma veliferum*	Acanthuridae
31401	Pennantfish/threadfin	*Alectis ciliaris*	Carangidae
31402	Malabar Trevally	*Alectis indicus*	Carangidae
31400	Jack (misc)	Carangidae	Carangidae
31420		*Carangini*	Carangidae
31419	Blue kingfish trevally	*Carangoides caeruleopinnatus*	Carangidae
31431	Shadow kingfish	*Carangoides dinema*	Carangidae
31422	Bar jack	*Carangoides ferdau*	Carangidae
31433	Yellow dotted trevally	*Carangoides fulvoguttatus*	Carangidae
31438	Headnotch trevally	*Carangoides hedlandensis*	Carangidae
31403	Goldspot trevally	*Carangoides orthogrammus*	Carangidae
31424	Barcheek trevally	*Carangoides plagiotaenia*	Carangidae
31425	Jacks (misc)	*Carangoides talamparoides*	Carangidae
31437	Trevally	*Carangoides uii*	Carangidae
31429	Trevally	*Caranx i'e'*	Carangidae

31406	Bluefin trevally	*Caranx melampygus*	Carangidae
31428	Brassy trevally	*Caranx papuensis*	Carangidae
31407	Bigeye trevally	*Caranx sexfasciatus*	Carangidae
31408	Mackerel scad	*Decapterus macarellus*	Carangidae
31423	Mackerel scad	*Decapterus macrosoma*	Carangidae
31421	Round scad	*Decapterus maruadsi*	Carangidae
31430	Round scad	*Decapterus russelli*	Carangidae
31409	Rainbow runner	*Elagatis bipinnulatus*	Carangidae
31410	Golden trevally	*Gnathanodon speciosus*	Carangidae
31439		*Megalaspis cordyla*	Carangidae
31435	Pilotfish	*Naucrates ductor*	Carangidae
31440	Elagatis, Scomberoides	*Naucratini*	Carangidae
31412	Leatherback	*Scomberoides lysan*	Carangidae
31415	Almaco jack	*Seriola rivoliana*	Carangidae
31416	Small spotted pompano	*Trachinotus bailloni*	Carangidae
31417	Silver or Snubnose pompano	*Trachinotus blochii*	Carangidae
31432	Mandibular kingfish	*Ulua mandibularis*	Carangidae
31418	Kingfish	*Uraspis helvola*	Carangidae
31436	Deep trevally	*Uraspis secunda*	Carangidae
31434	Whitemouth trevally	*Uraspis uraspis*	Carangidae
31413	Atulai	*Selar crumenophthalmus*	Atulai
31426	Atulai	*Atule mate*	Atulai
31427	Atulai	*Selar boops*	Atulai
32800	Emperors	Lethrinidae	Lethrinidae
32801	Yellow-Spot Emperor	*Gnathodentex aurolineatus*	Lethrinidae
32802	Grey Bream	*Gymnocranius griseus*	Lethrinidae
32804	Thumbprint Emperor	*Lethrinus harak*	Lethrinidae
32805	Yellowtail Emperor	*Lethrinus atkinsoni*	Lethrinidae
32806	Longface Emperor	*Lethrinus olivaceus*	Lethrinidae
32807	Ornate Emperor	*Lethrinus ornatus*	Lethrinidae
32808	Orange-Striped Emperor	*Lethrinus obsoletus*	Lethrinidae
32810	Black-Blotch Emperor	*Lethrinus semicinctus*	Lethrinidae
32811	Yellowlip Emperor	*Lethrinus xanthochilus*	Lethrinidae
32812	Bigeye Emperor	*Monotaxis grandoculus*	Lethrinidae
32813	Japanese Bream	*Gymnocranius euanus*	Lethrinidae
32814	Orange-Spotted Emperor	*Lethrinus erythracanthus*	Lethrinidae
32815	Large-Eye Bream	*Wattsia mossambica*	Lethrinidae
32816	Stout Emperor	*Gymnocranius sp*	Lethrinidae
32817	Smtoothed Emperor	*Lethrinus microdon*	Lethrinidae

32819	Longspine Emperor	*Lethrinus genivittatus*	Lethrinidae
32820	Pinkear Emperor	*Lethrinus lentjan*	Lethrinidae
32821	Blue-Spotted Bream	*Gymnocranius microdon*	Lethrinidae
32822	Longfin Emperor	*Lethrinus erythropterus*	Lethrinidae
32823	Blue-Lined Bream	*Gymnocranius grandoculus*	Lethrinidae
32824	Slender Emperor	*Lethrinus variegatus*	Lethrinidae
36402	Bucktooth Parrotfish	*Calotomus carolinus*	Scaridae
36420	Spineytooth Parrotfish	*Calotomus spinidens*	Scaridae
36403	Bicolor Parrotfish	*Cetoscarus bicolor*	Scaridae
36422	Parrotfish	*Chlorurus bleekeri*	Scaridae
36431	Parrotfish	*Chlorurus bowersi*	Scaridae
36408	Tan-Faced Parrotfish	*Chlorurus frontalis*	Scaridae
36410	Steephead Parrotfish	*Chlorurus microrhinos*	Scaridae
36433	Parrotfish	*Chlorurus pyrrhurus*	Scaridae
36416	Bullethead Parrotfish	*Chlorurus sordidus*	Scaridae
36404	Parrotfish	*Hipposcarus longiceps*	Scaridae
36405	Seagrass Parrotfish	*Leptoscarus vaigiensis*	Scaridae
36400	Parrotfishes	Scaridae	Scaridae
36406	Fil-Finned Parrotfish	*Scarus altipinnis*	Scaridae
36429	Parrotfish	*Scarus chameleon*	Scaridae
36423	Parrotfish	*Scarus dimidiatus*	Scaridae
36419	Parrotfish	*Scarus festivus*	Scaridae
36434	Yellowfin Parrotfish	*Scarus flavipectoralis*	Scaridae
36417	Tricolor Parrotfish	*Scarus forsteni*	Scaridae
36407	Vermiculate Parrotfish	*Scarus frenatus*	Scaridae
36409	Blue-Barred Parrotfish	*Scarus ghobban*	Scaridae
36411	Parrotfish	*Scarus globiceps*	Scaridae
36424	Java Parrotfish	*Scarus hypselosoma*	Scaridae
36418	Parrotfish	*Scarus* sp.	Scaridae
36432	Black Parrotfish	*Scarus niger*	Scaridae
36412	Parrotfish	*Scarus oviceps*	Scaridae
36425	Greenthroat Parrotfish	*Scarus prasiognathos*	Scaridae
36413	Pale Nose Parrotfish	*Scarus psittacus*	Scaridae
36426	Parrotfish	*Scarus quoyi*	Scaridae
36427	Parrotfish	*Scarus rivulatus*	Scaridae
36414	Parrotfish	*Scarus rubroviolaceus*	Scaridae
36415	Chevron Parrotfish	*Scarus schlegeli*	Scaridae
36428	Parrotfish	*Scarus spinus*	Scaridae
36435	Tricolor Parrotfish	*Scarus tricolor*	Scaridae

36421	Parrotfish	*Scarus xanthopleura*	Scaridae
33200	Goatfishes	Mullidae	Mullidae
33201	Yellowstriped Goatfish	*Mulloidichthys flavolineatus*	Mullidae
33202	Orange Goatfish	*Mulloidichthys pflugeri*	Mullidae
33219	Juvenile Goatfish	*Mulloidichthys ti'ao*	Mullidae
33203	Yellowfin Goatfish	*Mulloidichthys vanicolensis*	Mullidae
33216		*Parupeneus barberinoides*	Mullidae
33204	Dash And Dot Goatfish	*Parupeneus barberinus*	Mullidae
33205		*Parupeneus bifasciatus*	Mullidae
33210	White-Lined Goatfish	*Parupeneus ciliatus*	Mullidae
33206	Yellow Goatfish	*Parupeneus cyclostomus*	Mullidae
33208	Redspot Goatfish	*Parupeneus heptacanthus*	Mullidae
33214	Indian Goatfish	*Parupeneus indicus*	Mullidae
33211	Multibarred Goatfish	*Parupeneus multifasciatus*	Mullidae
33209	Sidespot Goatfish	*Parupeneus pleurostigma*	Mullidae
33217	Goatfish	*Parupeneus* sp.	Mullidae
33218	Goatfish	*Upeneus arge*	Mullidae
33212	Band-Tailed Goatfish	*Upeneus taeniopterus*	Mullidae
33215	Blackstriped Goatfish	*Upeneus tragula*	Mullidae
33213	Yellowbanded Goatfish	*Upeneus vittatus*	Mullidae
54501	Spiney Chiton	*Acanthopleura spinosa*	Mollusks
54410	Bubble Shells,Sea Hares	Acteonidae	Mollusks
54603	Antique Ark	*Anadara antiquata*	Mollusks
54602	Indo-Pacific Ark	*Arca navicularis*	Mollusks
54601	Ventricose Ark	*Arca ventricosa*	Mollusks
54600	Ark Shells	Arcidae	Mollusks
57742	Common Paper Nautilus	*Argonauta argo*	Mollusks
57745	Gruner'S Paper Nautilus	*Argonauta gruneri*	Mollusks
57741	Brown Paper Nautilus	*Argonauta hians*	Mollusks
57743	Nodose Paper Nautilus	*Argonauta nodosa*	Mollusks
57744	Noury'S Paper Nautilus	*Argonauta nouri*	Mollusks
57740	Paper Nautiluses	*Argonautidae*	Mollusks
56896	Pacific Sand Clam	*Asaphis violescens*	Mollusks
56891	Gaudy Sand Clam	*Aspaphis deflorata*	Mollusks
51751	Peron'S Sea Butterfly	*Atlanta peroni*	Mollusks
51750		Atlantidae	Mollusks
54424	Wh Pacific Atys	*Atys naucum*	Mollusks
54604	Almond Ark	*Babatia amygdalumtostum*	Mollusks
50840	Goblets,Dwarf Tritons	*Buccinidae*	Mollusks

54421	Ampule Bubble	*Bulla ampulla*	Mollusks
54420	Bubble Shells	Bullidae	Mollusks
54422	Lined Bubble	*Bullina lineata*	Mollusks
50796	Giant Frog Shell	*Bursa bubo*	Mollusks
50791	Warty Frog Shell	*Bursa bufonia*	Mollusks
50792	Blood-Stain Frog Shell	*Bursa cruentata*	Mollusks
50793	Granulate Frog Shell	*Bursa granularis*	Mollusks
50799	Lamarck'S Frog Shell	*Bursa lamarcki*	Mollusks
50798	Red-Mth Frog Shell	*Bursa lissostoma*	Mollusks
50794	Udder Frog Shell	*Bursa mammata*	Mollusks
50797	Ruddy Frog Shell	*Bursa rebeta*	Mollusks
50795	Wine-Mth Frog Shell	*Bursa rhodostoma*	Mollusks
50790	Frog Shells	Bursidae	Mollusks
50751	Umbilicate Ovula	*Calpurnus verrucosus*	Mollusks
50878	File Miter	*Cancilla filaris*	Mollusks
50842	Smoky Goblet	*Cantharus fumosus*	Mollusks
50841	Waved Goblet	*Cantharus undosus*	Mollusks
56721	Varitated Cardita	*Cardita variegata*	Mollusks
56720	Carditid Clams	Carditidae	Mollusks
50767	Vibex Bonnet	*Casmaria erinaceus*	Mollusks
50768	Heavy Bonnet	*Casmaria ponderosa*	Mollusks
50765	Helmet Shells	Cassidae	Mollusks
50766	Horned Helmet	*Cassius cornuta*	Mollusks
55022	3-Toothed Cavoline	*Cavolina tridentata*	Mollusks
55023	Unicate Cavoline	*Cavolina uncinata*	Mollusks
55021	Sea Butterfly	*Cavolinia cf globulosa*	Mollusks
55020	Sea Butterflies	*Cavolinidae*	Mollusks
50650	Turret,Worm-Shells	*Cerithiidae*	Mollusks
50654	Column Certh	*Cerithium columna*	Mollusks
50651	Giant Knobbed Certh	*Cerithium nodulosum*	Mollusks
56711	Lazarus Jewel Box	*Chama lazarus*	Mollusks
56710	Jewel Boxes	Chamidae	Mollusks
50781	Triton Trumpet	*Charonia tritonis*	Mollusks
50812	Ramose Murex	*Chicoreus ramosus*	Mollusks
54500	Chitons	Chitonidae	Mollusks
56623	Cook'S Scallop	*Chlamys cooki*	Mollusks
56621	Squamose Scallop	*Chlamys squamosa*	Mollusks
56500	Bivalves	*Class Bivalvia*	Mollusks
55027	Pyramid Clio	*Clio cuspidata*	Mollusks

55026	Irregular Urchins	*Clio pyramidata*	Mollusks
50652	Morus Certh	*Clypeomorus concisus*	Mollusks
56706	Punctate Lucina	*Codakia punctata*	Mollusks
50847	Maculated Dwarf Triton	*Columbraria muricata*	Mollusks
50845	Shiny Dwarf Triton	*Columbraria nitidula*	Mollusks
50846	Twisted Dwarf Triton	*Columbraria tortuosa*	Mollusks
50920	Cone Shells	Conidae	Mollusks
50952	Sand-Dusted Cone	*Conus arenatus*	Mollusks
50963	Princely Cone	*Conus aulicus*	Mollusks
50968	Aureus Cone	*Conus aureus*	Mollusks
50969	Gold-Leaf Cone	*Conus auricomus*	Mollusks
50947	Banded Marble-Cone	*Conus bandanus*	Mollusks
50971	Bubble Cone	*Conus bullatus*	Mollusks
50942	Captain Cone	*Conus capitaneus*	Mollusks
50932	Cat Cone	*Conus catus*	Mollusks
50924	Chaldean Cone	*Conus chaldeus*	Mollusks
50972	Comma Cone	*Conus connectens*	Mollusks
50922	Crowned Cone	*Conus coronatus*	Mollusks
50970	Cylindrical Cone	*Conus cylandraceus*	Mollusks
50926	Distantly-Lined Cone	*Conus distans*	Mollusks
50923	Hebrew Cone	*Conus ebraeus*	Mollusks
50936	Ivory Cone	*Conus eburneus*	Mollusks
50965	Episcopus Cone	*Conus episcopus*	Mollusks
50927	Pacific Yellow Cone	*Conus flavidus*	Mollusks
50928	Frigid Cone	*Conus frigidus*	Mollusks
50945	General Cone	*Conus generalis*	Mollusks
50961	Geography Cone	*Conus geographus*	Mollusks
50955	Acorn Cone	*Conus glans*	Mollusks
50946	Imperial Cone	*Conus imperialis*	Mollusks
50964	Ambassador Cone	*Conus legatus*	Mollusks
50938	Leopard Cone	*Conus leopardus*	Mollusks
50951	Lithography Cone	*Conus lithoglyphus*	Mollusks
50937	Lettered Cone	*Conus litteratus*	Mollusks
50929	Livid Cone	*Conus lividus*	Mollusks
50958	Luteus Cone	*Conus luteus*	Mollusks
50966	Dignified Cone	*Conus magnificus*	Mollusks
50930	Soldier Cone	*Conus miles*	Mollusks
50939	1000-Spot Cone	*Conus miliaris*	Mollusks
50935	Morelet'S Cone	*Conus moreleti*	Mollusks

50934	Muricate Cone	*Conus muriculatus*	Mollusks
50940	Music Cone	*Conus musicus*	Mollusks
50943	Weasel Cone	*Conus mustelinus*	Mollusks
50954	Obscure Cone	*Conus obscurus*	Mollusks
50959	Pertusus Cone	*Conus pertusus*	Mollusks
50921	Flea-Bite Cone	*Conus pulicarius*	Mollusks
50931	Rat Cone	*Conus rattus*	Mollusks
50967	Netted Cone	*Conus retifer*	Mollusks
50933	Blood-Stained Cone	*Conus sanguinolentus*	Mollusks
50957	Leaden Cone	*Conus scabriusculus*	Mollusks
50925	Marriage Cone	*Conus sponsalis*	Mollusks
50950	Striatellus Cone	*Conus striatellus*	Mollusks
50948	Striated Cone	*Conus striatus*	Mollusks
50956	Terebra Cone	*Conus terebra*	Mollusks
50944	Checkered Cone	*Conus tesselatus*	Mollusks
50953	Textile Cone	*Conus textile*	Mollusks
50962	Tulip Cone	*Conus tulipa*	Mollusks
50960	Varius Cone	*Conus varius*	Mollusks
50941	Flag Cone	*Conus vexillum*	Mollusks
50949	Calf Cone	*Conus vitulinus*	Mollusks
50832	Eroded Coral Shell	*Coralliophila erosa*	Mollusks
50831	Violet Coral Shell	*Coralliophila neritodidea*	Mollusks
50830	Coral Shells	*Coralliophilidae*	Mollusks
56662	Giant Oyster	*Crassostrea gigas*	Mollusks
56661	Mangrove Oyster	*Crassostrea mordax*	Mollusks
50813	Bionic Rock Shell	*Cronia biconica*	Mollusks
56624	Speciosus Scallop	*Cryptopecten speciosum*	Mollusks
55025	Cigar Pteropod	*Cuvierina columnella*	Mollusks
50770	Tritons	Cymatiidae	Mollusks
50784	Clandestine Triton	*Cymatium clandestinium*	Mollusks
50773	Jeweled Triton	*Cymatium gemmatum*	Mollusks
50776	Liver Triton	*Cymatium hepaticum*	Mollusks
50786	Wide-Lipped Triton	*Cymatium labiosum*	Mollusks
50782	Black-Spotted Triton	*Cymatium lotorium*	Mollusks
50774	Short-Neck Triton	*Cymatium muricinum*	Mollusks
50772	Nicobar Hairy Triton	*Cymatium nicobaricum*	Mollusks
50779	Common Hairy Triton	*Cymatium pileare*	Mollusks
50771	Aquatile Hairy Triton	*Cymatium pilere aquatile*	Mollusks
50783	Pear Triton	*Cymatium pyrum*	Mollusks

50775	Red Triton	*Cymatium rubeculum*	Mollusks
50785	Dwarf Hairy Triton	*Cymatium vespaceum*	Mollusks
50703	Gold-Ringer Cowry	*Cypraea annulus*	Mollusks
50726	Arabian Cowry	*Cypraea arabica*	Mollusks
50734	Eyed Cowry	*Cypraea argus*	Mollusks
50739	Golden Cowry	*Cypraea aurantium*	Mollusks
50738	Beck'S Cowry	*Cypraea beckii*	Mollusks
50733	Bistro Cowry	*Cypraea bistronatata*	Mollusks
50702	Snake'S Head Cowry	*Cypraea caputserpentis*	Mollusks
50710	Carnelian Cowry	*Cypraea carneola*	Mollusks
50740	Chinese Cowry	*Cypraea chinensis*	Mollusks
50732	Chick-Pea Cowry	*Cypraea cicercula*	Mollusks
50721	Clandestine Cowry	*Cypraea clandestina*	Mollusks
50715	Sieve Cowry	*Cypraea cribaria*	Mollusks
50713	Sowerby'S Cowry	*Cypraea cylindrica*	Mollusks
50717	Depressed Cowry	*Cypraea depressa*	Mollusks
50743	Dillwyn'S Cowry	*Cypraea dillywini*	Mollusks
50706	Eglantine Cowry	*Cypraea eglantina*	Mollusks
50708	Eroded Cowry	*Cypraea erosa*	Mollusks
50736	Globular Cowry	*Cypraea globulus*	Mollusks
50711	Honey Cowry	*Cypraea helvola*	Mollusks
50730	Swallow Cowry	*Cypraea hirundo*	Mollusks
50742	Humphrey'S Cowry	*Cypraea humphreysi*	Mollusks
50707	Isabelle Cowry	*Cypraea isabella*	Mollusks
50731	Lined-Lip Cowry	*Cypraea labrolineata*	Mollusks
50741	Limacina Cowry	*Cypraea limicina*	Mollusks
50704	Lynx Cowry	*Cypraea lynx*	Mollusks
50716	Reticulated Cowry	*Cypraea maculifera*	Mollusks
50705	Map Cowry	*Cypraea mappa*	Mollusks
50737	Marie'S Cowry	*Cypraea mariae*	Mollusks
50725	Humpback Cowry	*Cypraea mauritiana*	Mollusks
50723	Microdon Cowry	*Cypraea microdon*	Mollusks
50701	Money Cowry	*Cypraea moneta*	Mollusks
50722	Nuclear Cowry	*Cypraea nucleus*	Mollusks
50709	Porus Cowry	*Cypraea poraria*	Mollusks
50714	Punctata Cowry	*Cypraea punctata*	Mollusks
50729	Jester Cowry	*Cypraea scurra*	Mollusks
50712	Grape Cowry	*Cypraea staphlea*	Mollusks
50724	Stolid Cowry	*Cypraea stolida*	Mollusks

50720	Mole Cowry	*Cypraea talpa*	Mollusks
50728	Teres Cowry	*Cypraea teres*	Mollusks
50718	Tiger Cowry	*Cypraea tigris*	Mollusks
50727	Ventral Cowry	*Cypraea ventriculus*	Mollusks
50719	Pacific Deer Cowry	*Cypraea vitellus*	Mollusks
50735	Undulating Cowry	*Cypraea ziczac*	Mollusks
50700	Cowrys	Cypraeidae	Mollusks
55024	3-Spined Cavoline	*Diacria trispinosa*	Mollusks
50778	Anal Triton	*Distorso anus*	Mollusks
55100	Dorid Nudibranchs	Doridae	Mollusks
50823	Clatherate Drupe	*Drupa clathrata*	Mollusks
50821	Elegant Pacific Drupe	*Drupa elegans*	Mollusks
50820	Digitate Pacific Drupe	*Drupa grossularia*	Mollusks
50819	Purple Pacific Drupe	*Drupa morum*	Mollusks
50818	Prickley Pacific Drupe	*Drupa ricinus*	Mollusks
50822	Strawberry Drupe	*Drupa rubusidacaeus*	Mollusks
56622	Spectacular Scallop	*Excellichlamys spectiablis*	Mollusks
50850	Spindles	Fasciolariidae	Mollusks
56722	Pac Strawberry Cockle	*Fragum fragum*	Mollusks
56908	Tumid Venus	*Gafrarium tumidum*	Mollusks
50777	Rosy Gyre Triton	*Gyrineum roseum*	Mollusks
50780	Purple Gyre Triton	*Gyrinium pusillum*	Mollusks
50911	Little Love Harp	*Harpa amouretta*	Mollusks
50913	True Harp	*Harpa harpa*	Mollusks
50912	Major Harp	*Harpa major*	Mollusks
50910	Harp Shells	Harpidae	Mollusks
50989	Lance Auger	*Hastula lanceata*	Mollusks
50988	Pencil Auger	*Hastula penicillata*	Mollusks
55101	Spanish Dancer	*Hexabranchus sanguineus*	Mollusks
56881	Giant Clam	*Hippopus hippopus*	Mollusks
50806	Anatomical Murex	*Homalocanthia anatomica*	Mollusks
54423	Gr-Lined Paber Bubble	*Hydratina physis*	Mollusks
50875	Cone-Like Miter	*Imbricaria conularis*	Mollusks
50873	Olive-Shaped Miter	*Imbricaria olivaeformis*	Mollusks
50874	Bonelike Miter	*Imbricaria punctata*	Mollusks
56611	Saddle Tree Oyster	*Isognomon ephippium*	Mollusks
56610	Tree Oysters	*Isognomonidae*	Mollusks
54351	Janthina Snail	*Janthina janthina*	Mollusks
54350	Pelagic Snails	Janthinidae	Mollusks

50682	Chiragra Spider Conch	*Lambis chiragra*	Mollusks
50685	Ormouth Spider Conch	*Lambis crocota*	Mollusks
50681	Common Spider Conch	*Lambis lambis*	Mollusks
50684	Scorpio Conch	*Lambis scorpius scorpius*	Mollusks
50680	Spider Conch	*Lambis* sp.	Mollusks
50683	Giant Spider Conch	*Lambis truncata*	Mollusks
50851	Nobby Spindle	*Latirus nodatus*	Mollusks
50852	Spindle	*Latirus rudis*	Mollusks
56681	Fragile Lima	*Lima fragilis*	Mollusks
56682	Indo-Pac Spiny Lima	*Lima vulgaris*	Mollusks
56680	Limas	Limidae	Mollusks
56904	Camp Pitar Venus	*Lioconcha castrensis*	Mollusks
56906	Hieroglyphic Venus	*Lioconcha hieroglyphica*	Mollusks
56905	Ornate Pitar Venus	*Lioconcha ornata*	Mollusks
50642	Scabra Periwinkle	*Littorina scabra*	Mollusks
50641	Undulate Periwinkle	*Littorina undulata*	Mollusks
50640	Periwinkles	*Littorinidae*	Mollusks
56705	Lucinas	Lucinidae	Mollusks
50762	Apple Tun	*Malea pomum*	Mollusks
50811	Pinnacle Murex	*Marchia bipinnatus*	Mollusks
50809	Fenestrate Murex	*Marchia martinetana*	Mollusks
54430	Melampus Shells	Melampidae	Mollusks
54431	Yellow Melampus	*Melampus luteus*	Mollusks
57401	Flamboyant Cuttlefish	*Metasepia pfefferi*	Mollusks
54425	Mini Lined-Bubble	*Micromelo undatus*	Mollusks
54411	Ventricose Milda	*Milda ventricosa*	Mollusks
56626	Miraculous Scallop	*Mirapecten mirificus*	Mollusks
50897	Imperial Miter	*Miter imperalis*	Mollusks
50899	Acuminate Miter	*Mitra acuminata*	Mollusks
50890	Cardinal Miter	*Mitra cardinalis*	Mollusks
50893	Chrysalis Miter	*Mitra chrysalis*	Mollusks
50895	Gold-Mth Miter	*Mitra chrysostoma*	Mollusks
50889	Coffee Miter	*Mitra coffea*	Mollusks
50898	Contracted Miter	*Mitra contracta*	Mollusks
50892	Kettle Miter	*Mitra cucumaria*	Mollusks
50876	Rusty Miter	*Mitra ferruginea*	Mollusks
50891	Strawberry Miter	*Mitra fraga*	Mollusks
50888	Tesselate Miter	*Mitra incompta*	Mollusks
50872	Episcopal Miter	*Mitra mitra*	Mollusks

50883	Papal Miter	*Mitra papalis*	Mollusks
50894	Red-Painted Miter	*Mitra rubitincta*	Mollusks
50871	Pontifical Miter	*Mitra stictica*	Mollusks
50870	Miter Shells	Mitridae	Mollusks
50000	Mollusca	Mollusca	Mollusks
50801	Burnt Murex	*Murex burneus*	Mollusks
50800	Murex Shells	*Muricidae*	Mollusks
56505	Mussels	*Mytilidae*	Mollusks
50804	Tragonula Murex	*Naquetia trigonulus*	Mollusks
50803	Triquetra Murex	*Naquetia triquetra*	Mollusks
50817	Francolina Jopas	*Nassa francolina*	Mollusks
50855	Nassa Mud Snails	Nassariidae	Mollusks
50858	Granulated Nassa	*Nassarius graniferus*	Mollusks
50857	Margarite Nassa	*Nassarius margaritiferus*	Mollusks
50856	Pimpled Basket	*Nassarius papillosus*	Mollusks
50755	Moon Shells	Naticidae	Mollusks
57300	Nautilus	Nautilidae	Mollusks
57301	Chambered Nautilus	*Nautilus ponpilius*	Mollusks
50884	Clathrus Miter	*Neocancilla clathrus*	Mollusks
50896	Flecked Miter	*Neocancilla granitina*	Mollusks
50901	Butterfly Miter	*Neocancilla papilio*	Mollusks
50633	Ox-Palate Nerite	*Nerita albicilla*	Mollusks
50631	Plicate Nerite	*Nerita plicata*	Mollusks
50632	Polished Nerite	*Nerita polita*	Mollusks
50634	Reticulate Nerite	*Nerita signata*	Mollusks
50630	Nerites	Neritidae	Mollusks
50600	Diotocardia	O Archaeogastropoda	Mollusks
57700	Octopus	Octopodidae	Mollusks
57735	Common Octopus	*Octopus cyanea*	Mollusks
57734	Red Octopus	*Octopus luteus*	Mollusks
57736	Ornate Octopus	*Octopus ornatus*	Mollusks
57730	Octopus	*Octopus* sp.	Mollusks
57732	Pelagic Octopus	*Octopus* sp.	Mollusks
57733	Long-Armed Octopus	*Octopus* sp.	Mollusks
57731	Elongate Octopus	*Octopus teuthoides*	Mollusks
50861	Amethyst Olive	*Oliva annulata*	Mollusks
50863	Carnelian Olive	*Oliva carneola*	Mollusks
50862	Red-Mth Olive	*Oliva miniacea*	Mollusks
50864	Peg Olive	*Oliva paxillus*	Mollusks

50860	Olive Shells	Olividae	Mollusks
57500	Squids	*Order Teuthoidea*	Mollusks
56660	True Oysters	Ostreidae	Mollusks
54412	Cat'S Ear Otopleura	*Otopleura auriscati*	Mollusks
50753	Common Egg Cowry	*Ovula ovum*	Mollusks
50750	Egg Shells	Ovulidae	Mollusks
56620	Scallops	Pectinidae	Mollusks
56902	Crispate Venus	*Periglypta crispata*	Mollusks
56903	Youthful Venus	*Periglypta puerpera*	Mollusks
56901	Reticulate Venus	*Periglypta reticulata*	Mollusks
56601	Pearl Oyster	*Pinctada margaritfera*	Mollusks
56531	Bicolor Pen Shell	*Pinna bicolor*	Mollusks
56530	Pen Shells	Pinnidae	Mollusks
50756	Breast-Shaped Moon	*Polinices mamatus*	Mollusks
50757	Pear-Shaped Moon	*Polinices tumidus*	Mollusks
50844	Strawberry Goblet	*Pollia fragaria*	Mollusks
50843	Beautiful Goblet	*Pollia pulchra*	Mollusks
50752	Fruit Ovula	*Prionovula fruticum*	Mollusks
56600	Pearl Oysters	Pteriidae	Mollusks
50904	Crenulate Miter	*Pterygia crenulata*	Mollusks
50907	Fenestrate Miter	*Pterygia fenestrata*	Mollusks
50905	Nut Miter	*Pterygia nucea*	Mollusks
50902	Rough Miter	*Pterygia scabricula*	Mollusks
50810	Club Murex	*Pterynotus elongatus*	Mollusks
50807	Fluted Murex	*Pterynotus laqueatus*	Mollusks
50808	3-Winged Murex	*Pterynotus tripterus*	Mollusks
54413	Solid Pupa	*Pupa solidula*	Mollusks
50816	Perssian Purpura	*Purpura persica*	Mollusks
54401	Sulcate Pyram	*Pyramidella sulcata*	Mollusks
54400	Pyram Shells	Pyramidellidae	Mollusks
50833	Quoy'S Coral Shell	*Quoyula madreporarum*	Mollusks
50834	Rapa Snail	*Rapa rapa*	Mollusks
50653	Rough Vertigus	*Rhinoclavis aspera*	Mollusks
50655	Obelisk Vertigus	*Rhinoclavis sinensis*	Mollusks
50900	Chaste Miter	*Sabricola casta*	Mollusks
56625	Tiger Scallop	*Semipallium tigris*	Mollusks
57403	Broadclub Cuttlefish	*Sepia latimanus*	Mollusks
57402	Cuttlefish	*Sepia* sp.	Mollusks
57594	Bigfin Reef Squid	*Sepioteuthis lessoniana*	Mollusks

56511	Box Mussel	*Septifer bilocularis*	Mollusks
50805	Lacy Murex	*Siratus laciniatus*	Mollusks
56670	Thorny Oysters	Spondylidae	Mollusks
56671	Ducal Thorny Oyster	*Spondyulus squamosus*	Mollusks
56532	Baggy Pen Shell	*Streptopinna saccata*	Mollusks
50660	True Conchs	Strombidae	Mollusks
50665	Samar Conch	*Strombus dentatus*	Mollusks
50666	Fragile Conch	*Strombus fragilis*	Mollusks
50663	Gibbose Conch	*Strombus gibberulus*	Mollusks
50669	Lavender-Mouth Conch	*Strombus haemastoma*	Mollusks
50667	Silver-Lip Conch	*Strombus lentigninosus*	Mollusks
50662	Red-Lip Conch	*Strombus luhuanus*	Mollusks
50664	Micro Conch	*Strombus microurceus*	Mollusks
50661	Mutable Conch	*Strombus mutabilis*	Mollusks
50672	Pretty Conch	*Strombus plicatus*	Mollusks
50670	Laciniate Conch	*Strombus sinuatus*	Mollusks
50671	Bull Conch	*Strombus taurus*	Mollusks
50612	Pyramid Top	*Tectus pyramis*	Mollusks
56894	Box-Like Tellin	*Tellina capsoides*	Mollusks
56892	Cat'S Tongue Tellin	*Tellina linguafelis*	Mollusks
56895	Remie'S Tellin	*Tellina remies*	Mollusks
56893	Rasp Tellin	*Tellina scobinata*	Mollusks
56890	Tellin Clams	*Tellinidae*	Mollusks
50668	Terebellum Conch	*Terebellum terebellum*	Mollusks
50985	Similar Auger	*Terebra affinis*	Mollusks
50997	Fly-Spotted Auger	*Terebra areolata*	Mollusks
50996	Eyed Auger	*Terebra argus*	Mollusks
50987	Babylonian Auger	*Terebra babylonia*	Mollusks
50990	Certhlike Auger	*Terebra cerithiana*	Mollusks
50995	Short Auger	*Terebra chlorata*	Mollusks
50984	Crenulated Auger	*Terebra crenulata*	Mollusks
50982	Dimidiate Auger	*Terebra dimidiata*	Mollusks
50994	Tiger Auger	*Terebra felina*	Mollusks
50991	Funnel Auger	*Terebra funiculata*	Mollusks
50993	Spotted Auger	*Terebra gutatta*	Mollusks
50981	Marlinspike Auger	*Terebra maculata*	Mollusks
50986	Cloud Auger	*Terebra nubulosa*	Mollusks
50983	Subulate Auger	*Terebra subulata*	Mollusks
50992	Undulate Auger	*Terebra undulata*	Mollusks

50980	Auger Shells	Terebridae	Mollusks
50815	Belligerent Rock Shell	*Thais armigera*	Mollusks
50814	Tuberose Rock Shell	*Thais tuberosa*	Mollusks
50761	Partridge Tun	*Tonna perdix*	Mollusks
50760	Tun Shells	Tonnidae	Mollusks
56723	Angulate Cockle	*Trachycardium angulatum*	Mollusks
56882	Giant Clam	*Tridacna crocea*	Mollusks
56883	Lagoon Giant Clam	*Tridacna derasa*	Mollusks
56884	Giant Clam	*Tridacna gigas*	Mollusks
56885	Common Giant Clam	*Tridacna maxima*	Mollusks
56886	Fluted Giant Clam	*Tridacna squamosa*	Mollusks
56880	Giant Clams	Tridacnidae	Mollusks
50610	Top Shells	Trochidae	Mollusks
50611	Top Shell	*Trochus niloticus*	Mollusks
50613	Radiate Top	*Trochus radiatus*	Mollusks
50865	Vases	Turbinellidae	Mollusks
50620	Turban Shell	Turbinidae	Mollusks
50622	Silver-Mouth Turbin	*Turbo argyrostoma*	Mollusks
50623	Tapestry Turbin	*Turbo petholatus*	Mollusks
50621	Rough Turbin	*Turbo setosus*	Mollusks
50867	Ceramic Vase	*Vasum ceramicum*	Mollusks
50866	Common Pacific Vase	*Vasum turbinellus*	Mollusks
56900	Venus Shells	Veneridae	Mollusks
50887	Bernhard'S Miter	*Vexillum bernhardiana*	Mollusks
50882	Cancellaria Miter	*Vexillum cancellarioides*	Mollusks
50880	Saffron Miter	*Vexillum crocatum*	Mollusks
50879	Roughened Miter	*Vexillum exasperatum*	Mollusks
50885	Patriarchal Miter	*Vexillum patriarchalis*	Mollusks
50881	Half-Banded Miter	*Vexillum semifasciatum*	Mollusks
50903	Specious Miter	*Vexillum speciosum*	Mollusks
50886	Bumpy Miter	*Vexillum tuberosum*	Mollusks
50906	Turbin Miter	*Vexillum turbin*	Mollusks
50877	Decorated Miter	*Vexillum unifasciatum*	Mollusks
50802	Spotted Vitularia	*Vitularia miliaris*	Mollusks
41316	Manahak (Forktail Rabbitfish)	*Manahak lesso'*	Siganidae
41318	Manahak	*Manahak* sp.	Siganidae
41300	Rabbitfish	Siganidae	Siganidae
41301	Fork-Tail Rabbitfish	*Siganus argenteus*	Siganidae
41307	Seagrass Rabbitfish	*Siganus canaliculatus*	Siganidae

41308	Coral Rabbitfish	*Siganus corallinus*	Siganidae
41302	Pencil-Streaked Rabbitfish	*Siganus doliatus*	Siganidae
41303	Fuscescens Rabbitfish	*Siganus fuscescens*	Siganidae
41309	Golden Rabbitfish	*Siganus guttatus*	Siganidae
41311	Lined Rabbitfish	*Siganus lineatus*	Siganidae
41313	White-Spotted Rabbitfish	*Siganus oramin*	Siganidae
41310	Masked Rabbitfish	*Siganus puellus*	Siganidae
41314	Peppered Rabbitfish	*Siganus punctatissimus*	Siganidae
41304	Gold-Spotted Rabbitfish	*Siganus punctatus*	Siganidae
41315	Randal'S Rabbitfish	*Siganus randalli*	Siganidae
41305	Scribbled Rabbitfish	*Siganus spinus*	Siganidae
41306	Vermiculated Rabbitfish	*Siganus vermiculatus*	Siganidae
41312	Rabbitfish	*Siganus vulpinus*	Siganidae
32301	Silvermouth/Jobfish	*Aphareus furca*	Lutjanidae
32300	Snappers	Lutjanidae	Lutjanidae
32306	River Snapper	*Lutjanus argentimaculatus*	Lutjanidae
32325	Two-Spot Snapper	*Lutjanus biguttatus*	Lutjanidae
32307	Red Snapper	*Lutjanus bohar*	Lutjanidae
32334	Snapper	*Lutjanus boutton*	Lutjanidae
32326	Checkered Snapper	*Lutjanus decussatus*	Lutjanidae
32327	Blackspot Snapper	*Lutjanus ehrenbergi*	Lutjanidae
32335	Snapper	*Lutjanus fulviflamma*	Lutjanidae
32308	Flametail Snapper	*Lutjanus fulvus*	Lutjanidae
32309	Humpback Snapper	*Lutjanus gibbus*	Lutjanidae
32328	Malabar Snapper	*Lutjanus malabaricus*	Lutjanidae
32312	Onespot Snapper	*Lutjanus monostigma*	Lutjanidae
32311	Scribbled Snapper	*Lutjanus rivulatus*	Lutjanidae
32333	Snapper	*Lutjanus sebae*	Lutjanidae
32329	1/2-Barred Snapper	*Lutjanus semicinctus*	Lutjanidae
32330	One-Lined Snapper	*Lutjanus vitta*	Lutjanidae
32332	Bl And Wh Snapper	*Macolor macularis*	Lutjanidae
32313	Black Snapper	*Macolor niger*	Lutjanidae
32314	Fusilier	*Paracaesio sordidus*	Lutjanidae
32315	Yellowtail Fusilier	*Paracaesio xanthurus*	Lutjanidae
32322	Deepwater Snapper	*Randallichthys filamentosus*	Lutjanidae
49130	Shallow Snappers	Shallow Snappers	Lutjanidae
32331	Sailfin Snapper	*Symphorichthys spilurus*	Lutjanidae
28901	Red-Flushed Grouper	*Aethaloperca rogaa*	Serranidae
28956	Grouper	*Anyperodon leucogrammicus*	Serranidae

28908	Orange Grouper	*Cephalopholis analis*	Serranidae
28907	Peacock Grouper	*Cephalopholis argus*	Serranidae
28911	Brownbarred Grouper	*Cephalopholis boenack*	Serranidae
28909	Ybanded Grouper	*Cephalopholis igarashiensis*	Serranidae
28910	Leopard Grouper	*Cephalopholis leopardus*	Serranidae
28945	Coral Grouper	*Cephalopholis miniata*	Serranidae
28929	Harlequin Grouper	*Cephalopholis polleni*	Serranidae
28913	6-Banded Grouper	*Cephalopholis sexmaculata*	Serranidae
28912	Tomato Grouper	*Cephalopholis sonnerati*	Serranidae
28903	Grouper	*Cephalopholis sp*	Serranidae
28906	Pygmy Grouper	*Cephalopholis spiloparaea*	Serranidae
28914	Flag-Tailed Grouper	*Cephalopholis urodeta*	Serranidae
28915	Grouper	*Cromileptes altivelis*	Serranidae
28947	Orange Grouper	*Epinephelus caeruleopunctatus*	Serranidae
28948	Brown-Spotted Grouper	*Epinephelus chlorostigma*	Serranidae
28960	Orange Spot Grouper	*Epinephelus coioides*	Serranidae
28957	Grouper	*Epinephelus corallicola*	Serranidae
28946	Grouper	*Epinephelus cyanopodus*	Serranidae
28920	Blotchy Grouper	*Epinephelus fuscoguttatus*	Serranidae
28921	Hexagon Grouper	*Epinephelus hexagonatus*	Serranidae
28918	Grouper	*Epinephelus howlandi*	Serranidae
28922	Giant Grouper	*Epinephelus lanceolatus*	Serranidae
28958	Grouper	*Epinephelus macrospilos*	Serranidae
28923	Highfin Grouper	*Epinephelus maculatus*	Serranidae
28950	Malabar Grouper	*Epinephelus malabaricus*	Serranidae
28949	Bl-Spot Honeycomb Grouper	*Epinephelus melanostigma*	Serranidae
28925	Honeycomb Grouper	*Epinephelus merra*	Serranidae
28942	Grouper	*Epinephelus miliaris*	Serranidae
28916	Grouper	*Epinephelus morrhua*	Serranidae
28951	Wavy-Lined Grouper	*Epinephelus ongus*	Serranidae
28926	Marbled Grouper	*Epinephelus polyphekadion*	Serranidae
28953	Grouper	*Epinephelus retouti*	Serranidae
28930	7-Banded Grouper	*Epinephelus septemfasciatus*	Serranidae
28924	Tidepool Grouper	*Epinephelus socialis*	Serranidae
28952	4-Saddle Grouper	*Epinephelus spilotoceps*	Serranidae
28928	Greasy Grouper	*Epinephelus tauvina*	Serranidae
28902	Truncated Grouper	*Epinephelus truncatus*	Serranidae

28943	Wh-Margined Grouper	*Gracila albomarginata*	Serranidae
28938	Squaretail Grouper	*Plectropomus areolatus*	Serranidae
28937	Saddleback Grouper	*Plectropomus laevis*	Serranidae
28954	Leopard Coral Trout	*Plectropomus leopardus*	Serranidae
28955	Blue-Lined Coral Trout	*Plectropomus oligacanthus*	Serranidae
28940	Powell'S Grouper	*Saloptia powelli*	Serranidae
28900	Sea Basses,Groupers	Serranidae	Serranidae
28944	Whmargin Lyretail Grouper	*Variola albimarginata*	Serranidae
35902	Fringelip Mullet	*Crenimugil crenilabis*	Mugilidae
35903	Yellowtail Mullet	*Ellochelon vaigiensis*	Mugilidae
35901	Engel'S Mullet	*Moolgarda engeli*	Mugilidae
35906	Bluespot Mullet	*Moolgarda seheli*	Mugilidae
35904	Gray Mullet	*Mugil cephalus*	Mugilidae
35900	Mullets	Mugilidae	Mugilidae
35905	Acute-Jawed Mullet	*Neomyxus leuciscus*	Mugilidae
33900	Rudderfish	Kyphosidae	Kyphosidae
33901	Highfin Rudderfish	*Kyphosus cinerascens*	Kyphosidae
33902	Lowfin Rudderfish	*Kyphosus vaigiensis*	Kyphosidae
33903	Insular Rudderfish	*Kyphosus bigibbus*	Kyphosidae
69251	Spider Crab	*Achaeus japonicus*	CRE-Crustaceans
67500	Snapping Shrimp	Alphaeidae	CRE-Crustaceans
67501	Snapping Shrimp	*Alpheus bellulus*	CRE-Crustaceans
67502	Snapping Shrimp	*Alpheus paracrinitus*	CRE-Crustaceans
64999	Anchylomerids	*Anchylomeridae*	CRE-Crustaceans
67951	Slipper Lobster	*Arctides regalis*	CRE-Crustaceans
60101	Acorn Barnacle	*Balanus* sp	CRE-Crustaceans
62050	Mantis Shrimp	*Bathysquillidae*	CRE-Crustaceans
69201	Box Crab	*Calappa bicornis*	CRE-Crustaceans
69202	Box Crab	*Calappa calappa*	CRE-Crustaceans
69203	Box Crab	*Calappa hepatica*	CRE-Crustaceans
69200	Box Crabs	Calappidae	CRE-Crustaceans
69252	Decorator Crab	*Camposcia retusa*	CRE-Crustaceans
69350	Cancrids	Cancridae	CRE-Crustaceans
69501	7-11 Crab	*Carpilius convexus*	CRE-Crustaceans
69502	7-11 Crab	*Carpilius maculatus*	CRE-Crustaceans
69401	Red-Legged Sw Crab	*Charybdis erythrodactyla*	CRE-Crustaceans
69402	Red Sw Crab	*Charybdis hawaiiensis*	CRE-Crustaceans
69204	Box Crab	*Cycloes granulosa*	CRE-Crustaceans
69301	Elbow Crab	*Daldorfia horrida*	CRE-Crustaceans

68202	Marine Hermit Crab	*Dardanus gemmatus*	CRE-Crustaceans
68204	Marine Hermit Crab	*Dardanus megistos*	CRE-Crustaceans
68203	Marine Hermit Crab	*Dardanus pendunculatus*	CRE-Crustaceans
68201	Marine Hermit Crab	*Dardanus* sp	CRE-Crustaceans
67121	Commensal Shrimp	*Dasycaris zanzibarica*	CRE-Crustaceans
67000	Decapod Crustaceans	Decapoda	CRE-Crustaceans
68200	Marine Hermit Crabs	Diogenidae	CRE-Crustaceans
69161	Dorippid Crab	*Dorippe frascone*	CRE-Crustaceans
69171	Sponge Crab	*Dromia dormia*	CRE-Crustaceans
69170	Sponge Crabs	Dromiidae	CRE-Crustaceans
68701	Mole Crab	*Emerita pacifica*	CRE-Crustaceans
67851	Soft Lobster	*Enoplometopus debelius*	CRE-Crustaceans
67852	Hairy Lobster	*Enoplometopus occidentalis*	CRE-Crustaceans
69553	Redeye Crab	*Eriphia sebana*	CRE-Crustaceans
69554	Red-Reef Crab	*Etisus dentatus*	CRE-Crustaceans
69551	Red-Reef Crab	*Etisus splendidus*	CRE-Crustaceans
69555	Brown-Reef Crab	*Etisus utilis*	CRE-Crustaceans
62100	Mantis Shrimp	*Eurysquillidae*	CRE-Crustaceans
68500	Squat Lobsters	*Galatheidae*	CRE-Crustaceans
69850	Gecarcinids	*Gecarcinidae*	CRE-Crustaceans
67220	Bbee And Harlequin Shrimp	*Gnathophyllidae*	CRE-Crustaceans
67221	Bumblebee Shrimp	*Gnathophylloides mineri*	CRE-Crustaceans
67222	Bumblebee Shrimp	*Gnathophyllum americanum*	CRE-Crustaceans
62203	Mantis Shrimp	*Gonodactylaceus mutatus*	CRE-Crustaceans
62201	Mantis Shrimp	*Gonodactylellus affinis*	CRE-Crustaceans
62200	Mantis Shrimp	*Gonodactylidae*	CRE-Crustaceans
62202	Mantis Shrimp	*Gonodactylus chiragra*	CRE-Crustaceans
62204	Mantis Shrimp	*Gonodactylus platysoma*	CRE-Crustaceans
62205	Mantis Shrimp	*Gonodactylus smithii*	CRE-Crustaceans
69860	Shore Crabs	*Grapsidae*	CRE-Crustaceans
69861	Shore Crab	*Grapsus albolineatus*	CRE-Crustaceans
69862	Shore Crab	*Grapsus grapsus tenuicrustat*	CRE-Crustaceans
69950	Hapalocarcinids	*Hapalocarcinidae*	CRE-Crustaceans
62550	Mantis Shrimp	*Harposquillidae*	CRE-Crustaceans
62300	Mantis Shrimp	*Hemisquillidae*	CRE-Crustaceans
67104	Deepwater Shrimps	*Heteropenaeus sp*	CRE-Crustaceans
67210	Hump-Backed Shrimp	*Hippolytidae*	CRE-Crustaceans
69100	Homolids	*Homolidae*	CRE-Crustaceans

67853	Soft Lobster	*Hoplometopus holthuisi*	CRE-Crustaceans
67223	Harlequin Shrimp	*Hymenocera picta*	CRE-Crustaceans
64810	Hyperid Amphipods	*Hyperiidae*	CRE-Crustaceans
67921	Slipper Lobster	*Ibacus sp*	CRE-Crustaceans
69000	True Crabs	*Io Brachyura*	CRE-Crustaceans
67931	Long-Handed Lobster	*Justitia longimanus*	CRE-Crustaceans
67211	Hump-Backed Shrimp	*Koror misticius*	CRE-Crustaceans
69302	Elbow Crab	*Lambrus longispinis*	CRE-Crustaceans
67111	Palaemonid Shrimp	*Leander plumosus*	CRE-Crustaceans
68300	Lithodids	*Lithodidae*	CRE-Crustaceans
69421	Swimming Crab	*Lupocyclus grimquedentatus*	CRE-Crustaceans
64830	Lycaeids	*Lycaeidae*	CRE-Crustaceans
69151	3-Toothed Frog Crab	*Lyreidus tridentatus*	CRE-Crustaceans
62800	Mantis Shrimp	*Lysiosquillidae*	CRE-Crustaceans
60100	Barnacles	*Lythoglyptidae*	CRE-Crustaceans
69901	Telescope-Eye Crab	*Macrophthalmus telescopicus*	CRE-Crustaceans
69250	Spider Crabs	*Majidae*	CRE-Crustaceans
67101	Penaeid Prawn	*Metapenaeopsis* sp.1	CRE-Crustaceans
67102	Penaeid Prawn	*Metapenaeopsis* sp.2	CRE-Crustaceans
67103	Penaeid Prawn	*Metapenaeopsis* sp.3	CRE-Crustaceans
69205	Box Crab	*Mursia spinimanus*	CRE-Crustaceans
62900	Mantis Shrimp	*Nannosquillidae*	CRE-Crustaceans
67850	Soft Lobsters	*Nephropidae*	CRE-Crustaceans
69902	Large Ghost Crab	*Ocypode ceratopthalma*	CRE-Crustaceans
69903	Ghost Crab	*Ocypode cordimana*	CRE-Crustaceans
69904	Ghost Crab	*Ocypode saratum*	CRE-Crustaceans
69900	Ocypodids	*Ocypodidae*	CRE-Crustaceans
62350	Mantis Shrimp	*Odontodactylidae*	CRE-Crustaceans
62351	Mantis Shrimp	*Odontodactylus brevirostris*	CRE-Crustaceans
62352	Mantis Shrimp	*Odontodactylus scyallarus*	CRE-Crustaceans
62701	Mantis Shrimp	*Oratosquilla oratoria*	CRE-Crustaceans
62700	Mantis Shrimp	*Oratosquillidae*	CRE-Crustaceans
68400	Soldier Hermit Crab	*Paguridae*	CRE-Crustaceans
68401	Coral Hermit Crab	*Paguritta gracilipes*	CRE-Crustaceans
68402	Coral Hermit Crab	*Paguritta harmsi*	CRE-Crustaceans
67110	Palaemonid Shrimp	*Palaemonidae*	CRE-Crustaceans
67917	Mole Lobster	*Palinurellus wieneckii*	CRE-Crustaceans
67918	Painted Crayfish	*Panulirus albiflagellum*	CRE-Crustaceans

67911	Painted Crayfish	*Panulirus homarus*	CRE-Crustaceans
67912	Painted Crayfish	*Panulirus longipes*	CRE-Crustaceans
67914	Painted Crayfish	*Panulirus ornatus*	CRE-Crustaceans
67910	Painted Crayfish	*Panulirus sp*	CRE-Crustaceans
67916	Painted Crayfish	*Panulirus versicolor*	CRE-Crustaceans
69300	Elbow Crabs	*Parthenopidae*	CRE-Crustaceans
67100	Panaeid Prawns	*Penaeidae*	CRE-Crustaceans
67106	Penaeid Prawn	*Penaeus latisulcatus*	CRE-Crustaceans
67105	Penaeid Prawn	*Penaeus monodon*	CRE-Crustaceans
69864	Flat Rock Crab	*Percnon planissimum*	CRE-Crustaceans
67122	Commensal Shrimp	*Periclimenes amboinensis*	CRE-Crustaceans
67123	Commensal Shrimp	*Periclimenes brevicarpalis*	CRE-Crustaceans
67124	Commensal Shrimp	*Periclimenes cf ceratophthalmus*	CRE-Crustaceans
67125	Commensal Shrimp	*Periclimenes holthuisi*	CRE-Crustaceans
67126	Commensal Shrimp	*Periclimenes imperator*	CRE-Crustaceans
67127	Commensal Shrimp	*Periclimenes inornatus*	CRE-Crustaceans
67128	Commensal Shrimp	*Periclimenes kororensis*	CRE-Crustaceans
67129	Commensal Shrimp	*Periclimenes ornatus*	CRE-Crustaceans
67130	Commensal Shrimp	*Periclimenes psamathe*	CRE-Crustaceans
67131	Commensal Shrimp	*Periclimenes soror*	CRE-Crustaceans
67132	Commensal Shrimp	*Periclimenes tenuipes*	CRE-Crustaceans
67133	Commensal Shrimp	*Periclimenes venustus*	CRE-Crustaceans
68601	Porcelain Crab	*Petrolisthes lamarkii*	CRE-Crustaceans
64820	Phronimids	*Phronimidae*	CRE-Crustaceans
69863	Shore Crab	*Plagusia depressa tuberculata*	CRE-Crustaceans
64840	Platyscelids	*Platyscelidae*	CRE-Crustaceans
67134	Commensal Shrimp	*Pliopotonia furtiva*	CRE-Crustaceans
69461	Long-Eyed Swimming Crab	*Podophthalmus vigil*	CRE-Crustaceans
67135	Commensal Shrimp	*Pontonides uncigar*	CRE-Crustaceans
67120	Commensal Shrimp	*Pontoniidae*	CRE-Crustaceans
68600	Porcellanid Crabs	*Porcellanidae*	CRE-Crustaceans
69400	Swimming Crabs	*Portunidae*	CRE-Crustaceans
69432	Blue Swimming Crab	*Portunus pelagicus*	CRE-Crustaceans
69431	Swimming Crab	*Portunus sanguinolentus*	CRE-Crustaceans
62400	Mantis Shrimp	*Protosquillidae*	CRE-Crustaceans
62501	Mantis Shrimp	*Pseudosquilla ciliata*	CRE-Crustaceans
62500	Mantis Shrimp	*Pseudosquillidae*	CRE-Crustaceans
67231	Hingebeak Prawn	*Rhinchocinetes hiatti*	CRE-Crustaceans

67230	Hinge-Beaked Prawns	*Rhynchocinetidae*	CRE-Crustaceans
69471	Mangrove Crab	*Scylla serrata*	CRE-Crustaceans
67604	Solenocerids	*Solenoceridae*	CRE-Crustaceans
62600	Mantis Shrimp	*Squillidae*	CRE-Crustaceans
67136	Commensal Shrimp	*Stegopontonia commensalis*	CRE-Crustaceans
67200	Cleaner Shrimp	*Stenopodidae*	CRE-Crustaceans
67201	Banded Coral Shrimp	*Stenopus hispidus*	CRE-Crustaceans
62000	Mantis Shrimps	*Stomatopoda*	CRE-Crustaceans
67503	Snapping Shrimp	*Synalpheus carinatus*	CRE-Crustaceans
60102	Acorn Barnacle	*Tetraclitella divisa*	CRE-Crustaceans
69481	Swimming Crab	*Thalamita crenata*	CRE-Crustaceans
67212	Ambonian Shrimp	*Thor amboinensis*	CRE-Crustaceans
69598	Xanthid Crab	*Unid Megalops*	CRE-Crustaceans
69499	Portunid Crab	*Unid* sp.1	CRE-Crustaceans
69599	Xanthid Crab	*Unid* sp.1	CRE-Crustaceans
69498	Portunid Crab	*Unid* sp.2	CRE-Crustaceans
69597	Xanthid Crab	*Unid* sp.2	CRE-Crustaceans
67112	Palaemonid Shrimp	*Urocaridella antonbruunii*	CRE-Crustaceans
69500	Dark-Finger Coral Crabs	*Xanthidae*	CRE-Crustaceans
69870	Urchin Crab	*Zebrida adamsii*	CRE-Crustaceans
69552	Shallow Reef Crab	*Zosymus aeneus*	CRE-Crustaceans
24300	Squirrel,Soldierfishes	*Holocentridae*	Holocentridae
24398	Squirrelfishes	*Holocentrinae*	Holocentridae
24399	Soldierfishes	*Myripristinae*	Holocentridae
24313	Bronze Soldierfish	*Myripristis adusta*	Holocentridae
24314	Brick Soilderfish	*Myripristis amaena*	Holocentridae
24331	Doubletooth Soldierfish	*Myripristis amaena*	Holocentridae
24315	Bigscale Soldierfish	*Myripristis berndti*	Holocentridae
24324	Yellowfin Soldierfish	*Myripristis chryseres*	Holocentridae
24317	Pearly Soldierfish	*Myripristis kuntee*	Holocentridae
24318	Red Soldierfish	*Myripristis murdjan*	Holocentridae
24322	Scarlet Soldierfish	*Myripristis pralinia*	Holocentridae
24319	Violet Soldierfish	*Myripristis violacea*	Holocentridae
24320	White-Tipped Soldierfish	*Myripristis vittata*	Holocentridae
24326	White-Spot Soldierfish	*Myripristis woodsi*	Holocentridae
24309	Clearfin Squirrelfish	*Neoniphon argenteus*	Holocentridae
24312	Yellowstriped Squirrelfish	*Neoniphon aurolineatus*	Holocentridae
24310	Blackfin Squirrlefish	*Neoniphon opercularis*	Holocentridae
24311	Bloodspot Squirrelfish	*Neoniphon sammara*	Holocentridae

24340	Deepwater Soldierfish	*Ostichthys brachygnathus*	Holocentridae
24323	Deepwater Soldierfish	*Ostichthys kaianus*	Holocentridae
24321	Cardinal Squirrelfish	*Plectrypops lima*	Holocentridae
24301	Tailspot Squirrelfish	*Sargocentron caudimaculatum*	Holocentridae
24332	3-Spot Squirrelfish	*Sargocentron cornutum*	Holocentridae
24302	Crown Squirrelfish	*Sargocentron diadema*	Holocentridae
24330	Spotfin Squirrelfish	*Sargocentron dorsomaculatum*	Holocentridae
24334	Furcate Squirrelfish	*Sargocentron furcatum*	Holocentridae
24327	Samurai Squirrelfish	*Sargocentron ittodai*	Holocentridae
24333	Squirrelfish	*Sargocentron lepros*	Holocentridae
24328	Blackspot Squirrelfish	*Sargocentron melanospilos*	Holocentridae
24304	Finelined Squirrelfish	*Sargocentron microstoma*	Holocentridae
24305	Dark-Striped Squirrelfish	*Sargocentron praslin*	Holocentridae
24303	Speckled Squirrelfish	*Sargocentron punctatissimum*	Holocentridae
24306	Long-Jawed Squirrelfish	*Sargocentron spiniferum*	Holocentridae
24307	Blue-Lined Squirrelfish	*Sargocentron tiere*	Holocentridae
24308	Pink Squirrelfish	*Sargocentron tieroides*	Holocentridae
24329	Violet Squirrelfish	*Sargocentron violaceum*	Holocentridae
92102	Algae	*Enteromorpha clathrata*	Algae
92200	Algae	*Caulerpaceae*	Algae
92217	Algae	*Caulerpa racemosa*	Algae
93602	Algae	*Sargassum polycystum*	Algae
93604	Algae	*Turbinaria ornata*	Algae
95000	Algae	*Div Anthophyta*	Algae
95003	Algae	*Halodule uninervis*	Algae
36201	Chiseltooth Wrasse	*Anampses caeruleopunctatus*	Labridae
36297	Geographic Wrasse	*Anampses geographicus*	Labridae
36268	Wrasse	*Anampses melanurus*	Labridae
36202	Yellowtail Wrasse	*Anampses meleagrides*	Labridae
36203	Yellowbreasted Wrasse	*Anampses twisti*	Labridae
36205	Lyretail Hogfish	*Bodianus anthioides*	Labridae
36206	Axilspot Hogfish	*Bodianus axillaris*	Labridae
36288	2-Spot Slender Hogfish	*Bodianus bimaculatus*	Labridae
36269	Diana'S Hogfish	*Bodianus diana*	Labridae
36270	Blackfin Hogfish	*Bodianus loxozonus*	Labridae
36271	Mesothorax Hogfish	*Bodianus mesothorax*	Labridae

36243	Hogfish	*Bodianus tanyokidus*	Labridae
36209	Floral Wrasse	*Cheilinus chlorourus*	Labridae
36210	Red-Breasted Wrasse	*Cheilinus fasciatus*	Labridae
36211	Snooty Wrasse	*Cheilinus oxycephalus*	Labridae
36213	Tripletail Wrasse	*Cheilinus trilobatus*	Labridae
36216	Cigar Wrasse	*Cheilio inermis*	Labridae
36217	Yel-Cheeked Tuskfish	*Choerodon anchorago*	Labridae
36313	Harlequin Tuskfish	*Choerodon fasciatus*	Labridae
36305	Wrasse	*Cirrhilabrus balteatus*	Labridae
36272	Wrasse	*Cirrhilabrus cyanopleura*	Labridae
36273	Exquisite Wrasse	*Cirrhilabrus exquisitus*	Labridae
36306	Johnson'S Wrasse	*Cirrhilabrus johnsoni*	Labridae
36218	Wrasse	*Cirrhilabrus katherinae*	Labridae
36274	Yellowband Wrasse	*Cirrhilabrus luteovittatus*	Labridae
36307	Rhomboid Wrasse	*Cirrhilabrus rhomboidalis*	Labridae
36309	Red-Margined Wrasse	*Cirrhilabrus rubrimarginatus*	Labridae
36219	Clown Coris	*Coris aygula*	Labridae
36275	Dapple Coris	*Coris batuensis*	Labridae
36314	Pale-Barred Coris	*Coris dorsomacula*	Labridae
36220	Yellowtailed Coris	*Coris gaimardi*	Labridae
36221	Knife Razorfish	*Cymolutes praetextatus*	Labridae
36291	Finescale Razorfish	*Cymolutes torquatus*	Labridae
36300	Wandering Cleaner Wrasse	*Diproctacanthus xanthurus*	Labridae
36222	Sling-Jawed Wrasse	*Epibulus insidiator*	Labridae
36276	Sling-Jawed Wrasse	*Epibulus n sp*	Labridae
36223	Bird Wrasse	*Gomphosus varius*	Labridae
36224	2-Spotted Wrasse	*Halichoeres biocellatus*	Labridae
36277	Drab Wrasse	*Halichoeres chloropterus*	Labridae
36278	Canary Wrasse	*Halichoeres chrysus*	Labridae
36318	Wrasse	*Halichoeres dussumieri*	Labridae
36226	Checkerboard Wrasse	*Halichoeres hortulanus*	Labridae
36227	Weedy Surge Wrasse	*Halichoeres margaritaceus*	Labridae
36228	Dusky Wrasse	*Halichoeres marginatus*	Labridae
36279	Pinstriped Wrasse	*Halichoeres melanurus*	Labridae
36229	Black-Ear Wrasse	*Halichoeres melasmapomus*	Labridae
36311	Ornate Wrasse	*Halichoeres ornatissimus*	Labridae
36315	Seagrass Wrasse	*Halichoeres papilionaceus*	Labridae
36298	Wrasse	*Halichoeres prosopeion*	Labridae
36304	Wrasse	*Halichoeres purpurascens*	Labridae

36280	Richmond'S Wrasse	*Halichoeres richmondi*	Labridae
36281	Zigzag Wrasse	*Halichoeres scapularis*	Labridae
36312	Shwartz Wrasse	*Halichoeres shwartzi*	Labridae
36282	Wrasse	*Halichoeres sp*	Labridae
36230	3-Spot Wrasse	*Halichoeres trimaculatus*	Labridae
36225	Wrasse	*Halichoeres zeylonicus*	Labridae
36231	Striped Clown Wrasse	*Hemigymnus fasciatus*	Labridae
36232	1/2 &1/2 Wrasse	*Hemigymnus melapterus*	Labridae
36303	Wrasse	*Hologymnosus annulatus*	Labridae
36233	Ring Wrasse	*Hologymnosus doliatus*	Labridae
36234	Tubelip Wrasse	*Labrichthys unilineatus*	Labridae
36200	Wrasse	Labridae	Labridae
36235	Bicolor Cleaner Wrasse	*Labroides bicolor*	Labridae
36266	Bluestreak Cleaner Wrasse	*Labroides dimidiatus*	Labridae
36237	Black-Spot Cleaner Wrasse	*Labroides pectoralis*	Labridae
36283	Allen'S Wrasse	*Labropsis alleni*	Labridae
36238	Micronesian Wrasse	*Labropsis micronesica*	Labridae
36239	Wedge-Tailed Wrasse	*Labropsis xanthonota*	Labridae
36240	Leopard Wrasse	*Macropharyngodon meleagris*	Labridae
36284	Negros Wrasse	*Macropharyngodon negrosensis*	Labridae
36241	Seagrass Razorfish	*Novaculichthys macrolepidotus*	Labridae
36242	Dragon Wrasse	*Novaculichthys taeniourus*	Labridae
36207	Arenatus Wrasse	*Oxycheilinus arenatus*	Labridae
36264	2-Spot Wrasse	*Oxycheilinus bimaculatus*	Labridae
36208	Celebes Wrasse	*Oxycheilinus celebecus*	Labridae
36263	Bandcheek Wrasse	*Oxycheilinus digrammus*	Labridae
36215	Oriental Wrasse	*Oxycheilinus orientalis*	Labridae
36212	Ringtail Wrasse	*Oxycheilinus unifasciatus*	Labridae
36292	Wrasse	*Paracheilinus bellae*	Labridae
36293	Wrasse	*Paracheilinus* sp.	Labridae
36265	Wrasse	*Polylepion russelli*	Labridae
36294	Wrasse	*Pseudocheilinops ataenia*	Labridae
36244	Striated Wrasse	*Pseudocheilinus evanidus*	Labridae
36245	6 Line Wrasse	*Pseudocheilinus hexataenia*	Labridae
36246	8 Line Wrasse	*Pseudocheilinus octotaenia*	Labridae
36285	Line Wrasse	*Pseudocheilinus sp*	Labridae
36247	4 Line Wrasse	*Pseudocheilinus tetrataenia*	Labridae

36316	Rust-Banded Wrasse	*Pseudocoris aurantiofasciata*	Labridae
36317	Torpedo Wrasse	*Pseudocoris heteroptera*	Labridae
36286	Yamashiro'S Wrasse	*Pseudocoris yamashiroi*	Labridae
36267	Chiseltooth Wrasse	*Pseudodax moluccanus*	Labridae
36248	Polynesian Wrasse	*Pseudojuloides atavai*	Labridae
36249	Smalltail Wrasse	*Pseudojuloides cerasinus*	Labridae
36250	Wrasse	*Pterogogus cryptus*	Labridae
36296	Wrasse	*Pterogogus guttatus*	Labridae
36251	Red-Shoulder Wrasse	*Stethojulis bandanensis*	Labridae
36252	Wrasse	*Stethojulis strigiventor*	Labridae
36299	Wrasse	*Stethojulis trilineata*	Labridae
36253	2 Tone Wrasse	*Thalassoma amblycephalum*	Labridae
36255	6 Bar Wrasse	*Thalassoma hardwickii*	Labridae
36262	Jansen'S Wrasse	*Thalassoma janseni*	Labridae
36287	Crescent Wrasse	*Thalassoma lunare*	Labridae
36256	Sunset Wrasse	*Thalassoma lutescens*	Labridae
36257	Surge Wrasse	*Thalassoma purpureum*	Labridae
36258	5-Stripe Surge Wrasse	*Thalassoma quinquevittatum*	Labridae
36254	Xmas Wrasse	*Thalassoma trilobatum*	Labridae
36289	Wh-Barred Pygmy Wrasse	*Wetmorella albofasciata*	Labridae
36259	Bl-Spot Pygmy Wrasse	*Wetmorella nigropinnata*	Labridae
36290	Wrasse	*Xiphocheilus* sp.	Labridae
36261	Yblotch Razorfish	*Xyrichtys aneitensis*	Labridae
36301	Celebe'S Razorfish	*Xyrichtys celebecus*	Labridae
36302	Razorfish	*Xyrichtys geisha*	Labridae
36308	Yellowpatch Razorfish	*Xyrichtys melanopus*	Labridae
36260	Blue Razorfish	*Xyrichtys pavo*	Labridae
36401	Bumphead parrotfish	*Bolbometopon muricatum*	Labridae
36214	Napolean wrasse	*Cheilius undulatus*	Labridae
1101	Carcharhinidae	*Carcharhinus albimarginatus*	Carcharhinidae
1102	Carcharhinidae	*Carcharhinus amblyrhynchos*	Carcharhinidae
1104	Carcharhinidae	*Carcharhinus galapagensis*	Carcharhinidae
1106	Carcharhinidae	*Carcharhinus melanopterus*	Carcharhinidae
1201	Hammerhead	*Sphyrna lewini*	Carcharhinidae
1202	Hammerhead	*Sphyrna mokorran*	Carcharhinidae
1200	Hammerhead	Sphyrnidae	Carcharhinidae
44518	Starry Triggerfish	*Abalistes stellatus*	Other

20701	Barred Needlefish	*Ablennes hians*	Other
35050	Blackspot Sergeant	*Abudefduf lorenzi*	Other
35051	Yellowtail Sergeant	*Abudefduf notatus*	Other
35001	Banded Sergeant	*Abudefduf septemfasciatus*	Other
35002	Scis-Tail Sgt Major	*Abudefduf sexfasciatus*	Other
35003	Black Spot Sergeant	*Abudefduf sordidus*	Other
35004	Sergeant-Major	*Abudefduf vaigiensis*	Other
29150	Spiney Basslets	Acanthoclinidae	Other
29151	Hiatt'S Basslet	*Acathoplesiops hiatti*	Other
40537	Goby	*Acentrogobius bonti*	Other
44566	Seagrass Filefish	*Acreichthys tomentosus*	Other
25601	Shrimpfish	*Aeoliscus strigatus*	Other
2201	Spotted Eagle Ray	*Aetobatis narinari*	Other
2202	Eagle Ray	*Aetomyleaus maculatus*	Other
4801	Indo-Pacific Bonefish	*Albula glossodonta*	Other
4802	Bonefish	*Albula neoguinaica*	Other
4800	Bonefish	Albulidae	Other
17100	Lancetfishes	Alepisauidae	Other
17101	Lancetfish	*Alepisaurus ferox*	Other
40711	Dorothea'S Wriggler	*Allomicrodesmis dorotheae*	Other
39202	Blenny	*Alticus arnoldorum*	Other
44558	Unicorn Filefish	*Aluterus monoceros*	Other
44551	Filefish	*Aluterus scriptus*	Other
44552	Filefish	*Amanses scopas*	Other
28700	Glass Perch	Ambassidae	Other
28701	Glassie	*Ambassis buruensis*	Other
28702	Glassie	*Ambassis interrupta*	Other
35201	2-Spot Hawkfish	*Amblycirrhitus bimacula*	Other
40501	Goby	*Amblyeleotris faciata*	Other
40502	Goby	*Amblyeleotris fontaseni*	Other
40503	Goby	*Amblyeleotris guttata*	Other
40506	Goby	*Amblyeleotris randalli*	Other
40505	Brown-Barred Goby	*Amblyeleotris steinitzi*	Other
40507	Bluespotted Goby	*Amblyeleotris wheeleri*	Other
4306	Blue Pilchard	*Amblygaster clupeoides*	Other
4307	Spotted Pilchard	*Amblygaster sirm*	Other
35005	Damselfish	*Amblygliphidodon aureus*	Other
35006	Staghorn Damsel	*Amblygliphidodon curacao*	Other
35052	White-Belly Damsel	*Amblygliphidodon leucogaster*	Other

35053	Ternate Damsel	*Amblygliphidodon ternatensis*	Other
40523	Goby	*Amblygobius decussatus*	Other
40524	Goby	*Amblygobius hectori*	Other
40670		*Amblygobius linki*	Other
40525	Goby	*Amblygobius nocturnus*	Other
40526	Goby	*Amblygobius phalaena*	Other
40527	Goby	*Amblygobius rainfordi*	Other
40662	Goby	*Amblygobius sp*	Other
44816	Evileye Puffer	*Amblyrhinchotus honckenii*	Other
40504	Prawn Goby	*Amlbyeleotris periophthalma*	Other
35007	Org-Fin Anemonefish	*Amphiprion chrysopterus*	Other
35008	Clark'S Anemonefish	*Amphiprion clarkii*	Other
35095	Tomato Anemonefish	*Amphiprion frenatus*	Other
35009	Dusky Anemonefish	*Amphiprion melanopus*	Other
35096	False Clown Anemonefish	*Amphiprion ocellaris*	Other
35010	Pink Anemonfish	*Amphiprion peridaeraion*	Other
35097	3-Banded Anemonefish	*Amphiprion tricinctus*	Other
43507	Dragonet	*Anaora tentaculata*	Other
5601	Allardice'S Moray	*Anarchias allardicei*	Other
5646	Canton Island Moray	*Anarchias cantonensis*	Other
5602	Seychelles Moray	*Anarchias seychellensis*	Other
4901	Freshwater Eel	*Anguilla bicolor*	Other
4902	Freshwater Eel	*Anguilla marmorata*	Other
4900	Freshwater Eel	Anguillidae	Other
24250	Flashlightfish	Anomalopidae	Other
24251	Flashlightfish	*Anomalops katoptron*	Other
19200	Anglerfish	*Antenariidae*	Other
19201	Pigmy Frogfish	*Antennarius analis*	Other
19202	Frogfish	*Antennarius biocellatus*	Other
19203	Freckled Frogfish	*Antennarius coccineus*	Other
19204	Giant Frogfish	*Antennarius commersonii*	Other
19205	Bandtail Frogfish	*Antennarius dorehensis*	Other
19206	Sargassumfish	*Antennarius maculatus*	Other
19207	Spotfin Frogfish	*Antennarius nummifer*	Other
19208	Painted Frogfish	*Antennarius pictus*	Other
19209	Randall'S Frogfish	*Antennarius randalli*	Other
19210	Spiney-Tufted Frogfish	*Antennarius rosaceus*	Other
19211	Bandfin Frogfish	*Antennatus tuberosus*	Other

25201	Boarfish	*Antigonia malayana*	Other
26460	Velvetfishes	*Aploactinidae*	Other
30435	Cardinalfish	*Apogon amboinensis*	Other
30401	Broad-Striped Cardinalfish	*Apogon angustatus*	Other
30402	Bigeye Cardinalfish	*Apogon bandanensis*	Other
30403	Cryptic Cardinalfish	*Apogon coccineus*	Other
30436	Ohcre-Striped Cardinalfish	*Apogon compressus*	Other
30437	Redspot Cardinalfish	*Apogon dispar*	Other
30438	Longspine Cardinalfish	*Apogon doryssa*	Other
30455	Elliot'S Cardinalfish	*Apogon ellioiti*	Other
30462	Cardinalfish	*Apogon eremeia*	Other
30439	Evermann'S Cardinalfish	*Apogon evermanni*	Other
30404	Eyeshadow Cardinalfish	*Apogon exostigma*	Other
30405	Bridled Cardinalfish	*Apogon fraenatus*	Other
30441	Cardinalfish	*Apogon fragilis*	Other
30440	Gilbert'S Cardinalfish	*Apogon gilberti*	Other
30406	Guam Cardinalfish	*Apogon guamensis*	Other
30468		*Apogon hartzfeldii*	Other
30407	Iridescent Cardinalfish	*Apogon kallopterus*	Other
30408	Inshore Cardinalfish	*Apogon lateralis*	Other
30409	Bluestreak Cardinalfish	*Apogon leptacanthus*	Other
30457	Black Cardinalfish	*Apogon melas*	Other
30463	Cardinalfish	*Apogon nigripinnis*	Other
30412	Black-Striped Cardinalfish	*Apogon nigrofasciatus*	Other
30464	Cardinalfish	*Apogon notatus*	Other
30413	7-Lined Cardinalfish	*Apogon novemfasciatus*	Other
30442	Pearly Cardinalfish	*Apogon perlitus*	Other
30465	Cardinalfish	*Apogon rhodopterus*	Other
30443	Sangi Cardinalfish	*Apogon sangiensis*	Other
30415	Gray Cardinalfish	*Apogon savayensis*	Other
30456	Seale'S Cardinalfish	*Apogon sealei*	Other
30417	Cardinalfish	*Apogon sp*	Other
30414	Bandfin Cardinalfish	*Apogon taeniophorus*	Other
30410	Bandfin Cardinalfish	*Apogon taeniopterus*	Other
30416	3-Spot Cardinalfish	*Apogon trimaculatus*	Other
30418	Ocellated Cardinalfish	*Apogonichthys ocellatus*	Other
30444	Perdix Cardinalfish	*Apogonichthys perdix*	Other
30400	Cardinalfishes	Apogonidae	Other
34377	Angelfish	*Apolemichthys griffisi*	Other

34351	Flagfin Anglefish	*Apolemichthys trimaculatus*	Other
34376	Angelfish	*Apolemichthys xanthopunctatus*	Other
29201	2-Lined Soapfish	*Aporops bilinearis*	Other
6619	Snake Eel	*Apterichtus klazingai*	Other
30419	Twinspot Cardinalfish	*Archamia biguttata*	Other
30420	Orange-Lined Cardinalfish	*Archamia fucata*	Other
30445	Blackbelted Cardinalfish	*Archamia zosterophora*	Other
6206	Scheele'S Conger	*Ariosoma scheelei*	Other
43903	Flounder	*Arnoglossus intermedius*	Other
44801	Brown Puffer	*Arothron hispidus*	Other
44802	Puffer	*Arothron manilensis*	Other
44803	Puffer	*Arothron mappa*	Other
44804	White-Spot Puffer	*Arothron meleagris*	Other
44805	Black-Spotted Puffer	*Arothron nigropunctatus*	Other
44806	Star Puffer	*Arothron stellatus*	Other
44102	Black Spotted Sole	*Aseraggodes melanostictus*	Other
44103	Smith'S Sole	*Aseraggodes smithi*	Other
44104	Whitaker'S Sole	*Aseraggodes whitakeri*	Other
39257	Lance Blenny	*Aspidontus dussumieri*	Other
39203	Cleaner Mimic	*Aspidontus taeniatus*	Other
40539		*Asteropteryx semipunctatus*	Other
43905	Intermediate Flounder	*Asterorhombus intermedius*	Other
40538	Goby	*Asterropteryx ensiferus*	Other
21800	Silverside	Atherinidae	Other
21805	Tropical Silverside	*Atherinomorus duodecimalis*	Other
21806	Striped Silverside	*Atherinomorus endrachtensis*	Other
21803	Silverside	*Atherinomorus lacunosus*	Other
21804	Hardyhead Silverside	*Atherinomorus lacunosus*	Other
21801	Bearded Silverside	*Atherion elymus*	Other
39240	Blenny	*Atrosalarius fuscus holomelas*	Other
25300	Trumpetfish	Aulostomidae	Other
25301	Trumpetfish	*Aulostomus chinensis*	Other
40540	Goby	*Austrolethops wardi*	Other
40541	Goby	*Awaous grammepomus*	Other
40542	Goby	*Awaous guamensis*	Other
44501	Undulate Triggerfish	*Balistapus undulatus*	Other

44500	Triggerfishes	Balistidae	Other
44502	Clown Triggerfish	*Balistoides conspicillum*	Other
44503	Titan Triggerfish	*Balistoides viridescens*	Other
40543	Goby	*Bathygobius cocosensis*	Other
40544	Goby	*Bathygobius cotticeps*	Other
40545	Goby	*Bathygobius fuscus*	Other
20700	Needlefish	Belonidae	Other
29001	Soapfish	*Belonoperca chaubanaudi*	Other
24200	Lantern-Eye Fish	Berycidae	Other
24201	Flashlightfish	*Beryx decadactylus*	Other
25818	Pipefish	*Bhanotia nuda*	Other
6205	Conger Eel	*Blachea xenobranchialis*	Other
39218	Blenny	*Blenniella cyanostigma*	Other
39222	Blenny	*Blenniella gibbifrons*	Other
39239		*Blenniella paula*	Other
39221	Blenny	*Blenniella periophthalmus*	Other
39200	Blennies	Blenniidae	Other
43900	Flounders	Bothidae	Other
43901	Peacock Flounder	*Bothus mancus*	Other
43902	Leopard Flounder	*Bothus pantherinus*	Other
44559	Taylor'S Inflator Filefish	*Brachaluteres taylori*	Other
6601	Snake Eel	*Brachysomophis sauropsis*	Other
18201	Codlet	*Bregmaceros nectabanus*	Other
18200	Codlets	*Bregmacerotidae*	Other
18651	Free-Tailed Brotula	*Brosmophyciops pautzkei*	Other
18601	Reef Cusk Eel	*Brotula multibarbata*	Other
18602	Townsend'S Cusk Eel	*Brotula townsendi*	Other
40546	Goby	*Bryaninops amplus*	Other
40547	Goby	*Bryaninops erythrops*	Other
40548	Goby	*Bryaninops natans*	Other
40549	Goby	*Bryaninops ridens*	Other
40550	Goby	*Bryaninops youngei*	Other
25819	Pipefish	*Bulbonaricus brauni*	Other
40402	Gudgeon	*Butis amboinensis*	Other
18650	Livebearing Brotulas	Bythitidae	Other
40551	Goby	*Cabillus tongarevae*	Other
6602	Snake Eel	*Caecula polyophthalma*	Other
32351	Scissor-Tailed Fusilier	*Caesio caerulaurea*	Other
32355	Fusilier	*Caesio cuning*	Other

32356	Lunar Fusilier	*Caesio lunaris*	Other
32352	Yellowback Caesio	*Caesio teres*	Other
32350	Fusilier	*Caesionidae*	Other
29050	Goldies	*Callanthiidae*	Other
6603	Snake Eel	*Callechelys marmorata*	Other
6604	Snake Eel	*Callechelys melanotaenia*	Other
43500	Dragonets	Callionymidae	Other
43508	Delicate Dragonet	*Callionymus delicatulus*	Other
43501	Mangrove Dragonet	*Callionymus enneactis*	Other
43502	Simple-Spined Dragonet	*Callionymus simplicicornis*	Other
40559	Goby	*Callogobious sp*	Other
40552	Goby	*Callogobius bauchotae*	Other
40553	Goby	*Callogobius centrolepis*	Other
40554	Goby	*Callogobius hasselti*	Other
40555	Goby	*Callogobius maculipinnis*	Other
40556	Goby	*Callogobius okinawae*	Other
40557	Goby	*Callogobius plumatus*	Other
40558	Goby	*Callogobius sclateri*	Other
29401	Longfin	*Calloplesiops altivelis*	Other
40403	Sleeper	*Calumia godeffroyi*	Other
44553	Gray Leatherjacket	*Cantherhines dumerilii*	Other
44565	Specktacled Filefish	*Cantherhines fronticinctus*	Other
44554	Honeycomb Filefish	*Cantherhines pardalis*	Other
44504	Rough Triggerfish	*Canthidermis maculatus*	Other
44807	Puffer	*Canthigaster amboinensis*	Other
44808	Puffer	*Canthigaster bennetti*	Other
44815	Puffer	*Canthigaster compressa*	Other
44809	Sharp Back Puffer	*Canthigaster coronata*	Other
44810	Puffer	*Canthigaster epilampra*	Other
44811	Puffer	*Canthigaster janthinoptera*	Other
44812	Puffer	*Canthigaster leoparda*	Other
44819	Circle-Barred Toby	*Canthigaster ocellicincta*	Other
44820	Papuan Toby	*Canthigaster papua*	Other
44813	Sharpnose Puffer	*Canthigaster solandri*	Other
44814	Saddle Shpns Puffer	*Canthigaster valentini*	Other
25200	Boarfishes	Caproidae	Other
26700	Coral Crouchers	*Caracanthidae*	Other
26701	Velvetfish	*Caracanthus maculatus*	Other
26702	Velvetfish	*Caracanthus unipinna*	Other

18700	Pearlfish	*Carapodidae*	Other
18702	Pearlfish	*Carapus mourlani*	Other
1109	Blackfin Shark	*Carcharhinus limbatus*	Other
902	Great White Shark	*Carcharodon carcharius*	Other
25600	Shrimpfishes	*Centriscidae*	Other
34379	Golden Angelfish	*Centropyge aurantia*	Other
34352	Bicolor Angelfish	*Centropyge bicolor*	Other
34353	Dusky Angelfish	*Centropyge bispinosus*	Other
34354	Colin'S Angelfish	*Centropyge colini*	Other
34367	White-Tail Angelfish	*Centropyge flavicauda*	Other
34355	Lemonpeel Anglefish	*Centropyge flavissimus*	Other
34356	Herald'S Anglefish	*Centropyge heraldi*	Other
34357	Flame Anglefish	*Centropyge loriculus*	Other
34368	Multicolor Angelfish	*Centropyge multicolor*	Other
34358	Multibarred Angelfish	*Centropyge multifasciatus*	Other
34359	Black-Spot Anglefish	*Centropyge nigriocellus*	Other
34378	Midnight Angelfish	*Centropyge nox*	Other
34360	Shepard'S Anglefish	*Centropyge shepardi*	Other
34369	Keyhole Angelfish	*Centropyge tibicen*	Other
34361	Pearlscale Anglefish	*Centropyge vrolicki*	Other
28959	Grouper	*Cephalopholis cyanostigma*	Other
39008	Triplefin	*Ceratobregma helenae*	Other
34301	Threadfin Butterflyfish	*Chaetodon auriga*	Other
34330	E Triangular Butterflyfish	*Chaetodon barronessa*	Other
34302	Bennetts Butterflyfish	*Chaetodon bennetti*	Other
34331	Burgess' Butterflyfish	*Chaetodon burgessi*	Other
34303	Speckled Butterflyfish	*Chaetodon citrinellus*	Other
34304	Saddleback Butterflyfish	*Chaetodon ephippium*	Other
34305	Ylw-Crn Butterflyfish	*Chaetodon flavocoronatus*	Other
34306	Kleins Butterflyfish	*Chaetodon kleinii*	Other
34307	Lined Butterflyfish	*Chaetodon lineolatus*	Other
34308	Racoon Butterflyfish	*Chaetodon lunula*	Other
34316	Redfinned Butterflyfish	*Chaetodon lunulatus*	Other
34309	Black-Back Butterflyfish	*Chaetodon melannotus*	Other
34310	Mertens Butterflyfish	*Chaetodon mertensii*	Other
34332	Meyer'S Butterflyfish	*Chaetodon meyeri*	Other
34311	Butterflyfish	*Chaetodon modestus*	Other
34333	Spot-Tail Butterflyfish	*Chaetodon ocellicaudus*	Other
34334	8-Banded Butterflyfish	*Chaetodon octofasciatus*	Other

34312	Ornate Butterflyfish	*Chaetodon ornatissimus*	Other
34335	Spot-Nape Butterflyfish	*Chaetodon oxycephalus*	Other
34313	Spotbnded Butterflyfish	*Chaetodon punctatofasciatus*	Other
34314	4-Spotted Butterflyfish	*Chaetodon quadrimaculatus*	Other
34336	Latticed Butterflyfish	*Chaetodon rafflesii*	Other
34315	Retculted Butterflyfish	*Chaetodon reticulatus*	Other
34337	Dotted Butterflyfish	*Chaetodon semeion*	Other
34338	Oval-Spot Butterflyfish	*Chaetodon speculum*	Other
34340	Tinker'S Butterflyfish	*Chaetodon tinkeri*	Other
34329	Chevron Butterflyfish	*Chaetodon trifascialis*	Other
34317	Pac Dblsddl Butterflyfish	*Chaetodon ulietensis*	Other
34318	Teardrop Butterflyfish	*Chaetodon unimaculatus*	Other
34319	Vagabond Butterflyfish	*Chaetodon vagabundus*	Other
34300	Butterflyfish	*Chaetodontidae*	Other
34370	Vermiculated Angelfish	*Chaetodontoplus mesoleucus*	Other
37401	Saddled Sandburrower	*Chalixodytes tauensis*	Other
36701	Gaper	*Champsodon vorax*	Other
36700	Gapers	*Champsodontidae*	Other
9800	Milkfish	*Chanidae*	Other
5647	Long-Jawed Moray	*Channomuraena vittata*	Other
9801	Milkfish	*Chanos chanos*	Other
30458	Lined Cardinalfish	*Cheilodipterus artus*	Other
30466	Intermediate Cardinalfish	*Cheilodipterus intermedius*	Other
30446	Cardinalfish	*Cheilodipterus isostigma*	Other
30422	Lg-Toothed Cardinalfish	*Cheilodipterus macrodon*	Other
30423	5-Lined Cardinalfish	*Cheilodipterus quinquelineata*	Other
30421	Truncate Cardinalfish	*Cheilodipterus singapurensis*	Other
20601	Flying Fish	*Cheilopogon spilonopterus*	Other
20602	Flying Fish	*Cheilopogon spilopterus*	Other
20603	Flying Fish	*Cheilopogon unicolor*	Other
35089	Minstrel Fish	*Cheiloprion labiatus*	Other
35907	Ceram Mullet	*Chelon macrolepis*	Other
5400	False Moray Eel	Chlopsidae	Other
25802	Pipefish	*Choeroichthys brachysoma*	Other
25801	Pipefish	*Choeroichthys sculptus*	Other
37001	Duckbill	*Chrionema squamiceps*	Other

35011	Midget Chromis	*Chromis acares*	Other
35012	Bronze Reef Chromis	*Chromis agilis*	Other
35022	Yel-Speckled Chromis	*Chromis alpha*	Other
35013	Ambon Chromis	*Chromis amboinensis*	Other
35014	Yellow Chromis	*Chromis analis*	Other
35015	Black-Axil Chromis	*Chromis atripectoralis*	Other
35054	Dark-Fin Chromis	*Chromis atripes*	Other
35059	Blue-Axil Chromis	*Chromis caudalis*	Other
35060	Deep Reef Chromis	*Chromis delta*	Other
35017	Twin-Spot Chromis	*Chromis elerae*	Other
35018	Scaly Chromis	*Chromis lepidolepis*	Other
35055	Lined Chromis	*Chromis lineata*	Other
35019	Bicolor Chromis	*Chromis margaritifer*	Other
35056	Black-Bar Chromis	*Chromis retrofasciata*	Other
35049	Ternate Chromis	*Chromis ternatensis*	Other
35020	Vanderbilt'S Chromis	*Chromis vanderbilti*	Other
35016	Blue-Green Chromis	*Chromis viridis*	Other
35057	Weber'S Chromis	*Chromis weberi*	Other
35058	Yel-Axil Chromis	*Chromis xanthochir*	Other
35021	Black Chromis	*Chromis xanthura*	Other
35024	2-Spot Demoiselle	*Chrysiptera biocellata*	Other
35027	Surge Demoiselle	*Chrysiptera brownriggii*	Other
35025	Blue-Line Demoiselle	*Chrysiptera caeruleolineata*	Other
35062	Blue Devil	*Chrysiptera cyanea*	Other
35026	Gray Demoiselle	*Chrysiptera glauca*	Other
35090	Blue-Spot Demoiselle	*Chrysiptera oxycephala*	Other
35064	King Demoiselle	*Chrysiptera rex*	Other
35065	Talbot'S Demoiselle	*Chrysiptera talboti*	Other
35028	Tracey'S Demoiselle	*Chrysiptera traceyi*	Other
35091	1-Spot Demoiselle	*Chrysiptera unimaculata*	Other
34610	Peacock Bass	*Cichla ocellaris*	Other
34600	Cichlids	Cichlidae	Other
35211	Threadfin Hawkfish	*Cirrhitichthys aprinus*	Other
35202	Falco'S Hawkfish	*Cirrhitichthys falco*	Other
35203	Pixy Hawkfish	*Cirrhitichthys oxycephalus*	Other
35200	Hawkfish	Cirrhitidae	Other
35204	Stocky Hawkfish	*Cirrhitus pinnulatus*	Other
6620	Fringelip Snake Eel	*Cirricaecula johnsoni*	Other
39242	Chestnut Blenny	*Cirripectes castaneus*	Other

39204	Spotted Blenny	*Cirripectes fuscoguttatus*	Other
39243	Blenny	*Cirripectes perustus*	Other
39206	Barred Blenny	*Cirripectes polyzona*	Other
39205	Squiggly Blenny	*Cirripectes quagga*	Other
39244	Red-Streaked Blenny	*Cirripectes stigmaticus*	Other
39207	Red-Speckled Blenny	*Cirripectes variolosus*	Other
14802	Air-Breath Catfish	*Clarias batrachus*	Other
14801	Air-Breath Catfish	*Clarias macrocephalus*	Other
14800	Air-Breath Catfish	Clariidae	Other
4300	Herring,Sprat,Sardines	Clupeidae	Other
26461	Velvetfish	*Cocotropis larvatus*	Other
6201	White Eel	*Conger cinereus cinereus*	Other
6202	Conger Eel	*Conger oligoporus*	Other
6208	Conger Eel	*Conger sp*	Other
6200	White,Conger,Garden Eel	Congridae	Other
30306	Deepwater Glasseye	*Cookeolus boops*	Other
30304	Bulleye	*Cookeolus japonicus*	Other
34339	Orangebanded Coralfish	*Coradion chrysozonus*	Other
40590	Goby	*Coryphopterus signipinnis*	Other
25803	Network Pipefish	*Corythoichthys flavofasciatus*	Other
25820	Pipefish	*Corythoichthys haematopterus*	Other
25804	Reef Pipefish	*Corythoichthys intestinalis*	Other
25805	Bl-Breasted Pipefish	*Corythoichthys nigripectus*	Other
25821	Ocellated Pipefish	*Corythoichthys ocellatus*	Other
25822	Many-Spotted Pipefish	*Corythoichthys polynotatus*	Other
25823	Guilded Pipefish	*Corythoichthys schultzi*	Other
25824	Roughridge Pipefish	*Cosmocampus banneri*	Other
25806	D'Arros Pipefish	*Cosmocampus darrosanus*	Other
25825	Maxweber'S Pipefish	*Cosmocampus maxweberi*	Other
37400	Sand Burrowers	Creedidae	Other
35911	Mullet	*Crenimugil heterochilos*	Other
40560	Goby	*Cristagobius sp*	Other
40508	Goby	*Cryptocentroides insignis*	Other
40511	Goby	*Cryptocentrus cauruleomaculatus*	Other
40509	Goby	*Cryptocentrus cinctus*	Other
40510	Goby	*Cryptocentrus koumansi*	Other
40512	Goby	*Cryptocentrus*	Other

		leptocephalus	
40514	Goby	*Cryptocentrus sp.A*	Other
40513	Goby	*Cryptocentrus strigilliceps*	Other
40515	Goby	*Ctenogobiops aurocingulus*	Other
40516	Goby	*Ctenogobiops feroculus*	Other
40517	Goby	*Ctenogobiops pomastictus*	Other
40518	Long-Finned Prwn Goby	*Ctenogobiops tangarorai*	Other
27304	Flathead	*Cymbacephalus beauforti*	Other
35212	Swallowtail Hawkfish	*Cyprinocirrhites polyactis*	Other
20604	Flying Fish	*Cypselurus angusticeps*	Other
20605	Flying Fish	*Cypselurus poecilopterus*	Other
20606	Flying Fish	*Cypselurus speculiger*	Other
28501	Flying Gurnard	*Dactyloptena orientalis*	Other
28502	Flying Gurnard	*Dactyloptena petersoni*	Other
28500	Flying Gurnard	*Dactylopteridae*	Other
35029	Humbug Dascyllus	*Dascyllus aruanus*	Other
35066	Black-Tail Dascyllus	*Dascyllus melanurus*	Other
35030	Reticulated Dascyllus	*Dascyllus reticulatus*	Other
35031	3-Spot Dascyllus	*Dascyllus trimaculatus*	Other
2000	Stingray	Dasyatididae	Other
2001	Blue-Spotted Sting Ray	*Dasyatis kuhlii*	Other
26401	Scorpionfish	*Dendrochirus biocellatus*	Other
26402	Scorpionfish	*Dendrochirus brachypterus*	Other
26427	Zebra Lionfish	*Dendrochirus zebra*	Other
32701	Slatey Sweetlips	*Diagramma pictum*	Other
16701	Lanternfish	*Diaphus schmidti*	Other
18652	Bythitid	*Dinematichthys iluocoetenoides*	Other
44903	Porcupinefish	*Diodon eydouxi*	Other
44901	Porcupinefish	*Diodon hystrix*	Other
44902	Porcupinefish	*Diodon liturosus*	Other
44900	Porcupinefish	Diodontidae	Other
43503	Dragonet	*Diplogrammus goramensis*	Other
8801	Bristlemouth	*Diplophos sp*	Other
35067	White-Spot Damsel	*Dischistodus chrysopoecilus*	Other
35068	Black-Vent Damsel	*Dischistodus melanotus*	Other
35032	White Damsel	*Dischistodus perspicillatus*	Other
25808	Banded Pipefish	*Doryramphus dactyliophorus*	Other
25807	Bluestripe Pipefish	*Doryramphus excisus*	Other

25826	Janss' Pipefish	*Doryramphus janssi*	Other
25827	Negros Pipefish	*Doryramphus negrosensis negrsensi*	Other
4303	Sprat	*Dussumieria elopsoides*	Other
4302	Sprats	*Dussumieria sp.B*	Other
31300	Diskfishes	Echeneidae	Other
31304	Remora	*Echeneis naucrates*	Other
5603	Whiteface Moray	*Echidna leucotaenia*	Other
5604	Snowflake Moray	*Echidna nebulosa*	Other
5605	Girdled Moray Eel	*Echidna polyzona*	Other
5606	Unicolor Moray	*Echidna unicolor*	Other
1350	Bramble Shark	*Echinorhinidae*	Other
1351	Bramble Shark	*Echinorhinus brucus*	Other
1352	Bramble Shark	*Echinorhinus cookei*	Other
39264	Banda Clown Blenny	*Ecsenius bandanus*	Other
39208	Blenny	*Ecsenius bicolor*	Other
39209	Blenny	*Ecsenius opsifrontalis*	Other
39245	Blenny	*Ecsenius sellifer*	Other
39246	Blenny	*Ecsenius yaeyamaensis*	Other
6621	Snake Eel	*Elapsopsis versicolor*	Other
40400	Sleepers	Eleotrididae	Other
40401	Gudgeon	*Eleotris fusca*	Other
32201	Bonnetmouth	*Emmelichthys karnellai*	Other
32200	Bonnet Mouths	*Emmelichtyidae*	Other
18703	Pearlfish	*Encheliophis boraboraensis*	Other
18705	Pearlfish	*Encheliophis gracilis*	Other
18701	Pearlfish	*Encheliophis homei*	Other
18704	Pearlfish	*Encheliophis vermicularis*	Other
5607	Bayer'S Moray	*Enchelycore bayeri*	Other
5608	Bikini Atoll Moray	*Enchelycore bikiniensis*	Other
5655	Dark-Spotted Moray	*Enchelycore kamara*	Other
5609	White-Margined Moray	*Enchelycore schismatorhynchus*	Other
5610	Viper Moray	*Enchelynassa canina*	Other
39210	Blenny	*Enchelyurus kraussi*	Other
4406	Gold Anchovy	*Enchrasicholina devisi*	Other
4405	Blue Anchovy	*Enchrasicholina heterolobus*	Other
4401	Oceanic Anchovy	*Enchrasicholina punctifer*	Other
4400	Anchovies	Engraulidae	Other

43904	Flounder	*Engyprosopon sp*	Other
39001	Triplefin	*Enneapterygius hemimelas*	Other
39002	Triplefin	*Enneapterygius minutus*	Other
39003	Triplefin	*Enneapterygius nanus*	Other
39247	Blenny	*Entomacrodus caudofasciatus*	Other
39248	Blenny	*Entomacrodus cymatobiotus*	Other
39211	Blenny	*Entomacrodus decussatus*	Other
39212	Blenny	*Entomacrodus niuafooensis*	Other
39213	Blenny	*Entomacrodus sealei*	Other
39241	Blenny	*Entomacrodus stellifer*	Other
39214	Blenny	*Entomacrodus striatus*	Other
39215	Blenny	*Entomacrodus thalassinus thalassin*	Other
34000	Batfish	Ephippidae	Other
32202	Bonnetmouth	*Erythrocles scintillans*	Other
1301	Spiny Dogfish	*Etmopterus pusillus*	Other
20757	Ribbon Halfbeak	*Euleptorhamphus viridis*	Other
28601	Dragon Fish	*Eurypegasus draconis*	Other
4304	Mantis Shrimp	*Eutremus teres*	Other
40561	Kawakawa	*Eviota afelei*	Other
40562	Herring	*Eviota albolineata*	Other
40563	Goby	*Eviota bifasciata*	Other
40564	Goby	*Eviota cometa*	Other
40565	Goby	*Eviota distigma*	Other
40566	Goby	*Eviota fasciola*	Other
40567	Goby	*Eviota herrei*	Other
40568	Goby	*Eviota infulata*	Other
40569	Goby	*Eviota lachdebrerei*	Other
40570	Goby	*Eviota latifasciata*	Other
40571	Goby	*Eviota melasma*	Other
40572	Goby	*Eviota nebulosa*	Other
40573	Goby	*Eviota pellucida*	Other
40574	Goby	*Eviota prasina*	Other
40575	Goby	*Eviota prasites*	Other
40576	Goby	*Eviota punctulata*	Other
40577	Goby	*Eviota queenslandica*	Other
40579	Goby	*Eviota saipanensis*	Other
40578	Goby	*Eviota sebreei*	Other
40580	Goby	*Eviota sigillata*	Other

40581	Goby	*Eviota smaragdus*	Other
40585	Goby	*Eviota sp*	Other
40582	Goby	*Eviota sparsa*	Other
40583	Goby	*Eviota storthynx*	Other
40584	Goby	*Eviota zonura*	Other
6622	Snake Eel	*Evipes percinctus*	Other
39216	Blenny	*Exalias brevis*	Other
20600	Flying Fish	*Exocoetidae*	Other
20611	Flying Fish	*Exocoetus volitans*	Other
40586	Goby	*Exyrias belissimus*	Other
40587	Goby	*Exyrias puntang*	Other
25401	Cornetfish	*Fistularia commersoni*	Other
25400	Cornetfish	Fistulariidae	Other
30453	Bay Cardinalfish	*Foa brachygramma*	Other
30454	Cardinalfish	*Foa sp*	Other
34320	Longnosed Butterflyfish	*Forcipiger flavissimus*	Other
34321	Big Longnose Butterflyfish	*Forcipiger longirostris*	Other
30467	Cardinalfish	*Fowleria abocellata*	Other
30426	Marbled Cardinalfish	*Fowleria marmorata*	Other
30425	Spotcheek Cardinalfish	*Fowleria punctulata*	Other
30427	Variegated Cardinalfish	*Fowleria variegatus*	Other
40588	Goby	*Fusigobius longispinus*	Other
40589	Goby	*Fusigobius neophytus*	Other
1107	Tiger Shark	*Galeocerdo cuvier*	Other
31802	Lg-Toothed Ponyfish	*Gazza achlamys*	Other
31808	Toothed Ponyfish	*Gazza minuta*	Other
34362	Ornate Angelfish	*Genicanthus bellus*	Other
34371	Black-Spot Angelfish	*Genicanthus melanospilos*	Other
34364	Watanabe'S Angelfish	*Genicanthus watanabei*	Other
32600	Mojarras	Gerreidae	Other
32602	Deep-Bodied Mojarra	*Gerres abbreviatus*	Other
32601	Common Mojarra	*Gerres acinaces*	Other
32604	Filamentous Mojarra	*Gerres filamentosus*	Other
32603	Oblong Mojarra	*Gerres oblongus*	Other
32605	Oyena Mojarra	*Gerres oyena*	Other
32606	Mojarra	*Gerres punctatus*	Other
9200	Telescopefish	*Giganturidae*	Other
40591	Goby	*Gladigobius ensifera*	Other
40592	Goby	*Glossogobius biocellatus*	Other

40593	Goby	*Glossogobius celebius*	Other
40594	Goby	*Glossogobius guirus*	Other
39249	Blenny	*Glyptoparus delicatulus*	Other
40595	Goby	*Gnatholepis anjerensis*	Other
40601		*Gnatholepis caurensis*	Other
40596	Goby	*Gnatholepis scapulostigma*	Other
40597	Goby	*Gnatholepis sp.A*	Other
43400	Clingfish	Gobiesocidae	Other
40500	Goby	Gobiidae	Other
40598	Goby	*Gobiodon albofasciatus*	Other
40599	Goby	*Gobiodon citrinus*	Other
40602	Goby	*Gobiodon okinawae*	Other
40603	Goby	*Gobiodon quinquestrigatus*	Other
40604	Goby	*Gobiodon rivulatus*	Other
40605	Goby	*Gobiopsis bravoi*	Other
8802	Bristlemouth	*Gonostoma atlanticum*	Other
8803	Bristlemouth	*Gonostoma ebelingi*	Other
8800	Bristlemouths	*Gonostomatidae*	Other
6209	Orange-Barred Garden Eel	*Gorgasia preclara*	Other
6203	Conger Eel	*Gorgasia sp*	Other
29051	Goldies	*Grammatonotus sp.1*	Other
29052	Goldies	*Grammatonotus sp.2*	Other
41604	2-Lined Mackerel	*Grammatorcynos bilineatus*	Other
29002	Yellowstripe Soapfish	*Grammistes sexlineatus*	Other
29000	Soapfish	Grammistidae	Other
29003	Ocellate Soapfish	*Grammistops ocellatus*	Other
41001	Wormfish	*Gunnellichthys monostigma*	Other
41002	Onestripe Wormfish	*Gunnellichthys pleurotaenia*	Other
41011	Wormfish	*Gunnellichthys viridescens*	Other
30460	Philippine Cardinalfish	*Gymnapogon philippinus*	Other
30447	Cardinalfish	*Gymnapogon urospilotus*	Other
32361	Fusilier	*Gymnocaesio gymnopterus*	Other
5611	Zebra Moray	*Gymnomuraena zebra*	Other
5619	Moray Eel	*Gymnothorax berndti*	Other
5620	Buro Moray	*Gymnothorax buroensis*	Other
5624	Moray Eel	*Gymnothorax elegans*	Other
5635	Enigmatic Moray	*Gymnothorax enigmaticus*	Other
5621	Fimbriated Moray	*Gymnothorax fimbriatus*	Other
5622	Yellow-Margined Moray	*Gymnothorax flavimarginatus*	Other

5612	Brown Spotted Moray	*Gymnothorax fuscomaculatus*	Other
5623	Graceful-Tailed Moray	*Gymnothorax gracilicaudus*	Other
5625	Moray Eel	*Gymnothorax hepaticus*	Other
5626	Giant Moray	*Gymnothorax javanicus*	Other
5627	Blotch-Necked Moray	*Gymnothorax margaritophorus*	Other
5613	Marshall Isles Moray	*Gymnothorax marshallensis*	Other
5614	Dirty Yellow Moray	*Gymnothorax melatremus*	Other
5628	Whitemouth Moray	*Gymnothorax meleagris*	Other
5648	Monochrome Moray	*Gymnothorax monochrous*	Other
5629	1-Spot Moray	*Gymnothorax monostigmus*	Other
5630	Moray Eel	*Gymnothorax neglectus*	Other
5645	Yellowmouth Moray	*Gymnothorax nudivomer*	Other
5616	Pinda Moray	*Gymnothorax pindae*	Other
5649	Moray Eel	*Gymnothorax polyuranodon*	Other
5631	Richardson'S Moray	*Gymnothorax richardsoni*	Other
5632	Yellow-Headed Moray	*Gymnothorax rueppelliae*	Other
5618	Moray Eel	*Gymnothorax sp.cf Melatremus*	Other
5633	Undulated Moray	*Gymnothorax undulatus*	Other
5634	Zonipectis Moray	*Gymnothorax zonipectus*	Other
32700	Sweetlips	*Haemulidae*	Other
25811	Brock'S Pipefish	*Halicampus brocki*	Other
25828	Duncker'S Pipefish	*Halicampus dunckeri*	Other
25812	Samoan Pipefish	*Halicampus mataafae*	Other
25829	Glittering Pipefish	*Halicampus nitidus*	Other
44301	Spikefish	*Halimochirurgus alcocki*	Other
39004	Triplefin	*Helcogramma capidata*	Other
39005	Triplefin	*Helcogramma chica*	Other
39006	Triplefin	*Helcogramma hudsoni*	Other
35069	Damselfish	*Hemiglyphidodon plagiometopon*	Other
20751	Halfbeak	*Hemiramphus archipelagicus*	Other
20758	Halfbeak	*Hemiramphus far*	Other
20760	Halfbeak	*Hemiramphus lutkei*	Other
20750	Halfbeak	*Hemirhamphidae*	Other
34322	Pyrimid Butterflyfish	*Hemitaurichthys polylepis*	Other
34323	Butterflyfish	*Hemitaurichthys thompsoni*	Other
34324	Longfinned Bannerfish	*Heniochus acuminatus*	Other

34325	Pennant Bannerfish	*Heniochus chrysostomus*	Other
34341	Bannerfish	*Heniochus diphreutes*	Other
34326	Masked Bannerfish	*Heniochus monoceros*	Other
34327	Singular Butterflyfish	*Heniochus singularis*	Other
34328	Humphead Bannerfish	*Heniochus varius*	Other
4308	Gold Spot Herring	*Herklotsichthys quadrimaculatus*	Other
6204	Conger Eel	*Heteroconger hassi*	Other
40606	Goby	*Heteroeleotris sp*	Other
30301	Glasseye	*Heteropriacanthus cruentatus*	Other
2006	Whipray	*Himantura fai*	Other
2005	Wh Tail Whipray	*Himantura granulata*	Other
2003	Leopard Ray	*Himantura uarnak*	Other
25830	Pipefish	*Hippichthys cyanospilos*	Other
25831	Pipefish	*Hippichthys spicifer*	Other
25809	Pipefish	*Hippocampus histrix*	Other
25832	Pipefish	*Hippocampus kuda*	Other
19212	Sargassum Fish	*Histrio histrio*	Other
28965	Fairy Basslet	*Holanthias borbonius*	Other
28966	Fairy Basslet	*Holanthias katayamai*	Other
30801	Tilefish	*Hoplolatilus cuniculus*	Other
30802	Tilefish	*Hoplolatilus fronticinctus*	Other
30803	Tilefish	*Hoplolatilus starcki*	Other
21807	Silverside	*Hypoatherina barnesi*	Other
21808	Silverside	*Hypoatherina cylindrica*	Other
21802	Silverside	*Hypoatherina ovalaua*	Other
20753	Halfbeak	*Hyporhamphus acutus acutus*	Other
20754	Halfbeak	*Hyporhamphus affinis*	Other
20755	Halfbeak	*Hyporhamphus dussumieri*	Other
6623	Snake Eel	*Ichthyapus vulturus*	Other
26430	Spiny Devilfish	*Inimicus didactylus*	Other
21901	Keeled Silverside	*Iso hawaiiensis*	Other
35210	6-Band Hawkfish	*Isocirrhitus sexfasciatus*	Other
21900	Keeled Silversides	Isonidae	Other
39265	Beautiful Rockskipper	*Istiblennius bellus*	Other
39217	Blenny	*Istiblennius chrysospilos*	Other
39266	Streaky Rockskipper	*Istiblennius dussumieri*	Other
39219	Blenny	*Istiblennius edentulus*	Other

39267	Interrupted Rockskipper	*Istiblennius interruptus*	Other
39220	Blenny	*Istiblennius lineatus*	Other
40607	Goby	*Istigobius decoratus*	Other
40608	Goby	*Istigobius ornatus*	Other
40609	Goby	*Istigobius rigilius*	Other
40610	Goby	*Istigobius spence*	Other
41900	Billfishes	Istiophoridae	Other
901	Mackerel Shark	*Isurus oxyrhinchus*	Other
5402	Bl-Nostril False Moray	*Kaupichthys atronasus*	Other
5403	Shortfin False Moray	*Kaupichthys brachychirus*	Other
5401	Common False Moray	*Kaupichthys hyoproroides*	Other
40612	Goby	*Kellogella quindecimfasciata*	Other
40611	Goby	*Kelloggella cardinalis*	Other
40701	Sand Dart	*Kraemeria bryani*	Other
40702	Sand Dart	*Kraemeria cunicularia*	Other
40703	Sand Dart	*Kraemeria samoensis*	Other
40700	Sand Darts	Kraemeriidae	Other
30103	Dark-Margined Flagtail	*Kuhlia marginata*	Other
30101	Barred Flagtail	*Kuhlia mugil*	Other
30102	River Flagtail	*Kuhlia rupestris*	Other
30100	Flagtails	*Kuhliidae*	Other
44601	Longhorn Cowfish	*Lactoria cornuta*	Other
44602	Spiny Cowfish	*Lactoria diaphana*	Other
44605	Thornback Cowfish	*Lactoria fornasini*	Other
44817	Oceanic Blaasop	*Lagocephalus lagocephalus*	Other
44818	Silverstripe Blaasop	*Lagocephalus sceleratus*	Other
900			
6627	Oriental Snake Eel	*Lamnostoma orientalis*	Other
31800	Ponyfishes	Leiognathidae	Other
31806	Slipmouth	*Leiognathus bindus*	Other
31804	Slipmouth	*Leiognathus elongatus*	Other
31801	Common Slipmouth	*Leiognathus equulus*	Other
31805	Slipmouth	*Leiognathus smithursti*	Other
31803	Oblong Slipmouth	*Leiognathus stercorarius*	Other
6605	Saddled Snake Eel	*Leiuranus semicinctus*	Other
43401	Clingfish	*Lepadichthys caritus*	Other
43402	Clingfish	*Lepadichthys minor*	Other
35048	Fusilier Damsel	*Lepidozygus tapienosoma*	Other
16901	Barracudina	*Lestidium nudun*	Other

37402	Sand Burrower	*Limnichthys donaldsoni*	Other
43403	Clingfish	*Liobranchia stria*	Other
28991	Swissguard Basslet	*Liopropoma lunulatum*	Other
28997	Swissguard Basslet	*Liopropoma maculatum*	Other
28992	Swissguard Basslet	*Liopropoma mitratum*	Other
28993	Swissguard Basslet	*Liopropoma multilineatum*	Other
28994	Pallid Basslet	*Liopropoma pallidum*	Other
28995	Pinstripe Basslet	*Liopropoma susumi*	Other
28996	Redstripe Basslet	*Liopropoma tonstrinum*	Other
39251	Blenny	*Litobranchus fowleri*	Other
35908	Giantscale Mullet	*Liza melinoptera*	Other
32501	Triplefin	*Lobotes surinamensis*	Other
32500	Tripletails	Lobotidae	Other
40519	Goby	*Lotilia graciliosa*	Other
28981	Magenta Slender Basslet	*Luzonichthys waitei*	Other
28982	Whitley'S Slender Basslet	*Luzonichthys whitleyi*	Other
40613	Goby	*Macrodontogobius wilburi*	Other
40520	Goby	*Mahidolia mystacina*	Other
30800	Tilefishes	Malacanthidae	Other
30851	Quakerfish	*Malacanthus brevirostris*	Other
30852	Striped Blanquillo	*Malacanthus latovittatus*	Other
2301	Manta Ray	*Manta birostris*	Other
45001	Sharptail Sunfish	*Masturus lanceolatus*	Other
4700	Tarpons	*Megalopidae*	Other
4701	Indo-Pacific Tarpon	*Megalops cyprinoides*	Other
39233	Poison-Fang Blenny	*Meiacanthus anema*	Other
39223	Poison-Fang Blenny	*Meiacanthus atrodorsalis*	Other
39258	1-Stripe Poison-Fang Blenny	*Meiacanthus ditrema*	Other
39259	Striped Poison-Fang Blenny	*Meiacanthus grammistes*	Other
44505	Black Triggerfish	*Melichthys niger*	Other
44506	Pinktail Triggerfish	*Melichthys vidua*	Other
18653	Brotula	*Microbrotula* sp.	Other
41000	Wormfish	*Microdesmidae*	Other
25817	Anderson'S Shrt-Nosed Pipefish	*Micrognathus andersonii*	Other
25810	Pygmy Short-Nosed Pipefish	*Micrognathus brevirostris pygmaeus*	Other
25833	Pipefish	*Microphis brachyurus brachyurus*	Other

25834	Pipefish	*Microphis brevidorsalis*	Other
25835	Pipefish	*Microphis leiaspis*	Other
25836	Pipefish	*Microphis manadensis*	Other
25837	Pipefish	*Microphis retzii*	Other
25813	Ventricose Milda	*Minyichthys myersi*	Other
2300	Myer'S Pipefish	Mobulidae	Other
45000	Ocean Sunfishes	Molidae	Other
44550	Filefishes	Monacanthidae	Other
33300	Monos	Monodactylidae	Other
33301	Mono	*Monodactylus argenteus*	Other
18000	Codlings	Moridae	Other
5103	Rusty Spaghetti Eel	*Moringua ferruginea*	Other
5102	Java Spaghetti Eel	*Moringua javanica*	Other
5101	Spaghetti Eel	*Moringua microchir*	Other
5100	Worm Eel	Moringuidae	Other
40614	Goby	*Mugilogobius tagala*	Other
40615	Goby	*Mugilogobius villa*	Other
6300	Pike Eels	Muraenesocidae	Other
6301	Pike Conger	*Muraenesox cinereus*	Other
6612	Snake Eel	*Muraenichthys gymnotus*	Other
6606	Snake Eel	*Muraenichthys laticaudata*	Other
6607	Snake Eel	*Muraenichthys macropterus*	Other
6613	Snake Eel	*Muraenichthys schultzi*	Other
6614	Snake Eel	*Muraenichthys sibogae*	Other
5600	Morays	Muraenidae	Other
16700	Lanternfishes	Myctophidae	Other
16702	Laternfish	*Myctophum brachygnathos*	Other
2200	Eagle Ray	Myliobatidae	Other
6624	Snake Eel	*Myrichthys bleekeri*	Other
6608	Banded Snake Eel	*Myrichthys colubrinus*	Other
6610	Spotted Snake Eel	*Myrichthys maculosus*	Other
6615	Snake Eel	*Myrophis uropterus*	Other
200	Hagfish	Myxinidae	Other
201	Hagfish	*Eptaptretus carlhubbsi*	Other
39252	Combtooth Blenny	*Nannosalarius nativitatus*	Other
701	Nurse Shark	*Nebrius ferrugineus*	Other
1110	Lemon Shark	*Negaprion acutidens*	Other
41010	Decorated Dartfish	*Nemateleotris decora*	Other
41003	Helfrichs' Dartfish	*Nemateleotris helfrichi*	Other

41004	Fire Dartfish	*Nemateleotris magnifica*	Other
32400	Threadfin Breams	Nemipteridae	Other
32900	Breams	Nemipteridae	Other
32412	Forktail Bream	*Nemipterus furcosus*	Other
32409	Butterfly Bream	*Nemipterus hexadon*	Other
32410	Notched Butterfly Bream	*Nemipterus peronii*	Other
32411	Butterfly Bream	*Nemipterus tolu*	Other
35205	Flame Hawkfish	*Neocirrhitus armatus*	Other
35072	Royal Damsel	*Neoglyphidodon melas*	Other
35073	Yellowfin Damsel	*Neoglyphidodon nigroris*	Other
35070	Coral Demoiselle	*Neopomacentrus nemurus*	Other
35071	Freshwater Demoiselle	*Neopomacentrus taeniurus*	Other
35047	Violet Demoiselle	*Neopomacentrus violascens*	Other
42200	Man-Of-War Fish	Nomeidae	Other
39007	Triplefin	*Norfolkia brachylepis*	Other
44507	Redtooth Triggerfish	*Odonus niger*	Other
35909	Foldlip Mullet	*Oedalechilus labiosus*	Other
39263	Mangrove Blenny	*Omobranchus obliquus*	Other
39224	Blenny	*Omobranchus rotundiceps*	Other
39256	Blenny	*Omox biporos*	Other
18706	Bivalve Pearlfish	*Onuxodon fowleri*	Other
6600	Snake Eel	Ophichthidae	Other
6611	Dark-Shouldered Snake Eel	*Ophichthus cephalozona*	Other
18600	Cusk Eel	Ophidiidae	Other
40405	Sleeper	*Ophieleotris aporos*	Other
40406	Sleeper	*Ophiocara porocephala*	Other
36600	Jawfishes	Opisthognathidae	Other
36601	Variable Jawfish	*Opisthognathus* sp. A	Other
36602	Wass' Jawfish	*Opisthognathus* sp. B	Other
34700	Knifejaws	Oplegnathidae	Other
34701	Spotted Knifejaw	*Oplegnathus punctatus*	Other
40528	Goby	*Oplopomops diacanthus*	Other
40529	Goby	*Oplopomus oplopomus*	Other
40616	Goby	*Opua nephodes*	Other
700	Nurse,Zebra,Carpet Sharks	Orectolobidae	Other
34601	Tilapia	*Oreochromis mossambicus*	Other
44600	Boxfish, Cowfish	Ostraciidae	Other
44603	Cube Trunkfish	*Ostracion cubicus*	Other
44604	Spotted Trunkfish	*Ostracion meleagris meleagris*	Other

44606	Reticulate Boxfish	*Ostracion solorensis*	Other
35206	Longnose Hawkfish	*Oxycirrhitus typus*	Other
40407	Sleeper	*Oxyleotris lineolatus*	Other
44555	Longnose Filefish	*Oxymonacanthus longirostris*	Other
20759	Smallwing Flying Fish	*Oxyporhamphus micropterus micropter*	Other
40617	Goby	*Oxyurichthys guibei*	Other
40618	Goby	*Oxyurichthys microlepis*	Other
40619	Goby	*Oxyurichthys ophthalmonema*	Other
40620	Goby	*Oxyurichthys papuensis*	Other
40621	Goby	*Oxyurichthys tentacularis*	Other
40622	Goby	*Padanka* sp.	Other
40623	Goby	*Palutris pruinosa*	Other
40624	Goby	*Palutris reticularis*	Other
35207	Arc-Eyed Hawkfish	*Paracirrhitus arcatus*	Other
35208	Freckeled Hawkfish	*Paracirrhitus forsteri*	Other
35209	Whitespot Hawkfish	*Paracirrhitus hemistictus*	Other
40625	Goby	*Paragobiodon echinocephalus*	Other
40626	Goby	*Paragobiodon lacunicolus*	Other
40627	Goby	*Paragobiodon melanosoma*	Other
40628	Goby	*Paragobiodon modestus*	Other
40629	Goby	*Paragobiodon xanthosoma*	Other
41012	Seychelle'S Wormfish	*Paragunnellichthy seychellensis*	Other
16900	Barracudinas	Paralepididae	Other
44556	Blacksaddle Mimic	*Paraluteres prionurus*	Other
44560	Filefish	*Paramonacanthus cryptodon*	Other
44561	Filefish	*Paramonacanthus japonicus*	Other
37102	Latticed Sandperch	*Parapercis clathrata*	Other
37103	Cylindrical Sandperch	*Parapercis cylindrica*	Other
37101	Blk-Dotted Sandperch	*Parapercis millipunctata*	Other
37105	Red-Barred Sandperch	*Parapercis multiplicata*	Other
37106	Black-Banded Sandperch	*Parapercis tetracantha*	Other
37104	Blotchlip Sandperch	*Parapercis xanthozona*	Other
33402	Sandperch	*Parapriacanthus ransonneti*	Other
26433	Mcadam'S Scorpionfish	*Parascorpaena mcadamsi*	Other
26426	Mozambique Scorpionfish	*Parascorpaena mossambica*	Other

44105	Peacock Sole	*Pardachirus pavoninus*	Other
39225	Blenny	*Parenchelyurus hepburni*	Other
20607	Flying Fish	*Parexocoetus brachypterus*	Other
20608	Flying Fish	*Parexocoetus mento*	Other
41013	Beautiful Hover Goby	*Parioglossus formosus*	Other
41014	Lined Hover Goby	*Parioglossus lineatus*	Other
41015	Naked Hover Goby	*Parioglossus nudus*	Other
41016	Palustris Hover Goby	*Parioglossus palustris*	Other
41017	Rainford'S Hover Goby	*Parioglossus rainfordi*	Other
41018	Rao'S Hover Goby	*Parioglossus raoi*	Other
41019	Taeniatus Hover Goby	*Parioglossus taeniatus*	Other
41020	Vertical Hover Goby	*Parioglossus verticalis*	Other
2007	Shortsnouted Ray	*Pasinachus sephen*	Other
28600	Dragonfish	Pegasidae	Other
33400	Sweepers	*Pempherididae*	Other
33401	Bronze Sweeper	*Pempheris oualensis*	Other
34500	Armourheads	*Pentacerotidae*	Other
32901	Smalltooth Whiptail	*Pentapodus caninus*	Other
32902	3-Striped Whiptail	*Pentapodus trivittatus*	Other
37000	Duckbills	Percophidae	Other
40630	Goby	*Periophthalmus argentilineatus*	Other
40631	Goby	*Periophthalmus kalolo*	Other
44567	Yelloweye Filefish	*Pervagor alternans*	Other
44562	Orangetail Filefish	*Pervagor aspricaudatus*	Other
44557	Blackbar Filefish	*Pervagor janthinosoma*	Other
44563	Blackheaded Filefish	*Pervagor melanocephalus*	Other
44564	Blacklined Filefish	*Pervagor nigrolineatus*	Other
39260	Blenny	*Petroscirtes breviceps*	Other
39226	Blenny	*Petroscirtes mitratus*	Other
39261	Blenny	*Petroscirtes thepassi*	Other
39262	Blenny	*Petroscirtes variabilis*	Other
39227	Blenny	*Petroscirtes xestus*	Other
6625	Snake Eel	*Phenamonas cooperi*	Other
24202	Flashlightfish	*Photoblepheron palpebratus*	Other
25814	Pipefish	*Phoxocampus diacanthus*	Other
6626	Snake Eel	*Phyllophichthus xenodontus*	Other
18001	Codling	*Physiculus* sp.	Other
37100	Sand Perch	Pinguipedidae	Other
39228	Blenny	*Plagiotremus laudandus*	Other

39229	Red Sabbertooth Blenny	*Plagiotremus rhynorhynchus*	Other
39230	Blenny	*Plagiotremus tapienosoma*	Other
34001	Batfish	*Platax orbicularis*	Other
34002	Pinnate Spadefish	*Platax pinnatus*	Other
34003	Longfin Spadefish	*Platax teira*	Other
20702	Keeled Needlefish	*Platybelone argalus platyura*	Other
27300	Flathead	Platycephalidae	Other
32710	2-Lined Sweetlips	*Plectorhinchus albovittatus*	Other
32706	Celebes Sweetlips	*Plectorhinchus celebecus*	Other
32707	Harlequin Sweetlips	*Plectorhinchus chaetodonoides*	Other
32712	Sweetlip	*Plectorhinchus flavomaculatus*	Other
32703	Gibbus Sweetlips	*Plectorhinchus gibbosus*	Other
32708	Lined Sweetlips	*Plectorhinchus lessonii*	Other
32709	Goldman'S Sweetlips	*Plectorhinchus lineatus*	Other
32705	Giant Sweetlips	*Plectorhinchus obscurus*	Other
32704	Spotted Sweetlips	*Plectorhinchus picus*	Other
32713	Sweetlip	*Plectorhinchus sp*	Other
32702	Oriental Sweetlips	*Plectorhinchus vittatus*	Other
28987	Fourmanoir'S Basslet	*Plectranthias fourmanoiri*	Other
28968	Basslet	*Plectranthias kamii*	Other
28985	Long-Finned Basslet	*Plectranthias longimanus*	Other
28969	Pygmy Basslet	*Plectranthias nanus*	Other
28990	Basslet	*Plectranthias rubrifasciatus*	Other
28986	Basslet	*Plectranthias winniensis*	Other
35033	Dick'S Damsel	*Plectroglyphidodo dickii*	Other
35034	Bright-Eye Damsel	*Plectroglyphidodo imparipennis*	Other
35035	Johnston Isle Damsel	*Plectroglyphidodo johnstonianus*	Other
35036	Jewel Damsel	*Plectroglyphidodo lacrymatus*	Other
35037	White-Band Damsel	*Plectroglyphidodo leucozonus*	Other
35038	Phoenix Isle Damsel	*Plectroglyphidodo phoenixensis*	Other
29400	Longfins	Plesiopidae	Other
29402	Red-Tipped Longfin	*Plesiops caeruleolineatus*	Other

29403	Bluegill Longfin	*Plesiops corallicola*	Other
29405	Sharp-Nosed Longfin	*Plesiops oxycephalus*	Other
40632	Goby	*Pleurosicya bilobatus*	Other
40664	Caroline Ghost Goby	*Pleurosicya carolinensis*	Other
40665	Blue Coral Ghost Goby	*Pleurosicya coerulea*	Other
40666	Fringed Ghost Goby	*Pleurosicya fringella*	Other
40667	Michael'S Ghost Goby	*Pleurosicya micheli*	Other
40668	Common Ghost Goby	*Pleurosicya mossambica*	Other
40633	Goby	*Pleurosicya muscarum*	Other
40669	Plicata Ghost Goby	*Pleurosicya plicata*	Other
14900	Eel Catfishes	Plotosidae	Other
14901	Striped Eel Catfish	*Plotosus lineatus*	Other
6207	Barred Sand Conger	*Poeciloconger fasciatus*	Other
29004	Spotted Soapfish	*Pogonoperca punctata*	Other
36101	6 Feeler Threadfin	*Polydactylus sexfilis*	Other
17501	Beardfish	*Polymixia japonica*	Other
17500	Beardfish	Polymixiidae	Other
36100	Threadfins	Polynemidae	Other
34350	Angelfishes	Pomacanthidae	Other
34365	Emperor Anglefish	*Pomacanthus imperator*	Other
34372	Blue-Girdled Angelfish	*Pomacanthus navarchus*	Other
34375	Semicircle Angelfish	*Pomacanthus semicirculatus*	Other
34373	6-Banded Angelfish	*Pomacanthus sexstriatus*	Other
34374	Blue-Faced Angelfish	*Pomacanthus xanthometopon*	Other
35000	Damselfishes	Pomacentridae	Other
35087	Damselfish	*Pomacentrus adelus*	Other
35039	Ambon Damsel	*Pomacentrus amboinensis*	Other
35094	Goldbelly Damsel	*Pomacentrus auriventris*	Other
35074	Speckled Damsel	*Pomacentrus bankanensis*	Other
35081	Charcoal Damsel	*Pomacentrus brachialis*	Other
35075	Burrough'S Damsel	*Pomacentrus burroughi*	Other
35084	White-Tail Damsel	*Pomacentrus chrysurus*	Other
35076	Neon Damsel	*Pomacentrus coelestis*	Other
35077	Outer Reef Damsel	*Pomacentrus emarginatus*	Other
35078	Blue-Spot Damsel	*Pomacentrus grammorhynchus*	Other
35092	Lemon Damsel	*Pomacentrus moluccensis*	Other
35086	Nagasaki Damsel	*Pomacentrus nagasakiensis*	Other

35093	Black-Axil Damsel	*Pomacentrus nigromanus*	Other
35040	Sapphire Damsel	*Pomacentrus pavo*	Other
35082	Philippine Damsel	*Pomacentrus philippinus*	Other
35083	Reid'S Damsel	*Pomacentrus reidi*	Other
35085	Blueback Damsel	*Pomacentrus simsiang*	Other
35041	Princess Damsel	*Pomacentrus vaiuli*	Other
35088	Slender Reef-Damsel	*Pomachromis exilis*	Other
35042	Guam Damsel	*Pomachromis guamensis*	Other
32711	Common Javelinefish	*Pomadasyus kaakan*	Other
26404	Lg-Headed Scorpionfish	*Pontinus macrocephalus*	Other
26431	Scorpionfish	*Pontinus* sp.	Other
26452	Scopionfish	*Pontinus tentacularis*	Other
39231	Blenny	*Prealticus amboinensis*	Other
39232	Blenny	*Prealticus natalis*	Other
30300	Bigeyes	Priacanthidae	Other
30305	Bigeye	*Priacanthus alalaua*	Other
30302	Goggle-Eye	*Priacanthus hamrur*	Other
40634	Goby	*Priolepis cincta*	Other
40635	Goby	*Priolepis farcimen*	Other
40636	Goby	*Priolepis inhaca*	Other
40637	Goby	*Priolepis semidoliatus*	Other
30303	Bigeye	*Pristigenys meyeri*	Other
20609	Flying Fish	*Prognichthys albimaculatus*	Other
20610	Flying Fish	*Prognichthys sealei*	Other
42201	Freckeled Driftfish	*Psenes cyanophrys*	Other
44568	Rhino Leatherjacket	*Pseudalutarias nasicornis*	Other
30448	Cardinalfish	*Pseudamia amblyuroptera*	Other
30449	Cardinalfish	*Pseudamia gelatinosa*	Other
30450	Cardinalfish	*Pseudamia hayashii*	Other
30461	Cardinalfish	*Pseudamia zonata*	Other
30428	Cardinalfish	*Pseudamiops gracilicauda*	Other
28971	Bartlet'S Fairy Basslet	*Pseudanthias bartlettorum*	Other
28972	Bicolor Fairy Basslet	*Pseudanthias bicolor*	Other
28961	Red-Bar Fairy Basslet	*Pseudanthias cooperi*	Other
28973	Peach Fairy Basslet	*Pseudanthias dispar*	Other
28979	Fairy Basslet	*Pseudanthias huchtii*	Other
28974	Lori'S Anthias	*Pseudanthias lori*	Other
28962	Purple Queen	*Pseudanthias pascalus*	Other
28963	Sq-Spot Fairy Basslet	*Pseudanthias pleurotaenia*	Other

28975	Randall'S Fairy Basslet	*Pseudanthias randalli*	Other
28977	Smithvaniz' Fairy Basslet	*Pseudanthias smithvanizi*	Other
28964	Fairy Basslet	*Pseudanthias sp*	Other
28980	Fairy Basslet	*Pseudanthias squammipinnis*	Other
28976	Y Striped Fairy Basslet	*Pseudanthias tuka*	Other
28978	L-Finned Fairy Basslet	*Pseudanthias ventralis*	Other
5637	White Ribbon Eel	*Pseudechidna brummeri*	Other
44508	Ymargin Triggerfish	*Pseudobalistes flavimarginatus*	Other
44509	Blue Triggerfish	*Pseudobalistes fuscus*	Other
29100	Dottybacks	*Pseudochromidae*	Other
29101	Surge Dottyback	*Pseudochromis cyanotaenia*	Other
29102	Dusky Dottyback	*Pseudochromis fuscus*	Other
29103	Marshall Is Dottyback	*Pseudochromis marshallensis*	Other
29404	Dottyback	*Pseudochromis melanotaenia*	Other
29105	Long-Finned Dottyback	*Pseudochromis polynemus*	Other
29106	Magenta Dottyback	*Pseudochromis porphyreus*	Other
40638	Goby	*Pseudogobius javanicus*	Other
29202	Soapfish	*Pseudogramma polyacantha*	Other
29203	Soapfish	*Pseudogramma* sp.	Other
29200	Soapfishes	*Pseudogrammidae*	Other
34501	Amourhead	*Pseudopentaceros pectoralis*	Other
29111	Robust Dottyback	*Pseudoplesiops multisquamatus*	Other
29107	Revelle'S Basslet	*Pseudoplesiops revellei*	Other
29108	Rose Island Basslet	*Pseudoplesiops rosae*	Other
29110	Basslet	*Pseudoplesiops* sp.	Other
29109	Hidden Basslet	*Pseudoplesiops typus*	Other
41005	Blackfin Dartfish	*Ptereleotris evides*	Other
41021	Filament Dartfish	*Ptereleotris hanae*	Other
41006	Spot-Tail Dartfish	*Ptereleotris heteroptera*	Other
41009	Dartfish	*Ptereleotris lineopinnis*	Other
41007	Pearly Dartfish	*Ptereleotris microlepis*	Other
41008	Zebra Dartfish	*Ptereleotris zebra*	Other
32357	Yellowstreak Fusilier	*Pterocaesio lativittata*	Other
32353	Twinstripe Fusilier	*Pterocaesio marri*	Other
32360	Ruddy Fusilier	*Pterocaesio pisang*	Other

32362	Mosaic Fusilier	*Pterocaesio tesselatata*	Other
32354	Bluestreak Fusilier	*Pterocaesio tile*	Other
32358	3-Striped Fusilier	*Pterocaesio trilineata*	Other
26405	Spotfin Lionfish	*Pterois antennata*	Other
26406	Clearfin Lionfish	*Pterois radiata*	Other
26407	Turkeyfish	*Pterois volitans*	Other
26602	Ocellated Gurnard	*Pterygiotrigla multiocellata*	Other
26601	Gurnard	*Pterygiotrigla* sp.	Other
31301	Slender Suckerfish	*Ptheirichthys lineatus*	Other
34366	Regal Anglefish	*Pygoplites diacanthus*	Other
28989	Fairy Basslet	*Rabaulichthys* sp.	Other
45003	Trunkfish	*Ranzania laevis*	Other
41612	Mackerel	*Rastrelliger brachysoma*	Other
41610	Striped Mackerel	*Rastrelliger kanagurta*	Other
40639	Goby	*Redigobius bikolanus*	Other
40640	Goby	*Redigobius horiae*	Other
40641	Goby	*Redigobius sapangus*	Other
31302	Remora	*Remora remora*	Other
30451	Cardinalfish	*Rhabdamia cypselurus*	Other
30452	Cardinalfish	*Rhabdamia gracilis*	Other
39234	Blenny	*Rhabdoblenius rhabdotrachelus*	Other
39250		*Rhabdoblennius ellipes*	Other
39235	Blenny	*Rhabdoblennius snowi*	Other
1701	Guitarfish	*Rhinchobatus djiddensis*	Other
44510	Picassofish	*Rhinecanthus aculeatus*	Other
44511	Wedge Picassofish	*Rhinecanthus rectangulus*	Other
44520	Blackbelly Picassofish	*Rhinecanthus verrucosa*	Other
1700	Guitarfish	Rhinobatidae	Other
5636	Ribbon Eel	*Rhinomuraena quaesita*	Other
26428	Weedy Scorpionfish	*Rhinopias frondosa*	Other
31303	Remora	*Rhombochirus osteochir*	Other
44607	Smallnose Boxfish	*Rhynchostracion nasus*	Other
44608	Largenose Boxfish	*Rhynchostracion rhynorhynchus*	Other
9201	Telescopefish	*Rosaura indica*	Other
44569	Minute Filefish	*Rudarius minutus*	Other
39253		*Salarius alboguttatus*	Other
39236	Spotted Rock Blenny	*Salarius fasciatus*	Other
39255	Blenny	*Salarius luctuosus*	Other

39254	Blenny	*Salarius segmentatus*	Other
44000	Righteye Flounders	Samaridae	Other
44001	3 Spot Flounder	*Samariscus triocellatus*	Other
16001	Graceful Lizardfish	*Saurida gracilis*	Other
16002	Nebulous Lizardfish	*Saurida nebulosa*	Other
34100	Scats	Scatophagidae	Other
34101	Scat	*Scatophagus argus*	Other
40101	Schindleriid	*Schindleria praematurus*	Other
40100	Shindleriid	Schindleriidae	Other
6616	Snake Eel	*Schismorhinchus labialis*	Other
6617	Snake Eel	*Schultzidia johnstonensis*	Other
6618	Snake Eel	*Schultzidia retropinnis*	Other
32404	Spinecheek	*Scolopsis affinis*	Other
32402	2 Line Spinecheek	*Scolopsis bilineatus*	Other
32406	Ciliate Spinecheek	*Scolopsis ciliatus*	Other
32401	Bl And Wh Spinecheek	*Scolopsis lineatus*	Other
32403	Margarite'S Spinecheek	*Scolopsis margaritifer*	Other
32407	Spinecheek	*Scolopsis taeniopterus*	Other
32405	3 Line Spinecheek	*Scolopsis trilineatus*	Other
32408	Spinecheek	*Scolopsis xenochrous*	Other
41611	Narrow-Barred King Mackerel	*Scomberomorus commerson*	Other
26400	Scorpionfish	Scorpaenidae	Other
26413	Guam Scorpionfish	*Scorpaenodes guamensis*	Other
26429	Hairy Scorpionfish	*Scorpaenodes hirsutus*	Other
26414	Kellogg'S Scorpionfish	*Scorpaenodes kelloggi*	Other
26412	Minor Scorpionfish	*Scorpaenodes minor*	Other
26415	Coral Scorpionfish	*Scorpaenodes parvipinnis*	Other
26420	Blotchfin Scorpionfish	*Scorpaenodes varipinis*	Other
26417	Devil Scorpionfish	*Scorpaenopsis diabolus*	Other
26421	Pygmy Scorpionfish	*Scorpaenopsis fowleri*	Other
26422	Flasher Scorpionfish	*Scorpaenopsis macrochir*	Other
26416	Tassled Scorpionfish	*Scorpaenopsis oxycephala*	Other
26434	Papuan Scorpionfish	*Scorpaenopsis papuensis*	Other
26432	Scorpionfish	*Scorpaenopsis* sp.	Other
5654	Tiger Snake Moray	*Scuticaria tigrinis*	Other
26408	Yellowspotted Scorpionfish	*Sebastapistes cyanostigma*	Other
26409	Galactacma Scorpionfish	*Sebastapistes galactacma*	Other
26410	Mauritius Scorpionfish	*Sebastapistes mauritiana*	Other
26425	Barchin Scorpionfish	*Sebastapistes strongia*	Other

31807	Pugnose Soapy	*Secutor ruconius*	Other
28970	Basslet	*Selenanthias myersi*	Other
28988	Hawkfish Anthias	*Serranocirrhitus latus*	Other
40645	Goby	*Sicyopterus macrostetholepis*	Other
40646	Goby	*Sicyopterus micrurus*	Other
40647	Goby	*Sicyopterus* sp.	Other
40642	Goby	*Sicyopus leprurus*	Other
40644	Goby	*Sicyopus* sp.	Other
40643	Goby	*Sicyopus zosterophorum*	Other
5615	Peppered Moray	*Sideria picta*	Other
5617	White-Eyed Moray	*Sideria prosopeion*	Other
40530	Goby	*Signigobius biocellatus*	Other
40531	Goby	*Silhouettea* sp.	Other
30700	Sillagos	Sillaginidae	Other
30701	Cardinalfish	*Sillago sihama*	Other
30431	Cardinalfish	*Siphamia fistulosa*	Other
30459	Cardinalfish	*Siphamia fuscolineata*	Other
30430	Cardinalfish	*Siphamia versicolor*	Other
44101	Banded Sole	*Soleichthys heterohinos*	Other
44100	Soles	Soleidae	Other
25700	Ghost Pipefish	*Solenostomidae*	Other
25701	Ghost Pipefish	*Solenostomus cyanopterus*	Other
25702	Ornate Ghost Pipefish	*Solenostomus paradoxus*	Other
27305	Flathead	*Sorsogona welanderi*	Other
30434	Cardinalfish	*Sphaeramia nematoptera*	Other
30432	Cardinalfish	*Sphaeramia orbicularis*	Other
36004	Sharpfin Barracuda	*Sphyraena acutipinnis*	Other
36001	Great Barracuda	*Sphyraena barracuda*	Other
36008	Yellowtail Barracuda	*Sphyraena flavicauda*	Other
36003	Blackspot Barracuda	*Sphyraena forsteri*	Other
36007	Arrow Barracuda	*Sphyraena novaehollandiae*	Other
36002	Pygmy Barracuda	*Sphyraena obtusata*	Other
36006	Slender Barracuda	*Sphyraena putnamiae*	Other
36005	Blackfin Barracuda	*Sphyraena qenie*	Other
36000	Barracudas	Sphyraenidae	Other
4301	Blue Sprat	*Spratelloides delicatulus*	Other
4305	Silver Sprat	*Spratelloides gracilis*	Other
39237	Blenny	*Stanulus seychellensis*	Other
35043	White-Bar Gregory	*Stegastes albifasciatus*	Other

35044	Pacific Gregory	*Stegastes fasciolatus*	Other
35045	Farmerfish	*Stegastes lividus*	Other
35046	Dusky Farmerfish	*Stegastes nigricans*	Other
702	Leopard Shark	*Stegastoma varium*	Other
21809	Panatella Silverside	*Stenatherina panatella*	Other
40648	Goby	*Stenogobius genivittatus*	Other
40649	Goby	*Stenogobius* sp.	Other
8900	Hatchetfishes	Sternoptichidae	Other
40650	Goby	*Stiphodon elegans*	Other
40651	Goby	*Stiphodon* sp.	Other
4408	Samoan Anchovy	*Stolephorus apiensis*	Other
4404	Indian Anchovy	*Stolephorus indicus*	Other
4407	Gold Esurine Anchovy	*Stolephorus insularis*	Other
4409	Caroline Islands Anchovy	*Stolephorus multibranchus*	Other
4403	West Pacific Anchovy	*Stolephorus pacificus*	Other
4499	Anchovy	*Stolephorus* sp.	Other
20703	Reef Needlefish	*Strongylura incisa*	Other
20705	Littoral Needlefish	*Strongylura leiura leiura*	Other
5638	Giant Esturine Moray	*Strophidon sathete*	Other
44512	Scythe Triggerfish	*Sufflamen bursa*	Other
44513	Halfmoon Triggerfish	*Sufflamen chrysoptera*	Other
44514	Bridle Triggerfish	*Sufflamen freanatus*	Other
32371	Symphysanid	*Symphysanodon typus*	Other
32370	Sympysanodon	Symphysanodontidae	Other
26418	Stonefish	*Synanceia verrucosa*	Other
5700	Cutthroat Eel	Synaphobranchidae	Other
5701	Cutthroat Eel	*Synaphobranchus* sp.	Other
43504	Cirlcled Dragonet	*Synchiropus circularis*	Other
43511	Ladd'S Dragonet	*Synchiropus laddi*	Other
45308	Morrison'S Dragonet	*Synchiropus morrisoni*	Other
43505	Ocellated Dragonet	*Synchiropus ocellatus*	Other
43510	Dragonet	*Synchiropus* sp.	Other
43506	Mandarin Fish	*Synchiropus splendidus*	Other
43509	Pipefish, Seahorse	Syngnathidae	Other
25800	Alligator Pipefish	*Syngnathoides biaculeatus*	Other
25815	Lizardfish	Synodontidae	Other
16000	2-Spot Lizardfish	*Synodus binotatus*	Other
16003	Clearfin Lizardfish	*Synodus dermatogenys*	Other
16007	Reef Lizardfish	*Synodus englemanni*	Other

16004	Blackblotch Lizardfish	*Synodus jaculum*	Other
16005	Variegatus Lizardfish	*Synodus variegatus*	Other
16006	Leaf Fish	*Taenianotus triacanthus*	Other
26419	Goby	*Taenioides limicola*	Other
40652	Giant Reef Ray	*Taeniura meyeni*	Other
2002	Crescent-Banded Grunter	*Terapon jarbua*	Other
29901	Thornfishes	Teraponidae	Other
29900	Smooth Puffers	Tetraodontidae	Other
26451	Mangrove Waspfish	*Tetraroge barbata*	Other
26450	Waspfishes	Tetrarogidae	Other
4402	Little Priest	*Thryssa baelama*	Other
27302	Broadhead Flathead	*Thysanophrys arenicola*	Other
27303	Longsnout Flathead	*Thysanophrys chiltonae*	Other
27301	Fringlip Flathead	*Thysanophrys otaitensis*	Other
34602	Tilapia	*Tilapia zillii*	Other
33701	Banded Archerfish	*Toxotes jaculator*	Other
33700	Archerfishes	Toxotidae	Other
25816	Double-Ended Pipefish	*Trachyramphus bicoarctata*	Other
44300	Spikefishes	*Triacanthodidae*	Other
1108	Reef Whitetip Shark	*Triaenodon obesus*	Other
37200	Sand Divers	Trichonotidae	Other
37201	Micronesian Sand-Diver	*Trichonotus sp*	Other
26600	Gurnards	Triglidae	Other
40653	Goby	*Trimma caesiura*	Other
40654	Goby	*Trimma naudei*	Other
40655	Goby	*Trimma okinawae*	Other
40658	Goby	*Trimma* sp. A	Other
40659	Goby	*Trimma* sp. B	Other
40656	Goby	*Trimma taylori*	Other
40657	Goby	*Trimma tevegae*	Other
40660	Goby	*Trimmatom eviotops*	Other
44702	3 Tooth Puffer	*Triodon bursarius*	Other
44701	3 Tooth Puffer	*Triodon macropterus*	Other
44700	Tripletooth Puffers	Triodontidae	Other
39000	Triplefins	Tripterygiidae	Other
20706	Keeled Houndfish	*Tylosurus acus melanotus*	Other
20704	Houndfish	*Tylosurus crocodilis crocodilis*	Other
39009	Longjaw Triplefin	*Ucla xenogrammus*	Other
37800	Stargazers	*Uranoscopidae*	Other

37801	Stargazer	*Uranoscopus* sp.	Other
2004	Porcupine Ray	*Urogymnus africanus*	Other
5639	Unicolor Snake Moray	*Uropterygius concolor*	Other
5660	Fiji Moray Eel	*Uropterygius fijiensis*	Other
5650	Brown-Spotted Snake Eel	*Uropterygius fuscoguttatus*	Other
5651	Gosline'S Snake Moray	*Uropterygius goslinei*	Other
5652	Moon Moray	*Uropterygius kamar*	Other
5642	Lg-Headed Snake Moray	*Uropterygius macrocephalus*	Other
5640	Marbled Snake Moray	*Uropterygius marmoratus*	Other
5641	Tidepool Snake Moray	*Uropterygius micropterus*	Other
5653	Lg-Spotted Snake Moray	*Uropterygius polyspilus*	Other
5643	Moray Eel	*Uropterygius supraforatus*	Other
5644	Moray Eel	*Uropterygius xanthopterus*	Other
2008	Roundray	*Urotrygon daviesi*	Other
40532	Glass Goby	*Valenciennea muralis*	Other
40663	Parva Goby	*Valenciennea parva*	Other
40533	Goby	*Valenciennea puellaris*	Other
40534	Goby	*Valenciennea sexguttatus*	Other
40536	Goby	*Valenciennea* sp.	Other
40535	Goby	*Valenciennea strigatus*	Other
40521	Goby	*Vanderhorstia ambanoro*	Other
40661	Goby	*Vanderhorstia lanceolata*	Other
40522	Goby	*Vanderhorstia ornatissima*	Other
44515	Guilded Triggerfish	*Xanthichthys auromarginatus*	Other
44516	Bluelined Triggerfish	*Xanthichthys careuleolineatus*	Other
44521	Crosshatch Triggerfish	*Xanthichthys mento*	Other
40713	Wriggler	*Xenishthmus* sp.	Other
40710	Flathead Wriggler	Xenisthmidae	Other
40712	Barred Wriggler	*Xenisthmus polyzonatus*	Other
44517	Triggerfish	*Xenobalistes tumidipectoris*	Other
39238	Blenny	*Xiphasia matsubarai*	Other
41250	Moorish Idols	Zanclidae	Other
41251	Moorish Idol	*Zanclus cornutus*	Other
20756	Esturine Halfbeak	*Zenarchopterus dispar*	Other
49400	ASSORTED REEF FISH	Misc. Reeffish	Misc. Reeffish
49110	SHALLOW BOTTOMFISH	Misc. Shallow bottomfish	Misc. Shallow bottomfish

49100	ASSORTED BOTTOMFISH	Misc. Bottomfish	Misc. Bottomfish
72600	Crown-Of-Thorns	*Acanthaster planci*	Other Invertebrates
79301	Stonefish	*Actinopyga lecanora*	Other Invertebrates
79302	Blackfish	*Actinopyga miliaris*	Other Invertebrates
79303	Sea Cucumber	*Actinopyga obesa*	Other Invertebrates
79304	Sea Cucumber	*Actinopyga sp*	Other Invertebrates
72500	Starfish	Asterinidae	Other Invertebrates
72400	Starfish	Asteropidae	Other Invertebrates
72100	Starfish	Astropectinidae	Other Invertebrates
79801	Sea Cucumber	*Bohadschia argus*	Other Invertebrates
79802	Sea Cucumber	*Bohadschia graeffei*	Other Invertebrates
79803	Brown Sandfish	*Bohadschia marmorata*	Other Invertebrates
79804	Sea Cucumber	*Bohadschia paradoxa*	Other Invertebrates
79805	Sea Cucumber	*Bohadschia* sp.	Other Invertebrates
78900	Irregular Urchins	Brissidae	Other Invertebrates
97100	Jellyfish	*Cephea* sp.	Other Invertebrates
78100	Cidarians	Cidaridae	Other Invertebrates
71000	Crinoids	Class Crinoidea	Other Invertebrates
78000	Sea Urchins	Class Echinoidea	Other Invertebrates
78800		Clypeasteridae	Other Invertebrates
79400	Sea Cucumbers	Cucumariidae	Other Invertebrates
78301	Longspine Urchin	*Diadema savignyi*	Other Invertebrates
78302	Longspine Urchin	*Diadema setosum*	Other Invertebrates
78300	Sea Urchins	Diadematidae	Other Invertebrates
78700	Sea Urchins	Echinoidea	Other Invertebrates
78600	Sea Urchins	Echinometridae	Other Invertebrates
72800	Reef Starfish	Echinosteridae	Other Invertebrates
78304	Longspine Urchin	*Echinothrix calamaris*	Other Invertebrates
78303	Longspine Urchin	*Echinothrix diadema*	Other Invertebrates
78200	Sea Urchins	Echinothuriidae	Other Invertebrates
78605	Slate Pencil Urchin	Heterocentrotus mammillatus	Other Invertebrates
79201	Lollyfish	Holothuria atra	Other Invertebrates
79202	Pinkfish	Holothuria edulis	Other Invertebrates
79203	White Teatfish	*Holothuria fuscogilva*	Other Invertebrates
79204	Elephant'S Trunkfish	*Holothuria fuscopunctata*	Other Invertebrates
79205	Sea Cucumber	*Holothuria hilla*	Other Invertebrates
79206	Sea Cucumber	*Holothuria impatiens*	Other Invertebrates
79207	Sea Cucumber	*Holothuria leucospilota*	Other Invertebrates

79208	Sea Cucumber	*Holothuria* sp	Other Invertebrates
79200	Sea Cucumber	Holothuriidae	Other Invertebrates
79000	Sea Cucumbers	Holothuroidea	Other Invertebrates
72700	Spiney-Armed Starfish	*Mithrodia bradleyi*	Other Invertebrates
72300	Orange Starfish	*Ophidiaster confertus*	Other Invertebrates
72200	Starfish	Oreasteridae	Other Invertebrates
79500	Sea Cucumbers	Phyllophoridae	Other Invertebrates
78503	Common Urchin	*Pseudoboletia maculata*	Other Invertebrates
72000	Starfish	Asteroidea	Other Invertebrates
75000	Basket, Brittle, Serpentstars	Ophiuroidea	Other Invertebrates
72900	Starfish	Sphaerasteridae	Other Invertebrates
79100	Sea Cucumbers	Stichopodidae	Other Invertebrates
79101	Greenfish	*Stichopus chloronotus*	Other Invertebrates
79102	Sea Cucumber	*Stichopus horrens*	Other Invertebrates
79103	Sea Cucumber	*Stichopus noctivatus*	Other Invertebrates
79105	Sea Cucumber	*Stichopus* sp.	Other Invertebrates
79104	Curryfish	*Stichopus variegatus*	Other Invertebrates
79601	Sea Cucumber	*Synapta maculata*	Other Invertebrates
79602	Sea Cucumber	*Synapta media*	Other Invertebrates
79603	Sea Cucumber	*Synapta* sp.	Other Invertebrates
79600	Sea Cucumbers	Synaptidae	Other Invertebrates
78400	Sea Urchins	Temnopleuridae	Other Invertebrates
79901	Prickly Redfish	*Thelenota ananas*	Other Invertebrates
79902	Amberfish	*Thelenota anax*	Other Invertebrates
79903	Sea Cucumber	*Thelenota* sp.	Other Invertebrates
78502	Flower Urchin	*Toxopneustes pileolus*	Other Invertebrates
78500	Shortspine Urchins	Toxopneustidae	Other Invertebrates
78501	Shortspine Urchin	*Tripneustes gratilla*	Other Invertebrates

APPENDIX B. LIST OF PROTECTED SPECIES AND DESIGNATED CRITICAL HABITAT

Table B-1. Protected species found or reasonably believed to be found in or near Mariana Archipelago waters.

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Seabirds						
Wedge-Tailed Shearwater	*Ardenna pacifica*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Streaked Shearwater	*Calonectris leucomelas*	Not Listed	N/A	Rare visitor	Guam	Wiles 2003
Short-Tailed Shearwater	*Ardenna tenuirostris*	Not Listed	N/A	Common visitor	Both	Wiles 2003
Newell's Shearwater[a]	*Puffinus newelli (Puffinus auricularis newelli)*	Endangered	N/A	Rare visitor	Both	40 FR 44149, Wiles 2003
Audubon's Shearwater	*Puffinus lherminieri*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Matsudaira's Storm-Petrel	*Oceanodroma matsudairae*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
White-Tailed Tropicbird	*Phaethon lepturus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Red-Tailed Tropicbird	*Phaethon rubricauda*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Masked Booby	*Sula dactylatra*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Brown Booby	*Sula leucogaster*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Red-Footed Booby	*Sula sula*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Great Frigatebird	*Fregata minor*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Lesser Frigatebird	*Fregata ariel*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Black-Headed Gull	*Chroicocephalus ridibundus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Gull-Billed Tern	*Gelochelidon nilotica*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Great Crested Tern	*Thalasseus bergii*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Common Tern	*Sterna hirundo*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Black-Naped Tern	*Sterna sumatrana*	Not Listed	N/A	Rare visitor	Guam	Wiles 2003
Little Tern	*Sternula albifrons*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Sooty Tern	*Onychoprion fuscatus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
White-Winged Tern	*Chlidonias leucopterus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Brown Noddy	*Anous stolidus*	Not Listed	N/A	Common resident	Both	Wiles 2003
Black Noddy	*Anous minutus*	Not Listed	N/A	Common visitor	Both	Wiles 2003
White Tern	*Gygis alba*	Not Listed	N/A	Common resident	Both	Wiles 2003
Short-Tailed Albatross	*Phoebastria albatrus*	Endangered	N/A	Breed in Japan and NWHI, and range across the North Pacific Ocean. Potential range includes the Marianas archipelago.	N/A	35 FR 8495, 65 FR 46643, BirdLife International 2017
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Black-Footed Albatross	*Phoebastria nigripes*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
White-Necked Petrel	*Pterodroma cervicalis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Bonin Petrel	*Pterodroma hypoleuca*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Black-Winged Petrel	*Pterodroma nigripennis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Bulwer's Petrel	*Bulweria bulwerii*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Christmas Shearwater	*Puffinus nativitatis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Band-Rumped Storm-Petrel	*Oceanodroma castro*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Long-Tailed Jaeger	*Stercorarius longicaudus*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Laughing Gull	*Leucophaeus atricilla*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Herring Gull	*Larus argentatus*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Gray-Backed Tern	*Onychoprion lunatus*	Not Listed	N/A	Uncommon resident	CNMI	Wiles 2003
Sea Turtles						
Green Sea Turtle	*Chelonia mydas*	Endangered (Central West Pacific DPS)	N/A	An estimated 1000-2000 turtles forage in Guam/CNMI waters. Particularly common in winter and late spring.	Both	43 FR 32800, 81 FR 20057, Kolinski et al. 2000, Pritchard 1982, Honigman 1994
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered[b]	N/A	Small population nesting and foraging around Guam. Occur worldwide in tropical and subtropical waters.	Both	35 FR 8491, NMFS & USFWS 2007, Baillie & Groombridge 1996
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered[b]	N/A	Occasional sightings. Occur worldwide in tropical, subtropical, and subpolar waters.	Guam	35 FR 8491, Eldredge 2003, Eckert et al. 2012

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Loggerhead Sea Turtle	*Caretta caretta*	Endangered (North Pacific DPS)	N/A	No known sightings. Found worldwide along continental shelves, bays, estuaries and lagoons of tropical, subtropical, and temperate waters.	N/A	43 FR 32800, 76 FR 58868, Dodd 1990, USFWS 2005
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened (Entire species, except for the breeding population on the Pacific coast of Mexico, which is listed as endangered)	N/A	Believed to occasionally transit through area.	N/A	43 FR 32800, Starmer et al. 2005
Marine mammals						
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Non-strategic	Found worldwide in tropical and temperate waters.	CNMI	Mead 1989
Blue Whale	*Balaenoptera musculus*	Endangered	Strategic	No known sightings in CNMI but occur worldwide in tropical and warm-temperate waters. Known to occur in the western North Pacific.	N/A	35 FR 18319, McDonald et al. 2006, Stafford et al. 2001
Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Non-strategic	Distributed worldwide in tropical and warm-temperate waters	Both	Perrin et al. 2009
Bryde's Whale	*Balaenoptera edeni*	Not Listed	Non-strategic	Distributed widely across tropical and warm-temperate Pacific Ocean.	CNMI	Leatherwood et al. 1982
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Non-strategic	Occur worldwide.	CNMI	Heyning 1989
Dugong	*Dugong dugong*	Endangered	N/A (managed by USFWS)	Extremely rare. One confirmed sighting in Guam in 1975, and multiple anecdotal reports in Guam in 1985.	Guam	Randall et al. 1975, Eldredge 2003
Dwarf Sperm Whale	*Kogia sima*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Both	Nagorsen 1985
False Killer Whale	*Pseudorca crassidens*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	CNMI	Stacey et al. 1994
Fin Whale	*Balaenoptera physalus*	Endangered	Strategic	Infrequent sightings, occur throughout the North Pacific Ocean.	N/A	35 FR 18319, Oleson et al. 2015, Mizroch et al. 2009
Fraser's Dolphin	*Lagenodelphis hosei*	Not Listed	Non-strategic	Found worldwide in tropical waters.	CNMI	Perrin et al. 2009

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Humpback Whale	*Megaptera novaeangliae*	Endangered (Western North Pacific DPS)	Strategic	Occasional sightings in Guam/CNMI waters during winter breeding season.	Both	35 FR 18319, 81 FR 62259, Guarrige et al. 2007, SPWRC 2008
Killer Whale	*Orcinus orca*	Not Listed	Non-strategic	Found worldwide. Prefer colder waters within 800 km of continents.	Guam	Leatherwood & Dalheim 1978, Mitchell 1975, Baird et al. 2006
Longman's Beaked Whale	*Indopacetus pacificus*	Not Listed	Non-strategic	Found in tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa.	CNMI	Dalebout 2003
Melon-Headed Whale	*Peponocephala electra*	Not Listed	Non-strategic	Found in tropical and warm-temperate waters worldwide, primarily found in equatorial waters.	Both	Perryman et al. 1994
Minke Whale	*Balaenoptera acutorostrata*	Not Listed	Non-strategic	Uncommon in this region, usually seen over continental shelves in the Pacific Ocean.	CNMI	Brueggeman et al. 1990
Northern Elephant Seal	*Mirounga angustirostris*	Not Listed	Non-strategic	Females migrate to central North Pacific to feed on pelagic prey	N/A	Le Beouf et al. 2000
Pantropical Spotted Dolphin	*Stenella attenuata attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide.	Both	Perrin et al. 2009
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide.	CNMI	Ross & Leatherwood 1994
Pygmy Sperm Whale	*Kogia breviceps*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Guam	Caldwell & Caldwell 1989
Risso's Dolphin	*Grampus griseus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Both	Perrin et al. 2009
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	CNMI	Perrin et al. 2009
Sei Whale	*Balaenoptera borealis*	Endangered	Strategic	Extremely rare. Generally found in offshore temperate waters.	CNMI	35 FR 18319, Barlow 2003, Bradford et al. 2013
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Both	Shallenberger 1981, Baird et al. 2013, Bradford et al. 2013
Sperm Whale	*Physeter macrocephalus*	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the	Both	35 FR 18319, Rice 1960, Barlow 2006,

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
				region. Regularly sighted in waters around CNMI.		Lee 1993, Mobley et al. 2000, Shallenberger 1981
Spinner Dolphin	*Stenella longirostris*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters. Occur in shallow protected bays during the day, feed offshore at night.	Both	Norris and Dohl 1980, Norris et al. 1994, Hill et al. 2010, Andews et al. 2010, Karczmarski 2005, Perrin et al. 2009
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world	Both	Perrin et al. 2009
Elasmobranchs						
Giant manta ray	*Manta birostris*	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs.	Both	Dewar et al. 2008, Marshall et al. 2009, Marshall et al. 2011.
Oceanic whitetip	*Carcharhinus longimanus*	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C	Both	Bonfil et al. 2008, Backus et al, 1956, Strasburg 1958, Compagno 1984
Scalloped hammerhead	*Sphyrna lewini*	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m. Guam's inner Apra Harbor is a nursery habitat.	Both	Compagno 1984, Schulze-Haugen & Kohler 2003, Sanches 1991, Klimley 1993
Corals						
N/A	*Acropora globiceps*	Threatened	N/A	Occur on upper reef slopes, reef flats, and adjacent habitats in depths ranging from 0 to 8 m.	Both	Veron 2014

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
N/A	*Acropora retusa*	Threatened	N/A	Occur in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons, and depth range is 1 to 5 m.	Both	Veron 2014
N/A	*Seriatopora aculeata*	Threatened	N/A	Found in broad range of habitats including, but not limited to, upper reef slopes, mid-slope terraces, lower reef slopes, reef flats, and lagoons, and depth ranges from 3 to 40 m.	Both	Veron 2014

[a] Birds recorded in CNMI (including Guam) as Townsend's or Manx Shearwaters prior to the resolution of the Manx Shearwater complex were probably Newell's Shearwaters based on morphology and distribution (Drahos 1977, Wiles 2003).
[b] These species have critical habitat designated under the ESA. See Table B-2.

Table B-2. ESA-listed species' critical habitat in the Pacific Ocean[a].

Common Name	Scientific Name	ESA Listing Status	Critical Habitat	References
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered	None in the Pacific Ocean.	63 FR 46693
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Approximately 16,910 square miles (43,798 square km) stretching along the California coast from Point Arena to Point Arguello east of the 3,000 meter depth contour; and 25,004 square miles (64,760 square km) stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meter depth contour.	77 FR 4170
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered	Ten areas in the Northwestern Hawaiian Islands (NWHI) and six in the main Hawaiian Islands (MHI). These areas contain one or a combination of habitat types: Preferred pupping and nursing areas, significant haul-out areas, and/or marine foraging areas, that will support conservation for the species.	53 FR 18988, 51 FR 16047, 80 FR 50925
North Pacific Right Whale	*Eubalaena japonica*	Endangered	Two specific areas are designated, one in the Gulf of Alaska and another in the Bering Sea, comprising a total of approximately 95,200 square kilometers (36,750 square miles) of marine habitat.	73 FR 19000, 71 FR 38277

[a] For maps of critical habitat, see http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm.

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APPENDIX C: CRUSTACEAN LIFE HISTORY AND HABITAT REVIEW

OVERVIEW

This report presents a literature review of the life history and habitat requirements for each life stage for four species of reef-associated crustaceans that are landed in commercial fisheries Western Pacific region: two species of spiny lobster (*Panulirus marginatus* and *Scyllarides squammosus*), scaly slipper lobster (*Scyllarides squammosus*), and Kona crab (*Ranina ranina*).The most up to date information on the species distribution, fisheries in the Western Pacific Region, and life history is summarized. Tables summarizing the multiple dimensions of habitat use for each life stage (egg, larvae, post-larvae, juvenile, and adult) are also provided. The purpose of this report is to provide guidance in reviewing and updating essential fish habitat for reef associated crustaceans in the Western Pacific region.

1. HAWAIIAN SPINY LOBSTER (*PANULIRUS MARGINATUS)*

1.1. GENERAL DESCRIPTION AND DISTRIBUTION

Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida, 1986; FAO, 1991).The Hawaiian spiny lobster (*Panulirus marginatus*), also known as ula and banded spiny lobster, is endemic to the Hawaiian Archipelago and Johnston Atoll (Brock, 1973; Polovina and Moffitt, 1995). The highest abundances of spiny lobster are found in the Northwestern Hawaiian Islands (NWHI; Uchida and Tagami, 1984). A single male spiny lobster has been collected in the shallow waters of Johnston Atoll, but it is unknown if an established reproducing population exists here (Brock, 1973).

Although *P. marginatus* has a long pelagic larval duration, the spiny lobster exhibits significant population structure across the Hawaiian Archipelago with regional differentiation between the NWHI and main Hawaiian islands (MHI; Lacchei *et al.,* 2014). Larval exchange between populations in the MHI and NWHI is minimal and if it does occur, it is more likely larvae are transported from the MHI to NWHI than vice versa (Lacchei *et al.,* 2013).

From the mid-1970s to 1999 spiny lobsters were targeted in a commercial trap fishery in the NWHI (O'Malley, 2004). The NWHI commercial fishery was composed of 9-14 vessels, setting about 80 traps per day and taking 3, approximately 8 week trips per year (Polovina and Mitchum, 1992). Total effort in the commercial fishery was approximately 1 million trap hauls per year (Polovina *et al.,* 1995). Necker Island and Maro Reef accounted for over 60% of all lobster landings (Polovina and Mitchum, 1992).

1.2. FISHERIES

In 1983, a requirement for NWHI commercial lobsters fishers to submit logbooks was implemented and the fishery was managed with a minimum size of 5 cm tail-width (7.5 cm carapace length or CL) and no trapping in areas < 18 m. The depth restriction was to minimize disturbance to the Hawaiian monk seal (Parrish and Polovina, 1994). In 1996, a retain all regulation was implemented and replaced the 5 cm tail width (TL) minimum size due to the high discard mortality rate.

The NWHI commercial spiny lobster fishery peaked in 1985 with total landings exceeding 2.5 million pounds. After 1985, CPUE began to steadily decline, which has been attributed to a number of causes. In 1990, there was a recruitment collapse, which was attributed to climate change and shifts in the ecosystem's productivity (Polovina *et al.,* 1995). After this recruitment collapse, fishing continued and reduced the spawning stock biomass to low levels (Polovina *et al.,* 1995). In 2000, NMFS closed the NWHI spiny lobster fishery due to increasing uncertainty in the assessment of the population; area-based commercial closures from the NWHI Coral Reef Ecosystem Reserve in 2001 and the complete prohibition on commercial fishing in the Papahānaumokuākea Marine National Monument in 2006 have maintained the closure. Since the closure of the commercial fishery in 2000, there has been no evidence that the NWHI spiny lobster population has recovered (O'Malley, 2011; Lacchei *et al.,* 2014).

Currently, fewer than three commercial fishers in the MHI land spiny lobster with traps (NOAA Fisheries, 2017a), and approximately 19 commercial dive fishers land spiny lobsters (NOAA Fisheries, 2017b). In 2015, 5,744 lbs. of spiny lobster where landed commercially in the MHI fishery (DAR, 2015). Spiny lobsters are also targeted and landed by recreational and subsistence fishers in the MHI, but the extent of this fishery is unknown (MacDonald and Thompson, 1987). Management for the spiny lobster in the MHI includes a closed season from May-August, no taking of female lobsters, no spearing, and a minimum size of 3.25 inch CL.

1.3. LIFE HISTORY

1.3.1. GROWTH, MATURITY, MOVEMENT, AND NATURAL MORTALITY

Hawaiian spiny lobsters exhibit sexual dimorphism in growth with males growing faster than females (O'Malley, 2009). While temporal and spatial variation in growth rates for *Panulirus sp*. is uncommon, the temporal, spatial, and individual growth rates of spiny lobsters found in the NWHI is the highest that has ever been reported for any *Panulirus* species (O'Malley, 2009). The cause of the large variation in growth rates is unknown, but may be attributed to variability in prey regimes and/or environmental conditions (O'Malley *et al.,* 2012).

Growth in spiny lobsters is stepwise as they get larger by molting and difficult to describe with a continuous von Bertalanffy relationship (O'Malley and MacDonald, 2009). The molting process consists of 8 discrete stages (Lyle and MacDonald 1983). Mean annual growth rates of tagged male lobsters with a 75 mm CL varied between 3.55 to 15.85 mm, and the annual average growth rate of 70 mm CL tagged female lobsters varied between 1.866 mm to 15.84 mm (O'Malley and MacDonald, 2009).

Size at which female lobsters reach sexual maturity also varies spatially and temporally, and may be associated with density dependence (Polovina, 1989; DeMartini *et al.,* 2003). Estimates of onset of sexual maturity for females range between 57.99 mm CL and 74.8 mm CL (Polovina, 1989). The onset of female maturity was reportedly lower in banks after 10 years of heavy exploitation, which Polovina hypothesizes may be a compensatory response (Polovina, 1989).

Although the longevity of this species is not known, other tropical spiny lobster species live up to 20 years (Butler and MacDiarmid 2011). Annual natural mortality likely varies with size but is estimated on average to be 0.456 (Haight and Polovina, 1993)

1.3.2. REPRODUCTION

Female fecundity increases with both carapace length and tail-width (Honda, 1980; DeMartini *et al.,* 2003). Female lobsters have between 114,000 and 782,000 eggs per brood, and may have multiple broods per spawning season (DeMartini *et al.,* 2003). A 36% increase in average fecundity and a 5% increase in egg diameter was observed over a 30-year period and attributed to a compensatory response to decreased lobster densities and increased per capita food resources as a result of either natural cyclic declines in productivity and/or high exploitation rates from the commercial fishery (DeMartini *et al.,* 1993; DeMartini *et al.,* 2003). This increase in fecundity and egg size coincided with compensatory declines in size at maturity (DeMartini *et al.,* 2003).

Hawaiian spiny lobsters are dioecious and fertilization occurs externally (Uchida, 1986). Mature males will deposit a spermatophore on a mature females' abdomen (Uchida, 1986). Females then release the ova from the oviduct and simultaneously scratch and break the spermatophore open to release spermatozoa, which fertilize the eggs (WPRFMC, 1983). Females attach the fertilized eggs to setae of the female's pleopod. The eggs are visible and females carrying fertilized eggs on the pleopod are referred to as 'berried'. Females carry fertilized eggs for 30-40 days until they hatch into planktonic, pelagic larvae (Morris, 1968). Brooded eggs are orange when first extruded and change to a brown color before hatching (DeMartini *et al.,* 2003).

The spawning season of *P. marginatus* appears to vary within the NWHI chain. Around Nihoa, Necker Island, and French Frigate Shoals, ovigerous females occur in late summer and early winter; toward the northwestern end of the chain, ovigerous females are more abundant in early summer (Uchida *et al.,* 1980). Off O'ahu spawning has been throughout the year and peak activity is concentrated in May-August and low activity is apparent in November-January (McGinnis, 1972).

1.3.3. LARVAE AND RECRUITMENT

After hatching, pelagic phyllosoma larvae, drift in the ocean currents for 12 months and pass through 11 stages of development (MacDonald, 1986; Polovina and Moffitt, 1995). Larval phyllosoma make diurnal movements from 80-100 m during the day, to 10-20 m at night, and are found in high abundance on the surface at night during the new moon (Polovina and Moffitt 1995). Abundance of late stage phyllosomes are higher offshore (up to 25 nmi from 200 m contour) relative to the 200-m contour, which may be explained by either oceanographic currents and nearshore topography pushing larvae offshore and/or higher predation in nearshore areas (Polovina and Moffitt 1995). Although spiny lobsters have a long pelagic duration, banks differ substantially in the proportion of larvae they retain from resident spawners, as well as the portion of larvae they receive from other banks (Polovina *et al.,* 1999). Oceanographic processes such as the strength of the Subtropical Counter Current (SCC) at 26° N latitude, where it intersects with the Hawaiian Ridge and sea level height, play a large role in determining larval retention rates and survival of the pelagic phyllosoma. A high abundance of late stage larvae are found at 26° N suggesting recruitment is linked to the strength of the SCC (Polovina and Moffit, 1995).

This relationship is especially clear at Maro Reef in the NWHI, where a clear trend exists between sea level height and recruitment to the fishery 4 years later (Polovina *et al.,* 1995).

After 12 months, phyllosoma metamorphose into free swimming post-larval pueruli (Polovina and Moffitt, 1995). Pueruli actively swim to shallow, nearshore waters in preparation for settlement (MacDonald, 1986). Settlement is generally higher at the center of the Hawaiian Archipelago relative to the ends, and higher in the NWHI than the MHI (MacDonald, 1986). Other species of spiny lobster pueruli are capable horizontal, directed swimming of up to 40-60 km, but it is unknown how far pueruli of Hawaiian spiny lobster are able to move horizontally before settling (Pearce and Phillips, 1994). Large pulses in larvae settlement occur during new moon and first quarter lunar phase (MacDonald, 1986). However, seasonal, interannual, and geographic patterns of recruitment vary, which are determined to some extent by larval availability resulting from oceanographic conditions such as the strength of the subtropical counter current (MacDonald, 1986; Mitchum and Polovina, 1992; Polovina and Mitchum, 1994; Polovina and Moffitt, 1995; Polovina *et al.,* 1999).

Pueruli settle in depths between 1 and 30 m, and at low densities relative to other spiny lobster species (MacDonald, 1989; Polovina and Moffitt, 1995). While other *Panulirus* sp. use shallow nearshore algal, seagrass, and mangrove roots as nurseries, these types of habitats are poorly represented in Hawaii (MacDonald and Stimson, 1980). In the NWHI, there was no correlation found between shallow habitat and fishery production, suggesting that lobster pueruli may recruit directly to deeper waters from the pelagic habitat relative to other tropical lobster species (Parrish and Polovina, 1994). Upon settling, puerulus molts into the postpuerulus stage, typically around the time of the full moon (Macdonald, 1986).

1.3.4. JUVENILE STAGE

Although post-larval recruitment is influenced by the abundance of pueruli in the banks surrounding waters, differences in adult production between banks in the NWHI is also driven by availability of juvenile habitat (Parrish and Polovina, 1994; Polovina *et al.,* 1995). The habitat requirements of juvenile spiny lobsters are believed to be the bottleneck for adult lobster abundance (Parrish and Polovina, 1994). Observations of small lobsters between 1 and 30 m provide evidence that 30 m is the deepest that lobster larvae are able to settle (Polovina and Moffit, 1995). The highest abundances of juveniles are found in benthic habitat with intermediate (5-30 cm) vertical relief (Parrish and Polovina, 1994). Lower densities of juvenile lobster are found in habitats with low vertical relief (< 5 cm) and high vertical relief (>30 cm) (Parrish and Polovina, 1994). Intermediate vertical relief is provided by scattered coral colonies and algal fields, which are common habitats in the 2 most historically productive fishing grounds at Necker Island and Maro Reef (Parrish and Polovina, 1994). The intermediate vertical relief benthic habitat likely represents a compromise between shelter and abundance of predators; it is enough relief to provide some shelter, but in habitats with relief > 30 cm predatory reef fish such as sharks and jacks that prey on juvenile lobsters are more abundant.

Not only do benthic algae provide shelter, it may also play a role in the trophic ecology of lobsters (MacDiarmid *et al.,* 1991). Macroalgae that provide intermediate vertical relief found in the NWHI include *Dictopterus* sp., *Sargassum* sp., and *Padina* sp. Algal presence and growth is closely associated with temperature, thus northerly banks may be more susceptible to cooling and loss of algae cover resulting in reduced recruitment, increased natural predation, and potentially a reduction in food available to lobsters (Parrish and Polovina, 1994).

1.3.5. ADULT STAGE

Adult lobsters recruit to the fishery approximately 3 years after settling on to benthic habitat, which is slightly larger than the onset of sexual maturity (MacDonald 1985; Polovina and Mitchum, 1992). Generally adult lobsters are found in depths between 20 and 150 m at banks with summits less than 30 m deep, and do not move between banks, which can have depths over 4,000 m (Parrish and Polovina, 1994; Polovina *et al.,* 1995). The depth with highest abundance of lobsters varies with latitude and is likely a result of temperature (Uchida and Tagami, 1984). In the southern portion of the NWHI highest abundances were found in depths from 37 and 64 m, but north of Gardener Pinnacles higher abundances were found in depths of 10 to 36 m. Commercial fishers frequently fish in depths between 20 and 70 m (Polovina, 1993).

Vertical relief of habitat is not found to be correlated with adult lobster abundance (Parrish and Polovina, 1994). Perhaps this is because adult lobsters are less vulnerable to predators (Parrish and Polovina, 1994). Adult lobsters are often found in cracks and crevices of reefs, have been observed moving across open sandy areas between reef patches in pairs (MacDonald 1984), and are also found on the banks of deep slopes that are characterized by 'heavy seas, strong bottom surge, and swift currents' (Parrish and Kazama, 1994).

Unlike other *Panulirus* sp., adult lobsters do not undergo significant migrations. Tag and recapture studies in the NWHI found that the majority of lobsters moved < 1 km after over a year at liberty (O'Malley and Walsh, 2013). Limited movement patterns are likely because juvenile and adult lobster habitats are the same, offshore currents are within reach of newly hatched larvae, and the NWHI do not experience large seasonal shifts in water temperature (O'Malley and Walsh 2013).

P. marginatus are nocturnal predators (FAO, 1991) and are regarded as omnivorous, opportunistic scavengers (Pitcher, 1993). Food items reported from the diets of *Panulirus sp*. include echinoderms, crustaceans, mollusks (primarily gastropods), algae, and seagrass (Pitcher 1993). Catchability of spiny lobsters does not appear to be related to seasonal or lunar changes (MacDonald and Stimson, 1980)

1.4. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg	30-40 days (Morris,1968)	N/A	benthic (brooded by females)	N/A	N/A	N/A
Larvae (phyllosoma)	12 months (Polovina and Moffit, 1995)	N/A	80-100 m (daytime) 10- 20 m (night) (Polovina and Moffit, 1995).	Offshore (25 nmi from 200 nm contour) (Polovina and Moffit, 1995)	N/A	strength of the Subtropical Counter Current (SCC) at 26° N latitude and sea level height (Polovina, 1999)
Post-pueruli and Juvenile	~3 years (Polovina and Moffit, 1989)	N/A	1-30 m (Polovina and Moffit, 1995)	Settlement higher at center of Archipelago and in NWHI (MacDonald, 1986)	benthic habitat with intermediate (5-30 cm) vertical relief (Parrish and Polovina, 1994)	Temperature** (Polovina and Parrish, 1994)
Adult	Up to 20 years (Butler and MacDiarmid, 2011)*	echinoderms, crustaceans, mollusks, (primarily gastropods) algae, and seagrass (Pitcher, 1993)	between 20 and 150 m at banks with summits < 30 m deep (Polovina *et al.*, 1995)	Highest abundances in NWHI Maro Reef and Necker Island (Lacchei *et al.*, 2014)	Slopes of banks with rocky substrate or found in cracks and crevices in coral reef habitat (Polovina, 1989; Pitcher, 1993)	High abundance found in areas with heavy seas (4-6 ft.), strong bottom surge, and swift currents (1-2 knots) (Parrish and Kazama 1994) Also found in calm lagoon areas in the NWHI(Lacchei and Toonen, 2013)

*Based on other species of spiny lobster.
**Algal cover that provides intermediate relief habitat utilized by juveniles is impacted by temperature.

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2. RED SPINY LOBSTER (*PANULIRUS PENCILLATUS*)

2.1. SPECIES DESCRIPTION AND DISTRIBUTION

Panulirus pencillatus also known as the ula, red spiny lobster, and proghorn spiny lobsters, is found from the Indo-West to the Eastern Pacific, the widest known geographic distribution of any spiny lobster species (Cockcroft *et al.,* 2011). Two genetically distinct populations have been identified between the western/central and eastern Pacific (Abdullah *et al.,* 2014). The common name of the species comes from the body color of individuals found in the eastern Pacific, which is less fitting for *P. pencillatus* with a greenish body color that are found in the western/central Pacific (Abdullah *et al.,* 2014).

2.2. FISHERIES

Red spiny lobster is targeted by lobster fisheries throughout its range, and is considered overexploited in many regions (Cockcroft *et al.,* 2011). Due to its relatively shallow depth preference, it most typically is targeted using hands from spearfishers, or fishers who walk along the reef flat at night (Coutures, 2003). In the Western Pacific region, fisheries exist for the red spiny lobster in American Samoa, CNMI, Guam, and the MHI (McGinnis, 1972; Coutures, 2003; Porter *et al.,* 2005). It is the most abundant lobster species in American Samoa, one of the top landed invertebrate species in CNMI and has been heavily exploited in the MHI. Although not targeted in the NWHI lobster fishery, red spiny lobsters were landed in low numbers (DiNardo and Moffit, 2007).

2.3. LIFE HISTORY

2.3.1. GROWTH, MATURITY, NATURAL MORTALITY, AND MOVEMENT

Like other lobster species, *P. pencillatus* growth is step-wise and body size increases by molting (Coutures, 2003). Reported growth rates vary substantially by region and are likely affected by local factors such as temperature and growth. Growth rates are generally high in juveniles and decrease with age, specifically at the onset of maturity, when more energy is devoted towards reproductive growth and molting becomes less frequent (Courtes, 2003).

P. pencillatus are sexually dimorphic, males reach larger sizes and grow faster than females (Coutures, 2003). Size at 50% sexual maturity in the Western Pacific region is estimated at 6 cm CL, approximately 2-3 years after settling in benthic habitat (Ebert and Ford, 1986; Coutures, 2003). The largest male is reported as 16 cm carapace length (Richer de Forges and Laboute, 1995).

Although natural mortality rates (*M*) vary with size and age, an average *M* of 0.25 per year was estimated for lobsters in CNMI (Ebert and Ford, 1986). Large males may be more vulnerable to predation due to difficulty finding large dens (Coutures, 2003). Large males may be absent on reefs where large dens are not available due to high predation rates. Although specific mortality rates have not been reported for this species, other spiny lobsters lived up to 20 years (Butler and MacDiarmid, 2011).

2.3.2. REPRODUCTION

Spawning season varies by location. For example, Enewetak Atoll in the Marianas has a peak in berried females during the spring, while the presence of berried females in another nearby atoll peaked in the fall (Ebert and Ford, 1986). In Hawaiʻi, berried females are found throughout the year (MacDonald, 1971). The drivers behind seasonality of spawning are not known, but may be related to environmental factors such as temperature (Ebert and Ford 1986).

The relationship between size and fecundity of females is exponential, and females may spawn 2-3 times per year (MacDonald, 1971; Pitcher, 1992). Like other spiny lobster species, fertilization is external and occurs when the male deposits a spermatophore on the abdomen of the female which she scratches off to fertilize extruded eggs. Eggs are brooded for approximately one month before hatching as pelagic larvae (Chubb, 1994). Females release eggs in areas that allow the pelagic larvae to quickly drift offshore (Coutures, 2000).

2.3.3. LARVAE AND RECRUITMENT

Phyllosoma larvae drift in the pelagic environment for up to 8-9 months before settling (Matsuda *et al.,* 2006) where they are carried up to 3,700 km by ocean currents and gyres (Johnson, 1974). In larval tows across the Hawaiian archipelago, *P. pencillatus* phyllosoma were found in high abundance near Oʻahu, but were not present in any tows east of French Frigate or off of Midway Atoll (Johnson, 1968).

Limited information is available about *P. pencillatus* recruitment in the Western Pacific region, but they are believed to settle in the same benthic habitat utilized by adults, near the outer reef break (Coutures, 2003). In French Polynesia, *P. pencillatus* post-larvae make active settlement choices, with highest preference towards dead coral (Lecchini *et al.,* 2010). Recruitment also occurred on live coral, macroalgae, and sand (Lecchini *et al.,* 2010).

2.3.4. JUVENILE STAGE

No juvenile specific information was found in the literature, but they are thought to inhabit the same areas as adult lobster (Coutures, 2003).

2.3.5. ADULT STAGE

Red spiny lobsters occupy relatively shallow depths from 1-16 m deep on small islands or near arid coasts (Holthuis, 1991). In the Western Pacific adults are found in clear waters near fringing or reefs slopes that are exposed to high wave energy, habitat that is typically found on the windward exposure of islands in depths up to 5 m (George, 1992; Ebert and Ford, 1986). *P. pencillatus* are nocturnal, hiding in protected caves and corals, or under boulders during the day that are present in lagoons and the outer reef slope (George, 1972; MacDonald, 1979; Coutures, 2003). At night, lobster move up the spurs and grooves of surge channels at the reefs edge and into shallow reef flats to forage (Coutures, 2003).

P. pencillatus have a robust pereiopod, which may be an advantageous adaption that allows foraging in shallow, high energy wave environments where rates of foraging competition and predation may be lower (MacDonald, 1988). Spiny lobster feed on algae, crustaceans, echinoderms, polychaets, and mollusks found in reef flats (Graham, 1993). Females migrate further up the reef flat (closer to shore) than males at night, which may make them more susceptible to fishers walking on reef flats (Ebert and Ford, 1986).

In Hawaii, historical exploitation rates are higher in the MHI than in the NWHI due to the >18 m depth restriction that was used to manage the NWHI lobster fishery (Lacchei *et al.,* 2014). However, in general, abundances of spiny lobster are much higher in the MHI compared to the NWHI because of the larger area of available shallow habitat (Lacchei *et al.,* 2014). In Tutuila, American Samoa the total area of *P. pencillatus* habitat is small, a narrow ban that has a 20-25 m width around the reef edge. In CNMI the estimated density of lobsters per linear km is on average 126 (Ebert and Ford, 1986).

2.4. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg	1 month (Chubb, 2000)	N/A	Benthic (brooded by females)	N/A	N/A	Eggs hatched in areas accessible to currents (Coutures, 2003)
Larvae	8-9 months (Matsuda *et al.*, 2006)	N/A	Pelagic	Offshore	N/A (pelagic)	Oceanic gyres and currents (Johnson, 1997)
Juvenile	2-3 years (Ebert and Ford, 1986)	N/A	N/A	N/A	Dead coral, live coral, macroalgae, sand (Lecchini *et al.*, 2010)	N/A
Adult	Up to 20 years (Butler and MacDiarmid, 2011)*	Algae, crustaceans, echinoderms, polychaetes, mollusks (Hothuis, 1991)	0-5 m (George, 1972)	Most common on outer reef slopes of fringing reefs moving at night up surge channels at the reef edge and onto shallow reef flats (Coutures, 2003)	Reef or rocky areas with high vertical structure (Coutues, 2003)	Clear oceanic waters and high energy wave action typical of windward exposure (Holthuis, 1991)

*Based on other species of spiny lobster.

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3. SLIPPER LOBSTER (*SCYLLARIDES SQUAMOSUS*)

3.1. SPECIES DESCRIPTION AND FISHERIES

The scaly slipper lobster (*Scyllarides squamosus*), or ulu papapa, is found throughout the Indo-Pacific from east Africa to Japan, Hawai'i, Melanesia, and Australia (Butler *et al.,* 2011). In the NWHI *S. squamosus* is assumed to make up a single meta-population (DiNardo and Moffit, 2007).

S. squamosus made up a minor portion of catch in the NWHI from the 1970s to 1996 in fishers primarily targeting *P. marginatus*. From 1997-1999 several commercial vessels began targeting slipper lobster at Maro Reef (DeMartini and Kleiber, 1998), During the time that the NWHI lobster fishery was active, because little was known about the life history of the scaly slipper lobster, life history parameters were borrowed from the spiny lobster species that was also targeted in the fishery (O'Malley, 2011). However, recent studies on *S. squamosus* reveal life history characteristics between the two species are very different than previously thought (O'Malley, 2011). The NWHI was closed in 2000 due to uncertainty in assessment results and population status of both lobster species. Recent fishery independent surveys indicate that abundance of scaly slipper lobsters has not increased since that time (O'Malley, 2011).

In the MHI, the slipper lobster is managed with 7 cm tail width minimum size regulations.

3.2. LIFE HISTORY

3.2.1. GROWTH, MATURITY, NATURAL MORTALITY, AND MOVEMENT

Growth of *S. squammosus* varies by location. Growth is best described by the Schnute model; juveniles experience faster growth rates, which decline with the onset of maturity (O'Malley, 2011). In the NWHI, growth rates vary by bank; however, individual variation in growth at each bank is minimal (O'Malley, 2011).

Size at sexual maturity also varies by location, but has been reported occurring around 6.6-6.7 cm (Hearn *et al.,* 2007, Lavalli *et al.,* 2009). Adults can reach sizes up to 20 cm CL (Holthuis, 1991). Natural mortality varies by location and year (O'Malley, 2009), and adults do not move large distances (< 1 km; O'Malley and Walsh, 2013).

3.2.2. REPRODUCTION

In Hawai'i, ovigerous females are found throughout the year and peak in abundance during May and July when water is warmer (O'Malley 2011). Fecundity increases with size and ranges between 54,000 and 227,000 eggs per female (DeMartini and Williams, 2001; DiNardo and Moffitt 2007; Sekiguchi *et al.,* 2007).

3.2.3. LARVAE AND RECRUITMENT

The pelagic larvae duration of *S. squamosus* is between 3 - 6 months (DiNardo and Moffitt, 2007). Larvae have been found up to 20 km of coast of southwest O'ahu (Phillips and McWilliam, 1989) and in midwater trawls around the Marianas (Sekiguchi, 1990).

3.2.4. JUVENILE STAGE

There is no information on the juvenile stage of *S. squammosus*.

3.2.5. ADULT STAGE

S. squammosus are found in reefs and rocky areas (Holthuis, 1991). The reported depth range of this species varies by location. In Hawai‘i, the reported depth range is 30 – 120 m (DiNardo and Moffit, 2007). In other areas it is reported as 5-80 m with highest abundances at 20-50 m (Chan, 1998). Adult *S. squammosus* are found in very high densities in banks making them very vulnerable to trap fisheries (Clarke and Yoshimoto, 1990).

The scaly slipper lobster reaches sexual maturity between a 66-67 mm carapace length (DeMartinit and Kleiber, 1998) and can reach a maximum size of 15 cm carapace length (Holthuis, 1991) shelters during the day, and forages at night where it feeds mainly on bivalves (Chan, 1998; Lavalli and Spanier, 2007). Adults are known to feed on bivalves (Chan, 1998; Lavalli and Spanier, 2007).

3.3. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg			benthic (brooded by females)			
Larvae	3-6 month (DiNardo and Moffit, 2007)		pelagic	Offshore (at least 20 km) (Phillips and McWilliam, 1989)	N/A (pelagic)	Optimal temperature 25-29 C (Minagawa, 1990)
Juvenile						
Adult		Bivalves (Chan 1998, Lavalli *et al.,* 2007)	1-120 m (DiNardo and Moffit, 2007)	Most common on outer reef slopes of fringing reefs moving at night up surge channels at the reef edge and onto shallow reef flats (Courtes, 2003)	Reef and rocky areas (Holthuis, 1991)	

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4. KONA CRAB (*RANINA RANINA*)

4.1. GENERAL SPECIES DESCRIPTION AND DISTRIBUTION

The kona crab (*Ranina ranina*), also known as frog crab, red frog crab, papa'i kua loa, krab ziraf, and spanner crab is a large marine brachyuran which is targeted by both commercial and recreational fishers in Hawai'i. While Hawai'i represents the easternmost point of the Kona crab's range (Brown, 1985) commercial fisheries also exist in Australia, Japan, Philippines, Thailand, Seychelles Islands and Hawai'i (Brown, 1985; Tahil, 1983; Boulle, 1995; Krajangdara and Watanabe, 2005). The largest fishery for Kona crabs is found in Queensland, Australia where annual landings can reach over six million pounds making it the largest single species fishery in the State (Dichmont and Brown, 2010). No genetic information is currently available to determine the connectivity of Kona crabs across the Hawaiian Archipelago.

4.2. FISHERIES

A small commercial fishery for Kona crabs has operated continuously in the MHI since 1938, with an annual peak in landings of 70,000 lbs. occurred in 1972 (Vansant 1978). Additionally, a small number of crabs were landed in the NWHI and Kona crab were taken incidentally in the NWHI spiny lobster fishery (closed in 2000) (Brown 1985). Historically, the majority of Kona crab landings in Hawai'i have come from either Penguin Bank, located off the southwest coast of Moloka'i, or from the northwest coast of Ni'ihau (Onizuka, 1972). Several fishermen also operate off the north coast of O'ahu (Onizuka, 1972). Kona crab is thought to be a popular target for recreational fishers (Smith, 1993) however, the extent of the recreational fishery is not known.

Currently the State of Hawai'i Department of Aquatic Resources (HDAR) manages the MHI Kona crab stock as one management unit. The fishery is currently managed using four regulations: (1) seasonal closure May-August, (2) a minimum legal size of 4 inch carapace length, (3) no taking/killing of female crabs and (4) no spearing of crabs. The same regulations apply to recreational fishers. The WPRFMC does not have species-specific management measures applicable to federal waters.

4.3. LIFE HISTORY

4.3.1. GROWTH, MATURITY, MOVEMENT, AND NATURAL MORTALITY

Definitive growth rates of Kona crabs are not known but some partial information is available. In Australia two opposing hypotheses for the growth rates of Kona crabs have been proposed. The fast growth hypothesis estimates that crabs will reach a minimum legal size (4 inches) within 18 months will be 5.5 inches in 4 years and will attain maximum size within 8 to 9 years (Brown, 1986; Boullé, 1995). The slow growth hypothesis estimates that male crabs would take 4 years to reach minimum legal size (4 inches), nine years to attain 5.51-inch size and 14 - 15 years to attain maximum size found in this species (de Moussac, 1988; Chen and Kennelly, 1999; Brown *et al.,* 1999; Kirkwood *et al.,* 2005). Aquarium-reared Kona crabs were found to grow approximately 0.25 inches per week from the time they settle, until the time they have reached the ninth instar (Brown *et al.,* 2008).

The growth rates of Kona crabs are difficult to assess as their hard parts are lost during molting, and growth rates are stepwise between molts (Brown *et al.,* 1999). Catch and recapture methods to determine growth provide an overestimation of time between molts as time since last molt of recaptured crabs cannot be determined (Chen and Kennelly, 1999) and tagging can negatively affect growth rates (Brown *et al.,* 1999). An attempt at analyzing lipofuscin in the brain and eyestalks of the crabs to determine age was unsuccessful (Brown *et al.,* 2008) although this technique has been successful in other crustaceans (Sheehy and Prior, 2008). Due to high mortality rates of Kona crabs in captivity future attempts using this technique must begin with a larger sample size (Brown *et al.,* 2008). Overall, male Kona crabs grow faster than females and grow more per molt (Chen and Kennelly 1999; Brown *et al.,* 1999). Smaller crabs molt much more often than larger crabs. However, larger crabs experience more growth per molt (Chen and Kennelly, 1999). In Hawai‘i males grow on average 0.39 inches per molt and females grown an average of 0.30 inches per molt (Onizuka, 1972). The growth rates found in Kona crabs vary by region, as is typical for many crustaceans (Kruse, 1993). Factors such as temperature and food availability are correlated with the number of molts a crab experiences and how quickly a crab is able to grow (Brown *et al.,* 1999).

The size at which Kona crabs reach sexual maturity varies by region and sex. Color of Kona crabs may be a general indicator of their sexual maturity; immature crabs are white and turn orange as they mature (Fielding and Haley, 1976). In Hawai‘i, the majority of males were found to have mature spermatozoa at a 2.9 inch carapace length (Fielding and Haley, 1976). In Hawai‘i, over 87% of females were sexually mature with a 2.6 inch carapace length (Onizuka, 1972).

Natural mortality rates for Kona crabs in Hawai‘i are unknown (Onizuka, 1972). A preliminary estimate of natural mortality using the length converted catch curve was completed in the Seychelles Islands in the Indian Ocean. Natural mortality rates (M) in the Seychelles were estimated to be 0.8-0.9 yr^{-1} for female crabs and 1.0 yr^{-1} for males (de Moussac, 1988).

4.3.2. REPRODUCTION

Berried females (i.e., crabs that are bearing eggs) are found from May through September (Onizuka, 1972). The highest frequency of egg bearing females occurs in June and July. Ovarian growth for female Kona crabs occurs from February to May resulting in increased feeding during these months (Fielding and Haley, 1976). Feeding rates and thus emergence time in females has been found to be greatly correlated with their reproduction cycle (Kennelly and Watkins, 1994). Berried females rarely emerge from the sand causing catch rates for females to drop dramatically during certain times of the year (Skinner and Hill, 1987; Kennelly and Watkins, 1994). In months prior to breeding, emergence of females increases, as they search for food (Skinner and Hill, 1986).

In Kona crabs fertilization is external (Onizuka, 1972). Large brachyuran male crabs may be able to fertilize multiple females (Kruse, 1993). However, small male crabs may not be all of a female's eggs. A unique characteristic of brachyuran crabs is the ability of females to store sperm in the abdominal receptacle and successfully fertilize their eggs up to two years after copulation (Kruse, 1993). Male Kona crabs must be large enough to dig female crabs out of the sand and copulate (Skinner and Hill, 1986; Minagawa, 1993). The eggs are orange in color until a few days before hatching, when they turn brown (Onizuka, 1972). Eggs are brooded until they hatch 24 to 35 days after being fertilized (Onizuka, 1972).

4.3.3. LARVAE AND RECRUITMENT

Newly settled Kona crabs have been observed in the shallow waters of the surf break on a beach in west Maui (Layne Nakagawa, pers. comm.). Kona crab larvae spend several weeks as planktonic larvae which is their primary mechanism for dispersal (Brown, 1985). The first molt, when the larvae develop into a zoea I stage, is typically 7-8 days after the larvae hatch (Fielding, 1974). Six to seven days later a second molt occurs and the larvae develop into the zoea II stage. Prey density greatly affects the time between molts and the growth of these larval crabs (Minagawa and Murano, 1993a). Larvae begin to settle on the bottom 5-6 weeks after they have hatched (Brown *et al.,* 2008). The newly settled crabs typically have around a 0.40 inch carapace length (Brown *et al.,* 2008). The settlement cue for the larvae is unknown but they are presumed to settle in sandy substrata (Brown *et al.,* 2008). Larvae feed mostly during the day but little is known about the food preference of the larvae making aquaculture-rearing attempts unsuccessful to date (Minagawa and Murano, 1993b). Changes in temperature will affect the feeding habits of the larvae as water temperature is correlated with feeding rates (Minagawa and Murano, 1993b).

4.3.4. JUVENILE STAGE

The habitat of small juveniles is unknown but assumed to be similar to the adult habitat (Brown, 2001).

4.3.5. ADULT STAGE

Adult Kona crabs can reach up to 5.5-10.4 inches in length, and live up to 10 years (Pecl *et al.,* 2011). Adult Kona crabs are found in sandy substrata adjacent to coral reefs in areas subject to strong currents across the tropical and subtropical Indo-Pacific in depths ranging from 6 to 650 feet (Vansant, 1978). Most commercial Kona crab fishing in Hawaiʻi occurs from 50 to 150 feet (Vansant, 1978)

The crabs spend a majority of time buried in the sand to avoid predators which include sharks, rays, loggerhead turtles, large fish, and occasionally marine mammals (Skinner and Hill, 1986; Kennelly *et al.,* 1990). Kona crabs emerge from the sand to feed and mate (Skinner and Hill, 1986). Kona crabs are opportunistic scavengers but also feed on small fish and invertebrates (Onizuka, 1972).

4.4. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg	24-35 days (Onizuka, 1972)	N/A	benthic (brooded by females)	N/A	N/A	
Larvae	5-6 weeks (Brown *et al.*, 2008)		pelagic	Offshore	N/A (pelagic)	Temperature* (Minagawa and Murano, 1993b)
Juvenile		Similar to adults (Brown *et al.*, 2008)	Shallower than juveniles (pers. comm.)		Sandy substrata adjacent to coral reefs (Brown, 2008)	
Adult		Opportunistic scavengers but also feed on small fish and invertebrates (Onizuka, 1972)	2 – 200 m (Vansant, 1978)	Wide islands shelves (Thomas *et al.*, 2013)	Sandy substrata adjacent to coral reefs (smooth soft bottoms) (Brown, 2008)	Areas subject to strong currents (Vansant, 1978)

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