6.A.1(2)
129th SSC

7.E.1(2)
173rd CM

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

Western Pacific Regional Fishery Management Council
1164 Bishop St., Suite 1400
Honolulu, HI 96813

PHONE: (808) 522-8220
FAX: (808) 522-8226

www.wpcouncil.org

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.

Edited By: Marlowe Sabater, Asuka Ishizaki, Rebecca Walker, Thomas Remington, and Sylvia Spalding, WPRFMC.

This document can be cited as follows:
WPRFMC, 2018. Annual Stock Assessment and Fishery Evaluation Report for the Mariana Archipelago Fishery Ecosystem Plan 2017. Sabater, M., Ishizaki, A., Walker, R., Remington, T., Spalding, S. (Eds.) Western Pacific Regional Fishery Management Council. Honolulu, Hawaii 96813 USA.

The **Western Pacific Regional Fishery Management Council** acknowledges the valuable contributions of the following Plan Team members for drafting sections of this report:

Guam Division of Aquatic and Wildlife Resources: Brent Tibbatts, Jay Gutierrez

CNMI Division of Fish and Wildlife: Michael Tenorio, Trey Dunn

NMFS Pacific Islands Fisheries Science Center: Justin Hospital, Ivor Williams, Joe O'Malley, Brett Taylor, Michael Parke, Phoebe Woodworth-Jefcoats, John Marra, Tom Oliver, Frank Parrish, T. Todd Jones, Kirsten Leong, and Minling Pan.

NMFS Pacific Islands Regional Office: Melanie Brown

Pacific Islands Regional Planning Body: Sarah Pautzke

The Council also acknowledges the staff of the **NMFS PIFSC Western Pacific Fisheries Information Network** (WPacFIN) for providing the technical support to generate the data summaries.

The Council would like to thank the following individuals for their contributions to the report:
Eric Cruz, John Gourley, Dawn Golden, and Catherine Pham

This page was intentionally left blank.

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. Considering the CNMI bottomfish fishery, the price for BMUS reached a near-high of $4.75/lb. in 2017, though the revenue tallied for the year was among the lowest of the decade. The average cost of a bottomfish trip was nearly half of that in 2016 at $38 versus $65 one year ago. For the coral reef fishery in the area, the price of CREMUS remained steady at just under $3/lb. in the most recent 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, the price for BMUS fell to an all time low of $2.39/lb., and the average cost of a bottomfish trip was doubled compared to 2016 at $72. For the coral reef fishery in the area, the price of CREMUS also fell to an all time low of $2.40/lb in 2017, while the average cost of a spearfishing trip was slightly more expensive than 2016 at $45 (compared to $28 the previous year).

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.

Regarding the improvement of identifying precious coral essential fish habitat, the Archipelagic Plan Team endorses the Plan Team Precious Coral Working Group Report, and they recommend that the Council direct staff to develop an analysis of options to redefine EFH/HAPC for Council consideration for an FEP amendment.

Regarding the research priorities, the Archipelagic Plan Team adopts the changes proposed by the Social Science Planning Committee to the Human Communities section of the Council's MSRA five-year research priorities.

This page was intentionally left blank.

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

This page was intentionally left blank.

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. This fishery operated. 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 2000.

1.1.1.1 Bottomfish Fishery
The bottomfish fishery has not changed much from its early years. 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.

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*), Yelllowtail 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 thr 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%. 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 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 night time 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 confused for Rota or Tinian.

1.1.2.5 Life History

The CNMI DFW life history program began in 1996 with the redgill emperors (*L. rubrioperculatus*). Since then, sampling has been conducted on other species including: *A. lineatus*, Myriprestinae (*M. violacea, M. kuntee, M. pralinea, M. bernti, M. murdjan), L. harak, N. lituratus, C. 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 *S. rubroviolaceus, L. atkinsoni*, *P. barbarinus,* through funding provided by NOAA-NMFS. 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
2000					44	168	9
2001					67	285	0
2002					75	200	25
2003					90	299	40
2004					77	272	16
2005	59	157	258	42	78	417	29
2006	105	337	597	248	71	342	22
2007	127	413	601	36	62	314	1
2008	157	340	911	24	55	250	1
2009	184	324	870	24	64	241	25
2010	132	294	374	29	65	161	82
2011	119	327	388	14	67	162	87
2012	80	273	230	10	72	166	0
2013	108	277	297	2	71	191	0
2014	50	209	108	1	71	166	0
2015	44	193	83	15	57	119	2
2016	44	256	88	20	65	117	3
2017	37	241	122	57	66	120	6
10 year avg.	**96**	**273**	**347**	**20**	**65**	**169**	**21**
10 year SD	**50**	**47**	**292**	**15**	**5**	**45**	**33**
20 year avg.	**96**	**280**	**379**	**40**	**68**	**222**	**19**
20 year SD	**46**	**67**	**274**	**62**	**10**	**83**	**26**

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. 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) 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%]**
	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**

Fishery	Fishery statistics	Short-term (recent 10 years)	Long-term (20 years)
	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**
	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)		

Fishery	Fishery statistics	Short-term (recent 10 years)	Long-term (20 years)
	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**
	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 for all species caught using the bottomfishing gear: estimated lbs. (expanded) from the boat and shore-based creel surveys and estimated total lbs. from the commercial purchase system from 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 the available Bottomfish Management Unit Species (BMUS) catch time series: estimated lbs. (expanded) from the boat and shore-based creel surveys and estimated total lbs. from the commercial purchase system.

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). Need to finalize the CREMUS list to use for Creel and commercial landings and verify non-overlap between Bottomfish Complex and CREMUS. Also need to verify all shallow bottomfish are not included in CREMUS list.

Table 6. Summary of the predefined "coral reef fishery" (catch time series (for a discrete list of species: taken from CB lbs. and CS lbs. from the CREMUS module) from the boat and shore-based creel surveys and the commercial purchase system.

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 catch time series estimates using boat and shore-based creel survey data sets by gear type.

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 the 12 managed species complexes (rank ordered by management importance and average catch of recent 10 years) from the boat based creel data. The CREMUS complex comprise > 92% of the total boat based landing. (all BF and BMUS were deemed commercial).

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 the 11 managed species complexes (rank ordered by management importance and average catch of recent 10 years) from the shore-based creel data. The CREMUS complex comprise > 91% of the total shore based landing

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 that 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 comprise 99% 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 its pound 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 10. Catch per unit effort time series by dominant fishing methods from the shore-based fisheries.

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. Catch per unit effort time series by dominant fishing methods from the boat-based fisheries.

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 the coral reef and bottomfish fisheries. Shore-based fisheries are expressed in gear-hours (expanded total number of hours fishing

by total number of gears used). The boat-based fisheries are expressed in number of trips for bottomfish and number of gear hours for spear, troll, atulai, and castnest).

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 bottomfish fishery and number of gear in the boat and shore-based coral reef fishery. Cells marked with * indicates data is confidential due to less than 3 entities surveyed or reported.

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**

	Bottomfish		Coral Reef BB				Coral Reef SB Fishery		
Year	**# 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 the non-bottomfishing boat-based fisheries. Percent bycatch is calculated from the numbers caught and identified as bycatch versus all caught in the fishery.

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 bycatch estimates in the bottomfish fishery. Percent bycatch is calculated from the numbers caught and identified as bycatch versus all caught in the fishery.

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 shore-based fishery with all gears combined. Percent bycatch is calculated from the numbers caught and identified as bycatch versus all caught in the fishery.

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 Northern 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 between 2008 and 2018 for the CNMI crustacean and bottomfish fisheries.

CNMI Fisheries	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Lobster	6*	4*							1**		1**
Shrimp			2*	1*					1		
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 $B \le c\ B_{MSY}$ $F(B) = F_{MSY}$ 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 $SSBPR \leq 0.10$ $F(SSBPR) = 0.2\,F_{MSY}$ for $0.10 < SSBPR \leq SSBPR_{MIN}$ $F(SSBPR) = 0.4\,F_{MSY}$ for $SSBPR_{MIN} < SSBPR \leq SSBPR_{TARGET}$	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 extent (values are in percentage), defined as the proportion of fishing year landing relative to the ACL or OY, and the harvest capacity, defined as the remaining portion of the ACL or OY that can potentially be harvested in a given fishing year.

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

Cook, R., 2014. Report on the Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report to Center for Independent Experts.

Fricke, H. and Meischner, D., 1985. Depth limits of Bermudan scleractinian corals: a submersible survey. *Marine Biology*, *88*(2), pp.175-187.

Haddon, M., 2014. Center for Independent Experts (CIE) Peer Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.

Hart, S.R., Coetzee, M., Workman, R.K., Blusztajn, J., Johnson, K.T.M., Sinton, J.M., Steinberger, B. and Hawkins, J.W., 2004. Genesis of the Western Samoa seamount province: age, geochemical fingerprint and tectonics. *Earth and Planetary Science Letters*, *227*(1), pp.37-56.

Humphreys, R. and Moffitt, R., 1999. Unit 17-Western Pacific Bottomfish and Armorhead Fisheries. DOC, NOAA, NMFS Our Living Oceans–Report on the Status of US Living Marine Resources, pp.189-192.

Jones, C., 2014. Biomass Augmented Catch---MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.

Kahng, S.E. and Maragos, J.E., 2006. The deepest, zooxanthellate scleractinian corals in the world? *Coral Reefs*, *25*(2), pp.254-254.

Konter, J.G. and Jackson, M.G., 2012. Large volumes of rejuvenated volcanism in Samoa: Evidence supporting a tectonic influence on late-stage volcanism. *Geochemistry, Geophysics, Geosystems*, *13*(6).

Lang, J.C., 1974. Biological Zonation at the Base of a Reef: Observations from the submersible Nekton Gamma have led to surprising revelations about the deep fore-reef and island slope at Discovery Bay, Jamaica. *American Scientist*, *62*(3), pp.272-281.

Martell, S. and Froese, R., 2013. A simple method for estimating MSY from catch and resilience. *Fish and Fisheries*, *14*(4), pp.504-514.

Meyer, R. and Millar, R.B., 1999. Bayesian stock assessment using a state–space implementation of the delay difference model. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*(1), pp.37-52.

Moffitt, R.B., Brodziak, J., and Flores, T., 2007. Status of the Bottomfish Resources of American Samoa, Guam, and Commonwealth of the Northern Mariana Islands, 2005. NOAA Pacific Islands Fisheries Science Center Administrative Report H-07-04.

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.

Neall, V.E. and Trewick, S.A., 2008. The age and origin of the Pacific islands: a geological overview. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1508), pp.3293-3308.

NMFS, 2015. Specification of Annual Catch Limits and Accountability Measures for Pacific Island Coral Reef Ecosystem Fisheries in Fishing Years 2015 through 2018. Honolulu, HI 96813. 228 p.

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

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.

Restrepo, V.R., Thompson, G.G., Mace, P.M., Gabriel, W.L., Low, L.L., MacCall, A.D., Methot, R.D., Powers, J.E., Taylor, B.L., Wade, P.R. and Witzig, J.F., 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31, pp.1-54.

Sabater, M. and Kleiber, P., 2014. Augmented catch-MSY approach to fishery management in coral-associated fisheries. *Interrelationships between Corals and Fisheries*. CRC Press, Boca Raton, FL, pp.199-218.

Williams, I., 2010. U.S. Pacific Reef Fish Estimates Based on Visual Survey Data. NOAA Pacific Islands Fisheries Science Center Internal Report IR-10-024.

WPRFMC, 2011. Omnibus Amendment for the Western Pacific Region to Establish a Process for Specifying Annual Catch Limits and Accountability Measures. Honolulu, HI 96813.

Yau, A., Nadon, M., Richards, B., Brodziak, J., Fletcher, E., 2016. Stock assessment updates of the Bottomfish Management Unit species of American Samoa, the Commonwealth of the Northern Mariana Islands, and Guam in 2015 using data through 2013. U.S. Dept. of Commerce, NOAA Technical Memorandum, NMFS-PIFSC-51, 54 p.

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

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 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 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 [▲1%]**	**841 [▼6%]**
	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 catch time series for all species caught using the bottomfishing gear: estimated lbs. (expanded) from the boat and shore-based creel surveys and estimated total lbs. from the commercial purchase system

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**

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 the available Bottomfish Management Unit Species (BMUS) catch time series: estimated lbs. (expanded) from the boat and shore-based creel surveys and estimated total lbs. from the commercial purchase system

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 the predefined "coral reef fishery" catch time series (for a discrete list of species – taken from CB lbs. and CS lbs. from the CREMUS module) from the boat and shore-based creel surveys and the commercial purchase system.

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. Expanded catch time series estimates using boat and shore-based creel survey data sets by gear type.

	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 the 11 managed species complexes (rank ordered by management importance and average catch of recent 10 years) from the boat-based creel data. The CREMUS complex comprise > 67% of the total boat based landing

Year	Boat-based (Estimated Pounds)										
	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 the 10 managed species complexes (rank ordered by management importance and average catch of recent 10 years) from the shore-based creel data. The CREMUS complex comprise > 91% of the total boat based landing

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. Catch per unit effort time series by dominant fishing methods from the shore-based fisheries. CPUE estimates were derived from the top three- to five-dominant taxonomic groups that make up more than 50% of the catch. The percentage of catch is shown in parenthesis beside the method.

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. Catch per unit effort time series by dominant fishing methods from the boat-based fisheries. CPUE estimates were derived from the top three to five dominant taxonomic groups that make up more than 50% of the catch. The percentage of catch is shown in parenthesis beside the method.

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 from the coral reef and bottomfish fisheries. Shore-based fisheries are expressed in gear-hours (expanded total number of hours fishing by total number of gears used). The boat-based fisheries are expressed in number of trips for bottomfish and number of gear hours for spear, SCUBA, gillnet and troll)

	Shore-based gear-hours					Boat-based gear-hours				
Year	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	191438	506	484	104	176253	8051	140	64	7157862
10 year avg.	**6049**	**153222**	**1395**	**1015**	**86**	**155375**	**4436**	**798**	**266**	**5131003**
10 year SD	**2888**	**42683**	**1423**	**1592**	**65**	**100350**	**2616**	**1981**	**319**	**2284900**
20 year avg.	**8959**	**330242**	**10485**	**3527**	**138**	**322081**	**8497**	**2495**	**860**	**5601181**
20 year SD	**5370**	**314865**	**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 bottomfish fishery and number of gear in the boat and shore-based coral reef fishery. Cells marked with * indicates data is confidential due to less than three entities surveyed or reported.

	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 established SBRMs at that time.

The following are the recent bycatch estimates for the boat-based non-bottomfishing gear (Table 38), bottomfish fishery (Table 39), and shore-based fisheries with all gear-types 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 the boat-based non-bottomfishing gear type fisheries. Percent bycatch is calculated from the numbers caught and identified as bycatch versus all caught in the fishery.

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 bottomfish fishery. Percent bycatch is calculated from the numbers caught and identified as bycatch versus all caught in the fishery.

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 shore-based fishery (all gears combined). Percent bycatch is calculated from the numbers caught and identified as bycatch versus all caught in the fishery.

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 management unit species (MUS) in the EEZ seaward of the Territory 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.

1.2.12.4 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.

1.2.12.5 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.

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 January 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

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

1.2.13 Status Determination Criteria

1.2.13.1 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 the bottomfish management unit species in Guam

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY} B}{c\, B_{MSY}}$ for $B \le c\, B_{MSY}$ $F(B) = F_{MSY}$ 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 ($F_{RO\text{-}REBUILD}$) 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 the bottomfish management unit species in Guam

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

1.2.13.2 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.

1.2.13.2.1 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 $(1\text{-}M)B_{OY}$ 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 ($CPUE_{REF}$).

1.2.13.3 Current Stock Status

1.2.13.3.1 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

1.2.13.3.2 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.

Coral Reef MUS Complex	MSY (lbs.)
Bolbometopon muricatum – bumphead parrotfish	N.A.
Carcharhinidae – reef sharks	2,900

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

1.2.14.1 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.

1.2.14.2 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.

1.2.15 Best Scientific Information Available

1.2.15.1 Bottomfish fishery

1.2.15.1.1 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)

1.2.15.1.2 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.

1.2.15.1.3 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)

1.2.15.2 Coral reef fishery

1.2.15.2.1 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

1.2.15.2.2 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)

1.2.15.2.3 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.

1.2.16 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 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 (%) defined as the proportion of fishing year landing relative to the ACL or OY, and the harvest capacity defined as the remaining portion of the ACL or OY that can potentially be harvested in a given fishing year.

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.

1.2.17 Other Relevant Ocean-Uses and Fishery-Related Information

1.2.17.1 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.

1.2.17.2 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.

1.2.18 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.

1.2.19 References

Cook, R., 2014. Report on the Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.

Fricke, H. and Meischner, D., 1985. Depth limits of Bermudan scleractinian corals: a submersible survey. *Marine Biology*, *88*(2), pp.175-187.

Green, A.L., 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the U.S. Pacific Islands. Report submitted to the Western Pacific Regional Fishery Management Council. Honolulu, HI 96813. 278 p.

Haddon, M., 2014. Center for Independent Experts (CIE) Peer Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.

Hart, S.R., Coetzee, M., Workman, R.K., Blusztajn, J., Johnson, K.T.M., Sinton, J.M., Steinberger, B. and Hawkins, J.W., 2004. Genesis of the Western Samoa seamount province: age, geochemical fingerprint and tectonics. *Earth and Planetary Science Letters*, *227*(1), pp.37-56.

Hensley, R.A. and Sherwood, T.S., 1993. An overview of Guam's inshore fisheries. *Marine Fisheries Review*, *55*(2), pp.129-138.

Humphreys, R. and Moffitt, R., 1999. Unit 17-Western Pacific Bottomfish and Armorhead Fisheries. DOC, NOAA, NMFS Our Living Oceans–Report on the Status of US Living Marine Resources, pp.189-192.

Jones, C., 2014. Biomass Augmented Catch---MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.

Kahng, S.E. and Maragos, J.E., 2006. The deepest, zooxanthellate scleractinian corals in the world?. *Coral Reefs*, *25*(2), pp.254-254.

Konter, J.G. and Jackson, M.G., 2012. Large volumes of rejuvenated volcanism in Samoa: Evidence supporting a tectonic influence on late-stage volcanism. *Geochemistry, Geophysics, Geosystems*, *13*(6).

Lang, J.C., 1974. Biological Zonation at the Base of a Reef: Observations from the submersible Nekton Gamma have led to surprising revelations about the deep fore-reef and island slope at Discovery Bay, Jamaica. *American Scientist*, *62*(3), pp.272-281.

Martell, S. and Froese, R., 2013. A simple method for estimating MSY from catch and resilience. *Fish and Fisheries*, *14*(4), pp.504-514.

Meyer, R. and Millar, R.B., 1999. Bayesian stock assessment using a state–space implementation of the delay difference model. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*(1), pp.37-52.

Myers, R.F., 1997. Assessment of coral reef resources of Guam with emphasis on waters of federal jurisdiction. Report prepared for the Western Pacific Regional Fishery Management Council. Honolulu, HI 96813.

Moffitt, R.B., Brodziak, J., and Flores, T., 2007. Status of the Bottomfish Resources of American Samoa, Guam, and Commonwealth of the Northern Mariana Islands, 2005. NOAA Pacific Islands Fisheries Science Center Administrative Report H-07-04.

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.

Neall, V.E. and Trewick, S.A., 2008. The age and origin of the Pacific islands: a geological overview. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1508), pp.3293-3308.

NMFS, 2015. Specification of Annual Catch Limits and Accountability Measures for Pacific Island Coral Reef Ecosystem Fisheries in Fishing Years 2015 through 2018. Honolulu, HI 96813. RIN 0648-XD558. 228 p.

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

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.

Restrepo, V.R., Thompson, G.G., Mace, P.M., Gabriel, W.L., Low, L.L., MacCall, A.D., Methot, R.D., Powers, J.E., Taylor, B.L., Wade, P.R. and Witzig, J.F., 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31, pp.1-54.

Sabater, M. and Kleiber, P., 2014. Augmented catch-MSY approach to fishery management in coral-associated fisheries. *Interrelationships between Corals and Fisheries*. CRC Press, Boca Raton, FL, pp.199-218.

Williams, I. 2010. U.S. Pacific Reef Fish Estimates Based on Visual Survey Data. NOAA Pacific Islands Fisheries Science Center Internal Report IR-10-024.

WPRFMC, 2011. Omnibus Amendment for the Western Pacific Region to Establish a Process for Specifying Annual Catch Limits and Accountability Measures. Honolulu, HI 96813.

Yau, A., Nadon, M., Richards, B., Brodziak, J., Fletcher, E., 2016. Stock assessment updates of the Bottomfish Management Unit species of American Samoa, the Commonwealth of the Northern Mariana Islands, and Guam in 2015 using data through 2013. U.S. Dept. of Commerce, NOAA Technical Memorandum, NMFS-PIFSC-51, 54 p.

This page was intentionally left blank.

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.

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.

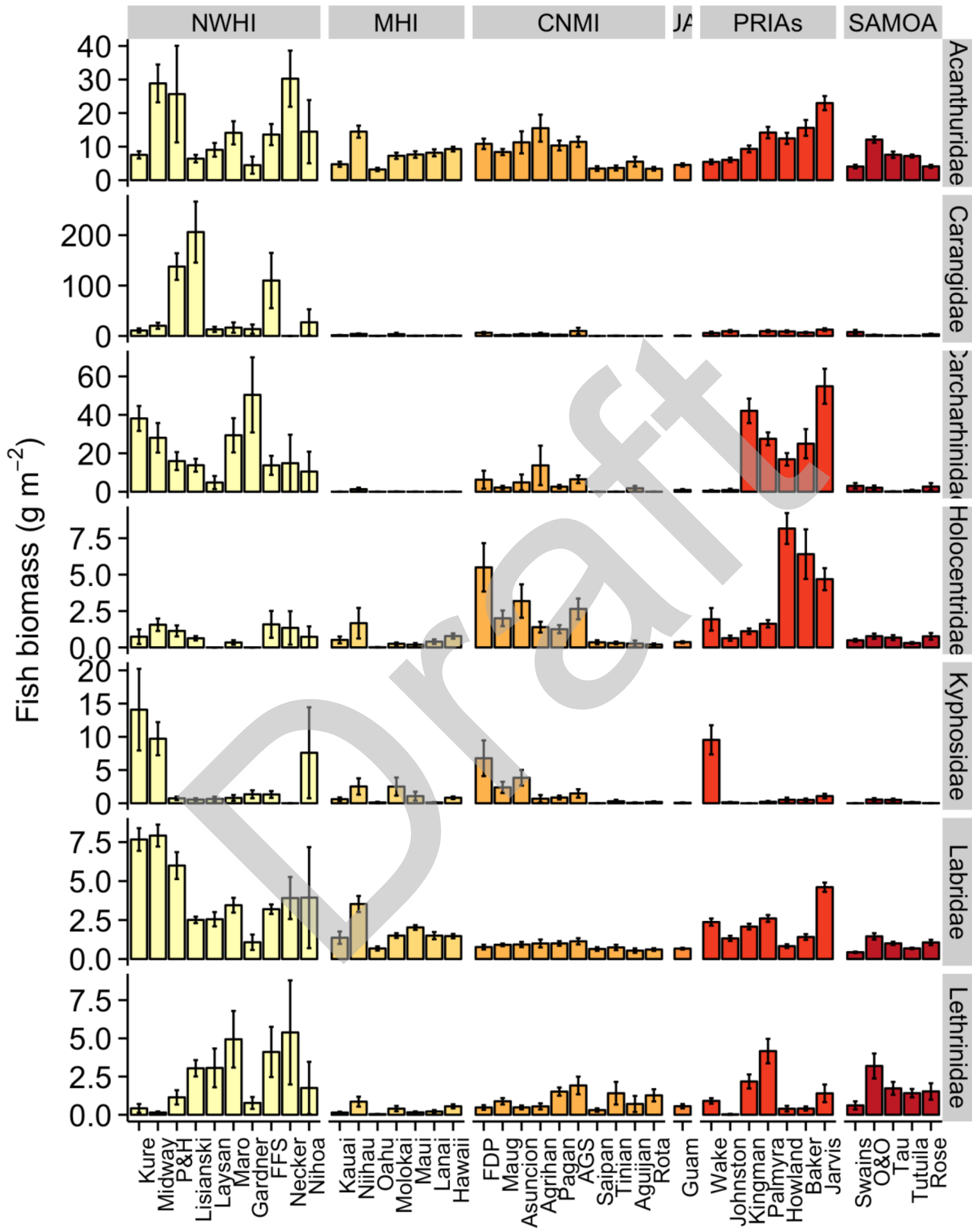
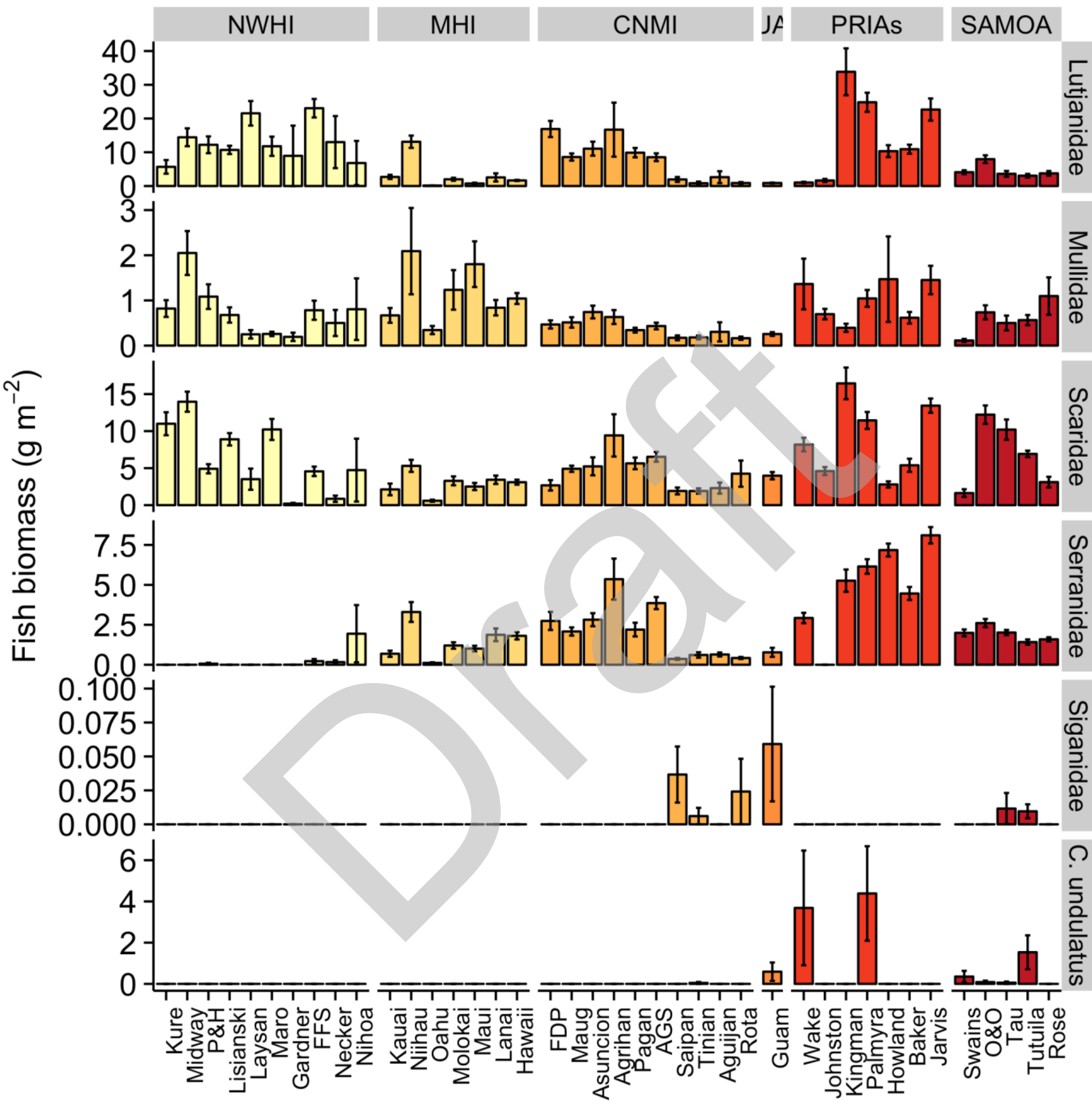


Figure 1. Mean fish biomass (g/m^2 ± standard error) of Coral Reef Management Unit Species (CREMUS) grouped by U.S. Pacific reef area from the years 2009-2015. Islands are ordered within region by latitude. Figure continued from previous page.



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.

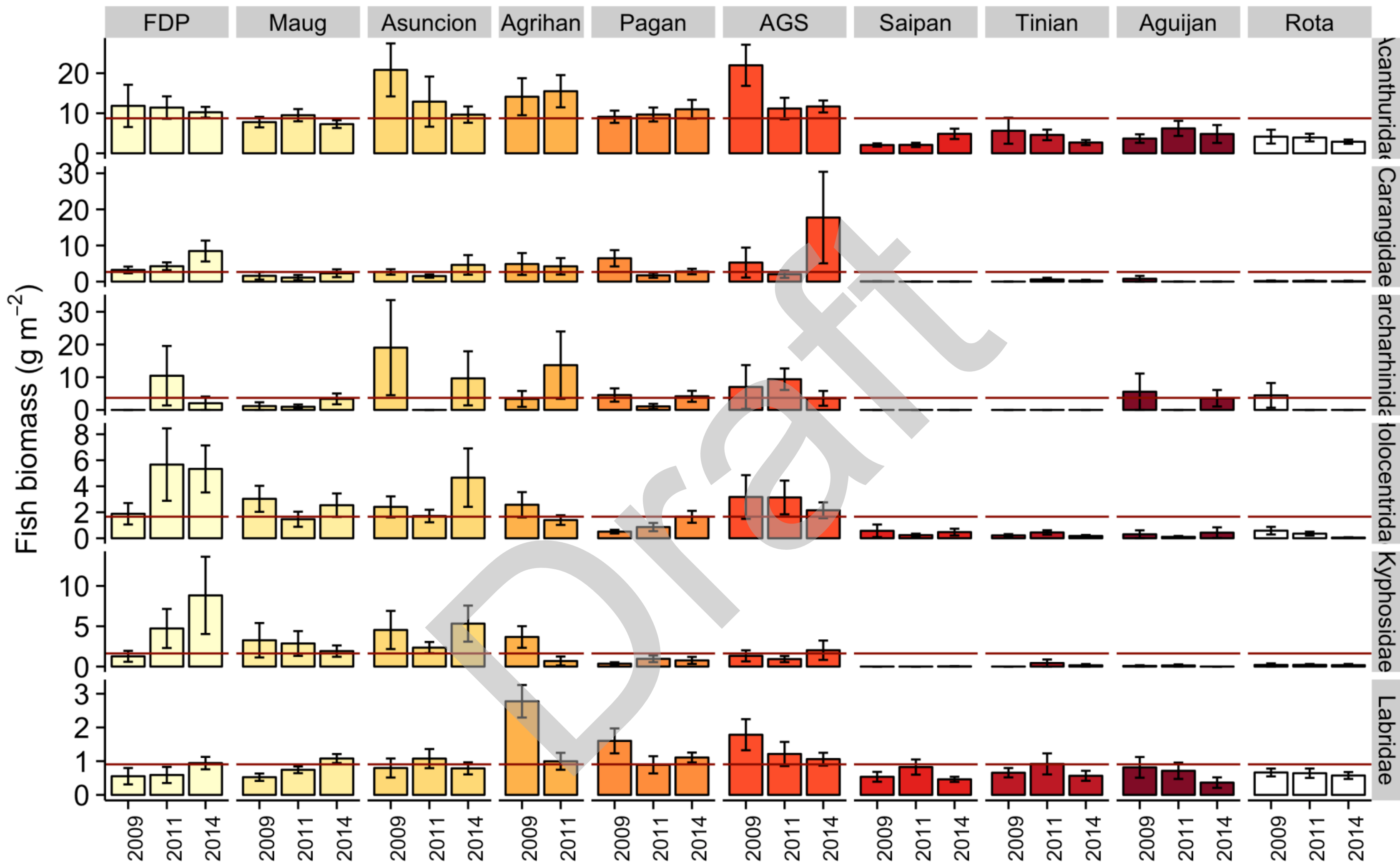
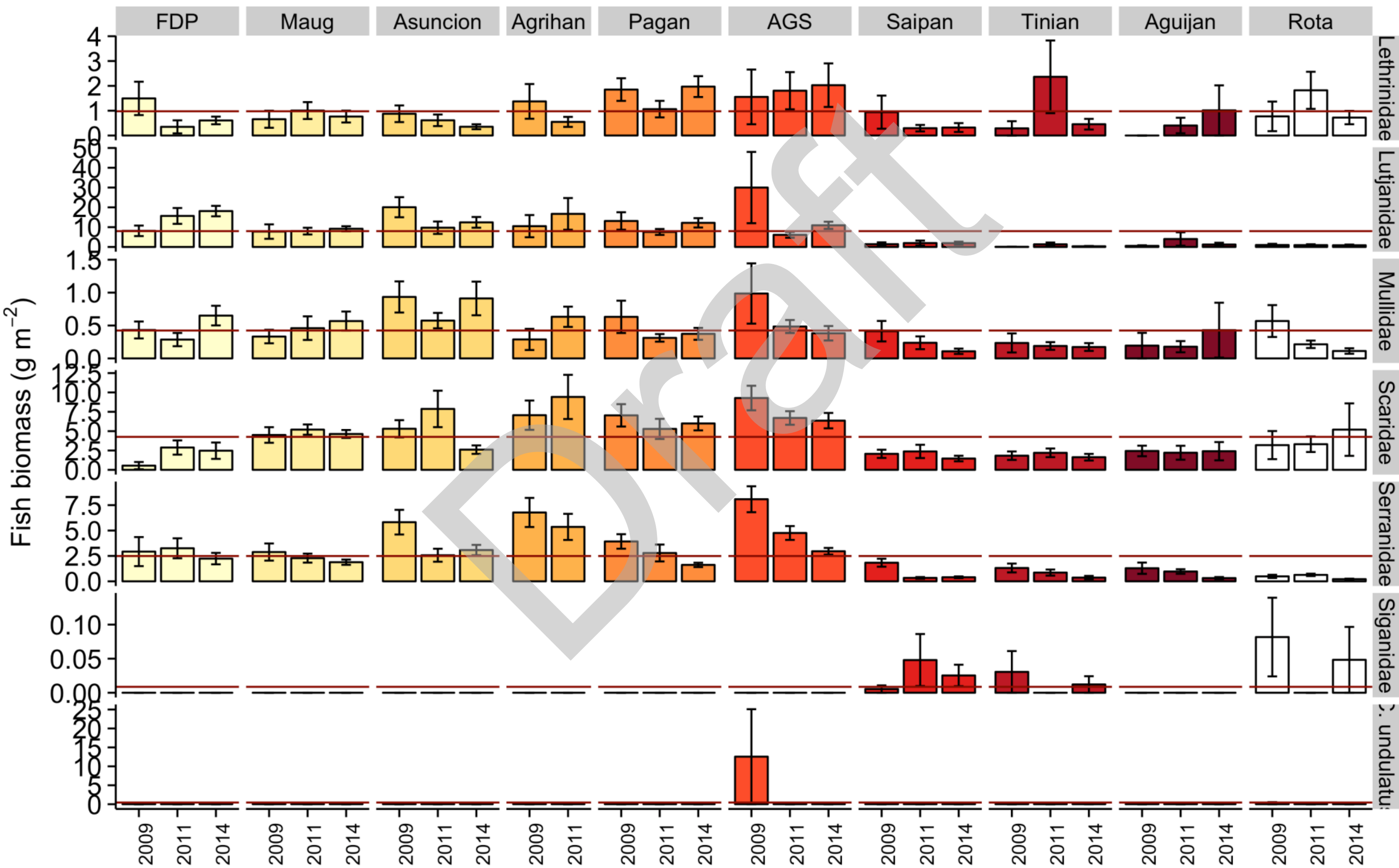

FDP
Maug
Asuncion
Agrihan
Pagan
AGS
Saipan
Tinian
Aguijan
Rota
Fish biomass (g m⁻²)
Acanthuridae
Carangidae
Carcharhinidae
Holocentridae
Kyphosidae
Labridae
2009
2011
2014
Draft

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 from previous page.



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.

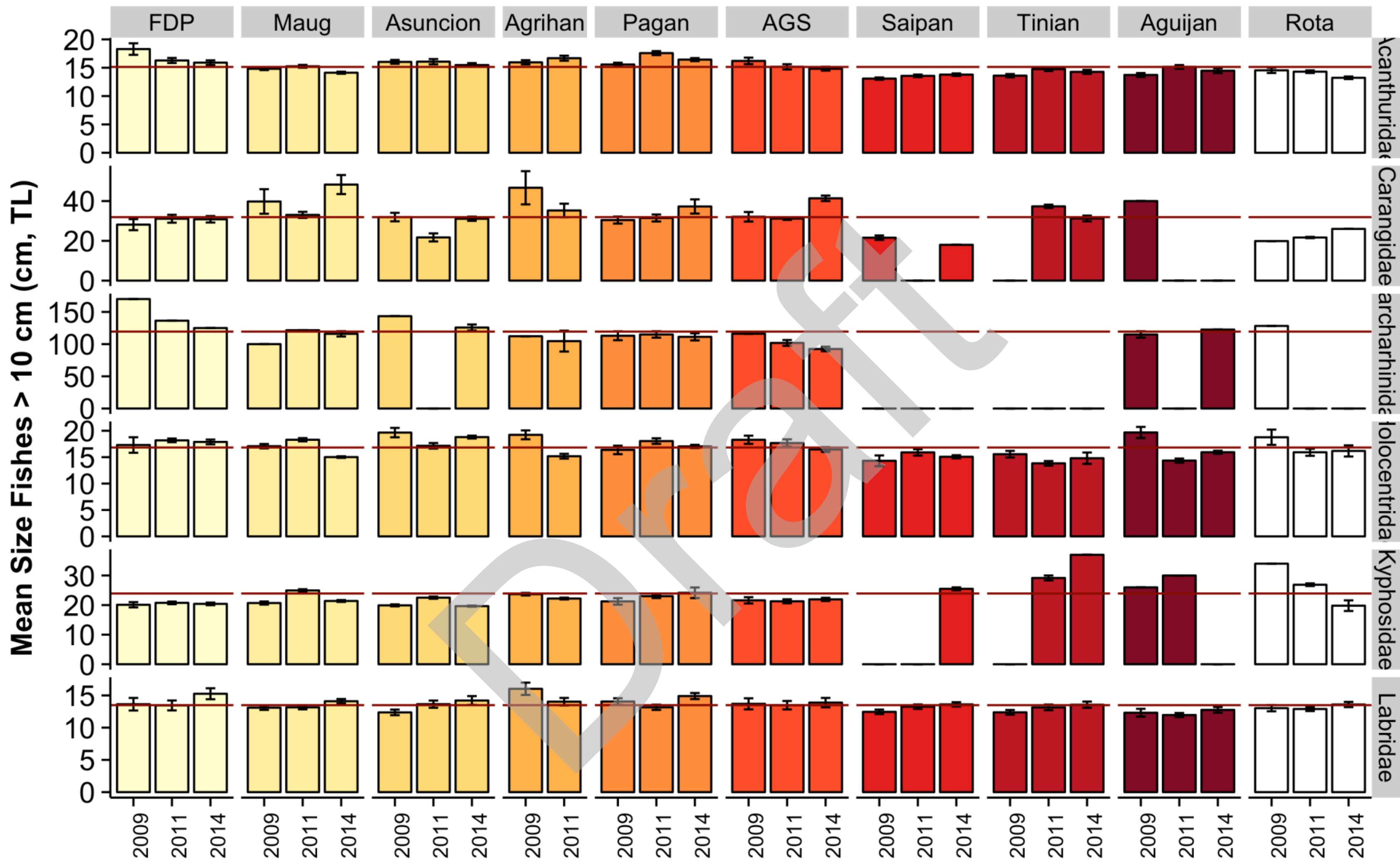
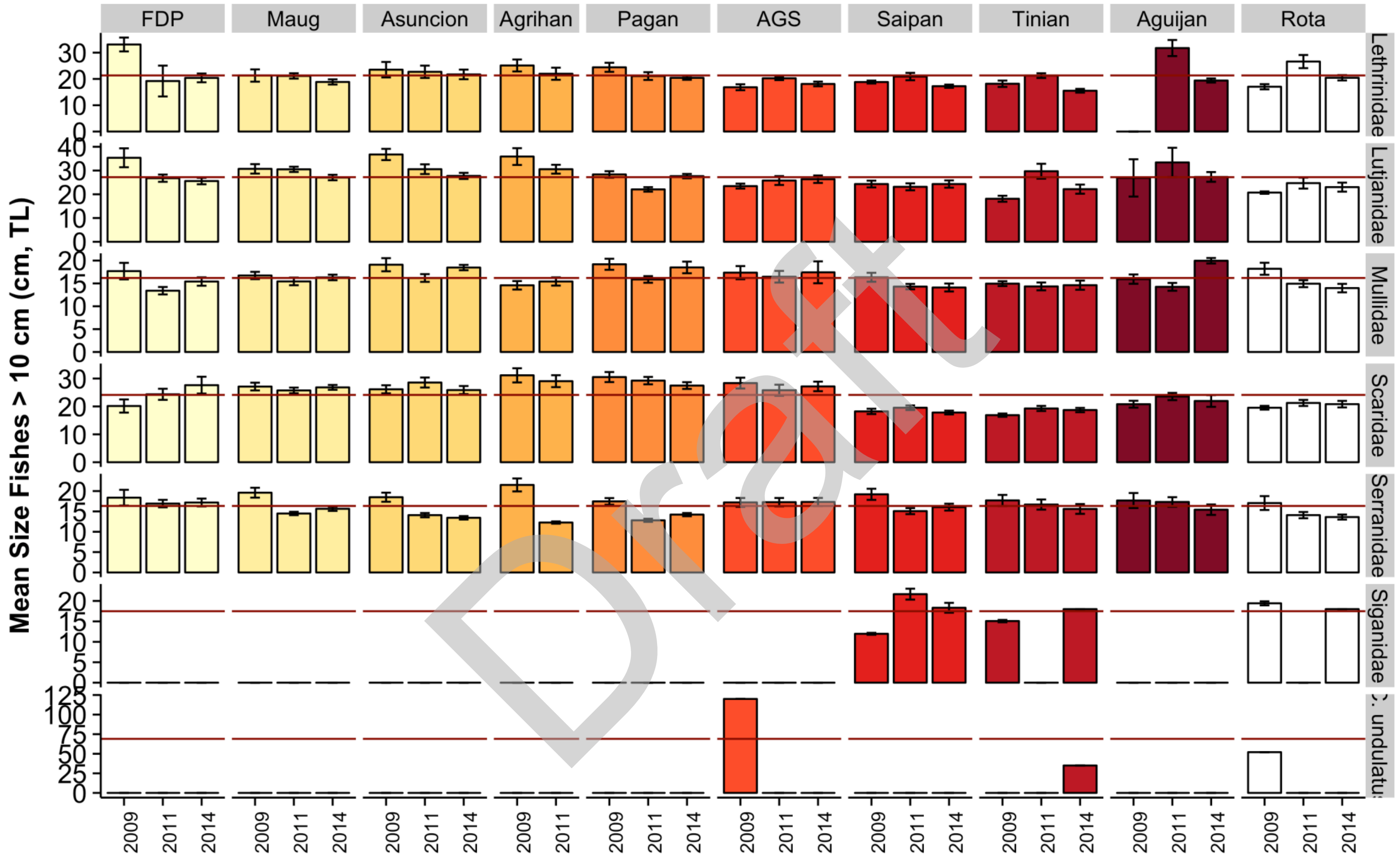


Figure 3. Mean fish size (cm, TL ± standard error) of CNMI CREMUS from the years 2009-2015. The CNMI mean estimates are plotted for reference (red line). Anatahan, Guguan, and Sarigan have been grouped. Figure continued on next page.


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

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**

Note:
(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.

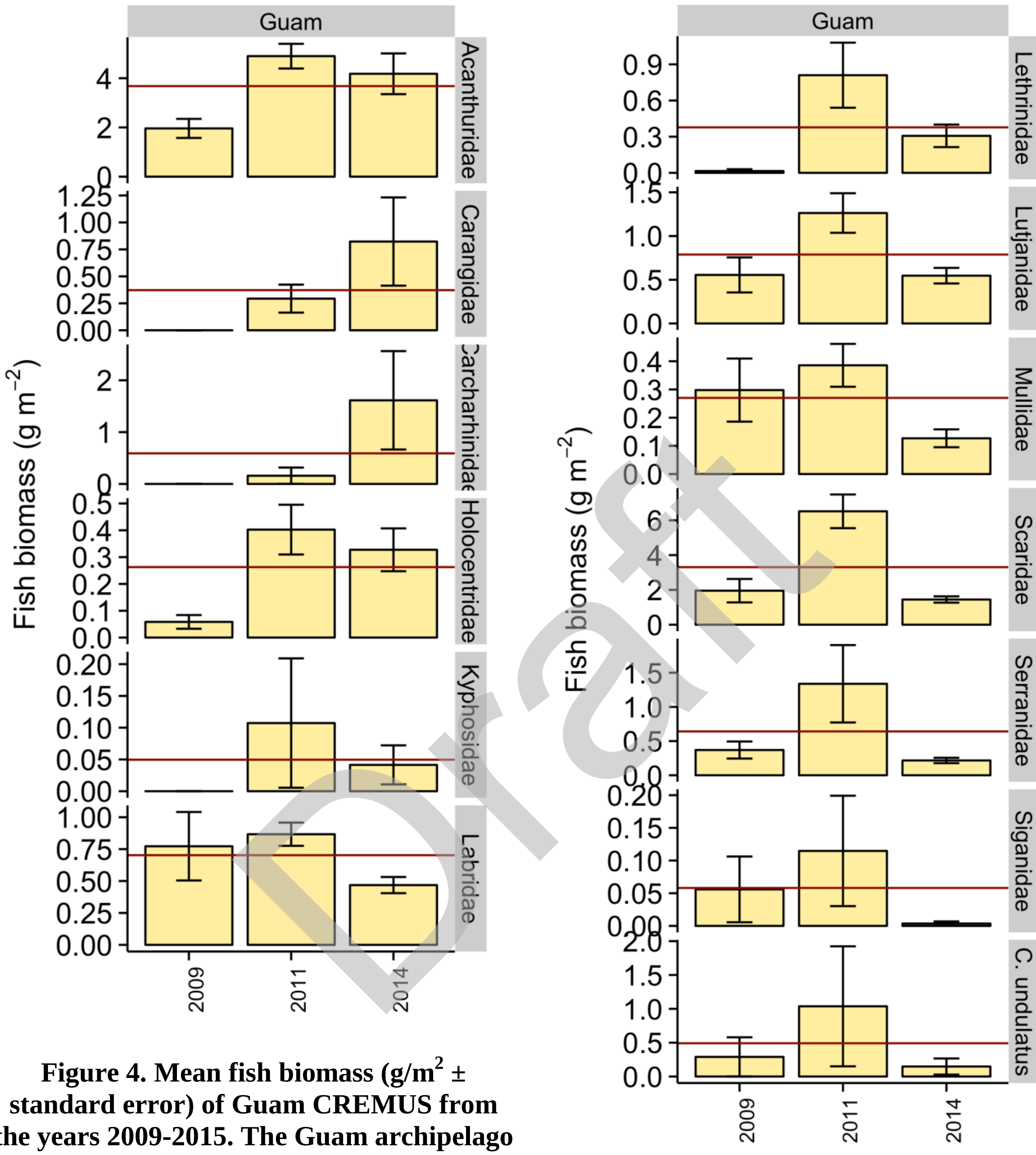


Figure 4. Mean fish biomass (g/m^2 ± standard error) of Guam CREMUS from the years 2009-2015. The Guam archipelago mean estimates are represented by the red line.

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:

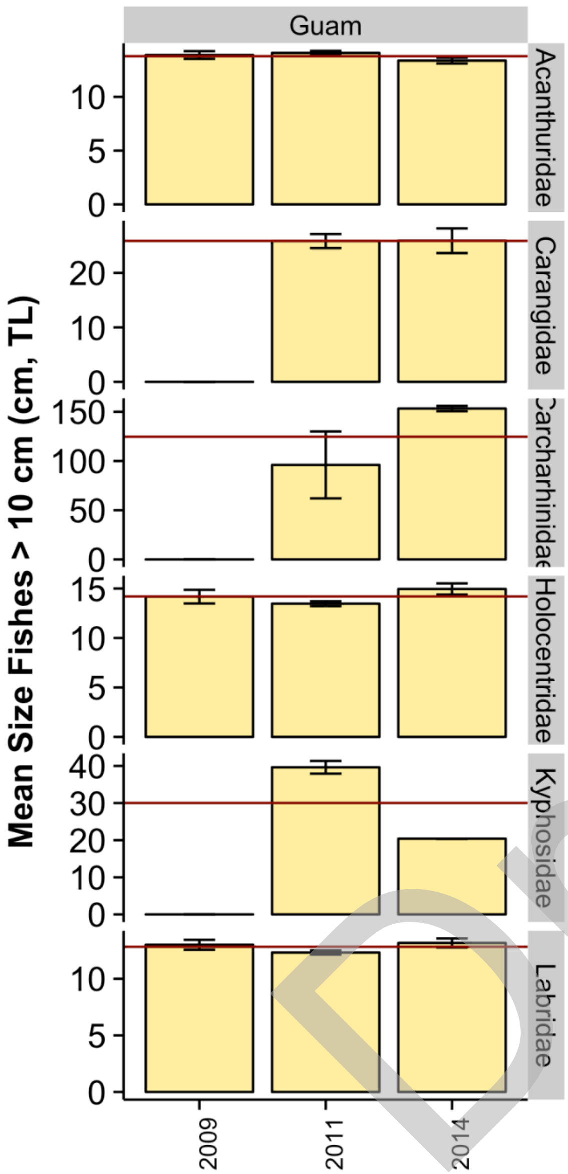
- ☐ Regional
- ☐ American Samoa
- ✓ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

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.



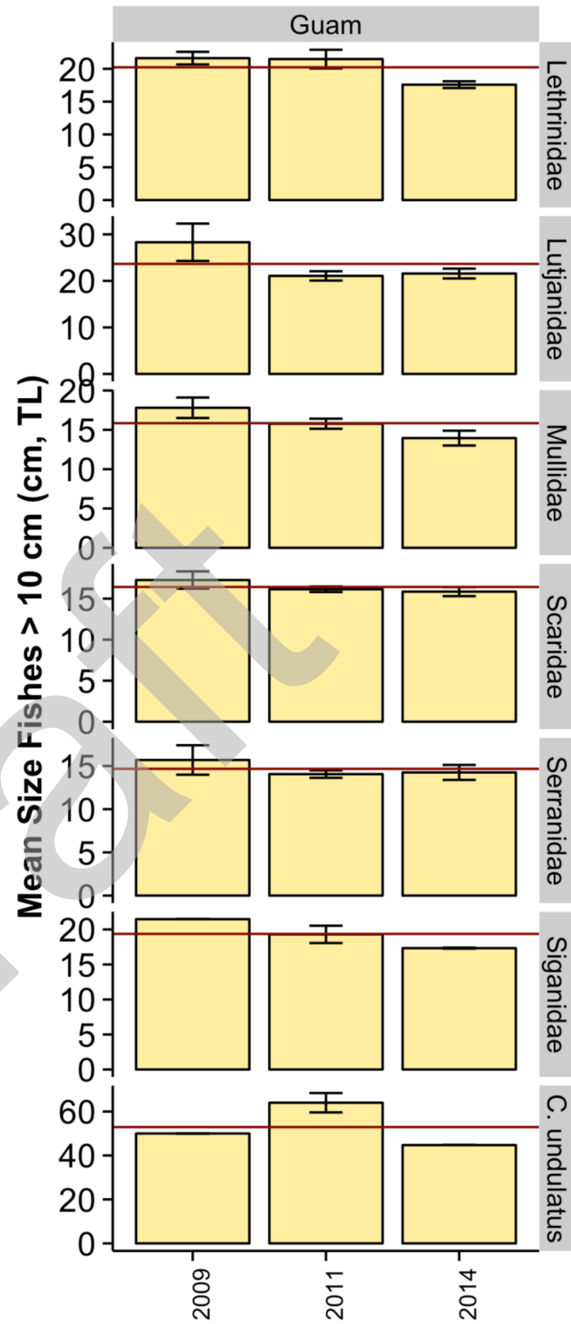


Figure 5. Mean fish size (cm, TL ± standard error) of Guam CREMUS from the years 2009-2015. The Guam mean estimates are plotted for reference (red line).

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

Note:
(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.

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 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. 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.

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]	0.32[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).

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	

Species	Length-derived parameters						Reference
	L_{max}	L_{bar}	*N*	*L-W*	*a*	*b*	
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	

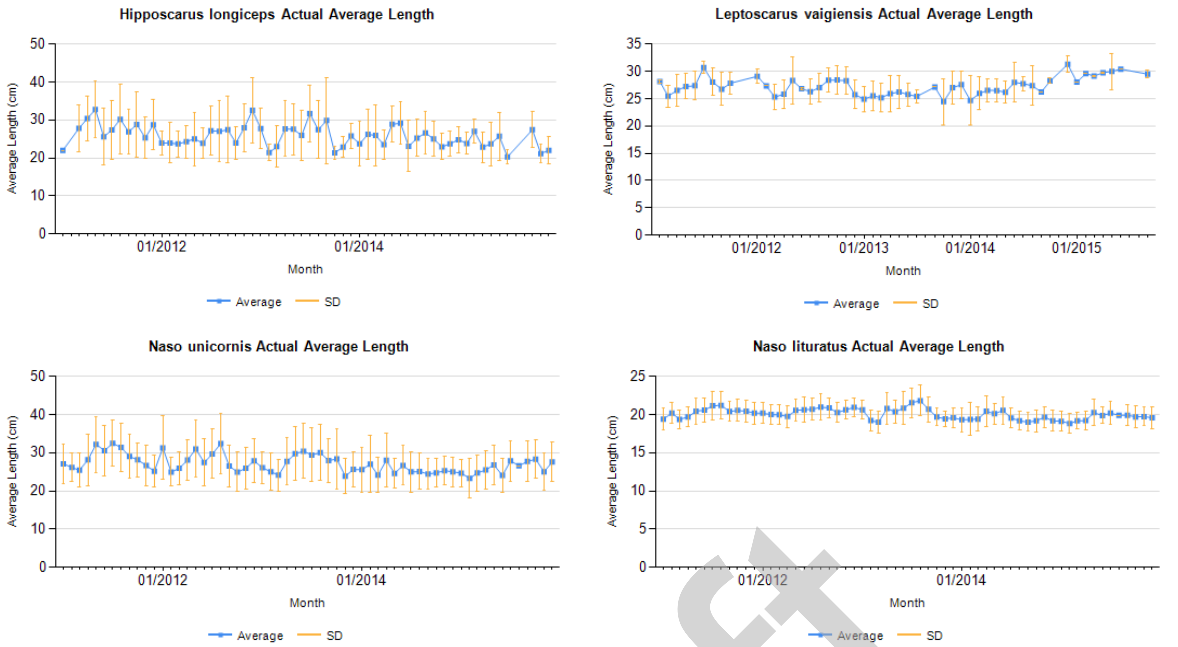
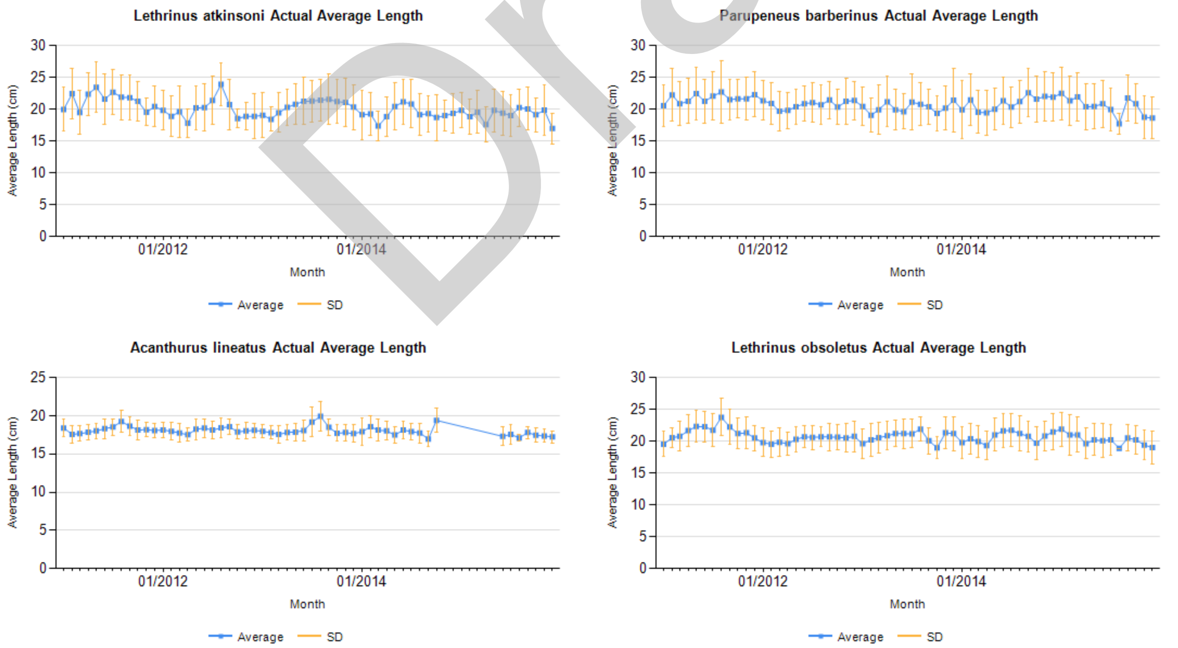
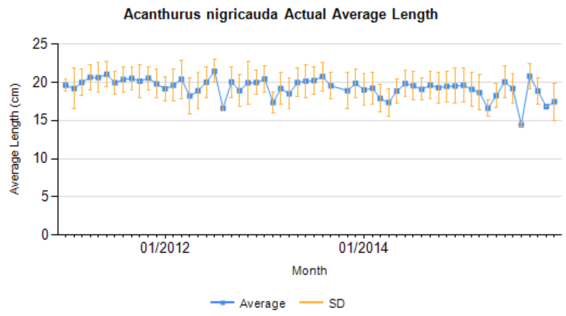
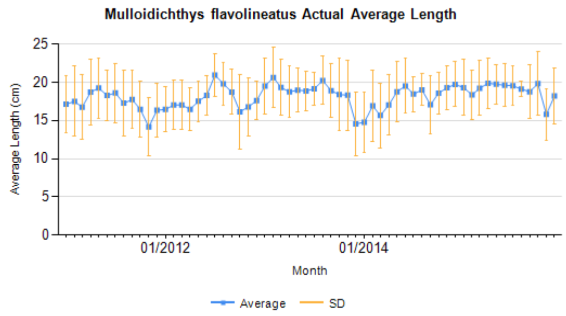
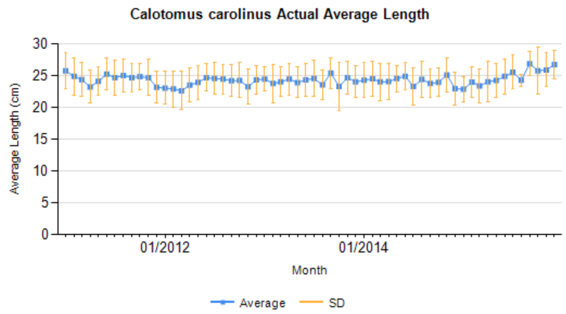


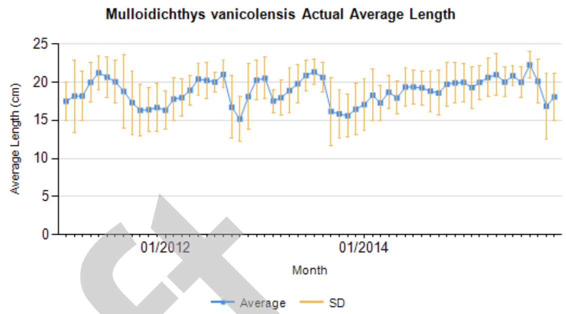
Figure 6. Average length over time of representative CNMI coral reef fish management unit species derived from the BioSampling Program. Continues to next two pages.

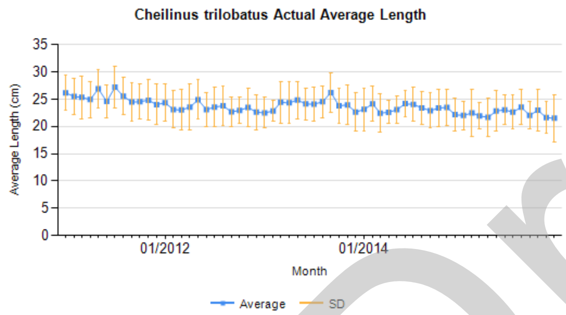


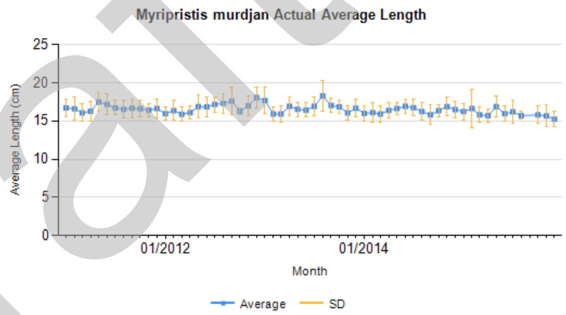

Acanthurus nigricauda Actual Average Length
Average Length (cm)
0
5
10
15
20
25
01/2012
01/2014
Month
Average
SD

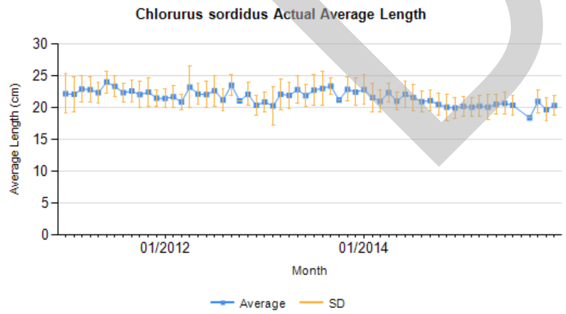

Mulloidichthys flavolineatus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
01/2012
01/2014
Month
Average
SD

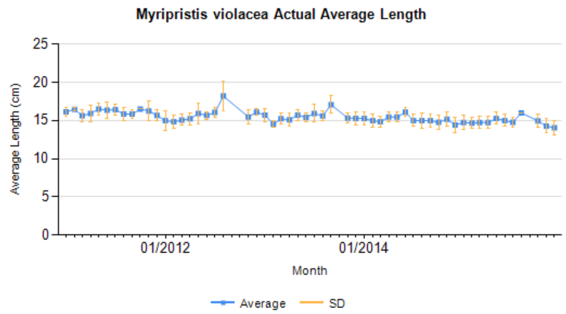

Calotomus carolinus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
01/2012
01/2014
Month
Average
SD

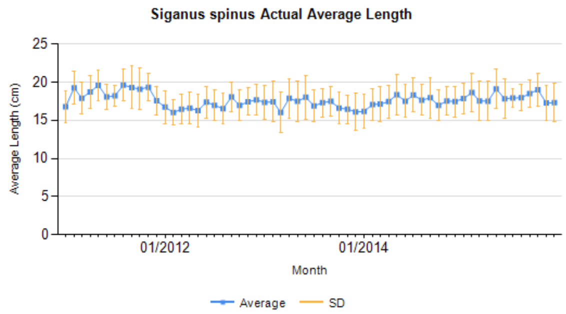

Mulloidichthys vanicolensis Actual Average Length
Average Length (cm)
0
5
10
15
20
25
01/2012
01/2014
Month
Average
SD

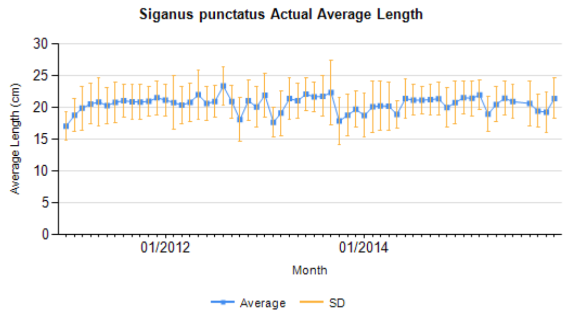

Cheilinus trilobatus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
35
01/2012
01/2014
Month
Average
SD

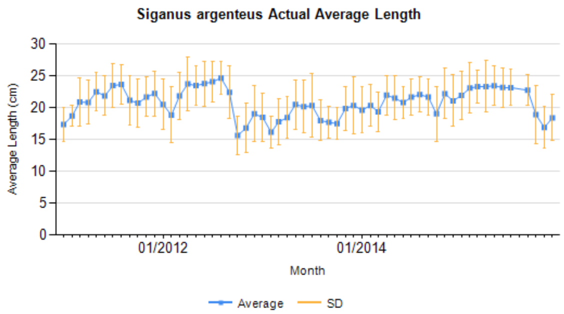

Myripristis murdjan Actual Average Length
Average Length (cm)
0
5
10
15
20
25
01/2012
01/2014
Month
Average
SD

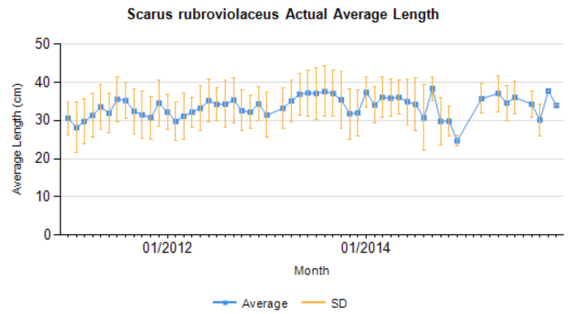

Chlorurus sordidus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
01/2012
01/2014
Month
Average
SD

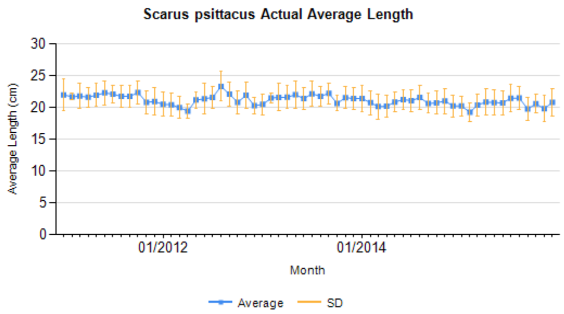

Myripristis violacea Actual Average Length
Average Length (cm)
0
5
10
15
20
25
01/2012
01/2014
Month
Average
SD

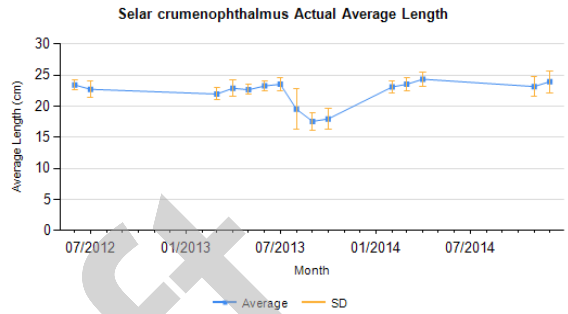

Siganus spinus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
01/2012
01/2014
Month
Average
SD

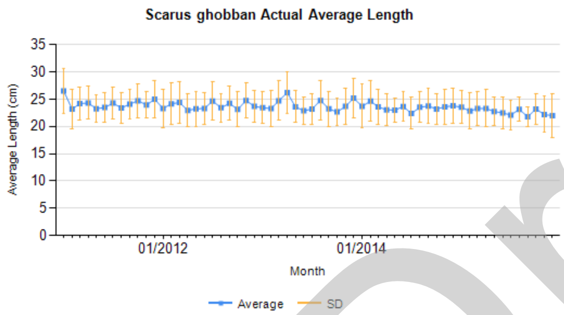

Siganus punctatus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
01/2012
01/2014
Month
Average
SD

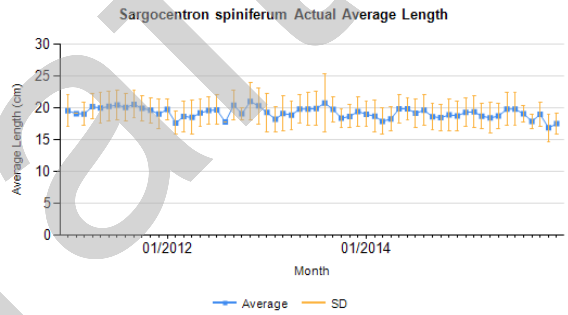

Siganus argenteus Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
01/2012
01/2014
Month
Average
SD


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


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


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


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


Sargocentron spiniferum Actual Average Length
Average Length (cm)
0
5
10
15
20
25
30
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

<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 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 Area

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.

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.

<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. 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.

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).

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.

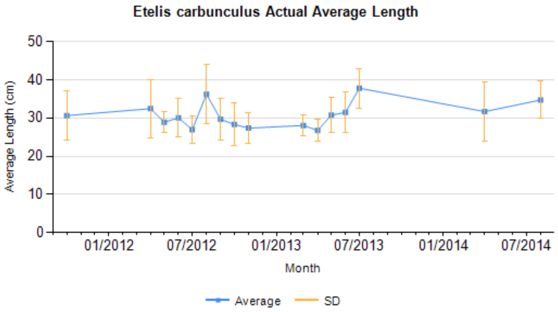
N_{L-W}* – *sample size for L-W regression is the number of samples used to generate the *a* & *b* coefficients.

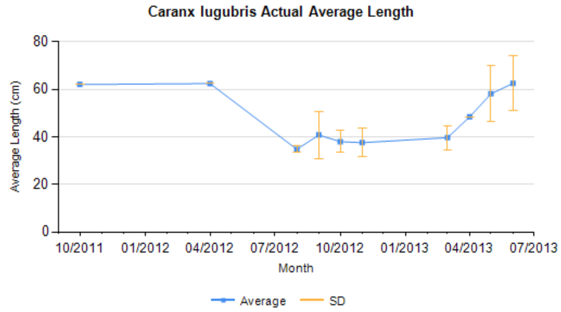
a* & *b* – *length-weight coefficients are the coefficients derived from the regression line fitted to all length and weight measured per species in the commercial bottomfish fishery. These values are used to convert length information to weight. Values are influenced by the life history characteristics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

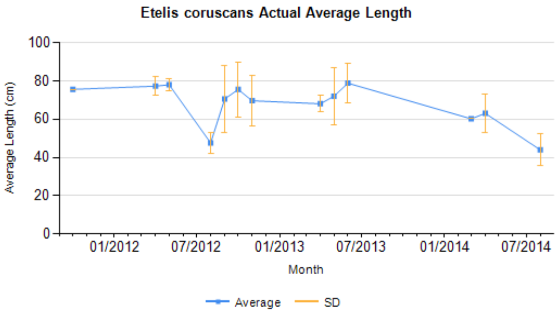
Rationale: Length-derived information is being used as an indicator of population status particularly for data poor stocks like coral reef fish. Average length (L_{bar}) was used as a principal stock assessment indicator variable for exploited reef fish population (Nadon *et al*., 2015). Average length 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.

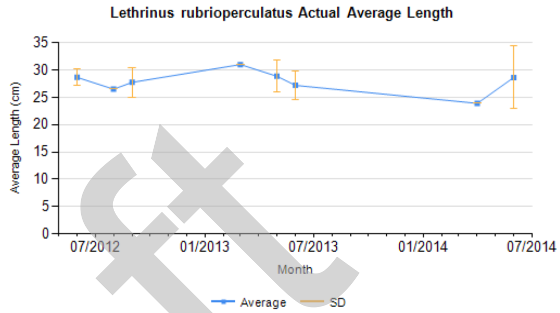
Table 54. Available length-derived information for various bottomfish species in CNMI.

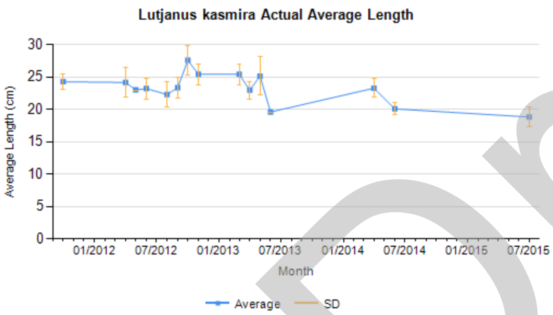
Species	Length-derived parameters						Reference
	L_{max}	L_{bar}	*N*	*L-W*	*a*	*b*	
Lethrinus rubrioperculatus	38.0	28.01	1,353	1,021	0.0185	2.9897	
Etelis carbunculus	53.5	30.18	685	685	0.0150	3.0430	
Pristipomoides auricilla	39.5	28.59	465	465	0.0189	3.0060	
Pristipomoides zonatus	45.4	32.99	371	370	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	

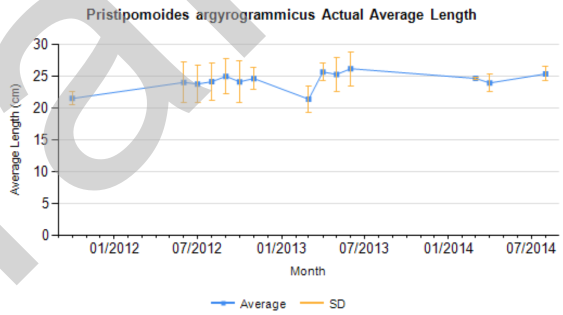

Etelis carbunculus Actual Average Length
Average Length (cm)
0
10
20
30
40
50
01/2012
07/2012
01/2013
07/2013
01/2014
07/2014
Month
Average
SD


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

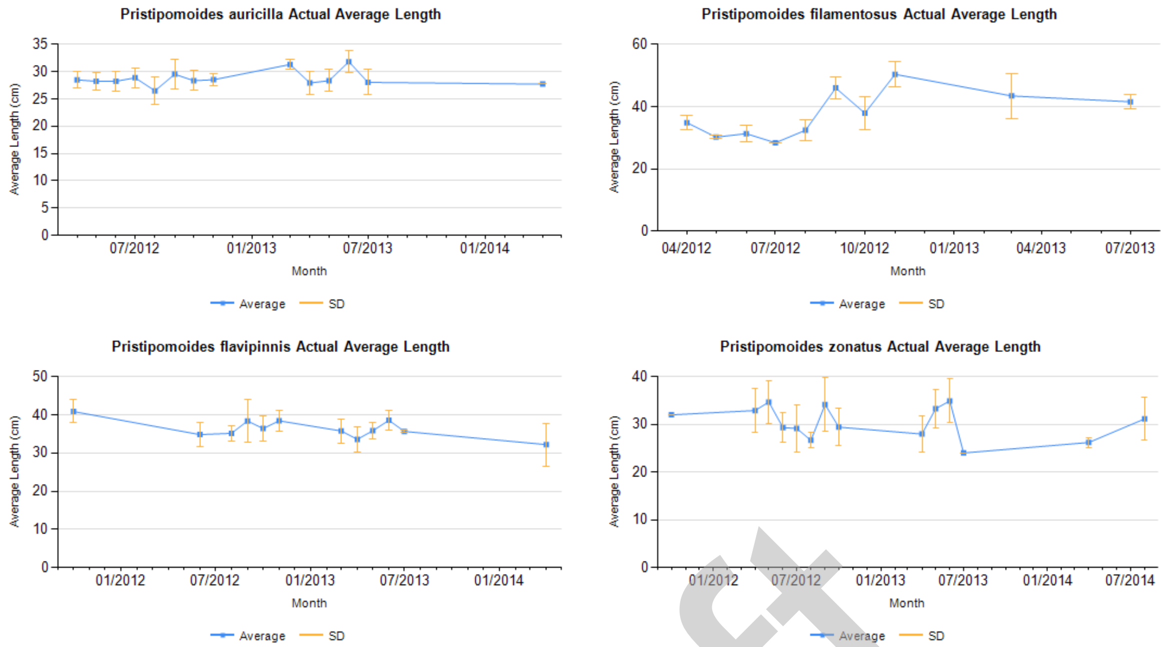


Figure 7. Average length over time of representative CNMI bottomfish management unit species derived from the BioSampling Program. Continued from previous page.

2.2.3 Guam Coral Reef Ecosystem – Reef Fish Life History

2.2.3.1 Age & Growth and Reproductive Maturity

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 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*Δ_{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 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. 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.

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
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 (m)[d]	-0.04 (f), -0.05 (m) [d]				401[d]		Taylor and Cruz (2017)
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]	493 d	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)
Siganus punctatus							NA		NA	

[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).

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.

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

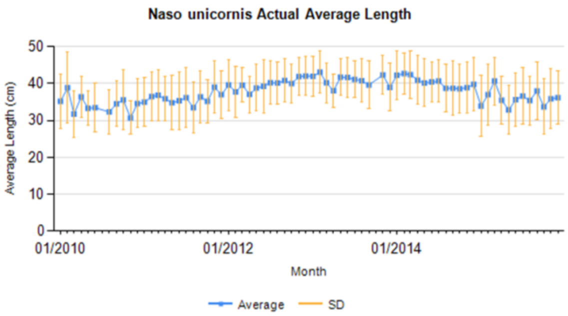
***a* & *b* – length-weight coefficients** are the coefficients derived from the regression line fitted to all length and weight measured per species in the commercial spear fishery. These values are used to convert length information to weight. Values are influenced by the life history characteristics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

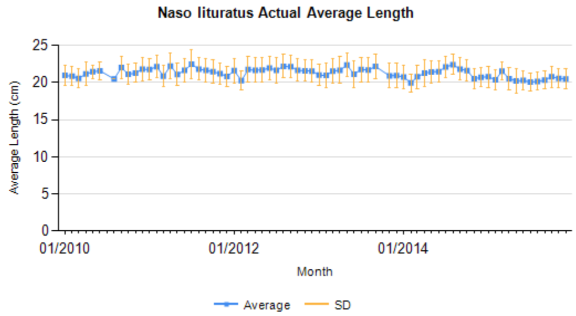
Rationale: Length-derived information is being used as an indicator of population status particularly for data-poor stocks like coral reef fish. Average length (L_{bar}) was used as a principal stock assessment indicator variable for exploited reef fish population (Nadon *et al*., 2015).

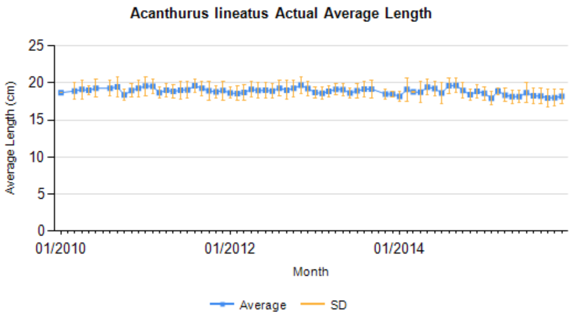
Average length was also shown to be correlated with population size (Kerr and Dickle, 2001). Maximum length (L_{max}), typically coupled with maximum age, is typically used as a proxy for fish longevity which has implications on the productivity and susceptibility of a species to fishing pressure. The 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.

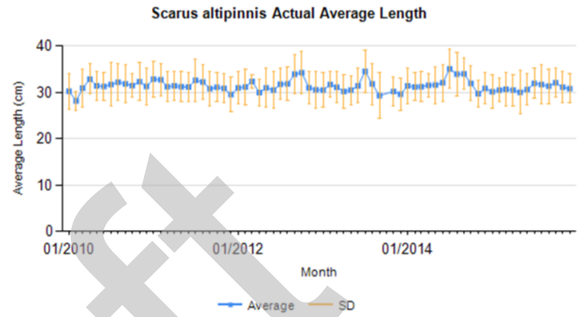
Table 56. Available length derived information for various coral reef species in Guam.

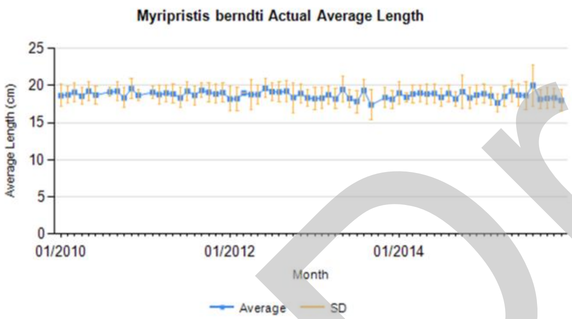
Species	Length-derived parameters						Reference
	L_{max}	L_{bar}	*n*	*L-W*	*a*	*b*	
Naso unicornis	57.2	38.02	15461		0.0278	2.9135	2010-2015 Guam Bio-Sampling Database
Naso lituratus	29.6	21.35	16702		0.0223	3.0264	
Acanthurus lineatus	28.9	19.04	4325		0.0473	2.8110	
Scarus altipinnis	46.4	31.16	3913		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	
Panulirus penicillatus							
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	

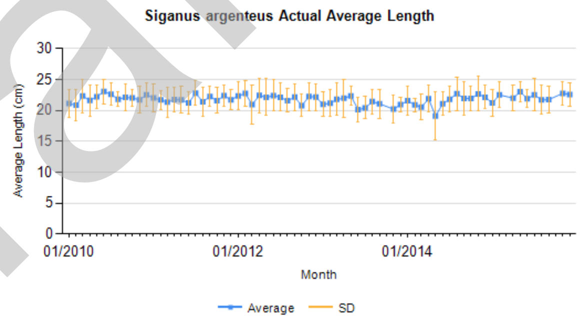

Naso unicornis Actual Average Length
Average Length (cm)
50
40
30
20
10
0
01/2010
01/2012
01/2014
Month
Average
SD

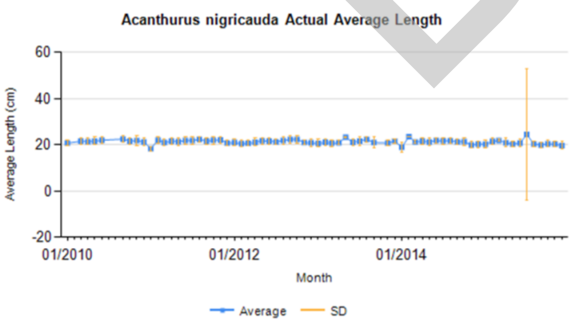

Naso lituratus Actual Average Length
Average Length (cm)
25
20
15
10
5
0
01/2010
01/2012
01/2014
Month
Average
SD

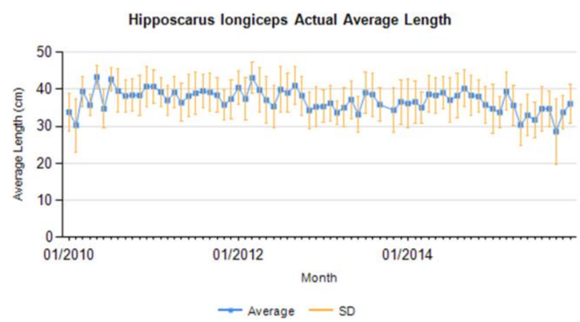

Acanthurus lineatus Actual Average Length
Average Length (cm)
25
20
15
10
5
0
01/2010
01/2012
01/2014
Month
Average
SD

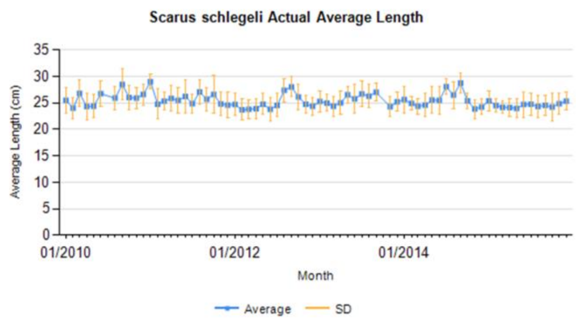

Scarus altipinnis Actual Average Length
Average Length (cm)
40
30
20
10
0
01/2010
01/2012
01/2014
Month
Average
SD

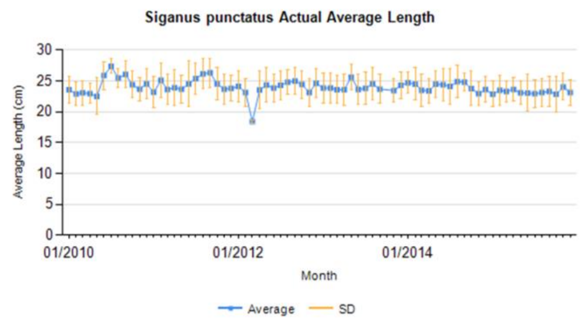

Myripristis berndti Actual Average Length
Average Length (cm)
25
20
15
10
5
0
01/2010
01/2012
01/2014
Month
Average
SD

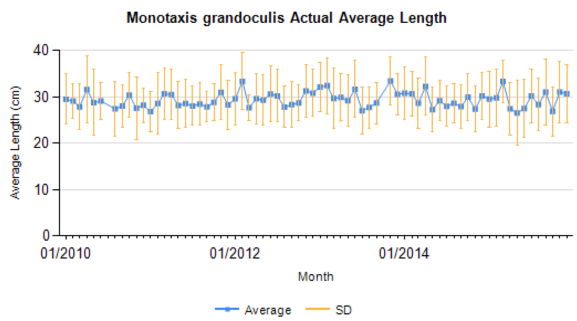

Siganus argenteus Actual Average Length
Average Length (cm)
30
25
20
15
10
5
0
01/2010
01/2012
01/2014
Month
Average
SD

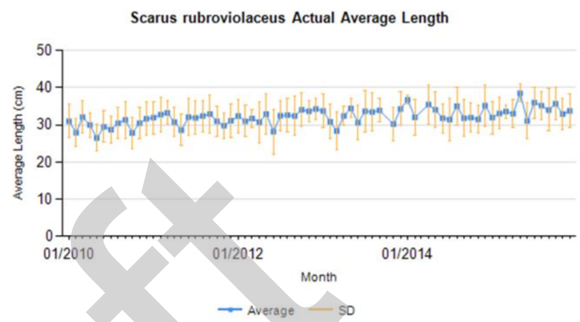

Acanthurus nigricauda Actual Average Length
Average Length (cm)
60
40
20
0
-20
01/2010
01/2012
01/2014
Month
Average
SD

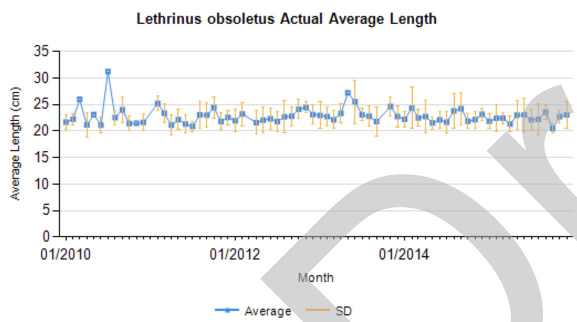

Hipposcarus longiceps Actual Average Length
Average Length (cm)
50
40
30
20
10
0
01/2010
01/2012
01/2014
Month
Average
SD

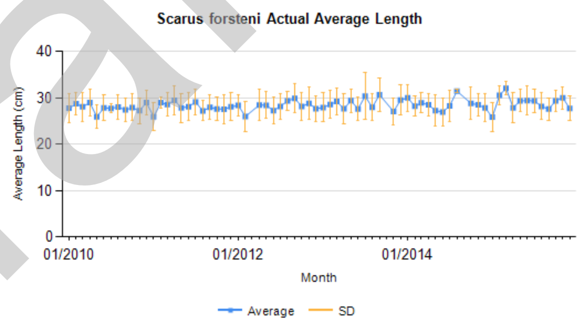

Scarus schlegeli Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

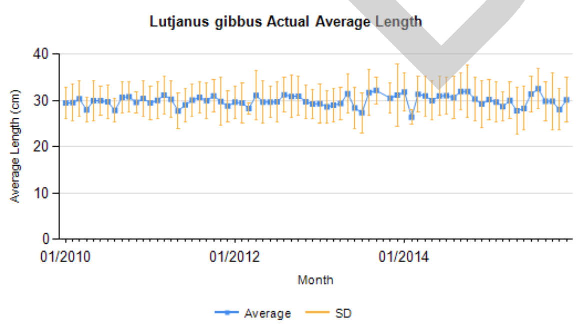

Siganus punctatus Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD


Monotaxis grandoculis Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD


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


Lethrinus obsoletus Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD


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


Lutjanus gibbus Actual Average Length
Average Length (cm)
Month
01/2010
01/2012
01/2014
Average
SD

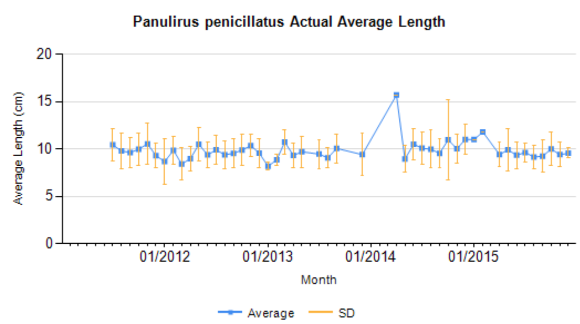

Panulirus penicillatus Actual Average Length
Average Length (cm)
Month
01/2012
01/2013
01/2014
01/2015
Average
SD

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

<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 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 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.

<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 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. 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.

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 (including in press).

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.

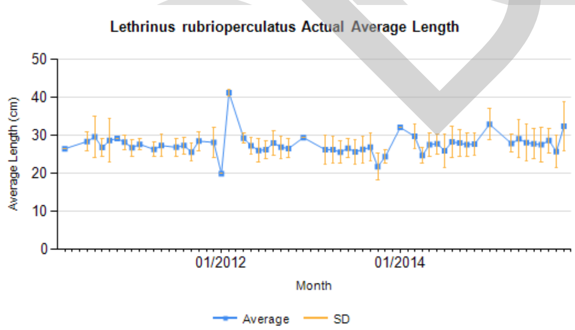
$N_{L\text{-}W}$ – ***sample size for L-W regression*** is the number of samples used to generate the a & b coefficients

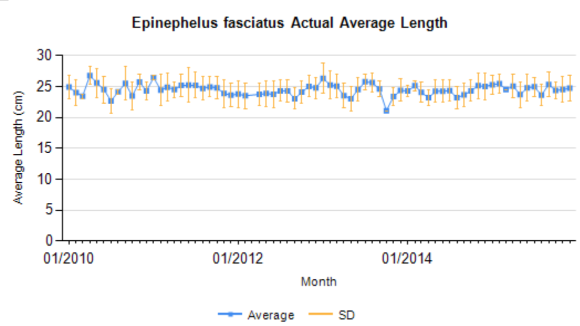
a & b – length-weight coefficients are the coefficients derived from the regression line fitted to all length and weight measured per species in the commercial spear fishery. These values are used to convert length information to weight. Values are influenced by the life history characteristics of the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





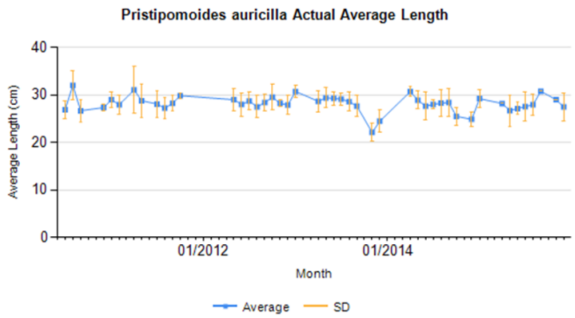


Figure 9. Average length over time of representative Guam BMUS derived from the BioSampling Program. Continued from previous page.

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.

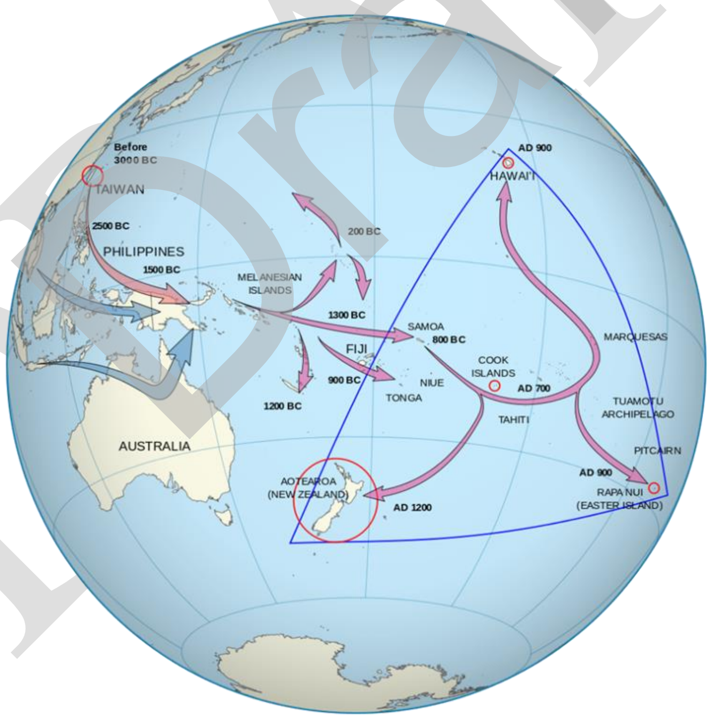


Figure 10. Settlement of the Pacific Islands, courtesy of Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg.

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 intoof 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.

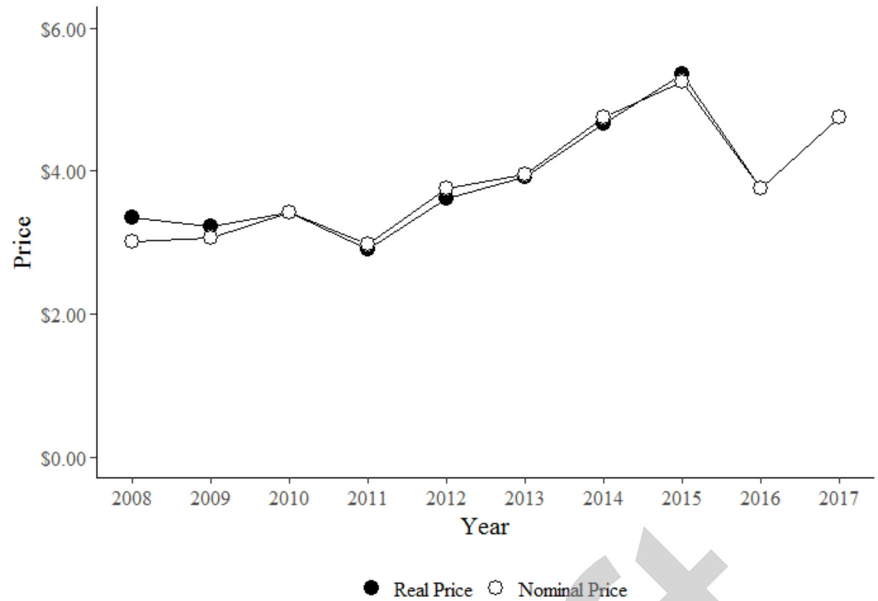
2.3.2.3 CNMI Bottomfish Fishery

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% identifyed deepwater bottomfish as their primary target, and 49% identifyed 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. Someself-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

2.2.5.1.1 This section will describe trends in commercial pounds sold, revenue, and prices for bottomfish fishery. **Error! Reference source not found.** presents the trends of commercial pounds sold and revenue of bottomfish fishery from 2008-2017, and

2.2.5.1.2 Figure **12** presents the trend of bottomfish price over the same period. Supporting data for **Error! Reference source not found.** and



2.2.5.1.3 Figure **12** are shown in Table 59. Table 59 also includes fish price and percent of pounds sold. In addition, the table includes both nominal and adjusted values. As shown in **Error! Reference source not found.**, the bottomfish fishery (pounds caught, pounds sold, and revenue) in CNMI has shown larger recent interannual variability, while fish price has been in an increasing trend over the past decade (

Figure **12**).

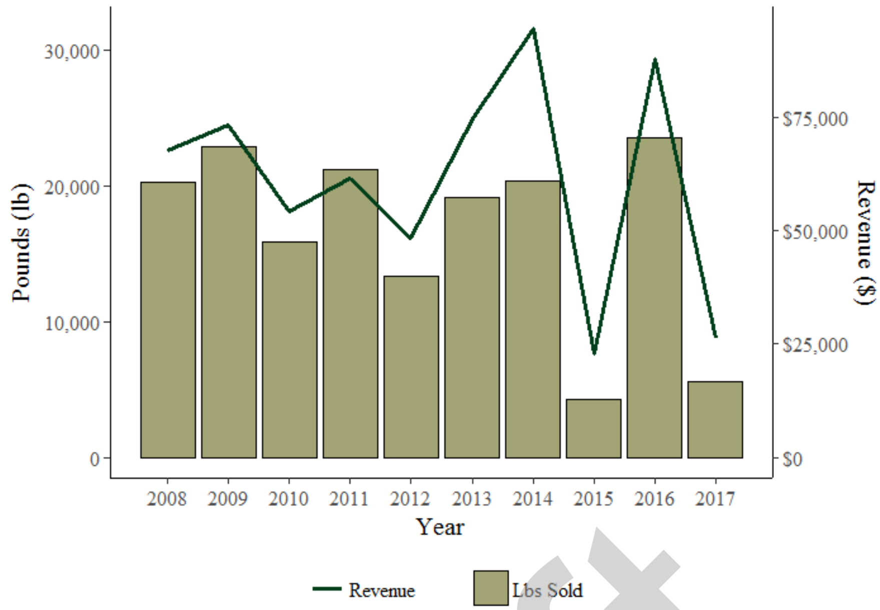


Figure 11. Pounds sold and revenues for the CNMI bottomfish fishery from 2018-2017 (adjusted to 2017 dollars).

Figure 12. Price of BMUS for the CNMI bottomfish fishery from 2008-2017.

Table 59. Commercial landings and revenue information of CNMI bottomfish fishery from 2008-2017*.

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue ($)	Estimated revenue ($ adjusted)	% of pounds sold	Fish price ($)	Fish price ($ adjusted)	CPI adjustor
2008	25,963	20,222	60,959	67,686	78%	3.01	3.35	1.110
2009	76,650	22,860	69,837	73,562	30%	3.05	3.22	1.053
2010	62,726	15,875	54,332	54,244	25%	3.42	3.42	0.998
2011	33,278	21,160	63,111	61,585	64%	2.98	2.91	0.976
2012	136,925	13,365	50,092	48,347	10%	3.75	3.62	0.965
2013	25,153	19,124	75,520	74,755	76%	3.95	3.91	0.990
2014	8,450	20,385	96,911	94,892	241%	4.75	4.65	0.979
2015	11,122	4,253	22,326	22,793	38%	5.25	5.36	1.021
2016	49,367	23,504	88,099	88,099	48%	3.75	3.75	1
2017	46,293	5,543	26,336	26,336	12%	4.75	4.75	1

Data source: PIFSC WPacFin (the pounds caught data were estimated from the expansion based on both boat base and shore base survey; the revenue data were estimated from commercial receipt book program).

*CPI 2017 for CNMI is not available. This report assumed the CPI value in 2017 was the same as 2016 for now, will adjust when CPI 2017 is available.

2.3.2.3.2 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 & 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 13 shows the trend of average trip costs for CNMI bottomfish trips during 2009–2017 (adjusted to 2017 dollars). Supporting data of Figure 13 are presented in Table 60. **Average trip costs for CNMI bottomfish trips from 2009–2017**. The trip costs seem to have substantial interannual variability. The average costs for a bottomfish trip was $38 in 2017.

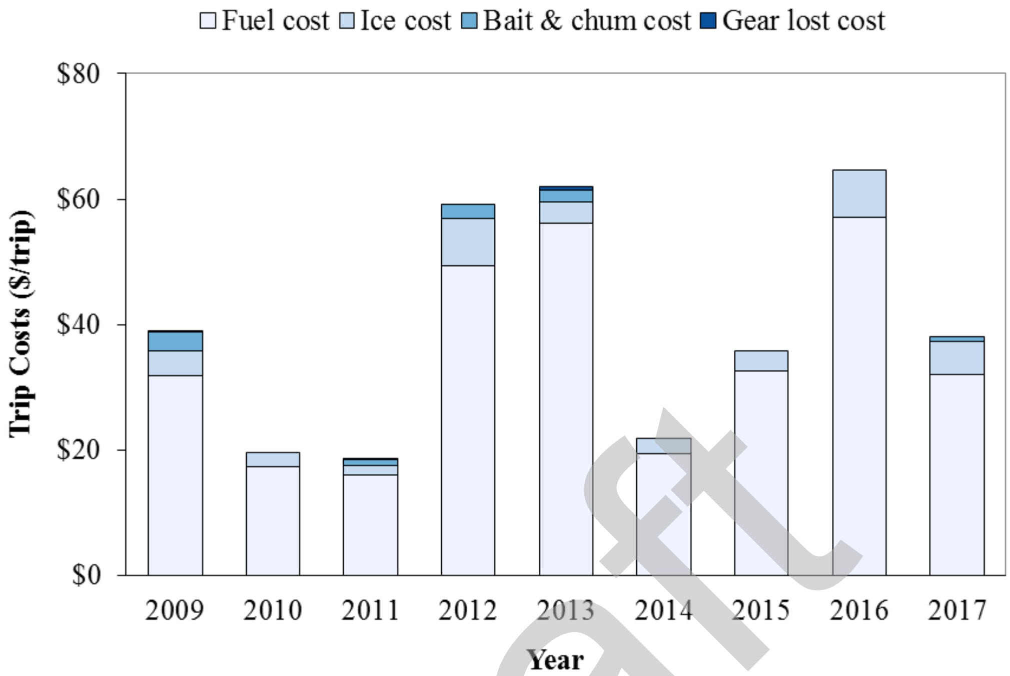


Figure 13. Average trip costs for CNMI bottomfish trips from 2009–2017 (adjusted to 2017 dollars).

Table 60. Average trip costs for CNMI bottomfish trips from 2009–2017. Data sourced from Chan and Pan Tech Memo (2018 in review).

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

2.3.2.4 CNMI Crustacean Fishery

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

2.3.2.5 CNMI Coral Reef Fishery

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, revenues, and prices for the CNMI coral reef fish fishery. Figure 14 presents the trends of commercial pounds sold and revenue of the coral reef fish fishery from 2008-2017, and Figure 15 presents the trend of fish price of coral reef fish sold during 2008-2017. Supporting data for Figure 14 and Figure 15 are shown in Table 61. Table 61 also includes fish price and % of pounds sold to the total pounds caught of the coral reef fish fishery. In addition, the table also includes both nominal and adjusted values. As showing in Figure 14, the coral reef fish fishery (pounds sold and revenue) in Guam in a declining trend (except for 2016). Fish price was relatively consistent around $2.76 in nominal value (Figure 15).

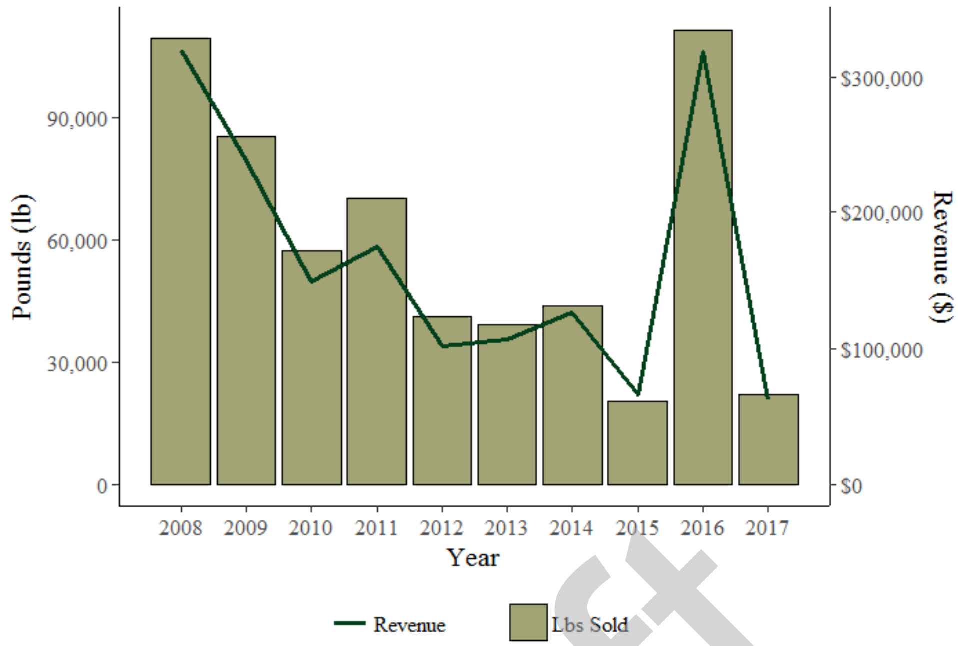


Figure 14. Pounds sold and revenue for the CNMI reef fish fishery from 2008-2017 (adjusted to 2017 dollars).

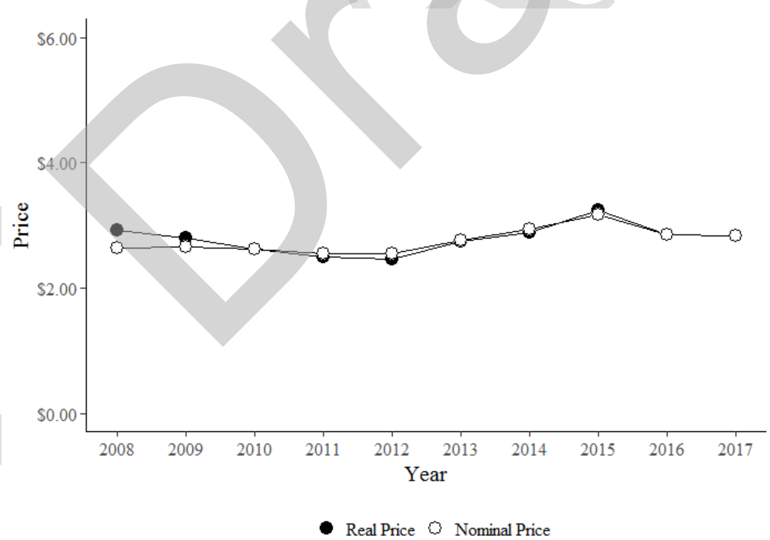


Figure 15. Price of CREMUS in the CNMI Reef Fishery from 2008-2017.

Table 61. Commercial landings and revenue information of CNMI coral reef fishery from 2008-2017.

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue ($)	Estimated revenue ($ adjusted)	% of pounds sold	Fish price ($)	Fish price ($ adjusted)	CPI adjustor
2008	103,893	109,400	288,243	320,050	105%	2.63	2.93	1.110
2009	103,873	85,325	226,324	238,395	82%	2.65	2.79	1.053
2010	71,472	57,169	149,515	149,274	80%	2.62	2.61	0.998
2011	71,991	70,339	179,571	175,229	98%	2.55	2.49	0.976
2012	59,265	41,158	105,145	101,483	69%	2.55	2.47	0.965
2013	89,846	39,127	108,128	107,033	44%	2.76	2.74	0.990
2014	22,513	43,797	128,988	126,301	195%	2.95	2.88	0.979
2015	29,318	20,274	64,263	65,606	69%	3.17	3.24	1.021
2016	31,660	111,633	318,953	318,953	353%	2.86	2.86	1
2017	19,871	21,889	62,092	62,092	110%	2.84	2.84	1

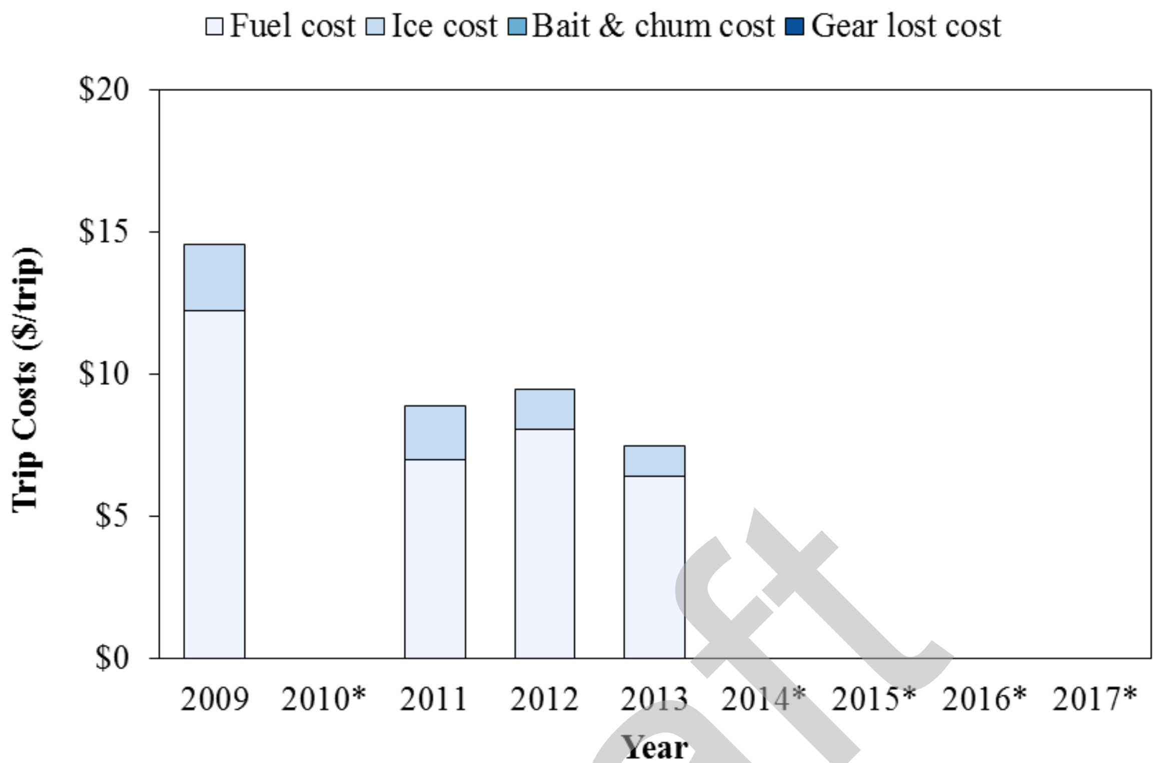
Data source: PIFSC WPacFin (the pounds caught data were estimated from the expansion based on both boat base and shore base survey; the revenue data were estimated from commercial receipt book program).

This report assumed the CPI value in 2017 was the same as 2016 for now, will adjust when the CPI 2017 data are available.

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 16 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 16 are listed in Table 62.



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

Figure 16. Average cost for CNMI spear/snorkel fishing trips from 2009–2017 (adjusted to 2017 dollars).

Table 62. Average cost for CNMI spear/snorkel fishing trips from 2009–2017 (adjusted to 2017 dollars). Data sourced from Chan and Pan Tech Memo (2018 in review).

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.

2.3.2.6 CNMI Precious Coral Fishery

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.

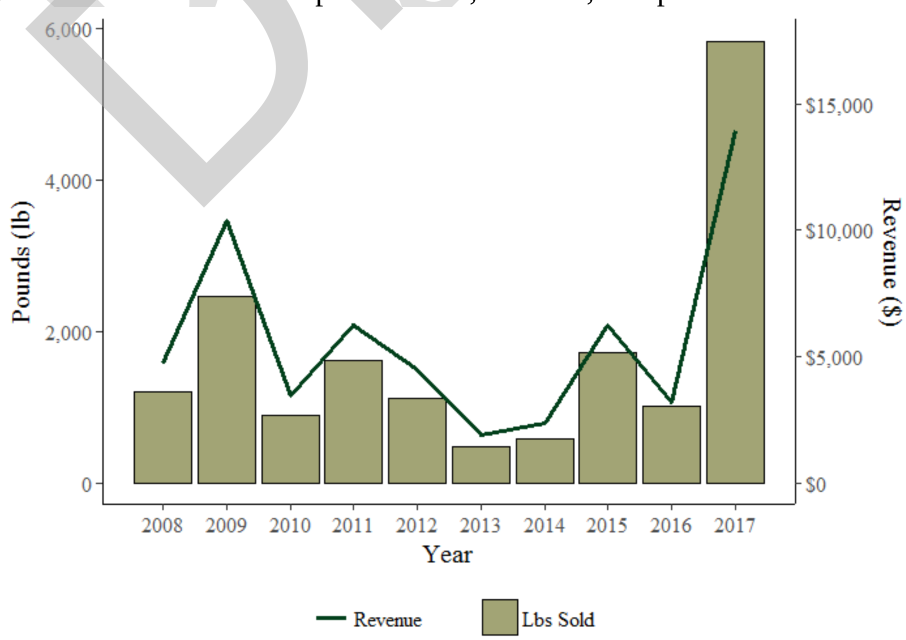
2.3.3.3 Guam Bottomfish Fishery

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%).

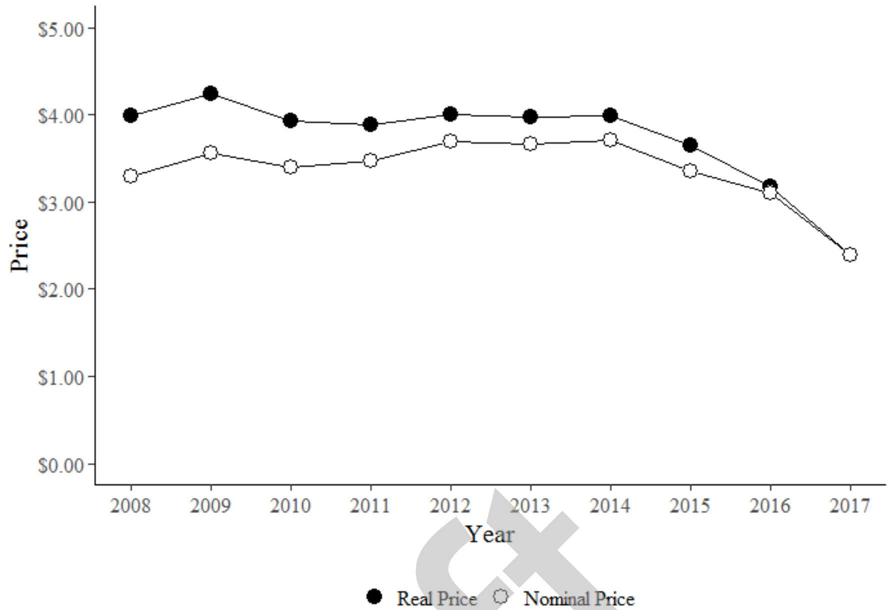
2.3.3.3.1 Commercial Participation, Landings, Revenue, Prices

This section describes trends in commercial pounds sold, revenue, and price for the Guam



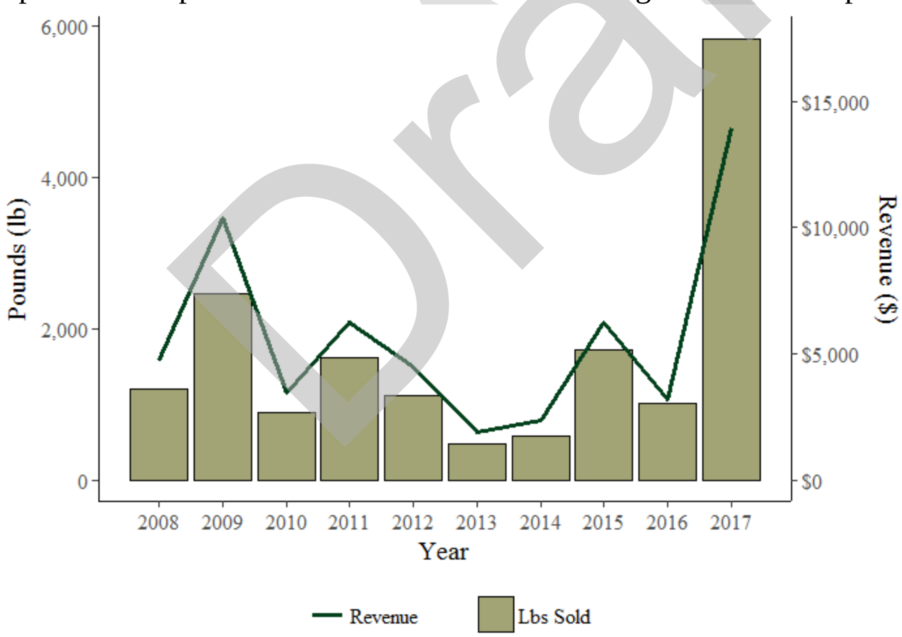
bottomfish fishery.

Figure 17 presents the trends of commercial pounds sold and revenues of bottomfish fishery



from 2008-2017, and

Figure 18 presents the price trend of bottomfish sold during the same time period. Supporting



data for

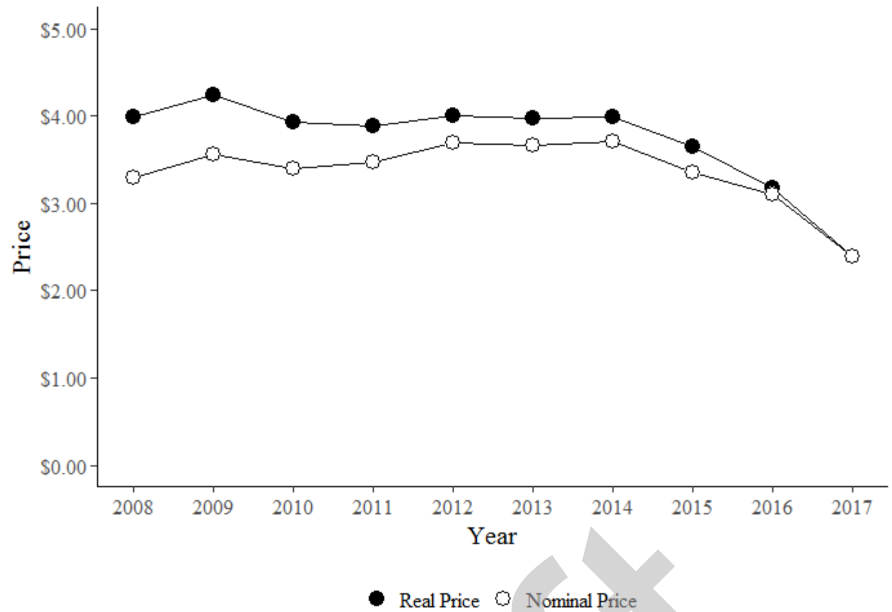


Figure 17 and

Figure 18 are shown in Table 63. Table 63 also includes fish price and the percentage of pounds sold relative to the total pounds caught for the bottomfish fishery. In addition, the table also includes both nominal and adjusted values. As shown in

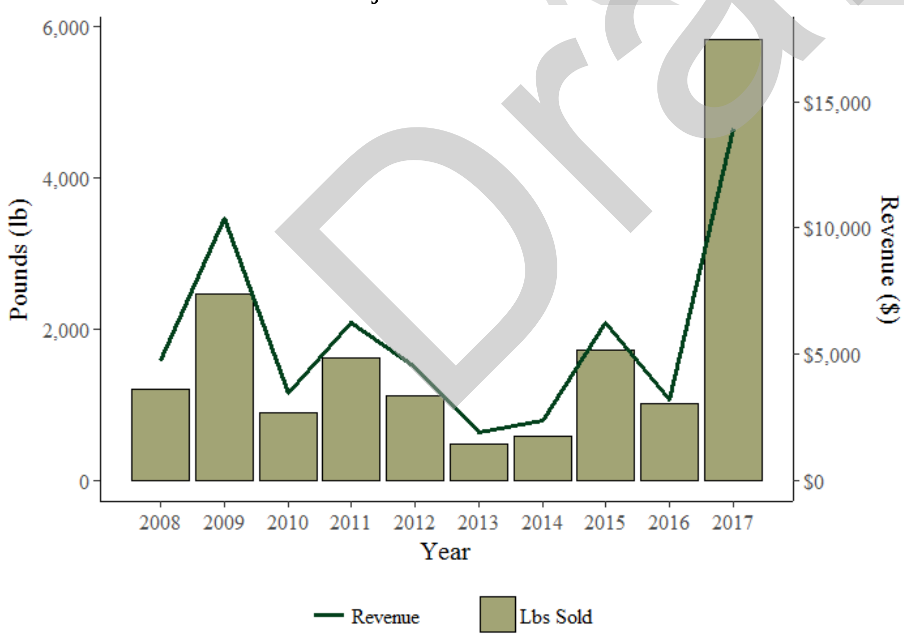


Figure 17. Pounds sold and revenue and prices, for the Guam bottomfish fishery from 2008-2017. pounds sold and revenue in Guam's bottomfish fishery was steady except for a spike in

2017. Fish price had been in a declining trend since 2014 (

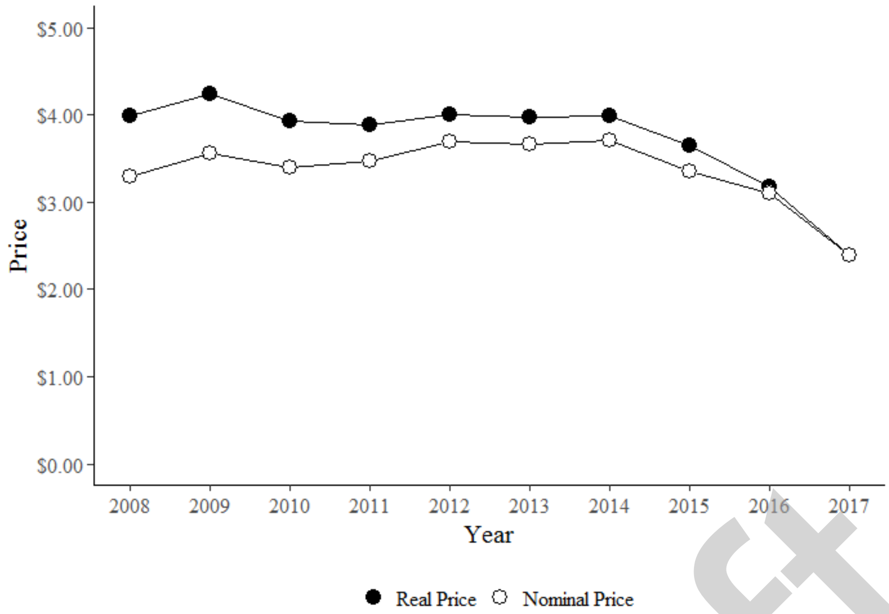


Figure 18).

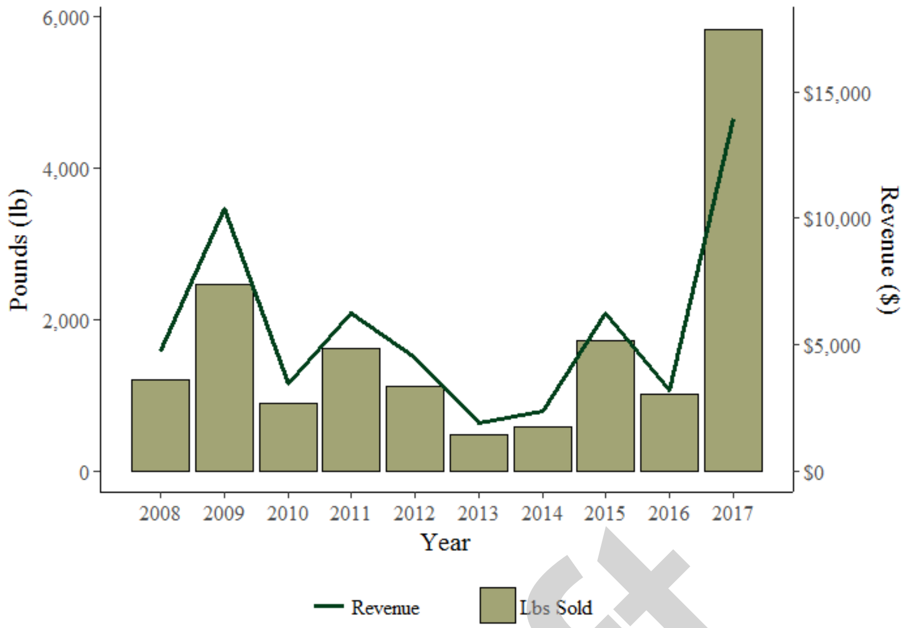


Figure 17. Pounds sold and revenue and prices, for the Guam bottomfish fishery from 2008-2017.

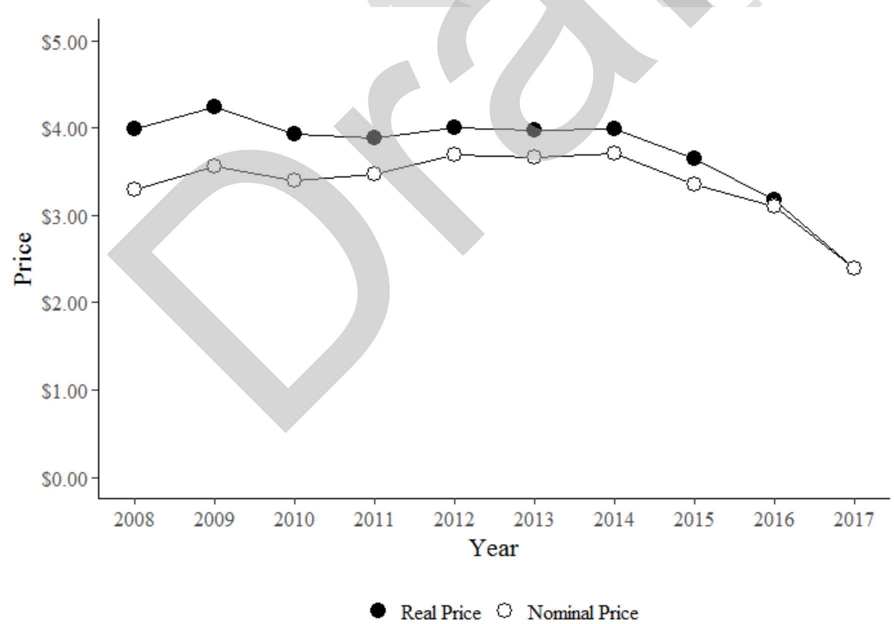


Figure 18. Price of BMUS for the Guam bottomfish fishery from 2008-2017.

Table 63. Commercial landings and revenue information of Guam bottomfish fishery from 2008-2017.

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue ($)	Estimated revenue ($ adjusted)	% of pounds sold	Fish price ($)	Fish price ($ adjusted)	CPI adjustor
2008	37,014	1,195	3,929	4,758	3%	3.29	3.29	1.211
2009	39,250	2,456	8,732	10,397	6%	3.56	3.56	1.191
2010	27,062	885	3,001	3,473	3%	3.39	3.39	1.157
2011	59,023	1,615	5,594	6,267	3%	3.46	3.46	1.120
2012	22,171	1,123	4,138	4,492	5%	3.68	3.68	1.086
2013	30,868	478	1,747	1,896	2%	3.65	3.65	1.085
2014	24,917	586	2,170	2,337	2%	3.70	3.70	1.077
2015	13,837	1,713	5,745	6,242	12%	3.35	3.35	1.087
2016	26,893	1,012	3,130	3,208	4%	3.09	3.09	1.025
2017	24,435	5,839	13983	13983	24%	2.39	2.39	1

Data source: PIFSC WPacFin (the pounds caught data were estimated from the expansion based on both boat base and shore base survey; the revenue data and price data were estimated from commercial receipt book program).

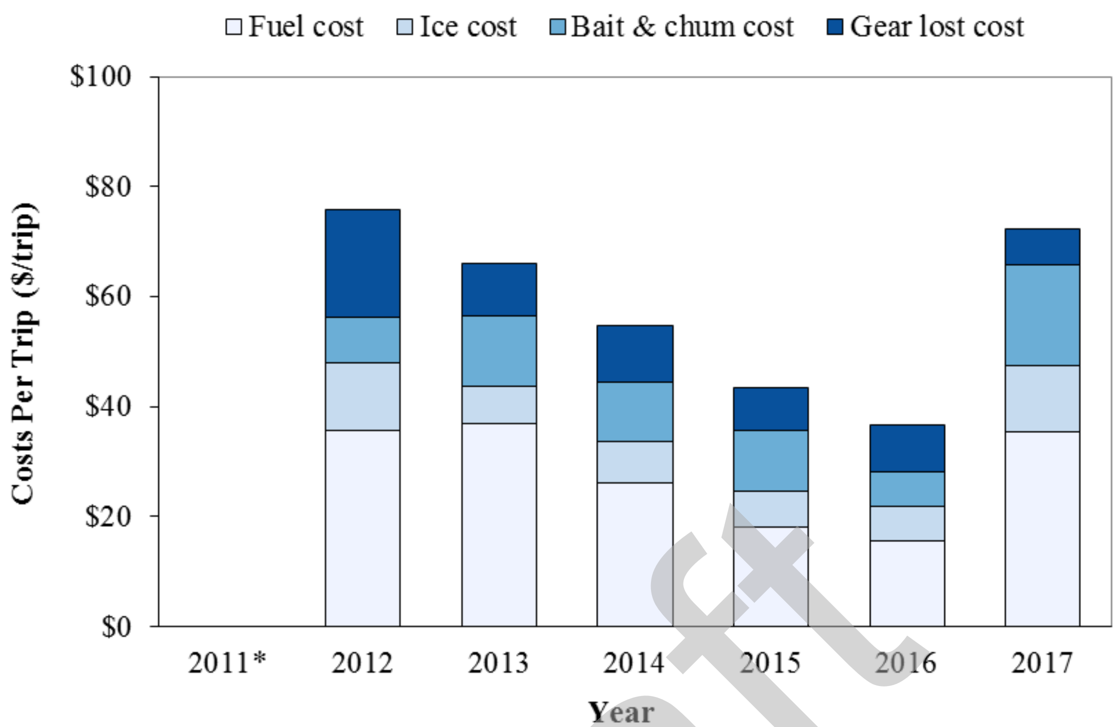
2.3.3.3.2 Costs of Fishing

Since 2011, the PIFSC Socioeconomics Program has 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 19 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 19 are presented in Table 64.



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

Figure 19. Average trip costs for Guam bottomfish fishing trips from 2009–2017 (adjusted to 2017 dollars).

Table 64. Average trip costs for Guam bottomfish fishing trips from 2009–2017. Data source: Chan and Pan, Tech Memo (2018 in review).

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.

2.3.3.4 Guam Crustacean Fishery

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

2.3.3.5 Guam Coral Reef Fishery

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 describes trends in commercial pounds sold, revenue, and prices for the Guam coral reef fish fishery over the past decade. Figure 20 presents the trends of commercial pounds sold and revenues of coral reef fish fishery during 2008-2017, and Figure 21 presents the trend of fish price of coral reef fish sold during 2008-2017. Supporting data for Figure 20 and Figure 21 are shown in Table 65. Table 65 also includes fish price and percentage of pounds sold relative to the total pounds caught in the bottomfish fishery. In addition, the table also includes both nominal and adjusted values. As shown in Figure 20, the coral reef fish fishery pounds sold and revenue in Guam were steady except for an increase in both landings and revenue in 2017. Fish price was steady from 2008 to 2015, but substantially decreased in both 2016 and 2017 (Figure 21).

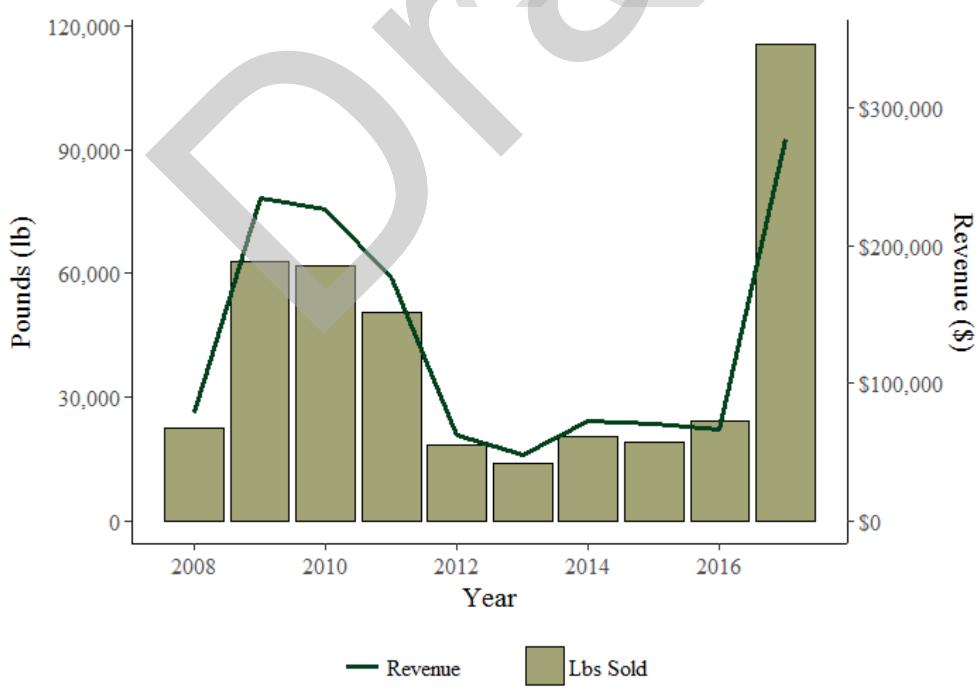


Figure 20. Pounds sold and revenue for the Guam reef fish fishery from 2008-2017.

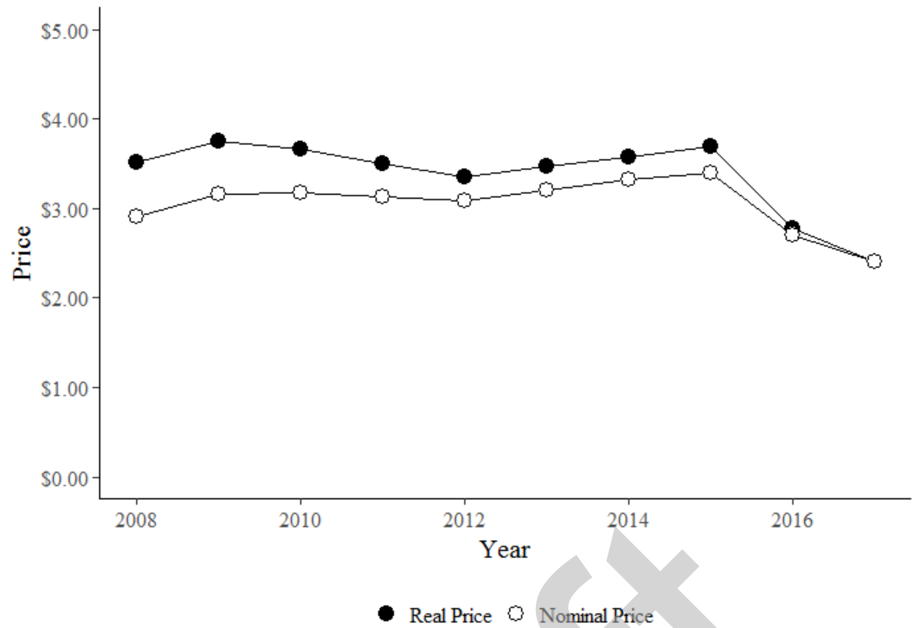


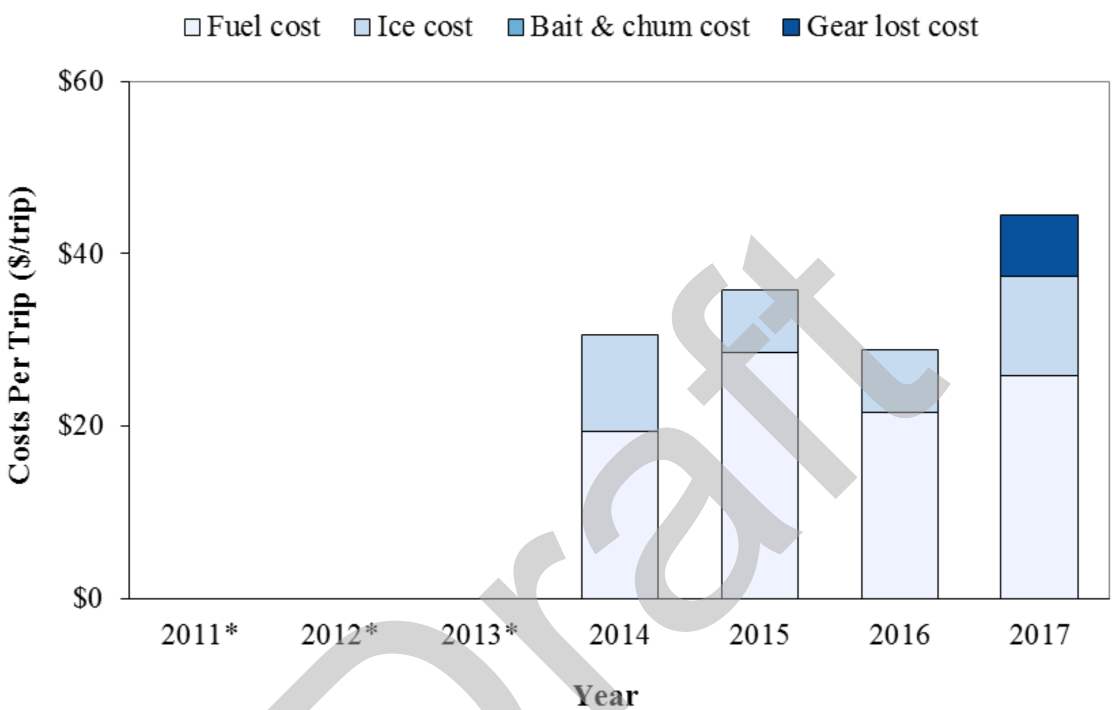
Figure 21. Price of CREMUS for the Guam reef fish fishery from 2008-2017.

Table 65. Commercial landings and revenue information of Guam coral reef fish fishery from 2008-2017. Data source: PIFSC WPacFin (the pounds caught data were estimated from the expansion based on both boat base and shore base survey; the revenue data and price data were estimated from commercial receipt book program).

Year	Estimated Pounds Caught (lb)	Estimated Pounds Sold (lb)	Estimated Revenue ($)	Estimated Revenue ($ Adjusted)	% of pounds sold	Fish Price ($)	Fish Price ($ adjusted)	CPI adjustor
2008	151,210	22,428	65,037	78,756	15%	2.90	3.51	1.210
2009	470,437	62,688	197,553	235,228	13%	3.15	3.75	1.19
2010	158,999	61,898	196,067	226,889	39%	3.17	3.67	1.158
2011	253,287	50,517	157,711	176,673	20%	3.12	3.50	1.122
2012	211,166	18,409	56,855	61,719	9%	3.09	3.35	1.084
2013	243,124	13,863	44,325	48,112	6%	3.20	3.47	1.084
2014	174,347	20,394	67,714	72,912	12%	3.32	3.58	1.078
2015	184,732	19,086	64,842	70,457	10%	3.40	3.69	1.085
2016	120,385	24,026	64,978	66,605	20%	2.70	2.77	1.026
2017	131,545	115,750	277,712	277,712	88%	2.40	2.40	1

2.3.3.5.2 Fishing Costs

The trip costs presented in Figure 22 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 fishing trips were in an increasing trend since 2014 to 2017. Supporting data for Figure 22 are presented in Table 66.



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

Figure 22. Average trip costs for Guam spear/snorkel trips from 2011–2017 (adjusted to 2017 dollars).

Table 66. Average trip costs for Guam spear/snorkel fish trips from 2011–2017. Data source: Chan and Pan, Tech Memo (2018 in review).

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.

2.3.3.6 Guam Precious Coral Fishery

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

Bennett, N.J., The, L., Ota, Y., Christie, P., Ayers, A., Day, J.C., Franks, P., Gill, D., Gruby, R.L., Kittinger, J.N. *et al*., 2017. An appeal for a code of conduct for marine conservation. *Marine Policy*, *81*, pp. 411-418. https://doi.org/10.1016/j.marpol.2017.03.035.

Kotowicz, D.M., Richmond, L., and Hospital, J., 2017. Exploring public knowledge, attitudes, and perceptions of the Marianas Trench Marine National Monument. Coastal Management. https://doi.org/10.1080/08920753.2017.1373451.

Pacific Islands Fisheries Science Center (PIFSC), 2017. Background and PIFSC Response: Panel Reports of the Economics and Human Dimensions Program Review. 18 p. https://go.usa.gov/xnDyP.

2.3.6 References

Allen, S.D. and Amesbury, J.R., 2012. Commonwealth of the Northern Mariana Islands as a fishing community. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFSPIFSC-36, 89 p. https://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_36.pdf.

Allen, S. and Bartram P., 2008. Guam as a fishing community. Pacific Islands Fisheries Science Center Administrative Report H-08-01, 61 p. https://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_08-01.pdf.

Grace-McCaskey, C. 2014. Examining the potential of using secondary data to better understand human-reef relationships across the Pacific. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96818-5007. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-14-01, 69 p. https://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_14-01.pdf.

Hospital, J. and Beavers, C., 2012. Economic and social characteristics of Guam's small boat fisheries. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-12-06, 60 p. + Appendices. https://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_12-06.pdf.

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.

Kotowicz, D.M. and Allen, S.D., 2015. Results of a survey of CNMI and Guam residents on the Marianas Trench Marine National Monument. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-13-009, 55 p. https://www.pifsc.noaa.gov/library/pubs/DR-13-009.pdf.

Kotowicz, D.M. and Richmond, L., 2013. Traditional Fishing Patterns in the Marianas Trench Marine National Monument. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-13-05, 54 p. https://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_13-05.pdf.

National Coral Reef Monitoring Program (NCRMP) Socioeconomic Monitoring for Guam – infographic, available at: https://www.coris.noaa.gov/monitoring/resources/GuamCoral.pdf.

PIFSC Socioeconomics Program, 2016. CNMI, American Samoa, and Guam Small Boat Fishery Trip Expenditure (2009 to present). Pacific Islands Fisheries Science Center, https://inport.nmfs.noaa.gov/inport/item/20627.

Polovina, J. and Dreflak, K. (Chairs), Baker, J., Bloom, S., Brooke, S., Chan, V., Ellgen, S., Golden, D., Hospital, J., Van Houtan, K., Kolinski, S., Lumsden, B., Maison, K., Mansker, M., Oliver, T., Spalding, S., Woodworth-Jefcoats, P., 2016. Pacific Islands Regional Action Plan: NOAA Fisheries climate science strategy. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-59, 33 p. doi:10.7289/V5/TM-PIFSC-59.

Richmond, L., and Kotowicz, D.M., 2015. Equity and access in marine protected areas: The history and future of 'traditional indigenous fishing' in the Marianas Trench Marine National Monument. *Applied Geography*, *59*, pp. 117-124. doi:10.1016/j.apgeog.2014.11.007.

Rubinstein, D., 2001. A Sociocultural Study of Pelagic Fishing Activities in Guam. Final progress report available from University of Hawaii Joint Institute for Marine and Atmospheric Research, Pelagic Fisheries Research Program. Also available at: http://www.soest.hawaii.edu/PFRP/pdf/rubinstein01.pdf.

Western Pacific Regional Fishery Management Council, 2016. Draft Fishery Ecosystem Plan for the Mariana Archipelago. Honolulu, HI. 114 p. + Appendices.

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 Interactions in the Marianas FEP Fisheries

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.

2.4.1.1 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.

2.4.1.2 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 67.

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 67. 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
Coral reef ecosystem (CNMI)	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.

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).

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).

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 CNMI 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).

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.

2.4.1.3 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).

2.4.2 Status of Protected Species Interactions in the Marianas FEP Fisheries
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.

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.

2.4.3 Identification of Emerging Issues

Several ESA-listed species are being evaluated for critical habitat designation (Table 68). 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 68. 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.

2.4.4 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:

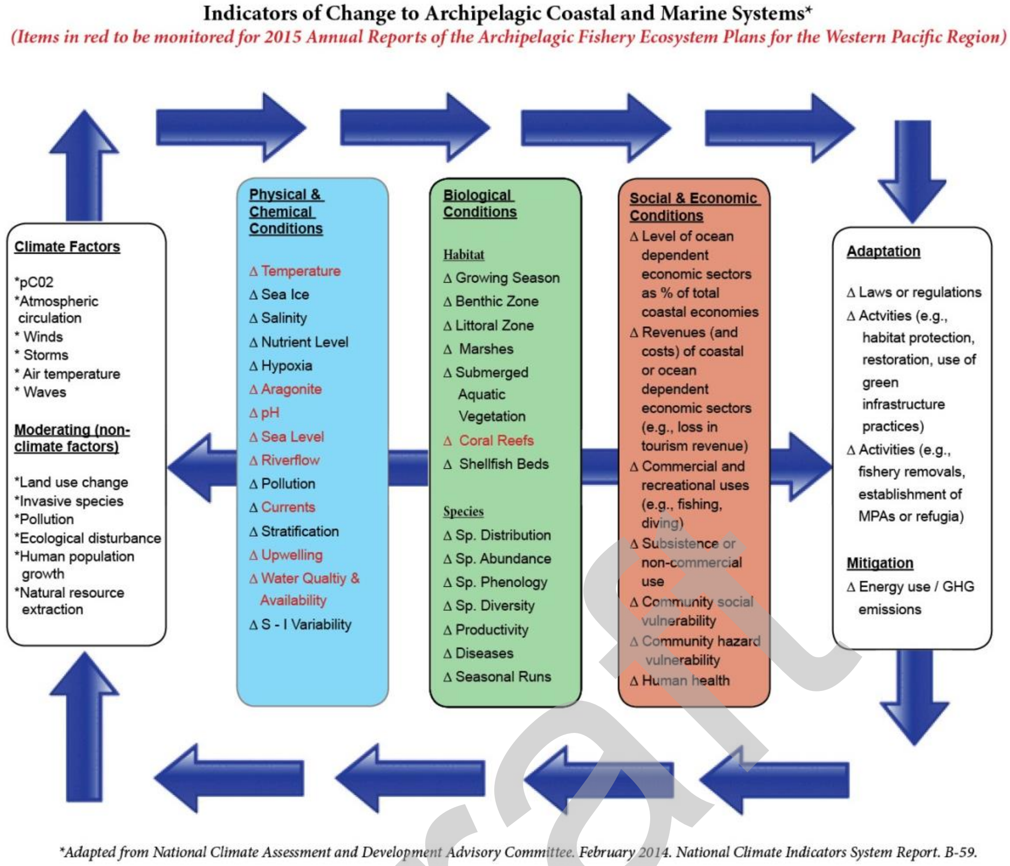


Figure 23. Simplified representation of the climate and non-climate stressors in the coastal and marine ecosystems.

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.

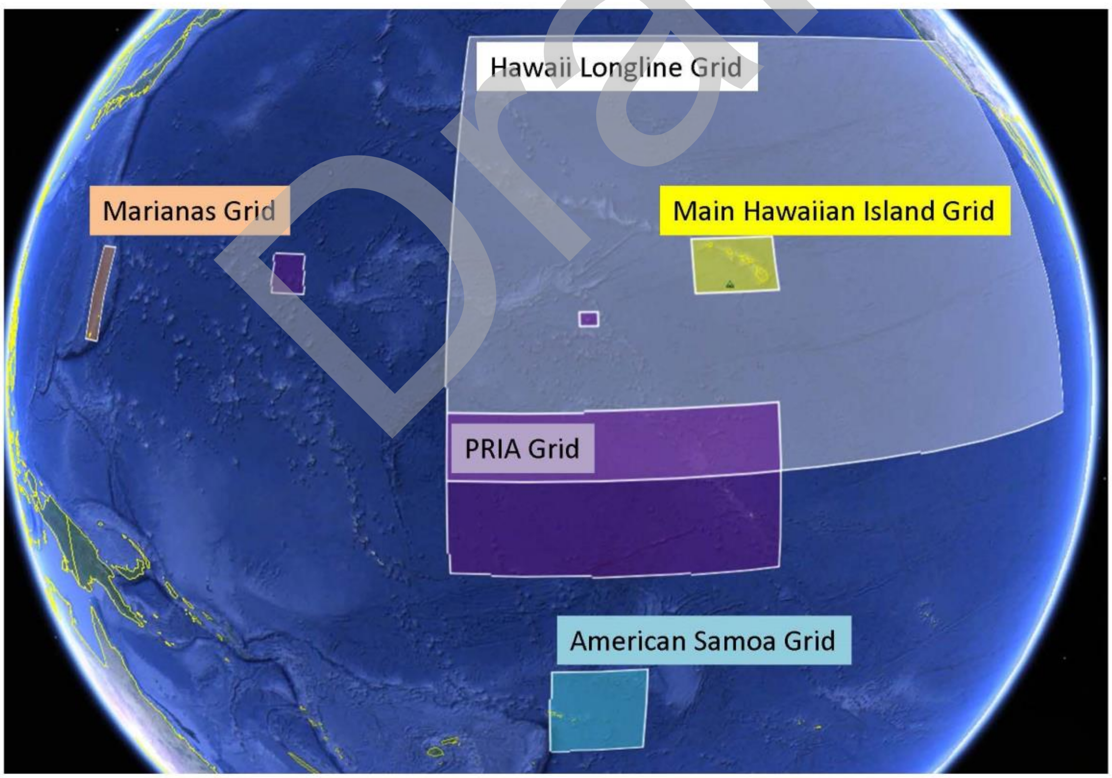


Figure 24. Regional spatial grids representing the scale of the climate change indicators being monitored.

Table 69. 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 Exposure (DHW)	Satellite remotely-sensed metric of time and temperature above thresholds relevant for coral bleaching. Metric used is Degree Heating Weeks (DHW).	The equatorial PRIA showed 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.

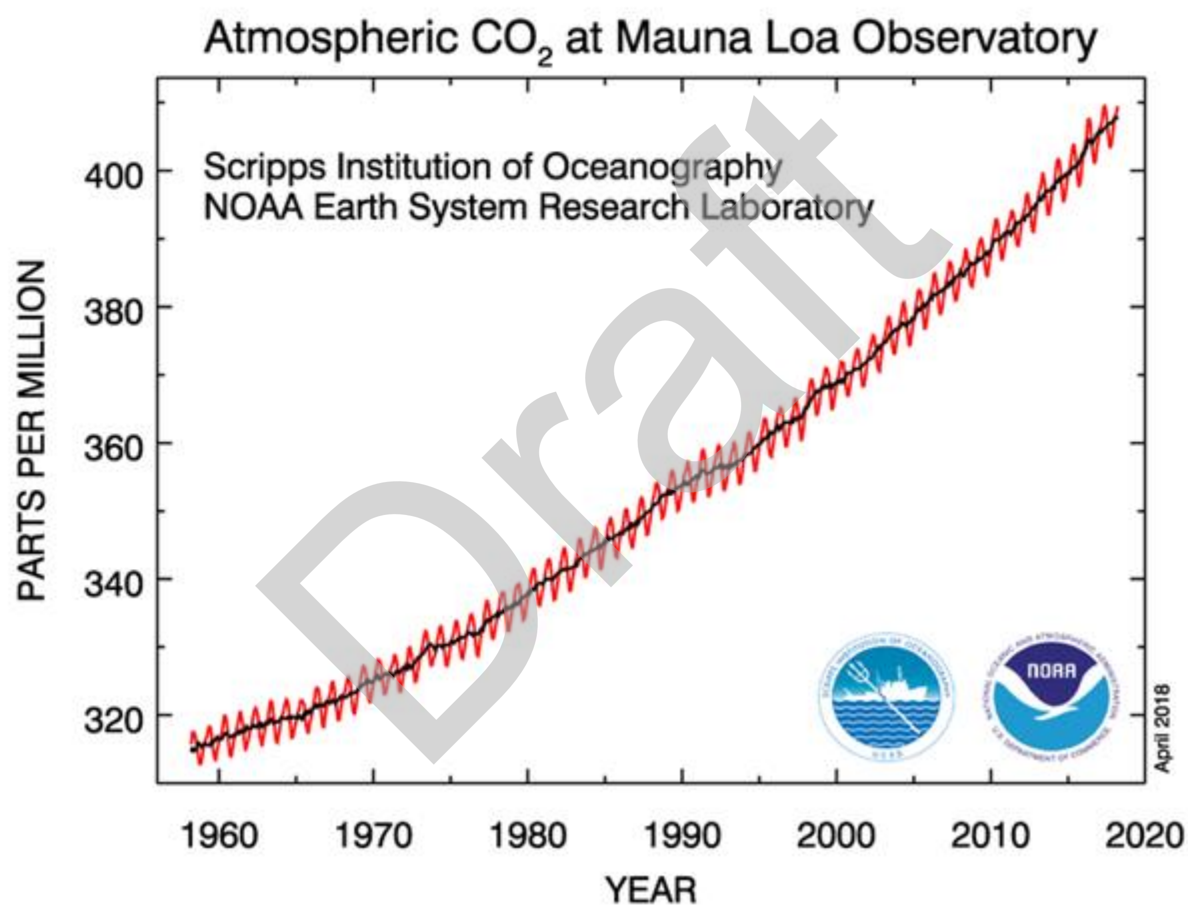


Figure 25. Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawai`i. Note: The red line shows monthly averages and the black line shows seasonally corrected data.

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

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).

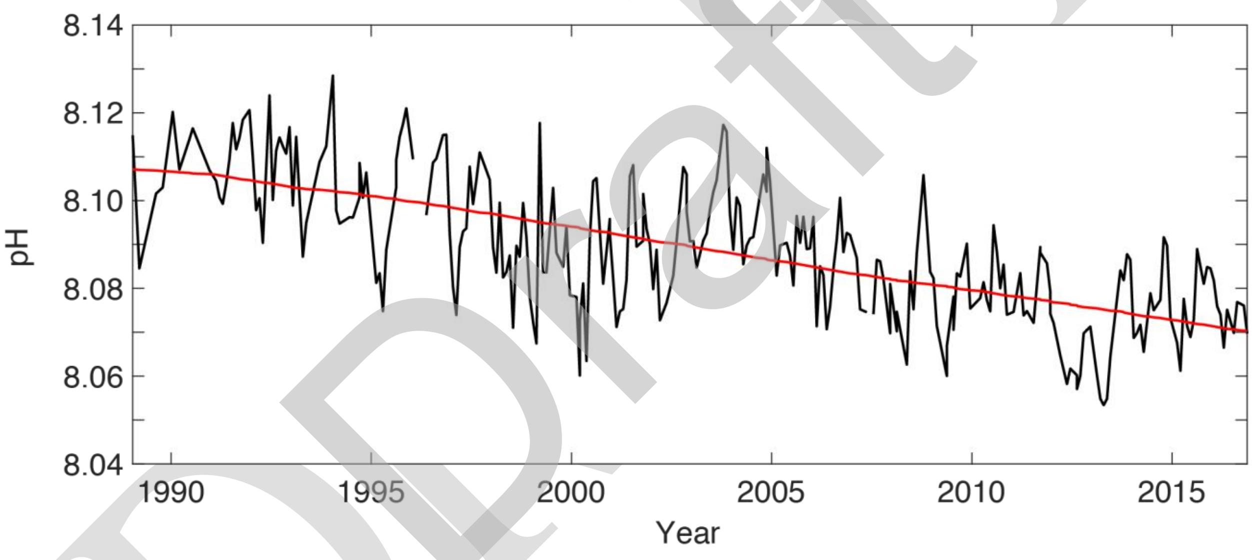


Figure 26. pH Trend at Station ALOHA, 1989 – 2016. **Note: Measured pH values are plotted in black. The linear fit to this time series is shown in red.**

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

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 VJ, Seibel BA, Feely RA, Orr JC, 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science*, 65: 414-432.

Feely RA, Alin SR, Carter B, Bednarsek N, Hales B, Chan F, Hill TM, Gaylord B, Sanford E, Byrne RH, Sabine CL, 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: 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.

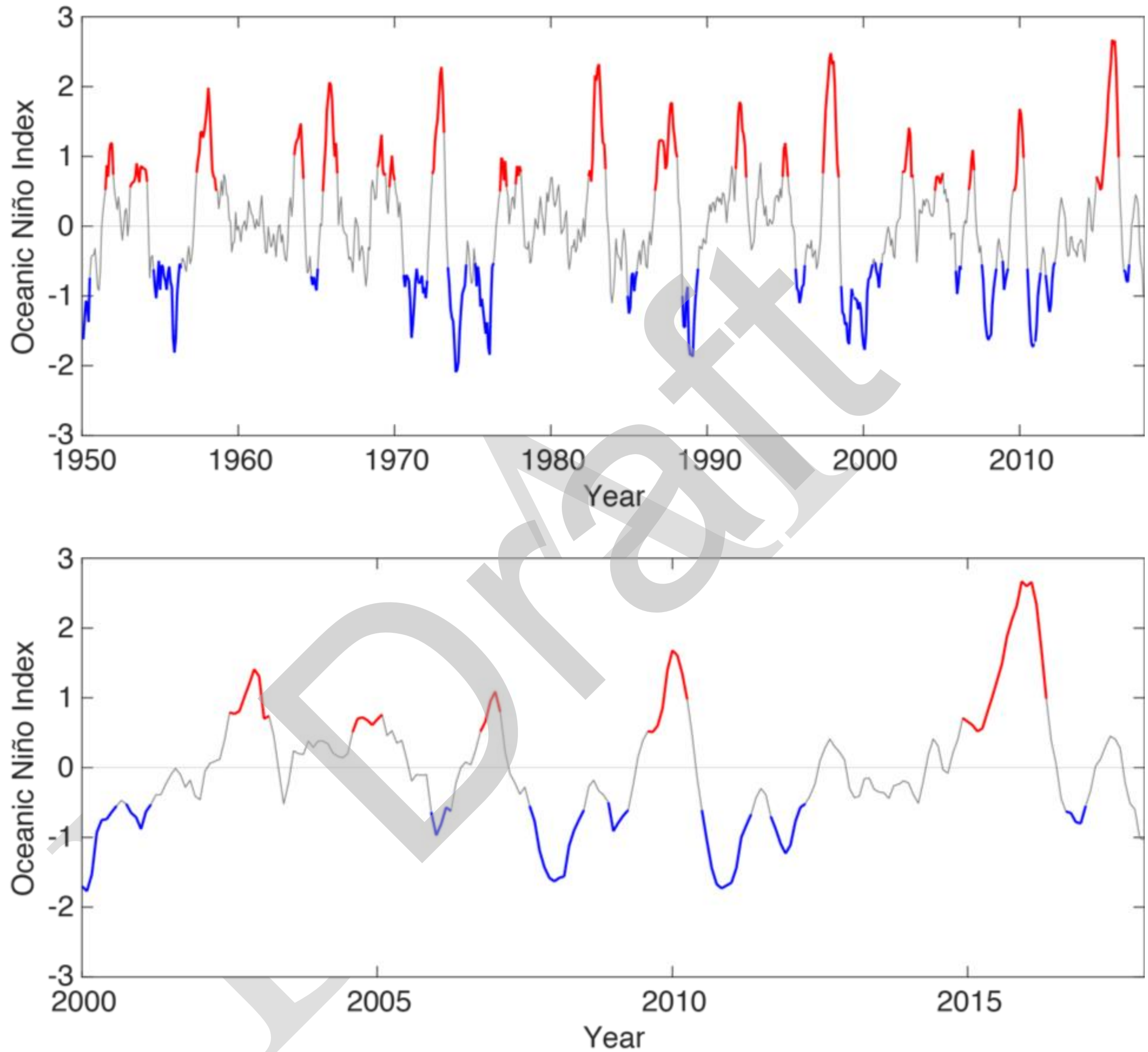


Figure 27. Oceanic Niño Index, 1950-2017 and 2000–2017. Note: Monthly time series of the Oceanic Niño Index for 1950 – 2017 (top) and 2000 – 2017 (bottom). El Niño periods are highlighted in red. La Niña periods are highlighted in blue.

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

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.

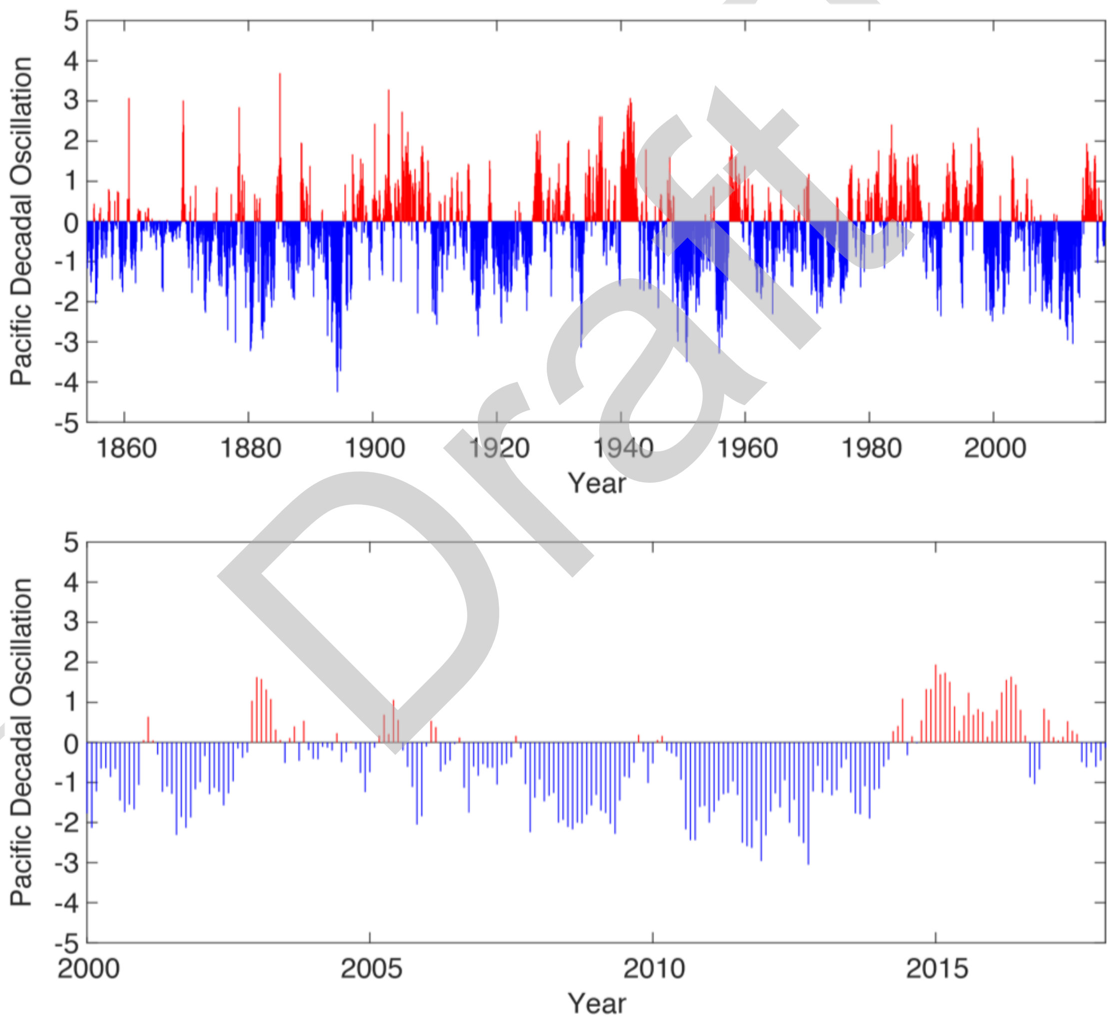


Figure 28. Pacific Decadal Oscillation, 1854–2017 and 2000–2017. Note: Monthly values of the Pacific Decadal Oscillation for 1854 – 2017 (top) and 2000 – 2017 (bottom). Positive, or warm, phases are plotted in red. Negative, or cool, phases are plotted in blue.

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

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:

Text from the OceanWatch Central Pacific Node:

(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.

Technical Summary:

Pathfinder v5 & GAC datasets: Text from: https://podaac-www.jpl.nasa.gov/dataset/ AVHRR_PATHFINDER_L3_SST_MONTHLY_NIGHTTIME_V5

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.
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 - Text from: https://www.star.nesdis.noaa.gov/sod/mecb/blended_validation/background.php

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°W and 75°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.

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

Region/Location: Global.

Data Source:

(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.

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.

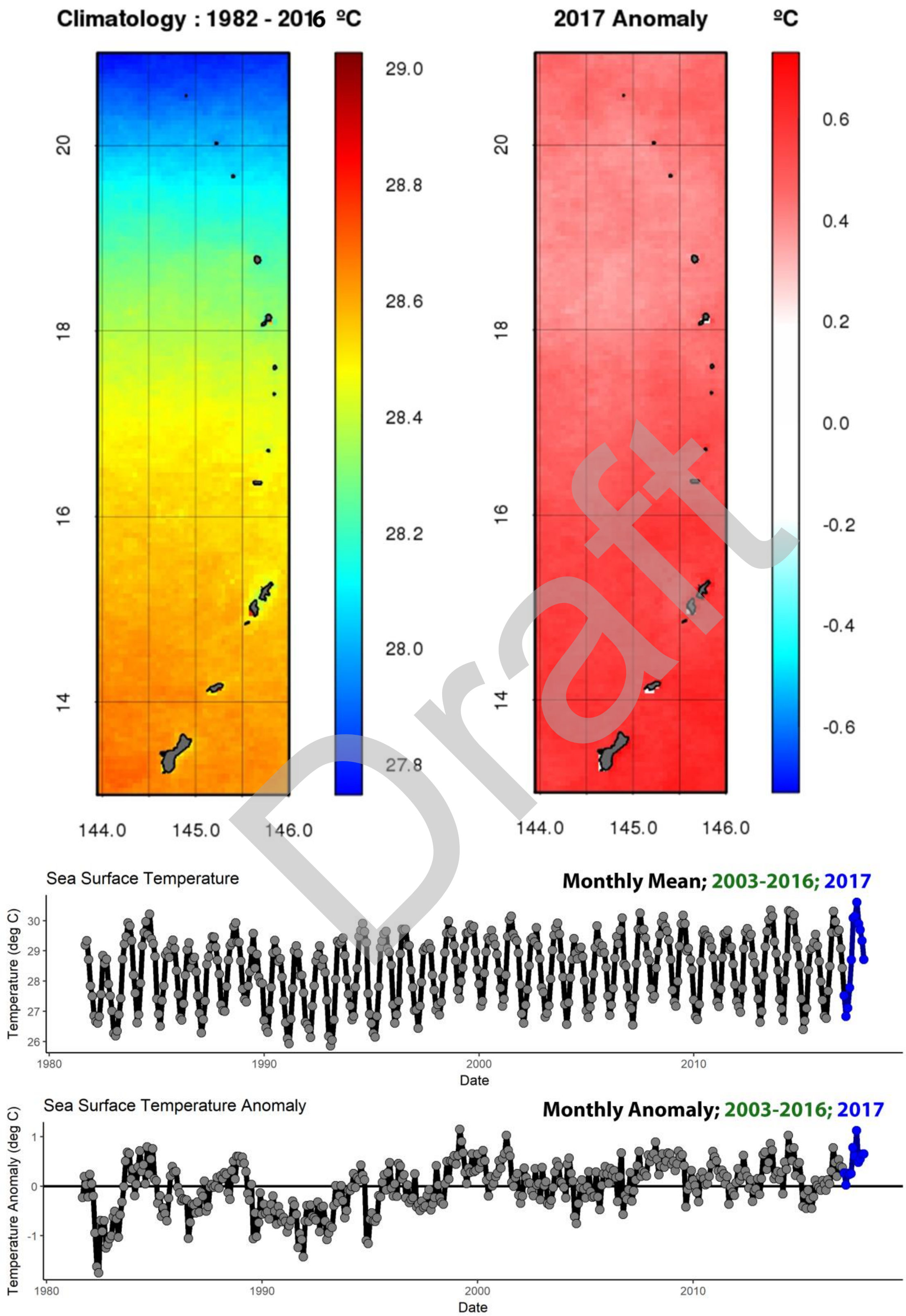


Figure 29: Sea surface temperature (SST) and SST Anomaly.

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 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:

Text inserted from the NOAA Coral Reef Watch website.

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.

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:

Text inserted from: https://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php

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.

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.

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.

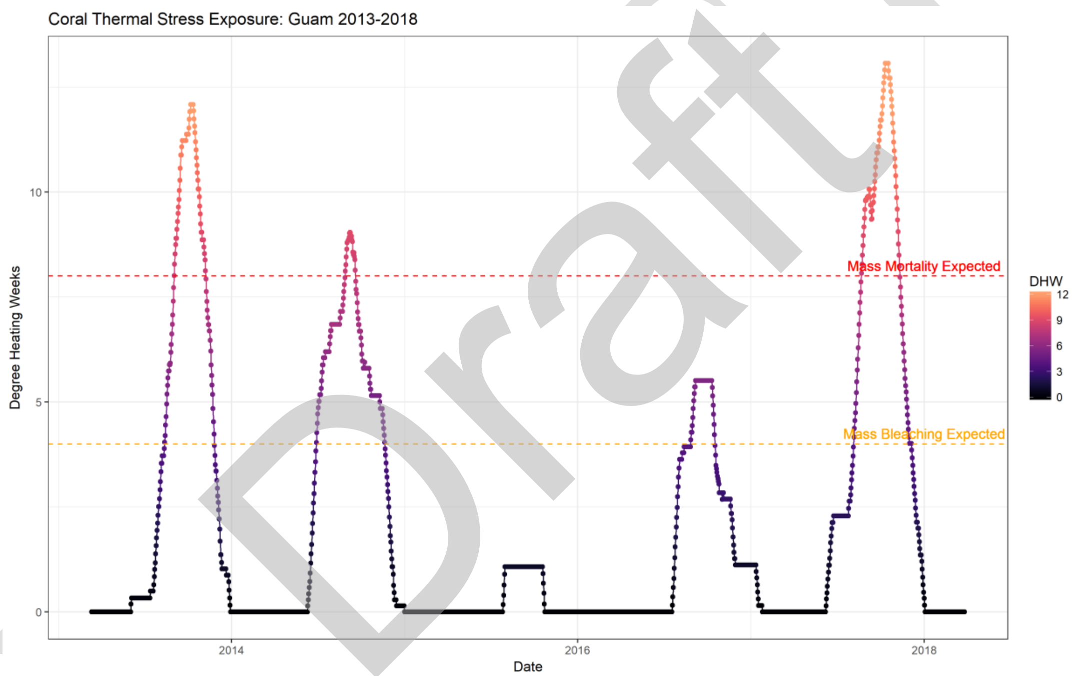


Figure 30. Coral Thermal Stress Exposure, Guam Virtual Station 2013-2017. Coral Reef Watch Degree Heating Weeks.

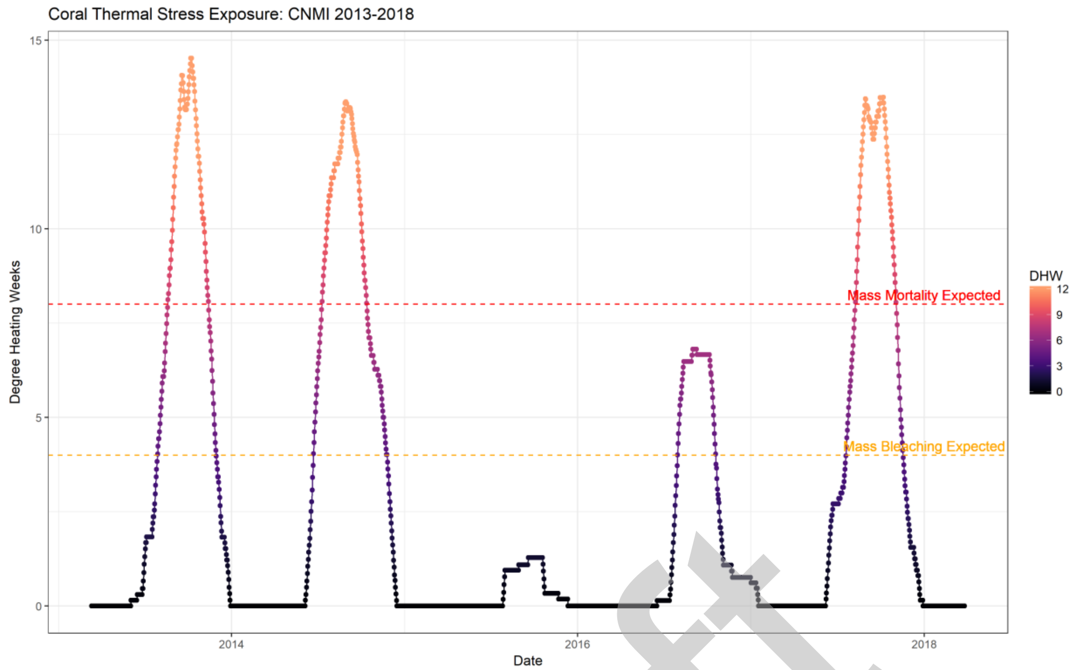


Figure 31. Coral Thermal Stress Exposure, Northern Marianas Virtual Station 2013-2017. Coral Reef Watch Degree Heating Weeks.

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:

Text inserted from the [OceanWatch Central Pacific Node:]()

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.

Technical Summary:

Text inserted from:

https://podaac-www.jpl.nasa.gov/dataset/MODIS_Aqua_L3_CHLA_Monthly_4km_V2014.0_R

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.

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.

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.

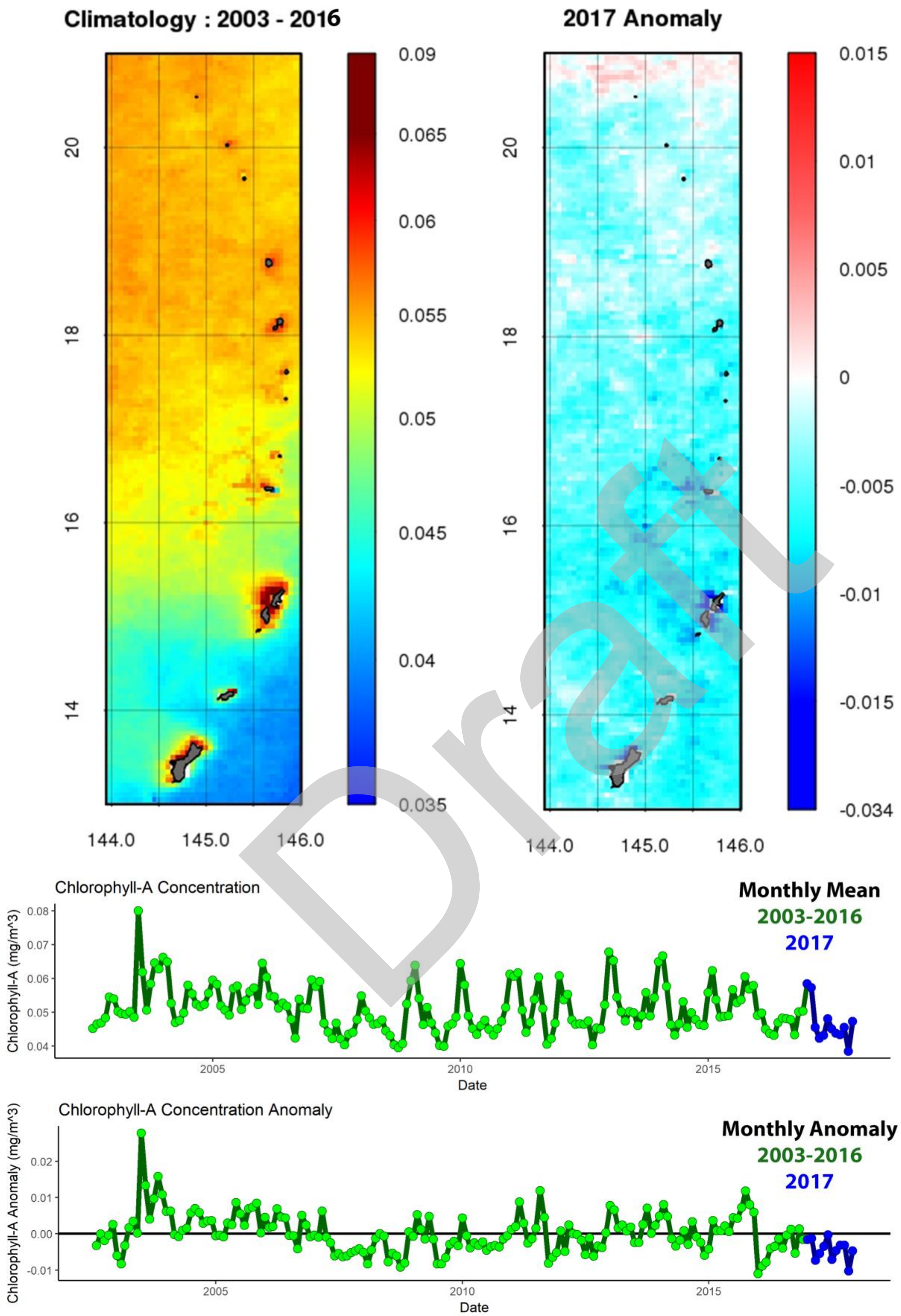


Figure 32. Chlorophyll-A (Chl-A) and Chl-A Anomaly.

2.5.3.6 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

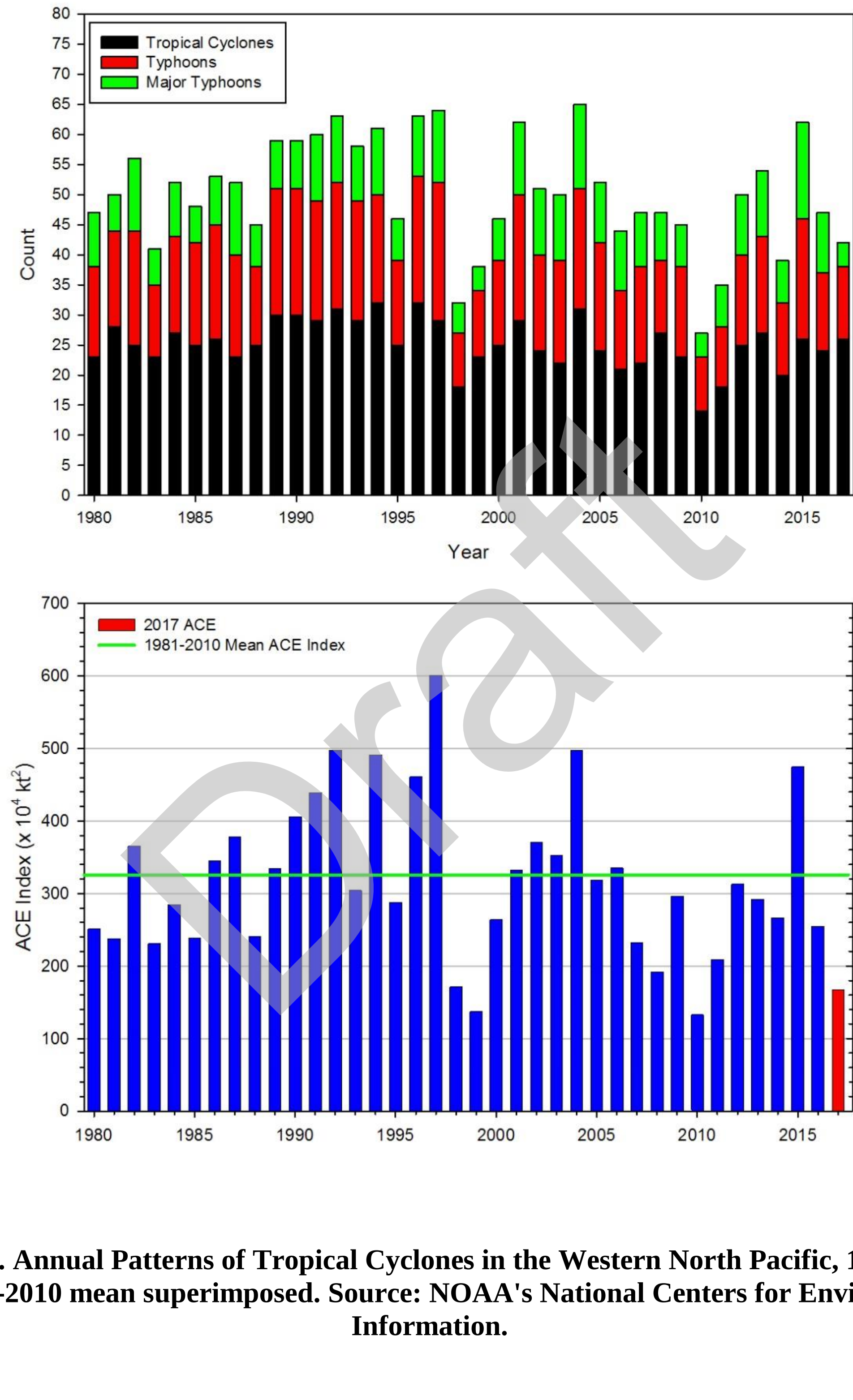


Figure 33. Annual Patterns of Tropical Cyclones in the Western North Pacific, 1980-2017, with 1981-2010 mean superimposed. Source: NOAA's National Centers for Environmental Information.

Western pacific climate / 2017 data

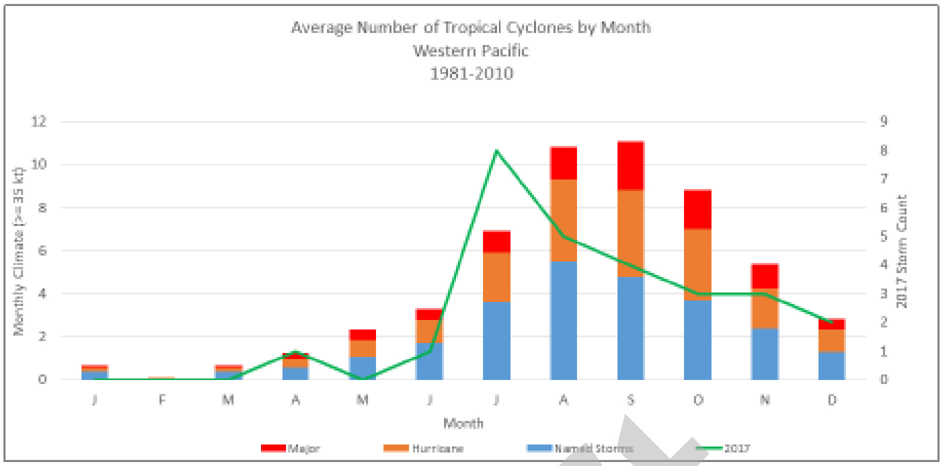


Figure 34: Seasonal Climatology of Tropical Cyclones in the Western Pacific, 1981-2010, with 2017 storms superimposed. Source: NOAA's National Centers for Environmental Information.

Further, we present the occurrence of “storm-force” winds, i.e. wind speeds greater than 34 knots.

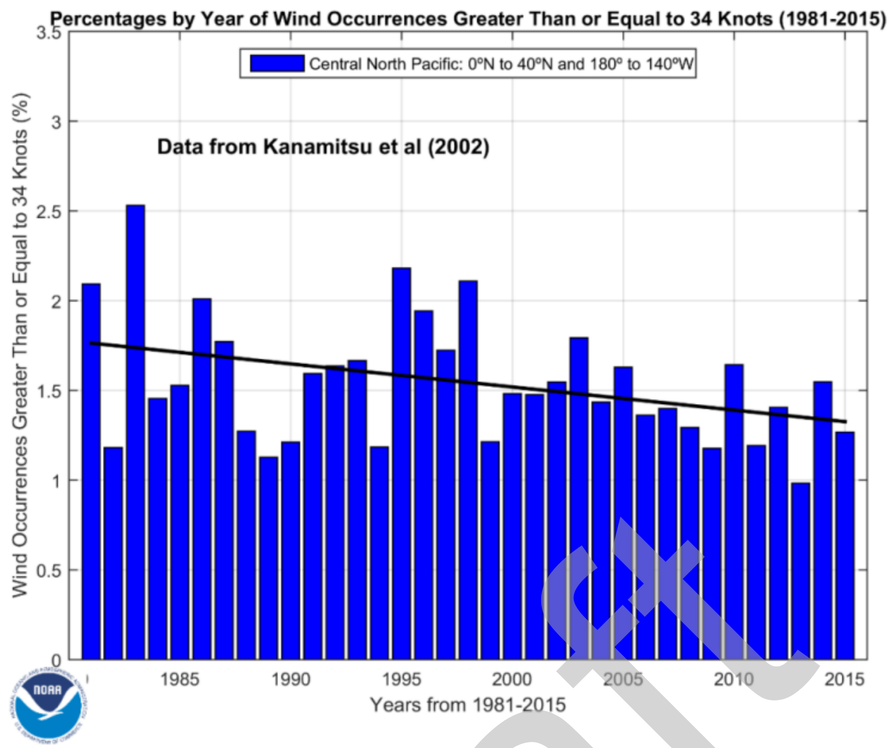


Figure 35. Storm-Force Wind in the Central North Pacific, 1981-2015.

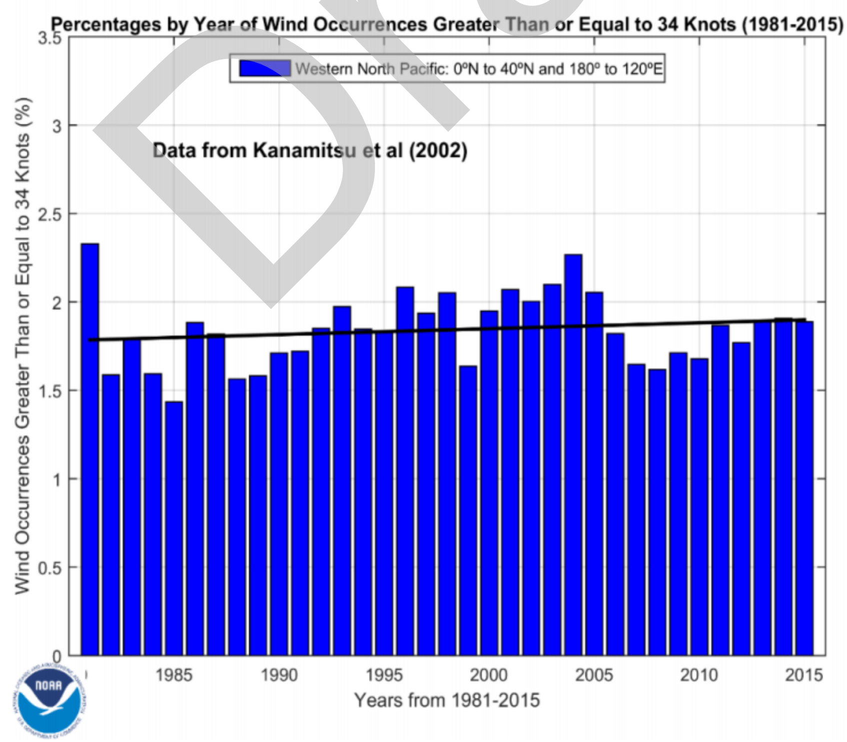


Figure 36. Storm-Force Wind in the Western North Pacific, 1981-2015.

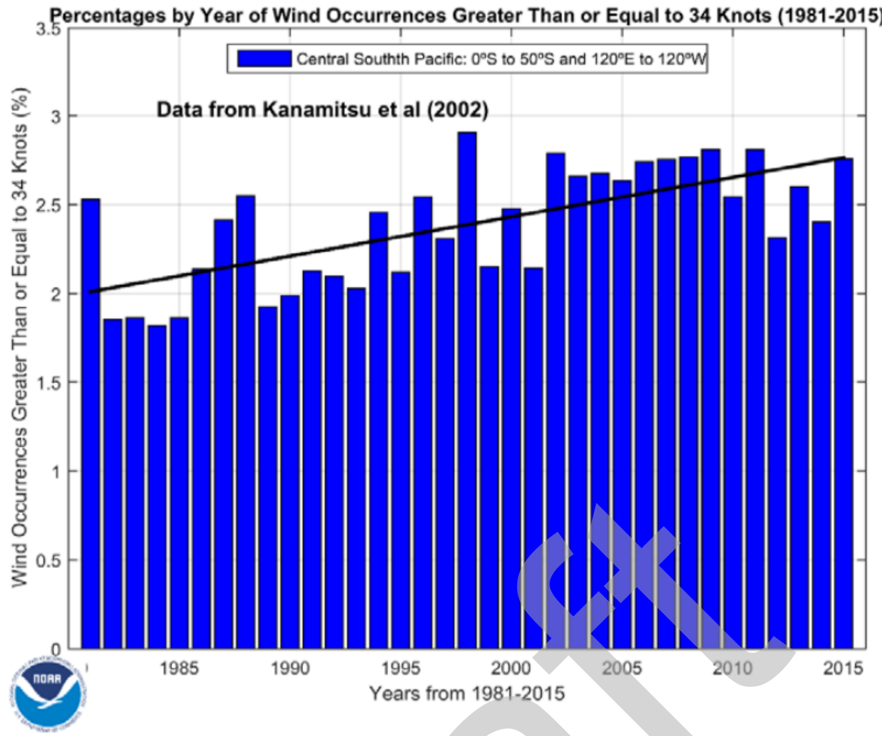


Figure 37. Storm-Force Wind in the Central South Pacific, 1981-2015.

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.

2.5.3.8 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.

Monthly and pentad CMAP estimates back to the 1979 are available from CPC ftp server.

[Text taken from: http://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.html]

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.

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, 2539 - 2558.

Huffman, G. J. and co-authors, 1997: The Global Precipitation Climatology Project (GPCP) combined data set. Bull. Amer. Meteor. Soc., 78, 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, 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, 2539-2558.

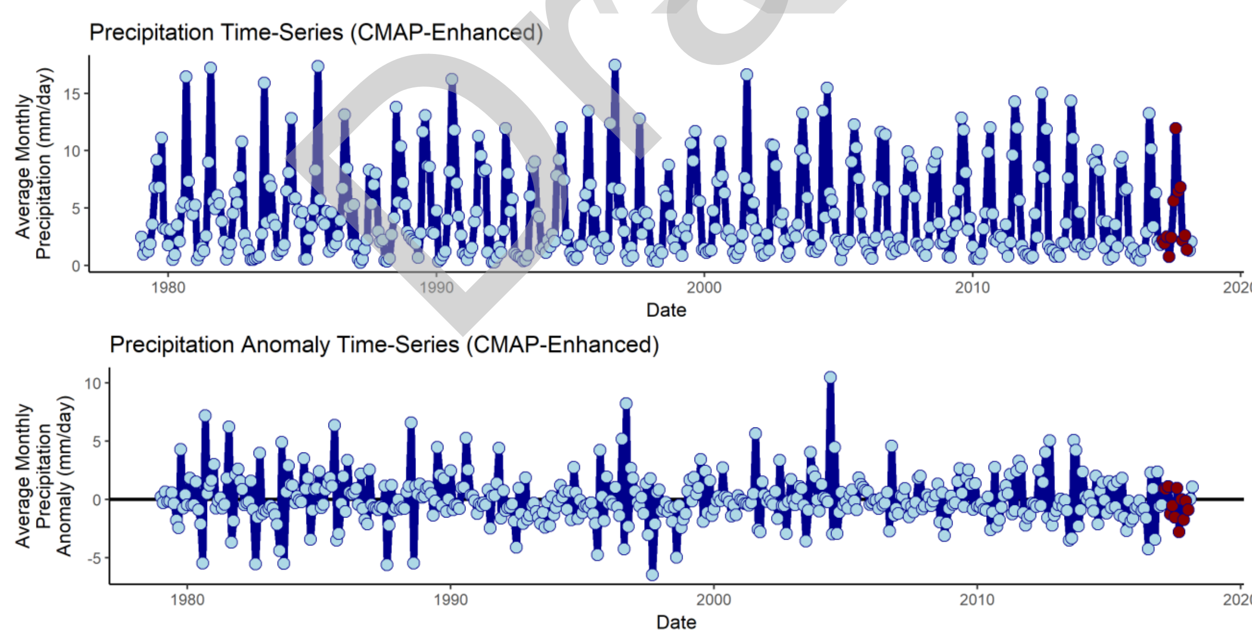


Figure 38: CMAP precipitation across the Mariana Grid. 2017 values in red.

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.)

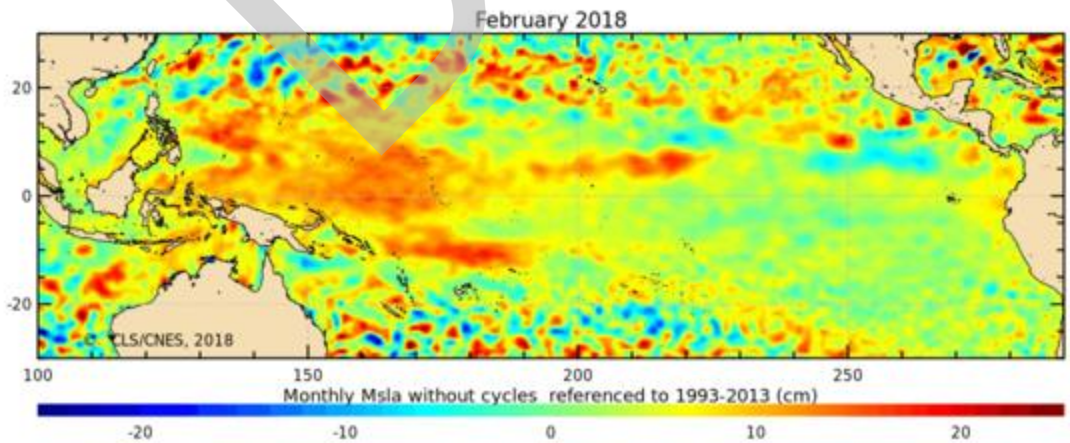


Figure 39a. Sea surface height and anomaly

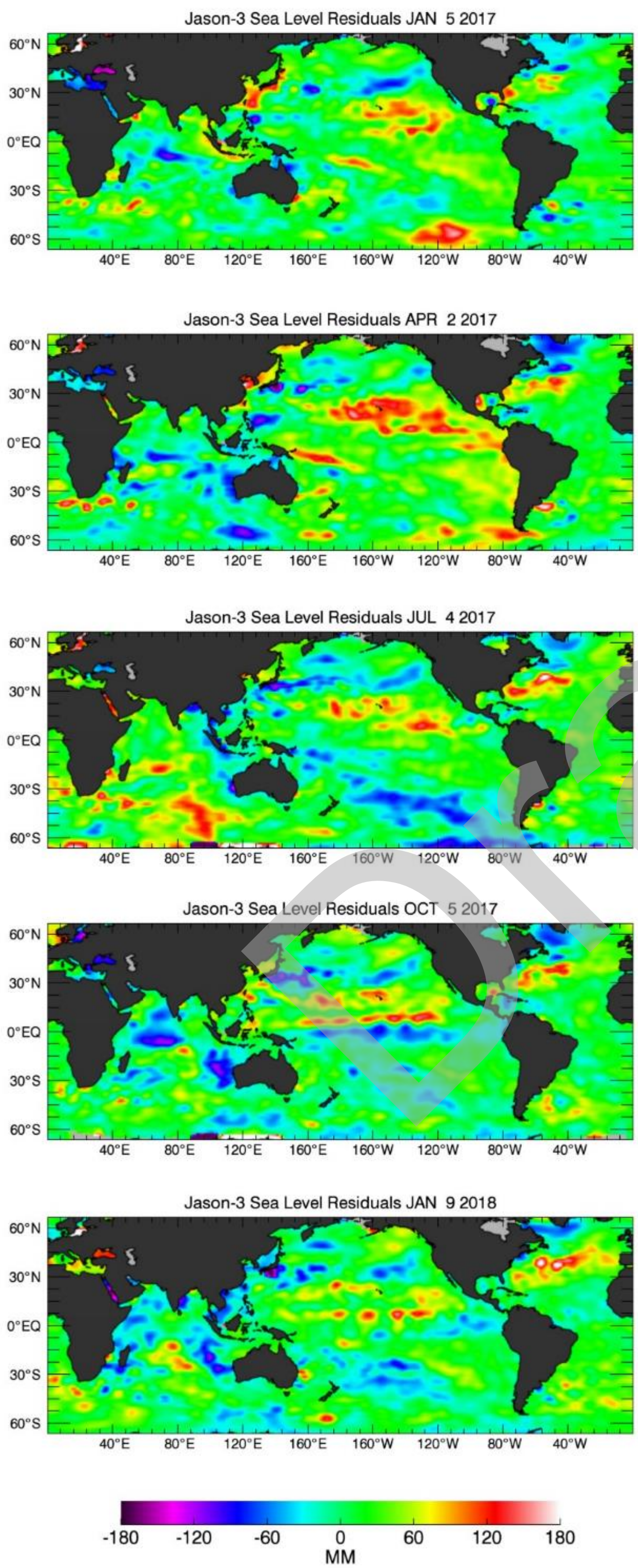
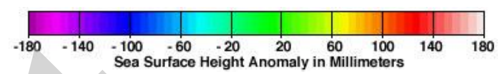


Figure 18b. Quarterly time series of mean sea level anomalies during 2017 show no pattern of El Niño throughout the year according to satellite altimetry measurements of sea level height (unlike 2015).

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 40 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.

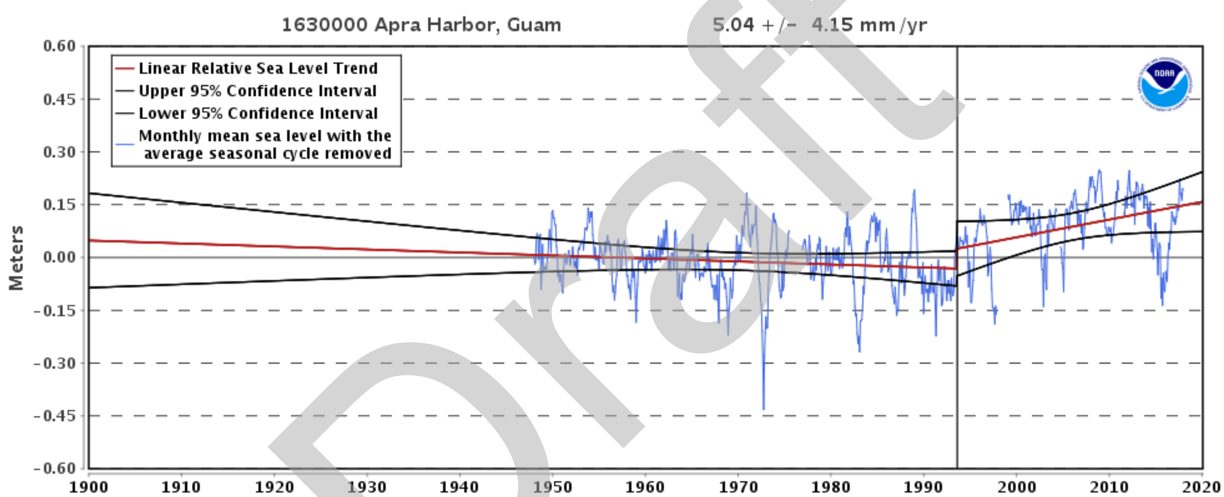


Figure 40. Monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents.

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.

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.

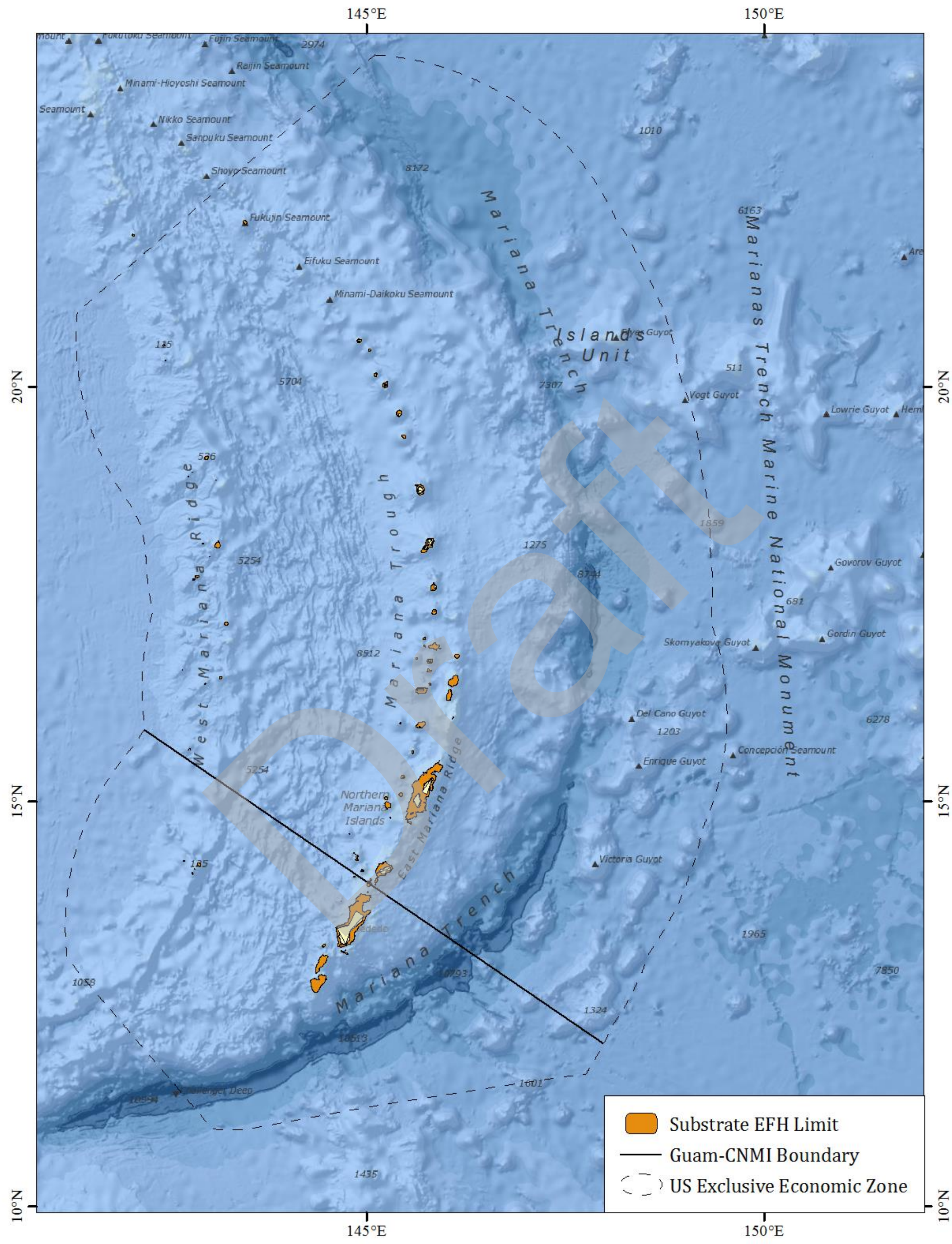


Figure 41. Substrate EFH Limit of 700 m isobath around the islands and surrounding banks of the Mariana Archipelago (from GRMT).

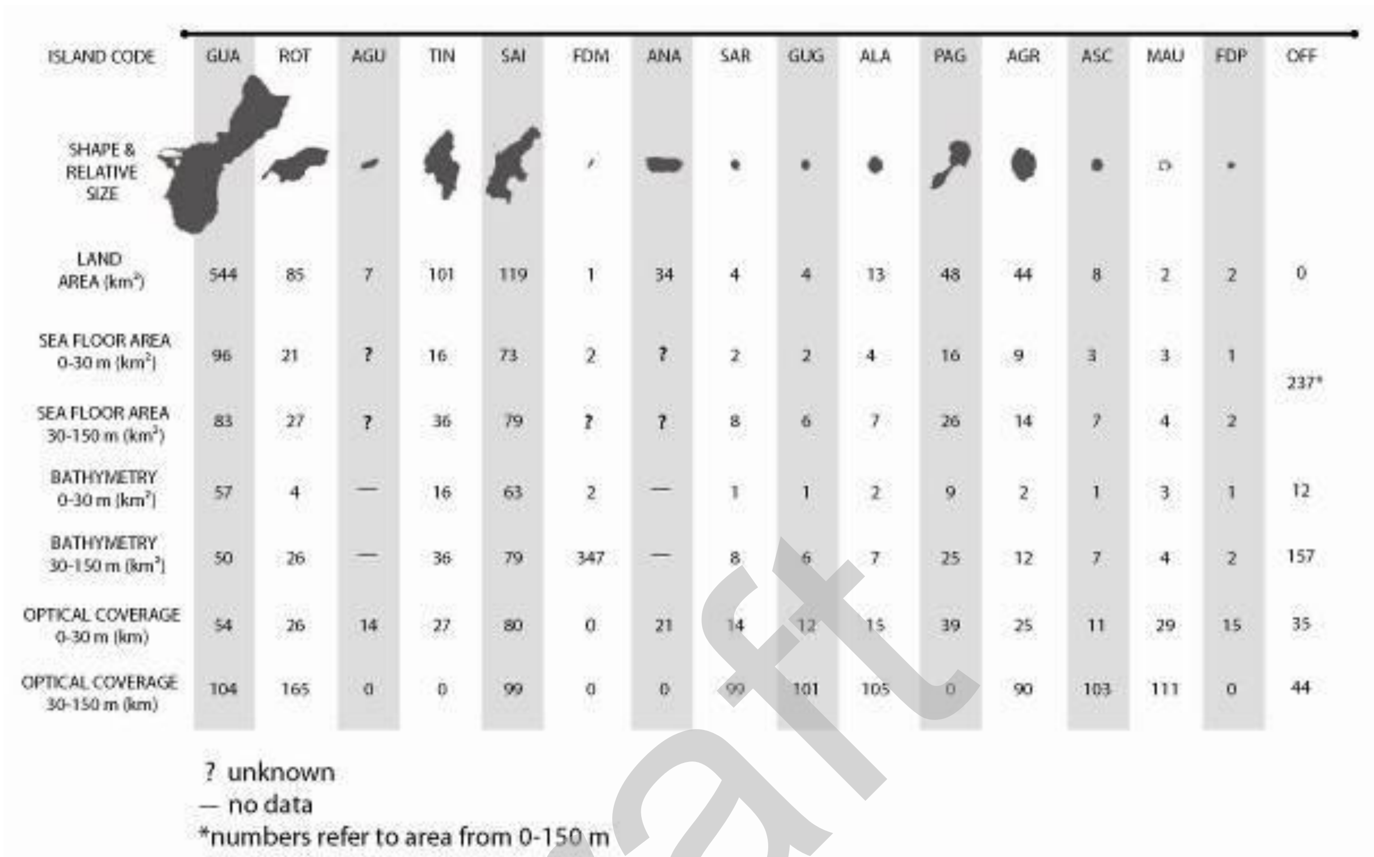
2.6.2.1 Habitat Mapping

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 70. 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 42.



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 42. CNMI Land and Seafloor Area and Primary Data Coverage (from CRCP, 2011).

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 min long and cover about two to three km of habitat. Each survey is divided into five-min segments, with data recorded separately per segment to allow for later location of observations within the ~ 200-300 m length of each segment. Throughout each survey, latitude and longitude of the survey track are recorded on the small boat using a GPS; and 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 71. 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 72. 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 73. 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 74. 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

Species	**Pelagic phase (larval stage)**	**Benthic phase**	**Source(s)**
Hemicorallium laauense (prev. C. laauense)	0	1	HURL Database
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 75. Level of EFH information available for Western Pacific bottomfish and seamount groundfish management unit species complex.

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
P. filamentosus (pink snapper)	0	0	1	2

Life History Stage	Eggs	Larvae	Juvenile	Adult
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 76. Level of EFH information available for the Western Pacific crustacean management unit species complex.

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

DesRochers, A., 2016. "Benthic Habitat Mapping." NOAA Fisheries Center, Honolulu, HI. Presentation. April 6, 2016.

Coral Reef Ecosystem Program; Pacific Islands Fisheries Science Center, 2016. Benthic Percent Cover Derived from Analysis of Benthic Images Collected during Towed-diver Surveys of the U.S. Pacific Reefs Since 2003 (NCEI Accession <unassigned>). NOAA National Centers for Environmental Information. Unpublished Dataset. April 5, 2016.

Miller, J., Battista, T., Pritchett, A., Rohmann, S., and Rooney, J., 2011. Coral Reef Conservation Program Mapping Achievements and Unmet Needs. March 14, 2011. 68 p.

Pacific Islands Fisheries Science Center Ecosystem Sciences Coral Reef Ecosystem Survey Methods. Benthic Monitoring. http://www.pifsc.noaa.gov/cred/survey_methods.php. Updated April 1, 2016. Accessed April 5, 2016.

Pacific Islands Fisheries Science Center, 2011. Coral reef ecosystems of American Samoa: a 2002–2010 overview. NOAA Fisheries Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-11-02, 48 p.

Pacific Islands Fisheries Science Center, 2010. Coral reef ecosystems of the Mariana Archipelago: a 2003–2007 overview. NOAA Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-10-002, 38 p.

Pacific Islands Fisheries Science Center, 2012. Coral reef ecosystem monitoring report of the Mariana Archipelago: 2003-2007. NOAA Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-12-01, 1124 p.

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.

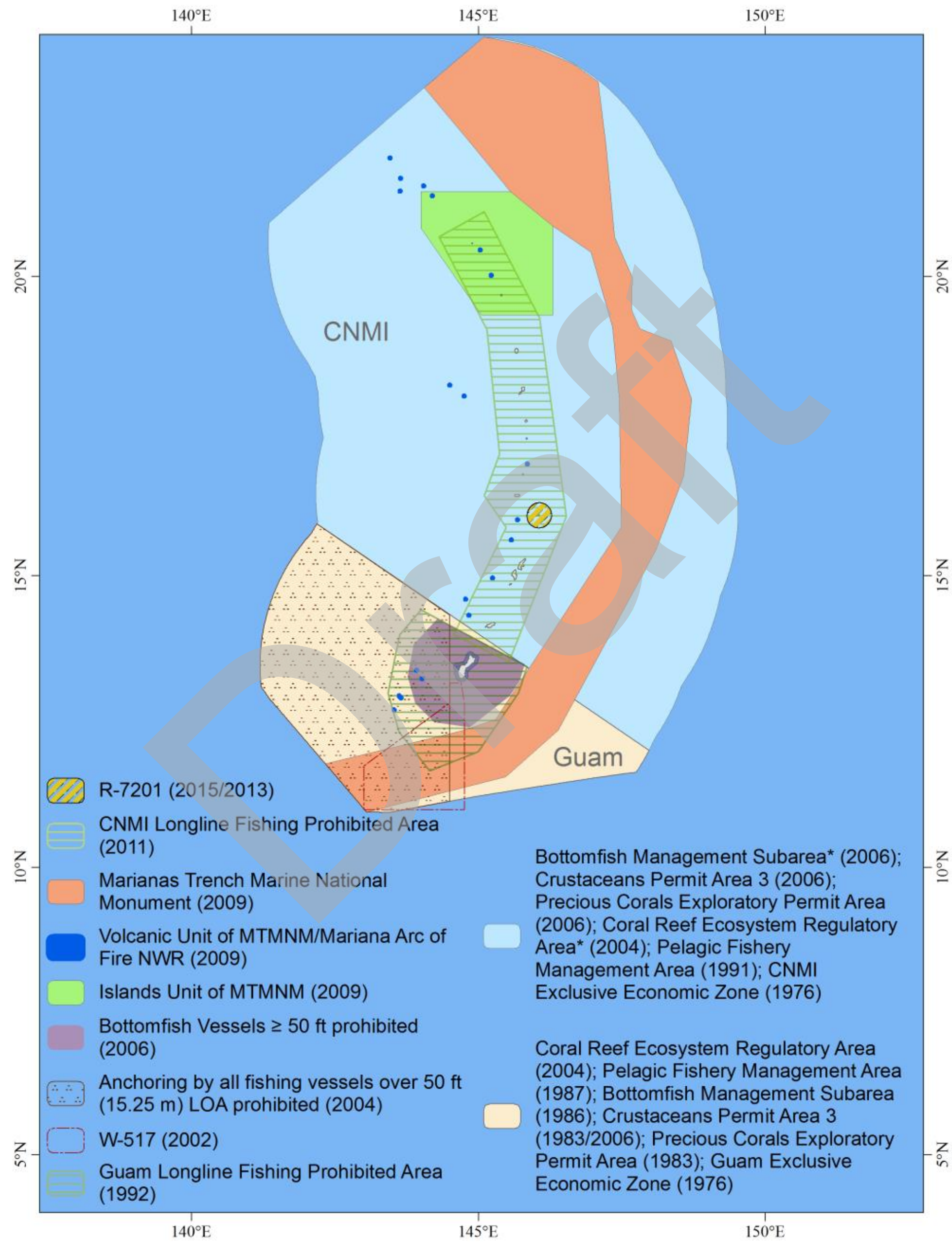
In order to meet the EFH and National Environmental Policy Act (NEPA) mandates, this annual report tracks activities that occur in the ocean that are of interest to the Council, and incidents or facilities that may contribute to cumulative impact. The National Marine Fisheries Service (NMFS) is responsible 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 77 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 43.



* 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 43. Regulated fishing areas of the Mariana Archipelago, including large access restrictions.

Table 77. MMAs established under FEPs from 50 CFR § 665.

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km²)	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 78. 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.

2.7.7 References

CNMI Joint Military Training EIS/OEIS. DOD to Issue Revise Draft EIS on CJMT. Accessed February 28, 2017. http://www.cnmijointmilitarytrainingeis.com/announcements/25.

Department of Defense; Department of the Navy. Record of Decision for the Final Supplemental Environmental Impact Statement for Guam and Commonwealth of the Northern Mariana Islands Military Relocation. 28 August 2015.

Department of Defense; Department of the Navy. Record of Decision for the Mariana Islands Training and Testing Final Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS). 23 July 2015.

Department of Defense; United States Air Force. Record of Decision for Divert Activities and Exercises, Commonwelath of the Northern Mariana Islands. December 7, 2016.

Department of Transportation. Modification of Restricted Area R-7201; Farallon de Medinilla Island, Mariana Islands. 47 FR 13389, March 13, 2017.

Environmental Impact Statement for Divert Activities and Exercises, Commonwealth of the Northern Mariana Islands. Home page. Accessed March 17, 2016. http://www.pacafdivertmarianaseis.com/index.html.

Ferdie De La Torre. DOJ: Federal court lacks jurisdiction. Saipan Tribune. November 25, 2016. http://www.saipantribune.com/index.php/doj-federal-court-lacks-jurisdiction/. Accessed February 28, 2017.

Fisheries in the Western Pacific. Title 50 *Code of Federal Regulations*, Pt. 665. Electronic

Code of Federal Regulations data current as of March 16, 2016. Viewed at http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=b28abb7da3229173411daf43959fcbd1&n=50y13.0.1.1.2&r=PART&ty=HTML#_top.

Fisheries in the Western Pacific; Western Pacific Bottomfish and Seamount Groundfish Fisheries; Guam Bottomfish Management Measures, Final Rule. *Federal Register* 71 (2 November 2006): 64474-64477. Downloaded from http://www.wpcouncil.org/bottomfish/Documents/FMP/Bottomfish%20A9%20Final%20Rule%202006.pdf.

Fisheries Off West Coast States and in the Western Pacific; Coral Reef Ecosystems Fishery Management Plan for the Western Pacific, Final Rule. *Federal Register* 69 (24 February 2004): 8336-8349. Downloaded from http://www.wpcouncil.org/precious/Documents/FMP/Amendment5-FR-FinalRule.pdf.

Letter sent from K. Simonds to R. Seman, CNMI DLNR on May 5, 2015.

Honolulu Civil Beat. The U.S. Military Won't Bomb Pagan Just Yet. March 9, 2017. Accessed March 9, 2017. http://www.civilbeat.org/2017/03/the-u-s-military-wont-bomb-pagan-or-tinian-just-yet/?mc_cid=1a464a317d&mc_eid=abaf3b9d93.

Honolulu Civil Beat. The U.S. Military Won't Bomb Pagan Just Yet. March 9, 2017. Accessed March 9, 2017. http://www.civilbeat.org/2017/03/the-u-s-military-wont-bomb-pagan-or-tinian-just-yet/?mc_cid=1a464a317d&mc_eid=abaf3b9d93.

Pelagic Fisheries of the Western Pacific Region, Final Rule. *Federal Register* 57 (4 March 1992): 7661-7665. Downloaded from http://www.wpcouncil.org/pelagic/Documents/FMP/Amendment5-FR-FinalRule.pdf.

Report to the President on 902 Consultations. Special Representatives of the United States and the Commonwealth of the Northern Mariana Islands. January 2017. http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/archive/2013/methodology.pdf. Accessed March 10, 2017.

Western Pacific Fisheries; Fishing in the Marianas Trench, Pacific Remote Islands, and Rose Atoll Marine National Monuments, Final Rule. *Federal Register* 78 (3 June 2013): 32996-33007. Downloaded from http://www.wpcouncil.org/precious/Documents/FMP/Amendment5-FR-FinalRule.pdf.

Western Pacific Pelagic Fisheries; Prohibiting Longline Fishing Within 30 nm of the Northern

Mariana Islands, Final Rule. *Federal Register* 76 (27 June 2011): 37287-37289. Downloaded from https://www.gpo.gov/fdsys/pkg/FR-2011-06-27/pdf/2011-16039.pdf.

Western Pacific Regional Fishery Management Council. Fishery Management Plan and Fishery Ecosystem Plan Amendments available from http://www.wpcouncil.org/.

Western Pacific Regional Fishery Management Council, 2015. Report of the CNMI Advisory Panel to the Western Pacific Regional Fishery Management Council, June 2015.

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 79.

Table 79. 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 80) 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 80. 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 44).

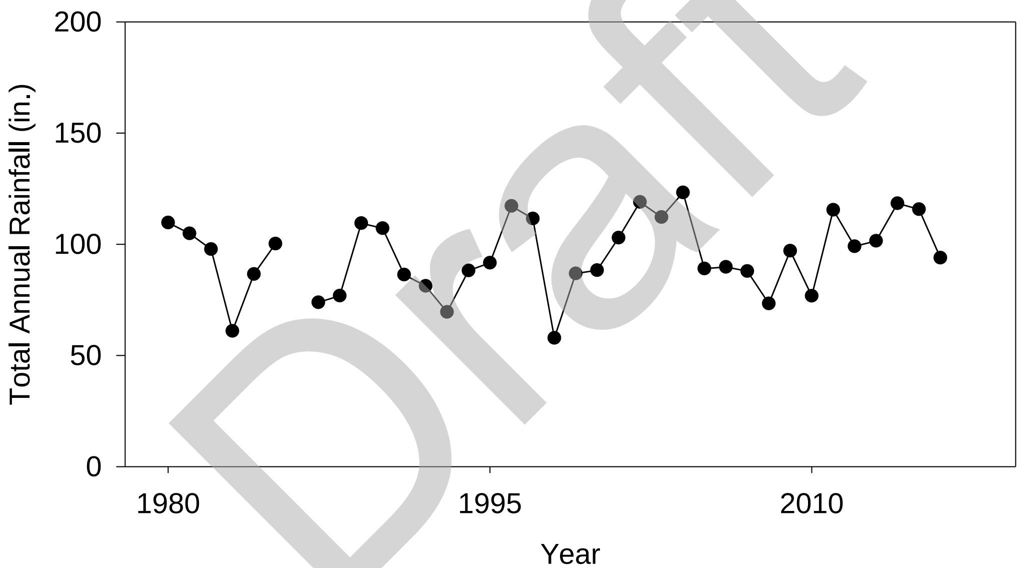


Figure 44. Total annual precipitation (in.) in Guam from 1980-2016.

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 45). 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 46a-b). Effort data also revealed that, despite catch statistics, the gill net had been sampled the least frequently among the top gears (Figure 46a-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 46c-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 47). 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.

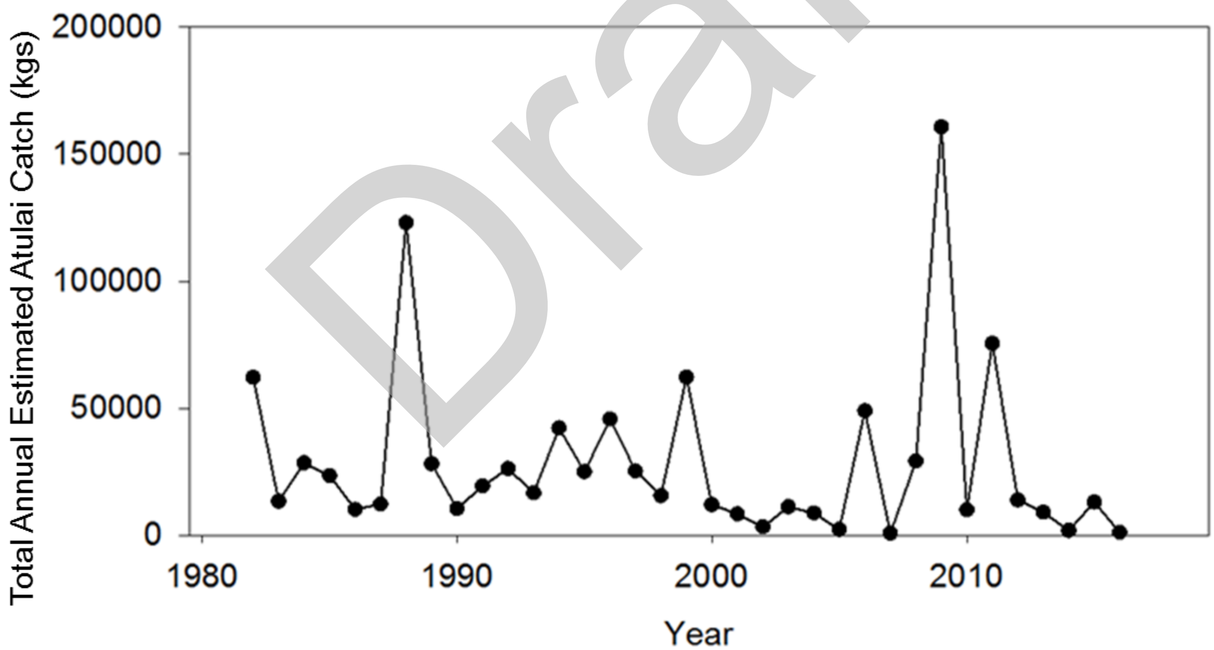


Figure 45. Time series of total annual estimated (i.e. expanded) landings of atulai in kilograms from Guam shore-and boat-based creel survey records from 1982-2016.

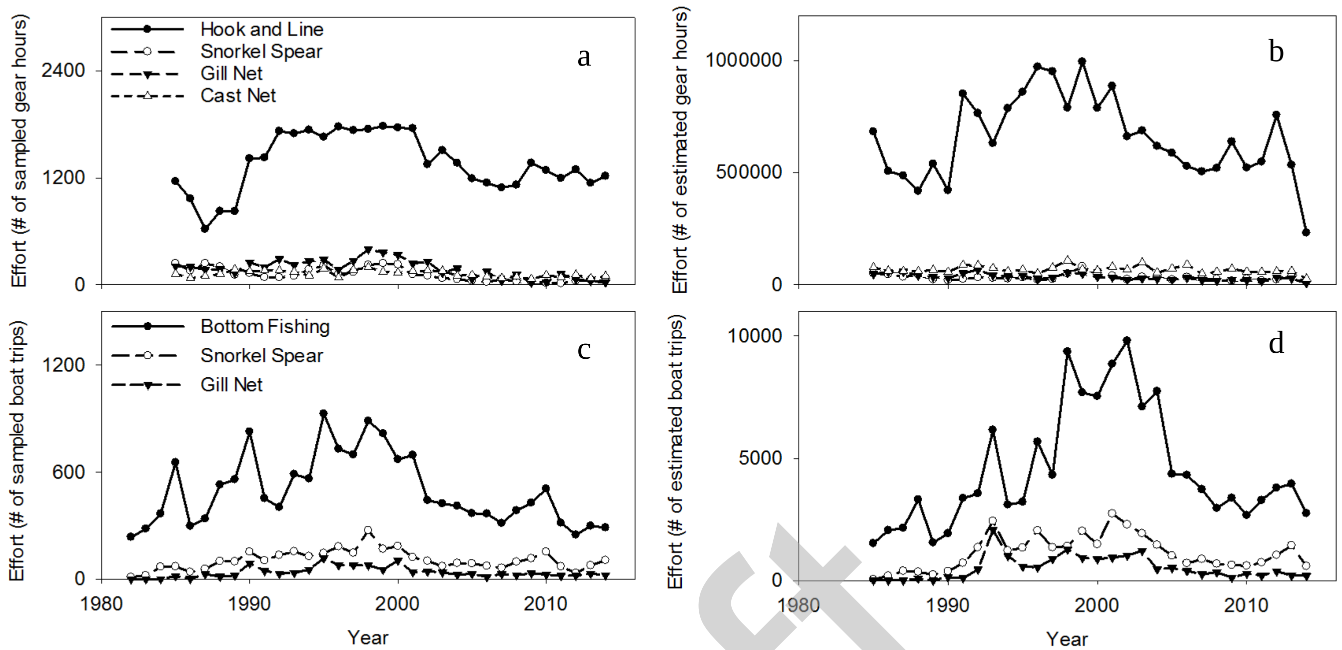


Figure 46. Time series of total sampled (left) and expanded (right) effort for top gear types in shore-based (top) and boat-based (bottom) creel surveys in Guam from 1982-2016.

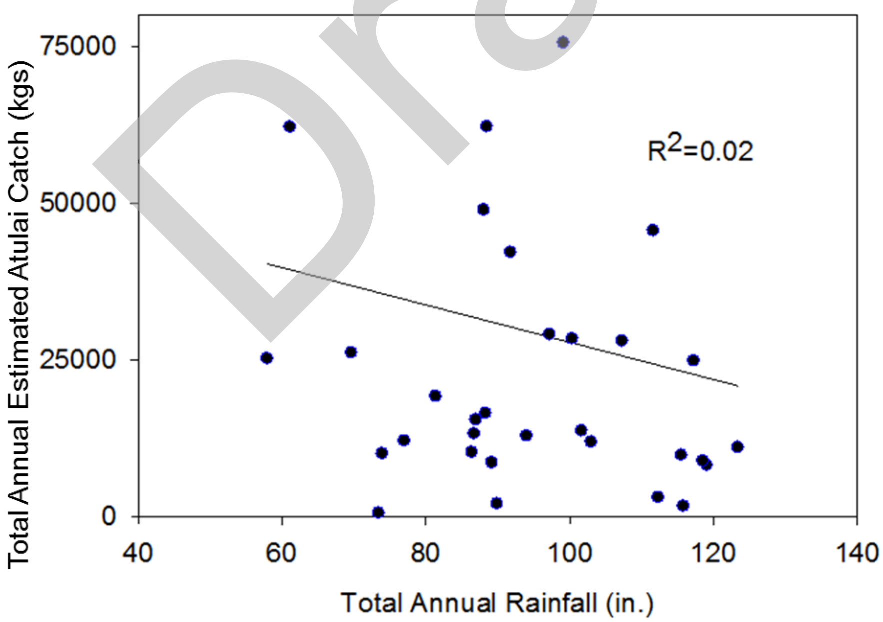


Figure 47. Linear regression between total atulai catch (kg) in the Guam shore-based and boat-based creel survey records and total annual rainfall (in.) from 1982-2016.

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 48). 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 48). 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.

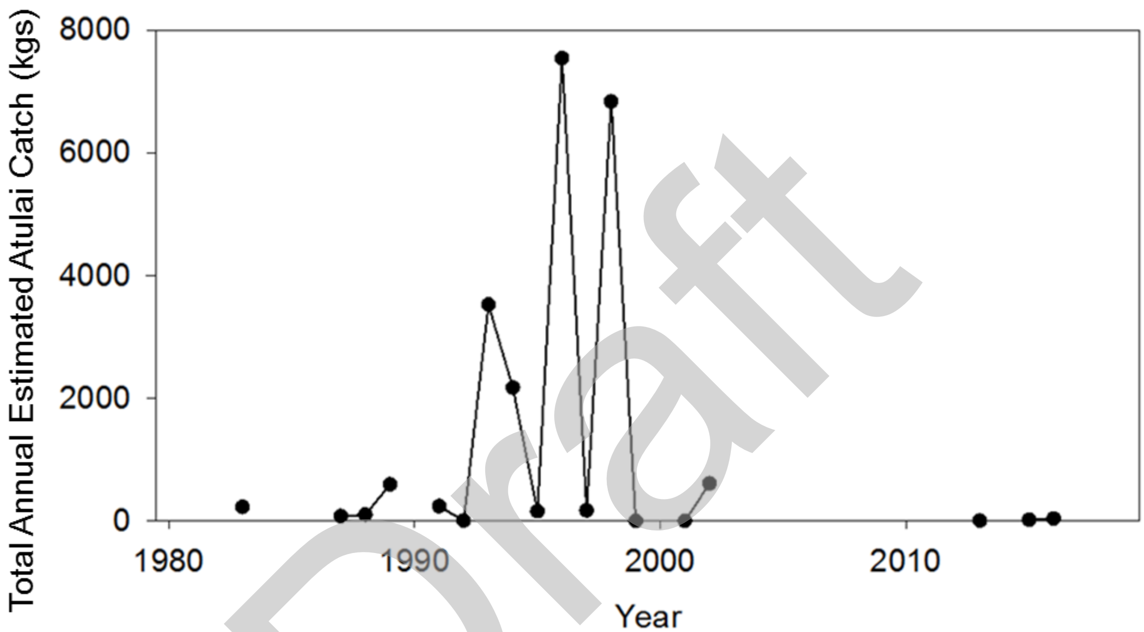


Figure 48. Time series of total annual expanded landings of *Decapterus macarellus* (kg) in Guam shore-and boat-based creel survey records from 1982-2016.

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 49. 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 49).

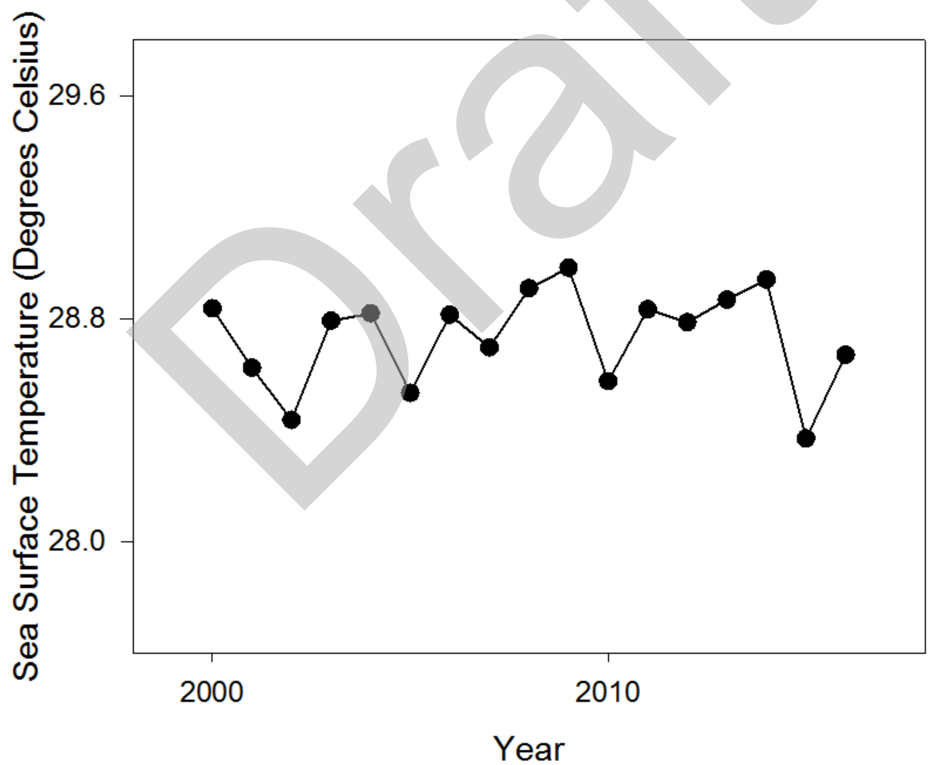


Figure 49. Time series of SST (°C) in the CNMI from 1985-2016 (CV = 0.55).

A time series of SST for Guam from 1985-2016 is shown in Figure 50. 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 50).

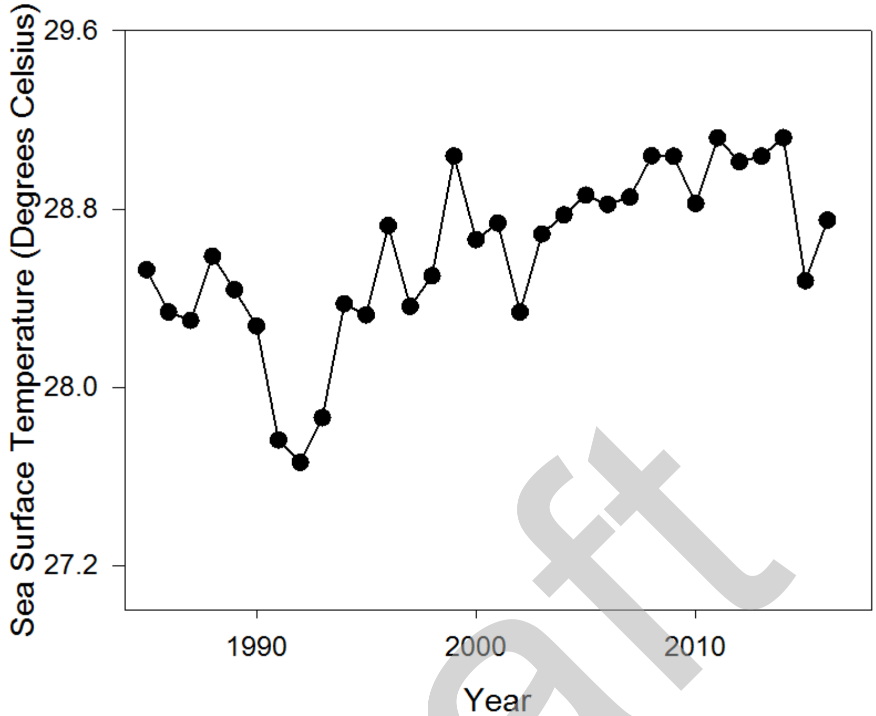


Figure 50. Time series of SST (°C) from 1985-2016 in Guam (CV = 1.38).

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 51. 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 51).

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 81 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 82. The comparisons between the two parameters showed a negatively significant relationship between 2000 and 2016 ($R^2 = 0.30$, $p = 0.02$; Table 82; Figure 52). 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 52).

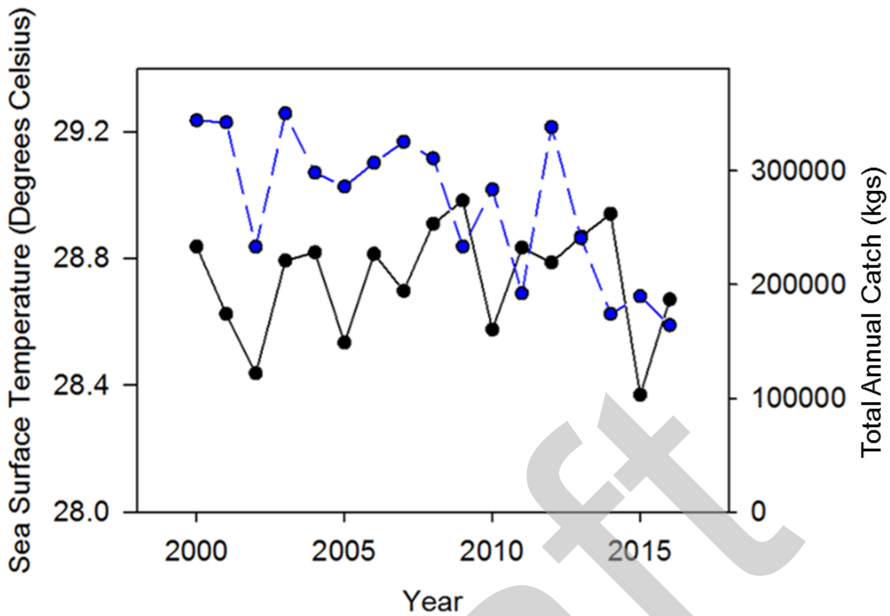


Figure 51. Time series of total annual catch (kg; blue) for the CNMI recreational coral reef fishery plotted alongside average annual SST (°C; black) from 2000-2016.

Table 81. 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 82. Correlation coefficients (*r*) between recreational coral reef fishery catch (kg) and SST (°C) in the CNMI for 12 top taxa harvested from 2000-2016. 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	**0.02**	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

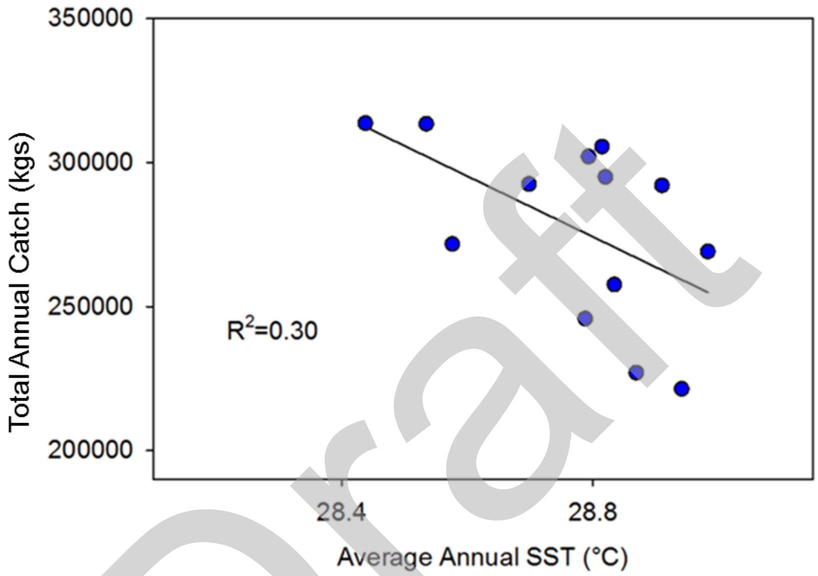


Figure 52. Linear regression showing the correlation between total annual catch (kg) in creel survey records and average annual SST (°C) in the CNMI from 2000-2016.

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 82). The strongest associations between fishery catch and SST were observed from the Mullids ($R^2 = 0.22$, $p = 0.06$; Figure 53a), Carangids ($R^2 = 0.09$, $p = 0.26$; Figure 53b), and Lutjanids ($R^2 = 0.03$, $p = 0.49$; Figure 53c). While the relationship between catch and temperature for families Mullidae and Carangidae were negative, the Lutjanidae family had a positive relationship (Table 82).

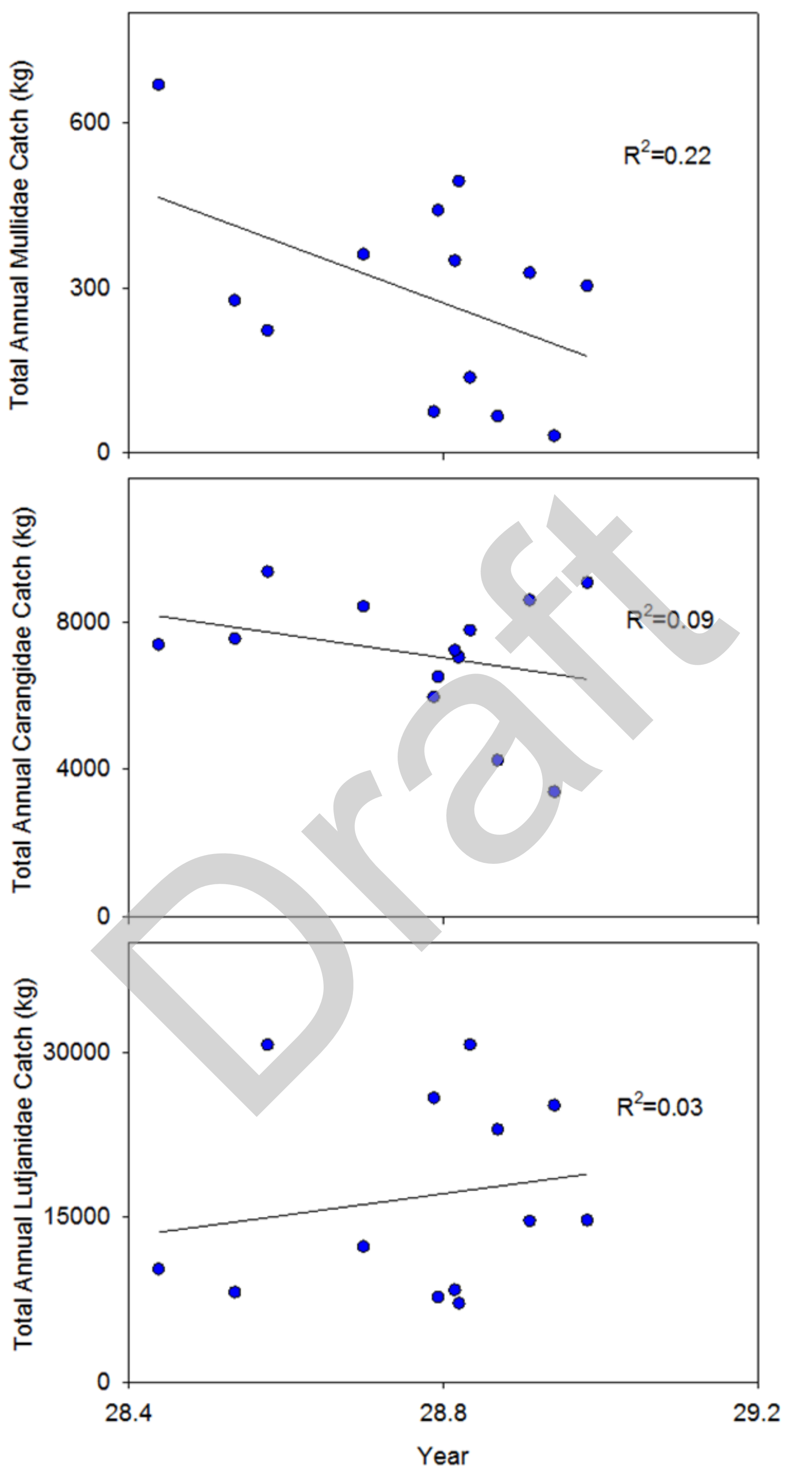


Figure 53. Linear regressions showing the three top correlations between total annual catch (kg) from creel survey records and average annual SST (°C) in the CNMI from for (a) Mullids, (b) Carangids, and (c) Lutjanids from 2000–2016.

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 54. 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 54).

Multiple linear regressions and correlation analyses were performed on time series of recreational coral reef fishery catch and annual mean SST from Guam (Table 83). 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 83; Figure 55). 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 55)

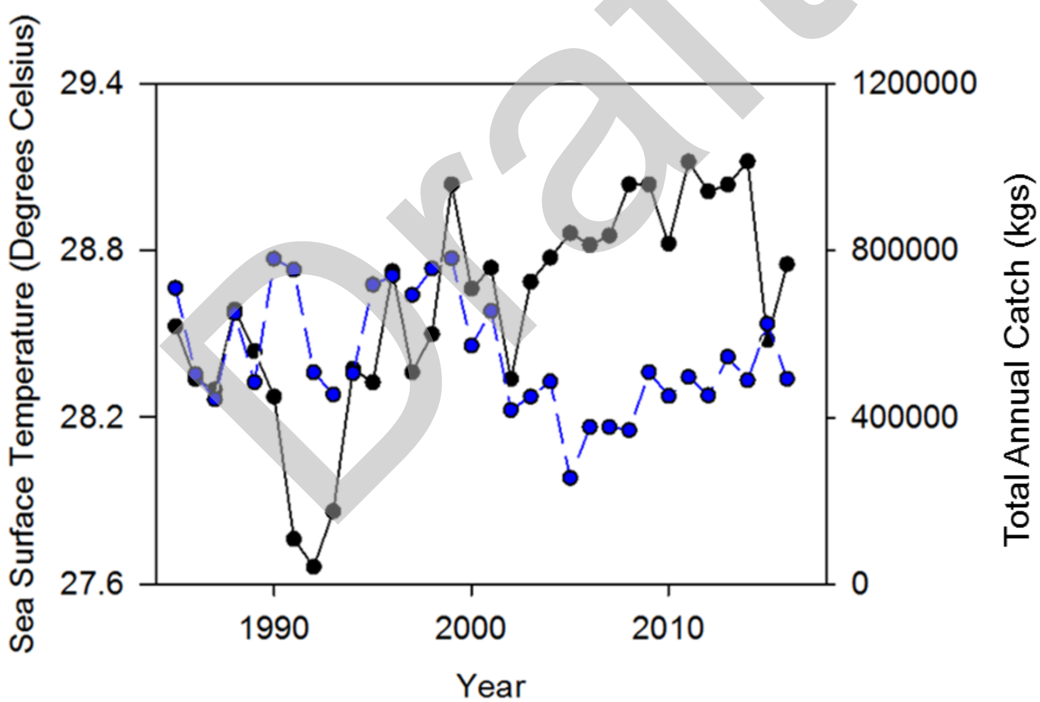


Figure 54. Time series of total annual catch (kg; blue) in the Guam shore-and boat-based creel survey records plotted with average annual SST (°C; black) from 1985-2016.

Table 83. Correlation coefficients (*r*) between recreational coral reef fishery catch (in kg) and SST (°C) in Guam for 12 top taxa harvested from 1985-2016. 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 = 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**

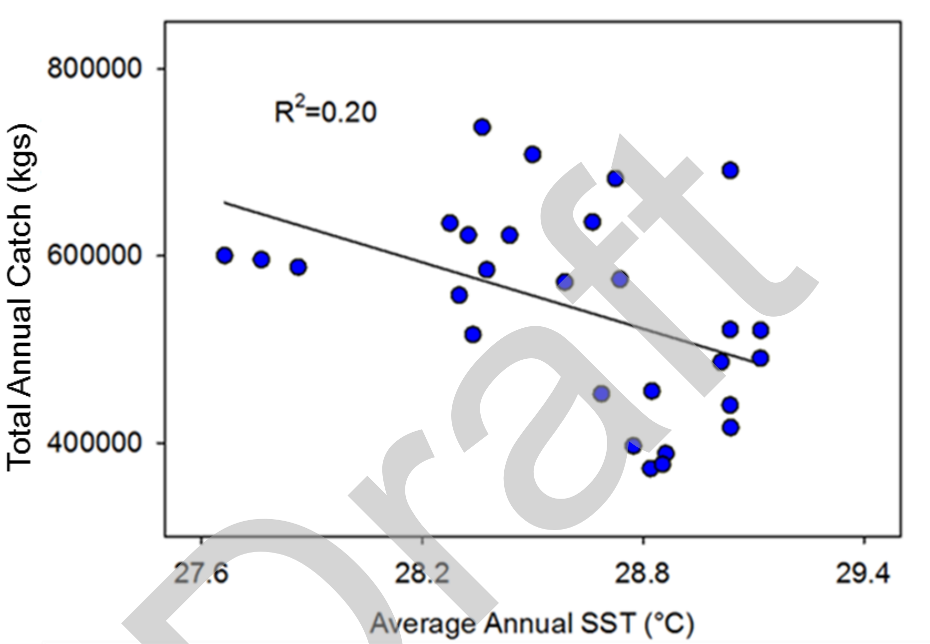


Figure 55. Linear regression between total annual catch (kg) for shore- and boat-based creel survey records and average annual SST (°C) in Guam from 1985-2016.

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 83). 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 83; Figure 56a). The next two strongest associations observed were for families Siganidae (R^2 = 0.50, p = 0.00; Figure 56b) and Mugilidae (R^2 = 0.43, p = 0.01; Figure 56c). 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.

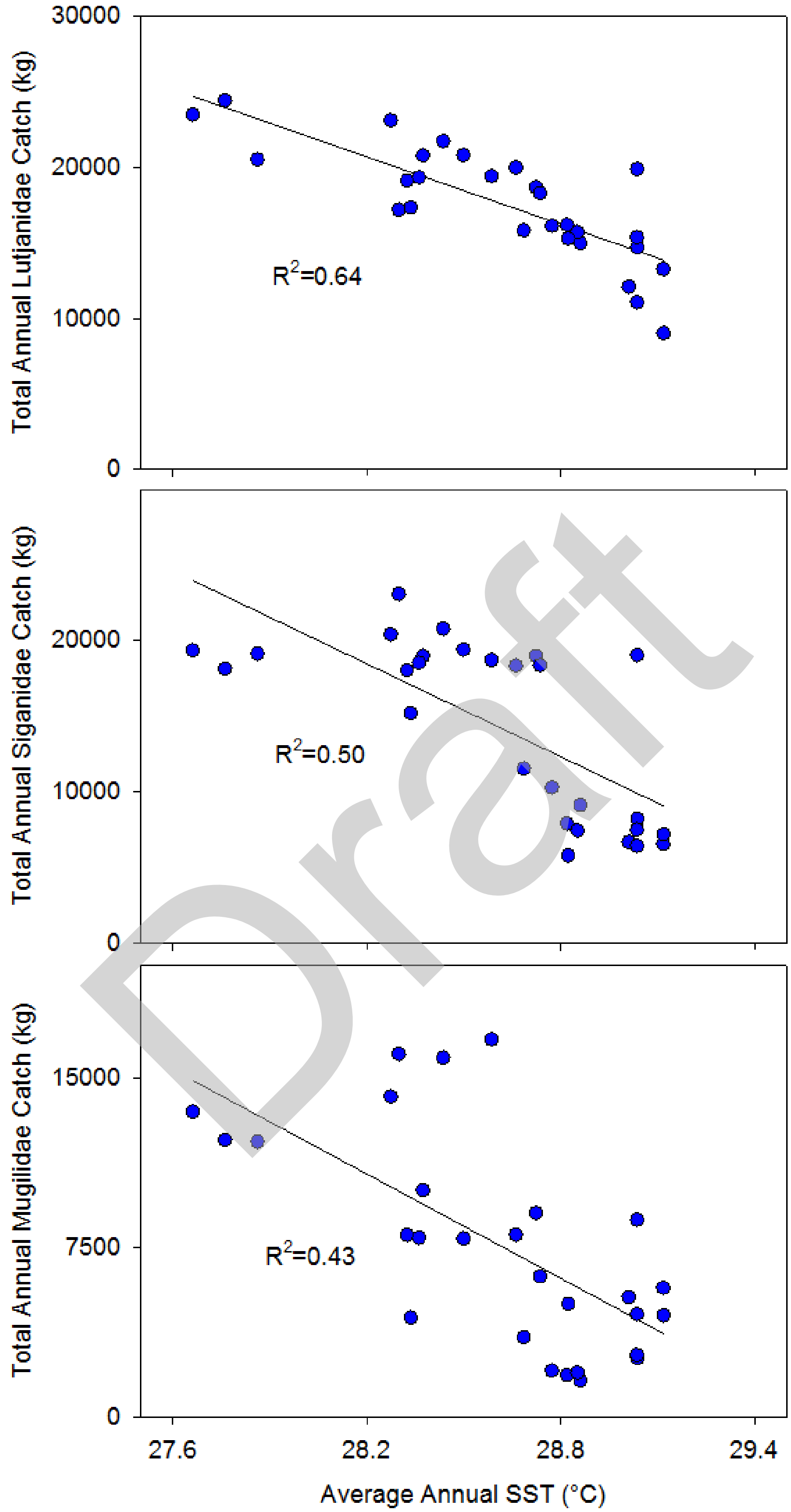


Figure 56. Linear regressions showing three top correlations between total annual catch (kg) for shore-and boat-based creel survey records and average annual SST (°C) in Guam for (a) Lutjanids, (b) Siganids, and (c) Mugilids from 1985–2016.

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 57. 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 57.

A time series of fluorometric chlorophyll-*a* concentrations (mg/m^3) for the years 1998-2016 in Guam is shown in Figure 58. 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 58).

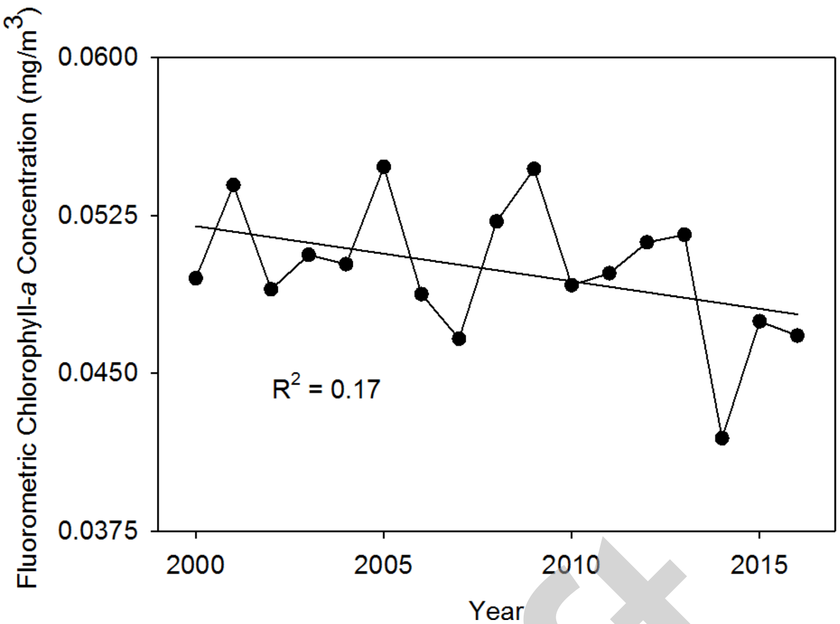


Figure 57. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around the CNMI from 1998-2016 (CV=6.28).

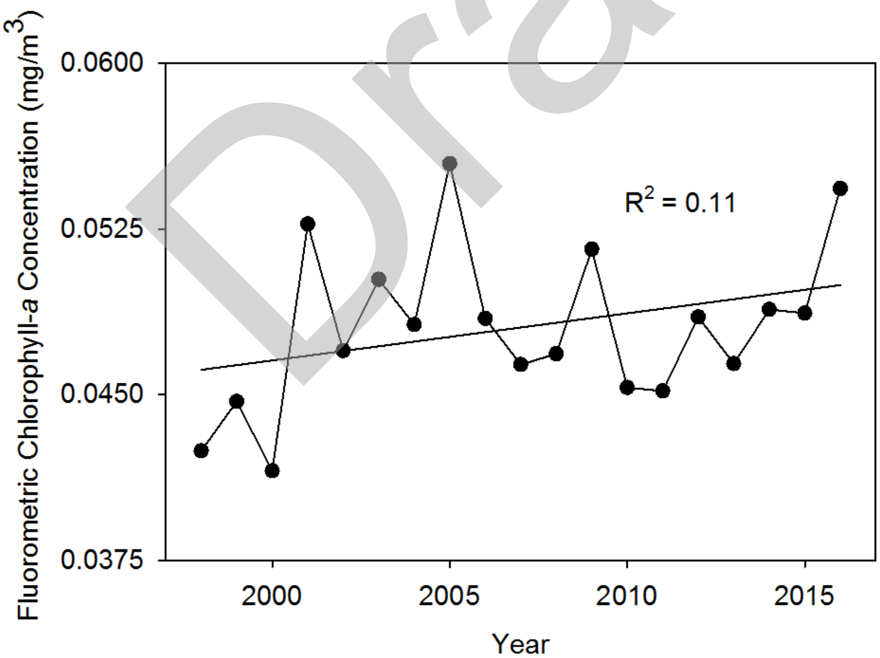


Figure 58. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around Guam from 1998-2016 (CV=7.03).

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 59. 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 59).

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 84; Figure 60). 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 60).

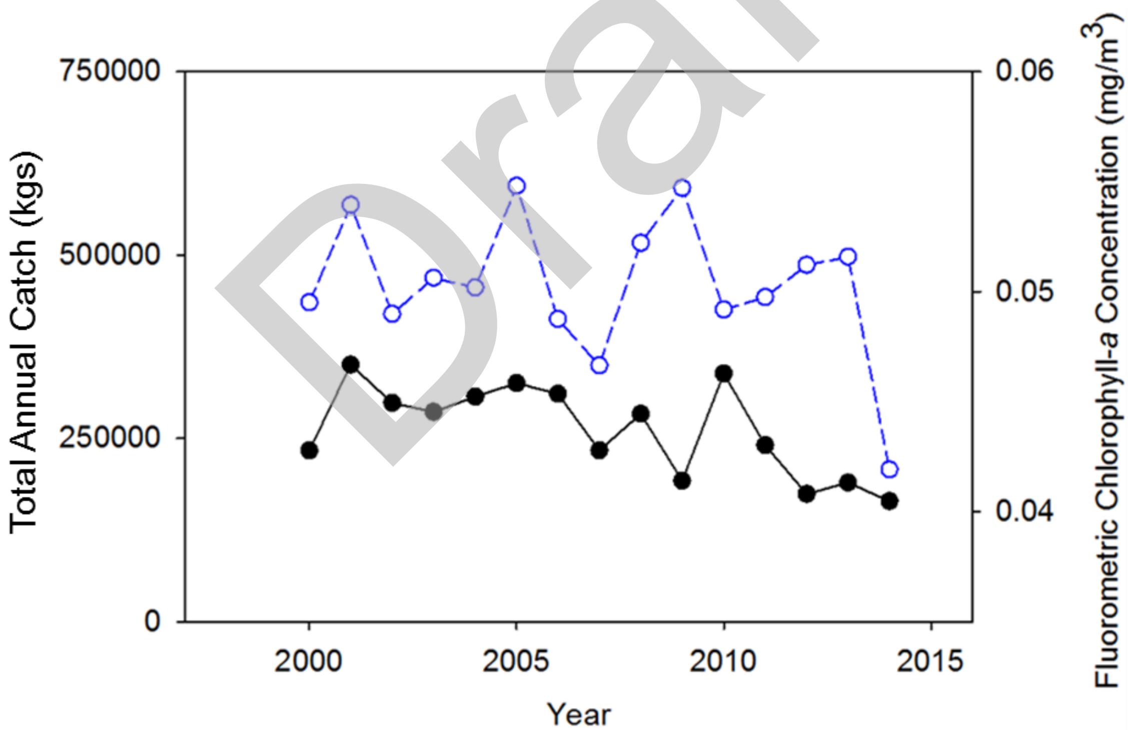


Figure 59. Comparison of the CNMI recreational reef fish catch (kg; black) from creel survey records with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 2000-2014 (r = 0.32).

Table 84. 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. Significant correlations are indicated in bold.

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

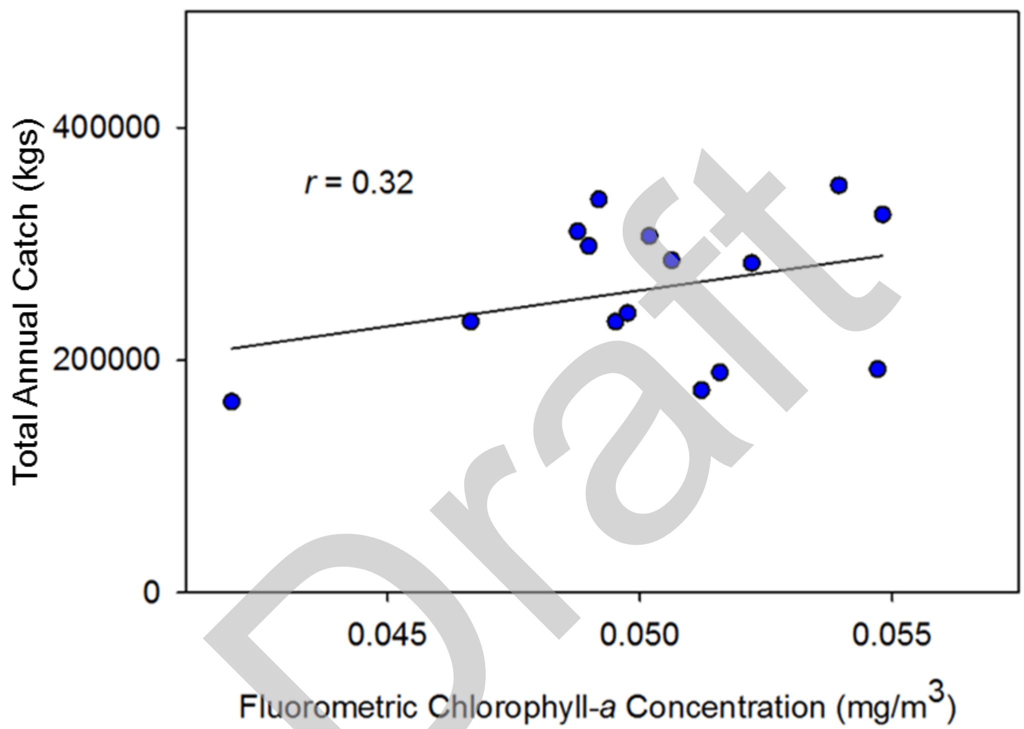


Figure 60. Linear regression between total annual catch (kg) phase lag (t+2 years) and fluorometric chlorophyll-a concentrations (mg/m^3) from CNMI (2000-2014).

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 84). 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 61a-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 84).

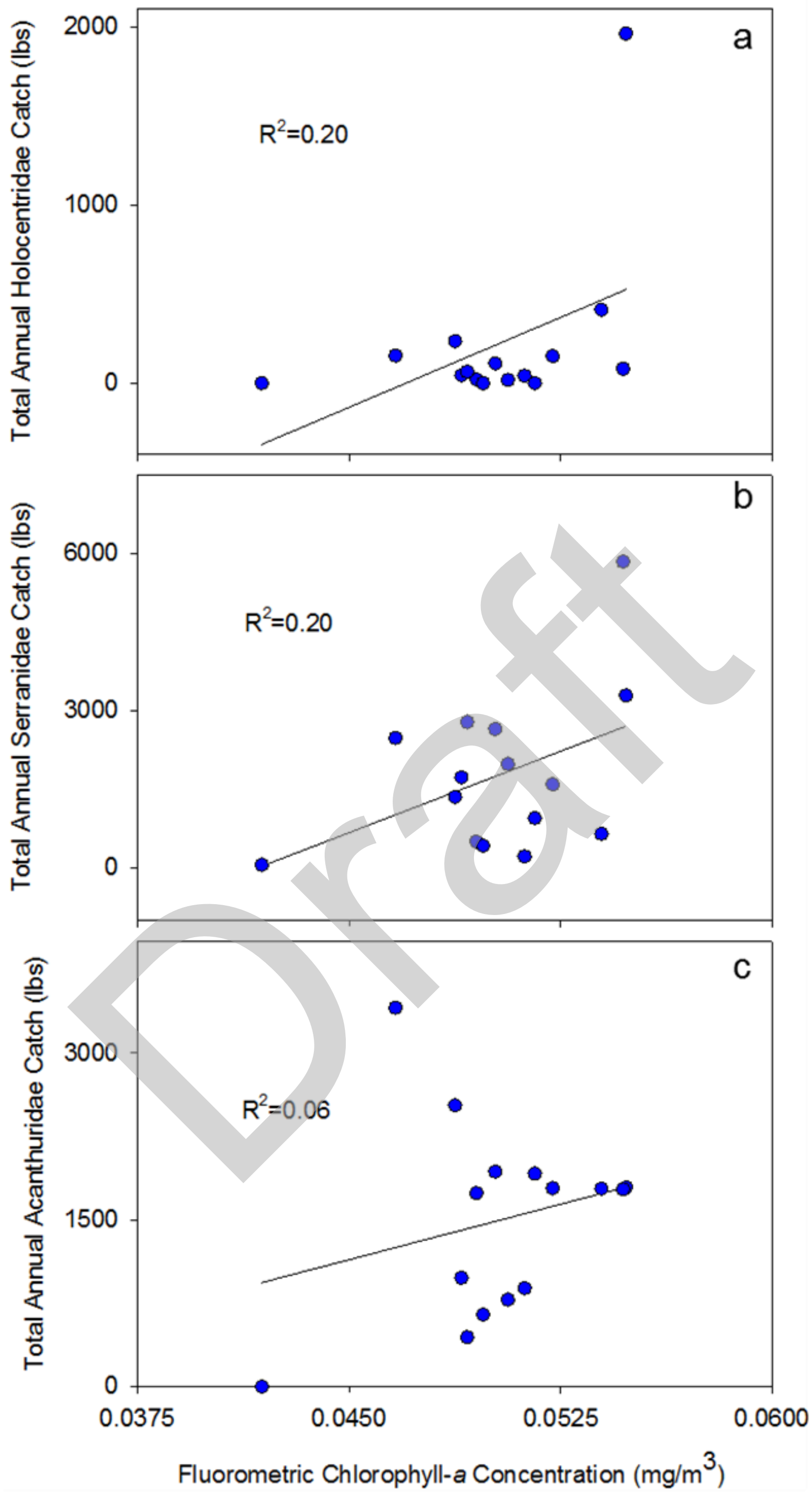


Figure 61. Linear regressions showing the three top correlations between total annual catch (kg) for the CNMI from creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) for (a) Holocentrids, (b) Serranids, and (c) Acanthurids from 2000–2014.

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 62. Catch levels were relatively variable over the course of the time series when considering the variation in pigment levels (CV=26.2; Figure 62). 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 62).

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 85; Figure 63). 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 85; Figure 63).

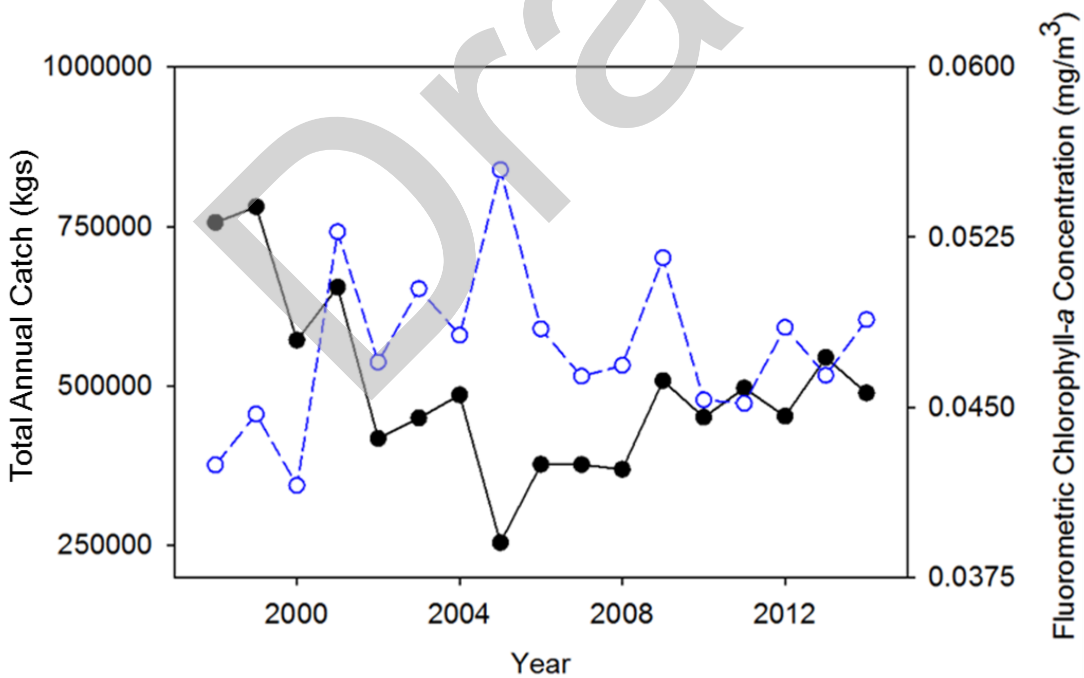


Figure 62. Comparison of Guam recreational reef fish catch for shore-and boat-based creel survey records (kg; black) with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 1998-2014.

Table 85. 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**

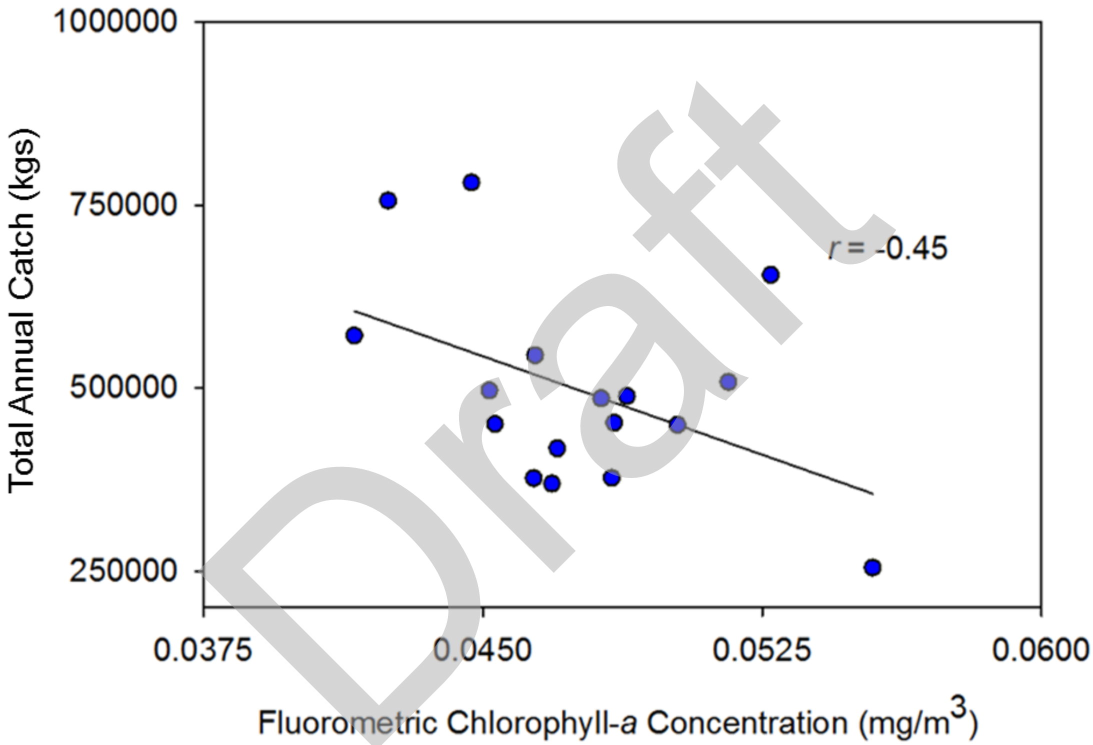


Figure 63. Linear regression between total annual catch (kg) for Guam shore-and boat-based creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) from 1998-2014.

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 85). 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 85; Figure 64a). 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 85; Figure 64b;). 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 85; Figure 64c); 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.

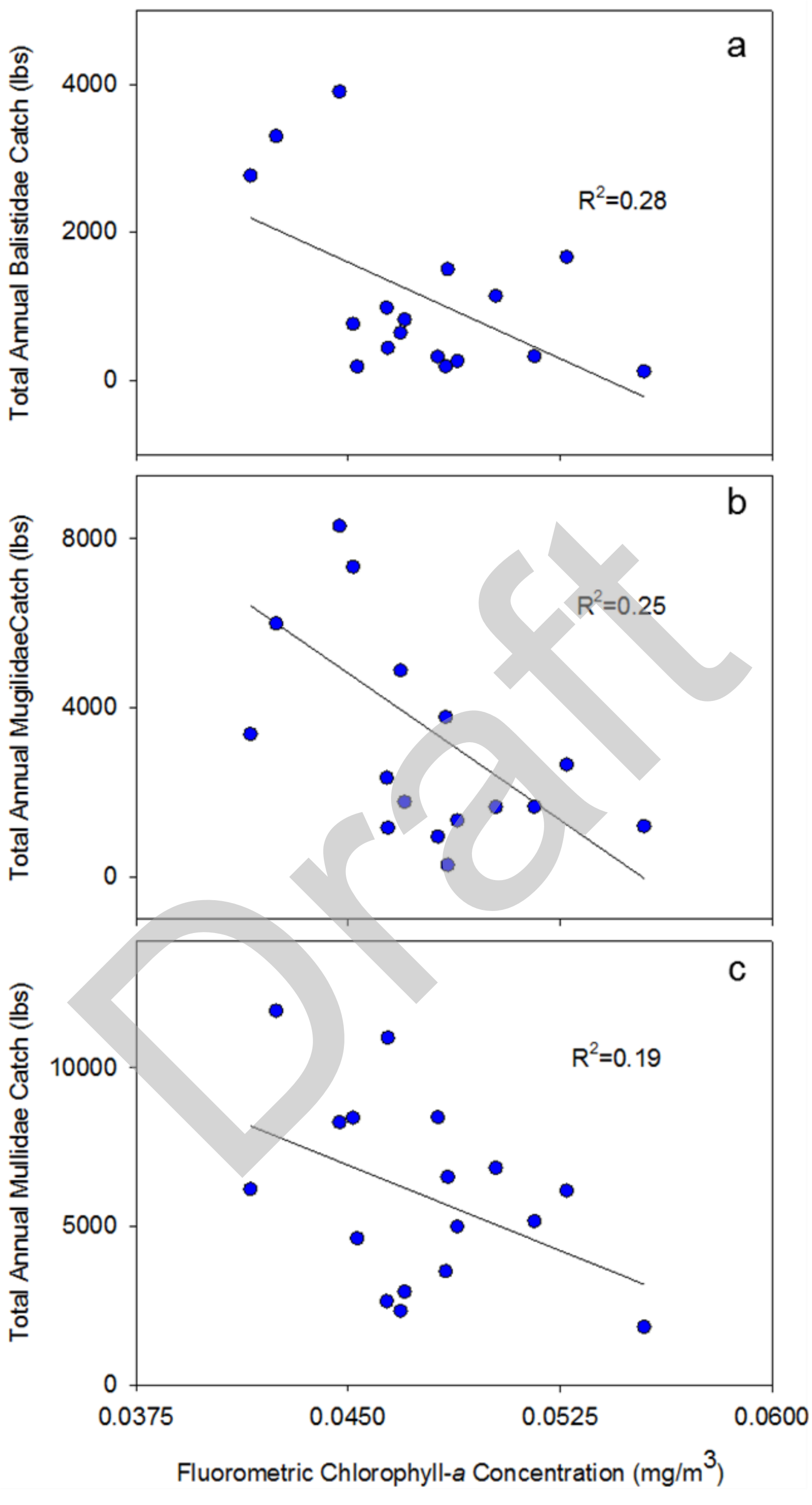


Figure 64. Linear regressions showing the three top correlations between total annual catch (kg) for Guam for shore-and boat-based creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) for (a) Balistidae, (b) Mugilidae, and (c) Mullidae from 1998–2014.

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 (Figure 10). The NMS final stress was morderate for the real runs (13.9), but low relative to stress from the randomization runs (31.0; Figure 10). 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 65).

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 66). Replicate NMS runs had similar stress levels for the final generated result.

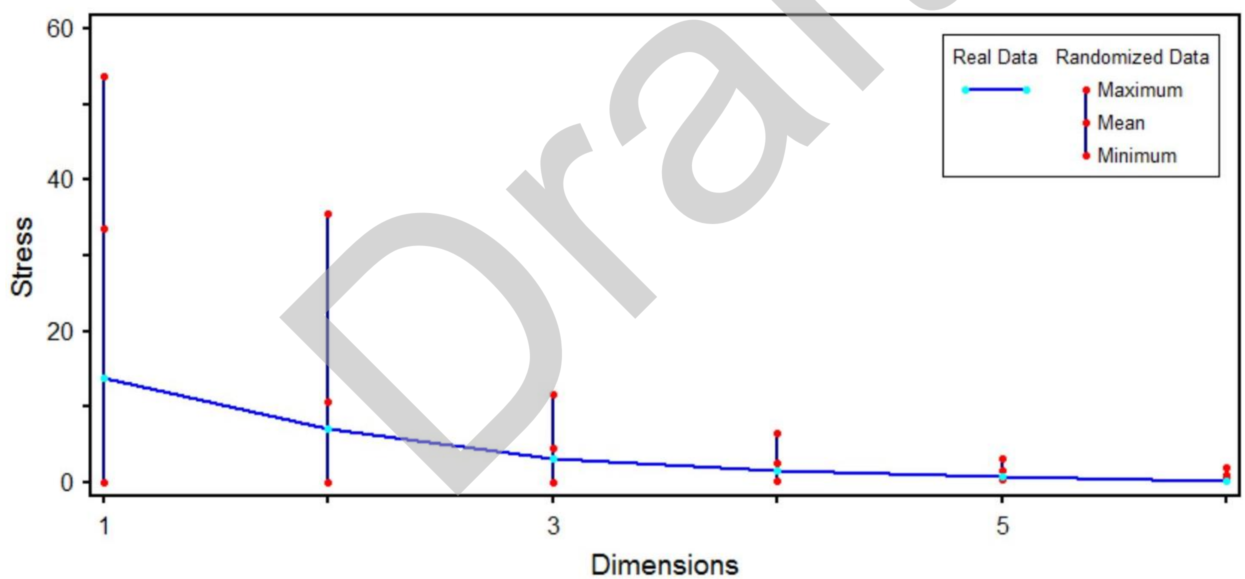


Figure 65. NMS scree plot showing the stress test to determine dimensionality for the final solution for the CNMI multivariate analysis. A one-axis solution was recommended.

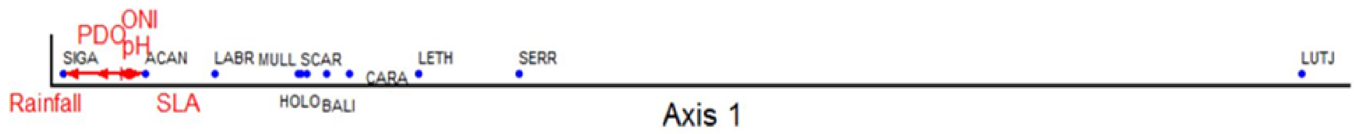


Figure 66. One-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters from the CNMI (2000 - 2014).

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 67). A majority of the families were clustered in ordination space, with the notable exception of Carangidae (Figure 68).

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 68). 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 68). Replicate NMS runs had similar stress levels for the final generated result.

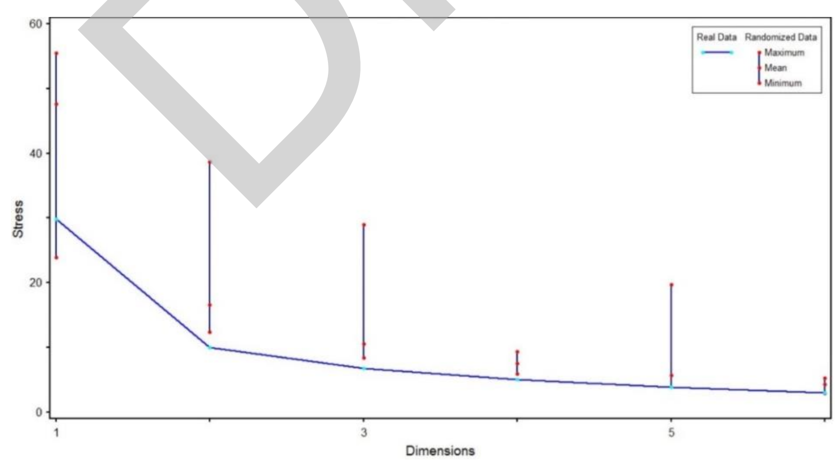


Figure 67. NMS scree plot showing the stress test to determine dimensionality for the final solution for the Guam multivariate analysis. A two-axis solution was recommended.

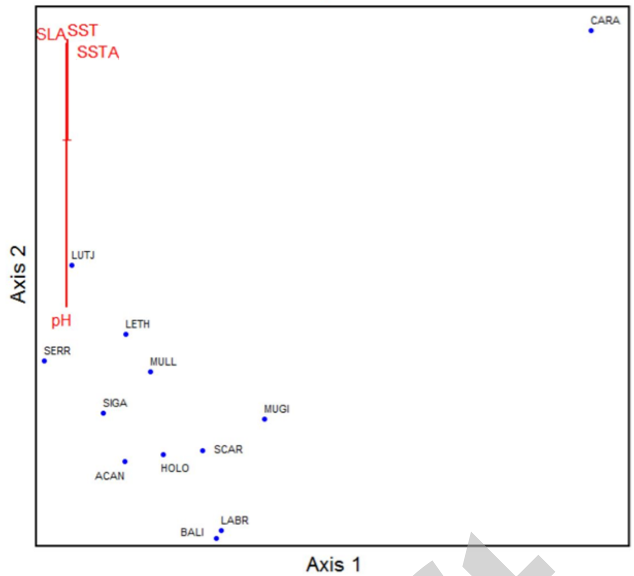


Figure 68. Two-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters from the Guam (1989-2014).

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

Ansell, A.D., Gibson, R.N., Barnes, M., and Press, U.C.L., 1996. Coastal fisheries in the Pacific Islands. *Oceanography and Marine Biology: an annual review*, *34*(395), 531 p.

Behrenfeld, M.J., T O'Malley, R., Siegel, D.A., McClain, C.R., Sarmiento, J.L., Feldman, G.C., Milligan, A.J., Falkowski, P.G., Letelier, R.M. and Boss, E.S., 2006. Climate-driven trends in contemporary ocean productivity. *Nature*, *444*(7120), 752 p.

Carton, J.A. and Giese B.S., 2008. A Reanalysis of Ocean Climate Using Simple Ocean Data Assimilation (SODA), *Mon. Weather Rev*., *136*, pp. 2999-3017.

Climate Prediction Center Internet Team, 2015. Cold and warm episodes by season. NOAA Center for Weather and Climate Prediction, Maryland, United States. Accessed March 2017. Available from http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml.

Hawhee, J.M., 2007. Western Pacific Coral Reef Ecosystem Report. Report prepared for the Western Pacific Regional Fishery Management Council, Honolulu, HI 96813 USA, 185.

Islam, M.S., and Tanaka, M., 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine pollution bulletin*, *48*(7), pp. 624-649.

Kitiona, F., Spalding, S., and Sabater, M., 2016. The impacts of climate change on coastal fisheries in American Samoa. University of Hawaii at Hilo, HI 96720 USA, 18 p.

Longhurst, A.R. and Pauly, D., 1987. The Ecology of Tropical Oceans. *Academic Press Inc.,London*, 407 p.

McClanahan, T.R., Graham, N.A., MacNeil, M.A., Muthiga, N.A., Cinner, J.E., Bruggemann, J.H., and Wilson, S.K., 2011. Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries. *Proceedings of the National Academy of Sciences*, *108*(41), pp.17230-17233.

Messié, M. and Radenac, M.H., 2006. Seasonal variability of the surface chlorophyll in the western tropical Pacific from SeaWiFS data. *Deep Sea Research Part I: Oceanographic Research Papers*, *53*(10), pp. 1581-1600.

NOAA/NESDIS/OceanWatch – Central Pacific, n.d. OceanWatch – Sea-surface Temperature, AVHRR Pathfinder v5.0 + GAC – Monthly. NOAA, Maryland, USA. Accessed March 2017. Available from <http://oceanwatch.pifsc.noaa.gov/thredds/dodsC/pfgac/monthly>.

NOAA/NOS/CO-OPS, n.d. Observed Water Levels. NOAA, Maryland, United States. Accessed March 2017. Available from https://tidesandcurrents.noaa.gov/waterlevels.html.

NOAA PDO, n.d. Pacific Decadal Oscillation Index. NOAA, Maryland, United States. Accessed March 2017. Available from http://research.jisao.washington.edu/pdo/PDO.latest.

NWS-G, n.d. National Weather Service Forecast Office, Tiyan, Guam. NOAA National Weather Service. Accessed March 2017. Available from http://w2.weather.gov/climate/xmacis.php?wfo=guam.

Ocean Colour Climate Change Initiative dataset, Version 3.1, European Space Agency. Accessed August 2017. Available from <http://www.esa-oceancolour-cci.org/>.

Ochavillo, D., 2012. Coral Reef Fishery Assessment in American Samoa. Department of Marine and Wildlife Resources, Pago Pago, American Samoa 96799 USA, 29 p.

Peck, J.E., 2016. Multivariate Analysis for Ecologists: Step-by- Step, Second edition. MjM Software Design, Gleneden Beach, OR. 192 p.

Remington, T.R. and Field, D.B., 2016. Evaluating biological reference points and data-limited methods in Western Pacific coral reef fisheries. Report prepared for the Western Pacific Regional Fishery Management Council, Honolulu, HI 96813 USA, 134 p.

Roemmich, D. and McGowan, J., 1995. Climatic warming and the decline of zooplankton in the California Current. *Science: New York then Washington*, pp. 1324-1324.

Richards B.L., Williams I.D., Vetter O.J., and Williams G.J., 2012. Environmental factors affecting large-bodied coral reef fish assemblages in the Mariana Archipelago. *PLoS ONE 7*(2), e31374.

Weng, K.C. and Sibert, J.R., 2000. Analysis of the Fisheries for two pelagic carangids inHawaii. Joint Institute for Marine and Atmospheric Research, University of Hawaii at Manoa, Honolulu, HI 96822 USA, 78 p.

Williams, I.D., Baum, J.K., Heenan, A., Hanson, K.M., Nadon, M.O., and Brainard, R.E., 2015. Human, Oceanographic and Habitat Drivers of Central and Western Pacific Coral Reef Fish Assemblages. *PLoS ONE 10*(5): e0129407.