ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT: MARIANA ARCHIPELAGO FISHERY ECOSYSTEM PLAN 2019

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The ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT for the MARIANA ARCHIPELAGO FISHERY ECOSYSTEM PLAN 2019 was drafted by the Fishery Ecosystem Plan Team. This is a collaborative effort primarily between the Western Pacific Regional Fishery Management Council (WPRFMC), National Marine Fisheries Service (NMFS)-Pacific Island Fisheries Science Center (PIFSC), Pacific Islands Regional Office (PIRO), Division of Aquatic Resources (HI,) Department of Marine and Wildlife Resources (American Samoa), Division of Aquatic and Wildlife Resources (Guam), and Division of Fish and Wildlife (CNMI).

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

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EXECUTIVE SUMMARY

As part of its five-year fishery ecosystem plan (FEP) review, the Western Pacific Regional Fishery Management Council (WPRFMC; the Council) identified its 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 chapter of this report first presents a general description of the local fisheries within the Commonwealth of Northern Mariana Islands (CNMI) and Guam, focusing on the management unit species (MUS), particularly bottomfish MUS (BMUS), accompanied by monitoring of ecosystem component species (ECS). The fishery data collection system is explained, encompassing boat-based creel surveys and commercial receipt books. Fishery meta-statistics for BMUS and ECS are organized into summary dashboard tables 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 along with annual catch limit (ACL) determinations.

For 2019 in CNMI, there were no instances of MUS exceeding their ACL because the only remaining MUS is the bottomfish multi-species complex, which did not have an ACL specified in 2019 due to the new benchmark stock assessment (Langseth et al., 2019) that was determined to be the best scientific information available. This was similar for Guam in 2019, as there was no ACL specified for the BMUS complex. While there used to be coral reef ecosystem management unit species (CREMUS) and crustacean management unit species (CMUS) that were actively managed using ACLs, an amendment to the Mariana Archipelago FEP in early 2019 reclassified most of the MUS as ECS except for bottomfish. ECS do not require ACL specifications or accountability measures but are still to be monitored regularly in the annual SAFE report through a one-year snapshot of the ten most caught ECS, complete catch time series of prioritized ECS as selected by Guam Division of Aquatic and Wildlife Resources (DAWR) and CNMI Division of Fish and Wildlife (DFW), as well as trophic and functional group biomass estimates from fishery independent surveys. Other existing management measures still apply to ECS.

In CNMI, BMUS catch decreased notably in 2019 to 21,012 pounds, a 45% decrease from the 10-year average and a 44% decrease from the 20-year average. BMUS catch from commercial purchase data in 2019, however, showed increases of 21% and 6% relative to the short- and long-term trends at 15,697 lbs. CPUE for BMUS harvested by the bottomfishing handline gear decreased for both metrics presented, pounds per trip and pounds per gear hour. There were 23 lbs./trip of BMUS harvested by bottomfishing (56% and 41% decreases from the 10- and 20-year averages, respectively), and approximately 2.42 lbs./gear hour of BMUS harvested by bottomfishing (43% and 22% decreases from the short- and long-term averages, respectively). The total estimated number of bottomfishing trips that harvested BMUS was just nine in 2019, a 50% decrease from the 10-year average and 68% decrease from the 20-year average. The estimated number of bottomfishing gear hours was 85 (78% and 81% decreases from short- and long-term trends, respectively). Bottomfishing participants also decreased in 2019, with an estimated eight unique vessels and the average number of fishermen per trip falling to just two. There was no recorded bycatch in 2019.

For the top ten landed ECS in CNMI in 2019, available data streams showed that the "surgeonfish" group had the most catch in the creel survey data, while "assorted reef fish" had the most catch in commercial data. The second most caught species was parrotfish for both the creel survey data and the commercial purchase data. Several other species had notable catch estimates in the creel survey data, including *Seriola dumerili* and *Epibulus insidiator*. Most of the remainder of the top ten ECS from commercial purchase data were family groups (e.g., Acanthuridae) due to how the species are organized during data collection.

For prioritized ECS (i.e., those selected by DFW) in CNMI, creel survey catch estimates for five of the seven species were zero in 2019. *Naso lituratus* and *Lethrinus harak* were the only two species with catch recorded in the boat-based creel surveys for the year. There were species codes for just six of the seven prioritized ECS species in CNMI commercial purchase data, as *Scarus ghobban* does not get actively recorded. In the data for the six available species, commercial purchase showed catches of zero for four species. Only *Naso lituratus* and *Siganus argenteus* had commercial data reported in 2019, both of which were lower than their 10-year and 20-year averages.

For the BMUS fishery in Guam in 2019, total estimated BMUS catch was 37,702 lbs., a 46% increase relative to the recent 10-year average and a 29% increase compared to the recent 20-year average. No commercial catch trends were reported due to issues with data confidentiality (i.e., less than three vendors reporting data). CPUE for BMUS harvested by the bottomfishing handline gear was presenting using two metrics in the 2019 report, pounds per trip and pounds per gear hour. There was 19 pounds of BMUS caught per trip in Guam in 2019, a 12% increase from the recent 10-year average and consistent with the 20-year average. CPUE in pounds per gear hour was 1.4505 for BMUS harvested with the bottomfishing handline gear, which coincided with decreases relative to the recent 10- and 20-year averages (27% and 14%, respectively). The total estimated number of fishing trips bottomfishing trips that harvested BMUS increased by 36% compared with the 10-year average to 76 trips, which also represented a 21% increase relative to the 20-year average. The number of bottomfishing gear hours on trips that harvested BMUS was 1,016, consistent with the 10-year average and a 2% increase to the 20-year average. The total estimated number of unique vessels harvested BMUS in Guam was 52, an increase to both the 10- and 20-year averages by 27% and 13%, respectively. The average number of fishers per trip was 3, which was consistent with the both the historical averages. Bycatch slightly increased in 2019 relative to the 10-year average but decreased compared to the 20-year average; this is due to the low amount of bycatch over recent years, as the number individual fish released was three (representing a bycatch rate of 0.35%).

For the top ten landed ECS in Guam in 2019, available data showed that "assorted reef fish" had the most catch in both the creel survey and commercial purchase data. The second most caught species was *Selar crumenophthalmus* (atulai). Several other species had notable catch estimates in the creel survey data, including *Aprion virescens*, *Naso lituratus*, and *Lethrinus obsoletus*. Most of the remainder of the top ten ECS from commercial purchase data were family groups (e.g., Scaridae and Lethrinidae) due to how the species are organized during data collection.

For prioritized ECS (i.e., those selected by DAWR) in Guam, 2019 creel survey catch estimates for five of the nine species were lower than both of their associated 10- and 20-year averages: *Naso unicornis*, *Lethrinus harak*, *Chlorurus frontalis*, *Caranx melampygus*, and *Scarus rubroviolaceus*, whose data indicated zero estimated catch in 2019. Two of the nine species (*Lethrinus olivaceus* and *Lutjanus fulvus*) had catch estimates that indicated increases in both their short- and long-term trends. Two species (*Siganus spinus* and *Epinephelus fasciatus*) had catch estimates from the creel survey data that were greater than their 10-year averages but lower than their 20-year averages. There was sufficient commercial purchase data for two of the nine prioritized ECS species, *N. unicornis* and *S. spinus*, that indicated large decreases (i.e., over 50% reductions) from their 10- and 20-year averages.

An Ecosystem Considerations chapter was added to the annual SAFE report following the Council's review of its FEPs and revised management objectives. Fishery independent ecosystem survey data, socioeconomics, protected species, climate and oceanographic, essential fish habitat, and marine planning information are included in the Ecosystem Considerations chapter.

Fishery independent ecosystem data were acquired through visual surveys conducted by the National Marine Fisheries Service (NMFS) Pacific Islands Fisheries Science Center (PIFSC) Reef Assessment and Monitoring Program (RAMP) under the Ecosystem Sciences Division (ESD) in CNMI, the Pacific Remote Island Areas (PRIAs), American Samoa, Guam, the Main Hawaiian Islands (MHI), and the Northwestern Hawaiian Islands (NWHI). This report describes mean fish biomass of functional, taxonomic, and trophic groups for coral reefs as well as habitat condition using mean coral coverage per island for each of these locations. Coral coverage in CNMI ranged from nearly 10% to just over 22% for the period between 2010 and 2019, while Guam had an average coral coverage of just over 15% in its reef areas averaged over the time. Fish biomass estimates in the CNMI averaged from 2010 to 2019 were relatively similar around Saipan, Tinian, Aguijan, and Rota for most groups, and were typically lower than biomass observed around Farallon de Pajaros, Maug, Asuncion Agrihan, Pagan, and Alamagan, Guguan, and Sarigan (AGS). Guam's fish biomass estimates were roughly on par with those from Saipan, Tinian, Aguijan, and Rota.

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 eight prioritized ECS and the 13 BMUS where available. The same nine life history parameters are provided for nine prioritized ECS and the 13 BMUS in Guam where available. Length derived parameters summarized for coral reef ECS and bottomfish in CNMI and Guam include maximum fish length, mean length, sample size for L-W regression, and length-weight coefficients. Length derived values are presented for the same ECS and BMUS as the life history parameters for both CNMI and Guam where available.

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 FEP 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, provides a summary of relevant studies and data for the Mariana Archipelago, presents available socioeconomic data (including annual data for revenue, fish price, and cost of fishing), and then lists relevant socioeconomic studies for fisheries within the Mariana Archipelago.

Considering the CNMI bottomfish fishery, there was an estimated total of 15,699 pounds sold for $35,840. Fish price increased from 2018 to 2019 to $6.10 per pound. The average cost of a bottomfish trip in CNMI in 2019 was higher than 2018 at $73 due to increased fuel cost. The top 10 ECS in CNMI had 25,160 pounds sold for a revenue of $89,314. Socioeconomic data on Guam's bottomfish fishery were unavailable due to data confidentiality in 2019. The cost of fishing in 2019 was lower than 2017 and 2018 at $46 per trip, mostly due to the reduced cost for lost gear. For the top 10 ECS in Guam, 46,430 pounds were sold for a revenue of $142,993. There were no data reported for the crustacean or precious coral fisheries in the CNMI or Guam.

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. In June 2019, NMFS reinitiated consultation for the Mariana Archipelago bottomfish fisheries due to the listing of the oceanic whitetip shark and giant manta ray under the Endangered Species Act (ESA), and determined that the conduct of these bottomfish fisheries during the period of consultation will not violate ESA Section 7(a)(2) and 7(d). In late 2018, NMFS concluded that Mariana Archipelago coral reef, crustacean, and precious coral fisheries will have no effect on the oceanic whitetip shark and giant manta ray.

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 Council has jurisdiction. 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 considering changing climate, provide historical context, and recognize patterns and trends.

The atmospheric concentration of carbon dioxide (CO_2) continued to increase exponentially with 2019 having the time series maximum at 411 ppm. The oceanic pH at Station ALOHA in Hawaii has shown a significant linear decrease of -0.0401 pH units, a roughly a 9.7% increase in acidity ([H+]), since 1989. The Oceanic Niño Index (ONI) that gauges the El Niño – Southern Oscillation (ENSO) cycle transitioned from weak El Niño to neutral conditions in 2019. The measure of the Pacific Decadal Oscillation (PDO) hovered around a zero value in 2019, as there were seven months that were slightly negative value and five months that were slightly positive. Tropical cyclone activity was roughly average in the Western North Pacific in 2019, with 26 named storms, 16 typhoons, and 10 super typhoons. Notably, Super Typhoon Hagibis was a Category 5 super typhoon that weakened to Category 2 before making landfall in Japan. Annual mean sea surface temperature (SST) around the Mariana Archipelago was 28.64ºC in 2019, and over the period of record, annual SST has increased at a rate of 0.024ºC/year. The annual anomaly was 0.292 ºC hotter than average, with intensification in the northern islands. The Mariana Archipelago experienced a coral heat stress event in late 2019 that reached its maximum in September. Annual mean chlorophyll-A was 0.044 mg/m^3 in 2019, and the annual anomaly was 0.0049 mg/m^3 lower than average. Over the period of record, annual chlorophyll-A has shown weak but significant linear decrease at a rate of 0.00036 mg/m^3. The local trend in sea level rise is 3.40 millimeters/year based on monthly mean sea level data from 1993 to 2019, which is equivalent to a change of 1.24 feet in 100 years.

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. In the 2017 annual reports, a literature review of the life history and habitat requirements for each life stage for four species of reef-associated crustaceans that are landed in commercial fisheries Western Pacific region was presented, including information on two species of spiny lobster (*Panulirus marginatus* and *Scyllarides squammosus*), scaly slipper lobster (*Scyllarides squammosus*), and Kona crab (*Ranina ranina*). For the 2019 annual report, a review of EFH for reef-associated crustaceans in the MHI and Guam has been included. The 2019 report also presents levels of EFH information available for Mariana Archipelago MUS. The National Standard guidelines also require a report on the condition of the habitat. In the 2019 annual report, data on benthic cover are included as indicators, pending development of habitat condition indicators for the Mariana Archipelago not represented in other sections of this report. The annual report addresses Council directives toward its Plan Team, but there were no directives associated with EFH in 2019.

The marine planning section of this report records activities with multi-year planning horizons and begins to track the cumulative impact of established facilities. Development of the report in the future will focus on identifying appropriate data streams. Military activities in the Marianas continue to impact fisheries and their access. There is an ongoing lawsuit regarding the Guam and CNMI military relocation Supplemental Environmental Impact Statement (SEIS), and the U.S. Court of Appeals for the Ninth Circuit announced it may hear oral arguments in early 2020. The Mariana Islands Training and Testing SEIS is expected in spring 2020. Both activities will likely impact access to fishing grounds at Ritidian Point on Guam and at Farallon de Medinilla in CNMI during live-fire exercises. A revised draft of the CNMI Joint Military Training Environmental Impact Statement (EIS) was expected sometime in early 2019, but no new information has been released. The draft SEIS for Tinian Divert Infrastructure Improvements was made available in May 2019, and the associated public review period ended at the beginning of July 2019. CNMI representatives previously requested a military liaison to be present at their advisory panel committee meetings especially to discuss the expired Memorandum of Understanding (MOU) for the Garapan Anchorage, but a new MOU was not signed in 2019. Meetings with military officials regarding restricted airspace around Farallon de Medinilla established that the 12 nmi radius is closed when exercises are being conducted, but a 3 nmi closure would instead be in effect year-round when exercises are not being conducted.

The Data Integration chapter of this report is under development. The chapter explores the potential association between fishery parameters and ecologically-associated variables that may be able to explain a portion of the variance in fishery-dependent data. A contractor completed preliminary evaluations in 2017, and results of exploratory analyses were included for the first time in the 2017 annual SAFE report. Suggested revisions during review by the Archipelagic

Plan Team delayed updates to be implemented for the chapter for the Mariana Archipelago. Added to the report for the first time in 2019 was a list of recent relevant abstracts from publications associated with data integration topics.

Results presented from the 2017 analyses showed that the catch of coral reef fisheries in Guam and CNMI generally had a negative association with local precipitation levels. The coral reef fishery catch in Guam was shown to have a negative relationship with chlorophyll-*a* concentration. There was no relationship uncovered between akule catch and precipitation despite a general understanding of the connection between the two factors. The catch of nearly all evaluated coral reef taxa in Guam had a negative relationship with sea surface temperature in the region, while species belonging the family Acanthuridae (surgeonfish and unicornfish) had no notable relationship. Multivariate analyses were employed in the Data Integration chapter to evaluate the aggregate effects of ecological parameters more completely on the evaluated fisheries. A non-metric multidimensional scaling analysis was not able to identify any significant levels of association between expanded creel survey catch data and a range of environmental parameters, however, the first axis of the analysis, which explains 91% of the variance, illustrated the strongest relationships with salinity (negative) and rainfall (positive).

Going forward with the data integration analyses and presentation of results for Chapter 3 of the annual SAFE reports, the Plan Team suggested several improvements to implement in the future: standardizing and correcting values in the time series, incorporating longer stretches of phase lag, completing comparisons on the species-level and by dominant gear types, incorporating local knowledge on shifts in fishing dynamics over the course of the time series, and utilizing the exact environmental data sets presented in the Ecosystem Consideration chapter of this annual SAFE report. Many of these recommendations were applied to a revisited analysis in the Hawaii annual SAFE report in 2018 with similar plans for Mariana Archipelago data integration analyses in future report cycles. Implementation of these suggestions will allow for the preparation of a more finalized version of the data integration chapter in coming years.

Regarding the revisions to the 2019 annual SAFE reports, the 2020 Archipelagic Plan Team generated several work items:

- Provide direction on report structure for next year, particularly for the protected species module.
- Add the revised list of research needs incorporating Plan Team input into the protected species module version for the Council meeting.
- Improve bycatch reporting in the SAFE report in coordination with the ongoing standardized bycatch reporting methodology review:
    - Develop a bycatch data sections for the Hawaii fisheries.
    - Improve bycatch data sections for American Samoa and Mariana Archipelago annual SAFE reports, where data are available.
- Incorporate discussed changes to the Fishery Performance and Ecosystem Components sections of annual SAFE reports.
- Explore other benthic cover categories in the future reports.
- Review the report on potential updates for the habitat module and identify the data streams that would be useful for the habitat module of the annual SAFE reports.
- Include summaries of the federal logbook data where available.

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
A_{50}	Age at 50% Maturity
$A\Delta_{50}$	Age at 50% Sex Reversal
ABC	Acceptable Biological Catch
ACE	Accumulated Cyclone Energy
ACL	Annual Catch Limits
ACT	Annual Catch Target
AM	Accountability Measure
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
B	Biomass
BE	Biological Evaluation
B_{FLAG}	Reference point indicating low biomass
BiOp	Biological Opinion
BMUS	Bottomfish Management Unit Species
BRFA	Bottomfish Restricted Fishing Areas
BSIA	Best Scientific Information Available
CFEAI	Commercial Fishing Economic Assessment Index
CFR	Code of Federal Regulations
CMAP	Merged Analysis of Precipitation (CPC)
CMUS	Crustacean Management Unit Species
CNMI	Commonwealth of the Northern Mariana Islands
CO-OPS	Center for Operational Oceanographic Products and Services (NOAA)
CPC	Climate Prediction Center (NOAA)
CPI	Consumer Price Index
CPUE	Catch per Unit Effort
CRED	Coral Reef Ecosystem Division (PIFSC)
CREP	Coral Reef Ecosystem Program (PIFSC)
CREMUS	Coral Reef Ecosystem Management Unit Species
CRW	Coral Reef Watch (NOAA)
CV	Coefficient of Variation
DAR	Division of Aquatic Resources (Hawaii)
DAWR	Division of Aquatic and Wildlife Resources (Guam)
DFW	Division of Fish and Wildlife (CNMI)
DGI	Daily Growth Increments
DHW	Degree Heating Weeks
DIC	Dissolved Inorganic Carbon
DMWR	Department of Marine and Wildlife Resources (American Samoa)
DOD	Department of Defense
DOJ	Department of Justice
DON	Department of Navy
DPS	Distinct Population Segment
E	Effort
EA	Environmental Assessment

Acronym	Meaning
EBFM	Ecosystem Based Fisheries Management
ECS	Ecosystem Component Species
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ENSO	El Niño - Southern Oscillation
EO	Executive Order
ESA	Endangered Species Act
ESRL	Earth Systems Research Laboratory (NOAA)
F	Fishing Mortality
FAD	Fish Aggregating Device
FL	Fork Length
FDM	Farallon de Medinilla
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FR	Federal Register
FSM	Federated States of Micronesia
FSWP	Fisheries Statistics of the Western Pacific
GFCA	Guam Fisherman’s Cooperative Association
GLM	General Linear Modeling
GOES	Geostationary Operational Environmental Satellite (NOAA)
GPS	Global Positioning System
H	Harvest
HAPC	Habitat Area of Particular Concern
HOT	Hawaii Ocean Time Series (UH)
HURL	Hawaii Undersea Research Laboratory (NOAA and UH)
k	von Bertalanffy Growth Coefficient
L_{50}	Length at 50% Maturity
$L\Delta_{50}$	Length at 50% Sex Reversal
L_{∞}	Asymptotic Length
L_{bar}	Mean Fish Length
L_{max}	Maximum Fish Length
LAA	Likely to Adversely Affect
LOC	Letter of Concurrence
LOF	List of Fisheries
M	Natural Mortality
MBTA	Migratory Bird Treaty Act
MFMT	Maximum Fishing Mortality Threshold
MHI	Main Hawaiian Islands
MITT	Mariana Islands Training and Testing
MLCD	Marine Life Conservation District
MMA	Marine Managed Area
MMPA	Marine Mammal Protection Act
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA)
Monument	Marianas Trench Marine National Monument

Acronym	Meaning
MOU	Memorandum of Understanding
MPA	Marine Protected Area
MPCC	Marine Planning and Climate Change
MPCCC	MPCC Committee (WPRFMC)
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level
MSST	Minimum Stock Size Threshold
MSU	Microwave Sounding Unit
MSY	Maximum Sustainable Yield
MUS	Management Unit Species
n	Sample Size
N_{L-W}	Sample Size for Length-Weigh Regression
N/A	Not Applicable
NAF	No Active Fishery
NASA	National Aeronautics and Space Administration
NCADAC	National Climate Assessment and Development Advisory Committee
NCDC	National Climatic Data Center (NOAA)
ND	Not Detected
NEPA	National Environmental and Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NLAA	Not Likely to Adversely Affect
NMFS	National Marine Fisheries Service (NOAA)
NMI	Northern Marina Islands
NMS	Non-metric Multidimensional Scaling
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NOS	National Ocean Service (NOAA)
NPDES	National Pollutant Discharge Elimination System
NS	National Standard
NTM	Notice to Mariners
NWHI	Northwestern Hawaiian Islands
NWS	National Weather Service
OEIS	Overseas Environmental Impact Statement
OFL	Overfishing Limits
ONI	Ocean Niño Index
OPI	OLR Precipitation Index (NOAA)
OLR	Outgoing Longwave Radiation
OY	Optimum Yield
PCMUS	Precious Coral Management Unit Species
PDO	Pacific Decadal Oscillation
Pelagic FEP	Fishery Ecosystem Plan for the Pacific Pelagic Fisheries
PIFSC	Pacific Island Fisheries Science Center (NMFS)
PIRCA	Pacific Islands Regional Climate Assessment

Acronym	Meaning
PIRO	Pacific Islands Regional Office (NMFS)
PMEL	Pacific Marine Environmental Laboratory (NOAA)
PMUS	Pelagic Management Unit Species
POES	Polar Operational Environmental Satellite (NOAA
PRIA	Pacific Remote Island Areas
RAMP	Reef Assessment and Monitoring Program (CRED)
ROD	Record of Decision
RPB	Regional Planning Body
SAFE	Stock Assessment and Fishery Evaluation
SBRM	Standardized Bycatch Reporting Methodologies
SEEM	Social, Economic, Ecological, Management (Uncertainty)
SEIS	Supplemental Environmental Impact Statement
SFA	Sustainable Fisheries Act
SODA	Simple Ocean Data Assimilation
SPC	Stationary Point Count
SSC	Scientific and Statistical Committee (WPRFMC)
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
SSBPR	Spawning Stock Biomass Proxy Ratio
t_0	Hypothetical Age at Length Zero
T_{max}	Maximum Age
TA	Total Alkalinity
TALFF	Total Allowable Level of Foreign Fishing
TBA	To Be Assigned
TBD	To Be Determined
TSI	Territory Science Initiative
UH	University of Hawaii
USAF	United States Air Force
USFWS	United States Fish and Wildlife Service
VBGF	von Bertalanffy Growth Function
VFP	Visual Fox Pro
WPacFIN	Western Pacific Fishery Information Network
WPR	Western Pacific Region
WPRFMC	Western Pacific Regional Fishery Management Council
WPSAR	Western Pacific Stock Assessment Review

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1 FISHERY PERFORMANCE

1.1 CNMI FISHERY DESCRIPTIONS

1.1.1 Background

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

Fisheries during the German occupation

During the German occupational period (1899-1914) a majority of the economic focus in the Northern Marianas was on the copra industry. Few commercial fisheries were noted during this period of time, as the German administration focused efforts on crop production and feral cattle trade (Russell, 1999). Chamorro 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 percent of total tuna landed in Micronesia (Bowers, 2001). However, efforts to develop the tuna fishery shifted to Palau and Federated States of Micronesia (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 World War 2, but quickly rebuilt afterwards with 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 and 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 Chamorro and Carolinians continued subsistence fishing in 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 flashlights 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 its fisheries over the past twenty years. In the mid-1990s, commercial fishing 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 in the Northern Islands of the CNMI peaked starting in the mid-1990s through 2002, with landings being both sold locally and exported to Japan. Troll fishing continued to be dominant during this period. An exploratory, deepwater shrimp fishery also developed, but did not last due to internal company issues and gear losses. Around this time, a sea cucumber fishery also began on Rota before migrating to Saipan; ultimately, however, 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 2000s, small-scale troll, bottom and reef fish fisheries persisted, with landings sold locally. Federal and state support was provided multiple times to further develop fisheries in the CNMI with intermittent success. An exploratory longline fishery was funded and operated in the CNMI in the mid-2000 for about two years, but eventually closed down due to low productivity of high-value, pelagic fish, among other issues within the business. A few larger (40-80’) bottomfishing vessels were also operational during this period, with a majority of them fishing the northern islands and offshore banks. A few of these vessels were recipients of financial assistance to improve their fishing capacities.

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

1.1.1.1 Bottomfish Fishery

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

Two distinct types of bottomfish fisheries are identified in the CNMI: shallow-water bottom fishing, which targets fish at depths down to 150 m, and deepwater 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 deepwater bottom fishing depths (>150m) include onaga (*Etelis corsucans*), ehu (*E. carbunculus*), yellowtail kalekale (*Pristipomiodes auricilla*), amberjack (*Seriola dumerili*), blueline gindai (*P. argyrogrammicus)*, gindai (*P. zonatus*), opakapaka (*P. filamentosus*), and eightbanded grouper (*Hyporthordus octofasciatus*), among other fish residing at similar depths.

Bottomfish Management Unit Species (BMUS) are not the only species caught in the shallow-bottom fishery. Deep-water bottomfishing requires more efficient fishing gears, such as hydraulic reels. Bottomfishing trips generally return during the day, but there is an unmeasured amount that occurs outside of survey hours from 2 AM to 10 AM. 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 occur on a relatively short-term basis (i.e., less than four years). The slight difference between shallow-water and deep-water 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 bottomfish fishermen to sustain their efforts for 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 years relative to previous decades. 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 and 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, with fishing trips to other islands being 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), scaridae (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.

In 2018, the Council drafted an Amendment 4 to the Mariana Archipelago Fishery Ecosystem Plan (FEP) that reclassified a large number of management unit species (MUS) as Ecosystem Component Species (ECS; WPRFMC, 2018). The final rule was posted in the Federal Register in early 2019 (84 FR 2767). This amendment reduces the number of MUS from 227 species and families to 13 in the Mariana Archipelago FEP. All former coral reef ecosystem MUS (CREMUS) and crustacean MUS (CMUS) were reclassified as ECS that do not require annual catch limit (ACL) specifications or accountability measures but are still to be monitored regularly to prioritize conservation and management efforts and to improve efficiency of fishery management in the region. All existing management measures, including reporting and record keeping, prohibitions, and experimental fishing regulations apply to ECS. If an ECS stock becomes a target of a Federal fishery in the future, the National Marine Fisheries Service and the Council may consider including that stock as a MUS to actively manage that stock. These species are still regularly monitored via other means (see Sections 1.1.5.3 and 2.1.2).

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 recent decades, 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 for expansion 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 nearshore fishery resources. These surveys were formerly known as the “CNMI offshore creel survey” but are now referred to as “boat-based” because they cover all fishing done from a boat. This is an important distinction because where the fishing activity is initiated (i.e. boat vs. 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 hiatus. The 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, DFW fishery staff reinitiated the creel survey program for the island's shore-based fishery following a hiatus of 11 years. The Western Lagoon starts from the northwest (Wing Beach) and extends to the southwest (Agingan Point) of Saipan, encompassing 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 and interview. The participation count involves counting the number of people fishing on randomly selected days and their method of fishing along the shoreline. The interview involves dialoging with fishermen to determine catch, method used, length and weights of fish, species composition, catch disposition, and if any fish were not kept (i.e., bycatch). The data collected from this program have been used to expand and create annual estimated landings for the shore-based fishery in the CNMI.

In October 2018, the islands of Saipan and Tinian were directly hit by Super Typhoon Yutu. The damage inflicted by the typhoon delayed both creel surveys and collection of commercial receipt invoices. About a month after the typhoon, creel surveys were regularly conducted again, and boat-based surveys followed soon thereafter. Vendors prioritized repairing typhoon-related damages to their businesses, and the number of invoices collected decreased as a result.

There were 30 boat-based surveys conducted between January 1 and June 30, 2019. 32 interviews were completed with an expanded catch of 591,875 lbs. The vessel/trailer participation survey is ongoing and includes all launching areas on the west coast of Saipan, where all boat-based fishing occurs. For this reporting period, a total of 312 boat vessels/trailers were recorded as "out fishing". During this period, the most common fishing methods encountered were trolling and bottomfishing. The expanded harvest estimate was 587,928 lbs. for trolling, while the estimate catch was 3,947 lbs. for bottomfishing.

There were 11 boat-based surveys conducted between July 1 and December 31, 2019. 37 interviews were completed with an expanded catch of 220,742 lbs. 215 boat vessels/trailers were registered as “out fishing”. Because the same vessel may be out fishing on more than one day, this count should not be used to estimate the total number of unique fishing vessels. During this period, the most common fishing methods encountered were trolling and bottom fishing. The expanded harvest estimate was 195,470 lbs. for trolling, while estimated catch was 19,653 lbs. for bottomfishing, and 5,619 lbs. for spear/snorkel.

Delays in accepting and processing the WPacFIN grant award resulted in boat-based surveys taking a hiatus from July to September. Surveys resumed after, and staff were instructed to be fastidious while conducting them to account for the potential data loss.

1.1.2.2 Vendor Invoice

The DFW has been collecting fishery statistics on Saipan’s commercial fishing fleet since the mid-1970s. With the assistance of the NMFS WPacFIN program, the DFW also expanded its fisheries monitoring programs to include the other two major inhabited islands in the CNMI, Rota and Tinian. The DFW’s principal method of collecting domestic commercial fisheries data is a dealer invoicing system, sometimes referred to as a “trip ticket” system. The DFW provides numbered two-part invoices to all purchasers of fresh fishery products (including hotels, restaurants, stores, fish markets, and roadside vendors). Dealers then complete an invoice each time they purchase fish directly from fishers; one copy goes to the DFW and one copy goes to their records. Some advantages of this data collection method are that it is relatively inexpensive to implement and maintain, and it is fairly easy to completely cover the commercial fisheries. The 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 percent 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 percent; however, coverage has been relatively mottled over the years. Previous volumes of FSWP reported only recorded landings, but in recent volumes, the data have been adjusted to represent 100 percent 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.

From January 1, 2019 to June 30, 2019, there were 930 invoices were collected from 23 vendors on Saipan. A total of 33,264.3 lbs. of fish were recorded from the sales receipt program valued at $102,973.89. From July 1, 2019 to December 31, 2019, there were 1,090 invoices collected from 24 vendors on Saipan. 28,864.4 lbs. of fish were recorded from the sales receipt program with a value of $80,510.49. Vendor participation increased to similar levels observed before Super Typhoon Yutu in the latter half of the 2019.

1.1.2.3 Bio-Sampling

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

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

1.1.2.4 Exemption Netting

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

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

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

1.1.2.5 Life History

The CNMI DFW life history program began in 1996 sampling the redgill emperors (*Lethrinus rubrioperculatus*). Since then, sampling has been conducted on other species, including *A. lineatus*, Myriprestinae (*Myripristis violacea, M. kuntee, M. pralinea, M. bernti, M. murdjan), L. harak, Naso lituratus*, *Chlorurus sordidus*, and *C. undulatus*. Other life history programs have also developed over the past years. In collaboration with NMFS, DFW personnel collect life history information on *Scarus rubroviolaceus*, *Lethrinus atkinsoni*, and *Parupeneus barbarinus* through funding provided by NOAA-NMFS. The life history survey captures biological information, including 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 a ticket receipt system and reviewed prior to being sent out for compilation by PIFSC. Most of the information entered into the system can only be identified to the family taxa.

1.1.2.7 Vessel Inventory

The most recent records obtained from CNMI Department of Public Safety (DPS) are from 2018. Their records are hand-written and do not exist electronically. 138 vessels were scheduled to be renewed by December 31, 2019. 10 vessels were registered as commercial fishing vessels. 91 were registered for personal use although an unknown amount was and continue to be used for commercial fishing regardless of their intended use specified on the registration. Others were registered for commercial recreation and government use. This work is also impacted by policies of the DPS, which manages vessel licensing. Going forward, additional emphasis will be put on improving the vessel inventory project, especially once the open data technician and data manager positions are filled at the CNMI DFW.

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 a random-stratified design applied to pre-scheduled surveys. The number of sampling days, participation runs, and catch interviews can be used to 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 number 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 Survey Meta-Data Statistics

Calculations:

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

Catch Interviews: In boat-based creel surveys, 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 CNMI boat-based creel survey meta-data

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
2000	44	168	9
2001	67	285	0

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
2002	75	200	25
2003	90	299	40
2004	77	272	16
2005	78	417	29
2006	71	342	22
2007	62	314	1
2008	55	250	1
2009	64	241	25
2010	65	161	82
2011	67	162	87
2012	72	166	0
2013	71	191	0
2014	71	166	0
2015	57	119	2
2016	65	117	3
2017	66	120	6
2018	54	126	1
2019	33	65	8
10-year avg.	**62**	**139**	**19**
10-year SD	**11**	**35**	**33**
20-year avg.	**65**	**209**	**18**
20-year SD	**12**	**88**	**25**

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; BMUS vendors are only from vendors that landed BMUS species.

Invoices: Count of the number of unique invoice numbers found in the commercial header data from the Commercial Receipt Book; BMUS vendors are only from vendors that landed BMUS species.

Table 2. Summary of CNMI commercial receipt book meta-data

Year	# Vendors	# Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
1983	42	2,930	13	55
1984	45	3,452	11	50
1985	*	*	*	*
1986	*	*	*	*

Year	# Vendors	# Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
1987	27	1,908	11	30
1988	16	2,204	7	23
1989	24	2,454	8	51
1990	23	2,218	5	19
1991	30	2,240	4	16
1992	55	3,233	3	4
1993	48	3,426	15	53
1994	55	3,722	17	89
1995	61	4,637	21	167
1996	73	5,870	25	231
1997	56	4,920	20	171
1998	53	6,374	21	220
1999	52	5,771	21	213
2000	49	6,892	16	210
2001	42	5,820	19	431
2002	33	5,611	17	268
2003	27	4,726	14	172
2004	25	3,720	13	99
2005	24	4,245	11	116
2006	21	4,541	10	154
2007	18	3,688	11	212
2008	13	3,242	10	221
2009	6	2,649	6	238
2010	5	1,708	5	134
2011	3	1,210	3	127
2012	20	1,630	12	192
2013	17	2,277	13	222
2014	17	2,034	12	152
2015	15	1,045	4	19
2016	16	2,407	9	175
2017	32	2,832	14	134
2018	38	4,530	16	98
2019	36	3,924	11	109
10-year avg.	**20**	**2,360**	**10**	**136**
10-year SD	**11**	**1,073**	**4**	**53**
20-year avg.	**23**	**3,437**	**11**	**174**
20-year SD	**12**	**1,578**	**4**	**82**

* Confidential (less than three vendors)

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* - *above 1 standard deviation*

- *decreasing trend in the time series* - *below 1 standard deviation*

- *no trend in the time series* - *within 1 standard deviation*

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

Table 3. Annual indicators for CNMI bottomfish fisheries describing performance and comparing estimates from 2019 with short- (10-year) and long-term (20-year) averages

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
Bottomfish	**Total estimated catch (lbs.)**		
All gears (BMUS only)	All BMUS from creel survey data	**21,012[▼45%]**	**21,012[▼44%]**
	All BMUS from commercial purchase data	**15,697[▲21%]**	**15,697[▲6%]**
	Catch-per-unit-effort (from boat-based creel surveys)		
Bottomfishing (BMUS only)	Bottomfishing lbs./trip	**23[▼56%]**	**23[▼41%]**
	Bottomfishing lbs./gr-h.	**0.2464[▼48%]**	**0.2464[▼8%]**
	Fishing effort (from boat-based creel surveys)		
Bottomfishing (BMUS only)	Estimated total bottomfishing trips	**9[▼50%]**	**9[▼68%]**
	Estimated total bottomfishing gear hours	**836[▼97%]**	**7836[▼97%]**
	Fishing participants (from boat-based creel surveys)		
Bottomfishing (BMUS only)	Estimated number of bottomfishing vessels	**8[▼20%]**	**8[▼56%]**
	Estimated average number of fishermen per bottomfishing trip	**2[▼67%]**	**2[▼60%]**
	Bycatch		
	# fish caught	**139[▼56%]**	**139[▼75%]**

	# fish kept	**139[▼56%]**	**139[▼75%]**
	# fish released	**0[no change]**	**0[▼100%]**

Table 4. Annual indicators for CNMI ECS fisheries describing performance and comparing 2019 estimates with short- (10-year) and long-term (20-year) averages

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
ECS	**Estimated catch (lbs.)**		
Prioritized ECS	*Acanturus lineatus* from creel survey data	**0[▼100%]**	**0[▼100%]**
	Acanturus lineatus from commercial purchase data	**0[▼100%]**	**0[▼100%]**
	Naso lituratus from creel survey data	**346[▲50%]**	**346[▼52%]**
	Naso lituratus from commercial purchase data	**320[▼73%]**	**320[▼73%]**
	Naso unicornis from creel survey data	**0[▼100%]**	**0[▼100%]**
	Naso unicornis from commercial purchase data	**0[▼100%]**	**0[▼100%]**
	Scarus ghobban from creel survey data	**0[▼100%]**	**0[▼100%]**
	Lethrinus harak from creel survey data	**1,979[▲14%]**	**1,979[▼4%]**
	Lethrinus harak from commercial purchase data	**0[no change]**	**0[no change]**
	Siganus argenteus from creel survey data	**0[▼100%]**	**0[▼100%]**
	Siganus argenteus from commercial purchase data	**293[▼84%]**	**293[▼93%]**
	Mulloidichthys flavolineatus from creel survey data	**0[▼100%]**	**0 [▼100%]**
	Mulloidichthys flavolineatus from commercial purchase data	**0[▼100%]**	**0[▼100%]**

1.1.5 Catch Statistics

The following section summarizes the catch statistics for bottomfish, the top ten landed ECS, and seven prioritized ECS in CNMI as decided by DFW. 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.

1.1.5.1 Catch by Data Stream

This section describes the estimated total catch from the 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 can capture the fishery better than the creel surveys.

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

Table 5. Summary of CNMI BMUS total catch (lbs.) from expanded boat-based creel surveys and the commercial purchase system for all gear types

Year	Boat-Based Creel Survey Estimates	Commercial Landings
1983		3,407
1984		3,463
1985		*
1986		*
1987		1,889
1988		2,413
1989		4,021
1990		1,273
1991		781
1992		158
1993		1,722
1994		5,459
1995		17,564
1996		32,294
1997		21,607
1998		25,529
1999		33,622
2000	67,252	14,751
2001	24,637	24,817
2002	24,603	24,296
2003	12,726	17,144
2004	30,407	11,292
2005	34,311	15,025
2006	35,279	11,837
2007	54,257	14,805
2008	21,118	15,098

Year	Boat-Based Creel Survey Estimates	Commercial Landings
2009	65,269	18,313
2010	56,007	12,971
2011	25,799	16,115
2012	137,495	10,591
2013	20,390	16,500
2014	7,740	16,334
2015	10,386	4,121
2016	54,335	17,717
2017	48,007	11,923
2018	650	7,258
2019	21,012	15,697
10-year avg.	**38,182**	**12,923**
10-year SD	**37,962**	**4,258**
20-year avg.	**37,584**	**14,830**
20-year SD	**29,692**	**4,723**

1.1.5.2 Expanded catch estimates by fishing method

Catch information is provided for the top boat-based fishing methods that comprise most of the annual BMUS catch in CNMI.

Calculations: The creel survey catch time series are the sum of the estimated weight for selected gear in all strata for all species all BMUS species.

Table 6. Total catch time series estimates (lbs.) for all species and BMUS only using CNMI expanded boat-based creel survey data for bottomfishing gears

Year	Bottomfishing		Spearfishing (Snorkel)	
	All	BMUS	All	BMUS
2000	99,106	62,990	27,918	4,262
2001	40,556	24,574	8,693	63
2002	37,621	23,945	9,990	159
2003	15,406	12,547	5,528	178
2004	40,060	30,407	7,452	0
2005	48,699	34,266	6,567	46
2006	61,157	34,951	8,553	15
2007	83,677	54,059	11,849	198
2008	51,075	19,744	15,516	1,334
2009	99,523	64,979	18,801	217
2010	82,211	56,007	5,814	0
2011	60,432	25,799	7,289	0

2012	157,445	137,495	8,513	0
2013	34,954	20,390	2,456	0
2014	15,291	7,740	2,257	0
2015	17,554	10,374	4,820	0
2016	56,983	53,906	0	0
2017	50,177	47,883	0	0
2018	4,347	90	4,087	0
2019	25,556	16,831	10,486	0
10-year avg.	**50,495**	**37,652**	**4,572**	**0**
10-year SD	**42,312**	**38,205**	**3,337**	**0**
20-year avg.	**54,092**	**36,949**	**8,329**	**324**
20-year SD	**35,520**	**29,686**	**6,421**	**949**

1.1.5.3 Top and Prioritized ECS in Boat-Based Fishery Catch

Catch can act as an indicator of fishery performance. Variations in the catch can be attributed to several factors, and there is no single explanatory variable for the observed trends. A one-year reflection of the top ten harvested species (by weight) is included to monitor which ECS are being caught the most annually. Additionally, CNMI DFW selected seven species that were reclassified as ECS that are still of priority to CNMI DFW for regular monitoring, and complete catch time series of these species are included in the report as well.

Calculations: Catch tallied from the boat-based expanded species composition data combining gear types for all species excluding BMUS, prioritized ECS, and pelagic MUS species.

Table 7a. Top ten landed species (lbs.) in CNMI ECS fisheries from expanded boat-based creel survey data in 2019

Common Name	Scientific Name	Catch
Surgeonfish	Acanthuridae (family)	4,060
Parrotfish (palakse)	Scaridae (family)	3,600
Amberjack	*Seriola dumerili*	3,003
Sling-jawed wrasse	*Epibulus insidiator*	1,671
Jobfish (uku)	*Aprion virescens*	808
Common parrotfish	*Scarus psittacus*	653
Octopus	*Octopus* spp.	594
Rudderfish (guili)	*Kyphosus* spp.	316
Grouper	Serranidae (family)	292
Yellowlip emperor	*Lethrinus xanthochilis*	268

Calculations: Catch tallied from commercial receipt data combining gear types for all species excluding BMUS, prioritized ECS, and pelagic MUS species.

Table 7b. Top ten landed species (lbs.) in CNMI ECS fisheries from commercial landings data in 2019

Common Name	Scientific Name	Catch
Assorted reef fish	Actinopterygii (class)	9,499
Parrotfish (palakse)	Scaridae (family)	4,463
Surgeonfish	Acanthuridae (family)	2,849
Bigeye scad (atulai)	*Selar crumenophthalmus*	1,655
Emperor (mafute)	Lethrinidae (family)	1,640
Rudderfish (guili)	Kyphosus spp.	1,103
Goatfish (satmoneti)	Mullidae (family)	1,071
Spiny lobster	*Panulirus* spp.	971
Rabbitfish (sesjun)	*Siganus spinus*	955
Jacks	Carangidae (family)	954

Calculations: Catch tallied from boat-based expanded species composition data for species identified as priority ECS by DFW (Appendix A).

Table 8a. Catch (lbs.) from expanded boat-based creel survey data for prioritized species in CNMI ECS fisheries

Year	*Acanthurus lineatus*	*Naso lituratus*	*Naso unicornis*	*Scarus ghobban*	*Lethrinus harak*	*Siganus argenteus*	*Mulloidichthys flavolineatus*
2000	0	1,189	43	0	0	955	0
2001	0	849	222	0	0	136	0
2002	0	2,238	981	0	0	1,034	0
2003	345	1,125	965	0	136	227	0
2004	601	458	323	0	0	11	0
2005	339	451	250	0	272	0	0
2006	249	375	1,662	0	2,676	28	7
2007	200	1,139	1,125	0	4,640	114	0
2008	0	636	135	0	7,318	317	0
2009	0	3,555	524	0	8,996	1,385	0
2010	0	600	0	0	1,063	615	0
2011	40	81	1,611	0	1,648	0	0
2012	155	190	0	0	6,941	0	0
2013	0	77	0	0	1,224	0	0
2014	34	223	0	0	1,819	736	0
2015	87	383	64	48	386	29	0
2016	0	0	0	0	408	0	0
2017	0	0	0	0	45	0	0
2018	0	412	0	0	1,896	489	47
2019	0	346	0	0	1,979	0	0

Year	*Acanthurus lineatus*	*Naso lituratus*	*Naso unicornis*	*Scarus ghobban*	*Lethrinus harak*	*Siganus argenteus*	*Mulloidichthys flavolineatus*
10-year avg.	**32**	**231**	**168**	**5**	**1,741**	**187**	**5**
10-year SD	**52**	**200**	**508**	**15**	**1,954**	**300**	**15**
20-year avg.	**103**	**716**	**395**	**2**	**2,072**	**304**	**3**
20-year SD	**166**	**856**	**558**	**11**	**2,734**	**423**	**11**

Calculations: Catch tallied from commercial purchase data for species identified as priority ECS by DFW (Appendix A). From the prioritized ECS list, *Scarus ghobban* is not included because there is no specific code for that species in the CNMI commercial coding system.

Table 8b. Catch (lbs.) from commercial purchase data for prioritized species in CNMI ECS fisheries

Year	*Acanthurus lineatus*	*Naso lituratus*	*Naso unicornis*	*Lethrinus harak*	*Siganus argenteus*	*Mulloidichthys flavolineatus*
2000	0	4,883	0	0	12,677	0
2001	0	4,500	0	0	8,408	0
2002	0	1,041	0	0	9,141	0
2003	0	143	0	0	7,161	0
2004	0	2	0	0	3,714	0
2005	0	64	0	0	2,571	0
2006	0	70	0	0	8,354	0
2007	0	426	0	0	5,909	0
2008	0	323	0	0	2,599	0
2009	0	313	0	0	1,312	0
2010	717	1,123	462	0	1,880	0
2011	0	2,804	1,804	0	2,185	0
2012	0	451	0	0	1,467	0
2013	0	759	0	0	2,331	0
2014	0	1,827	0	0	2,329	0
2015	0	1,380	0	0	1,569	0
2016	0	1,018	0	0	2,319	0
2017	0	1,664	0	0	3,063	18
2018	0	415	0	0	1,008	0
2019	0	320	0	0	293	0
10-year avg.	**72**	**1,176**	**227**	**0**	**1,844**	**2**
10-year SD	**227**	**774**	**573**	**0**	**790**	**6**
20-year avg.	**36**	**1,176**	**113**	**0**	**4,015**	**1**
20-year SD	**160**	**1,398**	**411**	**0**	**3,381**	**4**

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

This section summarizes the estimates for CPUE in the boat-based BMUS fisheries. The boat-based fisheries include the bottomfishing (handline gear) and spearfishing (snorkel). CPUE is reported as pounds per gear hour in the boat-based fishery.

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

All - lbs./trip: All catch and trips are tallied from landings by gear level, including non-BMUS species.

All - lbs./gr-hr.: All catch and trips are tallied from trips with data on the number of gears used and numbers of hours fished, including non-BMUS species.

BMUS - lbs./trip: Only BMUS catch and trips that landed BMUS species are tallied from landings by gear level.

BMUS - lbs./gr-hr.: Only BMUS catch and trips that landed BMUS are tallied from trips with data on the number of gears used and numbers of hours fished.

Table 9. CPUE (lbs./gear hour and lbs./trip) for bottomfishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfishing				Spearfishing (Snorkel)			
	All		BMUS		All		BMUS	
	Lbs/trip	Lbs/gr-hr	Lbs/trip	Lbs/gr-hr	Lbs/trip	Lbs/gr-hr	Lbs/trip	Lbs/gr-hr
2000	50	4.4368	55	4.7586	35	2.4301	64	5.3333
2001	17	1.6424	21	1.8869	19	1.4807	2	0.1111
2002	28	2.2220	32	2.3451	20	1.5498	3	0.3750
2003	21	1.7590	21	1.6403	29	2.0714	4	0.2857
2004	25	2.0320	20	1.5506	15	0.9051		
2005	26	2.0088	26	1.7245	21	1.8182	1	0.1481
2006	18	1.4271	17	1.2180	12	1.2473	1	0.1000
2007	28	2.6549	28	2.4243	15	1.0517	2	0.1212
2008	16	1.0346	13	0.8803	21	1.1861	6	0.2323
2009	19	0.7698	34	1.4728	21	1.3878	3	0.0833
2010	12	0.4043	11	0.3878	15	1.3214		
2011	11	0.3404	16	0.5351	38	2.7636		
2012	108	8.8291	156	9.8497	13	1.0250		
2013	46	4.2950	44	3.5939	20	1.3333		
2014	18	1.8688	32	3.6346	33	1.8868		
2015	34	2.7706	43	3.0000	19	3.2609		
2016	69	5.2814	78	5.6804				
2017	81	8.1575	115	12.9672				

Year	Bottomfishing				Spearfishing (Snorkel)			
	All		BMUS		All		BMUS	
	Lbs/trip	Lbs/gr-hr	Lbs/trip	Lbs/gr-hr	Lbs/trip	Lbs/gr-hr	Lbs/trip	Lbs/gr-hr
2018	5	0.4143	1	0.1429	9	0.8780		
2019	26	2.1859	23	2.4235	10	0.8261		
10-year avg.	**41**	**3.4547**	**52**	**4.2215**	**20**	**1.6619**		
10-year SD	**33**	**2.9645**	**47**	**4.0085**	**10**	**0.8488**		
20-year avg.	**33**	**2.7267**	**39**	**3.1058**	**20**	**1.5791**	**10**	**0.7544**
20-year SD	**25**	**2.3223**	**37**	**3.1308**	**8**	**0.6619**	**19**	**1.6215**

1.1.7 Effort Statistics

This section summarizes the effort trends in the CNMI bottomfish fishery. Fishing effort trends provide insights on the level of fishing pressure through time. Effort information is provided for the top boat-based fishing methods that comprise most of the annual catch.

Calculations: Effort estimates (in both trips and gear hours) are calculated from boat-based interview data. Trips are tallied according the interview data in boat-based creel surveys. Gear hours are generated by summing the data on number of gears used*number of hours fished collected from interviews by gear type. For the boat-based estimates, data collection started in 2000.

All - Trips: All trips tallied by gear type.

All - Gear-hrs: Gear hours tallied by gear type.

BMUS - Trips: Trips that landed BMUS tallied by gear type.

BMUS - Gear-hrs: Gear hours tallied by gear type for trips landed BMUS with data on both number of gears used and numbers of hours fished.

Table 10. Effort (trips and gear hours) for bottomfishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfish				Spear Snorkel			
	All		BMUS		All		BMUS	
	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs
2000	35	392	24	276	13	186	1	12
2001	50	529	20	221	14	181	1	18
2002	40	505	22	299	12	156	1	8
2003	34	403	25	323	8	112	2	28
2004	53	656	45	579	17	274	0	0
2005	124	1,600	85	1,285	25	286	3	27
2006	101	1,248	59	810	27	253	1	10
2007	81	852	48	552	32	464	4	66
2008	57	881	23	351	9	159	3	78
2009	100	1,901	34	488	19	280	2	24

Year	Bottomfish				Spear Snorkel			
	All		BMUS		All		BMUS	
	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs
2010	116	3,510	63	1,743	5	56	0	0
2011	134	4,439	37	1,097	4	55	0	0
2012	26	318	16	253	10	124	0	0
2013	29	309	16	197	5	74	0	0
2014	17	160	6	52	3	53	0	0
2015	14	170	7	100	4	23	0	0
2016	20	263	16	219	0	0	0	0
2017	13	127	7	61	0	0	0	0
2018	12	140	2	14	4	41	0	0
2019	13	156	9	85	2	23	0	0
10-year avg.	**39**	**959**	**18**	**382**	**4**	**45**	**0**	**0**
10-year SD	**43**	**1,523**	**18**	**544**	**3**	**35**	**0**	**0**
20-year avg.	**53**	**28**	**928**	**450**	**11**	**1**	**140**	**14**
20-year SD	**40**	**21**	**1,133**	**447**	**9**	**1**	**119**	**22**

1.1.8 Participants

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

Calculations: For boat-based data, the estimated number of unique vessels is calculated by tallying the number of vessels recorded in the interview data via vessel registration or name.

All: Total unique vessels by gear type.

BMUS: Unique vessels from trips that landed BMUS by gear type.

Table 11a. Estimated number of unique vessels for bottomfishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfishing		Spearfishing (Snorkel)	
	All	BMUS	All	BMUS
2000	24	18	12	1
2001	35	15	10	1
2002	25	15	11	1
2003	22	15	6	2
2004	29	24	13	0
2005	67	51	22	3
2006	60	42	18	1
2007	58	36	26	4

Year	Bottomfishing		Spearfishing (Snorkel)	
	All	BMUS	All	BMUS
2008	40	22	9	3
2009	55	27	16	2
2010	26	19	5	0
2011	31	15	4	0
2012	23	15	9	0
2013	25	15	4	0
2014	14	5	3	0
2015	12	6	4	0
2016	16	13	0	0
2017	12	6	0	0
2018	11	2	3	0
2019	12	8	2	0
10-year avg.	**18**	**10**	**3**	**0**
10-year SD	**7**	**5**	**2**	**0**
20-year avg.	**30**	**18**	**9**	**1**
20-year SD	**17**	**12**	**7**	**1**

Calculations: For boat-based data, the estimated number of fishermen per trip is calculated by filtering interviews that recorded the number of fishers, and then ∑fishers/∑trips.

All: Average fishers from all trips by gear type.

BMUS: Average fishers from trips that landed BMUS by gear type.

Table 11b. Estimated number of fishermen per trip for bottomfishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfishing		Spearfishing (Snorkel)	
	All	BMUS	All	BMUS
2000	4	3	4	8
2001	3	3	3	2
2002	4	4	3	2
2003	5	5	3	2
2004	4	5	4	0
2005	5	5	3	2
2006	4	4	3	3
2007	3	3	3	3
2008	6	6	4	4
2009	10	6	4	3
2010	21	19	2	0
2011	21	17	3	0
2012	2	2	4	0

Year	Bottomfishing		Spearfishing (Snorkel)	
	All	BMUS	All	BMUS
2013	2	2	2	0
2014	2	2	3	0
2015	2	2	2	0
2016	2	2	0	0
2017	2	2	0	0
2018	3	5	3	0
2019	2	2	3	0
10-year avg.	**6**	**6**	**3**	**0**
10-year SD	**8**	**6**	**1**	**0**
20-year avg.	**5**	**5**	**3**	**3**
20-year SD	**6**	**5**	**1**	**2**

1.1.9 Bycatch Estimates

This section focuses on Magnuson-Stevens Fishery Conservation and Management Act (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 recent bycatch estimates for the boat-based BMUS fishery.

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

Table 12. Time series of observed catch and bycatch in the CNMI bottomfish fishery

Year	# Caught	# Kept	# Released	% Bycatch
2000	493	481	12	2.43
2001	268	268	0	0
2002	474	474	0	0
2003	627	624	3	0.48
2004	756	756	0	0
2005	2206	2202	4	0.18
2006	874	874	0	0
2007	1325	1325	0	0
2008	241	241	0	0
2009	596	596	0	0

Year	# Caught	# Kept	# Released	% Bycatch
2010	614	614	0	0
2011	482	482	0	0
2012	456	456	0	0
2013	519	519	0	0
2014	57	57	0	0
2015	102	102	0	0
2016	636	636	0	0
2017	120	120	0	0
2018	6	6	0	0
2019	139	139	0	0
10-year avg.	**313**	**313**	**0**	**0**
10-year SD	**236**	**236**	**0**	**0**
20-year avg.	**550**	**549**	**1**	**0.15**
20-year SD	**490**	**489**	**3**	**0.53**

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 BMUS or bottomfish ECS in the EEZ around CNMI. Commercial fishing is 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 ECS 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 ECS while fishing for bottomfish MUS, crustacean MUS or ECS, 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 ECS 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 CNMI since 2007. Table 13 provides the number of permits issued for CNMI fisheries between 2010 and 2019. Historical data are from PIFSC, and 2018–2019 data are from the Pacific Islands Regional Office Sustainable Fisheries Division permits program.

Table 13. Number of Federal permit holders for the CNMI crustacean and bottomfish fisheries

CNMI Fisheries	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Lobster	0	0	0	0	0	0	1**	0	1**	0
Shrimp	2*	1*	0	0	0	0	1	0	0	0
Bottomfish	13	10	13	5	6	7	17	20	13	11

* 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 entire stock complex.

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 14.

Table 14. Overfishing threshold specifications for the BMUS in CNMI

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

$F(B) = F_{MSY}$ for $B > c\ B_{MSY}$		
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 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 15. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 15. Rebuilding control rules for the BMUS in CNMI

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

1.1.11.2 Current Stock Status

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 (Langseth et al., 2019) for the CNMI bottomfish management unit species complex (comprised of 11 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. The assessments used a state-space Bayesian surplus production model within the modeling framework Just Another Bayesian Biomass Assessment (JABBA), which included biological information and fishery-dependent data through 2017. 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 16. Stock assessment parameters for the BMUS complex (from Langseth et al., 2019)

Parameter	Value	Notes	Status
MSY	93.6 (48.8-205.3)	Expressed in 1000 lbs. (with 95% confidence interval)	
H_{2017}	0.12	Expressed in percentage	
H_{CR}	0.167 (0.084-0.315)	Expressed in percentage (with 95% confidence interval)	
H/H_{CR}	0.79		No overfishing occurring
B_{2017}	569.2	Expressed in thousand pounds	
B_{MSY}	570.6 (271.8-1,287)	Expressed in 1000 lbs. (with 95% confidence interval)	
B/B_{MSY}	1.08		Not overfished

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 papers, reports, and/or available data. These data are categorized into the different tiers in the control rule ranging from Tier 1 (i.e., most information available, typically a stock assessment) to Tier 5 (i.e., catch-only information). The control rules are applied to the BSIA. Tiers 1 to 3 involve conducting a Risk of Overfishing Analysis (denoted by P*) to quantify the scientific uncertainties associated with the assessment to specify the Acceptable Biological Catch (ABC), lowering the MSY-based OFL to the ABC. A Social, Ecological, Economic, and Management (SEEM) Uncertainty Analysis is performed to quantify the uncertainties associated with the SEEM factors, and a buffer is used to lower the ABC to an ACL. For Tier 4, which is comprised of stocks with MSY estimates but no active fisheries, the control rule is 91 percent of MSY. For Tier 5, which has catch-only information, the control rule is a one-third reduction in the median catch depending on a qualitative evaluation of stock status via expert opinion. ACL specification can choose from a variety of methods including the above mentioned SEEM analysis or a percentage buffer (i.e., percent reduction from ABC based on expert opinion) or the use of an Annual Catch Target (ACT). Specifications are done on an annual basis, but the Council normally produces a multi-year specification.

The AM for CNMI bottomfish fisheries is an overage adjustment. The next ACL is downward adjusted with the amount of overage from the previous ACL based on a three-year running average.

1.1.12.2 Current OFL, ABC, ACL, and Recent Catch

No ACLs were implemented by NMFS for CNMI MUS in 2019 due to new information contained in the new benchmark stock assessment (Langseth et al. 2019) that was determined to be BSIA. The catch shown in Table 17 takes the average of the most recent three years as recommended by the Council at its 160th meeting to avoid large fluctuations in catch due to high interannual variability in estimates.

Table 17. CNMI 2019 ACL table with three-year average catch (lbs.)

Fishery	MUS	OFL	ABC	ACL	Catch
Bottomfish	Bottomfish multi-species complex	N.A.	N.A.	N.A.	23,223

1.1.13 Best Scientific Information Available

1.1.13.1 Bottomfish Fishery

Stock Assessment Benchmark

The benchmark stock assessment for the Territory Bottomfish Management Unit Species complex was developed and finalized by Langseth et al. (2019). The assessments used a state-space Bayesian surplus production model within the modeling framework Just Another Bayesian Biomass Assessment (JABBA). Estimates of harvest rate (H), annual biomass (B), the harvest rate associated with overfishing as determined by the harvest control rule (H_{CR}), maximum sustainable yield (MSY), and the biomass at maximum sustainable yield (B_{MSY}) allowed for determination of stock status relative to reference points determining overfishing ($H/H_{CR} > 1$) and overfished ($B < 0.7 \times B_{MSY}$) status. Stock projections were conducted for 2020–2025 for a range of hypothetical 6-year catches, and the corresponding risk of overfishing was calculated.

Stock Assessment Updates

Updates to the 2007 benchmark done in 2012 (Brodziak et al., 2012) and 2015 (Yau et al., 2016). 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. (2016) was considered the best scientific information available for the Territory bottomfish MUS complex after undergoing a WPSAR Tier 3 panel review (Franklin et al., 2015) prior to the Langseth et al. (2019) benchmark stock assessment. This was the basis for the P* analysis and SEEM analysis the determined the risk levels to specify ABCs and ACLs.

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 determines 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 (OY) in the 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 MUS complex is defined to be the level of harvest equal to the ACL consistent with the goals and objectives of the FEPs 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 MSY (F_{MSY}). There are situations when the long-term means around MSY are lower than ACLs especially if the stock is known to be productive or relatively pristine or lightly fished. A stock can have catch levels and catch rates exceeding that of MSY over the short-term to lower the biomass to a level around the estimated MSY and still not jeopardize the stock.

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). normally summarizes the harvest extent and harvest capacity information for CNMI using three-year average catch, however, there was no specified ACL for CNMI BMUS in 2019 due new information that came to light in the most recent benchmark stock assessment (Langseth et al., 2019) that was determined to be BSIA.

Table 18 normally summarizes the harvest extent and harvest capacity information for CNMI using three-year average catch, however, there was no specified ACL for CNMI BMUS in 2019 due new information that came to light in the most recent benchmark stock assessment (Langseth et al., 2019) that was determined to be BSIA.

Table 18. CNMI proportion of harvest capacity and extent relative to the ACL in 2019

Fishery	MUS	ACL	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	Bottomfish multi-species complex	N.A.	23,223	N.A.	N.A.

1.1.15 Administrative and Regulatory Actions

This summary describes management actions NMFS implemented for insular fisheries in the CNMI during calendar year 2019.

February 8, 2019. Final rule: **Reclassifying Management Unit Species to Ecosystem Component Species**. This final rule reclassified certain management unit species in the Pacific Islands as ecosystem component species. The rule also updated the scientific and local names of certain species. The intent of this final rule was to prioritize conservation and management efforts and to improve efficiency of fishery management in the region. This rule was effective March 11, 2019.

1.2 GUAM FISHERY DESCRIPTIONS

1.2.1 Bottomfish Fishery

Bottomfishing in 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 ft.) 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 ft.) 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.

Many 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 exclusive economic zone (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*, and *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*, and *Pristipimoides* spp.

1.2.2 Ecosystem Component (formerly 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*, and *S. argenteus* (manahak, lesso).

Hook and line is the most common method of fishing for coral reef fish in Guam. In 2019, hook and line fishing accounted for around 62% of fishers and 67% of gear. Throw net (talaya) is the second most common method, accounting for about 16% of fishers and 15% of gear. Other methods include gill net, snorkel spearfishing, SCUBA spearfishing, surround net, drag net, hooks and gaffs, and gleaning.

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 2019, there were six vendors reporting sales. In order to improve this situation, the Council, Division of Aquatic and Wildlife Resources (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.

In 2018, the Council drafted an Amendment 4 to the Mariana Archipelago FEP that reclassified a large number MUS as ECS (WPRFMC, 2018). The final rule was posted in the Federal Register in early 2019 (84 FR 2767). This amendment reduces the number of MUS from 227 species/families to 13 in the Mariana Archipelago FEP. All former CREMUS and CMUS were reclassified as ECS that do not require ACL specifications or accountability measures but are still to be monitored regularly to prioritize conservation and management efforts and to improve efficiency of fishery management in the region. All existing management measures, including reporting and record keeping, prohibitions, and experimental fishing regulations apply to ECS. If an ECS stock becomes a target of a Federal fishery in the future, NMFS and the Council may consider including that stock as a MUS to actively manage that stock. These species are still regularly monitored via other means (see Sections 1.2.6.3 and 2.1.3).

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 and the commercial fishery program. The Sportfish Restoration Grant from the U.S. Fish and Wildlife Service (USFWS) 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 NMFS PIFSC. Identification of fish to the species level is the goal of Guam’s fishery staff.

The boat-based creel survey is a long-term program that collects 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 (TSI).

Oram et al. (2011) and Jasper et al. (2016) describe the fishery data collection process for the offshore program on Guam. 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 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 enough 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 number of invoices submitted and the number of vendors participating in the program. Variations in these meta-data affect the commercial landing and revenue estimates.

1.2.4.1 Creel Survey Meta-Data Statistics

Calculations:

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

Catch Interviews: In boat-based creel surveys, 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 19. Summary of Guam boat-based creel survey meta-data

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
1982	46	469	8
1983	47	431	34
1984	53	531	0
1985	66	812	0
1986	49	522	0
1987	48	612	0
1988	48	949	0
1989	48	931	2
1990	48	1,028	0
1991	48	1,019	1
1992	48	1,110	0
1993	52	1,119	0
1994	55	1,168	0
1995	96	1,613	4
1996	96	1,608	0
1997	96	1,358	0
1998	96	1,581	0
1999	96	1,367	3
2000	96	1,246	1

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
2001	96	908	6
2002	84	610	1
2003	78	446	0
2004	95	530	1
2005	97	552	0
2006	96	556	0
2007	96	500	0
2008	96	571	2
2009	96	803	0
2010	96	902	0
2011	96	645	0
2012	74	371	0
2013	96	561	1
2014	90	635	9
2015	97	651	13
2016	93	900	2
2017	92	820	10
2018	89	795	11
2019	93	786	3
10-year avg.	**92**	**707**	**5**
10-year SD	**6**	**158**	**5**
20-year avg.	**92**	**689**	**3**
20-year SD	**6**	**200**	**4**

1.2.4.2 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; BMUS vendors are only from vendors that landed BMUS species.

Invoices: Count of the number of unique invoice numbers found in the commercial header data from the Commercial Receipt Book; BMUS vendors are only from vendors that landed BMUS species.

Table 20. Summary of Guam commercial receipt book meta-data

Year	# Vendors	# Total Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
1982	*	*	*	*
1983	3	2,312	*	*
1984	3	2,587	3	48

Year	# Vendors	# Total Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
1985	*	*	*	*
1986	*	*	*	*
1987	*	*	*	*
1988	*	*	*	*
1989	*	*	*	*
1990	4	2,803	3	72
1991	3	2,512	*	*
1992	3	2,737	*	*
1993	3	2,664	*	*
1994	*	*	*	*
1995	3	1,565	*	*
1996	6	1,965	3	27
1997	7	2,923	4	41
1998	4	3,591	3	69
1999	5	3,410	3	177
2000	3	3,868	3	174
2001	3	4,155	3	286
2002	3	3,494	*	*
2003	*	*	*	*
2004	3	3,104	*	*
2005	3	2,649	*	*
2006	4	2,589	*	*
2007	*	*	*	*
2008	*	*	*	*
2009	*	*	*	*
2010	*	*	*	*
2011	*	*	*	*
2012	*	*	*	*
2013	*	*	*	*
2014	8	1,355	*	*
2015	9	1,361	*	*
2016	8	1,661	*	*
2017	11	1,996	4	104
2018	10	1,748	4	56
2019	6	1,176	*	*
10-year avg.	**6**	**1,548**	*****	*****
10-year SD	**4**	**296**	*****	*****
20-year avg.	**4**	**2,188**	*****	*****
20-year SD	**3**	**876**	*****	*****

* Confidential (less than three vendors)

1.2.5 Fishery Summary Dashboard Statistics

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

Legend Key:

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

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

Table 21. Annual indicators for Guam bottomfish fisheries describing performance and comparing 2019 estimates with short- (10-year) and long-term (20-year) averages

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
Bottomfish	**Total estimated catch (lbs.)**		
All gears (BMUS only)	All BMUS from creel survey data	**37,701[▲46%]**	**37,701[▲29%]**
	All BMUS from commercial purchase data	**No trends available due to confidentiality**	**No trends available due to confidentiality**
	Catch-per-unit-effort (from boat-based creel surveys)		
Bottomfishing (BMUS only)	Bottomfishing lbs./trip	**19[▲12%]**	**19[no change]**
	Bottomfishing lbs./gr-h.	**0.0196[▼19%]**	**0.0196[▼14%]**
	Fishing effort (from boat-based creel surveys)		
Bottomfishing (BMUS only)	Estimated total bottomfishing trips	**76[▲36%]**	**76[▲21%]**
	Estimated total bottomfishing gear hours	**75,276[▲28%]**	**75,276[▲19%]**
	Fishing participants (from boat-based creel surveys)		
Bottomfishing (BMUS only)	Estimated number of bottomfishing vessels	**52[▲27%]**	**52[▲13%]**
	Estimated average number of fishermen per bottomfishing trip	**3[no change]**	**3[no change]**
	Bycatch		
	# observed fish caught	**865[▲47%]**	**865[▲30%]**
	# observed fish kept	**862 [▲46%]**	**862[▲30%]**

	# fish released (bycatch)	3[▲200%]	3[▼40%]

Table 22. Annual indicators for Guam ECS fisheries describing performance and comparing 2019 estimates with short- (10-year) and long-term (20-year) averages

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
ECS	**Total estimated catch (lbs.)**		
Prioritized ECS	*Naso unicornis* from creel survey data	2,500[▼11%]	2,500[▼68%]
	Siganus spinus from creel survey data	278[▲62%]	278[▼19%]
	Siganus spinus from commercial purchase data	614 [▼72%]	614[▼50%]
	Lethrinus harak from creel survey data	3,017[▼28%]	3,017[▼25%]
	Chlorurus frontalis from creel survey data	251[▼42%]	251[▼56%]
	Epinephelus fasciatus from creel survey data	1,704[▲7%]	1,704[▼31%]
	Caranx melampygus from creel survey data	1,920[▼31%]	1,920[▼45%]
	Lethrinus olivaceus from creel survey data	1,929[▲89%]	1,929[▲3%]
	Lutjanus fulvus from creel survey data	907[▲59%]	907[▲76%]
	Scarus rubroviolaceus from creel survey data	0[▼100%]	0[▼100%]

1.2.6 Catch statistics

The following section summarizes the catch statistics for bottomfish, the top ten landed species, and nine prioritized species in Guam as decided by DAWR. 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 ECS and bottomfish fisheries.

1.2.6.1 Catch by Data Stream

This section describes the estimated total catch from the 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 can capture fishery data better than the creel surveys.

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

Table 23. Summary of Guam BMUS total catch (lbs.) from expanded boat-based creel surveys and the commercial purchase system for all gear types

Year	Boat-Based Creel Survey Estimates	Commercial Landings
1982	20,677	*
1983	36,150	*
1984	14,655	3,445
1985	38,960	*
1986	16,404	*
1987	24,279	*
1988	33,986	*
1989	44,799	*
1990	33,816	4,277
1991	31,546	*
1992	36,316	*
1993	39,073	*
1994	40,719	*
1995	27,194	*
1996	40,498	1,251
1997	21,255	1,957
1998	22,296	4,576
1999	40,773	20,940
2000	58,640	12,184
2001	43,696	10,554
2002	20,366	*
2003	29,506	*
2004	25,233	*
2005	29,087	*
2006	33,414	*
2007	22,576	*
2008	31,103	*
2009	35,029	*
2010	23,928	*
2011	52,230	*
2012	17,518	*
2013	27,277	*
2014	20,687	*
2015	10,782	*
2016	24,479	*

Year	Boat-Based Creel Survey Estimates	Commercial Landings
2017	14,653	4,002
2018	28,364	3,029
2019	37,701	*
10-year avg.	**25,762**	*
10-year SD	**11,396**	*
20-year avg.	**29,313**	*
20-year SD	**11,590**	*

*Confidential (less than three vendors)

1.2.6.2 Expanded Catch Estimates by Fishing Method

Catch information is provided for the top boat-based fishing methods that comprise most of the annual BMUS catch in Guam.

Calculations: The creel survey catch time series are the sum of the estimated weight for selected gear in all strata for all species and all BMUS species.

Table 24. Total catch time series estimates (lbs.) for all species and BMUS only using Guam expanded boat-based creel survey data for bottomfishing gears

Year	Bottomfish		Spearfishing (Snorkel)		Spearfishing (SCUBA)	
	All	BMUS	All	BMUS	All	BMUS
1982	41,329	20,677	420	0	0	0
1983	50,415	36,150	1,355	0	4,399	0
1984	57,412	14,525	14,108	87	5,460	43
1985	88,047	36,660	18,737	481	12,761	76
1986	34,515	14,904	12,545	10	5,145	92
1987	44,459	23,510	12,448	261	7,474	198
1988	67,038	32,204	24,712	1,717	10,649	50
1989	79,973	43,732	30,931	46	13,985	9
1990	61,401	32,827	28,871	0	22,273	393
1991	60,753	31,113	27,898	49	37,027	339
1992	78,174	33,303	35,162	179	25,226	1,938
1993	107,130	37,092	39,435	0	22,848	293
1994	105,283	40,310	37,554	0	27,244	247
1995	101,075	25,125	40,554	60	74,735	1,246
1996	129,708	38,618	67,446	255	91,810	698
1997	109,345	20,779	37,363	82	41,920	177
1998	99,601	21,618	56,442	272	68,198	314
1999	122,930	39,717	45,200	168	80,859	263
2000	115,837	56,095	42,403	282	116,072	1,052
2001	123,975	43,119	74,369	0	65,105	535

Year	Bottomfish		Spearfishing (Snorkel)		Spearfishing (SCUBA)	
	All	**BMUS**	**All**	**BMUS**	**All**	**BMUS**
2002	55,447	19,092	21,712	39	34,766	347
2003	82,224	29,057	22,649	0	40,093	77
2004	61,874	23,268	33,601	130	50,442	1,726
2005	62,651	27,838	15,036	256	27,934	896
2006	89,865	32,132	12,796	1,178	4,129	0
2007	57,750	20,363	18,516	357	11,316	1,835
2008	59,639	30,872	29,715	124	24,647	0
2009	89,997	34,369	22,669	305	28,947	0
2010	56,164	22,958	23,635	233	1,775	0
2011	88,694	50,576	26,483	0	67,431	26
2012	40,214	17,518	23,986	0	12,204	0
2013	42,602	14,425	20,816	0	2,771	0
2014	69,299	18,011	28,088	274	32,316	0
2015	29,395	10,253	22,371	0	30,654	0
2016	51,475	23,872	28,985	376	21,517	0
2017	46,715	14,096	17,045	88	9,854	0
2018	57,904	27,022	23,051	130	65,998	672
2019	64,030	36,968	18,361	25	6,690	0
10-year avg.	**54,649**	**23,570**	**23,282**	**113**	**25,121**	**70**
10-year SD	**15,934**	**11,574**	**3,696**	**130**	**23110**	**201**
20-year avg.	**67,288**	**27,595**	**26,314**	**190**	**32,733**	**358**
20-year SD	**23,765**	**11,784**	**12,806**	**261**	**27,987**	**572**

1.2.6.3 Top and Prioritized ECS in Boat-Based Fishery Catch

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. A one-year reflection of the top ten harvested species (by weight) is included to monitor which ECS are being caught the most annually. Additionally, Guam DAWR selected nine species that were reclassified as ECS that are still of priority to Guam DAWR for regular monitoring, and complete catch time series of these species are included in the report as well.

Calculations: Catch tallied from the boat-based expanded species composition data combining gear types for all species excluding BMUS, prioritized ECS, and pelagic MUS species.

Table 25a. Top ten landed ECS in Guam from boat-based creel survey data in 2019

Common Name	Scientific Name	Catch (lbs.)
Assorted reef fish	Assorted reef fish	10,385
Bigeye scad (atulai)	*Selar crumenophthalmus*	4,349
Jobfish	*Aprion virescens*	4,286
Orangespine unicornfish	*Naso lituratus*	3,911

Common Name	Scientific Name	Catch (lbs.)
Orange-striped emperor	*Lethrinus obsoletus*	2,831
Honeycomb grouper	*Epinephelus merra*	1,311
Greater amberjack	*Seriola dumerili*	1,212
Yellow spotted jack	*Carangoides orthogrammus*	968
Parrotfish	*Scarus globiceps*	917
Bigeye trevally	*Caranx sexfasciatus*	903

Calculations: Catch tallied from commercial receipt data combining gear types for all species excluding BMUS, prioritized ECS, and pelagic MUS species.

Table 25b. Top ten landed ECS in Guam from estimated commercial landings data in 2019

Common Name	Scientific Name	Catch (lbs.)
Reef fish	Actinopterygii (class)	19,808
Bigeye scad (atulai)	*Selar crumenophthalmus*	12,218
Parrotfish	Scaridae (family)	5,489
Emperor (mafute)	Lethrinidae (family)	3,169
Invertebrates	Animalia (kingdom)	1,632
Octopus	*Octopus* spp.	1,118
Jacks	Carangidae (family)	1,074
Grouper	Serranidae (family)	954
Blueline surgeonfish	*Acanthurus lineatus*	564
Orangespine unicornfish	*Naso lituratus*	404

Calculations: Catch tallied from boat-based expanded species composition data for species identified as priority ECS (Appendix A).

Table 26a. Catch (lbs.) from boat-based expansion data for prioritized species in Guam ECS fisheries

Year	***Naso unicornis***	***Siganus spinus***	***Lethrinus harak***	***Chlorurus frontalis***	***Epinephelus fasciatus***	***Caranx melampygus***	***Lethrinus olivaceus***	***Lutjanus fulvus***	***Scarus rubroviolaceus***
1982	0	0	0	0	335	490	43	8	0
1983	10	0	0	16	1,505	670	0	109	0
1984	383	0	0	0	669	96	174	0	0
1985	1,177	0	296	502	3,313	2,961	765	100	175
1986	305	0	33	572	610	512	458	95	288
1987	227	66	21	517	1,482	1,286	77	103	138
1988	1,219	84	127	2,409	3,967	869	214	192	1,906
1989	4,402	422	1,185	105	2,046	1,451	397	1,269	892
1990	4,648	670	2,628	2	1,348	2,861	3,757	202	628
1991	6,683	570	2,022	225	2,827	1,936	744	2,024	2,395
1992	15,510	418	1,544	3,157	2,126	735	1,484	1,018	1,594
1993	5,335	2,103	2,263	181	5,950	2,087	353	617	1,126
1994	6,089	426	3,098	832	2,342	2,606	5,470	3,108	809
1995	23,433	2,133	3,268	1,874	7,747	5,038	1,628	1,514	1,262
1996	40,676	935	6,523	1,221	6,017	8,961	2,700	1,853	983
1997	18,354	1,541	6,151	197	4,581	3,843	2,073	704	457
1998	26,540	1,464	3,293	2,478	8,678	2,913	586	749	708
1999	23,985	2,096	4,185	1,114	6,348	2,985	2,309	477	495
2000	34,700	646	4,188	78	3,607	4,846	4,081	920	1,941
2001	17,222	989	4,705	508	3,590	2,822	3,615	625	940
2002	12,329	1,012	3,675	158	2,030	4,179	11,890	172	49
2003	8,643	740	4,108	1,911	9,998	3,376	629	504	830
2004	18,734	24	5,669	30	3,608	5,622	2,700	238	0
2005	12,089	71	5,451	956	1,446	4,460	1,161	104	814
2006	1,283	192	1,960	268	2,766	6,357	257	297	159

Year	*Naso unicornis*	*Siganus spinus*	*Lethrinus harak*	*Chlorurus frontalis*	*Epinephelus fasciatus*	*Caranx melampygus*	*Lethrinus olivaceus*	*Lutjanus fulvus*	*Scarus rubroviolaceus*
2007	4,848	18	1,354	98	2,616	1,365	799	616	4,175
2008	10,882	1,341	1,023	1,915	1,894	5,349	179	424	375
2009	6,588	101	6,741	1,165	2,003	3,134	1,870	694	0
2010	4,291	0	4,164	847	2,061	1,751	1,454	495	178
2011	2,341	0	6,954	0	2,246	1,218	1,319	1,018	0
2012	93	15	4,781	431	1,073	1,000	414	791	0
2013	3,269	158	7,195	551	1,962	9,524	113	324	785
2014	5,950	344	8,231	115	1,590	5,394	2,729	773	0
2015	2,064	235	2,550	0	1,917	371	741	324	0
2016	2,226	614	2,132	332	1,114	3,669	375	144	453
2017	711	79	2,289	32	1,632	2,162	356	793	0
2018	4,578	0	503	1,752	672	855	756	134	30
2019	2,500	278	3,017	251	1,704	1,910	1,929	907	0
10-year avg.	**2,802**	**172**	**4,182**	**431**	**1,597**	**2,785**	**1,019**	**570**	**145**
10-year SD	**1,776**	**201**	**2,557**	**538**	**500**	**2,797**	**831**	**325**	**268**
20-year avg.	**7,767**	**343**	**4,035**	**570**	**2,476**	**3,468**	**1,868**	**515**	**536**
20-year SD	**8,309**	**406**	**2,203**	**646**	**1,950**	**2,294**	**2,627**	**292**	**992**

Calculations: Catch tallied from commercial purchase data for species identified as priority ECS (Appendix A). From the prioritized ECS list, only *Siganus spinus* is included because there are no specific species codes for the other eight prioritized species in the Guam commercial coding system, which tends to aggregate data into larger groups such as taxonomic family.

Table 26b. Catch (lbs.) from commercial purchase data for *Siganus spinus* in Guam

Year	*Siganus spinus*
1982	0
1983	26
1984	32
1985	116
1986	8
1987	0
1988	0
1989	0
1990	419
1991	11
1992	18
1993	0
1994	0
1995	0
1996	131
1997	84
1998	1,895
1999	3,450
2000	0
2001	15
2002	891
2003	170
2004	48
2005	0
2006	62
2007	81
2008	0
2009	0
2010	0
2011	77
2012	0
2013	145
2014	1,088
2015	572

Year	*Siganus spinus*
2016	2,377
2017	10,941
2018	6,262
2019	614
10-year avg.	**2,208**
10-year SD	**3,617**
20-year avg.	**1,229**
20-year SD	**2,775**

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

This section summarizes the estimates for CPUE in the boat-based fisheries both for all species and for BMUS only. The boat-based fisheries include the bottomfishing (handline gear), spearfishing (snorkel), and spearfishing (SCUBA). CPUE is reported as both pounds per gear hour and pounds per fishing trip in the boat-based fishery.

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

All - lbs./trip: All catch and trips are tallied from landings by gear level, including non-BMUS species.

All - lbs./gr-hr.: All catch and trips are tallied from trips with data on the number of gears used and numbers of hours fished, including non-BMUS species.

BMUS - lbs./trip: Only BMUS catch and trips that landed BMUS species are tallied from landings by gear level.

BMUS - lbs./gr-hr.: Only BMUS catch and trips that landed BMUS are tallied from trips with data on the number of gears used and numbers of hours fished.

Table 27. CPUE (lbs./gear hour and lbs./trip) for bottomfishing gears in the Guam boat-based fishery for all species and BMUS only

Year	Bottomfish				Spearfish (Snorkel)				Spearfish (SCUBA)			
	All		BMUS		All		BMUS		All		BMUS	
	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr
1982	27	2.9804	17	1.7678	7	2.4557			0	0.0000		
1983	23	2.9477	20	2.3322	7	1.6667			18	5.8928		
1984	28	3.1113	17	2.0308	39	2.3189	8	0.6667	24	4.9721	1	0.3333
1985	27	2.4127	17	1.4869	48	4.5320	6	0.5238	25	6.5827	2	0.5556
1986	23	2.3213	24	1.7770	43	4.1517	1	0.2000	20	4.3467	3	0.5000
1987	23	2.5543	18	1.7063	28	5.4609	4	0.8462	30	6.6600	3	0.5333
1988	21	2.0470	13	1.1149	35	6.0494	34	8.5000	20	7.4436	2	0.8000
1989	20	2.0972	15	1.5016	26	3.0735	1	0.1875	31	5.9778	1	0.2857
1990	21	1.9714	16	1.4451	22	3.6592			46	11.2994	6	1.0000
1991	19	2.1711	16	1.7610	24	4.4477	1	0.1250	47	14.4258	5	0.9705
1992	17	1.8832	11	1.0764	24	3.5194	3	0.5000	24	8.0667	10	2.1277
1993	19	1.8407	18	1.6922	21	3.3678			58	19.1070	5	1.2709
1994	26	2.4099	21	1.7297	25	3.6202			55	15.0625	4	0.8738
1995	13	0.9952	11	0.8471	31	3.7368	3	0.2500	89	17.2943	10	1.4909
1996	18	1.1629	16	1.2204	33	4.2093	3	1.0000	76	11.1851	7	0.4564
1997	14	0.9523	11	0.7171	25	3.0947	10	4.0000	81	14.5710	4	0.5385
1998	14	1.0103	10	0.7897	21	2.9303	5	0.3170	98	15.8821	2	0.2828
1999	16	1.0965	17	1.2082	17	2.0771	7	3.5000	100	14.8138	2	0.3077
2000	18	1.3369	19	1.2652	21	2.7212	24	24.0000	90	13.9828	4	0.4444
2001	20	1.6460	15	1.2636	56	4.6910	21	1.3125	69	10.9794	4	0.3947
2002	17	1.3706	14	1.1609	21	3.0062	1	0.0833	58	6.9565	12	1.2778
2003	21	1.5561	16	0.9489	40	5.0514			108	13.1981	3	0.2222
2004	24	1.9106	20	1.4692	28	3.4182	2	0.1111	81	9.1358	11	1.0323
2005	27	2.1847	31	2.2326	20	2.5622	6	1.1000	61	5.5541	13	0.5200

Year	Bottomfish				Spearfish (Snorkel)				Spearfish (SCUBA)			
	All		BMUS		All		BMUS		All		BMUS	
	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr	lbs/trip	lbs/gr-hr
2006	31	2.1537	26	1.4301	24	2.3030	16	1.0159	13	2.6939		
2007	30	2.2159	16	1.1718	31	3.2893	4	0.4211	100	8.0000	25	1.5625
2008	21	1.7548	17	1.2500	38	3.0544	2	0.1765	35	4.4894		
2009	29	2.1263	25	1.8459	23	2.7082	2	0.1628	63	7.0000		
2010	17	1.2138	13	0.8260	19	2.4203	1	0.2000	2	0.4444		
2011	37	2.7082	29	2.1370	41	5.1745			140	11.5052	1	0.1667
2012	21	2.0613	18	1.6227	58	7.6230			70	10.0000		
2013	19	1.5329	16	1.1190	28	2.2838			10	3.5294		
2014	24	1.3286	13	0.9106	35	2.3940	4	0.5000	33	8.6087		
2015	16	1.2879	15	1.1425	33	3.0245			58	2.6977		
2016	21	1.4899	17	1.1526	27	2.7552	4	0.2917	68	4.7859		
2017	19	1.3687	11	0.7040	16	1.9180	2	0.1622	43	5.3438		
2018	26	0.9780	21	0.3699	41	3.6643	3	0.1111	97	7.1759	29	1.7959
2019	20	1.6668	19	1.4505	17	1.4503	1	0.1250	45	2.9945		
10-yr avg	**22**	**1.5636**	**17**	**1.1435**	**32**	**3.2708**	**3**	**0.2317**	**57**	**5.7086**	**15**	**0.9813**
10-yr SD	**6**	**0.4707**	**5**	**0.4752**	**12**	**1.7509**	**1**	**0.1338**	**39**	**3.3535**	**14**	**0.8146**
20-yr avg.	**23**	**1.6946**	**19**	**1.2737**	**31**	**3.2757**	**6**	**1.9849**	**62**	**6.9538**	**11**	**0.8241**
20-yr SD	**5**	**0.4240**	**5**	**0.4397**	**12**	**1.3791**	**7**	**5.8966**	**34**	**3.6373**	**9**	**0.5729**

1.2.8 Effort Statistics

This section summarizes the effort trends in the Guam bottomfish fishery. Fishing effort trends provide insights on the level of fishing pressure through time. Effort information is provided for the top boat-based fishing methods that comprise most of the annual catch.

Calculations: Effort estimates (in both trips and gear hours) are calculated from boat-based interview data. Trips are tallied according the interview data in boat-based creel surveys. Gear hours are generated by summing the data on number of gears used*number of hours fished collected from interviews by gear type. For the boat-based estimates, data collection started in 1982.

All - Trips: All trips tallied by gear type.

All - Gear-hrs: Gear hours tallied by gear type.

BMUS - Trips: Trips that landed BMUS tallied by gear type.

BMUS - Gear-hrs: Gear hours tallied by gear type for trips landed BMUS with data on both number of gears used and numbers of hours fished.

Table 28. Effort (trips and gear hours) for bottomfishing gears in the Guam boat-based fishery for all species and BMUS only

Year	Bottomfish				Spearfish (Snorkel)				Spearfish (SCUBA)			
	All		BMUS		All		BMUS		All		BMUS	
	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs
1982	97	869	74	715	5	15	0	0	1	1	0	0
1983	89	683	66	566	6	24	0	0	13	40	0	0
1984	124	1,118	39	328	20	336	1	12	12	57	1	3
1985	217	2,391	139	1,635	19	203	4	42	36	139	3	9
1986	103	1,024	41	543	14	145	1	5	8	38	1	6
1987	114	1,041	72	758	20	101	3	13	11	50	3	15
1988	173	1,776	137	1,542	33	190	2	8	25	67	2	5
1989	187	1,790	127	1,307	24	204	3	16	24	123	1	4
1990	157	1,660	108	1,219	18	107	0	0	17	70	1	6
1991	152	1,316	92	852	20	109	2	16	27	89	5	24
1992	152	1,368	98	1,013	30	205	1	6	48	146	3	14
1993	164	1,700	81	842	38	242	0	0	29	87	4	15
1994	185	2,028	105	1,282	37	251	0	0	32	116	5	21
1995	302	3,860	127	1,613	56	464	1	12	56	287	8	56
1996	277	4,173	97	1,284	62	482	2	6	48	327	5	75
1997	238	3,554	75	1,183	41	328	1	3	27	150	2	13
1998	315	4,311	125	1,551	96	700	4	66	40	246	6	50
1999	285	4,039	112	1,549	51	428	1	2	43	290	9	65
2000	200	2,676	92	1,345	47	366	1	1	41	265	8	72
2001	197	2,337	95	1,161	22	261	1	16	29	182	4	38
2002	150	1,861	73	878	29	202	1	12	11	92	2	18
2003	107	1,411	55	905	22	175	0	0	13	106	2	23
2004	112	1,432	60	837	17	138	2	27	11	97	3	31
2005	121	1,510	69	946	24	186	2	10	7	76	1	25
2006	104	1,519	61	1,123	19	198	2	32	5	25	0	0

Year	Bottomfish				Spearfish (Snorkel)				Spearfish (SCUBA)			
	All		BMUS		All		BMUS		All		BMUS	
	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs	Trips	Gr-hrs
2007	84	1,126	55	745	13	121	2	19	2	25	1	16
2008	104	1,226	57	792	26	322	3	34	6	47	0	0
2009	146	1,979	76	1,019	28	233	4	43	3	27	0	0
2010	165	2,287	96	1,460	27	207	4	20	1	5	0	0
2011	101	1,373	62	840	15	118	0	0	4	49	1	6
2012	53	530	32	353	8	61	0	0	3	21	0	0
2013	60	763	31	437	12	148	0	0	3	9	0	0
2014	92	1,625	46	604	17	205	1	8	3	12	0	0
2015	73	887	34	432	17	184	0	0	4	86	0	0
2016	106	1,506	62	927	25	241	2	24	22	313	0	0
2017	115	1,573	69	1,073	31	256	2	19	4	32	0	0
2018	99	2,616	54	3,053	19	215	2	45	16	216	3	49
2019	127	1,525	76	1,016	20	217	1	8	6	91	0	0
10-year avg.	**99**	**1,469**	**56**	**1,019**	**19**	**185**	**1**	**12**	**7**	**83**	**0**	**6**
10-year SD	**31**	**613**	**20**	**753**	**7**	**57**	**1**	**14**	**6**	**98**	**1**	**15**
20-year avg.	**116**	**1,588**	**63**	**997**	**22**	**203**	**2**	**16**	**10**	**89**	**1**	**14**
20-year SD	**39**	**560**	**18**	**548**	**8**	**68**	**1**	**14**	**10**	**86**	**2**	**20**

1.2.9 Participants

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

Calculations: For boat-based data, the estimated number of unique vessels is calculated by tallying the number of vessels recorded in the interview data via vessel registration or name.

All: Total unique vessels by gear type.

BMUS: Unique vessels from trips that landed BMUS by gear type.

Table 29a. Estimated number of unique vessels for bottomfishing gears in the Guam boat-based fishery for all species and BMUS only

Year	Bottomfish		Spearfish (Snorkel)		Spearfish (SCUBA)	
	All	BMUS	All	BMUS	All	BMUS
1982	58	47	4	0	1	0
1983	51	41	5	0	4	0
1984	75	33	13	1	6	1
1985	97	66	9	3	21	3
1986	62	27	12	1	7	1
1987	71	42	14	3	8	2
1988	92	76	22	2	14	1
1989	100	70	20	3	18	1
1990	87	58	17	0	9	1
1991	96	65	19	2	19	4
1992	88	62	23	1	29	3
1993	116	53	25	0	20	4
1994	122	71	32	0	22	4
1995	170	82	39	1	30	5
1996	148	68	44	2	28	3
1997	126	51	31	1	18	2
1998	153	72	54	4	20	4
1999	152	69	44	1	16	6
2000	107	61	35	1	21	5
2001	131	73	18	1	16	3
2002	104	58	24	1	9	2
2003	80	48	21	0	9	2
2004	83	47	16	2	5	2
2005	78	42	16	2	6	1
2006	72	45	18	2	4	0

Year	Bottomfish		Spearfish (Snorkel)		Spearfish (SCUBA)	
	All	**BMUS**	**All**	**BMUS**	**All**	**BMUS**
2007	58	41	11	2	2	1
2008	78	44	19	3	3	0
2009	98	49	25	4	3	0
2010	103	61	22	4	1	0
2011	72	44	14	0	3	1
2012	46	29	8	0	2	0
2013	48	28	12	0	3	0
2014	69	39	12	1	3	0
2015	60	26	15	0	2	0
2016	75	41	18	2	10	0
2017	85	54	26	2	2	0
2018	67	37	16	2	7	3
2019	84	52	13	1	3	0
10-year avg.	**71**	**41**	**16**	**1**	**4**	**0**
10-year SD	**16**	**11**	**5**	**1**	**3**	**1**
20-year avg.	**80**	**46**	**18**	**2**	**6**	**1**
20-year SD	**20**	**12**	**6**	**1**	**5**	**1**

Calculations: For boat-based data, the estimated number of fishermen per trip is calculated by filtering interviews that recorded the number of fishers, and then ∑fishers/∑trips. A blank cell indicates insufficient data to generate an estimate of average fishers.

All: Average fishers from all trips by gear type.

BMUS: Average fishers from trips that landed BMUS by gear type.

Table 29b. Estimated number of fishermen per trip for bottomfishing gears in the Guam boat-based fishery for all species and BMUS only

Year	Bottomfish		Spearfish (Snorkel)		Spearfish (SCUBA)	
	All	**BMUS**	**All**	**BMUS**	**All**	**BMUS**
1982	2	2	3		1	
1983	2	2	2		1	
1984	3	3	4	3	2	1
1985	3	3	4	3	2	1
1986	3	2	3	1	3	2
1987	2	2	2	1	2	2
1988	3	3	3	2	2	1
1989	3	3	3	2	3	3
1990	3	3	4		3	4
1991	3	3	3	3	3	4
1992	3	3	4	1	3	3

Year	Bottomfish		Spearfish (Snorkel)		Spearfish (SCUBA)	
	All	**BMUS**	**All**	**BMUS**	**All**	**BMUS**
1993	3	3	3		4	4
1994	3	3	3		4	4
1995	4	3	3	2	4	5
1996	5	3	3	1	4	6
1997	6	4	3	5	4	4
1998	4	3	3	4	4	5
1999	4	3	3	2	4	4
2000	4	3	3	2	4	4
2001	3	2	3	2	4	5
2002	3	2	3	2	4	4
2003	3	3	4		4	4
2004	4	3	3	6	4	4
2005	3	2	3	3	3	5
2006	3	2	3	3	3	
2007	4	3	3	2	4	4
2008	3	2	3	3	3	
2009	3	2	3	3	4	
2010	3	3	3	3	3	
2011	3	3	4		4	3
2012	3	3	3		5	
2013	3	3	4		3	
2014	3	3	4	4	3	
2015	4	4	4		7	
2016	3	3	3	2	5	
2017	2	2	3	3	5	
2018	4	3	4	4	5	3
2019	3	3	4	5	7	
10-year avg.	**3**	**3**	**4**	**4**	**5**	**3**
10-year SD	**1**	**0**	**0**	**1**	**1**	**0**
20-year avg.	**3**	**3**	**3**	**3**	**4**	**4**
20-year SD	**1**	**1**	**0**	**1**	**1**	**1**

1.2.10 Bycatch Estimates

This section focuses on MSA § 303(a)(11), which requires that all FMPs establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures that, to the extent practicable, minimize bycatch and bycatch mortality. The MSA § 303(a)(11) standardized reporting methodology is commonly referred to as a ''Standardized Bycatch Reporting Methodology'' (SBRM) and was added to the

MSA by the Sustainable Fisheries Act of 1996 (SFA). The Council implemented omnibus amendments to FMPs in 2003 to address MSA bycatch provisions and establish SBRMs.

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

Table 30. Time series of observed catch and bycatch in the Guam BMUS fishery

Year	# Caught	# Kept	# Released	% Bycatch
1982	1,062	1,062	0	0
1983	940	940	0	0
1984	590	590	0	0
1985	1,830	1,830	0	0
1986	546	546	0	0
1987	1,313	1,313	0	0
1988	1,399	1,399	0	0
1989	2,028	2,028	0	0
1990	1,542	1,542	0	0
1991	1,366	1,366	0	0
1992	1,046	1,046	0	0
1993	946	946	0	0
1994	1,663	1,663	0	0
1995	1,449	1,449	0	0
1996	1,281	1,281	0	0
1997	983	983	0	0
1998	993	993	0	0
1999	1,081	1,081	0	0
2000	1,090	1,084	6	0.55
2001	1,023	1,007	16	1.56
2002	629	627	2	0.32
2003	497	477	20	4.02
2004	586	586	0	0
2005	616	616	0	0
2006	1,140	1,113	27	2.37
2007	417	410	7	1.68
2008	572	569	3	0.52
2009	860	860	0	0
2010	890	890	0	0
2011	707	707	0	0
2012	309	309	0	0
2013	293	293	0	0

Year	# Caught	# Kept	# Released	% Bycatch
2014	658	652	6	0.91
2015	366	366	0	0
2016	641	639	2	0.31
2017	766	766	0	0
2018	406	404	2	0.49
2019	865	862	3	0.35
10-year avg.	**590**	**589**	**1**	**0.21**
10-year SD	**216**	**216**	**2**	**0.29**
20-year avg.	**667**	**662**	**5**	**0.65**
20-year SD	**246**	**242**	**7**	**1.01**

1.2.11 Number of Federal Permit Holders

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

1.2.11.1 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 EEZ under the Mariana FEP:

1.2.11.2 Guam Large Vessel Bottomfish Permit

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

1.2.11.3 Special Coral Reef Ecosystem Permit

Regulations require the coral reef ecosystem special permit for anyone fishing for coral reef ECS 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 ECS while fishing for bottomfish MUS, crustacean ECS, 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 ECS caught in a low-use MPA.

1.2.11.4 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.

1.2.11.5 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 deep-water shrimp in the EEZ around American Samoa, Guam, CNMI, Hawaii, and the PRIAs.

There is no record of special coral reef or precious coral fishery permits issued for the EEZ around Guam since 2007. Table 31 provides the number of permits issued for Guam fisheries between 2010 and 2019. Historical data are from the PIFSC, and 2018–2019 data are from the PIRO Sustainable Fisheries Division permits program.

Table 31. Number of federal permits holders for the crustacean and bottomfish fisheries of Guam

Guam Fisheries	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Lobster	0	0	0	0	0	0	1**	0	1**	0
Shrimp	2*	1*	0	0	0	0	1	0	0	0
Bottomfish	1	1	4	2	2	1	1	1	1	0

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

1.2.12 Status Determination Criteria

1.2.12.1 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 32). 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.

Table 32. Overfishing threshold specifications for Guam BMUS

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 $c = \max(1\text{-}M, 0.5)$		

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 33. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 33. Rebuilding control rules for Guam BMUS

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

1.2.12.2 Current Stock Status

1.2.12.2.1 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 (Langseth et al., 2019) for the Guam bottomfish management unit species complex (comprised of 11 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. The assessments used a state-space Bayesian surplus production model within the modeling framework Just Another Bayesian Biomass Assessment (JABBA), which included biological information and fishery-dependent data through 2017. 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 in an overfished state but not undergoing overfishing.

Table 34. Stock assessment parameters for the Guam BMUS complex (from Langseth et al., 2019)

Parameter	Value	Notes	Status
MSY	42.1 (29.3-65.5)	Expressed in 1000 lbs. (with 95% confidence interval)	
H_{2017}	0.11	Expressed in percentage	
H_{CR}	0.17 (0.071 – 0.382)	Expressed in percentage (with 95% confidence interval)	
H/H_{CR}	0.81		No overfishing occurring
B_{2017}	143.0	Expressed in thousand pounds	
B_{MSY}	248.8 (107.1-636.8)	Expressed in 1000 lbs. (with 95% confidence interval)	
B/B_{MSY}	0.57		Overfished

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

1.2.13.1 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 papers, reports, and/or available data. These data are categorized into the different tiers in the control rule ranging from Tier 1 (i.e., most information available, typically a stock assessment) to Tier 5 (i.e., catch-only information). The control rules are applied to the BSIA. Tiers 1 to 3 involve conducting a Risk of Overfishing Analysis (denoted by P*) to quantify the scientific uncertainties associated with the assessment to specify the Acceptable Biological Catch (ABC), lowering the MSY-based OFL to the ABC. A Social, Ecological, Economic, and Management (SEEM) Uncertainty Analysis is performed to quantify the uncertainties associated with the SEEM factors, and a buffer is used to lower the ABC to an ACL. For Tier 4, which is comprised of stocks with MSY estimates but no active fisheries, the control rule is 91 percent of MSY. For Tier 5, which has catch-only information, the control rule is a one-third reduction in the median catch depending on a qualitative evaluation of stock status via expert opinion. ACL specification can choose from a variety of methods including the above mentioned SEEM analysis or a percentage buffer (i.e., percent reduction from ABC based on expert opinion) or the use of an Annual Catch Target (ACT). Specifications are done on an annual basis, but the Council normally produces a multi-year specification.

The AM for Guam bottomfish fisheries is an overage adjustment. The next ACL is downward adjusted with the amount of overage from the previous ACL based on a three-year running average.

1.2.13.2 Current OFL, ABC, ACL, and Recent Catch

No ACLs were implemented by NMFS for Guam MUS in 2019 due to new information contained in the new benchmark stock assessment (Langseth et al., 2019) that was determined to be BSIA. The catch shown in Table 35 takes the average of the most recent three years as recommended by the Council at its 160th meeting to avoid large fluctuations in catch due to high interannual variability in estimates.

Table 35. Guam 2019 ACL table with three-year average catch (lbs.)

Fishery	MUS	OFL	ABC	ACL	Catch
Bottomfish	Bottomfish multi-species complex	N.A.	N.A.	N.A.	26,906

1.2.14 Best Scientific Information Available

1.2.14.1 Bottomfish fishery

1.2.14.1.1 Stock assessment benchmark

The benchmark stock assessment for the Territory Bottomfish Management Unit Species complex was developed and finalized by Langseth et al. (2019). The assessments used a state-space Bayesian surplus production model within the modeling framework Just Another Bayesian Biomass Assessment (JABBA). Estimates of harvest rate (H), annual biomass (B), the harvest rate associated with overfishing as determined by the harvest control rule (H_{CR}), maximum sustainable yield (MSY), and the biomass at maximum sustainable yield (B_{MSY}) allowed for determination of stock status relative to reference points determining overfishing ($H/H_{CR} > 1$) and overfished ($B < 0.7 \times B_{MSY}$) status. Stock projections were conducted for 2020–2025 for a range of hypothetical 6-year catches, and the corresponding risk of overfishing was calculated.

1.2.14.1.2 Stock Assessment Updates

Updates to the 2007 benchmark were 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) prior to the Langseth et al. (2019) benchmark stock assessment. This was the basis for the P* analysis and SEEM analysis the determined the risk levels to specify ABCs and ACLs.

1.2.14.1.3 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 Harvest Capacity and Extent

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

- Will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems.
- Is prescribed on the basis of the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor.
- In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such a fishery [50 CFR §600.310(f)(1)(i)].

OY in the 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 MUS complex is defined to be the level of harvest equal to the ACL consistent with the goals and objectives of the FEPs 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 MSY (F_{MSY}). There are situations when the long-term means around MSY are lower than ACLs especially if the stock is known to be productive or relatively pristine or lightly fished. A stock can have catch levels and catch rates exceeding that of MSY over the short-term to lower the biomass to a level around the estimated MSY and still not jeopardize the stock.

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 TALFF. Table 36 normally summarizes the harvest extent and harvest capacity information for Guam using three-year average catch, however, there was no specified ACL for Guam BMUS in 2019 due new information that came to light in the most recent benchmark stock assessment (Langseth et al., 2019) that was determined to be BSIA.

Table 36. Guam ACL proportion of harvest capacity and extent in 2019

Fishery	MUS	ACL	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	Bottomfish multi-species complex	N.A.	26,906	N.A.	N.A.

1.2.16 Other Relevant Ocean-Uses and Fishery-Related Information

1.2.16.1 Marine Preserves

Guam has five locally managed 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 percent of Guam's coastline is located within these MPAs.

1.2.16.2 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 or other areas are 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 for all areas in 2019 was 90, equaling 316 closure days. Additional information and data can be found in Section 2.7.5 and Table 68.

1.2.17 Administrative and Regulatory Actions

This summary describes management actions NMFS implemented for insular fisheries in Guam during calendar year 2019.

February 8, 2019. Final rule: **Reclassifying Management Unit Species to Ecosystem Component Species**. This final rule reclassified certain management unit species in the Pacific Islands as ecosystem component species. The rule also updated the scientific and local names of certain species. The intent of this final rule was to prioritize conservation and management efforts and to improve efficiency of fishery management in the region. This rule was effective March 11, 2019.

2 ECOSYSTEM CONSIDERATIONS

2.1 CORAL REEF ECOSYSTEM PARAMETERS

2.1.1 Regional Reef Fish Biomass and Habitat Condition

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2019. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred.

Rationale: Reef fish biomass 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. Hard coral cover is an indicator of relative status of the organisms that build coral reef habitat and has been shown to be sensitive to changes in oceanographic regime, and a range of direct and indirect anthropogenic impacts. Most fundamentally, cover of hard corals has been increasingly impacted by temperature stress as a result of global heating.

Data Category: Fishery-independent

Timeframe: Triennial

Jurisdiction: American Samoa, Guam, the Commonwealth of the Northern Mariana Islands (CNMI), Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), and Pacific Remote Island Areas (PRIAs)

Spatial Scale: Regional

Data Source: Data used to generate cover and biomass estimates come from visual surveys conducted by the National Marine Fisheries Service (NMFS) Pacific Island Fisheries Science Center (PIFSC) Ecosystem Sciences Division (ESD) and their partners as part of the Pacific Reef Assessment and Monitoring Program (RAMP). Survey methods are described in detail in Ayotte et al. (2015). In brief, they 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 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.

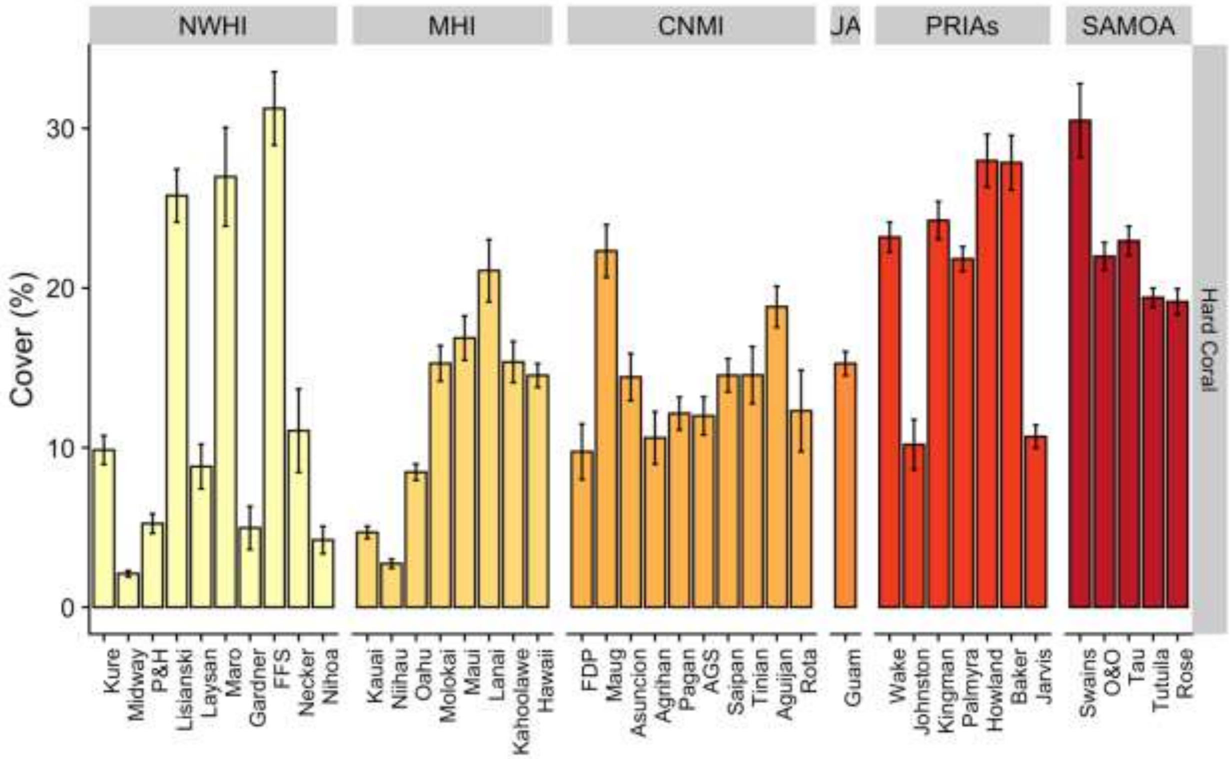


Figure 1. Mean coral cover (%) per U.S. Pacific island averaged over the years 2010-2019 by latitude

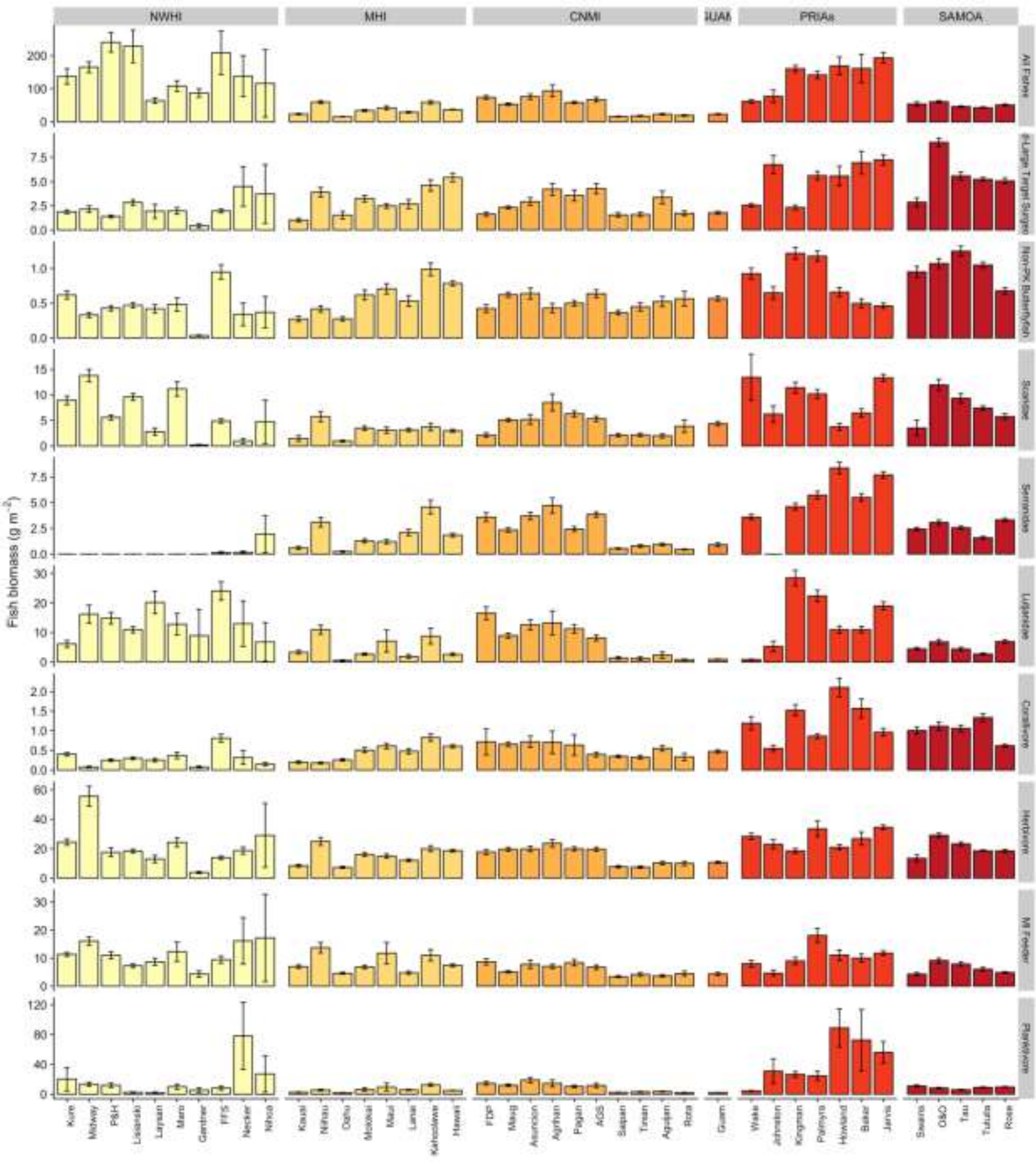


Figure 2. Mean fish biomass (g/m^2 ± standard error) of functional, taxonomic, and trophic groups by U.S. Pacific reef area from the years 2010-2019 by latitude. The group Serranidae excludes planktivorous members of that family – i.e. anthias, which can by hyper-abundant in some regions. Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group – as high biomass of that species at Wake overwhelms corallivore biomass at all other locations. The group 'MI Feeder' consists of fishes that primarily feed on mobile invertebrates

2.1.2 CNMI Reef Fish Biomass and Habitat Condition

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2019. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred.

Rationale: Reef fish biomass 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. Hard coral cover is an indicator of relative status of the organisms that build coral reef habitat and has been shown to be sensitive to changes in oceanographic regime, and a range of direct and indirect anthropogenic impacts. Most fundamentally, cover of hard corals has been increasingly impacted by temperature stress as a result of global heating.

Data Category: Fishery-independent

Timeframe: Triennial

Jurisdiction: CNMI

Spatial Scale: Island

Data Source: Data used to generate biomass and cover estimates comes from visual surveys conducted by NMFS PIFSC ESD and partners, as part of the Pacific RAMP Survey methods and sampling design, and methods to generate reef fish biomass are described in Section 2.1.1.

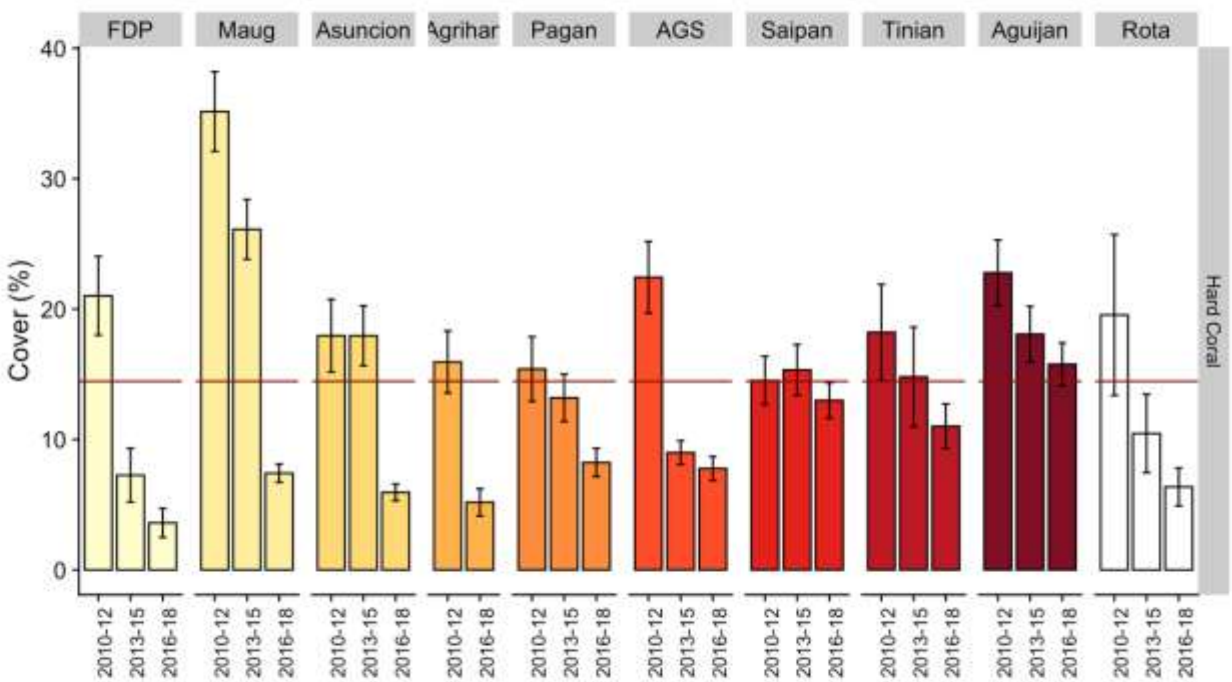


Figure 3. Mean coral cover (%) per island averaged over the years 2010-2019 by latitude with CNMI mean estimates plotted for reference (red line).

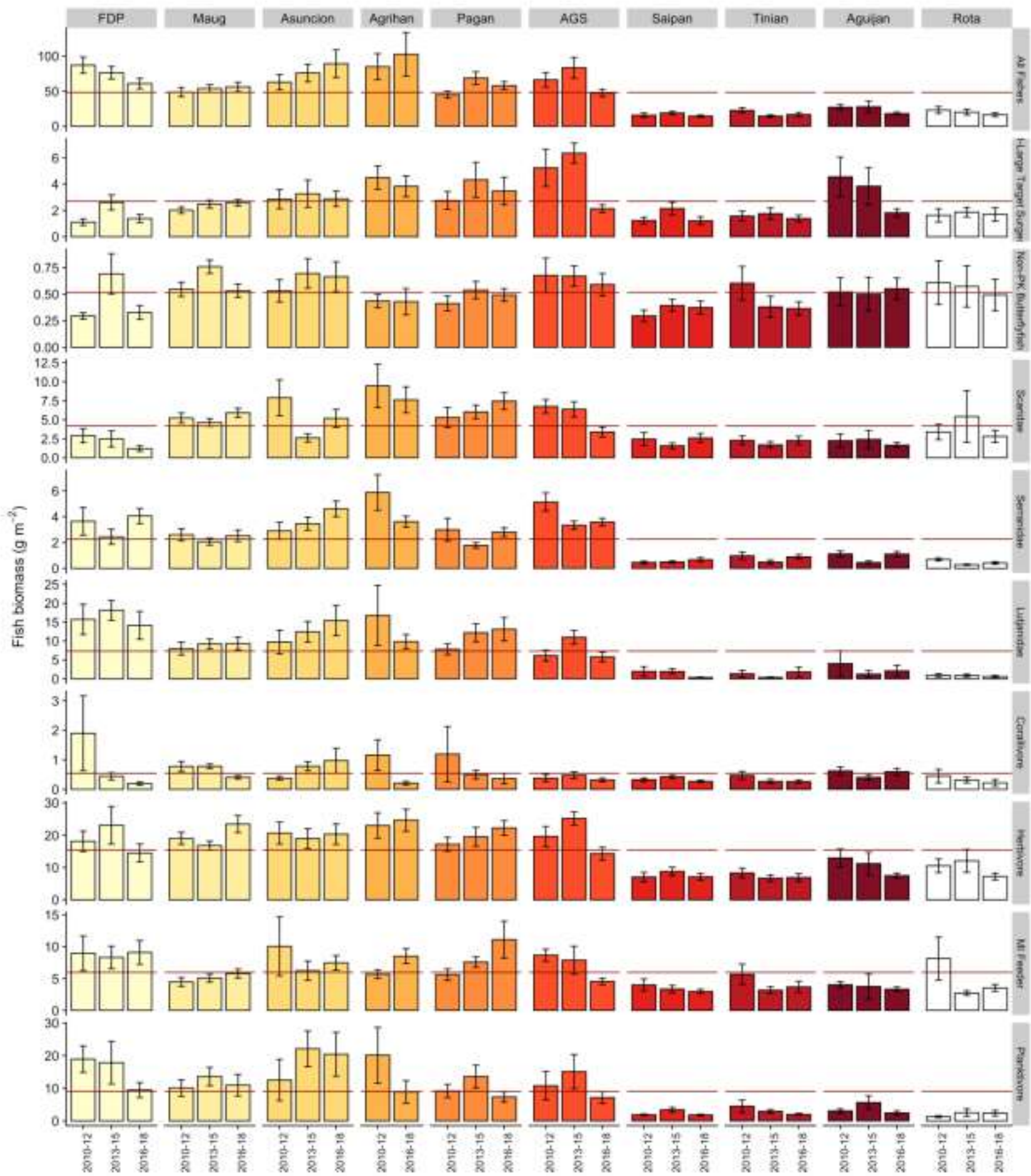


Figure 4. Mean fish biomass (g/m^2 ± standard error) of CNMI functional, taxonomic, and trophic groups from the years 2010-2019 by island. The group Serranidae excludes planktivorous members of that family – i.e. anthias, which can by hyper-abundant in some regions. Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group. The group 'MI Feeder' consists of fishes that primarily feed on mobile invertebrates; with CNMI mean estimates plotted for reference (red line)

2.1.3 Guam Reef Fish Biomass and Habitat Condition

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2019. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred.

Rationale: Reef fish biomass 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. Hard coral cover is an indicator of relative status of the organisms that build coral reef habitat and has been shown to be sensitive to changes in oceanographic regime, and a range of direct and indirect anthropogenic impacts. Most fundamentally, cover of hard corals has been increasingly impacted by temperature stress as a result of global heating.

Data Category: Fishery-independent

Timeframe: Triennial

Jurisdiction: Guam

Spatial Scale: Island

Data Source: Data used to generate biomass and cover estimates comes from visual surveys conducted by NMFS PIFSC ESD and partners, as part of the Pacific RAMP Survey methods and sampling design, and methods to generate reef fish biomass are described in Section 2.1.1.

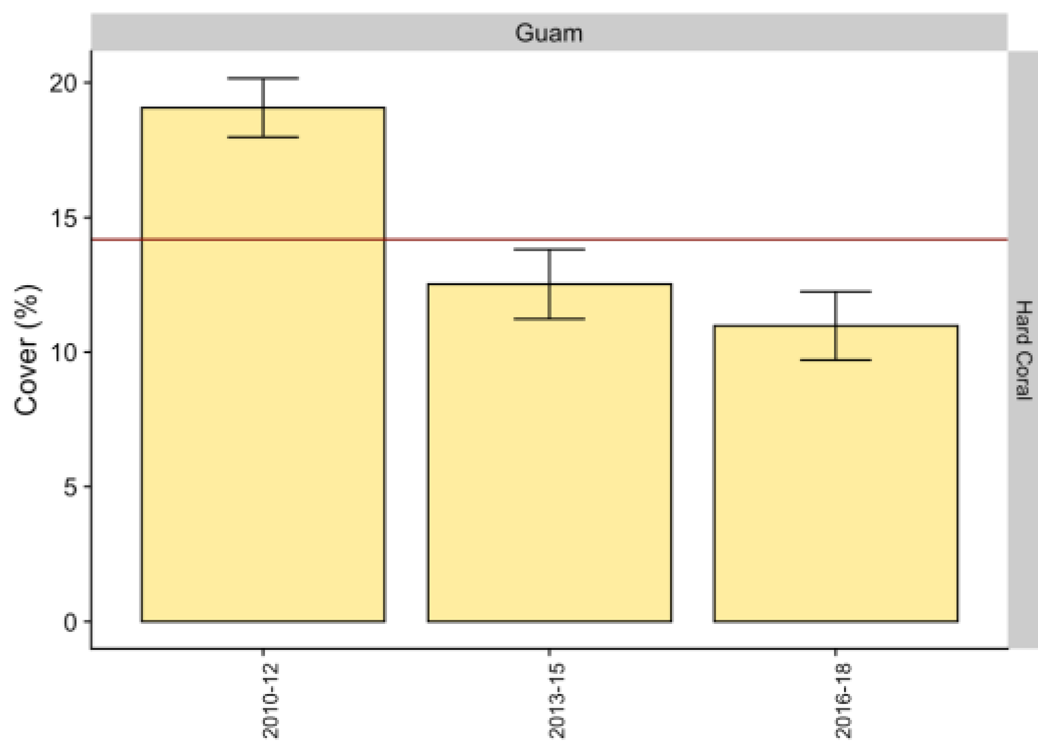


Figure 5. Mean coral cover (%) over the years 2010-2019 with mean for the entire time period plotted for reference (red line)

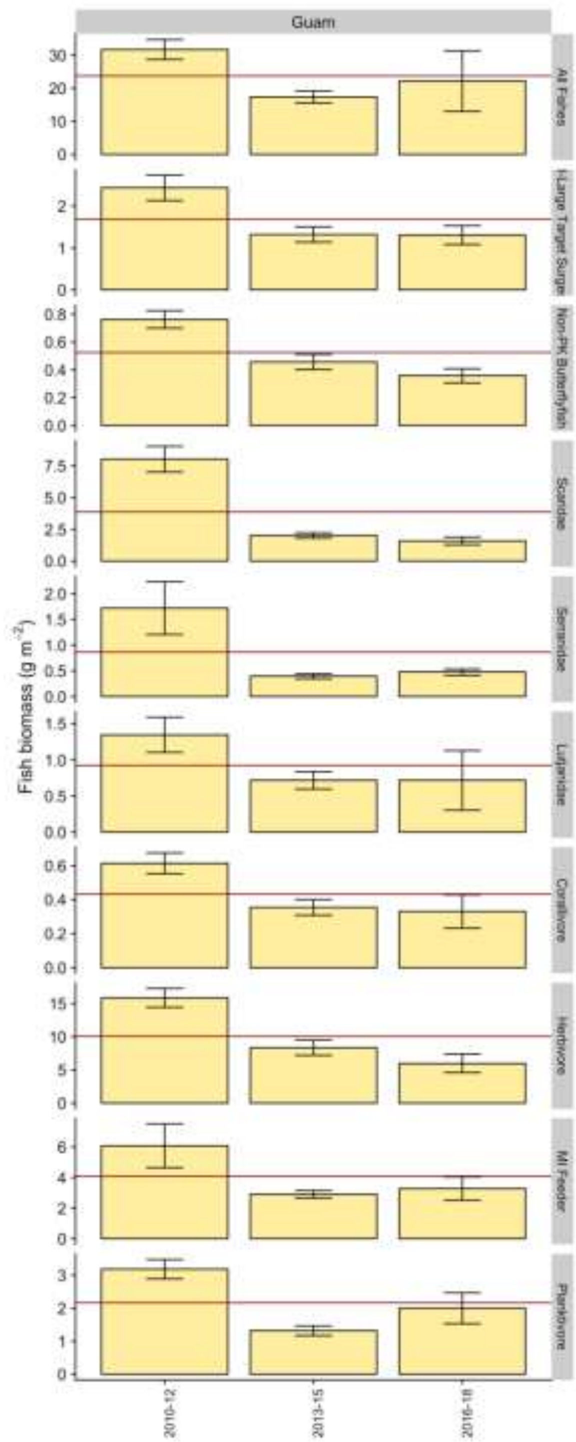


Figure 6. Mean fish biomass (g/m^2 ± standard error) of Guam functional, taxonomic, and trophic groups from the years 2010-2019. The group Serranidae excludes planktivorous members of that family – i.e. anthias, which can by hyper-abundant in some regions. Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group. The group 'MI Feeder' consists of fishes that primarily feed on mobile invertebrates; with Guam mean estimates plotted for reference (red line)

2.2 LIFE HISTORY AND LENGTH DERIVED PARAMETERS

The annual stock assessment and fishery evaluation (SAFE) report will serve as the repository of available life history information for the Western Pacific region. Life history data particularly age, growth, reproduction, and mortality information inform stock assessments on fish productivity and population dynamics. Some assessments, particularly for data poor stocks, utilize information from other areas that introduces biases and increase uncertainties in the population estimates. An archipelago specific life history parameter ensures accuracy in the input parameters used in the assessment.

The NMFS PIFSC Bio-Sampling Program allows for the collection of life history samples like otoliths and gonads from priority species in the bottomfish and coral reef fisheries. A significant number of samples are also collected during research cruises. These life history samples, once processed and examined, will contribute to the body of scientific information for the two data-poor fisheries in the region (coral reef fish and bottomfish). 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) prioritized coral reef ecosystem component species, and 2) management unit species (MUS). The prioritized coral reef species list was developed by the CNMI Department of Fish and Wildlife (DFW) and the Guam Division of Aquatic and Wildlife Resources (DAWR) in 2019. The MUS are the species that are listed in the federal ecosystem plan and are managed on a federal level. 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 markets. 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 Components 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 is based on several methods including 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. Fish growth is estimated by fitting the length-at-age data to a von Bertalanffy growth function (VBGF). 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, 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 age at 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the VBGF 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: Biological

Timeframe: N/A

Jurisdiction: CNMI

Spatial Scale: Archipelagic

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 (LHP). Refer to the “Reference” column in Table 37 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. Units are years.

L_∞ (asymptotic length) – One of three coefficients of the 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 estimated mean maximum length and not the observed maximum length. Units are centimeters.

***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) are not available for age determination. This parameter can be fixed at 0. Units are years.

***M* (natural mortality)** – This is a measure of the mortality rate for a fish stock 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 the 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. Units are years.

$A\Delta_{50}$ (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. Units are years.

L_{50} (length at which 50% of a fish population are capable of spawning) – 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 and growth. Units are centimeters.

$L\Delta_{50}$ (length of sex switching) – 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 and growth. Units are centimeters.

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. These parameters are also used as direct inputs into stock assessments. 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 and 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 37. Available age, growth, reproductive maturity, and natural mortality information for prioritized coral reef ecosystem component species in CNMI

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Acanthurus lineatus										
Lethrinus harak	f=9[d] m=9 [d]	f=37.2[d] m=27.3[d]	f=0.14[d] m=0.38[d]	f=-2.92[d] m=-1.11[d]		f=2.6[d] m=2.4[d]	f=0.43 m=0.4 4	f=19.6[d] m=18.7[d]		Trianni (2016)
Mulloidichthys flavolineatus	f=5[c] M=4[c]	f=25.55[c] m=21.80[c]	f=1.24[c] m=1.69[c]					f=15.8[c] m=16.1[c]		Reed et al., (in review)
Naso lituratus									NA	
Naso unicornis								238[b]	NA	
Scarus rubroviolaceus										
Scarus ghobban										
Siganus argenteus	7[d]	274[d]	0.9[d]	-0.3[d]	0.56[d]	1.3[d]	NA	218[d]	NA	Taylor et. al., (2016)

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

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

2.2.1.2 Fish Length Derived Parameters

<u>Description</u>: The NMFS Commercial Fishery Bio-sampling Program started in 2010. This program has two components: first is the Field/Market Sampling Program, and the second is the Lab Sampling 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, and 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 Bio-sampling Program was focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the northern islands. However, in 2020 the Program switched focus to the MUS. Sampling is conducted in partnership with the fish vendors and fishermen. 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: Biological

Timeframe: N/A

Jurisdiction: CNMI

Spatial Scale: Archipelagic

Data Source: NMFS Bio-sampling Program

Parameter definitions:

n* – *sample size is the total number of fish sampled for length for each species recorded in the Bio-Sampling Program database.

L_{max} – *maximum fish length* is the largest individual per species recorded in the Bio-Sampling Program database from the commercial spear fishery. This value is derived from measuring the length of individual samples for species occurring in the spear fishery. Units are centimeters.

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

a and b* – *length-weight coefficients are the coefficients derived from the regression line fitted to all length and weight measured by 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 an important component of fisheries monitoring and data poor stock assessment approaches. Maximum length (L_{max}), is used to derive missing species- and location-specific life history information (Nadon et al., 2015; Nadon and Ault, 2016; Nadon, 2019). The length-weight coefficients (*a* and *b* values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length is 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 ecosystem component fisheries.

Table 38. Available length derived information for prioritized coral reef ecosystem component species in CNMI

Species	Length derived parameters					Reference
	n	L_{max}	$N_{L\text{-}W}$	*a*	*b*	
Acanthurus lineatus	20228	23.5	4927	0.03882	2.868	Matthews et al., (2019)
Lethrinus harak	2697					
Mulloidichthys flavolineatus	12516	31.4	2798	0.0138	3.05	Matthews et al., (2019)

Species	Length derived parameters					Reference
	n	L_{max}	$N_{L\text{-}W}$	***a***	***b***	
Naso lituratus	28507	30.1	3868	0.0163	3.103	Matthews et al., (2019)
Naso unicornis	12481	53.6	4448	0.0269	2.908	Matthews et al., (2019)
Scarus ghobban[1]	7612	38.1	1644	0.0129	3.12	Matthews et al., (2019)
Scarus rubroviolaceus	4032	52.6	1830	0.0089	3.24	Matthews et al., (2019)
Siganus argenteus	14614	34.1	3961	0.0129	3.112	Matthews et al., (2019)

[1]did not have data to cover 30% of the total length range

2.2.2 CNMI Management Unit Species Life History

2.2.2.1 Age, Growth, and Reproductive Maturity

Description: Age determination is based on counts of yearly growth marks (annuli) and/or DGIs internally visible within transversely cut, thin sections of sagittal otoliths. Validated age determination is based on several methods including 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. Fish growth is estimated by fitting the length-at-age data to a VBGF. 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, 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 for the data based on statistical analyses. The mid-point of the 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 age at 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the VBGF 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 and 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 (i.e., 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 species have achieved reproductive maturity (A_{50}) and sex reversal ($A\Delta_{50}$).

Category: Biological

Timeframe: N/A

Jurisdiction: CNMI

Spatial Scale: Archipelagic

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 LHP. Refer to the "Reference" column in Table 39 for specific details on data sources by species.

Parameter definitions: Identical to Section 2.2.2.1

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 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 39. Available age, growth, reproductive maturity, and natural mortality information for MUS in CNMI

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Aphareus rutilans	Y	Y	Y	Y			NA		NA	Ralston and Williams (1988)
Caranx ignobilis										
Caranx lugubris										
Etelis carbunculus[1]							NA		NA	
Etelis coruscans	Y	Y	Y	Y			NA		NA	Ralston and Williams (1988)
Lethrinus rubrioperculatus	8[d]	31.5[d]	0.80[d]	-0.52[d]				23.2[d]	29.0[d]	Trianni (2011)
Lutjanus kasmira							NA		NA	
Pristipomoides auricilla[2]	18[d]	32.5[d]	0.60[d]		0.18[d]		NA		NA	O'Malley et al., (2019)

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Pristipomoides filamentosus[2]							NA		NA	
Pristipomoides flavipinnis	31	54.6[c]	0.19[c]			f=5.0[c] m=2.8[c]	NA	f=41.2[c] m=27.6[c]	NA	Villagomez (2019)
Pristipomoides sieboldii							NA		NA	Ralston and Williams (1988)
Pristpomoides zonatus	X[a]	X[a]	X[a]	X[a]			NA		NA	LHP (in prep)
Variola louti										

[1] *E. carbunculus* is now known to be comprised of two distinct, non-interbreeding lineages (Andrews et al. 2016). Both species occur in the Mariana Archipelago and are likely both captured by fishermen but reported as one species.
[2] Estimates are for the southern portion of the Mariana Archipelago
[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (including in press).

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

2.2.2.2 Fish Length Derived Parameters

Description: The NMFS Commercial Fishery Bio-sampling Program started in 2010. This program has two components: first is the Field/Market Sampling Program and the second is the Lab Sampling 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, and 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 Bio-sampling Program was focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the northern islands. However, in 2020 the Program switched focus to the MUS. Sampling is conducted in partnership with the fish vendors and fishermen. 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: Biological

Timeframe: N/A

Jurisdiction: CNMI

Spatial Scale: Island

Data Source: NMFS Bio-sampling Program

Parameter definitions: Identical to Section 2.2.1.2

Rationale: Length derived information is an important component of fisheries monitoring and data poor stock assessment approaches. Maximum length (L_{max}), is used to derive missing species- and location-specific life history information (Nadon et al., 2015; Nadon and Ault, 2016; Nadon, 2019). The length-weight coefficients (*a* and *b* values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length is 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 MUS fisheries.

Table 40. Available length derived information for MUS species in CNMI

Species	Length derived parameters					Reference
	n	L_{max}	$N_{L\text{-}W}$	***a***	***b***	
Aphareus rutilans	120					
Caranx ignobilis	6					
Caranx lugubris	132	82.5	130	0.0313	2.87	Matthews et al., (2019)
Etelis carbunculus[1]	746	53.5	685	0.0150	3.0430	2010-2015 CNMI Bio-Sampling Database
Etelis coruscans	377	96.4	325	0.0716	2.6147	2010-2015 CNMI Bio-Sampling Database
Lethrinus rubrioperculatus	1438	38.0	1353	0.0185	2.9897	2010-2015 CNMI Bio-Sampling Database
Lutjanus kasmira	422	32.5	258	0.0087	3.2307	2010-2015 CNMI Bio-Sampling Database
Pristipomoides auricilla	471	39.5	465	0.0189	3.0060	2010-2015 CNMI Bio-Sampling Database
Pristipomoides filamentosus	123	58.5	123	0.0773	2.5914	2010-2015 CNMI Bio-Sampling Database
Pristipomoides flavipinnis	179	51.5	168	0.0133	3.0762	2010-2015 CNMI Bio-Sampling Database
Pristipomoides sieboldii	112					
Pristpomoides zonatus	404	45.4	371	0.0180	3.0411	2010-2015 CNMI Bio-Sampling Database
Variola louti	6					

[1] *E. carbunculus* is now known to be comprised of two distinct, non-interbreeding lineages (Andrews et al. 2016). Both species occur in the Mariana Archipelago and are likely both captured by fishermen but reported as one species.

2.2.3 Guam Coral Reef Ecosystem Components 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 DGIs internally visible within transversely cut, thin sections of sagittal otoliths. Validated age determination is based on several methods including 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. Fish growth is estimated by fitting the length-at-age data to a VBGF. 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, 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 ($\boldsymbol{L_{50}}$). 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 age at 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the VBGF for that species and using the corresponding $\boldsymbol{L_{50}}$ 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: Biological

Timeframe: N/A

Jurisdiction: Guam

Spatial Scale: Archipelagic

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 LHP. Refer to the "Reference" column in Table 41 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. Units are years.

L_∞ (asymptotic length) – One of three coefficients of the 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 estimated mean maximum length and not the observed maximum length. Units are centimeters.

***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) are not available for age determination. This parameter can be fixed at 0. Units are years.

***M* (natural mortality)** – This is a measure of the mortality rate for a fish stock 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 the 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. Units are years.

$A\Delta_{50}$ (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. Units are years.

L_{50} (length at which 50% of a fish population are capable of spawning) – 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 and growth. Units are centimeters.

***L*Δ₅₀ (length of sex switching)** – 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 and growth. Units are centimeters.

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. These parameters are also used as direct inputs into stock assessments. 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 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 41. Available age, growth, reproductive maturity, and natural mortality information for prioritized coral reef ecosystem component species in Guam

Species	Age, growth, and reproductive maturity parameters							Reference
	T_{max}	L_∞	k	t_0	A_{50}	L_{50}	$L\Delta_{50}$	
Caranx melampygus	X[a]	X[a]	X[a]	X[a]	X[a]	X[a]	X[a]	LHP (in progress)
Chlorurus frontalis	11[d]	37.2[d]	0.71[d]	-0.058[d]	1.55[d]	24.0[d]	34.3[d]	Taylor and Choat (2014)
Epinephelus fasciatus								
Lethrinus harak								
Lethrinus olivaceus								
Lutjanus fulvus								
Naso unicornis	23[d]	49.3[d]	0.22[d]	-0.048[d]	f=4.0[d] m=3.2[d]	f=29.2[d] m=27.1[d]		Taylor et al., (2014)
Scarus rubroviolaceus	6[d]	37.6[d]	0.66[d]	-0.062[d]	1.91[d]	27.1[d]	32.9[d]	Taylor and Choat (2014)
Siganus spinus								

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

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

2.2.3.2 Fish Length Derived Parameters

Description: The NMFS Commercial Fishery Bio-sampling Program started in 2009. This program has two components: first is the Field/Market Sampling Program, and the second is the Lab Sampling 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, and 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 Bio-sampling Program was focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the northern islands. However, in 2020 the Program switched focus to the MUS. Sampling is conducted in partnership with the fish vendors and fishermen. The Market Sampling information includes (but not limited to): 1) fish length; 2) fish weight; 3) species identification; and 4) basic effort information.

Category: Biological

Timeframe: N/A

Jurisdiction: Guam

Spatial Scale: Archipelagic

Data Source: NMFS Bio-sampling Program

Parameter definitions:

n* – *sample size is the total number of fish sampled for length for each species recorded in the Bio-Sampling Program database.

L_{max} – *maximum fish length* is the largest individual per species recorded in the Bio-Sampling Program database from the commercial spear fishery. This value is derived from measuring the length of individual samples for species occurring in the spear fishery. Units are centimeters.

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

a and b* – *length-weight coefficients are the coefficients derived from the regression line fitted to all length and weight measured by 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 an important component of fisheries monitoring and data poor stock assessment approaches. Maximum length (L_{max}), is used to derive missing species- and location-specific life history information (Nadon et al. 2015, Nadon and Ault 2016, Nadon 2019). The length-weight coefficients (*a* and *b* values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length is 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 Guam coral reef fisheries.

Table 42. Available length derived information for prioritized coral reef ecosystem component species in Guam

Species	Length derived parameters					Reference
	n	L_{max}	$N_{L\text{-}W}$	a	b	
Caranx melampygus	1157	69.8	551	0.0228	2.95	Kamikawa et al., (2015)
Chlorurus frontalis	534	48.5	238	0.0172	3.08	Kamikawa et al., (2015)
Epinephelus fasciatus	4223	57.0	1701	0.0118	3.08	Kamikawa et al., (2015)
Lethrinus harak	886	29.9	258	0.0281	2.89	Kamikawa et al., (2015)
Lethrinus olivaceus	751	71.7	272	0.0200	2.93	Kamikawa et al., (2015)
Lutjanus fulvus	426	29.6	91	0.0134	3.12	Kamikawa et al., (2015)
Naso unicornis	20618	57.2	7790	0.0267	2.92	Kamikawa et al., (2015)
Scarus rubroviolaceus	2563	47.8	1713	0.0114	3.18	Kamikawa et al., (2015)
Siganus spinus	5475	27.0	890	0.0284	2.87	Kamikawa et al., (2015)

2.2.4 Guam Management Unit Species Life History

2.2.4.1 Age, Growth, and Reproductive Maturity

Description: Age determination is based on counts of yearly growth marks (annuli) and/or DGIs internally visible within transversely cut, thin sections of sagittal otoliths. Validated age determination is based on several methods including 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. Fish growth is estimated by fitting the length-at-age data to a VBGF. 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, 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 age at 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the VBGF 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: Biological

Timeframe: N/A

Jurisdiction: Guam

Spatial Scale: Archipelagic

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 LHP. Refer to the "Reference" column in Table 43 for specific details on data sources by species.

Parameter definitions: Identical to Section 2.2.3.1

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

Table 43. Available age, growth, reproductive maturity, and natural mortality information for MUS in Guam

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Aphareus rutilans							NA		NA	
Caranx ignobilis							NA		NA	
Caranx lugubris							NA		NA	
Etelis carbunculus[1]							NA		NA	
Etelis coruscans							NA		NA	
Lethrinus rubrioperculatus							NA		NA	
Lutjanus kasmira							NA		NA	
Pristipomoides auricilla[2]	18[d]	32.5[d]	0.60[d]		0.18[d]		NA		NA	O'Malley et al. (2019)
Pristipomoides filamentosus[2]	31	54.6[c]	0.19[c]			f=5.0[c] m=2.8[c]	NA	f=41.2[c] m=27.6[c]	NA	Villagomez (2019)
Pristipomoides flavipinnis							NA		NA	
Pristipomoides sieboldii							NA		NA	
Pristpomoides zonatus	X[a]	X[a]	X[a]		X[a]	X[a]	NA	X[a]	NA	LHP (in prep.)
Variola louti										

[1] *E. carbunculus* is now known to be comprised of two distinct, non-interbreeding lineages (Andrews et al. 2016). Both species occur in the Samoa Archipelago and were likely both captured by fishermen in the 1980s but reported as one species.
[2] Estimates are for the southern portion of the Mariana Archipelago.
[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (+ in press).

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

2.2.4.2 Fish Length Derived Parameters

<u>Description</u>: The NMFS Commercial Fishery Bio-sampling Program started in 2009. This program has two components: first is the Field/Market Sampling Program and the second is the LHP, 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, and 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 Bio-sampling Program was focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the northern islands. However, in 2020 the Program switched focus to the MUS. Sampling is conducted in partnership with the fish vendors and fishermen. The Market Sampling information includes (but not limited to): 1) fish length; 2) fish weight; 3) species identification; and 4) basic effort information.

Category: Biological

Timeframe: N/A

Jurisdiction: Guam

Spatial Scale: Island

Data Source: NMFS Bio-sampling Program

Parameter definition: Identical to Section 2.2.3.2

Rationale: Length derived information is an important component of fisheries monitoring and data poor stock assessment approaches. Maximum length (L_{max}), is used to derive missing species- and location-specific life history information (Nadon et al., 2015; Nadon and Ault, 2016; Nadon, 2019). The length-weight coefficients (*a* and *b* values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length is 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 Guam MUS fisheries.

Table 44. Available length derived information for MUS in Guam

Species	Length derived parameters					Reference
	n	L_{max}	N_{L-W}	*a*	*b*	
Aphareus rutilans	184	90.5	86	0.0343	2.77	Kamikawa et al., (2015)
Caranx ignobilis	371					
Caranx lugubris	309	80.8	58	0.0250	2.94	Kamikawa et al., (2015)
Etelis carbunculus[1]	888	63.4	575	0.0159	3.03	Kamikawa et al., (2015)
Etelis coruscans	476	95.0	255	0.0425	2.75	Kamikawa et al., (2015)
Lethrinus rubrioperculatus	7681	46.6	2196	0.0228	2.94	Kamikawa et al., (2015)
Lutjanus kasmira	1395	30.3	460	0.0128	3.12	Kamikawa et al., (2015)
Pristipomoides auricilla	3345	39.0	1210	0.0135	3.11	Kamikawa et al., (2015)
Pristipomoides filamentosus	277	67.4	114	0.0225	2.93	Kamikawa et al., (2015)
Pristipomoides flavipinnis	657	59.4[1]	223	0.0210	2.95	Kamikawa et al., (2015)
Pristipomoides sieboldii	411	63.2	130	0.0243	2.91	Kamikawa et al., (2015)
Pristpomoides zonatus	925	57.5	329	0.0180	3.04	Kamikawa et al., (2015)
Variola louti	1149	49.0	716	0.0130	3.09	Kamikawa et al., (2015)

[1]The value in Kamikawa et al. 2015 is suspiciously high (76.6 cm). Guam Bio-Sampling database L_{max} is more reasonable, albeit still high.

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 (WPRFMC, 2009). 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 7), which is reflected in local culture, customs, and traditions.

Figure 7. 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 180th meeting held in Utulei, Tutuila, American Samoa, the Council requested NMFS continue to support future recreational summits or workshops on noncommercial fisheries data to continue the national exchange on noncommercial fishery reporting issues and initiatives. In 2019, PIFSC conducted a study to describe and characterize fishing activities in the region that do not clearly meet the MSA definition of recreational fishing. The study included national workshops that included discussion of issues related to data and reporting issues (Leong et al. 2020).

At its 178th meeting held in Honolulu, Hawai‘i, the Council directed staff to work with NMFS and American Samoa DMWR, CNMI DFW, Guam DAWR and Hawai‘i DAR on the revisions to the fisheries modules of the Archipelagic SAFE Reports due to the changes in the MUS brought about by the ecosystem component designation. As a result, this section of the SAFE Report has been reorganized accordingly.

At its 176th meeting held in Honolulu, Hawai‘i, related to the Charter Fishery Cost Earning Survey, the Council encouraged PIFSC to maintain a regular schedule for the economic evaluations and monitoring of the fisheries in the Pacific Islands. To address this, in 2019, PIFSC has added a section titled *Ongoing Research and Information Collection*, which outlines planned economic data collections across the region, included in this and future SAFE reports.

Also at its 176th meeting held in Honolulu, Hawai‘i, the Council requested NMFS PIFSC Socioeconomics Program to evaluate the economic impacts on US Pacific Island fisheries from the 2018 amendment to the Billfish Conservation Act. PIFSC and JIMAR staff developed a preliminary analysis of market impacts related to the Billfish Conservation Act. This report was presented to Council staff in June 2019, and further developed as a PIFSC Internal Report (Chan, 2020).

At the 174th Council meetings in Saipan and Guam, PIFSC staff met with members of the Marianas fishing community to discuss their concerns related to shark depredation for both insular and pelagic fisheries across the Marianas Archipelago and consider possible research opportunities. PIFSC conducted research in 2019-2020 to engage the Marianas fishing community to better understand the nature of shark interactions and explore mitigation techniques aligned with community needs and values. Results are being analyzed and a report is expected in 2020.

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 (WPRFMC, 2009). 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 Chamorro 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 Chamorro's 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 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. Although the CNMI has transitioned to a tourism-based economy, fishing still plays an important cultural role and serves as a reliable source of local food (Ayers, 2018).

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 monthly 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 fishermen 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 a fishing derby in celebration of San Francisco, 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 bottomfishing, 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 important. 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.

2.3.2.2.1 CNMI Bottomfish

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

2.3.2.2.2 CNMI Reef Fish

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

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

2.3.2.2.3 CNMI Crustaceans

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

2.3.2.2.4 CNMI Precious Corals

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

2.3.2.3 CNMI Economic Performance

2.3.2.3.1 CNMI Bottomfish Commercial Participation, Landings, Revenue, Prices

This section will describe trends in commercial pounds sold, revenues and prices, for the CNMI bottomfish fishery. Figure 8 presents the trends of commercial pounds sold and revenues of bottomfish fishery (BMUS only) during 2010-2019 and Figure 9 presents the trend of fish price of bottomfish sold for the same period. Supporting data for Figure 8 and Figure 9 are shown in Table 45. The table also includes the percentage of pounds sold relative to estimates of total pounds landed for the bottomfish fishery. Both nominal and adjusted values are included. As shown in Figure 8, the commercial landings of CNMI bottomfish are quite stable except for 2015 and 2018. Fish price shows an increasing trend up to 2015 but dropped in 2016 and has increased again increased in recent years.

It is worth noting that the data for pounds caught and pounds sold are collected by two different data collection methods. The data of pounds sold are collected through "Commercial Sales Receipt Books" Program, while the data of pounds caught are collected through "Boat-based Creel Survey" and "Shore-based Creel Survey" (https://www.pifsc.noaa.gov/wpacfin/cnmi/Pages/cnmi_coll_3.php). Both data series are generated from an expansion algorithm built on a non-census data collection program, and the survey coverage rates of two data collection methods may change independently across individual years. Therefore, the two time series may not move coherently to each other. For example, the low percentage of pounds sold compared to pounds caught could be due to low coverage of dealer participation in the Commercial Receipt Books Program, or ratios exceeding 100% could reflect differences between commercially important species present in commercial markets that may not be encountered often in creel surveys. In 2014, the ratio of pounds sold to pound caught of BMUS was particularly high, 210%, while the total pounds sold in 2014 were similar to the figures in the previous years and the estimated pounds caught was particularly low for 2014. Similarly, there is a very large discrepancy in

2018. It seems that the data quality for the pounds landed estimation in these years may have some issues.

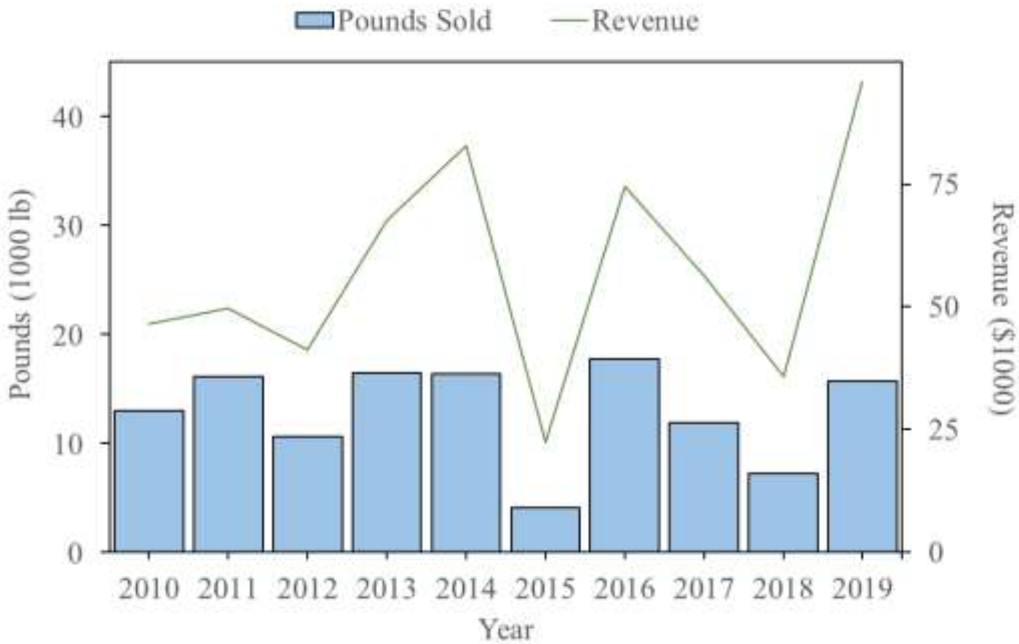


Figure 8. The commercial landings and revenues of BMUS, for the CNMI bottomfish fishery, 2010-2019 (Adjusted to 2019 dollars*)

Note: CPI information for CNMI were not available for 2016, 2017, 2018, and 2019, and the report assumed no CPI changes for the four years.

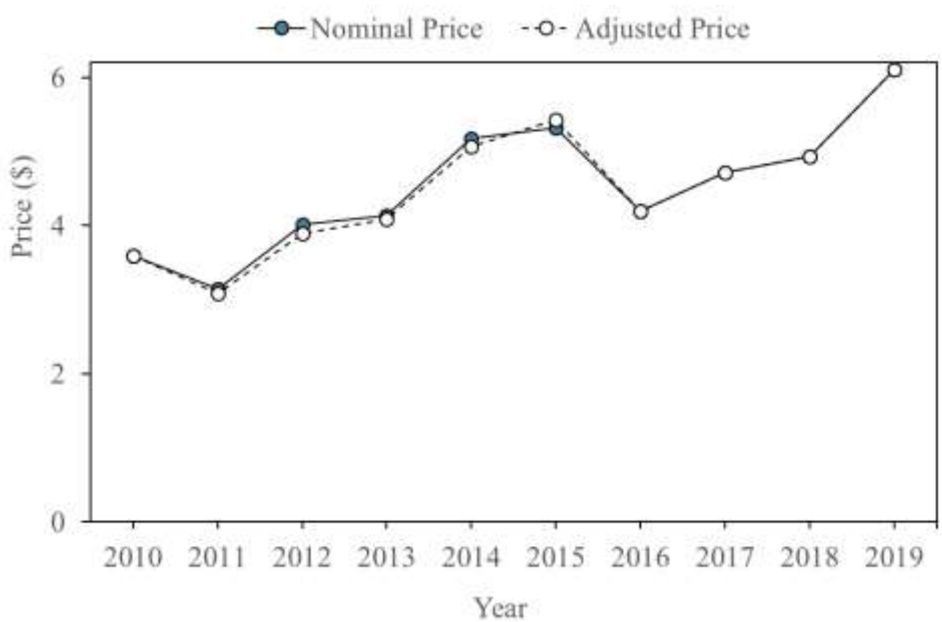


Figure 9. The prices of BMUS for the CNMI bottomfish fishery, 2010-2019

Table 45. Commercial landings and revenue information of CNMI bottomfish fishery, 2010-2019

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue ($)	Estimated revenue ($ adjusted)	% of pounds sold	Fish price ($)	Fish price ($ adjusted)	CPI adjustor
2010	56,007	12,970	46,595	46,595	23%	3.59	3.59	1
2011	25,799	16,115	50,757	49,742	62%	3.15	3.09	0.98
2012	137,496	10,591	42,471	41,197	8%	4.01	3.89	0.97
2013	20,392	16,500	68,211	67,529	81%	4.13	4.09	0.99
2014	7,740	16,334	84,508	82,818	211%	5.17	5.07	0.98
2015	10,386	4,122	21,917	22,355	40%	5.32	5.42	1.02
2016	54,334	17,717	74,445	74,445	33%	4.20	4.20	1
2017	48,007	11,925	56,241	56,241	25%	4.72	4.72	1
2018	650	7,260	35,840	35,840	1117%	4.94	4.94	1
2019	21,012	15,699	95,801	95,801	75%	6.10	6.10	1

Data source: PIFSC WPacFIN (* CPI information for CNMI were not available for 2016, 2017, 2018 and 2019 and the report assumed no CPI changes for the four years).

2.3.2.3.2 CNMI Bottomfish Costs of Fishing

Since 2009, PIFSC economists have maintained a continuous economic data collection program for small boat fisheries in Saipan through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN) (Chan and Pan, 2019). 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. 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 10 shows the trend of average trip costs for CNMI bottomfish trips during 2010–2019 (adjusted to 2019 dollars). Supporting data of Figure 10 are presented in Table 46. The trip costs seem to have substantial interannual variability. The average costs for a bottomfish trip was $73 in 2019, higher than the trip costs in 2018.

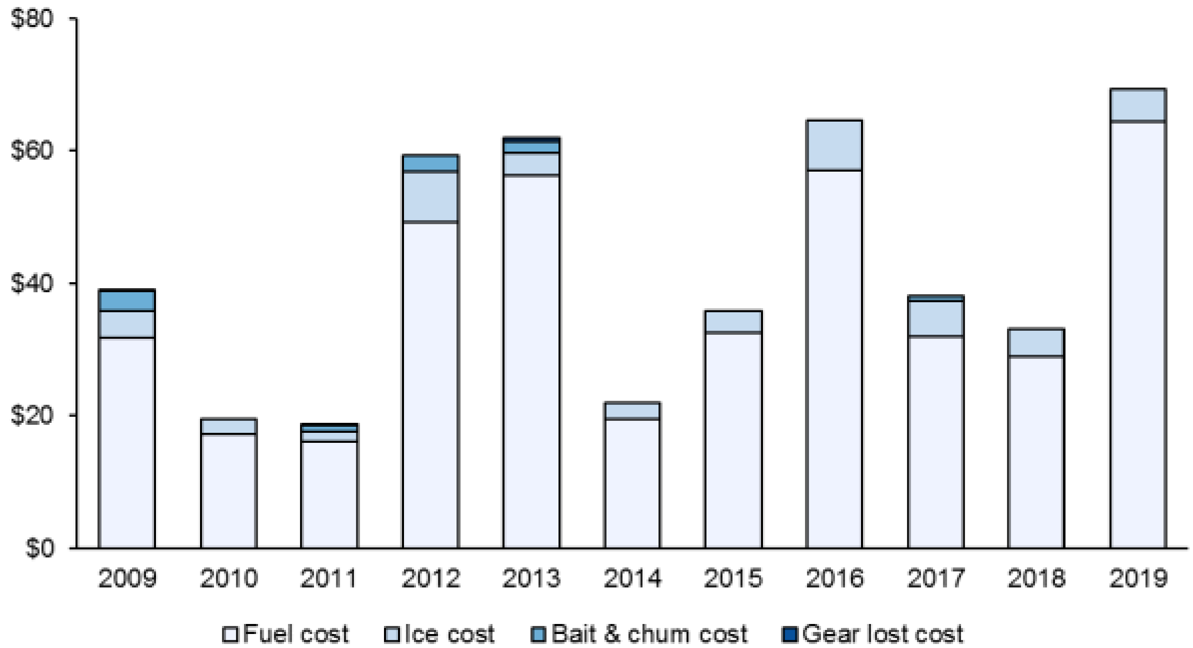


Figure 10. Average costs for CNMI bottomfish trips, 2010–2019 (adjusted to 2019 dollars*)

Table 46. Average trip costs for CNMI bottomfish trips, 2010–2019, adjusted to 2019 dollars*

Year	Total trip costs ($)	Total trip costs ($ adjusted)	Fuel cost ($ adjusted)	Ice cost ($ adjusted)	Bait & chum cost ($ adjusted)	Gear losted cost ($ adjusted)	Fuel price per gallon ($ adjusted)	CPI Adjustor
2009	40	42	31.8	4.0	2.9	0.1	3.5	1.053
2010	23	23	17.3	2.3	0.0	0.0	3.8	0.998
2011	24	23	16.0	1.5	1.0	0.1	4.6	0.976
2012	66	64	49.3	7.5	2.4	0.0	4.7	0.965
2013	68	67	56.2	3.4	1.7	0.6	5.0	0.990
2014	27	27	19.4	2.5	0.0	0.0	4.8	0.979
2015	39	40	32.6	3.2	0.0	0.0	4.2	1.021
2016	68	68	57.1	7.5	0.0	0.0	3.6	1.000
2017	42	42	32.1	5.4	0.7	0.0	3.9	1.000
2018	37	37	29.0	4.1	0.0	0.0	4.2	1.000
2019	73	73	64.4	4.9	0.0	0.0	3.9	1.000

* CPI information for CNMI were not available for 2016, 2017, 2018 and 2019 and the report assumed no CPI changes for the four years. Data source: PIFSC Continuous Cost Data Collection Program (Chan and Pan, 2019).

2.3.2.3.3 CNMI Ecosystem Component Species

Based on new guidelines for the archipelagic SAFE report from the Council, the SAFE report of this year highlights the top 10 ECS (sorted by landings) and the priority ECS (recommended by the local fishery management agency) caught by small boats or shoreline fishing. Please note the top 10 species list and the priority species list reported in the socioeconomic module may not be consistent with the lists reported in the fishery module in the previous sections. The inconsistences result from several factors: 1) differences in the data sources, 2) differences in the level of species groupings, 3) differences in commercial landing vs. total landings. First, the data for pounds caught and pounds sold are collected by two different data collection methods, as mentioned in the earlier section. The data of “pounds sold” (commercial landings) reported in this socioeconomics module were collected through “Commercial Sales Receipt Books” Program, while the data of pounds caught were collected through “Boat-based Creel Survey”. The survey coverage rates of two data collection methods may change independently in individual years. Secondly, the species groups used in the two data collection programs were different, as the species in the commercial receipt books usually were lumped into family levels or species groups while the species reported in the Creel Survey were more detailed at the species level. Third, fish species with higher total pounds caught may not necessarily lead to higher pounds sold in the markets. Therefore, the two series may not move coherently to each other.

Table 47 shows the commercial landings and revenue of the top 10 ECS in CNMI. The total pounds sold of the top 10 species/species groups was 25,160 pounds (valued at $89,314) in 2019, approximately 10,000 pounds lower than that in 2018. Compared to the pounds caught of the top 10 species (presented in the fishery module), the total pounds sold were near 10,000 pounds higher than pounds caught (10,265 pounds). Table 48 shows the ECS priority species. Eight fish species were suggested as the priority species (species of interests) for the area. Only two species of the eight species showed up in the commercial receipt books in 2019 and 2018.

Table 47. Top 10 ECS Commercial landings, revenue, and price

	2019			2018		
Top ECS Species	**Pounds Sold**	**Revenue**	**Price per Pound**	**Pounds Sold**	**Revenue**	**Price per Pound**
Assorted reef fish	9,499	25,106	2.64	10,943	28,739	2.63
Parrot (misc) /palakse/la	4,463	18,623	4.17	3,549	12,576	3.54
Surgeonfish (misc.)	2,849	8,130	2.85	4,483	11,496	2.56
Bigeye scad	1,655	5,283	3.19	3,925	12,667	3.23
Emperor (mafute/misc.)	1,640	4,589	2.80	6,095	17,560	2.88
Rudderfish/ guili	1,103	3,021	2.74	894	2,338	2.62
Goatfish/ satmoneti	1,071	3,060	2.86	1,929	4,993	2.59
Spiny lobster	971	15,003	15.45			
Rabbitfish (sesjun)	955	3,377	3.54			
Jacks (misc.)	954	3,122	3.27	904	2,717	3.01
Rabbitfishes (misc)				2,827	9,523	3.37
Rabbitfish (h.feda)				1136	3921	3.45
Sum	**25,160**	**89,314**	**3.55**	**36,685**	**106,530**	**2.90**

Data source: PIFSC WPacFIN, commercial receipt books.

Table 48. Priority ECS commercial landings, revenue, and price 2018 and 2019

	2019			2018		
Priority Species	**Pounds Sold**	**Revenue**	**Price per Pound**	**Pounds Sold**	**Revenue**	**Price per Pound**
Orangespine unicornfish	320	812	2.54	415	1,050	2.53
Forktail rabbitfish	293	1,023	3.49	1,008	3,441	3.41

Data source: PIFSC WPacFIN, commercial receipt books.

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 (WPRFMC, 2009). 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 Chamorro 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. Chamorro 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 Chamorro' 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, 2016).

Allen and Bartram (2008) reviewed the history of shoreline and inshore fishing in 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 in 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 in Guam: Chamorro, Micronesian, and Filipino. At that time, Chamorro comprised about 75% of the fishing parties encountered, while Micronesians constituted about 17% and Filipinos about 7%. A number of contemporary reef fishing methods in 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 in 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; 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 essential 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.

2.3.3.2.1 Guam Bottomfish

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

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

2.3.3.2.2 Guam Reef Fish

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

2.3.3.2.3 Guam Crustaceans

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

2.3.3.2.4 Guam Precious Corals

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

2.3.3.3 Guam Fishery Economic Performance

2.3.3.3.1 Guam Bottomfish Commercial Participations, Landings, Revenue, Prices

This section describes trends in commercial pounds sold, revenues and prices, for the Guam bottomfish fishery. Figure 11 presents the trends of commercial pounds sold and revenues of bottomfish fishery during 2010-2019 and Figure 12 presents the trend of total caught versus commercial landings pounds sold during 2010-2019 (for BMUS only). Supporting data for

Figure 11 and Figure 12 are shown in Table 49. Table 49 also includes the percentage of pounds sold to the total pounds caught of the bottomfish fishery. Both nominal and adjusted values are included in the table.

As showing in Figure 11, only two years of commercial landings and revenue are presented due to the number of respondents being fewer than 3 for the other years. The commercial landings of 2018 were lower than 2017. Trends in fish prices were not presented for the same data confidentiality concerns. The bottomfish fishery price in 2018 was $5.05 per pound on average. Compared to total pounds landed, the commercial landings of BMUS were only small portion. On average, in recent years (2009-2018), the pounds sold were only 15% of total estimated pounds caught. In 2018, the percentage pounds sold was 11% of total pounds caught. Bottomfish price have been steady in general, but there have been some variations in recent years.

It is worth noting that the data for pounds caught and pounds sold are collected by two different data collection methods. The data of pounds sold were collected through Commercial Sales Receipt Books Program, while the data of pounds caught were collected through Boat-based Creel Survey and Shore-based Creel Survey (https://www.pifsc.noaa.gov/wpacfin/guam/dawr/Pages/gdawr_coll_3.php). Both data series are generated from an expansion algorithm built on a non-census data collection program, and the survey coverage rates of two data collection methods may change independently across individual years. Therefore, the two time series may not move coherently to each other. For example, the low percentage of pounds sold compared to pounds caught could be due to the low coverage of dealer participation in the Commercial Receipt Books Program.

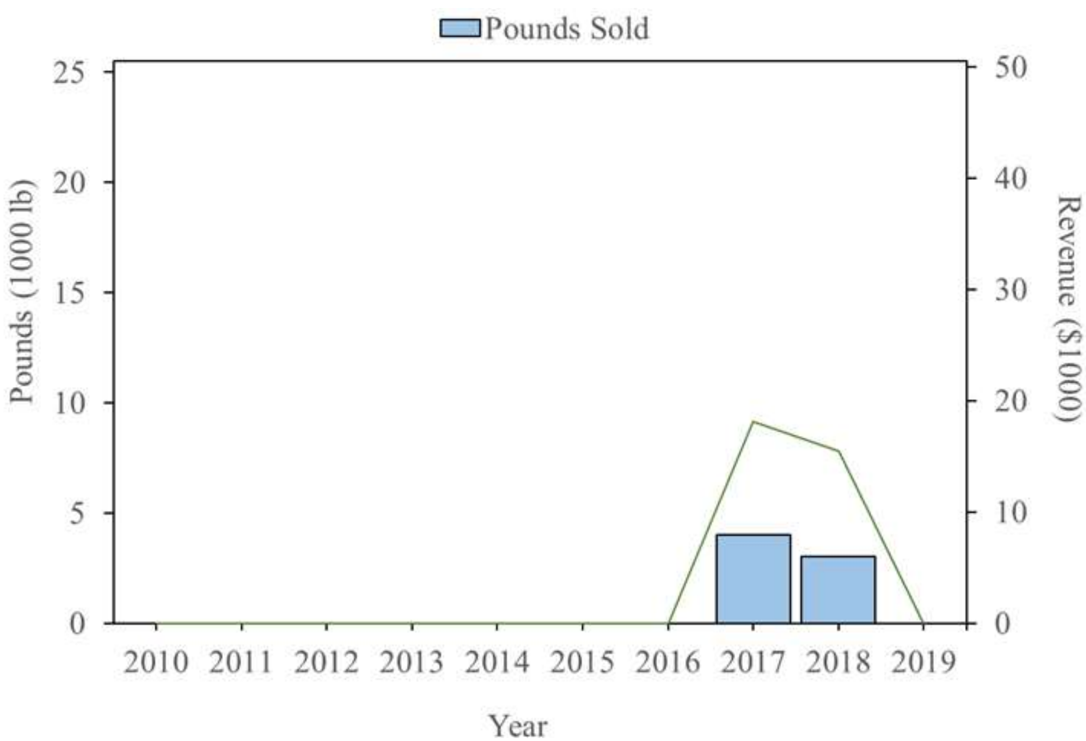


Figure 11. The pounds sold and revenues for the Guam bottomfish fishery, 2017-2018 (adjusted to 2018 dollars)

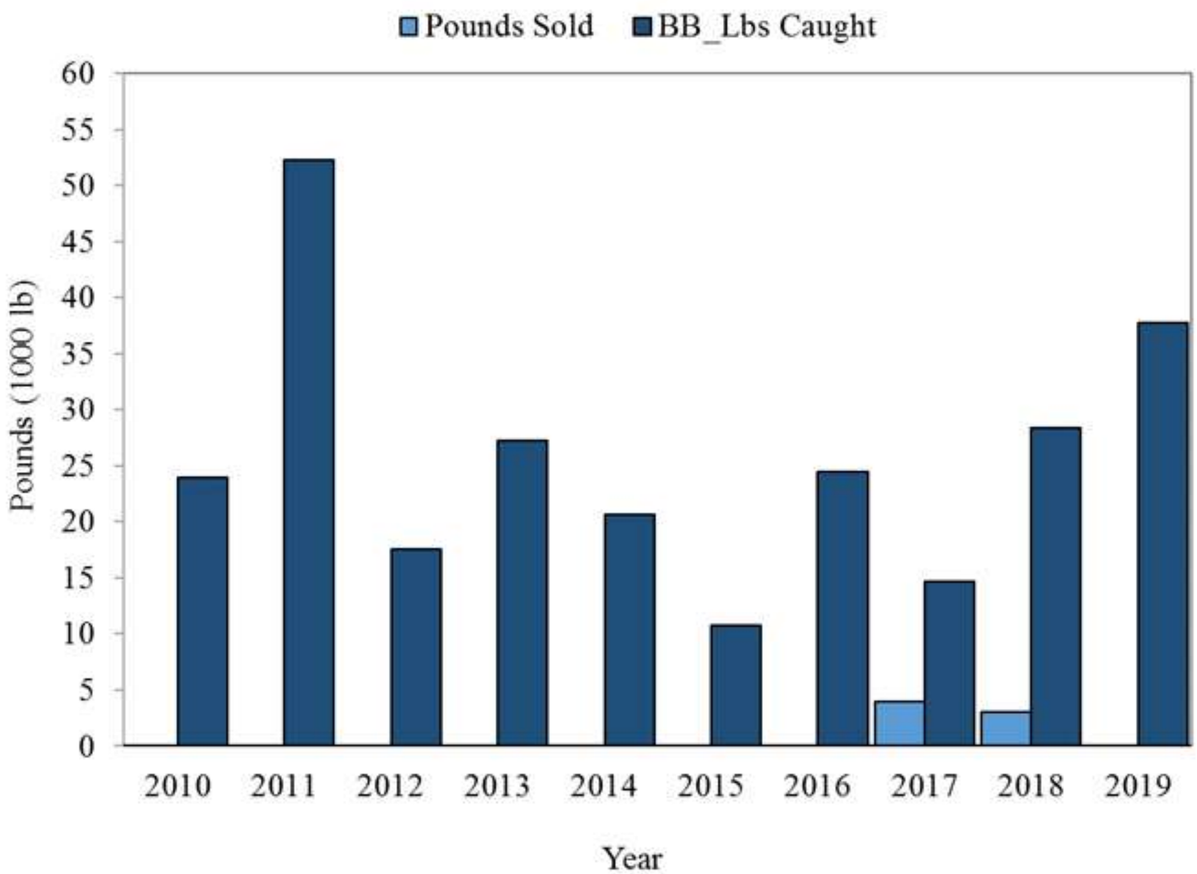


Figure 12. Pounds caught and pounds sold of BMUS for the Guam bottomfish fishery, 2010-2019

Table 49. Commercial landings, revenue, and price information of Guam bottomfish fishery, 2010-2019

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue ($)	Estimated revenue ($ adjusted)	% of pounds sold	Fish price ($)	Fish price ($ adjusted)	CPI adjustor
2010	23929	*	*	*	*	*	*	1.20
2011	52230	*	*	*	*	*	*	1.16
2012	17517	*	*	*	*	*	*	1.12
2013	27276	*	*	*	*	*	*	1.12
2014	20687	*	*	*	*	*	*	1.11
2015	10783	*	*	*	*	*	*	1.12
2016	24480	*	*	*	*	*	*	1.06
2017	14652	4002	17434	18131	27%	4.36	4.53	1.04
2018	28365	3028	15290	15443	11%	5.05	5.10	1.01
2019	37702	*	*	*	*	*	*	1.00

* Data are not presented due to the number of respondents was fewer than 3. Data source: PIFSC WPacFIN.

2.3.3.3.2 Guam Bottomfish Costs of Fishing

Since 2011, PIFSC economists have maintained a continuous economic data collection program for small boat fishing on Guam through collaboration with the PIFSC WPacFIN (Chan and Pan, 2019). 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. Metadata for these data are available online (PIFSC Socioeconomics Program, 2016). Guam trip cost estimates from 2011 for bottomfish fishing trips and other relevant cost information (such as estimates of annual fixed costs) are available in a one-time survey (Hospital and Beavers, 2012).

The time series of trip costs of Guam bottomfish fishing presented in Figure 13 are based on a continuous economic data collection program maintained by the PIFSC Socioeconomics Program through collaboration with the PIFSC WPacFIN. The fishing costs of bottomfish were in a declining trend from 2012-2016, and then went up substantially in 2017. The trip costs of 2018 and 2019 were lower than 2017. Supporting data for are presented in Table 50.

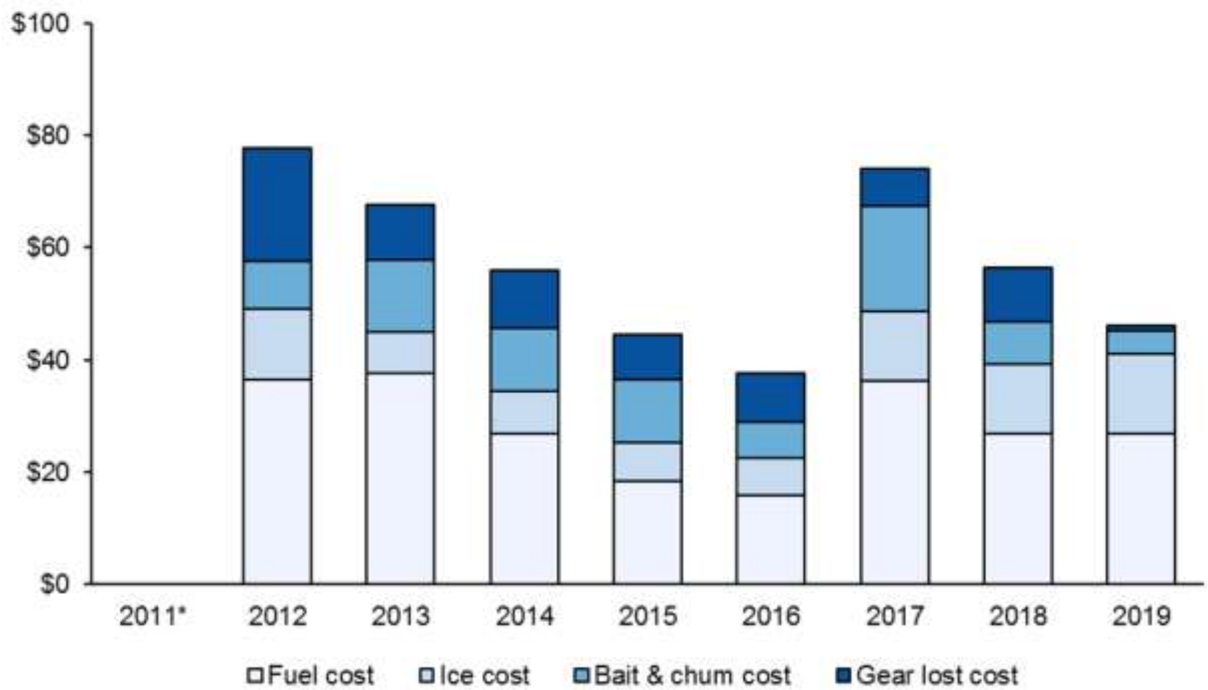


Figure 13. Average trip costs for Guam bottomfish fishing trips from 2011–2019 (adjusted to 2019 dollars).

* Data are not presented due to the number of boats (respondents) was fewer than 3.

Table 50. Average trip costs for Guam bottomfish fishing trips from 2011–2019

Year	Total trip costs ($)	Total trip costs ($ adjusted)	Fuel cost ($ adjusted)	Ice cost ($ adjusted)	Bait & chum cost ($ adjusted)	Gear losted cost ($ adjusted)	Fuel price per gallon ($ adjusted)	CPI Adjustor
2011*	-	-	-	-	-	-	-	1.16
2012	69.8	78.2	36.8	12.6	8.5	20.2	5.2	1.12
2013	60.8	68.1	38.0	7.2	13.1	9.8	5.3	1.12
2014	50.7	56.3	26.9	7.6	11.3	10.4	5.2	1.11
2015	40.0	44.8	18.6	6.8	11.4	8.0	4.4	1.12
2016	35.8	38.0	16.0	6.6	6.5	8.8	3.6	1.06
2017	72.2	75.1	36.8	12.5	19.0	6.8	3.8	1.04
2018	56.5	57.1	27.2	12.5	7.6	9.8	4.0	1.01
2019	46.1	46.1	26.8	14.1	4.3	0.9	3.8	1

2.3.3.3.3 Guam Ecosystem Component Species

Based on the new guideline for the archipelagic SAFE report from the Council, the SAFE report of this year highlighted the top 10 species (sorted by landings) and the priority species (recommended by the local fishery management agency) caught by small boats or shoreline fishing. Please note the top 10 species list and the priority species list reported in the socioeconomic module may not be consistent with the lists reported in the fishery module in the previous sections. The inconsistences result from several factors: 1) differences in the data sources, 2) differences in the level of species groupings, 3) differences in commercial landing vs. total landings. First, the data for pounds caught and pounds sold are collected by two different data collection methods, as mentioned in the earlier section. The data of "pounds sold" (commercial landings) reported in this socioeconomics module were collected through "Commercial Sales Receipt Books" Program, while the data of pounds caught were collected through "Boat-based Creel Survey". The survey coverage rates of two data collection methods may change independently in individual years. Secondly, the species groups used in the two data collection programs were different, as the species in the commercial receipt books usually were lumped into family levels or species groups while the species reported in the Creel Survey were more detailed at the species level. Third, fish species with higher total pounds caught may not necessarily lead to higher pounds sold in the markets. Therefore, the two series may not move coherently to each other.

Table 51 shows the commercial landings and revenue of the top 10 ECS in Guam. The total pounds sold of the top 10 species/species groups was 46,430 pounds (valued at $142,993) in 2019, approximately 34,000 pounds lower than that in 2018. Compared to the pounds caught of the top 10 species (presented in the fishery module), the total pounds sold of the top 10 ECS species were near 15,000 pounds higher than pounds caught. Nine fish species were suggested as the priority species (species of interests) for the area. However, none of the priority species showed up in the commercial receipt books in 2019 and 2018.

Table 51. Top 10 ECS commercial landings, revenue, and price 2018 and 2019

	2019			2018		
Top ECS Species	**Estimated Pounds Sold**	**Estimated Revenue**	**Price per Pound**	**Estimated Pounds Sold**	**Estimated Revenue**	**Price per Pound**
Reef fish	19,808	62,405	3.15	33,276	107,999	3.25
Bigeye scad (atulai)	12,218	36,753	3.01	5,859	16,856	2.88
Parrotfish	5,489	19,258	3.51	22,517	63,400	2.82
Mafute (emperor)	3,169	9,666	3.05	4,943	10,532	2.13
Invertebrates	1,632	1,632	1.00			
Octopus	1,118	4,049	3.62	4,220	15,660	3.71
Jacks	1,074	3,214	2.99			
Grouper	954	3,352	3.51	1,419	3,541	2.50
Blueline surgeonfish	564	1,417	2.51			
Orangespine unicornfish	404	1,247	3.09	1,602	3,334	2.08
Surgeonfish				2,578	6,045	2.34
Rabittfish (Hitting)				2,088	6,196	2.97
Snapper				1,767	4,251	2.41
Sum	**46,430**	**142,993**	**3.08**	**80,269**	**237,814**	**2.96**

Data source: PIFSC WPacFIN, commercial receipt books.

2.3.4 Ongoing Research and Information Collection

Each year, the PIFSC reports on the status of economic data collections for select regional commercial fisheries. This supports a national economic data monitoring effort known as the Commercial Fishing Economic Assessment Index (CFEAI). Details on the CFEAI and access to data from other regions is available at: https://www.st.nmfs.noaa.gov/data-and-tools/CFEAI-RFEAI/

The table below represents the most recent data available for CFEAI metrics for select regional commercial fisheries for 2019. Entries for Marianas insular fisheries are bolded in red. These values represent the most recent year of data for key economic data monitoring parameters (fishing revenues, operating costs, and fixed costs). The assessment column indicates the most recent publication year for specific economic assessments (returns above operating cost, profit), where available.

Table 52. Pacific Islands Region 2019 Commercial Fishing Economic Assessment Index

	2019 CFEAI				
	2019 Reporting Year (e.g. 1/2019-12/2019)				
	Data			Assessment	
Pacific Islands Fisheries	Fishing Revenue Most Recent Year	Operating Cost Most Recent Year	Fixed Cost Most Recent Year	Returns Above Operating Costs (Quasi Rent) Assessment Most Recent Year	Profit Assessment Most Recent Year
HI Longline	2019	2019	2013	2019	2016
ASam Longline	2019	2019	2016	2019	2019
HI Offshore Handline	2019	2014	2014	2019	2019
HI Small Boat (pelagic)	2019	2014	2014	2017	2019
HI Small Boat (bottomfish)	2019	2014	2014	2017	2019
HI Small Boat (reef)	2019	2014	2014	2017	2019
Guam Small boat	**2019**	**2019**	**2019**	**2019**	
CNMI Small boat	**2019**	**2019**	**2019**	**2019**	
ASam Small boat	2019	2019	2015	2019	

PIFSC also generates projections for upcoming fiscal years, and the table above provides the projected CFEAI report for 2020 (*all projected activities and analyses are subject to funding*). Based on early projections PIFSC intends to maintain ongoing economic data collections in the CNMI and Guam for small boat fisheries (Chan and Pan, 2019) during 2020.

PIFSC completed a cost-earnings survey of small boat fisheries in Guam and the CNMI during 2018-2019, to serve as an update to the previous 2011 cost-earnings survey (Hospital and Beavers, 2012; 2014). This 2018-2019 survey collected data on fishing revenues, operating costs, and fixed costs, as well as numerous elements related to fishing behavior, market participation, and fishery demographics. PIFSC intends for initial results of the 2018-2019 cost-earnings survey to be available in late 2020.

Table 53. Pacific Islands Region 2020 Commercial Fishing Economic Assessment Index

	2020 Projected CFEAI				
	2020 Reporting Year (e.g. 1/2020-12/2020)				
	Data			Assessment	
Pacific Islands Fisheries	Fishing Revenue Most Recent Year	Operating Cost Most Recent Year	Fixed Cost Most Recent Year	Returns Above Operating Costs (Quasi Rent) Assessment Most Recent Year	Profit Assessment Most Recent Year
HI Longline	2020	2020	2019	2020	2016
ASam Longline	2020	2020	2016	2020	2019
HI Offshore Handline	2020	2020	2020	2019	2019
HI Small Boat (pelagic)	2020	2020	2020	2017	2019
HI Small Boat (bottomfish)	2020	2020	2020	2017	2019
HI Small Boat (reef)	2020	2020	2020	2017	2019
Guam Small boat	**2020**	**2020**	**2019**	**2020**	
CNMI Small boat	**2020**	**2020**	**2019**	**2020**	
ASam Small boat	2020	2020	2020	2020	

Community social indicators have been generated for the CNMI and Guam (Kleiber *et al*., 2018) in accordance with a national project to describe and evaluate community well-being measured through social, economic, and psychological welfare (https://www.fisheries.noaa.gov/national/socioeconomics/social-indicators-fishing-communities-0) However, these indicators rely on Census data, and cannot be updated until 2020 Census data becomes available.

PIFSC scientists conducted research in the Marianas during 2019-2020 with the goal to engage the Marianas fishing community to better understand the nature of shark interactions and explore mitigation techniques aligned with community needs and values. Interviews, focus groups, and participant observation were conducted across Guam, Saipan, Tinian, and Rota. Nearly 100 stakeholders were engaged. Data analysis and reporting will be conducted in 2020.

2.3.5 Relevant PIFSC Economics and Human Dimensions Publications: 2019

Publication	MSRA Priority
Abrams KM, Leong K, Melena S, Teel T. 2019. Encouraging Safe Wildlife Viewing in National Parks: Effects of a Communication Campaign on Visitors' Behavior. Environmental Communication, 1-6. https://doi.org/10.1080/17524032.2019.1649291.	HC3.2.3
Chan HL, Pan M. 2019. Tracking economic performance indicators for small boat fisheries in America Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-79, 76 p.	HC1.1.1 HC1.1.7

https://doi.org/10.25923/8etp-x479.	
Duncan C, Patyk K, Wild MA, Shury T, Leong KM, Stephen C. 2019. Perspectives on wildlife health in national parks: concurrence with recent definitions of health. Human Dimensions of Wildlife.https://doi.org/10.1080/10871209.2019.1650402.	HC3.2.4
Hospital J, Schumacher B, Ayers A, Leong K, Severance C. 2019. A structure and process for considering social, economic, ecological, and management uncertainty information in setting of annual catch limits: SEEM* Pacific Islands Fisheries Science Center, PIFSC Internal Report, IR-19-011, 13 p.	IF5.1.2

2.4 PROTECTED SPECIES

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

2.4.1 Indicators for Monitoring Protected Species Interaction

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

2.4.2 FEP Conservation Measures

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

2.4.2.1 ESA Consultations

ESA consultations were conducted by NMFS and the U.S. Fish and Wildlife Service (USFWS; for species under their jurisdiction) to ensure ongoing fisheries operations managed under the Marianas FEP are not jeopardizing the continued existence of any ESA-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 54.

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.

Table 54. Summary of ESA consultations for Mariana Archipelago FEP Fisheries

Fishery	Consultation date	Consultation type[a]	Outcome[b]	Species
Bottomfish (CNMI & Guam)	3/8/2008	BiOp	NLAA	Loggerhead sea turtle
	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
	Initiated 6/5/2019	*Consultation ongoing*		Oceanic whitetip shark, giant manta ray
Coral reef ecosystem (CNMI & Guam)	3/7/2002	LOC	NLAA	Loggerhead sea turtle, leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, sei whale, sperm whale
	5/22/2002	LOC (USFWS)	NLAA	Green, hawksbill, leatherback, loggerhead and olive ridley turtles, Newell's shearwater, short-tailed albatross, Laysan duck, Laysan finch, Nihoa finch, Nihoa millerbird, Micronesian megapode, 6 terrestrial plants
	6/3/2008	LOC	NLAA	Green sea turtle, olive ridley sea turtle, hawksbill sea turtle, leatherback sea turtle, blue whale, fin whale, humpback whale, sei whale, sperm whale
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
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
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
Precious corals (CNMI & Guam)	10/4/1978	BiOp	Does not constitute threat	Sperm whale, leatherback sea turtle
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
Precious corals (Guam)	12/20/2000	LOC	NLAA	Humpback whale, green sea turtle, hawksbill sea turtle
All fisheries	4/29/2015	LOC	NLAA	Reef-building corals, scalloped hammerhead shark (Indo-west Pacific DPS)

[a] BiOp = Biological Opinion; LOC = Letter of Concurrence; BE = Biological Evaluation
[b] LAA = likely to adversely affect; NLAA = not likely to adversely affect.

2.4.2.1.1 Bottomfish Fishery

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

On June 5, 2019, NMFS reinitiated consultation for the Mariana Archipelago bottomfish fisheries due to the listing of the oceanic whitetip shark and giant manta ray under the ESA. On June 6, 2019, NMFS determined that the conduct of these bottomfish fisheries during the period of consultation will not violate ESA Section 7(a)(2) and 7(d).

2.4.2.1.2 Crustacean Fishery

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

On September 18, 2018, NMFS concluded that Mariana Archipelago crustacean fisheries will have no effect on the oceanic whitetip shark and giant manta ray.

2.4.2.1.3 Coral Reef Fishery

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

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

On September 18, 2018, NMFS concluded that Mariana Archipelago coral reef fisheries will have no effect on the oceanic whitetip shark and giant manta ray.

2.4.2.1.4 Precious Coral Fishery

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

On September 18, 2018, NMFS concluded that Mariana Archipelago precious coral fisheries will have no effect on the oceanic whitetip shark and giant manta ray.

2.4.2.2 Non-ESA Marine Mammals

The MMPA requires NMFS to annually publish a List of Fisheries (LOF) that classifies commercial fisheries in one of three categories based on the level of mortality and serious injury of marine mammals associated with that fishery. According to the 2020 LOF (85 FR 54543, April 16, 2020), the Guam and CNMI bottomfish fisheries operating under the Marianas FEP are classified as Category III fisheries (i.e., a remote likelihood of or no known incidental mortality and serious injury of marine mammals).

2.4.3 Status of Protected Species Interactions in the Marianas FEP Fisheries

2.4.3.1 Bottomfish Fisheries

2.4.3.1.1 Sea Turtle, Marine Mammal, and Seabird Interactions

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

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 sea turtle, marine mammal, or seabird species from this fishery have changed in recent years.

2.4.3.1.2 Elasmobranch Interactions

As indicated in Section 2.4.2.1, ESA consultation for newly listed elasmobranch species is ongoing. Available information on elasmobranch interactions in the Guam and CNMI bottomfish fishery are included here, based on the Biological Evaluation (BE) initiating ESA Section 7 consultation for the fishery (NMFS, 2019).

There is limited data on fishery interactions with oceanic white tip sharks in Pacific Island bottomfish fisheries. Where data exists, some datasets identified oceanic whitetip shark captures to the species level, while others categorized oceanic whitetip sharks and whitetip reef sharks as "whitetip shark."

Guam and CNMI bottomfish boat-based creel surveys indicate that fishermen catch whitetip reef sharks more frequently than oceanic whitetip sharks. From 1982 to 2017, Guam DAWR recorded 39 whitetip reef sharks and 3 oceanic whitetip sharks in the Guam boat-based creel survey (NMFS, 2019). There have been no records of oceanic whitetip sharks in the CNMI boat-based creel surveys administered by CNMI DFW since the start of the dataset in 2000.

While bottomfish fishing surveys in the main Hawaiian Islands (PIFSC unpublished survey) and Guam (Kendall Enterprise Inc. 2014) show records of whitetip reef shark captures, there have not been any oceanic whitetip sharks recorded in bottomfish surveys or other PIFSC research activities. In addition to the bottomfish surveys, PIFSC researchers have conducted limited bottomfish fishing in the Pacific Islands region for life history research purposes since 2007. They typically fish once to twice a year and land a maximum of 1,200 kg of bottomfish each time they fish. In the last five years (2013-2018), there was one trip each to Johnston Atoll, the CNMI, Guam, and American Samoa, and Samoa. There are no records of researchers catching oceanic whitetip sharks while conducting these activities. There was one record in Guam of an oceanic whitetip shark depredating hooked fish, but did not become hooked or entangled on the line (NMFS, 2019).

The federal commercial bottomfish logbook form in the CNMI has a write-in space for recording catch by species under the shark category. Between 2009, when logbooks were implemented, and 2017, fishermen recorded 33 sharks as "whitetip shark", which may be whitetip reef sharks or oceanic whitetip sharks. Based on catch composition associated with the whitetip shark captures, most records were associated with shallow-water fish species captures, which are more likely to be whitetip reef sharks. Twelve of the 33 whitetip shark captures were associated with deep-water bottomfish species, which could potentially be oceanic whitetip sharks (NMFS, 2019).

2.4.3.2 Coral Reef Fisheries

There are no observer data available for the Guam and CNMI 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 commercial coral reef fisheries will not affect marine mammals in any manner not considered or authorized under the MMPA.

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

2.4.3.3 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 MMPA.

2.4.4 Identification of Emerging Issues

Table 55 summarizes current candidate ESA species, recent listing status, and post-listing activity (critical habitat designation and recovery plan development). Impacts from FEP-managed fisheries on any new listings and critical habitat designations will be considered in future versions of this report.

Table 55. Status of candidate ESA species, recent ESA listing processes, and post-listing activities

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)	Designation not prudent; no areas within US jurisdiction that meet definition of critical habitat (85 FR 12898, 3/5/2020)	In development; recovery planning workshops convened in 2019; draft plan anticipated in late 2020.
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)	Designation not prudent; no areas within US jurisdiction that meet definition of critical habitat (84 FR 66652, 12/5/2019)	Recovery outline published 12/4/19 to serve as interim guidance until full recovery plan is developed.
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, proposed rule anticipated by July 2020	In development, expected TBA, interim recovery outline in place
Cauliflower coral	*Pocillopora meandrina*	Positive (83 FR 47592, 9/20/2018)	12-month finding anticipated by June 2020	TBA	N/A	N/A
Giant Clams	*Hippopus, H. porcellanus, Tridacna costata, T. derasa, T. gigas, T. Squamosa,* and *T. tevoroa*	Positive (82 FR 28946, 06/26/2017)	TBA (status review ongoing)	TBA	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**
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	TBA
Leatherback sea turtle	*Dermochelys coriacea*	Positive 90-day finding on a petition to identify the Northwest Atlantic leatherback turtle as a DPS (82 FR 57565, 12/06/2017)	TBA (status review and 12-month finding anticipated in 2020)	TBA	N/A	N/A
Humpback whale	*Megaptera novaeangliae*	Positive 90-day finding on petition to classify the North Pacific population as DPS and delist the DPS (78 FR 53391, 8/29/2013)	Revision of species-wide listing and listing of four DPSs as threatened or endangered (80 FR 22304)	Revision of species wide listing; Western North Pacific DPS listed as endangered (81 FR 62259, 9/8/2016)	Proposed; no critical habitat proposed for waters around the Mariana Archipelago (84 FR 54354, 10/9/2019); final rule TBA	TBA

2.4.5 Identification of Research, Data, and Assessment Needs

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

- Improve species identification of commercial and non-commercial fisheries data (e.g., outreach, use FAO species codes) to improve understanding of potential protected species impacts.
- Define and evaluate innovative approaches to derive robust estimates of protected species interactions in insular fisheries.
- Conduct genetic and telemetry research to improve understanding of population structure and movement patterns for listed elasmobranchs.
- Estimates of post release survival for incidental protected species.

2.5 CLIMATE AND OCEANIC INDICATORS

2.5.1 Introduction

Over the past few years, the Council has incorporated climate change into the overall management of the fisheries over which it has jurisdiction. This 2019 Annual SAFE Report includes a now standard chapter on indicators of climate and oceanic conditions in the Western Pacific region. These indicators reflect global climate variability and change as well as trends in local oceanographic conditions.

The 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 are numerous:

- 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 as well as the development of a Climate Science Strategy by NMFS in 2015 and the subsequent development of the Pacific Islands Regional Action Plan for climate science; and
- The Council's own engagement with NOAA as well as jurisdictional fishery management agencies in American Samoa, CNMI, Guam, and Hawaii as well as fishing industry representatives and local communities in those jurisdictions.

In 2013, the Council began restructuring its Marine Protected Area/Coastal and Marine Spatial Planning Committee to include a focus on climate change, and the committee was renamed as the Marine Planning and Climate Change (MPCC) Committee. In 2015, based on recommendations from the committee, the Council adopted its Marine Planning and Climate Change Policy and Action Plan, which provided guidance to the Council on implementing climate change measures, including climate change research and data needs. The revised Pelagic FEP (February 2016) included a discussion on climate change data and research as well as a new objective (Objective 9) that states the Council should consider the implications of climate change in decision-making, with the following sub-objectives:

- To identify and prioritize research that examines the effects of climate change on Council-managed fisheries and fishing communities.
- To ensure climate change considerations are incorporated into the analysis of management alternatives.
- To monitor climate change related variables via the Council's Annual Reports.
- To engage in climate change outreach with U.S. Pacific Islands communities.

Beginning with the 2015 report, the Council and its partners began providing continuing descriptions of changes in a series of climate and oceanic indicators.

This annual report focuses previous years' efforts by refining existing indicators and improving communication of their relevance and status. Future reports will include additional indicators as the information becomes available and their relevance to the development, evaluation, and revision of the FEPs becomes clearer. Working with national and jurisdictional partners, the

Council will make all datasets used in the preparation of this and future reports available and easily accessible.

2.5.2 Response to Previous Plan Team and Council Recommendations

There were no Council recommendations relevant to the climate and oceanic indicators section of the Annual SAFE Report in 2019.

At its 170th meeting from June 20-22, 2017, the Council directed staff to support the development of community training and outreach materials and activities on climate change. In addition, the Council directed staff to coordinate a "train-the-trainers" workshop that includes NOAA scientists who presented at the 6th Marine Planning and Climate Change Committee (MPCCC) meeting and the MPCCC committee members in preparation for community workshops on climate and fisheries. The Council and NOAA partnered to deliver the workshops in the fall of 2017 to the MPCCC members in Hawaii (with the Hawaii Regional Ecosystem Advisory Committee), as well as American Samoa, Guam, and the CNMI (with their respective Advisory Panel groups). Feedback from workshop participants has been incorporated into this year's climate and oceanic indicator section. To prepare for community outreach, Guam-based MPCCC members conducted a climate change survey and shared the results with the MPCCC at its 7th meeting on April 10th and 11th, 2018.

Prior to holding its 8th meeting, the MPCCC was disbanded in early 2019, re-allocating its responsibilities among its members already on other committees or teams, such as the Fishery Ecosystem Plan Teams.

2.5.3 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 impact ocean and coastal ecosystems and human communities. The Council adapted this model with considerations relevant to the fishery resources of the Western Pacific region:

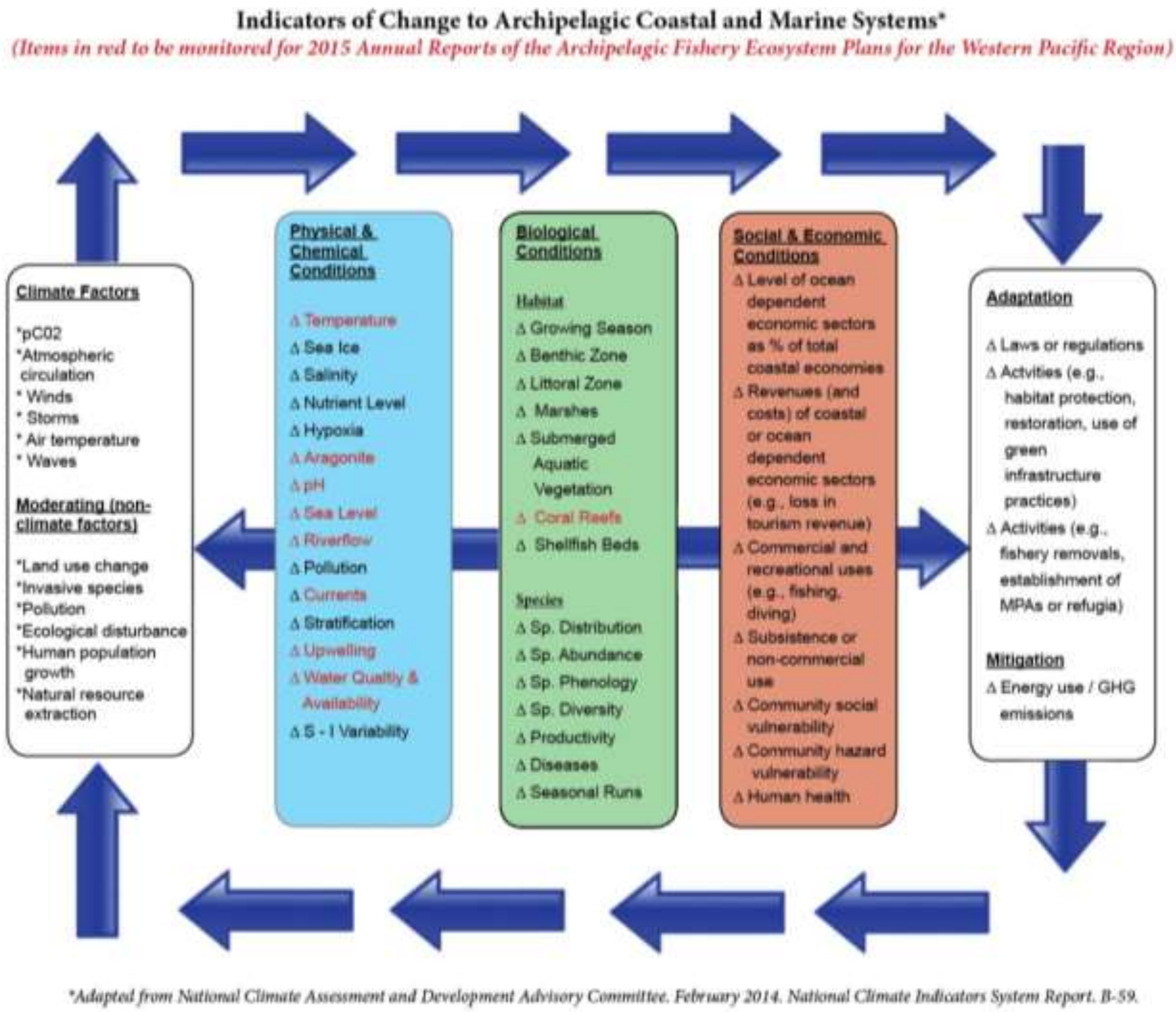


Figure 14. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability

As described in the 2014 NCADAC report, the conceptual model presents 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 annual SAFE reports, though the final list of indicators varied somewhat. Other indicators will be added over time as data become available and an understanding 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. This guide will ideally enable the Council and its partners to move forward from observations and correlations to understanding the specific nature of interactions, and to develop capabilities to predict future changes of importance in the developing, evaluating, and adapting of FEPs in the Western Pacific region.

2.5.4 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.

In this context, this section includes the following climate and oceanic indicators:

- Atmospheric concentration of carbon dioxide (CO_2)
- Oceanic pH at Station ALOHA;
- Oceanic Niño Index (ONI);
- Pacific Decadal Oscillation (PDO);
- Tropical cyclones;
- Sea surface temperature (SST);
- Coral Thermal Stress Exposure
- Chlorophyll-A (Chl-A)
- Rainfall
- Sea Level (Sea Surface Height)

Figure 15 and Figure 16 provide a description of these indicators and illustrate how they are connected to each other in terms of natural climate variability and anthropogenic climate change.

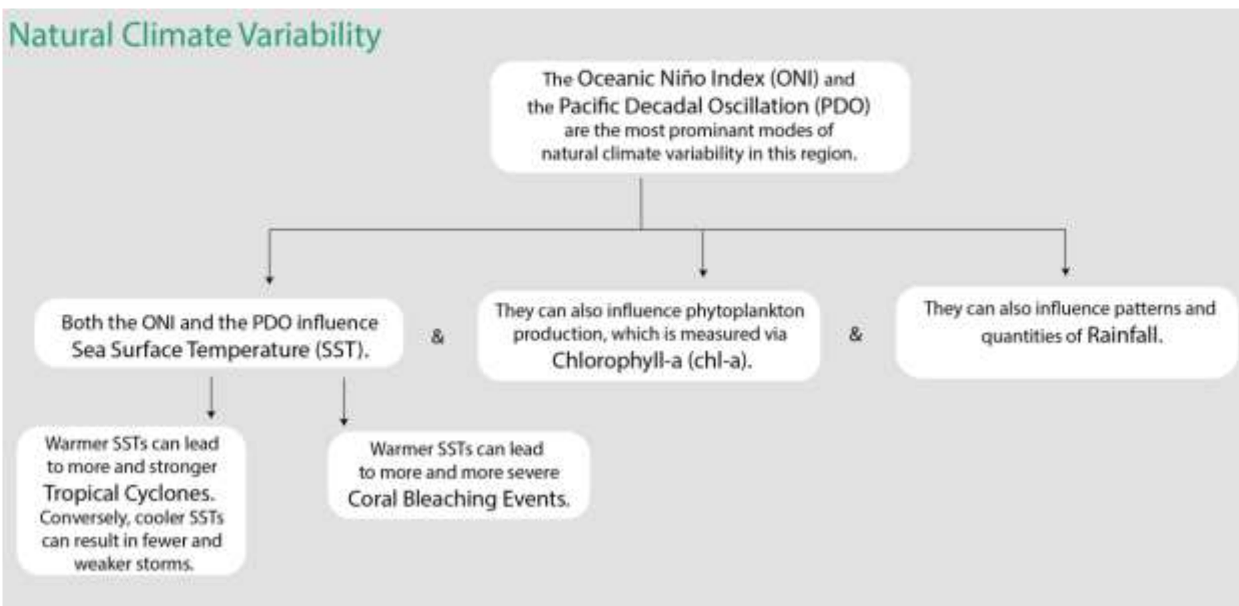


Figure 15. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability

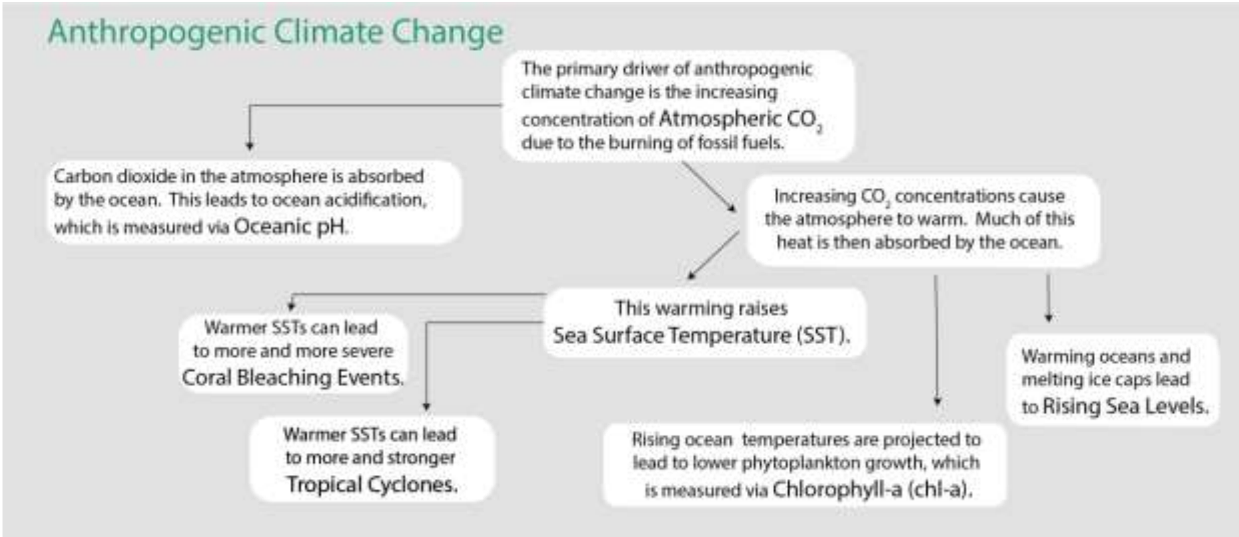


Figure 16. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of anthropogenic climate change

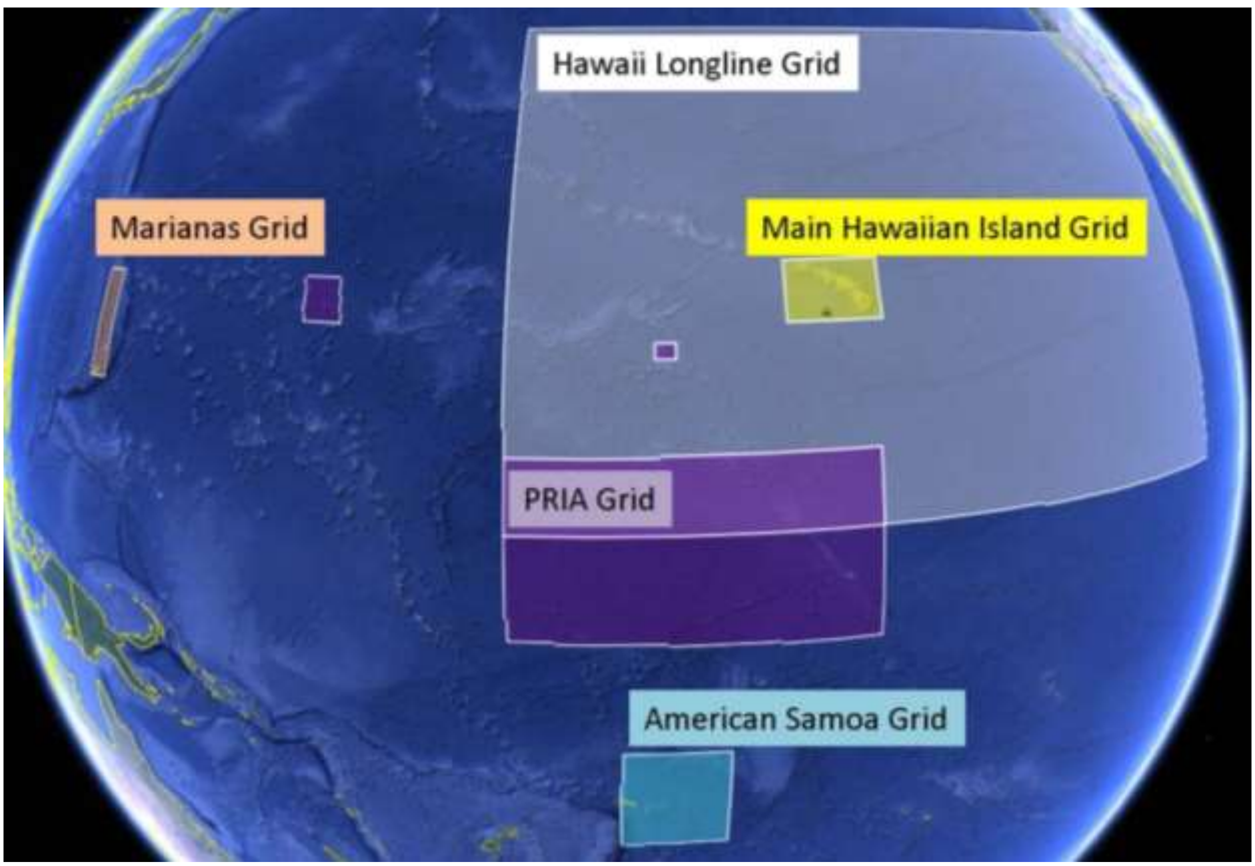


Figure 17. Regional spatial grids representing the scale of the climate change indicators being monitored

2.5.4.1 Atmospheric Concentration of Carbon Dioxide at Mauna Loa

Rationale: Atmospheric carbon dioxide (CO_2) 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 meaning that it is increasing at a faster rate each year. In 2019, the annual mean concentration of CO_2 was 411 ppm. In 1959, the first year of the time series, it was 316 ppm. The annual mean passed 350 ppm in 1988 and 400 ppm in 2015 (NOAA, 2020a).

Description: Monthly mean atmospheric carbon dioxide (CO_2) at Mauna Loa Observatory, Hawaii 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, Hawaii 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, Hawaii but representative of global atmospheric carbon dioxide concentration.

Measurement Platform: *In-situ* station.

Sourced from: Keeling et al. (1976), Thoning et al. (1989), and NOAA (2020a).

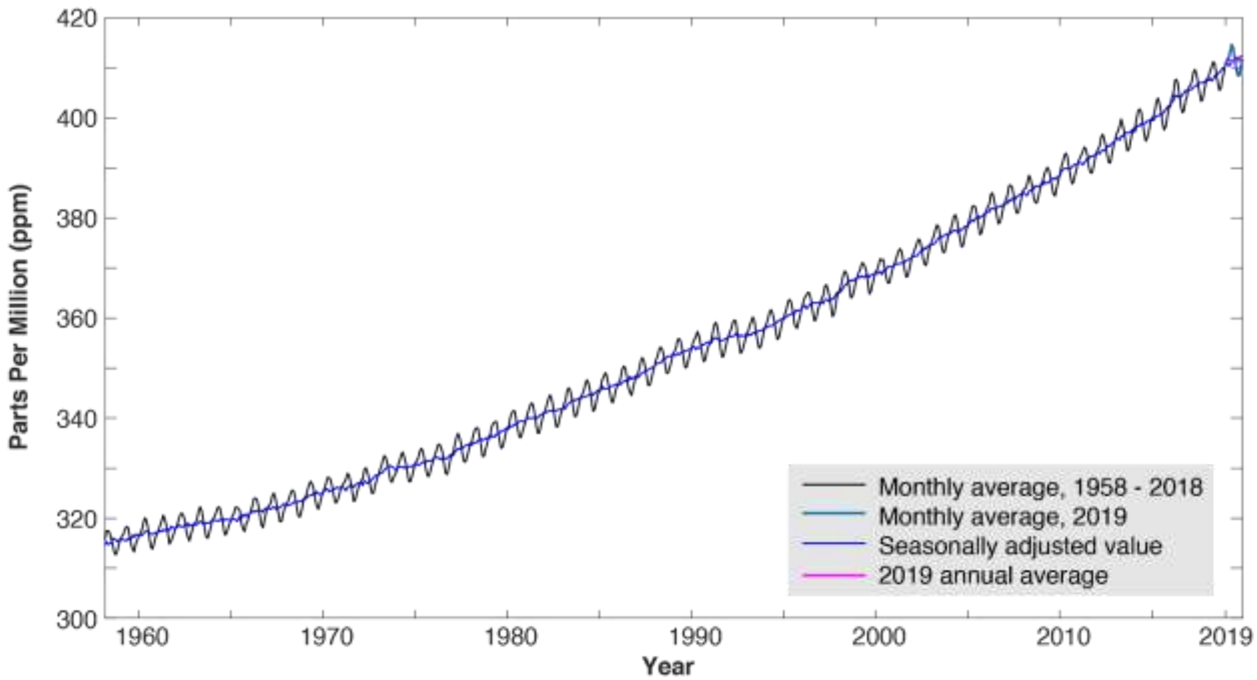


Figure 18. Monthly mean (red) and seasonally corrected (black) atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii

2.5.4.2 Oceanic pH

Rationale: Oceanic 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 limits the ability of marine organisms to build shells and other calcareous structures. Recent research has shown that pelagic organisms such as 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: The ocean is roughly 9.7% more acidic than it was nearly 30 years ago at the start of this time series. Over this time, pH has declined by 0.0401 at a constant rate. In 2018, the most recent year for which data are available, the average pH was 8.07. Additionally, small variations seen over the course of the year are now outside the range seen in the first year of the time series. The highest pH value reported for the most recent year (8.0743, down from a high of 8.0830 in 2017) is lower than the lowest pH value reported in the first year of the time series (8.0845).

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 2018 (2019 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. Oceanic pH is calculated from total alkalinity (TA) and dissolved inorganic carbon (DIC). TA represents the ocean's capacity to resist acidification as it absorbs CO_2 and the amount of CO_2 absorbed is captured through measurements of DIC. 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.

Measurement Platform: *In-situ* station.

Sourced from: Fabry et al. (2008), Feely et al. (2016). These data are based upon Hawaii Ocean Time-series observations supported by the U.S. National Science Foundation under Grant OCE-12-60164 a as described in Karl et al. (1996) and on its website (HOT, 2020).

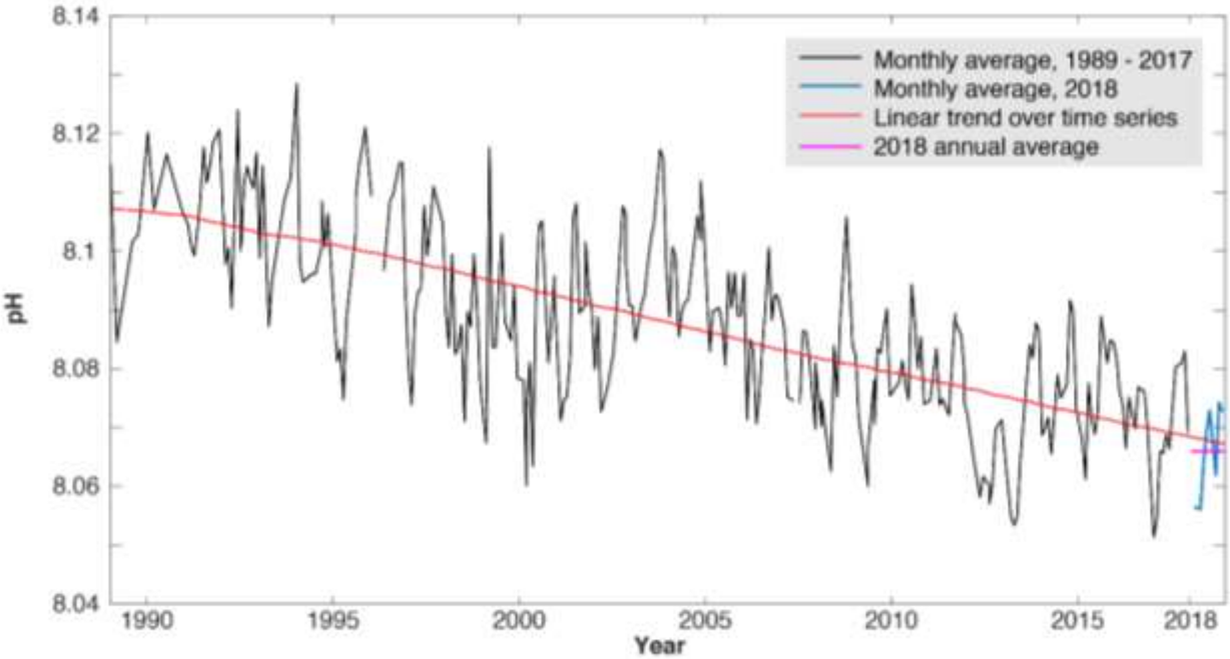


Figure 19. Oceanic pH (black) and its trend (red) at Station ALOHA from 1989 – 2018

2.5.4.3 Oceanic Niño Index

Rationale: The El Niño – Southern Oscillation (ENSO) cycle is known to have impacts on Pacific fisheries including tuna fisheries. The Oceanic Niño Index (ONI) focuses on ocean temperature, which has the most direct effect on these fisheries.

Status: In 2019, the ONI transitioned from a weak El Niño to neutral conditions.

Description: The three-month running mean of satellite remotely-sensed sea surface temperature (SST) anomalies in the Niño 3.4 region (5°S – 5°N, 120° – 170°W). The ONI is a measure of the 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 ENSO is measured using the Southern Oscillation Index.

Timeframe: Every three months.

Region/Location: Niño 3.4 region, 5°S – 5°N, 120° – 170°W.

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

Sourced from NOAA CPC (2020).

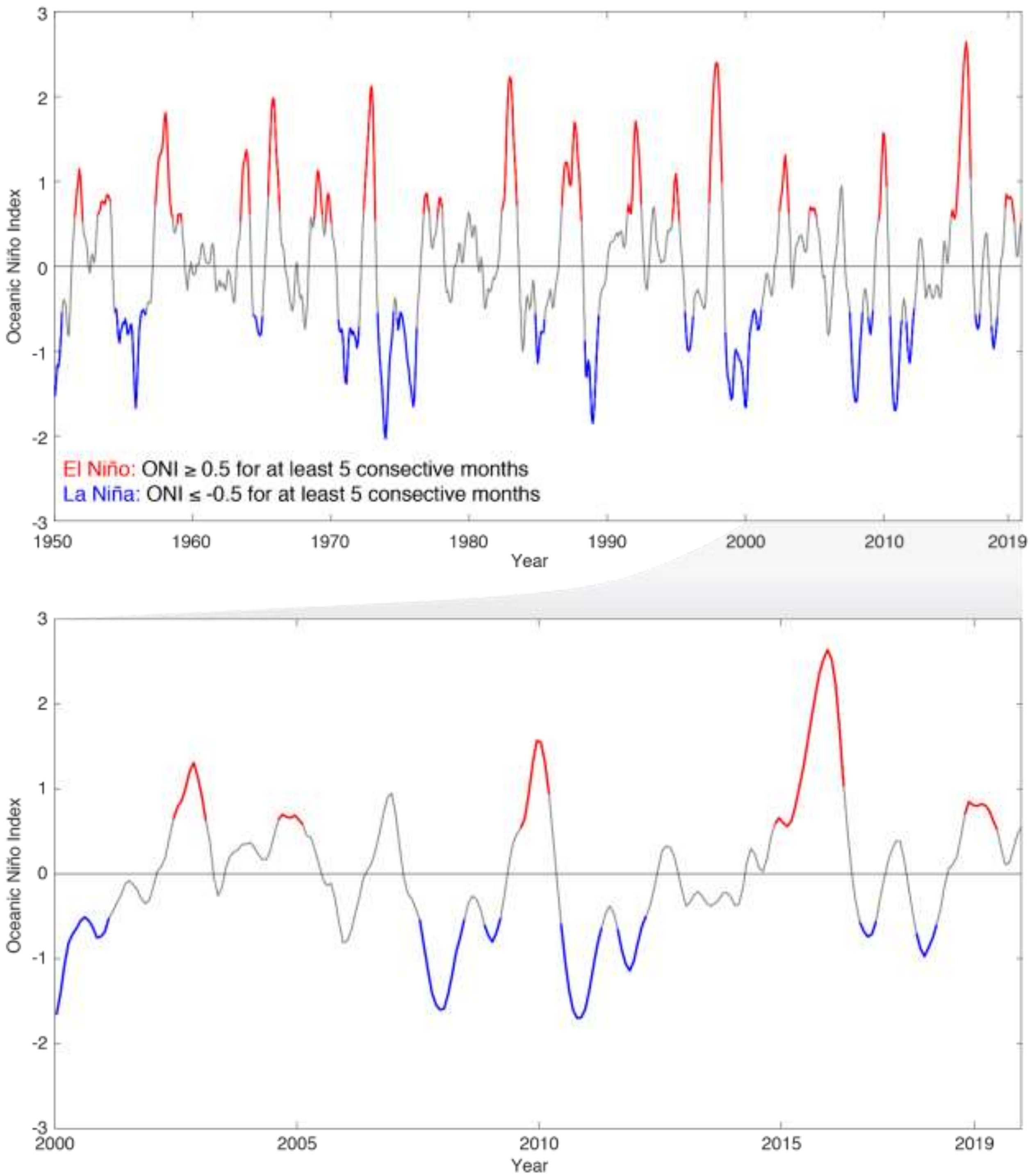


Figure 20. Oceanic Niño Index from 1950-2019 (top) and 2000–2019 (bottom) with El Niño periods in red and La Niña periods in blue

2.5.4.4 Pacific Decadal Oscillation

Rationale: The Pacific Decadal Oscillation (PDO) was initially named by 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 to 30 years (versus six to 18 months for ENSO events). The climatic fingerprints of the PDO are most visible in the Northeastern Pacific, but secondary signatures exist in the tropics.

Status: The PDO hovered around zero in 2019. The year was nearly evenly split between values that were slightly negative (seven months) and values that were slightly positive (five months).

Description: The PDO is often described as a long-lived El Niño-like pattern of Pacific climate variability. As seen with the better-known 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 SST is below average 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 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 NOAA (2020b).

Timeframe: Annual, monthly.

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

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

Sourced from: NOAA (2020b) and Mantua (2017).

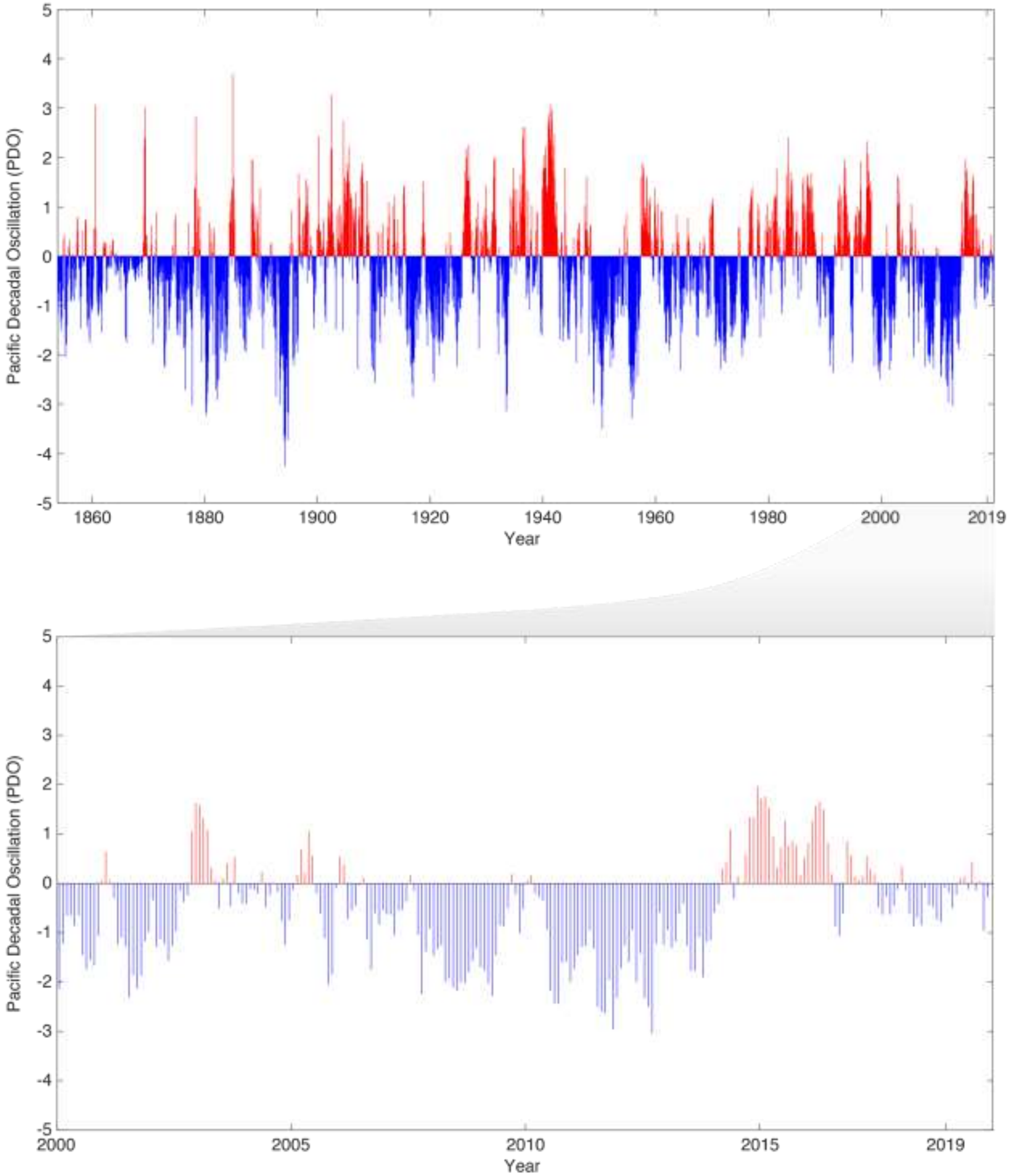


Figure 21. Pacific Decadal Oscillation from 1950–2018 (top) and 2000–2018 (bottom) with positive warm periods in red and negative cool periods in blue

2.5.4.5 Tropical Cyclones

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 Hawai`i longline fishery, for example, has had serious problems 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. Associated storm surge, the large volume of ocean water pushed toward shore by cyclones' strong winds, can cause severe flooding and destruction.

Status:

Eastern North Pacific. Overall, the 2019 eastern Pacific hurricane season featured near average activity. There were 17 named storms, of which seven became hurricanes and three became major hurricanes - category 3 or higher on the Saffir-Simpson Hurricane Wind Scale. This compares to the long-term averages of fifteen named storms, eight hurricanes, and four major hurricanes. There were also two tropical depressions that did not reach tropical storm strength. In terms of Accumulated Cyclone Energy (ACE), which measures the strength and duration of tropical storms and hurricanes, activity in the basin in 2019 was a little below the long-term mean. Summary inserted from https://www.nhc.noaa.gov/text/MIATWSEP.shtml.

Central North Pacific. Tropical cyclone activity in the central Pacific in 2019 was average. There were four named storms, of which one became a hurricane and one became a major hurricane. The ACE index was slightly below the 1981 – 2010 average of roughly 20 (x 10^4 knots^2).

Western North Pacific. Tropical cyclone activity was roughly average in the western Pacific in 2019. There were 26 named storms. Sixteen of these storms developed into typhoons, and ten of these typhoons were major. The ACE Index was below the 1981 – 2010 average. Of note was Super typhoon Hagibis. Hagibis was just the third category 5 tropical cyclone globally in 2019 (Super Typhoon Wutip and Hurricane Dorian were the others). Hagibis weakened to a category 2 storm before making landfall in Japan but was still one of the most damaging typhoons in history. The remnants of Hagibis transitioned to an extratropical cyclone that affected the Aleutian Islands and significantly altered the weather patterns over the North America in the subsequent days. Summary inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201910.

South Pacific. Tropical cyclone activity was average in the south Pacific region in 2019. There were nine named storms, four of which developed into cyclones and one of which was a major cyclone. The ACE Index was below average in 2019.

Description: This indicator uses historical data from the NOAA National Climate Data Center (NCDC) International Best Track Archive for Climate Stewardship to track the number of tropical cyclones in the western, central, eastern, and southern Pacific basins. This indicator also monitors the ACE Index and the Power Dissipation Index which are two ways of monitoring the frequency, strength, and duration of tropical cyclones based on wind speed measurements.

The annual frequency of storms passing through each basin is tracked and a stacked time series plot shows the representative breakdown of Saffir-Simpson hurricane categories.

Every cyclone has an ACE Index value, which is a number 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 knots; 39 mph). Therefore, a storm's ACE Index value accounts for both strength and duration. This plot shows the historical ACE values for each hurricane/typhoon season and has a horizontal line representing the average annual ACE value.

Timeframe: Annual.

Region/Location:

Eastern North Pacific: east of 140° W, north of the equator.

Central North Pacific: 180° - 140° W, north of the equator.

Western North Pacific: west of 180°, north of the equator.

South Pacific: south of the equator.

Measurement Platform: Satellite.

Sourced from: Knapp et al. (2010), Knapp et al. (2018).

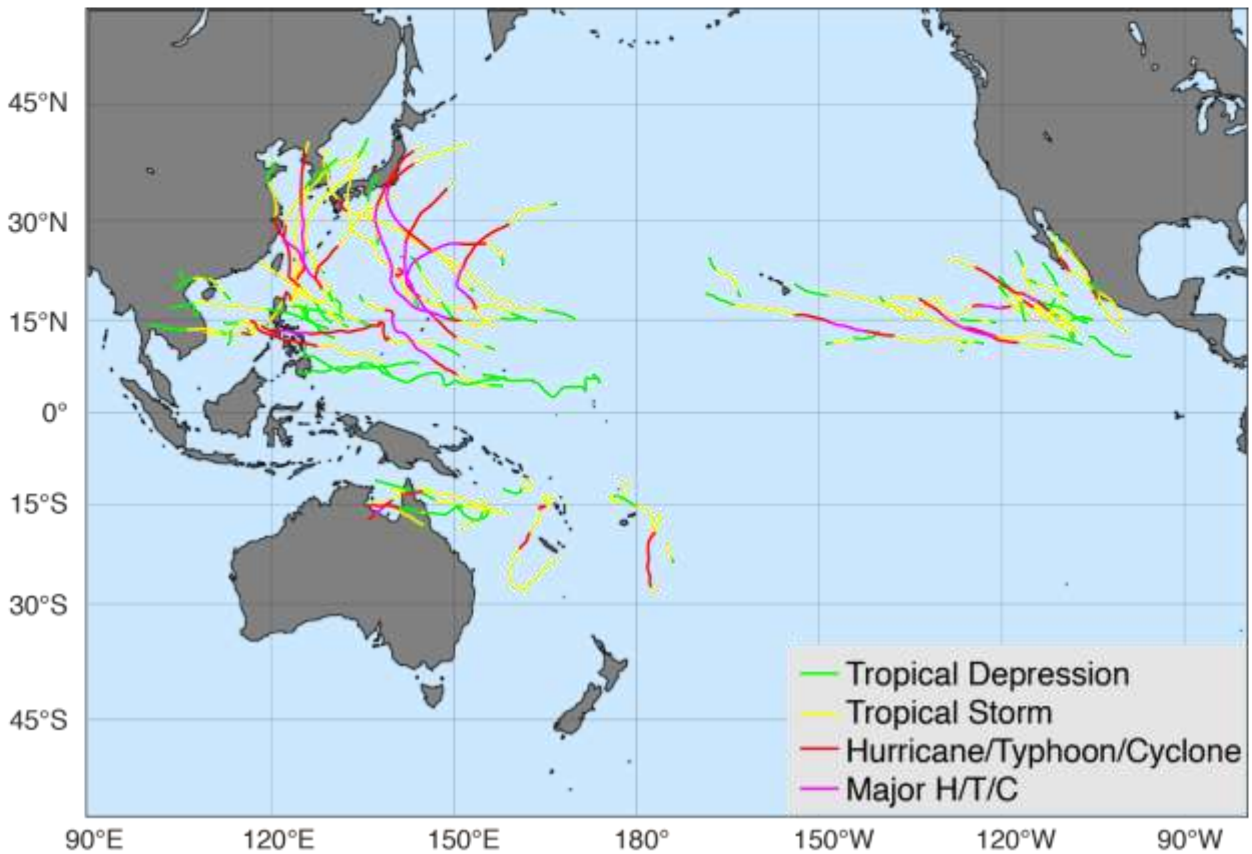


Figure 22. 2019 Pacific basin tropical cyclone tracks

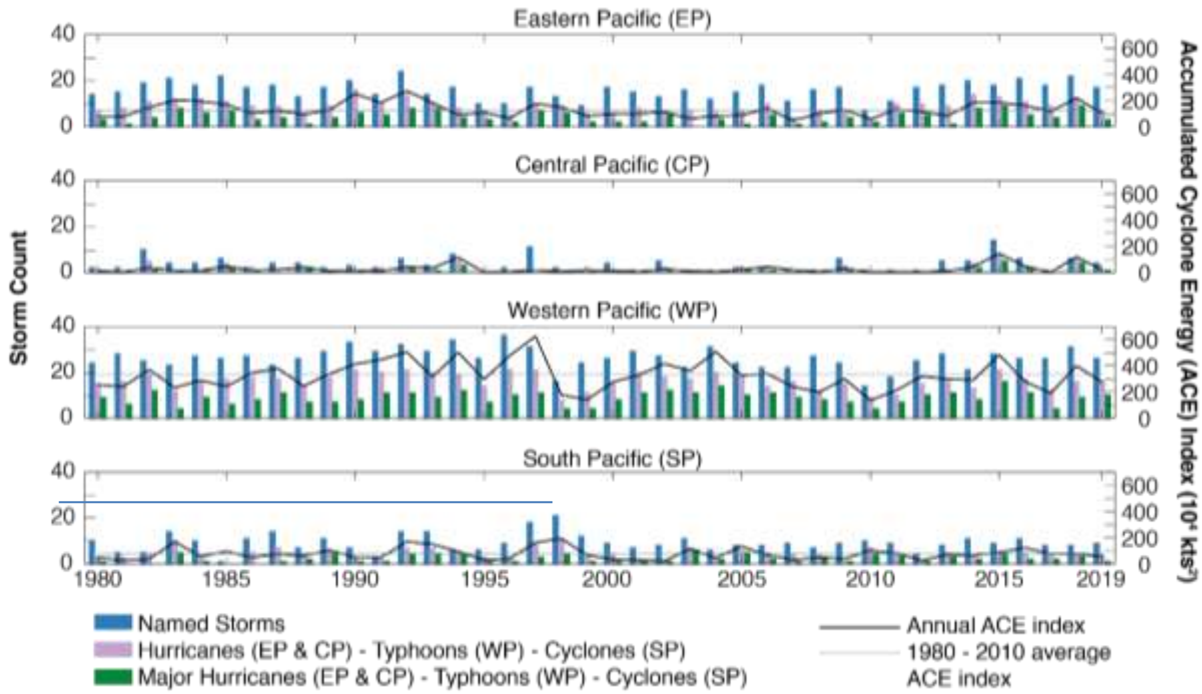


Figure 23. 2019 tropical storm totals by region

2.5.4.6 Sea Surface Temperature and Anomaly

Rationale: Sea surface temperature (SST) is one of the most directly observable existing measures for tracking increasing ocean temperatures. SST varies in response to natural climate cycles such as the ENSO and is projected to rise as a result of anthropogenic climate change. Both short-term variability and long-term trends in SST impact the marine ecosystem. Understanding the mechanisms through which organisms are impacted and the time scales of these impacts is an area of active research.

Status: Annual mean SST was 28.64ºC in 2019. Over the period of record, annual SST has increased at a rate of 0.024ºC/year. Monthly SST values in 2019 ranged from 26.80 – 30.21ºC, within the climatological range of 25.60 – 30.60 ºC. The annual anomaly was 0.292 ºC hotter than average, with intensification in the northern islands.

Note that from the top to bottom in Figure 24, panels show climatological SST (1985-2018), 2019 SST anomaly, time series of monthly mean SST, and time series of monthly SST anomaly. The white box in the upper panels indicates the area over which SST is averaged for the time series plots.

Description: Satellite remotely-sensed monthly SST is averaged across the Marianas Grid (13° – 21°N, 144° – 146°E). A time series of monthly mean SST averaged over the Mariana Archipelago Grid Region is presented alongside spatial climatology and anomalies.

Timeframe: Monthly.

Region/Location: Marianas Grid (13° – 21°N, 144° – 146°E).

Measurement Platform: Satellite.

Sourced from: NOAA OceanWatch (2020).

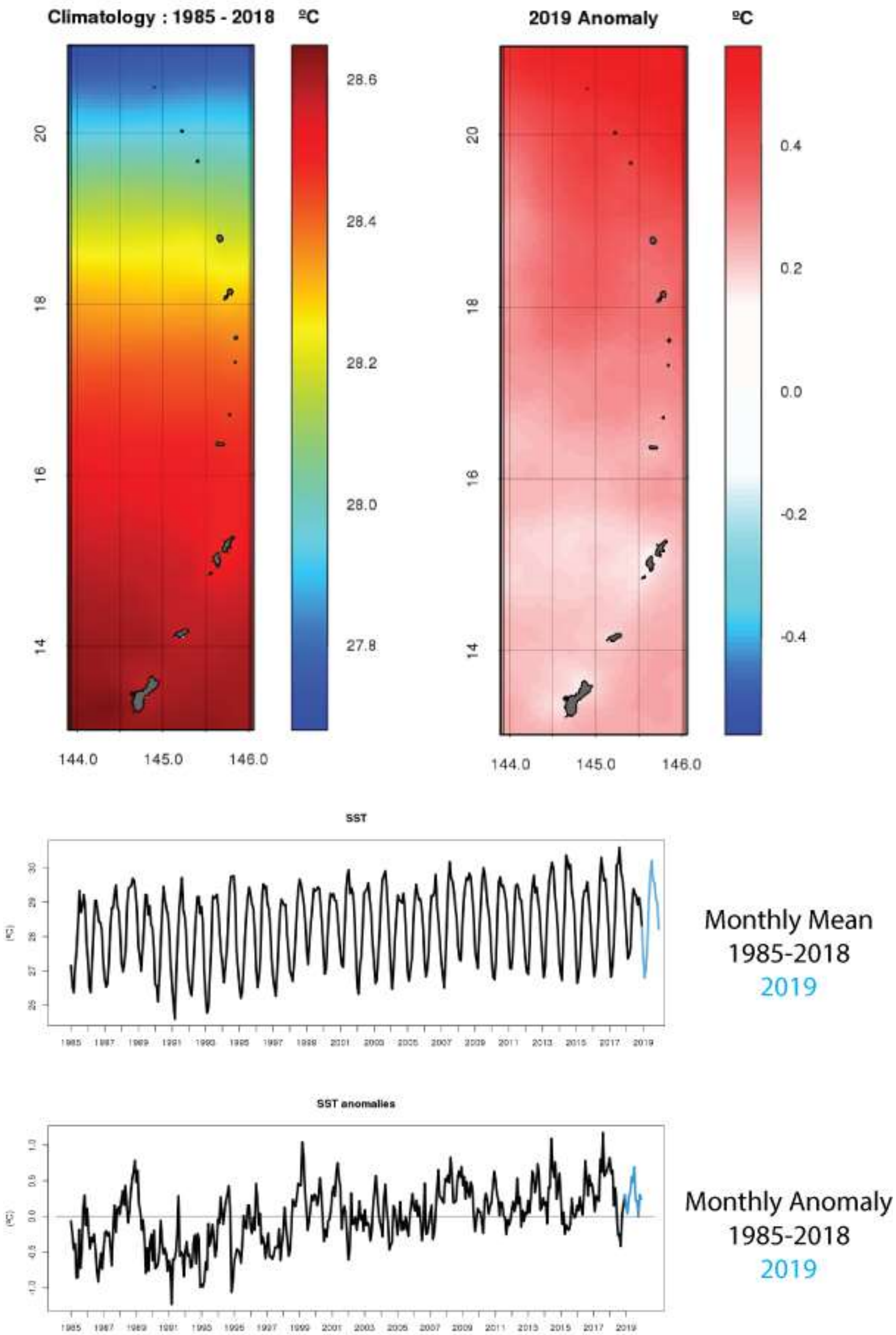


Figure 24. Sea surface temperature climatology and anomalies from 1982-2019

2.5.4.7 Coral Thermal Stress Exposure: Degree Heating Weeks

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

Status: After a series of stress events in 2013, 2014, 2016, and 2017, the Marianas experienced a coral heat stress event in late 2019 that reached its maximum in September 2019.

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 rolling sum weekly thermal anomalies over a 12-week period. Higher DHW measures imply a greater likelihood of mass coral bleaching or mortality from thermal stress.

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 daily 5-km satellite coral bleaching 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 (NOAA Coral Reef Watch, 2020).

Timeframe: 2014-2019, Daily data.

Region/Location: Global.

Sourced from: NOAA Coral Reef Watch (2020); https://coralreefwatch.noaa.gov/product/vs/timeseries/micronesia.php#northern_cnmi.

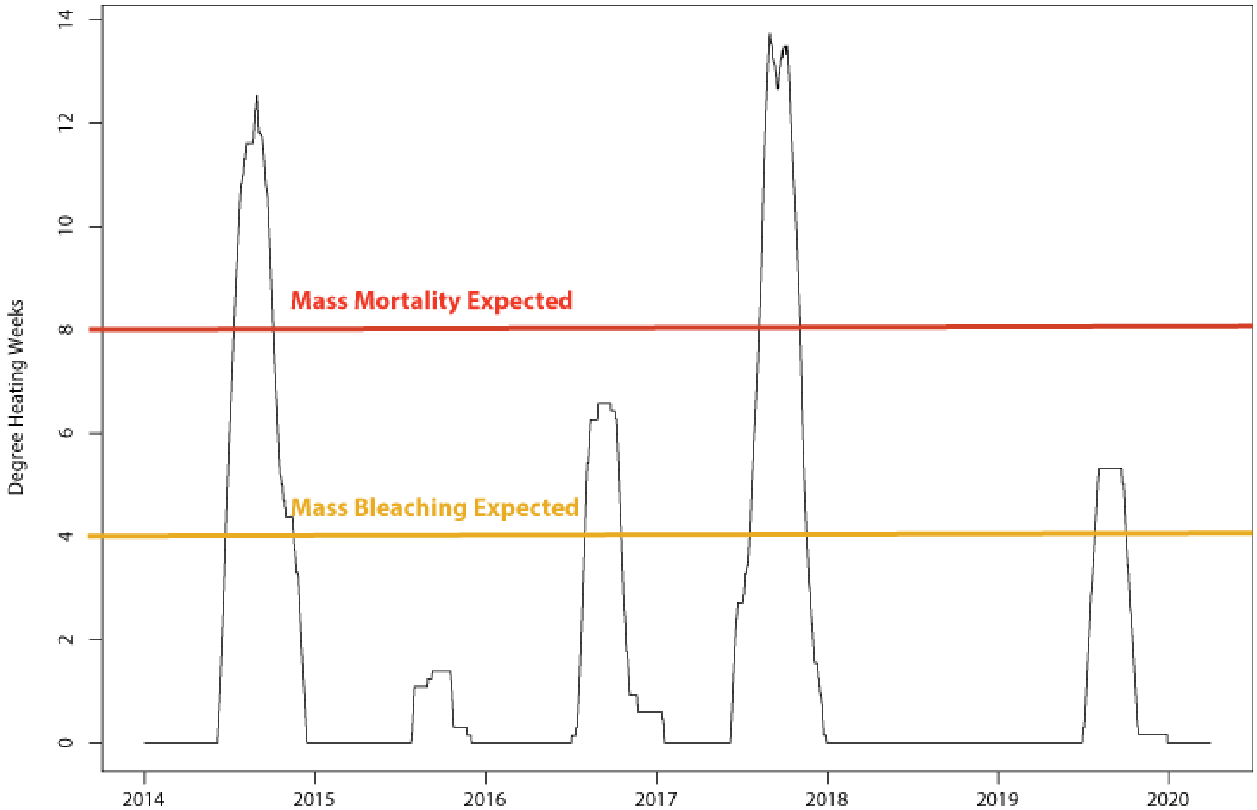


Figure 25. Coral Thermal Stress Exposure measured at CNMI Virtual Station 2014-2019 (Coral Reef Watch Degree Heating Weeks)

2.5.4.8 Chlorophyll-A and Anomaly

Rationale: Chlorophyll-A is one of the most directly observable measures we have for tracking increasing ocean productivity.

Status: Annual mean chlorophyll-A was 0.044 mg/m^3 in 2019. Over the period of record, annual chlorophyll-A has shown weak but significant linear decrease at a rate of 0.00036 mg/m^3. Monthly chlorophyll-A values in 2019 ranged from 0.040-0.052 mg/m^3, within the climatological range of 0.035 – 0.083 mg/m^3. The annual anomaly was essentially in line with climatological values – 0.0049 mg/m^3 lower than average.

Description: Chlorophyll-A Concentration from 1998-2019, derived from the ESA Ocean Color Climate Change Initiative dataset, v4.2. A monthly climatology was generated across the entire period (1982-2018) to provide both a 2019 spatial anomaly, and an anomaly time series.

ESA Ocean Color Climate Change Initiative dataset is a merged dataset, combining data from SeaWIFS, MODIS-Aqua, MERIS, and VIIRS to provide a homogeneous time-series of ocean color. Data was accessed from the OceanWatch Central Pacific portal.

Timeframe: 1998-2019, Daily data available, Monthly means shown.

Region/Location: Global.

Measurement Platform: SeaWIFS, MODIS-Aqua, MERIS, and VIIRS

Sourced from: NOAA OceanWatch (2020); https://oceanwatch.pifsc.noaa.gov/.

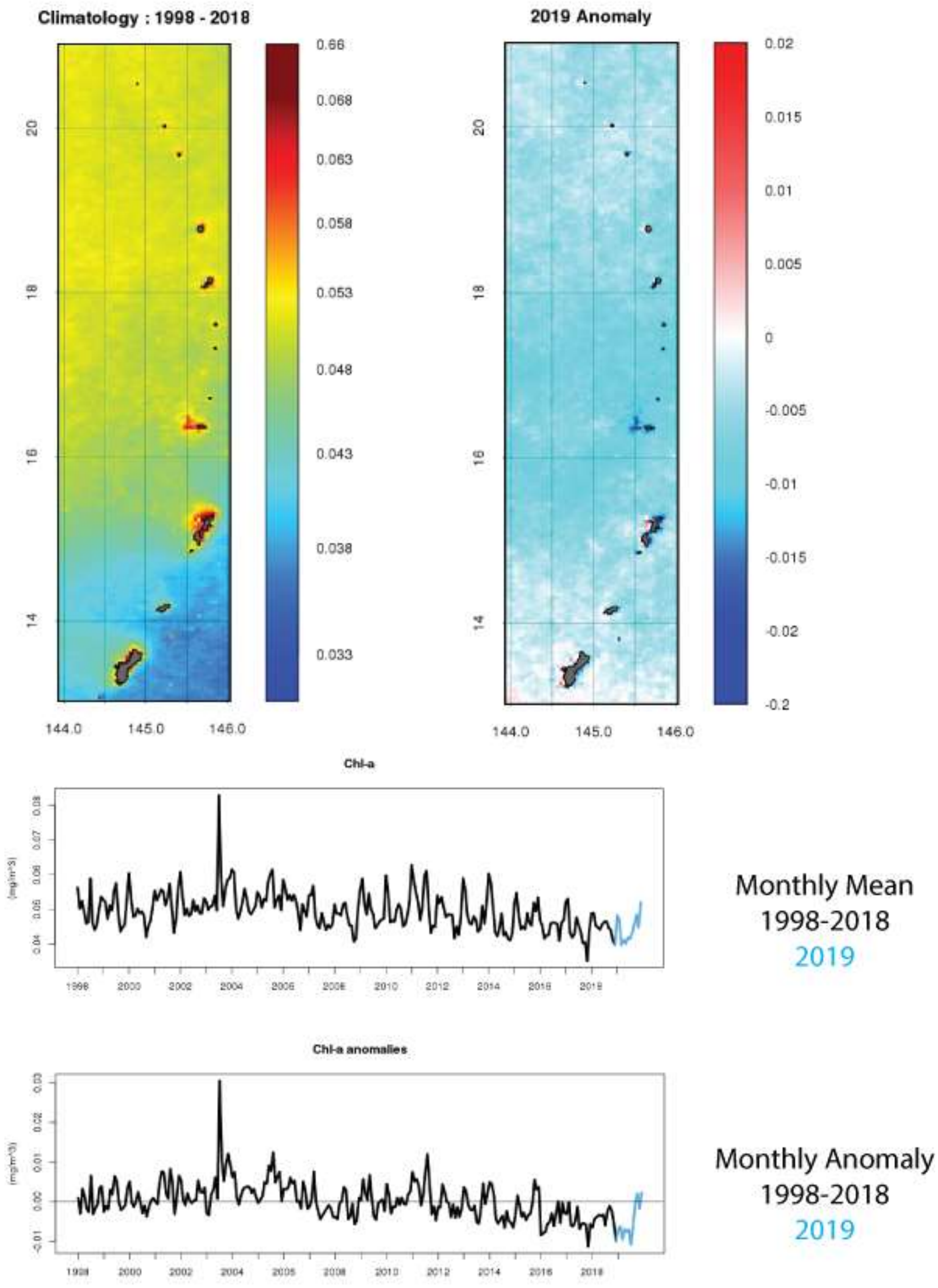


Figure 26. Chlorophyll-A (Chl-A) and Chl-A Anomaly from 1998-2019

2.5.4.9 Rainfall (CMAP Precipitation)

Rationale: Rainfall may have substantive effects on the nearshore environment and is a potentially important co-variate with the landings of particular stocks.

Description: The CPC Merged Analysis of Precipitation (CMAP) is a technique which produces pentad and monthly analyses of global precipitation in which observations from rain gauges are merged with precipitation estimates from several satellite-based algorithms, such as infrared and microwave (NOAA, 2002). The analyses are on a 2.5 x 2.5-degree latitude/longitude grid and extend back to 1979. *CMAP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at* https://www.esrl.noaa.gov/psd/. The data are comparable (but should not be confused with) similarly combined analyses by the Global Precipitation Climatology Project 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 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 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).

Timeframe: Monthly.

Region/Location: Global.

Measurement Platform: *In-situ* station gauges and satellite data.

Sourced from: CMAP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at https://www.esrl.noaa.gov/psd/; http://apdrc.soest.hawaii.edu/datadoc/cmap_month.php.

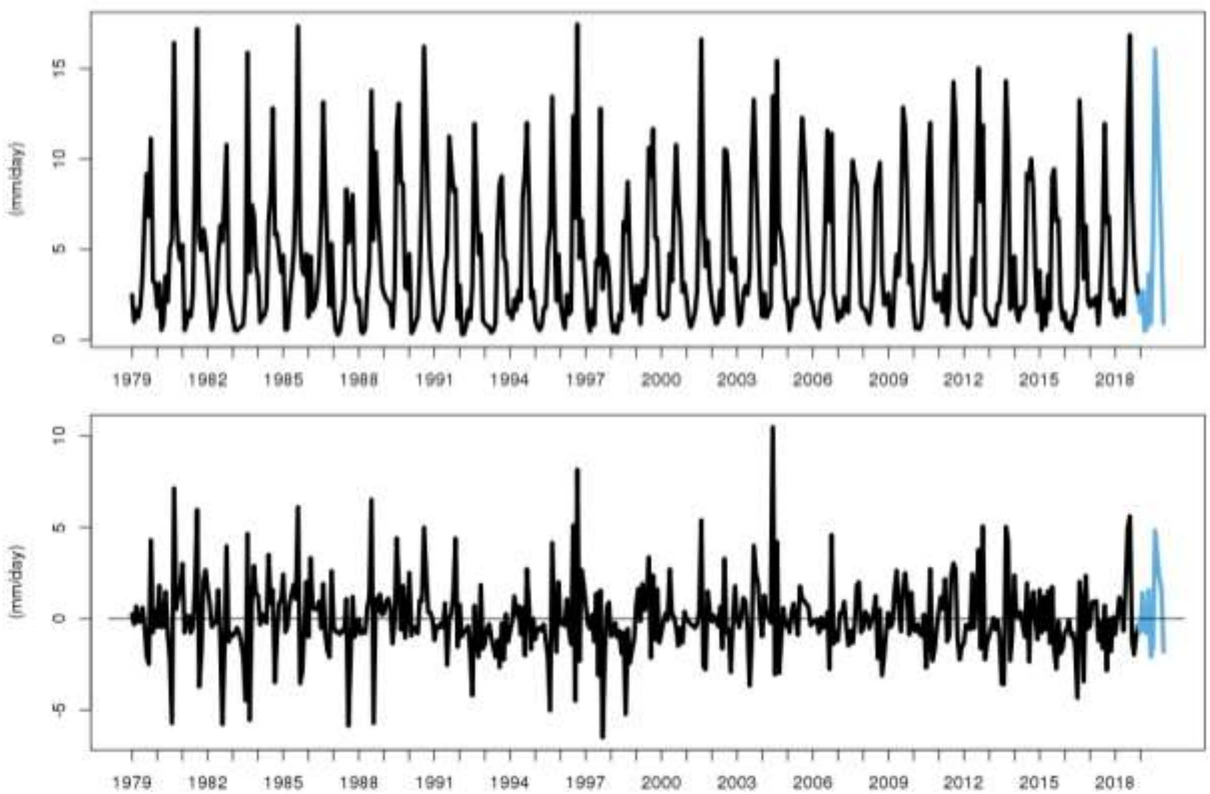


Figure 27. CMAP precipitation across the Marianas Grid with 2019 values in blue

2.5.3.9 Sea Level (Sea Surface Height and Anomaly)

Rationale: 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.

Description: Monthly mean sea level time series, including extremes

Timeframe: Monthly

Region/Location: Observations from selected sites within the Samoan Archipelago

Measurement Platform: Satellite and *in situ* tide gauges

Sourced from: Aviso (2020) and https://tidesandcurrents.noaa.gov/datum_options.html.

2.5.3.9.1 Basin-Wide Perspective

This image of the mean sea level anomaly for March 2019 compared to 1993-2013 climatology from satellite altimetry provides a glimpse into how the current weak El Niño continues to affect sea level across the Pacific Basin. The image captures the fact that sea level continues to be lower in the Western Pacific and higher in the Central and Eastern Pacific (a standard pattern during El Niño events - this basin-wide perspective provides a context for the location-specific sea level/sea surface height images that follow).

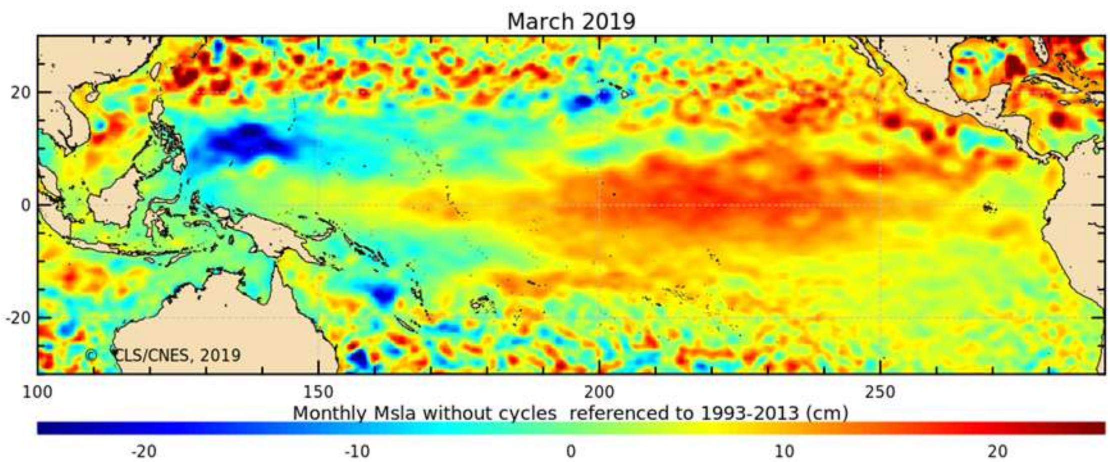


Figure 28a. Sea surface height and anomaly

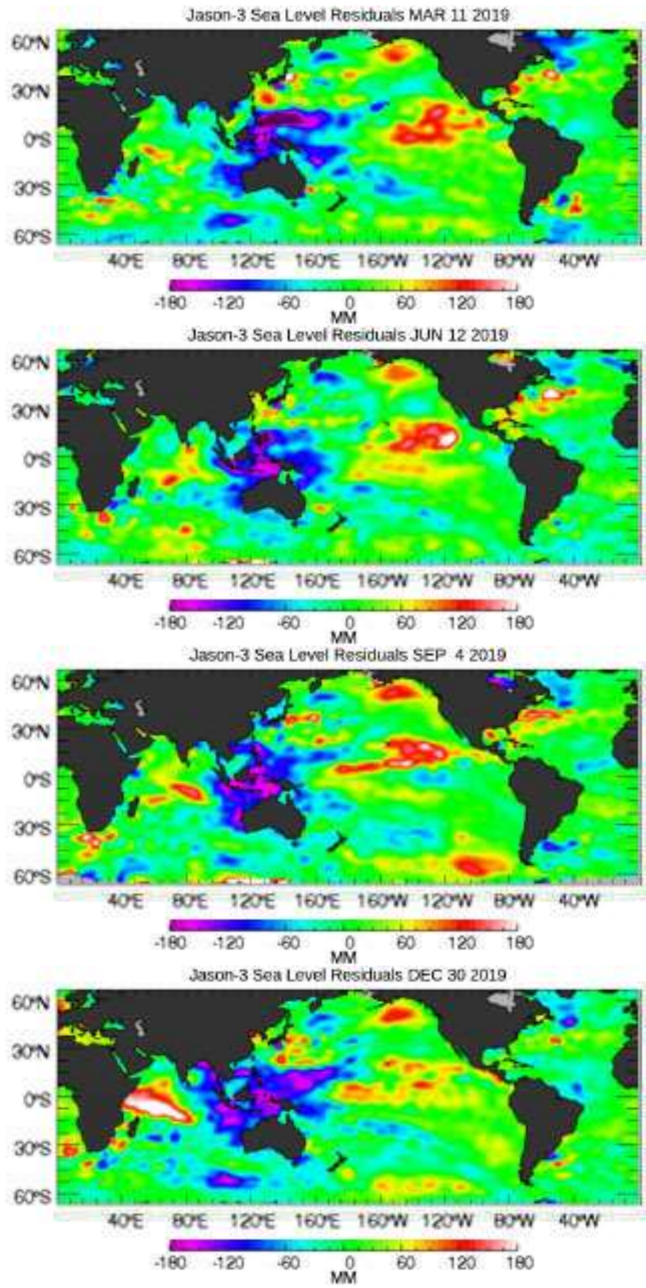
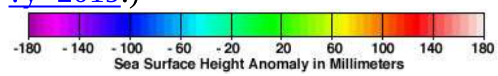


Figure 28b. Quarterly time series of mean sea level anomalies during 2019 show no pattern of El Niño throughout the year according to satellite altimetry measurements of sea level height (unlike 2015). (https://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2019.)



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 Center for Operational Oceanographic Products and Services [CO-OPS]).

The following figures and descriptive paragraphs were inserted from the NOAA Tides and Currents website. Figure 29 shows the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea Level datum established by CO-OPS. The calculated trends for all stations are available as a table in millimeters/year and in feet/century. If present, solid vertical lines indicate times of any major earthquakes in the vicinity of the station and dashed vertical lines bracket any periods of questionable data or datum shift.

The relative sea level rise trend is 3.40 millimeters/year with a 95% confidence interval of +/- 3.77 mm/yr. based on monthly mean sea level data from 1993 to 2019 which is equivalent to a change of 1.24 feet in 100 years. Trend for 1948-1993 was -0.85 +/- 1.76 mm/yr.

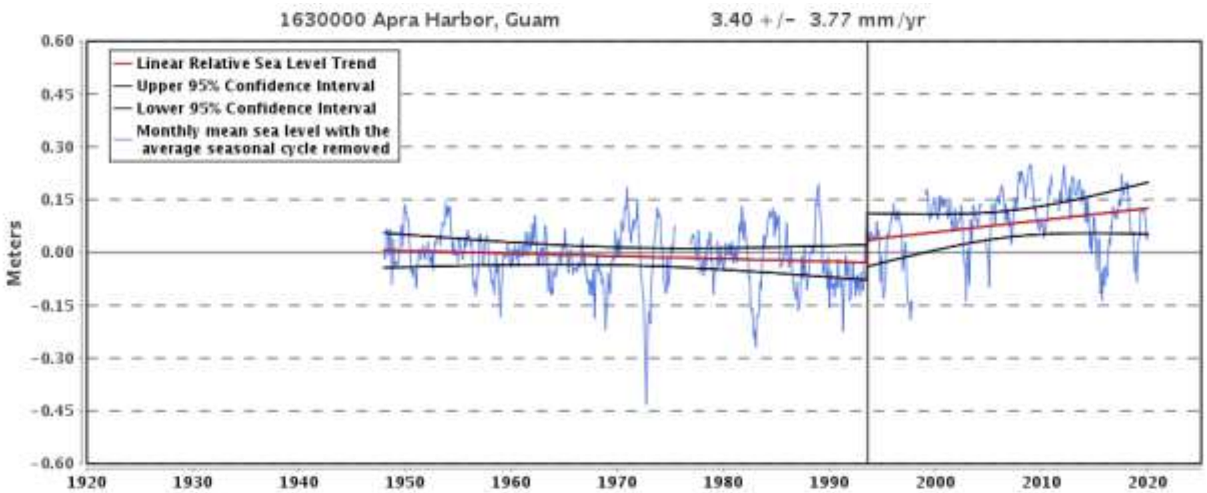


Figure 29. Monthly mean sea level without regular seasonal variability due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents

2.6 ESSENTIAL FISH HABITAT

2.6.1 Introduction

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) 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 MSA 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.

NMFS and the regional fishery management councils must describe and identify EFH in fishery management plans (FMPs) or fishery ecosystem plans (FEPs), 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 fishery management councils and NMFS to conduct a review and revision of the EFH components of FMPs 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 SAFE 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 FMPs include the description and identification of EFH, lists of prey species and locations for each managed species, and optionally, HAPC. 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 is described in the FEP but implemented in the annual SAFE report.

The Council has described EFH for five management unit species (MUS) under its management authority, some of which are no longer MUS: pelagic (PMUS), bottomfish (BMUS), crustaceans (CMUS), former coral reef ecosystem species (CREMUS), and precious corals (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 2.6.4;
- Updated research and information needs, which can be found in Section 2.6.5. These can be used to directly update the FEP; and
- 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:

- 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; and
- 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 172nd meeting in March 2018, the Council recommended that staff develop an omnibus amendment updating the non-fishing impact to EFH sections of the FEPs, incorporating the non-fishing impacts EFH review report by Minton (2017) by reference. An options paper has been developed. 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) stretches 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 hurricane season, and the Mariana Archipelago is periodically impacted by powerful typhoons.

The Mariana Trench is located to the east of the chain and includes the deepest point in the world's oceans. The vertical measurement from the seafloor to 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 EEZ. The coral reef ecosystems surrounding the islands in the Mariana Archipelago been the subject of a comprehensive monitoring program through the PIFSC Coral Reef Ecosystem Division (CRED) biennially since 2002, surveys are focused on the nearshore environments surrounding the islands, atolls, and reefs.

PIFSC CRED is now the Coral Reef Ecosystem Program (CREP) within the PIFSC Ecosystem Sciences Division (ESD) whose mission is to conduct multidisciplinary research, monitoring, and analysis of integrated environmental and living resource systems in coastal and offshore waters of the Pacific Ocean. This mission includes field research activities that cover near-shore island ecosystems such as coral reefs to open ocean ecosystems on the high seas. The ESD research focus includes oceanography, coral reef ecosystem assessment and monitoring, benthic habitat mapping, and marine debris surveys and removal. This broad focus enables ESD to analyze not only the current structure and dynamics of marine environments, but also to examine potential projections of future conditions such as those resulting from climate change impacts. Because humans are a key part of the ecosystem, our research includes the social, cultural, and economic aspects of fishery and resource management decisions (PIFSC, 2020. https://www.fisheries.noaa.gov/about/pacific-islands-fisheries-science-center). The CREP continues 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, 2010). CREP conducts comprehensive ecosystem monitoring surveys at about 50 islands, atolls, and shallow bank sites in the Western Pacific Region on a rotating schedule, based on operational capabilities. CREP coral reef monitoring reports provide the most comprehensive description of nearshore habitat quality in the region.

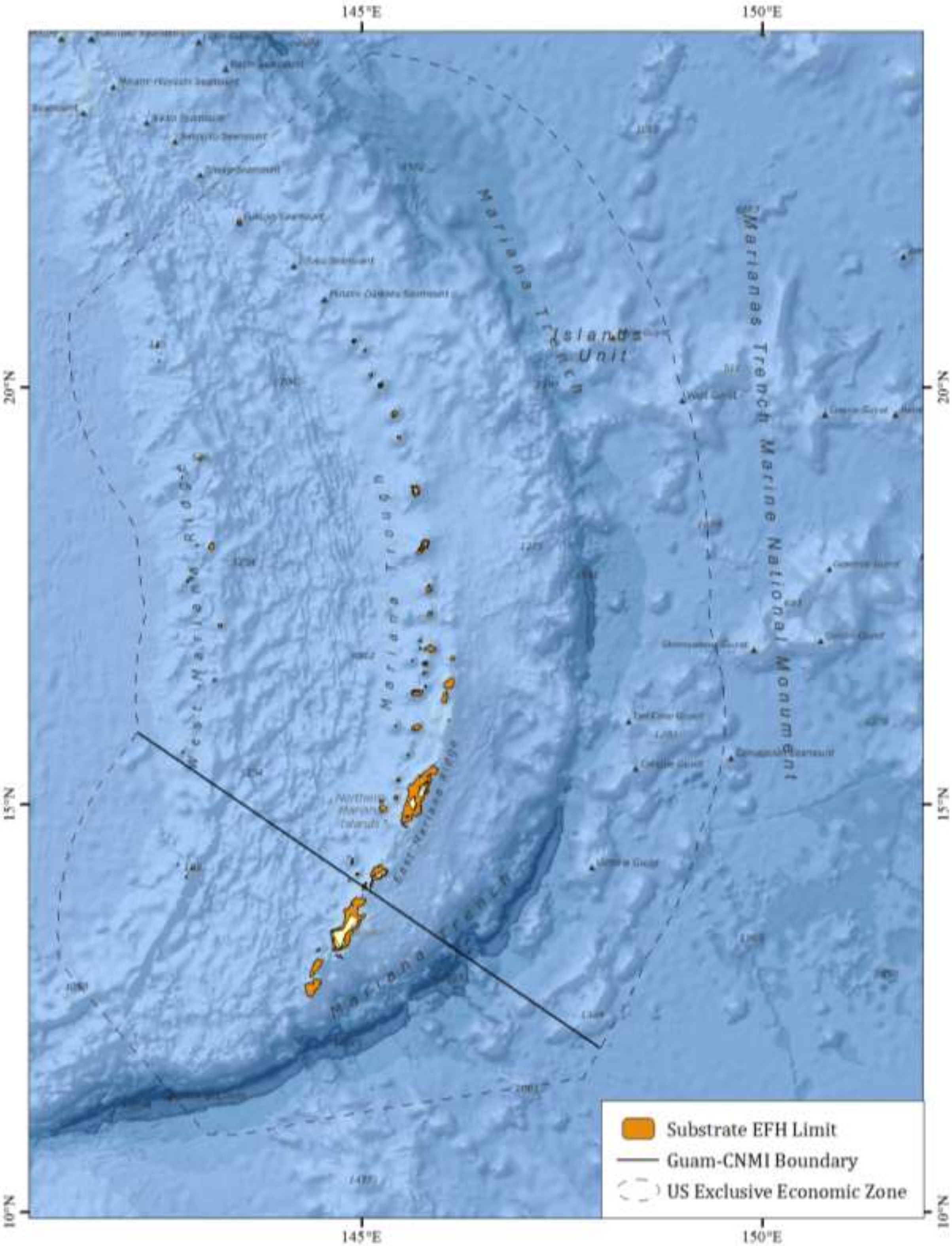


Figure 30. Substrate EFH Limit of 700 m isobath around the Mariana Archipelago (from Ryan et al., 2009)

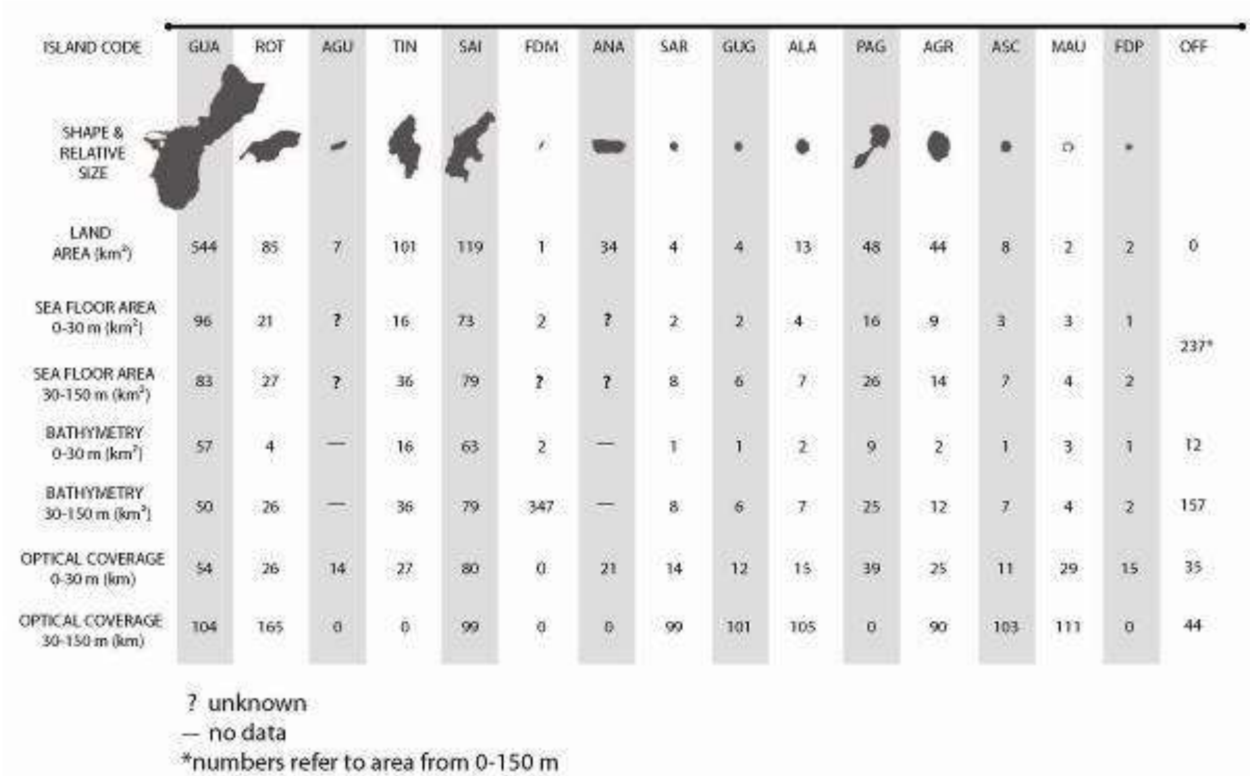
2.6.2.1 Habitat Mapping

Interpreted IKONOS benthic habitat maps in the 0-30 m depth range have been completed for all islands in the CNMI (Miller et al., 2011). Mapping products for the Marianas are available from the Pacific Islands Benthic Habitat Mapping Center (PIBHMC).

Table 56. Summary of habitat mapping in the Mariana Archipelago

Depth Range	Timeline/Mapping Product	Progress	Source
0-30 m	IKONOS Benthic Habitat Maps	All Islands	Miller et al. (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 Miller et al. (2011) in Figure 31.



ISLAND CODE	GUA	ROT	AGU	TIN	SAI	FDM	ANA	SAR	GUG	ALA	PAG	AGR	ASC	MAU	FDP	OFF
SHAPE & RELATIVE SIZE	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	(shape)	
LAND AREA (km²)	544	85	7	101	119	1	34	4	4	13	48	44	8	2	2	0
SEA FLOOR AREA 0-30 m (km²)	96	21	?	16	73	2	?	2	2	4	16	9	3	3	1	237*
SEA FLOOR AREA 30-150 m (km²)	83	27	?	36	79	?	?	8	6	7	26	14	7	4	2	
BATHYMETRY 0-30 m (km²)	57	4	—	16	63	2	—	1	1	2	9	2	1	3	1	12
BATHYMETRY 30-150 m (km²)	50	26	—	36	79	347	—	8	6	7	25	12	7	4	2	157
OPTICAL COVERAGE 0-30 m (km)	54	26	14	27	80	0	21	14	12	15	39	25	11	29	15	35
OPTICAL COVERAGE 30-150 m (km)	104	165	0	0	99	0	0	99	101	105	0	90	103	111	0	44

? unknown
— no data
*numbers refer to area from 0-150 m

Figure 31. Mariana Archipelago land and seafloor area and primary data coverage (from Miller et al., 2011)

2.6.2.2 Benthic Habitat

Juvenile and adult life stages of coral reef species 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 crustacean 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 are surveyed as a part of the Pacific Reef Assessment and Monitoring Program (RAMP) led by the PIFSC Ecosystem Sciences Division (ESD). Previously, Pacific RAMP surveys had benthic cover data summarized by island; these data are shown in Table 57 through Table 59. The benthic towed-diver survey method was used to monitor change in benthic communities. In this method, a pair of scuba divers (one collecting fish data, the other collecting benthic data) would be towed about one meter above the reef roughly 60 m behind a small boat at a constant speed of about 1.5 kt. Each diver maneuvers a tow board 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. 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 sea stars, sea cucumbers, free and boring urchins, and giant clams). The surveys are typically 50 minutes long and cover about two to three kilometers of habitat (PIFSC, 2016). However, this method was retired in 2016, and no new data will be appended to the time series.

More recently, the surveys began focusing on geographic sub-regions of islands for a more fine-scale summary of benthic cover; these data are shown in Table 60 through Table 62. A stratified random sampling design is used to determine status, trends, and variability of benthic communities at Rapid Ecological Assessment (REA) sites. In 2018, surveys at each REA site were conducted with one 10-meter squared belt transects, whereas two belt transects were used from 2013 to 2017. The survey domain encompasses the majority of the mapped area of reef and hard bottom habitats from 0 to 30 m depth. The stratification scheme includes (1) three depth categories (shallow: 0 to 6 m; mid-depth: >6 to 18 m; and deep: >18 to 30 m); (2) regional sub-island sectors; (3) reef zone components, including back reef, lagoon, and fore reef.

Coral colonies and their morphology are identified before measuring the colony size and assessing colony condition. Photoquadrats are used to derive estimates of benthic cover. The photoquadrat consists of a high-resolution digital camera mounted on a photoquadrat pole. Photoquadrat images are collected along the same two transects used for coral surveys at one-meter intervals, starting at 1 m and progressing to the 15-meter mark (images are not collected at the 0 m mark). This provides a total of 15 images per transect and 30 per site. In 2018, a single stage sampling scheme was implemented, which designates primary sample units (referred to sites) as grid cells containing >10% hard-bottom reef habitats. Also in 2018, a new method of determining survey effort was used by first determining the number of days spent at each island then by strata area and variance of target species at the island level (Swanson et al, 2018; Winston et al., 2019).

Table 57. Mean percent cover of live coral from RAMP sites collected from towed-diver surveys using previous methodology 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				

Year	2003	2005	2007	2009	2011	2014
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 58. Mean percent cover of macroalgae from RAMP sites collected from towed-diver surveys using previous methodology 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 59. Mean percent cover of crustose coralline algae from RAMP sites collected from towed-diver surveys using previous methodology 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

Year	2003	2005	2007	2009	2011	2014
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

Table 60. Mean percent cover of live coral from RAMP sites collected from belt transect surveys using updated methodology in the Mariana Archipelago

Island Area	2011	2014	2017
Agrihan	13.34		7.33
Alamagan	24.69	11.05	9.19
Guguan	18.20	13.18	11.35
Sarigan	10.49	6.02	5.42
Aguijan	19.38	13.54	17.65
Asuncion	12.06	18.04	6.56
Farallon de Pajaros	11.03	5.95	3.31
Guam (East)	11.62	11.27	10.02
Guam (MPAs)	15.25		10.67
Guam (MPAs minus Achang)		15.02	
Guam (West)	16.48	13.99	13.52
Maug	30.50	27.97	7.34
Pagan	12.58	11.21	9.41
Rota	14.85	6.74	9.05
Saipan	10.49	14.13	14.59
Tinian	13.80	12.95	10.42

Table 61. Mean percent cover of macroalgae from RAMP sites collected from belt transect surveys using updated methodology in the Mariana Archipelago

Island Area	2011	2014	2017
Agrihan	3.25		3.59
Alamagan	0.35	2.59	2.51
Guguan	0.71	1.63	1.43
Sarigan	1.14	3.67	1.09
Aguijan	2.35	3.00	8.89

Island Area	2011	2014	2017
Asuncion	5.47	2.11	3.43
Farallon de Pajaros	0.13	0.31	0.21
Guam (East)	6.70	7.92	5.20
Guam (MPAs)	7.20		5.00
Guam (MPAs minus Achang)		3.97	
Guam (West)	10.87	19.35	10.70
Maug	2.34	3.69	2.18
Pagan	3.74	8.00	3.35
Rota	4.45	6.03	5.26
Saipan	1.95	6.06	4.10
Tinian	3.01	5.36	6.44

Table 62. Mean percent cover of crustose coralline algae from RAMP sites collected from belt transect surveys using updated methodology in the Mariana Archipelago

Island Area	2011	2014	2017
Agrihan	2.71		5.19
Alamagan	1.31	2.20	3.81
Guguan	7.62	7.73	6.62
Sarigan	1.71	3.50	3.23
Aguijan	2.95	4.18	7.87
Asuncion	3.29	1.67	6.47
Farallon de Pajaros	1.58	0.70	1.70
Guam (East)	7.43	4.13	6.78
Guam (MPAs)	7.25		5.85
Guam (MPAs minus Achang)		6.49	
Guam (West)	5.87	3.21	5.11
Maug	2.97	4.00	7.48
Pagan	4.03	2.35	4.72
Rota	1.73	4.43	10.00
Saipan	1.52	3.59	3.12
Tinian	1.46	2.45	3.87

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 deep water 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, 150 m; and bottomfish, 400 m. Please see the Climate and Oceanic Indicators section (Section 2.5) for information related to oceanography and water quality.

2.6.3 Report on Review of EFH Information

A review of the biological components of crustacean EFH in Guam and Hawaii was finalized in 2019. This review can be found in Appendix C of this report. The non-fishing impacts and cumulative impacts components were reviewed in 2016 through 2017, which can be found in Minton (2017).

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:

- Level 1: Distribution data are available for some or all portions of the geographic range of the species.
- Level 2: Habitat-related densities of the species are available.
- Level 3: Growth, reproduction, or survival rates within habitats are available.
- 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 managed species' life stage. The existing level of data for individual MUS in each fishery are presented in tables per fishery.

The Hawaii Undersea Research Laboratory (HURL) is a center operating under the School of Ocean and Earth Sciences and Technology (SOEST) at the University of Hawaii and NOAA's Office of Ocean Exploration and Research. The unique deep-sea research operation runs the Pisces IV and V manned submersibles and remotely operated vehicles (ROVs) for investigating the undersea environment through hypothesis driven projects that address gaps in knowledge or scientific needs. HURL maintains a comprehensive video database, which includes biological and substrate data extracted from their dive video archives. Submersible and ROV data are collected from depths deeper than 40 m. Observations from the HURL video archives are considered Level 1 EFH information for deeper bottomfish and precious coral species which exist in the database though cannot be considered to observe absence of species. Survey effort is low compared to the range of species observed.

2.6.4.1 Precious Corals

EFH for precious corals was originally designated in Amendment 4 to the Precious Corals FMP (64 FR 19067, April 19, 1999) using the level of data found in Table 63.

Table 63. Level of EFH information available for former and current W. Pacific PCMUS from Hawaii

Species	Pelagic Phase (Larval Stage)	Benthic Phase	Source(s)
Pink Coral (*Corallium*)			
Pleurocorallium secundum (prev. *Corallium secundum*)	0	1	Figueroa and Baco (2014); HURL Database
C. regale	0	1	HURL Database
Hemicorallium laauense (prev. *C. laauense*)	0	1	HURL Database
Gold Coral			
Kulamanamana haumeaae	0	1	Sinniger et al. (2013); HURL Database
Callogorgia gilberti	0	1	HURL Database

Species	Pelagic Phase (Larval Stage)	Benthic Phase	Source(s)
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	1	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

EFH 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 64. Level of EFH information available for former and current W. Pacific BMUS and seamount groundfish MUS complexes

Life History Stage	Eggs	Larvae	Juvenile	Adult
Aphareus rutilans (red snapper/silvermouth)	0	0	0	1
Aprion virescens (gray snapper/jobfish)	0	0	1	1
Caranx ignoblis (giant trevally/jack)	0	0	1	1
C. lugubris (black trevally/jack)	0	0	0	1
Epinephelus faciatus (blacktip grouper)	0	0	0	1
E. quernus (sea bass)	0	0	1	1
Etelis carbunculus (red snapper)	0	0	1	1
E. coruscans (red snapper)	0	0	1	1
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	1
P. filamentosus (pink snapper)	0	0	1	1
P. flavipinnis (yelloweye snapper)	0	0	0	1
P. seiboldi (pink snapper)	0	0	1	1
P. zonatus (snapper)	0	0	0	1
Pseudocaranx dentex (thicklip trevally)	0	0	1	1
Seriola dumerili (amberjack)	0	0	0	1
Variola louti (lunartail grouper)	0	0	0	1
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

EFH for crustacean 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 65. Level of EFH information available for former and current W. Pacific CMUS

Life History Stage	Eggs	Larvae	Juvenile	Adult
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

2.6.5 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/CNMI 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 crustaceans.
- 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.

2.7 MARINE PLANNING

2.7.1 Introduction

Marine planning is a science-based management 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 (EO) 13547, *Stewardship of the Ocean, Our Coasts, and the Great Lakes*. EO 13158, *Marine Protected Areas*, 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:

- 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 (BRFAs), military installations, NWHI restrictions, and Marine Life Conservation Districts (MLCDs).
- Establish effective spatially-based fishing zones.
- Consider modifying or removing spatial-based fishing restrictions that are no longer necessary or effective in meeting their management objectives.
- 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 MMAs, the goals associated with those, and the most recent evaluation. Council research needs are identified and prioritized through the Five Year Research Priorities and other processes and are not tracked in this report.

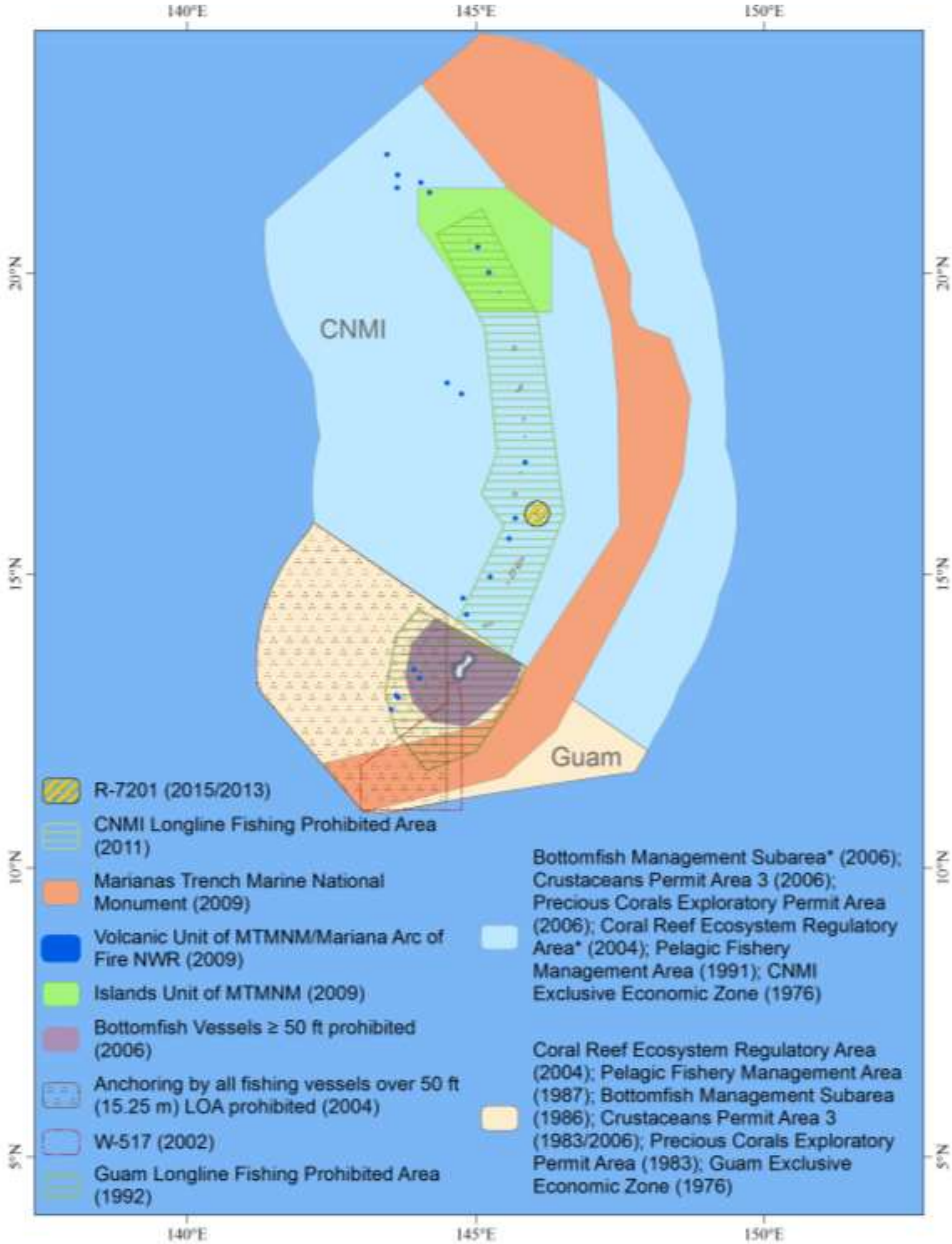
In order to meet the EFH and National Environmental Policy Act (NEPA) mandates, this annual report tracks activities that occur in the ocean that are of interest to the Council, and incidents or facilities that may contribute to cumulative impact. NMFS is responsible for NEPA compliance, and the Council must assess the environmental effects of ocean activities for the FEP's EFH cumulative impacts section.

2.7.2 Response to Previous Council Recommendations

There are no Council recommendations indicating review deadlines for Marianas MMAs.

2.7.3 Marine Managed Areas Established under FEPs

Council-established MMAs were compiled in Table 66 from 50 CFR § 665, Western Pacific Fisheries, the Federal Register, and Council amendment documents. All regulated fishing areas and large scale access restrictions, including the Mariana Trench Marine National Monument, are shown in Figure 32.



* The Coral Reef Ecosystem Regulatory Area excluded the portion of EEZ waters 0-3 miles around the CNMI. The Bottomfish Management Subarea was divided in the CNMI Inshore Area, which was that portion of the EEZ shoreward of 3 nautical miles of the shoreline of CNMI, and the CNMI Offshore Area, which was that portion of the EEZ seaward of 3 nautical miles from the CNMI shoreline.

Figure 32. Regulated fishing areas of the Mariana Archipelago

Table 66. MMAs established under FEPs from 50 CFR § 665

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Pelagic Restrictions								
Guam Longline Prohibited Area	Pelagic	Guam	665.806(a)(3) 57 FR 7661 Pelagic FMP Am. 5	50,192.88	Longline fishing prohibited	Prevent gear conflicts between longline vessels and troll/handline vessels.	1992	-
CNMI Longline Prohibited Area	Pelagic	Mariana Archipelago	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 FMP	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	-
Marianas Trench Marine National Monument	Mariana Archipelago	Mariana Archipelago	665.901(a) 78 FR 33003 Mariana Archipelago FEP Am. 3	-	Commercial fishing prohibited; non-commercial fishing authorized under permit	Minimize adverse human impacts on marine resources within the marine national monument.	2013	-

2.7.4 Fishing Activities and Facilities

There are no proposed or existing offshore aquaculture projects in Federal waters of neither Guam nor CNMI.

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 proposed or existing alternative energy facilities in Federal waters of neither Guam nor CNMI.

2.7.5.2 Military Training and Testing Activities and Impacts

The Department of Defense major planning activities in the region are summarized in Table 67. Activities that are no longer reasonably foreseeable or have been replaced with another planning activity were removed from the report, though may occur in previous reports. When a particular offshore area is in use for training or testing exercises by the U.S. military, 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 many popular fishing areas. NTMs from the military and the number of days affected for Guam and the CNMI are included in Table 68.

2.7.6 Pacific Islands Regional Planning Body Report

In June 2018, President Trump signed the EO 13840 *Regarding the Ocean Policy to Advance Economic, Security, and Environmental Interests of the United States*, which revoked EO 13547. The new EO eliminated the mandate for the federal government to participate in ocean planning at a regional level and eliminated the regional planning bodies. As such, the Pacific Islands Regional Planning Body (RPB) no longer exists and ocean planning will now occur at a local level led by Hawaii and the territories.

However, EO 13840 established a policy focused on public access to marine data and information and requires federal agencies to 1) coordinate activities regarding ocean-related matters and 2) facilitate the coordination and collaboration of ocean-related matters with governments and ocean stakeholders. To that end, the American Samoa Coastal and Marine Spatial Planning Data Portal was created by Marine Cadastre. The intent is for it to be expanded to include the Marianas, PRIA, and Hawaii and be titled the Pacific Islands Regional Marine Planner.

Spatial planning has occurred in CNMI in Saipan Lagoon. CNMI Division of Coastal Resources Management developed the Saipan Lagoon Use Management Plan, which was updated in 2017 and has an associated mapping tool.

Table 67. 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/Andersen Air Force Base, a live-fire individual training range complex at the Ritidian Unit of the Guam National Wildlife Refuge.	ROD published August 29, 2015 after release of Final SEIS on July 18, 2015 (80 FR 55838). Lawsuit 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. The case was lost in 2018 after a judge from the district court of CNMI agreed with the military that the Guam buildup and proposed training in the CNMI are not connected actions. The case was appealed, and the U.S. Court of Appeals for the Ninth Circuit announced it might hear oral arguments in early 2020. (http://www.saipantribune.com/index.php/doj-federal-court-lacks-jurisdiction/; https://www.guampdn.com/story/news/2019/10/08/cnmi-training-range-lawsuit-could-heard-us-court-appeals-hawaii/3905566002/).	Surface danger zone established at Ritidian – access restricted during training. Northern District Wastewater Treatment Plant will significantly impact nearshore water quality until it is upgraded.
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.	The 2019 MITT Final Supplemental EIS/OEIS is expected in spring 2020. Open House Public Meetings took place in March 2019. Public Comment was extended from March 18, 2019 to April 17, 2019 and is now closed. Meetings are ongoing to discuss FDM research activities and exercises. Meetings were previously held to discuss the Integrated Natural Resources Management Plan and plans for future surveys around FDM.	Access and habitat impact likely similar to previous analysis in 2015 EIS/OEIS (80 FR 46525).

Action	Description	Phase	Impacts
CNMI Joint Military Training	Establish unit and combined level training ranges on Tinian and Pagan.	Revised Draft EIS was expected in late 2018 or early 2019, but there is no new information on the EIS status. Lawsuit 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. The case was lost in 2018 after a judge from the district court of CNMI agreed with the military that the Guam buildup and proposed training in the CNMI are not connected actions. The case was appealed, and the U.S. Court of Appeals for the Ninth Circuit announced it might hear oral arguments in early 2020. Several meetings have been held with DFW and military officials to discuss relevant natural resource, land use, and social concerns regarding the proposed activities and prompted the reconsideration of proposed alternatives.	Significant access and habitat impacts.
Tinian Divert Infrastructure Improvements, Marianas	Improvements to airport and seaport (improving roads, installing fuel line) in CNMI for expanding mission requirements in Western Pacific.	ROD for Tinian Divert Infrastructure Improvements published in 2016 (81 FR 92791). The USAF has published a NOI to prepare a SEIS for the proposed Tinian Divert Infrastructure Improvements. The NOI began the public scoping process for the SEIS, which ended on May 31, 2018. Substantive comments received during the public scoping period will be taken into consideration during preparation of the Draft SEIS. The USAF published a Notice of Availability (NOA) for the Draft SEIS on May 17, 2019. The NOA began the public review period for the Draft SEIS, which ended on July 1, 2019. Substantive comments received during the public review period will be taken into consideration during preparation of the Final SEIS.	Adverse impacts to EFH minimal; access near Port of Tinian fuel transfer facility affected. Access and transit to fishing grounds.
Garapan Anchorage	Military Pre-Positioned Ships anchor and transit.	Expired Memorandum of Understanding with the CNMI government. As of 2019, a new MOU had not been signed.	Access, invasive species, unmitigated damage to reefs.

Action	Description	Phase	Impacts
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 (82 FR 13389). Proposed surface danger zone to 12 nmi. Meetings with military officials established that the 12 nmi radius is closed when exercises are being conducted, but a 3 nmi closure would instead be in effect year-round when exercises are not being conducted. 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.

Table 68. NTMs for Military Exercises in the Mariana Archipelago

Year	Location	Number of Notices to Mariners Issued	Number of Days Affected
2013	FDM	45	159
	W-517	24	54
2014	FDM	38	145
	W-517	24	49
2015	FDM	37	164
	W-517	33	87
2016	FDM	35	142
	W-517	50	139
	W-11	N/A	N/A
	W-12	N/A	N/A
2017	FDM	56	191
	W-517	46	119
	W-12	2	5
	W-11	N/A	N/A
2018	FDM	38	150
	W-517	49	107
	W-12	6	13
	W-11	1	1
2019	FDM	39	165

Year	Location	Number of Notices to Mariners Issued	Number of Days Affected
	W-517	27	65
	W-12	3	22
	W-11	6	27
	W-13	15	37

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 Mariana Archipelago and across the Western Pacific region. "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, NMFS PIFSC and 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. The archipelagic fisheries group developed nearly 30 potential fishery ecosystem relationships 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.

Brief introductory analyses, presented in this section and initially introduced in the 2017 report, were intended to be "proof of concept" such that similar evaluations could be carried out on remaining fishery data for the Mariana Archipelago in the future. However, the Archipelagic Fishery Ecosystem Plan Team determined that the quantitative analyses presented here were not sufficient to act as a model for future evaluations. Using the direction from the Plan Team, the data integration module was updated for the Hawaii Archipelagic annual SAFE report in 2018, but each of the remaining archipelagic reports still contains data integration assessments from 2017. The annual SAFE report for the Mariana Archipelago will be updated in the coming years similar to the annual SAFE report for the Hawaii Archipelago pending Plan Team support.

Going forward, 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.

To begin, this chapter described feedback from the Plan Team, SSC, and Council members on the initial drafts of the data integration module. Next, the chapter includes brief descriptions of past work on fishery ecosystem relationship assessment in 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 from 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.

Going forward with the analyses and presentation of results for the data integration chapter of the Marianas Archipelago Annual SAFE Report, the Plan Team suggested several improvements to implement in the coming year: standardizing and correcting values in CPUE time series, incorporating longer stretches of phase lag, completing comparisons on the species-level and by dominant gear types, incorporating local knowledge on shifts in fishing dynamics over the course of the time series, and utilizing the exact environmental data sets presented in the ecosystem consideration chapter of the annual report. Many of these recommendations were applied to datasets from Hawaii in 2018 and will similarly be done for Marianas data integration analyses in the upcoming report cycles. Implementation of these suggestions will allow for the preparation of a more finalized version of the data integration chapter in future report cycles.

3.1.2 2018 Recommendations for Chapter Development

At the 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.

The analyses presented in the data integration chapter of the 2018 Hawaii annual SAFE report are a reflection of a thoughtful re-approaching to these data integration evaluations based on this feedback. Additional data can be added to either time series as they are made available. Incorporating such recommendations into the 2018 version of the Mariana Archipelago 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 on climate and/or ecosystem change on coral reefs fish stocks of American Samoa using climate and oceanic indicators (see Section 2.5.4). 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., 2011). 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 crumenophthalmu*s 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; Weng and Sibert, 2000). The direct freshwater and nutrient input to reefs associated with increased precipitation can alter the physiochemical composition of the water, and it has been shown that reef assemblages are positively associated with this sort of increased ocean productivity (Williams et al. 2015). Data for precipitation in the Mariana Archipelago was gathered from local databases maintained by the National Weather Service (NWS-G). The time series of total annual precipitation from showed a non-significant, slightly variable trend over the last 30 years (R^2 = 0.05, CV = 19.5; Figure 33).

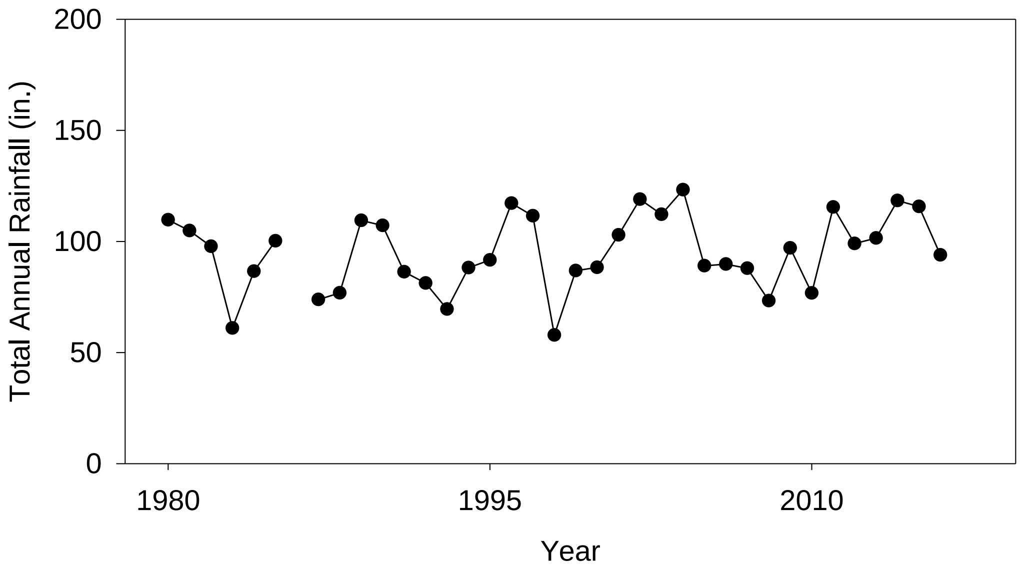


Figure 33. Total annual precipitation (in.) in Guam from 1980-2016

3.2.1.1 Evaluating relationship with atulai

Total annual estimated atulai catch in the Guam recreational coral reef fishery according to shore- and boat-based creel surveys showed no general trend over the last thirty years, with relatively large variability likely due to several years of catch orders of magnitude greater than previous or subsequent years (e.g., 2009; $R^2 = 0.01$; CV = 119.5; Figure 34). Combined effort statistics between shore- and boat-based creel survey statistics could not be generated because the proxies used to measure effort in each survey are different (i.e. number of gear hours versus number of boat trips). Similarly, because effort could not be standardized across the data sets, CPUE could not be generated on the individual family level at which these evaluations are taking place.

Examining effort, Guam shore-based creel survey data show that there are considerable differences in the number of samples recorded across gear types. The most frequently sampled gear in the shore-based survey was hook and line by an order of magnitude, and had catch estimated to be several times greater than that in the expanded dataset (Figure 35a-b). Effort data also revealed that, despite catch statistics, the gill net had been sampled the least frequently among the top gears (Figure 35a-b). Boat-based effort data show that bottom fishing was sampled approximately twice as much than the other three top gears, but the difference in the expanded estimates between were at least an order of magnitude greater (Figure 35c-d). Generally, each of the time series for prominent gear types in Guam showed a slight shift but seemingly no net change over the course of available data despite interannual variability.

Total estimated atulai catch and rainfall in Guam showed no statistical association with one another such that would allow for assessment of the fishery ecosystem relationship between the two (R^2=0.02; Figure 36). However, there seemed to be a slight observable negative relationship between the two (r = -0.15), indicating that catch may have experienced a minor decrease in years with more rainfall. Additionally, there was no association between annual rainfall amounts and total estimated atulai catch in Guam when only considering shore-based data, boat-based data, or prominent gear types.

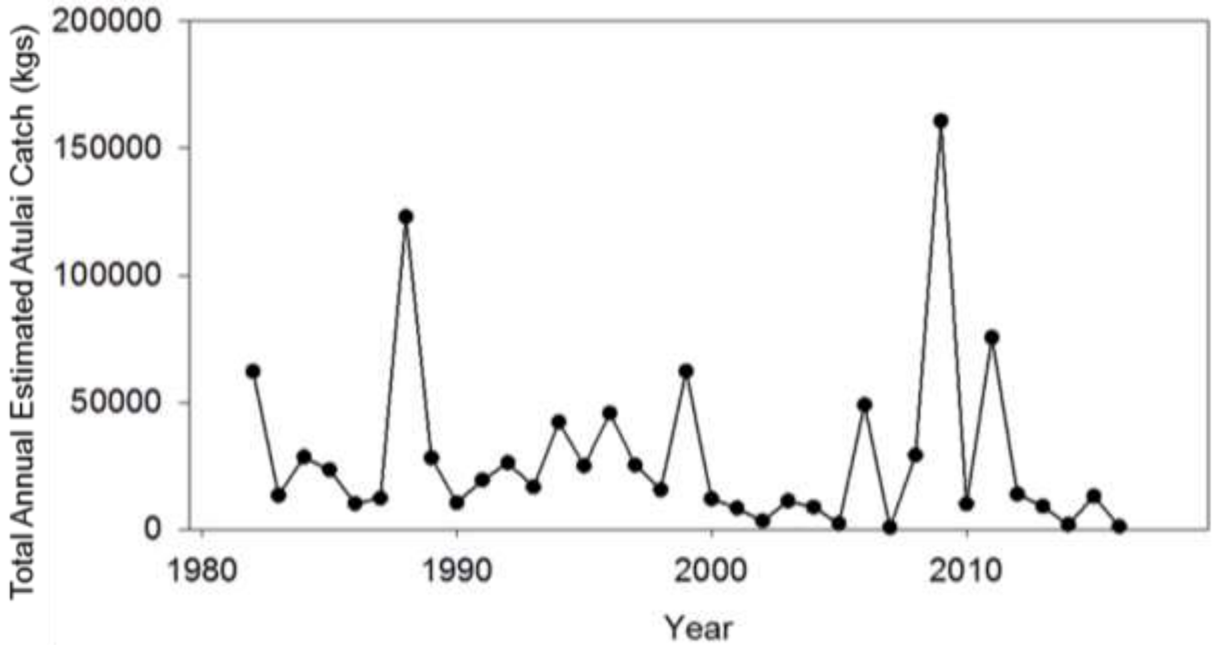


Figure 34. Time series of total annual estimated (i.e. expanded) landings of atulai in kilograms from Guam shore-and boat-based creel survey records from 1982-2016

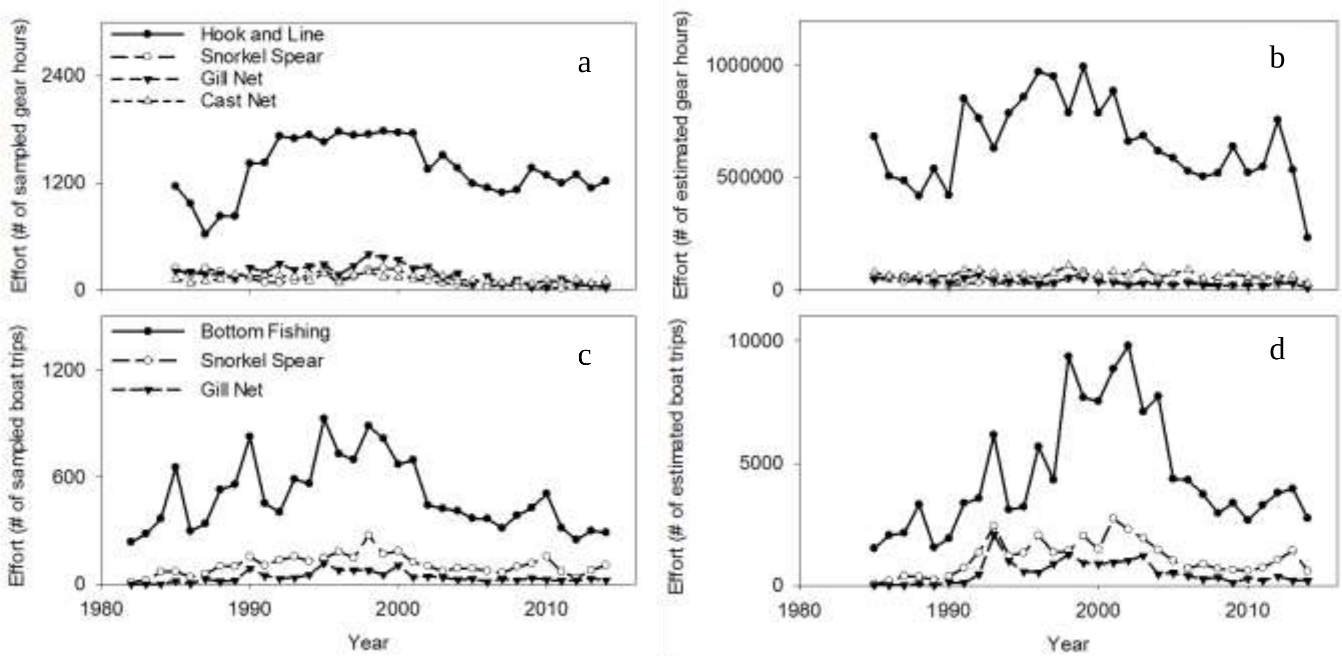


Figure 35. Time series of total sampled (left) and expanded (right) effort for top gear types in shore-based (top) and boat-based (bottom) creel surveys in Guam from 1982-2016

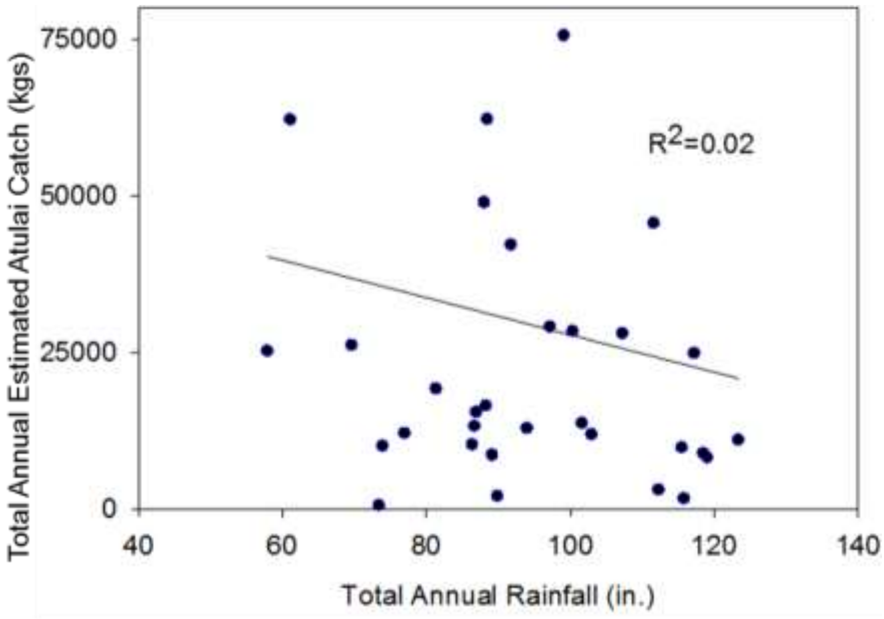


Figure 36. Linear regression between total atulai catch (kg) in the Guam shore-based and boat-based creel survey records and total annual rainfall (in.) from 1982-2016

3.2.1.2 Evaluating relationship with *D. macarellus*

Decapterus macarellus (i.e. mackerel scad) records from creel surveys in Guam were scant and had high variability, with estimated catch for many years being close to zero while others had close to 8,000 kg (R^2 = 0.01; CV = 278.4; Figure 37). Several years where mackerel scad catch data were available, they indicated a total amount landed of just a few kilograms (e.g. 1999, 2001, 2013, etc.; Figure 37). Because there were 17 of 35 total years with available mackerel scad catch data across gear types for the entire territory since 1982, many with extremely low catch estimates, the time series were not able to be used for comparison to rainfall records in the same region over the last thirty years.

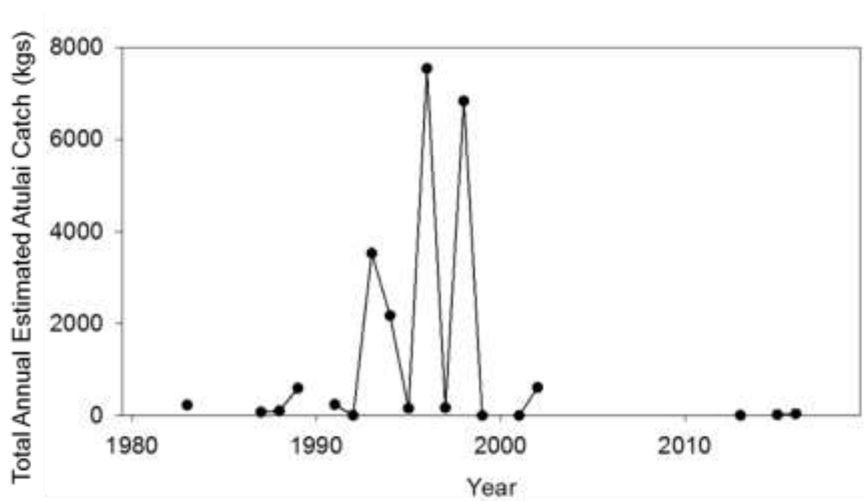


Figure 37. Time series of total annual expanded landings of *Decapterus macarellus* (kg) in Guam shore-and boat-based creel survey records from 1982-2016

In summary, no fishery ecosystem relationship could be established between atulai or mackerel scad catch with precipitation in Guam from 1982 till present without the incorporation of phase lag, and no standardized index/threshold characteristic of the association between the parameters could be identified representative of an immediate population response. The general lack of recreational harvest data for mackerel scad in Guam hindered the ability to determine whether a relationship exists with rainfall in that portion of the fishery. Analyses including atulai data had similar comparisons with rainfall data completed in the MHI as well, though no notable relationship between atulai catch and annual precipitation was identified there.

3.3 SEA SURFACE TEMPERATURE

Sea surface temperature (SST) is a commonly used diagnostic tool in monitoring climate change and its affects both regionally and globally, as it is representative of changes in ocean temperatures over time that can affect coastal fisheries (see Section 2.5.4). The potential influence of temperature-derived variables in fishery ecosystem relationships for U.S. Western Pacific coral reef stocks was deemed to be among the highest priority by the participants of the Workshop. Data for SST was gathered from the NOAA's AVHRR Pathfinder v5.0 through the OceanWatch program in the Central Pacific (NOAA/NESDIS/OceanWatch).

A time series of SST for the CNMI from 1985-2016 is shown in Figure 38. SST here had slightly less variability over time than Guam (CV = 0.55), again indicating relative stability. Unlike Guam, the CNMI did not seem to be observably increasing or decreasing over the time series of available data. The hottest temperature in the last three decades was approximately 29°C, where preceding SST had largely been stable over time. The average SST over the course of evaluated data was 28.8°C, slightly warmer than observed in Guam. The lowest recorded SST over the course of the time series was just about 27.5°C in the year 1996 (Figure 38).

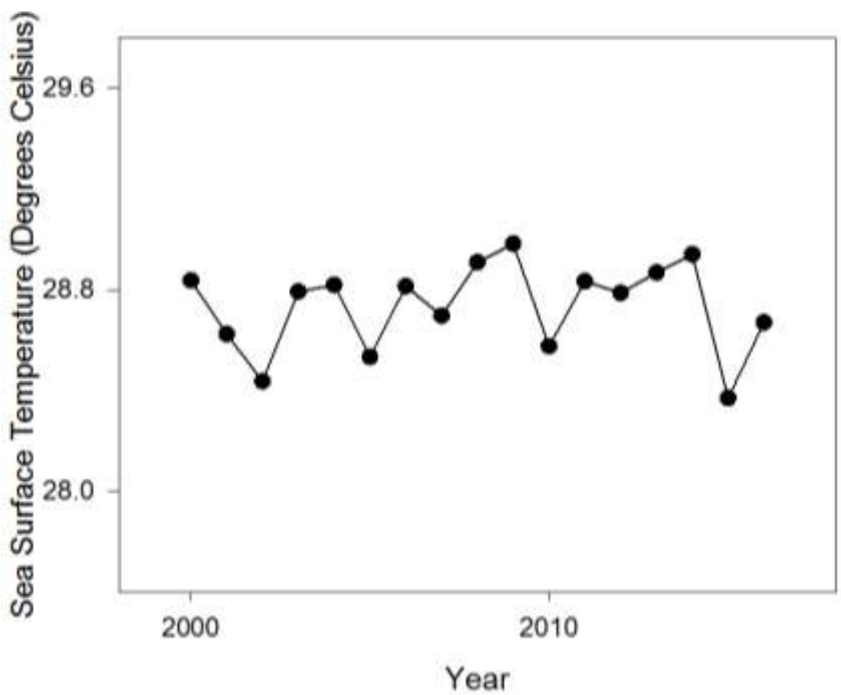


Figure 38. Time series of SST (°C) in the CNMI from 1985-2016 (CV = 0.55)

A time series of SST for Guam from 1985-2016 is shown in Figure 39. Temperature had low variability over time (CV = 1.38), suggesting relative stability. There was also a seeming increase in temperature over the last three decades, with some of the hottest temperatures recorded observed in the last five years. The average SST over the course of evaluated data was 28.6°C. The highest recorded SST over the course of the time series was just over 29°C in the year 1999, whereas the lowest was earlier in the 1990s (27.7°C; Figure 39).

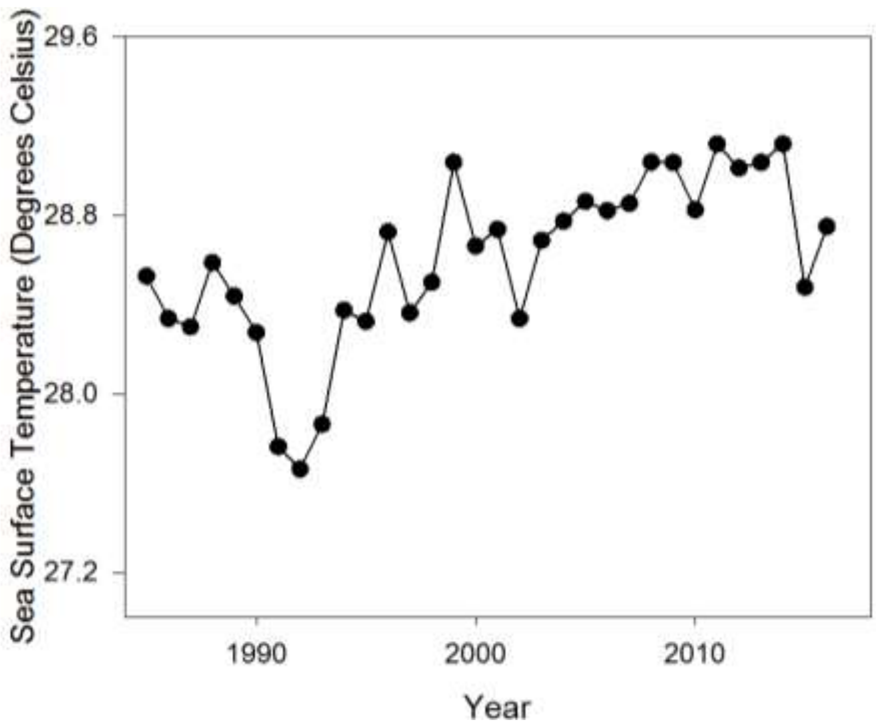


Figure 39. Time series of SST (°C) from 1985-2016 in Guam (CV = 1.38)

3.3.1 CNMI

3.3.1.1 Evaluating relationship for entire reef fishery

A plot showing the relationship between SST and catch time series from the recreational coral reef fishery in the CNMI from 2000-2016 is depicted in Figure 40. Landings were variable over the course of the time series (CV = 19.4), but less so than observed in catch time series in Guam. Total annual catch in the fishery has been observably decreasing over the last decade and a half despite an abrupt increase in 2013 resulting in the recorded maximum catch over this period (~338,000 kg). Recent recorded catch levels (i.e. for 2016) were the lowest for the fishery through the available time series of data (~165,000 kg; Figure 40).

In performing comparisons between fishery parameters and environmental variables such as SST, data were grouped in taxa categories based on family due to scarcity of data on the species level in many cases. Table 69 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 70. The comparisons between the two parameters showed a negatively significant relationship between

2000 and 2016 ($R^2 = 0.30$, $p = 0.02$; Table 70; Figure 41). The relationship between the total annual catch and average annual SST for the whole fishery were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 105,000 kg (Figure 41).

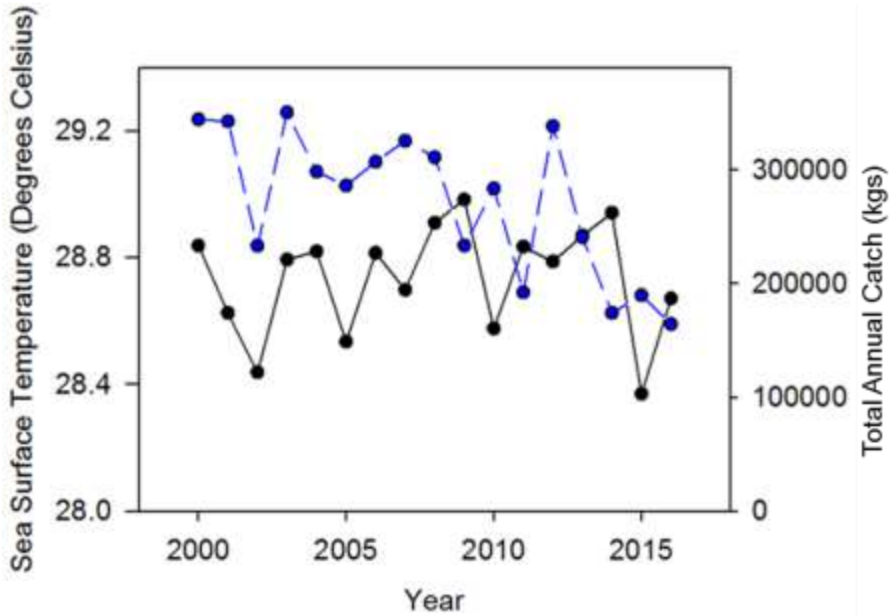


Figure 40. Time series of total annual catch (kg; blue) for the CNMI recreational coral reef fishery plotted alongside average annual SST (°C; black) from 2000-2016

Table 69. 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 70. Correlation coefficients (*r*) between recreational coral reef fishery catch (kg) and SST (°C) in the CNMI for 12 top taxa harvested from 2000-2016

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 17													
p	**0.02**	0.49	0.54	0.26	0.70	0.91	0.99	0.88	0.06	-	0.59	0.91	0.82
r	**-0.55**	0.18	-0.16	-0.29	-0.10	-0.03	0.00	-0.04	-0.47	-	0.14	0.03	-0.06
R^2	**0.30**	0.03	0.02	0.09	0.01	0.00	0.00	0.00	0.22	-	0.02	0.00	0.00

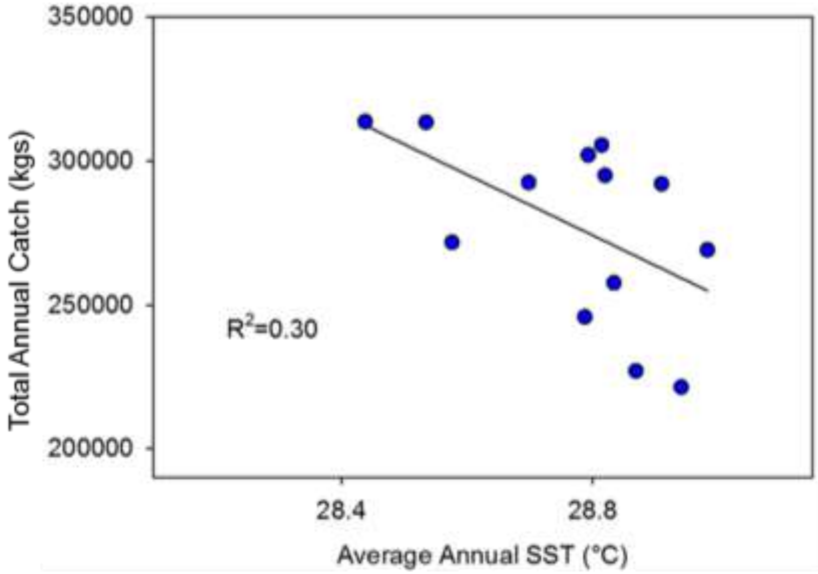


Figure 41. Linear regression showing the correlation between total annual catch (kg) in creel survey records and average annual SST (°C) in the CNMI from 2000-2016

3.3.1.2 Evaluating relationship for dominant taxa

Correlation and regression analyses were performed on prominent taxa in the CNMI recreational coral reef fishery, and it was found that no individual taxa had significant relationships with SST data (Table 70). The strongest associations between fishery catch and SST were observed from the Mullids ($R^2 = 0.22$, p = 0.06; Figure 42a), Carangids ($R^2 = 0.09$, p = 0.26; Figure 42b), and Lutjanids ($R^2 = 0.03$, p = 0.49; Figure 42c). While the relationship between catch and temperature for families Mullidae and Carangidae were negative, the Lutjanidae family had a positive relationship (Table 70).

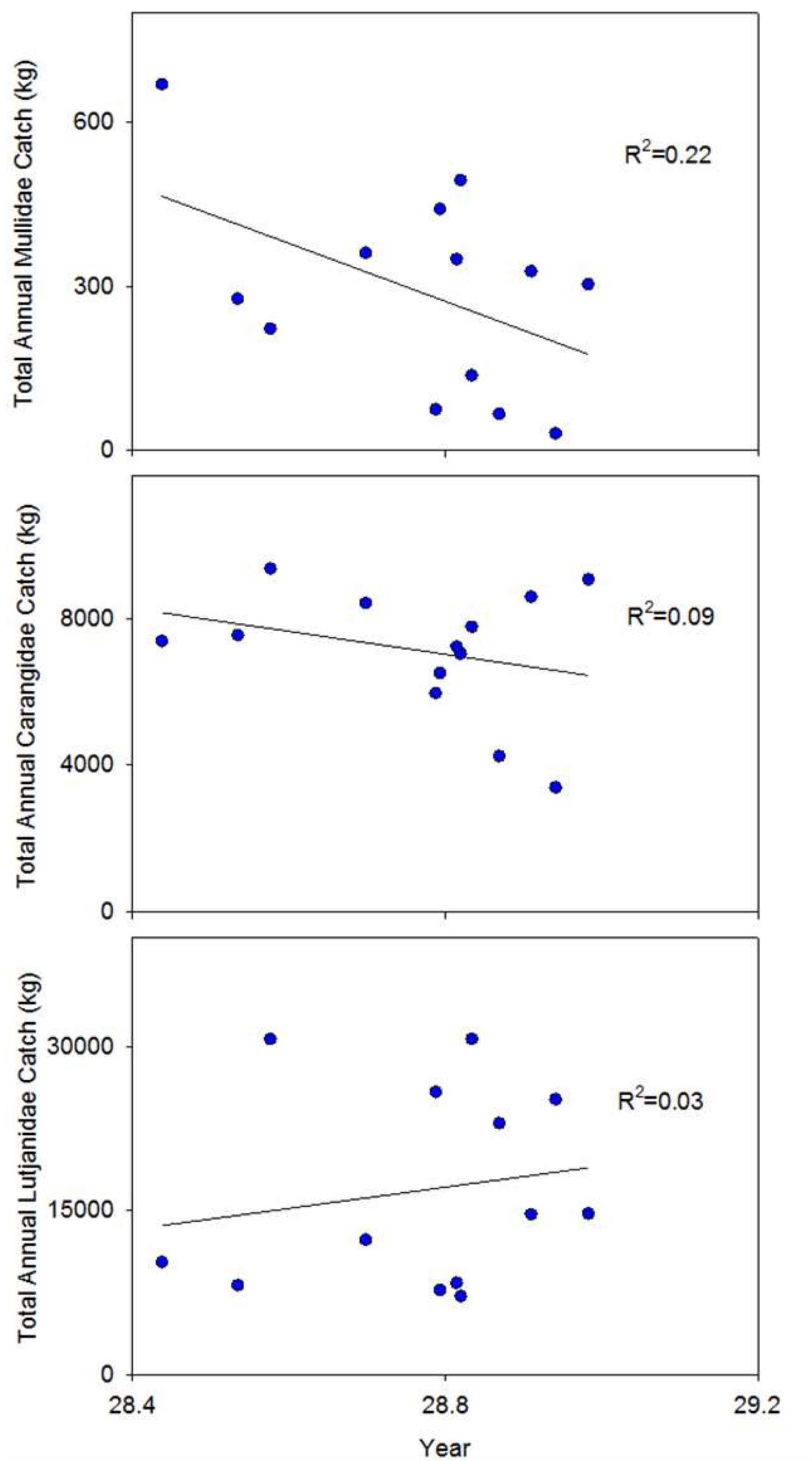


Figure 42. Linear regressions showing the three top correlations between total annual catch (kg) from creel survey records and average annual SST (°C) in the CNMI from for (a) Mullids, (b) Carangids, and (c) Lutjanids from 2000–2016

3.3.2 Guam

3.3.2.1 Evaluating relationship for entire reef fishery

An individual plot depicting the comparisons of time series of SST and catch from the recreational coral reef fishery in Guam from 1985-2016 is shown in Figure 43. Landings were variable over the course of the time series (CV = 28.1) though relatively stable, especially before the year 2000. There was a relatively abrupt observed decrease in total annual catch from 1998 to 2005, where recorded landings went from over half a million kg to approximately 180,000 kg in less than a decade. Catch has slightly rebounded since that minimum, with landings reaching over 400,000 kg in six of the last seven years (Figure 43).

Multiple linear regressions and correlation analyses were performed on time series of recreational coral reef fishery catch and annual mean SST from Guam (Table 71). 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 71; Figure 44). The relationship between the total annual catch and average annual SST were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 120,000 kg (Figure 44).

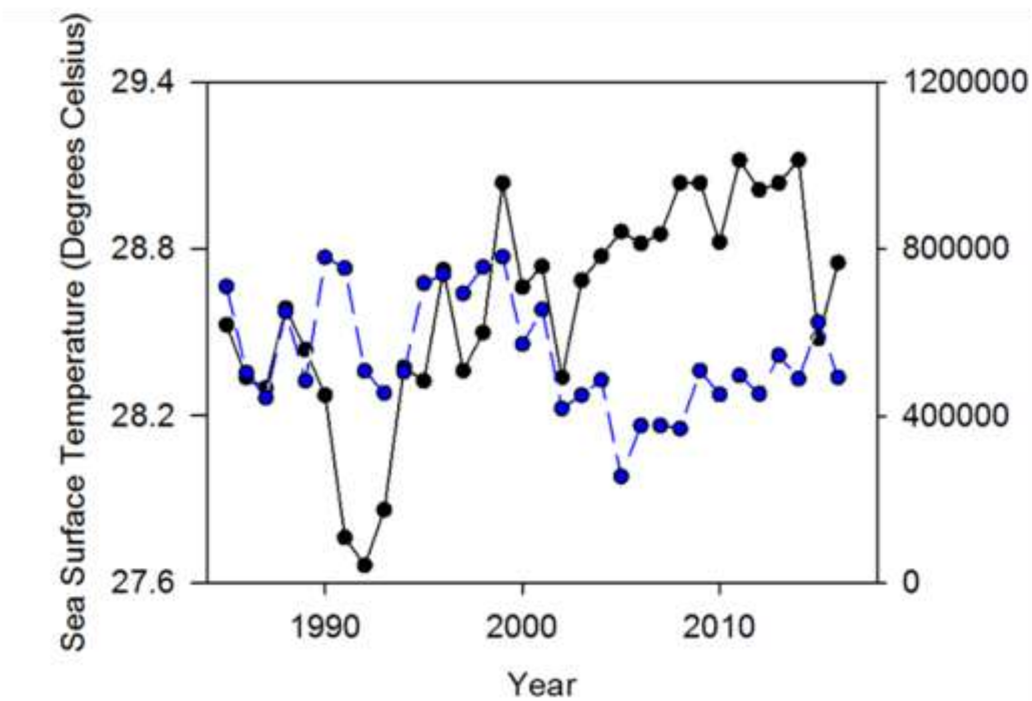


Figure 43. Time series of total annual catch (kg; blue) in the Guam shore-and boat-based creel survey records plotted with average annual SST (°C; black) from 1985-2016

Table 71. Correlation coefficients (*r*) between recreational coral reef fishery catch (in kg) and SST (°C) in Guam for 12 top taxa harvested from 1985-2016

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 28													
p	0.02	0.01	0.00	0.01	0.39	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00
r	-0.45	-0.80	-0.48	0.17	-0.50	-0.54	-0.71	-0.51	-0.56	-0.66	-0.60	-0.63	-0.43
R^2	0.20	0.64	0.23	0.03	0.25	0.30	0.50	0.26	0.31	0.43	0.35	0.39	0.18

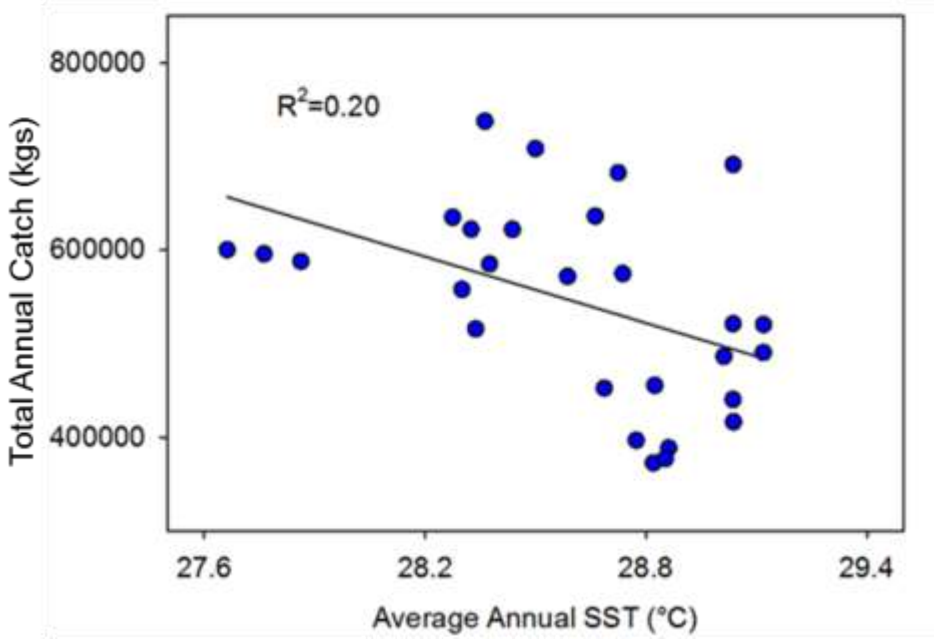


Figure 44. Linear regression between total annual catch (kg) for shore- and boat-based creel survey records and average annual SST (°C) in Guam from 1985-2016

3.3.2.2 Evaluating relationship for dominant taxa

Comparisons were made for the time series of catch for prevalent taxa in Guam's recreational reef fishery as well, and it was found that all except for the Acanthuridae family showed negative statistically significant correlations with SST (Table 71). 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 71; Figure 45a). The next two strongest associations observed were for families Siganidae (R^2 = 0.50, p = 0.00; Figure 45b) and Mugilidae (R^2 = 0.43, p = 0.01; Figure 45c). The regressions performed with temperature for taxa, suggesting negative relationships with temperature, also showed that for every degree of temperature increase in degrees Celsius, Siganidae and Mugilidae recreational catch in Guam would decrease by approximately 10,000 kg and 7,500 kg, respectively.

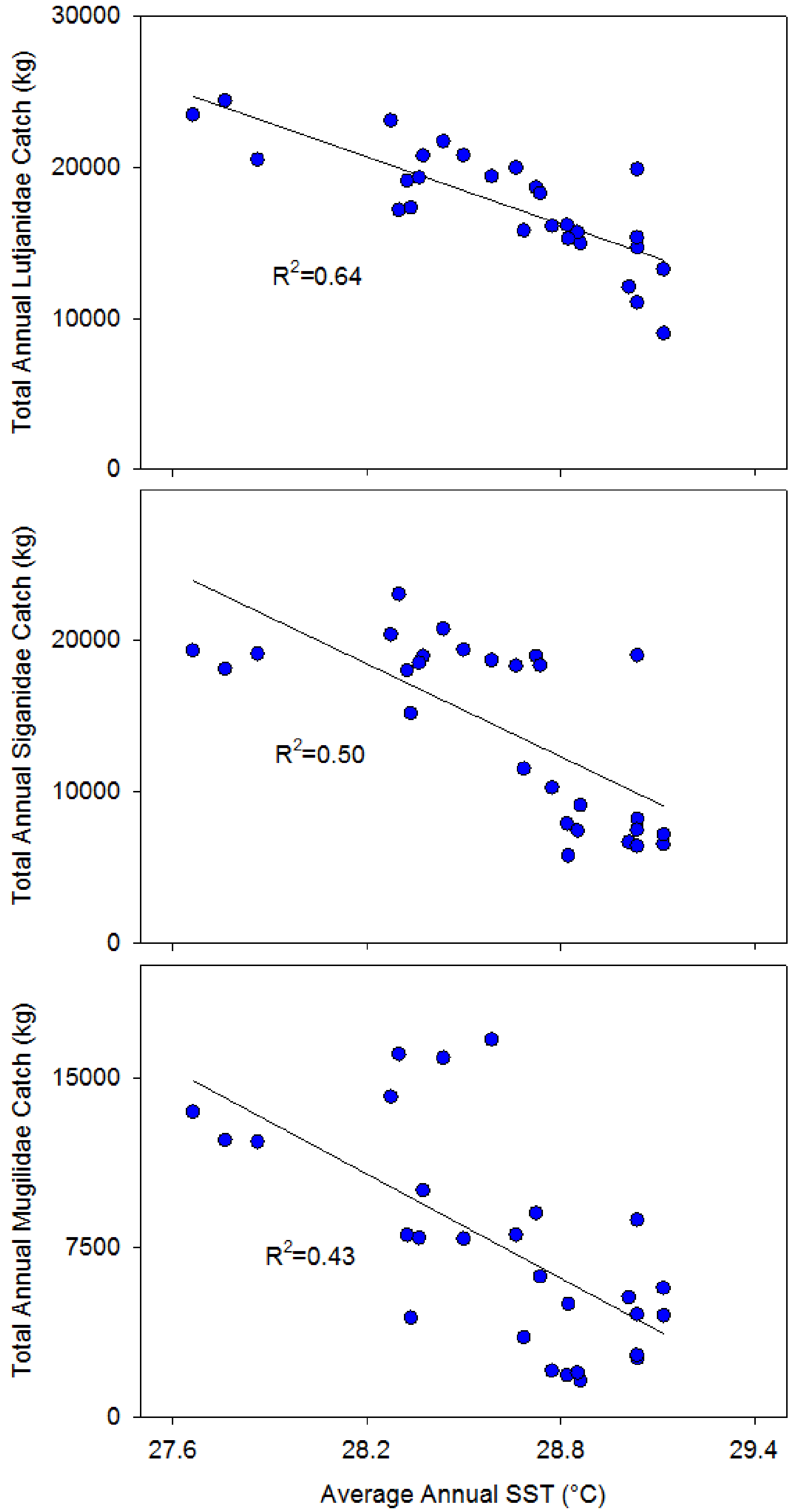


Figure 45. Linear regressions showing three top correlations between total annual catch (kg) for shore-and boat-based creel survey records and average annual SST (°C) in Guam for (a) Lutjanids, (b) Siganids, and (c) Mugilids from 1985–2016

In summary, Guam and the CNMI had fishery ecosystem relationships that could be identified for the entirety of the recreational coral reef fishery. The relationship between the total annual catch and average annual SST in Guam were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 120,000 kg The relationship between the total annual catch and average annual SST in the CNMI were associated such that for every degree Celsius of temperature increase, catch would decrease by approximately 105,000 kg

In Guam, the linear regressions performed showed that all evaluated taxa except for the Acanthurids had a statistically significant negative relationship with average annual temperature. The three strongest associations with SST were with the Lutjanids, Siganids, and Mugilids, such that the total annual catch for each would decrease by approximately 7,500-10,000 kg for every increase in SST by one degree Celsius. In the CNMI, conversely, there were no individual family groups whose catch data had statistically significant associations with temperature, though the strongest associations observed were the Mullids (relatively close to the threshold of significance, $p = 0.06$), Carangids, and Lutjanids. The relationships for families Mullidae and Carangidae were negative, though the Lutjanidae family displayed a positive relationship with SST.

3.4 PRIMARY PRODUCTIVITY

3.4.1 CNMI

Concentrations of the pigment chlorophyll-*a* are commonly used as an index of phytoplankton biomass that represents primary production, a commonly utilized tool in identifying eutrophication also noted to be among the highest priority fishery ecosystem relationships in the WPR by participants of the Workshop (Islam and Tanaka, 2004). In Pacific regions where interannual precipitation and associated coastal runoff are relatively high, the physiochemistry of nearshore reefs is especially impacted from accompanying nutrient input resulting in increased primary production (Ansell et al., 1996).

Long-term changes in regional primary productivity have the potential to change reef fish population abundance due to the susceptibility of these assemblages in shallow areas of coastal reefs to variations in water chemistry, especially when combined with the variability of other environmental parameters like sea surface temperature (Kitiona et al., 2016). For example, it has been suggested that warming ocean temperatures coupled with decreasing environmental productivity led to waning reef fish assemblages in the Southern California Bight, likely due to a reduction in upwelling that isolated nutrients at depth (Roemmich and McGowan, 1995). With recent progress in satellite and fluorometric measurements of oceanic surface waters, time series of global and regional primary production estimated using concentrations of chlorophyll-*a* have become increasingly available, and can be used for evaluating the impact of environmental productivity on reef fish population abundance and the marine food web in general (Behrenfed et al., 2006; Messié and Radenac, 2006). Data for the study at hand were gathered from the ESA Ocean Colour Climate Change Initiative dataset version 3.1.

Considering the Ocean Colour Climate Change Initiative dataset (v3.1) for CNMI, the time series of fluorometric chlorophyll-*a* concentrations (mg/m^3) for the years 1998-2016 in the region is shown in Figure 46. The chlorophyll concentrations had less variability than Guam (CV = 6.28) but was relatively higher in overall average concentration. Unlike Guam, however, pigment levels appeared to have been decreasing over the course of the time series despite the non-significant nature of the associated regression. Over the 15 years of evaluated data, the average chlorophyll-*a* concentration was 0.049 mg/m^3, though the lowest recorded level was seen in 2014 at 0.042 mg/m^3 Figure 46.

A time series of fluorometric chlorophyll-*a* concentrations (mg/m^3) for the years 1998-2016 in Guam is shown in Figure 47. Pigment concentration in the upper 200 meters had moderate variability over the course of the time series (CV=7.03). Also, there seemed to be a slight increase in pigment concentrations over the course of collected data despite the lack of a significant trend over the same time. The average chlorophyll-*a* concentration over this time was 0.048 mg/m^3, with the highest recorded levels being observed in 2005 at 0.055 mg/m^3 and the lowest occurring earlier in 2002 (0.042 mg/m^3; Figure 47).

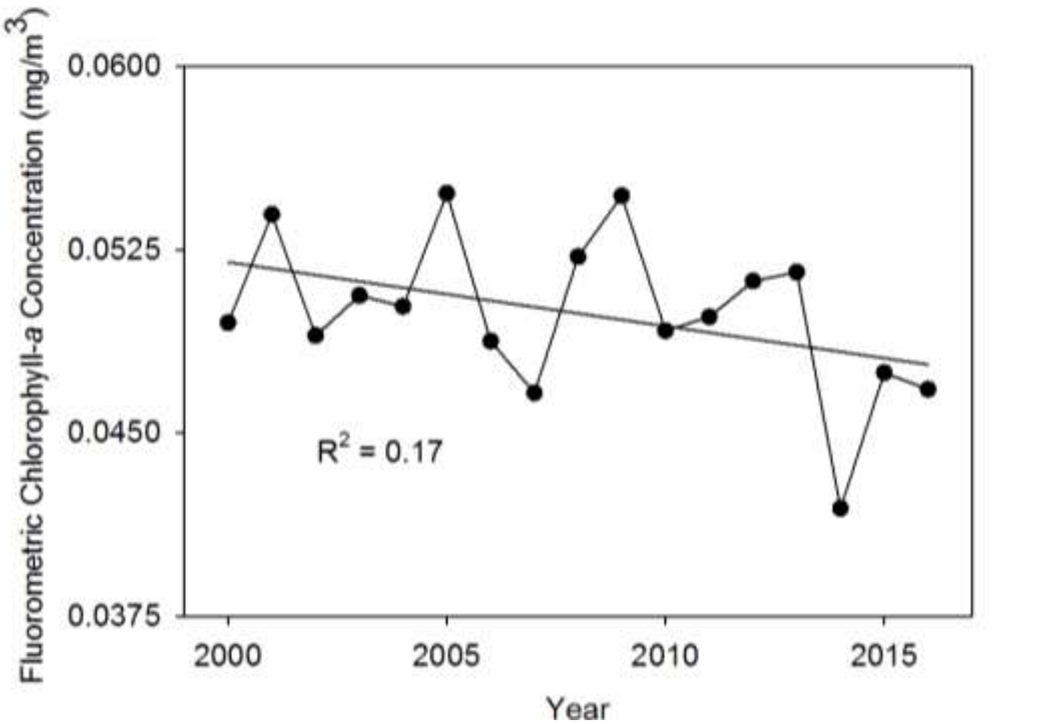


Figure 46. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around the CNMI from 1998-2016 (CV=6.28)

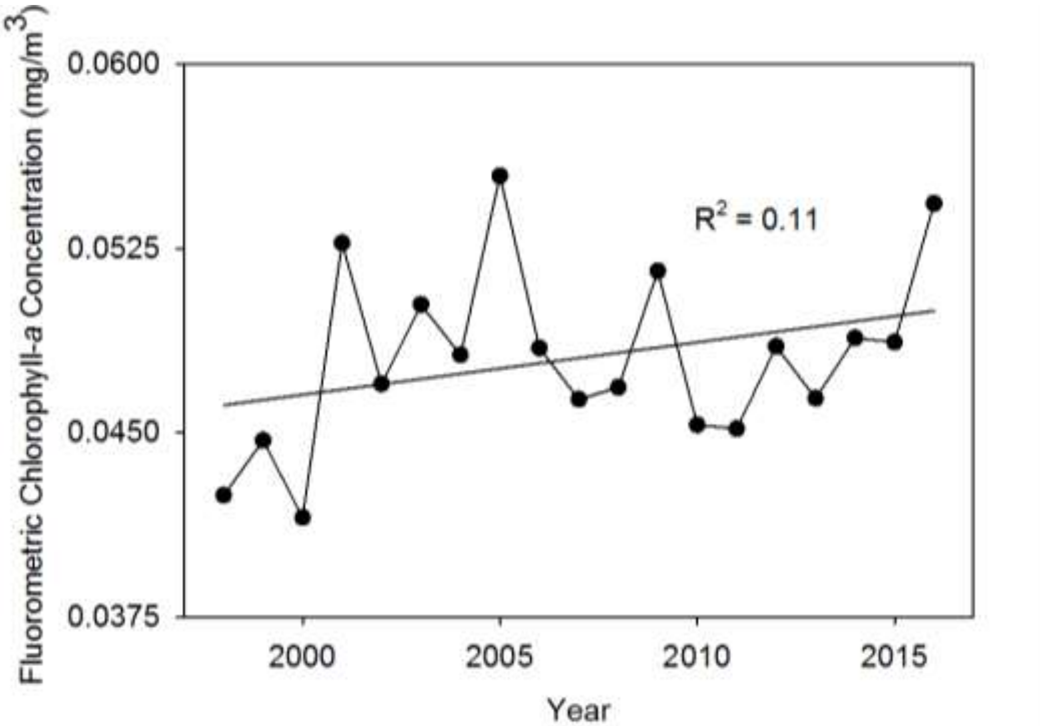


Figure 47. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around Guam from 1998-2016 (CV=7.03)

3.4.1.1 Evaluating relationship for entire reef fishery

A plot showing the relationship between these same chlorophyll levels and catch time series from the recreational coral reef fishery in the CNMI from 2000-2016 is depicted in Figure 48. Catch, again, was even more variable than the environmental data evaluated (CV=19.4) and was at about the same levels as Guam. Total annual catch in the fishery has been decreasing over the last decade and a half despite a spike in catch during 2013 that gave the maximum observed annual catch over this time series (~338,000 kg). The levels of current catch (i.e., for 2014-2016) are the lowest for the entirety of the recreational fishery over the past decade and a half (~165,000 kg; Figure 48).

In pattern with the analyses completed for Guam, linear regressions and correlation analyses were conducted for the time series of the CNMI recreational coral reef fishery catch (with phase lag) with fluorometric chlorophyll-*a* concentrations (mg/m^3) gathered for the 15 years between 2000-2014. The chlorophyll-*a* concentrations and total annual catch for the all harvested taxa had a positive relationship between 2000 and 2014, though the relationship was far from being considered statistically significant ($r = 0.32$, p = 0.25; Table 72; Figure 49). Though not significant, the regression was extrapolated to determine that, following this pattern, every increase of 0.01 mg/m^3 in chlorophyll-*a* concentration would cause increase by nearly 62,000 kg two years later for all the CNMI recreational reef fishery (R^2=0.11, p = 0.25; Figure 49).

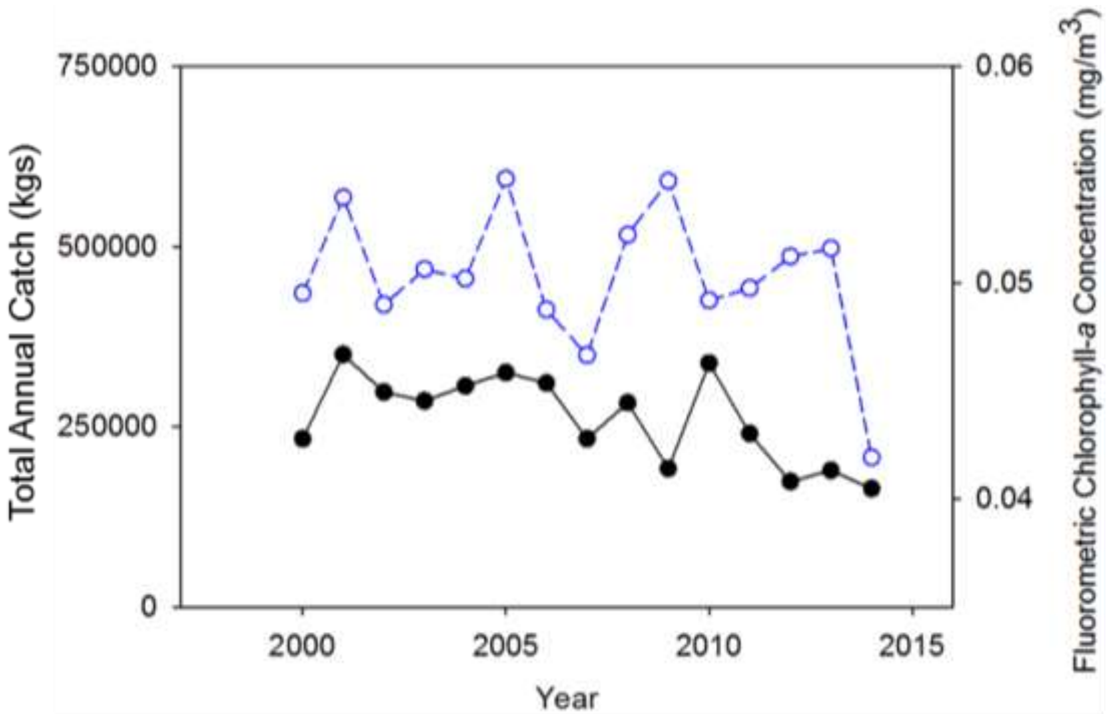


Figure 48. **Comparison of the CNMI recreational reef fish catch (kg; black) from creel survey records with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 2000-2014 (r = 0.32)**

Table 72. Correlation coefficients (r) from comparisons of time series of the CNMI recreational coral reef fishery annual catch (kg) and fluorometric chlorophyll-*a* concentrations (mg/m^3) from 2000-2014

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 15													
p	0.25	0.47	0.14	0.67	0.37	0.09	0.72	0.80	0.99	0.83	0.83	0.10	0.72
r	0.32	-0.20	-0.04	0.12	0.25	0.45	-0.10	-0.07	0.00	-0.06	-0.06	0.44	0.10
R^2	0.11	0.04	0.00	0.02	0.06	0.20	0.01	0.01	0.00	0.00	0.00	0.20	0.01

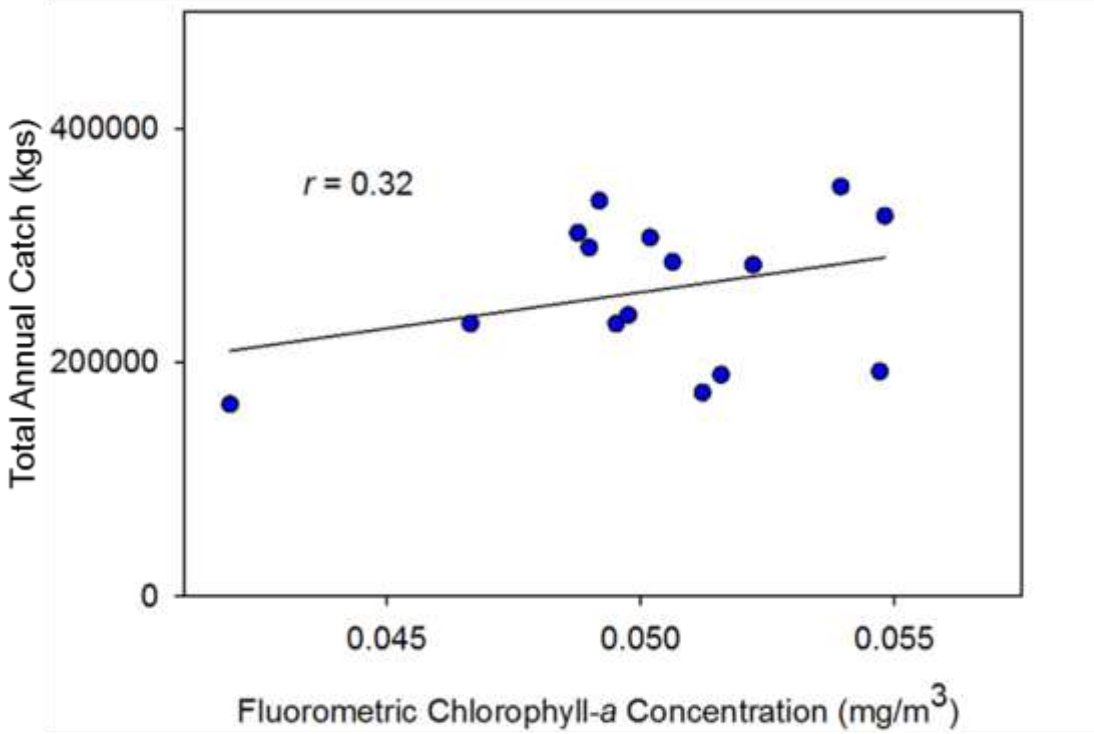


Figure 49. Linear regression between total annual catch (kg) phase lag (t+2 years) and fluorometric chlorophyll-a concentrations (mg/m^3) in CNMI from 2000-2014

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 72). Of the 12 analyzed groups, the three with the strongest (non-significant) relationship with local chlorophyll concentrations were the Serranids, the Acanthurids, and the Holocentrids (R^2 = 0.20, 0.20, 0.06, respectively; Figure 50a-c). It is interesting to note that, unlike Guam, the overall relationship between pigment concentration and catch for the entirety of the reef fishery in the region was positive, though non-significant (r = 0.32, p = 0.25), and the strongest determined associations among the analyzed taxa were all positive as well (Table 72).

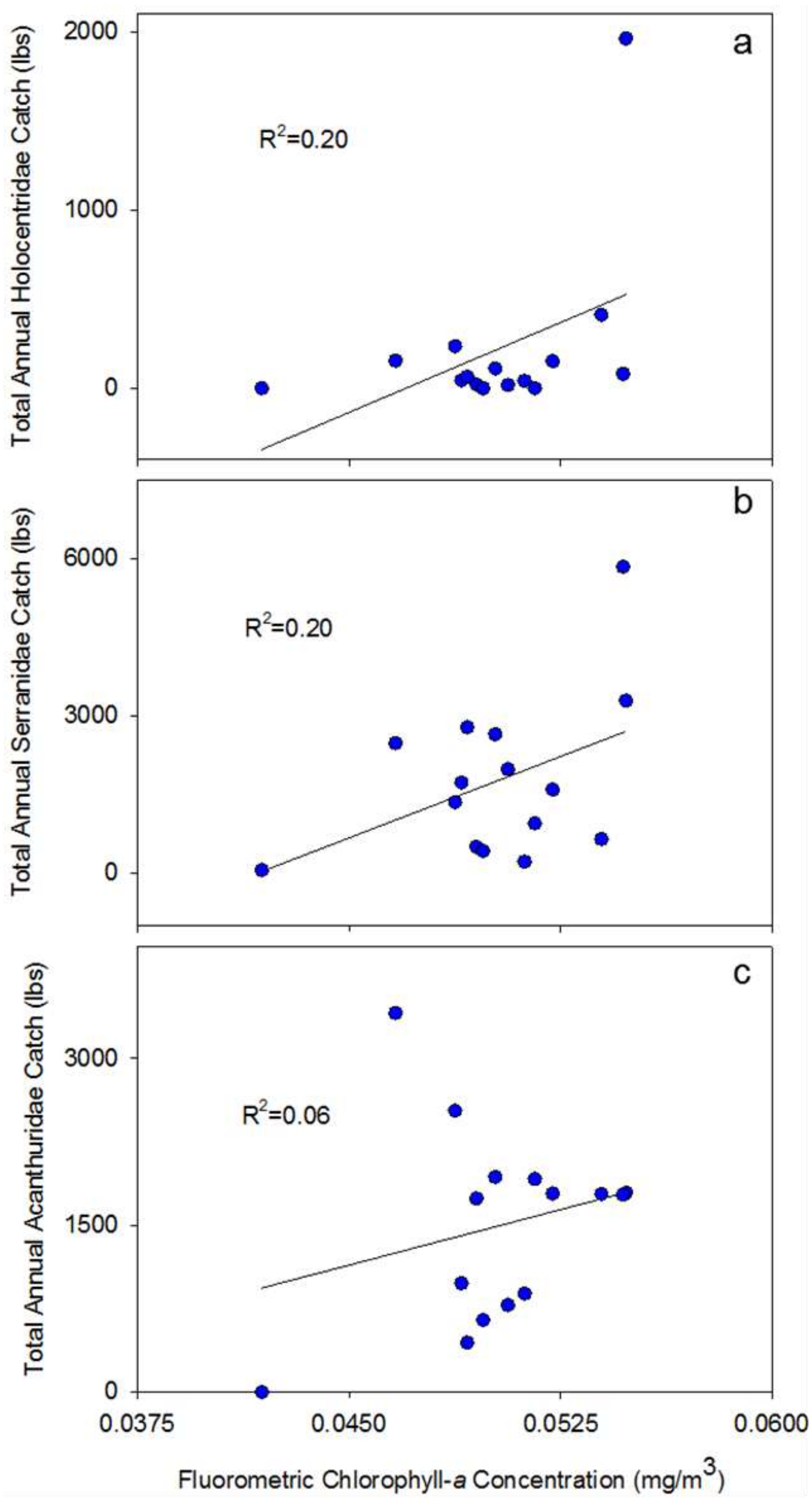


Figure 50. Linear regressions showing the three top correlations between total annual catch (kg) for the CNMI from creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) for (a) Holocentrids, (b) Serranids, and (c) Acanthurids from 2000–2014

3.4.2 Guam

3.4.2.1 Evaluating relationship for entire reef fishery

A plot depicting the comparison of the fluorometric chlorophyll-*a* concentrations and recreational coral reef fishery catch time series from 1998 - 2014 in Guam is shown in Figure 51. Catch levels were relatively variable over the course of the time series when considering the variation in pigment levels (CV=26.2; Figure 51). A gradual drop in total annual catch was observed starting from 1998 before stabilizing in the late 2000s, where recorded catch decreased to approximately a quarter million. and rose back up to over half a million kilograms in more recent years; it is of note that the minimum catch and maximum chlorophyll concentration depicted in this plot both occurred in the year 2005 (Figure 51).

Linear regressions and correlation analyses were conducted for the time series of the Guam recreational coral reef fishery catch (with phase lag) with fluorometric chlorophyll-*a* concentrations (mg/m^3) gathered from the Ocean Colour Climate Change Initiative dataset (v3.1) for the 17 years between 1998 and 2014. It was found that the chlorophyll concentrations and total annual catch for the all harvested taxa had a negative relationship between 1989 and 2015, though it was slightly over the threshold of significance (r = -0.45, p = 0.02; Table 73; Figure 52). The association was statistically significant, and it was determined that for every increase of 0.01 mg/m^3 in chlorophyll-*a* concentration, catch would approximately decrease by 180,000 kg after two years all of the Guam recreational fishery (R^2 = 0.20, p = 0.02; Table 73; Figure 52).

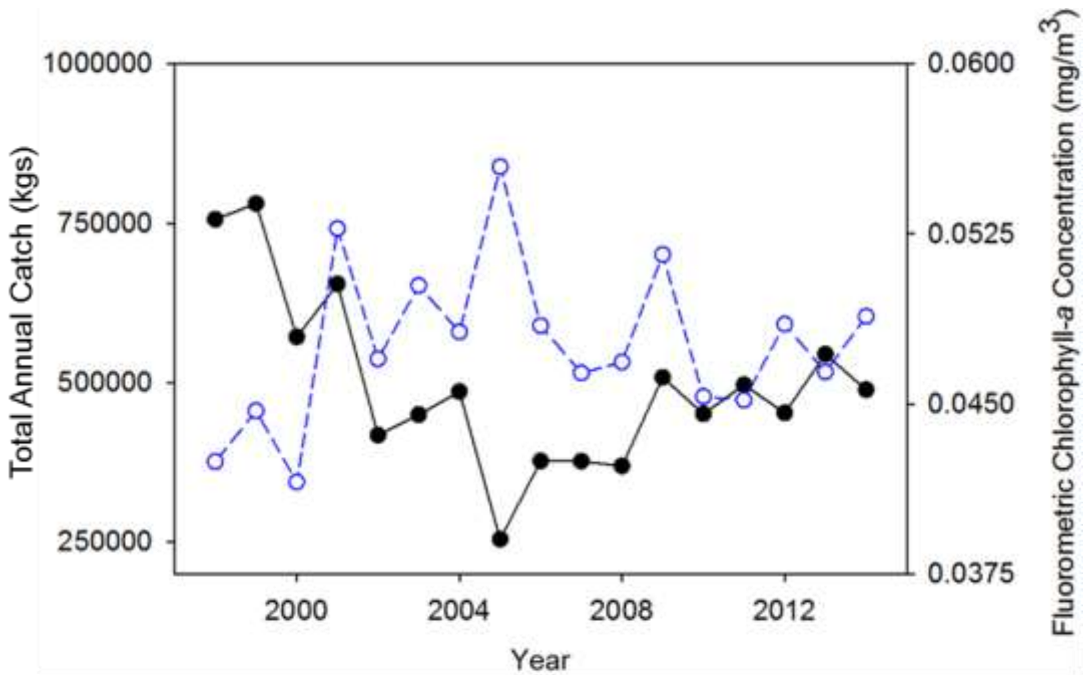


Figure 51. Comparison of Guam recreational reef fish catch for shore-and boat-based creel survey records (kg; black) with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 1998-2014

Table 73. Correlation coefficients (*r*) from comparisons of time series of for shore-and boat-based creel survey records in Guam (kg) and fluorometric chlorophyll-*a* concentrations

(mg/m^3) for 12 top taxa harvested from 1998 - 2014. Significant correlations are indicated in bold (α=0.05)

Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
n = 17													
p	0.07	0.62	0.16	0.73	0.44	0.51	0.17	0.42	0.08	**0.04**	0.47	0.21	**0.03**
r	-0.45	-0.13	-0.36	-0.09	-0.20	-0.17	-0.35	-0.21	-0.43	**-0.50**	-0.19	-0.32	**-0.53**
R^2	0.20	0.02	0.13	0.01	0.04	0.03	0.12	0.04	0.19	**0.25**	0.03	0.11	**0.28**

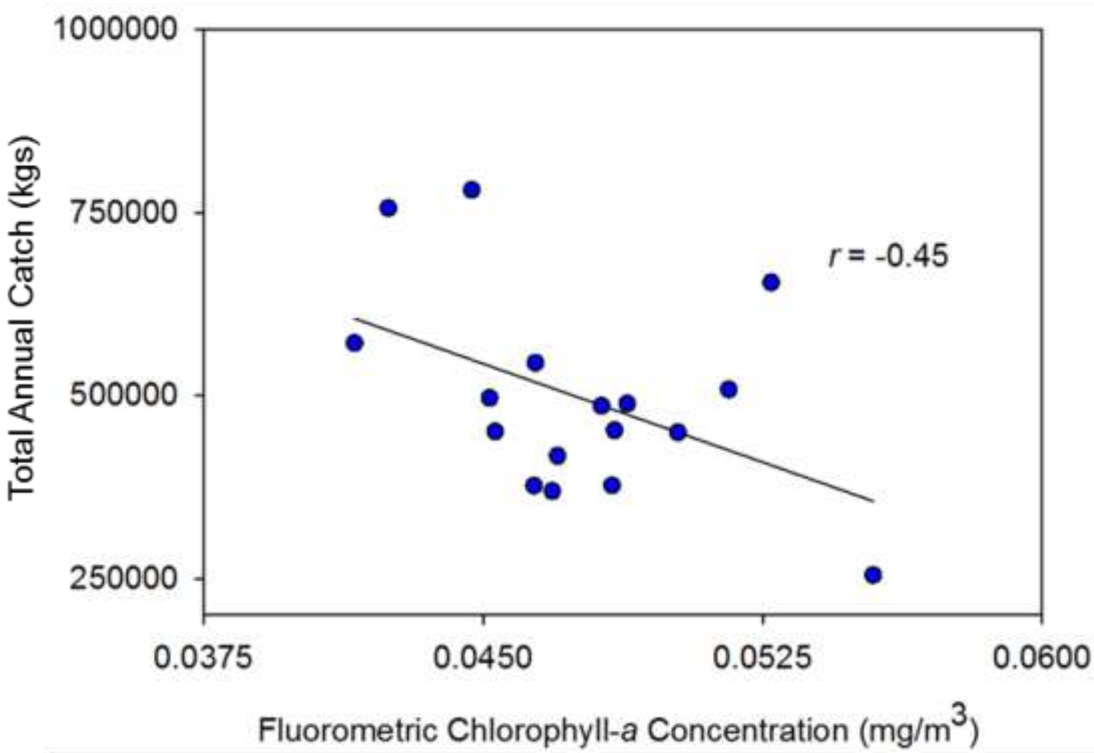


Figure 52. Linear regression between total annual catch (kg) for Guam shore-and boat-based creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) from 1998-2014

3.4.2.2 Evaluating relationship for dominant taxa

The several linear regression and correlation analyses performed for time series of catch on the taxa level of Guam's recreational reef fishery showed that for dominant taxa in the fishery, and only two of the 12 analyzed groups had statistically significant relationships with local chlorophyll concentrations: the Balistids and the Mugilids (Table 73). 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 73; Figure 53a). The relationship between catch of members of the Mugilidae group and chlorophyll concentration was also shown to be negatively significant, but to a lesser degree. With a rise of 0.01 mg/m^3 in chlorophyll-*a* levels, recreational catch of the Mugilids would decrease by approximately over 4,600 kg after two years for the group (R^2=0.25, p = 0.04; Table 73; Figure 53b;). The next strongest relationship as determined by the regressions was not significant, but was similarly negative

(Mullidae; R^2=0.19, p=0.08; Table 73; Figure 53c); all four of these potential fishery ecosystem relationships, however, were positive.

In the CNMI, there were no statistically significant relationships discovered between chlorophyll concentrations and any of the 12 prevalent taxa evaluated in this study, nor to the total fishery annual catch in its entirety. The lack of identifiable associations could have been attributed to the relatively short time series of data available for comparison at 15 years. While there were several families observed that had relationships on the cusp of being deemed significant according to resulting coefficients of determination, such as Serranidae and Holocentridae, they were positively associated.

In summary for Guam, it was determined that there existed a negatively significant relationship between reef recreational catch and fluorometric chlorophyll-*a* concentrations (mg/m^3) from the Ocean Colour Climate Change Initiative dataset (v3.1) for the entirety of the fishery. For every increase of 0.01 mg/m^3 in chlorophyll-*a* concentration, catch would approximately decrease by 180,000 kg across all harvested taxa two years later. Potential statistically significant fishery ecosystem relationships were also observed for the Balistidae and Mugilidae groups, where the catch of each group would decrease by approximately 1,700 and 4,600 kg, respectively, given two years of phase lag with a similar increase in fluorometric chlorophyll.

Uncertainty levels were relatively high in evaluations including chlorophyll-*a* concentrations due to the nature of incorporating phase lag and not smoothing the catch data. The largest issue in performing comparison analyses between catch from reef fisheries in the Mariana Archipelago and fluorometric chlorophyll-*a* concentrations was the relatively short time series (i.e. small sample size). Robust, homogenous time series highlighting interdecadal patterns in these regions were difficult to obtain due to time series merging several sources of chlorophyll concentration to elongate the range of continuous data. For example, the ESA’s OCC CCI dataset only permitted the use of less than two decades of data when evaluating the territories with the incorporation of phase lag. The length of the applied lag has a large impact in the patterns observed, so the relatively short extent of the available time series may obfuscate some of the identified relationships.

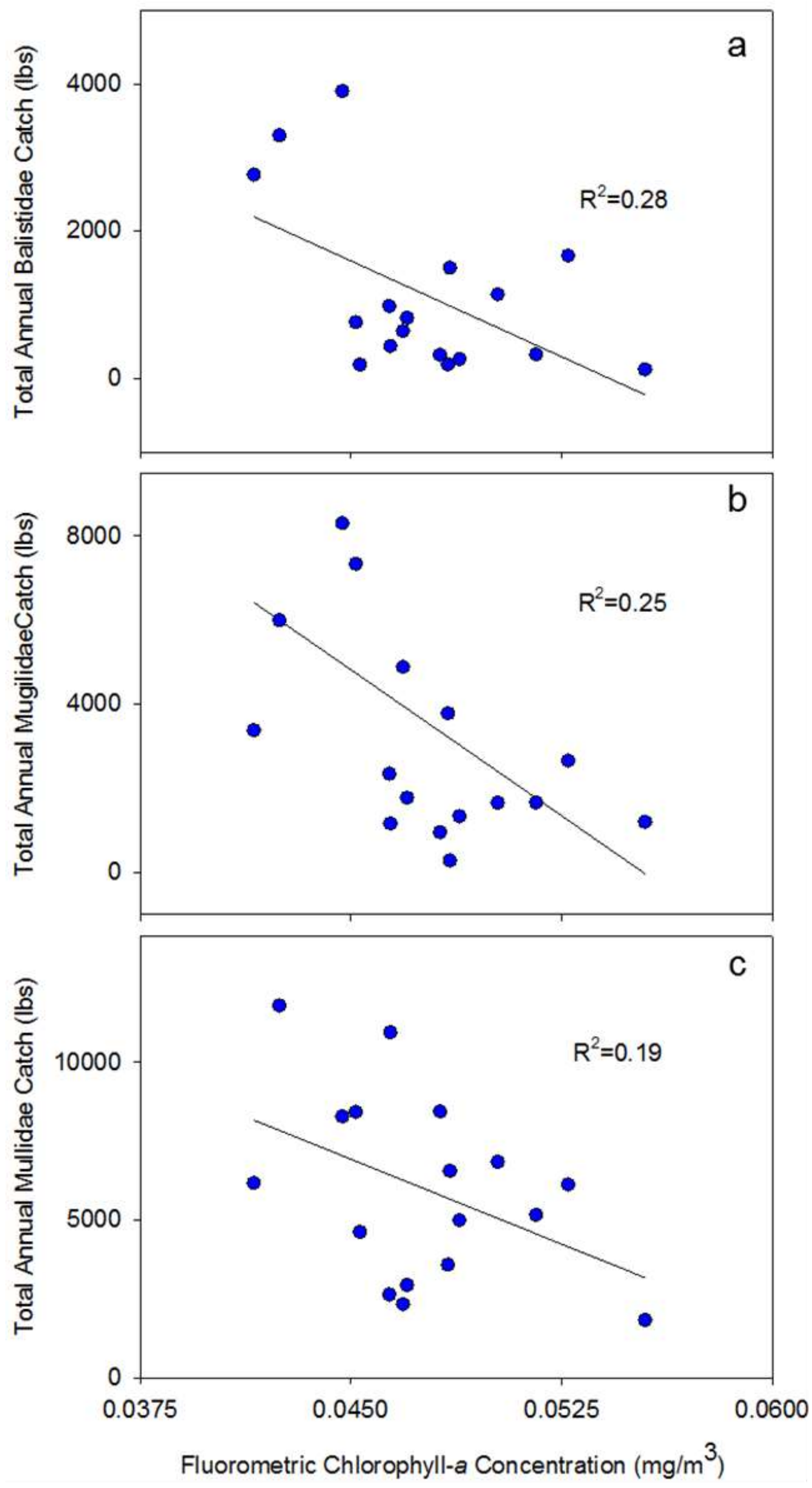


Figure 53. Linear regressions showing the three top correlations between total annual catch (kg) for Guam for shore-and boat-based creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) for (a) Balistidae, (b) Mugilidae, and (c) Mullidae from 1998–2014.

3.5 MULTIVARIATE ASSESSMENTS OF OTHER ECOSYSTEM VARIABLES

3.5.1 Non-metric Multidimensional Scaling

There were several other prioritized fishery ecosystem relationships for coral reefs in the Mariana Archipelago involving environmental parameters that were not to be addressed in this initial evaluation including: the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), sea level height, pH, dissolved oxygen, and salinity. Further descriptions of these climate and oceanic indicators are available in Section 2.5. 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 the Marianas were gathered from Simple Ocean Data Assimilation (SODA) version 3.3.1 (Carton and Giese, 2008). Rainfall estimates were obtained through the National Weather Service in the Mariana Archipelago (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 heterogeneous 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 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.

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 accounts for 87.2% of the cumulated variance observed in the CNMI boat-based creel survey data. The NMS final stress was morderate for the real runs (13.9), but low relative to stress from the randomization runs (31.0; Figure 54. NMS scree plot showing the stress test to determine dimensionality for the final solution for the CNMI multivariate analysis). The final ordination scores for the families considered were scaled on a gradient relative to the individual ordination axis, the overlying environmnetal joint biplot is situated to the left of the final ordination points (Figure 54).

The only environmental parameter included in this analysis that displayed a significant relationship with the lone axis was PDO, though that assoication was negative. (tau = -0.47), Although this NMS run was not able to identify any other environmental parameters significanlty correlated to the ordination axis, additionaly relatively strong associations exist between sea level height (tau = 0.33) and pH (-0.31; Figure 55). Replicate NMS runs had similar stress levels for the final generated result.

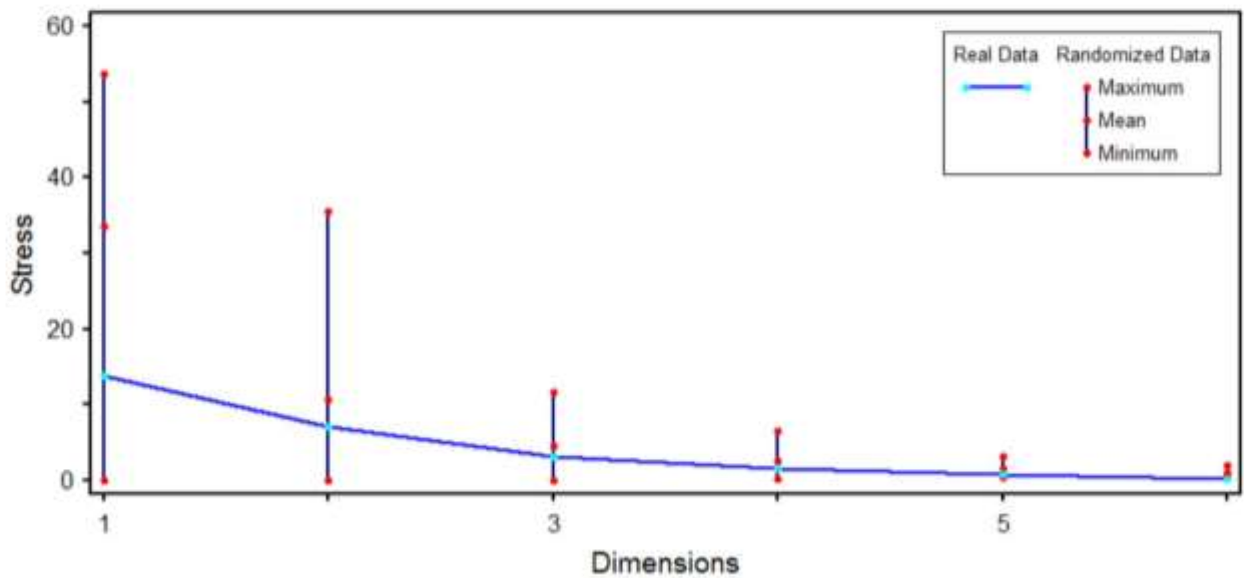


Figure 54. NMS scree plot showing the stress test to determine dimensionality for the final solution for the CNMI multivariate analysis; a one-axis solution was recommended

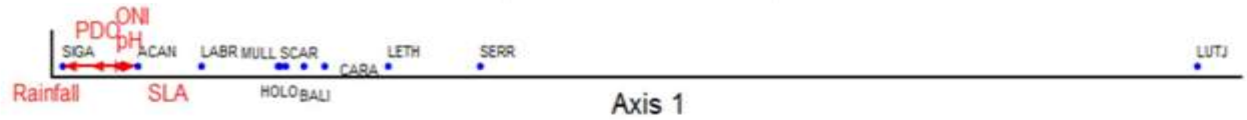


Figure 55. One-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters in the CNMI from 2000-2014

3.5.1.2 Guam

The Guam NMS identified two orthogonal axes for the final solution that accounted for 93.6% of the cumulative observed variance in shore- and boat-based creel survey data from Guam. The final stress for the Guam NMS barely less than 10, though it was notable lower than the average final stress from randomizations (14.2; Figure 56). A majority of the families were clustered in ordination space, with the notable exception of Carangidae (Figure 57).

The final ordination scores for the Guam NMS did not show any environmental parameters with a statistically significant correlation to the first axis ($r^2 = 0.62$; Figure 57). SST (tau = -0.50) and SSTA (tau = -0.50) were both negatively associated with the Axis 2 ($r^2 = 0.32$), and pH had a significantly positive relationship with the axis (tau = 0.56). Additionally, Axis 2 was shown to also be negatively associated with pH (tau = -0.37; Figure 57). Replicate NMS runs had similar stress levels for the final generated result.

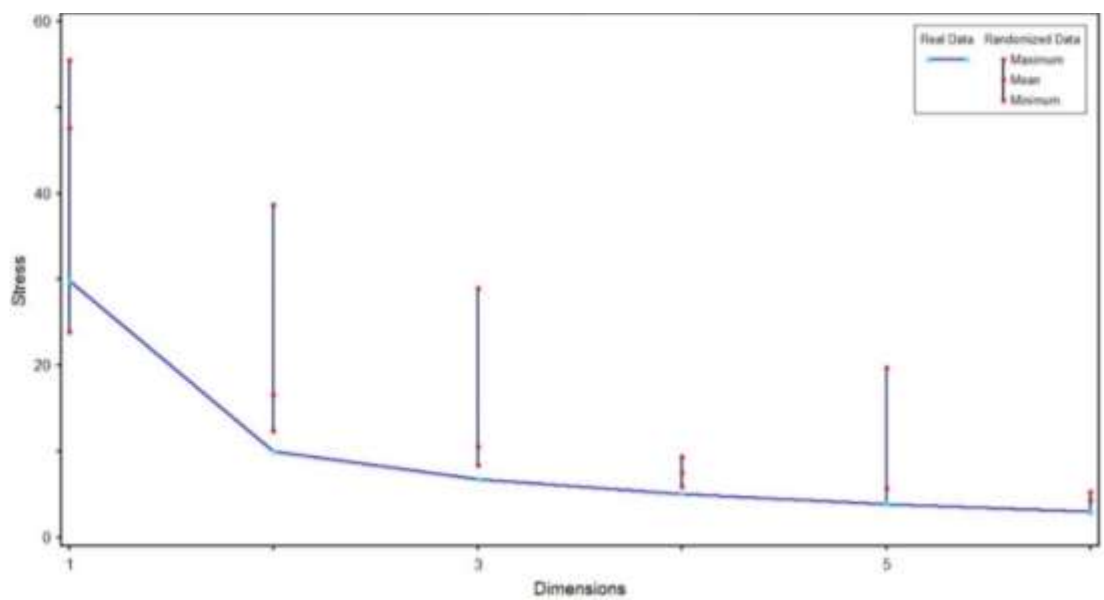


Figure 56. NMS scree plot showing the stress test to determine dimensionality for the final solution for the Guam multivariate analysis; two-axis solution was recommended

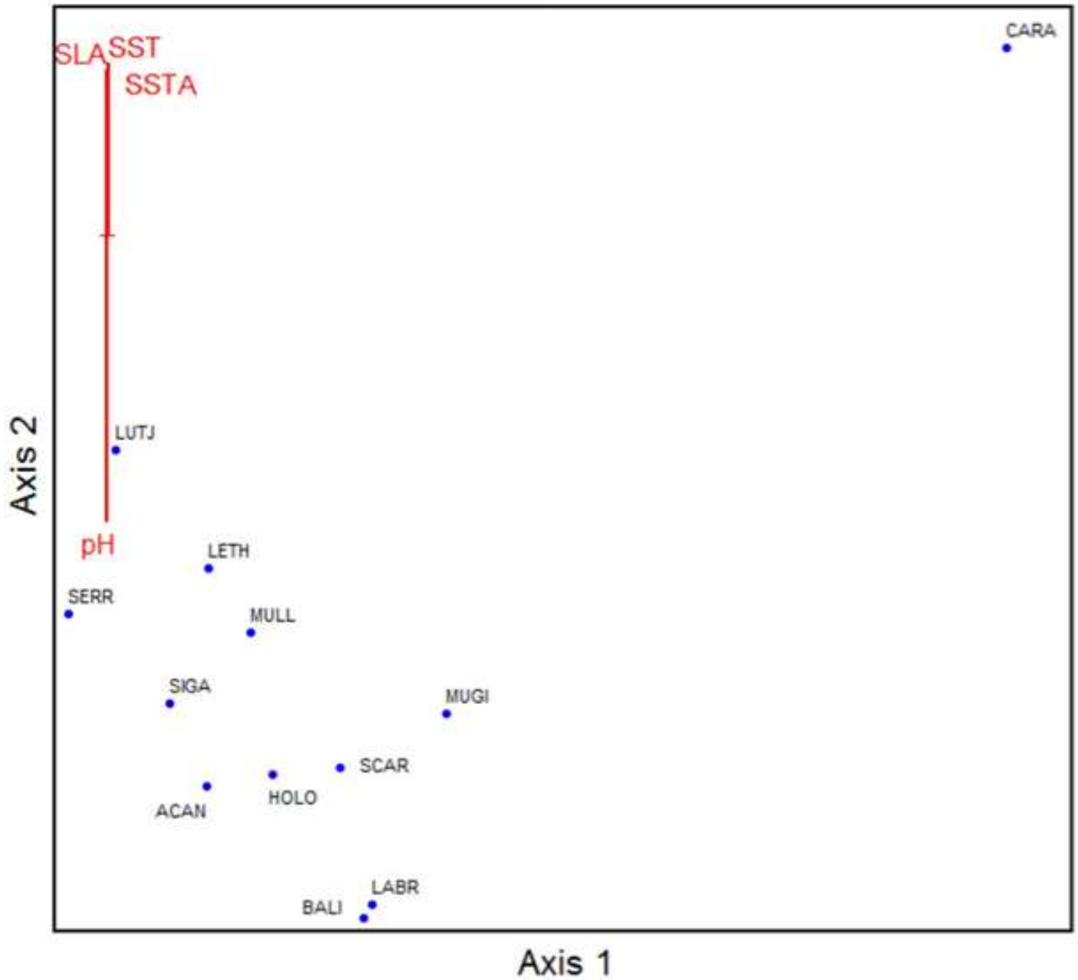


Figure 57. Two-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters in Guam from 1989-2014

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 RECENT RELEVANT ABSTRACTS

In this section, abstracts from primary journal articles published in 2019 and relevant to data integration are compiled. Collecting the abstracts of these articles is intended to further the goal of this section being used to guide adaptive management.

Darling, E.S., McClanahan, T.R., Maina, J. et al., 2019. Social–environmental drivers inform strategic management of coral reefs in the Anthropocene. ***Natural Ecology and Evolution*****,** ***3*****, pp. 1341-1350**

Without drastic efforts to reduce carbon emissions and mitigate globalized stressors, tropical coral reefs are in jeopardy. Strategic conservation and management requires identification of the environmental and socioeconomic factors driving the persistence of scleractinian coral assemblages—the foundation species of coral reef ecosystems. Here, we compiled coral abundance data from 2,584 Indo-Pacific reefs to evaluate the influence of 21 climate, social and environmental drivers on the ecology of reef coral assemblages. Higher abundances of framework-building corals were typically associated with: weaker thermal disturbances and longer intervals for potential recovery; slower human population growth; reduced access by human settlements and markets; and less nearby agriculture. We therefore propose a framework of three management strategies (protect, recover or transform) by considering: (1) if reefs were above or below a proposed threshold of >10% cover of the coral taxa important for structural complexity and carbonate production; and (2) reef exposure to severe thermal stress during the 2014–2017 global coral bleaching event. Our findings can guide urgent management efforts for coral reefs, by identifying key threats across multiple scales and strategic policy priorities that might sustain a network of functioning reefs in the Indo-Pacific to avoid ecosystem collapse.

Heenan, A., Williams, G.J., and I.D. Williams, 2019. Natural variation in coral reef trophic structure across environmental gradients. ***Frontiers in Ecology and the Environment*****,** ***18*****(2), pp. 69-75.**

Policies designed to address current challenges to the sustainability of fisheries generally use an ecosystem-based approach – one that incorporates interactions between fishes, fishers, and the environment. Fishing alters the trophic structure among coral reef fish but properly assessing those impacts requires an understanding of how and why that structure varies naturally across scales. Using a combination of small- and large-scale surveys, we generated biomass pyramids for 20 uninhabited Pacific islands, and found that (1) the distribution of reef fish biomass across trophic levels is highly scale dependent: trophic structures that appear top-heavy at small scales can take a variety of different states when data are integrated across the broader seascape; (2) reefs can have the greatest biomass at intermediate consumer levels, which we describe as "middle-driven" systems; and (3) in unfished coral reef systems, trophic structure is strongly predicted by energy into the base and middle of the food web, as well as by the interacting effect of water temperature.

Kendall, M.S., Poti, M., and A. Winship, 2019. Is Guam a regional source, destination, or stepping-stone for larvae of three fisheries species? ***Fisheries Oceanography*****,** ***28*****, pp. 159= 170.**

The pelagic larval duration (PLD) period of fish can influence dispersal, recruitment, and population connectivity, thereby potentially informing best strategies for fisheries management. Computer models were used to simulate the dispersal of larvae of three species, representing a range of PLDs, from the Pacific island of Guam and neighboring islands for a 9-year period (2004–2012) to gain insight into the best management strategies for these species. The species included two springtime spawners with shorter and longer PLDs, scribbled rabbitfish (*Siganus spinus*; 33 days) and yellowfin goatfish (*Mulloidichthys flavolineatus*; ~90 days maximum), and a fall spawner with a similarly long PLD, bluespine unicornfish (*Naso unicornis*; ~94 days maximum). An ocean circulation model coupled with a particle dispersal model provided simulated numbers of larvae settling at each island in relation to the island where they were spawned. Graph analysis was used to examine generational connections between islands. For *S. spinus*, self-seeding was the dominant means of replenishment at Guam. Local management actions to maintain adequate spawning stock may be a primary control on long-term sustainability for that fishery. In contrast, *N. unicornis* and *M. flavolineatus* populations at Guam were reliant on outside sources for 92%–98% of larval supply. For them, identifying and negotiating the preservation of upstream spawning potential in the Marshall Islands and Federated States of Micronesia will be needed. Guam played a relatively minor role in generational connectivity across the region. Shortest paths spanning the region often did not pass through Guam, or there were equally short paths through other islands.

McClanahan, T.R., Schroeder, R.E., Friedlander, A.M., Vigliola, L. et al., 2019. Global baselines and benchmarks for fish biomass: comparing remote reefs and fisheries closures. *Marine Ecology Progress Series*, *612*, pp. 167-192.

Baselines and benchmarks (B&Bs) are needed to evaluate the ecological status and fisheries potential of coral reefs. B&Bs may depend on habitat features and energetic limitations that constrain biomass within the natural variability of the environment and fish behaviors. To evaluate if broad B&Bs exist, we compiled data on the biomass of fishes in ~1000 reefs with no recent history of fishing in 19 ecoregions. These reefs spanned the full longitude and latitude of Indian and Pacific Ocean reefs and included older high-compliance fisheries closures (>15 yr closure) and remote reef areas (>9 h travel time from fisheries markets). There was no significant change in biomass over the 15 to 48 yr closure period but closures had only ~40% of the biomass (740 kg ha^{-1}, lower confidence interval [LCI] = 660 kg ha-1, upper confidence interval [UCI] = 810 kg ha^{-1}, n = 157) of remote tropical reefs (1870 [1730, 2000] kg ha^{-1}, n = 503). Remote subtropical reefs had lower biomass (950 [860, 1040] kg ha^{-1}, n = 329) than tropical reefs. Closures and remote reef fish biomass responded differently to environmental variables of coral cover, net primary productivity, and light, indicating that remote reefs are more limited by productivity and habitat than closures. Closures in fished seascapes are unlikely to achieve the biomass and community composition of remote reefs, which suggests fisheries benchmarks will differ substantially from wilderness baselines. A fishery benchmark (B_0) of ~1000 kg ha^{-1} adjusted for geography is suggested for fisheries purposes. For ecological purposes, a wilderness baseline of ~1900 kg ha^{-1} is appropriate for including large and mobile species not well protected by closures.

Nelson, W.G., Cruz, J., Guerrero, A.L, Bailey-Brock, J., and F. Cole, 2019. Benthic Ecological Condition Assessment of the Coastal Waters of Guam. EPA 600/R-19/239, U.S. EPA, Office of Research and Development, Center for Public Health and Environmental Assessment, Pacific Ecological Systems Division, Newport OR, 97365; 43 pp.

The U.S. Environmental Protection Agency, Guam EPA and other collaborators conducted a pilot condition assessment of near-shore waters of Guam as part of the National Coastal Assessment (NCA) program. Results indicated that chemical contamination of sediments by heavy metals, PAHs, PCBs, and legacy pesticides did not occur at levels potentially harmful to benthic systems, apart from limited areas within the highly altered Apra Harbor. There was also no indication of contaminant-related sediment toxicity to amphipods, nor correlation of holothurian tissue contamination with sediment contaminants. Similarly, there was little indication of altered benthic community composition indicative of pollutant impacts. The NCA survey results were consistent with results from other site-specific surveys of benthic condition conducted from Guam coastal waters. Several provisional indicators (benthic substrate, fish community, holothurian tissue contamination) proved operationally feasible to incorporate into the NCA assessment approach, but until benchmark values can be determined, their use in assessment of coastal condition will be limited. The pilot NCA assessment of Guam coastal waters provides a baseline that may be particularly valuable for assessing environmental change associated with currently proposed changes to military installations and population on the island.

Taylor, B.M., Choat, J.H., DeMartini, E.E., Hoey, A.S., Marshell, A., Priest, M.A., Rhodes, K.L., and M.G Meekan, 2019. *Journal of Animal Ecology*, *88*(12), pp. 1888-1900.

Variation in life-history characteristics is evident within and across animal populations. Such variation is mediated by environmental gradients and reflects metabolic constraints or tradeoffs that enhance reproductive outputs. While generalizations of life-history relationships across species provide a framework for predicting vulnerability to overexploitation, deciphering patterns of intraspecific variation may also enable recognition of peculiar features of populations that facilitate ecological resilience. This study combines age-based biological data from geographically disparate populations of bluespine unicornfish (*Naso unicornis*) - the most commercially-valuable reef-associated species in the insular Indo-Pacific - to explore the magnitude and drivers of variation in life span and examine the mechanism s enabling peculiar mortality schedules. Longevity and mortality schedules were investigated across eleven locations encompassing a range of latitudes and exploitation levels. The presence of different growth types was examined using back-calculated growth histories from otoliths. Growth-type dependent mortality (mortality rates associated with particular growth trajectories) was corroborated using population models that incorporated size-dependent competition. We found a threefold geographic variation in life span that was strongly linked to temperature, but not to anthropogenic pressure or ocean productivity. All populations consistently displayed a two - phase mortality schedule, with higher than expected natural mortality rates in earlier stages of post-settlement life. Reconstructed growth histories and population models demonstrated that variable growth types within populations can yield this peculiar biphasic mortality schedule, where fast growers enjoy early reproductive outputs at the expense of greater mortality, and benefit s for slow growers derive from extended reproductive outputs over a greater number of annual cycles. This promotes population resilience because individuals can take advantage of cycles of environmental change operating at both short and long-term scales. Our results highlight a prevailing, fundamental misperception when comparing the life histories of long - lived tropical ectotherms: the seemingly incongruent combination of extended life spans with high mortality rates was enabled by coexistence of variable growth types in a population. Thus a demographic profile incorporating contrasting growth and mortality strategies obscures the demographic effects of harvest across space or time in *N. unicornis* and possibly other ectotherms with the combination of longevity and asymptotic growth.

Venegas, R.M., Oliver, T., Liu, G., Heron, S.F., Clark, J., Pomeroy, N., Young, C., Eakin, M., and R.E. Brainard, 2019. The Rarity of Depth Refugia from Coral Bleaching Heat Stress in the Western and Central Pacific Islands. *Scientific Reports*, *9*, 19710.

Some researchers have suggested that corals living in deeper reefs may escape heat stress experienced by shallow corals. We evaluated the potential of deep coral reef refugia from bleaching stress by leveraging a long record of satellite-derived sea surface temperature data with a temporal, spatial, and depth precision of *in situ* temperature records. We calculated an *in situ* stress metric using a depth bias-adjusted threshold for 457 coral reef sites among 49 islands in the western and central Pacific Ocean over the period 2001–2017. Analysis of 1,453 heating events found no meaningful depth refuge from heat stress down to 38 m, and no significant association between depth and subsurface heat stress. Further, the surface metric underestimated subsurface stress by an average of 39.3%, across all depths. Combining satellite and *in situ* temperature data can provide bleaching-relevant heat stress results to avoid misrepresentation of heat stress exposure at shallow reefs.

Williams, I.D., Kindinger, T.L., Couch, C.S., Walsh, W.J., Dwayne, M., and T.A. Oliver, 2019. Can Herbivore Management Increase the Persistence of Indo-Pacific Coral Reefs? *Frontiers in Marine Science*, *6*, p. 557.

Due to climate change, coral reefs have experienced mass bleaching, and mortality events in recent years. Although coral reefs are unlikely to persist in their current form unless climate change can be addressed, local management can have a role to play by extending the time frame over which there are functional reef systems capable of recovery. Here we consider the potential application of one form of local management – management of herbivorous fishes. The premise behind this approach is that increased herbivory could shift reef algal assemblages to states that are benign or beneficial for corals, thereby increasing corals' ability to recover from destructive events such as bleaching and to thrive in periods between events. With a focus on Indo-Pacific coral reefs, we review what is known about the underlying processes of herbivory and coral-algal competition that ultimately affect the ability of corals to grow, persist, and replenish themselves. We then critically assess evidence of effectiveness or otherwise of herbivore management within marine protected areas (MPAs) to better understand why many MPAs have not improved outcomes for corals, and more importantly to identify the circumstances in which that form of management would be most likely to be effective. Herbivore management is not a panacea, but has the potential to enhance coral reef persistence in the right circumstances. Those include that: (i) absent management, there is an "algal problem" – i.e., insufficient herbivory to maintain algae in states that are benign or beneficial for corals; and (ii) management actions are able to increase net herbivory. As increased corallivory is a potentially widespread negative consequence of management, we consider some of the circumstances in which that is most likely to be a problem as well as potential solutions. Because the negative effects of certain algae are greatest for coral settlement and early survivorship, it may be that maintaining sufficient herbivory is particularly important in promoting recovery from destructive events such as mass bleaching. Thus, herbivore management can have a role to play as part of a wider strategy to manage and reduce the threats that currently imperil coral reefs.

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APPENDIX A: LIST OF SPECIES

CNMI AND GUAM MANAGEMENT UNIT SPECIES

1. Bottomfish Multi-species Stock Complex (FSSI)

DFW Creel Species Code	DAWR Creel Species Code	Species Name	Scientific Name
214	32302	red snapper, silvermouth (lehi)	*Aphareus rutilans*
112	31404	giant trevally, jack	*Caranx ignoblis*
111	31405	black trevally, jack	*Caranx lugubris*
241	28941	lunartail grouper (lyretail grouper)	*Variola lauti*
203	32304	red snapper (ehu)	*Etelis carbunculus*
210	32305	red snapper (onaga)	*Etelis coruscans*
350	32809	redgill emperor	*Lethrinus rubrioperculatus*
253	32310	blueline snapper	*Lutjanus kasmira*
None	32317	yellowtail snapper	*Pristipomoides auricilla*
212	32318	pink snapper (paka)	*Pristipomoides filamentosus*
209	32319	yelloweye snapper	*Pristipomoides flavipinnis*
207	32320	pink snapper (kalekale)	*Pristipomoides seiboldi*
204	32321	flower snapper (gindai)	*Pristipomoides zonatus*

CNMI AND GUAM MONITORED ECOSYSTEM COMPONENT SPECIES

1. Species Selected for Monitoring by DFW (CNMI)

DFW Creel Species Code	Species Name	Scientific Name
380	lined surgeonfish	*Acanthurus lineatus*
319	orangespine unicornfish	*Naso lituratus*
384	bluespine unicornfish	*Naso unicornis*
None	redlip parrotfish	*Scarus rubroviolaceus*
317	blue-barred parrotfish	*Scarus ghobban*
353	thumbprint/blackspot emperor	*Lethrinus harak*
304	forktail rabbitfish	*Siganus argenteus*

DFW Creel Species Code	Species Name	Scientific Name
370	yellowstripe goatfish	*Mulloidichthys flavolineatus*

2. Species Selected for Monitoring by DAWR (Guam)

DAWR Creel Species Code	Species Name	Scientific Name
41225	bluespine unicornfish	*Naso unicornis*
41305	scribbled rabbitfish	*Siganus spinus*
32804	thumbprint/blackspot emperor	*Lethrinus harak*
36408	Pacific slopehead parrotfish	*Chlorurus frontalis*
28917	blacktip grouper	*Epinephelus fasciatus*
31406	bluefin trevally	*Caranx melampygus*
32806	ornate emperor	*Lethrinus olivaceus*
32308	flametail snapper	*Lutjanus fulvus*
36414	redlip parrotfish	*Scarus rubroviolaceus*

3. Species Monitred by Trophic, Taxonomic, and FunCtional groups

The species presented in Section 2.1 are displayed according to both trophic level and functional group as an effort to foster continued monitoring of ecosystem component species that are no longer categorized as management unit species. These species are monitored according to their ecosystem function as opposed to individually. Monitoring based on these factors allows for a broader outlook on the ecological composition of fish communities in areas of the Western Pacific. For trophic groupings, “H” stands for “Herbivore”, “Cor” stands for “Corallivore”, “PK” stands for “Planktivore”, “MI” stands for “Mobile Invertebrate Feeder”, “SI” stands for “Sessile-Invertebrate Feeder, “Om” stands for “Omnivore”, and “Pisc” stands for “Piscovore”.

Family	Scientific Name	Trophic Group	Functional Group
Acanthuridae	*Naso lituratus*	H	Browsing Surgeons
Acanthuridae	*Naso tonganus*	H	Browsing Surgeons
Acanthuridae	*Naso unicornis*	H	Browsing Surgeons
Acanthuridae	*Naso brachycentron*	H	Browsing Surgeons
Acanthuridae	*Ctenochaetus cyanocheilus*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus strigosus*	H	Mid-Large Target Surgeons

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Acanthuridae	*Acanthurus nigroris*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus hawaiiensis*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus striatus*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus marginatus*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus lineatus*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus blochii*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus dussumieri*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus xanthopterus*	H	Mid-Large Target Surgeons
Chaetodontidae	*Chaetodon flavocoronatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon multicinctus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon punctatofasciatus*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon mertensii*	H	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon citrinellus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon pelewensis*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon lunulatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon melannotus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon rafflesii*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon ulietensis*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon fremblii*	SI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon quadrimaculatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon meyeri*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon reticulatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon trifascialis*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Heniochus chrysostomus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon bennetti*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon tinkeri*	SI	Non-PK Butterflyfish
Chaetodontidae	*Heniochus varius*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon ornatissimus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon unimaculatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon lunula*	SI	Non-PK Butterflyfish
Chaetodontidae	*Forcipiger longirostris*	MI	Non-PK Butterflyfish
Chaetodontidae	*Forcipiger flavissimus*	SI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon ephippium*	MI	Non-PK Butterflyfish
Chaetodontidae	*Heniochus monoceros*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon auriga*	SI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon vagabundus*	SI	Non-PK Butterflyfish

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Chaetodontidae	*Chaetodon semeion*	H	Non-PK Butterflyfish
Chaetodontidae	*Chaetodontidae*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Heniochus singularius*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon lineolatus*	SI	Non-PK Butterflyfish
Caracanthidae	*Caracanthus typicus*	MI	No Group
Gobiidae	*Eviota* sp.	MI	No Group
Pomacentridae	*Chrysiptera traceyi*	H	No Group
Apogonidae	*Ostorhinchus luteus*	Pk	No Group
Caracanthidae	*Caracanthus maculatus*	MI	No Group
Pseudochromidae	*Pseudochromis jamesi*	MI	No Group
Pomacentridae	*Chromis acares*	Pk	No Group
Serranidae	*Luzonichthys whitleyi*	Pk	No Group
Pomacentridae	*Pomachromis guamensis*	Pk	No Group
Pomacentridae	*Pomachromis richardsoni*	Pk	No Group
Gobiidae	*Fusigobius duospilus*	MI	No Group
Pomacentridae	*Plectroglyphidodon imparipennis*	MI	No Group
Microdesmidae	*Nemateleotris helfrichi*	Pk	No Group
Pomacentridae	*Chromis leucura*	Pk	No Group
Syngnathidae	*Doryrhamphus excisus*	Pk	No Group
Pomacentridae	*Pomacentrus coelestis*	Pk	No Group
Clupeidae	*Spratelloides delicatulus*	Pk	No Group
Pomacentridae	*Chrysiptera biocellata*	H	No Group
Pseudochromidae	*Pictichromis porphyreus*	MI	No Group
Pomacanthidae	*Centropyge fisheri*	H	No Group
Cirrhitidae	*Cirrhitops hubbardi*	MI	No Group
Gobiidae	*Amblyeleotris fasciata*	Pk	No Group
Pomacentridae	*Chromis lepidolepis*	Pk	No Group
Pomacentridae	*Chromis margaritifer*	Pk	No Group
Pomacentridae	*Chromis ternatensis*	Pk	No Group
Pomacentridae	*Chromis viridis*	Pk	No Group
Pomacentridae	*Chrysiptera cyanea*	Pk	No Group
Pomacentridae	*Dascyllus aruanus*	Pk	No Group
Pomacentridae	*Dascyllus reticulatus*	Pk	No Group
Engraulidae	*Encrasicholina purpurea*	Pk	No Group
Pomacentridae	*Neopomacentrus metallicus*	Pk	No Group
Pomacentridae	*Chromis amboinensis*	H	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Pomacentridae	*Chromis iomelas*	H	No Group
Pomacentridae	*Chrysiptera glauca*	H	No Group
Pomacentridae	*Chrysiptera taupou*	H	No Group
Labridae	*Labroides pectoralis*	MI	No Group
Labridae	*Pseudocheilinus hexataenia*	MI	No Group
Labridae	*Pseudocheilinus tetrataenia*	MI	No Group
Scorpaenidae	*Sebastapistes cyanostigma*	MI	No Group
Labridae	*Wetmorella nigropinnata*	MI	No Group
Pseudochromidae	*Pseudochromis* sp.	MI	No Group
Monacanthidae	*Pervagor marginalis*	Om	No Group
Pomacentridae	*Chromis alpha*	Pk	No Group
Pomacentridae	*Plectroglyphidodon phoenixensis*	H	No Group
Gobiidae	*Amblyeleotris guttata*	Pk	No Group
Atherinidae	*Atherinomorus insularum*	Pk	No Group
Pomacentridae	*Chromis caudalis*	Pk	No Group
Pomacentridae	*Chromis hanui*	Pk	No Group
Labridae	*Cirrhilabrus katherinae*	Pk	No Group
Microdesmidae	*Nemateleotris magnifica*	Pk	No Group
Apogonidae	*Ostorhinchus angustatus*	Pk	No Group
Serranidae	*Pseudanthias bartlettorum*	Pk	No Group
Tetraodontidae	*Canthigaster jactator*	H	No Group
Tetraodontidae	*Canthigaster janthinoptera*	H	No Group
Tetraodontidae	*Canthigaster valentini*	H	No Group
Pomacanthidae	*Centropyge shepardi*	H	No Group
Pomacentridae	*Chrysiptera brownriggii*	H	No Group
Monacanthidae	*Oxymonacanthus longirostris*	Cor	No Group
Cirrhitidae	*Amblycirrhitus bimacula*	MI	No Group
Cirrhitidae	*Cirrhitichthys falco*	MI	No Group
Labridae	*Labroides rubrolabiatus*	MI	No Group
Cirrhitidae	*Neocirrhites armatus*	MI	No Group
Labridae	*Pseudojuloides splendens*	MI	No Group
Apogonidae	*Ostorhinchus novemfasciatus*	Pk	No Group
Labridae	*Pteragogus cryptus*	MI	No Group
Scorpaenidae	*Sebastapistes* sp.	Pisc	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Scorpaenidae	*Taenianotus triacanthus*	Pisc	No Group
Pomacentridae	*Amphiprion perideraion*	Pk	No Group
Pomacentridae	*Chromis fumea*	Pk	No Group
Labridae	*Cirrhilabrus jordani*	Pk	No Group
Blenniidae	*Ecsenius bicolor*	Pk	No Group
Blenniidae	*Ecsenius midas*	Pk	No Group
Blenniidae	*Ecsenius opsifrontalis*	Pk	No Group
Pomacentridae	*Lepidozygus tapeinosoma*	Pk	No Group
Blenniidae	*Meiacanthus atrodorsalis*	Pk	No Group
Apogonidae	*Ostorhinchus apogonoides*	Pk	No Group
Pomacentridae	*Plectroglyphidodon lacrymatus*	Pk	No Group
Pomacentridae	*Pomacentrus brachialis*	Pk	No Group
Pomacentridae	*Pomacentrus nigriradiatus*	Pk	No Group
Pomacentridae	*Pomacentrus philippinus*	Pk	No Group
Pomacentridae	*Pomacentrus vaiuli*	Pk	No Group
Serranidae	*Pseudanthias dispar*	Pk	No Group
Serranidae	*Pseudanthias hawaiiensis*	Pk	No Group
Tetraodontidae	*Canthigaster bennetti*	H	No Group
Pomacanthidae	*Centropyge bispinosa*	H	No Group
Pomacanthidae	*Centropyge heraldi*	H	No Group
Pomacanthidae	*Centropyge loricula*	H	No Group
Blenniidae	*Cirripectes obscurus*	H	No Group
Blenniidae	*Cirripectes polyzona*	H	No Group
Blenniidae	*Cirripectes* sp.	H	No Group
Blenniidae	*Cirripectes springeri*	H	No Group
Blenniidae	*Cirripectes stigmaticus*	H	No Group
Blenniidae	*Cirripectes variolosus*	H	No Group
Callionymidae	*Callionymidae*	MI	No Group
Labridae	*Labroides phthirophagus*	MI	No Group
Pomacanthidae	*Paracentropyge multifasciata*	MI	No Group
Blenniidae	*Plagiotremus ewaensis*	MI	No Group
Blenniidae	*Plagiotremus goslinei*	MI	No Group
Scorpaenidae	*Sebastapistes coniorta*	MI	No Group
Monacanthidae	*Pervagor melanocephalus*	Om	No Group
Blenniidae	*Plagiotremus laudandus*	Par	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Blenniidae	*Plagiotremus rhinorhynchos*	Par	No Group
Blenniidae	*Plagiotremus tapeinosoma*	Par	No Group
Labridae	*Pseudocheilinus ocellatus*	MI	No Group
Pomacanthidae	*Centropyge flavissima & vroliki*	H	No Group
Pomacentridae	*Amblyglyphidodon curacao*	Om	No Group
Pomacentridae	*Amphiprion melanopus*	Pk	No Group
Pomacentridae	*Chromis agilis*	Pk	No Group
Gobiidae	*Istigobius* sp.	Pk	No Group
Pomacentridae	*Pomacentrus pavo*	Pk	No Group
Apogonidae	*Pristiapogon fraenatus*	Pk	No Group
Tetraodontidae	*Canthigaster epilampra*	H	No Group
Tetraodontidae	*Canthigaster solandri*	H	No Group
Blenniidae	*Cirripectes vanderbilti*	H	No Group
Pomacentridae	*Stegastes albifasciatus*	H	No Group
Pomacentridae	*Stegastes aureus*	H	No Group
Pomacentridae	*Stegastes marginatus*	H	No Group
Pomacentridae	*Plectroglyphidodon dickii*	Cor	No Group
Cirrhitidae	*Paracirrhites xanthus*	MI	No Group
Monacanthidae	*Paraluteres prionurus*	MI	No Group
Microdesmidae	*Microdesmidae*	Pk	No Group
Scorpaenidae	*Sebastapistes ballieui*	MI	No Group
Apogonidae	*Apogon kallopterus*	Pk	No Group
Pomacentridae	*Chromis weberi*	Pk	No Group
Labridae	*Cirrhilabrus exquisitus*	Pk	No Group
Syngnathidae	*Corythoichthys flavofasciatus*	Pk	No Group
Pomacentridae	*Dascyllus albisella*	Pk	No Group
Microdesmidae	*Gunnellichthys curiosus*	Pk	No Group
Apogonidae	*Pristiapogon kallopterus*	Pk	No Group
Serranidae	*Pseudanthias olivaceus*	Pk	No Group
Ptereleotridae	*Ptereleotris heteroptera*	Pk	No Group
Ptereleotridae	*Ptereleotris zebra*	Pk	No Group
Pomacanthidae	*Centropyge vrolikii*	H	No Group
Pomacentridae	*Plectroglyphidodon leucozonus*	H	No Group
Pomacentridae	*Plectroglyphidodon johnstonianus*	Cor	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Labridae	*Anampses melanurus*	MI	No Group
Apogonidae	*Cheilodipterus quinquelineatus*	MI	No Group
Cirrhitidae	*Cirrhitichthys oxycephalus*	MI	No Group
Cirrhitidae	*Cirrhitops fasciatus*	MI	No Group
Labridae	*Halichoeres biocellatus*	MI	No Group
Labridae	*Labroides dimidiatus*	MI	No Group
Labridae	*Labropsis micronesica*	MI	No Group
Labridae	*Macropharyngodon negrosensis*	MI	No Group
Labridae	*Pseudojuloides cerasinus*	MI	No Group
Labridae	*Pseudojuloides polynesica*	MI	No Group
Blenniidae	*Aspidontus taeniatus*	Par	No Group
Tetraodontidae	*Torquigener randalli*	MI	No Group
Pomacentridae	*Plectroglyphidodon sindonis*	H	No Group
Pomacanthidae	*Centropyge potteri*	H	No Group
Cirrhitidae	*Oxycirrhites typus*	Pk	No Group
Serranidae	*Pseudanthias bicolor*	Pk	No Group
Ptereleotridae	*Ptereleotris microlepis*	Pk	No Group
Pomacentridae	*Stegastes lividus*	H	No Group
Labridae	*Cirrhilabrus punctatus*	MI	No Group
Labridae	*Halichoeres margaritaceus*	MI	No Group
Labridae	*Pseudojuloides atavai*	MI	No Group
Holocentridae	*Sargocentron punctatissimum*	MI	No Group
Monacanthidae	*Pervagor janthinosoma*	Om	No Group
Pomacentridae	*Amphiprion clarkii*	Pk	No Group
Serranidae	*Anthias* sp.	Pk	No Group
Blenniidae	*Blenniella chrysospilos*	Pk	No Group
Chaetodontidae	*Chaetodon kleinii*	Pk	No Group
Pomacentridae	*Dascyllus trimaculatus*	Pk	No Group
Apogonidae	*Ostorhinchus maculiferus*	Pk	No Group
Serranidae	*Pseudanthias cooperi*	Pk	No Group
Gobiidae	*Amblygobius phalaena*	H	No Group
Tetraodontidae	*Canthigaster amboinensis*	H	No Group
Tetraodontidae	*Canthigaster coronata*	H	No Group
Pomacanthidae	*Centropyge flavissima*	H	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Pomacentridae	*Stegastes nigricans*	H	No Group
Labridae	*Halichoeres melanurus*	MI	No Group
Labridae	*Halichoeres melasmapomus*	MI	No Group
Labridae	*Labroides bicolor*	MI	No Group
Labridae	*Labropsis xanthonota*	MI	No Group
Cirrhitidae	*Paracirrhites arcatus*	MI	No Group
Labridae	*Pseudocheilinus evanidus*	MI	No Group
Labridae	*Pseudocheilinus octotaenia*	MI	No Group
Monacanthidae	*Pervagor aspricaudus*	Om	No Group
Ostraciidae	*Lactoria fornasini*	SI	No Group
Labridae	*Pseudojuloides* sp.	MI	No Group
Pomacentridae	*Abudefduf sexfasciatus*	Pk	No Group
Pomacentridae	*Chromis vanderbilti*	Pk	No Group
Pomacentridae	*Chromis xanthura*	Pk	No Group
Labridae	*Cirrhilabrus* sp.	Pk	No Group
Pomacanthidae	*Genicanthus watanabei*	Pk	No Group
Labridae	*Thalassoma amblycephalum*	Pk	No Group
Pomacanthidae	*Centropyge bicolor*	H	No Group
Serranidae	*Belonoperca chabanaudi*	MI	No Group
Labridae	*Coris centralis*	MI	No Group
Labridae	*Halichoeres ornatissimus*	MI	No Group
Malacanthidae	*Hoplolatilus starcki*	MI	No Group
Labridae	*Macropharyngodon meleagris*	MI	No Group
Labridae	*Oxycheilinus bimaculatus*	MI	No Group
Labridae	*Pteragogus enneacanthus*	MI	No Group
Labridae	*Stethojulis balteata*	MI	No Group
Labridae	*Stethojulis strigiventer*	MI	No Group
Labridae	*Stethojulis trilineata*	MI	No Group
Pomacentridae	*Stegastes* sp.	H	No Group
Apogonidae	*Apogon* sp.	Pk	No Group
Apogonidae	*Apogonidae*	Pk	No Group
Chaetodontidae	*Chaetodon miliaris*	Pk	No Group
Pomacentridae	*Dascyllus auripinnis*	Pk	No Group
Labridae	*Pseudocoris yamashiroi*	Pk	No Group
Labridae	*Stethojulis bandanensis*	Pk	No Group
Monacanthidae	*Cantherhines verecundus*	H	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Pomacanthidae	*Centropyge interrupta*	H	No Group
Pomacentridae	*Stegastes fasciolatus*	H	No Group
Blenniidae	*Exallias brevis*	Cor	No Group
Labridae	*Labrichthys unilineatus*	Cor	No Group
Labridae	*Halichoeres prosopeion*	MI	No Group
Labridae	*Macropharyngodon geoffroy*	MI	No Group
Gobiidae	*Valenciennea strigata*	MI	No Group
Ostraciidae	*Ostracion whitleyi*	SI	No Group
Scorpaenidae	*Dendrochirus barberi*	MI	No Group
Blenniidae	*Blenniidae*	Pk	No Group
Synodontidae	*Synodus binotatus*	Pisc	No Group
Pomacentridae	*Amphiprion chrysopterus*	Pk	No Group
Serranidae	*Pseudanthias pascalus*	Pk	No Group
Acanthuridae	*Ctenochaetus flavicauda*	H	No Group
Labridae	*Cheilinus oxycephalus*	MI	No Group
Holocentridae	*Sargocentron diadema*	MI	No Group
Holocentridae	*Sargocentron xantherythrum*	MI	No Group
Labridae	*Thalassoma quinquevittatum*	MI	No Group
Labridae	*Iniistius umbrilatus*	MI	No Group
Labridae	*Thalassoma* sp.	MI	No Group
Pomacentridae	*Pomacentridae*	Om	No Group
Pomacentridae	*Abudefduf notatus*	Pk	No Group
Chaetodontidae	*Hemitaurichthys polylepis*	Pk	No Group
Ptereleotridae	*Ptereleotris evides*	Pk	No Group
Labridae	*Anampses twistii*	MI	No Group
Apogonidae	*Cheilodipterus* sp.	MI	No Group
Labridae	*Cymolutes lecluse*	MI	No Group
Labridae	*Halichoeres hartzfeldii*	MI	No Group
Labridae	*Halichoeres marginatus*	MI	No Group
Pinguipedidae	*Parapercis clathrata*	MI	No Group
Pinguipedidae	*Parapercis schauinslandii*	MI	No Group
Labridae	*Choerodon jordani*	Om	No Group
Monacanthidae	*Pervagor* sp.	Om	No Group
Monacanthidae	*Pervagor spilosoma*	Om	No Group
Pomacanthidae	*Apolemichthys arcuatus*	SI	No Group
Holocentridae	*Neoniphon argenteus*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Apogonidae	*Cheilodipterus artus*	MI	No Group
Pomacentridae	*Chromis ovalis*	Pk	No Group
Labridae	*Bodianus mesothorax*	MI	No Group
Pinguipedidae	*Parapercis millepunctata*	MI	No Group
Labridae	*Halichoeres* sp.	MI	No Group
Serranidae	*Cephalopholis leopardus*	Pisc	No Group
Apogonidae	*Cheilodipterus macrodon*	Pisc	No Group
Pomacentridae	*Abudefduf vaigiensis*	Pk	No Group
Chaetodontidae	*Heniochus diphreutes*	Pk	No Group
Holocentridae	*Myripristis vittata*	Pk	No Group
Caesionidae	*Pterocaesio trilineata*	Pk	No Group
Labridae	*Thalassoma hardwicke*	Pk	No Group
Monacanthidae	*Cantherhines sandwichiensis*	H	No Group
Tetraodontidae	*Canthigaster rivulata*	H	No Group
Acanthuridae	*Zebrasoma flavescens*	H	No Group
Acanthuridae	*Zebrasoma scopas*	H	No Group
Monacanthidae	*Amanses scopas*	Cor	No Group
Labridae	*Anampses chrysocephalus*	MI	No Group
Labridae	*Anampses* sp.	MI	No Group
Labridae	*Bodianus axillaris*	MI	No Group
Labridae	*Bodianus prognathus*	MI	No Group
Labridae	*Coris dorsomacula*	MI	No Group
Labridae	*Coris venusta*	MI	No Group
Labridae	*Cymolutes praetextatus*	MI	No Group
Labridae	*Pseudocoris aurantiofasciata*	MI	No Group
Labridae	*Pseudocoris heteroptera*	MI	No Group
Scorpaenidae	*Pterois antennata*	MI	No Group
Holocentridae	*Sargocentron microstoma*	MI	No Group
Labridae	*Thalassoma jansenii*	MI	No Group
Nemipteridae	*Scolopsis lineata*	Om	No Group
Zanclidae	*Zanclus cornutus*	SI	No Group
Labridae	*Bodianus anthioides*	Pk	No Group
Chaetodontidae	*Hemitaurichthys thompsoni*	Pk	No Group
Acanthuridae	*Zebrasoma rostratum*	H	No Group
Kuhliidae	*Kuhlia sandvicensis*	Pk	No Group
Scorpaenidae	*Pterois sphex*	Pisc	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Synodontidae	*Synodontidae*	Pisc	No Group
Pomacentridae	*Chromis verater*	Pk	No Group
Pempheridae	*Pempheridae*	Pk	No Group
Serranidae	*Pseudanthias thompsoni*	Pk	No Group
Balistidae	*Xanthichthys auromarginatus*	Pk	No Group
Acanthuridae	*Ctenochaetus binotatus*	H	No Group
Labridae	*Anampses meleagrides*	MI	No Group
Labridae	*Iniistius aneitensis*	MI	No Group
Mullidae	*Parupeneus chrysonemus*	MI	No Group
Balistidae	*Sufflamen chrysopterum*	MI	No Group
Cirrhitidae	*Paracirrhites forsteri*	Pisc	No Group
Synodontidae	*Saurida gracilis*	Pisc	No Group
Holocentridae	*Myripristis kuntee*	Pk	No Group
Pempheridae	*Pempheris oualensis*	Pk	No Group
Pomacentridae	*Abudefduf septemfasciatus*	H	No Group
Acanthuridae	*Acanthurus nigricans*	H	No Group
Acanthuridae	*Acanthurus nigrofuscus*	H	No Group
Holocentridae	*Neoniphon aurolineatus*	MI	No Group
Pinguipedidae	*Parapercis* sp.	MI	No Group
Labridae	*Bodianus sanguineus*	Om	No Group
Synodontidae	*Synodus dermatogenys*	Pisc	No Group
Synodontidae	*Synodus variegatus*	Pisc	No Group
Pomacentridae	*Abudefduf sordidus*	H	No Group
Holocentridae	*Myripristis earlei*	MI	No Group
Pomacentridae	*Abudefduf abdominalis*	Pk	No Group
Pomacanthidae	*Genicanthus personatus*	Pk	No Group
Chaetodontidae	*Heniochus acuminatus*	Pk	No Group
Holocentridae	*Myripristis chryseres*	Pk	No Group
Holocentridae	*Myripristis woodsi*	Pk	No Group
Labridae	*Thalassoma lunare*	Pk	No Group
Acanthuridae	*Acanthurus achilles*	H	No Group
Acanthuridae	*Acanthurus achilles* & *nigricans*	H	No Group
Acanthuridae	*Acanthurus leucopareius*	H	No Group
Acanthuridae	*Acanthurus pyroferus*	H	No Group
Monacanthidae	*Cantherhines pardalis*	H	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Labridae	*Bodianus diana*	MI	No Group
Balistidae	*Rhinecanthus rectangulus*	MI	No Group
Holocentridae	*Sargocentron caudimaculatum*	MI	No Group
Holocentridae	*Sargocentron ensifer*	MI	No Group
Labridae	*Thalassoma duperrey* & *quinquevittatum*	MI	No Group
Labridae	*Thalassoma lutescens*	MI	No Group
Pomacanthidae	*Apolemichthys griffisi*	SI	No Group
Pomacanthidae	*Apolemichthys trimaculatus*	SI	No Group
Pomacanthidae	*Apolemichthys xanthopunctatus*	SI	No Group
Pomacanthidae	*Pygoplites diacanthus*	SI	No Group
Serranidae	*Epinephelus hexagonatus*	Pisc	No Group
Acanthuridae	*Acanthurus nubilus*	Pk	No Group
Muraenidae	*Gymnothorax melatremus*	MI	No Group
Labridae	*Pseudodax moluccanus*	MI	No Group
Labridae	*Thalassoma duperrey*	MI	No Group
Acanthuridae	*Acanthurus triostegus*	H	No Group
Serranidae	*Grammistes sexlineatus*	MI	No Group
Labridae	*Halichoeres hortulanus*	MI	No Group
Labridae	*Halichoeres trimaculatus*	MI	No Group
Serranidae	*Cephalopholis urodeta*	Pisc	No Group
Cirrhitidae	*Paracirrhites hemistictus*	Pisc	No Group
Acanthuridae	*Acanthurus thompsoni*	Pk	No Group
Siganidae	*Siganus spinus*	H	No Group
Balistidae	*Rhinecanthus lunula*	MI	No Group
Balistidae	*Sufflamen bursa*	MI	No Group
Ostraciidae	*Ostracion meleagris*	SI	No Group
Acanthuridae	*Acanthurus guttatus*	H	No Group
Cirrhitidae	*Cirrhitidae*	MI	No Group
Serranidae	*Cephalopholis spiloparaea*	Pisc	No Group
Labridae	*Oxycheilinus digramma*	Pisc	No Group
Scorpaenidae	*Scorpaenopsis diabolus*	Pisc	No Group
Scorpaenidae	*Scorpaenopsis* sp.	Pisc	No Group
Synodontidae	*Synodus ulae*	Pisc	No Group
Caesionidae	*Caesio lunaris*	Pk	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Balistidae	*Canthidermis maculata*	Pk	No Group
Hemiramphidae	*Hyporhamphus acutus*	Pk	No Group
Caesionidae	*Pterocaesio lativittata*	Pk	No Group
Caesionidae	*Pterocaesio tile*	Pk	No Group
Carangidae	*Selar crumenophthalmus*	Pk	No Group
Balistidae	*Xanthichthys mento*	Pk	No Group
Acanthuridae	*Ctenochaetus* sp.	H	No Group
Acanthuridae	*Naso thynnoides*	H	No Group
Balistidae	*Balistapus undulatus*	MI	No Group
Cirrhitidae	*Cirrhitus pinnulatus*	MI	No Group
Labridae	*Coris ballieui*	MI	No Group
Lethrinidae	*Gnathodentex aureolineatus*	MI	No Group
Malacanthidae	*Malacanthus brevirostris*	MI	No Group
Mullidae	*Mulloidichthys mimicus*	MI	No Group
Holocentridae	*Myripristis violacea*	MI	No Group
Labridae	*Novaculichthys taeniourus*	MI	No Group
Balistidae	*Rhinecanthus aculeatus*	MI	No Group
Synodontidae	*Saurida flamma*	Pisc	No Group
Acanthuridae	*Paracanthurus hepatus*	Pk	No Group
Caesionidae	*Caesionidae*	Pk	No Group
Holocentridae	*Holocentridae*	MI	No Group
Priacanthidae	*Heteropriacanthus carolinus*	Pk	No Group
Holocentridae	*Myripristis adusta*	Pk	No Group
Holocentridae	*Myripristis amaena*	Pk	No Group
Labridae	*Cheilinus chlorourus*	MI	No Group
Labridae	*Gomphosus varius*	MI	No Group
Lethrinidae	*Lethrinus harak*	MI	No Group
Holocentridae	*Neoniphon sammara*	MI	No Group
Serranidae	*Epinephelus melanostigma*	Pisc	No Group
Serranidae	*Epinephelus merra*	Pisc	No Group
Holocentridae	*Myripristis berndti*	Pk	No Group
Priacanthidae	*Priacanthus hamrur*	Pk	No Group
Priacanthidae	*Priacanthus meeki*	Pk	No Group
Acanthuridae	*Acanthurus albipectoralis*	H	No Group
Tetraodontidae	*Arothron nigropunctatus*	Cor	No Group
Mullidae	*Parupeneus insularis*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Mullidae	*Parupeneus pleurostigma*	MI	No Group
Holocentridae	*Sargocentron tiere*	MI	No Group
Labridae	*Thalassoma trilobatum*	MI	No Group
Mullidae	*Upeneus taeniopterus*	MI	No Group
Balistidae	*Melichthys vidua*	H	No Group
Serranidae	*Epinephelus spilotoceps*	Pisc	No Group
Lutjanidae	*Lutjanus semicinctus*	Pisc	No Group
Serranidae	*Pogonoperca punctata*	Pisc	No Group
Caesionidae	*Caesio caerulaurea*	Pk	No Group
Carangidae	*Decapterus macarellus*	Pk	No Group
Holocentridae	*Myripristinae*	Pk	No Group
Caesionidae	*Pterocaesio marri*	Pk	No Group
Balistidae	*Xanthichthys caeruleolineatus*	Pk	No Group
Labridae	*Iniistius pavo*	MI	No Group
Holocentridae	*Neoniphon opercularis*	MI	No Group
Holocentridae	*Neoniphon* sp.	MI	No Group
Mullidae	*Parupeneus crassilabris*	MI	No Group
Labridae	*Anampses cuvier*	MI	No Group
Labridae	*Cheilinus fasciatus*	MI	No Group
Siganidae	*Siganus punctatus*	H	No Group
Gobiidae	*Gobiidae*	MI	No Group
Scorpaenidae	*Pterois volitans*	Pisc	No Group
Balistidae	*Melichthys niger*	Pk	No Group
Priacanthidae	*Priacanthus* sp.	Pk	No Group
Monacanthidae	*Monacanthidae*	H	No Group
Siganidae	*Siganidae*	H	No Group
Diodontidae	*Diodon holocanthus*	MI	No Group
Mullidae	*Mulloidichthys vanicolensis*	MI	No Group
Mullidae	*Parupeneus multifasciatus*	MI	No Group
Balistidae	*Sufflamen fraenatum*	MI	No Group
Monacanthidae	*Cantherhines dumerilii*	Om	No Group
Pomacanthidae	*Pomacanthus imperator*	SI	No Group
Lethrinidae	*Lethrinus rubrioperculatus*	MI	No Group
Caesionidae	*Caesio teres*	Pk	No Group
Balistidae	*Odonus niger*	Pk	No Group
Acanthuridae	*Acanthurus nigricauda*	H	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Acanthuridae	*Acanthurus olivaceus*	H	No Group
Acanthuridae	*Zebrasoma veliferum*	H	No Group
Labridae	*Bodianus loxozonus*	MI	No Group
Labridae	*Coris gaimard*	MI	No Group
Labridae	*Hologymnosus annulatus*	MI	No Group
Labridae	*Hologymnosus doliatus*	MI	No Group
Mullidae	*Mulloidichthys flavolineatus*	MI	No Group
Acanthuridae	*Acanthurus maculiceps*	H	No Group
Kyphosidae	*Kyphosus hawaiiensis*	H	No Group
Cheilodactylidae	*Cheilodactylus vittatus*	SI	No Group
Ostraciidae	*Ostraciidae*	SI	No Group
Siganidae	*Siganus argenteus*	H	No Group
Labridae	*Anampses caeruleopunctatus*	MI	No Group
Serranidae	*Epinephelus fasciatus*	Pisc	No Group
Labridae	*Thalassoma ballieui*	MI	No Group
Labridae	*Thalassoma purpureum*	MI	No Group
Serranidae	*Cephalopholis miniata*	Pisc	No Group
Hemiramphidae	*Hemiramphidae*	Pk	No Group
Acanthuridae	*Acanthurus leucocheilus*	H	No Group
Ostraciidae	*Ostracion cubicus*	H	No Group
Bothidae	*Bothus mancus*	MI	No Group
Labridae	*Cheilinus* sp.	MI	No Group
Labridae	*Cheilinus trilobatus*	MI	No Group
Malacanthidae	*Malacanthus latovittatus*	MI	No Group
Labridae	*Oxycheilinus unifasciatus*	Pisc	No Group
Labridae	*Oxycheilinus* sp.	MI	No Group
Serranidae	*Epinephelus retouti*	Pisc	No Group
Mullidae	*Mulloidichthys pfluegeri*	MI	No Group
Serranidae	*Cephalopholis sexmaculata*	Pisc	No Group
Serranidae	*Cephalopholis sonnerati*	Pisc	No Group
Serranidae	*Gracila albomarginata*	Pisc	No Group
Mullidae	*Parupeneus cyclostomus*	Pisc	No Group
Belonidae	*Platybelone argalus*	Pisc	No Group
Acanthuridae	*Acanthurus mata*	Pk	No Group
Tetraodontidae	*Arothron meleagris*	Cor	No Group
Balistidae	*Balistoides conspicillum*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Labridae	*Hemigymnus fasciatus*	MI	No Group
Lethrinidae	*Lethrinus obsoletus*	MI	No Group
Mullidae	*Mullidae*	MI	No Group
Mullidae	*Parupeneus barberinus*	MI	No Group
Holocentridae	*Sargocentron* sp.	MI	No Group
Ephippidae	*Platax orbicularis*	Om	No Group
Serranidae	*Epinephelus macrospilos*	Pisc	No Group
Scorpaenidae	*Scorpaenopsis cacopsis*	Pisc	No Group
Kyphosidae	*Kyphosus cinerascens*	H	No Group
Labridae	*Cheilio inermis*	MI	No Group
Mullidae	*Parupeneus porphyreus*	MI	No Group
Serranidae	*Epinephelus socialis*	Pisc	No Group
Tetraodontidae	*Arothron hispidus*	MI	No Group
Holocentridae	*Sargocentron spiniferum*	MI	No Group
Carangidae	*Trachinotus baillonii*	Pisc	No Group
Labridae	*Epibulus insidiator*	MI	No Group
Serranidae	*Epinephelus howlandi*	Pisc	No Group
Labridae	*Bodianus albotaeniatus*	MI	No Group
Labridae	*Bodianus bilunulatus*	MI	No Group
Acanthuridae	*Acanthurus* sp.	H	No Group
Serranidae	*Aethaloperca rogaa*	Pisc	No Group
Serranidae	*Anyperodon leucogrammicus*	Pisc	No Group
Serranidae	*Cephalopholis argus*	Pisc	No Group
Serranidae	*Cephalopholis* sp.	Pisc	No Group
Serranidae	*Epinephelus maculatus*	Pisc	No Group
Holocentridae	*Myripristis murdjan*	Pk	No Group
Acanthuridae	*Naso brevirostris*	Pk	No Group
Acanthuridae	*Naso maculatus*	Pk	No Group
Acanthuridae	*Naso vlamingii*	Pk	No Group
Kyphosidae	*Kyphosus vaigiensis*	H	No Group
Muraenidae	*Gymnothorax eurostus*	MI	No Group
Labridae	*Hemigymnus melapterus*	MI	No Group
Balistidae	*Pseudobalistes flavimarginatus*	MI	No Group
Lethrinidae	*Lethrinus xanthochilus*	Pisc	No Group
Acanthuridae	*Naso caesius*	Pk	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Lethrinidae	*Monotaxis grandoculis*	MI	No Group
Serranidae	*Variola albimarginata*	Pisc	No Group
Labridae	*Coris flavovittata*	MI	No Group
Tetraodontidae	*Arothron mappa*	Om	No Group
Carangidae	*Carangoides ferdau*	Pisc	No Group
Carangidae	*Carangoides orthogrammus*	Pisc	No Group
Carangidae	*Scomberoides lysan*	Pisc	No Group
Acanthuridae	*Acanthuridae*	H	No Group
Lethrinidae	*Lethrinus amboinensis*	MI	No Group
Lethrinidae	*Lethrinus erythracanthus*	MI	No Group
Ephippidae	*Platax teira*	Om	No Group
Serranidae	*Plectropomus areolatus*	Pisc	No Group
Carangidae	*Gnathanodon speciosus*	Pisc	No Group
Serranidae	*Epinephelus polyphekadion*	Pisc	No Group
Serranidae	*Epinephelus tauvina*	Pisc	No Group
Muraenidae	*Gymnothorax breedeni*	Pisc	No Group
Acanthuridae	*Naso hexacanthus*	Pk	No Group
Acanthuridae	*Naso* sp.	Pk	No Group
Kyphosidae	*Kyphosus sandwicensis*	H	No Group
Kyphosidae	*Kyphosus* sp.	H	No Group
Balistidae	*Balistidae*	MI	No Group
Balistidae	*Balistoides viridescens*	MI	No Group
Muraenidae	*Echidna nebulosa*	MI	No Group
Haemulidae	*Plectorhinchus gibbosus*	MI	No Group
Balistidae	*Balistes polylepis*	MI	No Group
Tetraodontidae	*Tetraodontidae*	MI	No Group
Monacanthidae	*Aluterus scriptus*	Om	No Group
Ophichthidae	*Myrichthys magnificus*	MI	No Group
Aulostomidae	*Aulostomus chinensis*	Pisc	No Group
Muraenidae	*Enchelycore pardalis*	Pisc	No Group
Sphyraenidae	*Sphyraena helleri*	Pisc	No Group
Muraenidae	*Gymnothorax rueppelliae*	MI	No Group
Oplegnathidae	*Oplegnathus fasciatus*	MI	No Group
Serranidae	*Variola louti*	Pisc	No Group
Haemulidae	*Plectorhinchus picus*	MI	No Group
Haemulidae	*Plectorhinchus vittatus*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Lethrinidae	*Lethrinidae*	MI	No Group
Lethrinidae	*Lethrinus* sp.	MI	No Group
Oplegnathidae	*Oplegnathus punctatus*	MI	No Group
Carangidae	*Caranx papuensis*	Pisc	No Group
Muraenidae	*Gymnothorax steindachneri*	Pisc	No Group
Diodontidae	*Diodon hystrix*	MI	No Group
Labridae	*Labridae*	MI	No Group
Belonidae	*Belonidae*	Pisc	No Group
Carangidae	*Caranx lugubris*	Pisc	No Group
Carangidae	*Caranx sexfasciatus*	Pisc	No Group
Scombridae	*Euthynnus affinis*	Pisc	No Group
Scombridae	*Grammatorcynus bilineatus*	Pisc	No Group
Lethrinidae	*Lethrinus olivaceus*	Pisc	No Group
Acanthuridae	*Naso annulatus*	Pk	No Group
Ophidiidae	*Brotula multibarbata*	MI	No Group
Dasyatidae	*Urogymnus granulatus*	MI	No Group
Scombridae	*Sarda orientalis*	Pisc	No Group
Congridae	*Congridae*	Pisc	No Group
Congridae	*Heterocongrinae*	Pisc	No Group
Scombridae	*Katsuwonus pelamis*	Pisc	No Group
Echeneidae	*Echeneis naucrates*	Pk	No Group
Carangidae	*Trachinotus blochii*	MI	No Group
Carangidae	*Caranx melampygus*	Pisc	No Group
Muraenidae	*Gymnothorax meleagris*	Pisc	No Group
Tetraodontidae	*Arothron stellatus*	Cor	No Group
Labridae	*Coris aygula*	MI	No Group
Carangidae	*Pseudocaranx dentex*	Pisc	No Group
Muraenidae	*Scuticaria tigrina*	Pisc	No Group
Serranidae	*Plectropomus laevis*	Pisc	No Group
Serranidae	*Epinephelus* sp.	Pisc	No Group
Serranidae	*Serranidae*	Pisc	No Group
Belonidae	*Tylosurus crocodilus*	Pisc	No Group
Carangidae	*Alectis ciliaris*	Pisc	No Group
Muraenidae	*Enchelynassa canina*	Pisc	No Group
Muraenidae	*Gymnothorax undulatus*	Pisc	No Group
Muraenidae	*Gymnomuraena zebra*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Carangidae	*Carangidae*	Pisc	No Group
Fistulariidae	*Fistularia commersonii*	Pisc	No Group
Carangidae	*Caranx ignobilis*	Pisc	No Group
Carangidae	*Caranx* sp.	Pisc	No Group
Sphyraenidae	*Sphyraena qenie*	Pisc	No Group
Carangidae	*Elagatis bipinnulata*	Pisc	No Group
Chanidae	*Chanos*	H	No Group
Dasyatidae	*Taeniurops meyeni*	MI	No Group
Dasyatidae	*Dasyatidae*	MI	No Group
Carangidae	*Seriola dumerili*	Pisc	No Group
Carcharhinidae	*Carcharhinus melanopterus*	Pisc	No Group
Sphyraenidae	*Sphyraena barracuda*	Pisc	No Group
Scombridae	*Thunnus albacares*	Pisc	No Group
Carcharhinidae	*Triaenodon obesus*	Pisc	No Group
Labridae	*Cheilinus undulatus*	MI	No Group
Carcharhinidae	*Carcharhinus amblyrhynchos*	Pisc	No Group
Muraenidae	*Gymnothorax flavimarginatus*	Pisc	No Group
Scombridae	*Scombridae*	Pisc	No Group
Scombridae	*Gymnosarda unicolor*	Pisc	No Group
Muraenidae	*Muraenidae*	Pisc	No Group
Carcharhinidae	*Carcharhinus limbatus*	Pisc	No Group
Muraenidae	*Gymnothorax javanicus*	Pisc	No Group
Muraenidae	*Gymnothorax* sp.	Pisc	No Group
Ginglymostomatidae	*Nebrius ferrugineus*	Pisc	No Group
Myliobatidae	*Aetobatus ocellatus*	MI	No Group
Carcharhinidae	*Carcharhinus galapagensis*	Pisc	No Group
Sphyrnidae	*Sphyrna lewini*	Pisc	No Group
Sphyrnidae	*Sphyrnidae*	Pisc	No Group
Myliobatidae	*Mobula* sp.	Pk	No Group
Scaridae	*Scarus fuscocaudalis*	H	Parrotfish
Scaridae	*Calotomus zonarchus*	H	Parrotfish
Scaridae	*Chlorurus japanensis*	H	Parrotfish
Scaridae	*Scarus globiceps*	H	Parrotfish
Scaridae	*Scarus spinus*	H	Parrotfish
Scaridae	*Scarus psittacus*	H	Parrotfish

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Scaridae	*Scarus dubius*	H	Parrotfish
Scaridae	*Scarus oviceps*	H	Parrotfish
Scaridae	*Scarus schlegeli*	H	Parrotfish
Scaridae	*Chlorurus spilurus*	H	Parrotfish
Scaridae	*Scarus niger*	H	Parrotfish
Scaridae	*Scarus festivus*	H	Parrotfish
Scaridae	*Scarus frenatus*	H	Parrotfish
Scaridae	*Chlorurus frontalis*	H	Parrotfish
Scaridae	*Scarus dimidiatus*	H	Parrotfish
Scaridae	*Calotomus carolinus*	H	Parrotfish
Scaridae	*Scarus forsteni*	H	Parrotfish
Scaridae	*Scarus tricolor*	H	Parrotfish
Scaridae	*Scarus xanthopleura*	H	Parrotfish
Scaridae	*Hipposcarus longiceps*	H	Parrotfish
Scaridae	*Scarus altipinnis*	H	Parrotfish
Scaridae	*Chlorurus perspicillatus*	H	Parrotfish
Scaridae	*Scaridae*	H	Parrotfish
Scaridae	*Scarus rubroviolaceus*	H	Parrotfish
Scaridae	*Chlorurus microrhinos*	H	Parrotfish
Scaridae	*Cetoscarus ocellatus*	H	Parrotfish
Scaridae	*Scarus ghobban*	H	Parrotfish
Scaridae	*Chlorurus* sp.	H	Parrotfish
Scaridae	*Scarus* sp.	H	Parrotfish
Scaridae	*Bolbometopon muricatum*	Cor	Parrotfish
Lutjanidae	*Lutjanus fulvus*	MI	Snappers
Lutjanidae	*Lutjanus kasmira*	MI	Snappers
Lutjanidae	*Lutjanus gibbus*	MI	Snappers
Lutjanidae	*Lutjanus monostigma*	Pisc	Snappers
Lutjanidae	*Macolor macularis*	Pk	Snappers
Lutjanidae	*Aphareus furca*	Pisc	Snappers
Lutjanidae	*Macolor niger*	Pk	Snappers
Lutjanidae	*Macolor* sp.	Pk	Snappers
Lutjanidae	*Lutjanus bohar*	Pisc	Snappers
Lutjanidae	*Lutjanus argentimaculatus*	MI	Snappers
Lutjanidae	*Aprion virescens*	Pisc	Snappers

APPENDIX B: LIST OF PROTECTED SPECIES AND DESIGNATED CRITICAL HABITAT

Table B-1. Protected species found or reasonably believed to be found near or in Hawai`i shallow-set longline waters

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Seabirds					
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Black-Footed Albatross	*Phoebastria nigripes*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Short-Tailed Albatross	*Phoebastria albatrus*	Endangered	N/A	Breeding visitor in the NWHI	35 FR 8495, 65 FR 46643, Pyle & Pyle 2009
Northern Fulmar	*Fulmarus glacialis*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Kermadec Petrel	*Pterodroma neglecta*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Herald Petrel	*Pterodroma arminjoniana*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Murphy's Petrel	*Pterodroma ultima*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Mottled Petrel	*Pterodroma inexpectata*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Juan Fernandez Petrel	*Pterodroma externa*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Hawaiian Petrel	*Pterodroma sandwichensis (Pterodroma phaeopygia sandwichensis)*	Endangered	N/A	Breeding visitor in the MHI	32 FR 4001, Pyle & Pyle 2009
White-Necked Petrel	*Pterodroma cervicalis*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Bonin Petrel	*Pterodroma hypoleuca*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Black-Winged Petrel	*Pterodroma nigripennis*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Cook Petrel	*Pterodroma cookii*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Stejneger Petrel	*Pterodroma longirostris*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Pycroft Petrel	*Pterodroma pycrofti*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Bulwer Petrel	*Bulweria bulwerii*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Flesh-Footed Shearwater	*Ardenna carneipes*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Wedge-Tailed Shearwater	*Ardenna pacifica*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Buller's Shearwater	*Ardenna bulleri*	Not Listed	N/A	Migrant	Pyle & Pyle 2009

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Sooty Shearwater	*Ardenna grisea*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Short-Tailed Shearwater	*Ardenna tenuirostris*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Christmas Shearwater	*Puffinus nativitatis*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Newell's Shearwater	*Puffinus newelli (Puffinus auricularis newelli)*	Threatened	N/A	Breeding visitor	40 FR 44149, Pyle & Pyle 2009
Wilson's Storm-Petrel	*Oceanites oceanicus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Band-Rumped Storm-Petrel	*Oceanodroma castro*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Tristram Storm-Petrel	*Oceanodroma tristrami*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
White-Tailed Tropicbird	*Phaethon lepturus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Red-Tailed Tropicbird	*Phaethon rubricauda*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Masked Booby	*Sula dactylatra*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Brown Booby	*Sula leucogaster*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Red-Footed Booby	*Sula sula*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Great Frigatebird	*Fregata minor*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Lesser Frigatebird	*Fregata ariel*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Laughing Gull	*Leucophaeus atricilla*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Franklin Gull	*Leucophaeus pipixcan*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Ring-Billed Gull	*Larus delawarensis*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Herring Gull	*Larus argentatus*	Not Listed	N/A	Winter resident in the NWHI	Pyle & Pyle 2009
Slaty-Backed Gull	*Larus schistisagus*	Not Listed	N/A	Winter resident in the NWHI	Pyle & Pyle 2009
Glaucous-Winged Gull	*Larus glaucescens*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Brown Noddy	*Anous stolidus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Black Noddy	*Anous minutus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Blue-Gray Noddy	*Procelsterna cerulea*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
White Tern	*Gygis alba*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Sooty Tern	*Onychoprion fuscatus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Gray-Backed Tern	*Onychoprion lunatus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Little Tern	*Sternula albifrons*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Least Tern	*Sternula antillarum*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Arctic Tern	*Sterna paradisaea*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
South Polar Skua	*Stercorarius maccormicki*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Pomarine Jaeger	*Stercorarius pomarinus*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Parasitic Jaeger	*Stercorarius parasiticus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Long-Tailed Jaeger	*Stercorarius longicaudus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Sea turtles					
Green Sea Turtle	*Chelonia mydas*	Threatened (Central North Pacific DPS)	N/A	Most common turtle in the Hawaiian Islands, much more common in nearshore state waters (foraging grounds) than offshore federal waters. Most nesting occurs on French Frigate Shoals in the NWHI. Foraging and haul out in the MHI.	43 FR 32800, 81 FR 20057, Balazs et al. 1992, Kolinski et al. 2001
Green Sea Turtle	*Chelonia mydas*	Threatened (East Pacific DPS)	N/A	Nest primarily in Mexico and the Galapagos Islands. Little known about their pelagic range west of 90°W but may range as far as the Marshall Islands. Genetic testing confirmed that they are incidentally taken in the HI DSLL fishery.	43 FR 32800, 81 FR 20057, WPRFMC 2009, Cliffton et al. 1982, Karl & Bowen 1999
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered[a]	N/A	Small population foraging around Hawai`i and low level nesting on Maui and Hawai`i Islands. Occur worldwide in tropical and subtropical waters.	35 FR 8491, NMFS & USFWS 2007, Balazs et al. 1992, Katahira et al. 1994
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered[a]	N/A	Regularly sighted in offshore waters, especially at the southeastern end of the archipelago.	35 FR 8491, NMFS & USFWS 1997

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Loggerhead Sea Turtle	*Caretta caretta*	Endangered (North Pacific DPS)	N/A	Rare in Hawai`i. Found worldwide along continental shelves, bays, estuaries, and lagoons of tropical, subtropical, and temperate waters.	43 FR 32800, 76 FR 58868, Dodd 1990, Balazs 1979
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened (Entire species, except for the breeding population on the Pacific coast of Mexico, which is listed as endangered)	N/A	Rare in Hawai`i. Occurs worldwide in tropical and warm temperate ocean waters.	43 FR 32800, Pitman 1990, Balacz 1982
Marine mammals					
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Non-strategic	Found worldwide in tropical and temperate waters	Mead 1989
Blue Whale	*Balaenoptera musculus*	Endangered	Strategic	Acoustically recorded off of Oahu and Midway Atoll, small number of sightings around Hawai`i. Considered extremely rare, generally occur in winter and summer.	35 FR 18319, Bradford et al. 2013, Northrop et al. 1971, Thompson & Friedl 1982, Stafford et al. 2001
Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Non-strategic	Distributed worldwide in tropical and warm-temperate waters. Pelagic stock distinct from island-associated stocks.	Perrin et al. 2009, Martien et al. 2012
Bryde's Whale	*Balaenoptera edeni*	Not Listed	Unknown	Distributed widely across tropical and warm-temperate Pacific Ocean.	Leatherwood et al. 1982
Common Dolphin	*Delphinus delphis*	Not Listed	N/A	Found worldwide in temperate and subtropical seas.	Perrin et al. 2009
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Non-strategic	Occur year round in Hawaiian waters.	McSweeney et al. 2007
Dall's Porpoise	*Phocoenoides dalli*	Not Listed	Non-strategic	Range across the entire north Pacific Ocean.	Hall 1979
Dwarf Sperm Whale	*Kogia sima*	Not Listed	Non-strategic	Most common in waters between 500 m and 1,000 m in depth. Found worldwide in tropical and warm-temperate waters.	Nagorsen 1985, Baird et al. 2013

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
False Killer Whale	*Pseudorca crassidens*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters. Pelagic stock tracked to within 11 km of Hawaiian Islands.	Stacey et al. 1994, Baird et al. 2012, Bradford et al. 2015
Fin Whale	*Balaenoptera physalus*	Endangered	Strategic	Infrequent sightings in Hawai`i waters. Considered rare in Hawai`i, though may migrate into Hawaiian waters during fall/winter based on acoustic recordings.	35 FR 18319, Hamilton et al. 2009, Thompson & Friedl 1982
Fraser's Dolphin	*Lagenodelphis hosei*	Not Listed	Non-strategic	Found worldwide in tropical waters.	Perrin et al. 2009
Guadalupe Fur Seal	*Arctocephalus townsendi*	Threatened	Strategic	Extremely rare sightings. Little known about their pelagic distribution. Breed mainly on Isla Guadalupe, Mexico.	50 FR 51252, Gallo-Reynoso et al. 2008, Fleischer 1987
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered[a]	Strategic	Endemic tropical seal. Occurs throughout the archipelago. MHI population spends some time foraging in federal waters during the day.	41 FR 51611, Baker at al. 2011
Humpback Whale	*Megaptera novaeangliae*	Delisted Due to Recovery (Hawai`i DPS)	Strategic	Migrate through the archipelago and breed during the winter. Common during winter months when they are generally found within the 100 m isobath.	35 FR 18319, 81 FR 62259, Childerhouse et al. 2008, Wolman & Jurasz 1976, Herman & Antinoja 1977, Rice & Wolman 1978
Killer Whale	*Orcinus orca*	Not Listed	Non-strategic	Rare in Hawai`i. Prefer colder waters within 800 km of continents.	Mitchell 1975, Baird et al. 2006
Longman's Beaked Whale	*Indopacetus pacificus*	Not Listed	Non-strategic	Found in tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa. Rare in Hawai`i.	Dalebout 2003, Baird et al. 2013
Melon-Headed Whale	*Peponocephala electra*	Not Listed	Non-strategic	Found in tropical and warm-temperate waters worldwide, found primarily in equatorial waters. Uncommon in Hawai`i.	Perryman et al. 1994, Barlow 2006, Bradford et al. 2013

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Minke Whale	*Balaenoptera acutorostrata*	Not Listed	Non-strategic	Occur seasonally around Hawai`i	Barlow 2003, Rankin & Barlow 2005
North Pacific Right Whale	*Eubalaena japonica*	Endangered[a]	Strategic	Extremely rare in Hawai`i waters	35 FR 18319, 73 FR 12024, Rowntree et al. 1980, Herman et al. 1980
Northern Elephant Seal	*Mirounga angustirostris*	Not Listed	Non-strategic	Females migrate to central North Pacific to feed on pelagic prey.	Le Beouf et al. 2000
Northern Fur Seal	*Callorhinus ursinus*	Not Listed	Non-strategic	Occur throughout the North Pacific Ocean.	Gelatt et al. 2015
Pacific White-Sided Dolphin	*Lagenorhynchus obliquidens*	Not Listed	Non-strategic	Endemic to temperate waters of North Pacific Ocean. Occur both on the high seas and along continental margins.	Brownell et al. 1999
Pantropical Spotted Dolphin	*Stenella attenuata*	Not Listed	Non-strategic	Common and abundant throughout the Hawaiian archipelago. Pelagic stock occurs outside of insular stock areas (20 km for Oahu and 4-island stocks, 65 km for Hawai`i Island stock).	Baird et al. 2013, Oleson et al. 2013
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Non-strategic	Small resident population in Hawaiian waters. Found worldwide in tropical and subtropical waters.	McSweeney et al. 2009, Ross & Leatherwood 1994
Pygmy Sperm Whale	*Kogia breviceps*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Caldwell & Caldwell 1989
Risso's Dolphin	*Grampus griseus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Perrin et al. 2009
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide. Occasionally found offshore of Hawai`i.	Perrin et al. 2009, Baird et al. 2013, Barlow 2006, Bradford et al. 2013
Sei Whale	*Balaenoptera borealis*	Endangered	Strategic	Rare in Hawai`i. Generally found in offshore temperate waters.	35 FR 18319, Barlow 2003, Bradford et al. 2013

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide. Commonly observed around MHI and present around NWHI.	Shallenberger 1981, Baird et al. 2013, Bradford et al. 2013
Sperm Whale	*Physeter macrocephalus*	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the region. Sighted off the NWHI and the MHI.	35 FR 18319, Rice 1960, Lee 1993, Barlow 2006, Mobley et al. 2000, Shallenberger 1981
Spinner Dolphin	*Stenella longirostris*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters. Pelagic stock found outside of island-associated boundaries (10 nm).	Perrin et al. 2009
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world.	Perrin et al. 2009
Elasmobranchs					
Giant manta ray	*Manta birostris*	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs.	Dewar et al. 2008, Marshall et al. 2009, Marshall et al. 2011.
Oceanic whitetip shark	*Carcharhinus longimanus*	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C	Bonfil et al. 2008, Backus et al, 1956, Strasburg 1958, Compagno 1984
Scalloped hammerhead shark	*Sphyrna lewini*	Endangered (Eastern Pacific DPS)	N/A	Found in coastal areas from southern California to Peru.	Compagno 1984, Baum et al. 2007, Bester 2011
Scalloped hammerhead	*Sphyrna lewini*	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m.	Compagno 1984, Schulze-Haugen & Kohler 2003, Sanches 1991, Klimley 1993
Corals					

Common name	**Scientific name**	**ESA listing status**	**MMPA status**	**Occurrence**	**References**
N/A	*Acropora globiceps*	Threatened	N/A	Not confirmed in Hawai`i waters. Occur on upper reef slopes, reef flats, and adjacent habitats in depths ranging from 0 to 8 m	Veron 2014
N/A	*Acropora jacquelineae*	Threatened	N/A	Not confirmed in Hawai`i waters. Found in numerous subtidal reef slope and back-reef habitats, including but not limited to, lower reef slopes, walls and ledges, mid-slopes, and upper reef slopes protected from wave action, and depth range is 10 to 35 m.	Veron 2014
N/A	*Acropora retusa*	Threatened	N/A	Not confirmed in Hawai`i waters. Occur in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons, and depth range is 1 to 5 m.	Veron 2014
N/A	*Acropora speciosa*	Threatened	N/A	Not confirmed in Hawai`i waters. Found in protected environments with clear water and high diversity of *Acropora* and steep slopes or deep, shaded waters. Depth range is 12 to 40 meters and have been found in mesophotic habitat (40-150 m).	Veron 2014
N/A	*Euphyllia paradivisa*	Threatened	N/A	Not confirmed in Hawai`i waters. Found in environments protected from wave action on at least upper reef slopes, mid-slope terraces, and lagoons in depths ranging from 2 to 25 m depth.	Veron 2014
N/A	*Isopora crateriformis*	Threatened	N/A	Not confirmed in Hawai`i waters. Found in shallow, high-wave energy environments, from low tide to at least 12 meters deep, and have been reported from mesophotic depths (less than 50 m depth).	Veron 2014

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
N/A	*Seriatopora aculeata*	Threatened	N/A	Not confirmed in Hawai`i waters. Found in broad range of habitats including, but not limited to, upper reef slopes, mid-slope terraces, lower reef slopes, reef flats, and lagoons, and depth ranges from 3 to 40 m.	Veron 2014
Invertebrates					
Chambered nautilus	*Nautilus pompilius*	Threatened	N/A	Found in small, isolated populations throughout the Indo-Pacific on steep-sloped forereefs with sandy, silty, or muddy bottom substrates from depths of 100 m to 500 m.	83 FR 48948, CITES 2016

[a] These species have critical habitat designated under the ESA. See Table B-4.

Table B-2. Protected species found or reasonably believed to be found near or in Hawai`i deep-set longline waters

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Seabirds					
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Black-Footed Albatross	*Phoebastria nigripes*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Short-Tailed Albatross	*Phoebastria albatrus*	Endangered	N/A	Breeding visitor in the NWHI	35 FR 8495, 65 FR 46643, Pyle & Pyle 2009
Northern Fulmar	*Fulmarus glacialis*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Kermadec Petrel	*Pterodroma neglecta*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Herald Petrel	*Pterodroma arminjoniana*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Murphy's Petrel	*Pterodroma ultima*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Mottled Petrel	*Pterodroma inexpectata*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Juan Fernandez Petrel	*Pterodroma externa*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Hawaiian Petrel	*Pterodroma sandwichensis (Pterodroma phaeopygia sandwichensis)*	Endangered	N/A	Breeding visitor in the MHI	32 FR 4001, Pyle & Pyle 2009
White-Necked Petrel	*Pterodroma cervicalis*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Bonin Petrel	*Pterodroma*	Not Listed	N/A	Breeding visitor in the	Pyle & Pyle

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
	hypoleuca			NWHI	2009
Black-Winged Petrel	*Pterodroma nigripennis*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Cook Petrel	*Pterodroma cookii*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Stejneger Petrel	*Pterodroma longirostris*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Pycroft Petrel	*Pterodroma pycrofti*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Bulwer Petrel	*Bulweria bulwerii*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Wedge-Tailed Shearwater	*Ardenna pacifica*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Buller's Shearwater	*Ardenna bulleri*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Sooty Shearwater	*Ardenna grisea*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Short-Tailed Shearwater	*Ardenna tenuirostris*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Christmas Shearwater	*Puffinus nativitatis*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Newell's Shearwater	*Puffinus newelli (Puffinus auricularis newelli)*	Threatened	N/A	Breeding visitor	40 FR 44149, Pyle & Pyle 2009
Wilson's Storm-Petrel	*Oceanites oceanicus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Band-Rumped Storm-Petrel	*Oceanodroma castro*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Tristram Storm-Petrel	*Oceanodroma tristrami*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
White-Tailed Tropicbird	*Phaethon lepturus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Red-Tailed Tropicbird	*Phaethon rubricauda*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Masked Booby	*Sula dactylatra*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Nazca Booby	*Sula granti*	Not Listed	N/A	Vagrant	Pyle & Pyle 2009
Brown Booby	*Sula leucogaster*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Red-Footed Booby	*Sula*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Great Frigatebird	*Fregata minor*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Lesser Frigatebird	*Fregata ariel*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Laughing Gull	*Leucophaeus atricilla*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Franklin Gull	*Leucophaeus*	Not Listed	N/A	Migrant	Pyle & Pyle

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
	pipixcan				2009
Ring-Billed Gull	*Larus delawarensis*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Herring Gull	*Larus argentatus*	Not Listed	N/A	Winter resident in the NWHI	Pyle & Pyle 2009
Slaty-Backed Gull	*Larus schistisagus*	Not Listed	N/A	Winter resident in the NWHI	Pyle & Pyle 2009
Glaucous-Winged Gull	*Larus glaucescens*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Brown Noddy	*Anous stolidus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Black Noddy	*Anous minutus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Blue-Gray Noddy	*Procelsterna cerulea*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
White Tern	*Gygis alba*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Sooty Tern	*Onychoprion fuscatus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Gray-Backed Tern	*Onychoprion lunatus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Little Tern	*Sternula albifrons*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Least Tern	*Sternula antillarum*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Arctic Tern	*Sterna paradisaea*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
South Polar Skua	*Stercorarius maccormicki*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Pomarine Jaeger	*Stercorarius pomarinus*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Parasitic Jaeger	*Stercorarius parasiticus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Long-Tailed Jaeger	*Stercorarius longicaudus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Sea turtles					
Green Sea Turtle	*Chelonia mydas*	Threatened (Central North Pacific DPS)	N/A	Most common turtle in the Hawaiian Islands, much more common in nearshore state waters (foraging grounds) than offshore federal waters. Most nesting occurs on French Frigate Shoals in the NWHI. Foraging and haulout in the MHI.	43 FR 32800, 81 FR 20057, Balazs et al. 1992, Kolinski et al. 2001

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Green Sea Turtle	*Chelonia mydas*	Threatened (East Pacific DPS)	N/A	Nest primarily in Mexico and the Galapagos Islands. Little known about their pelagic range west of 90°W but may range as far as the Marshall Islands. Genetic testing confirmed that they are incidentally taken in the HI DSLL fishery.	43 FR 32800, 81 FR 20057, WPRFMC 2009, Cliffton et al. 1982, Karl & Bowen 1999
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered[a]	N/A	Small population foraging around Hawai`i and low level nesting on Maui and Hawai`i Islands. Occur worldwide in tropical and subtropical waters.	35 FR 8491, NMFS & USFWS 2007, Balazs et al. 1992, Katahira et al. 1994
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered[a]	N/A	Regularly sighted in offshore waters, especially at the southeastern end of the archipelago.	35 FR 8491, NMFS & USFWS 1997
Loggerhead Sea Turtle	*Caretta*	Endangered (North Pacific DPS)	N/A	Rare in Hawai`i. Found worldwide along continental shelves, bays, estuaries and lagoons of tropical, subtropical, and temperate waters.	43 FR 32800, 76 FR 58868, Dodd 1990, Balazs 1979
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened (Entire species, except for the breeding population on the Pacific coast of Mexico, which is listed as endangered)	N/A	Rare in Hawai`i. Occurs worldwide in tropical and warm temperate ocean waters.	43 FR 32800, Pitman 1990, Balacz 1982
Marine mammals					
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Non-strategic	Found worldwide in tropical and temperate waters	Mead 1989
Blue Whale	*Balaenoptera musculus*	Endangered	Strategic	Acoustically recorded off of Oahu and Midway Atoll, small number of sightings around Hawai`i. Considered extremely rare, generally occur in winter and summer.	35 FR 18319, Bradford et al. 2013, Northrop et al. 1971, Thompson & Friedl 1982, Stafford et al. 2001

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Non-strategic	Distributed worldwide in tropical and warm-temperate waters. Pelagic stock distinct from island-associated stocks.	Perrin et al. 2009, Martien et al. 2012
Bryde's Whale	*Balaenoptera edeni*	Not Listed	Unknown	Distributed widely across tropical and warm-temperate Pacific Ocean.	Leatherwood et al. 1982
Common Dolphin	*Delphinus delphis*	Not Listed	N/A	Found worldwide in temperate and subtropical seas.	Perrin et al. 2009
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Non-strategic	Occur year round in Hawaiian waters.	McSweeney et al. 2007
Dall's Porpoise	*Phocoenoides dalli*	Not Listed	Non-strategic	Range across the entire north Pacific Ocean.	Hall 1979
Dwarf Sperm Whale	*Kogia sima*	Not Listed	Non-strategic	Most common in waters between 500 m and 1,000 m in depth. Found worldwide in tropical and warm-temperate waters.	Nagorsen 1985, Baird et al. 2013
False Killer Whale	*Pseudorca crassidens*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters. Pelagic stock tracked to within 11 km of Hawaiian Islands.	Stacey et al. 1994, Baird et al. 2012, Bradford et al. 2015
Fin Whale	*Balaenoptera physalus*	Endangered	Strategic	Infrequent sightings in Hawai`i waters. Considered rare in Hawai`i, though may migrate into Hawaiian waters during fall/winter based on acoustic recordings.	35 FR 18319, Hamilton et al. 2009, Thompson & Friedl 1982
Fraser's Dolphin	*Lagenodelphis hosei*	Not Listed	Non-strategic	Found worldwide in tropical waters.	Perrin et al. 2009
Guadalupe Fur Seal	*Arctocephalus townsendi*	Threatened	Strategic	Rare sightings. Little known about their pelagic distribution. Breed mainly on Isla Guadalupe, Mexico.	50 FR 51252, Gallo-Reynoso et al. 2008, Fleischer 1987
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered[a]	Strategic	Endemic tropical seal. Occurs throughout the archipelago. MHI population spends some time foraging in federal waters during the day.	41 FR 51611, Baker at al. 2011

Common name	**Scientific name**	**ESA listing status**	**MMPA status**	**Occurrence**	**References**
Humpback Whale	*Megaptera novaeangliae*	Delisted Due to Recovery (Hawai`i DPS)	Strategic	Migrate through the archipelago and breed during the winter. Common during winter months when they are generally found within the 100 m isobath.	35 FR 18319, 81 FR 62259, Childerhouse et al. 2008, Wolman & Jurasz 1976, Herman & Antinoja 1977, Rice & Wolman 1978
Killer Whale	*Orcinus orca*	Not Listed	Non-strategic	Rare in Hawai`i. Prefer colder waters within 800 km of continents.	Mitchell 1975, Baird et al. 2006
Longman's Beaked Whale	*Indopacetus pacificus*	Not Listed	Non-strategic	Found in tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa. Rare in Hawai`i.	Dalebout 2003, Baird et al. 2013
Melon-Headed Whale	*Peponocephala electra*	Not Listed	Non-strategic	Found in tropical and warm-temperate waters worldwide, found primarily in equatorial waters. Uncommon in Hawai`i.	Perryman et al. 1994, Barlow 2006, Bradford et al. 2013
Minke Whale	*Balaenoptera acutorostrata*	Not Listed	Non-strategic	Occur seasonally around Hawai`i	Barlow 2003, Rankin & Barlow 2005
North Pacific Right Whale	*Eubalaena japonica*	Endangered[a]	Strategic	Extremely rare in Hawai`i waters	35 FR 18319, 73 FR 12024, Rowntree et al. 1980, Herman et al. 1980
Northern Elephant Seal	*Mirounga angustirostris*	Not Listed	Non-strategic	Females migrate to central North Pacific to feed on pelagic prey	Le Beouf et al. 2000
Northern Fur Seal	*Callorhinus ursinus*	Not Listed	Non-strategic	Range across the north Pacific Ocean.	Gelatt et al. 2015
Pacific White-Sided Dolphin	*Lagenorhynchus obliquidens*	Not Listed	Non-strategic	Endemic to temperate waters of North Pacific Ocean. Occur both on the high seas and along continental margins.	Brownell et al. 1999
Pantropical Spotted Dolphin	*Stenella attenuata*	Not Listed	Non-strategic	Common and abundant throughout the Hawaiian archipelago. Pelagic stock occurs outside of insular stock areas (20 km for Oahu and 4-island stocks, 65 km for Hawai`i Island stock)	Baird et al. 2013, Oleson et al. 2013

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Non-strategic	Small resident population in Hawaiian waters. Found worldwide in tropical and subtropical waters.	McSweeney et al. 2009, Ross & Leatherwood 1994
Pygmy Sperm Whale	*Kogia breviceps*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Caldwell & Caldwell 1989
Risso's Dolphin	*Grampus griseus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Perrin et al. 2009
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide. Occasionally found offshore of Hawai`i.	Perrin et al. 2009, Bradford et al. 2013, Barlow 2006, Baird et al. 2013
Sei Whale	*Balaenoptera borealis*	Endangered	Strategic	Rare in Hawai`i. Generally found in offshore temperate waters.	35 FR 18319, Barlow 2003, Bradford et al. 2013
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide. Commonly observed around MHI and present around NWHI.	Shallenberger 1981, Baird et al. 2013, Bradford et al. 2013
Sperm Whale	*Physeter macrocephalus*	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the region. Sighted off the NWHI and the MHI.	35 FR 18319, Rice 1960, Lee 1993, Barlow 2006, Mobley et al. 2000, Shallenberger 1981
Spinner Dolphin	*Stenella longirostris*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters. Pelagic stock found outside of island-associated boundaries (10 nm)	Perrin et al. 2009
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world	Perrin et al. 2009
Elasmobranchs					

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Giant manta ray	*Manta birostris*	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs.	Dewar et al. 2008, Marshall et al. 2009, Marshall et al. 2011.
Oceanic whitetip shark	*Carcharhinus longimanus*	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C	Bonfil et al. 2008, Backus et al, 1956, Strasburg 1958, Compagno 1984
Scalloped hammerhead shark	*Sphyrna lewini*	Endangered (Eastern Pacific DPS)	N/A	Found in coastal areas from southern California to Peru.	Compagno 1984, Baum et al. 2007, Bester 2011
Scalloped hammerhead shark	*Sphyrna lewini*	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m.	Compagno 1984, Schulze-Haugen & Kohler 2003, Sanches 1991, Klimley 1993
Corals					
N/A	*Acropora globiceps*	Threatened	N/A	Occur on upper reef slopes, reef flats, and adjacent habitats in depths ranging from 0 to 8 m.	Veron 2014
N/A	*Acropora jacquelineae*	Threatened	N/A	Found in numerous subtidal reef slope and back-reef habitats, including but not limited to, lower reef slopes, walls and ledges, mid-slopes, and upper reef slopes protected from wave action, and depth range is 10 to 35 m.	Veron 2014
N/A	*Acropora retusa*	Threatened	N/A	Occur in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons, and depth range is 1 to 5 m.	Veron 2014

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
N/A	*Acropora speciosa*	Threatened	N/A	Found in protected environments with clear water and high diversity of *Acropora* and steep slopes or deep, shaded waters. Depth range is 12 to 40 meters, and it has been found in mesophotic habitat (40-150 m).	Veron 2014
N/A	*Euphyllia paradivisa*	Threatened	N/A	Found in environments protected from wave action on at least upper reef slopes, mid-slope terraces, and lagoons in depths ranging from 2 to 25 m depth.	Veron 2014
N/A	*Isopora crateriformis*	Threatened	N/A	Found in shallow, high-wave energy environments, from low tide to at least 12 m deep, and have been reported from mesophotic depths (less than 50 m depth).	Veron 2014
N/A	*Seriatopora aculeata*	Threatened	N/A	Found in broad range of habitats including, but not limited to, upper reef slopes, mid-slope terraces, lower reef slopes, reef flats, and lagoons, and depth ranges from 3 to 40 m.	Veron 2014
Invertebrates					
Chambered nautilus	*Nautilus pompilius*	Threatened	N/A	Found in small, isolated populations throughout the Indo-Pacific on steep-sloped forereefs with sandy, silty, or muddy bottom substrates from depths of 100 m to 500 m.	83 FR 48948, CITES 2016

[a] These species have critical habitat designated under the ESA. See Table B-4.

Table B-3. Protected species found or reasonably believed to be found near or in American Samoa longline waters

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Seabirds					
Audubon's Shearwater	*Puffinus lherminieri*	Not Listed	N/A	Resident	Craig 2005
Black Noddy	*Anous minutus*	Not Listed	N/A	Resident	Craig 2005

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Black-Naped Tern	*Sterna sumatrana*	Not Listed	N/A	Visitor	Craig 2005
Blue-Gray Noddy	*Procelsterna cerulea*	Not Listed	N/A	Resident	Craig 2005
Bridled Tern	*Onychoprion anaethetus*	Not Listed	N/A	Visitor	Craig 2005
Brown Booby	*Sula leucogaster*	Not Listed	N/A	Resident	Craig 2005
Brown Noddy	*Anous stolidus*	Not Listed	N/A	Resident	Craig 2005
Christmas Shearwater	*Puffinus nativitatis*	Not Listed	N/A	Resident?	Craig 2005
Collared Petrel	*Pterodroma brevipes*	Not Listed	N/A	Resident?	Craig 2005
White Tern	*Gygis alba*	Not Listed	N/A	Resident	Craig 2005
Greater Crested Tern	*Thalasseus bergii*	Not Listed	N/A	Visitor	Craig 2005
Gray-Backed Tern	*Onychoprion lunatus*	Not Listed	N/A	Resident	Craig 2005
Great Frigatebird	*Fregata minor*	Not Listed	N/A	Resident	Craig 2005
Herald Petrel	*Pterodroma heraldica*	Not Listed	N/A	Resident	Craig 2005
Laughing Gull	*Leucophaeus atricilla*	Not Listed	N/A	Visitor	Craig 2005
Lesser Frigatebird	*Fregata ariel*	Not Listed	N/A	Resident	Craig 2005
Masked Booby	*Sula dactylatra*	Not Listed	N/A	Resident	Craig 2005
Newell's Shearwater	*Puffinus auricularis newelli*	Threatened	N/A	Visitor	40 FR 44149, Craig 2005
Red-Footed Booby	*Sula*	Not Listed	N/A	Resident	Craig 2005
Red-Tailed Tropicbird	*Phaethon rubricauda*	Not Listed	N/A	Resident	Craig 2005
Short-Tailed Shearwater	*Ardenna tenuirostris*	Not Listed	N/A	Visitor	Craig 2005
Sooty Shearwater	*Ardenna grisea*	Not Listed	N/A	Visitor	Craig 2005
Sooty Tern	*Sterna fuscata*	Not Listed	N/A	Resident	Craig 2005
Tahiti Petrel	*Pterodroma rostrata*	Not Listed	N/A	Resident	Craig 2005
Wedge-Tailed Shearwater	*Ardenna pacifica*	Not Listed	N/A	Resident?	Craig 2005
White-Necked Petrel	*Pterodroma cervicalis*	Not Listed	N/A	Visitor	Craig 2005
White-Faced Storm-Petrel	*Pelagodroma marina*	Not Listed	N/A	Visitor	Craig 2005
White-Tailed Tropicbird	*Phaethon lepturus*	Not Listed	N/A	Resident	Craig 2005
White-Throated Storm-Petrel	*Nesofregetta fuliginosa*	Not Listed	N/A	Resident?	Craig 2005
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Breed mainly in Hawai`i, and range across the North Pacific Ocean.	Causey 2008

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Hawaiian Petrel	*Pterodroma sandwichensis (Pterodroma phaeopygia sandwichensis)*	Endangered	N/A	Breed in MHI, and range across the central Pacific Ocean.	32 FR 4001, Simons & Hodges 1998
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Breed mainly in Hawai`i, and range across the North Pacific Ocean.	Causey 2009
Northern Fulmar	*Fulmarus glacialis*	Not Listed	N/A	Breed and range across North Pacific Ocean.	Hatch & Nettleship 2012
Short-Tailed Albatross	*Phoebastria albatrus*	Endangered	N/A	Breed in Japan and NWHI, and range across the North Pacific Ocean.	35 FR 8495, 65 FR 46643, BirdLife International 2017
Sea turtles					
Green Sea Turtle	*Chelonia mydas*	Endangered (Central South Pacific DPS)	N/A	Frequently seen. Nest at Rose Atoll in small numbers.	43 FR 32800, 81 FR 20057, Balacz 1994
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered[a]	N/A	Frequently seen. Nest at Rose Atoll, Swain's Island, and Tutuila.	35 FR 8491, NMFS & USFWS 2013, Tuato'o-Bartley et al. 1993
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered[a]	N/A	Very rare. One juvenile recovered dead in experimental longline fishing.	35 FR 8491, Grant 1994
Loggerhead Sea Turtle	*Caretta*	Endangered (South Pacific DPS)	N/A	No known sightings. Found worldwide along continental shelves, bays, estuaries and lagoons of tropical, subtropical, and temperate waters.	43 FR 32800, 76 FR 58868, Utzurrum 2002, Dodd 1990
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened (Entire species, except for the endangered breeding population on the Pacific coast of Mexico)	N/A	Rare. Three known sightings.	43 FR 32800, Utzurrum 2002
Marine mammals					
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Non-strategic	Found worldwide in tropical and temperate waters	Mead 1989
Blue Whale	*Balaenoptera musculus*	Endangered	Strategic	No known sightings. Occur worldwide and are known to be found in the western South Pacific.	35 FR 18319, Olson et al. 2015

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Non-strategic	Distributed worldwide in tropical and warm-temperate waters. Pelagic stock distinct from island-associated stocks.	Perrin et al. 2009, Martien et al. 2012
Bryde's Whale	*Balaenoptera edeni*	Not Listed	Unknown	Distributed widely across tropical and warm-temperate Pacific Ocean.	Leatherwood et al. 1982
Common Dolphin	*Delphinus delphis*	Not Listed	N/A	Found worldwide in temperate and subtropical seas.	Perrin et al. 2009
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Non-strategic	Occur worldwide.	Heyning 1989
Dwarf Sperm Whale	*Kogia sima*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Nagorsen 1985
False Killer Whale	*Pseudorca crassidens*	Not Listed	Unknown	Found in waters within the U.S. EEZ of A. Samoa	Bradford et al. 2015
Fin Whale	*Balaenoptera physalus*	Endangered	Strategic	No known sightings but reasonably expected to occur in A. Samoa. Found worldwide.	35 FR 18319, Hamilton et al. 2009
Fraser's Dolphin	*Lagenodelphis hosei*	Not Listed	Non-strategic	Found worldwide in tropical waters.	Perrin et al. 2009
Guadalupe Fur Seal	*Arctocephalus townsendi*	Threatened	Strategic	No known sightings. Little known about their pelagic distribution. Breed mainly on Isla Guadalupe, Mexico.	50 FR 51252, Gallo-Reynoso et al. 2008, Fleischer 1987
Humpback Whale	*Megaptera novaeangliae*	Delisted Due to Recovery (Oceania DPS)	Strategic	Migrate through the archipelago and breed during the winter in American Samoan waters.	35 FR 18319, 81 FR 62259, Guarrige et al. 2007, SPWRC 2008
Killer Whale	*Orcinus orca*	Not Listed	Non-strategic	Found worldwide. Prefer colder waters within 800 km of continents.	Leatherwood & Dalheim 1978, Mitchell 1975, Baird et al. 2006
Longman's Beaked Whale	*Indopacetus pacificus*	Not Listed	Non-strategic	Found in tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa.	Dalebout 2003
Melon-Headed Whale	*Peponocephala electra*	Not Listed	Non-strategic	Found in tropical and warm-temperate waters worldwide, primarily found in equatorial waters.	Perryman et al. 1994

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Minke Whale	*Balaenoptera acutorostrata*	Not Listed	Non-strategic	Uncommon in this region, usually seen over continental shelves in the Pacific Ocean.	Brueggeman et al. 1990
North Pacific Right Whale	*Eubalaena japonica*	Endangered[a]	Strategic	Extremely rare.	35 FR 18319, 73 FR 12024, Childerhouse et al. 2008, Wolman & Jurasz 1976, Herman & Antinoja 1977, Rice & Wolman 1978
Northern Elephant Seal	*Mirounga angustirostris*	Not Listed	Non-strategic	Females migrate to central North Pacific to feed on pelagic prey	Le Beouf et al. 2000
Pantropical Spotted Dolphin	*Stenella attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide.	Perrin et al. 2009
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide.	Ross & Leatherwood 1994
Pygmy Sperm Whale	*Kogia breviceps*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Caldwell & Caldwell 1989
Risso's Dolphin	*Grampus griseus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Perrin et al. 2009
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Unknown	Found in tropical to warm-temperate waters worldwide. Common in A. Samoa waters.	Perrin et al. 2009, Craig 2005
Sei Whale	*Balaenoptera borealis*	Endangered	Strategic	Generally found in offshore temperate waters.	35 FR 18319, Barlow 2003, Bradford et al. 2013
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide	Shallenberger 1981, Baird et al. 2013, Bradford et al. 2013
Sperm Whale	*Physeter macrocephalus*	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the region.	35 FR 18319, Rice 1960, Barlow 2006, Lee 1993, Mobley et al. 2000, Shallenberger 1981
Spinner Dolphin	*Stenella longirostris*	Not Listed	Unknown	Common in American Samoa, found in waters with mean depth of 44 m.	Reeves et al. 1999, Johnston et al. 2008

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world	Perrin et al. 2009
Elasmobranchs					
Giant manta ray	*Manta birostris*	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs.	Dewar et al. 2008, Marshall et al. 2009, Marshall et al. 2011.
Oceanic whitetip shark	*Carcharhinus longimanus*	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C.	Bonfil et al. 2008, Backus et al, 1956, Strasburg 1958, Compagno 1984
Scalloped hammerhead shark	*Sphyrna lewini*	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m.	Compagno 1984, Schulze-Haugen & Kohler 2003, Sanches 1991, Klimley 1993
Corals					
N/A	*Acropora globiceps*	Threatened	N/A	Occur on upper reef slopes, reef flats, and adjacent habitats in depths from 0 to 8 m	Veron 2014
N/A	*Acropora jacquelineae*	Threatened	N/A	Found in numerous subtidal reef slope and back-reef habitats, including but not limited to, lower reef slopes, walls and ledges, mid-slopes, and upper reef slopes protected from wave action, and its depth range is 10 to 35 m.	Veron 2014
N/A	*Acropora retusa*	Threatened	N/A	Occur in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons. Depth range is 1 to 5 m.	Veron 2014

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	References
N/A	*Acropora speciosa*	Threatened	N/A	Found in protected environments with clear water and high diversity of Acropora and steep slopes or deep, shaded waters. Depth range is 12 to 40 meters and have been found in mesophotic habitat (40-150 m).	Veron 2014
N/A	*Euphyllia paradivisa*	Threatened	N/A	Found in environments protected from wave action on at least upper reef slopes, mid-slope terraces, and lagoons in depths ranging from 2 to 25 m depth.	Veron 2014
N/A	*Isopora crateriformis*	Threatened	N/A	Found in shallow, high-wave energy environments, from low tide to at least 12 meters deep, and have been reported from mesophotic depths (less than 50 m depth).	Veron 2014
Invertebrates					
Chambered nautilus	*Nautilus pompilius*	Threatened	N/A	Found in small, isolated populations throughout the Indo-Pacific on steep-sloped forereefs with sandy, silty, or muddy bottom substrates from depths of 100 m to 500 m.	83 FR 48948, CITES 2016

[a] These species have critical habitat designated under the ESA. See Table B-4.

Table B-4. ESA-listed species' critical habitat in the Pacific Ocean[a]

Common Name	Scientific Name	ESA Listing Status	Critical Habitat	References
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered	None in the Pacific Ocean.	63 FR 46693
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Approximately 16,910 square miles (43,798 square km) stretching along the California coast from Point Arena to Point Arguello east of the 3,000 meter depth contour; and 25,004 square miles (64,760 square km) stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meter depth contour.	77 FR 4170
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered	Ten areas in the Northwestern Hawaiian Islands (NWHI) and six in the main Hawaiian Islands (MHI). These areas contain one or a combination of habitat types: Preferred pupping and nursing areas, significant haul-	53 FR 18988, 51 FR 16047, 80 FR 50925

			out areas, and/or marine foraging areas, that will support conservation for the species.	
North Pacific Right Whale	*Eubalaena japonica*	Endangered	Two specific areas are designated, one in the Gulf of Alaska and another in the Bering Sea, comprising a total of approximately 95,200 square kilometers (36,750 square miles) of marine habitat.	73 FR 19000, 71 FR 38277

[a] For maps of critical habitat, see https://www.fisheries.noaa.gov/national/endangered-species-conservation/critical-habitat.

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APPENDIX C: REVIEW OF ESSENTIAL FISH HABITAT FOR REEF-ASSOCIATED CRUSTACEANS IN THE WESTERN PACIFIC REGION

INTRODUCTION

Essential fish habitat under the Magnuson-Stevens Fishery Conservation and Management Act is defined as:" those waters necessary to fish for spawning, breeding, or growth to maturity". Habitat Areas of Particular Concern (HAPCs) are defined as subsets of EFH that are: "rare, stressed by development, provide important ecological functions for federally managed species, and/or are especially vulnerable to anthropogenic degradation".

In 2009, the Fishery Ecosystem Plans (FEPs) for Hawaii, American Samoa, and Marianas defined EFH for all reef-associated crustacean eggs and larvae as *"In the water column from the shoreline to the outer limit of the EEZ down to a depth of 150 m (75 fm)".* EFH for juveniles and adults for all reef associated crustaceans was defined as: "*all of the bottom habitat from the shoreline to a depth of 100 m (fm)".* Additionally, the 2009 Hawaii FEP defined HAPC for reef-associated crustaceans as: *"all banks in the NWHI with summits less than or equal to 30 m (15 fathoms) from the surface."* Species specific EFH for crustaceans was not defined in the FEP.

Reef-associated crustaceans landed in the Main Hawaiian Island commercial fishery include Kona crab (*Ranina ranina*), two species of spiny lobster (*Panulirus marginatus* and *P. penicillatus*), and slipper lobster species (*Scyllarides sp*.).Total commercial landings reported for reef associated crustaceans for the Main Hawaiian Island from 1948 – 2017 was 6,010,183 lbs. with the majority coming from Penguin Bank, an extended shelf area off Maui Nui. Kona crab (*Ranina ranina*) accounts for the majority (>60%) of the reef-associated crustacean reported landings from 1948-2017 in the Main Hawaiian Islands, followed by unidentified *Panulirus spp.* (~30 %), *Panulirus penicillatus* (~6%), *Panulirus marginatus* (~1%), and *Scyllardies* sp. (Figure C-1).

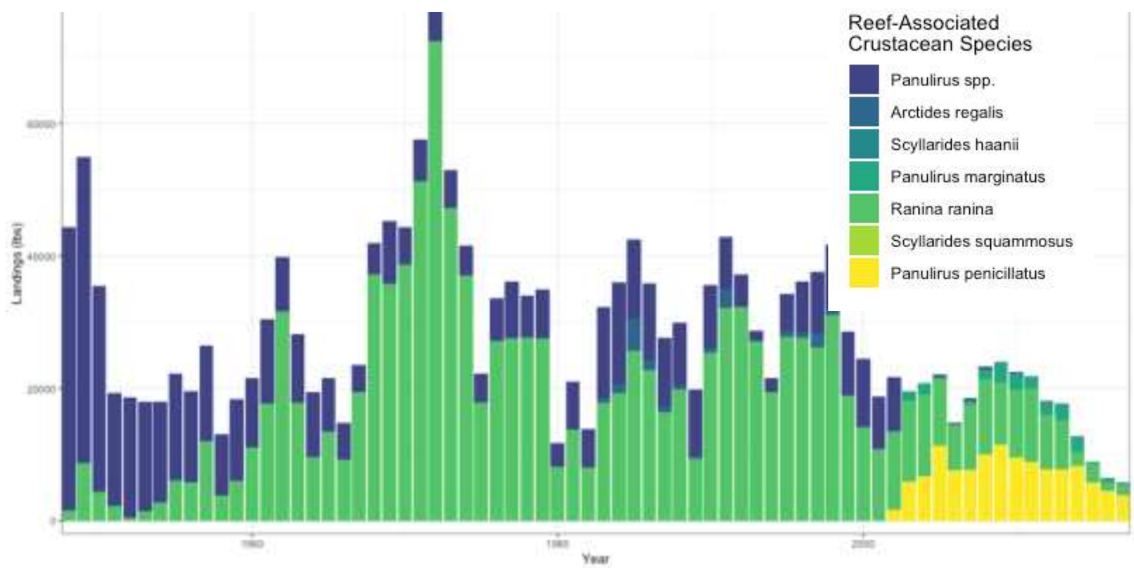

Figure C-1. Reported commercial landings of reef-associated crustaceans in the MHI from 1948 – 2017 (HDAR). Species/year combinations are only shown for data points that represent > 3 fishing licenses for confidentiality purposes.

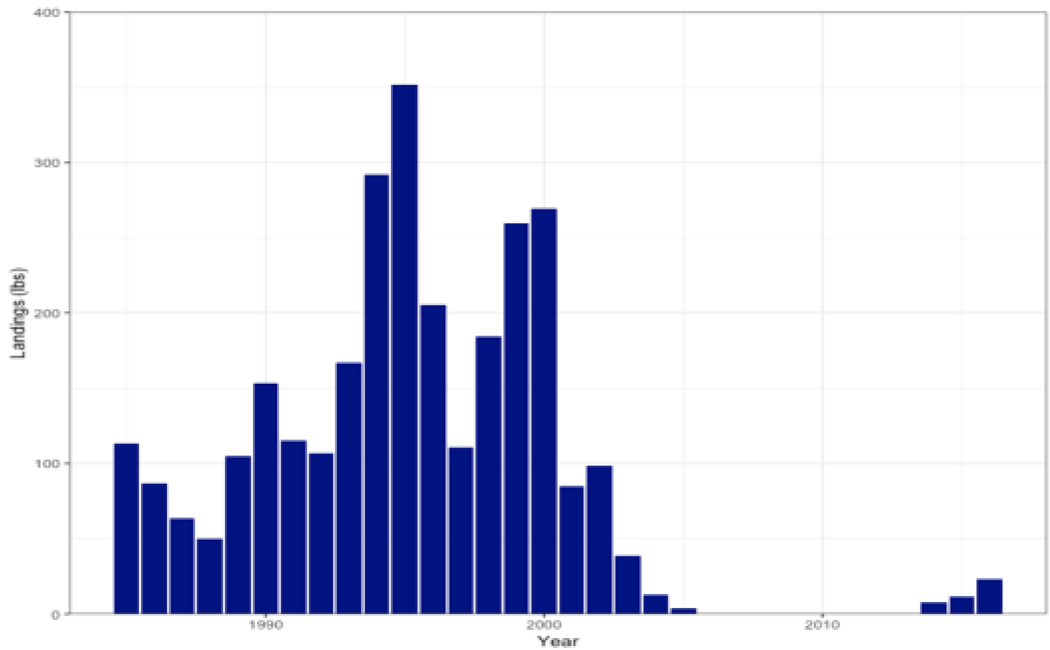

Figure C-2. Estimated landings of reef-associated crustaceans from1983-2016 (WPacFIN)

P. penicillatus accounts for over 90% of reef associated crustacean landings in Guam from 1983 -2016. Slipper lobster species account for approximately 8% of historical crustacean landings, and *P. versicolor*, *P. longipes*, and *P. ornatus* make up the remainder of the catch. In total, the estimated landings for reef-associated crustaceans from 1983-2016 was 3,012 lbs. (Figure C-2). The majority of reef associated crustacean catch was reported from the north east and south coasts of the island.

Sufficient data were not available to identify reef-associated crustaceans that may be present in CNMI or American Samoa's fisheries. Only two records of lobsters were available in the CNMI CFW creel survey data. The lobster in these data were not reported to the species level, but scientific literature suggests that *P. penicillatus* is the most abundant invertebrate landed in CNMI's fisheries (Coutures, 2003; Porter et al., 2005). Fishery data were not available to identify landed in American Samoa's reef-associated crustacean fishery. Literature states that a fishery for *P. penicillatus* exists in American Samoa, but no information was available on reef-associated crustaceans landed (McGinnis, 1972; Coutures, 2003; Porter et al., 2005).

The primary objectives of this project are to 1. Update the EFH definitions for reef-associated crustaceans in the Western Pacific U.S. and U.S. associated territories at each life stage and 2. Use the best available spatial data layers to map EFH for each species at each life stage. Due to the lack of information on commercial landings of reef-associated crustaceans in CNMI and American Samoa, EFH was only mapped for reef-associated crustaceans landed in the Main Hawaiian Islands and Guam. For a detailed literature review on life history and habitat requirements of reef-associated crustacean species see accompanying report titled: "A Review of Life History Characteristics and Essential Habitat for Reef-Associated Crustaceans in U.S. Associated Islands of the Western Pacific.

METHODS

Data: Description and Pre-processing

The first step in this analysis was to obtain available spatial data layers on depth and habitat for waters surrounding the Main Hawaiian Islands and Guam. Two data layers were obtained and used for each island to identify EFH for the life stage of each species: 1) 5 x 5 m resolution bathymetry data and 2) A 5 x 5 m data layer representing substrate hardness (backscatter data in MHI; substrate data in Guam), which can be utilized to differentiate between reef and sandy areas. Details on these spatial data layers used for each location are presented in Table C-1.

Table C-1. Spatial data layers used for mapping EFH of reef-associated crustaceans in the Main Hawaiian Islands and Guam

Archipelago	Data Layer	Description	Resolution	Reference
Main Hawaiian Islands (MHI)	Bathymetry (Figure C-10)	Synthesis grid of multi-beam bathymetry data	5 m	Smith et al. 2016
	Bathymetry (Figure C-11)	Synthesis grid of multi-beam bathymetry data	50 m	Smith et al. 2016
	Backscatter (Figure C-12)	Synthesis grid of multi-beam backscatter data	5 m	Smith et al. 2016
	Backscatter (Figure C-13)	Synthesis grid of multi-beam backscatter data	60 m	Smith et al. 2016
Guam	Bathymetry (Figure C-14)	Gridded multibeam bathymetry data is integrated with gridded lidar data collected from 2001 - 2008	5 m	Pacific Islands Benthic Habitat Mapping Center (PIBHMC) 2011
	Substrate data (Figure C-15)	Hard and soft bottom seafloor substrate map derived from an unsupervised classification of gridded backscatter and bathymetry derivatives	5 m	Pacific Islands Benthic Habitat Mapping Center (PIBHMC) 2008

All spatial data layers were pre-processed for analysis using the raster package (Hijmans, 2019) in R (RStudio, 2015). Data layers were projected to a WGS coordinate reference system using the projectRaster function and R's 'nearest neighbor' method. For the MHI, higher resolution data (50 m for bathymetry and 60 m backscatter) was used to fill areas not covered by the 5 m resolution data. The higher resolution data were resampled using the nearest neighbor technique to a 5 m resolution

Spatial Habitat Mapping

Habitat descriptions for each species and life stage presented in Table C-1 were transformed to quantitative threshold values for bathymetry and substrate hardness (Table C-2). Smith et al (2016) classified values in the backscatter layer as < 140 as soft substrate and values >= 140 as hard substrate. All lobster species are associated with reef habitat, so the suitable threshold range for the backscatter data were >=140. Kona crabs are associated with soft habitat, so the backscatter threshold for Kona crab was set to < 140. Substrate thresholds were not set for the egg/larvae life stage because they are pelagic and do not require a specific benthic habitat. For each species and life stage combination, values in the bathymetry layer that fell within the species threshold were reassigned to a 1, and values falling outside of the threshold values were assigned a zero. The same process was done for the backscatter/substrate layers. This resulted in a layer of suitable depths and substrate hardness for each species and life stage. The raster layers of suitable depth and suitable substrate hardness for each species and life stage were multiplied together and the resulting raster file had cell values of 0 or 1, with cell values of 1 representing only cells that met both the bathymetry and backscatter criteria specified in Table C-2 and the EFH for the species at that life stage.

Table C-2. Depth and habitat thresholds applied to bathymetry and backscatter layers for each species/life stage/location

Location	Species	Life Stage	Bathymetry Layer	Backscatter Layer
MHI	Kona crab (*Ranina ranina*)	Egg/larvae	0 - 150 m	NA
		Juvenile/Adult	>=2m and <= 200 m	< 140 (soft bottom)
	Spiny lobster (*P. panulirus*)	Egg/larvae	0 - 150 m	NA
		Juvenile	>=1 m and <= 30 m	>=140 (hard bottom)
		Adult	>=20 m and <= 150 m	>= 140 (hard bottom)
	Spiny lobster (*P. penicillatus*)	Egg/larvae	0 - 150 m	NA
		Juvenile/Adult	=< 16 m	>=140 (hard bottom)
	Slipper lobster (*Scyllarides* sp.)	Egg/larvae	0 - 150 m	NA
		Juvenile/adult	0-120 m	>=140 (hard bottom)
Guam	Spiny lobster (*P. penicillatus*)	Egg/larvae	0 - 150 m	NA
		Juvenile/Adult	=< 16 m	2 (hard bottom)
	Slipper lobster (*Scyllarides* sp.)	Egg/larvae	0 - 150 m	NA
		Juvenile/adult	0-120 m	>=140 (hard bottom)

RESULTS

Eggs and Larvae of Reef-Associated Crustaceans

EFH of egg and larvae Kona crab is presented in Figure C-3. Egg and larvae EFH for all reef-associated crustaceans was defined as the water column between 0 and 150 m depth from the shoreline out to 200 nm, or the top 150 m of the water column for entire Main Hawaiian Island Exclusive Economic Zone. The total estimated EFH area for egg and larvae is 895,346 km^2. Only ~0.6% (5,250 km^2) includes the whole water column (where depths are 0 to 150m, depicted in dark blue in Figure C-3). The remainder is the top 150 m of the water column.

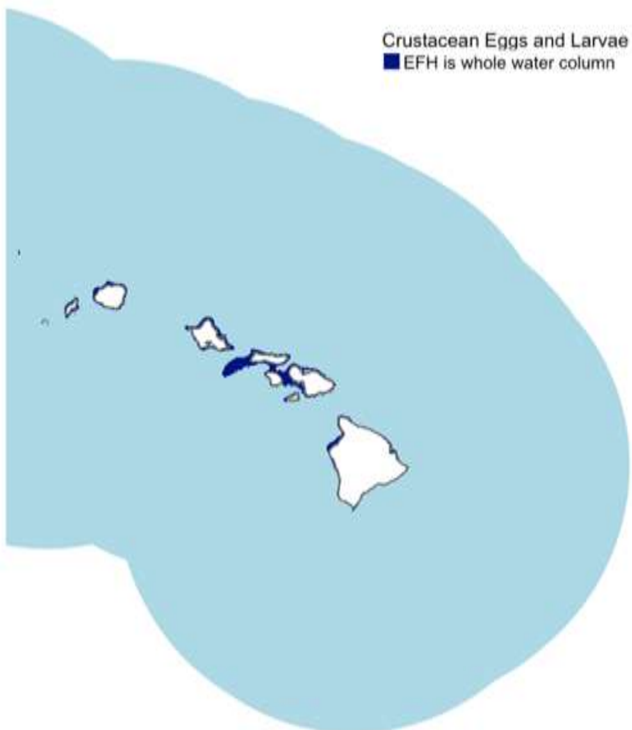

Figure C-3. EFH for eggs and larvae of reef-associated crustaceans in the MHI. Dark blue areas indicate where the entire water column is EFH (<=150 m) and light blue areas indicate where only the top 150 m of the water column is considered EFH

Kona crabs (Ranina ranina)

The estimated EFH area for juvenile and adult Kona crabs in the MHI was 3,866km^2 of benthic area (Figure C-4). EFH area for Kona crabs was defined as benthic areas in depths from 2 to 200 m with soft substrate. To help verify our results, Locations where Kona crabs were caught during a study on post release mortality of Kona crabs from Nov. 2017- April 2018 (Wiley and Pardee, 2018) were plotted over the identified EFH in Figure C-4 (navy dots). Coordinates of fishing locations all overlapped with areas we identified as EFH.

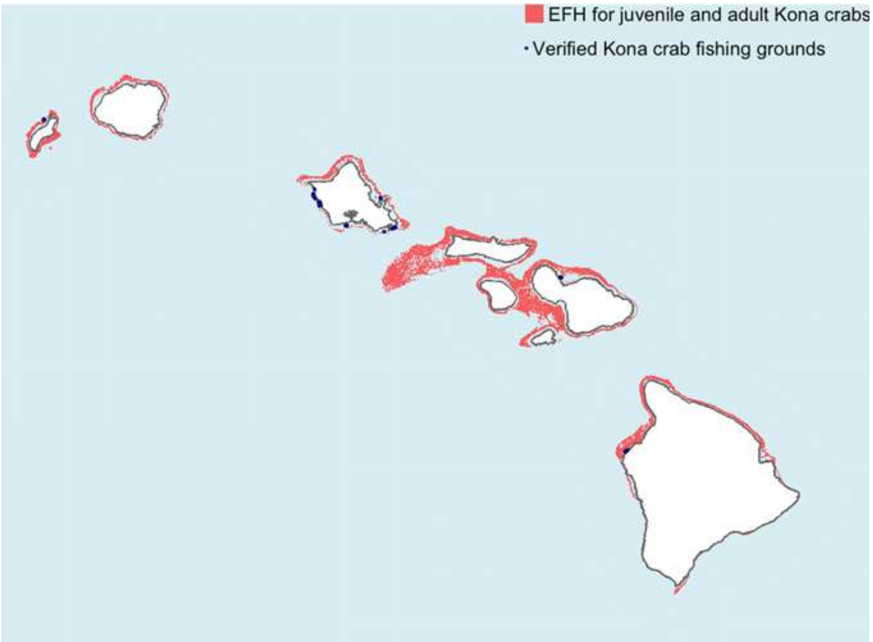

Figure C-4. EFH for juvenile and adult Kona crab (*R. ranina*) in the MHI (red) and verified Kona crab fishing locations (navy dots)

Spiny lobster (Panulirus marginatus)

The total estimated EFH for juvenile spiny lobster was 56.60 km^2 (Figure C-5a). Juvenile spiny lobster habitat was defined as benthic areas with depths from 1 to 30 m and hard substrate. The total estimated EFH area for adult spiny lobsters was 1,151.93 km^2 (Figure C-5b). Adult spiny lobster EFH was defined as benthic areas in depths from 20 to 150 m and hard substrate.

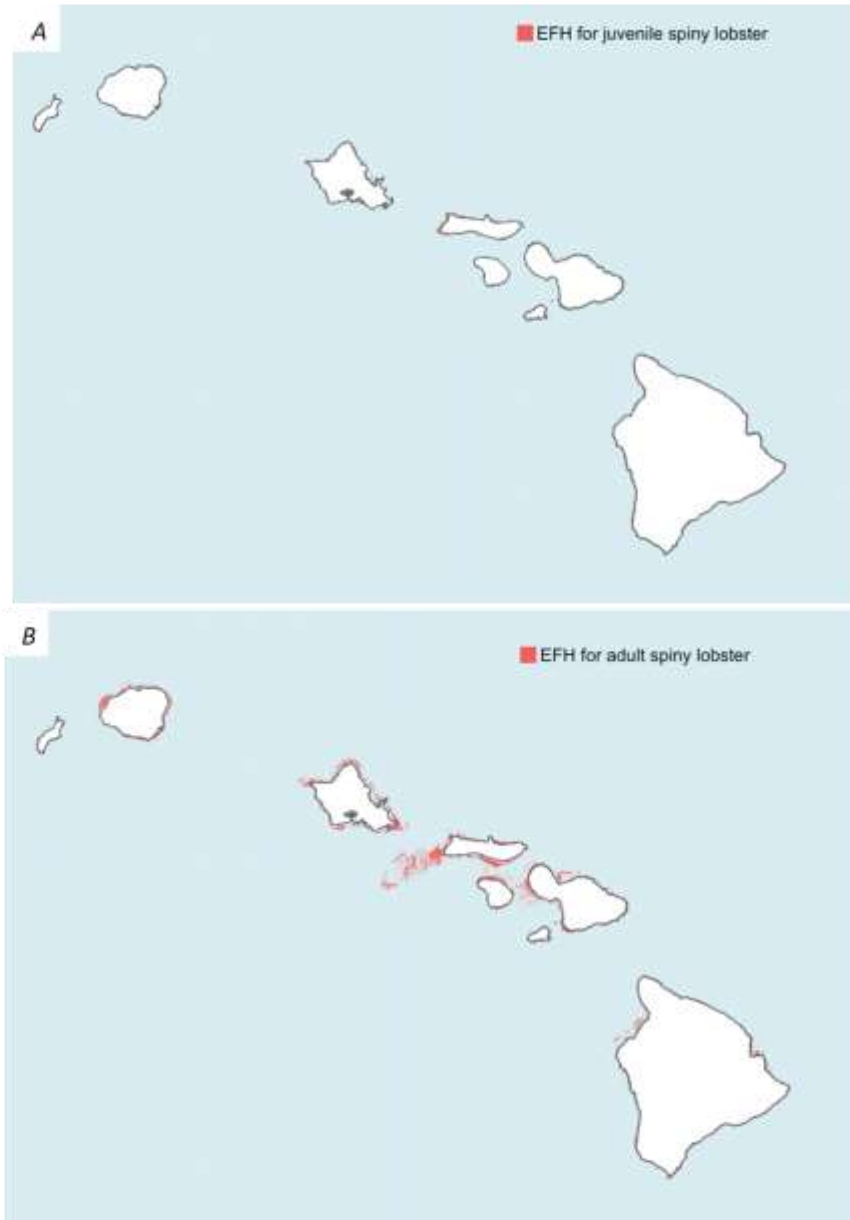

Figure C-5. EFH for juvenile (A) and adult (B) spiny lobster (*P. panulirus*) in the MHI

Pronghorn spiny lobster (Panulirus penicillatus)

The total estimated EFH area for juvenile and adult pronghorn spiny lobster was 706.95 km^2 for the Main Hawaiian Islands (Figure C-6), and 18.1 km^2 for Guam (Figure C-7). Juvenile and adult EFH for *P. penicillatus* were defined as areas in depths from 1-16 m with hard substrate.

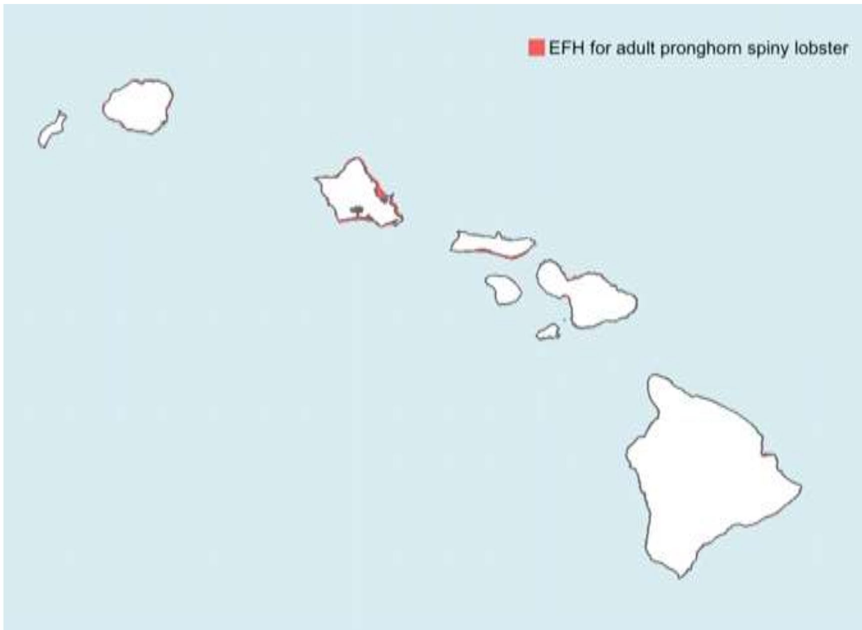

Figure C-6. EFH for juvenile and adult pronghorn spiny lobster (*P. penicillatus*) in the MHI

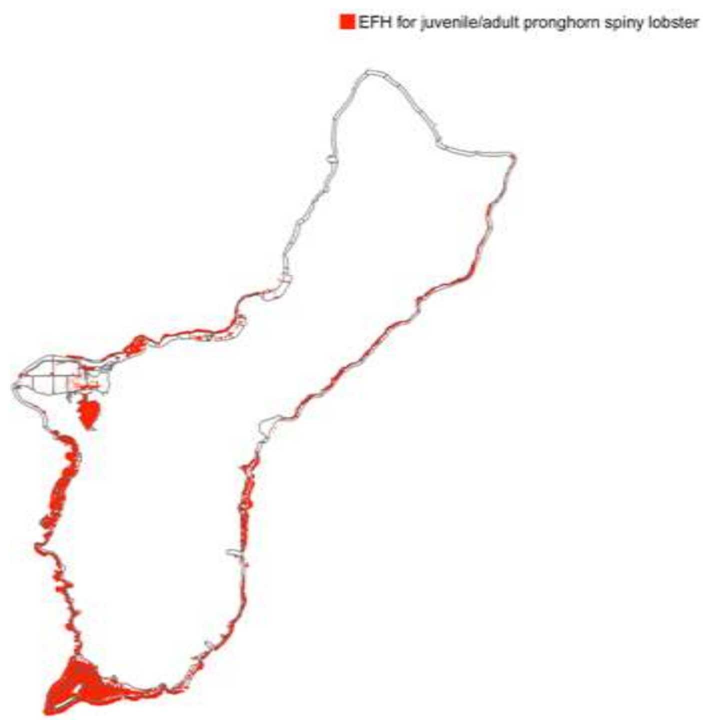

Figure C-7. EFH for juvenile and adult pronghorn spiny lobster (*P. penicillatus*) in Guam

Slipper lobster (Scyllarides squammosus)

The total estimated EFH area for juvenile and adult slipper lobster (*S. squammosus*) was 1,924 km^2 for the MHI (Figure C-8) and 79.75 km^2 for Guam (Figure C-9). Juvenile and adult EFH for *S. squammosus* were defined as areas in depths from 1-120 m with hard substrate.

Figure C-8. EFH for juvenile and adult slipper lobster (*S. squammosus*) in the MHI

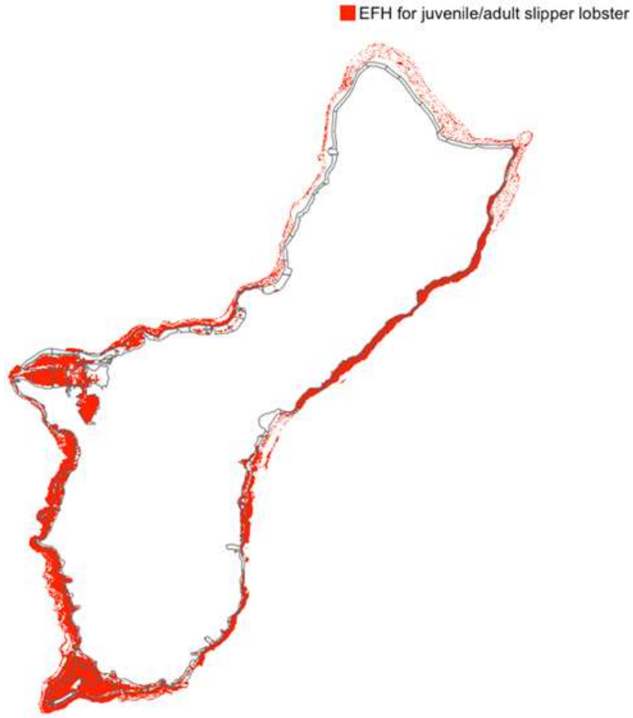

Figure C-9. EFH for juvenile and adult slipper lobster (*S. squammosus*) in Guam

APPENDIX C REFERENCES

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ADDENDUM TO APPENDIX C

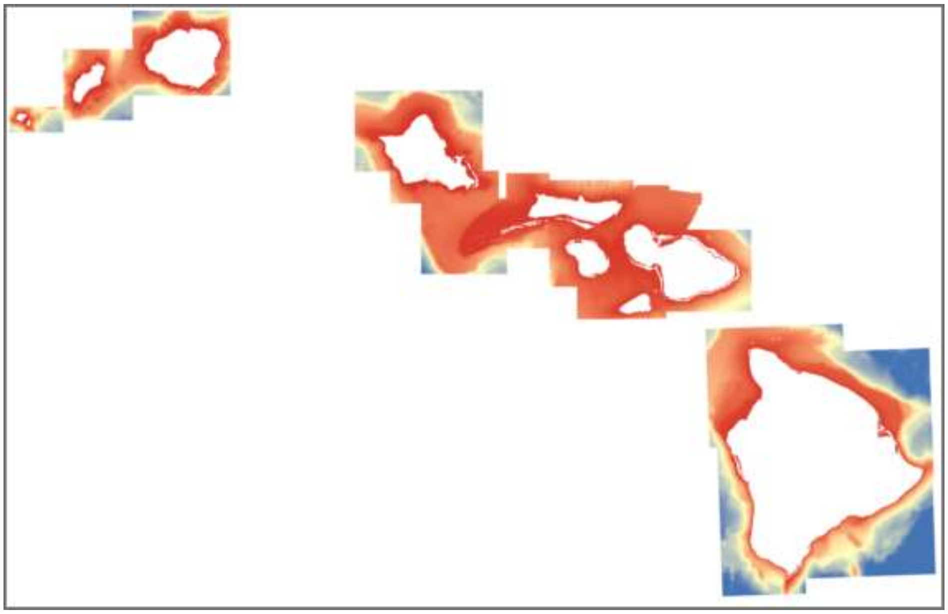

Figure C-10. Multibeam bathymetry synthesis grid (5 m) for Main Hawaiian Islands (Smith et al., 2016). Downloaded at: http://www.soest.hawaii.edu/HMRG/multibeam/bathymetry.php

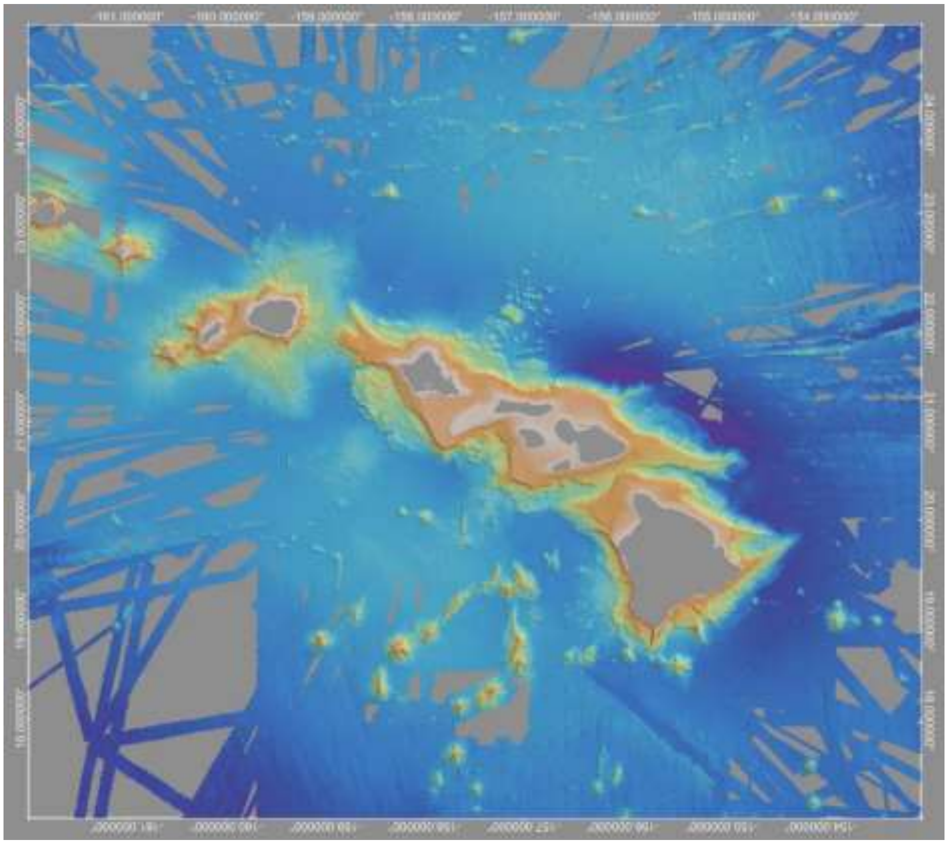

Figure C-11. Multibeam bathymetry synthesis grid (50 m) for Main Hawaiian Islands (Smith et al., 2016) Downloaded at: http://www.soest.hawaii.edu/HMRG/multibeam/bathymetry.php

Figure C-12. Backscatter synthesis grid (5 m) of substrate hardness of the Main Hawaiian Islands (Smith et al., 2016). Downloaded at: http://www.soest.hawaii.edu/HMRG/multibeam/backscatter.php

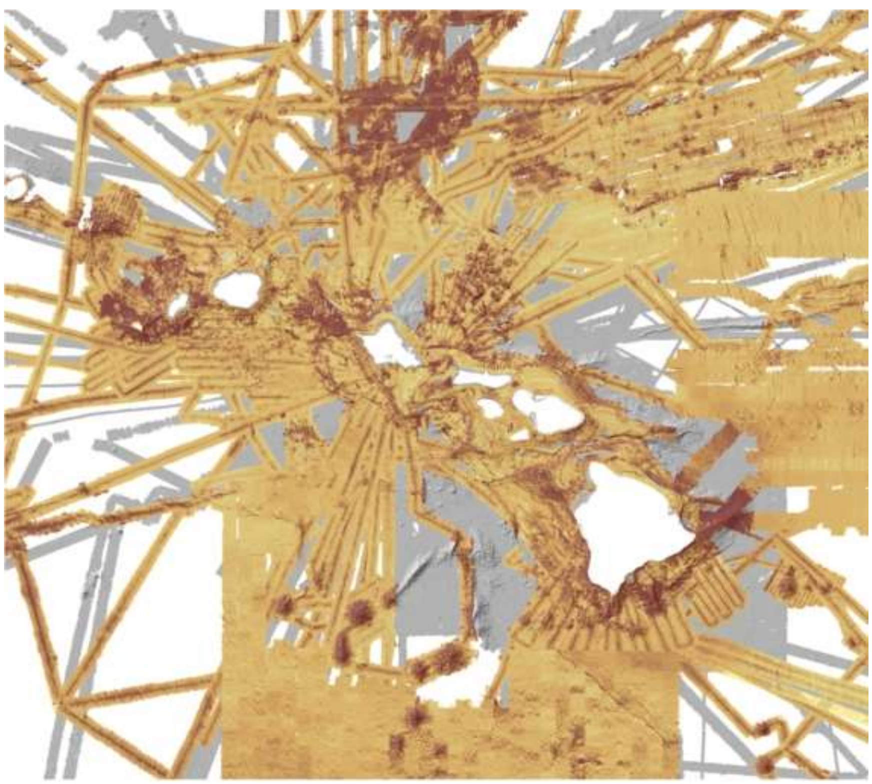

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Figure C-13. Backscatter synthesis grid (60 m) of substrate hardness of the Main Hawaiian Islands (Smith et al., 2016). Downloaded at: http://www.soest.hawaii.edu/HMRG/multibeam/backscatter.php

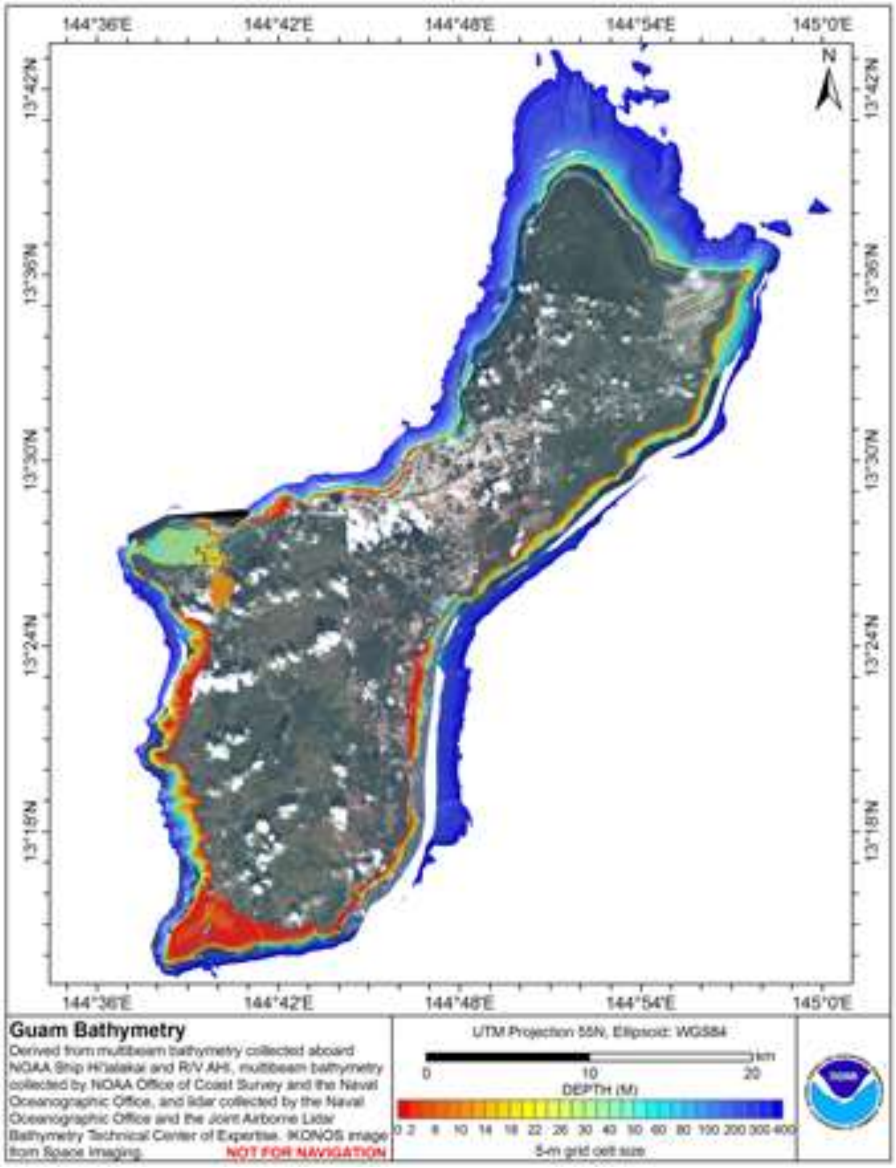

Figure C-14. Gridded (5 m) multibeam and lidar integrated bathymetry data of Guam (NOAA Pacific Islands Fisheries Science Center, and the Joint Institute for Marine and Atmospheric Research (JIMAR) University of Hawaii, 2011). Downloaded at: [<http://www.soest.hawaii.edu/pibhmc/cms/data-by-location/cnmi-guam/guam-island/bathymetry/>](http://www.soest.hawaii.edu/pibhmc/cms/data-by-location/cnmi-guam/guam-island/bathymetry/)

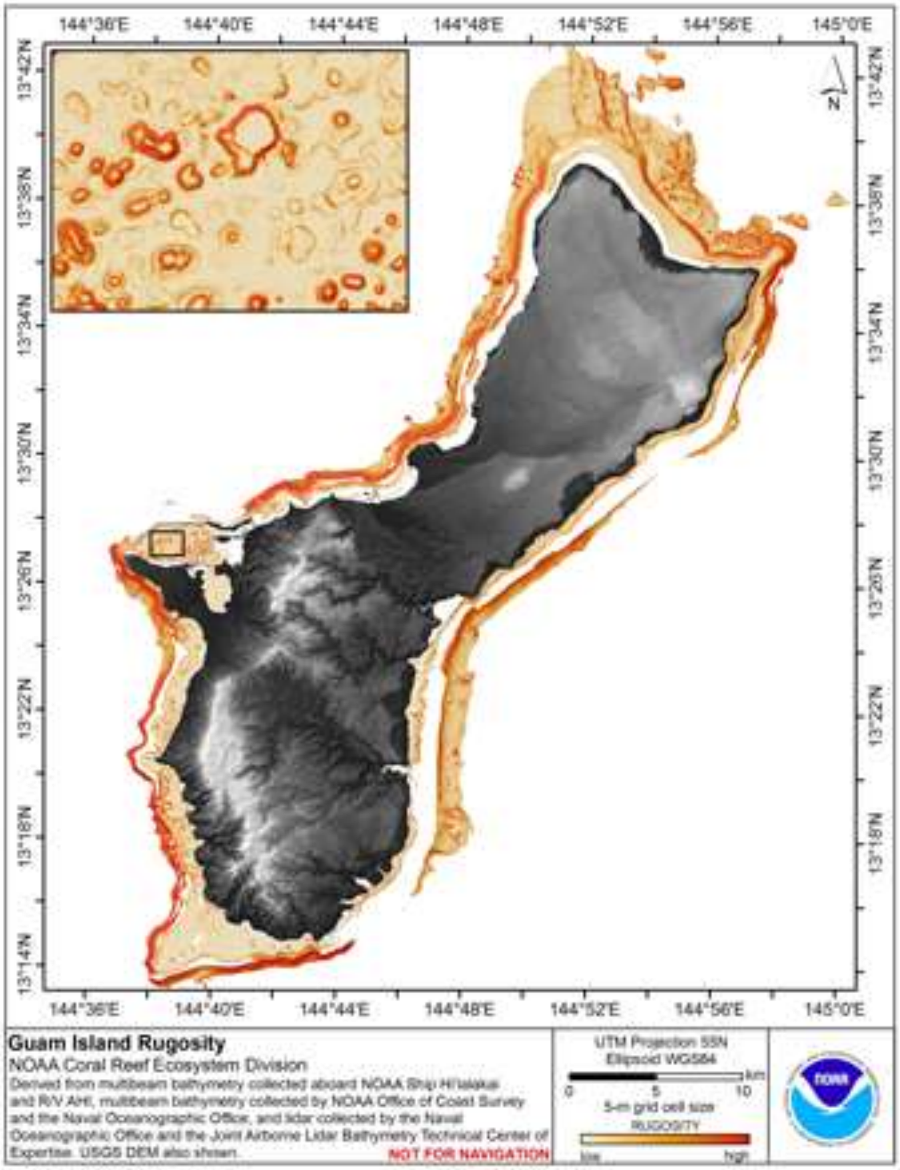

Figure C-15. Rugosity grid (5 m) derived from gridded bathymetry of the US Territory of Guam (NOAA Pacific Islands Fisheries Science Center Coral Reef Ecosystem Division Pacific Islands Benthic Habitat Mapping Center, 2011). Downloaded at: http://www.soest.hawaii.edu/pibhmc