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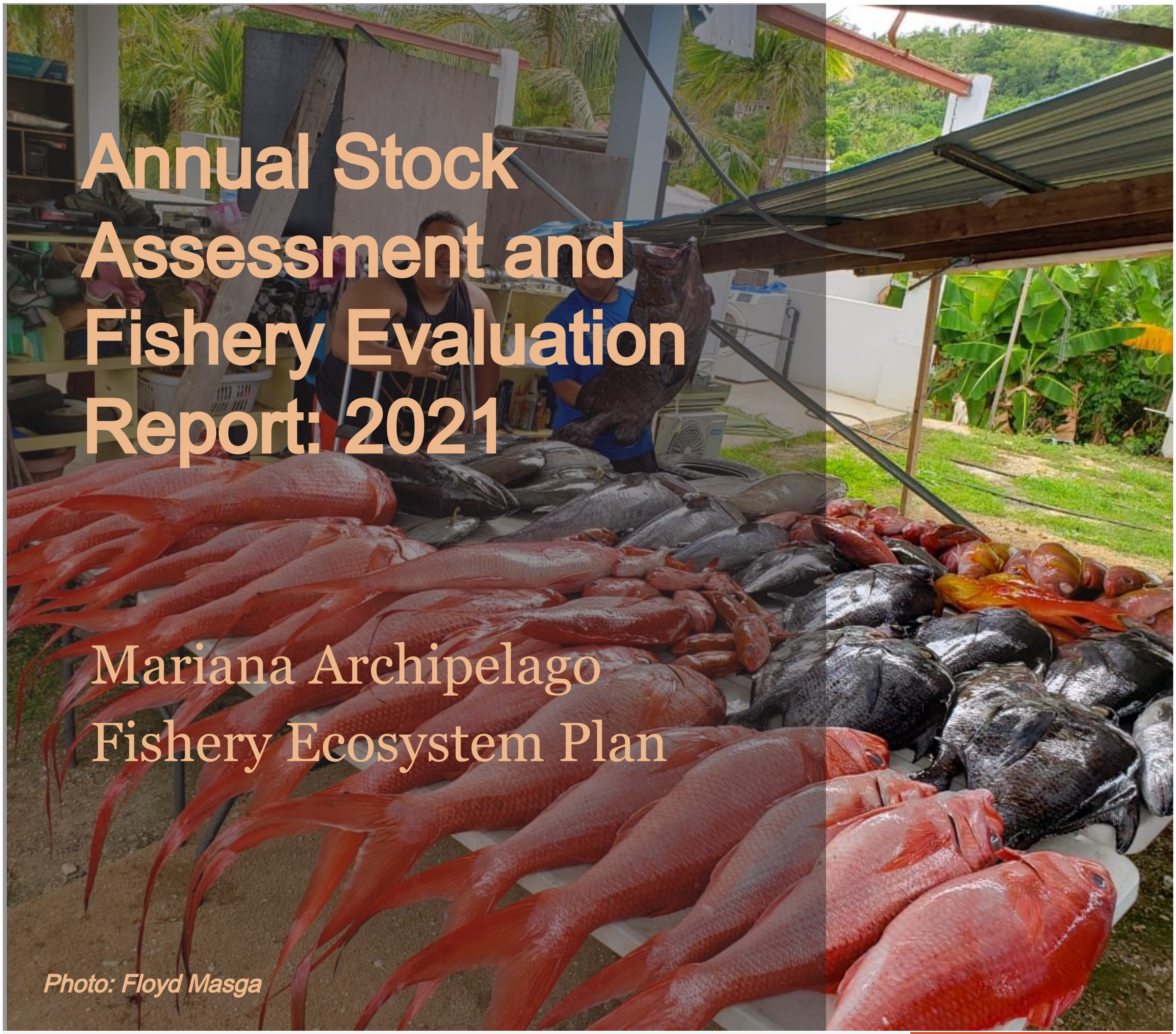

Annual Stock Assessment and Fishery Evaluation Report: 2021

Mariana Archipelago Fishery Ecosystem Plan

Photo: Floyd Masga

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The ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT for the MARIANA ARCHIPELAGO FISHERY ECOSYSTEM PLAN 2021 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), Hawaii Division of Aquatic Resources (HDAR), American Samoa Department of Marine and Wildlife Resources (DMWR), Guam Division of Aquatic and Wildlife Resources (DAWR), and Commonwealth of the Mariana Islands (CNMI) Division of Fish and Wildlife (DFW).

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.

Additionally, in 2020 and 2021, there were notable impacts to fishery operations due to the 2019 novel coronavirus (COVID-19) outbreak and subsequent recovery. Impacts associated with the pandemic, its restrictions, and recovery are described in Sections 1.1.2, 1.2.3, 2.1, 2.2, and 2.5.

Edited By: Thomas Remington, Lynker & Marlowe Sabater, Matt Seeley, and Asuka Ishizaki, WPRFMC.

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

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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), and accompanied by the monitoring of ecosystem component species (ECS). The fishery data collection system is explained, encompassing 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 implemented annual catch limits (ACLs).

In 2019, NMFS developed a stock assessment for the Guam and CNMI BMUS stock complexes (Langseth et al. 2019). While the CNMI BMUS were determined to be healthy, the Guam complex was determined to be overfished but not experiencing overfishing. In response to a notification from NMFS of the change in stock status for Guam BMUS, the Council developed a rebuilding plan for the fishery, including an ACL of 31,000 lb and in-season accountability measures, which became effective on March 21, 2022 (87 FR 9271, February 18, 2022).

In the CNMI, neither the total estimated BMUS catch for 2021 (74,855 lb) nor the recent three-year average catch of BMUS (47,151 lb) exceeded the ACL of 84,000 lb or the annual catch target (ACT) of 78,000 lb. Total estimated BMUS catch in Guam for 2021 (54,221 lb) and the recent three-year average catch of BMUS (33,352 lb) did exceed the ACL of 27,000 lb. The management provisions for Guam BMUS require that the ACL for the subsequent fishing year be downward adjusted by the amount of overage from the previous ACL based on a three-year running average.

There are no other MUS in Guam or the CNMI under the Mariana Archipelago FEP, as an amendment to the FEP in early 2019 reclassified most of the MUS as ECS except for the current BMUS (84 FR 2767, February 8, 2019). ECS do not require management under ACLs 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 the Guam Division of Aquatic and Wildlife Resources (DAWR) and the CNMI Division of Fish and Wildlife (DFW), as well as trophic and functional group biomass estimates from fishery independent surveys.

In the CNMI, total estimated BMUS catch notably increased in 2021 to 74,885 lb, a 78% increase from the 10-year (i.e., short-term) average and a 91% increase from the 20-year (i.e., long-term) average. BMUS catch from commercial purchase data in 2021 also showed increases of 132% relative to the historical trends at 36,301 lb. However, CPUE for BMUS harvested by the bottomfish handline gear were lower than the historical for both metrics presented, pounds per trip and pounds per gear hour, except when considering CPUE in pound per trip relative to the 20-year average. There were 41 lb/trip of BMUS harvested by bottomfish fishing (27 decrease from the 10-year average), and approximately 2.51 lb/gear hour of BMUS harvested by bottomfish fishing (45% and 16% decreases from the short- and long-term averages, respectively). The number of bottomfish fishing trips that harvested BMUS as tallied in the creel surveys was 67 in 2021, a notable 263% increase from the 10-year average and 176% increase from the 20-year average. The tallied number of bottomfish fishing gear hours was 995 (309% and 100% increases from the short- and long-term trends, respectively). Bottomfish fishing participants also increased in 2021, with an estimated 58 unique vessels but an average of just two fishermen per bottomfish fishing trip. There was no recorded bycatch in boat-based BMUS fisheries of the CNMI in 2021 and, considering non-BMUS, the boat-based fisheries had a bycatch rate of 0.14.

For the top ten landed ECS in CNMI in 2021, available data streams showed that the orangespine unicornfish (*Naso lituratus*; 5,743 lb) had the most catch in the creel survey data, while "miscellaneous parrotfish had the most catch in commercial data (14,046 lb). The second most caught species was the yellowstripe emperor (*Lethrinus obsoletus*; 4,719 lb) for the creel survey data and a group of assorted fish for the commercial purchase data (13,421 lb). Several other species had notable catch estimates in the creel survey data, including the blue-lined gindai (*Pristipomoides argyrogrammicus*) and blackspot emperor (*L. harak*). 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 categorized by vendors on the commercial receipts.

For prioritized ECS (i.e., those selected by DFW) in CNMI, all seven species notably exceeded this short- and long-term averages, with *N. lituratus* and *L. harak* having the highest catch levels. 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 two species, *Mulloidichthys flavolineatus* and *L. harak*. For the species for which data were available, 2021 catches exceeded the historical averages for all four species.

For the BMUS fishery in Guam in 2021, total estimated BMUS catch was 54,221 lb, a 117% increase relative to the recent 10-year average and a 96% 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 dealers and/or vendors reporting data). CPUE for BMUS harvested by the bottomfish handline gear was presenting using two metrics in the 2021 report, pounds per trip and pounds per gear hour. There was 30 pounds of BMUS caught per trip in Guam in 2021, a 76% increase from the recent 10-year average and a 58% increase from the 20-year average. CPUE in pounds per gear hour was 1.68 for BMUS harvested with the bottomfish handline gear, which coincided with increases relative to the recent 10- and 20-year averages (53% and 32%, respectively). The tallied number of fishing trips that harvested BMUS increased by 70% compared with the 10-year average to 92 trips, which also represented a 53% decrease relative to the 20-year average. The number of bottomfish fishing gear hours on trips that harvested BMUS was 1,652, a 62% increase from the 10-year average and a 65% increase to the 20-year average. The tallied number of unique vessels harvested BMUS in Guam was 56, an increase to both the

10- and 20-year averages by 40% and 27%, respectively. The average number of fishers per trip was 3, which was consistent with historical averages. There was no released BMUS in 2010, and a relatively low amount of non-BMUS released. The overall bycatch rate for Guam boat-based fisheries was 0.24% in 2021, representing a decrease from historical averages.

For the top ten landed ECS in Guam in 2021, available data showed that the bluespine unicornfish (*Naso unicornis*; 10,788 lb) had the most catch from creel survey data while “reef fish” had the most catch in the commercial purchase data (914 lb). The second most caught ECS in the creel survey data was assorted reef fish (9,591 lb) followed by miscellaneous shallow bottomfish (6,866). Several other species had notable catch estimates in the creel survey data, including *Trochus niloticus* and *Lethrinus xanthochilus*. Most of the remainder of the top ten ECS from commercial purchase data were family groups (e.g., Serranidae and Lethrinidae) due to how the species are categorized by vendors, with the exception of atulai (bigeye scad, *Selar crumenophthalmus*) and amberjack (*Seriola dumerili*).

For prioritized ECS (i.e., those selected by DAWR) in Guam, 2021 creel survey catch estimates for *Naso unicornis* and *Siganus spinus* were much higher than both of their associated 10- and 20-year averages. All other prioritized ECS had available data that indicated slight declines in catch relative to the historical trends. Commercial purchase invoices were only able to capture *S. spinus* from the DAWR-prioritized ECS, which had non-disclosed catch information for 2021 due to data confidentiality rules.

Federal permit data show that there were 18 bottomfish permit holders in the CNMI in 2021, but there were no active permits for lobster or shrimp. There were no active federal permits for Guam bottomfish, lobster, or shrimp fisheries. No catch data were reported in federal logbooks by permit holders for these fisheries in 2021.

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. A special section was added to the report in 2020 describing the impacts of COVID-19 on archipelagic fisheries and fishing communities of Guam and the CNMI, and this section was updated with information on impacts and recovery for the 2021 report.

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 (PRIA), 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 from 2010 to 2020. However, no surveys were conducted in 2020 or 2021 due to restrictions associated with COVID-19, so no new data were added to the summaries since the 2019 report.

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. This year, the reference for *Pristipomoides zontus* age and growth was updated for Guam and age and growth data for *Variola louti* were added for Guam.

The socioeconomics section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of the 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 36,303 pounds sold for $194,958. Fish price notably increased from 2020 to 2021 to $5.37 per pound. The average cost of a bottomfish trip in CNMI in 2021 was higher than 2020 at $66.20 due to increased costs for fuel and ice. The top 10 ECS in CNMI had 66,754 pounds sold for a revenue of $223,949. The majority of socioeconomic information for Guam’s bottomfish fishery were unavailable due to data confidentiality in 2021. The cost of fishing in 2021 was the a decadal high at $91.60 per trip, mostly due to the increased cost for fuel, ice, and lost gear.

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. On June 6, 2019 (extended on August 11, 2020, December 15, 2020, and February 9, 2022), NMFS determined that the conduct of these bottomfish fisheries during the period of consultation will not violate Endangered Species Act (ESA) Section 7(a)(2) and 7(d). In 2021, there were updates to the status of ESA listing processes for several species.

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 trend of atmospheric concentration of carbon dioxide (CO2) is increasing exponentially with a time series maximum at 416 ppm in 2021. Since 1989, the oceanic pH at Station ALOHA in Hawaii has shown a significant linear decrease of -0.042 pH units, or roughly a 10.2% increase in acidity ([H+]) and was 8.07 in 2020. The Oceanic Niño Index, which is a measure of the El Niño – Southern Oscillation (ENSO) phase, indicated La Niña conditions for most of 2021, with two consecutive neutral seasons punctuating the year mid-year. The Pacific Decadal Oscillation (PDO) was negative in 2021. The Accumulated Cyclone Energy (ACE) Index (x 104 kt2) was below average in Eastern and Central North Pacific and average in the Western North and South Pacific. Annual mean sea surface temperature (SST) around the Mariana Archipelago was 29.0 ºC in 2020, and over the period of record, annual SST has increased at a rate of 0.0247 ºC/year. The annual anomaly was 0.62 ºC hotter than average, with intensification in the northern islands. The Mariana Archipelago experienced a minor coral heat stress event in the second half of 2021 that reached its maximum in late June through August. Annual mean chlorophyll-*a* was 0.053 mg/m^3 in 2021, and the annual anomaly was 0.0016 mg/m^3 lower than average. Rainfall in the Mariana Archipelago was above average for most of 2021 and notably in the first half. The local trend in sea level rise is 4.17 millimeters/year based on monthly mean sea level data from 1993 to 2021, which is equivalent to a change of 1.37 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*). In the 2019 annual report, a review of EFH for reef-associated crustaceans in the MHI and Guam was included. The 2021 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 previous annual SAFE reports, data on benthic cover were 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 2021.

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. The US Army Corps of Engineers published a final rule on Oct. 8, 2021, amending regulations to establish a danger zone in the Pacific Ocean adjacent to the Mason Live-Fire Training Range Complex at Camp Blaz.

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. Going forward with the data integration analyses and presentation of results for Chapter 3 of the annual SAFE reports, the Council's Archipelagic Fishery Ecosystem Plan Team (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. The chapter will be updated in the future as resources allow. For the 2020 report, several recent relevant abstracts from primary publications related to data integration were added to the Data Integration chapter.

Plan Team members agreed to carry out the following recommendations, some of which are relevant to the Mariana Archipelago annual SAFE report:

Regarding American Samoa and Guam BMUS catch, the Archipelagic Plan Team:

1. Recommended the Council request PIFSC, DAWR, DMWR, and the Guam and American Samoa Advisory Panels review the reported increase and decrease, respectively, of total estimated BMUS landings in 2021 to determine whether the values are statistical and/or operational anomalies associated with data collection or if the values are indicative of the actual 2021 BMUS fishery performance.

Regarding the bycatch reporting improvements in the annual SAFE reports, the Archipelagic Plan Team:

2. Endorsed the current bycatch tables, noting that fisher-reported data may be biased downward, and recommends adding a separate table to describe the type of bycatch (e.g., a top-10 ranked species list and/or top 90 percentile) that comprises the number released for non-target species in the archipelagic bycatch tables.
3. Formed a working group comprised of Keith Bigelow, Brad Gough, Matt Seeley, Brian Ishida, and Thomas Remington to address the development of the top-10 ranked species and/or top 90 percentile list approach and the issue of reporting non-target species bycatch for MUS fisheries that are targeted by multiple gear types (e.g., uku in the main Hawaiian Islands).

Regarding the territorial non-commercial fisheries module to be included in the annual SAFE reports, the Archipelagic Plan Team:

4. Recommended the following members: Marc Nadon, Danika Kleiber, Ashley Tomita, and Keith Bigelow, finalize the configuration and content for the territorial non-commercial modules, based on the commercial catch summarization procedure presented to the APT, at the upcoming intersessional meeting for incorporation in the 2022 annual SAFE reports.
5. Recommended the following members: Bryan Ishida and Paul Murakawa, and Thomas Remington work with Hongguang Ma and Thomas Ogawa in the development of the Hawaii non-commercial module utilizing a similar approach as the NOAA Saltwater Recreational Fisheries Snapshot for Western Pacific Non-Commercial Fisheries.

Regarding the estimation of total catch, the Archipelagic Plan Team:

6. Recommended the Council request PIFSC to continue the development of scripts that would enable consistency between the catch time series used in stock assessment and the annual SAFE reports to improve the monitoring of catch relative to implemented Annual Catch Limits.

Regarding the management of ecosystem component species, the Archipelagic Plan Team:

7. Recommended the PIFSC-ESD coordinate with the Council in the planning of the EBFM Workshop, incorporating the management of ECS as a thematic area. The APT notes that providing separate data streams together to inform the status of ECS in the context of EBFM would be useful to support the territorial management process. Further, the APT recommends PIFSC-ESD invite staff from Office of Sustainable Fisheries to provide guidance on the NS1 provision for designating and managing ECS as part of the workshop in combination with provisions of NS1 criteria 10.

Regarding the aquaculture management framework alternatives, the Archipelagic Plan Team:

8. Endorsed Alternative 3, which includes an expanded scope for the management framework, but noted concerns regarding the proposed 20-year duration for issued permits, non-native species, and ensuring there are appropriate monitoring plans implemented. However, the APT notes that at least a portion of these appropriate monitoring plans will be implicit through the permitting process.

Regarding the alternatives for the NWHI fishing regulations, the Archipelagic Plan Team:

9. Deferred the development of recommendations until the Office of National Marine Sanctuaries provides explicit boundaries for the proposed sanctuary relative to the Papahānaumokuākea Marine National Monument. When the sanctuary boundaries are further defined, the Archipelagic Plan Team will revisit this topic at a future meeting.

Regarding the CNMI BMUS hierarchical cluster analysis, the Archipelagic Plan Team:

10. Recommended the Council endorse the proposed BMUS list for CNMI and include this BMUS list for consideration by the previously established Archipelagic Plan Team MSA subgroup in the development of their MSA requirement sections for the FEP amendment associated with the BMUS revisions.

Regarding the main Hawaiian Island Uku Essential Fish Habitat modeling approaches, the Archipelagic Plan Team:

11. Recommended the Council endorse both modeling approaches to formulate the habitat module of the annual SAFE report noting concerns regarding the limitations of the data inputs. The modules should include qualitative information to supplement the model results. PIFSC and Council should work towards improving the data inputs (i.e., seasonal pattern to distribution and spawning aggregation) and include commercial fishery data and size frequency data in future EFH modeling work.

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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
FRMD	Fisheries Research and Monitoring Division (PIFSC)
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
MCP	Marine Conservation Plan
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

Acronym	Meaning
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA)
Monument	Marianas Trench Marine National Monument (also MTMNM)
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; or National Marine Sanctuary
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
ONMS	Office of National Marine Sanctuaries (NOAA)
OPI	OLR Precipitation Index (NOAA)
OLR	Outgoing Longwave Radiation
OY	Optimum Yield
PCOR 1	Pandemic Condition of Readiness 1

Acronym	Meaning
PCMUS	Precious Coral Management Unit Species
PDO	Pacific Decadal Oscillation
Pelagic FEP	Fishery Ecosystem Plan for the Pacific Pelagic Fisheries
PIAFA	Pacific Insular Area Fishery Agreement
PIFSC	Pacific Island Fisheries Science Center (NMFS)
PIRCA	Pacific Islands Regional Climate Assessment
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
Secretary	Secretary of Commerce
SEEM	Social, Economic, Ecological, Management (Uncertainty)
SEIS	Supplemental Environmental Impact Statement
SFA	Sustainable Fisheries Act or Saipan's Fishermen Association
SFD	Sustainable Fisheries Division (PIRO)
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
SUA	Special Use Airspace
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 bigeye 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 bottomfish fishing 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') bottomfish fishing 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 bottomfish fishing 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 bottomfish fishing vessels are owned by vendors; there are, however, a few subsistence bottomfish fishermen 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 bottomfish fishing requires more efficient fishing gears, such as hydraulic reels. Bottomfish fishing 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 deepwater fishermen likely reflects the greater skill and investment required to participate in the deepwater bottomfish fishery. In addition, deepwater bottomfish fishing 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 5 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 published in the *Federal Register* in early 2019 (84 FR 2767, February 8, 2019). 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 (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 1.1.5.3 and 2.3).

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. To further improve data collection efforts, the CNMI instituted mandatory data submission for commercial fisheries. The CNMI is working on improving commercial licensing and data submission processes to meet recent data collection mandates. The CNMI is working with NOAA to further improve this mandate through exploring alternative fishery data collection programs.

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 nonstandard 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 were conducted on Saipan's Eastern beaches such as Laolao Bay, Obyan Beach, and Ladder Beach. However, effort to collect data from these areas have been very sporadic. Other accessible areas are not covered at this time due to existing limited resource availability and logistical constraints. With the assistance of the Fisheries Research and Monitoring Division (FRMD) 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 an eleven year hiatus. 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 counts and interviews. The participation counts involve counting the number of people fishing on randomly selected days and their method of fishing along the shoreline. The interviews involve some dialog 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.

In March 2020, the CNMI issued community restrictions to address the COVID-19 pandemic concerns. A number of measures, such as curfew restrictions, gathering restrictions, sanitation restrictions, office closures, travel restrictions, as well as fishing restrictions, were implemented during this time. These restrictions were reduced as the COVID -19 situation improved in the CNMI. This also significantly affected commerce within the CNMI as tourism is the main source of income. Fishing activities and businesses gradually opened back up as the situation improved. Participation increased as people entered the fishery due to being displaced by the pandemic and turned to fishing for alternative income. The DFW fishery data collection program activities were also limited by the COVID -19 restrictions. Sample days and hours were limited during the first few months of the restrictions. As restrictions were lifted, sampling effort for all fishery data collection programs increased and coverage improved.

There were 69 boat-based surveys conducted between January 1 and December 31, 2021. A total of 205 regular interviews and 51 opportunistic interviews were completed with an expanded catch of 73,017 lb. 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 87 unique bottomfishing vessels were recorded as “out fishing”.

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 NMFS, 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.

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
2002	75	200	25

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
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
2020	58	126	52
2021	69	205	51
10-yr avg.	**62**	**140**	**12**
10-yr SD	**11**	**39**	**20**
20-yr avg.	**66**	**203**	**23**
20-yr SD	**11**	**88**	**26**

1.1.3.2 Commercial Receipt Book Statistics

Calculations:

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

Year	# Vendors	# Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
1986	n.d.	n.d.	n.d.	n.d.
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	143
2012	20	1,630	12	192
2013	17	2,277	13	223
2014	17	2,034	12	152
2015	15	1,045	4	19
2016	16	2,407	9	175
2017	32	2,831	14	134
2018	39	4,581	16	98
2019	36	3,963	11	109
2020	33	3,319	9	288
2021	40	5,716	18	426
10-yr avg.	**27**	**2,980**	**12**	**182**
10-yr SD	**10**	**1,358**	**4**	**107**

Year	# Vendors	# Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
20-yr avg.	**22**	**3,257**	**11**	**179**
20-yr SD	**11**	**1,358**	**4**	**85**

n.d. = Confidential (less than three dealers and/or 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 2021 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 (lb)**		
All gears (BMUS only)	All BMUS from creel survey data	**74,885[▲78%]**	**74,885[▲91%]**
	All BMUS from commercial purchase data	**36,301[▲132%]**	**36,301[▲132%]**
	Catch-per-unit-effort (from boat-based creel surveys)		
Bottomfish fishing (BMUS only)	Bottomfish fishing lb/trip	**41[▼27%]**	**41[▲5%]**
	Bottomfish fishing lb/gr-h.	**2.51[▼45%]**	**2.51 [▼16%]**
	Fishing effort (from boat-based creel surveys)		
Bottomfish fishing (BMUS only)	Tallied bottomfish trips	**67[▲281%]**	**67[▲117%]**
	Tallied bottomfish gear hours	**995[▲309%]**	**995[▲100%]**
	Fishing participants (from boat-based creel surveys)		

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
Bottomfish fishing (BMUS only)	Tallied number of bottomfish fishing vessels	**58[▲263%]**	**58[▲176%]**
	Estimated average number of fishermen per bottomfish fishing trip	**2[no change]**	**2[▼60%]**
	Bycatch		
BMUS	# fish caught	**915[▲164%]**	**915[▲57%]**
	# fish discarded/released	**0[no change]**	**0[▼100%]**
	% bycatch	**0[no change]**	**0[▼100%]**

Table 4. Annual indicators for CNMI ECS fisheries describing performance and comparing 2021 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 (lb)**		
Prioritized ECS	*Acanthurus lineatus* from creel survey data	**3,300[▲794%]**	**3,300[▲1,109%]**
	Acanthurus lineatus from commercial data	**33[▲1,000%]**	**33[▼13%]**
	Naso lituratus from creel survey data	**5,743[▲556%]**	**5,743[▲491%]**
	Naso lituratus from commercial data	**2,840[▲249%]**	**2,840[▲404%]**
	Naso unicornis from creel survey data	**1,091[▲227%]**	**1,091[▲100%]**
	Naso unicornis from commercial data	**2,751[▲900%]**	**2,751[▲996%]**
	Scarus ghobban from creel survey data	**18[▲157%]**	**18[▲500%]**
	Lethrinus harak from creel survey data	**3,310[▲41%]**	**3,310[▲32%]**
	Lethrinus harak from commercial data	**NA[no change]**	**NA[no change]**
	Siganus argenteus from creel survey data	**276[▲80%]**	**276[▲5%]**
	Siganus argenteus from commercial data	**4,229[▲123%]**	**4,229[▲33%]**
	Mulloidichthys flavolineatus from creel survey data	**52[▲596%]**	**52[▲1,209%]**

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
	Mulloidichthys flavolineatus from commercial data	NA[▼100%]	NA[▼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. While the reporting of commercial landings for Guam boat-based archipelagic fisheries is often constrained by rules associated with data confidentiality (i.e., commercial data must be sourced by at least three vendors and/or dealers to be reported), the relative lack of vendor reports from Guam is likely related to non-participation by vendors rather than being reflective of a paucity of vendors.

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 (creel surveys and the commercial purchase reports).

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

Year	Boat-Based Creel Survey Estimates	Shore-Based Creel Survey Estimates	Total Creel Survey Estimates	Commercial Landings
1983	-	-	-	3,407
1984	-	-	-	3,463
1985	-	-	-	n.d.
1986	-	-	-	n.d.
1987	-	-	-	1,889
1988	-	-	-	2,413
1989	-	-	-	4,021
1990	-	-	-	1,273
1991	-	-	-	781
1992	-	-	-	158
1993	-	-	-	1,722
1994	-	-	-	5,459

Year	Boat-Based Creel Survey Estimates	Shore-Based Creel Survey Estimates	Total Creel Survey Estimates	Commercial Landings
1995	-	-	-	17,564
1996	-	-	-	32,294
1997	-	-	-	21,607
1998	-	-	-	25,529
1999	-	-	-	33,622
2000	67,252	-	67,252	14,751
2001	24,637	-	24,637	24,817
2002	24,603	-	24,603	24,296
2003	12,726	-	12,726	17,144
2004	30,407	-	30,407	11,292
2005	34,311	168	34,479	15,025
2006	35,279	5	35,284	11,837
2007	54,257	648	54,905	14,805
2008	21,118	69	21,187	15,098
2009	65,269	21	65,290	18,313
2010	56,007	2	56,009	12,971
2011	25,799	22	25,821	16,115
2012	137,495	84	137,579	10,591
2013	20,390	0	20,390	16,500
2014	7,740	166	7,906	16,334
2015	10,386	215	10,601	4,121
2016	54,335	36	54,371	17,717
2017	48,007	59	48,066	11,923
2018	650	2	652	7,258
2019	21,012	2	21,014	15,697
2020	45,547	36	45,583	20,071
2021	73,017	1,838	74,855	36,301
10-yr avg.	**41,858**	**271**	**42,129**	**15,651**
10-yr SD	**38,823**	**558**	**39,381**	**8,332**
20-yr avg.	**38,918**	**211**	**39,129**	**15,670**
20-yr SD	**29,889**	**448**	**30,337**	**6,406**

"-" = No data collected; "n.d." = Confidential (less than three dealers and/or vendors)

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 (lb) for all species and BMUS only using CNMI expanded boat-based creel survey data for bottomfish fishing gears

Year	Bottomfish		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
2020	73,773	45,358	6,892	189
2021	89,032	69,188	27,692	35
10-yr avg.	**52,511**	**40,926**	**6,720**	**22**
10-yr SD	**43,341**	**38,814**	**7,721**	**57**
20-yr avg.	**55,249**	**38,298**	**8,228**	**119**
20-yr SD	**35,075**	**29,890**	**6,393**	**290**

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 and pelagic MUS species.

Table 7a. Top ten landed species (lb) in CNMI ECS fisheries from expanded boat-based creel survey data in 2021

Common Name	Scientific Name	Catch
Orangespine unicornfish	*Naso lituratus*	5,743
Yellowstripe emperor	*Lethrinus obsoletus*	4,719
Blue lined gindai	*Pristipomoides argyrogrammicus*	3,810
Blackspot emperor	*Lethrinus harak*	3,310
Bluebanded surgeonfish	*Acanthurus lineatus*	3,300
Pacific longnose parrot	*Hipposcarus longiceps*	3,207
Rudderfish (misc.)	*Kyphosus* spp.	2,395
Yellowfin surgeonfish	*Acanthurus xanthopterus*	2,157
Parrotfish (misc.)	Scaridae (family)	1,635
Bluespine unicornfish	*Naso unicornis*	1,091

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

Table 7b. Top ten landed species (lb) in CNMI ECS fisheries from commercial landings data in 2021

Common Name	Scientific Name	Catch
Parrotfish (misc.)	Scaridae (family)	14,046
Assorted	Assorted	13,421
Surgeonfish (misc.)	Acanthuridae (family)	10,007
Orangespine unicornfish	*Naso lituratus*	5,716
Emperor (misc.)	Lethrinidae (family)	4,985
Goatfish	Mullidae (family)	4,606
Rabbitfish	*Siganus argenteus*	4,229
Bigeye scad	*Selar crumenophthalmus*	3,456
Jacks (misc.)	Carangidae (family)	3,383
Rudderfish	*Kyphosus* spp.	2,905

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

Table 8a. Catch (lb) 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

Year	*Acanthurus lineatus*	*Naso lituratus*	*Naso unicornis*	*Scarus ghobban*	*Lethrinus harak*	*Siganus argenteus*	*Mulloidichthys flavolineatus*
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
2020	113	1,382	2,186	0	5,387	0	22
2021	3,300	5,743	1,091	18	3,310	276	144
10-year avg.	**369**	**876**	**334**	**7**	**2,340**	**153**	**21**
10-year SD	**1,031**	**1,756**	**735**	**16**	**2,262**	**263**	**46**
20-year avg.	**273**	**971**	**546**	**3**	**2,507**	**263**	**11**
20-year SD	**731**	**1,416**	**688**	**11**	**2,736**	**398**	**33**

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 (lb) from commercial purchase data for prioritized species in CNMI ECS fisheries

Year	*Acanthurus lineatus*	*Naso lituratus*	*Naso unicornis*	*Lethrinus harak*	*Siganus argenteus*	*Mulloidichthys flavolineatus*
1983	0	0	0	0	7,644	0
1984	0	0	0	0	9,792	0
1985	0	0	0	0	3,826	0
1986	0	0	0	0	7,271	0
1987	0	0	0	0	4,061	0
1988	0	0	0	0	6,653	0
1989	0	0	0	0	8,434	0
1990	0	0	0	0	5,678	0
1991	0	0	0	0	3,858	0
1992	0	0	0	0	3,151	0
1993	0	0	0	0	1,603	0

Year	*Acanthurus lineatus*	*Naso lituratus*	*Naso unicornis*	*Lethrinus harak*	*Siganus argenteus*	*Mulloidichthys flavolineatus*
1994	0	0	0	0	2,181	0
1995	0	0	0	0	904	0
1996	0	1,434	0	0	1,338	0
1997	0	3,173	0	0	1,093	0
1998	0	106	0	0	5,956	0
1999	0	1,756	0	0	6,442	0
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
2020	0	2,840	0	0	384	0
2021	33	5,716	2,751	0	4,229	0
10-yr avg.	**3**	**1,639**	**275**	**0**	**1,899**	**2**
10-yr SD	**10**	**1,632**	**870**	**0**	**1,215**	**6**
20-yr avg.	**38**	**1,135**	**251**	**0**	**3,191**	**1**
20-yr SD	**160**	**1,371**	**717**	**0**	**2,539**	**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 bottomfish fishing (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 - lb/trip: All catch and trips are tallied from landings by gear level, including non-BMUS species.

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

BMUS - lb/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 (lb/trip and lb/gear hour) for bottomfish fishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfish				Spearfishing (Snorkel)			
	All		BMUS		All		BMUS	
	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr
2000	50	4.44	55	4.76	35	2.43	64	5.33
2001	17	1.64	21	1.89	19	1.48	2	0.11
2002	28	2.22	32	2.35	20	1.55	3	0.38
2003	21	1.76	21	1.64	29	2.07	4	0.29
2004	25	2.03	20	1.55	15	0.91	0	0
2005	26	2.01	26	1.72	21	1.82	1	0.15
2006	18	1.43	17	1.22	12	1.25	1	0.10
2007	28	2.65	28	2.42	15	1.05	2	0.12
2008	16	1.03	13	0.88	21	1.19	6	0.23
2009	19	0.77	34	1.47	21	1.39	3	0.08
2010	12	0.40	11	0.39	15	1.32	0	0
2011	11	0.34	16	0.54	38	2.76	0	0
2012	108	8.83	156	9.85	13	1.03	0	0
2013	46	4.30	44	3.59	20	1.33	0	0
2014	18	1.87	32	3.63	33	1.89	0	0
2015	34	2.77	43	3.00	19	3.26	0	0
2016	69	5.28	78	5.68	0	0	0	0
2017	81	8.16	115	12.97	0	0	0	0
2018	5	0.41	1	0.14	9	0.88	0	0
2019	26	2.19	23	2.42	10	0.83	0	0
2020	28	2.03	29	1.89	14	0.84	2	0.09
2021	39	2.73	41	2.51	37	1.89	2	0.05
10-yr avg.	**45**	**3.86**	**56**	**4.57**	**19**	**1.49**	**2**	**0.07**
10-yr SD	**30**	**2.79**	**45**	**3.94**	**10**	**0.84**	**0**	**0.02**

Year	Bottomfish				Spearfishing (Snorkel)			
	All		BMUS		All		BMUS	
	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr
20-yr avg.	**33**	**2.66**	**39**	**2.99**	**20**	**1.51**	**3**	**0.16**
20-yr SD	**25**	**2.34**	**36**	**3.19**	**9**	**0.67**	**1**	**0.11**

"NA" = No data collected.

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 to 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-hr: Gear hours tallied by gear type.

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

BMUS - Gr-hr: 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 bottomfish fishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfish				Spear Snorkel			
	All		BMUS		All		BMUS	
	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr
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
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

Year	Bottomfish				Spear Snorkel			
	All		BMUS		All		BMUS	
	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr
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
2020	51	710	30	463	8	130	2	35
2021	101	1,349	67	995	21	364	2	76
10-yr avg.	**29.6**	**370**	**17.6**	**243**	**5.70**	**83.2**	**0.40**	**11.1**
10-yr SD	**26.3**	**365**	**18.1**	**280**	**5.92**	**103**	**0.80**	**24.0**
20-yr avg.	**56.8**	**985**	**30.9**	**498**	**10.75**	**146**	**1.00**	**17.6**
20-yr SD	**40.9**	**1,127**	**22.9**	**456**	**9.28**	**129**	**1.26**	**26.0**

"NA" = No data available.

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 bottomfish fishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfish		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
2008	40	22	9	3

Year	Bottomfish		Spearfishing (Snorkel)	
	All	BMUS	All	BMUS
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
2020	44	27	8	2
2021	87	58	17	2
10-yr avg.	**26**	**16**	**5**	**0**
10-yr SD	**23**	**16**	**5**	**1**
20-yr avg.	**33**	**21**	**9**	**1**
20-yr SD	**21**	**15**	**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 bottomfish fishing gears in the CNMI boat-based fishery for all species and BMUS only

Year	Bottomfish		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

Year	Bottomfish		Spearfishing (Snorkel)	
	All	**BMUS**	**All**	**BMUS**
2012	2	2	4	0
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
2020	2	2	3	4
2021	2	2	4	6
10-yr avg.	**2**	**2**	**2**	**1**
10-yr SD	**0**	**1**	**1**	**2**
20-yr avg.	**5**	**5**	**3**	**1**
20-yr 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 and non-BMUS fisheries. The bycatch estimates presented here are self-reported by fishers during creel survey interviews, and thus, the data are likely biased downward.

Calculations: The number caught is the sum of the total number of individuals found in the raw data including bycatch. The number discarded or released is number of individuals marked as bycatch. Percent bycatch is the sum of all released divided by the number caught.

Table 12. Time series of catch and bycatch in the CNMI boat-based BMUS and non-BMUS fisheries

Year	BMUS			Non-BMUS			BMUS + Non-BMUS		
	# Caught	**# Discard or Release**	**% Bycatch**	**# Caught**	**# Discard or Release**	**% Bycatch**	**# Caught**	**# Discard or Release**	**% Bycatch**
2000	493	12	2.43	325	9	2.77	818	21	2.57
2001	268	0	0.00	663	1	0.15	931	1	0.11

Year	BMUS			Non-BMUS			BMUS + Non-BMUS		
	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch
2002	474	0	0.00	430	14	3.26	904	14	1.55
2003	627	3	0.48	250	33	13.20	877	36	4.10
2004	756	0	0.00	623	20	3.21	1379	20	1.45
2005	2206	4	0.18	1019	0	0.00	3225	4	0.12
2006	874	0	0.00	971	3	0.31	1845	3	0.16
2007	1325	0	0.00	785	0	0.00	2110	0	0.00
2008	241	0	0.00	917	0	0.00	1158	0	0.00
2009	596	0	0.00	1183	0	0.00	1779	0	0.00
2010	614	0	0.00	860	0	0.00	1474	0	0.00
2011	482	0	0.00	1252	0	0.00	1734	0	0.00
2012	456	0	0.00	326	0	0.00	782	0	0.00
2013	519	0	0.00	338	0	0.00	857	0	0.00
2014	57	0	0.00	159	0	0.00	216	0	0.00
2015	102	0	0.00	94	0	0.00	196	0	0.00
2016	636	0	0.00	85	0	0.00	721	0	0.00
2017	120	0	0.00	194	0	0.00	314	0	0.00
2018	6	0	0.00	101	0	0.00	107	0	0.00
2019	139	0	0.00	105	0	0.00	244	0	0.00
2020	516	0	0.00	692	0	0.00	1208	0	0.00
2021	915	0	0.00	566	2	0.35	1481	2	0.14
10-yr avg.	**347**	**0**	**0.00**	**266**	**0**	**0.04**	**613**	**0**	**0.01**
10-yr SD	**288**	**0**	**0.00**	**203**	**1**	**0.11**	**449**	**1**	**0.04**
20-yr avg.	**583**	**0**	**0.03**	**548**	**4**	**1.02**	**1131**	**4**	**0.38**
20-yr SD	**492**	**1**	**0.11**	**381**	**8**	**2.96**	**763**	**9**	**0.96**

1.1.10 Federal Logbook Data

1.1.10.1 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 Archipelago FEP.

1.1.10.1.1 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.

1.1.10.1.2 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 FEP who incidentally catches CNMI coral reef ECS while fishing for BMUS, 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 ECS caught in a low-use MPA.

1.1.10.1.3 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.

1.1.10.1.4 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 (PRIA), 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 2012 and 2021. Data are from the NMFS Pacific Islands Regional Office (PIRO) Sustainable Fisheries Division (SFD) permits program.

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

CNMI Fisheries	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Bottomfish	14	5	7	7	18	25	14	9	14	18
Lobster	0	0	0	0	1*	0	1*	0	0	0
Shrimp	0	0	0	1	1	0	0	0	0	0

Source: PIRO SFD unpublished data.
* Permits apply to multiple areas and may include American Samoa, Guam, CNMI, and PRIA.

1.1.10.2 Summary of Catch and Effort for FEP Fisheries

The Mariana Archipelago FEP requires fishermen to obtain a federal permit to fish for certain MUS in federal waters and to report all catch and discards. While NMFS annually issues permits for various FEP fisheries, there is currently limited available data on the level of catch or effort made by federal non-longline permit holders. Determining the level of fishing activity through the required federal logbook reporting for each fishery helps establish the level of non-longline fishing occurring in federal waters to assess whether there is a continued need for active conservation and management measures (e.g., annual catch limits) for these fisheries. For each FEP fishery, the number of federal permits issued since the federal permit and logbook reporting requirements became effective as well as available catch and effort data are presented in Table 14 through Table 16. NMFS has never issued a federal permit for precious coral or coral reef fishing in federal waters around CNMI. Therefore, catch and effort data are not presented for these fisheries.

1.1.10.2.1 Commercial Bottomfish Fishery

Table 14. Summary of available federal logbook data for the commercial bottomfish fishery in CNMI

Year	No. of Federal Bottomfish Permits Issued[1]	No. of Federal Bottomfish Permits Reporting Catch	No. of Trips in CNMI EEZ	Total Reported Logbook Catch (lb)			Total Reported Logbook MUS Release/Discard (#s)	
				Bottomfish MUS & ECS[2]	*Coral Reef ECS[2]*	*Pelagic MUS*	*Bottomfish MUS & ECS[2]*	*Coral Reef ECS[2]*
2009	3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2010	12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2011	9	3	16	1,985	1,420	1,115		13
2012	14	5	40	2,309	1,765	159	52	10
2013	5	4	9	3,103	632	300		
2014	7	0						
2015	7	0						
2016	18	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2017	25	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2018	14	0						
2019	9	0						
2020	14	0						
2021	18	0						

[1] Source: PIRO SFD unpublished data.
[2] On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify some BMUS and all CREMUS in the Mariana Archipelago as ECS.
Notes: Federal permit and reporting requirements for CNMI bottomfish became effective on May 6, 2009 (74 FR 15373, April 6, 2009); n.d. = Not available due to confidentiality.

1.1.10.2.2 Spiny and Slipper Lobster

Table 15. Summary of available federal logbook data for lobster fisheries in CNMI

Year	No. of Federal Lobster Permits Issued[1]	No. of Federal Lobster Permits Reporting Catch	No. of Trips in CNMI EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (lb)	
				Spiny lobster ECS[2]	*Slipper lobster ECS[2]*	*Spiny lobster ECS[2]*	*Slipper lobster ECS[2]*
2006	2	0					
2007	2	0					
2008	7	0					
2009	0						

Year	No. of Federal Lobster Permits Issued[1]	No. of Federal Lobster Permits Reporting Catch	No. of Trips in CNMI EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (lb)	
				Spiny lobster ECS[2]	*Slipper lobster ECS*[2]	*Spiny lobster ECS*[2]	*Slipper lobster ECS*[2]
2010	0						
2011	0						
2012	0						
2013	0						
2014	0						
2015	0						
2016	1*	0					
2017	0						
2018	1*	0					
2019	0						
2020	0						
2021	0						

[1] Source: PIRO Sustainable Fisheries unpublished data.
[2] On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify all CMUS in the Mariana Archipelago as ECS.
* Permits apply to multiple areas and may include American Samoa, Guam, CNMI, and PRIA.
Note: Federal permit and reporting requirements for CNMI lobster fisheries became effective on December 4, 2006 (71 FR 69496, December 1, 2006).

1.1.10.2.3 Deepwater Shrimp

Table 16. Summary of available federal logbook data for deepwater shrimp fisheries in CNMI

Year	No. of Federal Shrimp Permits Issued[1]	No. of Federal Shrimp Permits Reporting Catch	No. of Trips in CNMI EEZ	Total Reported Logbook Shrimp ECS[2] Catch (lb)	Total Reported Logbook Shrimp ECS[2] Release/Discard (lb)
2009	0				
2010	2	n.d.	n.d.	n.d.	n.d.
2011	2	0			
2012	0				
2013	0				
2014	0				
2015	1	0			
2016	1	0			
2017	0				
2018	0				
2019	0				

Year	No. of Federal Shrimp Permits Issued[1]	No. of Federal Shrimp Permits Reporting Catch	No. of Trips in CNMI EEZ	Total Reported Logbook Shrimp ECS[2] Catch (lb)	Total Reported Logbook Shrimp ECS[2] Release/Discard (lb)
2020	0				
2021	0				

[1] Source: PIRO SFD unpublished data.
[2] On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify all CMUS in the Mariana Archipelago as ECS.
Notes: Federal permit and reporting requirements for CNMI bottomfish became effective on June 29, 2009 (74 FR 25650, May 29, 2009); n.d. = Not available due to confidentiality.

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 the 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 section. The latest estimate 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 17.

Table 17. Overfishing threshold specifications for the BMUS in CNMI

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY}\,B}{c\,B_{MSY}}$ for $B \leq c\,B_{MSY}$ $F(B) = F_{MSY}$ 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 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 SSBPR 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 SSBPR, are specified as indicated in Table 18. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 18. Rebuilding control rules for the BMUS in CNMI

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

1.1.11.2 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 CPUE for the multi-species complexes as a whole. At this time, it is not possible to partition these effort measures among the various BMUS. The most recent stock assessment (Langseth et al. 2019) for the CNMI BMUS 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 19. 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 lb (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 1000 lb	
B_{MSY}	570.6 (271.8-1,287)	Expressed in 1000 lb (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 usual AM for CNMI bottomfish fisheries is an overage adjustment in which the next year's ACL is downward adjusted by 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

On May 7, 2021, NMFS implemented an ACL of 84,000 lb for CNMI BMUS from 2020 to 2023 (86 FR 24511), and an ACT of 78,000 lb was also implemented. If the recent three-year average catch exceeds the ACT but remains below the ACL, then an overage adjustment would not be applied. The catch shown in Table 20 takes the average catch 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 creel survey estimates.

Table 20. CNMI 2021 ACL table with three-year average catch (lb)

Fishery	MUS	OFL	ABC	ACL	ACT	Catch
Bottomfish	Bottomfish multi-species complex	95,000	84,000	84,000	78,000	47,151

1.1.13 Best Scientific Information Available

1.1.13.1 Bottomfish Fishery

1.1.13.1.1 Stock Assessment Benchmark

The benchmark stock assessment for the Territory BMUS complexes was developed and finalized by Langseth et al. (2019). The assessments used a state-space Bayesian surplus production model within the JABBA modeling framework. 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.

1.1.13.1.2 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 BSIA for the Territory bottomfish MUS complex after undergoing a Western Pacific Stock Assessment Review (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* and SEEM analyses that previously determined risk levels to specify past ABCs and ACLs.

1.1.13.1.3 Other Information Available

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

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, relatively pristine, or lightly fished. A stock can have catch levels and 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).

summarizes the harvest extent and harvest capacity for the CNMI, tracking annual catch of BMUS against the most recently implemented ACL (86 FR 24511, May 7, 2021).

Table 21 summarizes the harvest extent and harvest capacity for the CNMI, tracking annual catch of BMUS against the most recently implemented ACL (86 FR 24511, May 7, 2021).

Table 21. CNMI proportion of harvest capacity and extent relative to the ACL in 2021

Fishery	MUS	ACL	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	Bottomfish multi-species complex	84,000	74,855	89.1	10.9

1.1.15 Administrative and Regulatory Actions

This summary describes management actions NMFS implemented for insular fisheries in the CNMI during calendar year 2021.

On May 7, 2021, NMFS published a final rule (86 FR 24511), effective June 7, 2021, setting bottomfish ACLs, ACTs, and AMs to correct or mitigate any overages for Guam and the CNMI. For the CNMI, the final rule implemented an ACL of 84,000 lb and an ACT of 78,000 lb for fishing years 2020-2023.

1.2 GUAM FISHERY DESCRIPTIONS

1.2.1 Bottomfish Fishery

Bottomfish fishing 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, deepwater species have made up a significant portion of the total expanded bottomfish fishing catch.

Most fishers 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 bottomfish fishing 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 bottomfish fishing 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 Rosa, 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: bottomfish fishing 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 lb) 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 *Pristipomoides* 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*, *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. rubroviolaceus*, *S. ghobban*, *S. schlegeli*, *Siganus spinus* (manahak), and *S. argenteus* (lesso).

Hook and line is the most common method of fishing for coral reef fish in Guam. In 2021, hook and line fishing accounted for around 70% of fishers and 74% of gear in inshore participation surveys. Throw net (talaya) is the second most common method, accounting for about 15% of fishers and 14% of gear. Other methods include gill net, snorkel 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 2021, there was one vendor 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 5 to the Mariana Archipelago FEP that reclassified a large number MUS as ECS (WPRFMC 2018). The final rule was published in the *Federal Register* in early 2019 (84 FR 2767, February 8, 2019), and reduced 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 2.3.3).

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 programs are the shore-based and boat-based data programs 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- and shore-based creel surveys are part of 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 Western Pacific Fisheries Information Network (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.

1.2.3.1 Effects of COVID-19 on DAWR Creel Survey Data Collection

The response of the Guam Government to COVID-19 slightly impacted DAWR's ability to conduct creel surveys and collect fishery data in 2021. Restrictions on interactions with fishers were lifted January 18, 2021. Normally, there are six shore-based creel surveys and two participation surveys completed per month. DAWR completed eight participation surveys and four creel surveys in January 2021 (Table 22). After January, inshore survey efforts returned to normal with two participation and six creel surveys per month. Due to COVID restrictions on carrying passengers, no contractors were able to provide aerial survey services, and no aerial surveys were performed in 2021. Boat-based creel surveys were similarly impeded for the first part of January 2021. Three boat based creel surveys were completed in January, and survey efforts returned to normal levels beginning in February with eight boat based creel surveys per month (Table 22).

Table 22. Number of inshore creel and participation surveys completed by DAWR in 2021

Month	Inshore Creel Surveys Completed	Participation Surveys Completed	Aerial Surveys Completed
January	4	8	0
February	6	2	0
March	6	2	0
April	6	2	0
May	6	2	0
June	6	2	0
July	6	2	0
August	6	2	0
September	6	2	0
October	6	2	0
November	6	2	0
December	6	2	0
Total	**70**	**30**	**0**

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 23. 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	1028	0
1991	48	1019	1
1992	48	1110	0
1993	52	1119	0
1994	55	1168	0
1995	96	1613	4
1996	96	1608	0
1997	96	1358	0
1998	96	1581	0
1999	96	1367	3
2000	96	1246	1
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

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
2016	93	900	2
2017	92	820	10
2018	89	795	11
2019	93	786	3
2020	96	349	1
2021	96	886	2
10-year avg.	**92**	**675**	**5**
10-year SD	**6**	**189**	**5**
20-year avg.	**92**	**643**	**3**
20-year SD	**6**	**166**	**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 24. Summary of Guam commercial receipt book meta-data

Year	# Vendors	# Total Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
1982	n.d.	n.d.	n.d.	n.d.
1983	3	2,312	n.d.	n.d.
1984	3	2,587	3	48
1985	n.d.	n.d.	n.d.	n.d.
1986	n.d.	n.d.	n.d.	n.d.
1987	n.d.	n.d.	n.d.	n.d.
1988	n.d.	n.d.	n.d.	n.d.
1989	n.d.	n.d.	n.d.	n.d.
1990	4	2,803	3	72
1991	3	2,512	n.d.	n.d.
1992	3	2,737	n.d.	n.d.
1993	3	2,664	n.d.	n.d.
1994	n.d.	n.d.	n.d.	n.d.
1995	3	1,565	n.d.	n.d.
1996	6	1,965	3	27
1997	7	2,923	4	41
1998	4	3,591	3	69

Year	# Vendors	# Total Invoices Collected	# BMUS Vendors	# BMUS Invoices Collected
1999	5	3,410	3	177
2000	3	3,868	3	174
2001	3	4,155	3	286
2002	3	3,498	n.d.	n.d.
2003	n.d.	n.d.	n.d.	n.d.
2004	3	3,107	n.d.	n.d.
2005	3	2,649	n.d.	n.d.
2006	4	2,589	n.d.	n.d.
2007	n.d.	n.d.	n.d.	n.d.
2008	n.d.	n.d.	n.d.	n.d.
2009	n.d.	n.d.	n.d.	n.d.
2010	n.d.	n.d.	n.d.	n.d.
2011	n.d.	n.d.	n.d.	n.d.
2012	n.d.	n.d.	n.d.	n.d.
2013	n.d.	n.d.	n.d.	n.d.
2014	8	1,355	n.d.	n.d.
2015	9	1,361	n.d.	n.d.
2016	8	1,661	n.d.	n.d.
2017	11	1,996	4	104
2018	10	1,748	4	56
2019	6	1,200	n.d.	n.d.
2020	n.d.	n.d.	n.d.	n.d.
2021	n.d.	n.d.	n.d.	n.d.
10-year avg.	**6**	**1,308**	**2**	**77**
10-year SD	**4**	**436**	**1**	**36**
20-year avg.	**4**	**1,850**	**2**	**106**
20-year SD	**3**	**755**	**1**	**47**

"n.d." = 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 25. Annual indicators for Guam bottomfish fisheries describing performance and comparing 2021 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 (lb)**		
All gears (BMUS only)	All BMUS from creel survey data	**54,221[▲117%]**	**54,221[▲96%]**
	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)		
Bottomfish fishing (BMUS only)	Bottomfish fishing lb/trip	**30[▲76%]**	**30[▲58%]**
	Bottomfish fishing lb/gr-hr	**1.68[▲53%]**	**1.68[▲32%]**
	Fishing effort (from boat-based creel surveys)		
Bottomfish fishing (BMUS only)	Tallied bottomfish trips	**92[▲70%]**	**92[▲53%]**
	Tallied bottomfish gear hours	**1,652[▲62%]**	**1,652[▲65%]**
	Fishing participants (from boat-based creel surveys)		
Bottomfish fishing (BMUS only)	Tallied number of bottomfish fishing vessels	**56[▲40%]**	**56[▲27%]**
	Estimated average number of fishermen per bottomfish fishing trip	**3[no change]**	**3[no change]**
	Bycatch		
BMUS	# fish caught	**859[▲57%]**	**859[▲39%]**
	# fish discarded/released	**0[▼100%]**	**0[▼100%]**
	% bycatch	**0[▼100%]**	**0[▼100%]**

Table 26. Annual indicators for Guam ECS fisheries describing performance and comparing 2021 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 boat-based catch (lb)**		
Prioritized ECS	*Naso unicornis* from creel survey data	**10,788[▲200%]**	**10,788[▲83%]**
	Siganus spinus from creel survey data	**3,222[▲381%]**	**3,222[▲532%]**
	Siganus spinus from commercial purchase data	**0[▼100%]**	**0[▼100%]**
	Lethrinus harak from creel survey data	**619[▼80%]**	**619[▼83%]**
	Chlorurus frontalis from creel survey data	**485[▼37%]**	**485[▼46%]**
	Epinephelus fasciatus from creel survey data	**935[▼61%]**	**935[▼78%]**
	Caranx melampygus from creel survey data	**134[▼64%]**	**134[▼70%]**
	Lethrinus olivaceus from creel survey data	**1,038[▲25%]**	**1,038[▼32%]**
	Lutjanus fulvus from creel survey data	**262[▼36%]**	**262[▼40%]**
	Scarus rubroviolaceus from creel survey data	**144[▲2%]**	**144[▼64%]**

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

Year	Boat-Based Creel Survey Estimates	Shore-Based Creel Survey Estimates	Total Creel Survey Estimates	Commercial Landings
1982	20,677	-	20,677	n.d.
1983	36,150	-	36,150	n.d.
1984	14,655	-	14,655	3,445
1985	38,960	-	38,960	n.d.
1986	16,404	386	16,790	n.d.
1987	24,279	12	24,291	n.d.
1988	33,986	3,092	37,078	n.d.
1989	44,799	76	44,875	n.d.
1990	33,816	1,635	35,451	4,277
1991	31,546	1,641	33,187	n.d.
1992	36,316	2,337	38,653	n.d.
1993	39,073	368	39,441	n.d.
1994	40,719	222	40,941	n.d.
1995	27,194	892	28,086	n.d.
1996	40,498	1	40,499	1,251
1997	21,255	24	21,279	1,957
1998	22,296	34	22,330	4,576
1999	40,773	46	40,819	20,940
2000	58,640	79	58,719	12,184
2001	43,696	34	43,730	10,554
2002	20,366	30	20,396	n.d.
2003	29,506	0	29,506	n.d.
2004	25,233	20	25,253	n.d.
2005	29,087	2	29,089	n.d.
2006	33,414	3	33,417	n.d.
2007	22,576	3	22,579	n.d.
2008	31,103	4	31,107	n.d.
2009	35,029	46	35,075	n.d.
2010	23,928	211	24,139	n.d.
2011	52,230	50	52,280	n.d.
2012	17,518	4	17,522	n.d.
2013	27,277	218	27,495	n.d.
2014	20,687	24	20,711	n.d.
2015	10,782	73	10,855	n.d.
2016	24,479	1	24,480	n.d.
2017	14,653	82	14,735	4,002
2018	28,364	363	28,727	3,029
2019	28,849	143	28,992	n.d.
2020	16,844	0	16,844	n.d.

Year	Boat-Based Creel Survey Estimates	Shore-Based Creel Survey Estimates	Total Creel Survey Estimates	Commercial Landings
2021	54,214	7	54,221	n.d.
10-year avg.	**24,905**	**92**	**24,997**	**3,320**
10-year SD	**12,955**	**113**	**13,068**	**2,167**
20-year avg.	**27,576**	**68**	**27,644**	**5,084**
20-year SD	**11,317**	**96**	**11,413**	**2,850**

"-" = No data collected; "n.d." = 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 28. Total catch time series estimates (lb) for all species and BMUS only using Guam expanded boat-based creel survey data for bottomfish fishing 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

Year	Bottomfish		Spearfishing (Snorkel)		Spearfishing (SCUBA)	
	All	BMUS	All	BMUS	All	BMUS
2001	123,975	43,119	74,369	0	65,105	535
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	44,208	28,448	13,557	18	15,532	0
2020	33,030	16,565	8,336	25	2,801	0
2021	95,285	54,123	31,945	91	0	0
10-year avg.	**51,013**	**22,934**	**21,818**	**100**	**19,365**	**67**
10-year SD	**18,398**	**13,280**	**6,882**	**122**	**18,856**	**202**
20-year avg.	**60,722**	**25,993**	**22,250**	**181**	**24,256**	**279**
20-year SD	**19,160**	**11,623**	**6,465**	**260**	**19,773**	**555**

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 and pelagic MUS species.

Table 29a. Top ten landed ECS in Guam from boat-based creel survey data in 2021

Common Name	Scientific Name	Catch (lb)
Bluespine unicornfish	*Naso unicornis*	10,788

Common Name	Scientific Name	Catch (lb)
Assorted reef fish	Assorted reef fish	9,591
Shallow bottomfish	Misc. shallow bottomfish	6,866
Yellowlip emperor	*Lethrinus xanthochilus*	5,474
Top shell	*Trochus niloticus*	4,444
Jacks, trevallys	*Carangidae* (family)	3,590
Scribbled rabbitfish	*Siganus spinus*	3,222
Bigeye scad	*Selar crumenophthalmus*	2,933
Orangespine unicornfish	*Naso lituratus*	1,759
Honeycomb grouper	*Epinephelus merra*	1,558

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

Table 29b. Top ten landed ECS in Guam from estimated commercial landings data in 2021

Common Name	Scientific Name	Catch (lb)
Reef fish	Actinopterygii (class)	914
Mafute (emperor)	Lethrinidae (family)	547
Grouper	Serranidae (family)	526
Miscellaneous	Miscellaneous	508
Uku (gray snapper)	*Aprion virescens*	97
Bigeye scad (atulai)	*Selar crumenophthalmus*	85
Amberjack	*Seriola dumerili*	82
Bottomfish	Percoidei (suborder)	52
Blueline surgeonfish	*Acanthurus lineatus*	47
Jacks	Carangidae (family)	41

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

Table 30a. Catch (lb) 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	5,375	418	1,909	178	756	1,654	905	367	0
2020	940	1,614	804	1,787	1,335	187	882	198	0
2021	10,788	3,222	619	347	485	935	1,038	262	144
100year avg.	**3,599**	**670**	**3,101**	**553**	**1,254**	**2,575**	**831**	**411**	**141**
100year SD	**3,221**	**1,014**	**2,737**	**665**	**520**	**2,928**	**730**	**270**	**267**
200year avg.	**5,901**	**510**	**3,606**	**644**	**2,160**	**3,128**	**1,528**	**434**	**400**
200year SD	**4,927**	**794**	**2,446**	**694**	**1,992**	**2,443**	**2,549**	**266**	**936**

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 30b. Catch (lb) from commercial purchase data for *Siganus spinus* in Guam

Year	*Siganus spinus*
1982	n.d.
1983	n.d.
1984	99
1985	n.d.
1986	n.d.
1987	n.d.
1988	n.d.
1989	n.d.
1990	419
1991	n.d.
1992	n.d.
1993	n.d.
1994	n.d.
1995	n.d.
1996	131
1997	84
1998	1,895
1999	4,628
2000	907
2001	15
2002	n.d.
2003	n.d.
2004	n.d.
2005	n.d.
2006	n.d.
2007	n.d.
2008	n.d.
2009	n.d.
2010	n.d.
2011	n.d.
2012	n.d.
2013	n.d.
2014	n.d.
2015	n.d.

Year	*Siganus spinus*
2016	n.d.
2017	11,277
2018	6,507
2019	n.d.
2020	n.d.
2021	n.d.
10-year avg.	**8,892**
10-year SD	**3,373**
20-year avg.	**8,892**
20-year SD	**3,373**

n.d. = non-disclosed due to confidentiality rules.

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

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

BMUS - lb/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 31. CPUE (lb/gear hour and lb/trip) for bottomfish fishing 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	
	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr
1982	27	2.98	17	1.77	7	2.46	0	0	0	0	0	0
1983	23	2.95	20	2.33	7	1.67	0	0	18	5.89	0	0
1984	28	3.11	17	2.03	39	2.32	8	0.67	24	4.97	1	0.33
1985	27	2.41	17	1.49	48	4.53	6	0.52	25	6.58	2	0.56
1986	23	2.32	24	1.78	43	4.15	1	0.20	20	4.35	3	0.50
1987	23	2.55	18	1.71	28	5.46	4	0.85	30	6.66	3	0.53
1988	21	2.05	13	1.11	35	6.05	34	8.50	20	7.44	2	0.80
1989	20	2.10	15	1.50	26	3.07	1	0.19	31	5.98	1	0.29
1990	21	1.97	16	1.45	22	3.66	0	0	46	11.30	6	1.00
1991	19	2.17	16	1.76	24	4.45	1	0.13	47	14.43	5	0.97
1992	17	1.88	11	1.08	24	3.52	3	0.50	24	8.07	10	2.13
1993	19	1.84	18	1.69	21	3.37	0	0	58	19.11	5	1.27
1994	26	2.41	21	1.73	25	3.62	0	0	55	15.06	4	0.87
1995	13	1.00	11	0.85	31	3.74	3	0.25	89	17.29	10	1.49
1996	18	1.16	16	1.22	33	4.21	3	1.00	76	11.19	7	0.46
1997	14	0.95	11	0.72	25	3.09	10	4.00	81	14.57	4	0.54
1998	14	1.01	10	0.79	21	2.93	5	0.32	98	15.88	2	0.28
1999	16	1.10	17	1.21	17	2.08	7	3.50	100	14.81	2	0.31
2000	18	1.34	19	1.27	21	2.72	24	24.00	90	13.98	4	0.44
2001	20	1.65	15	1.26	56	4.69	21	1.31	69	10.98	4	0.39
2002	17	1.37	14	1.16	21	3.01	1	0.08	58	6.96	12	1.28
2003	21	1.56	16	0.95	40	5.05			108	13.20	3	0.22
2004	24	1.91	20	1.47	28	3.42	2	0.11	81	9.14	11	1.03
2005	27	2.18	31	2.23	20	2.56	6	1.10	61	5.55	13	0.52

Year	Bottomfish				Spearfish (Snorkel)				Spearfish (SCUBA)			
	All		BMUS		All		BMUS		All		BMUS	
	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr
2006	31	2.15	26	1.43	24	2.30	16	1.02	13	2.69	0	0
2007	30	2.22	16	1.17	31	3.29	4	0.42	100	8.00	25	1.56
2008	21	1.75	17	1.25	38	3.05	2	0.18	35	4.49	0	0
2009	29	2.13	25	1.85	23	2.71	2	0.16	63	7.00	0	0
2010	17	1.21	13	0.83	19	2.42	1	0.20	2	0.44	0	0
2011	37	2.71	29	2.14	41	5.17	0	0	140	11.51	1	0.17
2012	21	2.06	18	1.62	58	7.62	0	0	70	10.00	0	0
2013	19	1.53	16	1.12	28	2.28	0	0	10	3.53	0	0
2014	24	1.33	13	0.91	35	2.39	4	0.50	33	8.61	0	0
2015	16	1.29	15	1.14	33	3.02	0	0	58	2.70	0	0
2016	21	1.49	17	1.15	27	2.76	4	0.29	68	4.79	0	0
2017	19	1.37	11	0.70	16	1.92	2	0.16	43	5.34	0	0
2018	26	0.51	21	0.37	41	3.66	3	0.11	97	7.18	29	1.80
2019	20	1.67	19	1.45	17	1.45	1	0.13	45	2.99	0	0
2020	14	1.18	13	0.85	9	1.07	1	0.50	76	4.78	0	0
2021	27	1.73	30	1.68	23	1.88	2	0.26	0	0	0	0
10-yr avg	**21**	**1.42**	**17**	**1.10**	**29**	**2.81**	**2**	**0.28**	**56**	**5.55**	**29**	**1.80**
10-yr SD	**4**	**0.39**	**5**	**0.39**	**13**	**1.76**	**1**	**0.15**	**24**	**2.40**	**0**	**0**
20-yr avg.	**23**	**1.67**	**19**	**1.27**	**29**	**3.05**	**3**	**0.35**	**61**	**6.26**	**13**	**0.94**
20-yr SD	**6**	**0.48**	**6**	**0.46**	**11**	**1.44**	**4**	**0.31**	**34**	**3.20**	**10**	**0.60**

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-hr: Gear hours tallied by gear type.

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

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

Table 32. Effort (trips and gear hours) for bottomfish fishing 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-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr
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

Year	Bottomfish				Spearfish (Snorkel)				Spearfish (SCUBA)			
	All		BMUS		All		BMUS		All		BMUS	
	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr
2006	104	1,519	61	1,123	19	198	2	32	5	25	0	0
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	5,010	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
2020	74	858	42	626	17	149	1	2	3	48	0	0
2021	153	2,414	92	1,652	44	532	4	35	0	0	0	0
10-year avg.	**95**	**1,669**	**54**	**1,017**	**21**	**221**	**1**	**14**	**6**	**83**	**0**	**5**
10-year SD	**30**	**1,231**	**20**	**775**	**10**	**117**	**1**	**15**	**7**	**98**	**1**	**15**
20-year avg.	**107**	**1,621**	**60**	**986**	**22**	**205**	**2**	**17**	**6**	**69**	**1**	**8**
20-year SD	**30**	**905**	**17**	**566**	**8**	**93**	**1**	**15**	**5**	**75**	**1**	**14**

"NA" = No data available.

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 33a. Estimated number of unique vessels for bottomfish fishing 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
2007	58	41	11	2	2	1

Year	Bottomfish		Spearfish (Snorkel)		Spearfish (SCUBA)	
	All	**BMUS**	**All**	**BMUS**	**All**	**BMUS**
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
2020	63	35	14	1	3	0
2021	95	56	28	3	0	0
10-year avg.	**69**	**40**	**16**	**1**	**4**	**0**
10-year SD	**15**	**10**	**6**	**1**	**3**	**1**
20-year avg.	**76**	**44**	**17**	**2**	**4**	**1**
20-year SD	**16**	**10**	**5**	**1**	**3**	**1**

"NA" = No data available.

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 33b. Estimated number of fishermen per trip for bottomfish fishing 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	0	1	0
1983	2	2	2	0	1	0
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	0	3	4

Year	Bottomfish		Spearfish (Snorkel)		Spearfish (SCUBA)	
	All	**BMUS**	**All**	**BMUS**	**All**	**BMUS**
1991	3	3	3	3	3	4
1992	3	3	4	1	3	3
1993	3	3	3	0	4	4
1994	3	3	3	0	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	0	4	4
2004	4	3	3	6	4	4
2005	3	2	3	3	3	5
2006	3	2	3	3	3	0
2007	4	3	3	2	4	4
2008	3	2	3	3	3	0
2009	3	2	3	3	4	0
2010	3	3	3	3	3	0
2011	3	3	4	0	4	3
2012	3	3	3	0	5	0
2013	3	3	4	0	3	0
2014	3	3	4	4	3	0
2015	4	4	4	0	7	0
2016	3	3	3	2	5	0
2017	2	2	3	3	5	0
2018	4	3	4	4	5	3
2019	3	3	4	5	7	0
2020	3	3	4	6	6	0
2021	3	3	4	4	0	0
10-year avg.	**3**	**3**	**4**	**3**	**5**	**0**
10-year SD	**1**	**0**	**0**	**2**	**2**	**1**
20-year avg.	**3**	**3**	**3**	**3**	**4**	**1**
20-year SD	**0**	**1**	**0**	**2**	**2**	**2**

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.

The following are recent bycatch estimates for the boat-based BMUS and non-BMUS fisheries. The bycatch estimates presented here are self-reported by fishers during creel survey interviews, and thus, the data are likely biased downward.

Calculations: The number caught is the sum of the total number of individuals found in the raw data including bycatch. The number discarded or released is number of individuals marked as bycatch. Percent bycatch is the sum of all released divided by the number caught.

Table 34. Time series of observed catch and bycatch in Guam boat-based fisheries

Year	BMUS			Non-BMUS			BMUS + Non-BMUS		
	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch
1982	1,062	0	0.00	535	0	0.00	1,597	0	0.00
1983	940	0	0.00	567	0	0.00	1,507	0	0.00
1984	590	0	0.00	2,757	0	0.00	3,347	0	0.00
1985	1,830	0	0.00	3,010	0	0.00	4,840	0	0.00
1986	546	0	0.00	1,078	0	0.00	1,624	0	0.00
1987	1,313	0	0.00	1,206	0	0.00	2,519	0	0.00
1988	1,399	0	0.00	1,603	0	0.00	3,002	0	0.00
1989	2,028	0	0.00	1,534	0	0.00	3,562	0	0.00
1990	1,542	0	0.00	1,328	0	0.00	2,870	0	0.00
1991	1,366	0	0.00	1,417	0	0.00	2,783	0	0.00
1992	1,046	0	0.00	1,481	0	0.00	2,527	0	0.00
1993	946	0	0.00	1,947	0	0.00	2,893	0	0.00
1994	1,663	0	0.00	2,067	0	0.00	3,730	0	0.00
1995	1,449	0	0.00	3,536	0	0.00	4,985	0	0.00
1996	1,281	0	0.00	3,963	0	0.00	5,244	0	0.00
1997	983	0	0.00	3,359	0	0.00	4,342	0	0.00
1998	993	0	0.00	4,145	0	0.00	5,138	0	0.00
1999	1,081	0	0.00	3,857	0	0.00	4,938	0	0.00
2000	1,090	6	0.55	2,815	526	18.69	3,905	532	13.62
2001	1,023	16	1.56	2,873	607	21.13	3,896	623	15.99
2002	629	2	0.32	1,875	351	18.72	2,504	353	14.10

Year	BMUS			Non-BMUS			BMUS + Non-BMUS		
	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch
2003	497	20	4.02	1,391	171	12.29	1,888	191	10.12
2004	586	0	0.00	1,218	122	10.02	1,804	122	6.76
2005	616	0	0.00	1,090	66	6.06	1,706	66	3.87
2006	1,140	27	2.37	1,048	118	11.26	2,188	145	6.63
2007	417	7	1.68	955	132	13.82	1,372	139	10.13
2008	572	3	0.52	1,085	118	10.88	1,657	121	7.30
2009	860	0	0.00	1,991	77	3.87	2,851	77	2.70
2010	890	0	0.00	1,698	29	1.71	2,588	29	1.12
2011	707	0	0.00	1,421	45	3.17	2,128	45	2.11
2012	309	0	0.00	615	37	6.02	924	37	4.00
2013	293	0	0.00	929	44	4.74	1,222	44	3.60
2014	658	6	0.91	1,794	163	9.09	2,452	169	6.89
2015	366	0	0.00	1,054	70	6.64	1,420	70	4.93
2016	641	2	0.31	1,033	45	4.36	1,674	47	2.81
2017	766	0	0.00	1,547	26	1.68	2,313	26	1.12
2018	406	2	0.49	1,115	27	2.42	1,521	29	1.91
2019	865	3	0.35	982	44	4.48	1,847	47	2.54
2020	302	0	0.00	525	16	3.05	827	16	1.93
2021	859	0	0.00	1,259	5	0.40	2,118	5	0.24
10-yr avg.	**547**	**1**	**0.21**	**1,085**	**48**	**4.29**	**1,632**	**49**	**3.00**
10-yr SD	**224**	**2**	**0.29**	**363**	**42**	**2.42**	**529**	**44**	**1.84**
20-yr avg.	**619**	**4**	**0.55**	**1,231**	**85**	**6.73**	**1,850**	**89**	**4.74**
20-yr SD	**226**	**7**	**1.01**	**384**	**78**	**4.68**	**535**	**80**	**3.53**

1.2.11 Federal Logbook Data

1.2.11.1 Number of Federal Permit Holders

The CFR, Title 50, Part 665 requires the following federal permits for Guam fisheries in the EEZ under the Mariana Archipelago FEP.

1.2.11.1.1 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 ECS in the EEZ seaward of Guam.

1.2.11.1.2 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 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.

1.2.11.1.3 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.

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

There is no record of special coral reef or precious coral fishery permits issued for the EEZ around Guam since 2007. Table 35 provides the number of permits issued for Guam fisheries between 2012 and 2021. Data are from the NMFS PIRO SFD permits program.

Table 35. Number of federal permits holders for the crustacean and bottomfish fisheries of Guam

Guam Fisheries	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Bottomfish	2	2	2	1	1	1	1	0	0	0
Lobster	0	0	0	0	1*	0	1*	0	0	0
Shrimp	0	0	0	1	1	0	0	0	0	0

Source: PIRO SFD unpublished data.
*Permits apply to multiple areas and may include American Samoa, Guam, CNMI, and PRIA.

1.2.11.2 Summary of Catch and Effort for FEP Fisheries

The Marianas Archipelago FEP requires fishermen to obtain a federal permit to fish for certain MUS in federal waters and to report all catch and discards. While NMFS annually issues permits for various FEP fisheries, there is currently limited available data on the level of catch or effort made by federal non-longline permit holders. Determining the level of fishing activity through the required federal logbook reporting for each fishery helps establish the level of non-longline fishing occurring in federal waters to assess whether there is a continued need for active conservation and management measures (e.g., annual catch limits) for these fisheries. For each FEP fishery, the number of federal permits issued since the federal permit and logbook reporting requirements became effective as well as available catch and effort data are presented in Table 36 through Table 38.

NMFS has never issued a federal permit for precious coral or coral reef fishing in federal waters around Guam. Therefore, catch and effort data is not presented for these fisheries.

1.2.11.2.1 Large Vessel Bottomfish Fishery

Table 36. Summary of available federal logbook data for the large vessel bottomfish fishery in Guam

Year	No. of Federal Bottomfish Permits Issued[1]	No. of Federal Bottomfish Permits Reporting Catch	No. of Trips in Guam EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook MUS Release/Discard (lb)	
				Bottomfish MUS & ECS[2]	*Coral Reef ECS[2]*	*Bottomfish MUS & ECS[2]*	*Coral Reef ECS[2]*
2006	0						
2007	1	0					
2008	2	0					
2009	1	0					
2010	6	0					
2011	6	0					
2012	2	0					
2013	2	0					
2014	2	0					
2015	1	0					
2016	1	0					
2017	1	0					
2018	1	0					
2019	0						
2020	0						
2021	0						

[1] Source: PIRO SFD unpublished data.
[2] On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify some BMUS and all CREMUS in the Mariana Archipelago as ECS.
Note: Federal permit and reporting requirements for large vessels in Guam's bottomfish fishery became effective on December 4, 2006 (71 FR 69496, December 1, 2006).

1.2.11.2.2 Spiny and Slipper Lobster Fishery

Table 37. Summary of available federal logbook data for lobster fisheries in Guam

Year	No. of Federal Lobster Permits Issued[1]	No. of Federal Lobster Permits Reporting Catch	No. of Trips in Guam EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (lb)	
				Spiny lobster ECS[2]	*Slipper lobster ECS[2]*	*Spiny lobster ECS[2]*	*Slipper lobster ECS[2]*
2004	0						
2005	0						
2006	2	0					
2007	2	0					

Year	No. of Federal Lobster Permits Issued[1]	No. of Federal Lobster Permits Reporting Catch	No. of Trips in Guam EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (lb)	
				Spiny lobster ECS[2]	*Slipper lobster ECS*[2]	*Spiny lobster ECS*[2]	*Slipper lobster ECS*[2]
2008	7	0					
2009	0						
2010	0						
2011	0						
2012	0						
2013	0						
2014	0						
2015	0						
2016	1*	0					
2017	0						
2018	1*	0					
2019	0						
2020	0						
2021	0						

[1] Source: PIRO SFD unpublished data.
[2] On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify all CMUS in the Mariana Archipelago as ECS.
* Permits apply to multiple areas and may include American Samoa, Guam, CNMI, and PRIA.
Note: Federal permit and reporting requirements for CNMI lobster fisheries became effective on December 6, 2006 (71 FR 69496, December 1, 2006).

1.2.11.2.3 Deepwater Shrimp Fishery

Table 38. Summary of available federal logbook data for deepwater shrimp fisheries in Guam

Year	No. of Federal Shrimp Permits Issued[1]	No. of Federal Shrimp Permits Reporting Catch	No. of Trips in Guam EEZ	Total Reported Logbook Shrimp ECS[2] Catch (lb)	Total Reported Logbook Shrimp ECS[2] Release/Discard (lb)
2009	0				
2010	2	0			
2011	2	0			
2012	0				
2013	0				
2014	0				
2015	1	0			
2016	1	0			
2017	0				

Year	No. of Federal Shrimp Permits Issued[1]	No. of Federal Shrimp Permits Reporting Catch	No. of Trips in Guam EEZ	Total Reported Logbook Shrimp ECS[2] Catch (lb)	Total Reported Logbook Shrimp ECS[2] Release/Discard (lb)
2018	0				
2019	0				
2020	0				
2021	0				

[1] Source: PIRO SFD unpublished data
[2] On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify all CMUS in the Mariana Archipelago as ECS.
Note: Federal permit and reporting requirements for deepwater shrimp fisheries became effective on June 29, 2009 (74 FR 25650, May 29, 2009).

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 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 39). The value of M used to determine the reference point values is not specified in this section. 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 39. 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 $c = \max(1-M, 0.5)$		

Standardized values of fishing effort (E) and 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 ($SSBP_t$) 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 SSBPR 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 $SSBPR_{MIN}$. 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 SSBPR, are specified as indicated in Table 40. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 40. 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 CPUE for the multi-species complexes as a whole. At this time, it is not possible to partition these effort measures among the various BMUS. The most recent stock assessment (Langseth et al. 2019) for the Guam BMUS 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 41. 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 lb (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 1000 lb	
B_{MSY}	248.8 (107.1-636.8)	Expressed in 1000 lb (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

On May 7, 2021, NMFS implemented an ACL of 27,000 lb for Guam BMUS from 2020 to 2022 (86 FR 24511). The catch shown in Table 42 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 creel survey estimates.

Table 42. Guam 2021 ACL table with three-year average catch (lb)

Fishery	MUS	OFL	ABC	ACL	Catch
Bottomfish	Bottomfish multi-species complex	36,000	27,000	27,000	33,352

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. 2016). 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. (2016) is considered the BSIA for the Guam BMUS complex after undergoing a Western Pacific Stock Assessment Review (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* and SEEM analyses that previously determined the risk levels to specify past 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.

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)].

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 TALFF.

Table 43 summarizes the harvest extent and harvest capacity information for Guam tracking the annual catch against the most recently implemented ACL (86 FR 24511, May 7, 2021).

Table 43. Guam ACL proportion of harvest capacity and extent in 2021

Fishery	MUS	ACL	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	Bottomfish multi-species complex	27,000	54,221	200.8	0.0

1.2.16 Other Relevant Ocean-Uses and Fishery-Related Information

1.2.16.1 Territorial 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 2,930 trolling and bottom fishing trips to these southern banks, an average of more than 83 trips per year. Available data from 2021 indicate that

NTMs were associated with 80 closure days for W-517, though these data are not complete. Additional information and data can be found in Table 67 in Section 2.9.5.

1.2.17 Administrative and Regulatory Actions

This summary describes management actions NMFS implemented for insular fisheries in Guam during calendar year 2021.

On May 7, 2021, NMFS published a final rule (86 FR 24511), effective June 7, 2021, setting bottomfish ACLs, ACTs, and AMs to correct or mitigate any overages for Guam and the CNMI. For Guam, the final rule implemented an ACL of 27,000 lb for fishing years 2020-2022.

On November 15, 2021, NMFS published a notice of availability for Amendment 6 to the Fishery Ecosystem Plan for the Mariana Archipelago that would establish a rebuilding plan for the Guam bottomfish stock complex (86 FR 62982). This action was in response to NMFS determination of February 10, 2020, that the Guam bottomfish stock complex is overfished and that, consistent with Section 304(e) of the Magnuson-Stevens Fishery Conservation and Management Act and implementing regulations at 50 CFR 600.310(j), the Council and NMFS must take action within two years to rebuild the overfished stock, that is, by February 2022.

On November 26, 2021, NMFS published a proposed rule to implement Amendment 6 and the rebuilding plan (86 FR 67426). When approved, the final rule implementing Amendment 6 would consist of a 31,000 lb ACL and two AMs starting in 2022. As an in-season AM, if NMFS projects that the fishery will reach the ACL in any year, it would close the fishery in federal waters for the remainder of that year. As an additional AM, if subsequent analyses indicate that the fishery exceeded the ACL during a year, NMFS would close the fishery in federal waters until NMFS and the Territory of Guam would implement a coordinated management approach and implement regulations to ensure that the catch in both federal and territorial waters is maintained at levels that allow the stock to rebuild. The rebuilding plan would remain in place until NMFS determines that the stock complex is rebuilt, which is expected to take nine years.

2 ECOSYSTEM CONSIDERATIONS

2.1 COVID IMPACTS

Fishing communities and island economies across the Pacific Islands Region continued to experience pandemic-related impacts during 2021. Key metrics of recovery include tourism and unemployment, both of which drive seafood demand and have implications for fishing activity and markets. Despite these challenges, the fishing community across the Mariana Archipelago (commercial fishers, non-commercial fishers, and seafood vendors) played a vital role in supporting local food systems, nutrition, food security, and promoting social cohesion. This importance is amplified in the face of natural disasters and human health crises, and fishing communities across the Pacific Islands Region have adapted to continue these crucial functions in the face of this unprecedented disruption.

2.1.1 Guam

The island of Guam did not see any tourism rebound in 2021 as calendar year arrivals were down 76% relative to 2020, reflecting a 95% decline relative to 2019[1]. While Guam experienced some growth (+48%) in domestic visitors from the US mainland and Hawaii, these gains were far outweighed by continued foreign travel restrictions from Asia (i.e., Guam's primary market), resulting in over 90% declines in arrivals from Japan, Korea, and China. This lack of progress in tourism rebound was a primary driver for unemployment levels to remain high on the island of Guam, although the situation improved each quarter throughout 2021[2]. The unemployment rate on Guam was 7.2% in December 2021, down from a December 2020 high of 19.4%.

While boat-based landings for bottomfish management unit species was significantly higher in 2021 relative to the previous 10-years, commercial fishing revenues for 2021 cannot be presented due to confidentiality considerations as fewer than three vendors reported commercial data in 2021. As noted in the socioeconomic module (Section 2.5), costs of bottomfish fishing in 2021 were considerably higher than 2020 across all expenditure components (including fuel, ice, bait, and lost gear), likely influencing the economic performance of the bottomfish fishery.

2.1.2 CNMI

Similar to Guam, the CNMI did not see any tourism rebound in 2021 as arrivals were down 86% relative to 2020[3] due to continued travel restrictions. A travel bubble program with South Korea was introduced during mid-2021 in an effort to build a model for rebuilding tourism in the CNMI[4]. Unemployment data are unavailable for the CNMI during 2021.

Trends in fishery landings and revenues are confounded by significant improvements in vendor reporting on Saipan during 2021. However, commercial landings and revenues for pelagic and insular fisheries were up approximately 55% and 59%, respectively. These values represent increases of 27% and 29% for landings and revenues, respectively, relative to a five year (2015 to 2019) pre-pandemic baseline. As noted in the socioeconomic module (Section 2.5), costs of bottomfish fishing in 2021 were higher than 2020 largely due to increased fuel costs.

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[1] https://www.guamvisitorsbureau.com/research/statistics/visitor-arrival-statistics.
[2] https://bls.guam.gov/.
[3] https://drive.google.com/file/d/14z56Q4sCwABjwcnqnq6Zeq7tqr1dwBFE/view.
[4] https://drive.google.com/file/d/102Bc8dd2Fzx4whUl9Y1bxDF93xOrqOup/view.

2.2 FISHER OBSERVATIONS

Hawaii fishermen Clay Tam and Roy Morioka started the fisher observations initiative in 2020 to add traditional and local ecological knowledge, and on-the-water observations to fishery-dependent data sources in the annual SAFE reports. Fisher observations from 2020 can be found in the pelagic and the respective archipelagic reports (WPRFMC 2021a; WPRFMC 2021b; WPRFMC 2021c; WPRFMC 2021d).

In 2021, the Council collected archipelagic fisher observations during quarterly advisory panel meetings for Guam and the CNMI. Input collected by fishers during these meetings was limited to Advisory Panel members. The Council also convened a meeting dedicated to Mariana Archipelago fisher observations on February 23, 2022. This meeting included Guam and CNMI Advisory Panel members but also included other individuals from their respective fishing communities. The full results from these fisher observation meetings will be made available as a PIFSC data report. The Mariana Archipelago fisher observations from 2021 presented here will begin with a summary of information from quarterly advisory panel meetings, separated by island, followed by a summary of archipelagic fisher observations data collected from the February meeting.

2.2.1 Information from Advisory Panel Meetings

2.2.1.1 CNMI

During the summer, an advisory panel member noted an algae bloom in the Tinian Marina and erosion at Tinian beaches, which made shoreline fishing access difficult. In the fall, advisory panel members noted increases in fuel prices and shark depredation. Shark depredation was observed on bottomfish fishing trips down to depths of 500 feet. At depths deeper than 500 feet, the likelihood for depredation decreased. An algal bloom also occurred within the Saipan lagoon.

2.2.1.2 Guam

In the summer, warmer than normal water temperatures may have affected fish movement. One advisory panel member also reported that bottomfishers were catching more fish when the northern islands were erupting. The bottomfish continued biting through the fall, with similar reports from Maug, where fishers were catching fish higher off the bottom. Rough weather later in the year limited fishing trips.

2.2.2 Information from the Annual Summit

On February 23, 2022, from 6:00 to 7:30 pm Chamorro Standard Time, the Council convened a fisher observations meeting with advisory panel members from Guam and the CNMI, along with other members of the fishing community. Hawaii fishermen Clay Tam and Roy Morioka convened and facilitated the meeting, and it was attended remotely by 14 Guam and CNMI fishers, Council staff, and three PIFSC staff. The focus of the meeting was to describe notable fishery events, changes in timing of fisheries events, issues to which the Council should pay attention, and consideration for causes behind any changes. Discussions were based upon an interview guide developed by advisory panel members, Council staff, and PIFSC staff members on the Council's Social Science Planning Committee (SSPC). Participants were asked follow up questions as needed related to different social, economic, ecological, and management (SEEM) aspects of the fishery to facilitate their use in fisheries science and management. These four

SEEM categories comprise a qualitative construct that have been used to complement the quantitative P* construct and process, and provide additional guidance when setting annual catch limits (Hospital et al. 2019).

The Guam and CNMI fisher observations meeting was not recorded, but PIFSC staff along with Council staff took detailed notes during the meeting and captured attendee quotes verbatim when possible, and if not verbatim, at least captured all main ideas. Main ideas were categorized topically using the SEEM categories, then into additional sub-categories to provide further detail on fisher observations from Guam and CNMI fishers in 2021. Below, their observations of archipelagic fisheries are separated and described using the SEEM categories.

2.2.2.1 Social

Social aspects of Guam and CNMI fisher observations were primarily related to fishing infrastructure and COVID-19 impacts. Rota fishers were pleased with the new marina but added that it still needs restrooms and water to rinse off boats. Improvements are also underway for Garapan fishing base. In terms of COVID-19 impacts, Guam fishers reported fewer boats fishing as COVID restrictions lifted and CNMI fishers expected increases in tournament participation as restrictions lifted there. Military training and exercises affected both Guam and CNMI fishers. Some fishers claimed they no longer received notices ahead of upcoming training exercises. A new military divert on Tinian is slated for completion in 2024-2025, but it is unclear to what affect, if any, it will have on fisheries. One CNMI fisher reported that friends shared their catch with him, which allowed him to keep eating fish even though he was not able to fish during the year.

2.2.2.2 Economic

The costs of fishing increased in Guam and the CNMI, with fuel prices upwards of $7 per gallon on Tinian, nearly $7 dollars on Rota, and in the $6 range on Saipan. These costs were compounded by increases in prices for fishing gear such as rods, reels, and lures. Reductions in visitor arrivals further limited market opportunities in Guam and the CNMI. In the CNMI, market prices dropped further when convoys travel to the northern islands and sell their large catches to local markets.

2.2.2.3 Ecological (Biological and Physical/Oceanographic)

A Guam fisher noted a good manahak run on the east side in May, but few runs thereafter. Another Guam fisher reported that all his bonita catch were spitting up manahak. He noted a large school of manahak outside of Agat Marina that was around each time he went fishing. A CNMI fisher observed a small baby rabbitfish run in November. Another CNMI fisher noted no atulai in the markets and indicated that their atulai run was short-lived and lasted just a week or two. One night he observed 15 small vessels catching atulai, but the activity stopped abruptly in October and November. Another CNMI fisher reported that atulai get wiped out immediately as soon were present. CNMI fishers noted a lot of turtles in the local marinas and in the lagoon in Saipan.

Spawning for onaga around the CNMI was not as good as the past few years. One fisher reported that it was not a good spawning group but added that onaga were bigger and better in early 2022. Another bottomfish fisher noted that there were almost no gonads on the onaga they caught, and they were good-sized fish. Thus, the fish were still in the early stages of maturity but not yet spawning. A Guam fisher heard that baby trevally and atulai were arriving early, as they usually arrive in June. He noted that the seasonal runs were not happening during the normal seasons and it is unclear whether it is due to overfishing or climate change. One Guam fisher reported chasing a school of medina down to Galvez Bank, 10 miles away. The fisher had 14 hits, but only landed seven individuals due to the sharks. Shark depredation seems to be getting worse around Guam, which left one fisher wondering if they recognize the sound of boats. The Guam fisher reported that deep bottomfish fishing had not been good, especially with all the sharks around. Due to the sharks, they only landed 1 to 2 bottomfish per trip.

The wind and weather returned to normal in 2021 after a long period of calm water in 2020. Some Guam bottomfish fishers were able to catch fish despite the strong wind and rough weather, but the rough water made some trips back to port more difficult. Similar wind and weather conditions were noted in the CNMI. Large tides were noted on Guam around Anderson Air Force Base and some high tides were experienced in the marina. Another fisher observed that they used to only get high tides during the summer, but now they seem to have extremely high tides year round. In terms of currents, one Guam fisher felt that the water was cooler and the currents were stronger in 2021. Another Guam fisher felt that the timing of currents had changed, but he was still able to catch bottomfish despite strong currents that forced him to switch to 6 pound weights instead of the normal 3 pounds in order to get his lines down to preferred depth and habitats.

2.2.2.4 Management Uncertainty

There were no comments from fishers pertaining to management.

2.3 CORAL REEF ECOSYSTEM PARAMETERS

2.3.1 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 2020. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new surveys occurred in 2020 or 2021 due to COVID-19 and the numbers presented here are identical to the 2019 report.

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 (PRIA)

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.

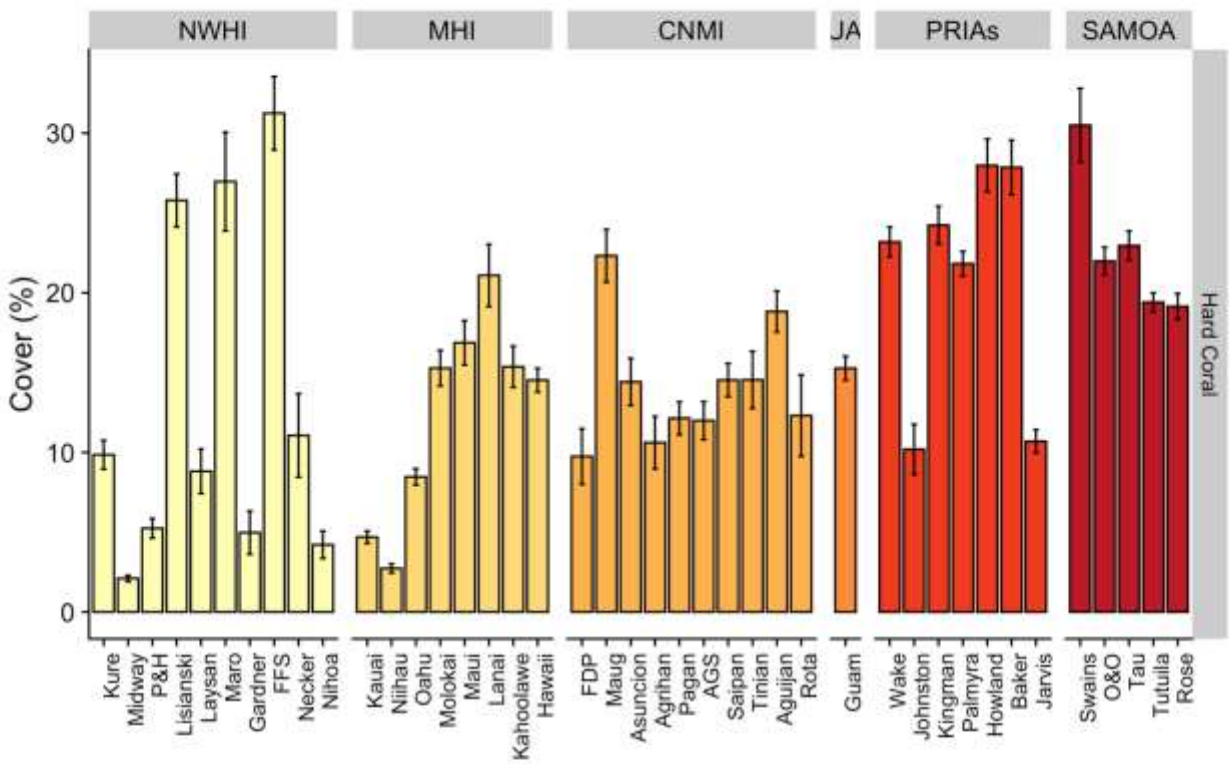


Figure 1. Mean coral cover (%) per U.S. Pacific island averaged over the years 2010-2020 by latitude

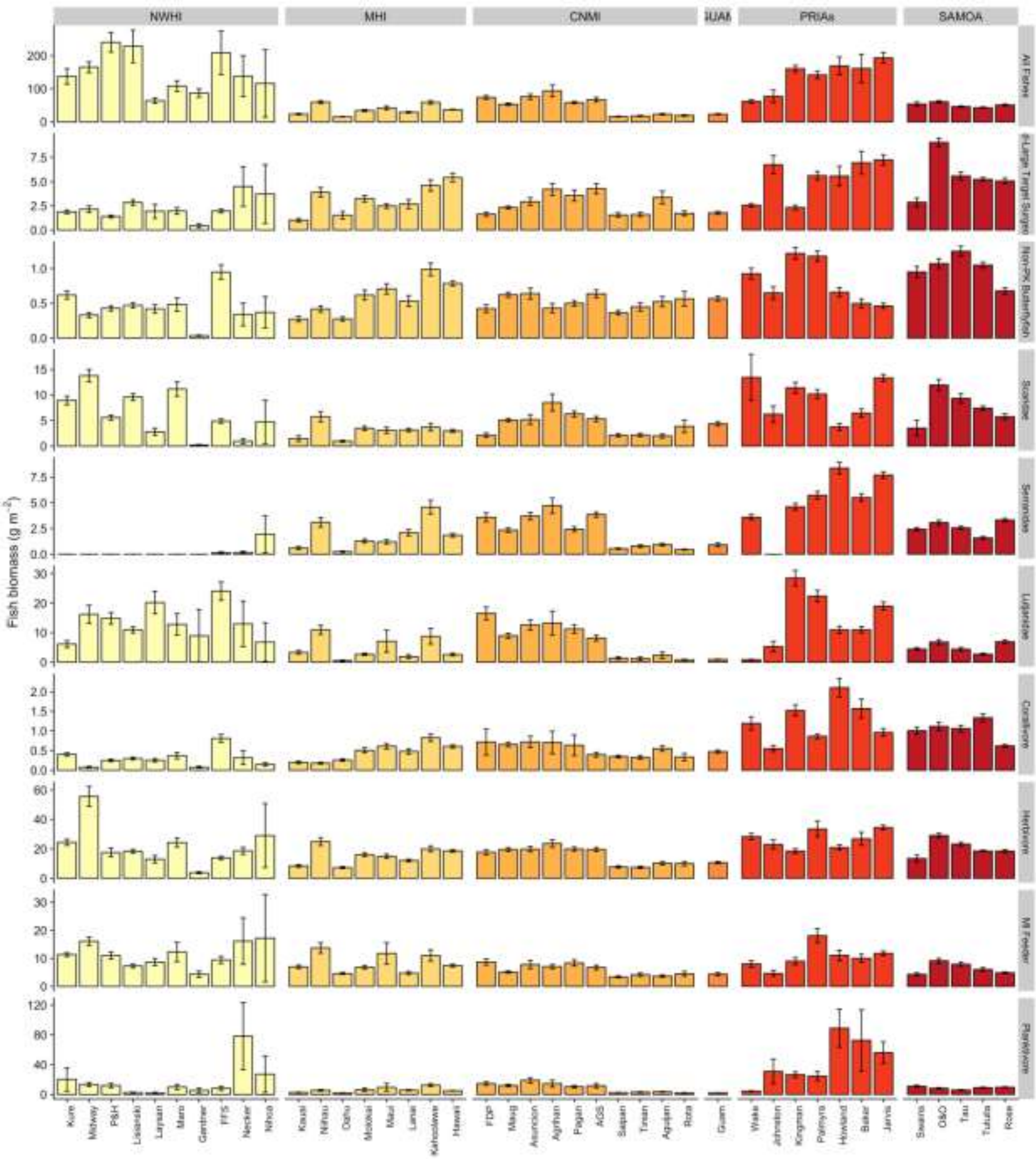


Figure 2. Mean fish biomass (g/m^2 ± standard error) of functional, taxonomic, and trophic groups by U.S. Pacific reef area from the years 2010-2020 by latitude. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can by hyper-abundant in some regions). Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group – as high biomass of that species at Wake Island overwhelms corallivore biomass at all other locations. The group 'MI Feeder' consists of fishes that primarily feed on mobile invertebrates

2.3.2 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 2020. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new surveys occurred in 2020 or 2021 due to COVID-19 and the numbers presented here are identical to the 2019 report.

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 2.3.1.

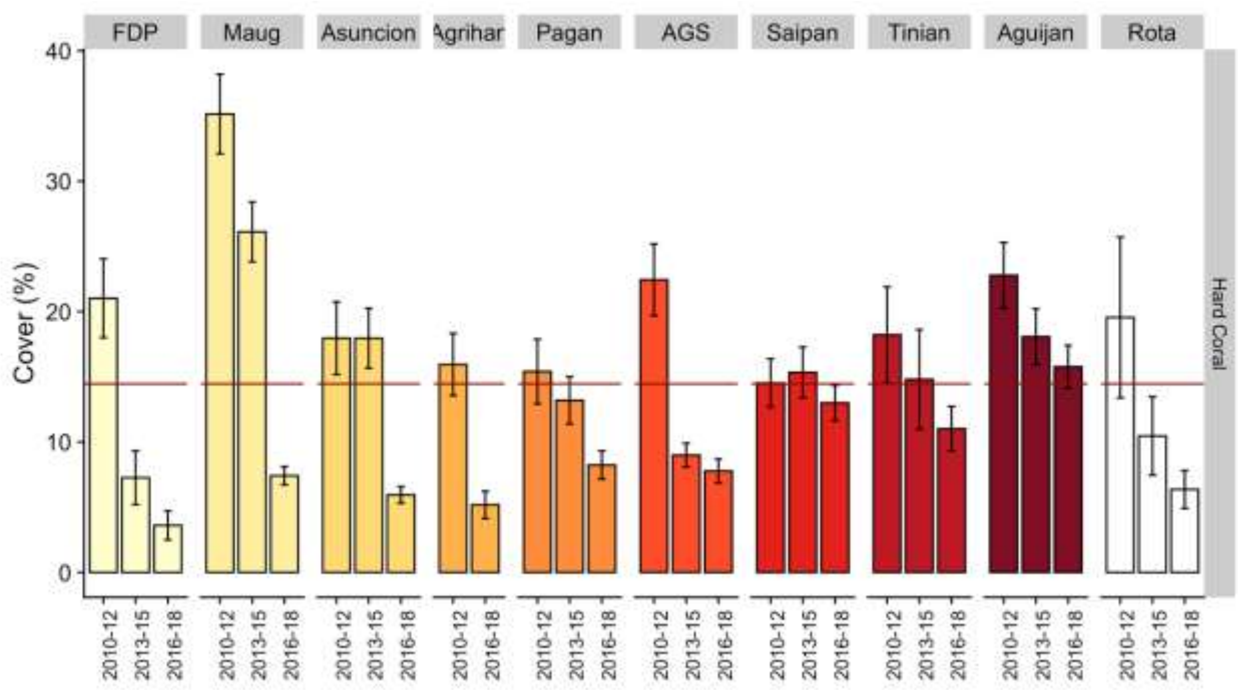


Figure 3. Mean coral cover (%) per island averaged over the years 2010-2020 by latitude with CNMI mean estimates plotted for reference (red line)

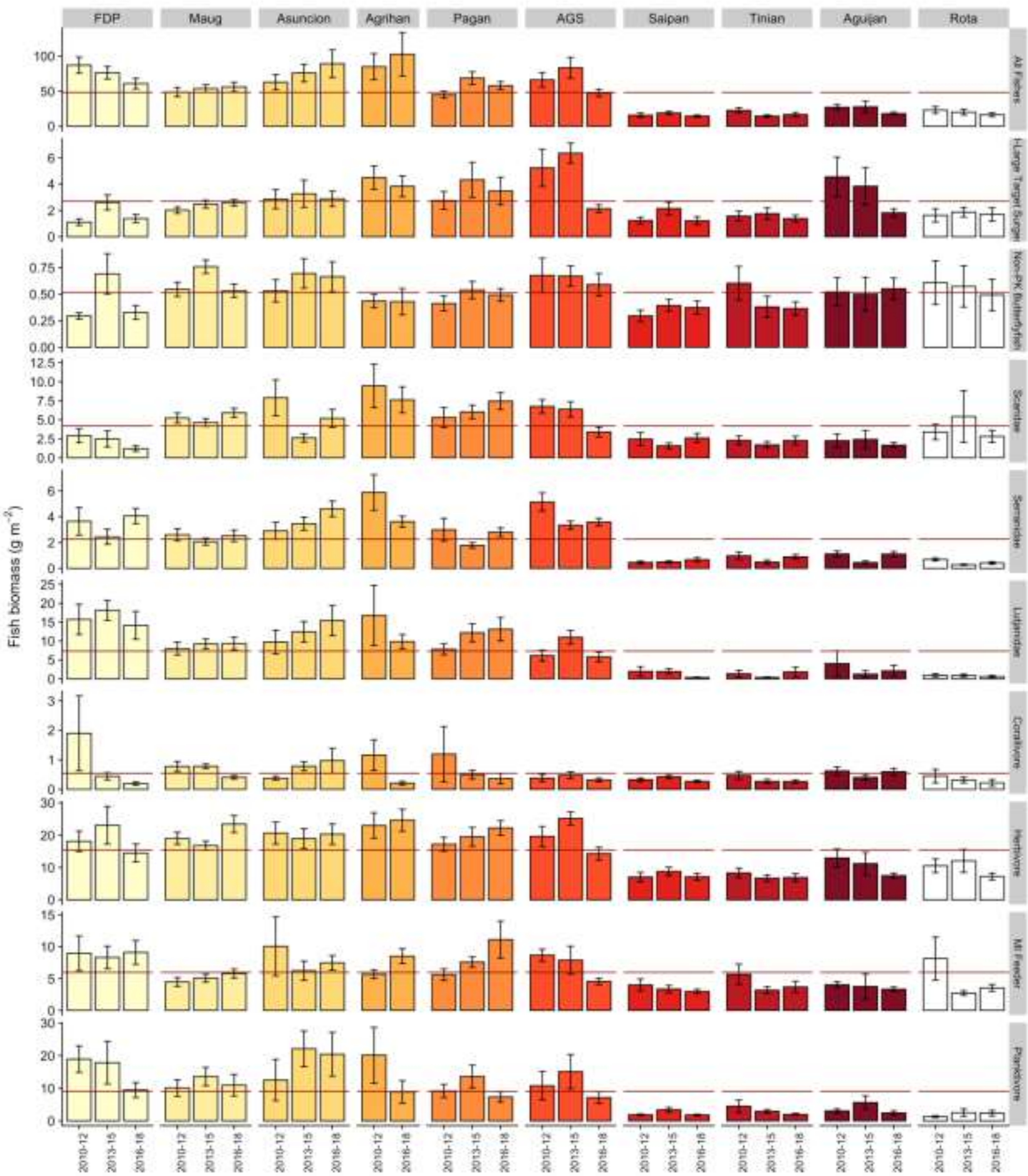


Figure 4. Mean fish biomass (g/m^2 ± standard error) of CNMI functional, taxonomic, and trophic groups from the years 2010-2020 by island. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can by hyper-abundant in some regions). Similarly, the bumphead parrotfish, *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)

2.3.3 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 2020. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new surveys occurred in 2020 or 2021 due to COVID-19 and the numbers presented here are identical to the 2019 report.

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 2.3.1.

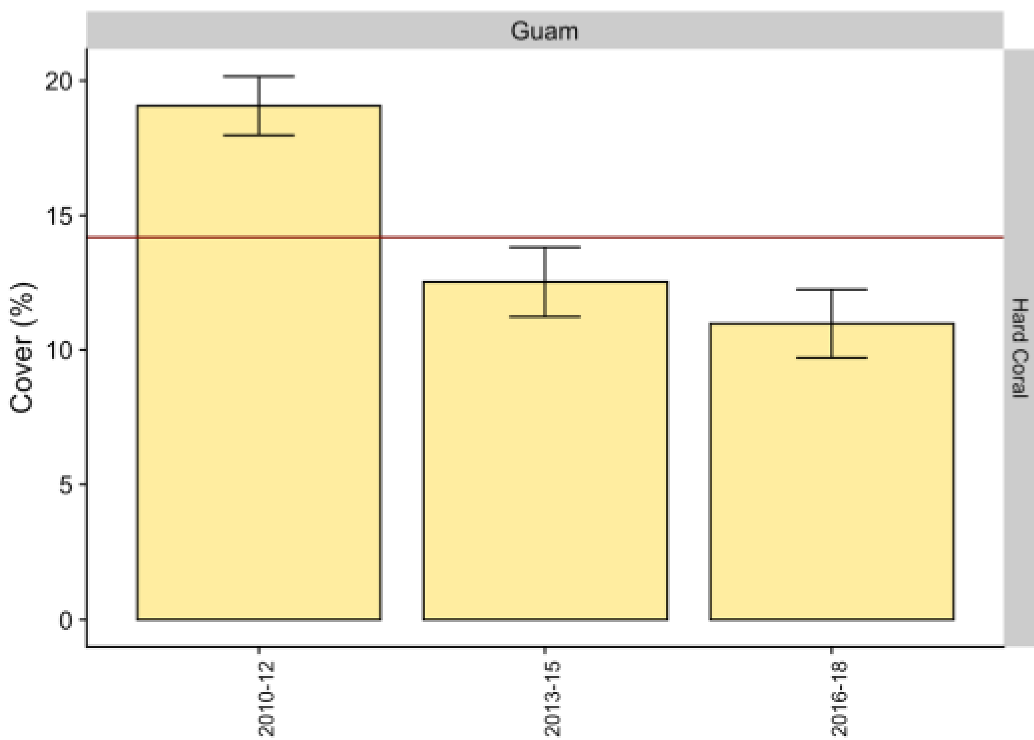


Figure 5. Mean coral cover (%) over the years 2010-2020 with mean for the entire time period plotted for reference (red line)

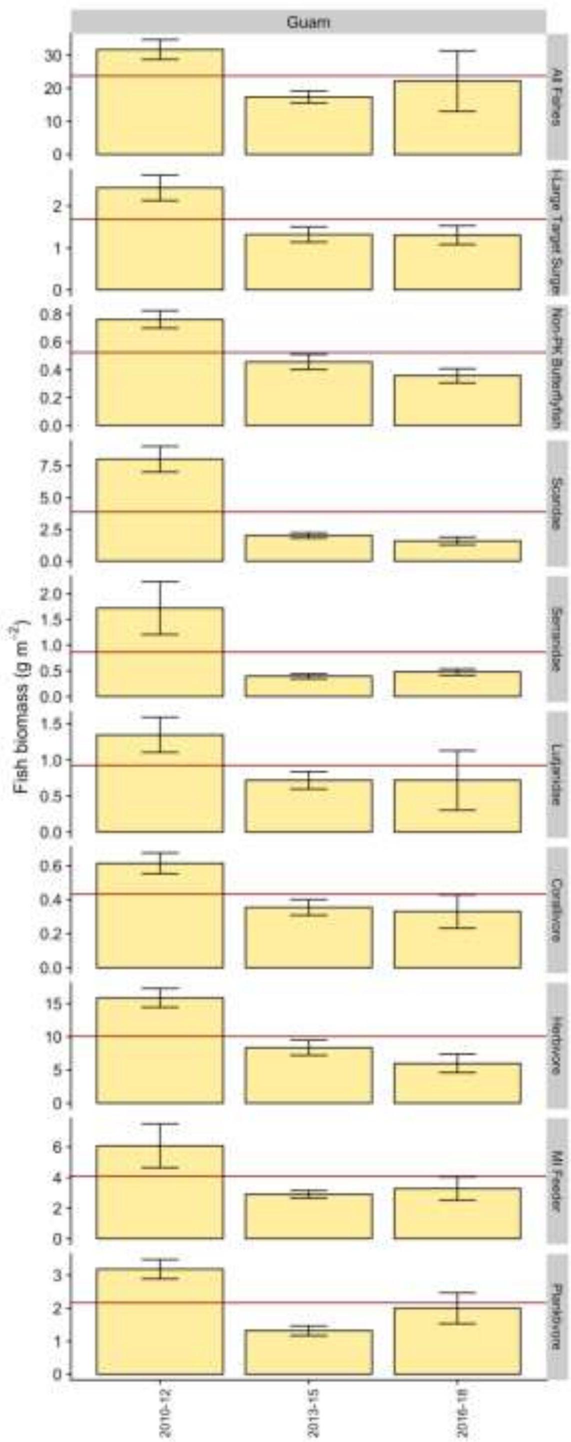


Figure 6. Mean fish biomass (g/m^2 ± standard error) of Guam functional, taxonomic, and trophic groups from the years 2010-2020. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can by hyper-abundant in some regions). Similarly, the bumphead parrotfish, *Bolbometopon 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)

2.4 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.

2.4.1 CNMI Coral Reef Ecosystem Components Life History

2.4.1.1 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 44 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 44. 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[d] m=0.44[d]	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. (2020)
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 is 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 the "Reference" column.

2.4.1.2 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: 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 45. 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	20,228	23.5	4927	0.03882	2.868	Matthews et al. (2019)
Lethrinus harak	2,697					
Mulloidichthys flavolineatus	12,516	31.4	2798	0.0138	3.05	Matthews et al. (2019)
Naso lituratus	28,507	30.1	3868	0.0163	3.103	Matthews et al. (2019)
Naso unicornis	12,481	53.6	4448	0.0269	2.908	Matthews et al. (2019)
Scarus ghobban[1]	7,612	38.1	1644	0.0129	3.12	Matthews et al. (2019)

Species	Length derived parameters					Reference
	n	L_{max}	$N_{L\text{-}W}$	a	b	
Scarus rubroviolaceus	4,032	52.6	1830	0.0089	3.24	Matthews et al. (2019)
Siganus argenteus	14,614	34.1	3961	0.0129	3.112	Matthews et al. (2019)

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

2.4.2 CNMI Management Unit Species Life History

2.4.2.1 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 46 for specific details on data sources by species.

Parameter Definitions: Identical to Section 2.4.2.1

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 46. 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							NA		NA	
Caranx ignobilis										
Caranx lugubris										
Etelis carbunculus[1]							NA		NA	
Etelis coruscans							NA		NA	
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)
Pristipomoides filamentosus[2]	31[c]	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	
Pristipomoides zonatus	X[a]	X[a]	X[a]	X[a]			NA		NA	LHP (in prep)

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
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 is 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 the "Reference" column.

2.4.2.2 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 2.4.1.2

<u>Rationale</u>: 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 47. Available length derived information for MUS species in CNMI

Species	Length derived parameters					Reference
	n	L_{max}	N_{L-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					
Pristipomoides 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.

2.4.3 Guam Coral Reef Ecosystem Components Life History

2.4.3.1 Age, Growth, and Reproductive Maturity

<u>Description</u>: 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 48 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 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 48. 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 is 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 the "Reference" column.

2.4.3.2 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 49. 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	1,157	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	4,223	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	20,618	57.2	7790	0.0267	2.92	Kamikawa et al. (2015)
Scarus rubroviolaceus	2,563	47.8	1713	0.0114	3.18	Kamikawa et al. (2015)
Siganus spinus	5,475	27.0	890	0.0284	2.87	Kamikawa et al. (2015)

2.4.4 Guam Management Unit Species Life History

2.4.4.1 Age, Growth, and Reproductive Maturity

<u>Description</u>: 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 50 for specific details on data sources by species.

Parameter Definitions: Identical to Section 2.4.3.1

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.

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 is 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 the "Reference" column.

Table 50. 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[c]	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	
Pristipomoides zonatus	f=19[d] m=30[d]	f=35.3[d] m=38.3[d]	f=0.27[d] m=0.29[d]	f=-2.03[d] m=-1.54[d]	0.22[d]	f=1.54[d] m=1.79[d]	NA	f=22.5[d] m=24.12[d]	NA	Schemmel et al. (2021)
Variola louti	f=11[c] m=14[c]	43.5[c]	0.26[c]	-1.1[c]	0.20[c]	2.2[c]	5.9[c]	26.0[c]	35.5[c]	Schemmel et al. (in prep)

[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).

2.4.4.2 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 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 2.4.3.2

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 51. 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)

Species	**Length derived parameters**					**Reference**
	n	L_{max}	$N_{L\text{-}W}$	***a***	***b***	
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[2]	223	0.0210	2.95	Kamikawa et al. (2015)
Pristipomoides sieboldii	411	63.2	130	0.0243	2.91	Kamikawa et al. (2015)
Pristipomoides 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] *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] 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.

2.5 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.

2.5.1 Response to Previous Council Recommendations

At its 185th meeting held via web conference in March 2021, the Council directed staff to review and analyze EO 13985 to Advance Racial Equity and Support Underserved Communities through the Federal Government. PIFSC staff are involved in the development of the NOAA strategy and are including concerns from the Pacific Islands Region into the national strategy.

Also at the 185th meeting, the Council directed staff to work with the SSC subgroup to finalize the plan incorporating PIFSC recommendations and the socioeconomic priorities identified by the SSPC in April 2021. These recommendations were included in the revised SSC plan.

At its 186th meeting held via web conference in June 2021, the Council directed the SSPC to work with the Advisory Panels to explore conducting periodic check-ins with the fishing communities to provide information for the fishery observations section of the SAFE report. The AP and SSPC formed a small working group that developed a framework for systematic gathering of fisher observations as part of the regular AP meetings for a new section of the SAFE report. The first set of meetings following this format will be held in 2022.

At its 189th meeting held via web conference in December 2021, PIFSC Social-Ecological and Economic Systems (SEES) Program staff presented the results of a cooperative project to develop a stakeholder engagement strategy in support of the territory bottomfish stock assessments, using Guam as a study site. The project is intended to be replicated in the other territories. The Council recommended the PIFSC SEES Program, in collaboration with the Council's Education and Outreach Program, develop a stakeholder engagement framework for American Samoa, CNMI, and Hawaiʻi to improve collaboration between stakeholders for the territorial bottomfish stock assessment. SEES staff have continued to work with the stock assessment program on stakeholder engagement and recently hired a staff member to focus on this type of engagement.

2.5.2 CNMI

2.5.2.1 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 17th and 18th 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).

Examination of the seascape of compliance across the US Pacific Island region found, that while the literature highlights the importance of enforcement, local experts emphasized barriers of capacity, governance process, and the lack of data. This suggests that non-instrumental and governance approaches can complement enforcement and should be part of an integrated compliance approach both in the region (Ayers and Leong 2020).

2.5.2.2 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 lb 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 than the general population and of comparable affluence. Pelagic trolling was the most popular gear type, followed by deepwater bottomfish fishing, shallow-water bottomfish fishing, 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.

2.5.2.2.1 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 bottomfish fishing. In general, deepwater bottomfish fishing 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%).

2.5.2.2.2 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).

2.5.2.2.3 CNMI Crustaceans

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

2.5.2.2.4 CNMI Precious Corals

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

2.5.2.3 CNMI Economic Performance

2.5.2.3.1 CNMI Bottomfish Commercial Participation, Landings, Revenue, Prices

This section will describe trends in commercial pounds sold, revenues and prices, for the CNMI bottomfish fishery.

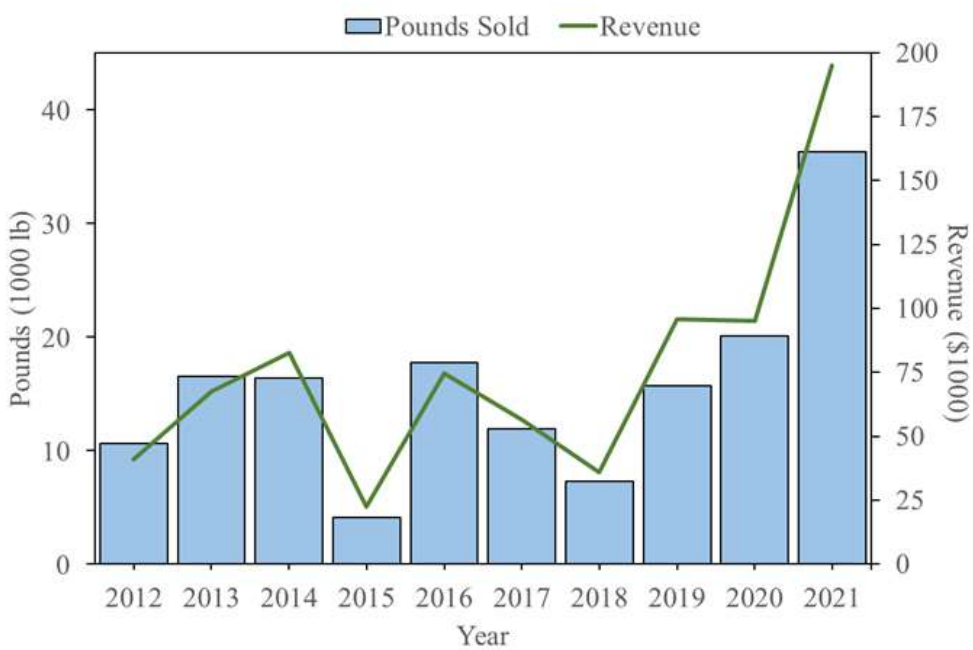


Figure **8** presents the trends of commercial pounds sold and revenues of bottomfish fishery (BMUS and boat-base creel surveys only) during 2012-2021 and Figure 9 presents the trend of fish price of bottomfish sold for the same period. Supporting data for

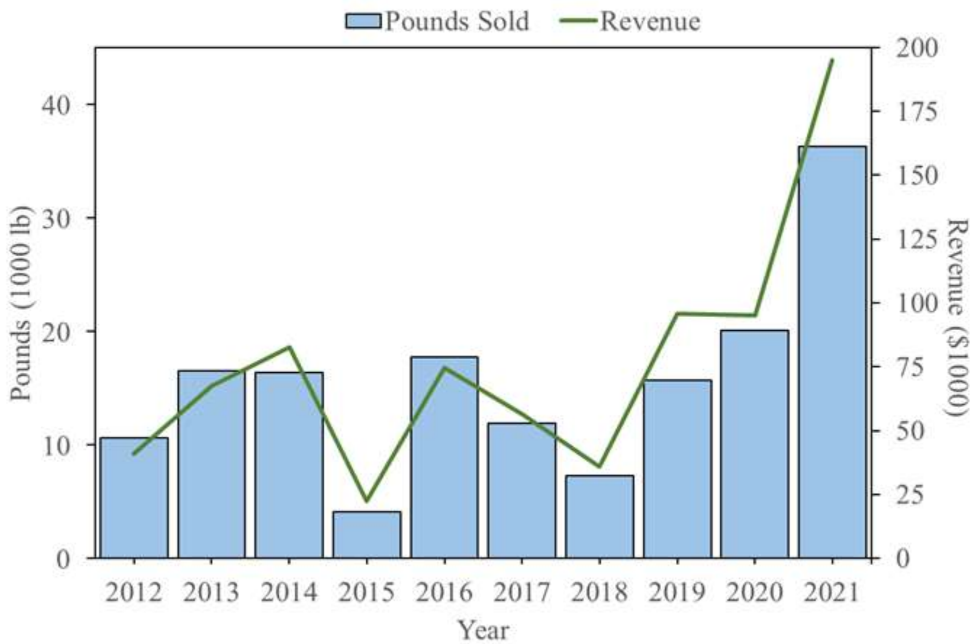
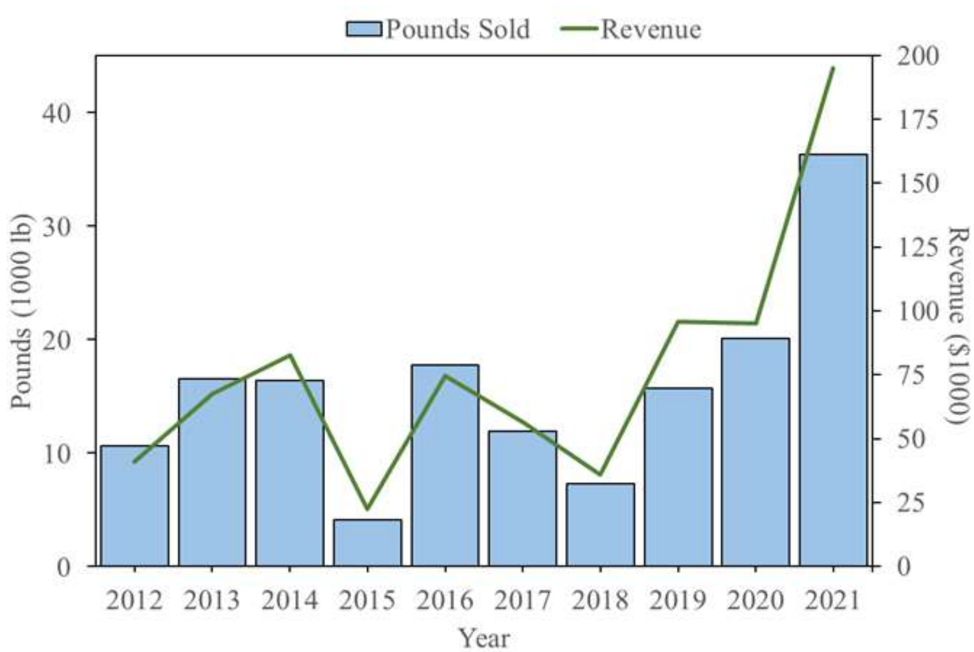


Figure **8** and Figure 9 are shown in Table 52. The table also includes the percentage of pounds sold relative to estimates of total pounds landed for the bottomfish fishery. Both nominal and adjusted values are included.



As shown in

Figure **8**, the commercial landings of CNMI bottomfish are quite stable except for two years (2015 and 2020). Commercial landings and revenue in 2021 were at a historical high considering the period of 2012-2021 at 36,303 pounds landed valued at $194,958. The pounds sold were 50% of the total landings in 2021. The 2021 increase in commercial landings are likely due to the improvement in reporting from more vendors. A mandatory reporting requirement was implemented in 2019 and outreach efforts have likely resulted in more vendors reporting. In total 37 out of an estimated 42 vendors reported in 2021. Fish prices dropped in 2020 from but it went up to $5.37 in 2021, although it was lower than the fish price ($6.10/lb) in 2019, which was the highest in the past 10 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" (only "Boat-based Creel Survey" information were included in the SAFE report since the majority of the BMUS were caught by boat fishing trips). 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 dealers participating 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 previous years and the estimated pounds caught were particularly low for 2014. Similarly, there is a very large discrepancy in 2018. It seems that there could be data quality concerns for the pounds landed estimation in some years.

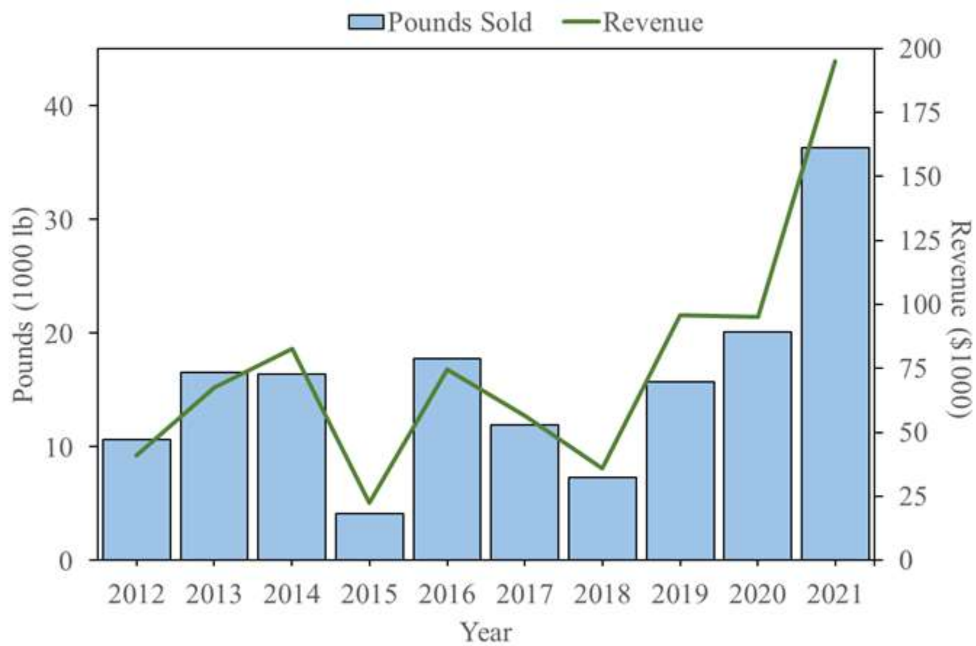


Figure 8. The commercial landings and revenues of BMUS, for the CNMI bottomfish fishery, 2012-2021 (Adjusted to 2021 dollars*)

*Note: CPI information for CNMI were not available since 2016, so this report assumed no CPI changes for the recent five years.

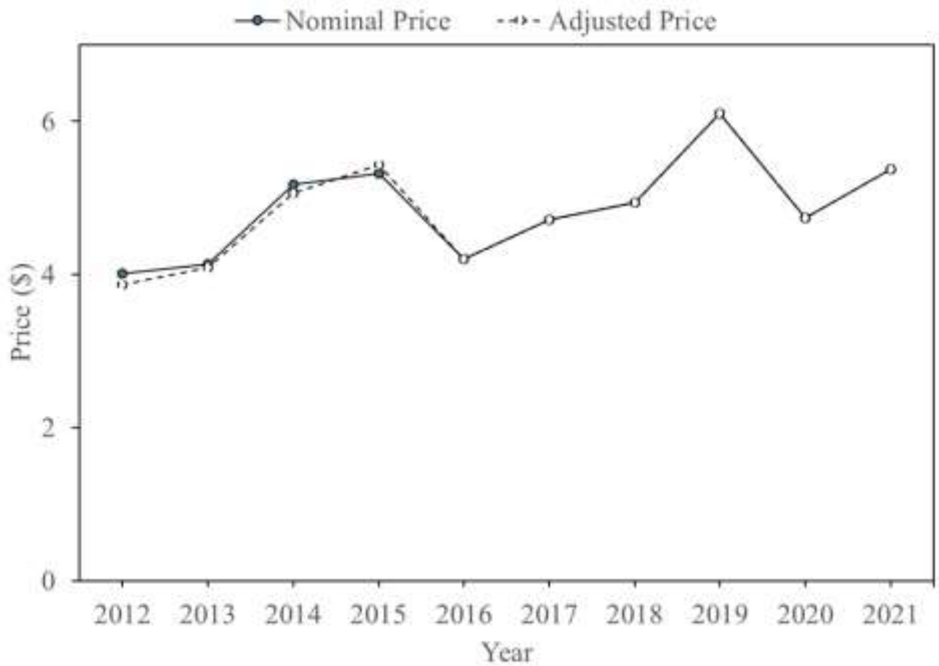


Figure 9. The prices of BMUS for the CNMI bottomfish fishery, 2012-2021

Table 52. Commercial landings and revenue information of CNMI bottomfish fishery, 2012-2021

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue ($)	Estimated revenue ($ adj.)	% of pounds sold	Fish price ($)	Fish price ($ adj.)	CPI adjustor
2012	137,496	10,591	42,471	40,985	8%	4.01	3.87	0.965
2013	20,392	16,500	68,211	67,529	81%	4.13	4.09	0.99
2014	7,740	16,334	84,508	82,733	211%	5.17	5.07	0.979
2015	10,386	4,122	21,917	22,377	40%	5.32	5.43	1.021
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
2020	45,547	20,071	95,197	95,197	44%	4.74	4.74	1
2021	73,017	36,303	194,958	194,958	50%	5.37	5.37	1

Data source: PIFSC FRMD-WPacFIN boat-based creel surveys (* CPI information for CNMI were not available since 2016, so this report assumed no CPI changes for the five years).

2.5.2.3.2 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 PIFSC FRMD (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 PIFSC. 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 PIFSC. Figure 10 shows the trend of average trip costs for CNMI bottomfish trips during 2012–2021 (adjusted to 2021 dollars). Supporting data of Figure 10 are presented in Table 53. The trip costs seem to have substantial interannual variability. The average cost for a bottomfish trip was $66 in 2021, higher than the trip costs in 2021, due to increased fuel cost. The cost data summaries were generated by excluding outliners (cases with >10 gallons/hours fished).

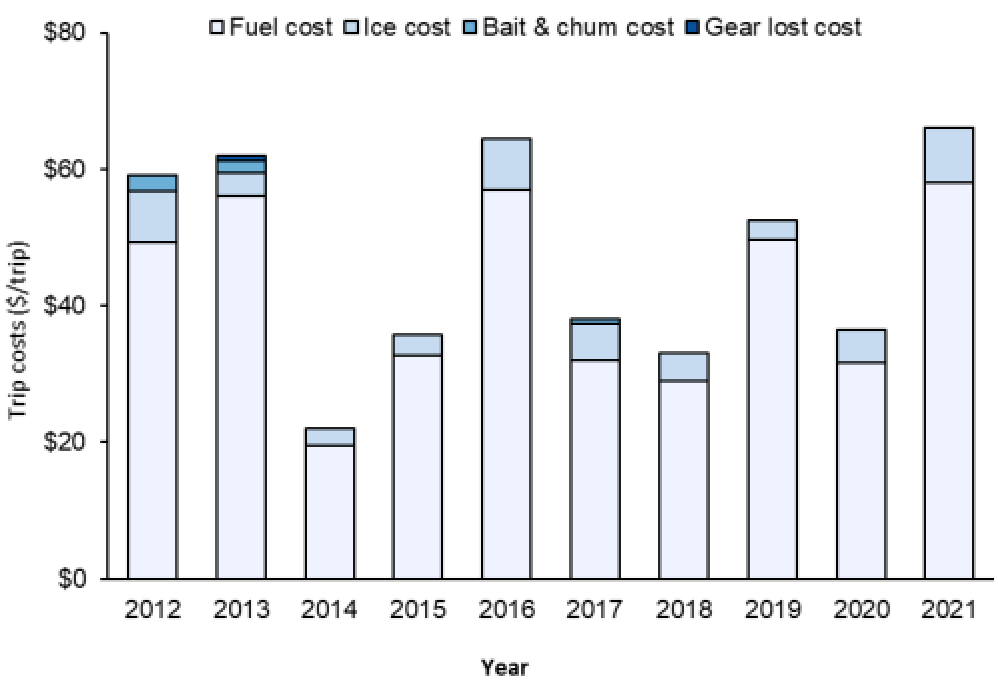


Figure 10. Average costs for CNMI bottomfish trips, 2012–2021 (adjusted to 2021dollars*)

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

Table 53. Average trip costs for CNMI bottomfish trips, 2012–2021, adjusted to 2021dollars*

Year	Total trip costs ($)	Total trip cost adj. ($)	Fuel cost adj. ($)	Ice cost adj. ($)	Bait cost adj. ($)	Gear losted adj. ($)	Fuel price adj. ($/gallon)	CPI Adjustor
2012	61	59	49	8	2	0	4.74	0.965
2013	63	62	56	3	2	1	4.96	0.990
2014	22	22	19	3	0	0	4.83	0.979
2015	35	36	33	3	0	0	4.16	1.021
2016	65	65	57	8	0	0	3.59	1.000
2017	38	38	32	5	1	0	3.87	1.000
2018	33	33	29	4	0	0	4.17	1.000
2019	53	53	50	3	0	0	3.94	1.000
2020	37	37	32	5	0	0	3.90	1.000
2021	66	66	58	8	0	0	4.79	1

* CPI information for CNMI were not available for 2016 and the year after. Data source: PIFSC Continuous Cost Data Collection Program (Chan and Pan 2019).

2.5.2.3.3 CNMI Ecosystem Component Species

Based on new guidelines for the archipelagic SAFE report from the Council, this section highlights the top 10 Ecosystem Component Species (ECS) (sorted by landings) and the priority ECS (selected 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 data sources, 2) differences in 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 for "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 54 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 66,754 lb (valued at $223,949) in 2021, nearly double to the values of 2020.

Table **55** shows the ECS priority species. Eight fish species were suggested as priority species (species of interests) for the area. Only one species of the eight species showed up in the commercial receipt books in 2021 and 2020. Comparison between commercial landings vs. total landings might not be straight forward since two data series were collected under different data collection systems and the species/species groupings might not be consistent between the two.

Table 54. Top 10 ECS Commercial landings, revenue, and price, 2020 and 2021

	2021			2020		
Top ECS Species	Pounds Sold	Revenue	Price per Pound	Pounds Sold	Revenue	Price per Pound
Assorted	13,421	40,376	3.01	11,000	32,630	2.97
Bigeye scad	3,456	13,437	3.89			
Jacks (misc.)	3,383	10,362	3.06	2,209	6,463	2.93
Rabbitfish/hitting	4,229	16,760	3.96			
Rudderfish/guili	2,905	8,962	3.09	1,856	5,109	
Emperor (mafute/misc.)	4,985	15,357	3.08	3,777	10,797	
Parrot (misc)/palakse/la	14,046	58,544	4.17	5,599	21,996	3.93
Surgeonfish (misc.)	10,007	29,755	2.97	7,750	20,900	2.70
Orangespine unicornfish	5,716	16,804	2.94	2,840	7,922	2.79
Goatfish/satmoneti	4,606	13,592	2.95	1,245	3,474	2.79
Squirrelfish/sagamelon				862	2,407	2.79
Unicornfish/tataga				1,029	2,841	2.76
Sum	66,754	**223,949**	3.35	38,167	**114,539**	3.00

Data source: PIFSC FRMD-WPacFIN boat-based creel survey, commercial receipt books.

Table 55. Priority ECS commercial landings, revenue, and price 2020 and 2021

	2021			2020		
Priority Species	Pounds Sold	Revenue ($)	Price ($/lb)	Pounds Sold	Revenue ($)	Price ($/lb)
Orangespine unicornfish	5,716	16,804	2.94	2,840	7,922	2.79

Data source: PIFSC FRMD, commercial receipt books.

2.5.3 Guam

2.5.3.1 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 in 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 (NCRMP 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 bottomfish fishing 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 in 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 in 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.

2.5.3.2 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, bottomfish fishing, 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 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.

2.5.3.2.1 Guam Bottomfish

Allen and Bartram (2008) reviewed the history of the bottomfish fishery in Guam, which consists of both shallow- and deepwater 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 bottomfish fishing 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%).

2.5.3.2.2 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%).

2.5.3.2.3 Guam Crustaceans

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

2.5.3.2.4 Guam Precious Corals

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

2.5.3.3 Guam Fishery Economic Performance

2.5.3.3.1 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 2012-2021 and Figure 12 presents the trend of total caught versus commercial landings pounds sold during 2012-2021 (for BMUS and boat-base surveys only). Supporting data for Figure 11 and Figure 12 are shown in Table 56. Table 56 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. However, only two years (2017 and 2018) of data are presented in the charts and tables, because the data for most of the other years were confidential due to fewer than three participating vendors in the data.

As shown in Figure 11, only two years (2017 and 2018) of commercial landings and revenue are presented. The total commercial landings and revenue were estimated/expanded based on the sample data provided by dealers who participated the receipt book data collection program. Trends in fish prices were not presented for the same data confidentiality concerns. The commercial landings were approximately 4,000 pounds, valued 17,434 in 2017, and 3,000 pounds valued 15,290 in 2018. The bottomfish fishery price in 2018 was $5.05 per pound and $4.36 in 2017 on average. Compared to total pounds landed, the commercial landings of BMUS were only small portion. On average, in the two years (2017 and 2018), the pounds sold were only 19% of total estimated pounds caught. Bottomfish prices have been steady in general, but there have been some variations in recent years. In 2021, the total commercial landings were higher than the 10-year-average and also higher than 2019 (the year prior the pandemic). However the ratio of the commercial landings to the total landings of BMUS was lower in 2021, while total landings were the highest among the past 10 years, more than two times of the 10 years average.

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. 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.

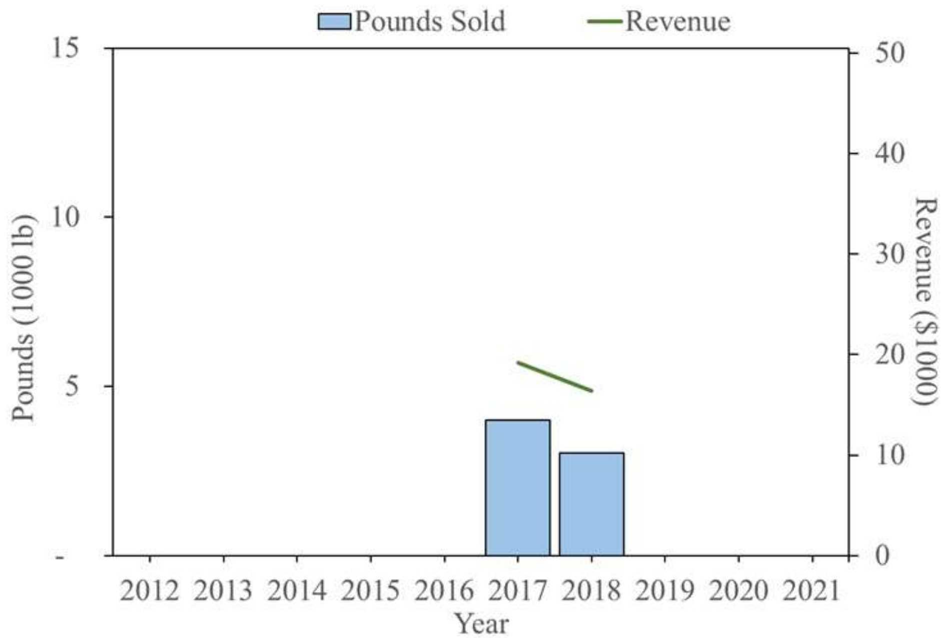


Figure 11. The pounds sold and revenues for the Guam bottomfish fishery, 2012-2021 (adjusted to 2021 dollars)

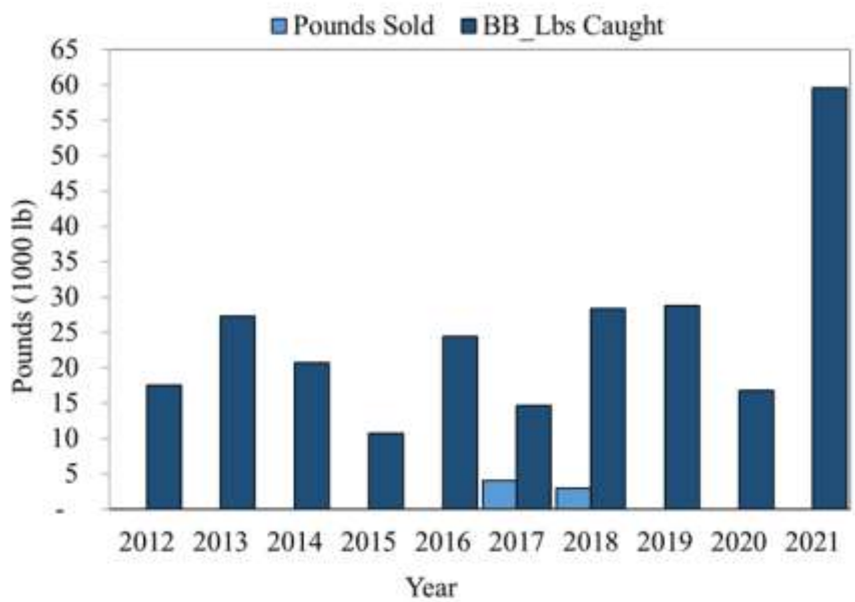


Figure 12. Pounds caught and pounds sold of BMUS for the Guam bottomfish fishery, 2012-2021

Table 56. Commercial landings, revenue, and price information of Guam bottomfish fishery, 2012-2021

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue ($)	Estimated revenue ($ adj.)	% of pounds sold	Fish price ($)	Fish price ($ adj.)	CPI adjustor
2012	17,517	*	*	*	*	*	*	1.195
2013	27,276	*	*	*	*	*	*	1.195
2014	20,687	*	*	*	*	*	*	1.186
2015	10,783	*	*	*	*	*	*	1.197
2016	24,480	*	*	*	*	*	*	1.130
2017	14,652	4,002	17,434	19,212	27%	4.36	4.80	1.102
2018	28,365	3,028	15,290	16,437	11%	5.05	5.43	1.075
2019	28,849	*	*	*	*	*	*	1.056
2020	16,844	*	*	*	*	*	*	1.038
2021	59,593	*	*	*	*	*	*	1

* Confidential (fewer than 3 participating vendors). Data source: PIFSC FRMD-WPacFIN.

2.5.3.3.2 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 PIFSC FRMD (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 PIFSC. 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 PIFSC FRMD-WPacFIN. The fishing costs of bottomfish were in a declining trend from 2012-2016, and then went up substantially in 2017. 2021 trip costs went up significantly compared to 2020, due to increasing costs across all cost items. . Supporting data for are presented in Table 57. The cost data summaries were generated by excluding outliners (cases with >10 gallons/hours fished).

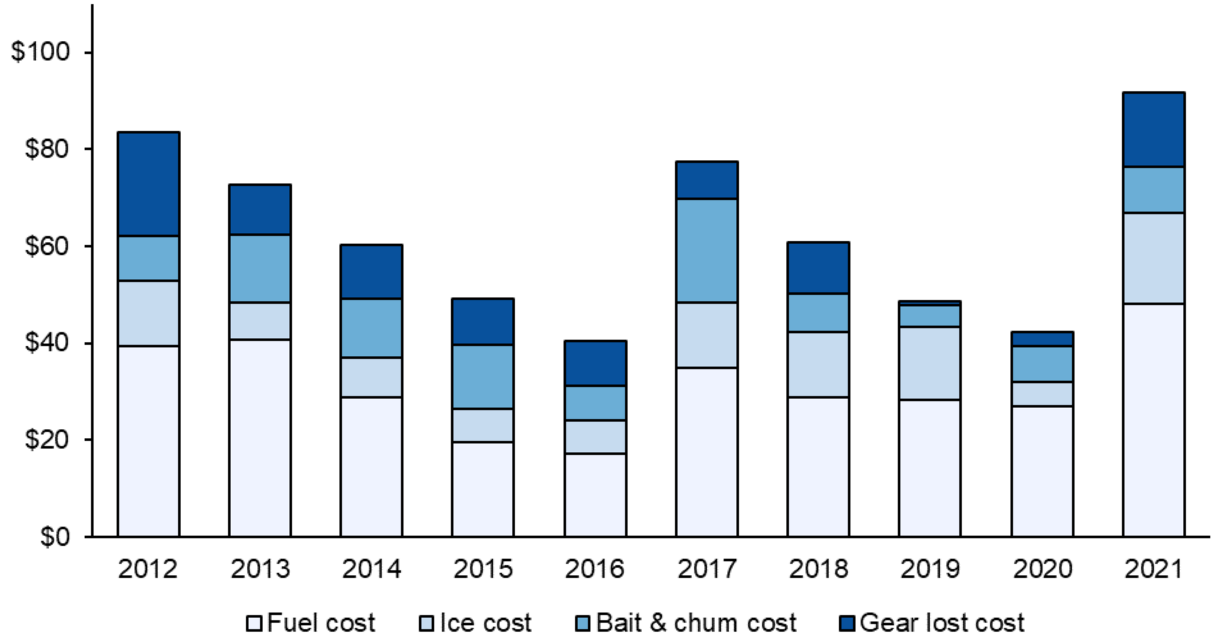


Figure 13. Average trip costs for Guam bottomfish fishing trips from 2012–2021 (adjusted to 2021 dollars).

Table 57. Average trip costs for Guam bottomfish fishing trips from 2012–2021

Year	Total trip costs ($)	Total trip cost adj. ($)	Fuel cost adj. ($)	Ice cost adj. ($)	Bait cost adj. ($)	Gear losted adj. ($)	Fuel price adj. ($/gallon)	CPI Adjustor
2012	70	84	39	14	9	22	5.53	1.188
2013	61	73	41	8	14	10	5.70	1.198
2014	51	60	29	8	12	11	5.61	1.131
2015	41	49	19	7	13	9	4.67	1.103
2016	36	40	17	7	7	9	3.85	1.075
2017	70	78	35	13	21	8	3.99	1.056
2018	57	61	29	13	8	10	4.20	1.038
2019	46	49	28	15	5	1	4.05	1.000
2020	41	42	27	5	7	3	3.46	1.236
2021	92	92	48	19	10	15	4.38	1.197

2.5.3.3.3 Guam Ecosystem Component Species

Based on the new guideline for the archipelagic SAFE report from the Council, this section highlights 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 data sources, 2) differences in 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 for "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. In the case of the top 10 species in Guam, the sum of the top 10 commercial species landings is higher than the sum of the top 10 species landings. 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 58 shows the commercial landings and revenue of the top 10 ECS in Guam for 2020 and 2021. However, the data are not presented here due to confidentiality concerns for these two years. The total pounds sold of the top 10 species/species groups in 2020, was only 37% of the 2019 level. In 2021, it went down further. Regarding to the nine priority species (species of interests) for the area, only one species showed up with commercial landings in 2020, but not in 2021. The detailed commercial landings data were confidential.

Table 58. Top 10 ECS commercial landings, revenue, and price, 2020 and 2021*

	2021			2020		
Top ECS Species	Estimated Pounds Sold	Estimated Revenue	Price per Pound	Estimated Pounds Sold	Estimated Revenue	Price per Pound
Bigeye scad (atulai)	*	*	*	*	*	*
Jacks	*	*	*	*	*	*
Bottom fish	*	*	*	*	*	*
Grouper	*	*	*	*	*	*
Uku (gray snapper)	*	*	*	*	*	*
Amberjack	*	*	*	*	*	*
Reef fish	*	*	*	*	*	*
Mafute (emperor)	*	*	*	*	*	*
Blueline surgeonfish	*	*	*			
Miscellaneous	*	*	*			
Parrotfish				*	*	*
Surgeonfish				*	*	*
Sum	*	*	*	*	*	*

* Confidential (fewer than 3 participating vendors).

2.5.4 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 2021. 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 59. Pacific Islands Region 2021 Commercial Fishing Economic Assessment Index

	2021 CFEAI				
	2021 Reporting Year (e.g. 1/2021-12/2021)				
	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	2021	2021	2013	2021	2016
ASam Longline	2021	2021	2016	2021	2019
HI Offshore Handline	2021	2014	2014	2019	2019
HI Small Boat (pelagic)	2021	2021	2021	2017	2019
HI Small Boat (bottomfish)	2021	2021	2021	2017	2019
HI Small Boat (reef)	2021	2021	2021	2017	2019
Guam Small boat	**2021**	**2021**	**2019**	**2019**	
CNMI Small boat	**2021**	**2021**	**2019**	**2019**	
ASam Small boat	2021	2021	2021	2019	

PIFSC maintained ongoing economic data collections in the CNMI and Guam for small boat fisheries (Chan and Pan 2019) during 2021.

PIFSC also generates projections for upcoming fiscal years, and the table below provides the projected CFEAI report for 2022 (*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 2022.

Table 60. Pacific Islands Region 2022 Commercial Fishing Economic Assessment Index

	2022 Projected CFEAI				
	2022 Reporting Year (e.g. 1/2022-12/2022)				
	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	2022	2022	2022	2022	2022
ASam Longline	2022	2022	2016	2022	2016
HI Offshore Handline	2022	2014	2014	2019	2019
HI Small Boat (pelagic)	2022	2021	2021	2022	2022
HI Small Boat (bottomfish)	2022	2021	2021	2022	2022
HI Small Boat (reef)	2022	2021	2021	2022	2022
Guam Small boat	**2022**	**2022**	**2019**	**2019**	
CNMI Small boat	**2022**	**2022**	**2019**	**2019**	
ASam Small boat	2022	2022	2021	2022	

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. Efforts to complete the analysis of the 2018-2019 cost-earnings have been delayed due to staff departures coupled with COVID-19 monitoring requirements and PIFSC intends final survey results to be published in early 2022.

Community social indicators have been generated for Guam and the CNMI (Kleiber et al. 2018) in accordance with a national project to describe and evaluate community well-being in terms of environmental justice, economic vulnerability, and gentrification pressure (https://www.fisheries.noaa.gov/national/socioeconomics/social-indicators-coastal-communities). However, these indicators rely on Census data, and cannot be updated until 2020 Census data becomes available, perhaps in 2022

2.5.5 Relevant PIFSC Economics and Human Dimensions Publications: 2021

Publication	**MSRA priority**
Hedelin B, Gray S, Woehlke S, BenDor TK, Singer A, Jordan R, Zellner M, Giabbanelli P, Glynn P, Jenni K, Jetter A, Kolagani N, Laursen B, Leong KM, et al. 2021. What's left before participatory modeling can fully support real-world environmental planning processes: A case study review. Environmental Modelling & Software. 143:105073. https://doi.org/10.1016/j.envsoft.2021.105073	HC2.1.2 HC2.2.1 HC2.2.2 IF8.1.1
Hospital J, Leong K, Sweeney J. 2021. Pacific Islands Fisheries Impacts from COVID-19. 10p. (in: NOAA Fisheries National COVID-19 Preliminary Baseline Impact Assessment). https://media.fisheries.noaa.gov/2021-02/Initial-COVID-19-Impact-Assessment-webready.pdf	HC1.1.1 HC2.1.3 HC2.2.1

Hospital J, Iwane M, Kleiber D, Leong K, Sweeney J. 2021. Pacific Islands Fisheries Impacts from COVID-19 – Pacific Islands Snapshot March – July 2020. 10p. https://media.fisheries.noaa.gov/2021-02/Pacific-Islands-COVID-19-Impact-Snapshot-webready.pdf	HC1.1.1 HC2.1.3 HC2.2.1
Hospital J, Iwane M, Kleiber D, Leong K, Sweeney J. 2021. Pacific Islands Fisheries Impacts from COVID-19 (in NMFS. 2021. U.S. Seafood Industry and For-hire Sector Impacts from COVID-19: 2020 in Perspective. NOAA Tech. Memo. NMFS-SPO-221, 88 p. https://spo.nmfs.noaa.gov/sites/default/files/TM221.pdf	HC1.1.1 HC2.1.3 HC2.2.1
Johnson E, Champ JG, Leong K, Melena S. 2021. Content evaluation of the response to the centennial Find Your Park Campaign. Natural Resource Report. NPS/NRSS/NROC/NRR-2021/2242. National Park Service. Fort Collins, Colorado. https://doi.org/10.36967/nrr-2284970	HC3.2.4
Kasperski S, DePiper GS, Blake S, Colburn LL, Jepson M, Haynie AC, Karnauskas M, Leong KM, Lipton D, Masi M, et al. 2021. Assessing the State of Coupled Social-Ecological Modeling in Support of Ecosystem Based Fisheries Management in the U.S. Front. Mar. Sci. https://doi.org/10.3389/fmars.2021.631400	HC2.1.1 HC2.1.2 HC2.1.4 IF8.1.1
Pan M. 2021. Maximum Economic Yield and Non-Linear Catchability. North American Journal of Fisheries Management. http://doi.org/10.1002/nafm.10661	IF3.1.2
Tommasi D, deReynier YL, Townsend H, Harvey CJ, Satterthwaite W, Marshall KN, Kaplan IC, Brodie S, Field J, Hazen E, et al. 2021. A Case Study in Connecting Fisheries Management Challenges With Models and Analysis to Support Ecosystem-Based Management in the California Current Ecosystem. Frontiers in Marine Science. 8:776. https://doi.org/10.3389/fmars.2021.624161	IF8.1.1 IF8.1.6 HC2.1.2
Williams GD, Andrews KS, Brown JA, Gove JM, Hazen EL, Leong KM, Montenero KA, Moss JH, Rosellon-Druker JM, Schroeder ID, Siddon E. 2021. Place-Based Ecosystem Management: Adapting Integrated Ecosystem Assessment Processes for Developing Scientifically and Socially Relevant Indicator Portfolios. Coastal Management. 49(1):46-71. https://doi.org/10.1080/08920753.2021.1846154	IF8.1.1 HC2.2.1 HC3.1.3

2.6 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.

2.6.1 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.

2.6.2 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.

2.6.2.1 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 61.

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 61. 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.

2.6.2.1.1 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 (extended on August 11, 2020, December 15, 2020, and February 9, 2022), 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).

2.6.2.1.2 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.

2.6.2.1.3 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 on 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.

2.6.2.1.4 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.

2.6.2.2 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 2022 LOF (87 FR 23122, April 19, 2022) 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).

2.6.3 Status of Protected Species Interactions in the Marianas FEP Fisheries

2.6.3.1 Bottomfish Fisheries

2.6.3.1.1 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.

2.6.3.1.2 Elasmobranch Interactions

As indicated in Section 2.6.2.1, 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).

2.6.3.2 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.

2.6.3.3 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.

2.6.4 Identification of Emerging Issues

Table 62 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 62. 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 U.S. jurisdiction that meet definition of critical habitat (85 FR 12898, 3/5/2020)	In development; recovery planning workshops convened in 2019.
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 U.S. 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; recovery planning workshop planned for 2021.
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)	Critical habitat proposed (85 FR 76262, 11/27/2021), comment period extended through 5/26/2021 (86 FR 16325)	In development, interim recovery outline in place; recovery workshops convened in May 2021.
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
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)	No critical habitat designated for waters around the Mariana Archipelago (86 FR 21082, 4/21/21)	TBA
Shortfin Mako Shark	*Isurus oxyrinchus*	Positive (86 FR 19863, 04/15/2021	TBA (status review ongoing)	TBA	N/A	N/A

2.6.5 Identification of Research, Data, and Assessment Needs

[*THIS SECTION MAY BE UPDATED FOLLOWING THE PLAN TEAM MEETING*]

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.

2.7 CLIMATE AND OCEANIC INDICATORS

2.7.1 Introduction

Over the past several years, the Council has incorporated climate change into the overall management of the fisheries over which it has jurisdiction. This 2020 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 Committee (MPCCC). 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. However, 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.

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.

2.7.2 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 for the Mariana Archipelago in 2021.

2.7.3 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).

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.

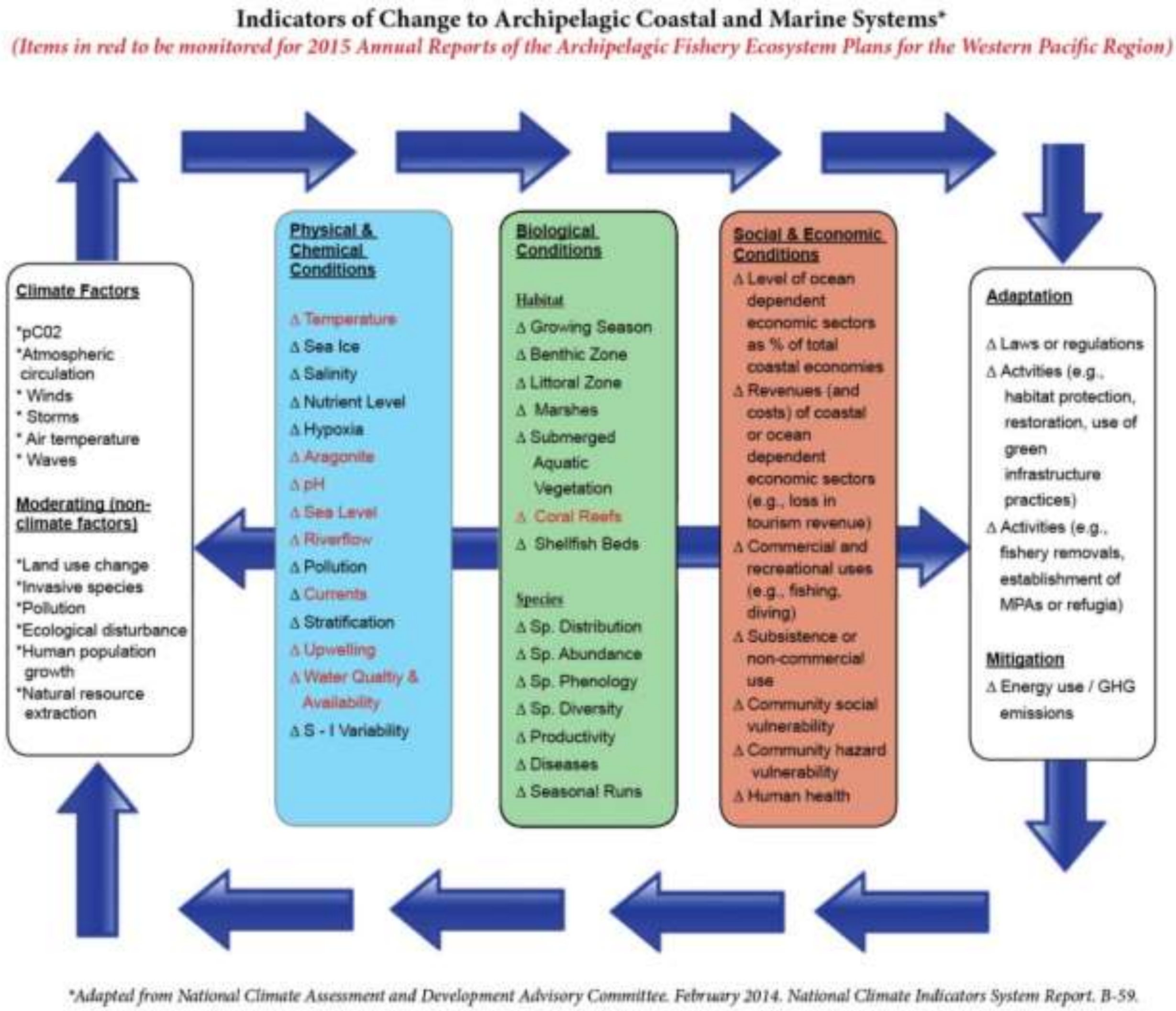


Figure 14. Indicators of change of archipelagic coastal and marine systems; conceptual model

2.7.4 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.

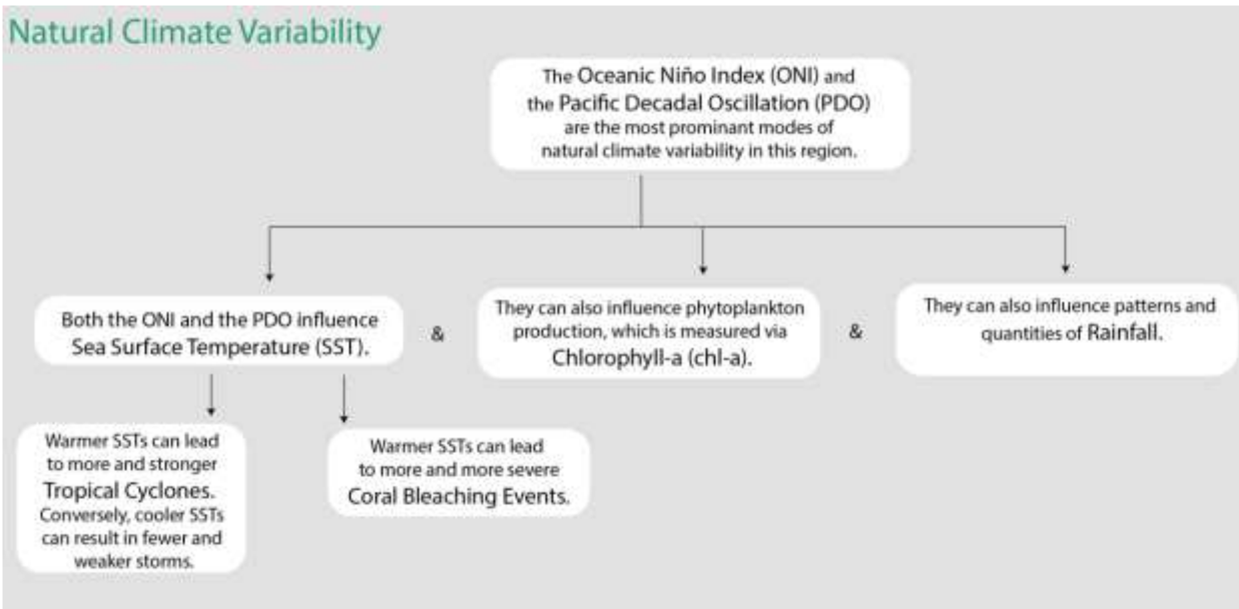


Figure 15. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability

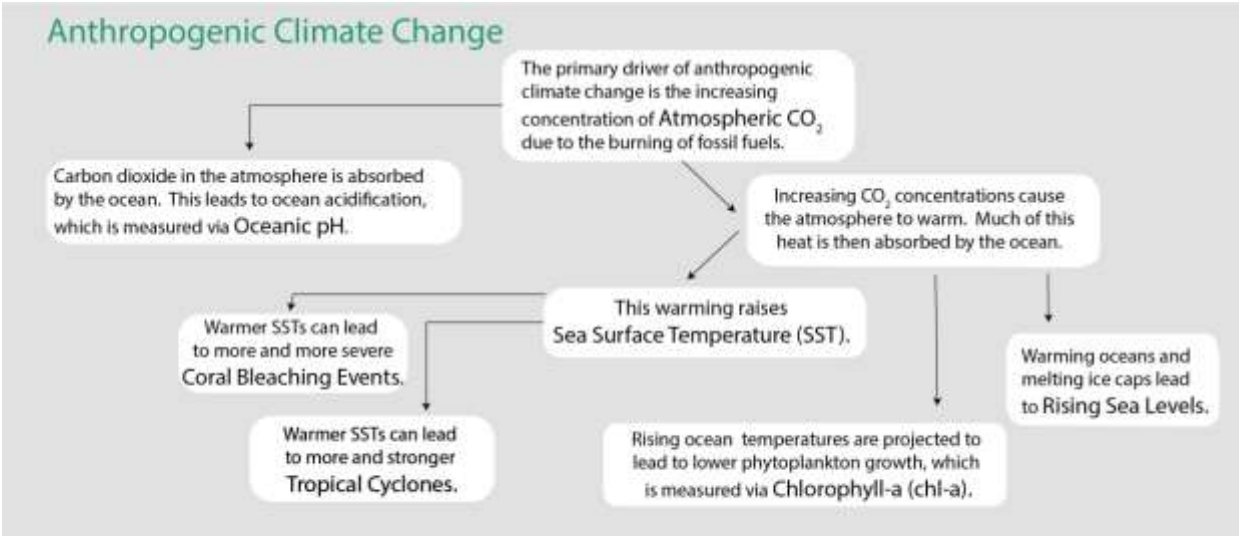


Figure 16. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of anthropogenic climate change

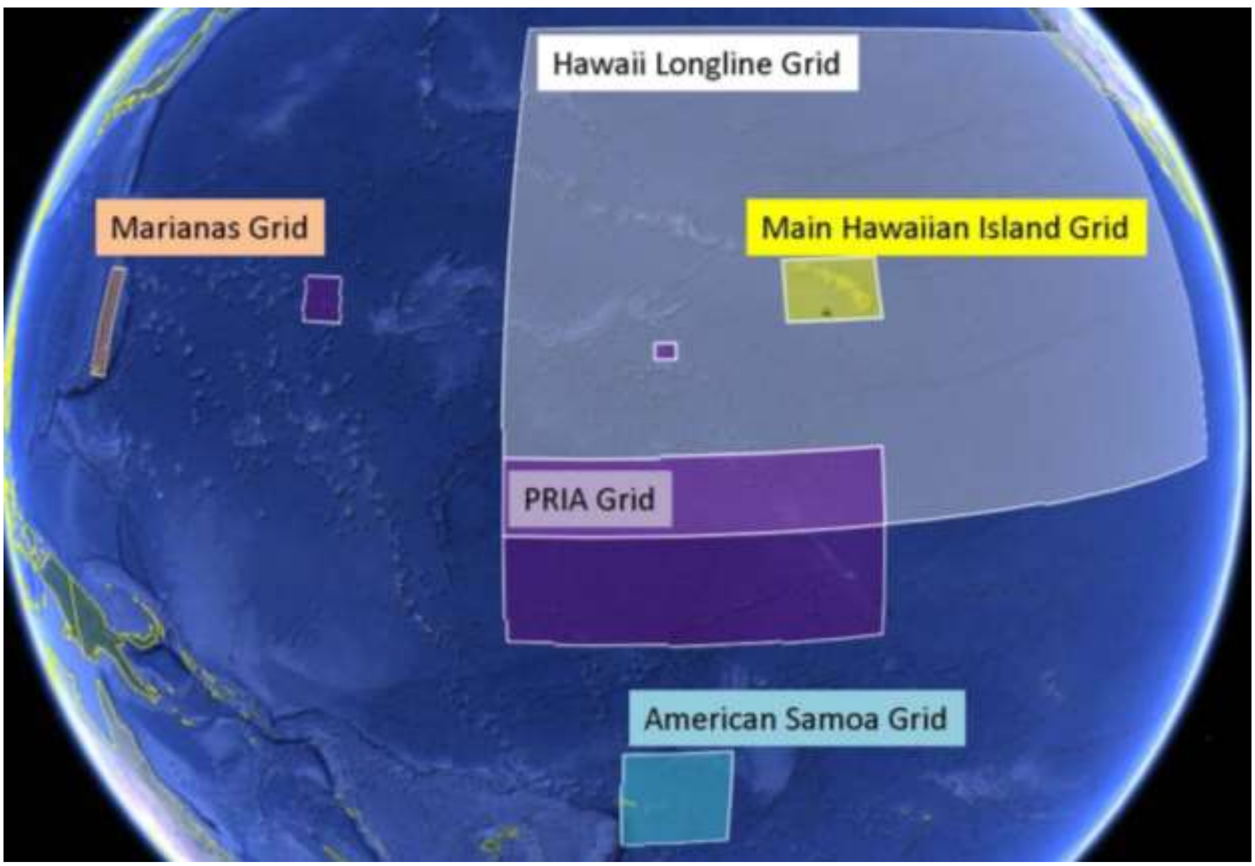


Figure 17. Regional spatial grids representing the scale of the climate change indicators being monitored

2.7.4.1 Atmospheric Concentration of Carbon Dioxide at Mauna Loa

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

Status: Atmospheric CO_2 is increasing exponentially. This means that atmospheric CO_2 is increasing more quickly over time. In 2021, the annual mean concentration of CO_2 was 416 ppm. This is the highest annual value recorded. This year also saw the highest monthly value, which was 419 ppm. In 1959, the first year of the time series, the atmospheric concentration of CO_2 was 316 ppm. The annual mean passed 350 ppm in 1988, and 400 ppm in 2015.

Description: Monthly mean atmospheric carbon dioxide (CO_2) at Mauna Loa Observatory, Hawai‘i in parts per million (ppm) from March 1958 to present. The observed increase in monthly average carbon dioxide concentration is primarily due to CO_2 emissions from fossil fuel burning. Carbon dioxide remains in the atmosphere for a very long time, and emissions from any location mix throughout the atmosphere in approximately one year. The annual variations at Mauna Loa, Hawai‘i are due to the seasonal imbalance between the photosynthesis and respiration of terrestrial plants. During the summer growing season, photosynthesis exceeds respiration, and CO_2 is removed from the atmosphere. In the winter (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 its larger land mass.

Timeframe: Annual, monthly.

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

Measurement Platform: *In-situ* station.

Data available at: https://gml.noaa.gov/ccgg/trends/data.html.

Sourced from: Keeling et al. (1976), Thoning et al. (1989), and NOAA (2022a).

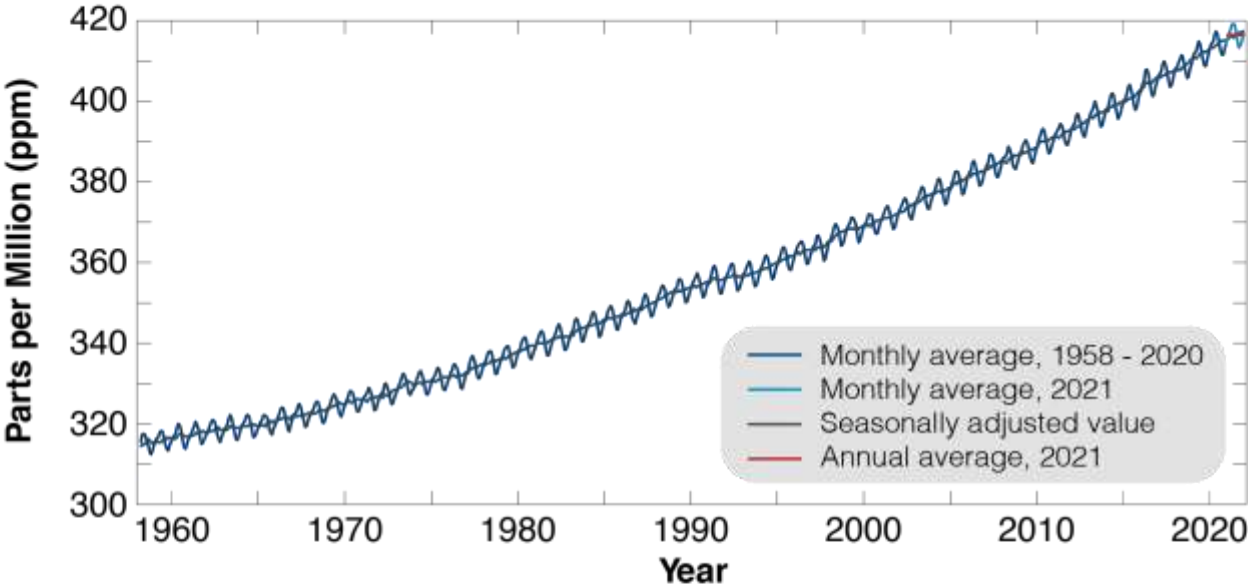


Figure 18. Monthly mean (black) and seasonally corrected (blue) atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii

2.7.4.2 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 10.2% more acidic than it was 30 years ago at the start of this time series. Over this time, pH has declined by 0.042 at a constant rate. In 2020, 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 outside the range seen in the first year of the time series for the fourth year in a row. The highest pH value reported for the most recent year (8.077) is lower than the lowest pH value reported in the first year of the time series (8.083).

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 2020 (2021 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). Total alkalinity 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.

Data available at: https://hahana.soest.hawaii.edu/hot/hot-dogs/bseries.html.

Sourced from: Fabry et al. (2008), Feely et al. (2016), and the Hawaii Ocean Time Series as described in Karl and Lukas (1996) and on its website (HOT 2022) using the methodology provided by Zeebe and Wolf-Gladrow (2001).

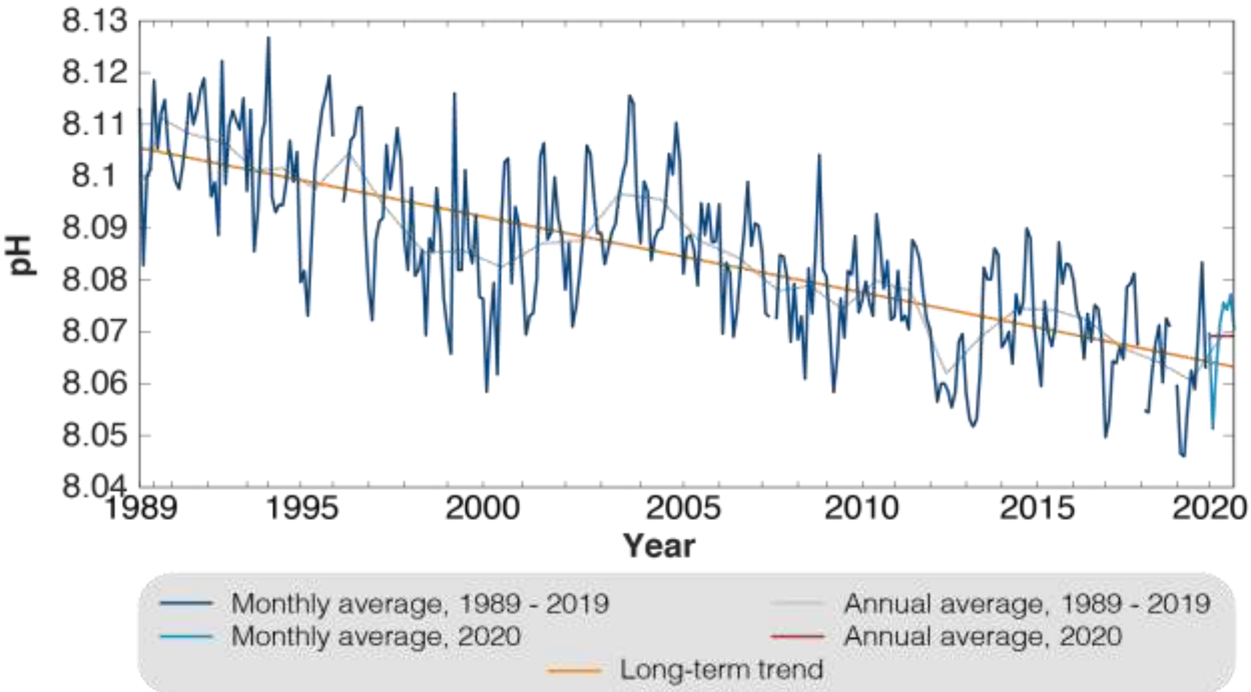


Figure 19. Time series and long-term trend of oceanic pH measured at Station ALOHA from 1989-2020

2.7.4.3 Oceanic Niño Index

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

Status: The ONI indicated La Niña conditions for most of 2021, with two consecutive neutral seasons punctuating the year mid-year. In 2021, the ONI ranged from -1.1 to -0.4. This is within the range of values observed previously in the time series.

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

Data available at: https://www.cpc.ncep.noaa.gov/data/indices/oni.ascii.txt.

Sourced from NOAA CPC (2022).

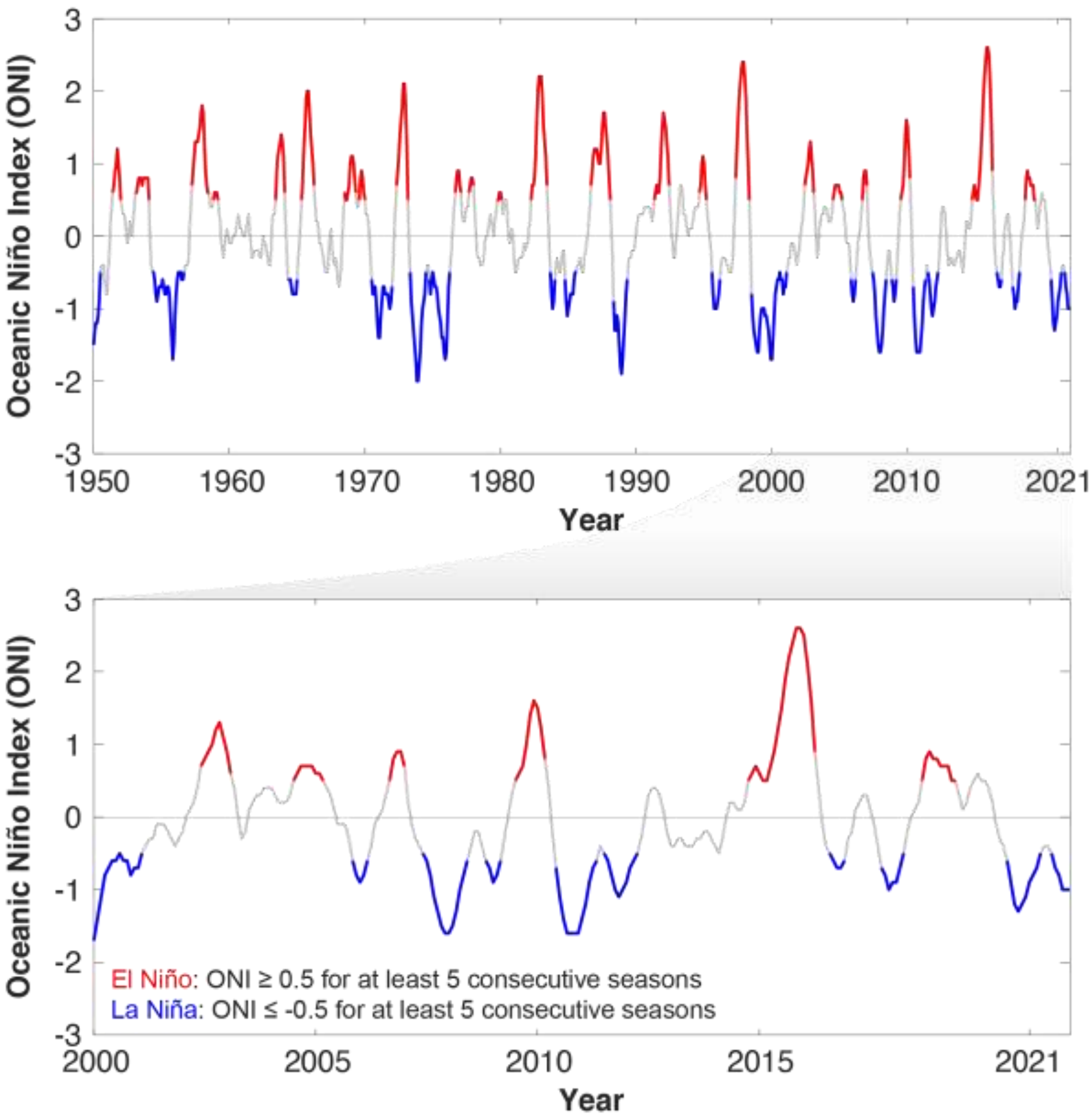


Figure 20. Oceanic Niño Index from 1950-2021 (top) and 2000-2021 (bottom) with El Niño periods in red and La Niña periods in blue

2.7.4.4 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 was negative in 2021. The index ranged from -2.66 to -0.56 over the course of the year. This is within the range of values observed previously in the time series.

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 [central] 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. Description inserted from NOAA (2021b).

Timeframe: Annual, monthly.

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

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

Data available at: https://psl.noaa.gov/pdo/.

Sourced from: NOAA (2022b), Mantua (1997), and Newman (2016).

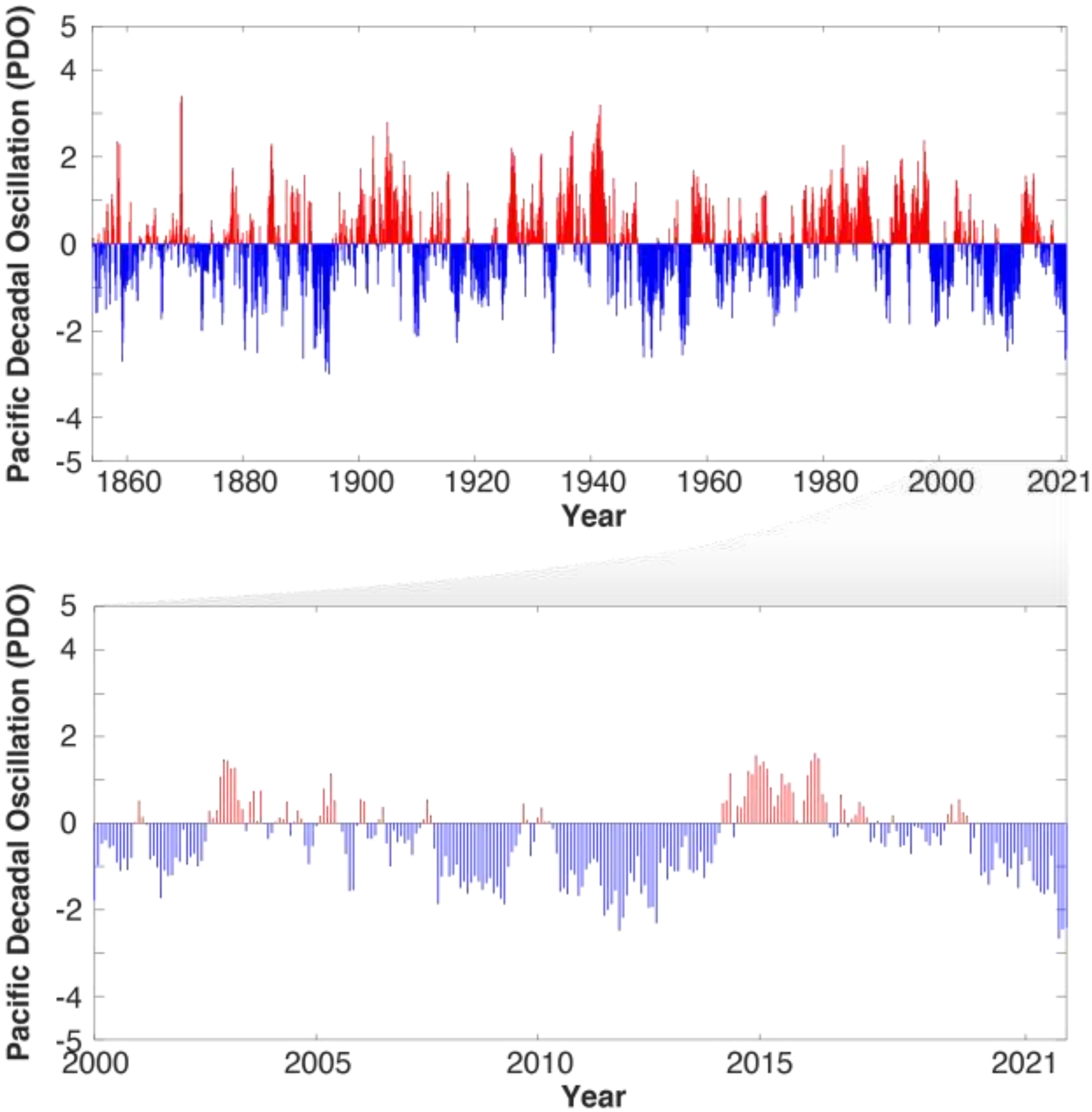


Figure 21. Pacific Decadal Oscillation from 1950-2021 (top) and 2000-2021 (bottom) with positive warm periods in red and negative cool periods in blue

2.7.4.5 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. In the East Pacific in 2021, the 19 named storms and eight hurricanes were both near normal. However, only two storms became major hurricanes, which is less than half of normal. The Accumulated Cyclone Energy (ACE) was also about 30% below the 1991–2020 average. The beginning and end of the hurricane season were noteworthy. The East Pacific had four named storms in June, which tied for the 4th most on record. The total of five for the year through June tied a record as well. Additionally, two tropical cyclones formed in November in the eastern Pacific basin. Based on a 30-year climatology (1991–2020), one named storm typically forms in November every second or third year. However, this is the fourth straight November with at least one named storm forming. In addition, both Sandra and Terry were tropical storms simultaneously, which is the first time this has occurred in the eastern Pacific in November.

Summary inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202113#summary, https://www.nhc.noaa.gov/text/MIATWSEP.shtml, and https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202106.

Central North Pacific. Tropical cyclone activity in the central Pacific in 2021 was below the 1991–2020 average. There was only one named storm, which did not reach hurricane status. However, the remnants of the Eastern Pacific's Hurricane Linda caused heavy rainfall over the main Hawaiian Islands in August. On average (1991–2020), the central Pacific sees four named storms, two hurricanes, and one major hurricanes. The 2021 ACE index was about two orders of magnitude, or roughly 100 times, below the 1991–2020 average. Information on Hurricane Linda inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202108.

Western North Pacific. Tropical cyclone activity was below the 1991–2020 average in 2021. The 23 named storms in the West Pacific in 2021 was near normal (1991–2020), but the ten typhoons and five typhoons were both among the five lowest years since 1981. The ACE was also about 30% below the 1991–2020 average in the West Pacific. Portions of the summary inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202113#summary

South Pacific. Tropical cyclone activity in the South Pacific was roughly average in 2021. The 10 named storms, 4 cyclones, and 2 major cyclones were very close to the 1991–2020 average of 9 named storms, 5 cyclones and 2 major cyclones. The 2021 ACE index was also close to the 1991–2020 average. Of note, the South Pacific produced two named storms in late January, including Tropical Cyclone Ana. Ana brought heavy rain and flooding to Fiji, which has been impacted by an unusual number of tropical cyclones in 2020–2021. Portions of the summary inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202101

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 Accumulated Cyclone Energy (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 Figure 22 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. Figure 23 shows the 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.

Data available at: https://www.ncei.noaa.gov/data/international-best-track-archive-for-climate-stewardship-ibtracs/v04r00/access/csv.

Sourced from: Knapp et al. (2010), Knapp et al. (2018), and NOAA (2022c).

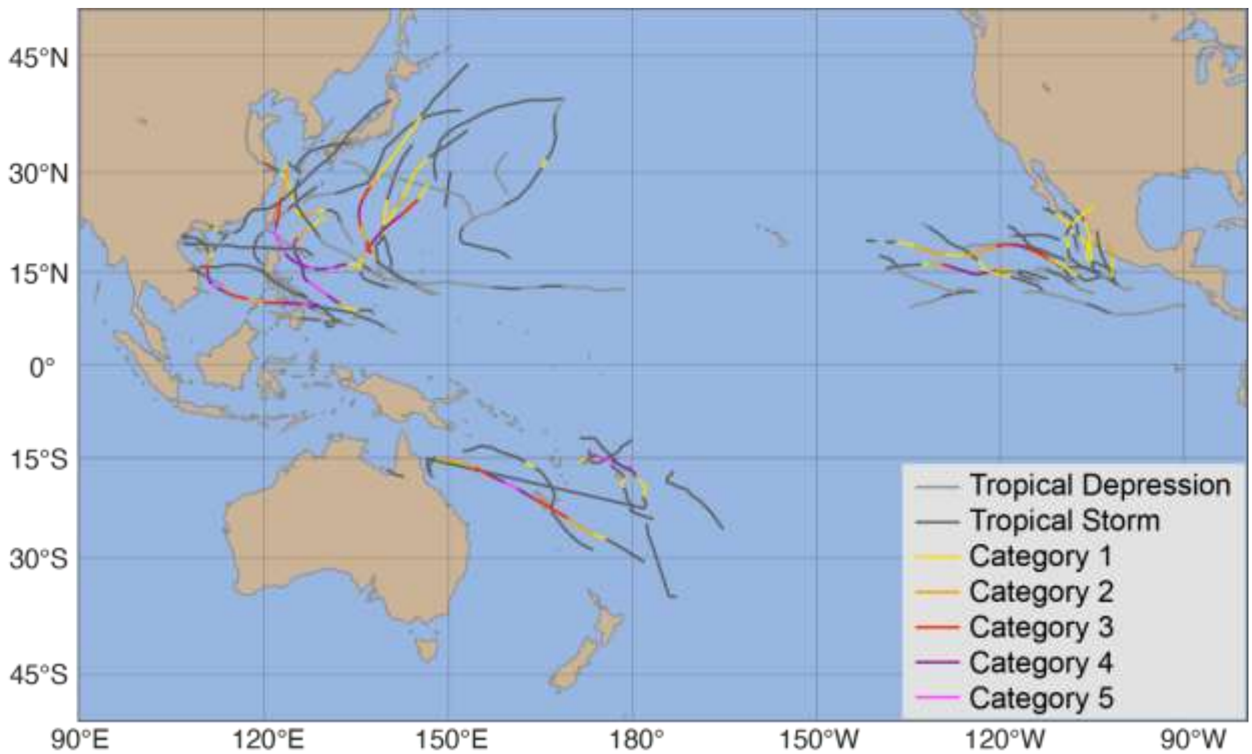


Figure 22. 2021 Pacific basin tropical cyclone tracks

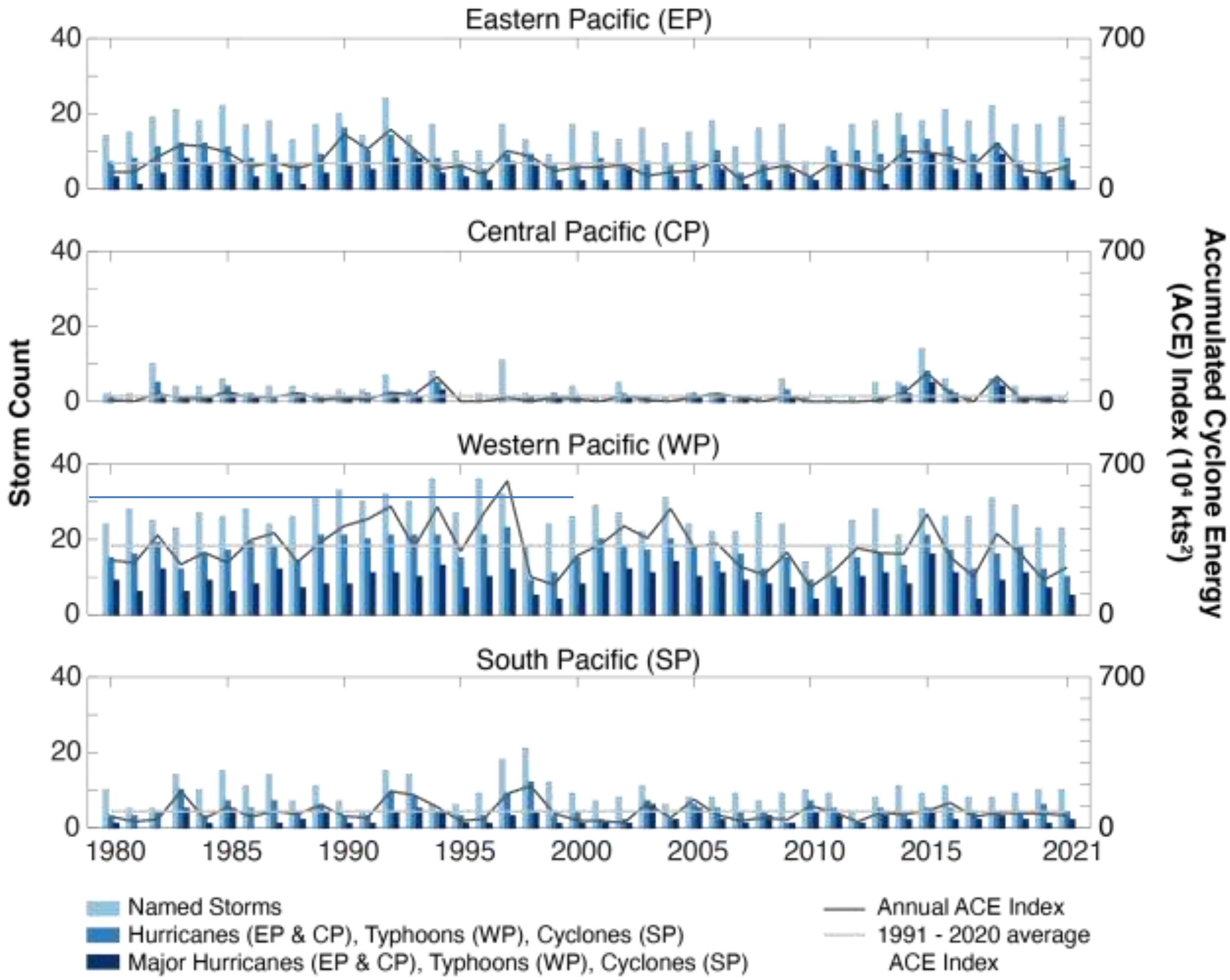


Figure 23. 2021 tropical storm totals by region

2.7.4.6 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 El Niño – Southern Oscillation (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 29.0ºC in 2021. Over the period of record, annual SST has increased at a rate of 0.0247ºC/year. Monthly SST values in 2021 ranged from 26.67 – 29.95ºC, within the climatological range of 25.61 – 30.60 ºC. The annual anomaly was 0.62 ºC hotter than average, with intensification in the northern islands.

Note that from the top to bottom in Figure 24, panels show climatological SST (1985-2020), 2021 SST anomaly, time series of monthly mean SST, and time series of monthly SST anomaly.

Description: Satellite remotely-sensed monthly sea surface temperature (SST) is averaged across the Marianas Grid (13° – 21°N, 144° – 146°E). A time series of monthly mean SST averaged over the American Samoa Grid Region is presented. Additionally, spatial climatology and anomalies are shown. Data from NOAA Coral Reef Watch CoralTemp v3.1.

Timeframe: Monthly.

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

Measurement Platform: Satellite.

Source: NOAA OceanWatch (2022a).

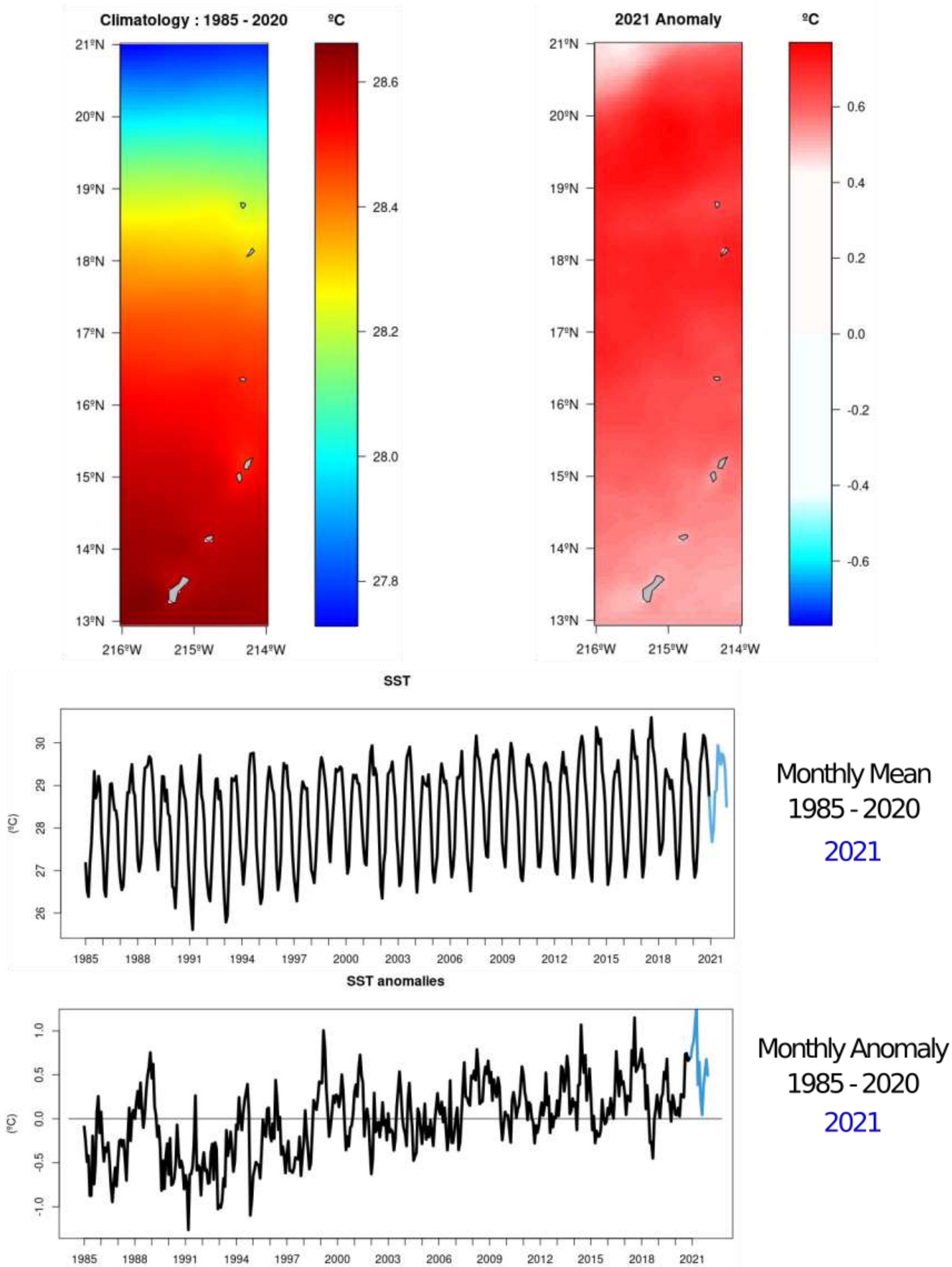


Figure 24. Sea surface temperature climatology and anomalies from 1985-2021

2.7.4.7 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, 2017, 2019 and 2020, the Marianas experienced minor coral heat stress event in the second half of 2021 that reached its maximum in late June through August.

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 (CRW) daily 5-km satellite coral bleaching Degree Heating Week (DHW) product presented here shows accumulated heat stress, which can lead to coral bleaching and death. The scale goes from 0 to 20 °C-weeks. The DHW product accumulates the instantaneous bleaching heat stress (measured by Coral Bleaching HotSpots) during the most-recent 12-week period. It is directly related to the timing and intensity of coral bleaching. Significant coral bleaching usually occurs when DHW values reach 4 °C-weeks. By the time DHW values reach 8 °C-weeks, widespread bleaching is likely and significant mortality can be expected (NOAA Coral Reef Watch 2021).

Timeframe: 2014-2021, Daily data.

Region/Location: Global.

Sourced from: NOAA Coral Reef Watch (2022).

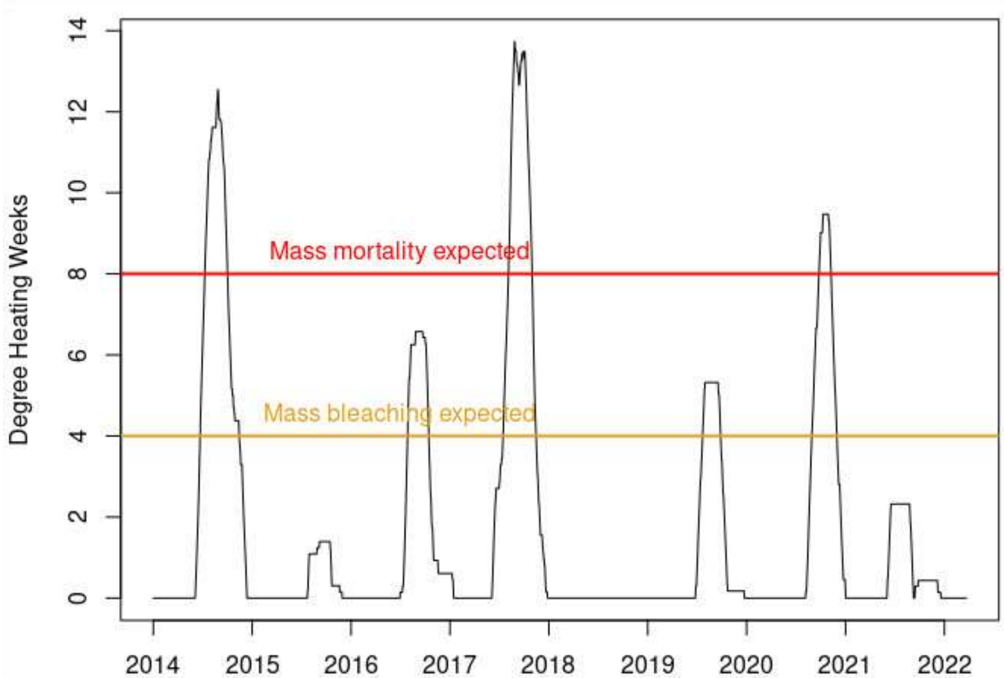


Figure 25. Coral Thermal Stress Exposure measured at CNMI Virtual Station 2014-2021 (Coral Reef Watch Degree Heating Weeks)

2.7.4.8 Chlorophyll-A and Anomaly

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

Status: Annual mean Chl-A was 0.053 mg/m^3 in 2021. Over the period of record, annual Chl-A has shown weak but significant linear decrease at a rate of 0.00044 mg/m^3. Monthly Chl-A values in 2021 ranged from 0.048-0.060 mg/m^3, within the climatological range of 0.042 – 0.100 mg/m^3. The annual anomaly was 0.0016 mg/m^3 lower than average.

Description: Chlorophyll-A Concentration from 1998-2021, derived from the ESA Ocean Color Climate Change Initiative dataset, v5.0. A monthly climatology was generated across the entire period (1998-2020) to provide both a 2021 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: 1998-2021, Daily data available, Monthly means shown.

Region/Location: Global.

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

Sourced from: NOAA OceanWatch (2022b).

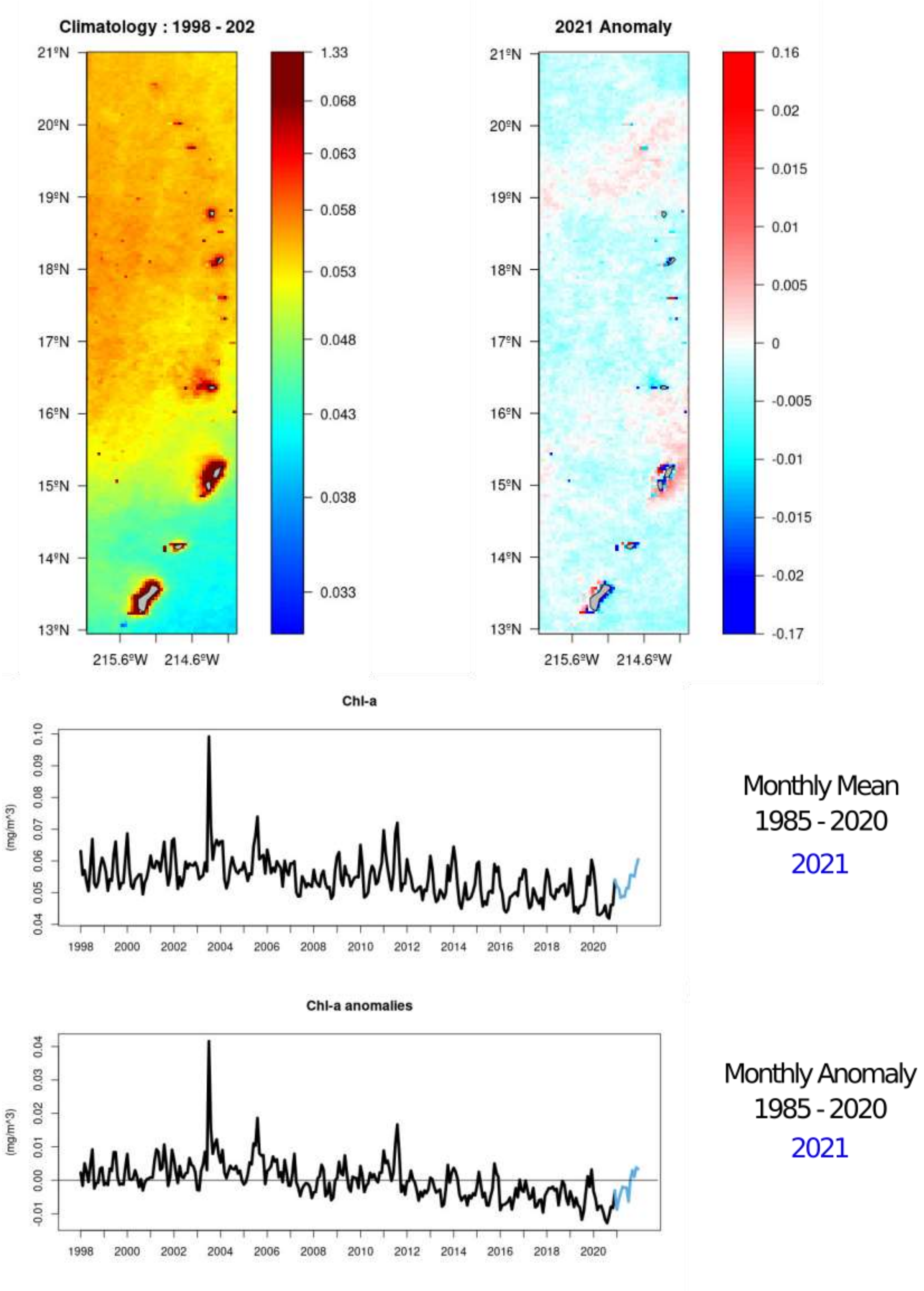


Figure 26. Chlorophyll-A (Chl-A) and Chl-A Anomaly from 1998-2021

2.7.4.9 Rainfall

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 are provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their website 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).

Text inserted from https://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.shtml.

Timeframe: Monthly.

Region/Location: Global.

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

Sourced from: APDRC (2022).

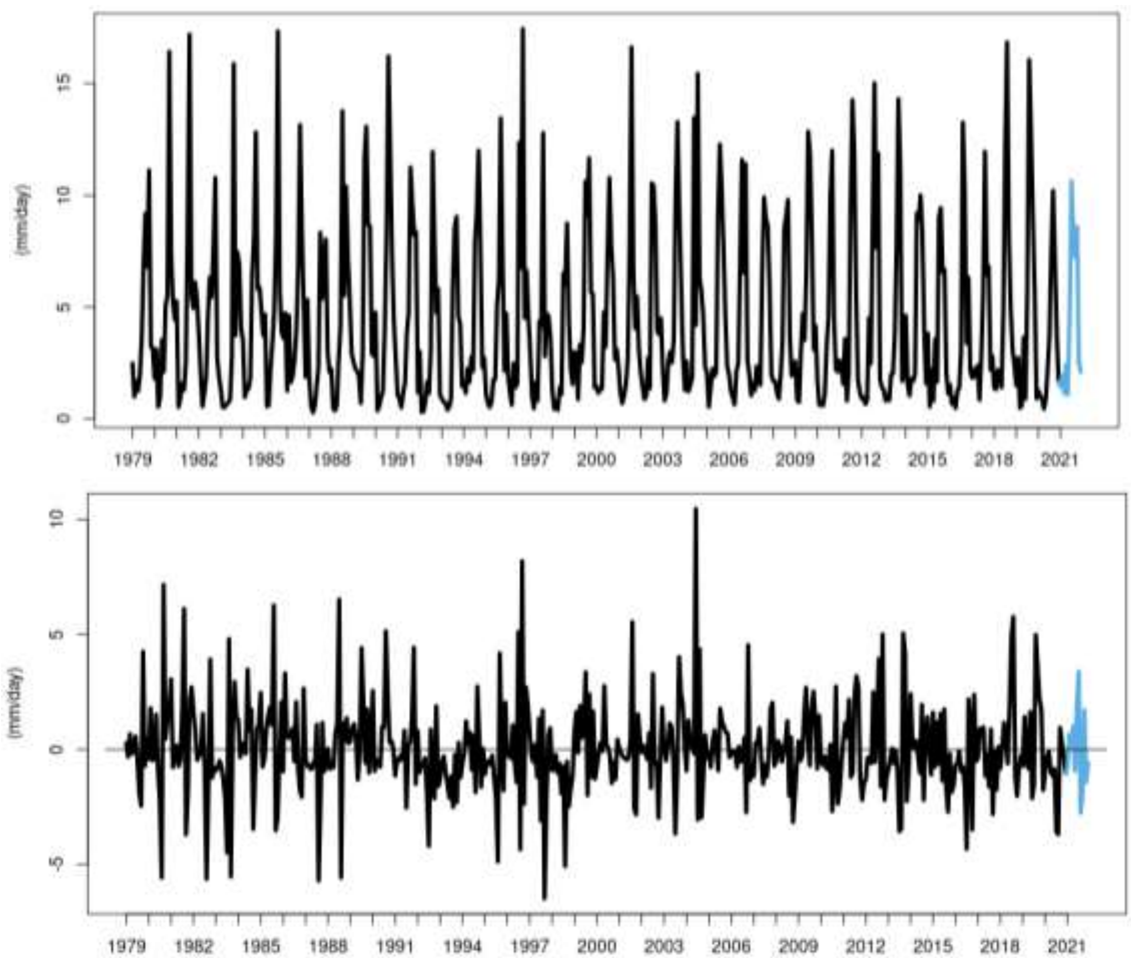


Figure 27. CMAP precipitation (top) and anomaly (bottom) across the Marianas Grid with 2021 values in blue

2.5.3.9 Sea Level (Sea Surface Height and Anomaly)

Rationale: Coastal: Rising sea levels can result in a number of coastal impacts, including inundation of infrastructure, increased damage resulting from storm-driven waves and flooding, and saltwater intrusion into freshwater supplies.

Description: Monthly mean sea level time series of local and basin-wide sea surface height and sea surface height anomalies, 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 (2021), NOAA (2022e), and NOAA CoastWatch (2022).

2.5.3.9.1 Basin-Wide Perspective

This image of the mean sea level anomaly for March 2021 compared to 1993-2016 climatology from satellite altimetry provides a glimpse into the 2021 weak La Niña conditions across the Pacific Basin. The image captures the fact that sea level is higher in the Western Pacific and lower in the Central and Eastern Pacific (this basin-wide perspective provides a context for the location-specific sea level/sea surface height images that follow).

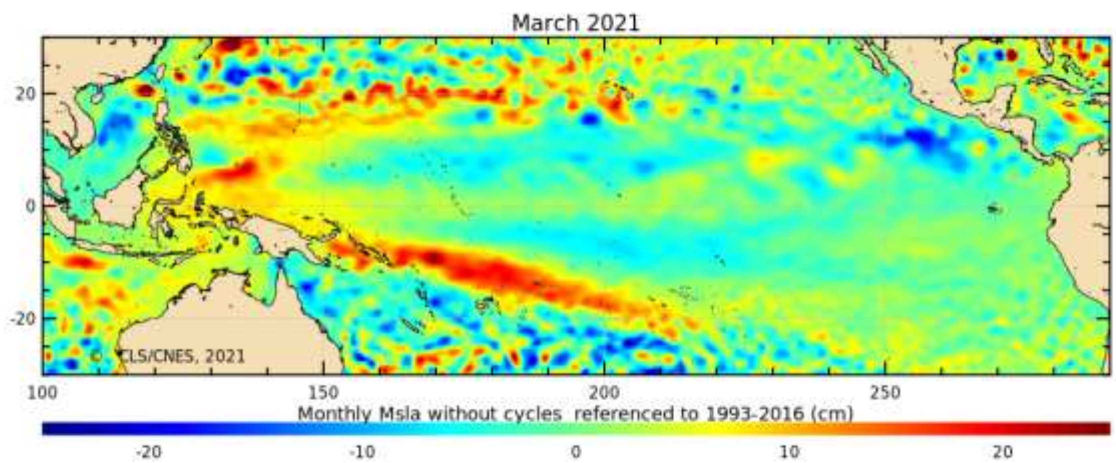


Figure 28a. Sea surface height and anomaly

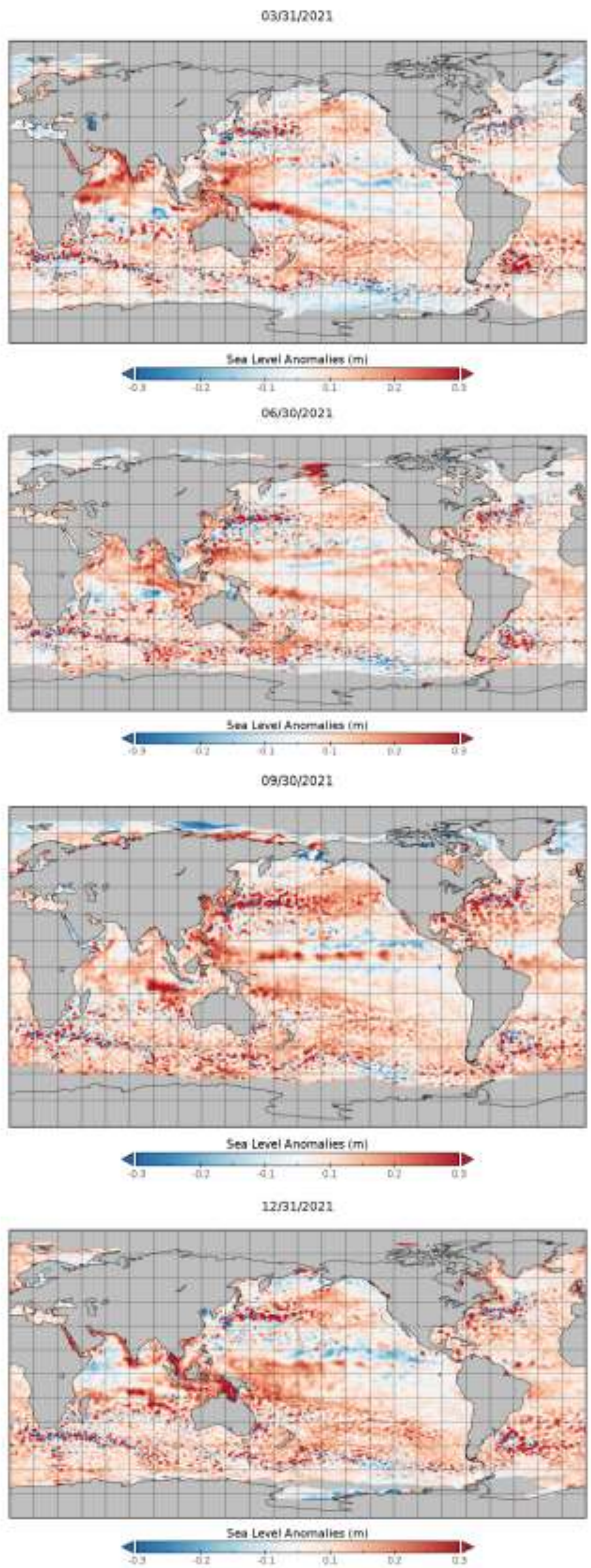


Figure 28b. Quarterly time series of mean sea level anomalies during 2021.

Altimetry data are provided by the NOAA Laboratory for Satellite Altimetry, accessed from NOAA CoastWatch (2022).

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, or 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 trend is 4.17 millimeters/year with a 95% confidence interval of +/- 3.41 mm/yr based on monthly mean sea level data from 1993 to 2021 which is equivalent to a change of 1.37 feet in 100 years. The trend for 1948-1993 is -0.85 +/- 1.76 mm/yr.

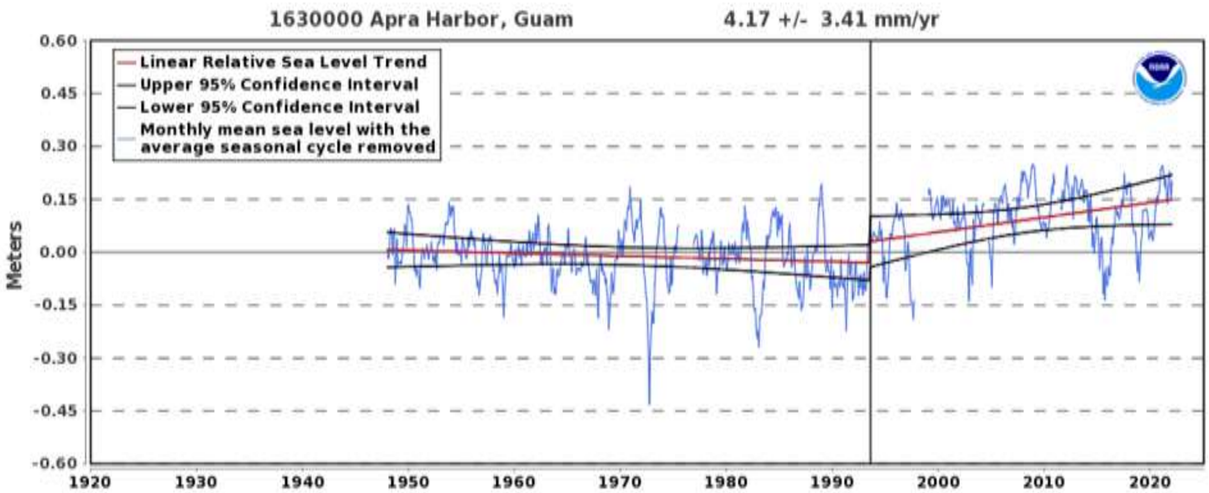


Figure 29. Monthly mean sea level without regular seasonal variability due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents

Source: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=1630000.

2.8 ESSENTIAL FISH HABITAT

2.8.1 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. Fishery management actions must be evaluated for impacts to all EFH and HAPC in the area of effect and not just the EFH and HAPC for the fishery to which the management action applies.

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 (BSIA) concerning the past, present, and possible future condition of EFH described by the FEPs.

2.8.1.1 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, most 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 2.8.4;
- Updated research and information needs, which can be found in Section 2.8.5. 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.

2.8.1.2 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.

2.8.1.3 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.

At its 187th meeting in September 2021, the Council recommended that the Chair recommend at the October 2021 CCC meeting that NMFS work with the Council to review EFH guidance in terms of how that guidance requiring the Council to identify and describe how EFH has been applied in the Western Pacific Region.

2.8.2 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 was replaced by the Coral Reef Ecosystem Program (CREP) within the PIFSC Ecosystem Sciences Division (ESD) before being shifted to the Archipelagic Research Program (ARP). No field work was conducted in the Mariana Archipelago in 2021 to provide data that would enable updates to habitat use by MUS or trends in habitat condition.

2.8.2.1 Habitat Mapping

No new habitat mapping was conducted in 2021. A field effort in 2022 should provide new bathymetry and backscatter data for many areas in the Mariana Archipelago, and supplement coral reef habitat data as well.

2.8.2.2 Benthic Habitat

Juvenile and adult bottomfish EFH extends from the shoreline to the 400 m isobath (64 FR 19067, April 19, 1999).

2.8.2.2.1 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 ESD. No RAMP field work was conducted in the Mariana Archipelago in 2021.

2.8.2.3 Oceanography, Water Quality, and Other Environmental Data

The water column is also designated as EFH for selected MUS life stages at various depths. For larval stages of all species except deepwater shrimp, the water column is EFH from the shoreline to the EEZ. Coral reef species egg and larval EFH is to a depth of 100 m; crustaceans, 150 m; and bottomfish, 400 m. Please see the Climate and Oceanic Indicators section (Section 2.7) for information related to oceanography and water quality.

While no substantial field research data efforts occurred in 2021, satellite and buoy data are continuously collected and archived. PIFSC staff recently developed an advanced data compilation tool, the Environmental Data Summary (EDS), that gives users a simple, consistent way to enhance existing in situ observations with external gridded environmental data. The EDS is written in R and provides users an interface to NOAA CoastWatch and OceanWatch datasets through the ERDDAP server protocol. The EDS allows users to download, filter, and/or extract large amounts of gridded and tabular data given user-defined time stamps and geographical coordinates. The various external environmental data summarized at individual survey sites can aid scientists in assessing and understanding how environmental variabilities impact living marine resources. The EDS outputs were summarized at the National Coral Reef Monitoring Program (NCRMP) Rapid Ecological Assessment (REA) site level from 2000 to 2020 across 57 islands covered by the survey. PIFSC is planning to expand the utility of EDS with a broader range of gridded NOAA CoastWatch and OceanWatch data products (e.g., wave, wind) at finer spatiotemporal scales (e.g., water columns). Target data content includes spatial data (e.g., remote sensing), modeled data (e.g., Regional Ocean Modeling Systems), and socioeconomic data, including human density

2.8.3 Report on Review of EFH Information

There were no EFH reviews completed in 2021. A review of the biological components of crustacean EFH in Guam and Hawaii was finalized in 2019 and can be found in Appendix C of the 2019 reports for the Hawaiian and Mariana Archipelagos (WPRFMC 2020a, WPRFMC 2020b). The non-fishing impacts and cumulative impacts components were reviewed in 2016 through 2017, which can be found in Minton (2017).

2.8.4 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.

2.8.4.1 Bottomfish and Seamount Groundfish

EFH for bottomfish was originally designated in Amendment 6 to the Bottomfish and Seamount Groundfish FMP (64 FR 19067, April 19, 1999). To analyze the potential effects of a proposed fishery management action on EFH, one must consider all designated EFH, but research examining depth and habitat requirements for most species is generally lacking (PIFSC 2021). The levels of information available for Mariana Archipelago BMUS did not change in 2021

Table 63. Level of EFH information available for the Mariana Archipelago BMUS complex

Life History Stage	Eggs	Larvae	Juvenile	Adult
Aphareus rutilans (red snapper/silvermouth)	0	0	0	1
Caranx ignobilis (giant trevally/jack)	0	0	1	1
C. lugubris (black trevally/jack)	0	0	0	1
Etelis carbunculus (red snapper)	0	0	1	1
E. coruscans (red snapper)	0	0	1	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. sieboldii (pink snapper)	0	0	1	1
P. zonatus (snapper)	0	0	0	1
Variola louti (lunartail grouper)	0	0	0	1

Table 64. EFH and HAPC for Mariana Archipelago BMUS

Guam BMUS	EFH	HAPC
Lehi (*Aphareus rutilans*) Giant trevally (*Caranx ignobilis*) Black trevally (*Caranx lugubris*) Ehu (*Etelis carbunculus*) Onaga (*E. coruscans*) Redgill emperor (*Lethrinus rubrioperculatus*) Blueline snapper (*Lutjanus kasmira*) Yellowtail snapper (*Pristipomoides auricilla*) Opakapaka (*P. filamentosus*) Yelloweye snapper (*P. flavipinnis*) Kalekale (*P. sieboldii*) Gindai (*P. zonatus*) Lunartail grouper (*Variola louti*)	**Eggs and larvae:** the water column extending from the shoreline to the outer limit of the EEZ down to a depth of 400 m (200 fathoms, fm). **Juvenile/adults:** the water column and all bottom habitat extending from the shoreline to a depth of 400 m (200 fm)	All slopes and escarpments between 40-280 m (20 and 140 fm)

2.8.5 Project Updates

The PIFSC ESD planned to conduct the NOAA's National Coral Reef Monitoring Program (NCRMP) - Pacific Region surveys aboard the NOAA Ship *Rainier*, which provides scientific information to support ecosystem approaches to management and conservation of coral reefs. Diver-based surveys include fine-scale, rapid ecological assessment (REA) surveys of reef fishes and corals, as well as surveys to monitor nearshore physical and ecological factors associated with ocean acidification and general water quality, including data on water temperature, salinity, and other physical and biological characteristics of the coral reef environment using an assortment of oceanographic sampling and monitoring instruments, including systems deployed from the ship and underwater moored instruments. Survey areas include reef area around Guam and the Northern Mariana Islands of Rota, Aguijan, Tinian, Saipan, Sarigan, Zealandia Bank, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply Reef, and Farallon de Pajaros. Since its inception in 2000, NCRMP-Pacific (formally known as Pacific Reef Assessment and Monitoring Program or RAMP) has established baseline ecosystem assessments and conducted long-term monitoring that integrates biological observations with water quality and oceanographic data as part of a long-term NOAA effort to monitor the status and trends of U.S. coral reef ecosystems. This cruise was delayed due to COVID, and the cruise departed in March 2022.

Research is ongoing to analyze a synthesized dataset (i.e., federal and jurisdictional data) to look at trends in benthic communities over space in time across the Mariana Archipelago. In 2022, the response of fish communities will be layered on top of this effort. A group of PIFSC staff is analyzing changes in benthic and fish composition across the PRIA. There's particular interest in both of these projects to determine variance in response to bleaching events.

Life history research is ongoing that attempts to determine spatial variability along latitudinal gradients in the Mariana Archipelago. The research plans to identify spatial variability in life history parameters across the archipelago and provide insights into how fish may respond to climate change as well as specific extreme thermal events. Creation of multiple individual time series (chronologies) for a complex of species (deepwater snappers, coral reef fish, coral)

2.8.6 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:

2.8.6.1 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.

2.8.6.2 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.

2.9 MARINE PLANNING

2.9.1 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.

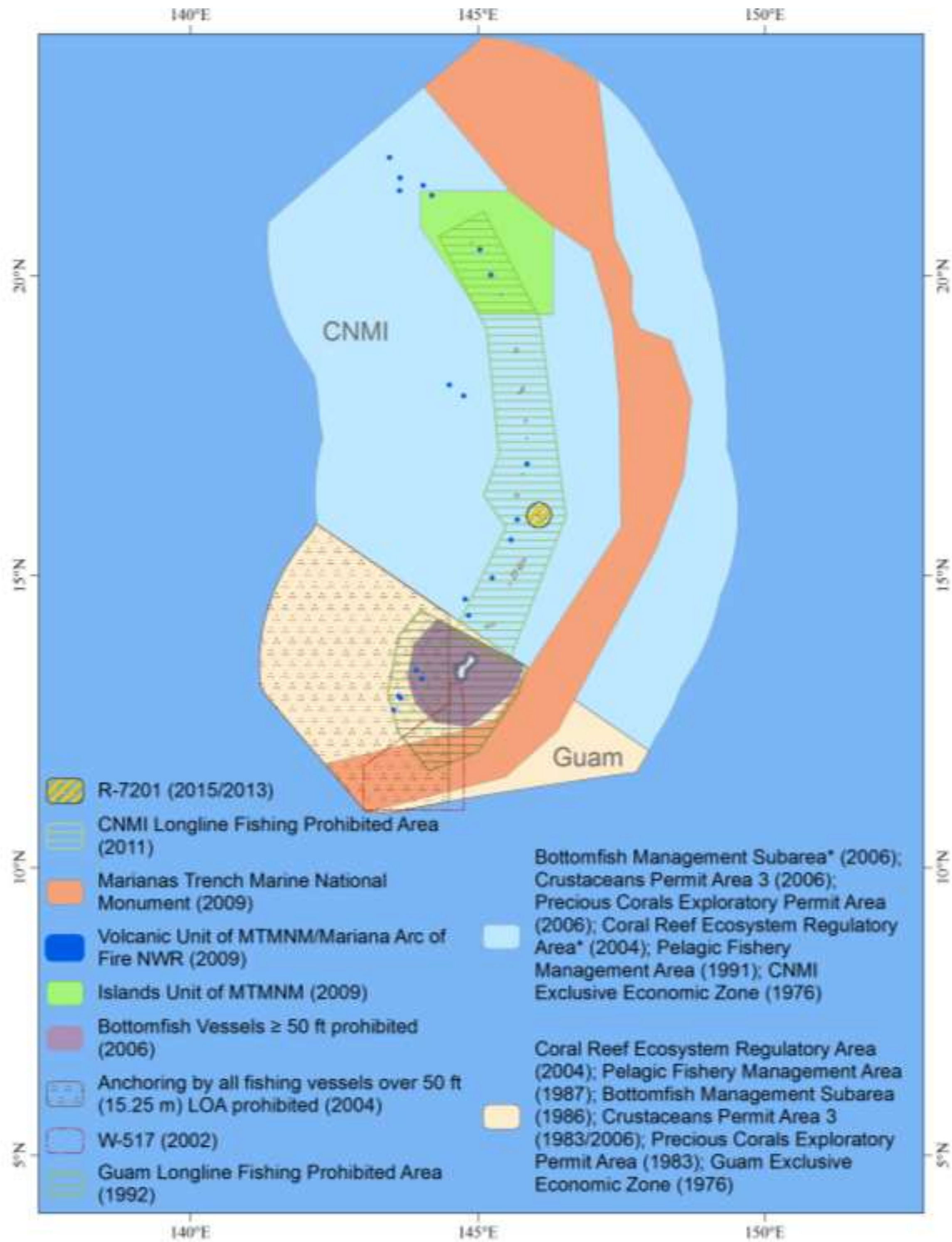
In order to meet the EFH and National Environmental Policy Act (NEPA) mandates, this annual report tracks activities that occur in the ocean that are of interest to the Council, and incidents or facilities that may contribute to cumulative impact. NMFS is responsible for NEPA compliance, and the Council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

2.9.2 Response to Previous Council Recommendations

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

2.9.3 Marine Managed Areas Established under FEPs

Council-established MMAs were compiled in Table 65 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 (MTMNM), are shown in Figure 30.



* 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 30. Regulated fishing areas of the Mariana Archipelago

Table 65. 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	-

2.9.3.1 Mariana Trench National Marine Sanctuary Nomination – Five-Year Review

On January 21, 2022, the NOAA Office of National Marine Sanctuaries (ONMS) began facilitation of a review of the nomination for the Mariana Trench National Marine Sanctuary (NMS) at the five-year interval by requesting written and oral comments (87 FR 3284). On March 10, 2022, the NOAA OMNS extended the public comment period by an additional 45 days through April 25, 2022 (87 FR13709). ONMS will review information to its 11 evaluation criteria for inclusion in the inventory of nominations, emphasizing any new information about the significance of the area's natural or cultural resources, changes to any threats to these resources, and any updates to the management framework of the area. The original nominating parties for the NMS were Pew Charitable Trusts and Friends of the Marianas Trench, which will also have an opportunity to provide input on relevant information. Following information gathering and internal analysis, NOAA will make a final determination on whether or not the Mariana Trench NMS nomination will remain in the inventory for another five-year period.

The potential development of an NMS for the Mariana Trench is an issue of debate for residents of the Mariana Archipelago. The Marianas Trench Marine National Monument (MTMNM) already exists in the area, and the creation of an NMS would have the potential to further restrict fishing access or limit the potential for fisheries development within the EEZ around the CNMI. Regarding the nomination of the Mariana Trench NMS, concerns have been raised about the potential to expand the NMS beyond the boundaries of the MTMNM, the expansion of fishing restrictions to the water column within the Trench Unit of the MTMNM, and the current lack of community support and public confusion surrounding the nomination letter submitted by Friends of the Marianas Trench (Tenorio, pers. comm., April 4, 2022).

2.9.4 Fishing Activities and Facilities

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

2.9.5 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.

2.9.5.1 Alternative Energy Facilities

There are no proposed or existing alternative energy facilities in federal waters of neither Guam nor CNMI.

2.9.5.2 Military Training and Testing Activities and Impacts

The Department of Defense major planning activities in the region are summarized in Table 66. 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 67. The areas for which NTMs are issued are presented in Figure 31.

In addition to the Department of Defense activities detailed in Table 66, the U.S. military proposed the development of a small arms firing range near the shoreline in northwest Tinian. Several concerns were brought to the military regarding the proposed firing range, including issues with fishing access in the associated spatial closure area, issues with access to dive sites in the area, issues with the increased distance that boaters would have to travel to transit between Tinian and Saipan, and issues regarding boater safety due to having to travel further west from Tinian and losing access to the calmer waters nearshore (Tenorio, pers. comm., April 4, 2022).

Table 66. 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.	Record of Decision (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. The case was lost in 2018 when a judge from the District Court of CNMI stated that the Guam buildup and proposed training in the CNMI are not connected actions. The case was appealed, and the US Court of Appeals for the Ninth Circuit affirmed the District Court's dismissal in 2020. Marine Corps Base Camp Blaz was activated on October 1, 2020. The US Army Corps of Engineers published a final rule on Oct. 8, 2021, amending regulations to establish a danger zone in the Pacific Ocean adjacent to the Mason Live-Fire Training Range Complex at Camp Blaz.	Danger zone established in the waters adjacent to 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 was 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, were used to update the MITT.	The MITT Final Supplemental EIS/OEIS was released in June 2020. ROD published on August 7, 2020, to continue training and testing activities in the study area (85 FR 47952). Meetings occurred 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. In July 2020, NMFS implemented regulations regarding to the incidental take of marine mammals in the MITT area (85 FR 46302).	Access and habitat impact similar to previously analyzed activities in the 2015 EIS/OEIS (80 FR 29701).

Action	Description	Phase	Impacts
CNMI Joint Military Training	Establish unit and combined level training ranges on Tinian and Pagan.	The revised Draft EIS was expected in late 2018 or early 2019, but there is no new information on the status of the EIS. Lawsuit filed for segmentation and range of reasonable alternatives under NEPA. DOJ asked U.S. 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 affirmed the District Court's dismissal in 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. Community engagement is also ongoing.	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 the 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 were 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 were taken into consideration during preparation of the Final SEIS, which had an NOA published in July 2020 (85 FR 43580). Ground was broken on the Tinian Divert airfield on Feb. 22, 2022, which is expected to be completed by Oct. 9, 2025.	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 2022, 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 U.S. 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 67. 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	NA	NA
	W-12	NA	NA
2017	FDM	56	191
	W-517	46	119
	W-12	2	5
	W-11	NA	NA
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
2020	FDM	17	62
	W-517	12	26
	W-12	5	10
	W-11	3	8
	W-13	15	62
2021*	FDM	N/A	49
	W-517	N/A	80
	W-12	N/A	32
	W-11	N/A	41
	W-13	N/A	63

*Data for 2021 are incomplete. The number of notices to mariners is not able to be reported for 2021 due to changes in how the Department of Defense presents aggregate NTM data. Additionally, military departments did not issue NTMs from August to December of 2021, so the presented data are from January to July 2021.

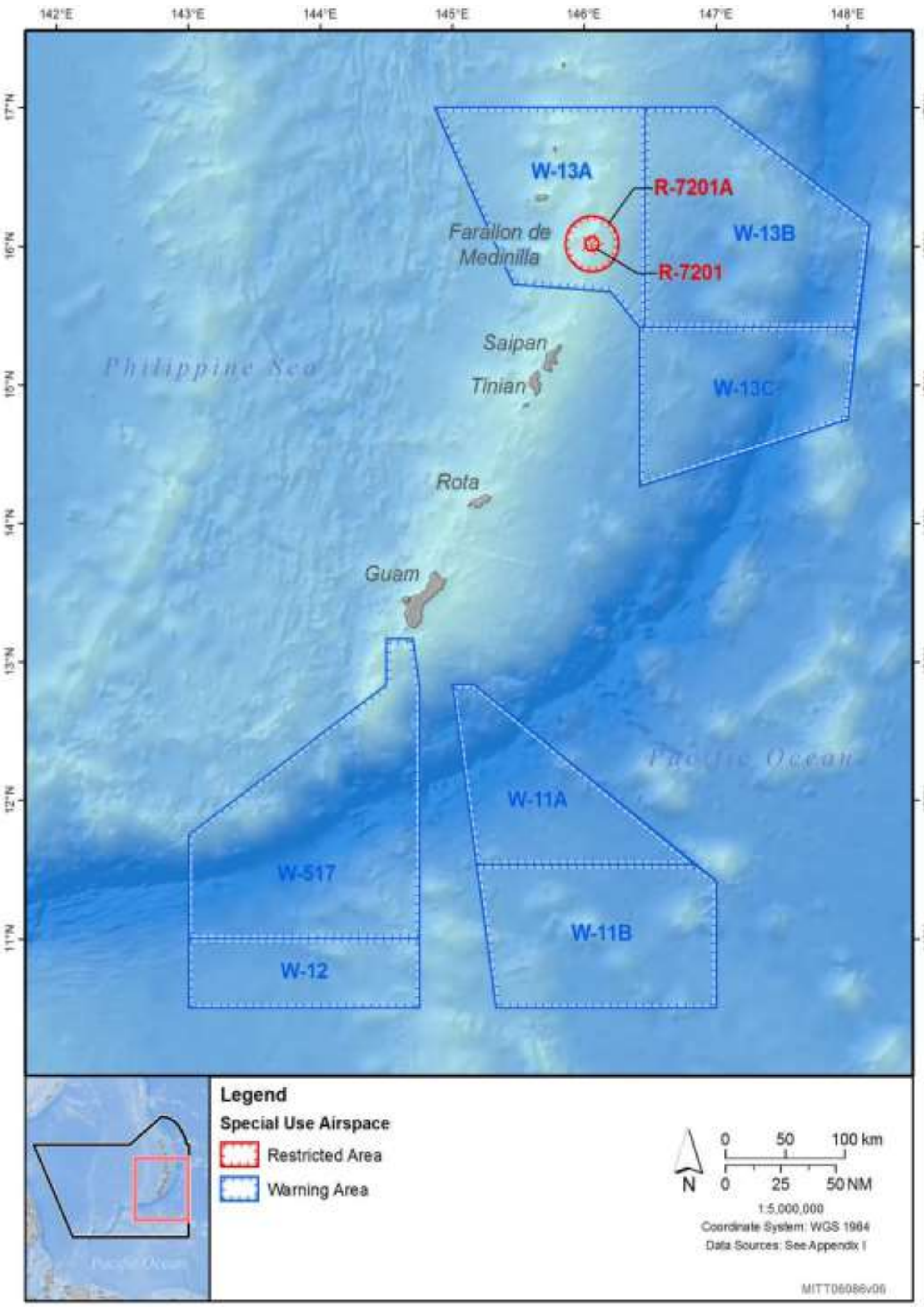


Figure 31. Map showing Warning Areas around the Mariana Archipelago

2.9.6 Mariana Archipelago Spatial Planning Initiatives

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.

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 Mariana Archipelago 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 32).

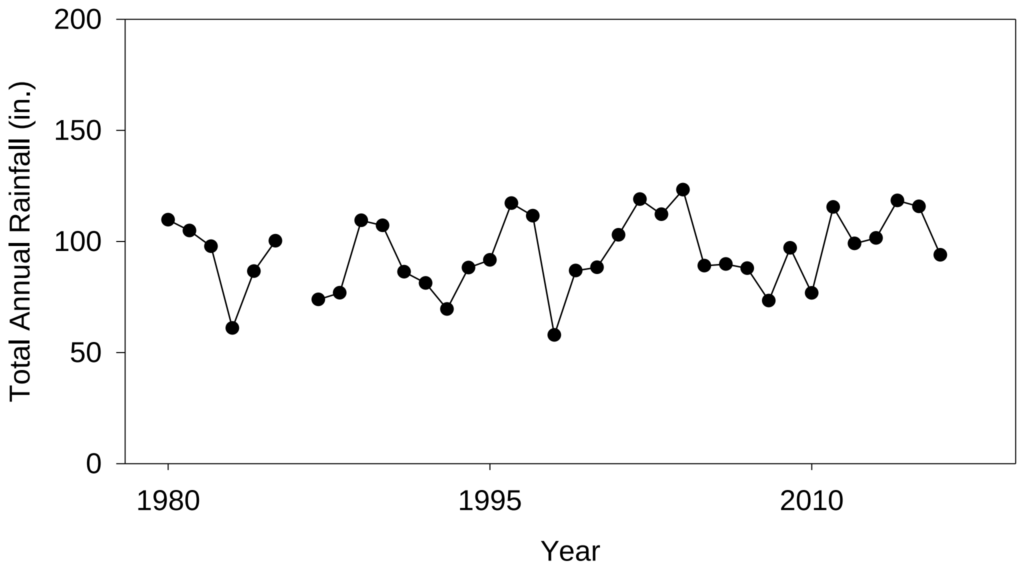


Figure 32. Total annual precipitation (in.) in Guam from 1980-2016

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 33). 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 34a-b). Effort data also revealed that, despite catch statistics, the gill net had been sampled the least frequently among the top gears (Figure 34a-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 34c-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 35). 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.

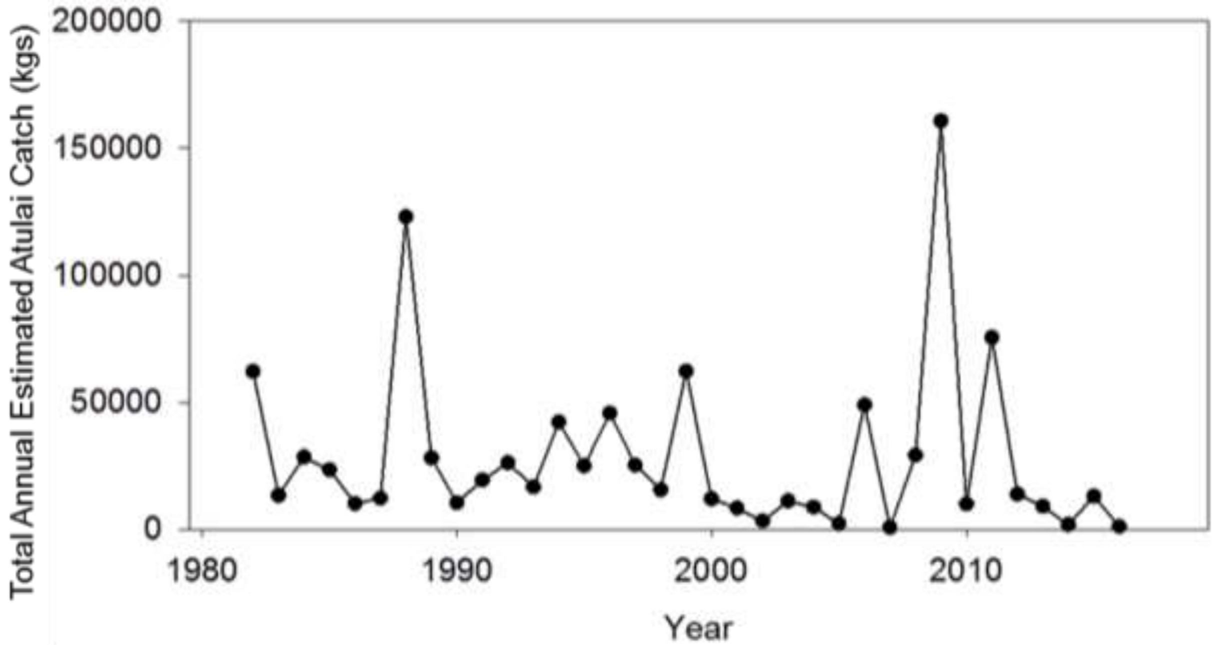


Figure 33. Time series of total annual estimated (i.e., expanded) landings of atulai in kilograms from Guam shore-and boat-based creel survey records from 1982-2016

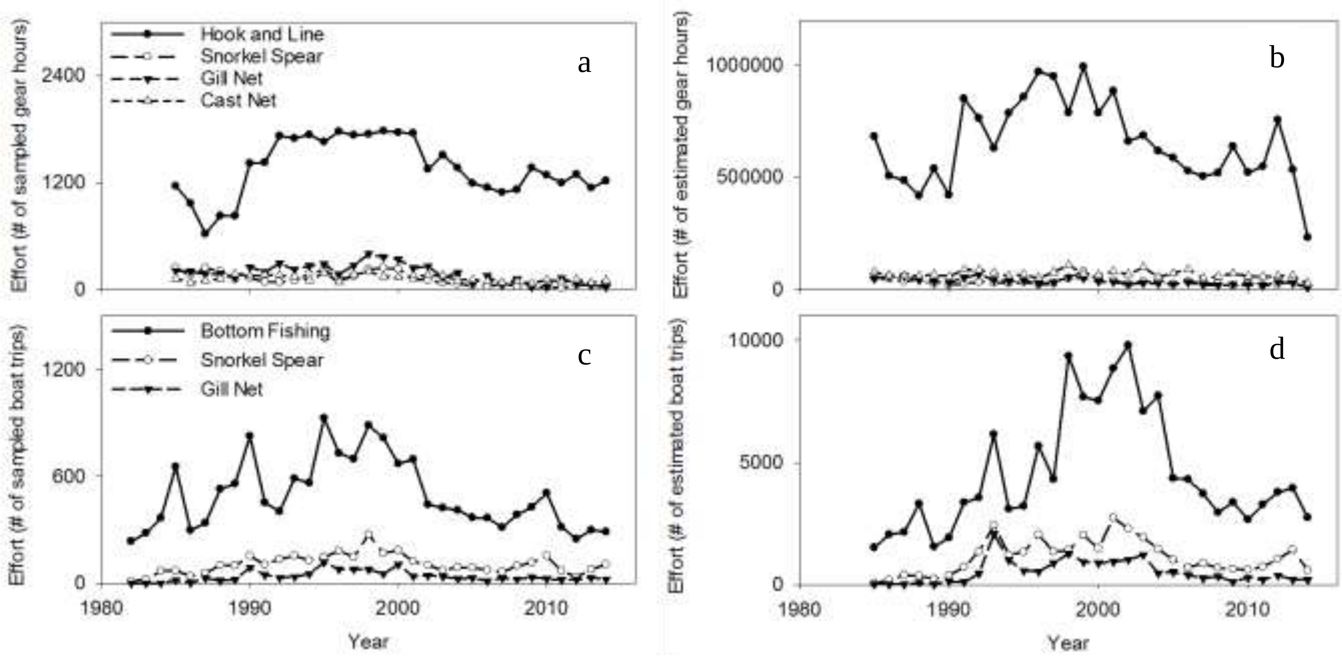


Figure 34. Time series of total sampled (left) and expanded (right) effort for top gear types in shore-based (top) and boat-based (bottom) creel surveys in Guam from 1982-2016

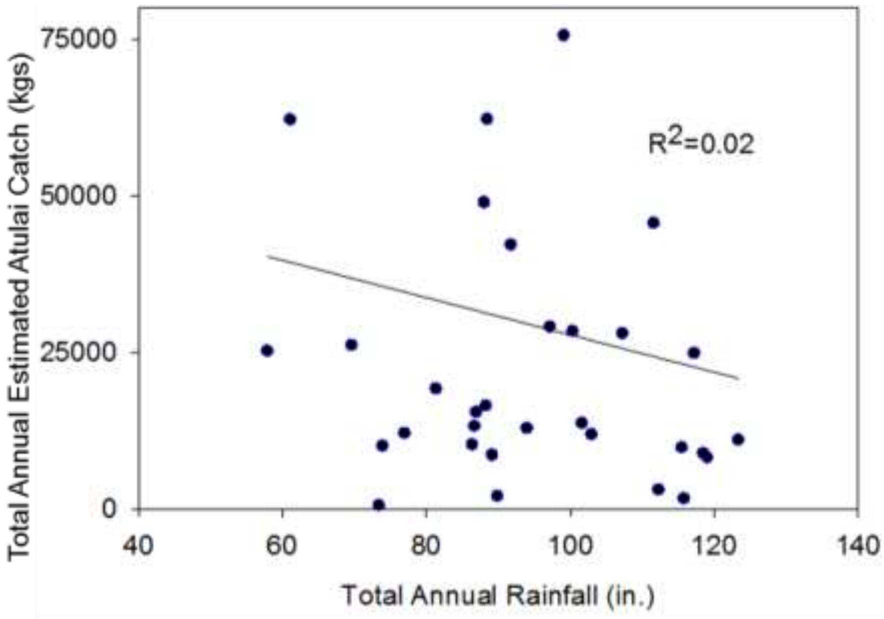


Figure 35. Linear regression between total atulai catch (kg) in the Guam shore-based and boat-based creel survey records and total annual rainfall (in.) from 1982-2016

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 36). 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 36). 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.

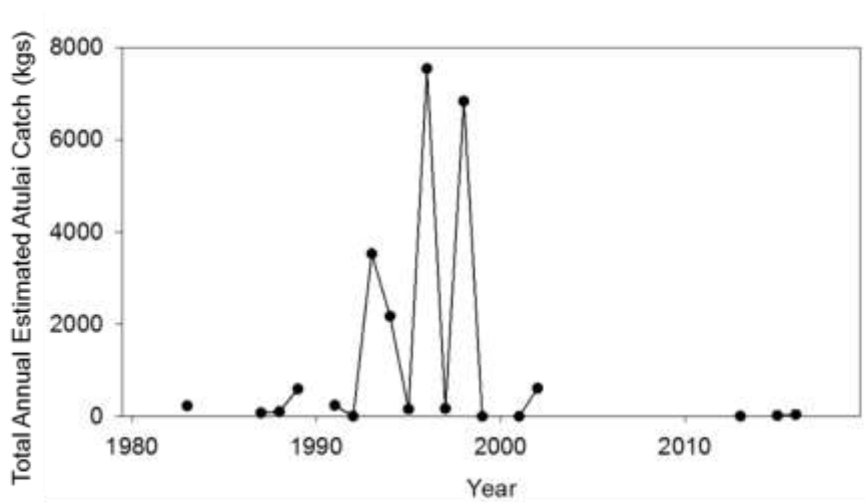


Figure 36. Time series of total annual expanded landings of *Decapterus macarellus* (kg) in Guam shore-and boat-based creel survey records from 1982-2016

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 37. 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 37).

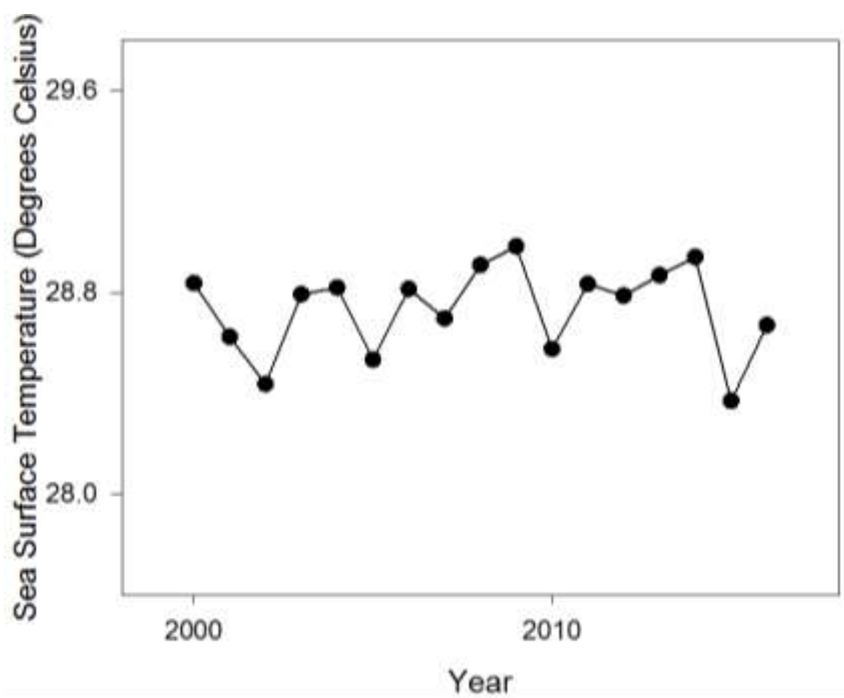


Figure 37. Time series of SST (°C) in the CNMI from 1985-2016 (CV = 0.55)

A time series of SST for Guam from 1985-2016 is shown in Figure 38. 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 38).

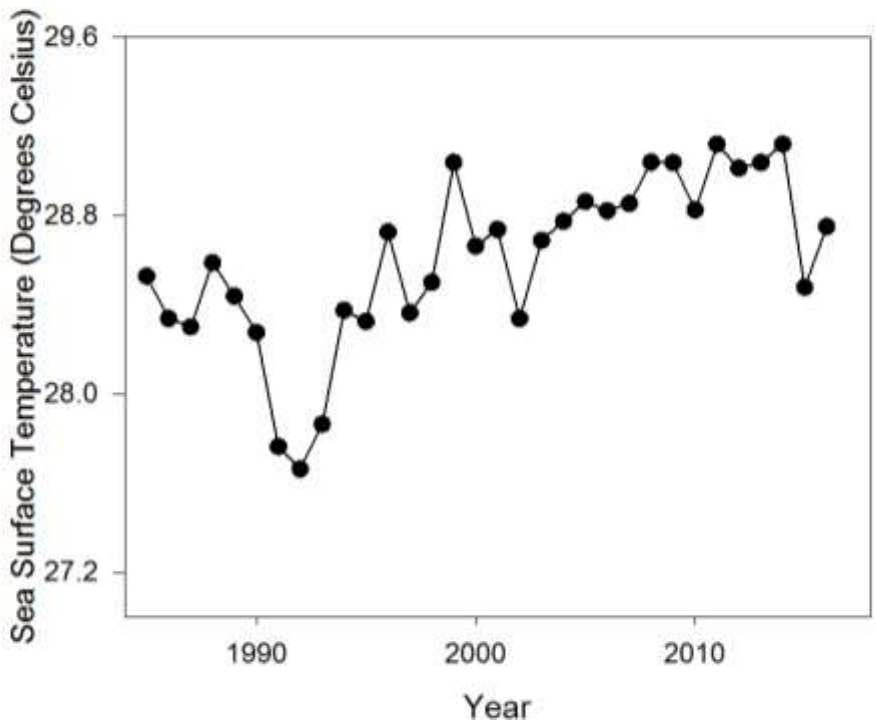


Figure 38. Time series of SST (°C) from 1985-2016 in Guam (CV = 1.38)

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 39. 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 39).

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 68 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 69. The comparisons between the two parameters showed a negatively significant relationship between 2000 and 2016 (R^2 = 0.30, p = 0.02; Table 69; Figure 40). 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 40).

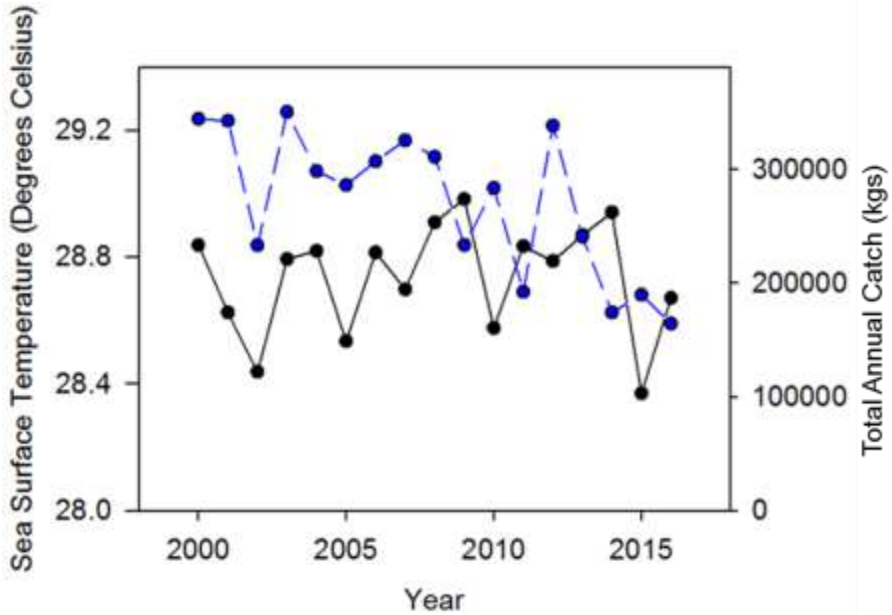


Figure 39. Time series of total annual catch (kg; blue) for the CNMI recreational coral reef fishery plotted alongside average annual SST (°C; black) from 2000-2016

Table 68. 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 69. 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

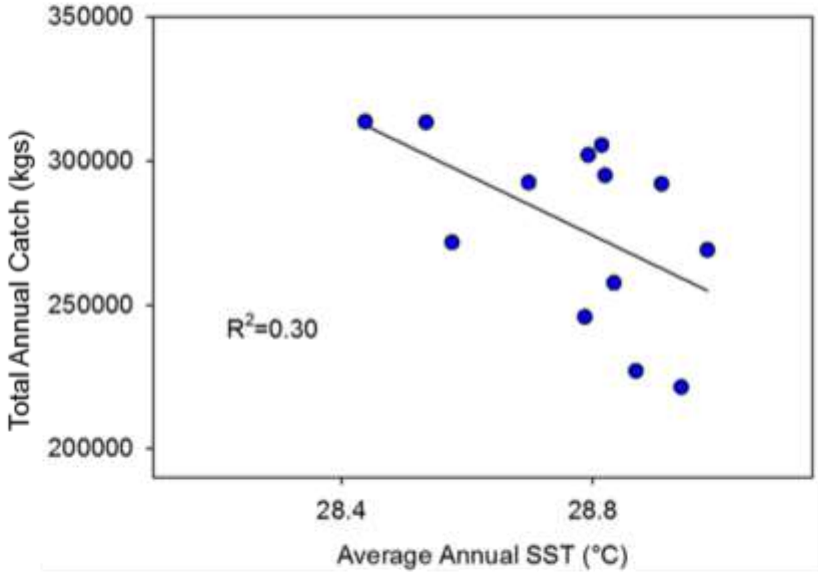


Figure 40. Linear regression showing the correlation between total annual catch (kg) in creel survey records and average annual SST (°C) in the CNMI from 2000-2016

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 69). The strongest associations between fishery catch and SST were observed from the Mullids ($R^2 = 0.22$, p = 0.06; Figure 41a), Carangids ($R^2 = 0.09$, p = 0.26; Figure 41b), and Lutjanids ($R^2 = 0.03$, p = 0.49; Figure 41c). While the relationship between catch and temperature for families Mullidae and Carangidae were negative, the Lutjanidae family had a positive relationship (Table 69).

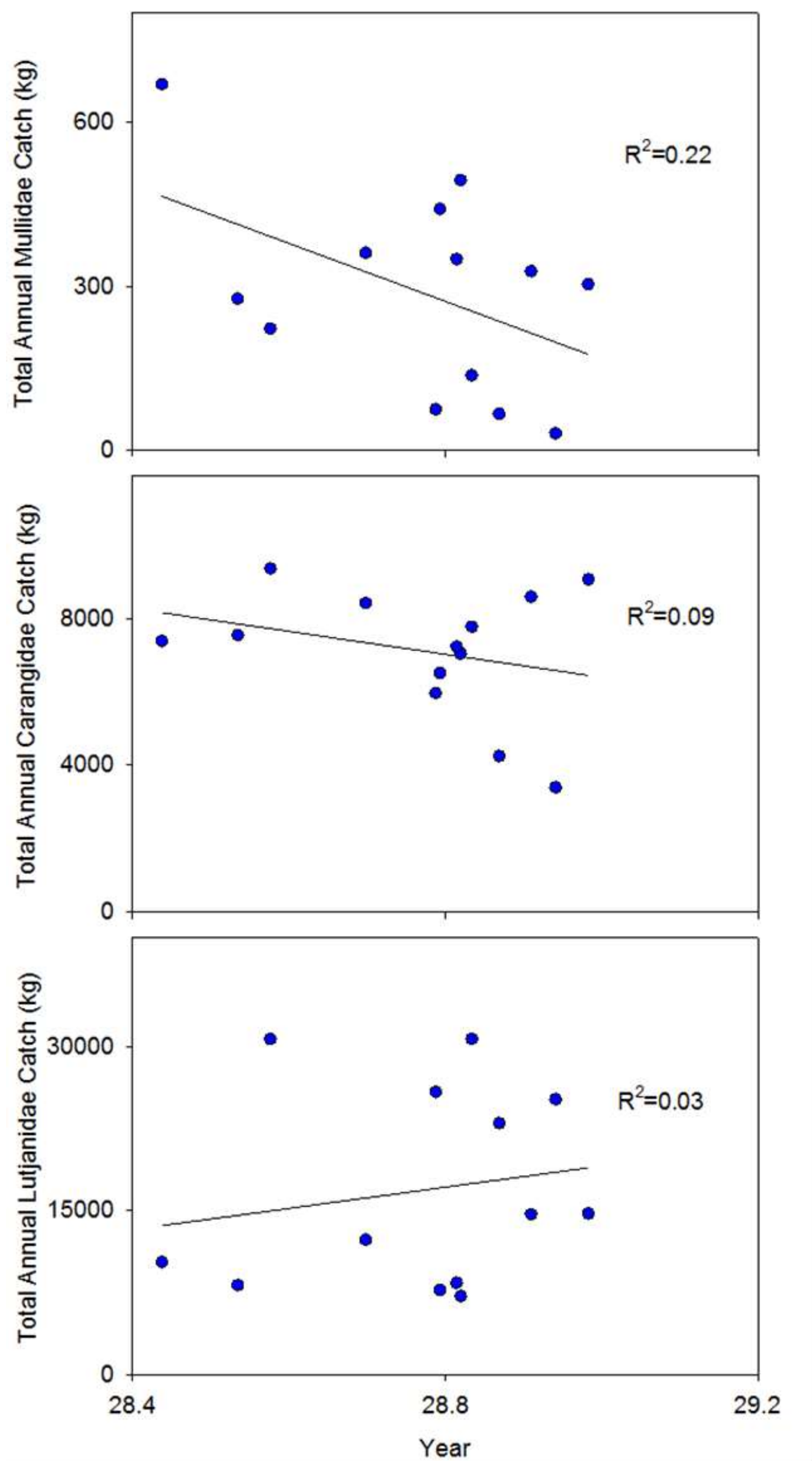


Figure 41. Linear regressions showing the three top correlations between total annual catch (kg) from creel survey records and average annual SST (°C) in the CNMI from for (a) Mullids, (b) Carangids, and (c) Lutjanids from 2000–2016

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 42. 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 42).

Multiple linear regressions and correlation analyses were performed on time series of recreational coral reef fishery catch and annual mean SST from Guam (Table 70). 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 70; Figure 43). 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 43).

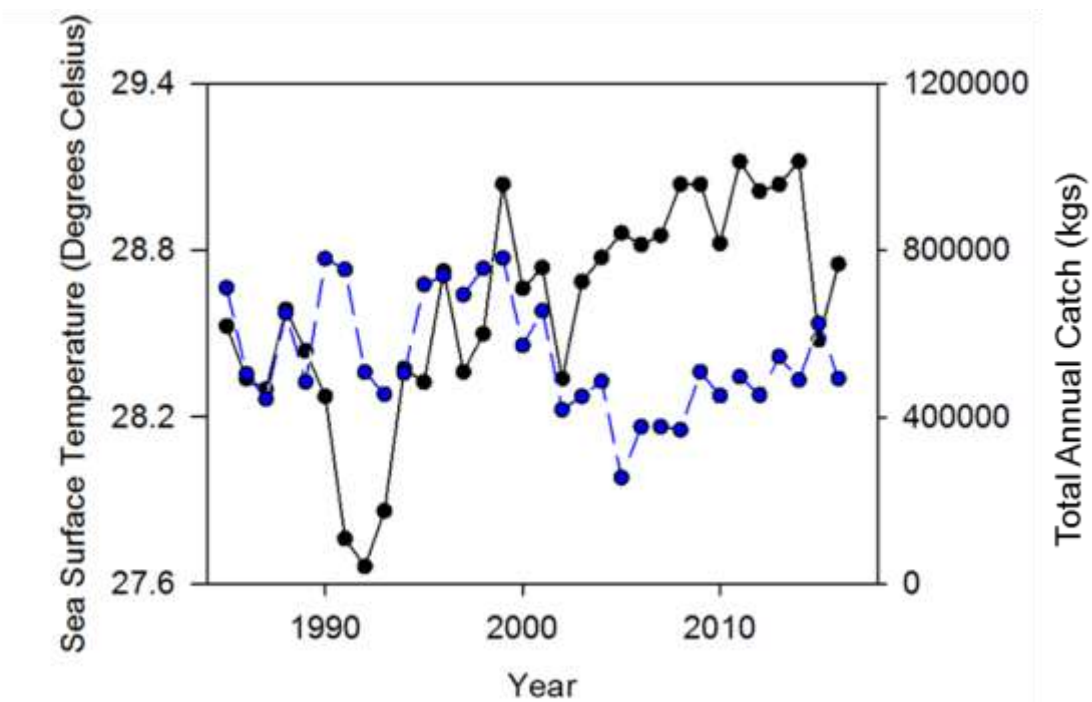


Figure 42. Time series of total annual catch (kg; blue) in the Guam shore-and boat-based creel survey records plotted with average annual SST (°C; black) from 1985-2016

Table 70. 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

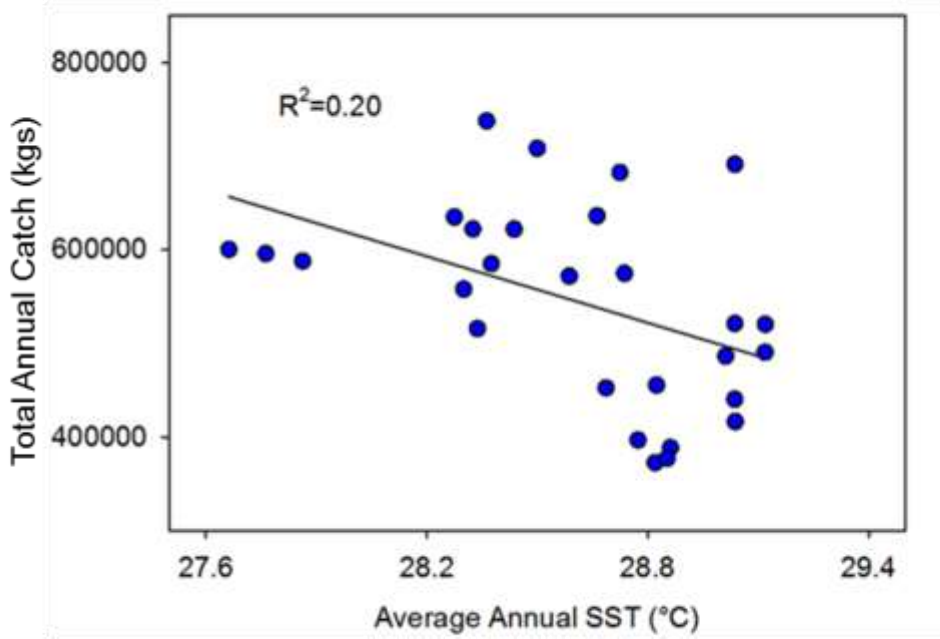


Figure 43. Linear regression between total annual catch (kg) for shore- and boat-based creel survey records and average annual SST (°C) in Guam from 1985-2016

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 70). 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 70; Figure 44a). The next two strongest associations observed were for families Siganidae (R^2 = 0.50, p = 0.00; Figure 44b) and Mugilidae (R^2 = 0.43, p = 0.01; Figure 44c). 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.

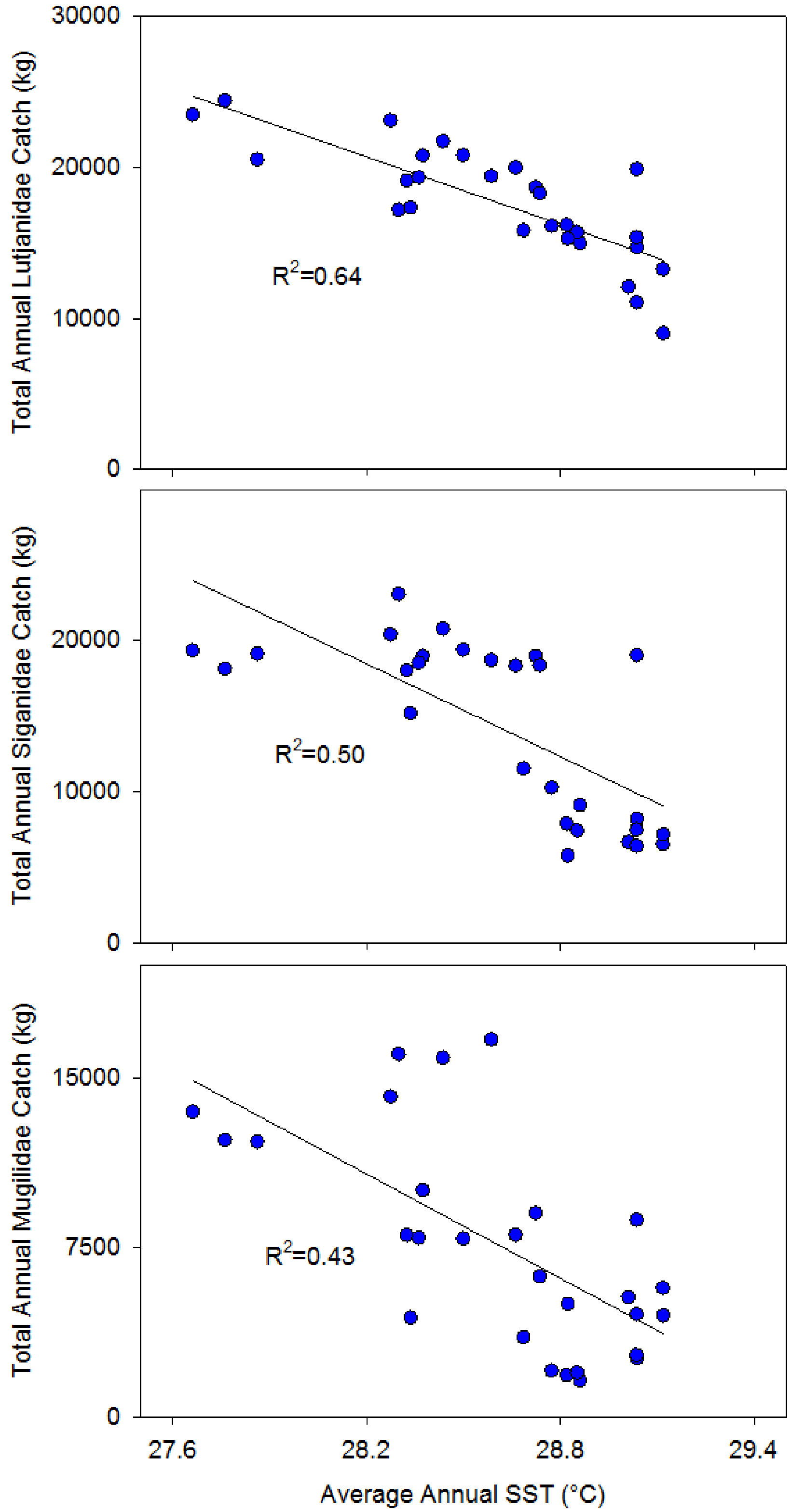


Figure 44. Linear regressions showing three top correlations between total annual catch (kg) for shore-and boat-based creel survey records and average annual SST (°C) in Guam for (a) Lutjanids, (b) Siganids, and (c) Mugilids from 1985–2016

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 (Behrenfeld 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 45. 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 45.

A time series of fluorometric chlorophyll-*a* concentrations (mg/m^3) for the years 1998-2016 in Guam is shown in Figure 46. 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 46).

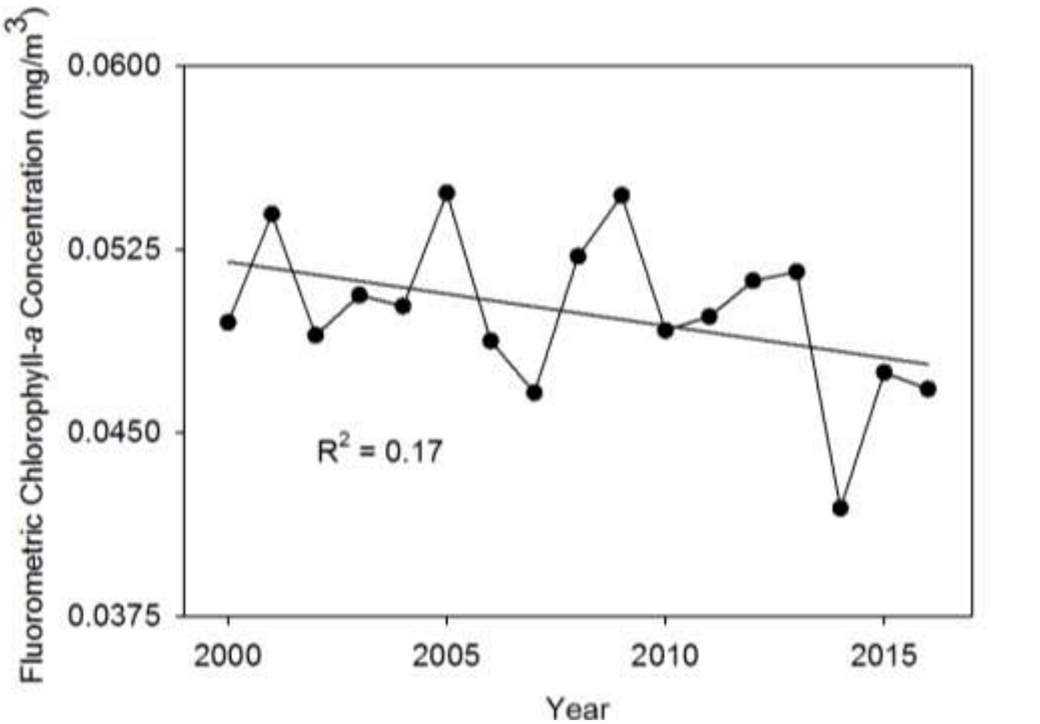


Figure 45. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around the CNMI from 1998-2016 (CV=6.28)

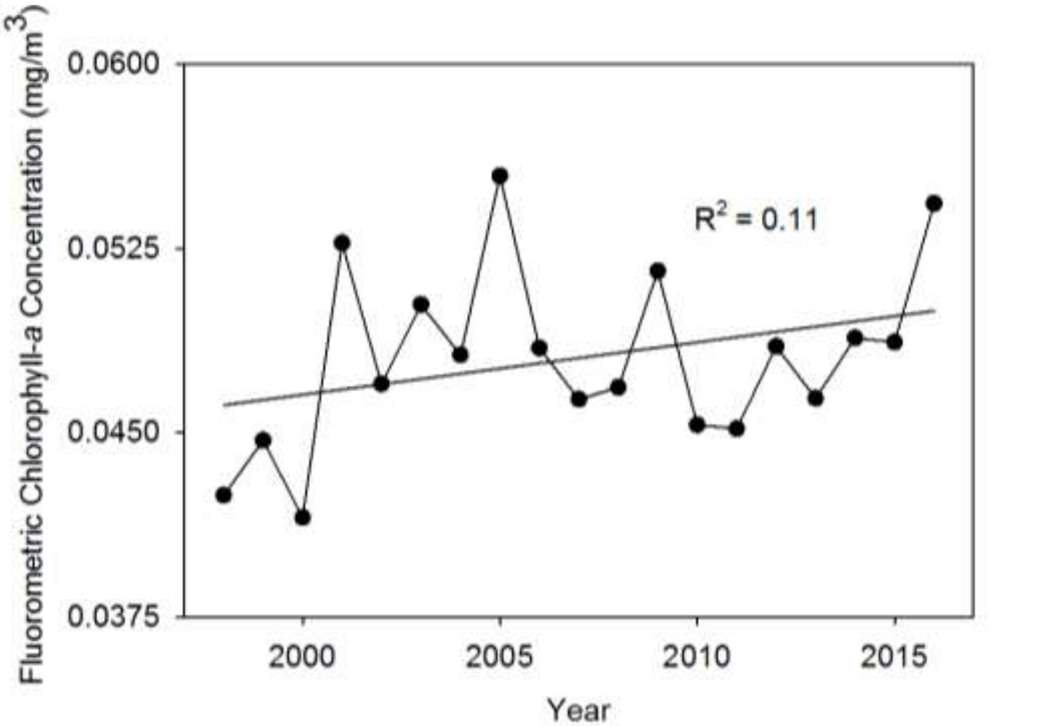


Figure 46. Time series of fluorometric chlorophyll-a concentrations (mg/m^3) around Guam from 1998-2016 (CV=7.03)

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 47. 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 47).

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 71; Figure 48). 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 48).

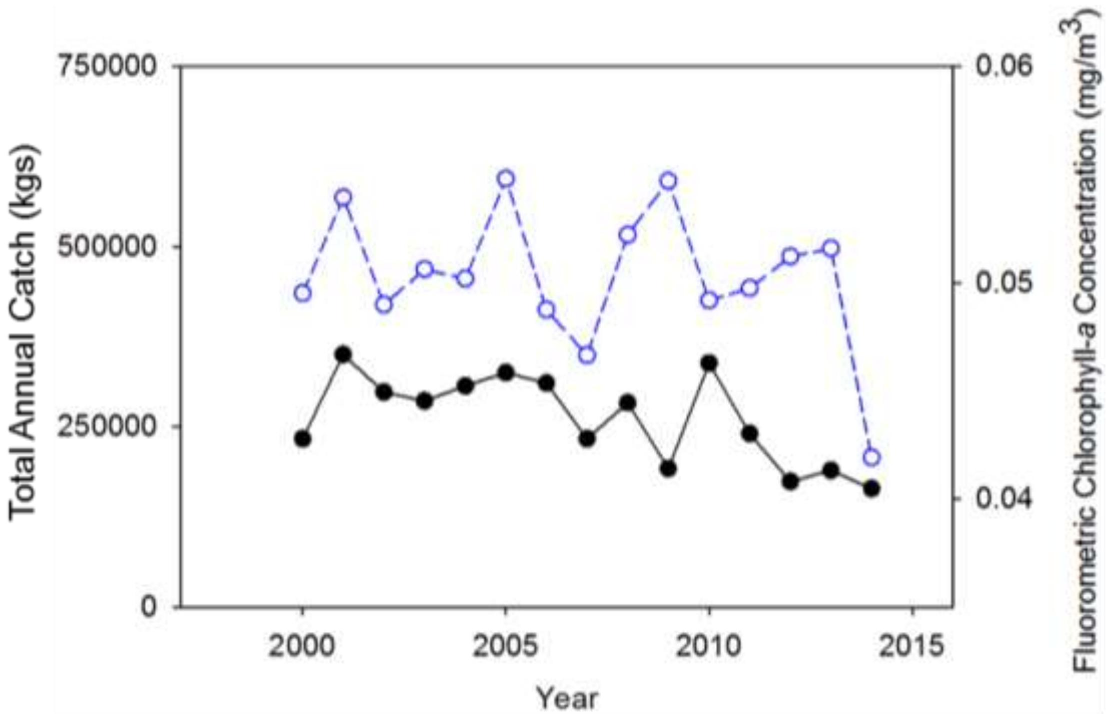


Figure 47. Comparison of the CNMI recreational reef fish catch (kg; black) from creel survey records with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 2000-2014 (*r* = 0.32)

Table 71. 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

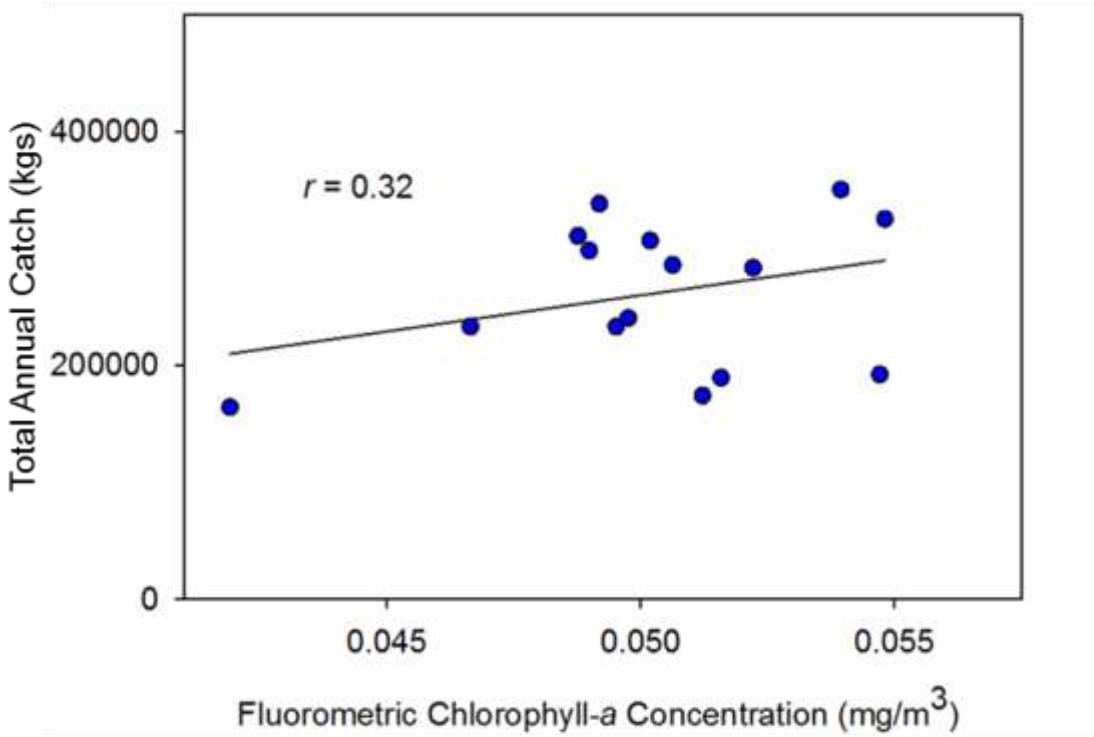


Figure 48. Linear regression between total annual catch (kg) phase lag (t+2 years) and fluorometric chlorophyll-a concentrations (mg/m^3) in CNMI from 2000-2014

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 71). 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 49a-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 71).

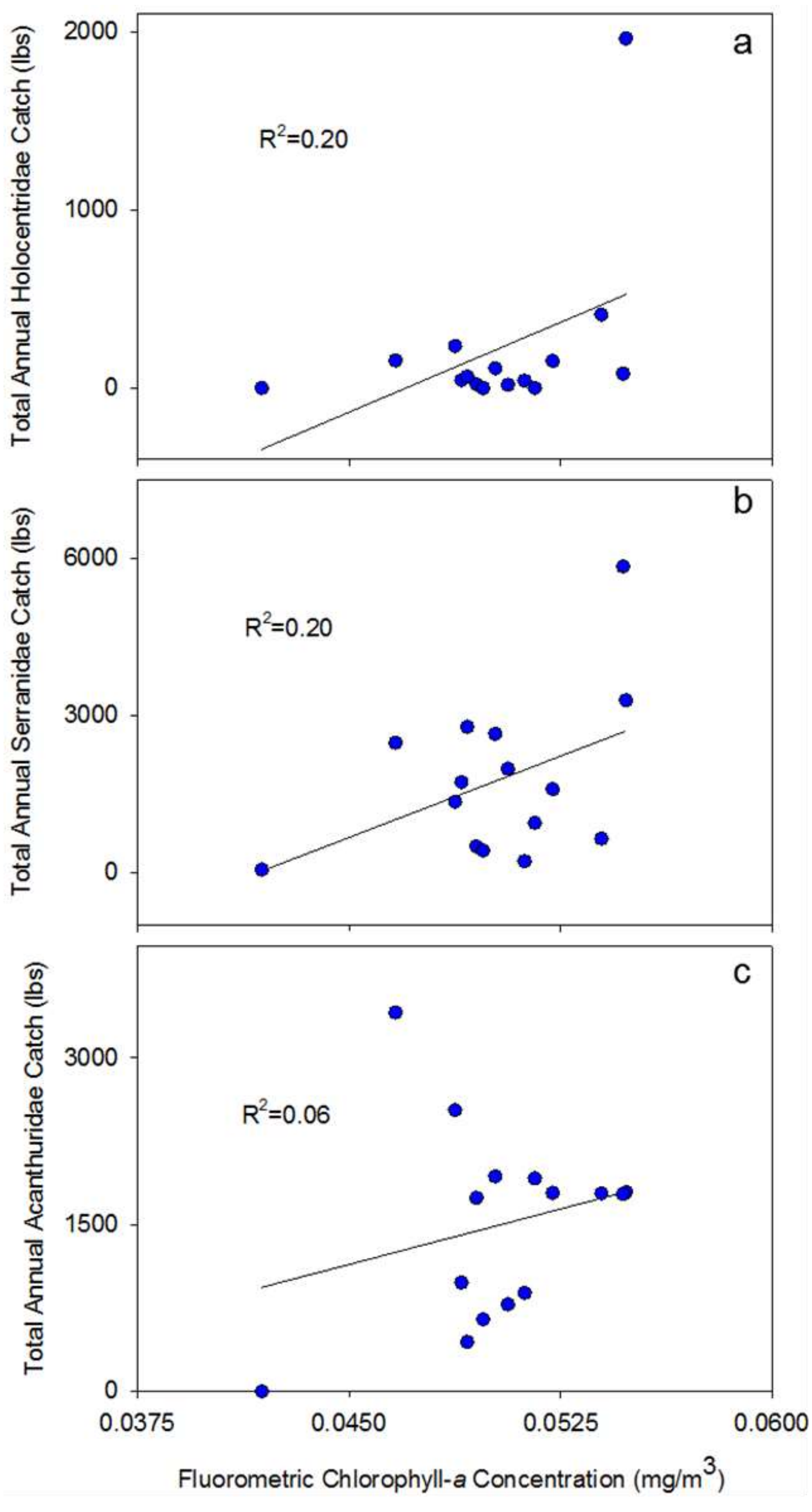


Figure 49. Linear regressions showing the three top correlations between total annual catch (kg) for the CNMI from creel survey records with phase lag (t+2 years) and fluorometric

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 50. Catch levels were relatively variable over the course of the time series when considering the variation in pigment levels (CV=26.2; Figure 50). 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 50).

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 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 72; Figure 51). 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 72; Figure 51).

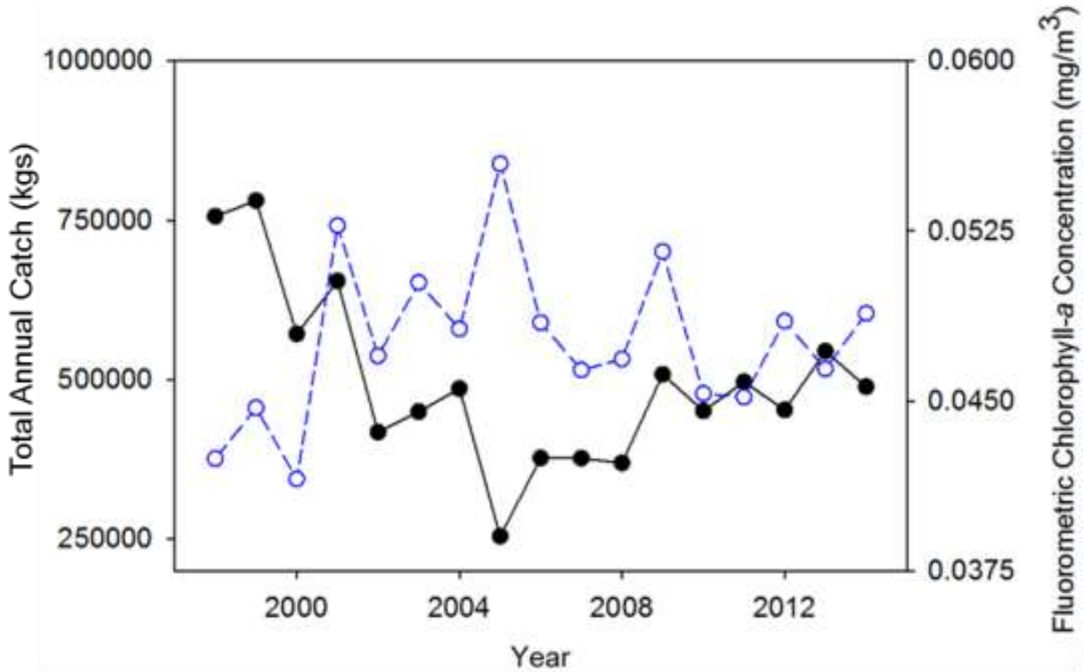


Figure 50. Comparison of Guam recreational reef fish catch for shore-and boat-based creel survey records (kg; black) with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3; blue) from 1998-2014

Table 72. 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**

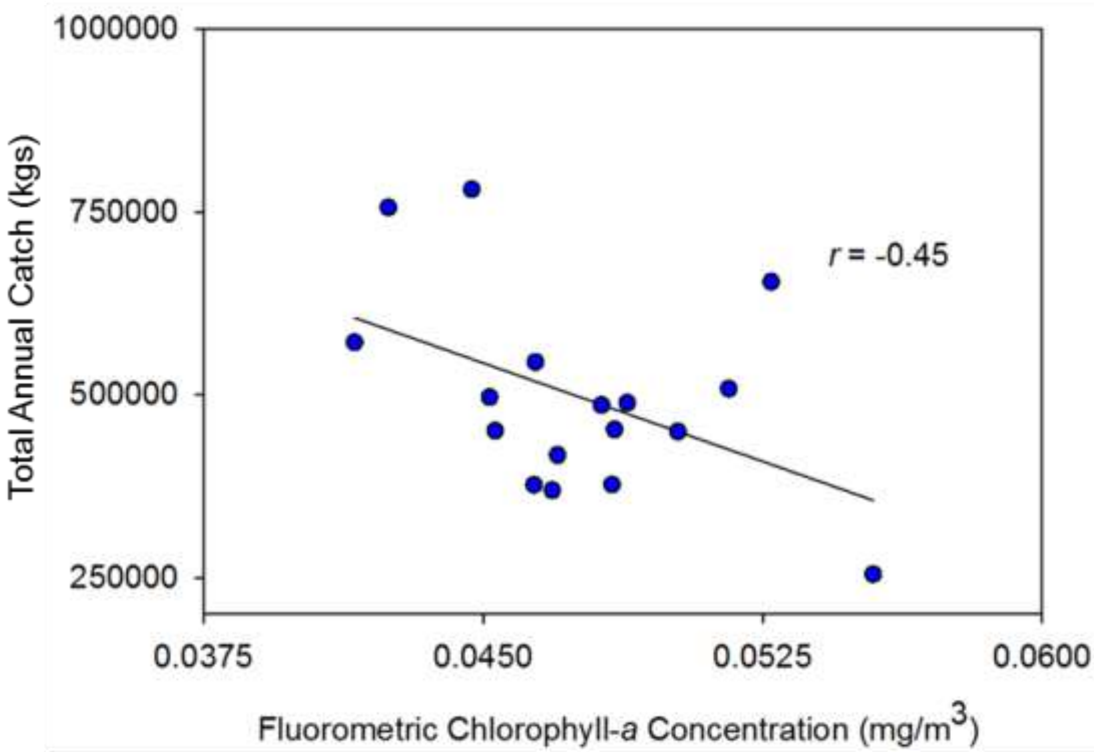


Figure 51. Linear regression between total annual catch (kg) for Guam shore-and boat-based creel survey records with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^3) from 1998-2014

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 72). 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 72; Figure 52a). 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 72; Figure 52b;). 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 72; Figure 52c); 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.

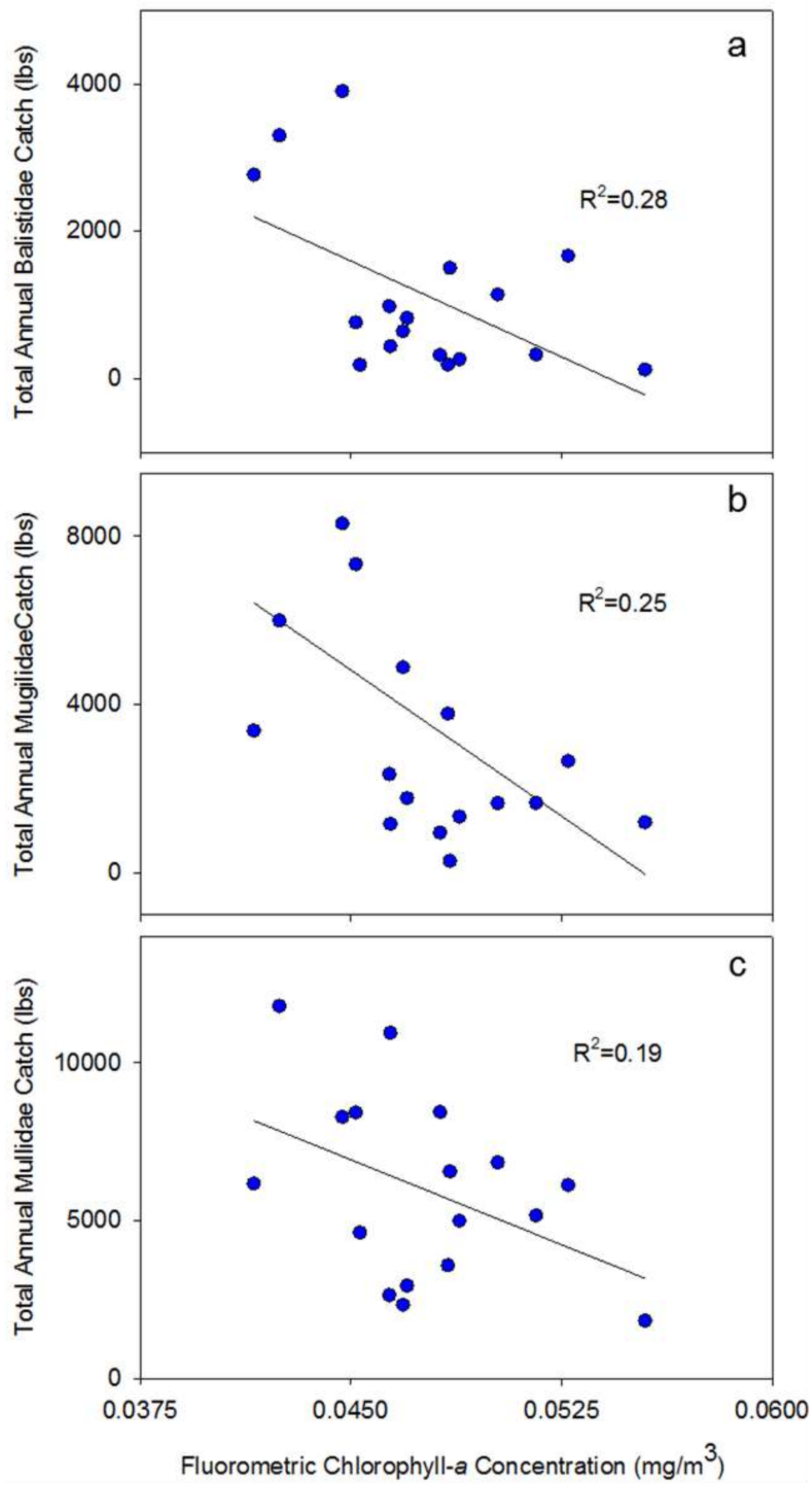


Figure 52. Linear regressions showing the three top correlations between total annual catch (kg) for Guam for shore-and boat-based creel survey records with phase lag (t+2 years)

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 (CPC 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 53. 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 53).

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

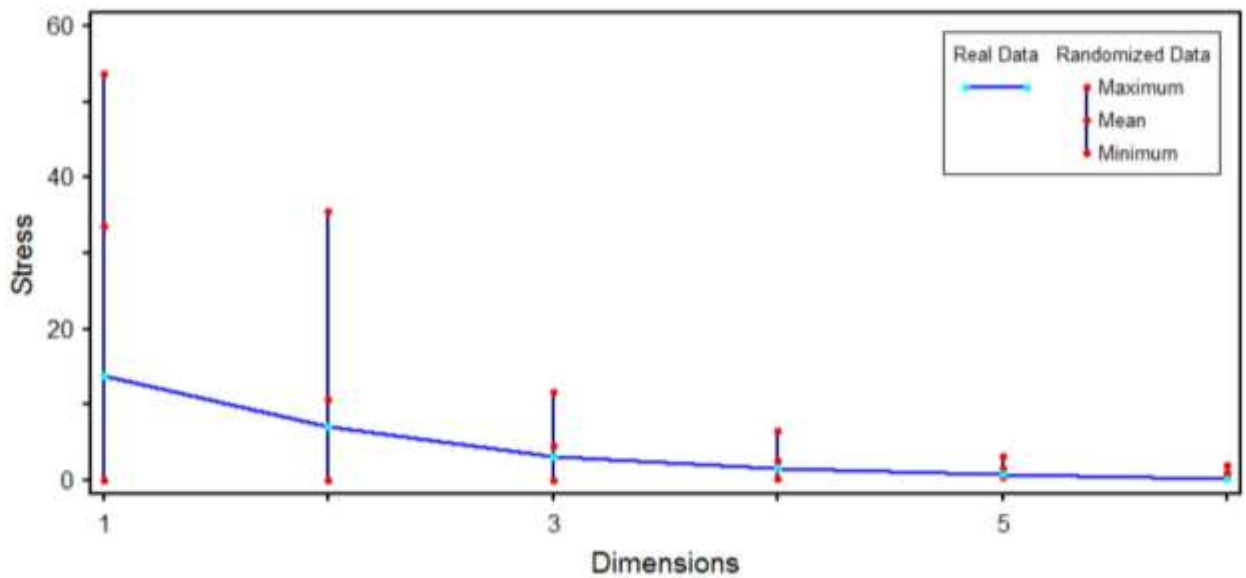


Figure 53. NMS scree plot showing the stress test to determine dimensionality for the final solution for the CNMI multivariate analysis; a one-axis solution was recommended

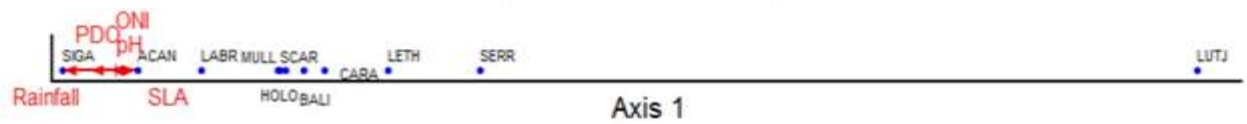


Figure 54. One-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters in the CNMI from 2000-2014

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 55). A majority of the families were clustered in ordination space, with the notable exception of Carangidae (Figure 56).

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

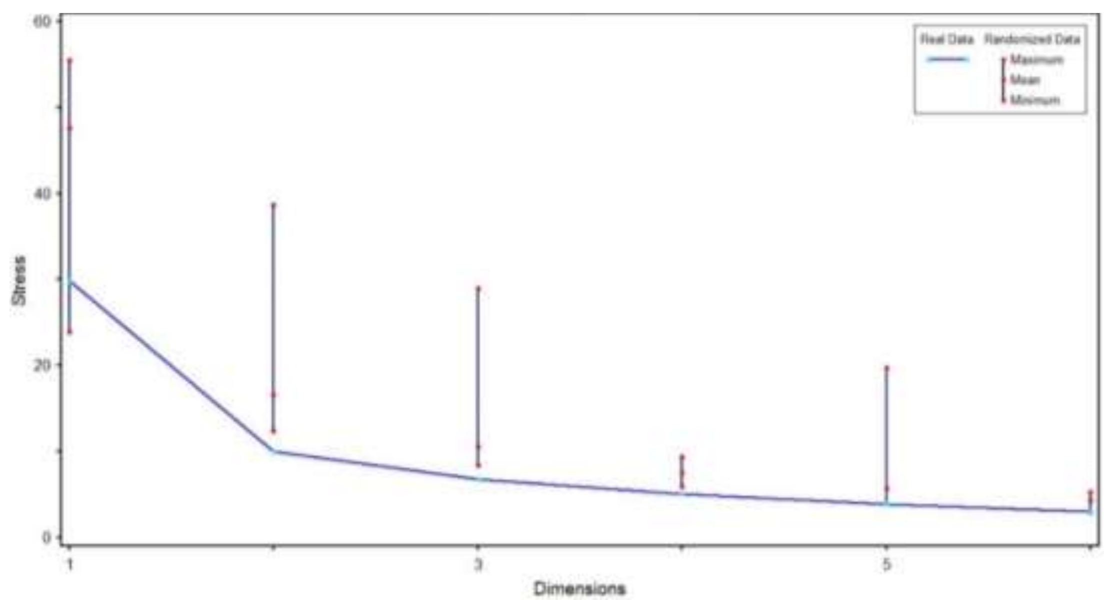


Figure 55. NMS scree plot showing the stress test to determine dimensionality for the final solution for the Guam multivariate analysis; two-axis solution was recommended

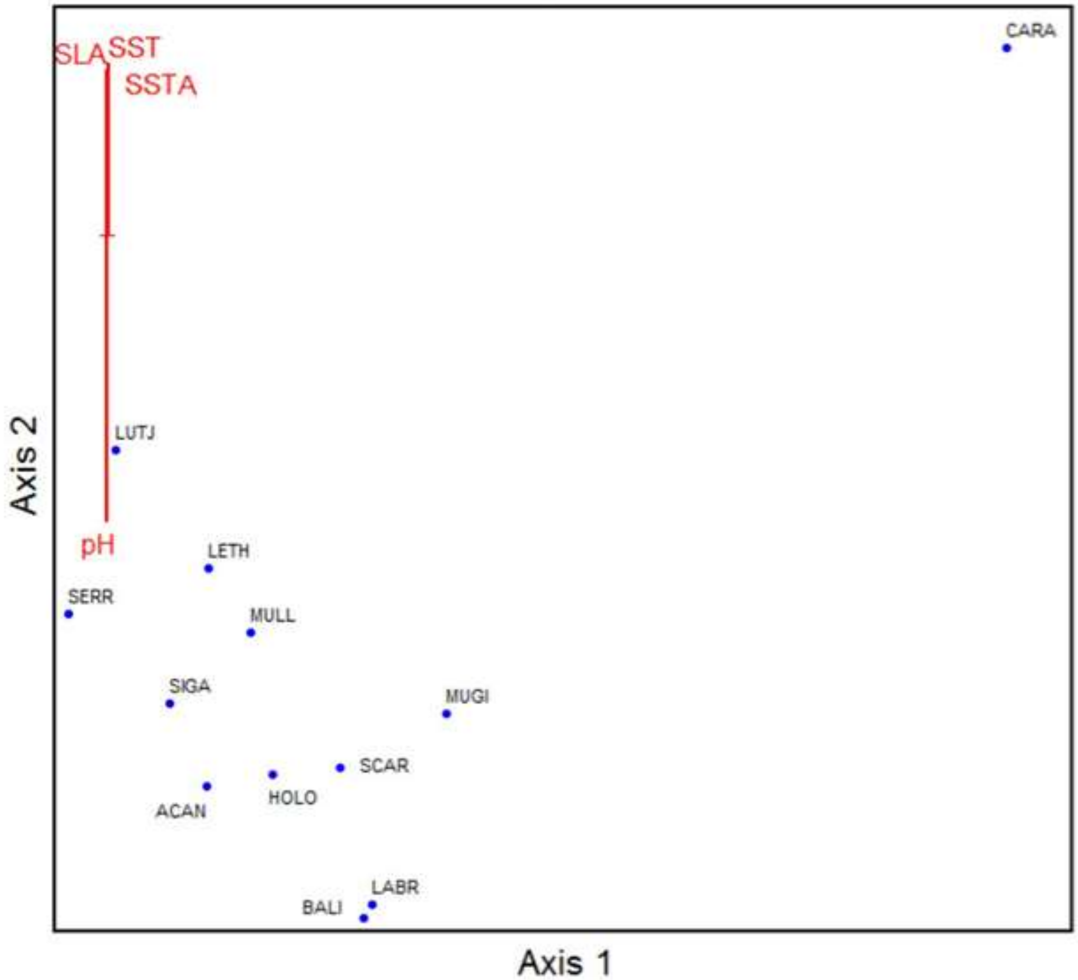


Figure 56. Two-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters in Guam from 1989-2014

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 2021 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.

Becker EA, Forney KA, Oleson EM, Bradford AL, Moore JE, Barlow J. 2021. Habitat-based density estimates for cetaceans within the waters of the U.S. Exclusive Economic

Zone around the Hawaiian Archipelago. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-116, 38 p. https://doi.org/10.25923/x9q9-rd73.

The Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) 2017 was conducted in waters within the United States (U.S.) Exclusive Economic Zone (EEZ) around the Hawaiian Archipelago (henceforth "Hawaiian EEZ" for brevity) from 6 July through 1 December 2017 (Yano et al. 2018). The primary objective of this line-transect survey was to collect cetacean sighting data to support the derivation of cetacean density estimates using both design-based analyses and habitat modeling techniques. This report summarizes the results of the habitat modeling effort. The design-based estimates are described separately in Bradford et al. (in review).

Berger AM, Deroba JJ, Bosley KM, Goethel DR, Langseth BJ, Schueller AM, Hanselman DH. 2021. Incoherent dimensionality in fisheries management: consequences of misaligned stock assessment and population boundaries. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsaa203.

Fisheries policy inherently relies on an explicit definition of management boundaries that delineate the spatial extent over which stocks are assessed and regulations are implemented. However, management boundaries tend to be static and determined by politically negotiated or historically identified population (or multi-species) units, which create a potential disconnect with underlying, dynamic population structure. The consequences of incoherent management and population or stock boundaries were explored through the application of a two-area spatial simulation–estimation framework. Results highlight the importance of aligning management assessment areas with underlying population structure and processes, especially when fishing mortality is disproportionate to vulnerable biomass among management areas, demographic parameters (growth and maturity) are not homogenous within management areas, and connectivity (via recruitment or movement) unknowingly exists among management areas. Bias and risk were greater for assessments that incorrectly span multiple population segments (PSs) compared to assessments that cover a subset of a PS, and these results were exacerbated when there was connectivity between PSs. Directed studies and due consideration of critical PSs, spatially explicit models, and dynamic management options that help align management and population boundaries would likely reduce estimation biases and management risk, as would closely coordinated management that functions across population boundaries.

Donovan MK, Burkepile DE, Kratochwill C, Shlesinger T, Sully S, Oliver TA, Hodgson G, Freiwald J, van Woesik R. 2021. Local conditions magnify coral loss after marine heatwaves. *Science*. *372*(6545):977-80. https://doi.org/10.1126/science.abd9464.

Climate change threatens coral reefs by causing heat stress events that lead to widespread coral bleaching and mortality. Given the global nature of these mass coral mortality events, recent studies argue that mitigating climate change is the only path to conserve coral reefs. Using a global analysis of 223 sites, we show that local stressors act synergistically with climate change to kill corals. Local factors such as high abundance of macroalgae or urchins magnified coral loss in the year after bleaching. Notably, the combined effects of increasing heat stress and macroalgae intensified coral loss. Our results offer an optimistic premise that effective local management, alongside global efforts to mitigate climate change, can help coral reefs survive the Anthropocene.

Friedland KD, Smolinski S, Tanaka KR. 2021. Contrasting patterns in the occurrence and biomass centers of gravity among fish and macroinvertebrates in a continental shelf ecosystem. *Ecol Evol*. *11*(5). https://doi.org/10.1002/ece3.7150.

The distribution of a group of fish and macroinvertebrates (n = 52) resident in the US Northeast Shelf large marine ecosystem were characterized with species distribution models (SDM), which in turn were used to estimate occurrence and biomass center of gravity (COG). The SDMs were fit using random forest machine learning and were informed with a range of physical and biological variables. The estimated probability of occurrence and biomass from the models provided the weightings to determine depth, distance to the coast, and along-shelf distance COG. The COGs of occupancy and biomass habitat tended to be separated by distances averaging 50 km, which approximates half of the minor axis of the subject ecosystem. During the study period (1978–2018), the biomass COG has tended to shift to further offshore positions whereas occupancy habitat has stayed at a regular spacing from the coastline. Both habitat types have shifted their along-shelf distances, indicating a general movement to higher latitude or to the Northeast for this ecosystem. However, biomass tended to occur at lower latitudes in the spring and higher latitude in the fall in a response to seasonal conditions. Distribution of habitat in relation to depth reveals a divergence in response with occupancy habitat shallowing over time and biomass habitat distributing in progressively deeper water. These results suggest that climate forced change in distribution will differentially affect occurrence and biomass of marine taxa, which will likely affect the organization of ecosystems and the manner in which human populations utilize marine resources.

Gonzalez-Mon B, Bodin Ö, Lindkvist E, Frawley TH, Giron-Nava A, Basurto X, Nenadovic M, Schlüter M. 2021. Spatial diversification as a mechanism to adapt to environmental changes in small-scale fisheries. Environmental Science & Policy, 116, pp.246-257.

Small-scale fisheries' actors increasingly face new challenges, including climate driven shifts in marine resource distribution and productivity. Diversification of target species and fishing locations is a key mechanism to adapt to such changes and maintain fisheries livelihoods. Here we explore environmental and institutional factors mediating how patterns of spatial diversification (i.e., utilization of alternative fishing grounds) and target species diversification change over time. Using small-scale fisheries in Baja California Sur (Mexico) as a case study, we adopt a social-ecological network approach to conduct a spatially explicit analysis of fisheries landings data (2008–2016). This approach quantifies relative patterns of diversification, and when combined with a qualitative analysis of existing literature, enables us to illuminate institutional and environmental factors that may influence diversification strategies. Our results indicate that interannual changes in spatial diversification are correlated with regional oceanographic change, while illustrating the heterogeneity and dynamism of diversification strategies. Rather than acting in isolation, we hypothesize that environmental drivers likely operate in combination with existing fisheries regulations and local socioeconomic context to mediate spatial diversification. We argue that small-scale fisheries policies need to better account such linkages as we move towards an increasingly variable environment. Overall, our results highlight spatial diversification as a dynamic process and constitute an important step towards understanding and managing the complex mechanisms through which environmental changes affect small-scale fisheries.

Heneghan RF, Galbraith E, Blanchard JL, Harrison C, Barrier N, Bulman C, Cheung W, Coll M, Eddy TD, Erauskin-Extramiana M, Everett JD, et al. 2021. Disentangling diverse

responses to climate change among global marine ecosystem models. Progress in Oceanography:102659 https://doi.org/10.1016/j.pocean.2021.102659.

Climate change is warming the ocean and impacting lower trophic level (LTL) organisms. Marine ecosystem models can provide estimates of how these changes will propagate to larger animals and impact societal services such as fisheries, but at present these estimates vary widely. A better understanding of what drives this inter-model variation will improve our ability to project fisheries and other ecosystem services into the future, while also helping to identify uncertainties in process understanding. Here, we explore the mechanisms that underlie the diversity of responses to changes in temperature and LTLs in eight global marine ecosystem models from the Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP). Temperature and LTL impacts on total consumer biomass and ecosystem structure (defined as the relative change of small and large organism biomass) were isolated using a comparative experimental protocol. Total model biomass varied between −35% to +3% in response to warming, and -17% to +15% in response to LTL changes. There was little consensus about the spatial redistribution of biomass or changes in the balance between small and large organisms (ecosystem structure) in response to warming, an LTL impacts on total consumer biomass varied depending on the choice of LTL forcing terms. Overall, climate change impacts on consumer biomass and ecosystem structure are well approximated by the sum of temperature and LTL impacts, indicating an absence of nonlinear interaction between the models' drivers. Our results highlight a lack of theoretical clarity about how to represent fundamental ecological mechanisms, most importantly how temperature impacts scale from individual to ecosystem level, and the need to better understand the two-way coupling between LTL organisms and consumers. We finish by identifying future research needs to strengthen global marine ecosystem modelling and improve projections of climate change impacts.

Hyrenbach KD, Ishizaki A, Polovina J, Ellgen S (Eds.). 2021. The factors influencing albatross interactions in the Hawaii longline fishery: Towards identifying drivers and quantifying impacts. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-122, 163 p. https://doi.org/10.25923/nb95-gs31.

The Hawaii longline fishery has been required to use seabird mitigation measures under the Pacific Pelagic Fishery Management Plan (current Fishery Ecosystem Plan, or FEP) since 2001. In the past decade since the successful implementation of seabird mitigation measures, the fishery has seen a gradual increasing trend in Black-footed (*Phoebastria nigripes*, BFAL) and Laysan (*P. immutabilis*, LAAL) albatross interactions, with higher rates of Black-footed albatross interactions since 2015. A published analysis conducted by Gilman and colleagues (2016) using data from October 2004 to May 2014, indicated that albatross interaction rates significantly increased during years of higher annual mean multivariate El Niño index (MEI), suggesting that oceanographic changes may have contributed to these changes in albatross catch rates. This analysis also showed a significant increasing trend in the number of albatross attending fishing vessels which may have contributed to the increasing catch rates. Moreover, the higher interaction rates observed during the recent El Niño event (2015–2016) further underscore the potential links between ocean conditions and albatross longline interactions.

Jardim E, Azevedo M, Brodziak J, Brooks EN, Johnson KF, Klibansky N, Millar CP, Minto C, Mosqueira I, Nash RD, et al. 2021. Operationalizing ensemble models for scientific advice to fisheries management. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsab010.

This paper explores the possibility of using the ensemble modelling paradigm to fully capture assessment uncertainty and improve the robustness of advice provision. We identify and discuss advantages and challenges of ensemble modelling approaches in the context of scientific advice. There are uncertainties associated with every phase in the stock assessment process: data collection, assessment model choice, model assumptions, interpretation of risk, up to the implementation of management advice. Additionally, the dynamics of fish populations are complex, and our incomplete understanding of those dynamics and limited observations of important mechanisms, necessitate that models are simpler than nature. The aim is for the model to capture enough of the dynamics to accurately estimate trends and abundance, and provide the basis for robust advice about sustainable harvests. The status quo approach to assessment modelling has been to identify the "best" model and generate advice from that model, mostly ignoring advice from other model configurations regardless of how closely they performed relative to the chosen model. We discuss and make suggestions about the utility of ensemble models, including revisions to the formal process of providing advice to management bodies, and recommend further research to evaluate potential gains in modelling and advice performance.

Kaplan IC, Gaichas SK, Stawitz CC, Lynch PD, Marshall KN, Deroba JJ, Masi M, Brodziak JK, Aydin KY, Holsman K, et al. 2021. Management Strategy Evaluation: Allowing the Light on the Hill to Illuminate More Than One Species. Frontiers in Marine Science. 8:688. https://doi.org/10.3389/fmars.2021.624355.

Management strategy evaluation (MSE) is a simulation approach that serves as a "light on the hill" (Smith, 1994) to test options for marine management, monitoring, and assessment against simulated ecosystem and fishery dynamics, including uncertainty in ecological and fishery processes and observations. MSE has become a key method to evaluate trade-offs between management objectives and to communicate with decision makers. Here we describe how and why MSE is continuing to grow from a single species approach to one relevant to multi-species and ecosystem-based management. In particular, different ecosystem modeling approaches can fit within the MSE process to meet particular natural resource management needs. We present four case studies that illustrate how MSE is expanding to include ecosystem considerations and ecosystem models as 'operating models' (i.e., virtual test worlds), to simulate monitoring, assessment, and harvest control rules, and to evaluate tradeoffs via performance metrics. We highlight United States case studies related to fisheries regulations and climate, which support NOAA's policy goals related to the Ecosystem Based Fishery Roadmap and Climate Science Strategy but vary in the complexity of population, ecosystem, and assessment representation. We emphasize methods, tool development, and lessons learned that are relevant beyond the United States, and the additional benefits relative to single-species MSE approaches.

Kasperski S, DePiper GS, Blake S, Colburn LL, Jepson M, Haynie1 AC, Karnauskas M, Leong KM, Lipton D, Masi M, et al. 2021. Assessing the State of Coupled Social-Ecological Modeling in Support of Ecosystem Based Fisheries Management in the U.S. Front. Mar. Sci. https://doi.org/10.3389/fmars.2021.631400.

There has been a proliferation of coupled social-ecological systems (SES) models created and published in recent years. However, the degree of coupling between natural and social systems varies widely across the different coupled models and is often a function of the disciplinary background of the team conducting the research. This manuscript examines models developed for and used by NOAA Fisheries in support of Ecosystem Based Fisheries Management (EBFM) in the United States. It provides resource managers and interdisciplinary scientists insights on the strengths and weaknesses of the most commonly used SES models: end-to-end models, conceptual models, bioeconomic models, management strategy evaluations (MSEs), fisher behavior models, integrated social vulnerability models, and regional economic impact models. These model types are not unique to the literature, but allow us to differentiate between one-way coupled models – where outputs from one model are inputs into a second model of another discipline with no feedback to the first model, and two-way coupled models – where there are linkages between the natural and social system models. For a model to provide useful strategic or tactical advice, it should only be coupled to the degree necessary to understand the important dynamics/responses of the system and to create management-relevant performance metrics or potential risks from an (in)action. However, one key finding is to not wait to integrate! This paper highlights the importance of "when" the coupling happens, as timing affects the ability to fully address management questions and multi-sectoral usage conflicts that consider the full SES for EBFM or ecosystem based management (EBM) more generally.

McNamara KE, Westoby R, Chandra A. 2021. Exploring climate-driven non-economic loss and damage in the Pacific Islands. Current Opinion in Environmental Sustainability, 50, pp.1-11.

Non-economic loss and damage induced by climate change in the Pacific Islands region has been reported as fears of cultural loss, deterioration of vital ecosystem services, and dislocation from ancestral lands, among others. This paper undertakes an in-depth systematic review of literature from the frontlines of the Pacific Islands to ascertain the complexities of non-economic loss and damage from climate change. We synthesise knowledge to date on different but inter-connected categories of non-economic loss and damage, namely: human mobility and territory, cultural heritage and Indigenous knowledge, life and health, biodiversity and ecosystem services, and sense of place and social cohesion. Identifying gaps and possibilities for future research agendas is presented. Synthesising knowledge to date and identifying remaining gaps about non-economic loss and damage is an important step in taking stock of what we already know and fostering action and support for addressing loss and damage in the years to come.

Politikos DV, Rose KA, Curchitser EN, Checkley DM Jr , Rykaczewski RR, Fiechter J. 2021. Climate variation and anchovy recruitment in the California current: a cause-and-effect analysis of an end-to-end model simulation. Marine Ecology Progress Series.Volume 680:111-136. https://doi.org/10.3354/meps13853.

Interannual and regime (decadal) scale changes in climate affect the spatial distribution and productivity of marine fish species in numerous ecosystems. We analyzed a historical simulation (1965-2000) from an end-to-end ecosystem model of anchovy population dynamics for the California Current System to untangle the effects of warm versus cool conditions on recruitment. A 3-dimensional coupled hydrodynamic-NPZD (nitrogen-phytoplankton-zooplankton-detritus) model (ROMS-NEMURO) provided the physical conditions (circulation, temperature) and 3 zooplankton concentrations as inputs to an anchovy full life cycle individual-based model (IBM). Our analysis was focused on isolating the effects of the well-documented El Niño Southern Oscillation signal and 3 climate regimes on spawning habitat, development, and survival of eggs and yolk-sac larvae, growth and survival of larvae and juveniles, and ultimately recruitment of anchovy. The major drivers of lowered recruitment success in warm years and in warmer regimes were reduced survival and growth rates of eggs and larvae that resulted from the poleward shift of adults in response to warmer temperatures prior to spawning. Three model-data comparisons showed the model deviated from empirically derived values of annual recruitment success but agreed with data for annual mean latitude of egg distributions and predicted larval consumption rates versus measured zooplankton concentrations. More effort is needed to improve certain biological aspects of the IBM so that it can replicate empirically estimated recruitment fluctuations. Overall, the altered responses of anchovy to changing climate in the California Current domain illustrate the benefit of the present mechanistic approach to infer how anchovy may respond under future ecosystem conditions.

Smith JA, Tommasi D, Welch H, Hazen EL, Sweeney J, Brodie S, Muhling B, Stohs SM, Jacox MG. 2021. Comparing Dynamic and Static Time-Area Closures for Bycatch Mitigation: A Management Strategy Evaluation of a Swordfish Fishery. Frontiers in Marine Science. 8:272. https://doi.org/10.3389/fmars.2021.630607.

Time-area closures are a valuable tool for mitigating fisheries bycatch. There is increasing recognition that dynamic closures, which have boundaries that vary across space and time, can be more effective than static closures at protecting mobile species in dynamic environments. We created a management strategy evaluation to compare static and dynamic closures in a simulated fishery based on the California drift gillnet swordfish fishery, with closures aimed at reducing bycatch of leatherback turtles. We tested eight operating models that varied swordfish and leatherback distributions, and within each evaluated the performance of three static and five dynamic closure strategies. We repeated this under 20 and 50% simulated observer coverage to alter the data available for closure creation. We found that static closures can be effective for reducing bycatch of species with more geographically associated distributions, but to avoid redistributing bycatch the static areas closed should be based on potential (not just observed) bycatch. Only dynamic closures were effective at reducing bycatch for more dynamic leatherback distributions, and they generally reduced bycatch risk more than they reduced target catch. Dynamic closures were less likely to redistribute fishing into rarely fished areas, by leaving open pockets of lower risk habitat, but these closures were often fragmented which would create practical challenges for fishers and managers and require a mobile fleet. Given our simulation’s catch rates, 20% observer coverage was sufficient to create useful closures and increasing coverage to 50% added only minor improvement in closure performance. Even strict static or dynamic closures reduced leatherback bycatch by only 30–50% per season, because the simulated leatherback distributions were broad and open areas contained considerable bycatch risk. Perfect knowledge of the leatherback distribution provided an additional 5–15% bycatch reduction over a dynamic closure with realistic predictive accuracy. This moderate level of bycatch reduction highlights the limitations of redistributing fishing effort to reduce bycatch of broadly distributed and rarely encountered species, and indicates that, for these species, spatial management may work best when used with other bycatch mitigation approaches. We recommend future research explores methods for considering model uncertainty in the spatial and temporal resolution of dynamic closures.

Syddall V, Thrush S, Fisher K, 2021. Transdisciplinary analysis of Pacific tuna fisheries: A research framework for understanding and governing oceans as social-ecological systems. *Marine Policy*, *134*, p.104783.

Western and Central Pacific (WCP) tuna fisheries are faced with complex and interlinked social and ecological challenges including high seas management issues, setting sustainable limits, human rights violations, and illegal, unreported, and unregulated (IUU) activities. However, strong but narrow disciplinary science persist to dominate governance. Effective governance across complex multi-scale systems in the WCP tuna fishery requires a more integrated understanding of social-ecological systems (SES). Transdisciplinary problem solving informed by participatory, social-ecological resilience research, and political ecology has the potential to reveal complicated interactions and connections across ocean SES networks. Social-Ecological-Oceans Systems Framework (SECO) was developed to capture the breadth and depth of the system and address interactions and connections between separate system components. SECO develops a practical integrated approach using accessible methods for addressing a large complex ocean system such as the WCP tuna fisheries. The framework offers a rapid transdisciplinary assessment and opens space for their deeper transdisciplinary analyses. This exploratory framework, as the WCP tuna case example shows, starts to reveal issues at scales that are not likely to be addressed by the strong single disciplinary approaches to governance now prevailing. The transdisciplinary research approach was developed to be responsive to diverse participants' knowledge, including local communities, scientists (social and biophysical), industry experts, economists, and fisheries managers. SECO was applied to place-specific studies, Suva, Fiji and Honiara and Gizo, Solomon Islands in the WCP tuna fishery. This validated SECO to ensure robustness and reliability

Tanaka KR, Van Houtan KS, Mailander E, Dias BS, Galginaitis C, O'Sullivan J, Lowe CG, Jorgensen SJ. 2021. North Pacific warming shifts the juvenile range of a marine apex predator. Scientific Reports. 11:3373. https://doi.org/10.1038/s41598-021-82424-9.

During the 2014–2016 North Pacific marine heatwave, unprecedented sightings of juvenile white sharks (*Carcharodon carcharias*) emerged in central California. These records contradicted the species established life history, where juveniles remain in warmer waters in the southern California Current. This spatial shift is significant as it creates potential conflicts with commercial fisheries, protected species conservation, and public safety concerns. Here, we integrate community science, photogrammetry, biologging, and mesoscale climate data to describe and explain this phenomenon. We find a dramatic increase in white sharks from 2014 to 2019 in Monterey Bay that was overwhelmingly comprised of juvenile sharks < 2.5 m in total body length. Next, we derived thermal preferences from 22 million tag measurements of 14 juvenile sharks and use this to map the cold limit of their range. Consistent with historical records, the position of this cold edge averaged 34° N from 1982 to 2013 but jumped to 38.5° during the 2014–2016 marine heat wave. In addition to a poleward shift, thermally suitable habitat for juvenile sharks declined 223.2 km2 year−1 from 1982 to 2019 and was lowest in 2015 at the peak of the heatwave. In addition to advancing the adaptive management of this apex marine predator, we discuss this opportunity to engage public on climate change through marine megafauna.

Timmers MA, Jury CP, Vicente J, Bahr KD, Webb MK, Toonen RJ. 2021. Biodiversity of coral reef cryptobiota shuffles but does not decline under the combined stressors of ocean warming and acidification. Proceedings of the National Academy of Sciences. Volume 118: Issue 39. https://doi.org/10.1073/pnas.2103275118.

Although climate change is expected to decimate coral reefs, the combined impacts of ocean-warming and acidification on coral reef biodiversity remains largely unmeasured. Here, we present a two-year mesocosm experiment to simulate future ocean acidification and ocean-warming to quantify the impacts on species richness, community composition, and community structure. We find that species richness is equivalent between the dual-stressor and present-day treatments but that the community shuffles, undoubtedly altering ecosystem function. However, our ability to predict the outcomes of such community shuffling remains limited due to the critical knowledge gap regarding ecological functions, life histories, and distributions for most members of the cryptobenthic community that account for the majority of the biodiversity within these iconic ecosystems.

Whitney JL, Gove JM, McManus MA, Smith KA, Lecky J, Neubauer P, Phipps JE, Contreras EA, Kobayashi DR, Asner GP. 2021. Surface slicks are pelagic nurseries for diverse ocean fauna. Scientific Reports. 11(1):1-8. https://doi.org/10.1038/s41598-021-81407-0.

Most marine animals have a pelagic larval phase that develops in the coastal or open ocean. The fate of larvae has profound effects on replenishment of marine populations that are critical for human and ecosystem health. Larval ecology is expected to be tightly coupled to oceanic features, but for most taxa we know little about the interactions between larvae and the pelagic environment. Here, we provide evidence that surface slicks, a common coastal convergence feature, provide nursery habitat for diverse marine larvae, including > 100 species of commercially and ecologically important fishes. The vast majority of invertebrate and larval fish taxa sampled had mean densities 2–110 times higher in slicks than in ambient water. Combining in-situ surveys with remote sensing, we estimate that slicks contain 39% of neustonic larval fishes, 26% of surface-dwelling zooplankton (prey), and 75% of floating organic debris (shelter) in our 1000 km^2 study area in Hawai‘i. Results indicate late-larval fishes actively select slick habitats to capitalize on concentrations of diverse prey and shelter. By providing these survival advantages, surface slicks enhance larval supply and replenishment of adult populations from coral reef, epipelagic, and deep-water ecosystems. Our findings suggest that slicks play a critically important role in enhancing productivity in tropical marine ecosystems.

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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 ignobilis*
111	31405	black trevally, jack	*Caranx lugubris*
241	28941	lunartail grouper (lyretail grouper)	*Variola louti*
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 sieboldii*
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*
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 Monitored 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
Labridae	*Bodianus diana*	MI	No Group
Balistidae	*Rhinecanthus rectangulus*	MI	No Group
Holocentridae	*Sargocentron caudimaculatum*	MI	No Group
Holocentridae	*Sargocentron ensifer*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional 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
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

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
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 Mariana Archipelago waters

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Seabirds						
Wedge-Tailed Shearwater	*Ardenna pacifica*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Streaked Shearwater	*Calonectris leucomelas*	Not Listed	N/A	Rare visitor	Guam	Wiles 2003
Short-Tailed Shearwater	*Ardenna tenuirostris*	Not Listed	N/A	Common visitor	Both	Wiles 2003
Newell's Shearwater[a]	*Puffinus newelli (Puffinus auricularis newelli)*	Endangered	N/A	Rare visitor	Both	40 FR 44149, Wiles 2003
Audubon's Shearwater	*Puffinus lherminieri*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Matsudaira's Storm-Petrel	*Oceanodroma matsudairae*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
White-Tailed Tropicbird	*Phaethon lepturus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Red-Tailed Tropicbird	*Phaethon rubricauda*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Masked Booby	*Sula dactylatra*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Brown Booby	*Sula leucogaster*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Red-Footed Booby	*Sula*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Great Frigatebird	*Fregata minor*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Lesser Frigatebird	*Fregata ariel*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Black-Headed Gull	*Chroicocephalus ridibundus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Gull-Billed Tern	*Gelochelidon nilotica*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Great Crested Tern	*Thalasseus bergii*	Not Listed	N/A	Uncommon visitor	Both	Wiles 2003
Common Tern	*Sterna hirundo*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Black-Naped Tern	*Sterna sumatrana*	Not Listed	N/A	Rare visitor	Guam	Wiles 2003
Little Tern	*Sternula albifrons*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
Sooty Tern	*Onychoprion fuscatus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003
White-Winged Tern	*Chlidonias leucopterus*	Not Listed	N/A	Rare visitor	Both	Wiles 2003

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Brown Noddy	*Anous stolidus*	Not Listed	N/A	Common resident	Both	Wiles 2003
Black Noddy	*Anous minutus*	Not Listed	N/A	Common visitor	Both	Wiles 2003
White Tern	*Gygis alba*	Not Listed	N/A	Common resident	Both	Wiles 2003
Short-Tailed Albatross	*Phoebastria albatrus*	Endangered	N/A	Breed in Japan and NWHI, and range across the North Pacific Ocean. Potential range includes the Marianas archipelago.	N/A	35 FR 8495, 65 FR 46643, BirdLife International 2017
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Black-Footed Albatross	*Phoebastria nigripes*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
White-Necked Petrel	*Pterodroma cervicalis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Bonin Petrel	*Pterodroma hypoleuca*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Black-Winged Petrel	*Pterodroma nigripennis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Bulwer's Petrel	*Bulweria bulwerii*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Christmas Shearwater	*Puffinus nativitatis*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Band-Rumped Storm-Petrel	*Oceanodroma castro*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Long-Tailed Jaeger	*Stercorarius longicaudus*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Laughing Gull	*Leucophaeus atricilla*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Herring Gull	*Larus argentatus*	Not Listed	N/A	Rare visitor	CNMI	Wiles 2003
Gray-Backed Tern	*Onychoprion lunatus*	Not Listed	N/A	Uncommon resident	CNMI	Wiles 2003
Sea Turtles						
Green Sea Turtle	*Chelonia mydas*	Endangered (Central West Pacific DPS)	N/A	An estimated 1000-2000 turtles forage in Guam/CNMI waters. Particularly common in winter and late spring.	Both	43 FR 32800, 81 FR 20057, Kolinski et al. 2000, Pritchard 1982, Honigman 1994
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered[b]	N/A	Small population nesting and foraging around Guam. Occur worldwide in tropical and subtropical waters.	Both	35 FR 8491, NMFS & USFWS 2007, Baillie & Groombridge 1996
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered[b]	N/A	Occasional sightings. Occur worldwide in tropical, subtropical, and subpolar waters.	Guam	35 FR 8491, Eldredge 2003, Eckert et al. 2012

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Loggerhead Sea Turtle	*Caretta caretta*	Endangered (North Pacific DPS)	N/A	No known sightings. Found worldwide along continental shelves, bays, estuaries, and lagoons of tropical, subtropical, and temperate waters.	N/A	43 FR 32800, 76 FR 58868, Dodd 1990, USFWS 2005
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened (Entire species, except for the breeding population on the Pacific coast of Mexico, which is listed as endangered)	N/A	Believed to occasionally transit through area.	N/A	43 FR 32800, Starmer et al. 2005
Marine mammals						
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Non-strategic	Found worldwide in tropical and temperate waters.	CNMI	Mead 1989
Blue Whale	*Balaenoptera musculus*	Endangered	Strategic	No known sightings in CNMI but occur worldwide in tropical and warm-temperate waters. Known to occur in the western North Pacific.	N/A	35 FR 18319, McDonald et al. 2006, Stafford et al. 2001
Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Non-strategic	Distributed worldwide in tropical and warm-temperate waters	Both	Perrin et al. 2009
Bryde's Whale	*Balaenoptera edeni*	Not Listed	Non-strategic	Distributed widely across tropical and warm-temperate Pacific Ocean.	CNMI	Leatherwood et al. 1982
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Non-strategic	Occur worldwide.	CNMI	Heyning 1989
Dugong	*Dugong dugong*	Endangered	N/A (managed by USFWS)	Extremely rare. One confirmed sighting in Guam in 1975, and multiple anecdotal reports in Guam in 1985.	Guam	Randall et al. 1975, Eldredge 2003
Dwarf Sperm Whale	*Kogia sima*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Both	Nagorsen 1985
False Killer Whale	*Pseudorca crassidens*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	CNMI	Stacey et al. 1994
Fin Whale	*Balaenoptera physalus*	Endangered	Strategic	Infrequent sightings, occur throughout the North Pacific Ocean.	N/A	35 FR 18319, Oleson et al. 2015, Mizroch et al. 2009
Fraser's Dolphin	*Lagenodelphis hosei*	Not Listed	Non-strategic	Found worldwide in tropical waters.	CNMI	Perrin et al. 2009

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
Humpback Whale	*Megaptera novaeangliae*	Endangered (Western North Pacific DPS)	Strategic	Occasional sightings in Guam/CNMI waters during winter breeding season.	Both	35 FR 18319, 81 FR 62259, Guarrige et al. 2007, SPWRC 2008
Killer Whale	*Orcinus orca*	Not Listed	Non-strategic	Found worldwide. Prefer colder waters within 800 km of continents.	Guam	Leatherwood & Dalheim 1978, Mitchell 1975, Baird et al. 2006
Longman's Beaked Whale	*Indopacetus pacificus*	Not Listed	Non-strategic	Found in tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa.	CNMI	Dalebout 2003
Melon-Headed Whale	*Peponocephala electra*	Not Listed	Non-strategic	Found in tropical and warm-temperate waters worldwide, primarily found in equatorial waters.	Both	Perryman et al. 1994
Minke Whale	*Balaenoptera acutorostrata*	Not Listed	Non-strategic	Uncommon in this region, usually seen over continental shelves in the Pacific Ocean.	CNMI	Brueggeman et al. 1990
Northern Elephant Seal	*Mirounga angustirostris*	Not Listed	Non-strategic	Females migrate to central North Pacific to feed on pelagic prey	N/A	Le Beouf et al. 2000
Pantropical Spotted Dolphin	*Stenella attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide.	Both	Perrin et al. 2009
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide.	CNMI	Ross & Leatherwood 1994
Pygmy Sperm Whale	*Kogia breviceps*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters.	Guam	Caldwell & Caldwell 1989
Risso's Dolphin	*Grampus griseus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Both	Perrin et al. 2009
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	CNMI	Perrin et al. 2009
Sei Whale	*Balaenoptera borealis*	Endangered	Strategic	Extremely rare. Generally found in offshore temperate waters.	CNMI	35 FR 18319, Barlow 2003, Bradford et al. 2013
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Both	Shallenberger 1981, Baird et al. 2013, Bradford et al. 2013
Sperm Whale	*Physeter macrocephalus*	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the	Both	35 FR 18319, Rice 1960, Barlow 2006,

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
				region. Regularly sighted in waters around CNMI.		Lee 1993, Mobley et al. 2000, Shallenberger 1981
Spinner Dolphin	*Stenella longirostris*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters. Occur in shallow protected bays during the day, feed offshore at night.	Both	Norris and Dohl 1980, Norris et al. 1994, Hill et al. 2010, Andrews et al. 2010, Karczmarski 2005, Perrin et al. 2009
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world	Both	Perrin et al. 2009
Elasmobranchs						
Giant manta ray	*Manta birostris*	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs.	Both	Dewar et al. 2008, Marshall et al. 2009, Marshall et al. 2011.
Oceanic whitetip	*Carcharhinus longimanus*	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C	Both	Bonfil et al. 2008, Backus et al. 1956, Strasburg 1958, Compagno 1984
Scalloped hammerhead	*Sphyrna lewini*	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m. Guam's inner Apra Harbor is a nursery habitat.	Both	Compagno 1984, Schulze-Haugen & Kohler 2003, Sanches 1991, Klimley 1993
Corals						
N/A	*Acropora globiceps*	Threatened	N/A	Occur on upper reef slopes, reef flats, and adjacent habitats in depths ranging from 0 to 8 m.	Both	Veron 2014

Common name	Scientific name	ESA listing status	MMPA status	Occurrence	Guam/ CNMI	References
N/A	*Acropora retusa*	Threatened	N/A	Occur in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons, and depth range is 1 to 5 m.	Both	Veron 2014
N/A	*Seriatopora aculeata*	Threatened	N/A	Found in broad range of habitats including, but not limited to, upper reef slopes, mid-slope terraces, lower reef slopes, reef flats, and lagoons, and depth ranges from 3 to 40 m.	Both	Veron 2014

[a] These species have critical habitat designated under the ESA. See Table B-2.

Table B-2. ESA-listed species' critical habitat in the Pacific Ocean[a]

Common Name	Scientific Name	ESA Listing Status	Critical Habitat	References
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered	None in the Pacific Ocean.	63 FR 46693
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Approximately 16,910 square miles (43,798 square km) stretching along the California coast from Point Arena to Point Arguello east of the 3,000 meter depth contour; and 25,004 square miles (64,760 square km) stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meter depth contour.	77 FR 4170
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered	Ten areas in the Northwestern Hawaiian Islands (NWHI) and six in the main Hawaiian Islands (MHI). These areas contain one or a combination of habitat types: Preferred pupping and nursing areas, significant haul-out areas, and/or marine foraging areas, that will support conservation for the species.	53 FR 18988, 51 FR 16047, 80 FR 50925
North Pacific Right Whale	*Eubalaena japonica*	Endangered	Two specific areas are designated, one in the Gulf of Alaska and another in the Bering Sea, comprising a total of approximately 95,200 square kilometers (36,750 square miles) of marine habitat.	73 FR 19000, 71 FR 38277

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

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