# ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT: AMERICAN SAMOA ARCHIPELAGO FISHERY ECOSYSTEM PLAN 2017

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

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

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# Executive Summary

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

The fishery performance section of this report first presents a general description of the local fisheries, including both bottomfish and coral reef management unit species (MUS). The fishery data collection system encompasses shore-based and boat-based creel surveys, commercial receipt books, and fisher inventories. The fishery statistics for each MUS are organized into a meta-data summary table to showcase the values for the most recent fishing year in comparison to short-term (10-year) and long-term (20-year) averages. Time series for catch and effort statistics are also presented. For 2017, there was no MUS catch in American Samoa that exceeded the prescribed annual catch limits (ACLs).

The bottomfish fishery performance in American Samoa appeared to show a slight decrease. Relative to the short-term average, total catch of all species caught with the bottomfishing gear declined by 30%, and total landings sold also decreased by 23% but were within the 10-year variations in catch. Considering only BMUS on a short-term basis, total estimated catch decreased by 14% while the commercial landings decreased by 41%; this indicates that the majority of the BMUS catch was non-commercial. In relation to the short-term average presented, catch-per-unit-effort (CPUE) and bycatch from the bottomfish fishery each exhibited notable decreases. The amount of effort in the bottomfish fishery (measured in gear-hours) increased by 35% in 2017 relative to average values from the last decade, while the total number of participants increased by 106% compared to the short-term average.

Coral reef fishery performance appeared to have mixed trends. The 2017 catch from the boat-based fisheries in American Samoa was 38% lower than the short-term average in continuing a decreasing trend over the past two decades. The shore-based coral reef fisheries had an estimated catch in 2017 that was 65% lower than the short-term average catch of the preceding 10-year increasing trend. The CPUE in the coral reef boat-based fisheries was higher in the mixed bottomfishing and trolling methods than in the spearfishing method over the same time period. Trolling CPUE had decreased 72% in 2017 in the midst of a 10-year increasing trend. The shore-based rod-and-reel fishery showed a lower estimated CPUE, whereas the spear, gleaning, and gill net fisheries had higher CPUE. Fishing effort values were lower this year for five coral reef fishery methods than the previous year; boat-based spear, trolling, and shore-based rod-and-reel each had a higher fishing effort than the short-term average. Data showed that shore-based hook-and-line effort had significantly decreased in 2017 to two total gear-hours (i.e. a 96% decrease).

An ecosystem considerations section was added to the annual SAFE report following the Council's review of its fishery ecosystem plans and revised management objectives. Fishery independent ecosystem survey data, human dimensions, protected species, climate and oceanographic indicators, essential fish habitat, and marine planning information are included in the ecosystem considerations chapter.

Fishery independent ecosystem survey data were acquired through visual surveys conducted in American Samoa, the Pacific Remote Island Areas, the Commonwealth of Northern Mariana Islands, Guam, the Main Hawaiian Islands, and the Northwest Hawaiian Islands; the data illustrate mean fish biomass for reef areas in these locations. Additionally, the mean reef fish biomass and mean size of fishes (>10 centimeters) found in American Samoa are presented by sampling year and reef area. Finally, reef fish population estimates for various study sites in American Samoa are provided for hardbottom habitat (0-30 meters).

For American Samoa, 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 several species of both coral reef fish and bottomfish. Several length-derived parameters for coral reef fish and bottomfish were also summarized and included: maximum fish length, mean length, sample size, sample size for L-W regression, and length-weight coefficients. Values for 23 species of reef fish and two species of bottomfish are presented for American Samoa.

The socioeconomics section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of the Fishery Ecosystem Plan for the American Samoan Archipelago. It meets the objective "Support Fishing Communities" adopted at the 165$^{th}$ 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 American Samoa, gives summaries of relevant data and studies for each American Samoan fishery, and concludes with available socioeconomic data. There were no new data reported for neither the crustacean nor the precious coral fisheries in the territory. Considering the American Samoan bottomfish fishery, the average cost for a bottomfishing trip was roughly $120, similar to 2016. For the coral reef fishery in the region, the average cost of a spearfishing trip was nominally cheaper than 2016 at $55.

The protected species section of this report summarizes information and monitors protected species interactions in fisheries managed under the American Samoa 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 American Samoa bottomfish and coral reef fisheries that would affect the potential for interactions with protected species, and there is no other information to indicate that impacts to protected species in these fisheries have changed in recent years. There are currently no crustacean or precious coral fisheries operating in federal waters around American Samoa.

The climate change section of this report includes indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Western Pacific Regional Fishery Management Council has responsibility. In developing this section, the Council relied on a number of recent reports conducted in the context of the U.S. National Climate Assessment including, most notably, the 2012 Pacific Islands Regional Climate Assessment and the Ocean and Coasts chapter of the 2014 report on a Pilot Indicator System prepared by the National Climate Assessment and Development Advisory Committee. The primary goal for selecting the indicators used in this report is to provide fisheries-related communities, resource managers, and businesses with climate-related situational awareness. In this context, indicators were selected to be fisheries-relevant and informative, build intuition about current conditions in light of changing climate, provide historical context, and identify patterns and trends. The trend of atmospheric concentration of carbon dioxide ($CO_2$), for example, has been increasing exponentially with a time series maximum at 406.53 ppm in 2017. Since 1989, the oceanic pH at Station Aloha in Hawaii has shown a statistically significant linear decrease of -0.0386 pH units, or roughly a 9% increase in acidity ([H+]). Coral bleaching patterns were evident on the reef slope areas around 30 to 50 feet deep along a large portion of the main island of Tutuila in the last quarter of 2017. The central Pacific saw seven named storms in 2017, three of which were hurricanes and two major.

The American Samoa Archipelago FEP and National Standard 2 guidelines require that this report include a report on the review of essential fish habitat (EFH) information. The 2017 annual report includes cumulative impacts on EFH. The guidelines also require a report on the condition of the habitat. In the 2017 annual report, 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*).The most up to date information is summarized on species distribution, fishery performance in the Western Pacific region, and life history. The annual report is also meant to address any Council directives toward its plan team, however there were no directives associated with EFH in 2017.

The marine planning section of the annual report tracks activities with multi-year planning horizons and begins to track the cumulative impact of established facilities. Development of the report in later years will focus on identifying appropriate data streams. No ocean activities with multi-year planning horizons were identified for American Samoa. However, the Pacific Islands Regional Planning Body (RPB), established under the National Ocean Policy, adopted the following goals for the coming year: finalize the American Samoa Ocean Plan, transfer data portal prototype to permanent site and identify data gaps, and increase funding. This plan will be used as the template for other jurisdictions represented in the RPB. American Samoa stakeholders have identified a vision, goals, and objectives for the ocean plan, which have been endorsed by the RPB.

The data integration chapter of this report is still under development. The archipelagic data integration chapter explores the potential association between fishery parameters and precipitation, primary productivity, and temperature-derived variables. A contractor has recently completed these analyses, and results of exploratory analyses have been included for the first time in 2017; however, suggested revisions at the request of the Plan Team will be implemented before inclusion in the subsequent 2018 reports. Presented results showed that the non-commercial coral reef fishery in American Samoa generally showed no association with the environmental parameters assessed. Members of the family Scaridae (i.e. parrotfish) showed a negative relationship with sea surface temperature in the region, while species in the family Mullidae displayed a positive relationship. No statistically significant association was uncovered between the fishery and chlorophyll-*a* concentrations despite the incorporation of phase lag. A non-metric multidimensional scaling analysis showed that, while presented evaluations were not able to identify any significant levels of association between expanded creel catch data and a range of environmental parameters, the first axis, responsible for explaining 91% of the variance, illustrated the strongest relationships with salinity (negative) and rainfall (positive).

In continuing on with the analyses and presentation of results for the data integration chapter, 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. Implementation of these suggestions will allow for the preparation of a more finalized version of the data integration chapter in the coming year.

The 2018 Archipelagic Plan Team had the following recommendations relevant to this 2017 FEP SAFE Report:

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

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

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

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## ACRONYMS AND ABBREVIATIONS

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

| Acronym | Meaning |
|---|---|
| MPCC | Marine Planning and Climate Change |
| MPCCC | Council's MPCC Committee |
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| MSFCMA | Magnuson-Stevens Fishery Conservation and Management Act |
| MSST | Minimum Stock Size Threshold |
| MSY | Maximum Sustainable Yield |
| MUS | management unit species |
| NCADAC | National Climate Assessment & Development Advisory Committee |
| NCDC | National Climatic Data Center |
| NEPA | National Environmental and Policy Act |
| NESDIS | National Environmental Satellite, Data, and Information Service |
| NMFS | National Marine Fisheries Service |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NWHI | Northwestern Hawaiian Islands |
| OFL | Overfishing Limits |
| ONI | Ocean Niño Index |
| OR&R | Office of Response and Restoration |
| OY | Optimum Yield |
| PacIOOS | Pacific Integrated Ocean Observing System |
| PCMUS | Precious Coral Management Unit Species |
| Pelagic FEP | Fishery Ecosystem Plan for the Pacific Pelagic Fisheries |
| PI | Pacific Islands |
| PIBHMC | Pacific Island Benthic Habitat Mapping Center |
| PIFSC | Pacific Island Fisheries Science Center |
| PIRCA | Pacific Islands Regional Climate Assessment |
| PIRO | NOAA NMFS Pacific Islands Regional Office |
| PMUS | pelagic management unit species |
| POES | Polar Operational Environmental Satellite |
| PRIA | Pacific Remote Island Areas |
| RAMP | Reef Assessment and Monitoring Program |
| RPB | Regional Planning Body |
| SAFE | Stock Assessment and Fishery Evaluation |
| SBRM | Standardized Bycatch Reporting Methodologies |
| SDC | Status Determination Criteria |
| SEEM | Social, Economic, Ecological, Management uncertainties |
| SPC | Stationary Point Count |
| SST | Sea Surface Temperature |
| USACE | United States Army Corps of Engineers |
| WPacFIN | Western Pacific Fishery Information Network |
| WPRFMC | Western Pacific Regional Fishery Management Council |
| WPSAR | Western Pacific Stock Assessment Review |
| WW3 | Wave Watch 3 |

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# 1 FISHERY PERFORMANCE

## 1.1 FISHERY DESCRIPTIONS

The Samoa Archipelago is a remote chain of 13 islands of varying sizes and an atoll, located $14^0$ south of the equator near the International Date Line. The islands lie between 13° and 14° latitude south and 169° and 173° longitude west, about 480 km (300 mi) from west to east, covering an area of 3,030 sq. km (1,170 sq. miles). With its tropical setting and its latitudinal range lying within the known limits of coral growth, coral reefs fringe the islands and atolls in the archipelago. The archipelago is approximately 4,200 km south of Hawai'i in the central South Pacific Ocean. The archipelago is divided into two political entities: the Independent Samoa and American Samoa. The Independent Samoa has two large islands, Upolu and Savaii, and eight islets. American Samoa is comprised of five volcanic islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'u), one low-island (Swains Island), and a coral atoll (Rose Atoll). The five volcanic islands that are part of the American Samoa territory are very steep with mountainous terrain and high sea cliffs and of various sizes. Tutuila Island, the largest (137 $km^2$) and most populated island, is the most eroded with the most extensive shelf area and has banks and barrier reefs. Aunuu is a small island very close to Tutuila. Ofu and Olosega (together as 13 $km^2$) are twin volcanic islands separated by a strait which is a shallow and narrow break in the reef flat between the islands. Tau is the easternmost island (45 $km^2$) with a more steeply-sloping bathymetry.

The Samoa archipelago was formed by a series of volcanic eruptions from the "Samoan hotspot" (Hart *et al*., 2000). Based on the classic hotspot model, Savaii Island (the westernmost) in Samoa would be the oldest and Tau island (the easternmost) in American Samoa the youngest of the islands in the archipelago. Geological data indicate that Savaii is about four to five million years old, Upolu in Samoa about two to three million years old, Tutuila about 1.5 million years old, Ofu-Olosega about 300,000 years old, and Tau about 100,000 years old. Swains and Rose are built on much older volcanoes, they but are not part of the Samoan volcanic chain (Hart *et al*., 2004). The geological age and formation of Rose Atoll is not well known, and Swains is part of the Tokelau hot-spot chain which is anywhere from 59 to 72 million years old (Neall and Trewick, 2008; Konter *et al*., 2008). There are numerous banks in the archipelago, the origins of which are not well known. The South Bank near Tutuila Island, for instance, is of another geological origin.

American Samoa experiences occasional cyclones due to its geographic location in the Pacific. Cyclones occur on one- to 13-year intervals, with the six strong occurrences happening over the last 30 years (Esau, 1981; Tusi, 1987; Ofa, 1990; Val, 1991; Heta, 2004 and; Olaf, 2005). The territory had two tsunamis in the last 100 years due to its proximity to the geologically active Tonga Trench.

It is in this geological and physical setting that the Samoans have established their culture over the last 3,500 years. For three millennia, the Samoans have relied on the ocean for their sustenance. Fish and fishing activities constitute an integral part of the "fa'a samoa", or the Samoan culture. Fish are also used for chiefly position entitlements and other cultural activities during the "fa'a lalave" or ceremonies.

### 1.1.1 Bottomfish Fishery

Deep, zooxanthellate, scleractinian coral reefs that have been documented in the Pacific often occur around islands in clear tropical oceanic waters (Lang, 1974; Fricke and Meischner, 1985; Kahng and Maragos, 2006). These mesophotic coral ecosystems are found at depths of 30-40 m up to 150 m, and have been exploited by bottomfishing fishermen mainly targeting snappers, emperors, and groupers. Bottomfishing utilizing traditional canoes by the indigenous residents of American Samoa has been a subsistence practice since the Samoans settled on the Tutuila, Manua, and Aunu'u islands. It was not until the early 1970s that the bottomfish fishery developed into a commercial scheme utilizing motorized boats. The bottomfish fishery of American Samoa was typically comprised of commercial overnight bottomfish handlining using skipjack as bait on 28 to 30 foot-long aluminum/plywood "alia" (a term used for larger boats in Samoa). Imported bottomfish from the independent state of Samoa help satisfy demand, however the imports weaken the local bottomfish fishery. A government-subsidized program, called the Dory Project, was initiated in 1972 to develop the offshore fisheries into a commercial venture, and resulted in an abrupt increase in the size of the fishing fleet and total landings. In 1982, a fisheries development project aimed at exporting high-priced deepwater snappers to Hawaii initiated another notable increase in bottomfish landings and revenue. Between 1982 and 1988, the botttomfish fishery accounted for as much as half of the total commercial landings (by weight).

American Samoa's bottomfish fishery was a relatively larger size between 1982 and 1985 when it was new and expanding. In 1988, a decline in bottomfish fisheries occurred as many skilled and full-time commercial fishermen converted to trolling. Additionally, profits and revenue in bottomfishing suffered from four separate hurricanes; Tusi in 1987, Ofa in February of 1990, Val in December of 1991, Heta in January of 2004, and the 2009 tsunami. The gradual depletion of newly-discovered banks and migration of many fishermen into other fishing vendors resulted in the decline of landings through the mid-1980s. Fuel prices have gradually risen in the past four years causing yet another strain on the bottomfish fisheries. The average price of bottomfish has also declined due to the shift in demand from local to imported bottomfish that complete closely with local prices. In 2004, 60% of coolers imported from the independent state of Samoa on the Lady Naomi Ferry were designated for commercial sale; data from the Commercial Invoice System show that half of these coolers were filled with bottomfish.

Beginning in 1988, the nature of American Samoa's fisheries changed dramatically with a shift in importance from bottomfishing to trolling. In the past eight years, the dominant fishing method has been longlining (by weight). Bottomfishing has been in decline for years, but it was dealt a final devastating blow by the impacts of the 2009 tsunami. A fishery failure was declared, and the U.S. Congress allocated $1 million to revive the fishery. This fund has been used to repair boats damaged by the tsunami, maintain the floating docks used by the alia boats, and build a boat ramp. In 2013, the American Samoan government also implemented a subsidy program that provided financial relief associated the rising fuel prices; the fuel price has since become notably lower.

### 1.1.2 Coral Reef Fishery

Traditional coral reef fishing in the lagoons and shallow reef areas has included methods such as gleaning and using bamboo poles with lines and baits or with a multi-pronged spear attached.

The deepwater and pelagic fisheries have traditionally used wooden canoes, hand-woven sennit lines with shell hooks and stone sinkers, and lures made of wood and shell pieces.

Presumably, the change from traditional to present-day fishing methods started with Western contact in the 18$^{th}$ century. Today the fisheries in American Samoa can be broadly categorized in terms of habitat and target species as either pelagic fisheries, bottomfish fisheries in mesophotic reefs, or nearshore coral reef fisheries. For creel monitoring program purposes, fisheries are either subsistence (i.e. primarily shore-based and mostly for personal consumption) or commercial (i.e. primarily boat-based and mostly sold). Bottomfishing is a combination of mesophotic reef fishing and/or pelagic fishing (i.e. trolling). The coral reef fishery involves gleaning, spearfishing (snorkel or free dive from shore or using boat), rod-and-reel using nylon lines and metal hooks, bamboo pole, throw nets, and gillnets. SCUBA spearfishing was introduced in 1994, restricted for use by native American Samoans around 1997-1998, and finally banned in 2002 following recommendations by biologists from the Department of Marine and Wildlife Resources and local scientists.

## 1.2 FISHERY DATA COLLECTION SYSTEM

American Samoa has been regularly conducting fishery-dependent monitoring since 1982 for the boat-based fishery and since the 1970s for the shore-based component (though the database was established in the 1990s). The boat-based fishery is mostly trolling for tuna, skipjacks, and trevally, and bottomfishing mostly targets snappers, emperors, and groupers. The shore-based fishery is mostly gleaning for shellfish and octopus, rod-and-reel fishing for groupers and jacks, and spearfishing for surgeonfish and parrotfish. Both boat- and shore-based data collection involve two runs: first is the participation run used to determine the number of boats/fisherman out to fish and identify the type of gear being used; second is the interview run where the fishermen are interviewed for the effort and economic data while also measuring the length and weight of each fish identified to the species level.

### 1.2.1 Boat-Based Creel Survey

The boat-based data collection focuses mostly on the main docks in Fagatogo and Pago Pago, and on opportunistically surveying sites like Aunuu, Auasi, and Asili. Both boat- and shore-based data collection are also being conducted in Manu'a. The boat-based data collection in Ofu-Olosega and Tau are opportunistic since there is no set schedule for boats to go out and land their catches.

The survey follows a random stratified design. The stratification is by survey area, weekday/weekend, and time of day. The survey is divided into two phases: 1) participation run; and 2) catch interview phase. The participation run attempts to estimate the amount of participation by counting the number of boats "not on the dock" or the presence of trailers. The catch interview phase occurs after the participation run that documents catch composition, catch-per-unit-effort (CPUE), length-weight information, catch disposition, and some socio-economic information. The data is transcribed weekly into the WPacFIN database. Catch expansion is done on an annual scale through a simple expansion algorithm using expanded effort and CPUE. For more details of the boat-based creel survey see Oram *et al*. (in press).

### 1.2.2 Shore-Based Creel Survey

The shore-based data collection follows the same general scheme as the boat-based creel survey, and by randomly selects eight-hour periods and locations four to five times per week to conduct necessary runs. Survey locations are: western Tutuila from Vailoa to Amanave, central Tutuila from Aua to Nuuuli, eastern Tutuila from Lauli'i to Tula, while the Manu'a routes are relatively more complicated. The following data are generated through these creel collection programs: 1) catch landings; 2) effort; 3) CPUE; 4) catch composition; 5) length (accurate to the nearest centimeter); 6) weight (lbs.). The survey follows a random stratified design. The stratification is by survey area, weekday/weekend, and time of day. The survey is divided into two phases: the participation run and the catch interview phase. The participation run attempts to estimate the amount of participation by counting the number of fishermen along the shoreline. The gear type, number of gears, and number of fishers are recorded. The catch interview phase occurs after the participation run, and documents catch composition, CPUE, length-weight information, catch disposition, and some socioeconomic information. The data is transcribed weekly into the WPacFIN database. Catch expansion is done on an annual basis through an expansion algorithm using expanded effort and CPUE values. For more details of the shore-based creel survey see Oram et al. (in press).

### 1.2.3 Commercial Receipt Book System

Entities that sell any seafood products are required by law to report their sales to DMWR (ASCA § 24.0305). This is done through a receipt book system collected on the fifth day of every month. Information required to be reported are: (a) the weight and number of each species of fish or shellfish received; (b) the name of the fisherman providing the fish or shellfish; (c) boat name and registration number, if applicable; (d) the name of the dealer; (e) the date of receipt; (f) the price paid per species; (g) the type of fishing gear used; (h) whether the fish or shellfish are intended for sale in fresh, frozen, or processed form; (i) which fish or shellfish were taken within/outside of territorial waters; and (j) other statistical information the department may require.

### 1.2.4 Boat Inventory

An annual boat inventory is being conducted to track down fishing boats and determine their ownership. This will provide information on how many boats are potentially available to engage in the fishery.

## 1.3 META-DATA DASHBOARD STATISTICS

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

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

### 1.3.1 Creel Survey Meta-Data Statistics

**Calculations:** Shore-based data

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

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

# Catch Interviews: Count of the number of unique occurrences of the combination of date and run number in the participation detail data/count of unique surveyor initials and date in PAR. This is divided into two categories, interviews conducted during a complete survey (Regular), and opportunistic interviews (Opportunistic) which are completed on days when the whole survey is not conducted.

**Calculation:** Boat-based data

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

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

**Table 1. Summary of creel survey meta-data describing survey performance parameters with potential influence on the creel survey expansion from 1986-2017.**

| Year | Shore-based | | | | Boat-based | | |
|---|---|---|---|---|---|---|---|
| | # Interview Days | # Participation Runs | # Catch Interviews | | # Sample Days | # Catch Interviews | |
| | | | Regular | Opportunistic | | Regular | Opportunistic |
| 1986 | | | | | 186 | 682 | 1 |
| 1987 | | | | | 110 | 346 | 0 |
| 1988 | 124 | 0 | 179 | 0 | 158 | 470 | 0 |
| 1989 | 126 | 0 | 184 | 0 | 160 | 514 | 0 |
| 1990 | 145 | 261 | 393 | 0 | 160 | 331 | 21 |
| 1991 | 129 | 458 | 349 | 0 | 134 | 281 | 4 |
| 1992 | 84 | 274 | 133 | 0 | 127 | 244 | 4 |
| 1993 | 140 | 305 | 255 | 0 | 140 | 285 | 8 |
| 1994 | 167 | 544 | 382 | 0 | 209 | 516 | 5 |
| 1995 | 157 | 524 | 302 | 0 | 239 | 638 | 8 |
| 1996 | 136 | 230 | 218 | 0 | 222 | 654 | 3 |
| 1997 | 82 | 0 | 108 | 0 | 226 | 1135 | 1 |
| 1998 | 104 | 0 | 143 | 0 | 229 | 1067 | 1 |
| 1999 | 34 | 0 | 51 | 0 | 207 | 887 | 0 |
| 2000 | 52 | 0 | 67 | 0 | 206 | 729 | 0 |
| 2001 | 0 | 0 | 0 | 0 | 205 | 441 | 2 |
| 2002 | 20 | 293 | 42 | 38 | 194 | 376 | 0 |
| 2003 | 5 | 196 | 7 | 11 | 220 | 503 | 0 |
| 2004 | 0 | 409 | 0 | 0 | 239 | 506 | 5 |
| 2005 | 33 | 437 | 51 | 4 | 238 | 340 | 0 |
| 2006 | 53 | 695 | 89 | 21 | 238 | 325 | 7 |
| 2007 | 119 | 1143 | 227 | 50 | 251 | 485 | 6 |
| 2008 | 86 | 904 | 127 | 13 | 225 | 303 | 11 |
| 2009 | 98 | 963 | 173 | 10 | 165 | 174 | 9 |
| 2010 | 102 | 892 | 176 | 5 | 188 | 168 | 2 |
| 2011 | 139 | 1234 | 246 | 39 | 240 | 203 | 1 |
| 2012 | 77 | 648 | 108 | 9 | 269 | 285 | 14 |
| 2013 | 107 | 1028 | 191 | 156 | 262 | 245 | 0 |
| 2014 | 68 | 925 | 77 | 27 | 236 | 254 | 26 |
| 2015 | 84 | 953 | 150 | 43 | 233 | 247 | 26 |
| 2016 | 98 | 891 | 144 | 18 | 224 | 165 | 47 |
| 2017 | 65 | 658 | 121 | 35 | 222 | 139 | 33 |
| **10 year avg.** | **92** | **910** | **151** | **36** | **226** | **218** | **17** |
| **10 year SD** | **21** | **160** | **45** | **42** | **29** | **53** | **15** |
| **20 year avg.** | **67** | **613** | **110** | **24** | **225** | **392** | **10** |
| **20 year SD** | **40** | **405** | **71** | **34** | **24** | **244** | **13** |

### 1.3.2 Commercial Receipt Book Statistics

**Calculations:**

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

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

**Table 2. Summary of commercial receipt book meta-data describing reporting parameters with potential influence on total commercial landing estimates from 1998-2017.**

| Year | Number of Vendors | Total Invoices Collected |
|---|---|---|
| 1998 | 21 | 1693 |
| 1999 | 19 | 1452 |
| 2000 | 18 | 1110 |
| 2001 | 31 | 1095 |
| 2002 | 25 | 940 |
| 2003 | 29 | 1055 |
| 2004 | 26 | 811 |
| 2005 | 58 | 794 |
| 2006 | 51 | 868 |
| 2007 | 53 | 966 |
| 2008 | 40 | 704 |
| 2009 | 37 | 570 |
| 2010 | 28 | 486 |
| 2011 | 25 | 648 |
| 2012 | 26 | 699 |
| 2013 | 32 | 581 |
| 2014 | 38 | 902 |
| 2015 | 43 | 1281 |
| 2016 | 40 | 855 |
| 2017 | 37 | 732 |
| **10 year avg.** | **35** | **746** |
| **10 year SD** | **6** | **215** |
| **20 year avg.** | **34** | **912** |
| **20 year SD** | **11** | **297** |

Note: only data for years with greater than three vendors reporting.

## 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*

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

**Table 3. Annual indicators for coral reef and bottomfish fisheries describing performance comparing current estimates with short- (10-year) and long-term (20-year) averages.**

| **Fishery** | **Fishery statistics** | **Short-term (recent 10 years)** | **Long-term (recent 20 years)** |
|---|---|---|---|
| **Bottomfish** | **Estimated catch (lbs.)** | | |
| All species caught in the bottom-fishing gear | Boat and shore creel data estimated (expanded) total lbs. (all BF trips) | **17,573[▼30%]** | **17,573[▼19%]** |
| | Estimated total lbs. (all species) Commercial Purchase Data | **5,693[▼23%]** | **5,693[▼58%]** |
| Bottomfish MUS only | Total Creel Data Estimated (expanded) total lbs. (all BF trips) | **17,425[▼14%]** | **17,425 [▼2%]** |
| | Estimated total lbs. (all species) Commercial Purchase Data | **1,137[▼41%]** | **1,137[▼52% ]** |
| | **CPUE (lbs./fishing hours)** | | |
| | Creel Data only | **0.0208[▼61%]** | **0.0208[▼79%]** |

| | | | |
|---|---|---|---|
| | **Fishing effort *(*only available for creel data*)*** | | |
| | Estimated (expanded) total gear-hours using bottomfishing method | **416,150[▲35% ]** ⬌ ⊙ | **416,150[▲83% ]** ⬈ ⊙ |
| | **Fishing participants** | | |
| | Estimated total # of fishers that went bottomfishing | **2,195[▲106%]** ⬈ ⊕ | **2,195 [▲123%]** ⬈ ⊕ |
| | **Bycatch (all boat-based)** | | |
| | # bycatch caught | **2,351[▼65%]** ⬊ ⊙ | **2,351[▼62%]** ⬊ ⊖ |
| | # bycatch released | **None** | **None** |
| | # bycatch kept | **2,351[▼65%]** ⬊ ⊙ | **2,122[▼62%]** ⬊ ⊖ |
| **Coral Reef** | **Estimated catch (lbs.)** | | |
| | Boat-based Creel Data (expanded estimate, all gears) | **27,758[▼38%]** ⬊ ⊖ | **36,085[▼36%]** ⬊ ⊙ |
| | Shore-based Creel Data (expanded estimate, all gears) | **12,789[▼65%]** ⬈ ⊙ | **12,789[▼45%]** ⬊ ⊖ |
| | Commercial Purchase Data | **41,163[▼19%]** ⬌ ⊙ | **41,163[▼21%]** ⬌ ⊙ |
| | **CPUE (lbs./fishing hours)** | | |
| | BB mixed-method | **0.0507[▼95%]** ⬌ ⊙ | **0.0507[▼96%]** ⬌ ⊙ |
| | BB spear | **0.0139[▼90%]** ⬊ ⊙ | **0.0139[▼98%]** ⬊ ⊖ |
| | BB troll | **0.0596[▼72%]** ⬈ ⊖ | **0.0596[▼68%]** ⬌ ⊖ |
| | SB hook and line | **N/A** | **N/A** |
| | SB rod and reel | **0.0249[▲18%]** ⬌ ⊙ | **0.0249[▲6%]** ⬌ ⊙ |
| | SB spear | **0.2[▲87%]** ⬈ ⊕ | **N/A** |
| | SB gleaning | **0.4889[▲30%]** ⬈ ⊙ | **0.4889[▲47%]** ⬈ ⊙ |
| | SB gill net | **0.3269 [▼61%]** ⬈ ⊕ | **N/A** |
| | **Fishing effort (# of gear hours by gear type)** | | |
| | BB mixed-method | **59,361[▼4%]** ⬈ ⊙ | **59,361[▲83%]** ⬌ ⊙ |

| | | | |
|---|---|---|---|
| | BB spear | **109,568[▲15%]** | **109,568[▲95%]** |
| | BB troll | **149,490[▲129%]** | **149,490 [▲59%]** |
| | SB H&L | **2[▼96%]** | **2[▼93%]** |
| | SB rod and reel | **24,969[▲52%]** | **24,969[▲115%]** |
| | SB spear | **950[▼97%]** | **950[▼95%]** |
| | SB gleaning | **204[▼65%]** | **204[▼76%]** |
| | SB gillnet | **52[▼71%]** | **52[▼71%]** |
| | **Fishing participants (# of fishers)** | | |
| | BB mixed-method | **2,474[▲105%]** | **2,474[▲129%]** |
| | BB spear | **2,372[▲3%]** | **2,372[▲2%]** |
| | BB troll | **2,404[▲123%]** | **2,404[▲148%]** |
| | SB hook and line | **47[▼28%]** | **47[▼59%]** |
| | SB rod and reel | **992[▼35%]** | **992[▼53%]** |
| | SB spear | **120[▼67%]** | **N/A** |
| | SB gleaning | **220[▼51%]** | **220[▼79%]** |
| | SB gill net | **7[▼94%]** | **7[▼97%]** |
| | **Boat-based Bycatch** | | |
| | # bycatch caught | **3,118[▼73%]** | **3,118[▼72%]** |
| | # bycatch released | **None** | **None** |
| | # bycatch kept | **3,118[▼73%]** | **3,118[▼72%]** |
| | **Shore-based Bycatch** | | |
| | # bycatch caught | **1,386[▼54%]** | **N/A** |
| | # bycatch released | **None** | **N/A** |
| | # bycatch kept | **1,386[▼54%]** | **N/A** |

## 1.5 CATCH STATISTICS

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

### 1.5.1 Catch by Data Stream

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

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

**Table 4. Summary time series of catch for all species caught using the bottomfishing gear: estimated lbs. (expanded) from the boat and shore-based creel surveys and estimated total lbs. from the commercial purchase system from 1989-2017.**

| Year | Creel Survey Estimates | | Creel Total | Commercial landings |
|---|---|---|---|---|
| | Boat-based | Shore-based | | |
| 1989 | 28708 | | 28708 | |
| 1990 | 10796 | 2009 | 12805 | |
| 1991 | 12136 | 345 | 12481 | 4383 |
| 1992 | 8673 | 1132 | 9805 | 4756 |
| 1993 | 11634 | 403 | 12037 | 4849 |
| 1994 | 30116 | 567 | 30683 | 6100 |
| 1995 | 25340 | 262 | 25602 | 24315 |
| 1996 | 26924 | 1531 | 28455 | 24482 |
| 1997 | 27174 | | 27174 | 15757 |
| 1998 | 11204 | | 11204 | 19032 |
| 1999 | 13675 | | 13675 | 12133 |
| 2000 | 14098 | | 14098 | 19273 |
| 2001 | 30962 | | 30962 | 25101 |
| 2002 | 24275 | | 24275 | 28229 |
| 2003 | 13520 | | 13520 | 21675 |
| 2004 | 22015 | 45 | 22060 | 15138 |
| 2005 | 13955 | 334 | 14289 | 13563 |
| 2006 | 7649 | 1206 | 8855 | 23187 |
| 2007 | 23497 | 4883 | 28380 | 15983 |
| 2008 | 33256 | 4804 | 38060 | 17195 |
| 2009 | 42633 | 798 | 43431 | 12632 |
| 2010 | 8232 | 1067 | 9299 | 5115 |
| 2011 | 25017 | 2104 | 27121 | 3405 |
| 2012 | 14780 | 414 | 15194 | 2687 |
| 2013 | 27888 | 5019 | 32907 | 6363 |
| 2014 | 15392 | 878 | 16270 | 5224 |
| 2015 | 23213 | 4560 | 27773 | 3942 |
| 2016 | 20893 | 4140 | 25033 | 10696 |
| 2017 | 16498 | 1075 | 17573 | 5639 |
| **10-year avg.** | **22780** | **2486** | **25266** | **7290** |
| **10-year SD** | **9531** | **1808** | **10287** | **4453** |
| **20-year avg.** | **20133** | **2238** | **21699** | **13311** |
| **20-year SD** | **8727** | **1886** | **9596** | **7649** |

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

**Table 5. Summary of the available Bottomfish Management Unit Species (BMUS) catch time series: estimated lbs. (expanded) from the boat- and shore-based creel surveys and estimated lbs. from the commercial purchase system from 1989-2017.**

| Year | Creel survey Estimates | | Creel Total | Commercial landings |
|---|---|---|---|---|
| | Boat-based | Shore-based | | |
| 1989 | 28547 | | 28547 | |
| 1990 | 10181 | 2009 | 12190 | |
| 1991 | 12136 | 345 | 12481 | 2242 |
| 1992 | 8240 | 1132 | 9372 | 1928 |
| 1993 | 11174 | 403 | 11577 | 3541 |
| 1994 | 29991 | 560 | 30551 | 3024 |
| 1995 | 23507 | 262 | 23769 | 5259 |
| 1996 | 24280 | 1040 | 25320 | 1143 |
| 1997 | 26857 | | 26857 | 419 |
| 1998 | 10717 | | 10717 | 851 |
| 1999 | 12911 | | 12911 | 3197 |
| 2000 | 14043 | | 14043 | 3693 |
| 2001 | 30876 | | 30876 | 3447 |
| 2002 | 23734 | | 23734 | 1448 |
| 2003 | 13407 | | 13407 | 2511 |
| 2004 | 15478 | 45 | 15523 | 3233 |
| 2005 | 9395 | 334 | 9729 | 2490 |
| 2006 | 5107 | 1206 | 6313 | 3142 |
| 2007 | 12409 | 4883 | 17292 | 4001 |
| 2008 | 26596 | 4804 | 31400 | 4996 |
| 2009 | 42541 | 798 | 43339 | 3035 |
| 2010 | 8208 | 1067 | 9275 | 1084 |
| 2011 | 15170 | 2090 | 17260 | 711 |
| 2012 | 3234 | 414 | 3648 | 1161 |
| 2013 | 6071 | 4999 | 11070 | 882 |
| 2014 | 15382 | 878 | 16260 | 3140 |
| 2015 | 23194 | 4528 | 27722 | 2047 |
| 2016 | 20865 | 3954 | 24819 | 1131 |
| 2017 | 16451 | 974 | 17425 | 1137 |
| **10-year avg.** | **17771** | **2451** | **20222** | **1932** |
| **10 year SD** | **10883** | **1794** | **11168** | **1314** |
| **20-year avg.** | **16289** | **2212** | **17838** | **2367** |
| **20-year SD** | **9270** | **1873** | **9545** | **1224** |

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

**Table 6. Summary of the catch time series for the CREMUS complex from the boat- and shore-based creel surveys and the commercial purchase system from 1989-2017.**

| Year | Creel survey Estimates | | Creel Total | Commercial Landings |
|---|---|---|---|---|
| | Boat-based | Shore-based | | |
| 1989 | 63301 | | 63301 | |
| 1990 | 9511 | 132471 | 141982 | |
| 1991 | 10825 | 216896 | 227721 | 16515 |
| 1992 | 9397 | 104056 | 113453 | 7589 |
| 1993 | 12902 | 86078 | 98980 | 18830 |
| 1994 | 57061 | 50935 | 107996 | 38263 |
| 1995 | 27101 | 56018 | 83119 | 84337 |
| 1996 | 29319 | 86339 | 115658 | 88835 |
| 1997 | 110448 | | 110448 | 114337 |
| 1998 | 89663 | | 89663 | 107484 |
| 1999 | 73818 | | 73818 | 76414 |
| 2000 | 62843 | | 62843 | 59693 |
| 2001 | 39909 | | 39909 | 47975 |
| 2002 | 36437 | | 36437 | 52352 |
| 2003 | 23306 | | 23306 | 43690 |
| 2004 | 23277 | 2847 | 26124 | 25919 |
| 2005 | 12853 | 29520 | 42373 | 36165 |
| 2006 | 12537 | 29211 | 41748 | 44713 |
| 2007 | 50678 | 39897 | 90575 | 43916 |
| 2008 | 46837 | 38189 | 85026 | 36765 |
| 2009 | 58124 | 13762 | 71886 | 35772 |
| 2010 | 67646 | 53031 | 120677 | 21694 |
| 2011 | 49950 | 63863 | 113813 | 28398 |
| 2012 | 32606 | 19939 | 52545 | 38581 |
| 2013 | 54615 | 44815 | 99430 | 41533 |
| 2014 | 37439 | 18930 | 56369 | 66387 |
| 2015 | 48349 | 25185 | 73534 | 80005 |
| 2016 | 24839 | 76266 | 101105 | 117871 |
| 2017 | 27758 | 12789 | 40547 | 41163 |
| **10-year avg.** | **44816** | **36677** | **81493** | **50817** |
| **10-year SD** | **13156** | **21131** | **25691** | **27739** |
| **20-year avg.** | **43674** | **23412** | **67086** | **52325** |
| **20-year SD** | **20001** | **22671** | **28571** | **25075** |

### 1.5.2 Expanded Catch Estimates by Fishing Method

Catch information is provided for the top shore- and boat-based fishing methods (i.e. those that contribute >90% of the annual catch for the region).

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

**Table 7. Total expanded catch time series estimates (lbs.) using shore- and boat-based creel survey data by gear type from 1990-2017.**

| Year | Shore-based methods | | | | | | Boat-based methods | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R&R | Spear | Gleaning | Gill net | H&L | Throw net | Bottomfish | Bottom/Troll Mix | Spear | Troll* |
| 1990 | 688 | 0 | 1462 | 0 | 505 | 1278 | 2423 | 3725 | 1360 | 23283 |
| 1991 | 1591 | 0 | 539 | 0 | 396 | 721 | 3887 | 4154 | 717 | 18383 |
| 1992 | 192 | 0 | 480 | 0 | 19 | 661 | 3610 | 0 | 0 | 27235 |
| 1993 | 389 | 0 | 836 | 0 | 67 | 516 | 4728 | 766 | 70 | 12163 |
| 1994 | 608 | 0 | 1038 | 0 | 27 | 390 | 5027 | 1736 | 988 | 33544 |
| 1995 | 490 | 0 | 1240 | 124 | 54 | 252 | 2791 | 3994 | 0 | 48438 |
| 1996 | 417 | 0 | 863 | 39 | 21 | 691 | 5303 | 2834 | 0 | 29546 |
| 1997 | 201 | 0 | 470 | 0 | 0 | 566 | 6407 | 2122 | 9124 | 19596 |
| 1998 | 345 | 0 | 679 | 0 | 462 | 445 | 2971 | 70 | 785 | 4846 |
| 1999 | 118 | 0 | 126 | 0 | 209 | 171 | 2266 | 103 | 746 | 12376 |
| 2000 | 104 | 0 | 327 | 0 | 0 | 168 | 1235 | 36 | 0 | 1445 |
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 5186 | 0 | 1479 | 5095 |
| 2002 | 134 | 57 | 59 | 15 | 6 | 90 | 3597 | 0 | 1245 | 3804 |
| 2003 | 7 | 23 | 45 | 0 | 0 | 13 | 8687 | 1574 | 1250 | 20341 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 0 | 7957 | 3023 | 463 | 21613 |
| 2005 | 25 | 80 | 3 | 55 | 0 | 39 | 5408 | 4016 | 30 | 11567 |
| 2006 | 122 | 190 | 23 | 60 | 1 | 211 | 7109 | 1169 | 601 | 14557 |
| 2007 | 360 | 854 | 350 | 323 | 33 | 315 | 18692 | 1125 | 7362 | 12040 |
| 2008 | 199 | 302 | 94 | 31 | 2 | 96 | 20080 | 1073 | 3713 | 20136 |
| 2009 | 203 | 564 | 87 | 53 | 12 | 193 | 34875 | 2226 | 8913 | 2862 |
| 2010 | 97 | 526 | 102 | 29 | 20 | 234 | 7988 | 507 | 23170 | 3461 |
| 2011 | 280 | 2225 | 160 | 167 | 19 | 214 | 10737 | 5249 | 18890 | 13634 |
| 2012 | 82 | 520 | 63 | 117 | 6 | 153 | 5390 | 1133 | 7279 | 8552 |
| 2013 | 303 | 4777 | 184 | 87 | 151 | 511 | 6098 | 1787 | 16770 | 7865 |
| 2014 | 95 | 844 | 18 | 7 | 15 | 132 | 10184 | 1313 | 7214 | 17097 |
| 2015 | 422 | 628 | 20 | 18 | 15 | 246 | 13339 | 3769 | 3814 | 5551 |
| 2016 | 372 | 547 | 77 | 39 | 23 | 192 | 5469 | 7636 | 1730 | 10350 |
| 2017 | 621 | 190 | 66 | 17 | 0 | 187 | 6613 | 2604 | 1563 | 7972 |
| **10 year avg.** | **267** | **1112** | **87** | **57** | **26** | **216** | **12077** | **2730** | **9306** | **9748** |
| **10 year SD** | **162** | **1334** | **50** | **49** | **42** | **108** | **8726** | **2119** | **7261** | **5386** |
| **20 year avg.** | **216** | **685** | **138** | **57** | **54** | **201** | **9194** | **1921** | **5351** | **10258** |
| **20 year SD** | **157** | **1118** | **162** | **78** | **113** | **122** | **7592** | **1950** | **6640** | **6027** |

### 1.5.3 Top Species in Shore- and 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. The 10 species groups in the shore and boat-based catch records from the coral reef fishery make up 85% and 70% of the total annual catches, respectively.

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

The averages for Table 8 below were calculated from catch estimates for the entire time series across each of the CREMUS groupings. The average catch for each grouping is ranked from the highest to lowest. The dominant groups that make up more than half of the total annual catch are reported.

The averages for Table 9 below were calculated from catch estimates from the entire time series for each CREMUS grouping. The average catch is ranked from the highest to lowest. The dominant groups that make up more than 60% of the catch are reported.

**Table 8. Catch time series of the 11 managed species complexes (rank ordered by management importance and average catch of the most recent decade) from boat-based creel data from 1989-2017.**

| Year | Bottomfish | BMUS | Surgeonfish | Snappers | Emperors | Parrotfish | Groupers | Jacks | Crustaceans | Squirrelfish | Atulai |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 28708 | 28547 | 19229 | 5922 | 4222 | 7962 | 4797 | 3961 | 4602 | 4448 | 0 |
| 1990 | 10797 | 10182 | 824 | 1149 | 1669 | 319 | 512 | 1017 | 186 | 148 | 108 |
| 1991 | 12138 | 12138 | 388 | 2441 | 2053 | 167 | 1040 | 760 | 155 | 271 | 0 |
| 1992 | 8672 | 8239 | 0 | 683 | 3905 | 0 | 298 | 1269 | 0 | 35 | 0 |
| 1993 | 11634 | 11174 | 221 | 1405 | 2292 | 330 | 1926 | 636 | 50 | 233 | 0 |
| 1994 | 30118 | 29993 | 9277 | 4459 | 6169 | 15557 | 4626 | 3440 | 1526 | 816 | 0 |
| 1995 | 25339 | 23506 | 1588 | 2222 | 4853 | 2960 | 2594 | 4675 | 294 | 457 | 2 |
| 1996 | 26923 | 24280 | 3560 | 1847 | 7458 | 1409 | 1824 | 2915 | 413 | 679 | 22 |
| 1997 | 27173 | 26856 | 49629 | 3881 | 5784 | 17553 | 7155 | 2930 | 5319 | 3696 | 272 |
| 1998 | 11203 | 10716 | 35789 | 1293 | 1341 | 22231 | 4797 | 2676 | 4728 | 1264 | 0 |
| 1999 | 13675 | 12912 | 34665 | 2127 | 1342 | 13769 | 4773 | 1794 | 2136 | 2599 | 0 |
| 2000 | 14099 | 14044 | 22286 | 1291 | 8977 | 10905 | 3489 | 3578 | 1769 | 2546 | 631 |
| 2001 | 30964 | 30877 | 5802 | 4840 | 11448 | 953 | 1641 | 1766 | 1677 | 510 | 55 |
| 2002 | 24274 | 23733 | 4751 | 3081 | 14576 | 1528 | 2275 | 2721 | 753 | 1381 | 0 |
| 2003 | 13521 | 13408 | 3088 | 4108 | 6793 | 844 | 1338 | 1122 | 1034 | 584 | 0 |
| 2004 | 22015 | 15477 | 2338 | 3351 | 1633 | 732 | 1691 | 1848 | 645 | 525 | 0 |
| 2005 | 13955 | 9395 | 106 | 3348 | 579 | 74 | 803 | 735 | 29 | 181 | 0 |
| 2006 | 7649 | 5106 | 753 | 1435 | 449 | 481 | 600 | 507 | 253 | 276 | 36 |
| 2007 | 23498 | 12411 | 5615 | 4331 | 5914 | 3069 | 1454 | 959 | 1654 | 739 | 2585 |
| 2008 | 33254 | 26595 | 3203 | 8075 | 7582 | 2220 | 3240 | 1280 | 1151 | 1095 | 1759 |
| 2009 | 42635 | 42543 | 7872 | 16944 | 10280 | 4889 | 3587 | 2362 | 2861 | 1309 | 198 |
| 2010 | 8230 | 8206 | 25301 | 3269 | 2365 | 14712 | 1970 | 410 | 14358 | 2243 | 14 |
| 2011 | 25017 | 15169 | 10515 | 5597 | 4177 | 6909 | 2379 | 186 | 3160 | 1726 | 37 |
| 2012 | 14780 | 3234 | 1588 | 1384 | 1201 | 1762 | 367 | 472 | 573 | 368 | 3481 |
| 2013 | 27889 | 6072 | 6733 | 3834 | 2220 | 2422 | 1231 | 1162 | 1791 | 994 | 1092 |
| 2014 | 15390 | 15379 | 8539 | 8430 | 4943 | 7803 | 2778 | 932 | 140 | 810 | 157 |
| 2015 | 23214 | 23195 | 11137 | 10360 | 8425 | 11886 | 2043 | 735 | 11 | 942 | 0 |
| 2016 | 20894 | 20866 | 1423 | 10126 | 1435 | 2937 | 1555 | 1476 | 269 | 429 | 72 |
| 2017 | 16499 | 16451 | 3239 | 11556 | 847 | 3015 | 1421 | 2432 | 1093 | 375 | 0 |
| **10-year avg.** | **22780** | **17771** | **7955** | **7958** | **4348** | **5856** | **2057** | **1145** | **2541** | **1029** | **681** |
| **10-year SD** | **9532** | **10883** | **6689** | **4384** | **3190** | **4231** | **926** | **734** | **4073** | **577** | **1088** |
| **20-year avg.** | **20133** | **16289** | **9737** | **5439** | **4826** | **5657** | **2172** | **1458** | **2004** | **1045** | **506** |
| **20-year SD** | **8728** | **9270** | **10646** | **4091** | **4104** | **5911** | **1228** | **897** | **3065** | **720** | **960** |

**Table 9. Catch time series of the 10 managed CREMUS complexes (rank ordered by management importance and average catch of the most recent decade) from shore-based creel data from 1989-2017.**

| Year | Shore-based Estimated Pounds | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Atulai | Mollusks | Surgeonfish | Parrotfish | Mullet | Grouper | Squirrel | Wrasse | Crustaceans | Snappers |
| 1989 | 0 | 598 | 19229 | 7962 | 0 | 4797 | 4448 | 180 | 4602 | 5922 |
| 1990 | 46943 | 10586 | 16904 | 1551 | 18013 | 2756 | 2100 | 135 | 634 | 4486 |
| 1991 | 113429 | 18171 | 22154 | 5071 | 1593 | 6815 | 5454 | 864 | 2443 | 4843 |
| 1992 | 7412 | 9517 | 19696 | 3376 | 4213 | 6376 | 10895 | 172 | 1926 | 1525 |
| 1993 | 7642 | 40015 | 19418 | 4070 | 1001 | 8406 | 2910 | 308 | 2700 | 2656 |
| 1994 | 12942 | 16739 | 28082 | 24460 | 694 | 8780 | 3095 | 298 | 4592 | 6228 |
| 1995 | 22 | 22752 | 22845 | 17034 | 2068 | 10898 | 4537 | 167 | 6538 | 3492 |
| 1996 | 26003 | 25515 | 21719 | 20315 | 1336 | 8009 | 10662 | 354 | 4534 | 2670 |
| 1997 | 477 | 614 | 62857 | 28384 | 28 | 11186 | 5313 | 0 | 9816 | 4691 |
| 1998 | 0 | 1624 | 50269 | 36887 | 0 | 8788 | 2696 | 482 | 7868 | 1887 |
| 1999 | 668 | 1823 | 53995 | 31979 | 429 | 8179 | 5212 | 185 | 4412 | 2587 |
| 2000 | 811 | 65 | 37994 | 23883 | 215 | 6403 | 4453 | 0 | 2577 | 2074 |
| 2001 | 376 | 171 | 11868 | 7692 | 23 | 2898 | 1448 | 0 | 2787 | 5378 |
| 2002 | 374 | 70 | 11393 | 7256 | 0 | 3684 | 2386 | 0 | 1515 | 3625 |
| 2003 | 0 | 512 | 13387 | 6049 | 10 | 2105 | 1815 | 60 | 1813 | 4715 |
| 2004 | 98 | 808 | 6605 | 4588 | 435 | 2452 | 1243 | 330 | 1191 | 4277 |
| 2005 | 1417 | 7394 | 13943 | 7169 | 2563 | 3669 | 1760 | 3157 | 4025 | 4109 |
| 2006 | 769 | 4460 | 11936 | 9774 | 3441 | 4357 | 1287 | 1940 | 7490 | 2748 |
| 2007 | 5264 | 13182 | 24812 | 9935 | 2862 | 7065 | 2461 | 1145 | 3995 | 6291 |
| 2008 | 8280 | 17989 | 16049 | 6728 | 1210 | 6384 | 3598 | 2381 | 3104 | 9331 |
| 2009 | 436 | 3297 | 21897 | 9134 | 471 | 6221 | 3953 | 805 | 4061 | 19692 |
| 2010 | 2124 | 4783 | 44497 | 38793 | 2241 | 4573 | 7253 | 687 | 18084 | 3994 |
| 2011 | 16222 | 8231 | 40570 | 22749 | 2663 | 4521 | 6635 | 125 | 6028 | 6084 |
| 2012 | 7636 | 4602 | 29247 | 10394 | 1253 | 2088 | 2377 | 200 | 1677 | 1813 |
| 2013 | 7281 | 18130 | 33493 | 11394 | 3295 | 3461 | 3691 | 568 | 3513 | 4818 |
| 2014 | 739 | 7276 | 49675 | 20086 | 743 | 6597 | 4479 | 220 | 1574 | 9649 |
| 2015 | 5018 | 6120 | 63257 | 31018 | 721 | 5494 | 5472 | 180 | 1177 | 11363 |
| 2016 | 2276 | 29213 | 70692 | 45230 | 950 | 9347 | 10683 | 407 | 6411 | 12256 |
| 2017 | 503 | 2950 | 21789 | 11830 | 257 | 3651 | 2095 | 209 | 1851 | 12433 |
| **10-year avg.** | **5052** | **10259** | **39117** | **20736** | **1380** | **5234** | **5024** | **578** | **4748** | **9143** |
| **10-year SD** | **4730** | **8216** | **17263** | **12809** | **960** | **1940** | **2462** | **641** | **4771** | **4953** |
| **20-year avg.** | **3015** | **6635** | **31368** | **17628** | **1189** | **5097** | **3750** | **654** | **4258** | **6456** |
| **20-year SD** | **4055** | **7424** | **18620** | **12437** | **1162** | **2143** | **2340** | **846** | **3752** | **4521** |

## 1.6 CATCH-PER-UNIT-EFFORT (CPUE) STATISTICS

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

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

**Table 10. CPUE time series for dominant fishing methods in the shore-based fishery from 1990-2017 for the top dominant groups (that make up more than 50% of the annual catch).**

| Year | Gear CPUE (lbs./gear hour) | | | | |
|---|---|---|---|---|---|
| | R&R | Spear | Gleaning | Gill net | H&L |
| 1990 | 0.0532 | NULL | 0.5061 | NULL | 0.037 |
| 1991 | 0.0561 | NULL | 0.1922 | NULL | 0.0299 |
| 1992 | 0.5486 | NULL | 0.4786 | NULL | 0.1152 |
| 1993 | 0.0745 | NULL | 0.2136 | NULL | 5.5833 |
| 1994 | 0.0322 | NULL | 0.0943 | NULL | 0.0229 |
| 1995 | 0.0904 | NULL | 0.0792 | 4.5926 | 0.0741 |
| 1996 | 0.0925 | NULL | 0.2517 | 0.1866 | 0.0367 |
| 1997 | | | | | |
| 1998 | | | | | |
| 1999 | | | | | |
| 2000 | | | | | |
| 2001 | | | | | |
| 2002 | 0.0124 | 2.28 | 0.2341 | 2.5 | 0.375 |
| 2003 | 0.0374 | 1.0952 | 0.4945 | 0 | 0 |
| 2004 | | | | | |
| 2005 | 0.047 | 0.1379 | 0.25 | 3.9286 | 0 |
| 2006 | 0.0341 | 0.1 | 0.1769 | 0.5714 | 0.5 |
| 2007 | 0.012 | 0.1069 | 0.0594 | 0.2553 | 0.6735 |
| 2008 | 0.0455 | 0.0944 | 0.1741 | 0.5741 | 0.1333 |
| 2009 | 0.0166 | 0.1112 | 0.1014 | 0.4907 | 0.24 |
| 2010 | 0.0226 | 0.0502 | 0.488 | 0.725 | 0.6667 |
| 2011 | 0.0105 | 0.0319 | 0.1309 | 0.3591 | 0.2468 |
| 2012 | 0.0138 | 0.1337 | 0.3462 | 0.1275 | 0.3333 |
| 2013 | 0.0157 | 0.0213 | 0.381 | 0.956 | 1.1185 |
| 2014 | 0.0335 | 0.0799 | 0.9 | 0.2333 | 5 |
| 2015 | 0.0098 | 0.1661 | 0.3704 | 0.6 | 0.625 |
| 2016 | 0.0182 | 0.1796 | 0.3775 | 3.9 | 0.2018 |
| 2017 | 0.0249 | 0.2 | 0.4889 | 0.3269 | 0 |
| **10 year avg.** | **0.0211** | **0.1068** | **0.3758** | **0.8293** | **0.8565** |
| **10 year SD** | **0.0106** | **0.0594** | **0.2184** | **1.0493** | **1.4155** |
| **20 year avg.** | **0.0236** | **0.3192** | **0.3316** | **1.1106** | **0.7224** |
| **20 year SD** | **0.0123** | **0.5808** | **0.2061** | **1.2732** | **1.2222** |

**Table 11. CPUE time series for dominant fishing methods in the boat-based fishery from 1986-2017, derived from the top three to five dominant taxonomic groups that make up more than half of the annual catch.**

| Year | Boat-based CPUE (lbs./fishing hours) | | | |
|---|---|---|---|---|
| | Bottomfishing | Bottom/Troll Mix | Spear | Troll |
| 1986 | 0.0242 | 0.0633 | 0.1295 | 0.0237 |
| 1987 | 0.2486 | 0.0905 | 0.1038 | 0.0411 |
| 1988 | 0.1611 | 0.2023 | 0.078 | 0.061 |
| 1989 | 0.2189 | 0.1531 | 0.1812 | 0.0252 |
| 1990 | 0.2227 | 0.2841 | 0.6667 | 0.0496 |
| 1991 | 0.1002 | 0.3337 | 3.1867 | 0.062 |
| 1992 | 0.16 | 0 | 0 | 0.1005 |
| 1993 | 0.0754 | 1.5958 | 0.9333 | 0.0761 |
| 1994 | 0.0674 | 0.3674 | 1.0228 | 0.0436 |
| 1995 | 0.1424 | 0.1411 | 0 | 0.0321 |
| 1996 | 0.1469 | 0.7409 | 0 | 0.0533 |
| 1997 | 0.1147 | 0.4486 | 0.3283 | 0.0491 |
| 1998 | 0.2814 | 0.7292 | 5.4514 | 0.184 |
| 1999 | 0.3536 | 5.7222 | 1.7933 | 0.1317 |
| 2000 | 0.3869 | 3 | 0 | 0.391 |
| 2001 | 0.1717 | 0 | 0.7043 | 0.2042 |
| 2002 | 0.062 | 0 | 0.5231 | 0.3254 |
| 2003 | 0.0687 | 0.8211 | 1.0629 | 0.0628 |
| 2004 | 0.0285 | 0.2928 | 1.3538 | 0.0548 |
| 2005 | 0.0709 | 0.2499 | 3 | 0.0633 |
| 2006 | 0.0404 | 0.3619 | 0.7457 | 0.0811 |
| 2007 | 0.0355 | 0.2856 | 0.0396 | 0.1147 |
| 2008 | 0.0425 | 0.3794 | 0.0984 | 0.1609 |
| 2009 | 0.0526 | 0.5162 | 0.3038 | 0.2901 |
| 2010 | 0.0921 | 7.6818 | 0.0642 | 0.2161 |
| 2011 | 0.0888 | 0.486 | 0.1406 | 0.2276 |
| 2012 | 0.0528 | 0.9257 | 0.447 | 0.4691 |
| 2013 | 0.052 | 0.3961 | 0.1181 | 0.0936 |
| 2014 | 0.0565 | 0.3245 | 0.0594 | 0.1252 |
| 2015 | 0.0307 | 0.1911 | 0.1371 | 0.1243 |
| 2016 | 0.0396 | 0.0962 | 0.0429 | 0.3796 |
| 2017 | 0.0208 | 0.0507 | 0.0139 | 0.0596 |
| **10 year avg.** | **0.0528** | **1.1048** | **0.1425** | **0.2146** |
| **10 year SD** | **0.0216** | **2.205** | **0.1268** | **0.1247** |
| **20 year avg.** | **0.1014** | **1.2506** | **0.8473** | **0.188** |
| **20 year SD** | **0.1067** | **2.0546** | **1.3168** | **0.1208** |

## 1.7 EFFORT STATISTICS

This section summarizes the effort trends in the coral reef and bottomfish fishery. Fishing effort trends provide insights on the level of fishing pressure through time. Effort information is provided for the top shore-based and boat-based fishing methods that contribute 70% and 85% of the annual catch.

**Calculations:** Effort estimates (in gear-hours) are generated by summing the effort data collected from interviews by gear type. For the Shore-based estimates, the database was started in 1990 despite data collection beginning in the 1970s.

**Table 12. Effort (in gear-hours) for dominant fishing methods in the coral reef and bottomfish fisheries from 1986-2017.**

| Year | Shore-based gear hours | | | | | Boat-based gear hours | | | |
|---|---|---|---|---|---|---|---|---|---|
| | R&R | Spear | Gleaning | Gill net | H&L | Bottom | Bottom/Troll Mix | Spear | Troll |
| 1986 | | | | | | 744246 | 272557 | 77520 | 2098512 |
| 1987 | | | | | | 10368 | 136072 | 94644 | 1033006 |
| 1988 | | | | | | 45114 | 50220 | 201500 | 1006845 |
| 1989 | | | | | | 20713 | 80388 | 74501 | 1823029 |
| 1990 | 12936 | 0 | 2889 | 0 | 13653 | 11137 | 13410 | 2040 | 457300 |
| 1991 | 28380 | 0 | 2805 | 0 | 13261 | 40255 | 14442 | 225 | 294930 |
| 1992 | 350 | 0 | 1003 | 0 | 165 | 23374 | 0 | 0 | 273612 |
| 1993 | 5220 | 0 | 3913 | 0 | 12 | 66215 | 480 | 15 | 146376 |
| 1994 | 18860 | 0 | 11005 | 0 | 1178 | 76900 | 4900 | 1656 | 785880 |
| 1995 | 5421 | 0 | 15660 | 27 | 729 | 19950 | 28768 | 0 | 1954350 |
| 1996 | 4510 | 0 | 3429 | 209 | 572 | 34656 | 4284 | 0 | 589380 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 59631 | 4730 | 26634 | 499260 |
| 1998 | 0 | 0 | 0 | 0 | 0 | 10764 | 96 | 144 | 30753 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 6408 | 12 | 416 | 107177 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 3192 | 12 | 0 | 3619 |
| 2001 | | | | | | 31540 | 0 | 2100 | 31616 |
| 2002 | 10816 | 25 | 252 | 6 | 16 | 57988 | 0 | 2380 | 11248 |
| 2003 | 187 | 21 | 91 | 0 | 0 | 105222 | 1349 | 756 | 238392 |
| 2004 | | | | | | 519726 | 9800 | 266 | 369104 |
| 2005 | 532 | 580 | 12 | 14 | 1 | 54540 | 13596 | 10 | 170016 |
| 2006 | 3575 | 1900 | 130 | 105 | 2 | 155709 | 3230 | 650 | 171270 |
| 2007 | 29882 | 7986 | 5893 | 1265 | 49 | 524706 | 3939 | 164016 | 98154 |
| 2008 | 4371 | 3200 | 540 | 54 | 15 | 460290 | 3838 | 37000 | 120776 |
| 2009 | 12231 | 5074 | 858 | 108 | 50 | 654515 | 4312 | 24840 | 8494 |
| 2010 | 4284 | 10472 | 209 | 40 | 30 | 84240 | 66 | 316820 | 10362 |
| 2011 | 26543 | 69776 | 1222 | 465 | 77 | 123804 | 11016 | 124146 | 51471 |
| 2012 | 5922 | 3888 | 182 | 918 | 18 | 98600 | 1173 | 15222 | 15222 |
| 2013 | 19352 | 224349 | 483 | 91 | 135 | 203548 | 4032 | 138726 | 71052 |
| 2014 | 2838 | 10564 | 20 | 30 | 3 | 184052 | 5593 | 119583 | 152492 |
| 2015 | 42880 | 3780 | 54 | 30 | 24 | 470106 | 439999 | 27820 | 46508 |
| 2016 | 20400 | 3045 | 204 | 10 | 114 | 378658 | 86825 | 40560 | 25986 |
| 2017 | 24969 | 950 | 135 | 52 | 2 | 416150 | 59361 | 109568 | 149490 |
| **10 year avg.** | **16379** | **33510** | **391** | **180** | **47** | **307396** | **61622** | **95429** | **65185** |
| **10 year SD** | **12267** | **66535** | **370** | **277** | **44** | **184485** | **129187** | **86549** | **53520** |
| **20 year avg.** | **11599** | **19201** | **571** | **177** | **30** | **227188** | **32412** | **56251** | **94160** |
| **20 year SD** | **12447** | **52138** | **1330** | **344** | **40** | **205089** | **95959** | **80499** | **91740** |

## 1.8 PARTICIPANTS

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

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

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

**Table 13. Estimated number of fishers in the bottomfish fishery (w/ gear counts), the boat-based, and the shore-based coral reef fishery from 1986-2017.**

| Year | Bottomfish | | Coral Reef Boat-based | | | Coral Reef Shore-based | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # gears | # trips | Bottom/ Troll Mix | Spear | Troll | R&R | Spear | Gleaning | Gill Net | H&L |
| 1986 | 935 | 288 | 871 | 1909 | 1003 | | | | | |
| 1987 | 922 | 70 | 935 | 1710 | 1026 | | | | | |
| 1988 | 919 | 125 | 1163 | 1629 | 1189 | | | | | |
| 1989 | 962 | 115 | 1456 | 1903 | 1253 | | | | | |
| 1990 | 828 | 73 | 1098 | 1556 | 1044 | 10147 | 0 | 7219 | 0 | 16962 |
| 1991 | 947 | 117 | 1114 | 1643 | 1125 | 14498 | 0 | 8406 | 0 | 8234 |
| 1992 | 816 | 121 | 0 | 0 | 996 | 3558 | 0 | 11685 | 0 | 850 |
| 1993 | 913 | 151 | 973 | 365 | 1053 | 7338 | 0 | 15308 | 0 | 1005 |
| 1994 | 913 | 246 | 1136 | 2190 | 979 | 9710 | 0 | 9243 | 0 | 4710 |
| 1995 | 905 | 131 | 905 | 0 | 1322 | 6194 | 0 | 10917 | 125 | 1655 |
| 1996 | 812 | 185 | 876 | 0 | 991 | 12493 | 0 | 7202 | 212 | 9684 |
| 1997 | 970 | 199 | 958 | 1389 | 1248 | | | | | |
| 1998 | 954 | 54 | 936 | 1872 | 1224 | | | | | |
| 1999 | 751 | 107 | 626 | 1252 | 994 | | | | | |
| 2000 | 879 | 160 | 942 | 0 | 868 | | | | | |
| 2001 | 804 | 252 | 0 | 1043 | 1054 | | | | | |
| 2002 | 943 | 378 | 0 | 1560 | 790 | 4102 | 2492 | 3233 | 256 | 192 |
| 2003 | 803 | 272 | 595 | 805 | 624 | 4158 | 1821 | 3909 | 211 | 402 |
| 2004 | 1786 | 402 | 885 | 1475 | 753 | 3199 | 1372 | 1233 | 139 | 158 |
| 2005 | 604 | 220 | 712 | 1565 | 690 | 1444 | 636 | 1255 | 189 | 86 |
| 2006 | 843 | 160 | 991 | 1118 | 777 | 1540 | 297 | 708 | 281 | 119 |
| 2007 | 1006 | 331 | 951 | 1366 | 886 | 1847 | 566 | 562 | 223 | 67 |
| 2008 | 1015 | 468 | 1208 | 1345 | 876 | 1376 | 549 | 789 | 89 | 80 |
| 2009 | 1131 | 622 | 1092 | 1595 | 691 | 976 | 529 | 758 | 66 | 54 |
| 2010 | 1012 | 251 | 945 | 1712 | 671 | 712 | 500 | 339 | 51 | 51 |
| 2011 | 982 | 265 | 895 | 1863 | 807 | 1927 | 642 | 363 | 65 | 98 |
| 2012 | 644 | 264 | 1467 | 748 | 741 | 1418 | 437 | 402 | 207 | 41 |
| 2013 | 1451 | 413 | 1233 | 1795 | 823 | 1550 | 490 | 588 | 34 | 87 |
| 2014 | 782 | 401 | 1222 | 1819 | 995 | 700 | 279 | 231 | 73 | 12 |
| 2015 | 986 | 469 | 20200 | 1630 | 965 | 2627 | 300 | 226 | 62 | 57 |
| 2016 | 2993 | 400 | 1195 | 1622 | 965 | 4363 | 255 | 696 | 10 | 74 |
| 2017 | 2870 | 406 | 2859 | 2670 | 2689 | 998 | 126 | 213 | 7 | 40 |
| **10 year avg.** | **1387** | **396** | **3232** | **1680** | **1022** | **1665** | **411** | **461** | **66** | **59** |
| **10 year SD** | **798** | **108** | **5681** | **452** | **566** | **1058** | **154** | **216** | **53** | **24** |
| **20 year avg.** | **1162** | **315** | **2164** | **1519** | **944** | **2059** | **706** | **969** | **123** | **101** |
| **20 year SD** | **644** | **136** | **4400** | **424** | **426** | **1207** | **621** | **1037** | **89** | **89** |

WPacFIN recommended an alternative method for monitoring fishing participation. The fishery data collectors additionally count the number of gears being for each fishing method.

| Year | Bottomfish | | Coral Reef Boat-based | | | Coral Reef Shore-based | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # fishers | # gears | Bottom/Troll Mix | Spear | Troll | R&R | Spear | Gleaning | Gill net | H&L |
| 1986 | 954 | 935 | 876 | 1909 | 1032 | | | | | |
| 1987 | 941 | 922 | 909 | 1696 | 1055 | | | | | |
| 1988 | 911 | 919 | 1109 | 1629 | 1119 | | | | | |
| 1989 | 1013 | 962 | 1313 | 1875 | 1236 | | | | | |
| 1990 | 809 | 828 | 1074 | 1556 | 1071 | 10298 | 0 | 7758 | 0 | 17282 |
| 1991 | 913 | 947 | 961 | 1643 | 1132 | 14574 | 0 | 8578 | 0 | 8244 |
| 1992 | 788 | 816 | 0 | 0 | 986 | 3783 | 0 | 11990 | 0 | 882 |
| 1993 | 864 | 913 | 973 | 1825 | 1150 | 7683 | 0 | 16242 | 0 | 1034 |
| 1994 | 885 | 913 | 1095 | 1278 | 958 | 10169 | 0 | 9308 | 0 | 4758 |
| 1995 | 889 | 905 | 891 | 0 | 1019 | 6236 | 0 | 10942 | 410 | 1663 |
| 1996 | 846 | 812 | 783 | 0 | 932 | 13424 | 0 | 7218 | 294 | 9994 |
| 1997 | 909 | 970 | 958 | 1449 | 997 | | | | | |
| 1998 | 936 | 954 | 936 | 1872 | 1048 | | | | | |
| 1999 | 751 | 751 | 939 | 1252 | 872 | | | | | |
| 2000 | 879 | 879 | 942 | 0 | 887 | | | | | |
| 2001 | 770 | 804 | 0 | 1043 | 832 | | | | | |
| 2002 | 943 | 943 | 0 | 1560 | 822 | 4945 | 2965 | 3821 | 511 | 281 |
| 2003 | 965 | 803 | 845 | 1252 | 849 | 4523 | 1993 | 4024 | 268 | 422 |
| 2004 | 960 | 1786 | 932 | 1896 | 804 | 3430 | 1446 | 1474 | 324 | 195 |
| 2005 | 844 | 604 | 842 | 1565 | 742 | 1581 | 739 | 1289 | 206 | 86 |
| 2006 | 953 | 843 | 991 | 1386 | 814 | 1632 | 313 | 735 | 389 | 146 |
| 2007 | 1008 | 1006 | 951 | 1549 | 947 | 2030 | 559 | 582 | 396 | 73 |
| 2008 | 1042 | 1015 | 890 | 1372 | 908 | 1566 | 549 | 827 | 169 | 101 |
| 2009 | 1145 | 1131 | 1092 | 1884 | 802 | 1089 | 556 | 785 | 132 | 78 |
| 2010 | 1042 | 1012 | 945 | 1950 | 1036 | 839 | 525 | 347 | 93 | 55 |
| 2011 | 959 | 982 | 878 | 2016 | 939 | 1828 | 489 | 341 | 129 | 95 |
| 2012 | 667 | 644 | 1531 | 800 | 888 | 1300 | 301 | 384 | 390 | 35 |
| 2013 | 835 | 1451 | 1380 | 1838 | 973 | 1591 | 430 | 596 | 57 | 94 |
| 2014 | 765 | 782 | 884 | 1848 | 891 | 700 | 210 | 247 | 61 | 12 |
| 2015 | 911 | 986 | 906 | 1630 | 927 | 2118 | 242 | 234 | 94 | 53 |
| 2016 | 1092 | 2993 | 1092 | 1612 | 1013 | 3260 | 260 | 500 | 20 | 78 |
| 2017 | 2195 | 2870 | 2474 | 2732 | 2404 | 992 | 120 | 220 | 7 | 47 |
| **10 year avg.** | **1065** | **1387** | **1207** | **1768** | **1078** | **1528** | **368** | **448** | **115** | **65** |
| **10 year SD** | **403** | **798** | **473** | **468** | **446** | **717** | **152** | **211** | **103** | **28** |
| **20 year avg.** | **983** | **1162** | **1081** | **1635** | **970** | **2089** | **731** | **1025** | **203** | **116** |
| **20 year SD** | **302** | **644** | **381** | **411** | **339** | **1241** | **744** | **1149** | **152** | **101** |

## 1.9 BYCATCH ESTIMATES

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

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

**Table 14. Time series of bycatch in non-bottomfish boat-based fisheries from 1986-2017.**

| Year | Boat-based non-bottomfishing gear types | | | |
|---|---|---|---|---|
| | Numbers caught | Kept | Released | % bycatch |
| 1986 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 | 0 |
| 1988 | 43 | 43 | 0 | 0 |
| 1989 | 0 | 0 | 0 | 0 |
| 1990 | 0 | 0 | 0 | 0 |
| 1991 | 0 | 0 | 0 | 0 |
| 1992 | 5277 | 5277 | 0 | 0 |
| 1993 | 2637 | 2637 | 0 | 0 |
| 1994 | 7562 | 7562 | 0 | 0 |
| 1995 | 10279 | 10279 | 0 | 0 |
| 1996 | 7088 | 7088 | 0 | 0 |
| 1997 | 24977 | 24977 | 0 | 0 |
| 1998 | 17491 | 17491 | 0 | 0 |
| 1999 | 16705 | 16705 | 0 | 0 |
| 2000 | 12642 | 12641 | 1 | 0.0001 |
| 2001 | 8651 | 8649 | 2 | 0.0002 |
| 2002 | 6531 | 6522 | 9 | 0.0014 |
| 2003 | 8936 | 8931 | 5 | 0.0006 |
| 2004 | 8611 | 8604 | 7 | 0.0008 |
| 2005 | 5036 | 5036 | 0 | 0 |
| 2006 | 6306 | 6306 | 0 | 0 |
| 2007 | 17555 | 17555 | 0 | 0 |
| 2008 | 9799 | 9799 | 0 | 0 |
| 2009 | 9630 | 9630 | 0 | 0 |
| 2010 | 22283 | 22283 | 0 | 0 |
| 2011 | 18659 | 18659 | 0 | 0 |
| 2012 | 15512 | 15512 | 0 | 0 |
| 2013 | 13919 | 13919 | 0 | 0 |
| 2014 | 11560 | 11560 | 0 | 0 |
| 2015 | 7280 | 7280 | 0 | 0 |
| 2016 | 5257 | 5257 | 0 | 0 |
| 2017 | 3118 | 3118 | 0 | 0 |
| **10 year avg.** | **11702** | **11702** | **0** | **0** |
| **10 year SD** | **5679** | **5679** | **0** | **0** |
| **20 year avg.** | **11274** | **11273** | **1** | **0.0002** |
| **20 year SD** | **5193** | **5194** | **3** | **0.0004** |

**Table 15. Time series of bycatch in the bottomfish fishery from 1986-2017.**

| Year | Boat-based bottomfishing | | | |
|---|---|---|---|---|
| | Numbers caught | Kept | Released | % bycatch |
| 1986 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 | 0 |
| 1988 | 91 | 91 | 0 | 0 |
| 1989 | 0 | 0 | 0 | 0 |
| 1990 | 0 | 0 | 0 | 0 |
| 1991 | 0 | 0 | 0 | 0 |
| 1992 | 2440 | 2440 | 0 | 0 |
| 1993 | 2394 | 2394 | 0 | 0 |
| 1994 | 7657 | 7657 | 0 | 0 |
| 1995 | 3405 | 3405 | 0 | 0 |
| 1996 | 5999 | 5999 | 0 | 0 |
| 1997 | 5193 | 5193 | 0 | 0 |
| 1998 | 1844 | 1844 | 0 | 0 |
| 1999 | 5630 | 5630 | 0 | 0 |
| 2000 | 6438 | 6438 | 0 | 0 |
| 2001 | 6202 | 6202 | 0 | 0 |
| 2002 | 6959 | 6959 | 0 | 0 |
| 2003 | 7797 | 7796 | 1 | 0.0001 |
| 2004 | 6734 | 6734 | 0 | 0 |
| 2005 | 3684 | 3684 | 0 | 0 |
| 2006 | 5833 | 5833 | 0 | 0 |
| 2007 | 6936 | 6936 | 0 | 0 |
| 2008 | 8588 | 8588 | 0 | 0 |
| 2009 | 19521 | 19521 | 0 | 0 |
| 2010 | 5021 | 5021 | 0 | 0 |
| 2011 | 7359 | 7359 | 0 | 0 |
| 2012 | 5137 | 5137 | 0 | 0 |
| 2013 | 4525 | 4525 | 0 | 0 |
| 2014 | 4462 | 4462 | 0 | 0 |
| 2015 | 7268 | 7268 | 0 | 0 |
| 2016 | 2122 | 2122 | 0 | 0 |
| 2017 | 2351 | 2351 | 0 | 0 |
| **10 year avg.** | **6635** | **6635** | **0** | **0** |
| **10 year SD** | **4728** | **4728** | **0** | **0** |
| **20 year avg.** | **6221** | **6221** | **0** | **0** |
| **20 year SD** | **3572** | **3572** | **0** | **0** |

**Table 16. Time series of bycatch in shore-based fisheries for all gears from 2005-2017.**

| Year | Shore-based (all gears) | | | |
|---|---|---|---|---|
| | Numbers caught | Kept | Released | % bycatch |
| 2005 | 658 | 655 | 3 | 0.0046 |
| 2006 | 1619 | 1613 | 6 | 0.0037 |
| 2007 | 5442 | 5441 | 1 | 0.0002 |
| 2008 | 2145 | 2145 | 0 | 0 |
| 2009 | 2199 | 2199 | 0 | 0 |
| 2010 | 1994 | 1993 | 1 | 0.0005 |
| 2011 | 3981 | 3980 | 1 | 0.0003 |
| 2012 | 1572 | 1572 | 0 | 0 |
| 2013 | 9220 | 9214 | 6 | 0.0007 |
| 2014 | 1829 | 1829 | 0 | 0 |
| 2015 | 2469 | 2469 | 0 | 0 |
| 2016 | 3302 | 3302 | 0 | 0 |
| 2017 | 1386 | 1386 | 0 | 0 |
| **10 year avg.** | **3010** | **3009** | **1** | **0.0002** |
| **10 year SD** | **2201** | **2199** | **2** | **0.0002** |
| **20 year avg.** | **2909** | **2908** | **1** | **0.0008** |
| **20 year SD** | **2178** | **2177** | **2** | **0.0015** |

## 1.10 NUMBER OF FEDERAL PERMIT HOLDERS

In American Samoa, regulations at Title 50 Code of Federal Regulations, Part 665 require the following Federal permits for fishing in the EEZ:

### 1.10.1 Special Coral Reef Ecosystem Permit

Regulations require the special coral reef ecosystem fishing permit for anyone fishing for coral reef ecosystem management unit species (MUS) in a low-use 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 American Samoa coral reef ecosystem MUS while fishing for bottomfish MUS, crustacean MUS, western Pacific pelagic MUS, precious coral, or seamount groundfish. Regulations require a transshipment permit for any receiving vessel used to land or transship potentially harvested coral reef taxa, or any coral reef ecosystem MUS caught in a low-use MPA.

### 1.10.2 Western Pacific Precious Coral

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

### 1.10.3 Western Pacific Crustacean Permit

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

There is no record of special coral reef or precious coral fishery permits issued for the EEZ around American Samoa since 2007. NMFS has issued few crustacean fishery permits as shown in Table 17. Table 17 provides the number of permits issued to American Samoa FEP fisheries between 2007 and 2017. Historical data are from the PIFSC accessed on February 9, 2017, and 2017 data are from the PIRO Sustainable Fisheries Division permits program as of January 5, 2018.

**Table 17. Number of federal permits holders for the American Samoa crustacean fisheries between 2007 and 2017.**

| Crustacean Fishery | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lobster | 1 | 6* | 4* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Shrimp | 0 | 0 | 0 | 1* | 1* | 0 | 0 | 1 | 0 | 0 | 0 |

*Same permit applies to American Samoa, Guam, and CNMI.

## 1.11 STATUS DETERMINATION CRITERIA

### 1.11.1 Bottomfish Fishery

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

The MSY control rule is used as the maximum fishing mortality threshold (MFMT). The MFMT and minimum stock size threshold (MSST) are specified based on the recommendations of Restrepo *et al*. (1998) and both are dependent on the natural mortality rate (M). The value of M used to determine the reference point values is not specified in this document. The latest estimate published annually in the SAFE report is used, and the value is occasionally re-estimated using the best available information. The range of M among species within a stock complex is taken into consideration when estimating and choosing the M to be used for the purpose of computing the reference point values.

In addition to the thresholds MFMT and MSST, a warning reference point, $B_{FLAG}$, is specified at some point above the MSST to provide a trigger for consideration of management action prior to B reaching the threshold. MFMT, MSST, and $B_{FLAG}$ are specified as indicated in Table 18.

**Table 18. Overfishing threshold specifications for BMUS.**

| MFMT | MSST | $B_{FLAG}$ |
|---|---|---|
| $F(B) = \frac{F_{MSY} B}{c\, B_{MSY}}$ for $B \le c\, B_{MSY}$<br>$F(B) = F_{MSY}$ for $B > c\, B_{MSY}$ | $c\, B_{MSY}$ | $B_{MSY}$ |
| where $c$ = max (1-M, 0.5) | | |

Standardized values of fishing effort (E) and catch-per-unit-effort (CPUE) are used as proxies for F and B, respectively, so $E_{MSY}$, $CPUE_{MSY}$, and $CPUE_{FLAG}$ are used as proxies for $F_{MSY}$, $B_{MSY}$, and $B_{FLAG}$, respectively.

In cases where reliable estimates of $CPUE_{MSY}$ and $E_{MSY}$ are not available, they would be estimated from catch and effort times series, standardized for all identifiable biases. $CPUE_{MSY}$ would be calculated as half of a multi-year average reference CPUE, called $CPUE_{REF}$. The multi-year reference window would be objectively positioned in time to maximize the value of $CPUE_{REF}$. $E_{MSY}$ would be calculated using the same approach or, following Restrepo *et al.* (1998), by setting $E_{MSY}$ equal to $E_{AVE}$, where $E_{AVE}$ represents the long-term average effort prior to declines in CPUE. When multiple estimates are available, the more precautionary is used.

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

**Table 19. Recruitment overfishing control rule specifications for bottomfish MUS.**

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

### 1.11.2 Coral Reef Fishery

Available biological and fishery data are poor for all coral reef ecosystem management unit species in American Samoa. There is scant information on the life histories, ecosystem dynamics, fishery impact, community structure changes, yield potential, and management reference points for many coral reef ecosystem species. Additionally, total fishing effort cannot be adequately partitioned between the various management unit species (MUS) for any fishery or area. Biomass, maximum sustainable yield, and fishing mortality estimates are not available for any single MUS. Once these data are available, fishery managers can establish limits and reference points based on the multi-species coral reef ecosystem as a whole.

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

Individual species that are part of a multi-species complex will respond differently to an OY-determined level of fishing effort ($F_{OY}$). Thus, for a species complex that is fished at $F_{OY}$, managers still must track individual species' mortality rates in order to prevent species-specific population declines that would lead to depletion.

For the coral reef fishery, the multi-species complex as a whole is used to establish limits and reference points for each area. Available data for a particular species are used to evaluate the status of individual MUS stocks in order to prevent recruitment overfishing when possible. When better data and the appropriate multi-species stock assessment methodologies become available, all stocks will be evaluated independently, without proxy.

#### 1.11.2.1 Establishing Reference Point Values

Standardized values of catch per unit effort (CPUE) and effort (E) are used to establish limit and reference point values, which act as proxies for relative biomass and fishing mortality, respectively. Limits and reference points are calculated in terms of $CPUE_{MSY}$ and $E_{MSY}$ included in Table 20.

**Table 20. Status determination criteria for the coral reef MUS using CPUE-based proxies.**

| Value | Proxy | Explanation |
|---|---|---|

| | | |
|---|---|---|
| MaxFMT ($F_{MSY}$) | $E_{MSY}$ | 0.91 $CPUE_{MSY}$ |
| $F_{OY}$ | 0.75 $E_{MSY}$ | suggested default scaling for target |
| $B_{MSY}$ | $CPUE_{MSY}$ | operational counterpart |
| $B_{OY}$ | 1.3 $CPUE_{MSY}$ | simulation results from Mace (1994) |
| MinSST | 0.7 $CPUE_{MSY}$ | suggested default (1-M)$B_{MSY}$ with M=0.3* |
| $B_{FLAG}$ | 0.91 $CPUE_{MSY}$ | suggested default (1-M)$B_{OY}$ with M=0.3* |

When reliable estimates of $E_{MSY}$ and $CPUE_{MSY}$ are not available, they are generated from time series of catch and effort values, standardized for all identifiable biases using the best available analytical tools. $CPUE_{MSY}$ is calculated as one-half a multi-year moving average reference CPUE ($CPUE_{REF}$).

### 1.11.3 Current Stock Status

#### 1.11.3.1 Bottomfish

Biological and other fishery data are poor for all bottomfish species in the America Samoa Archipelago. Generally, data are only available on commercial landings by species and catch-per-unit-effort (CPUE) for the multi-species complexes as a whole. At this time it is not possible to partition these effort measures among the various bottomfish MUS. The most recent stock assessment update (Yau *et al*., 2016) for the American Samoa bottomfish management unit species complex (comprised of 17 species of shallow and deep species of snapper, grouper, jacks, and emperors) was based on estimate of total catch, an abundance index derived from the nominal CPUE generated from the creel surveys, and a fishery-independent point estimate of MSY from the Our Living Oceans Report (Humphreys and Moffitt, 1999; Moffitt and Humphreys, 2009). The assessment utilized a state-space surplus production model with explicit process and observation error terms (Meyer and Millar, 1999). Determinations of overfishing and overfished status can then be made by comparing current biomass and harvest rates to MSY-level reference points. To date, the American Samoa BMUS is not subject to overfishing and is not overfished (
Table 21).

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

| **Parameter** | **Value** | **Notes** | **Status** |
|---|---|---|---|
| MSY | 76.74 ± 14.06 | Expressed in 1000 lbs. (± std. error) | |
| $H_{2013}$ | 0.039 | Expressed in percentage | |
| $H_{MSY}$ | 0.238 ± 0.062 | Expressed in percentage (± std. error) | |

| | | | |
|---|---|---|---|
| $H/H_{MSY}$ | 0.17 | | No overfishing occurring |
| $B_{2013}$ | 661.3 | Expressed in thousand pounds | |
| $B_{MSY}$ | 333.7 ± 65.3 | Expressed in 1000 lbs. (± std. error) | |
| $B/B_{MSY}$ | 1.98 | | Not overfished |

#### 1.11.3.2 Coral reef

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

For ACL specification purposes, MSYs in the coral reef fisheries are determined by using the Biomass-Augmented Catch-MSY approach (Sabater and Kleiber, 2014). This method estimates MSY using plausible combination rates of population increase (denoted by *r*) and carrying capacity (denoted by *k*) assumed from the catch time series, resilience characteristics (from FishBase), and biomass from existing underwater census surveys done by the Pacific Island Fisheries Science Center. This method was applied to species complexes grouped by taxonomic families. The most recent MSY estimates are found in Table 22. The SSC utilized the MSYs for the coral reef MUS complexes as the OFLs.

**Table 22. Best available MSY estimates for the CREMUS.**

| Coral Reef MUS Complex | MSY (lbs.) |
|---|---|
| *Selar crumenophthalmus* – atulai / bigeye scad | 45,300 |
| Acanthuridae – surgeonfish | 148,600 |
| Carangidae – jacks | 24,300 |
| Crustaceans – crabs | 7,800 |
| Holocentridae – squirrelfish | 16,800 |
| Kyphosidae – chubs/rudderfish | 2,600 |
| Labridae – wrasses | 19,000 |
| Lethrinidae – emperors | 23,700 |
| Lutjanidae – snappers | 65,400 |
| Mollusks – turbo snail; octopus; giant clams | 12,700 |
| Mugilidae – mullets | 8,200 |
| Mullidae – goatfish | 29,600 |
| Scaridae – parrotfish | 294,600 |

| Coral Reef MUS Complex | MSY (lbs.) |
|---|---|
| Serranidae – groupers | 30,500 |
| Siganidae – rabbitfish | 200 |
| All Other CREMUS Combined<br>- Other CRE-finfish<br>- Other invertebrates<br>- Misc. bottomfish<br>- Misc. reef fish<br>- Misc. shallow bottomfish | 28,500 |
| *Cheilinus undulatus* – humphead (Napoleon) wrasse | N.A. |
| *Bolbometopon muricatum* – bumphead parrotfish | N.A. |
| Carcharhinidae – reef sharks | 2,300 |

## 1.12 OVERFISHING LIMIT, ACCEPTABLE BIOLOGICAL CATCH, AND ANNUAL CATCH LIMITS

### 1.12.1 Brief Description of the ACL Process

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

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

### 1.12.2 Current OFL, ABC, ACL, and Recent Catch

The most recent multiyear specification of OFL, ABC, and ACL for the coral reef fishery was completed in the 160$^{th}$ Council meeting on June 25 to 27, 2014. The specification covers fishing year 2015, 2016, 2017, and 2018 for the coral reef MUS complexes. A P* and SEEM analysis was performed for this multiyear specification (NMFS, 2015). For the bottomfish, it was a roll over from the previous specification since an assessment update was not available for fishing year 2017.

**Table 23. American Samoa 2017 ACL table with three-year recent average catch (lbs.).**

| Fishery | MUS | OFL | ABC | ACL | Catch |
|---|---|---|---|---|---|
| Bottomfish | Bottomfish multi-species complex | N.A. | 106,000 | 106,000 | 22,233 |
| Crustacean | Deepwater shrimp | N.A. | 80,000 | 80,000 | N.A.F. |
| | Spiny lobster | 7,300 | 5,100 | 4,845 | 826 |
| | Slipper lobster | N.A. | 30 | 30 | 13.6 |
| | Kona crab | N.A. | 3,200 | 3,200 | N.A.F. |
| Precious coral | Black coral | 8,250 | 790 | 790 | N.A.F. |
| | Precious coral in AS expl. area | N.A. | 2,205 | 2,205 | N.A.F. |
| Coral Reef | *S. crumenophthalmus* | N.A. | N.A. | N.A. | 1,707 |
| | Acanthuridae-surgeonfish | N.A. | N.A. | N.A. | 11,352 |
| | Carangidae-jacks | N.A. | N.A. | N.A. | 9,058 |
| | Crustaceans-crabs | N.A. | N.A. | N.A. | 1,932 |
| | Holocentridae-squirrelfish | N.A. | N.A. | N.A. | 1,932 |
| | Kyphosidae-rudderfish | N.A. | N.A. | N.A. | 667 |
| | Labridae-wrasse | N.A. | N.A. | N.A. | 254 |
| | Lethrinidae-emperors | N.A. | N.A. | N.A. | 5,657 |
| | Lutjanidae-snappers | N.A. | N.A. | N.A. | 18,543 |
| | Mollusk-turbo snails; octopus; clams | N.A. | N.A. | N.A. | 12,377 |
| | Mullidae-goatfish | N.A. | N.A. | N.A. | 644 |
| | Mugilidae-mullets | N.A. | N.A. | N.A. | 569 |
| | Scaridae-parrotfish | N.A. | N.A. | N.A. | 3,900 |
| | Serranidae-groupers | N.A. | N.A. | N.A. | 3,356 |
| | Siganidae-rabbitfish | N.A. | N.A. | N.A. | 391 |
| | All other CREMUS combined | N.A. | N.A. | N.A. | 1,866 |
| | *Cheilinus undulatus* | N.A. | N.A. | N.A. | 3 |
| | *Bolbometopon muricatum* | N.A. | N.A. | N.A. | N.D. |
| | Carcharhinidae-reef sharks | N.A. | N.A. | N.A. | 60 |

The catch shown in Table 23 takes the average of the recent three years as recommended by the Council at its 160th meeting to avoid large fluctuations in catch due to data quality and outliers. ACLs were not specified by NMFS for the coral reef ecosystem MUS because NMFS has recently acquired new information that require additional environmental analyses to support the Council's ACL recommendations for these management unit species (50 CFR Part 665). "N.A.F." indicates no active fisheries to date. "N.D." indicates no data available or the species was not detected in the surveys.

## 1.13 BEST SCIENTIFIC INFORMATION AVAILABLE

### 1.13.1 Bottomfish fishery

#### 1.13.1.1 Stock Assessment Benchmark

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

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

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

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

#### 1.13.1.2 Stock Assessment Updates

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

#### 1.13.1.3 Other Information Available

Approximately every five years PIFSC administers a socioeconomic survey to small boat fishermen in American Samoa. 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.

### 1.13.2 Coral reef fishery

#### 1.13.2.1 Stock Assessment Benchmark

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

The first attempt to use a model-based approach in assessing the coral reef MUS complexes was done in 2014 using a biomass-based population dynamics model (Sabater and Kleiber, 2014). This model was based on the original Martell and Froese (2013) model but was augmented with biomass information to relax the assumption behind carrying capacity. It estimates MSY based on a range of rate of population growth (*r*) and carrying capacity (*k*) values. The best available information for the coral reef stock assessment is as follows:

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

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

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

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

#### 1.13.2.2 Stock Assessment Updates

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

#### 1.13.2.3 Other Information Available

Approximately every five years PIFSC administers a socioeconomic survey to small boat fishermen in American Samoa. 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.

PIFSC and the Council conducted a workshop with various stakeholders in CNMI to identify factors and quantify uncertainties associated with the social, economic, ecological, and management of the coral reef fisheries (Sievanen and McCaskey, PIFSC internal report). The criteria developed from this workshop had been applied to American Samoa. Scoring was conducted with representatives from American Samoa. This was the basis for the SEEM analysis that determined the risk levels to specify ACLs.

## 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 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 fishery [50 CFR §600.310(f)(1)(i)].

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

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

The harvest extent, in this case, is defined as the level of catch harvested in a fishing year relative to the ACL or OY. The harvest capacity is the level of catch remaining in the annual catch limit that can potentially be used for the total allowable level of foreign fishing (TALFF). in 2017.

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

**Table 24. The 2017 proportion of harvest extent and harvest capacity.**

| Fishery | MUS | ACL | Catch | Harvest extent (%) | Harvest capacity (%) |
|---|---|---|---|---|---|
| Bottomfish | Bottomfish multi-species complex | 106,000 | 22,233 | 20.9 | 79.1 |
| Crustacean | Deepwater shrimp | 80,000 | N.A.F. | 0.0 | 100.0 |
| | Spiny lobster | 4,845 | 826 | 17.0 | 83.0 |
| | Slipper lobster | 30 | 14 | 46.7 | 53.3 |
| | Kona crab | 3,200 | N.A.F. | 0.0 | 100.0 |
| Precious | Black coral | 790 | N.A.F. | 0.0 | 100.0 |

| Fishery | MUS | ACL | Catch | Harvest extent (%) | Harvest capacity (%) |
|---|---|---|---|---|---|
| coral | Precious coral in AS expl. area | 2,205 | N.A.F. | 0.0 | 100.0 |
| Coral Reef | *Selar crumenophthalmus* | N.A. | 1,707 | N.A. | N.A. |
| | Acanthuridae-surgeonfish | N.A. | 11,352 | N.A. | N.A. |
| | Carangidae-jacks | N.A. | 9,058 | N.A. | N.A. |
| | Crustaceans-crabs | N.A. | 1,932 | N.A. | N.A. |
| | Holocentridae-squirrelfish | N.A. | 1,932 | N.A. | N.A. |
| | Kyphosidae-rudderfish | N.A. | 667 | N.A. | N.A. |
| | Labridae-wrasse | N.A. | 254 | N.A. | N.A. |
| | Lethrinidae-emperors | N.A. | 5,657 | N.A. | N.A. |
| | Lutjanidae-snappers | N.A. | 18,543 | N.A. | N.A. |
| | Mollusk-turbo snails; octopus; clams | N.A. | 12,377 | N.A. | N.A. |
| | Mullidae-goatfish | N.A. | 644 | N.A. | N.A. |
| | Mugilidae-mullets | N.A. | 569 | N.A. | N.A. |
| | Scaridae-parrotfish | N.A. | 3,900 | N.A. | N.A. |
| | Serranidae-groupers | N.A. | 3,356 | N.A. | N.A. |
| | Siganidae-rabbitfish | N.A. | 391 | N.A. | N.A. |
| | All other CREMUS combined | N.A. | 1,866 | N.A. | N.A. |
| | *Cheilinus undulatus* | N.A. | 3 | N.A. | N.A. |
| | *Bolbometopon muricatum* | N.A. | N.D. | N.A. | N.A. |
| | Carcharhinidae-reef sharks | N.A. | 60 | N.A. | N.A. |

## 1.15 ADMINISTRATIVE AND REGULATORY ACTIONS

NMFS implemented two management actions related to the American Samoa FEP after the April 2017 Joint FEP Plan Team meeting. NMFS published the following harvest specifications, as described below:

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

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

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# 2 ECOSYSTEM CONSIDERATIONS

## 2.1 CORAL REEF FISH ECOSYSTEM PARAMETERS

### 2.1.1 Regional Reef Fish Biomass

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

**Category:**

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

**Timeframe:** Triennial

**Jurisdiction:**

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

**Spatial Scale:**

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

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

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

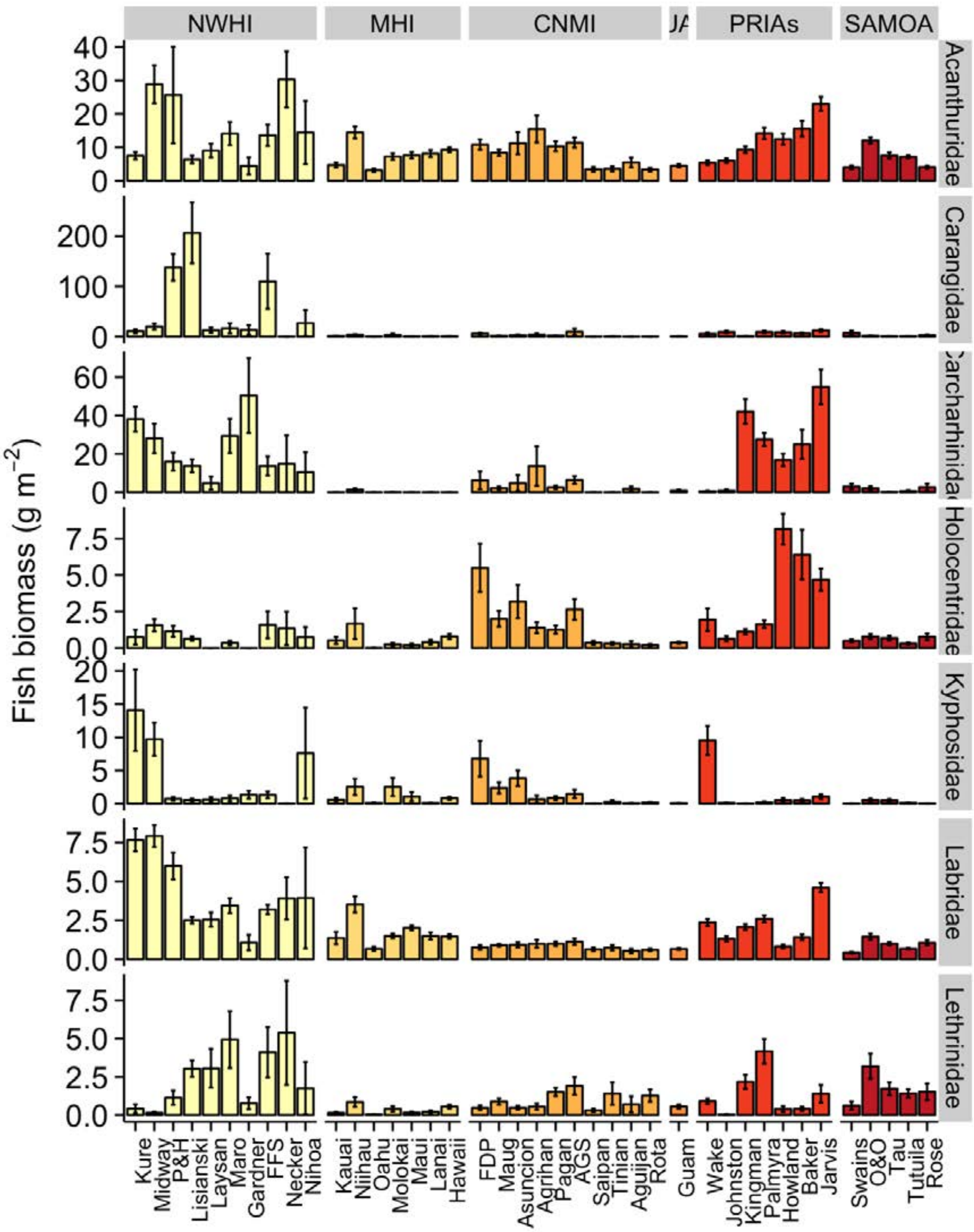
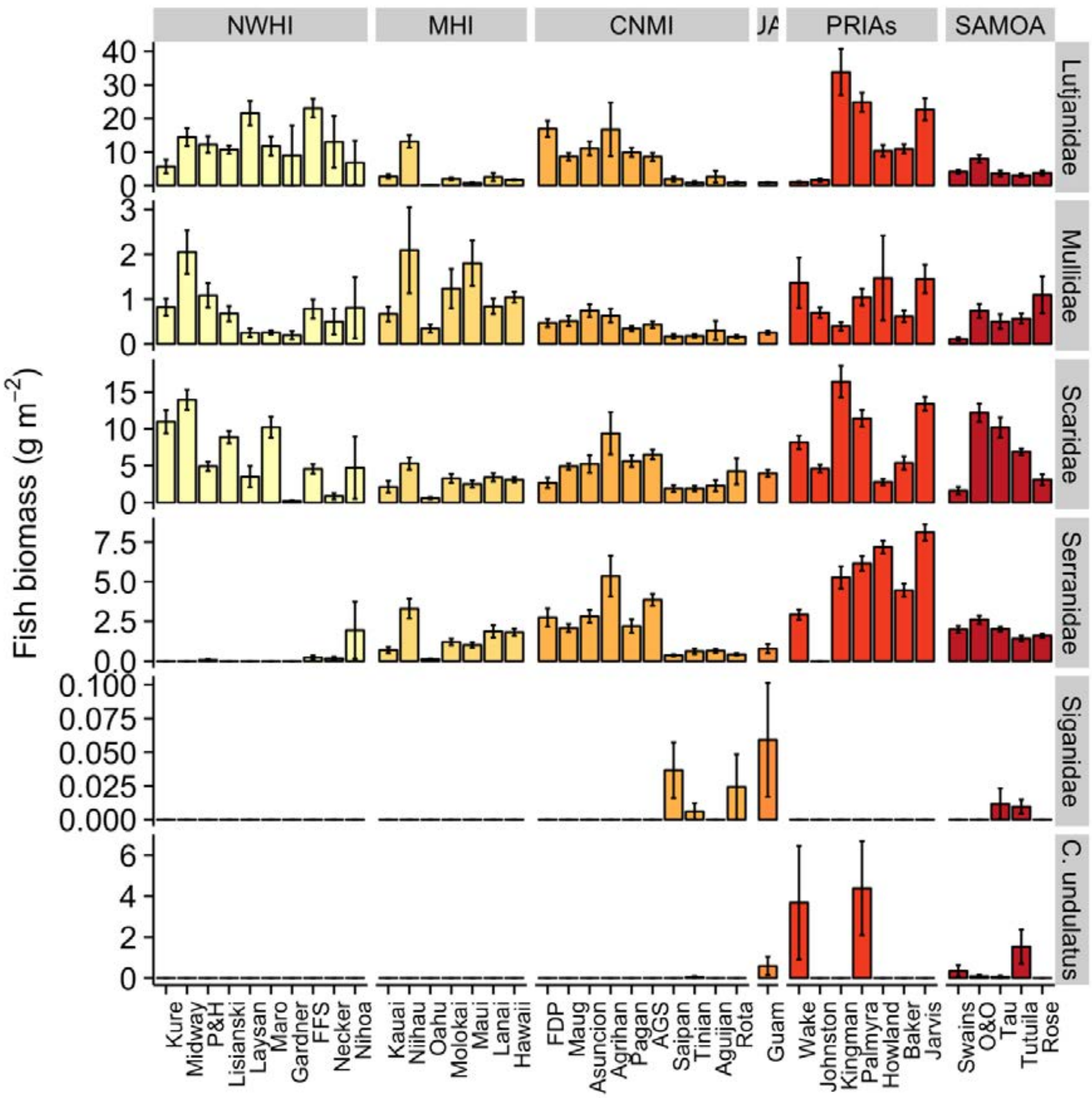


**Figure 1. Mean fish biomass (g/m$^2$ ± standard error) of CREMUS grouped by U.S. Pacific reef area from the years 2009-2015. Islands are ordered by latitude. Figure continued from previous page.**



### 2.1.2 Archipelagic Reef Fish Biomass

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

**Category:**

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

**Timeframe:** Triennial

**Jurisdiction:**

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

**Spatial Scale:**

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

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

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

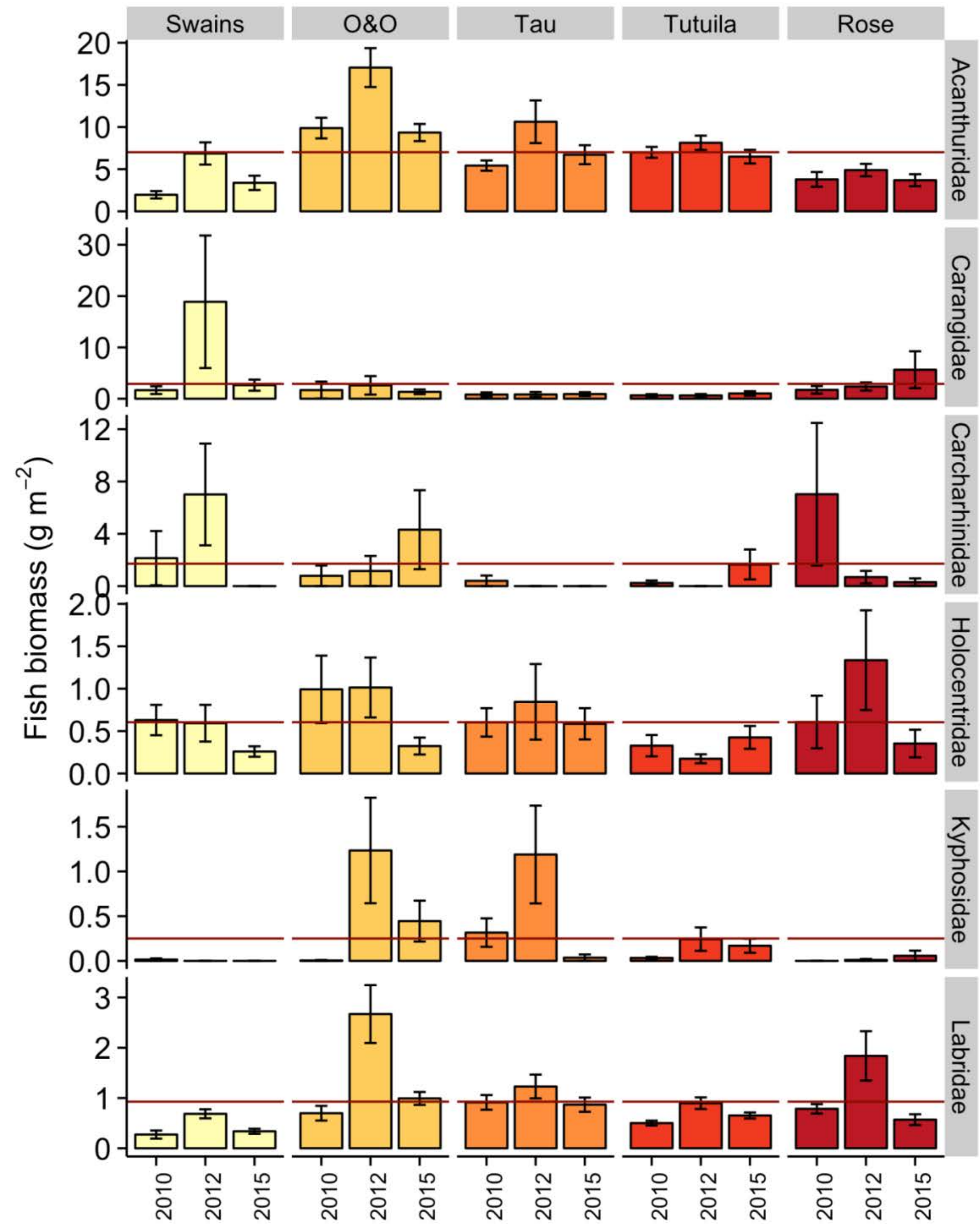
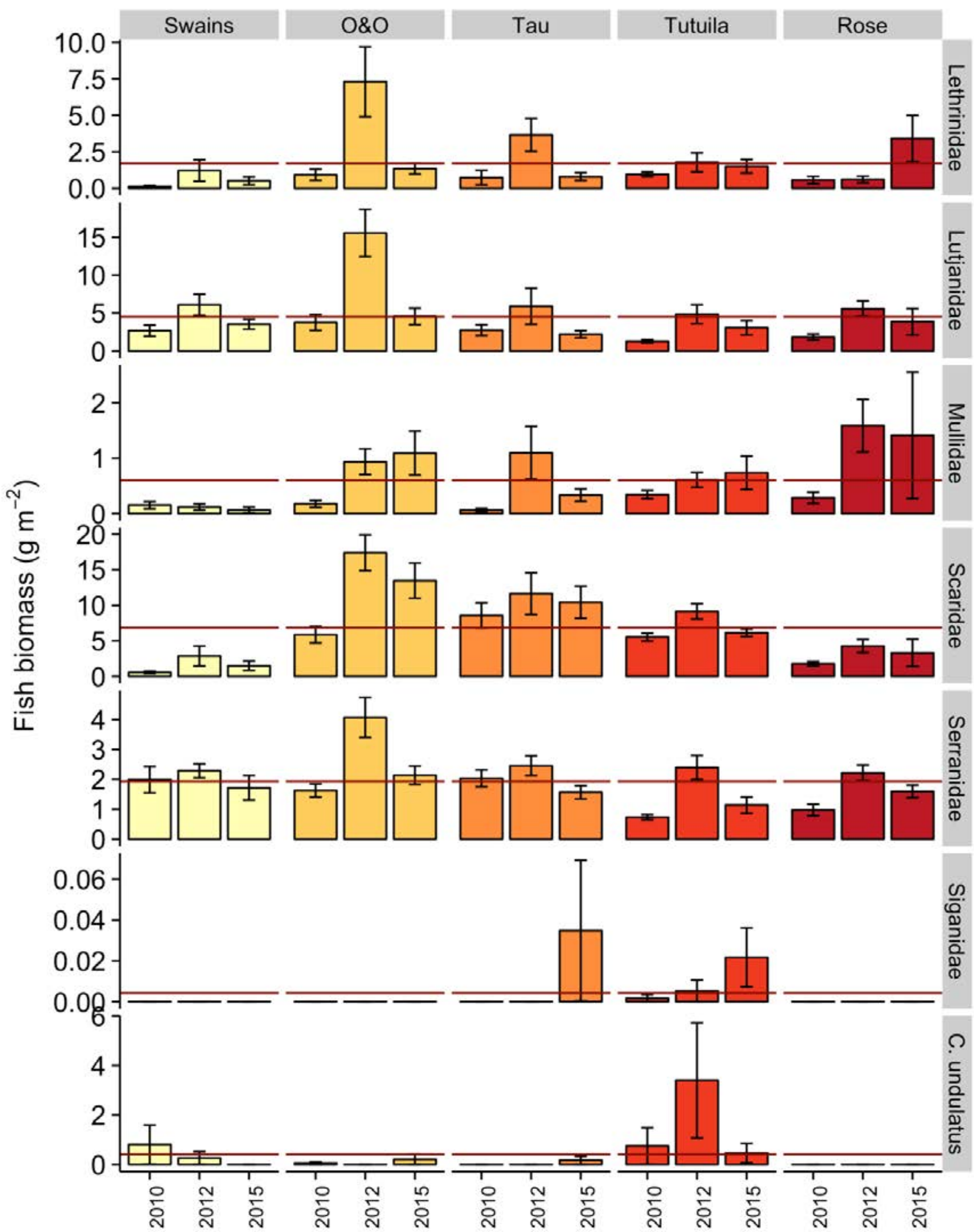

Swains
O&O
Tau
Tutuila
Rose
Acanthuridae
Carangidae
Carcharhinidae
Holocentridae
Kyphosidae
Labridae
Fish biomass (g m⁻²)
2010
2012
2015

**Figure 2. Mean fish biomass (g/m$^2$ ± standard error) of American Samoa CREMUS from 2009-2015. The American Samoa archipelago mean estimates are represented by the red line. Figure continued from previous page.**



### 2.1.3 Archipelagic Mean Size

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

**Category:**

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

**Timeframe:** Triennial

**Jurisdiction:**

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

**Spatial Scale:**

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

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

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

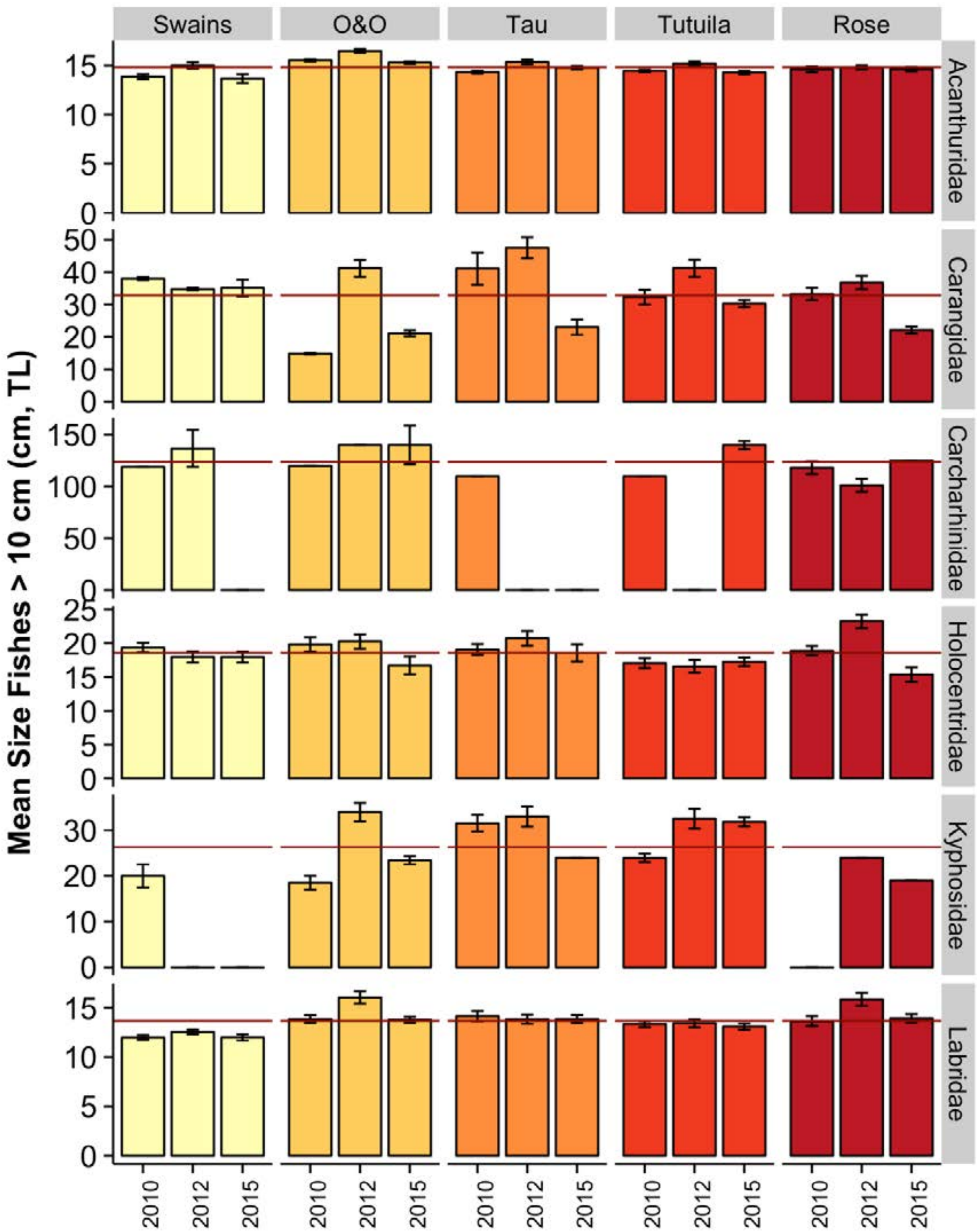
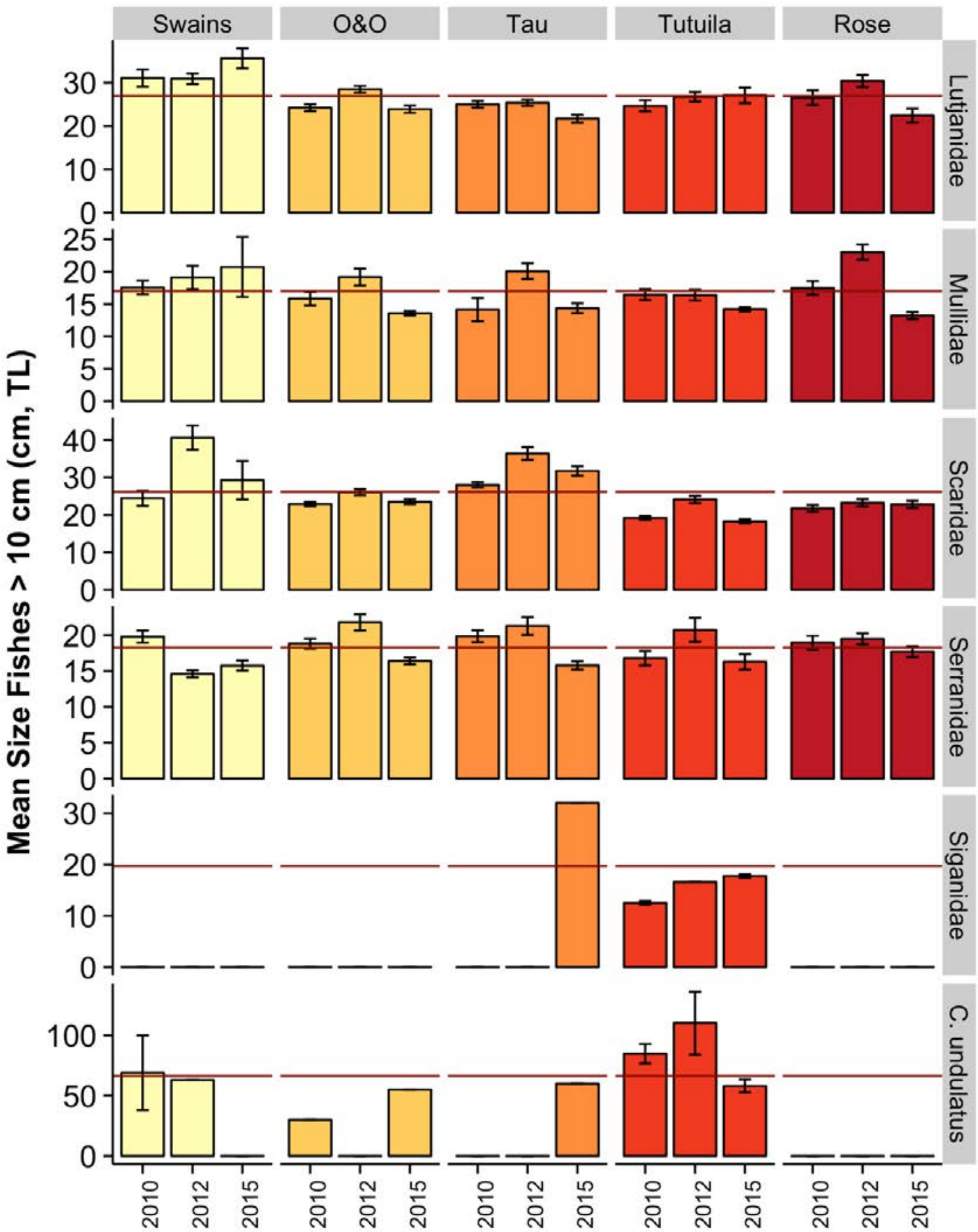

Swains
O&O
Tau
Tutuila
Rose
Acanthuridae
Carangidae
Carcharhinidae
Holocentridae
Kyphosidae
Labridae
Mean Size Fishes > 10 cm (cm, TL)
2010
2012
2015

**Figure 3. Mean fish size (cm, TL ± standard error) of American Samoa CREMUS from the years 2009-2015. The American Samoa archipelago mean estimates are plotted for reference (red line). Figure continued from previous page.**



### 2.1.4 Reef Fish Population Estimates

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

**Category:**

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

**Timeframe:** Triennial

**Jurisdiction:**

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

**Spatial Scale:**

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

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

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

**Table 25. Reef fish population estimates for American Samoa CREMUS in 0-30 m hardbottom habitat only. *N* is number of sites surveyed per island.**

| Island | Total area of reef (Ha) | *N* | Estimated population biomass (metric tons) in survey domain of < 30 m hard bottom | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Acanthuridae | Carangidae | Carcharhinids | Holocentridae | Kyphosidae | Labridae |
| Swains | 281 | 94 | 11.4 | 21.7 | 8.6 | 1.4 | 0.0 | 1.2 |
| Ofu & Olosega | 793 | 112 | 95.9 | 14.9 | 16.5 | 6.2 | 4.5 | 11.5 |
| Tau | 904 | 92 | 68.6 | 7.7 | 1.2 | 6.1 | 4.6 | 9.1 |
| Tutuila | 4,182 | 374 | 301.4 | 32.4 | 26.5 | 12.9 | 6.2 | 28.6 |
| Rose | 442 | 129 | 18.2 | 14.4 | 11.8 | 3.4 | 0.1 | 4.7 |
| South Bank | 25 | 2 | 0.3 | 0.9 | - | 0.0 | - | 0.0 |
| **TOTAL** | **6,627** | **803** | **497.0** | **91.7** | **64.8** | **30.1** | **15.5** | **55.3** |
| **Island** | **Total area of reef (Ha)** | ***N*** | **Lethrinidae** | **Lutjanidae** | **Mullidae** | **Scaridae** | **Serranidae** | **Siganidae** |
| Swains | 281 | 94 | 1.7 | 11.5 | 0.3 | 4.6 | 5.6 | - |
| Ofu & Olosega | 793 | 112 | 25.3 | 63.2 | 5.8 | 97.0 | 20.7 | - |
| Tau | 904 | 92 | 15.6 | 32.7 | 4.5 | 92.2 | 18.2 | 0.1 |
| Tutuila | 4,182 | 374 | 59.2 | 128.1 | 23.6 | 289.5 | 59.4 | 0.4 |
| Rose | 442 | 129 | 6.8 | 16.6 | 4.9 | 13.8 | 7.0 | - |
| South Bank | 25 | 2 | 0.1 | - | - | - | - | - |
| **TOTAL** | **6,627** | **803** | **109.0** | **252.9** | **39.3** | **498.5** | **111.4** | **0.5** |

Notes: (1) No *Bolbometopon muricatum* were recorded during American Samoa surveys.
(2) *Cheilinus undulatus* were observed at Swains (1.0 t), Ofu & Olosega (0.7 t), Tau (0.5t), and Tutuila (64.2 t).

## 2.2 LIFE HISTORY INFORMATION AND LENGTH-DERIVED VARIABLES

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

The NMFS Bio-Sampling Program allows for significant collection of life history samples like otoliths and gonads from priority species in the bottomfish and coral reef fisheries. These life history samples, once processed and data extracted, will contribute to the body of scientific information for the two data-poor fisheries in the region. The life history information available from the region will be monitored by the Fishery Ecosystem Plan Team and will be tracked through this section of the report.

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

### 2.2.1 Coral Reef Fish Life History

#### 2.2.1.1 Age, Growth, & Reproductive Maturity

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

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

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

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

**Timeframe:** N/A

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

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

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

**Parameter definitions:**

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

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

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

$t_0$ **(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 $L_\infty$) and typically assumes a negative value when specimens representing early growth phases (0+ to 1+ ages) are not available for age determination.

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

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

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

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

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

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

**Table 26. Available age, growth, and reproductive maturity information for coral reef species targeted for life history sampling (otoliths and gonads) in American Samoa.**

| Species | Age, growth, reproductive maturity parameters | | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| | $T_{max}$ | $L_\infty$ | $k$ | $t_0$ | $M$ | $A_{50}$ | $A\Delta_{50}$ | $L_{50}$ | $L\Delta_{50}$ | |
| *Lethrinus xanthochilus* | 19[c] | 39.6 (f), 40.5 (m)[c] | 0.67 (f), 0.63 (m)[c] | -0.12 (f), -0.12 (m)[c] | 0.22[c] | 2.1 (f)[c] | | 30.0 (f)[c] | | Taylor *et al.*, in review |
| *Lutjanus gibbus* | 27[c] | 28.9 (f), 38.8 (m)[c] | 0.66 (f), 0.32 (m)[c] | -0.29 (f), -0.29 (m)[c] | 0.15[c] | 3.2 (f)[c] | | 24.9 (f)[c] | | Taylor *et al.*, in review |
| *Lutjanus rufolineatus* | 12 [c] | 21.8 (f) 23.3 (m)[c] | 0.86 (f) 0.80 (m)[c] | -0.20 (f), -0.20 (m)[c] | 0.35[c] | 16.4 (f)[c] | | | | Taylor *et al.*, in review |
| *Myripristis amaena* | | | | | | | NA | | NA | |
| *Myripristis* | | | | | | | NA | 166[b] | NA | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *berndti* | | | | | | | | | | |
| *Myripristis murdjan* | | | | | | | NA | | NA | |
| *Naso unicornis* | X[a] | X[a] | X[a] | X[a] | | X[a] | NA | X[a] | NA | |
| *Sargocentron caudimaculatum* | | | | | | | NA | | NA | |
| *Sargocentron spiniferum* | | | | | | | NA | | NA | |
| *Sargocentron tiere* | | | | | | | NA | 150[b] | NA | |
| *Scarus rubrovioaceus* | 14[d] | 40.6 (f), 47.8 (m)[d] | 0.63 (f), 0.50 (m)[d] | -0.06 (f), -0.06 (m)[d] | | 2.6 (f) [d] | | 31.9 (f)[d] | 42.3[d] | Taylor and Pardee (2017) |

[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 years; $L_\infty$, $L_{50}$, and $L\Delta_{50}$ are in mm fork length (FL); $k$ is in units of year$^{-1}$; X means the parameter estimate is too preliminary and Y means the published age and growth parameter estimates are based on DGI numerical integration technique and likely to be inaccurate. Superscript letters indicate status of parameter estimate (see footnotes below table). Published or in press publications ([d]) are shown in "Reference" column.

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

- Broad scale look at commercial landings (by fisher/trip, gear, 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 American Samoa, the Bio-Sampling is focused on the commercial coral reef spear fishery with occasional sampling of the bottomfish fishery occurring locally and less frequently at the northern islands. Sampling is conducted in partnership with the fish vendors. The Market Sampling information includes (but not limited to): 1) fish length; 2) fish weight; 3) species identification; and 4) basic effort information.

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

**Timeframe:** N/A

**Jurisdiction:**

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

**Spatial Scale:**

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

**Data Source:** NMFS Bio-Sampling Program

**Parameter definition:**

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

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

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

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

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

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

**Table 27. Available length-derived information for 23 reef species in American Samoa.**

| Species | Length-derived parameters | | | | | | Reference |
|---|---|---|---|---|---|---|---|
| | $L_{max}$ | $L_{bar}$ | *n* | *L-W* | *a* | *b* | |
| *Acanthurus lineatus* | 24.5 | 18.8 | 1955 | 0.87 | 0.068 | 2.68 | |
| *Ctenochaetus striatus* | 25.2 | 18.0 | 424 | 0.87 | 0.043 | 2.83 | |
| *Naso lituratus* | 47.4 | 22.2 | 8752 | 0.93 | 0.022 | 3.02 | |
| *Sargocentron tiere* | 25.0 | 18.0 | 3002 | 0.85 | 0.069 | 2.62 | |
| *Chlorurus japanensis* | 46.2 | 26.4 | 6852 | 0.97 | 0.018 | 3.07 | |
| *Naso unicornis* | 55.0 | 32.3 | 5042 | 0.99 | 0.033 | 2.85 | |
| *Scarus rubroviolaceus* | 54 | 34.9 | 4556 | 0.99 | 0.012 | 3.17 | |
| *Panulirus penicillatus* | 15.8 | 9.1 | 3365 | 0.94 | 2.614 | 2.41 | |
| *Scaru oviceps* | 44.5 | 23.6 | 3987 | 0.97 | 0.013 | 3.17 | |
| *Myripristis berndti* | 27.2 | 17.8 | 4228 | 0.89 | 0.100 | 2.53 | |
| *Acanthurus nigricans* | 36.0 | 16.9 | 3003 | 0.79 | 0.171 | 2.42 | |
| *Lutjanus gibbus* | 56.8 | 30.9 | 2291 | 0.96 | 0.04 | 2.8 | |
| *Lethrinus xanthochilus* | 54.5 | 36.8 | 2186 | 0.97 | 0.028 | 2.85 | |
| *Epinephelus melanostigma* | 54.9 | 26.5 | 2653 | 0.95 | 0.012 | 3.10 | |
| *Myripristis amaena* | 22.5 | 16.9 | 2849 | 0.82 | 0.149 | 2.39 | |
| *Acanthurus guttatus* | 24.5 | 16.8 | 1872 | 0.87 | 0.084 | 2.69 | |
| *Panulirus* sp. | 15.3 | 8.6 | 3331 | 0.91 | 5.755 | 2.06 | |
| *Myripristis murdjan* | 27.5 | 17.0 | 1707 | 0.84 | 0.72 | 1.83 | |
| *Scarus frenatus* | 44.5 | 26.9 | 1777 | 0.98 | 0.014 | 3.14 | |
| *Selar crumenopthalmus* | 32.7 | 19.3 | 298 | 0.96 | 0.007 | 3.30 | |
| *Parupeneus bifasciatus* | 34.5 | 22.6 | 1413 | 0.96 | 0.015 | 3.12 | |
| *Variola albimarginatus* | 43.6 | 27.0 | 965 | 0.89 | 0.122 | 2.42 | |
| *Scarus globiceps* | 33.9 | 23.5 | 1258 | 0.95 | 0.02 | 3.03 | |

### 2.2.2 Bottomfish Life History

#### 2.2.2.1 Age, Growth, & reproductive Maturity

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

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

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

**Category**:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

**Timeframe**: N/A

**Jurisdiction**:

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

**Spatial Scale**:

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

**Data Source**: Sources of data are directly derived from field samples collected at sea on NOAA research vessels and from the American Samoa contracted bio-sampling team which samples the catch of fishermen and local fish vendors. Laboratory analyses and data generated from these analyses reside with the PIFSC Life History Program. Refer to the "Reference" column in Table 3 for specific details on data sources by species.

**Parameter definitions**:

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

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

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

***$t_0$* (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 $L_\infty$) and typically assumes a negative value when specimens representing early growth phases (0+ to 1+ ages) are not available for age determination.

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

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

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

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

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

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

**Table 28. Available age, growth, and reproductive maturity information for bottomfish species targeted for life history sampling (otoliths and gonads) in American Samoa. Symbols listed are identical to those found in Table 26.**

| Species | Age, growth, and reproductive maturity parameters | | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| | $T_{max}$ | $L_\infty$ | $k$ | $t_0$ | $M$ | $A_{50}$ | $A\Delta_{50}$ | $L_{50}$ | $L\Delta_{50}$ | |
| *Aphareus rutilans* | | | | | | | NA | | NA | |
| *Aprion virescens* | | | | | | | NA | | NA | |
| *Etelis carbunculus* | | | | | | | NA | | NA | |
| *Etelis coruscans* | | | | | | | NA | | NA | |
| *Lethrinus amboinensis* | | | | | | | | | | |
| *Lethrinus xanthochilus* | | | | | | | | | | |
| *Lutjanus gibbus* | | | | | | | NA | | NA | |
| *Pristipomoides auricilla* | | | | | | | NA | | NA | |
| *Pristipomoides filamentosus* | | | | | | | NA | | NA | |
| *Pristipomoides flavipinnis* | X[a] | X[a] | X[a] | X[a] | X[a] | | NA | | NA | O'Malley *et al*., in prep. |
| *Pristipomoides sieboldii* | | | | | | | NA | | NA | |
| *Pristipomoides zonatus* | | | | | | | NA | | NA | |

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

### 2.2.2.2 Fish Length Derived Parameters

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

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

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

**Category:**

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

**Timeframe:** N/A

**Jurisdiction:**

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

**Spatial Scale:**

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

**Data Source:** NMFS BioSampling Program

**Parameter definition:**

$L_{max}$ – ***maximum fish length*** is the longest fish per species recorded in the BioSampling Program from the commercial spear fishery. This value is derived from measuring the fork length of individual samples for species occurring in the spear fishery.
$L_{bar}$ – ***mean length*** is the average value of all lengths recorded from the commercial spear fishery. This can be influenced by gear selectivity since the commercial spear fishery has a typical-size target based on customer demand. This can also be influenced by size regulations.

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

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

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

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

**Table 29. Available length-derived information for two bottomfish in American Samoa.**

| Species | Length derived parameters | | | | | | Reference |
|---|---|---|---|---|---|---|---|
| | $L_{max}$ | $L_{bar}$ | *n* | *L-W* | *a* | *b* | |
| *Lutjanus kasmira* | 35.0 | 22.3 | 459 | 0.92 | 0.017 | 3.02 | |
| *Lethrinus rubrioperculatus* | 57 | 27.3 | 2348 | 0.97 | 0.029 | 2.86 | |

#### 2.2.2.3 References


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

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

## 2.3 SOCIOECONOMICS

This section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures and the achievements of the Fishery Ecosystem Plan (FEP) for the Pacific Remote Island Area (PRIA; Western Pacific Regional Fishery Management Council, 2016). It meets the objective of "Support Fishing Communities" adopted at the 165th Council meeting; specifically, it identifies the various social and economic groups within the regions' 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 the PRIA.

In 1996, the Magnuson-Stevens Fishery Conservation and Management Act's National Standard 8 (NS8) specified that conservation and management measures nee to account for the importance of fishery resources in fishing communities, to support sustained participation in the fisheries, and to minimize adverse economic impacts, provided that these considerations do not compromise conservation. Unlike other regions of the U.S., the settlement of the Western Pacific region was intimately tied to the ocean, which is reflected in local culture, customs, and traditions (Figure 4).

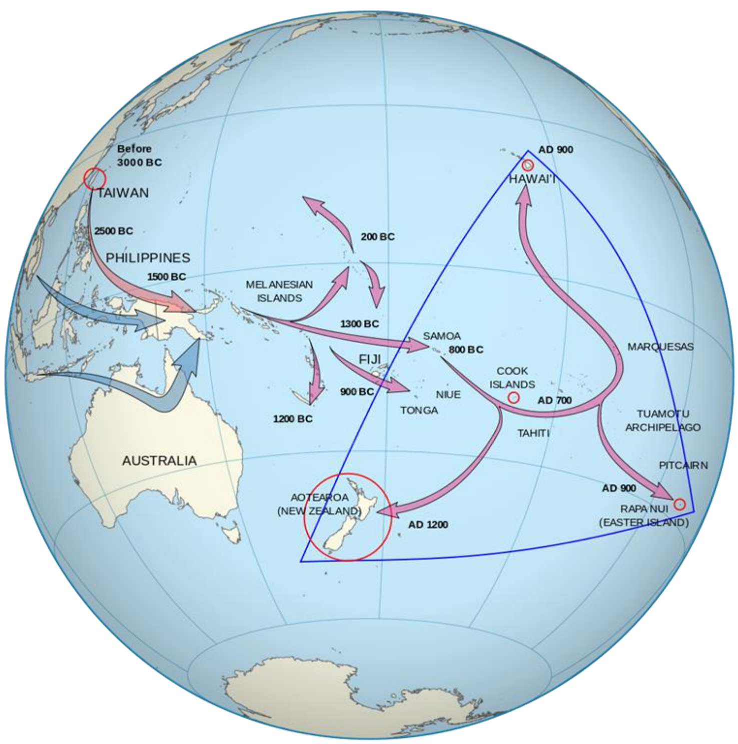



**Figure 4. Settlement of the Pacific Islands, courtesy Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg.**

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 have a similar reliance on marine resources. Thus, fishing and seafood are integral to 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 in the language, customs, ceremonies, and community events. The amount of available seafood can also affect seasonality in prices of fish. Because fishing is such an integral part of the culture, it is difficult to discern commercial from non-commercial fishing where most trips involving multiple motivations and multiple uses of the fish caught. While the economic perspective is an important consideration, fishermen report other motivations, such as customary exchange, as being equally important. Due to changing economies and westernization, waning recruitment of younger fishermen is becoming a concern for the sustainability of fishing and fishing traditions in the region.

### 2.3.1 Response to Previous Council Recommendations

At its 165th meeting held in Honolulu, HI, the Council approved modifications to the FEP objectives, one of which is to identify the various social and economic groups within the region's fishing communities and their interconnections, in support of fishing communities. This chapter meets this objective.

At its 166th meeting held in Tumon, Guam, the Council directed staff to develop a brief report identifying data sources, quality, and coverage for each required socioeconomic parameter in the annual/SAFE reports, as resources permit. This report should also identify the quality and coverage of this data, as well as any data gaps. The data synthesis was conducted and used to guide the development of this chapter with further input and guidance from the Council Social Science Planning Committee and Archipelagic Plan Team.

The Council also directed the Plan Team for future annual FEP SAFE reports:

- To include the human perspective, the importance of the community, and the extended cultural and social values of fishing in the dashboard summary format. This chapter is the first effort at including the importance of community and extended cultural and social values into a SAFE report in this region.
- To include enhanced information on social, economic, and cultural impacts of a changing climate and increased pressure on the ocean and its resources. PIFSC developed a Regional Action Plan and Climate Science Strategy as a first step in providing this information (Polovina *et al*., 2016).

### 2.3.2 Introduction

Fishing has played a crucial role in American Samoan culture and society since the Samoan archipelago was settled. An overview of American Samoa history, culture, geography, and relationship with the U.S. is described in Section 1.3 of the Fishery Ecosystem Plan for American Samoa (Western Pacific Regional Fishery Management Council, 2016a). Over the past decade, a number of studies have synthesized details about the role of fishing and marine resources in American Samoa, as well as information about the people who engage in the fisheries or use fishery resources (e.g. Armstrong, *et al*., 2011; Grace-McCaskey, 2015; Levine and Allen, 2009; Richmond and Levine, 2012). These studies describe the importance of marine resources in cultural, economics, and subsistence aspects of American Samoan village life. Fishing was held in high esteem in traditional Samoan culture, with fishing skill bringing high social status and fishing activities figuring prominently in mythology. The basic components of Samoan social structure are the family and village, with the family acting as the central unit. The village leadership decides, according to season, what sort of community fishing should take place. The tautai, or master fishermen, of the village were key decision makers who were awarded higher status than others who might otherwise outrank him when it came to matters of fishing. Village-level systems of governance and resource tenure are still largely intact, and American Samoan cultural systems and representation are formally incorporated into the territorial government. Reciprocity is emphasized over individual accumulation. Gifts of food, especially fish and other marine resources, mark every occasion and are a pivotal part of American Samoan social structure to this day.

Recent studies have found that American Samoa is homogeneous both ethnically and culturally (Levine *et al*., 2016; Richmond and Levine, 2012). Polynesians account for the vast majority of the territory's people (93%), and the primary language spoken at home is Samoan (91%) though English is often spoken in school and business settings. Contemporary American Samoan culture is characterized by a combination of traditional Samoan values and systems of social organization with a strong influence from Christianity. Maintaining "*fa'a samoa*", or "the Samoan way", was considered a priority under the territorial constitution. Given the cultural homogeneity, nearly everyone in American Samoa accepts and complies with Samoan traditions of land and resource tenure.

However, over the last half century or so, fishing has become less prominent as a central and organized community force. During this time, modern fishing gears and technologies were introduced, tuna canneries became a major economic force in Pago Pago, the population more than tripled, and the gradual but continuous introduction of Western cultural norms and practices altered American Samoans' relationship with the sea. While many traditions and village-based systems of governance have been maintained, the islands have experienced a shift from a subsistence-oriented economy, where sharing of fish catch was extremely important, to a cash-based economy, where fishing is often viewed as a more commercial venture.

A recent study by Levine *et al*. (2016) found that American Samoans still consume seafood frequently, with 78% of respondents stating that they eat fish or seafood once a week or more. Most American Samoans purchase seafood from stores or restaurants, with 65% of survey respondents listing these sellers as their first or second choice for obtaining seafood. Other common means for obtaining fish include markets and roadside vendors (45%) and fish caught by household members (37%). These results corroborate Levine and Allen's (2009) observation that American Samoans largely rely on, and in many cases prefer, store-bought food to locally caught fish, with the majority of fish consumed in American Samoa imported from neighboring Samoa.

The introduction of outboard engines and other technology in the 1950s and 1960s allowed American Samoan boats to go farther and faster, but also made it necessary for boat owners and operators to sell a portion of their catch to pay for fuel and engine maintenance. The disruption of other traditional values, as well as the introduction of a cash economy based primarily on government jobs and cannery employment, also decreased reliance on traditional, subsistence fishing; this allowed commercial fishing to develop on the islands (Levine and Allen, 2009).

Unlike other areas of the Western Pacific region, American Samoa also experienced the development of domestic industrial-scale fisheries, including tuna processing, transshipment, and home port industries. These domestic industrial fisheries came about due to the harbor at Pago Pago, 390,000 $km^2$ of EEZ, and certain special provisions of U.S. law, which allowed the development of American Samoa's decades-old fish processing industry. For example, the territory is exempt from the Nicholson Act, which prohibits foreign ships from landing their catch in U.S. ports, and American Samoan products with less than 50% market value from foreign sources enter the U.S. duty-free.

The two most important economic sectors are the American Samoa Government (ASG), which receives income and capital subsidies from the federal government, and tuna canning. According to the Statistical Yearbook, main imports include fish brought in for processing (American Samoa Government, 2016). Exports are primarily canned tuna and by-products, including fish meal and pet food. In 2016, domestic exports from American Samoa were valued at $385,152,000, of which $371,214,000 (or 96%) came from canned tuna sale (American Samoa Government, 2016). Private business and commerce comprise a smaller third sector. Unlike some of their neighbors in the South Pacific, American Samoa has never been known for having a robust tourist industry.

In 2016, the ASG employed 6,585 people accounting for 37% of the total workforce in the territory (American Samoa Government, 2016), and the private sector employed 8,502 people (Figure 5). The canneries employed 2,843 people, accounting 16% of the workforce. Ancillary businesses involved in re-provisioning the fishing fleet also generated a notable number of jobs and income for local residents.

The canneries in American Samoa have been operating since 1954, represent the largest private-sector source of employment in the region, and, until recently, were the principle industry in the territory. Although as many as 90% of cannery workers are not American Samoa citizens, the canneries play a large role in the American Samoa economy (e.g. delivering goods or services to tuna processors, and improving buying patterns of cannery workers). Trends in world trade, specifically reductions in tariffs, have been reducing the competitive advantage of American Samoa's duty-free access to the U.S. canned tuna market, and the viability of the canneries has been in question for nearly the past decade. In 2009, the Chicken of the Sea cannery closed, resulting in a loss of approximately 2,000 jobs. It was bought by Tri Marine International, which invested $70 million in rebuilding and expansion, and reopened in 2015. In October 2016, Sunkist Co. suspended operations due to lack of fish, in part due to Effort Limit Area for Purse Seine (ELAPS) closures (Pacific Islands Report, 2016). That same month, Tri Marine International announced that it would suspend production indefinitely in December 2016 (Honolulu Star Advertiser, 2016), and there are currently no plans to reopen (Pacific Islands Report, 2017). Tuna cannery closures in American Samoa are likely to have significant impacts on the American Samoa economy and communities, although the specific effects are still unknown.

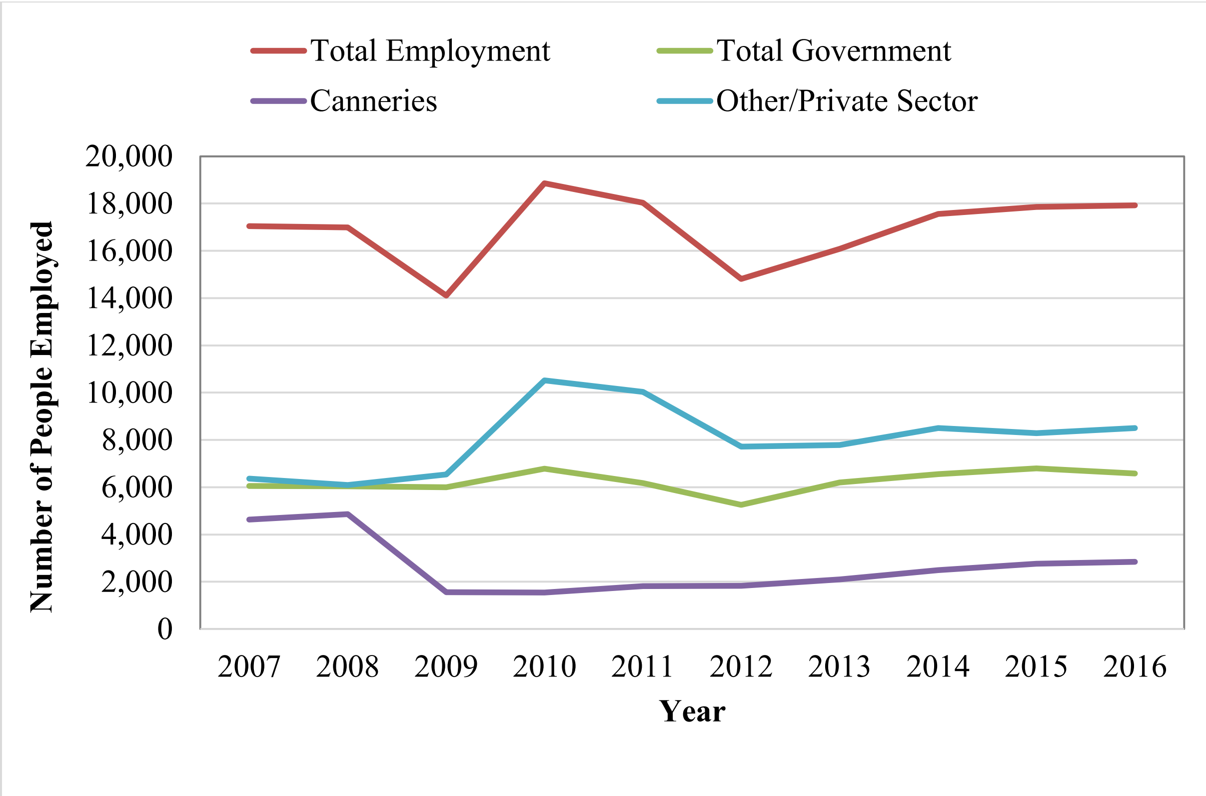



**Figure 5. American Samoa Employment Estimates from 2007-2016; sourced from the American Samoa Statistical Yearbook 2016, American Samoa Government (2016).**

**Table 30. Supporting data for Figure 5.**

| Labor force status | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Employment | 17,047 | 16,990 | 14,108 | 18,862 | 18,028 | 14,806 | 16,089 | 17,565 | 17,853 | 17,930 |
| Total Government | 6,052 | 6,035 | 6,004 | 6,782 | 6,177 | 5,258 | 6,198 | 6,556 | 6,804 | 6,585 |
| Canneries | 4,633 | 4,861 | 1,562 | 1,553 | 1,815 | 1,827 | 2,108 | 2,500 | 2,759 | 2,843 |
| Other/Private Sector | 6,362 | 6,094 | 6,542 | 10,527 | 10,036 | 7,721 | 7,783 | 8,509 | 8,290 | 8,502 |

Even before Tri Marine International's closure, American Samoa's economy was identified as being in a highly transitional state that should be monitored closely (Grace McCaskey, 2015). It will be important to monitor any changes and developments related to the tuna industry, given the historically close connection between the tuna canneries, employment levels, population trends, and the economic welfare of the territory. It is also possible that increased federal aid in recent years has obfuscated the full extent of the economic recession.

Members of the American Samoa fishing community have also expressed concerns about the impact of National Marine Sanctuary of American Samoa (NMSAS) expansion as well as the management of fishing activities in the Rose Atoll Marine National Monument. In both of these cases, the local communities have been concerned about the impacts of regulation on fishing practices and broader social and cultural issues.

While pelagic fisheries play a larger role in the broader economy, insular fisheries are fundamentally important from a socio-cultural and dietary standpoint (Levine and Allen, 2009). Village leaders still have a significant degree of control over the nearshore waters, enforcing their own village rules and regulations despite the waning strength of many of these village-based management systems. The American Samoa Department of Marine and Wildlife Resources (DMWR) is the primary agency for fisheries management. The DMWR also monitors the status of nearshore fish and marine habitats through the collection of fishery independent data, however it has limited patrolling and enforcement capacity. In 2000, the DMWR initiated the Community-based Fisheries Management Program (CFMP) to assist villages in managing and conserving their inshore fishery resources through a voluntary scheme of co-management with the government. In general, villages manage their marine areas through establishment of village marine protected areas (MPAs) sometimes called VMPAs to distinguish this program from federal or territorial MPAs. Because VMPAs are managed by local communities that have a direct interest in their success, compliance with fishing bans is generally high, and most villages with MPAs actively enforce their own rules.

Richmond and Levine (2012) described the role of community-based marine resource management in American Samoa. Organized trips for specialized fishing are marked by considerable ceremony and tradition. While more frequent in the past, organized fishing efforts continue to take place in a few villages in American Samoa. Village-wide fish drives are timed with the tides and the spawning of certain species, and after these efforts, the fish are traditionally distributed to all village families who participated in the fishing.

In 2017, understanding the relationship of pelagic fisheries to cultural fishing practices typically associated with insular fisheries has taken on greater importance. During the peak of longline landings in 2002, the National Marine Fisheries Service (NMFS) created a Large Vessel Prohibited Area (LVPA) to prevent gear conflicts and catch competition between large and small vessels, and to preserve opportunities for fishing by American Samoa's small boat ("alia") fleet (NOAA, 2017). Since the creation of the LVPA in 2002, both large and small vessels have experienced declining catch rates, fish prices, and increasing fuel and operating costs. In 2016, NMFS published an exemption to the LVPA rule to allow large U.S. vessels holding a Federal American Samoa longline limited entry permit to fish in portions of the LVPA (NOAA, 2016). NMFS and the Western Pacific Regional Fisheries Management Council (WPRFMC) were then sued by the American Samoa government, who claimed that the 1900 and 1904 Deeds of

Cession were not considered in the rulemaking process. The U.S. District Court ruled in favor of American Samoa in March 2017, requiring NMFS to preserve American Samoan cultural fishing practices as part of the obligations of the Deeds of Cession. The discussion of what defines cultural fishing and how it can be preserved is ongoing.

### 2.3.3 People Who Fish

Few studies have been conducted that include demographics or other information about people who fish in American Samoa. Information at the fishery level will be reported in the fishery specific sections below. Qualitative research has resulted in some general observations about trends in fishing by American Samoans.

One household survey by Levine *et al*. (2016) found that over half of residents participate in fishing or gathering of marine resources. Approximately 15% reported fishing once a week or more and over 30% of households stated that they engaged in fishing or gathering at least once a month. Commercial fishing is very uncommon in American Samoa, with only 3% of those who fish stated that they frequently did so to sell their catch and 62% never selling their catch. More commonly, people fish to feed themselves and their family or to give to extended friends, family, pastors, and village leaders.

While fishing and marine resources are universally considered to be important aspects of *fa'a samoa*, limited income has made American Samoans less inclined to engage in strenuous fishing activities when food imports are relatively more available (Levine and Allen, 2009). Only a small number of American Samoans engage in boat-based or commercial fishing. Although unemployment in the territory has increased, the percentage of individuals participating in subsistence activities (including fishing for food or home use) decreased between 2000 and 2013 (Grace McCaskey, 2015). However, a large number of island residents have been employed by the canneries in Pago Pago, which facilitated the availability of low-cost fish for many residents and ensured that the livelihood of American Samoans are still tightly tied to fishing activities.

As described in the FEP, American Samoans have been discouraged from working on foreign longline vessels delivering tuna to the canneries for a number of reasons, including harsh working conditions, low wages, and long fishing trips. While American Samoans prefer employment on the U.S. purse seine vessels, the capital-intensive nature of purse seine operations limits the number of job opportunities for locals in that sector.

Local fishermen have indicated an interest in participating in the more lucrative overseas markets for fresh fish. However, they are limited by inadequate shore-side ice and cold storage facilities, as well as infrequent and expensive air transportation.

As noted by Levine and Allen (2009), the trend of decreasing reliance on local fish as a food source is reflective of a society that has been undergoing a shift from a subsistence-oriented economy to a cash economy. Changes such as a decrease in leisure time, a shift in dietary preferences towards store-bought foods, a preference to buy fish at the market rather than expend effort in fishing, and an increased availability of inexpensive imported reef fish from Western Samoa and Tonga are also likely contributing to decreasing rates of subsistence fishing in the region (Richmond and Levine, 2012).

### 2.3.4 Bottomfish

Levine and Allen (2009) described the bottomfish fishery as part of their review of American Samoa as a fishing community. Prior to the arrival of Europeans in Samoa, the indigenous people had developed specialized techniques for catching bottomfish from outrigger canoes (paopao). Some of the bottomfish, such as trevally (malauli), held a particular social significance and were reserved for the matai chiefs.

In the early 1970s, the American Samoa Office of Economic Opportunity (OEO) funded the Dory Project, which provided easy credit and loans to fishermen to develop offshore fisheries. Records indicate that 70% of these dories were engaged in bottomfishing activities, conducted primarily at night on the shallow reef area around Tutuila. The result was an abrupt increase in the fishing fleet and total landings, but the limited nearshore bottomfish habitat meant that catch rates there declined rapidly and fishermen began to venture farther offshore to previously unexploited seamounts and banks to maintain profitable catch rates.

In the 1980s, dories were replaced by alia catamarans, larger, more powerful boats that could stay multiple days at sea. Alias primarily engaged in trolling and bottomfishing, and spearfishing, netting, and vertical longlining were used on occasion. Bottomfishing peaked between 1982 and 1988, with landings comprised as much as half of the total catch of the commercial fishery in American Samoa. In December 1980, a fish market opened in Fagatogo, which allowed fishermen to market their catch at a centralized, relatively sanitary location. Although the price for bottomfish rose between the 1970s and 1980s, it was still difficult for fishermen to make a profit from bottomfish sales due to competition with sales of inexpensive incidental catch from longline and purse seine vessels landing at the canneries.

Since 1988, there has been with a steady decrease in the importance of bottomfish fishing, as people converted to trolling and longlining for pelagic species, increasing fuel prices forced others out of the fishery, and imported fish from Western Samoa and Tonga became more available. Markrich and Hawkins (2016) noted that recently there have been fewer than 20 boats active in the bottomfish fishery. The demand for bottomfish varies depending on the need for fish at government and cultural events, though alia fishermen do return to bottomfish fishing during periods when longline catches or prices are low.

#### 2.3.4.1 Commercial Participation, Landings, Revenues, and Prices

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

#### 2.3.4.2 Costs of Fishing

Since 2009, PIFSC economists have maintained a continuous economic data collection program in American Samoa through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). The economic data collection gathers fishing expenditure data for boat-based reef fish, bottomfish, and pelagic fishing trips on an ongoing basis. Data for fishing trip expenses include; gallons of fuel used, price per gallon of fuel, cost of ice used, cost of bait & chum used, cost of fishing gear lost, and the engine type of the boat. These economic data are collected from same subset of fishing trips as the boat-based creel survey carried out by the local fisheries management agencies and WPacFIN.

Figure 6 shows the average trip costs for American Samoa bottomfish trips during 2009–2017. In 2017, the average trip costs of bottomfish trips were $120, similar to 2016. Supporting data for Figure 6 are presented in Table 31.

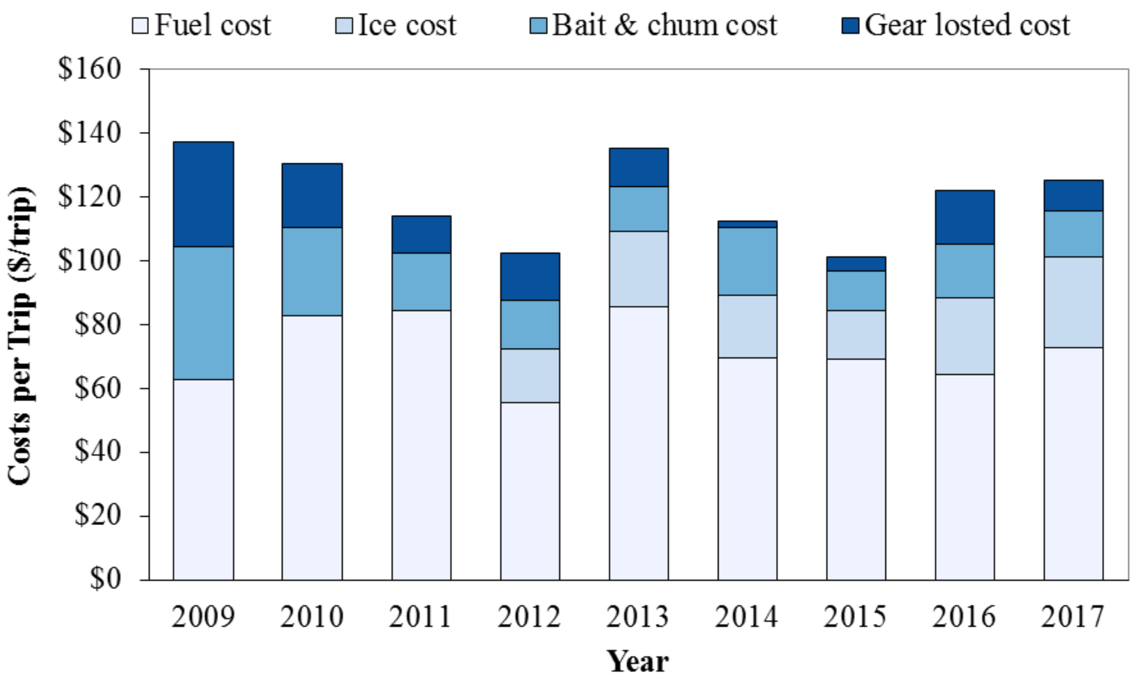



**Figure 6. Average costs adjusted for American Samoa coral reef fishing trips from 2009–2017 adjusted to 2017 dollars.**

**Table 31. Average and itemized costs for American Samoa bottomfish trips from 2009–2017 adjusted to 2017 dollars.**

| Year | Total trip costs ($) | Total trip costs ($) (adjusted) | Fuel cost ($) | Fuel cost ($) (adjusted) | Ice cost ($) | Ice cost ($) (adjusted) | Gear losted cost ($) | Gear losted cost ($) (adjusted) | Bait & chum cost ($) | Bait & chum cost ($) (adjusted) | CPI adjustor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 113 | 137 | 52 | 63 | - | - | 27 | 33 | 34 | 42 | 1.215 |
| 2010 | 112 | 130 | 71 | 83 | - | - | 17 | 20 | 24 | 28 | 1.159 |
| 2011 | 106 | 114 | 79 | 84 | - | - | 11 | 12 | 17 | 18 | 1.072 |
| 2012 | 99 | 102 | 54 | 56 | 16 | 17 | 14 | 15 | 15 | 15 | 1.038 |
| 2013 | 133 | 135 | 84 | 86 | 23 | 24 | 12 | 12 | 14 | 14 | 1.018 |
| 2014 | 111 | 113 | 69 | 70 | 19 | 20 | 2 | 2 | 21 | 21 | 1.011 |
| 2015 | 99 | 101 | 68 | 69 | 15 | 15 | 4 | 4 | 12 | 13 | 1.020 |
| 2016 | 119 | 122 | 63 | 64 | 23 | 24 | 17 | 17 | 16 | 17 | 1.021 |
| 2017 | 125 | 125 | 73 | 73 | 29 | 29 | 10 | 10 | 15 | 15 | 1.000 |

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

### 2.3.5 Reef Fish

American Samoa's nearshore fishing is focused on the narrow fringing coral reef that partially surrounds the islands (Levine and Allen, 2009; Richmond and Levine, 2012). A diverse array of fish and shellfish is harvested by local residents on an almost daily basis. Most fishing is accomplished by individuals on foot in areas adjacent to their village. While the gender division in fishing is not as strict as it was in the past, women, and children still predominantly engage in gathering shellfish and small fish in the intertidal zone, while men fish farther off shore. Traditionally, women were not permitted by Samoan custom to fish outside the reef. Common fishing techniques included intertidal gleaning, diving, rod and reel, netting and trapping (including communal fish drives), and boat-based fishing.

There are a number of traditional fisheries associated with seasonal runs of certain species. Atule, or bigeye scad (*Selar crumenophthalmus*), is a coastal migratory species that spawns in mass near shore. Atule are caught through a village-wide effort in some areas where they spawn, with villagers driving the fish to a central location to be harvested. I'asina (juvenile goatfish) are caught in hand-woven funnel traps called enu. Thousands of i'asina may appear along sandy shorelines during the months of October–April. The palolo worm *(Palola viridis)*, a coral-dwelling polychaete worm, is another unique species that is caught in large numbers in the Samoa Islands during spawning events. Palolo generally emerge once a year, one week after the full moon in October or November, to release their reproductive segments (epitokes) into nearshore waters. These epitokes are a local delicacy, and Samoans will gather in the thousands at midnight on the predicted spawning event to collect them in hand nets and screens.

Despite increasing levels of participation in the commercial fishing industry in American Samoa, most nearshore fishermen do not sell their catch. Traditionally, fish in American Samoa are not sold, but shared with others or distributed amongst the community. Many American Samoans still believe that some species, such as the palolo, should not be sold at the risk of ruining catch in future years. Sharing fish amongst the wider village community is still an important cultural practice. For example, atule are divided equally amongst village members after a group harvesting event, and palolo are still distributed to family members with a portion reserved for village pastors. However, since the advent of refrigeration, people are more likely to catch more fish during mass spawning events and share fewer, as they can be stored for longer periods for personal use.

The American Samoa Department of Marine and Wildlife Resources (DMWR) have conducted inshore creel surveys along the southern shore of Tutuila Island since 1990. They documented a significant decrease in the level of shoreline fishing effort over the past three decades despite the increase in the human population over the same time period.

Studies that have examined how residents value coral reef resources found that most people perceive coral reefs as an important food source that also provides passive benefits associated with culture, biodiversity, and community (Levine and Allen, 2009; Levine *et al*,. 2016). Less importance was placed on the ecosystem, recreational benefits, shoreline protection, or other direct-use benefits. Because there is relatively little tourism, the economic value of American Samoa's coral reefs has been estimated to be relatively lower than other islands in the Western Pacific region; an analysis in 2004 estimated their value at $5 million per year (Grace-McCaskey, 2014).

#### 2.3.5.1 Commercial Participation, Landings, Revenues, and Prices

*This section will describe trends in commercial participation, landings, revenues, and prices as data allow for the American Samoa coral reef fishery. Supporting figures and tables will be added in future reports.*

#### 2.3.5.2 Costs of Fishing

Since 2009, PIFSC economists have maintained a continuous economic data collection program in American Samoa through collaboration with the PIFSC Western Pacific Fisheries Information Network (WPacFIN). The economic data collection gathers fishing expenditure data for boat-based reef fish, bottomfish, and pelagic fishing trips on an ongoing basis. Data for fishing trip expenses include; gallons of fuel used, price per gallon of fuel, cost of ice used, cost of bait and chum used, cost of fishing gear lost, and the engine type of the boat. These economic data are collected from same subset of fishing trips as the boat-based creel survey carried out by the local fisheries management agencies and WPacFIN.

Figure 7 shows the average trip costs for American Samoa coral reef fish fishing trips during 2009–2017. In 2017, the average trip costs of coral reef fish trips were $55, similar to 2016. Supporting data for Figure 7 are presented in Table 32.

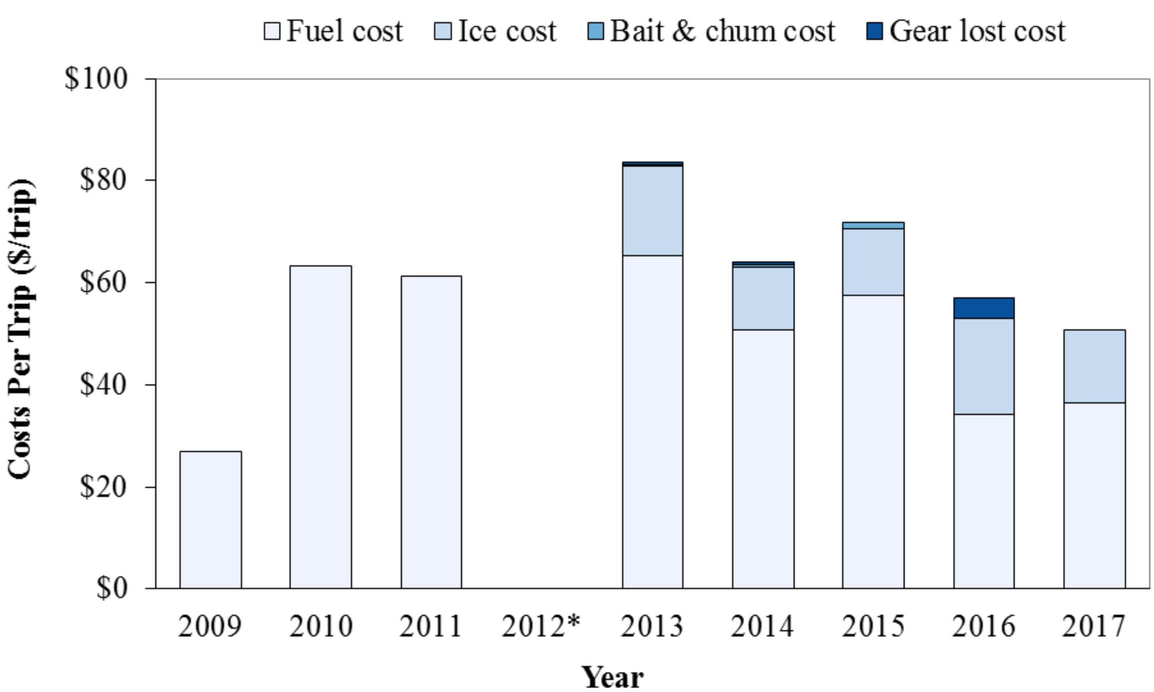



**Figure 7. Average costs adjusted to 2017 dollars for American Samoa spearfishing trips from 2009–2017 adjusted to 2017 dollars.**

*Data for 2012 are not presented due to less than three observations.

**Table 32. Average trip costs and itemized costs for American Samoa coral reef fish trips from 2009–2017 adjusted to 2017 dollars.**

| Year | Total trip costs ($) | Total trip costs ($) (adjusted) | Fuel cost ($) | Fuel cost ($) (adjusted) | Ice cost ($) | Ice cost ($) (adjusted) | Gear losted cost ($) | Gear losted cost ($) (adjusted) | Bait & chum cost ($) | Bait & chum cost ($) (adjusted) | CPI adjustor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 22 | 27 | 22 | 27 | - | - | 0 | 0 | 0 | 0 | 1.215 |
| 2010 | 55 | 63 | 55 | 63 | - | - | 0 | 0 | 0 | 0 | 1.159 |
| 2011 | 57 | 61 | 57 | 61 | - | - | 0 | 0 | 0 | 0 | 1.072 |
| 2012* | - | - | - | - | - | - | - | - | - | - | 1.038 |
| 2013 | 82 | 84 | 64 | 65 | 17 | 18 | 1 | 1 | 0 | 0 | 1.018 |
| 2014 | 63 | 64 | 50 | 51 | 12 | 12 | 0 | 0 | 0 | 0 | 1.011 |
| 2015 | 71 | 72 | 56 | 58 | 13 | 13 | 0 | 0 | 1 | 1 | 1.020 |
| 2016 | 56 | 57 | 33 | 34 | 18 | 19 | 4 | 4 | 0 | 0 | 1.021 |
| 2017 | 55 | 55 | 40 | 40 | 14 | 14 | 0 | 0 | 0 | 0 | 1.000 |

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

### 2.3.6 Crustaceans

In American Samoa, spiny lobsters constitute the bulk of the crustacean fishery (description available in Markrich and Hawkins, 2016). Lobsters are often present at important meals in American Samoa such as weddings, funerals, and holidays. In the past, lobsters were typically harvested and consumed on the family and village level. They are now primarily caught by commercial fishermen in territorial waters and purchased by the public at market. Crustaceans harvested in American Samoa are processed at sea on the vessel and marketed as fresh product or as frozen lobster tails.

#### 2.3.6.1 Commercial Participation, Landings, Revenues, and Prices

*This section will describe trends in commercial participation, landings, revenues, and prices as data allow for the American Samoa crustacean fishery. Supporting figures and tables will be added in future reports.*

### 2.3.7 Precious Corals

There is currently no socioeconomics information specific to this fishery. Subsequent reports will include new data as resources allow.

#### 2.3.7.1 Commercial Participation, Landings, Revenues, and Prices

*This section will describe trends in commercial participation, landings, revenues, and prices as data allow for the American Samoa precious coral fishery. Supporting figures and tables will be added in future reports.*

### 2.3.8 Ongoing Research and Information Collection

Social indicators are being compiled for American Samoa, following the methodology for the national project to describe and evaluate community well-being in terms of social, economic, and psychological welfare (https://www.st.nmfs.noaa.gov/humandimensions/social-indicators/index).

In addition, a web-based tool is being developed to compile relevant socioeconomic data into a "Community Snapshot" by Census County Division or equivalent.

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

### 2.3.9 Relevant PIFSC Economics and Human Dimensions Publications: 2017

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PIFSC, 2017. Background and PIFSC Response: Panel Reports of the Economics and Human Dimensions Program Review. 18 p. https://go.usa.gov/xnDyP.

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Grace-McCaskey, C.A., 2015. American Samoa Fishing Community Profile: 2013 Update. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96818-5007.

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

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WPRFMC, 2018. Annual Stock Assessment and Fishery Evaluation Report for the American Samoa Archipelago Fishery Ecosystem 2017. Sabater, M., Ishizaki, A., Walker, R., Remington, T., Spalding, S. (Eds.) Western Pacific Regional Fishery Management Council. Honolulu, HI..80 p. + Appendices.

WPRFMC, 2016b. Minutes of the 168th Meeting of the Western Pacific Regional Fishery Management Council. Honolulu, HI. 124 p.

## 2.4 PROTECTED SPECIES

This section of the report summarizes information on protected species interactions in fisheries managed under the American Samoa 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), Marine Mammal Protection Act (MMPA), and/or Migratory Bird Treaty Act (MBTA). A list of protected species found in or near American Samoa waters and a list of critical habitat designations in the Pacific Ocean are included in Appendix B.

### 2.4.1 Indicators for Monitoring Protected Species Interactions

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

#### 2.4.1.1 FEP Conservation Measures

Bottomfish, precious coral, coral reef and crustacean fisheries managed under this FEP have not had reported interactions with protected species, and no specific regulations are in place to mitigate protected species interactions. Destructive gear such as bottom trawls, bottom gillnets, explosives and poisons are prohibited under this FEP, and these provide benefit to protected species by preventing potential interactions with non-selective fishing gear.

#### 2.4.1.2 ESA Consultations

ESA consultations were conducted by NMFS and the U.S. Fish and Wildlife Service (for species under their jurisdiction including seabirds) to ensure ongoing fisheries operations managed under the American Samoa FEP are not jeopardizing the continued existence of any listed species or adversely modifying critical habitat. The results of these consultations conducted under section 7 of the ESA are briefly described below and summarized in Table 33.

**Table 33. Summary of ESA consultations for American Samoa FEP Fisheries.**

| Fishery | Consultation date | Consultation type[a] | Outcome[b] | Species |
|---|---|---|---|---|
| Bottomfish | 3/8/2002 | BiOp | NLAA | Blue whale, fin whale, green sea turtle, hawksbill sea turtle, humpback whale, leatherback sea turtle, loggerhead sea turtle, olive ridley sea turtle, sei whale, sperm whale |
| Coral reef ecosystem | 3/7/2002 | LOC | NLAA | Blue whale, fin whale, green sea turtle, hawksbill sea turtle, humpback whale, leatherback sea turtle, loggerhead sea turtle, olive ridley sea turtle, sei whale, sperm whale |

| Fishery | Consultation date | Consultation type[a] | Outcome[b] | Species |
|---|---|---|---|---|
| | 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 |
| Crustaceans | 9/28/2007 | LOC | NLAA | Blue whale, fin whale, green sea turtle, hawksbill sea turtle, humpback whale, leatherback sea turtle, loggerhead sea turtle, olive ridley sea turtle, sei whale, sperm whale |
| Precious corals | 10/4/1978 | BiOp | Does not constitute threat | Leatherback sea turtle, sperm whale |
| | 12/20/2000 | LOC | NLAA | Green sea turtle, hawksbill sea turtle, humpback whale |
| All fisheries | 4/9/2015 | LOC | NLAA | Reef-building corals, scalloped hammerhead shark (Indo-West Pacific DPS) |

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

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

#### 2.4.1.2.1 Bottomfish Fishery

In a biological opinion issued on March 3, 2002, NMFS concluded that the ongoing operation of the Western Pacific Region’s bottomfish and seamount groundfish fisheries is not likely to jeopardize the continued existence of five sea turtle species (loggerhead, leatherback, olive ridley, green and hawksbill turtles) and five marine mammal species (humpback, blue, fin, sei and sperm whales). NMFS also concluded in an informal consultation dated April 9, 2015 that fisheries managed under the American Samoa FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark and ESA-listed reef-building corals.

#### 2.4.1.2.2 Crustacean Fishery

An informal consultation completed by NMFS on September 28, 2007 concluded that American Samoa 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). NMFS also concluded in an informal consultation dated April 9, 2015 that fisheries managed under the American Samoa FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark and ESA-listed reef-building corals.

#### 2.4.1.2.3 Coral Reef Ecosystem Fishery

An informal consultation completed by NMFS on March 7, 2002 concluded that the American Samoa coral reef ecosystem 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). NMFS also concluded in an informal consultation dated April 9, 2015 that fisheries managed under the American Samoa FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark and ESA-listed reef-building corals.

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 terrestrial plants) and listed species shared with NMFS (i.e., sea turtles).

#### 2.4.1.2.4 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. An informal consultation completed by NMFS on December 20, 2000 concluded that American Samoa precious coral fisheries are not likely to adversely affect humpback whales, green turtles or hawksbill turtles. An additional informal consultation completed by NMFS on April 9, 2015 concluded that fisheries managed under the American Samoa FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark and ESA-listed reef-building corals.

### 2.4.1.3 Non-ESA Marine Mammals

The MMPA requires NMFS to annually publish a List of Fisheries (LOF) that classifies commercial fisheries in one of three categories based on the level of mortality and serious injury of marine mammals associated with that fishery. According to the 2017 LOF (82 FR 3655, January 12, 2017), the American Samoa bottomfish fishery is classified as a Category III fishery (i.e. a remote likelihood of or no known incidental mortality and serious injury of marine mammals).

## 2.4.2 Status of Protected Species Interactions in the American Samoa FEP Fisheries

#### 2.4.2.1.1 Bottomfish Fishery

There are no observer data available for the American Samoa bottomfish fishery. However based on the information in the 2002 BiOp for fisheries operating under the American Samoa FEP, these fisheries are not expected to interact with any ESA-listed species in Federal waters around American Samoa. NMFS has also concluded that the American Samoa bottomfish commercial fisheries will not affect marine mammals in any manner not considered or authorized under the Marine Mammal Protection Act.

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

##### 2.4.2.1.2 Crustacean Fishery

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

##### 2.4.2.1.3 Coral Reef Fishery

There are no observer data available for the American Samoa 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 American Samoa. NMFS has also concluded that the American Samoa coral reef commercial fisheries will not affect marine mammals in any manner not considered or authorized under the Marine Mammal Protection Act.

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

##### 2.4.2.1.4 Precious Coral Fishery

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

### 2.4.3 Identification of Emerging Issues

Several species are currently candidates for listing under the ESA, and several more ESA-listed species are being evaluated for critical habitat designation (Table 34). If these species are listed or critical habitat are designated, they will be included in this SAFE report and impacts from FEP-managed fisheries will be evaluated under applicable mandates.

**Table 34. Candidate ESA species, and ESA-listed species being evaluated for critical habitat designation.**

| Species | | Listing process | | | Post-listing activity | |
|---|---|---|---|---|---|---|
| **Common name** | **Scientific name** | **90-day finding** | **12-month finding / Proposed rule** | **Final rule** | **Critical Habitat** | **Recovery Plan** |
| Oceanic whitetip shark | *Carcharhinus longimanus* | Positive (81 FR 1376, 1/12/2016) | Positive, threatened (81 FR 96304, 12/29/2016) | Public comment period closed 3/29/2017, final rule expected 12/29/2017 | N/A | N/A |
| Pacific bluefin tuna | *Thunnus orientalis* | Positive (81 FR 70074, 10/11/2016) | In progress, expected 6/2017 | N/A | N/A | N/A |
| Chambered nautilus | *Nautilus pompilius* | Positive (81 FR 58895, 8/26/2016) | In progress, expected 5/2017 | N/A | N/A | N/A |
| Giant manta ray | *Manta birostris* | Positive (81 FR 8874, 2/23/2016) | Positive, threatened (82 FRN 3694, 1/12/2017) | Public comment period closed 3/13/2017, final rule expected 1/2018 | N/A | N/A |
| Reef manta ray | *Manta alfredi* | Positive (81 FR 8874, 2/23/2016) | Not warranted (82 FRN 3694, 1/12/2017) | N/A | N/A | N/A |
| Corals | N/A | Positive for 82 species (75 FR 6616, 2/10/2010) | Positive for 66 species (77 FR 73219, 12/7/2012) | 20 species listed as threatened (79 FR 53851, 9/10/2014) | In development, proposal expected 2017 | In development, expected TBA, interim recovery outline in place |
| Green sea turtle | *Chelonia mydas* | Positive (77 FR 45571, 8/1/2012) | Identification of 11 DPSs, endangered and threatened (80 FR 15271, 3/23/2015) | 11 DPSs listed as endangered and threatened (81 FR 20057, 4/6/2016) | In development, proposal expected 2017 | TBA |

### 2.4.4 Identification of Research, Data and Assessment Needs

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

- Improve the precision of non-commercial fisheries data to improve understanding of potential protected species impacts.

- Define and evaluate innovative approaches to derive robust estimates of protected species interactions in insular fisheries.

## 2.5 CLIMATE AND OCEANIC INDICATORS

### 2.5.1 Introduction

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

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

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

### 2.5.2 Conceptual Model

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

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

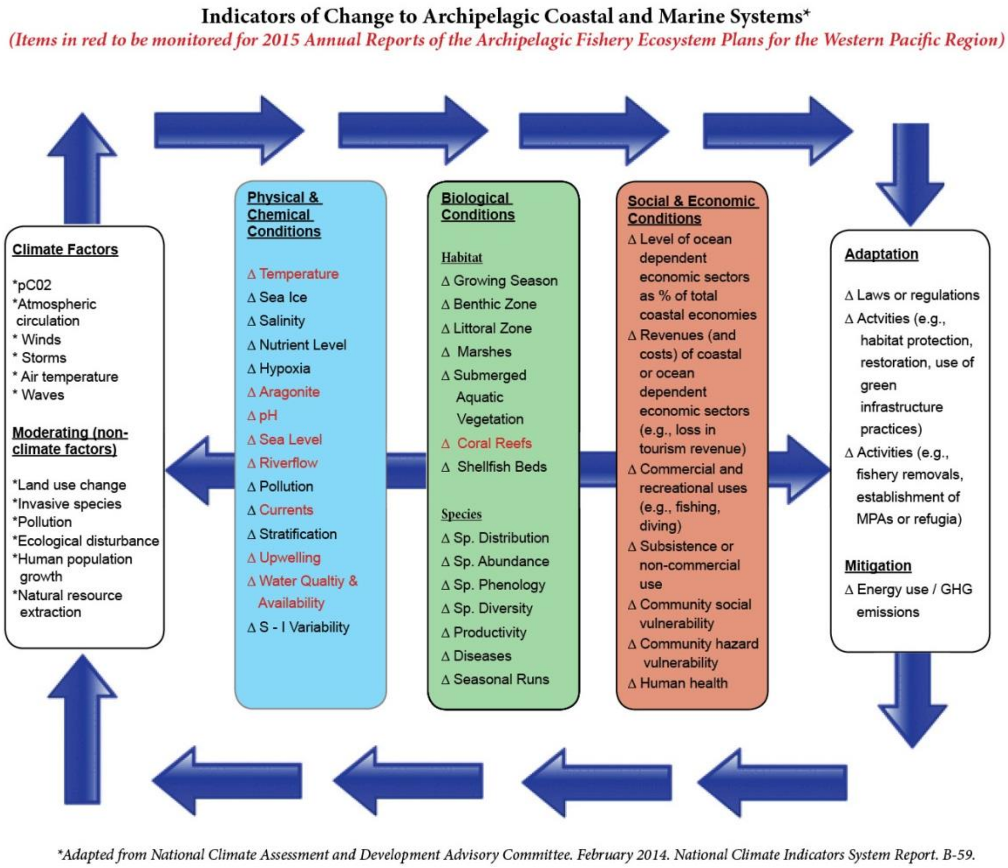


**Figure 8. Simplified representation of the climate and non-climate stressors in the coastal and marine ecosystems.**

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

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

### 2.5.3 Selected Indicators

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

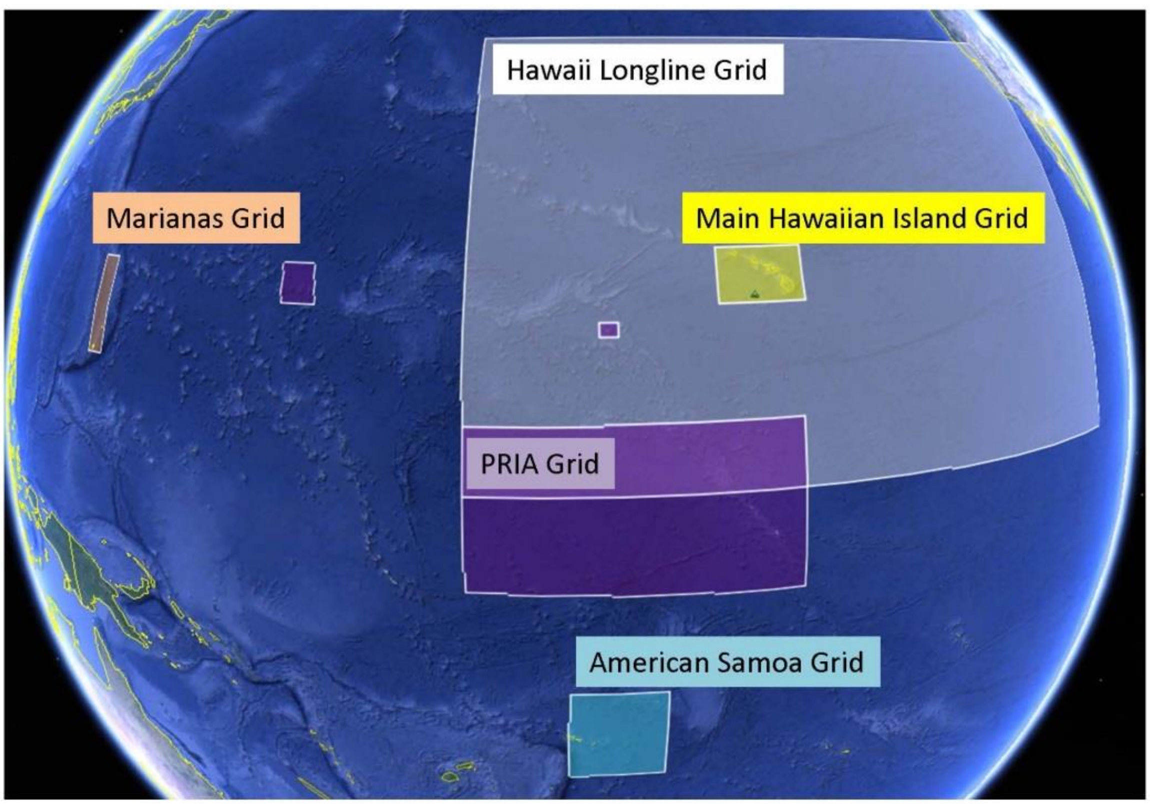


**Figure 9. Regional spatial grids representing the scale of the climate change indicators being monitored.**

**Table 35. Climate and Ocean Indicator Summary.**

| Indicator | Definition and Rationale | Indicator Status |
|---|---|---|
| Atmospheric Concentration of Carbon Dioxide ($CO_2$) | Atmospheric concentration $CO_2$ at Mauna Loa Observatory. Increasing atmospheric $CO_2$ is a primary measure of anthropogenic climate change. | Trend: increasing exponentially<br><br>2017: time series mean 406.53 ppm |
| Oceanic pH | Ocean surface pH at Station ALOHA. Ocean pH provides a measure of ocean acidification. Increasing ocean acidification limits the ability of marine organisms to build shells and other hard structures. | Trend: pH is decreasing at a rate of 0.039 pH units per year, equivalent to 0.4% increase in acidity per year |
| Oceanic Niño Index (ONI) | Sea surface temperature anomaly from Niño 3.4 region (5°N - 5°S, 120° - 170°W). This index is used to determine the phase of the El Niño – Southern Oscillation (ENSO), which has implications across the region, affecting migratory patterns of key commercial fish stocks which in turn affect the location, safety, and costs of commercial fishing. | 2017: ENSO Neutral |
| Pacific Decadal Oscillation (PDO) | PDO can be thought of as a long-lived, multi-decadal ENSO cycle that has well-documented fishery implications related to ocean temperature and productivity. | 2017:<br>positive (warm) from Jan – June, negative (cool) from Jul – Dec |
| Sea Surface Temperature* (SST) | Satellite remotely-sensed sea surface temperature. SST is projected to rise, and impacts phenomena ranging from winds to fish distribution. | SST in waters surrounding most of PRIA ranged between 27-30º C with 2017 showing anomalies dependent on latitude: along the equator, 2017 showed a negative anomaly, while at ~4 deg N, the 2017 anomaly moves positive. |
| Coral Thermal Bleaching Exposure (DHW) | Satellite remotely-sensed metric of time and temperature above thresholds relevant for coral bleaching. Metric used is Degree Heating Weeks (DHW). | The equatorial PRIA showed prolonged, substantial DHW stress in 2015-2016, in which DHW values exceeded the range in which mass mortality is expected (DHW>8). Wake Atoll showed more regular, but less prolonged heating events (’14, ’15, ’17). |
| Chlorophyll-A (Chl-A) | Satellite remotely-sensed chlorophyll-a. Chl-A is projected to drop over much of the central Pacific, and is directly linked ecosystem productivity. | The Chl-A around the PRIA ranges from 0.08 to 0.35 $mg/m^3$, with 2017 showing a near-zero and spatially variable anomaly. |

| | | |
|---|---|---|
| Tropical Cyclones | Measures of tropical cyclone occurrence, strength, and energy. Tropical cyclones have the potential to significantly impact fishing operations. | Eastern Pacific, 2017: 31 storms, a level slightly lower than average. |
| | | South Pacific, 2017: 6 storms, low – lowest since 2012. |
| | | Central Pacific, 2017: 0 storms. Very low. |
| Rainfall/Precipitation | CMAP re-analysis of CPC Precipitation Data | 2017 showed negative anomalies in rainfall. |
| Sea Level/Sea Surface Height | Monthly mean sea level time series, including extremes. Data from satellite altimetry & in situ tide gauges. Rising sea levels can result in a number of coastal impacts, including inundation of infrastructure, increased damage resulting from storm-driven waves and flooding, and saltwater intrusion into freshwater supplies. | Although varying over time the monthly mean sea level trend is increasing. |

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

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

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

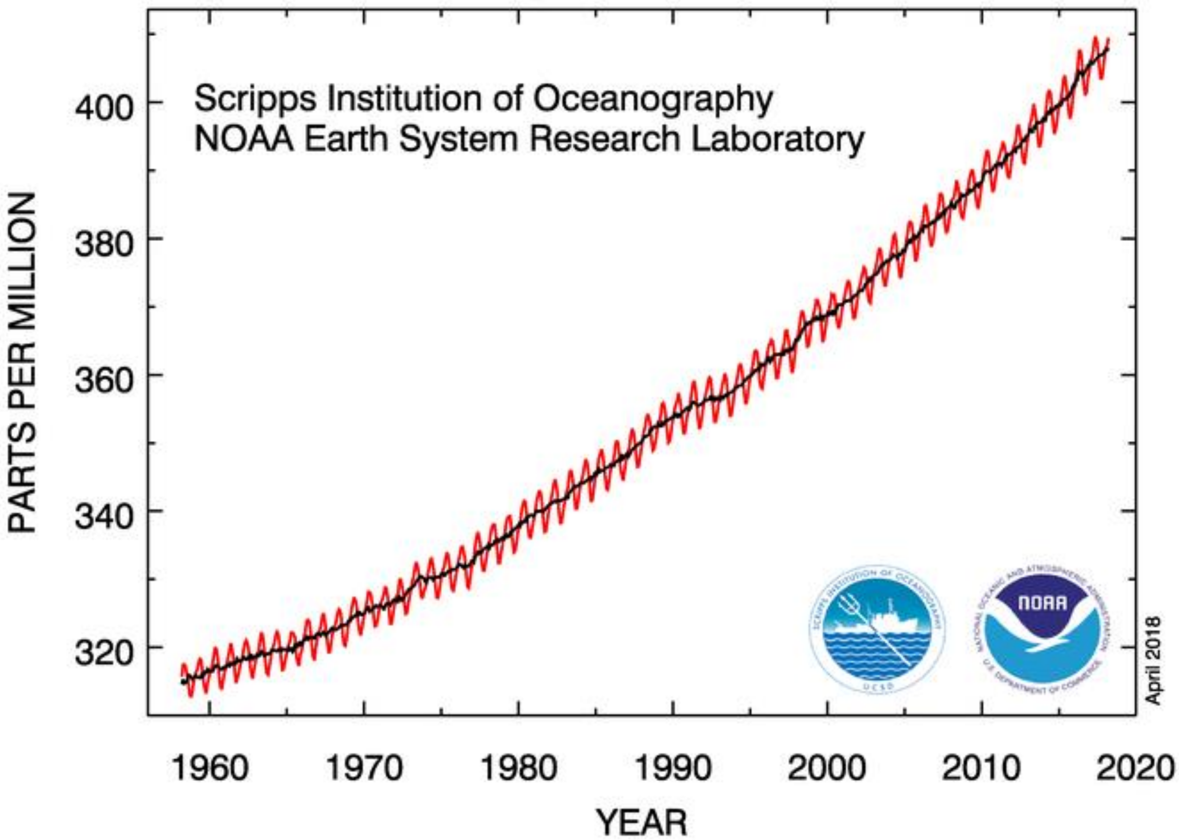


**Figure 10. Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawai`i. Note: The red line shows monthly averages and the black line shows seasonally-corrected data.**

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

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

Timeframe: Annual, monthly

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

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

Measurement Platform: *In-situ* station

#### 2.5.3.1.1 References

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

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

#### 2.5.3.2 Oceanic pH

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

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

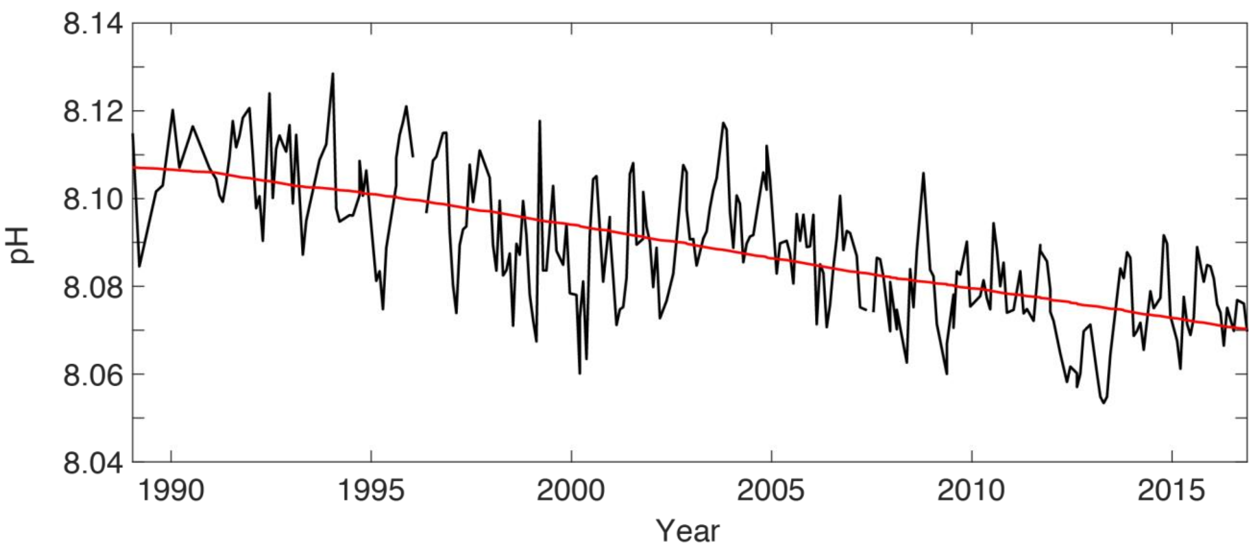


**Figure 11. pH Trend at Station ALOHA, 1989 – 2016. Note: Measured pH values are plotted in black. The linear fit to this time series is shown in red.**

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

Timeframe: Monthly

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

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

Measurement Platform: *In-situ* station

#### 2.5.3.2.1 References

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

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

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

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

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

#### 2.5.3.3 Oceanic Niño Index

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

Status: The ONI was neutral in 2017.

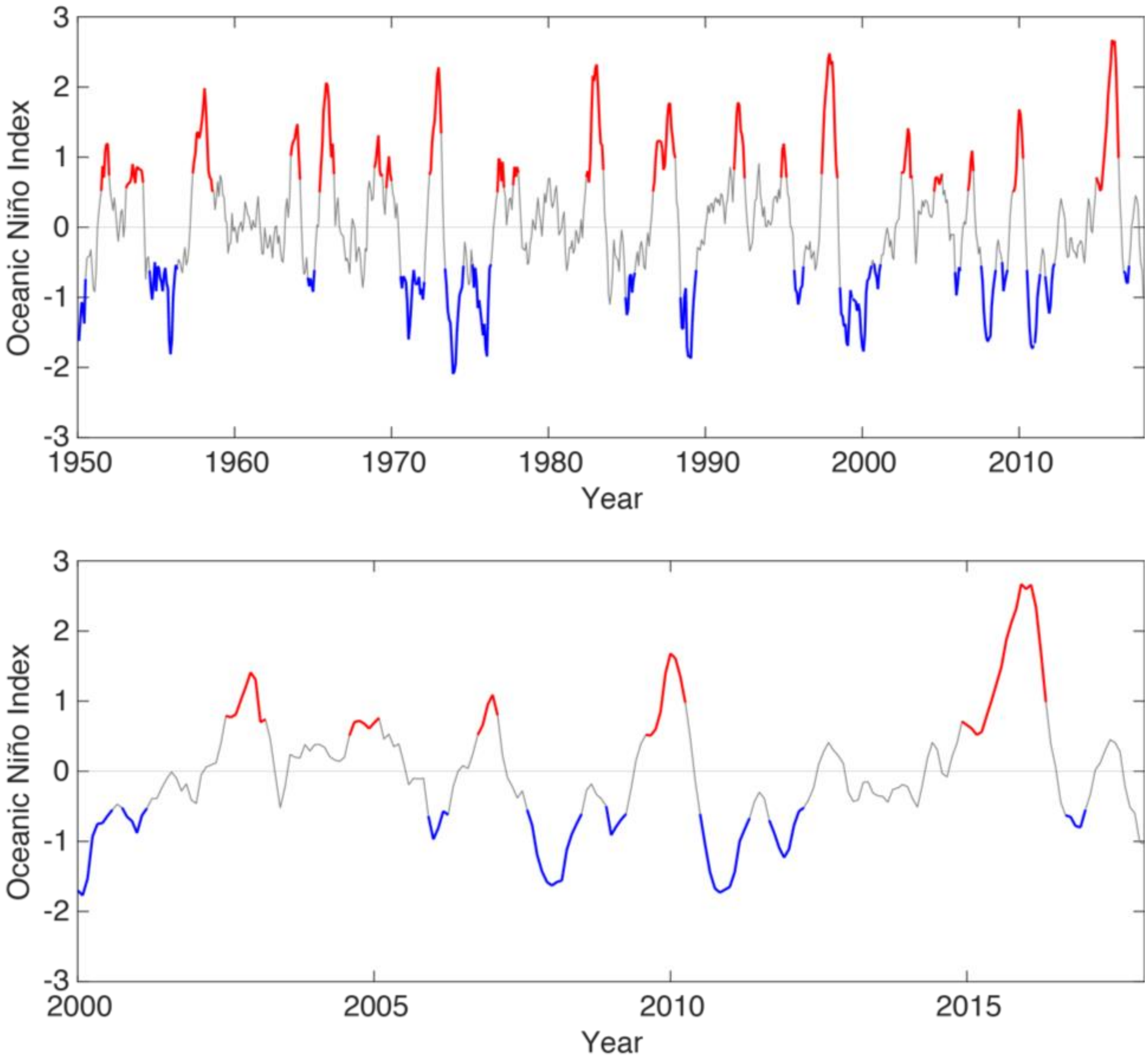


**Figure 12. Oceanic Niño Index, 1950-2017 and 2000–2017. Note: Monthly time series of the Oceanic Niño Index for 1950 – 2017 (top) and 2000 – 2017 (bottom). El Niño periods are highlighted in red. La Niña periods are highlighted in blue.**

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

Timeframe: Every three months

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

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

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

#### 2.5.3.3.1 References

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

### 2.5.3.4 Pacific Decadal Oscillation

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

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

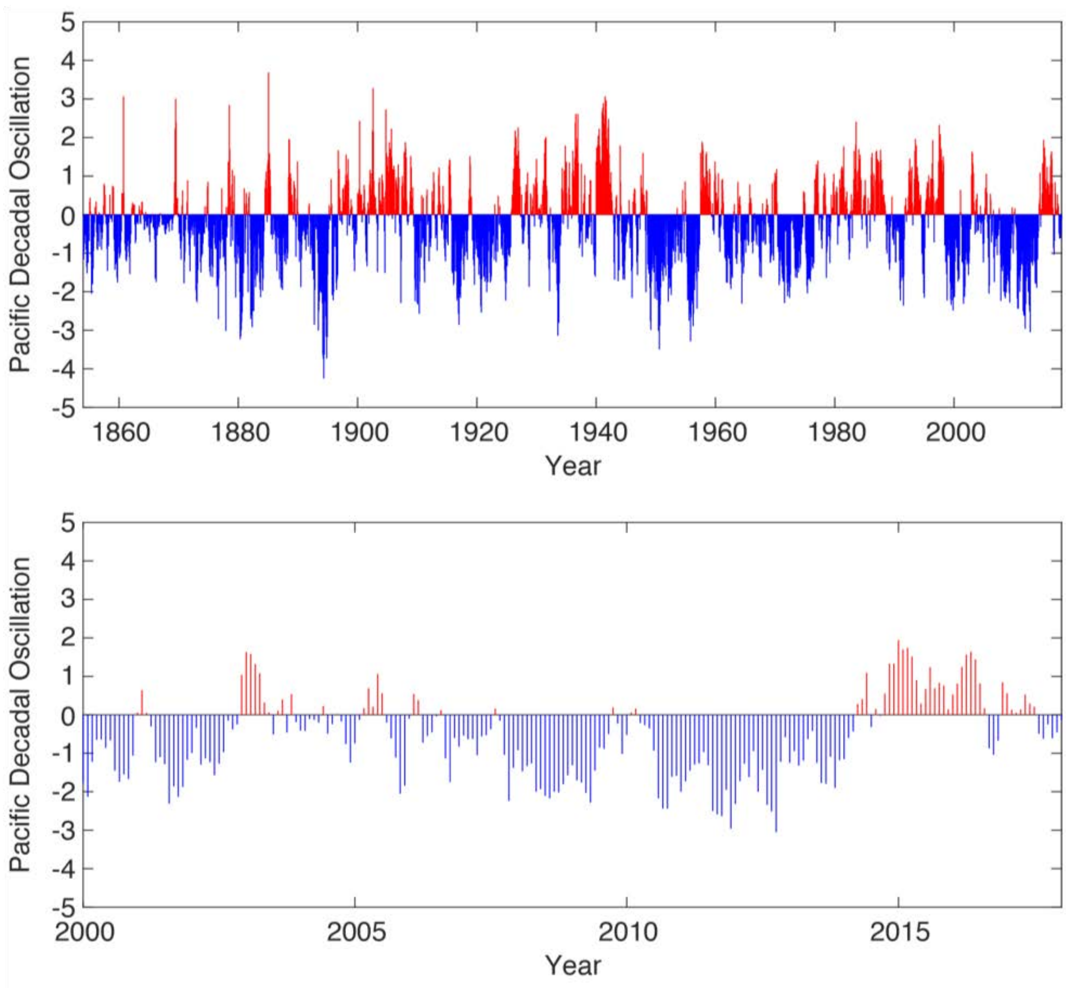


**Figure 13. Pacific Decadal Oscillation, 1854–2017 and 2000–2017. Note: Monthly values of the Pacific Decadal Oscillation for 1854 – 2017 (top) and 2000 – 2017 (bottom). Positive, or warm, phases are plotted in red. Negative, or cool, phases are plotted in blue.**

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

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

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

Timeframe: Annual, monthly

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

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

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

#### 2.5.3.4.1 References

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

#### 2.5.3.5 Sea Surface Temperature & Anomaly

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

Short Descriptions:

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

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

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

Technical Summaries:

*Pathfinder v5 & GAC datasets-*

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

perspective, the Pathfinder program was originally initiated in the 1990s as a joint NOAA/NASA research activity for reprocessing of satellite based data sets including SST.
The AVHRR is a space-borne scanning sensor on the National Oceanic and Atmospheric Administration (NOAA) family of Polar Orbiting Environmental Satellites (POES) having an operational legacy that traces back to the Television Infrared Observation Satellite-N (TIROS-N) launched in 1978. AVHRR instruments measure the radiance of the Earth in 5 (or 6) relatively wide spectral bands. The first two are centered around the red (0.6 micrometer) and near-infrared (0.9 micrometer) regions, the third one is located around 3.5 micrometer, and the last two sample the emitted thermal radiation, around 11 and 12 micrometers, respectively. The legacy 5 band instrument is known as AVHRR/2 while the more recent version, the AVHRR/3 (first carried on the NOAA-15 platform), acquires data in a 6th channel located at 1.6 micrometer. Typically the 11 and 12 micron channels are used to derive SST sometimes in combination with the 3.5 micron channel. For the Pathfinder SST algorithm only the 11 and 12 micron channels are used. The NOAA platforms are sun synchronous generally viewing the same earth location twice a day (latitude dependent) due to the relatively large AVHRR swath of approximately 2400 km.
The highest ground resolution that can be obtained from the current AVHRR instruments is 1.1 km at nadir.

This particular dataset is produced from Global Area Coverage (GAC) data that are derived from an on-board sample averaging of the full resolution global AVHRR data. Four out of every five samples along the scan line are used to compute on average value and the data from only every third scan line are processed, yielding an effective 4 km resolution at nadir. The collection of NOAA satellite platforms used in the AVHRR Pathfinder SST time series includes NOAA-7, NOAA-9, NOAA-11, NOAA-14, NOAA-16, NOAA-17, and NOAA-18. These platforms contain "afternoon" orbits having a daytime ascending node of between 13:30 and 14:30 local time (at time of launch) with the exception of NOAA-17 that has a daytime descending node of approximately 10:00 local time. SST AVHRR Pathfinder includes separate daytime and nighttime daily, 5 day, 8 day, monthly and yearly datasets. This particular dataset represent nighttime monthly averaged observations. (Text from: https://podaac-www.jpl.nasa.gov/dataset/ AVHRR_PATHFINDER_L3_SST_MONTHLY_NIGHTTIME_V5.)

*GOES-POES dataset -*

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

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

The GOES-11 and 12 imagers observe both northern and southern hemisphere every half an hour. These 5-band (0.6, 3.9, 6.7, 10.7, 12 or 13.3 micron) and 4-band (0.6, 3.9, 6.7, 10.7. or 13.3

micron) images are processed to retrieve SST retrievals at 4-km resolution. The window infrared channels determine the SST, and all channels (except the 6.7 and 13.3 µm) determine the cloud contamination. These retrievals are remapped, averaged, and composited hourly and posted to a server for user access. The retrievals are available approximately 90 minutes after the nominal epoch of the SST determinations. Three-hour and 24-hour averages are also made available. CoastWatch Regional Imagery is generated every three hours by combining the 1hourly SST images for these areas. (Text from: https://www.star.nesdis.noaa.gov/sod/mecb/blended_validation/background.php.)

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

Region/Location: Global.

Data Source:

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

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

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

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

#### 2.5.3.5.1 References

Li, X., Pichel, W.G., Clemente-Colón, P., and Sapper J.F., 2001a. Deriving the operational nonlinear multi-channel sea surface temperature algorithm coefficients for NOAA-15 AVHRR/3, *Int. J. Remote Sens*., *22*(4), pp. 699 - 704.

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

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

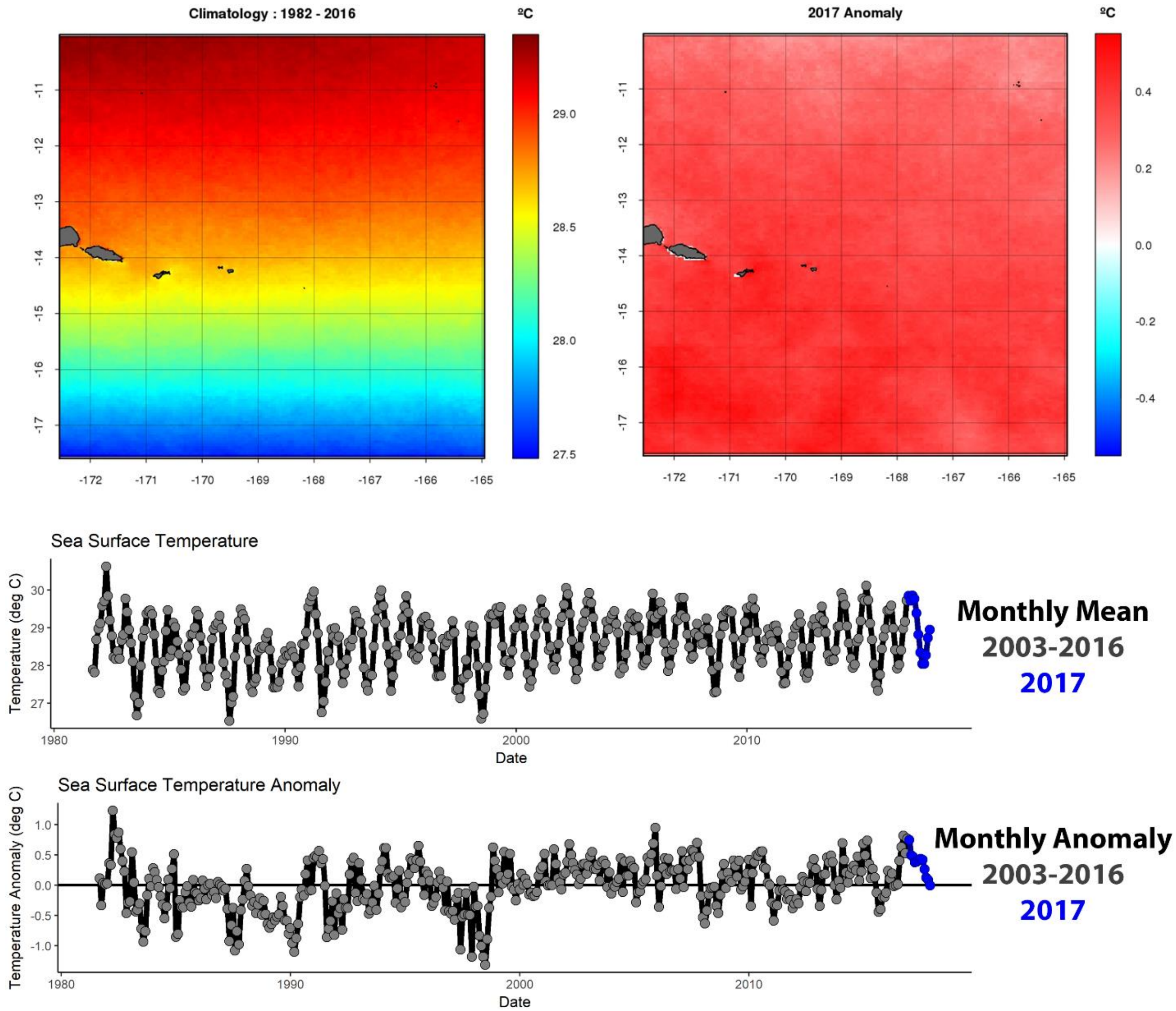



**Figure 14. Sea surface temperature (SST) and SST Anomaly from 2003-2017.**

#### 2.5.3.6 Coral Thermal Stress Exposure: Degree Heating Weeks

Description: Here we present a metric of exposure to thermal stress that is relevant to coral bleaching. Degree Heating Weeks (DHW) measure time and temperature above a reference 'summer maximum', presented as 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.

Short Description:

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

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. (Text inserted from the NOAA Coral Reef Watch website.)

Technical Summary:

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

A significantly improved climatology was introduced in the Version 3 products. It was derived from a combination of NOAA/NESDIS' 2002-2012 reprocessed daily global 5km Geo-Polar Blended Night-only SST Analysis and the 1985-2002 daily global 5km SST reanalysis, produced by the United Kingdom Met Office, on the Operational SST and Sea Ice Analysis (OSTIA) system. The near-real-time OSTIA SST was recently incorporated into the generation of NESDIS' operational daily 5km Blended SST that CRW's 5km coral bleaching heat stress monitoring product suite is based on. Hence, the 2002-2012 reprocessed 5km Geo-Polar Blended SST that has just become available, extended with the 1985-2002 portion of the 5km OSTIA SST reanalysis, is the best historical 1985-2012 global SST dataset for deriving a climatology that is internally consistent and compatible with CRW's near-real-time 5km satellite coral bleaching heat stress monitoring products. Although the reprocessed 5km Geo-Polar Blended SST dataset is available to the end of 2016, to be consistent with the time period (1985-2012) of the climatology used in our Version 2 5km product suite, the Version 3 climatology is based on the same time period. It was then re-centered to the center of the baseline time period of 1985-1990 plus 1993, using the method described in Heron *et al.,* (2015)and Liu *et al.,* (2014), and was based on our monitoring algorithm (also described in these articles). More recent years may be incorporated in the climatology for future versions of CRW's 5 km products, but potential impacts on the products require further evaluation first.

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

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

Regional Virtual Stations Product Description: NOAA Coral Reef Watch (CRW) has developed a set of experimental 5 km Regional Virtual Stations (213 total).
NOAA CRW also expanded the geographic network of 5 km Virtual Stations to include all coral reefs around the world, based on available references. These included the Millennium Coral Reef project maps, the IUCN Coral Reefs of the World three-volume set, the UNEP/WCMC World Atlas of Coral Reefs, several country scale atlas publications, and a few other resources. These references were also used to develop the outline (in black) for each 5 km Regional Virtual Station. Each Virtual Station outline is based on a global 5 km reef pixel mask developed by NOAA CRW, with the addition of a 20 km buffer around each 5 km reef mask. If we have missed a coral reef that you know of, please let us know the name and coordinates of the missing reef. (Text inserted from: https://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php.)

Timeframe: 2013-2017, Daily data.

Region/Location: Global.

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

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

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

### 2.5.3.6.1 References

Liu, G., Heron, S.F., Eakin, C.M., Muller-Karger, F.E., Vega-Rodriguez, M., Guild, L.S., De La Cour, J.L., Geiger, E.F., Skirving, W.J., Burgess, T.F. and Strong, A.E., 2014. Reef-scale thermal stress monitoring of coral ecosystems: new 5-km global products from NOAA Coral Reef Watch. *Remote Sensing*, *6*(11), pp.11579-11606.

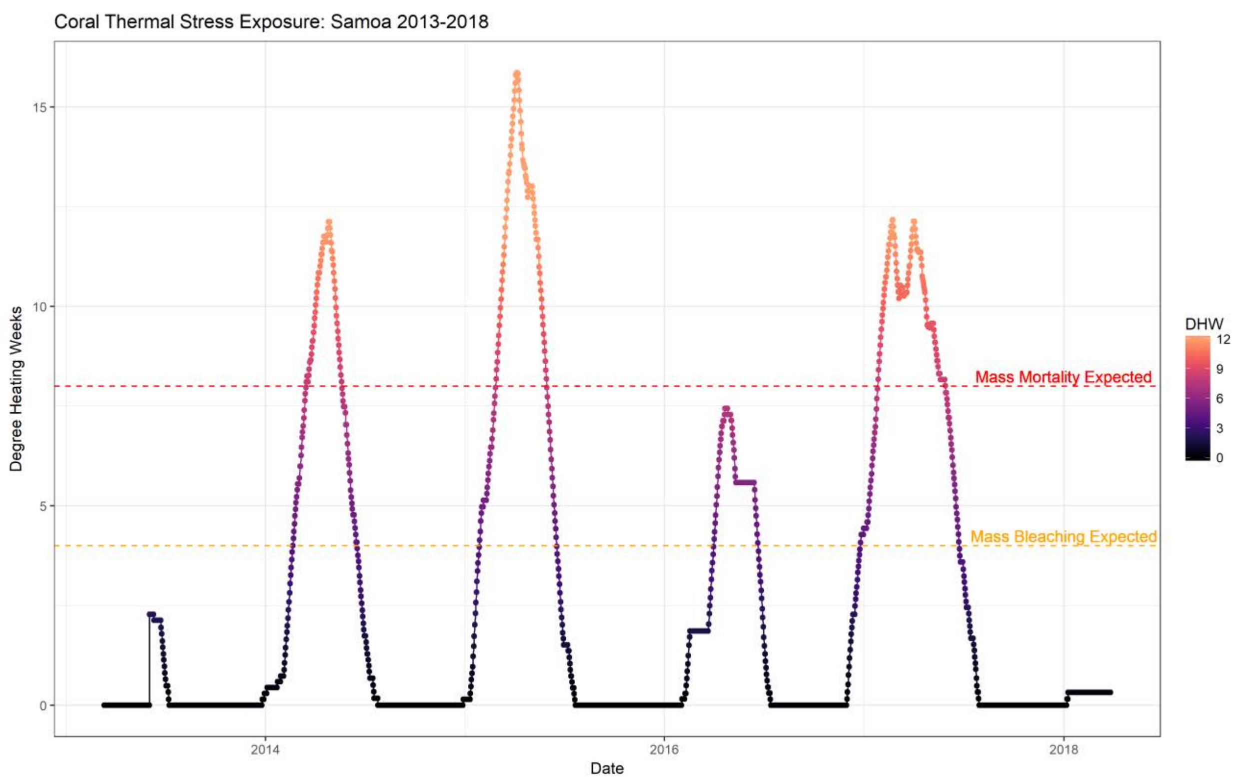



**Figure 15. Coral Thermal Stress Exposure measured at Samoa Virtual Station 2013-2017 (Coral Reef Watch Degree Heating Weeks).**

#### 2.5.3.7 Chlorophyll-A and Anomaly

Description: Chlorophyll-A Concentration from 2002-2017, derived from the MODIS Ocean Color sensor aboard the NASA Aqua Satellite. A monthly climatology was generated across the entire period (1982-2017) to provide both a 2017 spatial anomaly, and an anomaly time series.

Short Description:

The MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor was deployed onboard the NASA Aqua satellite. It is a multi-disciplinary sensor providing data for the ocean, land, aerosol, and cloud research and is used for detecting chlorophyll-a concentrations in the world's oceans, among other applications. Aqua MODIS views the entire Earth's surface every 2 days, acquiring data in 36 spectral bands. The data available here is the latest reprocessing from June 2015, which NASA undertook to correct for some sensor drift issues.( Text inserted from the OceanWatch Central Pacific Node).

Technical Summary:

The Moderate-resolution Imaging Spectroradiometer (MODIS) is a scientific instrument (radiometer) launched by NASA in 2002 on board the Aqua satellite platform (a second series is on the Terra platform) to study global dynamics of the Earth’s atmosphere, land and oceans. MODIS captures data in 36 spectral bands ranging in wavelength from 0.4 um to 14.4 um and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). The Aqua platform is in a sun synchronous, near polar orbit at 705 km altitude and the MODIS instrument images the entire Earth every 1 to 2 days. The Level 3 standard mapped image (SMI) chlorophyll-a dataset has a monthly temporal resolution and 4.6 km (at the equator) spatial resolution. The SMI dataset is an image representation of binned MODIS data (more detailed information on the SMI format can be found at http://oceancolor.gsfc.nasa.gov). The MODIS Aqua instrument provides quantitative data on global ocean bio-optical properties to examine oceanic factors that affect global change and to assess the oceans' role in the global carbon cycle, as well as other biogeochemical cycles. Subtle changes in chlorophyll-a signify various types and quantities of marine phytoplankton (microscopic marine plants), the knowledge of which has both scientific and practical applications. This is a local dataset derived from the NASA Ocean Biology Processing Group (OBPG) meant to expose these data to tools and services at the PO.DAAC. (Text inserted from:

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

Timeframe: 2003-2017, Daily data available, Monthly means shown.

Region/Location: Global.

Data Source:

“MODIS-Aqua (ERDDAP Monthly)” http://oceanwatch.pifsc.noaa.gov/doc.html

Measurement Platform: *MODIS sensor on NASA Aqua Satellite*

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

### 2.5.3.7.1 References


Savchenko, A., Ouzounov, D., Ahmad, S., Acker, J., Leptoukh, G., Koziana, J., and Nickless, D., 2004. Terra and Aqua MODI products available from NASA GES DAAC. *Advances in Space Research*, *34*(4), pp. 710-714.

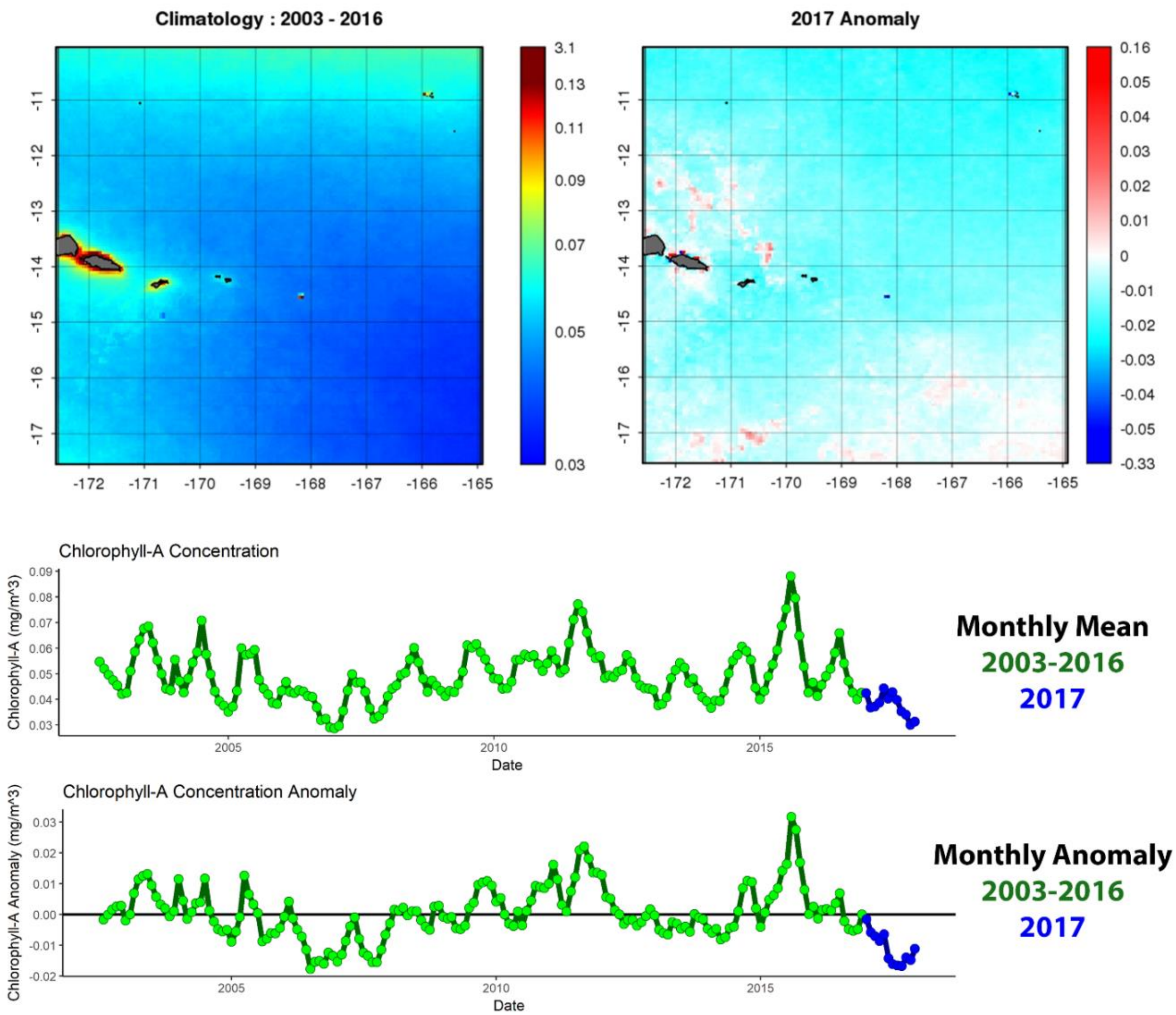




**Figure 16. Chlorophyll-A (Chl-A) and Chl-A Anomaly from 2003-2017.**

#### 2.5.3.8 Heavy Weather (Tropical Cyclones & Storm-Force Winds)

Description: This indicator uses historical data from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) International Best Track Archive for Climate Stewardship (IBTrACS; Knapp *et al.,* 2010) to track the number of tropical cyclones in the western, central, and south Pacific basins. This indicator also monitors the Accumulated Cyclone Energy (ACE) Index, one way of monitoring the strength and duration of tropical cyclones based only on wind speed measurements.

The annual frequency of storms passing through the Pacific basin is tracked and a stacked time series plot shows the representative breakdown of the Saffir-Simpson hurricane categories. Three solid color groups in the graph represent a) the annual number of named storms, b) the annual number of typhoons, and c) the annual number of major typhoons (Cat 3 and above).

Every cyclone has an ACE Index value, which is a computed value based on the maximum wind speed measured at six-hourly intervals over the entire time that the cyclone is classified as at least a tropical storm (wind speed of at least 34 knot; 39 mph). Therefore, a storm's ACE Index value accounts for both strength and duration. This plot shows the historical ACE values for each typhoon season and has a solid line representing the 1981-2010 average ACE value.

In addition, we also plot the percentage occurrence of "storm-force" winds, wind occurrences greater than, or equal to, 34 knots since 1980 in the three sub-regions. The value of 34 knots represents "Gale, fresh gale" on the Beaufort scale, which corresponds to 5-8 m wave heights and boating becomes very challenging. Characterizing the percent occurrence of these gale-force winds gives an indication of storminess5 frequency within each sub-region. Indeed, slight increases in the frequency of gale-force winds are noted in both the South and Western Pacific basins, while a downward trend is evident in the Central Pacific. (Marra *et al.,* 2017)

Timeframe: Yearly.

Region/Location: Hawaii and U.S. Affiliated Pacific Islands.

Data Source/Responsible Party: NCEI's International Best Track Archive for Climate Stewardship (IBTrACS).

Measurement Platform: Satellite.

Rationale: The effects of tropical cyclones are numerous and well-known. At sea, storms disrupt and endanger shipping traffic as well as fishing effort and safety. The Hawaii longline fishery, for example, had serious problems between August and November 2015 with vessels dodging storms at sea, delayed departures and inability to make it safely back to Honolulu because of bad weather. When cyclones encounter land, their intense rains, and high winds can cause severe property damage, loss of life, soil erosion, and flooding. The associated storm surge, the large volume of ocean water pushed toward shore by the cyclone's strong winds, can cause severe flooding and destruction.

Neither the Pacific ENSO Applications Climate Center nor the Bulletin of the AMS has yet published their annual tropical cyclone report covering the central or south pacific in 2017.

While reports on activity during 2017 are not yet available for the south and central pacific, the NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2017, published online January 2018, notes that "The 2017 East Pacific hurricane season had 18 named storms, including nine hurricanes, four of which became major." The 1981-2010 average number of named storms in the East Pacific was 16.5, with 8.9 hurricanes, and 4.3 major hurricanes. Five Eastern Pacific tropical cyclones made landfall in 2017. Tropical Storm Selma made landfall in El Salvador and tropical storms Beatrix, Calvin, Lidia and Hurricane Max made landfall in Mexico. Tropical Storm Selma was the first named tropical cyclone on record to make landfall in El Salvador. Tropical Storm Adrian formed on May 9th, marking the earliest occurrence of a named storm in the East Pacific basin. The previous earliest occurrence was Tropical Storm Alma forming on May 12, 1990. For the first year since 2012 no tropical cyclones passed near the Hawaiian Islands. The ACE index for the East Pacific basin during 2016 was 98 ($x10^4$ $knots^2$), which is below the 1981-2010 average of 132 ($x10^4$ $knots^2$), and the lowest since 2013." Inserted from: https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713.

#### 2.5.3.8.1 References


NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2017, published online January 2018, retrieved on March 30, 2018. Accessed from http://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713.

Kanamitsu, M., Ebisuzaki, W., Woollen, J., Yang, S.K., Hnilo, J.J., Fiorino, M. and Potter, G.L., 2002. NCEP–DOE AMIP-II Reanalysis (R-2), *B. Am. Meteorol. Soc.*, *83*, pp. 1631–1643, https://doi.org/10.1175/BAMS-83- 11-1631.

Knapp, K.R., M.C. Kruk, D.H. Levinson, H.J. Diamond, and C.J. Neumann, 2010: The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bulletin of the American Meteorological Society*, *91*, pp. 363-376. doi:10.1175/2009BAMS2755.1.

State of Environmental Conditions in Hawaii and the U.S. Affiliated Pacific Islands under a Changing Climate, 2017. Coordinating Authors: J.J. Marra and M.C. Kruk. Contributing Authors: M. Abecassis; H. Diamond; A. Genz; S.F. Heron; M. Lander; G. Liu; J. T. Potemra; W.V. Sweet; P. Thompson; M.W. Widlansky; and P. Woodworth-Jefcoats. September, 2017. NOAA NCEI.

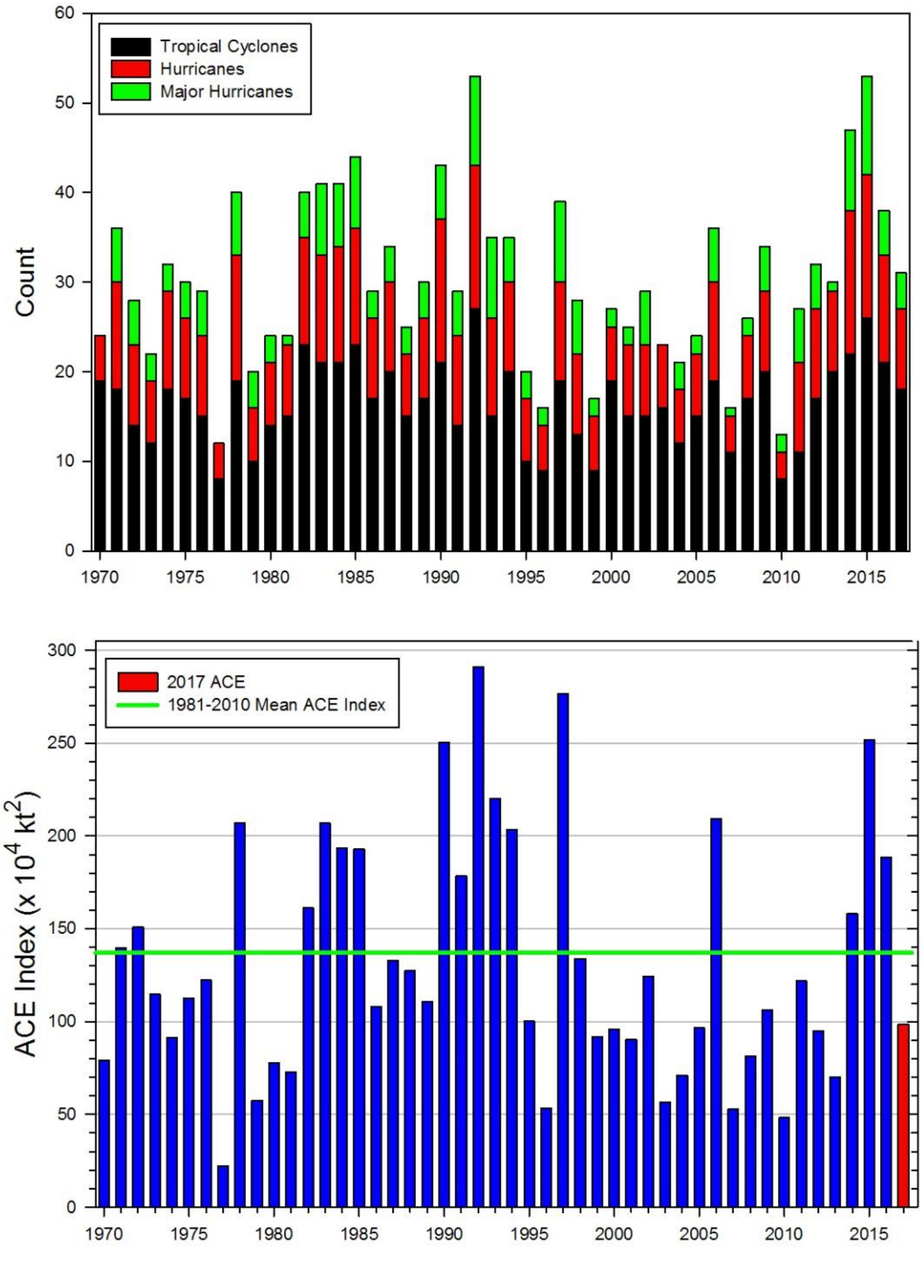



**Figure 17. Annual Patterns of Tropical Cyclones in the Eastern Pacific from 1970-2017 with 1981-2010 mean superimposed (sourced from NOAA's National Hurricane Center).**

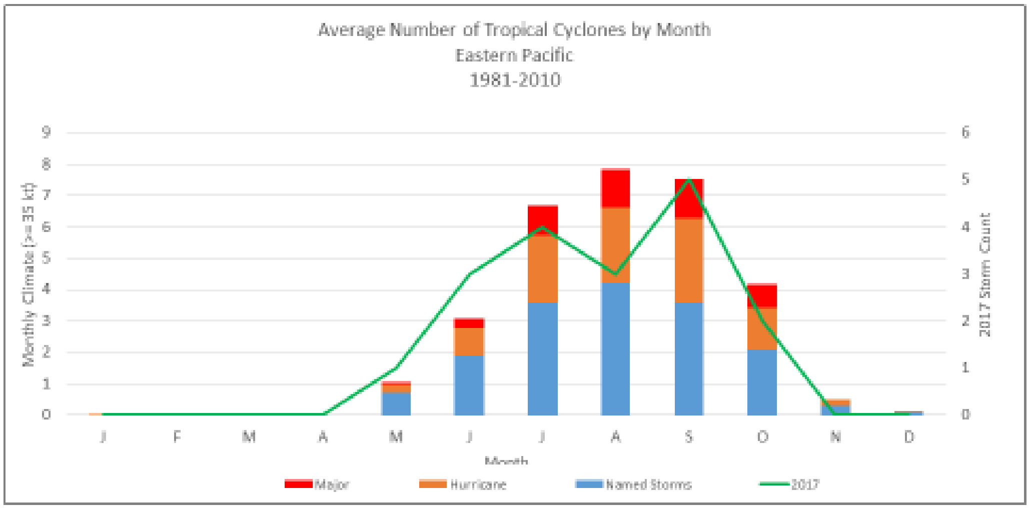



**Figure 18. Seasonal Climatology of Tropical Cyclones in the Eastern Pacific from 1981-2010 with 2017 storms superimposed (sourced from NOAA's National Hurricane Center).**

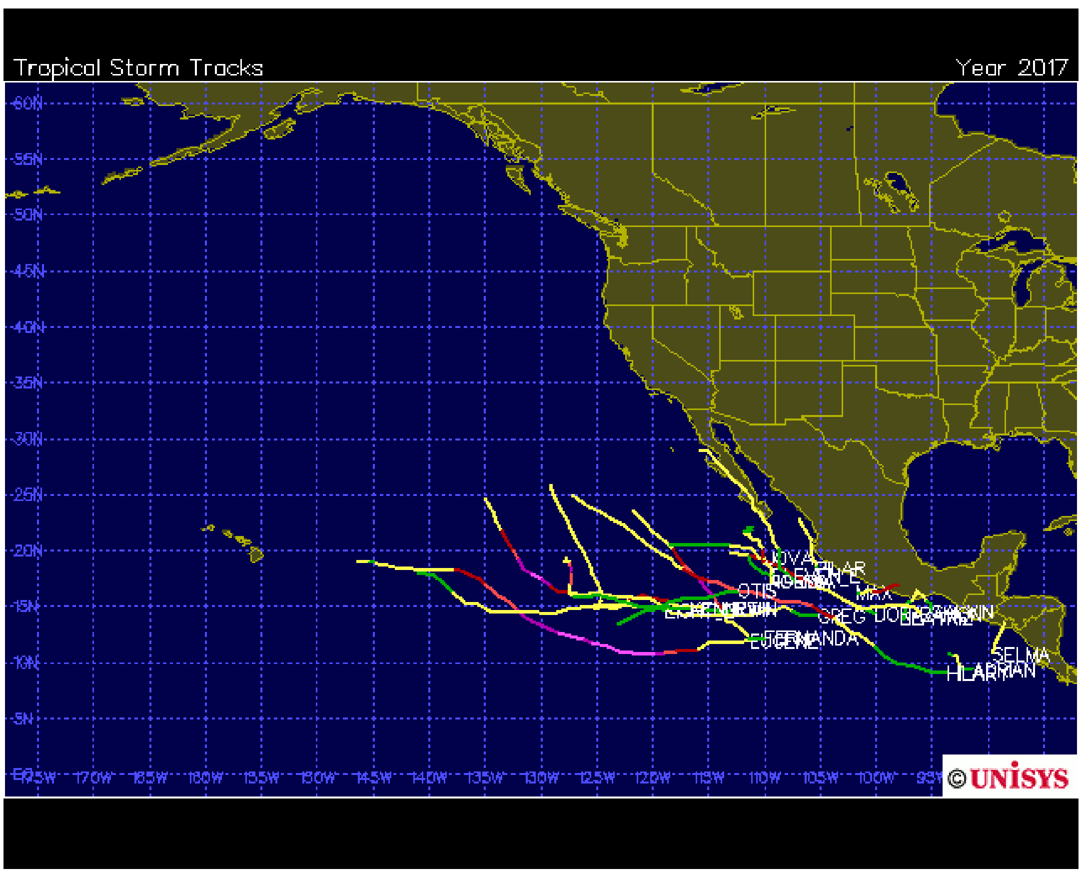



**Figure 19. Eastern Pacific Cyclone Tracks in 2017.**

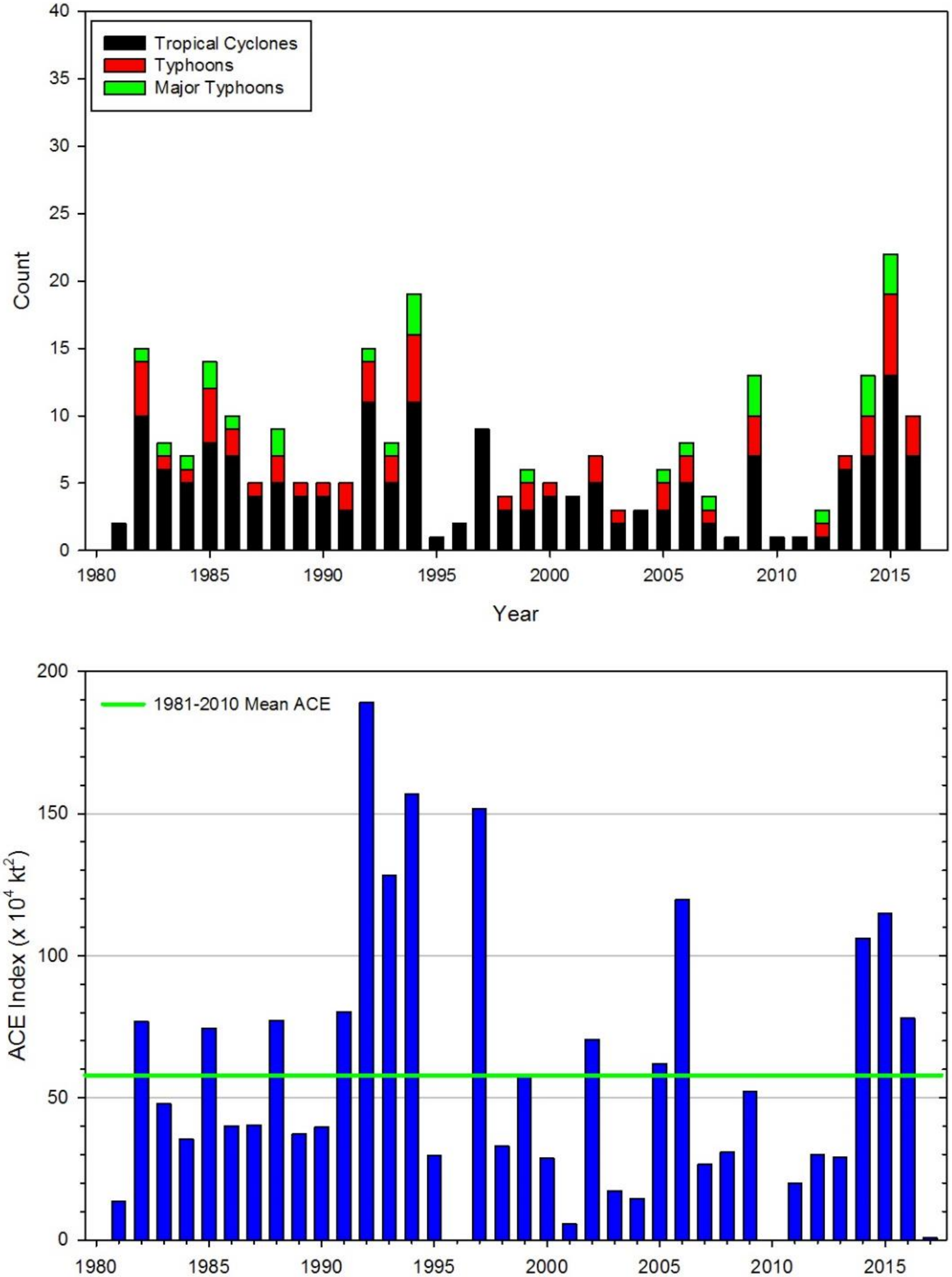



**Figure 20. Annual Patterns of Tropical Cyclones in the Central Pacific, 1980-2017, with 1981-2010 mean superimposed (sourced from NOAA's National Hurricane Center).**

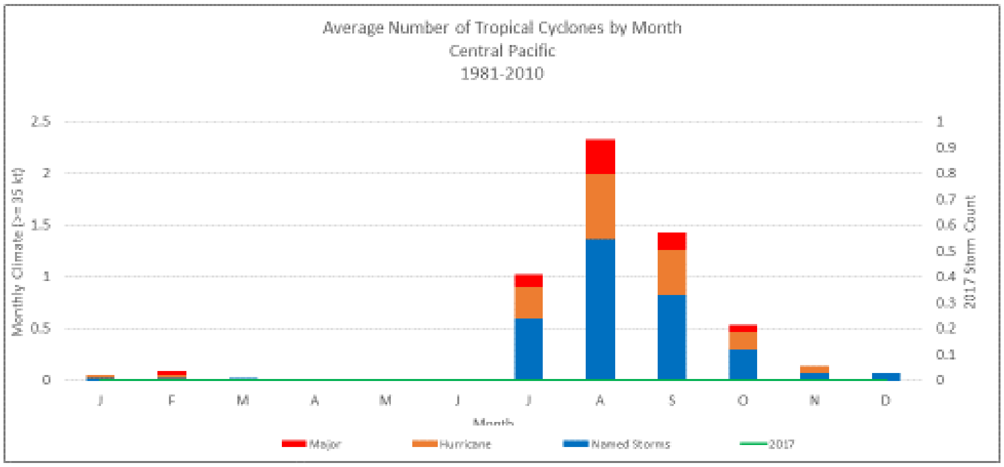



**Figure 21. Seasonal Climatology of Tropical Cyclones in the Central Pacific, 1981-2010, with 2017 storms (zero) superimposed (sourced from NOAA's National Hurricane Center).**

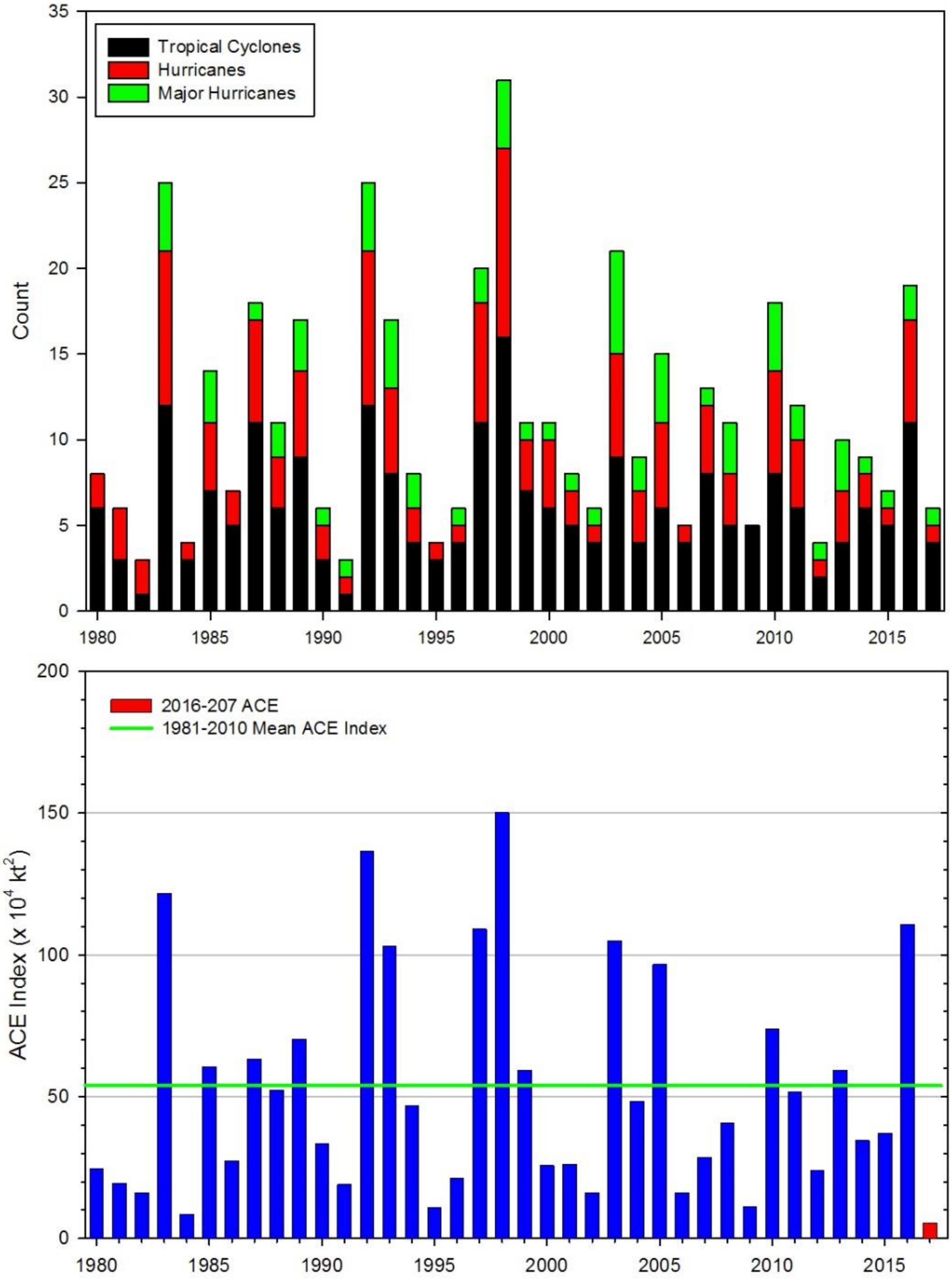



**Figure 22. Annual Patterns of Tropical Cyclones in the South Pacific, 1980-2017, with 1981-2010 mean superimposed. Source: NOAA's National Hurricane Center.**

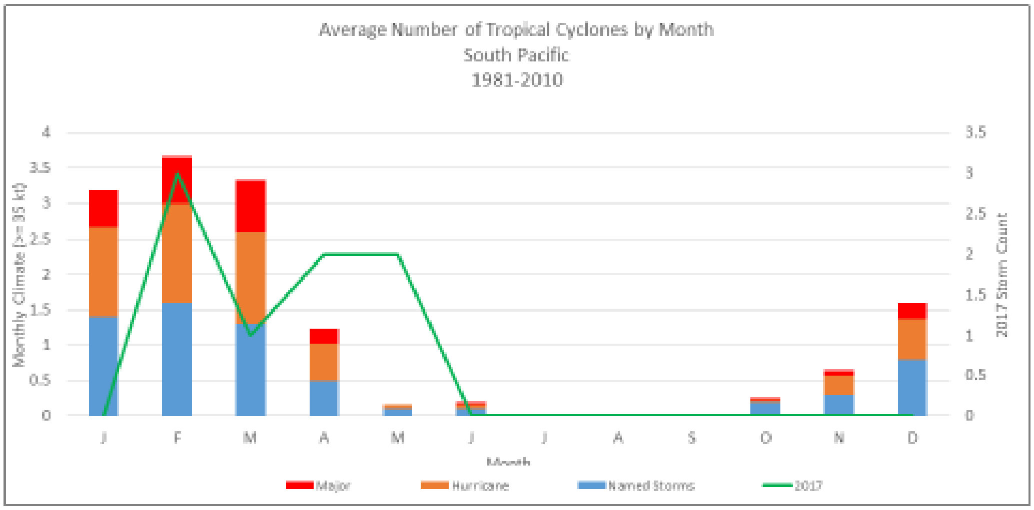



**Figure 23. Seasonal Climatology of Tropical Cyclones in the South Pacific, 1981-2010, with 2017 storms (zero) superimposed. Source: NOAA's National Hurricane Center.**

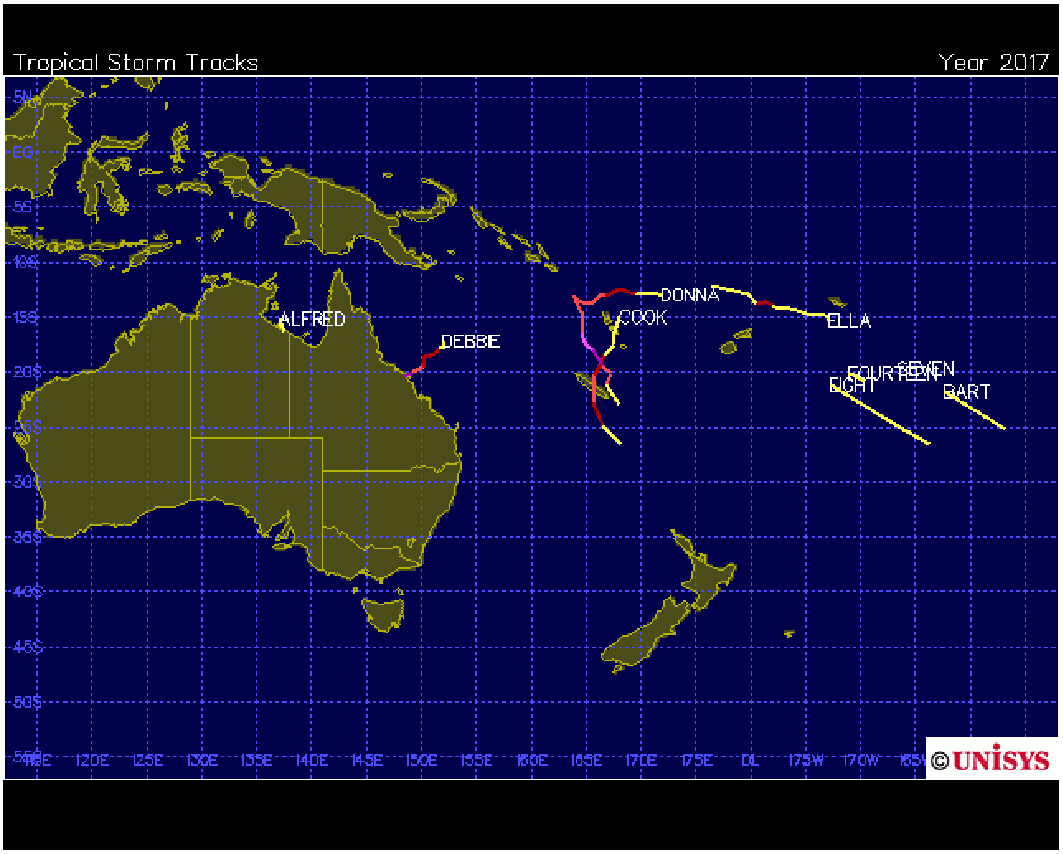



**Figure 24. South Pacific Cyclone Tracks in 2017.**

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

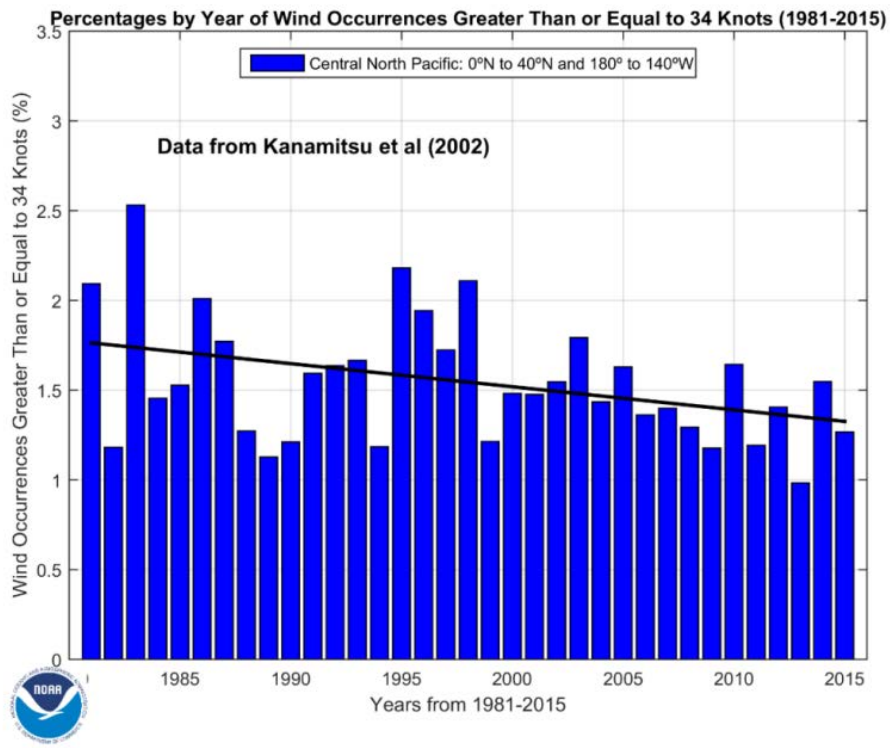



**Figure 25. Storm-Force Wind in the Central North Pacific from 1981-2015.**

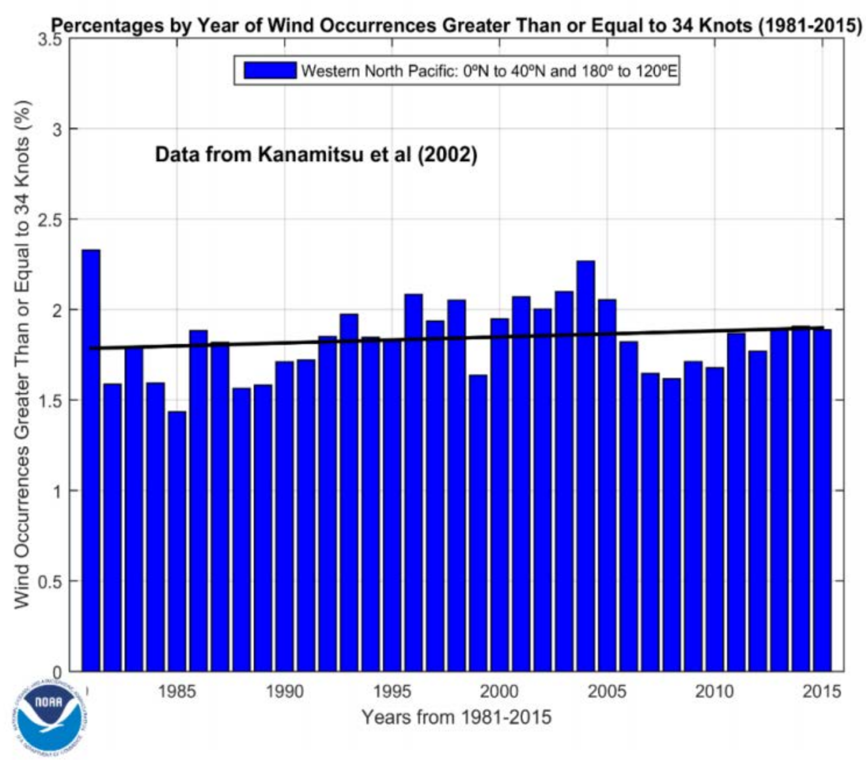



**Figure 26. Storm-Force Wind in the Western North Pacific from 1981-2015.**

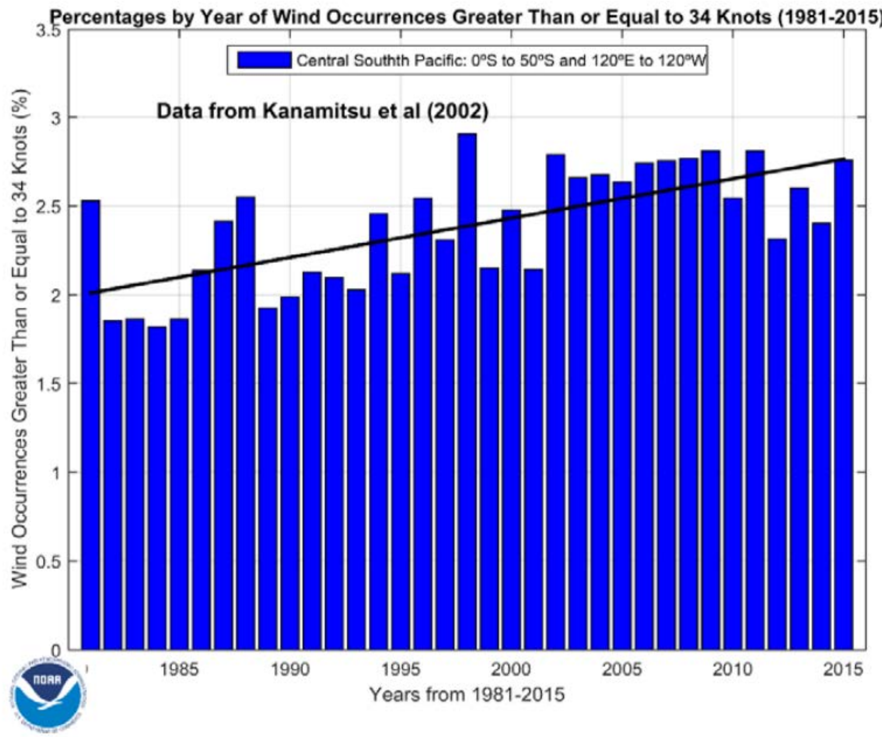



**Figure 27. Storm-Force Wind in the Central South Pacific from 1981-2015.**

#### 2.5.3.9 Rainfall (CMAP Precipitation)

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

Description: The CPC Merged Analysis of Precipitation ("CMAP") is a technique which produces pentad and monthly analyses of global precipitation in which observations from rain gauges are merged with precipitation estimates from several satellite-based algorithms (infrared and microwave). The analyses are on a 2.5 x 2.5 degree latitude/longitude grid and extend back to 1979. These data are comparable (but should not be confused with) similarly combined analyses by the Project, which are described in Huffman *et al*. (1997).

It is important to note that the input data sources to make these analyses are not constant throughout the period of record. For example, SSM/I (passive microwave - scattering and emission) data became available in July of 1987; prior to that the only microwave-derived estimates available are from the MSU algorithm (Spencer, 1993) which is emission-based thus precipitation estimates are available only over oceanic areas. Furthermore, high temporal resolution IR data from geostationary satellites (every 3-hr) became available during 1986; prior to that, estimates from the OPI technique (Xie and Arkin, 1997) are used based on OLR from polar orbiting satellites.

The merging technique is thoroughly described in Xie and Arkin (1997). Briefly, the methodology is a two-step process. First, the random error is reduced by linearly combining the satellite estimates using the maximum likelihood method, in which case the linear combination coefficients are inversely proportional to the square of the local random error of the individual data sources. Over global land areas the random error is defined for each time period and grid location by comparing the data source with the rain gauge analysis over the surrounding area. Over oceans, the random error is defined by comparing the data sources with the rain gauge observations over the Pacific atolls. Bias is reduced when the data sources are blended in the second step using the blending technique of Reynolds (1988). Here the data output from step 1 is used to define the "shape" of the precipitation field and the rain gauge data are used to constrain the amplitude. (Text taken from: http://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.html.)

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

The monthly data set consists of two files containing monthly averaged precipitation rate values. Values are obtained from 5 kinds of satellite estimates (GPI,OPI,SSM/I scattering, SSM/I emission and MSU) and gauge data. The enhanced file also includes blended NCEP/NCAR Reanalysis Precipitation values. (Text taken from: https://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html#detail.)

Timeframe: Monthly.

Region/Location: Global.

Data Source: CMAP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at https://www.esrl.noaa.gov/psd/.

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

### 2.5.3.9.1 References

Huffman, G.J., Adler, R.F., Arkin, P., Chang, A., Ferraro, R., Gruber, A., Janowiak, J., McNab, A., Rudolf, B. and Schneider, U., 1997. The global precipitation climatology project (GPCP) combined precipitation dataset. *Bulletin of the American Meteorological Society*, *78*(1), pp.5-20.

Reynolds, R.W., 1988. A real-time global sea surface temperature analysis. *Journal of Climate*, *1*(1), pp. 75-87.

Spencer, R.W., 1993. Global oceanic precipitation from the MSU during 1979—91 and comparisons to other climatologies. Journal of Climate, 6(7), pp.1301-1326.

Xie, P. and Arkin, P.A., 1997. Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bulletin of the American Meteorological* Society, *78*(11), pp. 2539-2558.

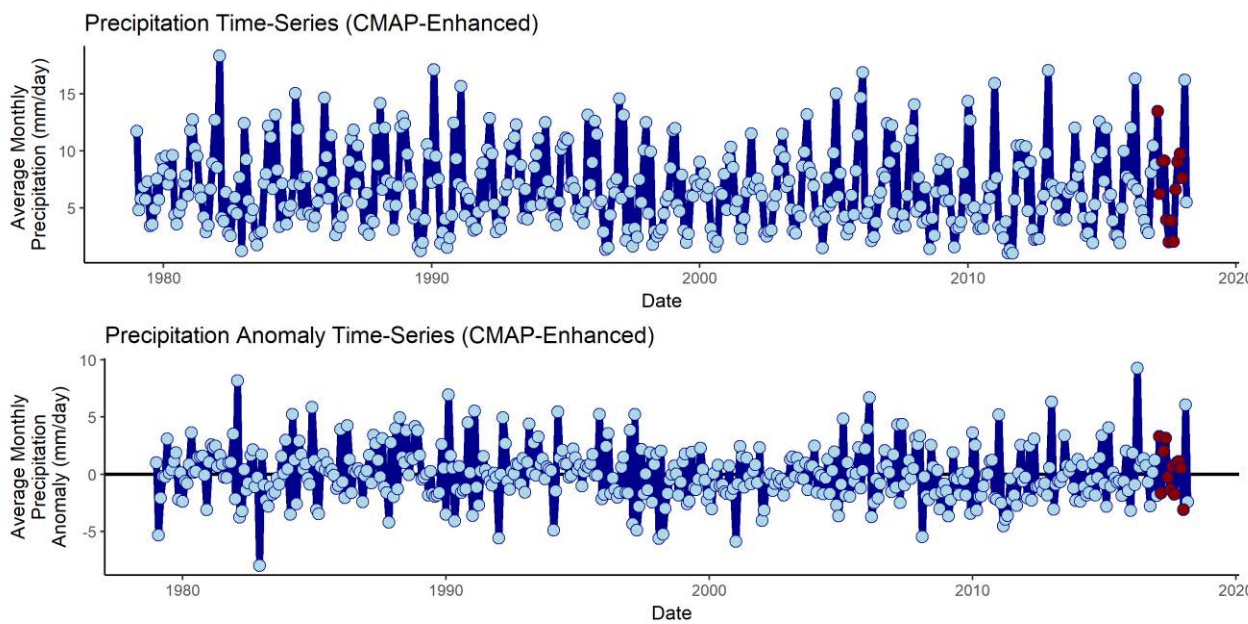



**Figure 28. CMAP precipitation across the American Samoa Longline Grid. 2017 values are in red.**

### 2.5.3.9 Sea Level (Sea Surface Height and Anomaly)

Description: Monthly mean sea level time series, including extremes

Timeframe: Monthly

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

Data Source/Responsible Party: Basin-wide context from satellite altimetry:
http://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/el-nino-bulletin.html

Quarterly time series of mean sea level anomalies from satellite altimetry:
http://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2015

Sea Surface Height and Anomaly from NOAA Ocean Service, Tides and Currents, Sea Level Trends: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1770000

Measurement Platform: Satellite and *in situ* tide gauges

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

#### 2.5.3.9.1 Basin-Wide Perspective

This image of the mean sea level anomaly for February 2016 compared to 1993-2013 climatology from satellite altimetry provides a glimpse into how the 2015-2016 El Niño continues to affect sea level across the Pacific Basin. The image captures the fact that sea level continues to be lower in the Western Pacific and higher in the Central and Eastern Pacific (a standard pattern during El Niño events. This basin-wide perspective provides a context for the location-specific sea level/sea surface height images that follow.)

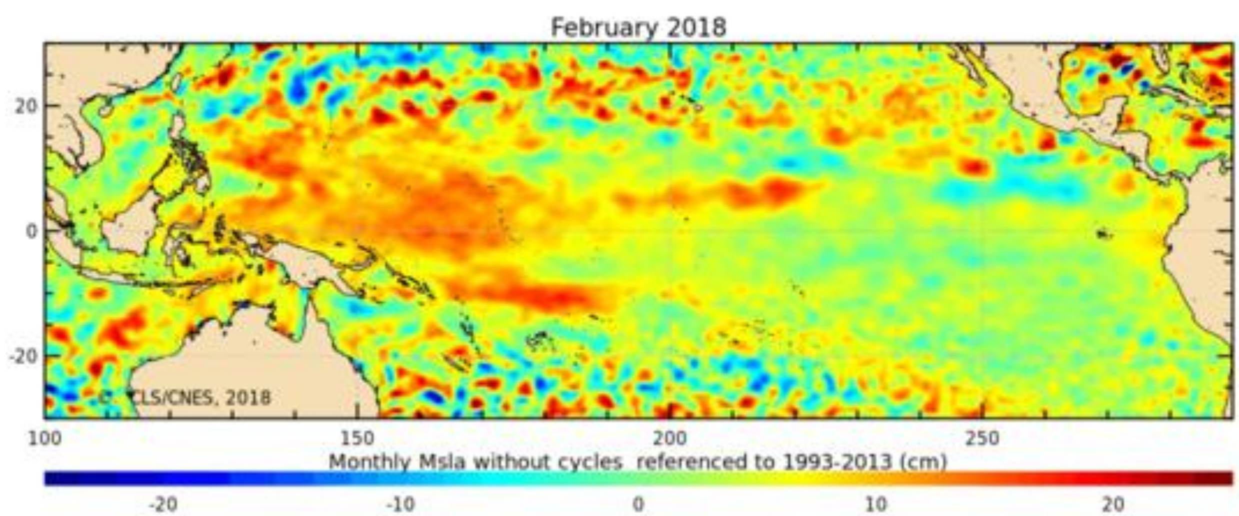



**Figure 29a. Sea surface height and anomaly.**

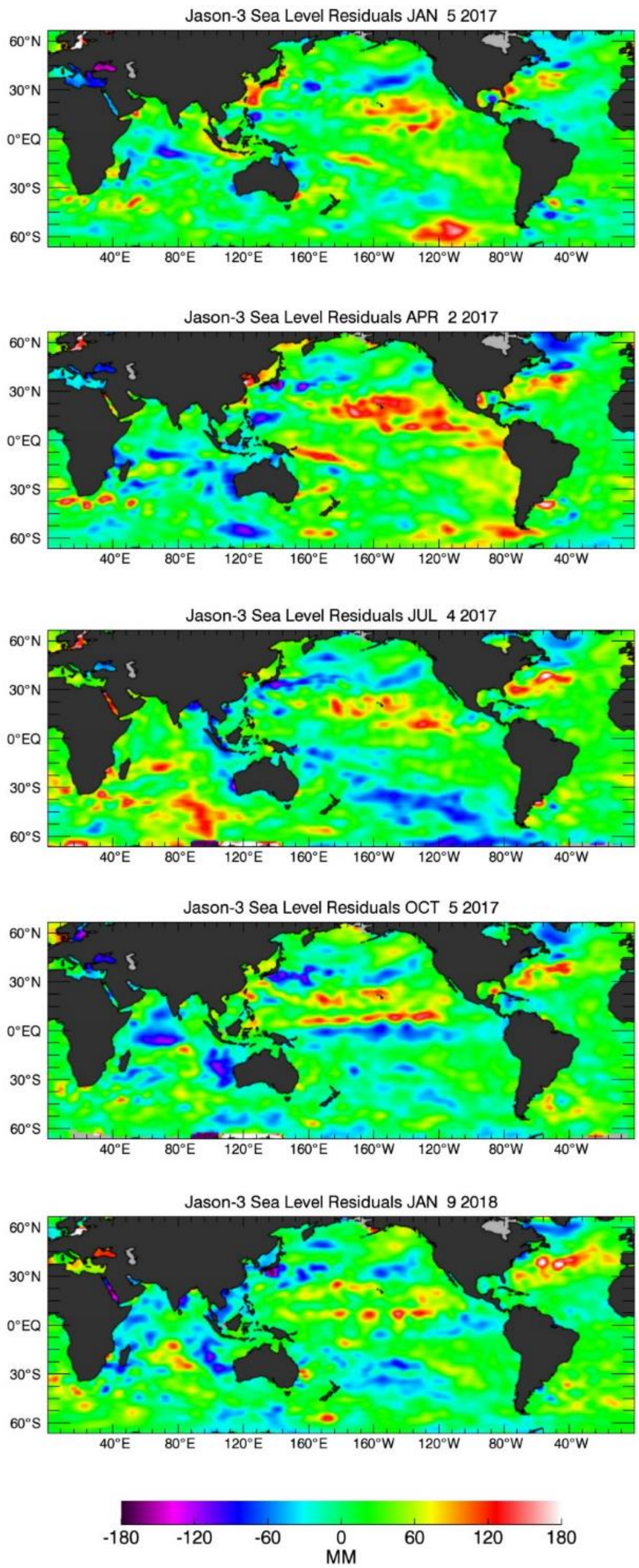
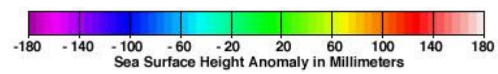



**Figure 29b.** Quarterly time series of mean sea level anomalies during 2017 show no pattern of El Niño throughout the year according to satellite altimetry measurements of sea level height (unlike 2015).

http://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2017)



#### 2.5.3.9.2 Local Sea Level

These time-series from *in situ* tide gauges provide a perspective on sea level trends within each Archipelago (Tide Station Time Series from NOAA/COOPS).

The following figures and descriptive paragraphs were inserted from https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1770000.

Figure 30 shows the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea Level datum established by CO-OPS. The calculated trends for all stations are available as a table in millimeters/year and in feet/century (0.3 meters = 1 foot). If present, solid vertical lines indicate times of any major earthquakes in the vicinity of the station and dashed vertical lines bracket any periods of questionable data or datum shift.

The monthly extreme water levels include a Mean Sea Level (MSL) trend of 2.21 millimeters/year with a 95% confidence interval of +/- 0.81 millimeters/year based on monthly MSL data from 1948 to 2009 which is equivalent to a change of 0.73 feet in 100 years.

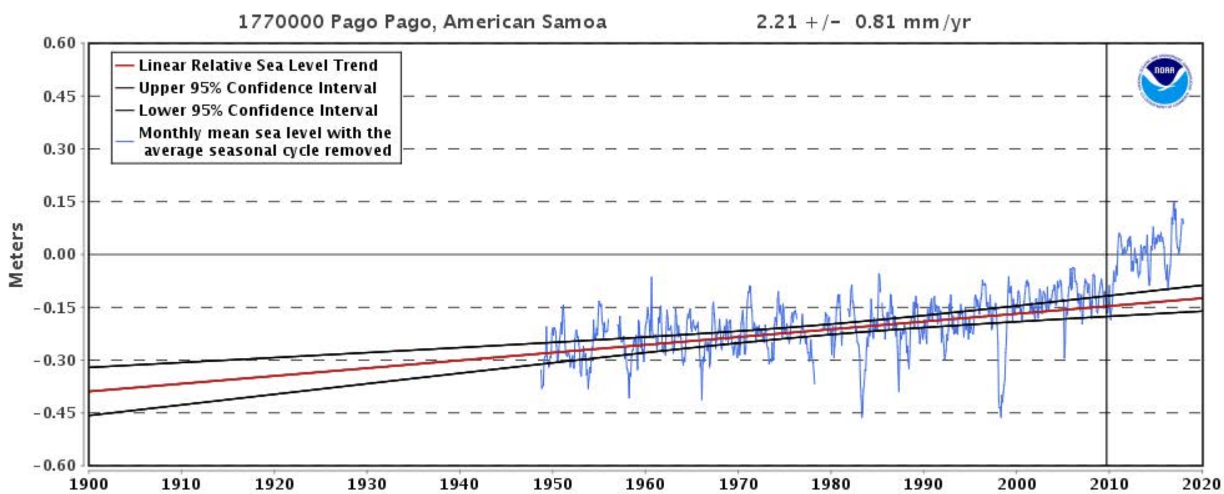



**Figure 30. Monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents.**

## 2.6 ESSENTIAL FISH HABITAT

### 2.6.1 Introduction

The Magnuson-Stevens Fishery Conservation and Management Act includes provisions concerning the identification and conservation of essential fish habitat (EFH), and under the EFH final rule, habitat areas of particular concern (HAPC) (50 Code of Federal Regulations [CFR] 600.815). The Magnuson-Stevens Act defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." HAPC are those areas of EFH identified pursuant to 50 CFR 600.815(a)(8), and meeting one or more of the following considerations: (1) ecological function provided by the habitat is important; (2) habitat is sensitive to human-induced environmental degradation; (3) development activities are, or will be, stressing the habitat type; or (4) the habitat type is rare.

The National Marine Fisheries Service (NMFS) and regional Fishery Management Councils (Councils) must describe and identify EFH in fishery management plans (FMPs), minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. Federal agencies that authorize, fund, or undertake actions that may adversely affect EFH must consult with NMFS, and NMFS must provide conservation recommendations to federal and state agencies regarding actions that would adversely affect EFH. Councils also have the authority to comment on federal or state agency actions that would adversely affect the habitat, including EFH, of managed species.

The EFH Final Rule strongly recommends regional fisheries management councils and NMFS to conduct a review and revision of the EFH components of fisheries management plans every five years (600.815(a)(10)). The council's FEPs state that new EFH information should be reviewed, as necessary, during preparation of the annual reports by the Plan Teams. Additionally, the EFH Final Rule states "Councils should report on their review of EFH information as part of the annual Stock Assessment and Fishery Evaluation (SAFE) report prepared pursuant to §600.315(e)." The habitat portion of the annual report is designed to meet the FEP requirements and EFH Final Rule guidelines regarding EFH reviews.

National Standard 2 guidelines recommend that the SAFE report summarize the best scientific information available concerning the past, present, and possible future condition of EFH described by the FEPs.

#### 2.6.1.1 EFH Information

The EFH components of fisheries management plans include the description and identification of EFH, lists of prey species and locations for each managed species, and optionally, habitat areas of particular concern. Impact-oriented components of FMPs include federal fishing activities that may adversely affect EFH; non-federal fishing activities that may adversely affect EFH; non-fishing activities that may adversely affect EFH; conservation and enhancement recommendations; and a cumulative impacts analysis on EFH. The last two components include the research and information needs section, which feeds into the Council's Five Year Research Priorities, and the EFH update procedure, which is described in the FEP but implemented in the annual report.

The Council has described EFH for five management unit species (MUS) under its management authority: pelagic (PMUS), bottomfish (BMUS), crustaceans (CMUS), coral reef ecosystem (CREMUS), and precious corals (PCMUS). The AS FEP describes EFH for the BMUS, CMUS, CREMUS, and PCMUS.

EFH reviews of the biological components, including the description and identification of EFH, lists of prey species and locations, and HAPC, consist of three to four parts:

- Updated species descriptions, which can be found appended to the SAFE report. These can be used to directly update the FEP.
- Updated EFH levels of information tables, which can be found in Section 2.6.5.
- Updated research and information needs, which can be found in Section 2.6.6. These can be used to directly update the FEP.
- An analysis that distinguishes EFH from all potential habitats used by the species, which is the basis for an options paper for the Council. This part is developed if enough information exists to refine EFH.

#### 2.6.1.2 Habitat Objectives of FEP

The habitat objective of the FEP is to refine EFH and minimize impacts to EFH, with the following subobjectives:

a. Review EFH and HAPC designations every five years based on the best available scientific information and update such designations based on the best available scientific information, when available

b. Identify and prioritize research to: assess adverse impacts to EFH and HAPC from fishing (including aquaculture) and non-fishing activities, including, but not limited to, activities that introduce land-based pollution into the marine environment.

This annual report reviews the precious coral EFH components and non-fishing impacts components, resetting the five-year timeline for review. The Council's support of non-fishing activities research is monitored through the program plan and five year research priorities, not the annual report.

#### 2.6.1.3 Response to Previous Council Recommendations

At its 170$^{th}$ meeting, the Council directed staff to develop options for refining precious corals essential fish habitat for the Council's consideration, based on the review in the 2016 SAFE report. The options paper is under development.

At its 170$^{th}$ meeting, the Council directed staff to scope the non-fishing impacts review, from the 2016 SAFE reports, through its advisory bodies. The American Samoa Regional Ecosystem Advisory Committee provided comments on the non-fishing impacts review at a meeting held October 15, 2017, in Utulei.

### 2.6.2 Habitat Use by MUS and Trends in Habitat Condition

American Samoa is made up of five high volcanic islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'u) with fringing reefs, two coral atolls (Rose Atoll or Muliava and Swains Island), and several seamounts and banks. The high islands have surrounding banks where sand can accumulate, in contrast with the Rose and Swains, where slopes plunge steeply to abyssal depths (PIFSC 2008). Tutuila is the largest island in the territory, and has banks (320 sq. km) surrounding the island that extend between one and nine km offshore (PIBHMC) and extends more than three km from shore in most places (PIFSC, 2008). The islands of Ofu, Olosega, and Ta'u make up the Manu'a Islands group, which have more limited shallow submerged banks (Figure 31). The nearshore habitat consists of narrow reef flat lagoons and fringing coral reefs (PIFSC, 2008). While the five high, volcanic islands are part of the hot-spot chain that also includes the surrounding seamounts of Muli, Vailulu'u, South Bank and independent Samoa, Swains Island is part of the Tokelau hot-spot chain (Neall and Trewick, 2008). Rose Atoll's geological origin is not well studied.

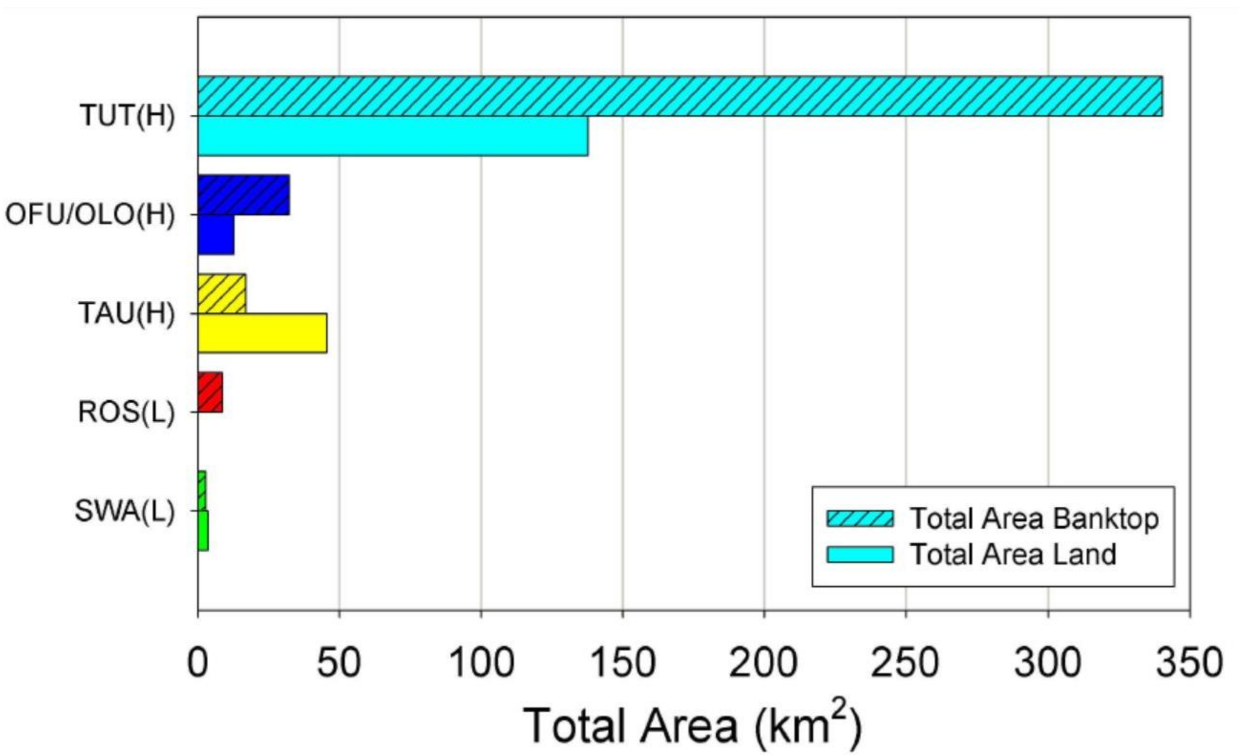



**Figure 31. Total banktop area and total terrestrial land area of Tutuila and Aunu'u (TUT), Ofu and Olosega (OFU/OLU), Ta'u (TAU), Rose (ROS), and Swains (SWA). High volcanic islands are denoted with the letter 'H', low carbonate islands/atolls with the letter 'L'.**

Essential fish habitat in the Territory of American Samoa for the four MUS comprises all substrate from the shoreline to the 700 m isobath (Figure 32). The entire water column is described as EFH from the shoreline to the 700 m isobath, and the water column to a depth of 400 m is described as EFH from the 700 m isobath to the limit or boundary of the exclusive economic zone (EEZ). While the coral reef ecosystems surrounding the islands in American Samoa have been the subject of a comprehensive monitoring program through the PIFSC Coral

Reef Ecosystem Program (CREP), the offshore banks and pelagic environment in which MSA-managed fisheries operate have been less studied. However, American Samoa's Territorial Monitoring Program has been monitoring bleaching in two backreef lagoon pools on Tutuila from Dec. 2003 to present.

The mission of the PIFSC CREP is to "provide high-quality, scientific information about the status of coral reef ecosystems of the U.S. Pacific islands to the public, resource managers, and policymakers on local, regional, national, and international levels" (PIFSC 2011). CREP's Reef Assessment and Monitoring Program (RAMP) conducts comprehensive ecosystem monitoring surveys at about 50 island, atoll, and shallow bank sites in the Western Pacific Region on a one to three year schedule (PIFSC, 2008). CRED coral reef monitoring reports provide the most comprehensive description of nearshore habitat quality in the region. The benthic habitat mapping program provides information on the quantity of habitat.

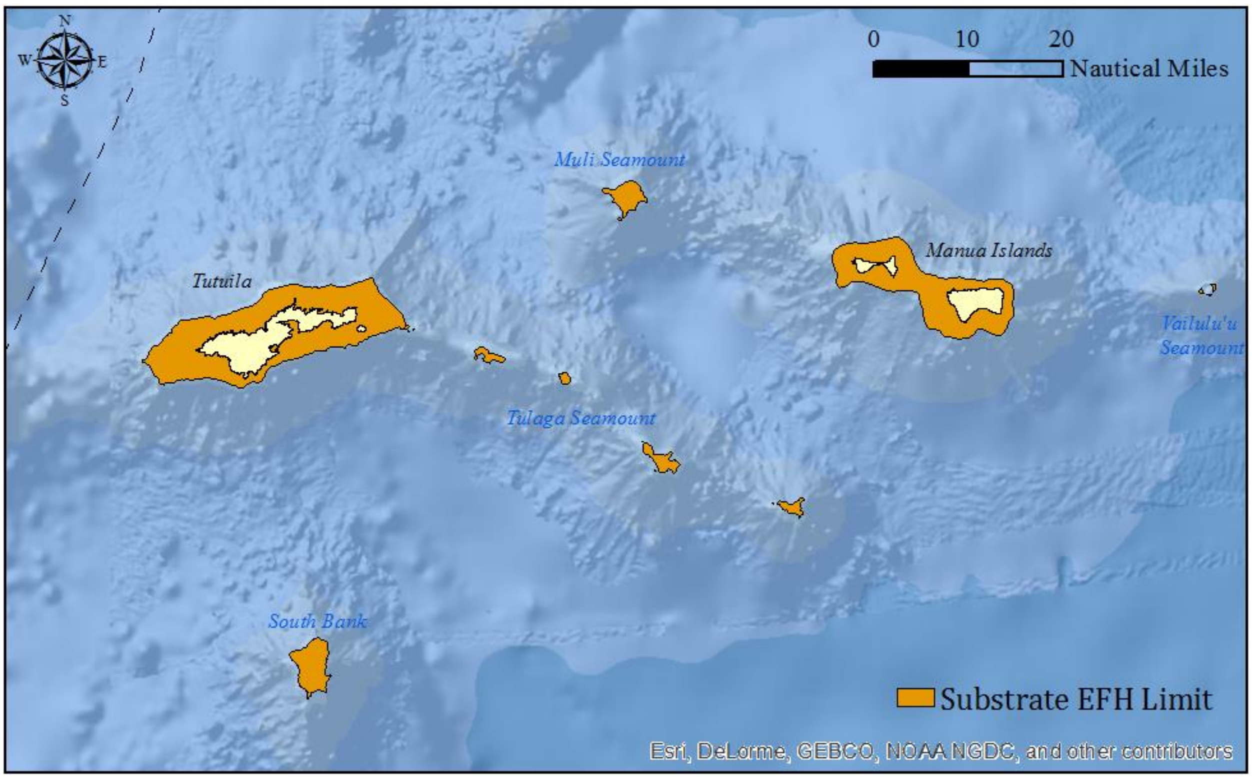



**Figure 32. Substrate EFH limit of 700 m isobath around the high islands and surrounding banks of American Samoa. Sourced from GMRT.**

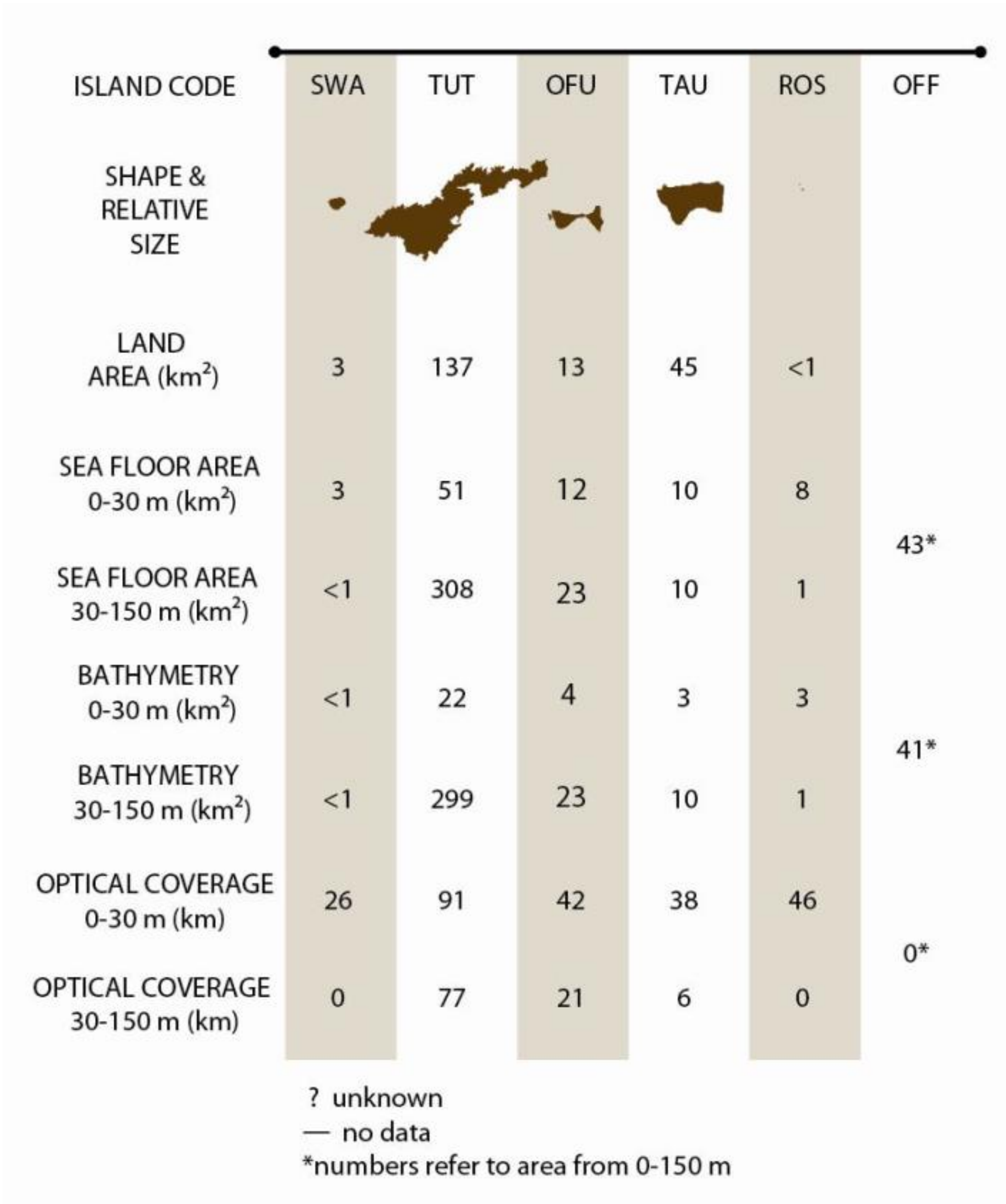
### 2.6.2.1 Habitat Mapping

Interpreted IKONOS benthic habitat maps in the 0-30 m depth range have been completed for all islands in American Samoa (CRCP, 2011). Between the PIBHMC and academically collected data, there is nearly 100% multibeam coverage of the territory between 20 and 3000 m depths (PIBHMC).

**Table 36. Summary of habitat mapping in American Samoa.**

| Depth Range | Timeframe/Mapping Product | Progress | Source |
|---|---|---|---|
| 0-30 m | 2000-2010 Bathymetry | 39% | DesRochers, 2016 |
| | IKONOS Benthic Habitat Maps | All | NCCOS Data Collections: Territory Benthic Habitat Maps |
| | 2011-2015 Satellite WorldView 2 Bathymetry | 1% | DesRochers, 2016 |
| | 2011-2015 Multibeam Bathymetry | - | DesRochers, 2016 |
| 30-150 m | 2000-2010 Bathymetry | 97% | DesRochers, 2016 |
| | 2011 – 2015 Multibeam Bathymetry | - | DesRochers, 2016 |
| 20-3000 m | Multibeam Bathymetry | Nearly 100% mapping coverage | Pacific Islands Benthic Habitat Mapping Center |

The land and seafloor area surrounding the islands of American Samoa as well as primary data coverage are reproduced from CRCP 2011 in Figure 33.



| ISLAND CODE | SWA | TUT | OFU | TAU | ROS | OFF |
|---|---|---|---|---|---|---|
| SHAPE & RELATIVE SIZE | | | | | | |
| LAND AREA (km²) | 3 | 137 | 13 | 45 | <1 | |
| SEA FLOOR AREA 0-30 m (km²) | 3 | 51 | 12 | 10 | 8 | 43* |
| SEA FLOOR AREA 30-150 m (km²) | <1 | 308 | 23 | 10 | 1 | |
| BATHYMETRY 0-30 m (km²) | <1 | 22 | 4 | 3 | 3 | 41* |
| BATHYMETRY 30-150 m (km²) | <1 | 299 | 23 | 10 | 1 | |
| OPTICAL COVERAGE 0-30 m (km) | 26 | 91 | 42 | 38 | 46 | 0* |
| OPTICAL COVERAGE 30-150 m (km) | 0 | 77 | 21 | 6 | 0 | |

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

**Figure 33. American Samoa Land and Seafloor Area and Primary Data Coverage (from CRCP, 2011).**

#### 2.6.2.1.1 Benthic Habitat

Juvenile and adult life stages of coral reef MUS and crustaceans including spiny and slipper lobsters and Kona crab extends from the shoreline to the 100 m isobath (64 FR 19067, April 19, 1999). All benthic habitat is considered EFH for crustaceans species (64 FR 19067, April 19, 1999), while the type of bottom habitat varies by family for coral reef species (69 FR 8336, February 24, 2004). Juvenile and adult bottomfish EFH extends from the shoreline to the 400 m isobath (64 FR 19067, April 19, 1999), and juvenile and adult deepwater shrimp habitat extends from the 300 m isobath to the 700 m isobath (73 FR 70603, November 21, 2008).

Table 37 shows the depths of geologic features, the occurrence of MUS EFH at that feature, and the availability of long-term monitoring data at diving depths.

**Table 37. Occurrence of EFH by feature.**

| Feature | Summit Minimum Depth | Coral Reef/Crustaceans (w/o Deepwater Shrimp) | Bottomfish | Deepwater Shrimp | Long Term Monitoring |
|---|---|---|---|---|---|
| Tutuila | Emergent | ✓ | ✓ | ✓ | ✓ |
| Manu'a Group | Emergent | ✓ | ✓ | ✓ | ✓ |
| Swains Island | Emergent | ✓ | ✓ | ✓ | ✓ |
| Rose Atoll | Emergent | ✓ | ✓ | ✓ | ✓ |
| Muli Seamount | 50 m | ✓ | ✓ | ✓ | |
| Tulaga Seamount | | ✓ | ✓ | ✓ | |
| South Bank | | ✓ | ✓ | ✓ | 2010 only |
| Vailulu'u Seamount | 580 m | | | ✓ | |

#### 2.6.2.1.2 RAMP Indicators

Benthic percent cover of coral, macroalgae, and crustose coralline algae from CRED are found in the following tables. CRED uses the benthic towed-diver survey method to monitor changes in benthic composition. In this method, "a pair of scuba divers (one collecting fish data, the other collecting benthic data) is towed about one meter above the reef roughly 60 m behind a small boat at a constant speed of about 1.5 kt. Each diver maneuvers a towboard platform, which is connected to the boat by a bridle and towline and outfitted with a communications telegraph and various survey equipment including a downward-facing digital SLR camera (Canon EOS 50D, Canon Inc., Tokyo). The benthic towed diver records general habitat complexity and type (e.g., spur and groove, pavement), percent cover by functional-group (hard corals, stressed corals, soft corals, macroalgae, crustose coralline algae, sand, and rubble) and for macroinvertebrates (crown-of-thorns sea stars, sea cucumbers, free and boring urchins, and giant clams).

Towed-diver surveys are typically 50 min long and cover about two to three km of habitat. Each survey is divided into five-minute segments, with data recorded separately per segment to allow for later location of observations within the ~200-300 meter length of each segment. Throughout each survey, latitude and longitude of the survey track are recorded on the small boat using a GPS; and after the survey, diver tracks are generated with the GPS data and a layback algorithm that accounts for position of the diver relative to the boat. (PIFSC Website, 2016).

**Table 38. Mean percent cover of live coral from RAMP sites collected from towed-diver surveys in American Samoa.**

| Year | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2015 |
|---|---|---|---|---|---|---|---|
| Ofu & Olosega | 18.1 | 14.21 | 17.76 | 21.21 | 18.88 | 31.43 | 38.4 |
| Rose | 26.23 | 24.2 | 17.99 | 17.83 | 14.45 | 23.83 | 27.8 |
| South Bank | | | | | 2.09 | | |
| Swains | 59.92 | 32.36 | 43.91 | 37.5 | 31.82 | 53.13 | 39.54 |
| Tau | 28.39 | 23.35 | 19.04 | 20.22 | 18.21 | 29.93 | 35.22 |
| Tutuila | 26.17 | 18.93 | 13.52 | 19.75 | 18.2 | 27.55 | 26.56 |

**Table 39. Mean percent cover of macroalgae from RAMP sites collected from towed-diver surveys in American Samoa.**

| Year | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2015 |
|---|---|---|---|---|---|---|---|
| Ofu & Olosega | 14.74 | 24.76 | 5.35 | 7.74 | 4.61 | 8.64 | 6.42 |
| Rose | 16.1 | 26.46 | 5.99 | 16.86 | 12.67 | 18.52 | 25.13 |
| South Bank | | | | | 26.25 | | |
| Swains | 14.6 | 26.69 | 36.07 | 30.44 | 23.8 | 27.45 | 26.69 |
| Tau | 12.43 | 30.14 | 9.15 | 7.5 | 4.12 | 5.8 | 5.59 |
| Tutuila | 12.71 | 32.38 | 10.24 | 10.49 | 7.25 | 9.17 | 11.54 |

**Table 40. Mean percent cover of crustose coralline algae from RAMP sites collected from towed-diver surveys in American Samoa.**

| Year | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2015 |
|---|---|---|---|---|---|---|---|
| Ofu & Olosega | 38.13 | 41.58 | 42.97 | 37.93 | 19.86 | 24.34 | 30.05 |
| Rose | 35.4 | 43.13 | 47.45 | 42.74 | 59.12 | 55.44 | 50.53 |
| South Bank | | | | | 1.76 | | |
| Swains | 15.29 | 30.48 | 19.4 | 17.08 | 22.76 | 24.61 | 17.08 |
| Tau | 31.83 | 21.46 | 27.7 | 29.38 | 19.72 | 20.88 | 25.25 |
| Tutuila | 17.46 | 28.23 | 17.09 | 25.25 | 17.58 | 16.94 | 18.2 |

#### 2.6.2.2 Oceanography and Water Quality

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

### 2.6.3 Report on Review of EFH Information

One EFH review was drafted this year; the review of the biological components of crustaceans EFH can be found in Appendix C.

### 2.6.4 EFH Levels

NMFS guidelines codified at 50 C.F.R. § 600.815 recommend Councils organize data used to describe and identify EFH into the following four levels:

- 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 particular managed species' life stage. The existing level of data for individual MUS in each fishery are presented in tables per fishery. In subsequent SAFE reports, each fishery section will include the description of EFH method used to assess the value of the habitat to the species, description of data sources used if there was analysis; and description of method for analysis.

Levels of EFH Information are presented in this section first with databases that include observations of multiple species, separated by depth, and then by current or former MUS grouping.

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

#### 2.6.4.1 Precious Corals

Essential Fish Habitat for precious corals was originally designated in Amendment 4 to the Precious Corals Fishery Management Plan (64 FR 19067, April 19, 1999), using the level of data found in the table. EFH was not designated in American Samoa. There has been very little survey effort to identify precious corals in the management area of the American Samoa FEP.

**Table 41. Level of EFH information available for Western Pacific precious corals management unit species from the Hawaiian Islands.**

| Species | Pelagic phase (larval stage) | Benthic phase | Source(s) |
|---|---|---|---|
| **Pink Coral (*Corallium)*** | | | |
| *Pleurocorallium secundum* (prev. *Corallium secundum)* | 0 | 1 | Figueroa & Baco, 2014<br>HURL Database |
| *C. regale* | 0 | 1 | HURL Database |
| *Hemicorallium laauense (prev. C. laauense)* | 0 | 1 | HURL Database |
| **Gold Coral** | | | |
| *Kulamanamana haumeaae* | 0 | 1 | Sinniger, *et al.* (2013)<br>HURL Database |
| *Callogorgia gilberti* | 0 | 1 | HURL Database |
| *Narella* spp. | 0 | 1 | HURL Database |
| **Bamboo Coral** | | | |
| *Lepidisis olapa* | 0 | 1 | HURL Database |
| *Acanella* spp. | 0 | 1 | HURL Database |
| **Black Coral** | | | |
| *Antipathes griggi* (prev. *Antipathes dichotoma)* | 0 | 2 | Opresko, 2009<br>HURL Database |
| *A. grandis* | 0 | 1 | HURL Database |
| *Myriopathes ulex* (prev. *A. ulex)* | 0 | 1 | Opresko, 2009<br>HURL Database |

#### 2.6.4.2 Bottomfish and Seamount Groundfish

Essential Fish Habitat for bottomfish and seamount groundfish was originally designated in Amendment 6 to the Bottomfish and Seamount Groundfish FMP (64 FR 19067, April 19, 1999).

**Table 42. Level of EFH information available for the Western Pacific BMUS and seamount groundfish management unit species complex.**

| Life History Stage | Eggs | Larvae | Juvenile | Adult |
|---|---|---|---|---|
| Bottomfish: (scientific/English common) | | | | |
| *Aphareus rutilans* (red snapper/silvermouth) | 0 | 0 | 0 | 2 |
| *Aprion virescens* (gray snapper/jobfish) | 0 | 0 | 1 | 2 |
| *Caranx ignoblis* (giant trevally/jack) | 0 | 0 | 1 | 2 |
| *C. lugubris* (black trevally/jack) | 0 | 0 | 0 | 2 |
| *Epinephelus faciatus* (blacktip grouper) | 0 | 0 | 0 | 1 |

| Life History Stage | Eggs | Larvae | Juvenile | Adult |
|---|---|---|---|---|
| *E. quernus* (sea bass) | 0 | 0 | 1 | 2 |
| *Etelis carbunculus* (red snapper) | 0 | 0 | 1 | 2 |
| *E. coruscans* (red snapper) | 0 | 0 | 1 | 2 |
| *Lethrinus amboinensis* (ambon emperor) | 0 | 0 | 0 | 1 |
| *L. rubrioperculatus* (redgill emperor) | 0 | 0 | 0 | 1 |
| *Lutjanus kasmira* (blueline snapper) | 0 | 0 | 1 | 1 |
| *Pristipomoides auricilla* (yellowtail snapper) | 0 | 0 | 0 | 2 |
| *P. filamentosus* (pink snapper) | 0 | 0 | 1 | 2 |
| *P. flavipinnis* (yelloweye snapper) | 0 | 0 | 0 | 2 |
| *P. seiboldi* (pink snapper) | 0 | 0 | 1 | 2 |
| *P. zonatus* (snapper) | 0 | 0 | 0 | 2 |
| *Pseudocaranx dentex* (thicklip trevally) | 0 | 0 | 1 | 2 |
| *Seriola dumerili* (amberjack) | 0 | 0 | 0 | 2 |
| *Variola louti* (lunartail grouper) | 0 | 0 | 0 | 2 |
| | | | | |
| Seamount Groundfish: | | | | |
| *Beryx splendens* (alfonsin) | 0 | 1 | 2 | 2 |
| *Hyperoglyphe japonica* (ratfish/butterfish) | 0 | 0 | 0 | 1 |
| *Pseudopentaceros richardsoni* (armorhead) | 0 | 1 | 1 | 3 |

#### 2.6.4.3 Crustaceans

Essential Fish Habitat for crustaceans MUS was originally designated in Amendment 10 to the Crustaceans FMP (64 FR 19067, April 19, 1999). EFH definitions were also approved for deepwater shrimp through an amendment to the Crustaceans FMP in 2008 (73 FR 70603, November 21, 2008).

**Table 43. Level of EFH information available for the CMUS complex.**

| Life History Stage | Eggs | Larvae | Juvenile | Adult |
|---|---|---|---|---|
| Crustaceans: (english common\scientific) | | | | |
| Spiny lobster (*Panulirus marginatus*) | 2 | 1 | 1-2 | 2-3 |
| Spiny lobster (*Panulirus pencillatus*) | 1 | 1 | 1 | 2 |
| Common slipper lobster (*Scyllarides squammosus*) | 2 | 1 | 1 | 2-3 |
| Ridgeback slipper lobster (*Scyllarides haanii*) | 2 | 0 | 1 | 2-3 |
| Chinese slipper lobster (*Parribacus antarcticus*) | 2 | 0 | 1 | 2-3 |
| Kona crab (*Ranina ranina*) | 1 | 0 | 1 | 1-2 |

#### 2.6.4.4 Coral Reef

Essential Fish Habitat for coral reef ecosystem species was originally designated in the Coral Reef Ecosystem FMP (69 FR 8336, February 24, 2004). An EFH review of CREMUS will not be undertaken until the Council completes its process of re-designating certain CREMUS into the ecosystem component classification. Ecosystem component species do not require EFH designations, as they are not a managed species.

### 2.6.5 Research and Information Needs

Based, in part, on the information provided in the tables above the Council identified the following scientific data which are needed to more effectively address the EFH provisions:

#### 2.6.5.1 All FMP Fisheries

- Distribution of early life history stages (eggs and larvae) of management unit species by habitat.
- Juvenile habitat (including physical, chemical, and biological features that determine suitable juvenile habitat).
- Food habits (feeding depth, major prey species etc.).
- Habitat-related densities for all MUS life history stages.
- Growth, reproduction, and survival rates for MUS within habitats.

#### 2.6.5.2 Bottomfish Fishery

- Inventory of marine habitats in the EEZ of the Western Pacific region.
- Data to obtain a better SPR estimate for American Samoa's bottomfish complex.
- Baseline (virgin stock) parameters (CPUE, percent immature) for the Guam/CNMI deep-water and shallow-water bottomfish complexes.
- High resolution maps of bottom topography/currents/water masses/primary productivity.
- Habitat utilization patterns for different life history stages and species.

#### 2.6.5.3 Crustaceans Fishery

- Identification of post-larval settlement habitat of all CMUS.
- Identification of "source/sink" relationships in the NWHI and other regions (i.e. relationships between spawning sites settlement using circulation models, genetic techniques, etc.).
- Establish baseline parameters (CPUE) for the Guam/Northern Marinas crustacean populations.
- Research to determine habitat related densities for all CMUS life history stages in American Samoa, Guam, Hawaii, and CNMI.
- High resolution mapping of bottom topography, bathymetry, currents, substrate types, algal beds, and habitat relief.

#### 2.6.5.4 Precious Corals Fishery

- Distribution, abundance, and status of precious corals in American Samoa.

### 2.6.6 References

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Brainard, R. and Balwani, S., 2008. Coral Reef Ecosystem Monitoring Report for America Samoa: 2002-2006. NOAA Fisheries Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-08-02, 514 p.

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

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## 2.7 MARINE PLANNING

### 2.7.1 Introduction

Marine planning is a science-based tool being utilized regionally, nationally and globally to identify and address issues of multiple human uses, ecosystem health and cumulative impacts in the coastal and ocean environment. The Council's efforts to formalize incorporation of marine planning in its actions began in response to Executive Order 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes. Executive Order 13158, Marine Protected Areas (MPAs), proposes that agencies strengthen the management, protection, and conservation of existing MPAs, develop a national system of MPAs representing diverse ecosystems, and avoid causing harm to MPAs through federal activities. MPAs, or marine managed areas (MMAs) are one tool used in fisheries management and marine planning.

At its 165$^{th}$ meeting in March 2016, in Honolulu, Hawai`i, the Council approved the following objective for the FEPs: Consider the Implications of Spatial Management Arrangements in Council Decision-making. The following sub-objectives apply:

a. Identify and prioritize research that examines the positive and negative consequences of areas that restrict or prohibit fishing to fisheries, fishery ecosystems, and fishermen, such as the Bottomfish Fishing Restricted Areas, military installations, NWHI restrictions, and Marine Life Conservation Districts.
b. Establish effective spatially-based fishing zones.
c. Consider modifying or removing spatial-based fishing restrictions that are no longer necessary or effective in meeting their management objectives.
d. As needed, periodically evaluate the management effectiveness of existing spatial-based fishing zones in Federal waters.

In order to monitor implementation of this objective, this annual report includes the Council's spatially-based fishing restrictions or marine managed areas (MMAs), the goals associated with those, and the most recent evaluation. Council research needs are identified and prioritized through the 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. The National Marine Fisheries Service (NMFS) is responsible for NEPA compliance, and the Council must assess the environmental effects of ocean activities for the FEP's EFH cumulative impacts section. These are redundant efforts; therefore, this report can provide material or suggest resources to meet both mandates.

### 2.7.2 Response to Previous Council Recommendations

At its 147$^{th}$ meeting, the Council recommended a no-take area from 0-12 nautical miles around Rose Atoll with the Council to review the no-take regulations after three years. Please see the 2017 Pelagic SAFE report for an evaluation of the no-take regulations.

At its 162$^{nd}$ meeting, the Council recommended a regulatory amendment for the temporary exemption to the Large Vessel Protected Area (LVPA) by American Samoa longline limited entry permitted vessels greater than 50ft in length. The Council will review the LVPA exemption on an annual basis with regards, but not limited to, catch rates of fishery participants; small vessel participation; and fisheries development initiatives. The LVPA regulations have been vacated through legal action and Council action following the court's ruling is ongoing.

**Regarding the U.S. District Court's Decision on the LVPA exemption rule, the Council:**

6a) Directs staff to work with NMFS and NOAA General Counsel on reviewing the judge's decision and to evaluate next steps which could include requesting the Court to stay the decision pending reconsideration or appeal of the courts' decision.

6b) Directs staff to present options for consideration at the June Council meeting for a Council recommendation on any necessary or appropriate LVPA regulations.

### 2.7.3 Marine Managed Areas established under FEPs

Council-established marine managed areas (MMAs) were compiled in

Table 44 from 50 CFR § 665, Western Pacific Fisheries, the Federal Register, and Council amendment documents. Geodesic areas were calculated in square kilometers in ArcGIS 10.2. All regulated fishing areas and large MMAs, including Rose Atoll Marine National Monument, are shown in Figure 34.

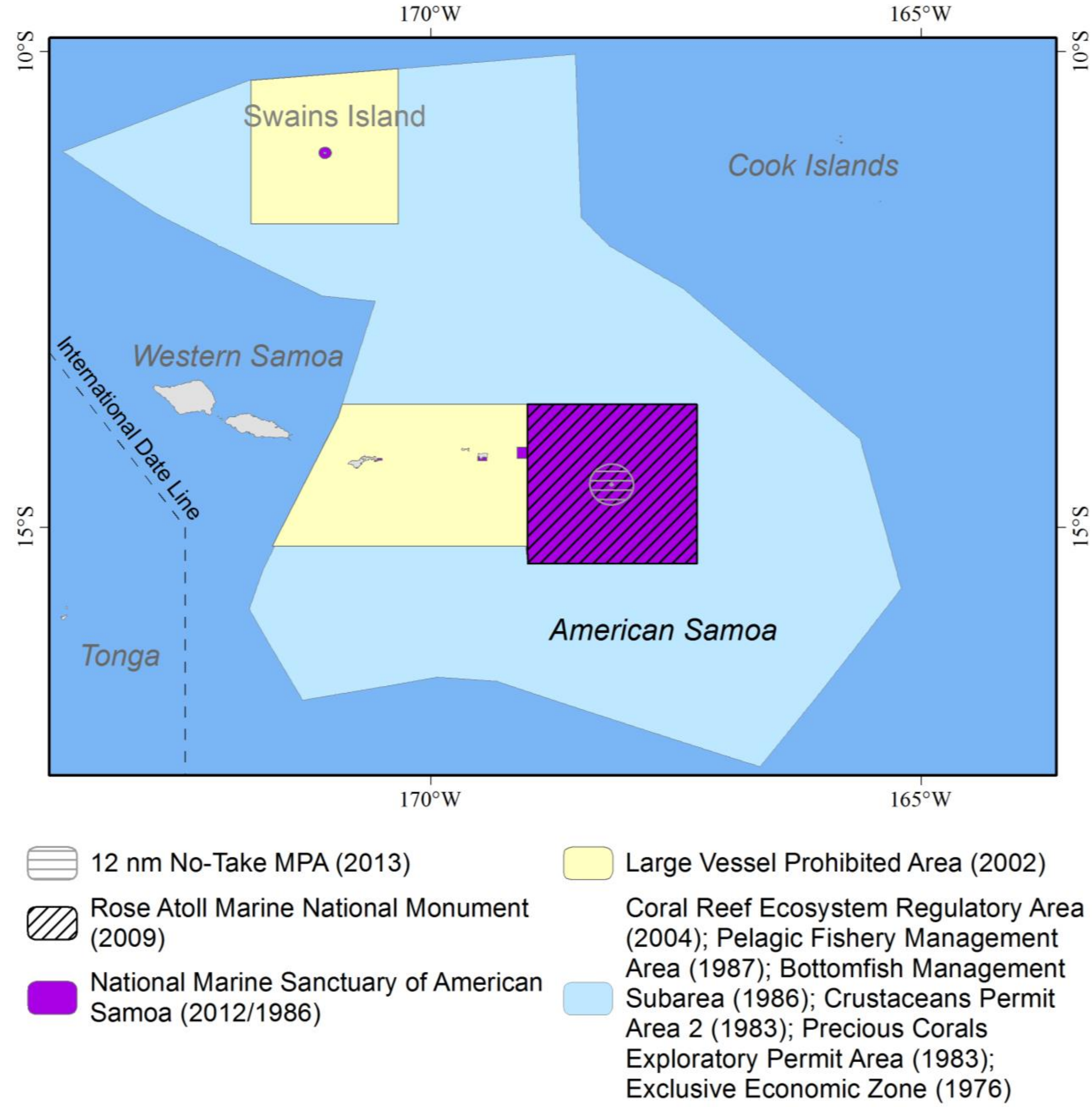


**Figure 34. Regulated fishing areas of American Samoa.**

**Table 44. MMAs established under FEPs from 50 CFR § 665.**

| Name | FEP | Island | 50 CFR /FR /Amendment Reference | Marine ($km^2$) Area | Fishing Restriction | Goals | Most Recent Evaluation | Review Deadline |
|---|---|---|---|---|---|---|---|---|
| Large Vessel Prohibited Area | Pelagic (American Samoa) | Tutuila, Manu'a , and Rose Atoll | 665.806 (b)(1) 81 FR 5619 | 74,857.32 | Vessels ≥ 50 ft. prohibited | Prevent gear conflict with smaller alia vessels; longline vessels >50 ft. exempted from 12 to 50 nm to improve the viability of the American Samoa longline fishery and achieve optimum yield from the fishery while preventing overfishing | Jan 29, 2016 | - |
| Large Vessel Prohibited Area | Pelagic (American Samoa) | Swains Island | 665.806 (b)(2) 81 FR 5619 Pelagic FEP | 28,352.17 | Vessels ≥ 50 ft. prohibited | Prevent gear conflict with smaller alia vessels; longline vessels over 50 ft. exempted between 12 and 50 nm due to improve the viability of the American Samoa longline fishery and achieve optimum yield from the fishery while preventing overfishing | Jan 29, 2016 | - |
| Rose Atoll No-Take MPA/Rose Atoll Marine National Monument | American Samoa Archipelag o/ Pelagic | Rose Atoll | 665.99 and 665.799(a)(2) 69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 American Samoa FEP Am. 3 | - | All Take Prohibited | Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nmi | June 3, 2013 | June 3, 2016 (Council to review no-take regulations after three years). PPT deferred in 2017 |

### 2.7.4 Fishing Activities and Facilities

There are no aquaculture activities occurring in the waters of American Samoa at this time.

### 2.7.5 Non-Fishing activities and Facilities

There are no alternative energy facilities or military training and testing activities occurring in the Federal or territorial waters of American Samoa at this time. The Plan Team will add to this section as new facilities are proposed and/or built.

### 2.7.6 Pacific Islands Regional Planning Body Report

The Council is a member of the Pacific Islands RPB and as such, the interests of the Council will be incorporated into the CMS plan. It is through the Council member that the Council may submit recommendations to the Pacific Islands RPB.

The Pacific Islands RPB met in Honolulu from February 14-15, 2018. The RPB's American Samoa Ocean Planning Team has completed its draft Regional Ocean Plan, on which the RPB provided comments and endorsement. CNMI and Guam Ocean Planning Teams have held their kick-off meetings. The RPB, by consensus, adopted the following goals for 2018: finalize the American Samoa Ocean Plan; continue planning in Guam and CNMI including conducting coastal and marine spatial planning training; transfer data portal prototype to permanent site and identify data gaps; and increase funding.

### 2.7.7 References

Fisheries in the Western Pacific. Title 50 *Code of Federal Regulations,* Pt. 665. Electronic Code of Federal Regulations data current as of March 16, 2016. Viewed at http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=b28abb7da3229173411daf43959fcbd1&n=50y13.0.1.1.2&r=PART&ty=HTML#_top.

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

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

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# 3 DATA INTEGRATION

## 3.1 INTRODUCTION

### 3.1.1 Potential Indicators for Insular 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 American Samoa and across the Western Pacific region (WPR). "Fishery ecosystem relationships" are those associations between various fishery-dependent data measures (e.g. catch, effort, or catch-per-unit-effort), and other environmental attributes (e.g. precipitation, sea surface temperature, primary productivity) that may contribute to observed trends or act as potential indicators of the status of prominent stocks in the fishery. These analyses represent a first step in a sequence of exploratory analyses that will be utilized to inform new assessments of what factors may be useful going forward.

To support the development of Chapter 3 of the annual SAFE report, staff from the Council, National Marine Fisheries Service (NMFS), Pacific Islands Fisheries Science Center (PIFSC), Pacific Islands Regional Offices (PIRO), and Triton Aquatics (consultants), held a SAFE Report Data Integration Workshop (hereafter, "the Workshop") convened on November 30, 2016 to identify potential fishery ecosystem relationships relevant to local policy in the WPR and determine appropriate methods to analyze them. Participants are listed in Table 45.

**Table 45. Participants of the Data Integration Workshop held in late 2016.**

| Name | Affiliation | Name | Affiliation |
|---|---|---|---|
| Keith Bigelow | PIFSC | Kevin Kelley | Consultant/PIRO |
| Chris Boggs | PIFSC | Eric Kingma | Council |
| Rusty Brainard | PIFSC | Don Kobayashi | PIFSC |
| Paul Dalzell | Council | Tom Oliver | PIFSC |
| Joshua DeMello | Council | Michael Parke | PIFSC |
| Stefanie Dukes | PIFSC | Frank Parrish | PIFSC |
| Sarah Ellgen | PIRO | Marlowe Sabater | Council |
| Jamison Gove | PIFSC | Sylvia Spalding | Council |
| Justin Hospital | PIFSC | Rebecca Walker | Council |
| Asuka Ishizaki | Council | Mariska Weijerman | PIFSC |
| Ariel Jacobs | PIRO | Ivor Williams | PIFSC |

Following background presentations and discussions regarding ecosystem-based fishery management (EBFM) and previous attempts at data integration, participants were segregated into two smaller working groups to brainstorm island and pelagic fishery and environmental/ecological relationships that may be of use in this section. Several guided questions were provided for every combination of variables:

- What can we reasonably expect to learn from or monitor with the results?
- How does it inform Council decision-making, consistent with the purposes of the FEP?
- Is it part of an ongoing research initiative?

The archipelagic fisheries group developed nearly 30 potential fishery ecosystem relationships (Table 46) to examine across bottomfish, coral reef, and crustacean fisheries based on data reliability, suitability of methodology, repeatability on an annual basis, and how well analyses could potentially inform management decisions.

**Table 46. List of prioritized potential fishery ecosystem relationships in insular areas of Western Pacific island regions developed by the archipelagic fisheries group at the Data Integration Workshop.**

| **Relationships** | **FEP** | **Score** | **Rank** |
|---|---|---|---|
| Bottomfish catch/effort/CPUE/species composition and benthos/substrate (i.e. depth, structure) | All | 22 | 3 |
| Bottomfish catch/effort/ CPUE /species composition and Pacific Decadal Oscillation | All | 20 | 3 |
| Coral reef fish/fishery/biomass and temperature-derived variable | All | 20 | 3 |
| Akule/opelu and precipitation (MHI and Guam) | HI | 20 | 3 |
| Bottomfish catchability and wind speed | All | 19 | 3 |
| Coral reef fish/fishery/biomass and chlorophyll-*a* (with phase lag) | All | 19 | 3 |
| Bottomfish Catch /CPUE and lunar cycle/moon phase | All | 19 | 3 |
| Bottomfish catch/effort/ CPUE /species composition and sea-level height (eddy feature) | All | 18 | 2 |
| Coral reef fish/fishery/biomass and Pacific Decadal Oscillation | All | 18 | 2 |
| Green/red spiny lobster catch/CPUE and vertical relief | HI | 18 | 2 |
| Green/red spiny lobster catch/CPUE and Pacific Decadal Oscillation | HI | 18 | 2 |
| Bottomfish catchability and fishing conditions (i.e. surface, subsurface current, speed, and direction) | All | 17 | 2 |
| Coral reef fish/fishery/biomass and moon phase | All | 17 | 2 |
| Coral reef fish/fishery/biomass and Oceanic Niño Index | All | 17 | 2 |
| Coral reef fish/fishery/biomass and sea-level height | All | 17 | 2 |

| | | | |
|---|---|---|---|
| Coral reef fish/fishery/biomass and pH | All | 17 | 2 |
| Bottomfish catch/effort/ CPUE /species composition and temperature-derived variable (e.g. temperature at depth) | All | 16 | 2 |
| Bottomfish catch/effort/ CPUE /species composition and chlorophyll-*a* (with phase lag) | All | 16 | 2 |
| Bottomfish catch/effort/ CPUE /species composition and precipitation | All | 16 | 2 |
| Coral reef fish/fishery/biomass and structural complexity /benthic habitat | All | 16 | 2 |
| Bottomfish catch/effort/ CPUE /species composition and dissolved oxygen | All | 15 | 2 |
| Coral reef fish/fishery/biomass and precipitation | All | 14 | 2 |
| Bottomfish catch/effort/ CPUE /species composition and pH | All | 13 | 2 |
| Bottomfish catch/effort/ CPUE /species composition and predator abundance | All | 12 | 2 |
| Coral reef fish/fishery/biomass and salinity | All | 12 | 2 |
| Coral reef fish/fishery/biomass and dissolved oxygen | All | 12 | 2 |
| Bottomfish catch/effort/ CPUE /species composition and salinity | All | 10 | 1 |

To begin, this chapter will include brief descriptions of past work on fishery ecosystem relationship assessment in coral reefs of the U.S. Western Pacific, followed by initial evaluations of relationships previously recommended for analysis by participants of the Workshop using current data streams in American Samoa. The evaluations completed were exploratory in nature, and were used as the first step of analyses to know which comparisons may hold more utility going forward; they will likely undergo heavy revision before finalized in the coming year. Regardless, those relationships deemed potentially relevant were emphasized and recommended for further analysis. In subsequent years, this chapter will be updated with analyses through the SAFE report process to include more of the described climate change indicators from Section 2.5.3, and as the strength of certain fishery ecosystem relationships relevant to advancing ecosystem-based fishery management are determined.

## 3.2 2018 RECOMMENDATIONS AND DIRECTION FOR CHAPTER DEVELOPMENT

The results presented here represent the first-step in exploratory analyses looking to identify strong potential correlates to act as a foundation to be built upon for more thorough data integration analyses in the near future.

At the most recent FEP Plan Team Meeting held on April 30th – May 1st, 2018, participants were presented preliminary data integration results shown here, and provided detailed recommendations to support the ongoing development of the data integration section of the Archipelagic Annual SAFE Report. These suggestions, both general and specific, will be implemented in the coming year to ensure that more refined analyses comprise the data integration section. FEP Plan Team participants recommended that:

- CPUE data should be standardized and calculated in a more robust fashion, measuring the average catch per unit effort rate over the course of a year to analyze variance.
- Analyses of fishery performance data against environmental variables should focus on dominant gear types rather than the entirety of the fishery or other gear aggregates (e.g. purse seine harvest of *Selar crumenophthalmus* in the MHI).
- There should be additional phase lag implemented in the analyses
- Local knowledge of fishery dynamics, especially pertaining to shifting gear preferences, should be utilized. Changes in dynamics that may have impacted observed fishery trends over the course of available time series, both discreetly and long-term for taxa-specific and general changes should be emphasized.
- Spatial specificity and precision should be increased for analyses of environmental variables in relation to areas commonly fished.

At its 172nd Council meeting, the WPRFMC provided no formal recommendations. However, it was suggested by individual Council members that, in addition to implementing additional data streams when time series of sufficient length become available (e.g. bio-sampling data), that the results should be standardized in such that they can be presented as estimated potential percent change in the fishery in response to measured environmental variability.

At its 128th meeting, the Science and Statistical Committee (SSC) was also presented the preliminary data integration results shown here. Going forward, the SSC suggested the use of multivariate assessment in the form of Structural Equation Models to determine difference in parameters between years, but there existed disagreement as to whether these analyses should be used only as precedence for more thorough univariate assessments. Additionally, it was suggested that examining the potential fishery ecosystem relationships from an energetics perspective may emphasize changes in the fishery associated with ecological change. However, it was noted that such relationships between fishery and environmental parameters, if they exist, may already be (or should already be) represented in prevailing stock assessments.

Incorporating such recommendations into the 2018 version of the Annual SAFE Report will mark the beginning of a standardized process to implement current data integration analyses on an annual basis. Doing so will promote more proactive management action with respect to ecosystem-based fishery management objectives.

## 3.3 PAST WORK

Richards *et al.* (2012) performed a study on a range environmental factors that could potentially affect the distribution of large-bodied coral reef fish in Mariana Archipelago. Large-bodied reef fish were determined to typically be at the greatest risk of overfishing, and their distribution in the region was shown to be negatively associated with human population density. Additionally, depth, sea surface temperature (SST), and distance to deep water were identified as important environmental factors to large-bodied coral reef fish, whereas topographic complexity, benthic habitat structure, and benthic cover had little association with reef fish distribution in the Mariana Archipelago.

Kitiona *et al.* (2016) completed a study of the impacts climate and/or ecosystem change on coral reefs fish stocks of American Samoa using climate and oceanic indicators (see Section 2.5.3). The evaluation of environmental variables showed that certain climate parameters (e.g. SST anomaly, sea level height, precipitation, and tropical storm days) are likely linked to fishery performance. It was also noted that larger natural disturbances in recent decades, such as cyclones and tsunamis, negatively impacted reef fish assemblages and lowed reef fishery CPUE in American Samoa (Ochavillo *et al*., 2012).

On a larger spatial scale, an analysis of various drivers on coral reef fish populations across 37 U.S.-affiliated islands in the Central and Western Pacific was performed by Williams *et al.* (2015), and evaluated relationships between fish biomass in these reefs with human and environmental factors. Again, reef fish assemblages were negatively associated with increasing human population density (even at relatively low levels) across the WRP, but were positively associated with elevated levels of ocean productivity across islands. The authors warned, however, that the ability of reefs surrounding uninhabited islands to maintain fish populations varies, and that high biomass observed in remote areas (e.g. the NWHI) may not necessarily be reflective of baselines or recovery response levels for all reef systems.

A common method of EBFM used in coral reef ecosystems is the implementation of biological reference points, statistical indicators of potential overfishing used to help determine how a fishery is performing relative to these points at a given time (McClanahan *et al*., 2007). Hawhee (2007) adapted this idea, generating biological reference points in the form of CPUE-based proxies to be used as indicators for reef fish stocks in the WPR. However, the devised method was determined to be inappropriate for application in management of reef stocks in the U.S. Western Pacific due to the lack of a historical CPUE to use as a baseline for the reference points and their limit thresholds (Remington and Field, 2016).

## 3.4 SEA SURFACE TEMPERATURE

Sea surface temperature (SST) is a commonly used diagnostic tool in monitoring climate change and its affects both regionally and globally, as it is representative of changes in ocean temperatures over time that can affect coastal fisheries (see Section 2.5.3). 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). Future work will utilize time series of SST described in Section 2.5.3in hopes of better integrating analyses that have already been completed as well as avoiding redundant effort. Available catch and effort data streams were supplied from creel surveys completed by the American Samoa Department of Marine and Wildlife and submitted for organization by WPacFIN. These surveys, while not able to entirely capture the noncommercial aspect of reef fisheries in the WPR, represent the best data available for these sorts of analyses. Efforts are being made to improve information streams in data-poor fisheries across the U.S. Western Pacific.

A time series of SST for American Samoa from 1989-2016 is shown in Figure 35. The SST for American Samoa over this period had relatively little variability (CV = 1.15). SST has been seemingly increasing over the course of available data, though its variability appeared to be decreasing in the last decade. This decrease followed the hottest observed temperatures in the last three decades at just over 29°C in 2005. The lowest recorded SST over the course of the time series was approximately 28°C in the first year of evaluated data.

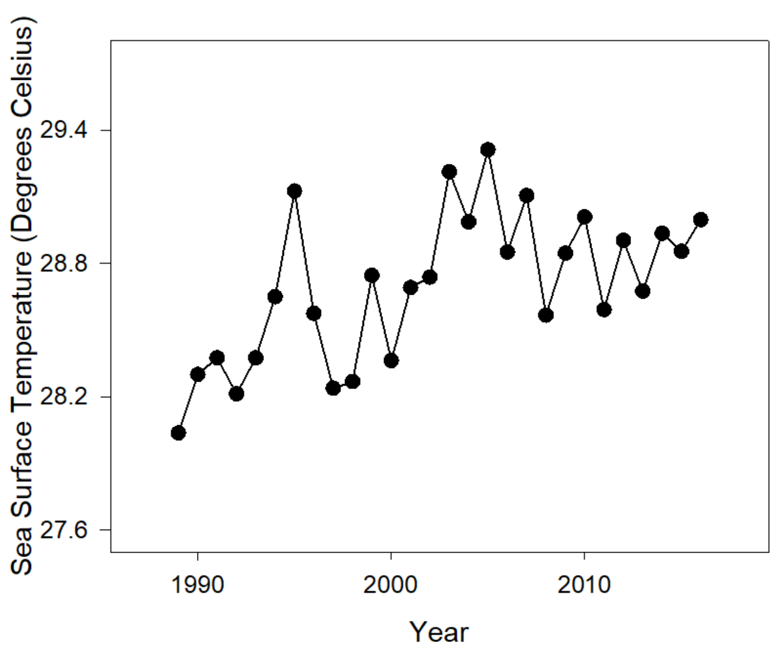


**Figure 35. Average annual SST (°C) in American Samoa from 1985-2016 (CV = 1.15).**

### 3.4.1 Evaluating relationship for entire recreational reef fishery

Figure 36 shows a plot depicting the relationship between SST and catch time series for the recreational coral reef fishery in American Samoa from 1989-2016. Landings were notably variable over the course of the time series (CV = 91.4), likely attributed to a large multi-year inflation in catch from 1993 to 2000. Total annual catch in the fishery had been observably decreasing over the last decade despite following an abrupt maximum in the late 1990s (~965,000 lbs.). Recent recorded catch levels (i.e. 2016) are among the lowest for the fishery through the available time series of data (~105,000 lbs.; Figure 36).

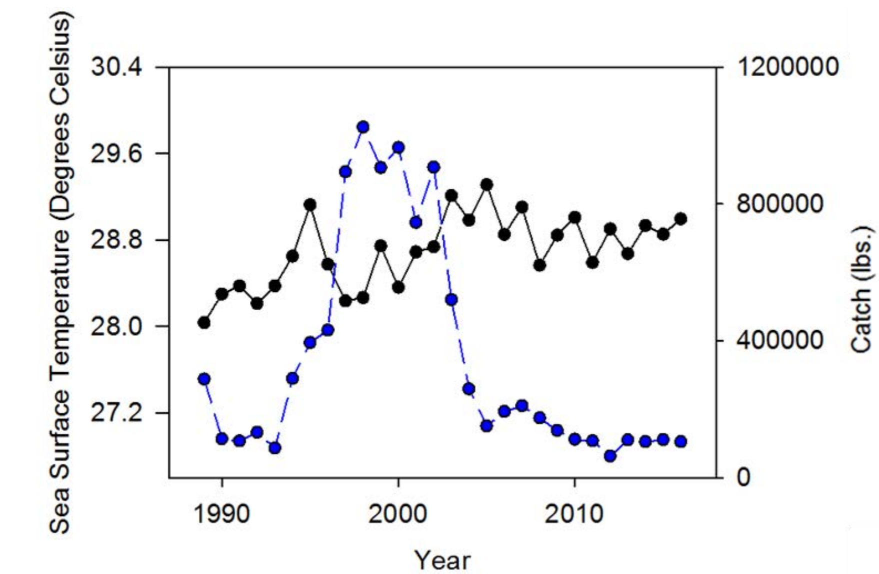


**Figure 36. Total annual catch (lbs.; blue) for the American Samoa recreational coral reef fishery plotted with average annual SST (°C; black) from 1989-2016.**

In performing comparisons between fishery parameters and environmental variables such as SST, data were grouped into categories based on family due to data scarcity for species-level analyses in many cases. Table 47 displays the different dominant family groups considered in this evaluation alongside their common names. Note that because fishery performance with respect to participation/effort has not changed in large amounts over the past three decades, analyzing the only species-level information available in terms of creel survey catch can give some indication as to the potential for a fishery ecosystem relationship.

**Table 47. Families recorded in creel survey data in the U.S. Western Pacific evaluated in these analyses.**

| 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 |

Linear regressions and correlation analyses on time series of recreational coral reef fishery catch and annual mean SST from American Samoa were performed (Table 48). Assessments measuring this potential relationship for the entirety of the recreational coral reef fishery catch in American Samoa showed no general relationship between 1989 and 2016 ($R^2 = 0.06$, p = 0.20; Table 48; Figure 37). The observed association between the two parameters appeared to associate negatively over time despite the lack of a statistically significant trend (Figure 37).

**Table 48. Correlation coefficients (*r*) between recreational coral reef fishery catch (lbs.) and SST (°C) in American Samoa for 12 taxa harvested from 1989-2016. Significant correlations are indicated in bold (α=0.05).**

| Taxa Code | Total Catch | LUTJ | LETH | CARA | ACAN | SERR | SIGA | SCAR | MULL | MUGI | LABR | HOLO | BALI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **n = 24** | | | | | | | | | | | | | |
| ***p*** | 0.20 | 0.43 | 0.24 | 0.96 | 0.052 | 0.30 | 0.78 | **0.02** | **0.03** | 0.22 | 0.78 | 0.15 | 0.17 |
| ***r*** | -0.25 | 0.17 | 0.25 | 0.01 | -0.40 | -0.22 | -0.06 | **-0.47** | **0.44** | 0.26 | -0.06 | -0.30 | 0.29 |
| ***$R^2$*** | 0.06 | 0.03 | 0.06 | 0.00 | 0.16 | 0.05 | 0.00 | **0.22** | **0.19** | 0.07 | 0.00 | 0.09 | 0.09 |

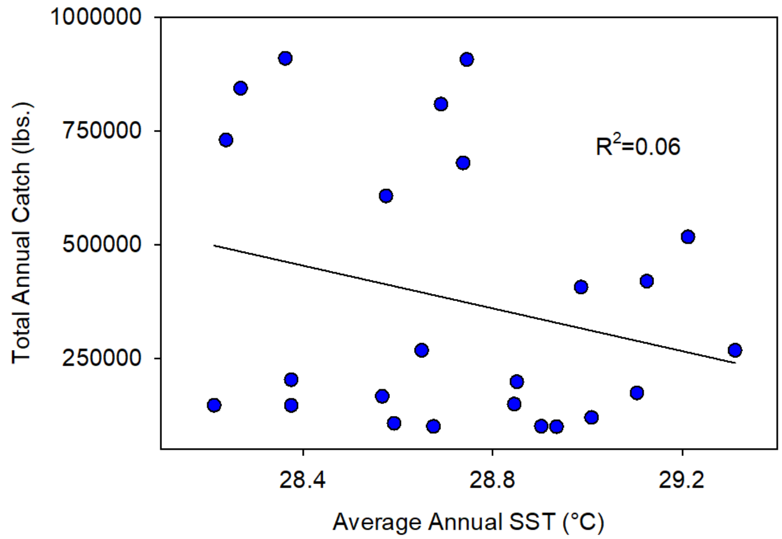


**Figure 37. Linear regression showing the correlation between total annual catch (lbs.) for the recreational coral reef fishery and average annual sea surface temperature (°C) in American Samoa from 1989-2016.**

### 3.4.2 Evaluating relationships for dominant taxa

Similar linear regressions were performed for the time series of SST with catch for dominant family groups in American Samoa as well, and it was found that two of the 12 evaluated families had statistically significant relationships with average annual temperature in the surface waters surrounding the archipelago (Table 48). The strongest relationship observed was between SST and annual Scaridae catch and negative, where the regression suggested that for every degree Celsius of temperature increase, catch would decrease by approximately 5,000 lbs. ($R^2 = 0.22$, $p = 0.02$; Table 48; Figure 38a). Note that because participation statistics could not be taken into consideration for these types of analyses on a family- and gear-specific level, it is always possible that changes in catch could be reflective of changes in effort over time that could not be observed in the available data. This section will be updated with more integrated forms of analysis in upcoming years as resources allow.

The next strongest association observed was for the Mullidae family, which was shown to have catch levels with positive statistical significance to SST such that every increase in one degree Celsius would hypothetically increase annual catch by less than 100 lbs. (~67 lbs.; $R^2 = 0.19$, $p = 0.03$; Table 48; Figure 38b) The third strongest fishery ecosystem relationship identified in this region between catch and SST was for the Acanthurids, which fell short of the threshold of significance by 0.002 ($R^2$=0.16, p=0.052; Table 48; Figure 38c). Despite the narrow miss for statistical significance at the $\alpha = 0.05$ level, the generated regression equation suggested that landings of this family would decrease by almost ~10,000 lbs. for every 1°C increase temperature.

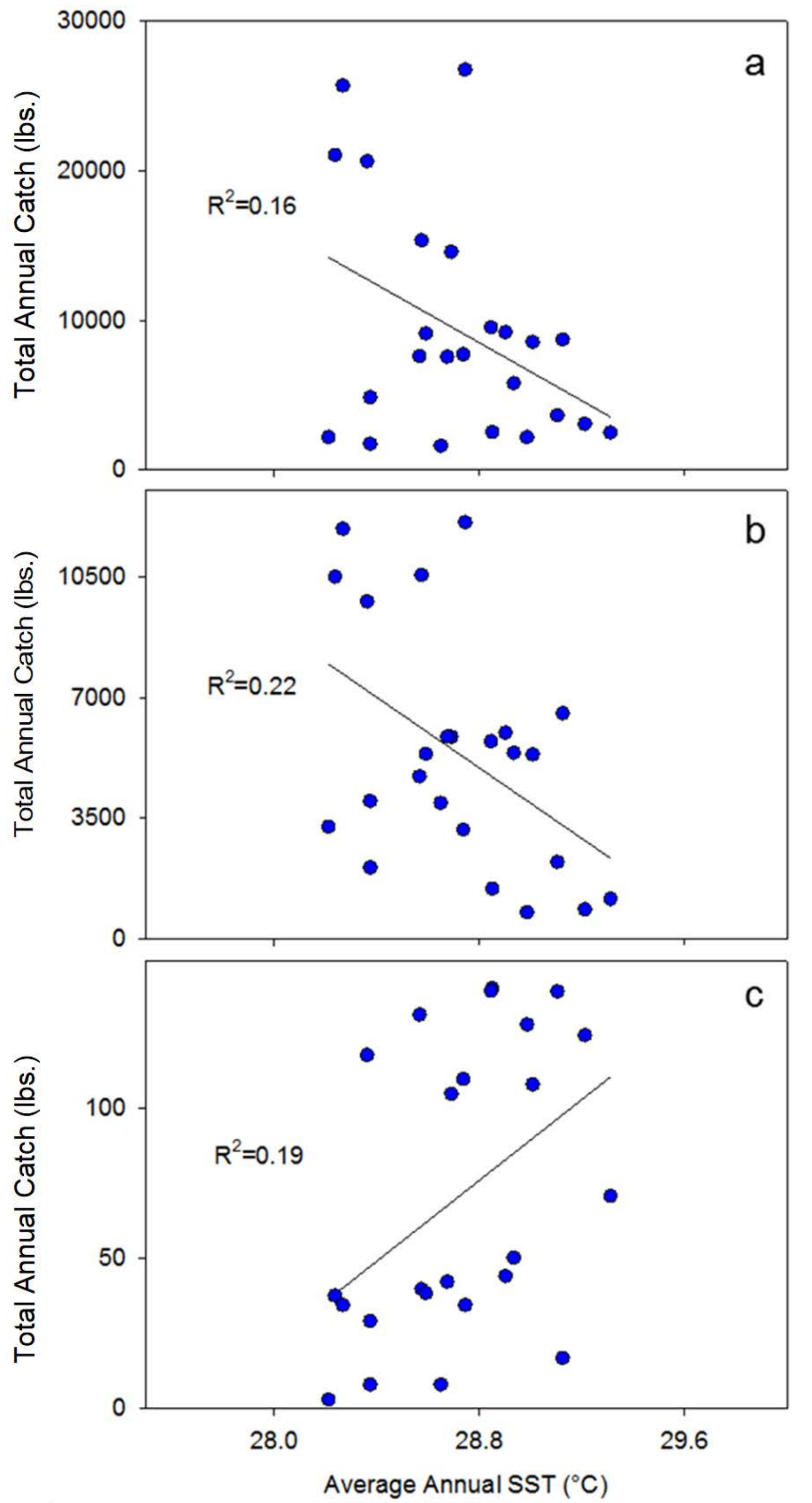


**Figure 38. Linear regressions showing the three top correlations between total annual catch (lbs.) for the recreational coral reef fishery and average annual SST (°C) in American Samoa for (a) Acanthurids, (b) Scarids, and (c) Mullids from 1989-2016.**

## 3.5 PRIMARY PRODUCTIVITY

Concentrations of the pigment chlorophyll-*a* are frequently used as an index of phytoplankton biomass to represent primary production, are a commonly utilized tool in identifying eutrophication, and are noted to be among the highest priority fishery ecosystem relationships in the WPR by participants of the Workshop as well (Islam and Tanaka, 2004). In Pacific regions where interannual precipitation and associated coastal runoff are relatively high, the physio-chemistry of nearshore reefs can especially be impacted by nutrient input accompanying precipitation and result 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, likely due to a reduction in upwelling that isolated nutrients at depth, led to waning reef fish assemblages in the Southern California Bight (Roemmich and McGowan, 1995). With recent progress in satellite and fluorometric measurements of oceanic surface waters, time series of global and regional primary production generated using chlorophyll-*a* concentration estimates have become increasingly available, and are commonly used for evaluating the impact of environmental productivity on reef fish population abundance and the marine food web in general (Behrenfed *et al.*, 2006; Messié and Radenac, 2006). Data for the study at hand were gathered from the ESA Ocean Colour Climate Change Initiative dataset version 3.1.

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 as is typically done for creel survey information. The largest issue in performing comparison analyses between catch levels from reef fisheries in American Samoa and fluorometric chlorophyll-*a* concentrations was the relatively short time series (i.e. small sample size) muddying any signals that might have been teased out. Robust, homogenous time series highlighting interdecadal patterns in these regions were difficult to obtain due to time series merging several sources of chlorophyll concentration information to elongate the range of continuous data. For example, the ESA's Ocean Colour Climate Change Initiate 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.

Time series of fluorometric chlorophyll-*a* concentrations ($mg/m^3$) from 1998 to 2016 in American Samoa is shown in Figure 39. The chlorophyll levels had relatively low variability over the course of evaluated data (CV = 4.90; Figure 39). Local chlorophyll-*a* concentrations appeared to be increasing over the course of the time series, despite the non-significant nature of the trend. Given the 17 available years of data, the average chlorophyll-*a* concentration was 0.039 $mg/m^3$, and the lowest recorded level was seen at the inception of the time series in 2005 at 0.036 $mg/m^3$ (Figure 39).

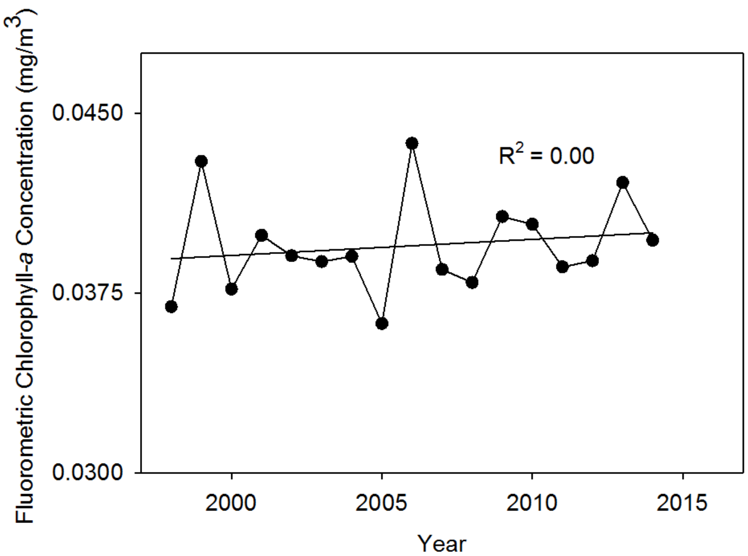


**Figure 39. Fluorometric chlorophyll-a concentrations (mg/m$^3$) from 1998–2016 (CV = 4.90).**

### 3.5.1 Evaluating relationship for entire recreational reef fishery

A comparison plot depicting the relationship between chlorophyll-*a* concentrations and catch time series gathered through creel surveys measuring American Samoa's recreational coral reef fishery from 1998 to 2014 is depicted in Figure 43. Catch for this region was relatively variable (CV=91.6) likely due to a large spike seen at the beginning of evaluated data in the early 2000s. Despite the abrupt maximum in 1998 (>1 million lbs.), total annual catch for the noncommercial reef fishery in American Samoa has been in decline through recent years. Current recorded catch levels (i.e. averaged over 2014 to 2016) are among the lowest for the fishery through the available time series of data (less than 100,000 lbs.; Figure 40).

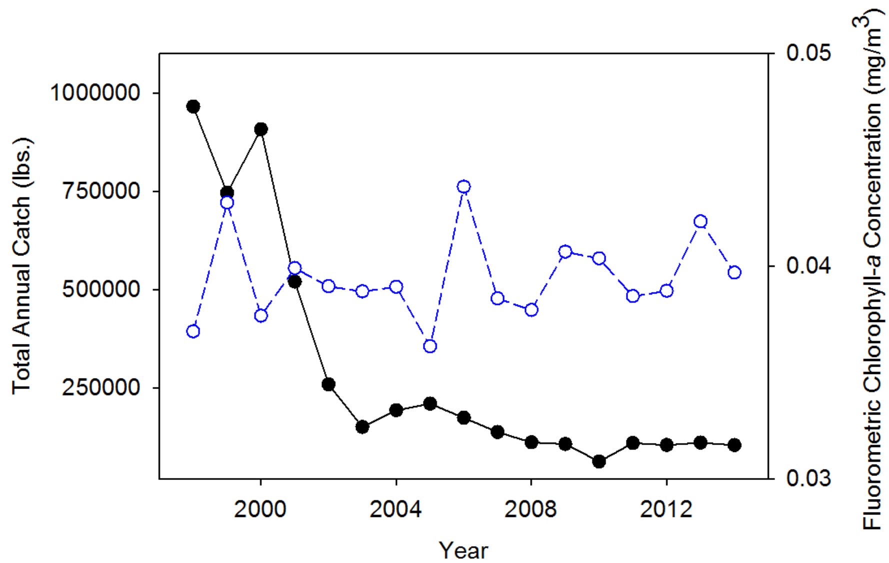


**Figure 40. Comparison of American Samoa recreational reef fish catch (lbs.; black) and chlorophyll-*a* concentrations (mg/m$^3$; blue) from 1998 – 2014 and two years of time lag.**

The linear regressions performed between noncommercial reef catch in American Samoa and fluorometric chlorophyll-*a* concentrations (mg/m$^3$) are shown in Figure 41. The chlorophyll-*a* concentrations and total annual catch for the all harvested taxa in the American Samoa noncommercial reef fishery had a negative relationship, but the association was not statistically significant to warrant further analysis especially with such a short time series of available data ($r = -0.15$, $p = 0.57$; Table 49; Figure 41). Several outliers in catch (from 1998 to 2001, the beginning of available primary productivity information) aided in complicating evaluation of the relationship between the parameters.

**Table 49. Correlation coefficients (*r*) from comparisons of time series of American Samoa recreational coral reef fishery annual catch (lbs.) and fluorometric chlorophyll-*a* concentrations (mg/m$^3$) for 12 top taxa harvested from 1998 – 2014.**

| Taxa Code | Total Catch | LUTJ | LETH | CARA | ACAN | SERR | SIGA | SCAR | MULL | MUGI | LABR | HOLO | BALI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| n = 17 | | | | | | | | | | | | | |
| *p* | 0.57 | 0.25 | 0.29 | 0.62 | 0.28 | 0.99 | 0.17 | 0.54 | 0.82 | 0.65 | 0.37 | 0.13 | 0.09 |
| *r* | -0.15 | 0.32 | 0.27 | -0.13 | -0.28 | 0.00 | 0.35 | -0.16 | 0.06 | 0.12 | -0.23 | -0.38 | -0.42 |
| $R^2$ | 0.02 | 0.10 | 0.08 | 0.02 | 0.08 | 0.00 | 0.12 | 0.03 | 0.00 | 0.01 | 0.05 | 0.14 | 0.18 |

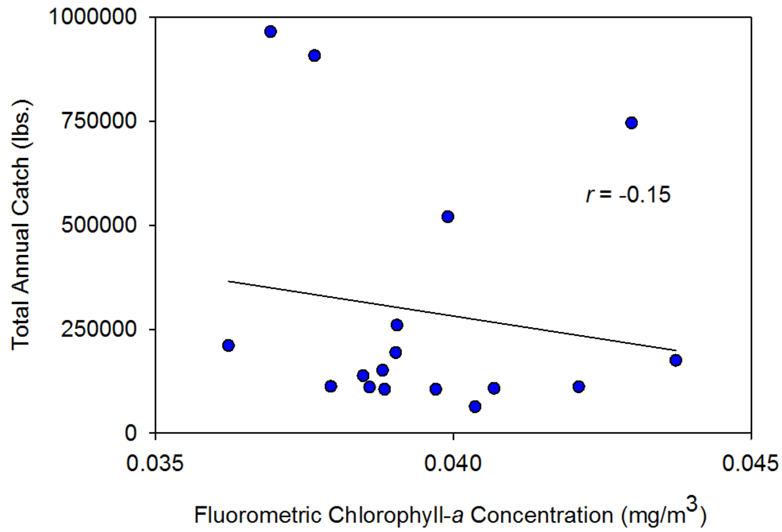


**Figure 41. Linear regression showing between total annual catch (lbs.) for the American Samoa recreational coral reef fishery with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m$^3$) from 1998-2014.**

### 3.5.2 Evaluating relationships with dominant taxa

After performing similar comparison analyses on the catch time series of the evaluated taxa for American Samoa, it was discovered that zero of the 12 displayed a statistically significant relationship with fluorometric chlorophyll-*a* concentrations in the area (Table 49). The strongest associations identified, though non-significant, were between estimated pigment levels and the catch time series of the Lutjanids ($R^2 = 0.10$; p = 0.25), Holocentrids ($R^2 = 0.10$; p = 0.25), and Acanthurids ($R^2 = 0.08$; p = 0.28); the relationships for Holocentridae and Acanthuridae were trending negative despite the lack of statistical significance (Table 49; Figure 42a-c).

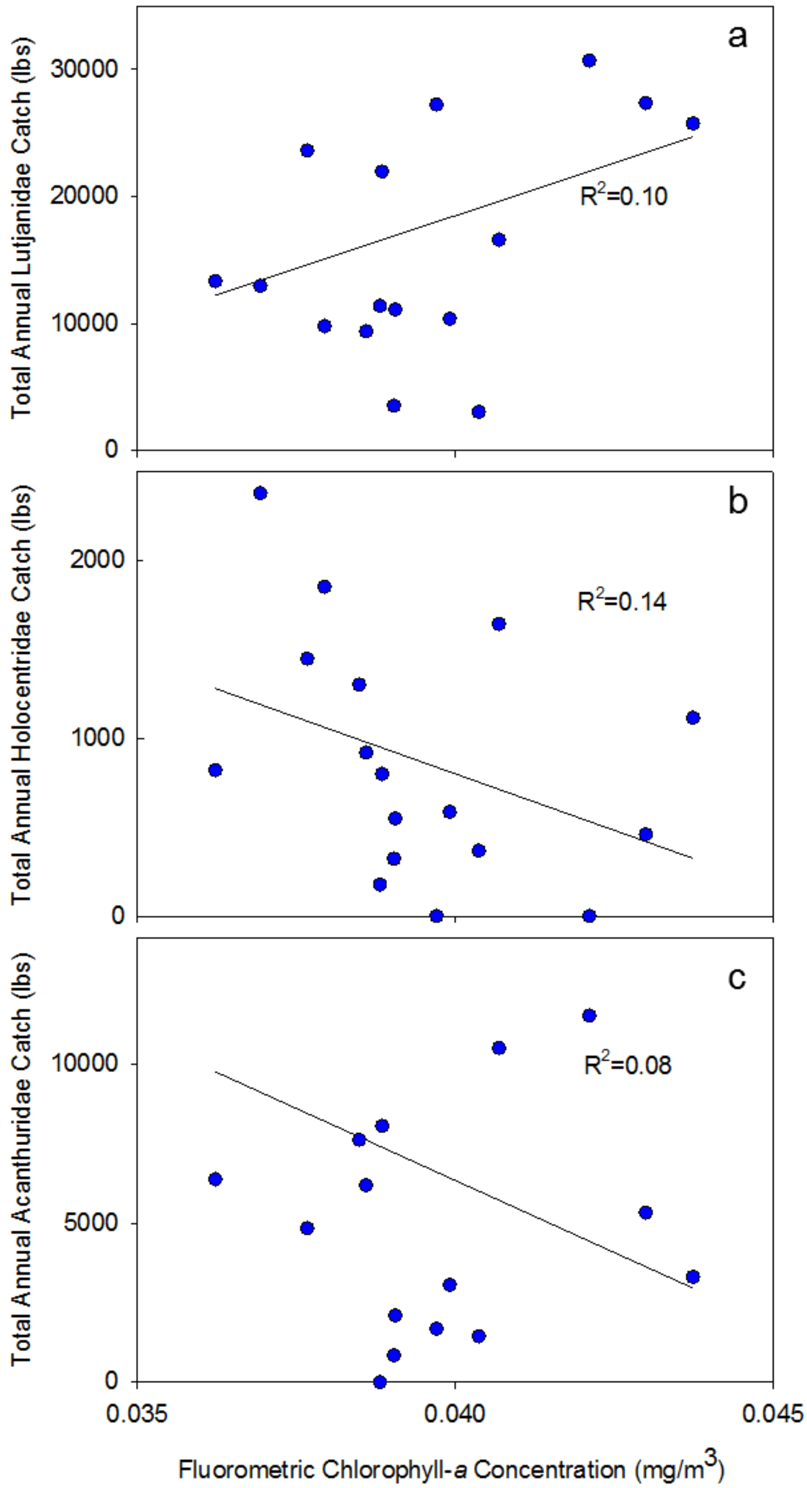


**Figure 42. Linear regressions showing three correlations between total annual catch (lbs.) for the American Samoa recreational coral reef fishery and fluorometric chlorophyll-*a* concentrations (mg/m$^3$) for (a) Lutjanids, (b) Holocentrids, and (c) Acanthurids from 1998–2014 with phase lag (t+2 years).**

## 3.6 MULTIVARIATE ASSESSMENTS OF ADDITIONAL ENVIRONMENTAL VARIABLES

### 3.6.1 Non-Metric Multidimensional Scaling

There were several other prioritized fishery ecosystem relationships for coral reefs in the American Samoa involving environmental parameters that were not to be addressed in this initial evaluation including: the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), sea level height, pH, dissolved oxygen, and salinity. Further descriptions of these climate and oceanic indicators are available in Section 2.5.3. Sea surface height data were aggregated from the Ocean Service, Tides, and Currents, and Sea Level database operated (NOAA/NOS/CO-OPS). Basin-wide data ONI were taken from NOAA's Nation Centers for Environmental Information- Equatorial Pacific Sea Surface Temperature Database (Climate Prediction Center Internet Team 2015). Similarly, PDO data were obtained from NOAA's Earth System Research Laboratory Physical Sciences Division originally derived from OI.v1 and OI.v2 SST parameters (NOAA PDO). Salinity data for American Samoa were gathered from Simple Ocean Data Assimilation (SODA) version 3.3.1 (Carton and Giese, 2008). Rainfall estimates were obtained through the local National Weather Service in American Samoa (NWS-AS).

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, is most commonly utilized when looking to identify patterns in heterogenous species response data (Peck, 2016). For this study, NMS was used to help identify associations between coral reef fishery parameters and ecological/environmental factors using the program PC-ORD 7. To ensure the same length of time series for all catch and environmental variables considered thus allowing for the general inclusion of more parameters, data was analyzed from 1989 to 2015. The generated axes represented the best fit of patterns of redundancy in the catch data used as input, and the resulting ordination scores were 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 PC-ORD 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 American Samoa test, data from 12 families from 1989-2014 (26 years) were included along with eight variables of environmental data collected during the same time period.

The resulting ordination scores from the NMS analysis performed on boat-based expanded creel survey catch records and the previously mentioned environmental parameters selected two completely orthogonal ordination axes in the final solution, accounting for 94.7% of variance observed in the American Samoa boat-based creel survey data (Figure 43). The NMS final stress was low for the real runs (8.05) relative to stress from the randomization runs (15.1), suggesting interpretable results (Figure 43).

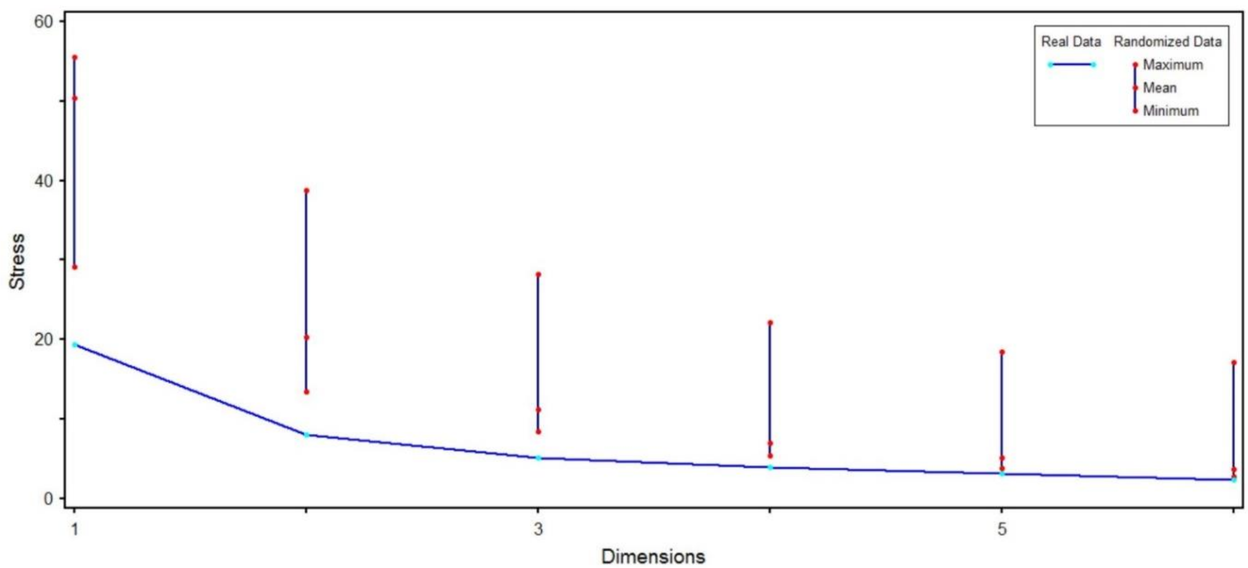


**Figure 43. NMS scree plot showing the stress test to determine dimensionality for the final solution for the American Samoa multivariate analysis.**

The final ordination scores for the families considered were relatively tightly clustered in a positive gradient relative to the two ordination axes, though two prominent groupings are observable with more traditional reef species in the lower left and bottomfish/shallow lagoon species comprising the upper right cluster (Figure 44). While this evaluation was not able to identify any significant levels of association between expanded creel catch data and several environmental parameters, the first axis ($r^2 = 0.91$), illustrated the strongest relationships with salinity (tau = -0.23) and rainfall (tau = 0.21; Figure 44). Analyses including time series of precipitation levels in American Samoa may be useful going forward.

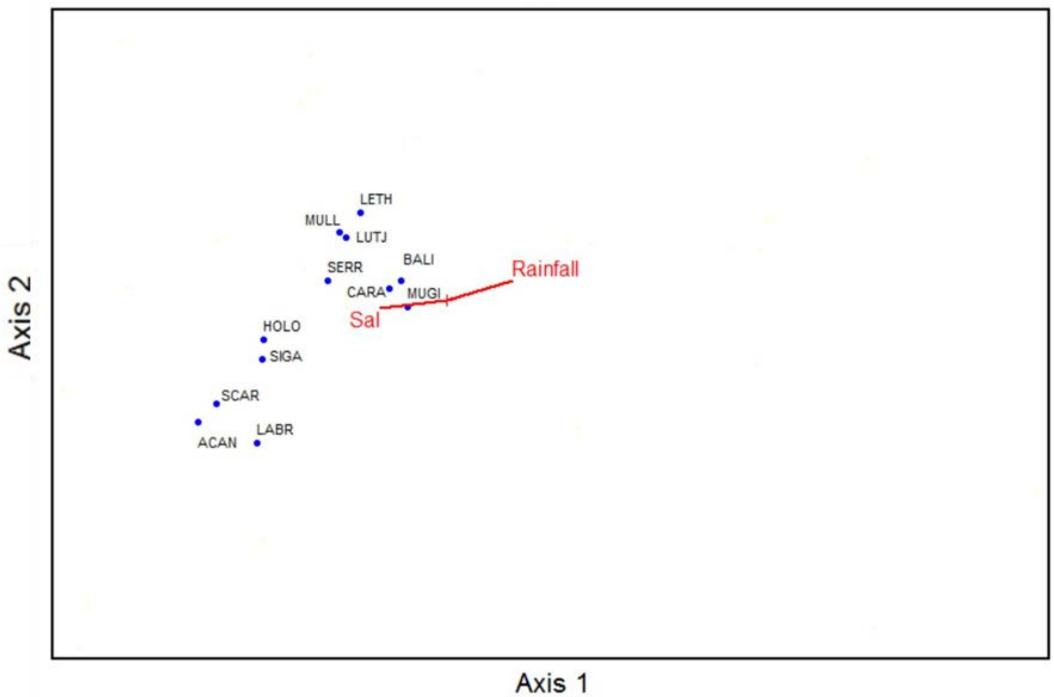


**Figure 44. Two-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters in American Samoa from 1989-2014.**

Time series of catch from prominent species and species complexes from American Samoa generally showed weak associations with environmental variable data gathered over the same time period. 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 though little indication of existing fishery ecosystem relationships could be identified. 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.

## 3.7 REFERENCES

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# APPENDIX A: LIST OF MANAGEMENT UNIT SPECIES

## AMERICAN SAMOA

### 1. Bottomfish Multi-species Stock Complex (FSSI)

| DMWR Creel Species Code | Species Name | Scientific Name |
|---|---|---|
| 247 | red snapper, silvermouth (lehi) (silverjaw jobfish) | *Aphareus rutilans* |
| 239 | grey snapper, jobfish | *Aprion virescens* |
| 119 | giant trevally, jack | *Caranx ignoblis* |
| 111 | black trevally, jack | *Caranx lugubris* |
| 221 | blacktip grouper | *Epinephelus fasciatus* |
| 229 | lunar tail grouper (yellow edge lyretail) | *Variola laoti* |
| 249 | red snapper | *Etelis carbunculus* |
| 248 | longtail snapper | *Etelis coruscans* |
| 262 | ambon emperor | *Lethrinus amboinensis* |
| 267 | redgill emperor | *Lethrinus rubrioperculatus* |
| 231 | blueline snapper | *Lutjanis kasmira* |
| 246 | yellowtail snapper (goldflag jobfish) | *Pristipomoides auricilla* |
| 242 | pink snapper (paka) | *Pristimpomoides filamentosus* |
| 241 | yelloweye snapper | *Pristipomoides flavipinnis* |
| none | pink snapper (kalekale) | *Pristipomoides seiboldi* |
| 245 | flower snapper (gindai) | *Pristipomoides zonatus* |
| 126 | amberjack | *Seriola dumerili* |

### 2. Crustacean deep-water shrimp complex (non-FSSI)

| DMWR Creel Species Code | Species Name | Scientific Name |
|---|---|---|
| none | deepwater shrimp | *Heterocarpus* spp. |

**3. Crustacean spiny lobster complex (non-FSSI)**

| DMWR Creel Species Code | Species Name | Scientific Name |
|---|---|---|
| 504 | spiny lobster | *Panulirus marginatus* |
| 504 | spiny lobster | *Panulirus penicillatus* |

**4. Crustacean slipper lobster complex (non-FSSI)**

| DMWR Creel Species Code | Species Name | Scientific Name |
|---|---|---|
| 505 | Slipper lobster | Scyllaridae |

**5. Crustacean Kona crab complex (non-FSSI)**

| DMWR Creel Species Code | Species Name | Scientific Name |
|---|---|---|
| 502 | Kona crab | *Ranina ranina* |

**6. Precious coral black coral complex (non-FSSI)**

| DMWR Creel Species Code | Species Name | Scientific Name |
|---|---|---|
| none | Black Coral | *Anitpathes dichotoma* |
| none | Black Coral | *Antipathes grandis* |
| none | Black Coral | *Antipathes ulex* |

**7. Exploratory area precious coral (except black coral) (non-FSSI)**

| DMWR Creel Species Code | Species Name | Scientific Name |
|---|---|---|
| none | Pink coral | *Corallium secundum* |
| none | Pink coral | *Corallium regale* |
| none | Pink coral | *Corallium laauense* |
| none | Bamboo coral | *Lepidisis olapa* |
| none | Bamboo coral | *Acanella* spp. |

| | | |
|---|---|---|
| none | Gold Coral | *Gerardia* spp. |
| none | Gold Coral | *Callogorgia gilberti* |
| none | Gold Coral | *Narella* spp. |
| none | Gold Coral | *Calyptrophora* spp. |

**8. Coral reef ecosystem (non-FSSI)**

| DMWR Creel Species Code | Species Name | Scientific Name | Grouping |
|---|---|---|---|
| 328 | Achilles tang | *Acanthurus achilles* | Acanthuridae |
| 337 | Barred unicornfish | *Naso thynnoides* | Acanthuridae |
| 3311 | Bignose unicornfish | *Naso vlamingii* | Acanthuridae |
| 336 | Black tongue unicornfish | *Naso hexacanthius* | Acanthuridae |
| 3205 | Blackstreak surgeonfish | *Acanthurus nigricauda* | Acanthuridae |
| 321 | Blue-banded surgeonfish | *Acanthurus lineatus* | Acanthuridae |
| 3206 | Bluelined surgeonfish | *Acanthurus nigroris* | Acanthuridae |
| 339 | Bluespine unicornfish | *Naso unicornis* | Acanthuridae |
| 326 | Brown surgeonfish | *Acanthurus nigrofuscus* | Acanthuridae |
| 323 | Convict tang | *Acanthurus triostegus* | Acanthuridae |
| 3203 | Elongate surgeonfish | *Acanthurus mata* | Acanthuridae |
| 3201 | Eye-striped surgeonfish | *Acanthurus dussumeiri* | Acanthuridae |
| 335 | Gray unicornfish | *Naso caesius* | Acanthuridae |
| 333 | Humpback unicornfish | *Naso brachycentron* | Acanthuridae |
| 338 | Humpnose unicornish | *Naso tuberosus* | Acanthuridae |
| 3208 | Mimic surgeonfish | *Acanthurus pyorferus* | Acanthuridae |
| 327 | Naso tang | *Naso* spp. | Acanthuridae |
| 332 | Orangespine unicornfish | *Naso lituratus* | Acanthuridae |
| 3207 | Orange-spot surgeonfish | *Acanthurus olivaceus* | Acanthuridae |
| 3281 | Pacific sailfin tang | *Zebrasoma veliferum* | Acanthuridae |
| 329 | Ringtail surgeonfish | *Acanthurus blochii* | Acanthuridae |
| 334 | Spotted unicornfish | *Naso brevirostris* | Acanthuridae |
| 322 | Striped bristletooth | *Ctenochaetus striatus* | Acanthuridae |
| 320 | Surgeonfishes/tangs | *Acanthurus* sp. | Acanthuridae |
| 3221 | Twospot bristletooth | *Ctenochaetus binotatus* | Acanthuridae |
| 330 | Unicornfishes (misc.) | *Naso* spp. | Acanthuridae |
| 3202 | Whitebar surgeonfish | *Acanthurus leucopareius* | Acanthuridae |
| 3204 | Whitecheek surgeonfish | *Acanthurus nigricans* | Acanthuridae |
| 331 | Whitemargin unicornfish | *Naso annulatus* | Acanthuridae |
| 325 | Whitespotted surgeonfish | *Acanthurus guttatus* | Acanthuridae |

| | | | |
|---|---|---|---|
| 3222 | Yellow-eyed bristletooth | *Ctenochaetus strigosus* | Acanthuridae |
| 324 | Yellowfin surgeonfish | *Acanthurus xanthopterus* | Acanthuridae |
| 390 | Inshore snappers | Lutjanidae | Lutjanidae |
| 238 | Brown jobfish | *Aphareus furca* | Lutjanidae |
| 256 | Scarlet snapper | *Etelis radiosus* | Lutjanidae |
| 392 | Red snapper | *Lutjanus bohar* | Lutjanidae |
| 235 | Twinspot/red snapper | *Lutjanus bohar* | Lutjanidae |
| 233 | Yellow margined snapper | *Lutjanus fulvus* | Lutjanidae |
| 236 | Humpback snapper | *Lutjanus gibbus* | Lutjanidae |
| 234 | Onespot snapper | *Lutjanus monostigma* | Lutjanidae |
| 232 | Rufous snapper | *Lutjanus rufolineatus* | Lutjanidae |
| 237 | Blood snapper | *Lutjanus sanguineus* | Lutjanidae |
| 257 | Timor snapper | *Lutjanus timorensis* | Lutjanidae |
| 251 | Black snapper | *Macolor niger* | Lutjanidae |
| 253 | Kusakar's snapper | *Paracaesio kusakarii* | Lutjanidae |
| 252 | Stone's snapper | *Paracaesio stonei* | Lutjanidae |
| 250 | Multidens snapper | *Pristipomoides multidens* | Lutjanidae |
| 102 | Bigeye scad | *Selar crumenophthalmus* | Atule |
| 524 | Mangrove clam | *Anodontia edentula* | Mollusk |
| 522 | Pen shell clam | *Atrina rigida* | Mollusk |
| 523 | Pipi clam | *Donax deltoides* | Mollusk |
| 510 | Squid | *Teuthida* | Mollusk |
| 521 | Clams (misc.) | *Bivalvia* | Mollusk |
| 531 | Cone snail | *Conus* sp. | Mollusk |
| 5061 | Octopus (cyanea) | *Octopus cyanea* | Mollusk |
| 5062 | Octopus (ornatus) | *Octopus ornatus* | Mollusk |
| 506 | Octopus | *Octopus* sp. | Mollusk |
| 520 | Giant clam | *Tridacna* sp. | Mollusk |
| 530 | Turban snail | *Trochus* sp. | Mollusk |
| 536 | Green snails | *Turbo* sp. | Mollusk |
| 116 | Blue kingfish trevally | *Carangoides caeruleopinnatus* | Carangidae |
| 114 | Goldspot trevally | *Carangoides orthogrammus* | Carangidae |
| 109 | Trevally (misc.) | *Carangoides* sp. | Carangidae |
| 110 | Jacks (misc.) | *Caranx* sp. | Carangidae |
| 113 | Bluefin trevally | *Caranx melampygus* | Carangidae |
| 115 | Brassy trevally | *Caranx papuensis* | Carangidae |
| 112 | Bigeye trevally | *Caranx sexfasciatus* | Carangidae |
| 410 | Rainbow runner | *Elagatis bipinnulatus* | Carangidae |
| 106 | Leatherback | *Scomberoides lysan* | Carangidae |

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|---|---|---|---|
| 127 | Snubnose pompano | *Trachinotus blochii* | Carangidae |
| 117 | Whitemouth trevally | *Uraspis secunda* | Carangidae |
| 104 | Mackerel scad (opelu) | *Decapterus* sp. | Carangidae |
| 260 | Emperors (misc.) | Lethrinidae | Lethrinidae |
| 255 | Goldenline bream | *Gnathodentex aureolineatus* | Lethrinidae |
| 264 | Yellowspot emperor | *Gnathodentex aurolineatus* | Lethrinidae |
| 263 | Blueline bream | *Gymnocranius grandoculis* | Lethrinidae |
| 266 | Orangespot emperor | *Lethrinus erythracanthus* | Lethrinidae |
| 261 | Longnose emperor | *Lethrinus elongatus* | Lethrinidae |
| 254 | Bigeye emperor | *Monotaxis grandoculis* | Lethrinidae |
| 2601 | Sweetlip emperor | *Lethrinus miniatus* | Lethrinidae |
| 3501 | Stareye parrotfish | *Calotomus carolinus* | Scaridae |
| 3503 | Longnose parrotfish | *Hipposcarus longiceps* | Scaridae |
| 3502 | Yellowband parrotfish | *Scarus schlegeli* | Scaridae |
| 350 | Parrotfishes (misc.) | *Scarus* sp. | Scaridae |
| 380 | Inshore groupers | Serranidae | Serranidae |
| 211 | Eightbar grouper | *Epinephelus octofasciatus* | Serranidae |
| 206 | Giant grouper | *Epinephelus lanceolatus* | Serranidae |
| 202 | Golden hind | *Cephalopholis aurantia* | Serranidae |
| 212 | Greasy grouper | *Epinephelus tauvina* | Serranidae |
| 210 | Groupers (misc.) | *Epinephelus* sp. | Serranidae |
| 224 | Hexagon grouper | *Epinephelus hexagonatus* | Serranidae |
| 209 | Honeycomb grouper | *Epinephelus merra* | Serranidae |
| 207 | Longspine grouper | *Epinephelus longispinnis* | Serranidae |
| 228 | Netfin grouper | *Epinephelus miliaris* | Serranidae |
| 208 | One-bloch grouper | *Epinephelus melanostigma* | Serranidae |
| 213 | Peacock grouper | *Cephalopholis argus* | Serranidae |
| 205 | Pygmy grouper | *Cephalopholis spiloparaea* | Serranidae |
| 217 | Saddleback grouper | *Plectropomus laevis* | Serranidae |
| 204 | Six-banded grouper | *Cephalopholis sexmaculatus* | Serranidae |
| 201 | Slender grouper | *Anyperodon leucogrammicus* | Serranidae |
| 227 | Smalltooth grouper | *Epinephelus microdon* | Serranidae |
| 226 | Spotted grouper | *Epinephelus maculatus* | Serranidae |
| 216 | Squaretail grouper | *Plectropomus areolatus* | Serranidae |
| 223 | Striped grouper | *Epinephelus morrhua* | Serranidae |
| 215 | Tomato grouper | *Cephalopholis sennerati* | Serranidae |
| 203 | Ybanded grouper | *Cephalopholis igarashiensis* | Serranidae |
| 222 | Yellowspot grouper | *Epinephelus timorensis* | Serranidae |
| 218 | Leopard coral trout | *Plectropomus leopardus* | Serranidae |

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|---|---|---|---|
| 219 | Powell's grouper | *Saloptia powelli* | Serranidae |
| 220 | White-edged lyretail | *Variola albimarginata* | Serranidae |
| 345 | Bigscale soldierfish | *Myripristis berndti* | Holocentridae |
| 348 | Blackfin squirrelfish | *Neoniphon opercularis* | Holocentridae |
| 359 | Blackspot squirrelfish | *Sargocentron melanospilos* | Holocentridae |
| 3414 | Blotcheye soldierfish | *Myripristis murdjan* | Holocentridae |
| 3511 | Bluelined squirrelfish | *Sargocentron tiere* | Holocentridae |
| 3411 | Brick soldierfish | *Myripristis amaena* | Holocentridae |
| 342 | Bronze soldierfish | *Myripristis adusta* | Holocentridae |
| 353 | Crown squirrelfish | *Sargocentron diadema* | Holocentridae |
| 3413 | Double tooth soldierfish | *Myripristis hexagona* | Holocentridae |
| 356 | Filelined squirrelfish | *Sargocentron microstoma* | Holocentridae |
| 3513 | Hawaiian squirrelfish | *Sargocentron xantherythrum* | Holocentridae |
| 343 | Pearly soldierfish | *Myripristis kuntee* | Holocentridae |
| 354 | Peppered squirrelfish | *Sargocentron punctatissimum* | Holocentridae |
| 3512 | Pink squirrelfish | *Sargocentron tieroides* | Holocentridae |
| 341 | Saber squirrelfish | *Sargocentron spiniferum* | Holocentridae |
| 351 | Sammara squirrelfish | *Neoniphon sammara* | Holocentridae |
| 344 | Scarlet soldierfish | *Myripristis pralinius* | Holocentridae |
| 340 | Squirrelfish | *Sargocentron* sp. | Holocentridae |
| 352 | Tailspot squirrelfish | *Sargocentron caudimaculatum* | Holocentridae |
| 346 | Violet soldierfish | *Myripristis violaceus* | Holocentridae |
| 358 | Violet squirrelfish | *Sargocentron violaceum* | Holocentridae |
| 3415 | Whitetip soldierfish | *Myripristis vittata* | Holocentridae |
| 3412 | Yellowfin soldierfish | *Myripristis chryseres* | Holocentridae |
| 347 | Yellowstriped squirrelfish | *Neoniphon aurolineatus* | Holocentridae |
| 130 | Mullets | Mullets | Mugilidae |
| 1301 | Fringelip mullet | Mullets | Mugilidae |
| 1303 | Diamond scale mullet | Mullets | Mugilidae |
| 1302 | False mullet | Mullets | Mugilidae |
| | Crabs | Decapoda | CRE-crustacean |
| 509 | Grapsid crab | Graspidae | CRE-crustacean |
| 5013 | Pa'a crab | *Ocypode ceratopthalma* | CRE-crustacean |
| 5011 | Seven-11 crab | *Carpilius maculatus* | CRE-crustacean |
| 5012 | Small crab | Decapoda | CRE-crustacean |
| 503 | Mangrove crab | *Scylla serrate* | CRE-crustacean |
| 5014 | Large red crab | *Sesama erythrodactyla* | CRE-crustacean |
| 507 | Hermit crab | *Coenobita clypeatus* | CRE-crustacean |
| | Bumphead parrotfish | *Bolbometopon muricatum* | Bumphead parrotfish |

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|---|---|---|---|
| 3601 | Napoleon wrasse | *Cheilius undulatus* | Napoleon wrasse |
| 1540 | Reef sharks (misc.) | Carcharhinidae | Carcharhinidae |
| 1541 | Silvertip shark | *Carcharhinus albimarginatus* | Carcharhinidae |
| 1542 | Grey reef shark | *Carcharhinus amblyrhynchos* | Carcharhinidae |
| 1543 | Galapagos shark | *Carcharhinus galapagenis* | Carcharhinidae |
| 154 | Blacktip reef shark | *Carcharhinus melanopterus* | Carcharhinidae |
| | White tip reef shark | *Carcharhinus triaenodon* | Carcharhinidae |
| 158 | Hammerhead shark | Sphyrnidae | Carcharhinidae |
| 500 | Invertebrates (misc.) | n/a | Invertebrate |
| 550 | Sea urchins (misc.) | Diadema | Invertebrate |
| 553 | Black sea urchin | Diadema | Invertebrate |
| 552 | White sea urchin | *Salmacis* spp. | Invertebrate |
| 827 | Cubed loli | *Holothuria atra* (cubed) | Invertebrate |
| 828 | Cubed leapord sea cucumber | *Bahadschia argus* (cubed) | Invertebrate |
| 824 | Surf redfish | *Actinopyga maurtiana* | Invertebrate |
| 822 | Sea cucumber (misc.) | Cucumariidae | Invertebrate |
| 823 | Sea cucumber - gau | Cucumariidae | Invertebrate |
| 821 | Sea cucumber gonads | Cucumariidae | Invertebrate |
| 825 | Leapord sea cucumber | *Bahadschia argus* | Invertebrate |
| 820 | Loli | *Holothuria atra* | Invertebrate |
| 132 | Flyingfish | Exocoetidae | Other CRE-Finfish |
| 133 | Cornetfish | *Fistularia commersonii* | Other CRE-Finfish |
| 135 | Mojarras | Gerreidae | Other CRE-Finfish |
| 181 | Gobies | Gobiidae | Other CRE-Finfish |
| 357 | Sweetlips | *Plectorhinchus* sp. | Other CRE-Finfish |
| 136 | Halfbeaks | Hemiramphidae | Other CRE-Finfish |
| 363 | Flagtails | Kuhliidae | Other CRE-Finfish |
| 3631 | Barred flagtail | *Kuhlia mugil* | Other CRE-Finfish |
| 720 | Mountain bass | *Kuhlia* sp. | Other CRE-Finfish |
| 137 | Ponyfish | Leiognathidae | Other CRE-Finfish |
| 368 | Tilefishes | Malacanthus sp. | Other CRE-Finfish |
| 460 | Sunfish | *Masturus lanceolatus* | Other CRE-Finfish |
| 138 | Filefishes | *Monacanthidae* | Other CRE-Finfish |
| 139 | Silver batfish | *Monodactylus argenteus* | Other CRE-Finfish |
| 176 | Moray eels | *Gymnothorax* sp. | Other CRE-Finfish |
| 175 | Dragon eel | *Enchelycore pardalis* | Other CRE-Finfish |
| 1741 | Yellowmargin moray eel | *Gymnothorax flavimarginatus* | Other CRE-Finfish |
| 1742 | Giant moray eel | *Gymnothorax javanicus* | Other CRE-Finfish |
| 174 | Spotted moray eels | *Gymnothorax* sp. | Other CRE-Finfish |

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|---|---|---|---|
| 1743 | Undulated moray eel | *Gymnothorax undulatus* | Other CRE-Finfish |
| 160 | Rays | Batiodea | Other CRE-Finfish |
| 162 | Eagle ray | *Aetobatis narinari* | Other CRE-Finfish |
| 906 | Monogram monocle bream | *Scolopsis monogramma* | Other CRE-Finfish |
| 152 | Nurse shark | *Pempheris* sp. | Other CRE-Finfish |
| 379 | Sweepers | Pempheridae | Other CRE-Finfish |
| 185 | Prettyfins | Cyprinididae | Other CRE-Finfish |
| 140 | Threadfin | *Polynemus* sp. | Other CRE-Finfish |
| 143 | Angelfishes | *Centropyge flavissimus* | Other CRE-Finfish |
| 1431 | Emperor angelfish | *Pomacanthus imperator* | Other CRE-Finfish |
| 3181 | Banded sergeant | *Abudefduf septemfasciatus* | Other CRE-Finfish |
| 318 | Sergeant major | *Abudefduf sp.* | Other CRE-Finfish |
| 142 | Damselfish | *Dascyllus trimaculatus* | Other CRE-Finfish |
| 365 | Bigeyes | Priacanthidae | Other CRE-Finfish |
| 367 | Glasseye | *Heteropriacanthus cruentatus* | Other CRE-Finfish |
| 366 | Paeony bulleye | *Priacanthus blochii* | Other CRE-Finfish |
| 369 | Moontail bullseye | *Priacanthus hamrur* | Other CRE-Finfish |
| 349 | Bigeye squirrelfish | Priacanthus sp. | Other CRE-Finfish |
| 184 | Dottybacks | Pseudochromidae | Other CRE-Finfish |
| 144 | Scorpionfishes | Scorpaenidae | Other CRE-Finfish |
| 146 | Lionfish | Pterois sp. | Other CRE-Finfish |
| 145 | Stonefish | Synaceia sp. | Other CRE-Finfish |
| 122 | Small barracuda | Sphyraenidae | Other CRE-Finfish |
| 121 | Great barracuda | *Sphyraena barracuda* | Other CRE-Finfish |
| 123 | Bigeye barracuda | *Sphyraena forsteri* | Other CRE-Finfish |
| 124 | Heller's barracuda | *Sphyraena helleri* | Other CRE-Finfish |
| 125 | Blackfin barracuda | *Sphyraena qenie* | Other CRE-Finfish |
| 120 | Barracudas (misc.) | *Sphyraena sp.* | Other CRE-Finfish |
| 191 | Seahorses | Sygnathidae | Other CRE-Finfish |
| 147 | Lizardfish | Synodontidae | Other CRE-Finfish |
| 355 | Terapon perch | *Terapon jarbua* | Other CRE-Finfish |
| 388 | Moorish Idol | *Zanclus cornutus* | Other CRE-Finfish |
| 710 | Freshwater eel | *Anguilla marmorata* | Other CRE-Finfish |
| 187 | Flashlightfishes | *Anomalopidae* | Other CRE-Finfish |
| 189 | Frogfishes | *Antennariidae* | Other CRE-Finfish |
| 315 | Cardinalfish | *Apogonidae* | Other CRE-Finfish |
| 103 | Silversides | *Hypoathernia temminckii* | Other CRE-Finfish |
| 101 | Trumpetfish | *Aulostomus chinensis* | Other CRE-Finfish |
| 383 | Triggerfish | Balistidae | Other CRE-Finfish |

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|---|---|---|---|
| 3821 | Orangestripe triggerfish | *Balistapus undulatus* | Other CRE-Finfish |
| 382 | Clown triggerfish | *Balistoides conspicillum* | Other CRE-Finfish |
| 387 | Titan triggerfish | *Balistoides viridescens* | Other CRE-Finfish |
| 134 | Needlefish | Belonidae | Other CRE-Finfish |
| 105 | Blennies | Blennidae | Other CRE-Finfish |
| 3051 | Angler flatfish | *Asterorhombus fijiensis* | Other CRE-Finfish |
| 107 | Gold banded fusilier | *Caesio caerulaurea* | Other CRE-Finfish |
| 186 | Coral crouchers | *Caracanthus maculatus* | Other CRE-Finfish |
| 385 | Butterflyfishes (misc.) | *Chaetodon sp.* | Other CRE-Finfish |
| 3851 | Butterflyfish (auriga) | *Chaetodon auriga* | Other CRE-Finfish |
| 3854 | Saddleback butterflyfish | *Chaetodon ephippium* | Other CRE-Finfish |
| 3852 | Racoon butterflyfish | *Chaetodon lunula* | Other CRE-Finfish |
| 3853 | Butterflyfish (melanotic) | *Chaetodon melannotus* | Other CRE-Finfish |
| 180 | Milkfish | *Chanos chanos* | Other CRE-Finfish |
| 700 | Tilapia | *Tilapia zillii* | Other CRE-Finfish |
| 319 | Two spotted hawkfish | *Amplycirrhitus bimacula* | Other CRE-Finfish |
| 3191 | Stocky hawkfish | *Cirrhitus pinnalatus* | Other CRE-Finfish |
| 3192 | Flame hawkfish | *Neocirrhites armatus* | Other CRE-Finfish |
| 131 | Herrings | Clupeidae | Other CRE-Finfish |
| 173 | White eel | *Conger cinereus* | Other CRE-Finfish |
| 172 | Conger eels | *Conger sp.* | Other CRE-Finfish |
| 386 | Porcupinefish | *Diodon (Porcupine)* sp. | Other CRE-Finfish |
| 183 | Remoras | *Echeneidae* | Other CRE-Finfish |
| 188 | Anchovies | *Engraulidae* | Other CRE-Finfish |
| 182 | Batfishes | *Ephippidae* | Other CRE-Finfish |
| 200 | Bottomfish (misc.) | n/a | Misc. Bottomfish |
| 300 | Reef fish (misc.) | n/a | Misc. Reef Fish |
| 3606 | Arenatus wrasse | *Oxycheilinus arenatus* | Wrasse |
| 3605 | Bandcheck wrasse | *Oxycheilinus diagrammus* | Wrasse |
| 3610 | Barred thicklip | *Hemigymnus fasciatus* | Wrasse |
| 3614 | Bird wrasse | *Hemigymnus fasciatus* | Wrasse |
| 3609 | Blackeye thicklip | *Hemigymnus melapterus* | Wrasse |
| 3616 | Checkerboard wrasse | *Halichoeres hortulanus* | Wrasse |
| 3615 | Cheilinus wrasse (misc.) | *Cheilinus sp.* | Wrasse |
| 361 | Christmas wrasse | *Thalassoma trilobata* | Wrasse |
| 3608 | Cigar wrasse | *Cheilio inermus* | Wrasse |
| 3613 | Red ribbon wrasse | *Thalassoma quinquevittaitum* | Wrasse |
| 3619 | Rockmover wrasse | *Novaculichthys taeniorus* | Wrasse |
| 3611 | Sunset wrasse | *Thalassoma lutescens* | Wrasse |

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|---|---|---|---|
| 3612 | Surge wrasse | *Thalassoma purpureum* | Wrasse |
| 3602 | Triple tail wrasse | *Cheilinus trilobatus* | Wrasse |
| 3617 | Weedy surge wrasse | *Halichoeres margaritaceus* | Wrasse |
| 3607 | Whitepatch wrasse | *Xyrichtys aneitensis* | Wrasse |
| 360 | Wrasses (misc.) | *Labridae* | Wrasse |
| 3603 | Floral wrasse | *Cheilinus chlorourus* | Wrasse |
| 3604 | Harlequin tuskfish | *Cheilinus fasciatus* | Wrasse |
| 3033 | Rudderfish (biggibus) | *Kyphosus bigibus* | Rudderfish |
| 303 | Rudderfish (cinerascens) | *Kyphosus cinerascens* | Rudderfish |
| 3032 | Western drummer | *Kyphosus cornelii* | Rudderfish |
| 3034 | Rudderfish | *Kyphosus sp.* | Rudderfish |
| 3031 | Lowfin drummer | *Kyphosus vaigiensis* | Rudderfish |
| 3734 | Goatfish (misc.) | *Mullidae* | Goatfish |
| 371 | Yellowstripe goatfish | *Mulloidichthys flavolineatus* | Goatfish |
| 375 | Orange goatfish | *Mulloidichthys pfluegeri* | Goatfish |
| 370 | Yellow goatfishes | *Mulloidichthys sp.* | Goatfish |
| 372 | Yellowfin goatfish | *Mulloidichthys vanicolensis* | Goatfish |
| 373 | Dash-and-dot goatfish | *Parupeneus barberinus* | Goatfish |
| 3731 | Doublebar goatfish | *Parupeneus bifasciatus* | Goatfish |
| 3732 | White-lined goatfish | *Parupeneus ciliatus* | Goatfish |
| 374 | Yellowsaddle goatfish | *Parupeneus cyclostomus* | Goatfish |
| 376 | Redspot goatfish | *Parupeneus heptacanthus* | Goatfish |
| 377 | Indian goatfish | *Parupeneus indicus* | Goatfish |
| 378 | Parupenus insularis | *Parupeneus insularis* | Goatfish |
| 3733 | Multi-barred goatfish | *Parupeneus multifasciatus* | Goatfish |
| 381 | Side spot goatfish | *Parupeneus pleurostigma* | Goatfish |
| 3370 | Banded goatfish (misc.) | *Parupeneus sp.* | Goatfish |
| 310 | Rabbitfish | *Siganidae* | Rabbitfish |
| 3101 | Forktail rabbitfish | *Siganus aregenteus* | Rabbitfish |
| 311 | Scribbled rabbitfish | *Siganus spinus* | Rabbitfish |
| 801 | Red algae | Red Algae | Rabbitfish |
| 800 | Seaweeds | Seaweeds | Rabbitfish |

# APPENDIX B. LIST OF PROTECTED SPECIES AND DESIGNATED CRITICAL HABITAT

**Table B-1. Protected species found or reasonably believed to be found in or near American Samoa waters.**

| Common Name | Scientific Name | ESA Listing Status | MMPA Status | Occurrence | References |
|---|---|---|---|---|---|
| **Seabirds** | | | | | |
| Audubon's Shearwater | *Puffinus lherminieri* | Not Listed | N/A | Resident | Craig, 2005 |
| Black Noddy | *Anous minutus* | Not Listed | N/A | Resident | Craig, 2005 |
| Black-Naped Tern | *Sterna sumatrana* | Not Listed | N/A | Visitor | Craig, 2005 |
| Blue-Gray Noddy | *Procelsterna cerulea* | Not Listed | N/A | Resident | Craig, 2005 |
| Bridled Tern | *Onychoprion anaethetus* | Not Listed | N/A | Visitor | Craig, 2005 |
| Brown Booby | *Sula leucogaster* | Not Listed | N/A | Resident | Craig, 2005 |
| Brown Noddy | *Anous stolidus* | Not Listed | N/A | Resident | Craig, 2005 |
| Christmas Shearwater | *Puffinus nativitatis* | Not Listed | N/A | Resident? | Craig, 2005 |
| Collared Petrel | *Pterodroma brevipes* | Not Listed | N/A | Resident? | Craig, 2005 |
| White Tern | *Gygis alba* | Not Listed | N/A | Resident | Craig, 2005 |
| Greater Crested Tern | *Thalasseus bergii* | Not Listed | N/A | Visitor | Craig, 2005 |
| Gray-Backed Tern | *Onychoprion lunatus* | Not Listed | N/A | Resident | Craig, 2005 |
| Great Frigatebird | *Fregata minor* | Not Listed | N/A | Resident | Craig, 2005 |
| Herald Petrel | *Pterodroma heraldica* | Not Listed | N/A | Resident | Craig, 2005 |
| Laughing Gull | *Leucophaeus atricilla* | Not Listed | N/A | Visitor | Craig, 2005 |
| Lesser Frigatebird | *Fregata ariel* | Not Listed | N/A | Resident | Craig, 2005 |
| Masked Booby | *Sula dactylatra* | Not Listed | N/A | Resident | Craig, 2005 |
| Newell's Shearwater | *Puffinus auricularis newelli* | Threatened | N/A | Visitor | 40 FR 44149, Craig, 2005 |
| Red-Footed Booby | *Sula sula* | Not Listed | N/A | Resident | Craig, 2005 |
| Red-Tailed Tropicbird | *Phaethon rubricauda* | Not Listed | N/A | Resident | Craig, 2005 |
| Short-Tailed Shearwater | *Ardenna tenuirostris* | Not Listed | N/A | Visitor | Craig, 2005 |
| Sooty Shearwater | *Ardenna grisea* | Not Listed | N/A | Visitor | Craig, 2005 |
| Sooty Tern | *Sterna fuscata* | Not Listed | N/A | Resident | Craig, 2005 |
| Tahiti Petrel | *Pterodroma* | Not Listed | N/A | Resident | Craig, 2005 |

| Common Name | Scientific Name | ESA Listing Status | MMPA Status | Occurrence | References |
|---|---|---|---|---|---|
| | *rostrata* | | | | |
| Wedge-Tailed Shearwater | *Ardenna pacifica* | Not Listed | N/A | Resident? | Craig, 2005 |
| White-Necked Petrel | *Pterodroma cervicalis* | Not Listed | N/A | Visitor | Craig, 2005 |
| White-Faced Storm-Petrel | *Pelagodroma marina* | Not Listed | N/A | Visitor | Craig, 2005 |
| White-Tailed Tropicbird | *Phaethon lepturus* | Not Listed | N/A | Resident | Craig, 2005 |
| White-Throated Storm-Petrel | *Nesofregetta fuliginosa* | Not Listed | N/A | Resident? | Craig, 2005 |
| **Sea Turtles** | | | | | |
| Green Sea Turtle | *Chelonia mydas* | Endangered (Central South Pacific DPS) | N/A | Frequently seen. Nest at Rose Atoll in small numbers. | 43 FR 32800, 81 FR 20057, Balacz 1994 |
| Hawksbill Sea Turtle | *Eretmochelys imbricata* | Endangered[a] | N/A | Frequently seen. Nest at Rose Atoll, Swain's Island, and Tutuila. | 35 FR 8491, NMFS & USFWS 2013, Tuato'o-Bartley *et al.,* 1993 |
| Leatherback Sea Turtle | *Dermochelys coriacea* | Endangered[a] | N/A | Very rare. One juvenile recovered dead in experimental longline fishing. | 35 FR 8491, Grant, 1994 |
| Loggerhead Sea Turtle | *Caretta caretta* | Endangered (South Pacific DPS) | N/A | No known sightings. Found worldwide along continental shelves, bays, estuaries and lagoons of tropical, subtropical, and temperate waters. | 43 FR 32800, 76 FR 58868, Utzurrum 2002, Dodd, 1990 |
| Olive Ridley Sea Turtle | *Lepidochelys olivacea* | Threatened (Entire species, except for the breeding population on the Pacific coast of Mexico, which is listed as endangered) | N/A | Rare. Three known sightings. | 43 FR 32800, Utzurrum, 2002 |
| **Marine mammals** | | | | | |
| Blainville's Beaked Whale | *Mesoplodon densirostris* | Not Listed | Non-strategic | Found worldwide in tropical and temperate waters | Mead, 1989 |
| Blue Whale | *Balaenoptera musculus* | Endangered | Strategic | No known sightings. Occur worldwide, and are known to be found in the western South Pacific. | 35 FR 18319, Olson *et al.,* 2015 |
| Bottlenose Dolphin | *Tursiops truncatus* | Not Listed | Non-strategic | Distributed worldwide in tropical and warm-temperate waters | Perrin *et al.,* 2009 |

| Common Name | Scientific Name | ESA Listing Status | MMPA Status | Occurrence | References |
|---|---|---|---|---|---|
| Bryde's Whale | *Balaenoptera edeni* | Not Listed | Unknown | Distributed widely across tropical and warm-temperate Pacific Ocean. | Leatherwood *et al.,* 1982 |
| Common Dolphin | *Delphinus delphis* | Not Listed | N/A | Found worldwide in temperate and subtropical seas. | Perrin *et al.,* 2009 |
| Cuvier's Beaked Whale | *Ziphius cavirostris* | Not Listed | Non-strategic | Occur worldwide. | Heyning, 1989 |
| Dwarf Sperm Whale | *Kogia sima* | Not Listed | Non-strategic | Found worldwide in tropical and warm-temperate waters. | Nagorsen, 1985 |
| False Killer Whale | *Pseudorca crassidens* | Not Listed | Unknown | Found in waters within the US EEZ of A. Samoa | Bradford *et al.,* 2015 |
| Fin Whale | *Balaenoptera physalus* | Endangered | Strategic | No known sightings. Found worldwide. | 35 FR 18319, Hamilton *et al.,* 2009 |
| Fraser's Dolphin | *Lagenodelphis hosei* | Not Listed | Non-strategic | Found worldwide in tropical waters. | Perrin *et al.,* 2009 |
| Humpback Whale | *Megaptera novaeangliae* | Delisted Due to Recovery (Oceania DPS) | Strategic | Migrate through the archipelago and breed during the winter in American Samoan waters. | 35 FR 18319, 81 FR 62259, Guarrige *et al.,* 2007, SPWRC, 2008 |
| Killer Whale | *Orcinus orca* | Not Listed | Non-strategic | Found worldwide. Prefer colder waters within 800 km of continents. | Leatherwood & Dalheim, 1978, Mitchell, 1975, Baird *et al.,* 2006 |
| Longman's Beaked Whale | *Indopacetus pacificus* | Not Listed | Non-strategic | Found in tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa. | Dalebout, 2003 |
| Melon-Headed Whale | *Peponocephala electra* | Not Listed | Non-strategic | Found in tropical and warm-temperate waters worldwide, primarily found in equatorial waters. | Perryman *et al.,* 1994 |
| Minke Whale | *Balaenoptera acutorostrata* | Not Listed | Non-strategic | Uncommon in this region, usually seen over continental shelves in the Pacific Ocean. | Brueggeman *et al.,* 1990 |
| Pantropical Spotted Dolphin | *Stenella attenuata attenuata* | Not Listed | Non-strategic | Found in tropical and subtropical waters worldwide. | Perrin *et al.,* 2009 |
| Pygmy Killer Whale | *Feresa attenuata* | Not Listed | Non-strategic | Found in tropical and subtropical waters worldwide. | Ross & Leatherwood, 1994 |
| Pygmy Sperm Whale | *Kogia breviceps* | Not Listed | Non-strategic | Found worldwide in tropical and warm-temperate waters. | Caldwell & Caldwell, 1989 |
| Risso's Dolphin | *Grampus griseus* | Not Listed | Non-strategic | Found in tropical to warm-temperate waters | Perrin *et al.,* 2009 |

| Common Name | Scientific Name | ESA Listing Status | MMPA Status | Occurrence | References |
|---|---|---|---|---|---|
| | | | | worldwide. | |
| Rough-Toothed Dolphin | *Steno bredanensis* | Not Listed | Unknown | Found in tropical to warm-temperate waters worldwide. Common in A. Samoa waters. | Perrin *et al.,* 2009, Craig, 2005 |
| Sei Whale | *Balaenoptera borealis* | Endangered | Strategic | Generally found in offshore temperate waters. | 35 FR 18319, Barlow, 2003, Bradford *et al.,* 2013 |
| Short-Finned Pilot Whale | *Globicephala macrorhynchus* | Not Listed | Non-strategic | Found in tropical to warm-temperate waters worldwide. | Shallenberger, 1981, Baird *et al.,* 2013, Bradford *et al.,* 2013 |
| Sperm Whale | *Physeter macrocephalus* | Endangered | Strategic | Found in tropical to polar waters worldwide, most abundant cetaceans in the region. | 35 FR 18319, Rice, 1960, Barlow, 2006, Lee, 1993, Mobley *et al.,* 2000, Shallenberger, 1981 |
| Spinner Dolphin | *Stenella longirostris* | Not Listed | Unknown | Common in American Samoa, found in waters with mean depth of 44 m. | Reeves *et al.,* 1999, Johnston *et al.,* 2008 |
| Striped Dolphin | *Stenella coeruleoalba* | Not Listed | Non-strategic | Found in tropical to warm-temperate waters throughout the world. | Perrin *et al.,* 2009 |
| **Elasmobranchs** | | | | | |
| Giant manta ray | *Manta birostris* | Threatened | N/A | Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs. | Dewar *et al.*, 2008, Marshall *et al.*,, 2009, Marshall *et al.*, 2011. |
| Oceanic whitetip | *Carcharhinus longimanus* | Threatened | N/A | Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C | Bonfil *et al.*, 2008, Backus *et al.*, 1956, Strasburg, 1958, Compagno, 1984 |
| Scalloped Hammerhead | *Sphyrna lewini* | Threatened (Indo-West Pacific DPS) | N/A | Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m. | Compagno, 1984, Schulze-Haugen & Kohler, 2003, Sanches, 1991, Klimley, 1993 |

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

[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 http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm.

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# APPENDIX C: CRUSTACEAN LIFE HISTORY AND HABITAT REVIEW

## OVERVIEW

This report presents a literature review of the life history and habitat requirements for each life stage for four species of reef-associated crustaceans that are landed in commercial fisheries Western Pacific region: two species of spiny lobster (*Panulirus marginatus* and *Scyllarides squammosus*), scaly slipper lobster (*Scyllarides squammosus*), and Kona crab (*Ranina ranina*).The most up to date information on the species distribution, fisheries in the Western Pacific Region, and life history is summarized. Tables summarizing the multiple dimensions of habitat use for each life stage (egg, larvae, post-larvae, juvenile, and adult) are also provided. The purpose of this report is to provide guidance in reviewing and updating essential fish habitat for reef associated crustaceans in the Western Pacific region.

## 1. HAWAIIAN SPINY LOBSTER (*PANULIRUS MARGINATUS)*

### 1.1. GENERAL DESCRIPTION AND DISTRIBUTION

Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida, 1986; FAO, 1991).The Hawaiian spiny lobster (*Panulirus marginatus*), also known as ula and banded spiny lobster, is endemic to the Hawaiian Archipelago and Johnston Atoll (Brock, 1973; Polovina and Moffitt, 1995). The highest abundances of spiny lobster are found in the Northwestern Hawaiian Islands (NWHI; Uchida and Tagami, 1984). A single male spiny lobster has been collected in the shallow waters of Johnston Atoll, but it is unknown if an established reproducing population exists here (Brock, 1973).

Although *P. marginatus* has a long pelagic larval duration, the spiny lobster exhibits significant population structure across the Hawaiian Archipelago with regional differentiation between the NWHI and main Hawaiian islands (MHI; Lacchei *et al.,* 2014). Larval exchange between populations in the MHI and NWHI is minimal and if it does occur, it is more likely larvae are transported from the MHI to NWHI than vice versa (Lacchei *et al.,* 2013).

From the mid-1970s to 1999 spiny lobsters were targeted in a commercial trap fishery in the NWHI (O'Malley, 2004). The NWHI commercial fishery was composed of 9-14 vessels, setting about 80 traps per day and taking 3, approximately 8 week trips per year (Polovina and Mitchum, 1992). Total effort in the commercial fishery was approximately 1 million trap hauls per year (Polovina *et al.,* 1995). Necker Island and Maro Reef accounted for over 60% of all lobster landings (Polovina and Mitchum, 1992).

### 1.2. FISHERIES

In 1983, a requirement for NWHI commercial lobsters fishers to submit logbooks was implemented and the fishery was managed with a minimum size of 5 cm tail-width (7.5 cm carapace length or CL) and no trapping in areas < 18 m. The depth restriction was to minimize disturbance to the Hawaiian monk seal (Parrish and Polovina, 1994). In 1996, a retain all regulation was implemented and replaced the 5 cm tail width (TL) minimum size due to the high discard mortality rate.

The NWHI commercial spiny lobster fishery peaked in 1985 with total landings exceeding 2.5 million pounds. After 1985, CPUE began to steadily decline, which has been attributed to a number of causes. In 1990, there was a recruitment collapse, which was attributed to climate change and shifts in the ecosystem's productivity (Polovina *et al.,* 1995). After this recruitment collapse, fishing continued and reduced the spawning stock biomass to low levels (Polovina *et al.,* 1995). In 2000, NMFS closed the NWHI spiny lobster fishery due to increasing uncertainty in the assessment of the population; area-based commercial closures from the NWHI Coral Reef Ecosystem Reserve in 2001 and the complete prohibition on commercial fishing in the Papahānaumokuākea Marine National Monument in 2006 have maintained the closure. Since the closure of the commercial fishery in 2000, there has been no evidence that the NWHI spiny lobster population has recovered (O'Malley, 2011; Lacchei *et al.,* 2014).

Currently, fewer than three commercial fishers in the MHI land spiny lobster with traps (NOAA Fisheries, 2017a), and approximately 19 commercial dive fishers land spiny lobsters (NOAA Fisheries, 2017b). In 2015, 5,744 lbs. of spiny lobster where landed commercially in the MHI fishery (DAR, 2015). Spiny lobsters are also targeted and landed by recreational and subsistence fishers in the MHI, but the extent of this fishery is unknown (MacDonald and Thompson, 1987). Management for the spiny lobster in the MHI includes a closed season from May-August, no taking of female lobsters, no spearing, and a minimum size of 3.25 inch CL.

## 1.3. LIFE HISTORY

### 1.3.1. GROWTH, MATURITY, MOVEMENT, AND NATURAL MORTALITY

Hawaiian spiny lobsters exhibit sexual dimorphism in growth with males growing faster than females (O'Malley, 2009). While temporal and spatial variation in growth rates for *Panulirus sp*. is uncommon, the temporal, spatial, and individual growth rates of spiny lobsters found in the NWHI is the highest that has ever been reported for any *Panulirus* species (O'Malley, 2009). The cause of the large variation in growth rates is unknown, but may be attributed to variability in prey regimes and/or environmental conditions (O'Malley *et al.,* 2012).

Growth in spiny lobsters is stepwise as they get larger by molting and difficult to describe with a continuous von Bertalanffy relationship (O'Malley and MacDonald, 2009). The molting process consists of 8 discrete stages (Lyle and MacDonald 1983). Mean annual growth rates of tagged male lobsters with a 75 mm CL varied between 3.55 to 15.85 mm, and the annual average growth rate of 70 mm CL tagged female lobsters varied between 1.866 mm to 15.84 mm (O'Malley and MacDonald, 2009).

Size at which female lobsters reach sexual maturity also varies spatially and temporally, and may be associated with density dependence (Polovina, 1989; DeMartini *et al.,* 2003). Estimates of onset of sexual maturity for females range between 57.99 mm CL and 74.8 mm CL (Polovina, 1989). The onset of female maturity was reportedly lower in banks after 10 years of heavy exploitation, which Polovina hypothesizes may be a compensatory response (Polovina, 1989).

Although the longevity of this species is not known, other tropical spiny lobster species live up to 20 years (Butler and MacDiarmid 2011). Annual natural mortality likely varies with size but is estimated on average to be 0.456 (Haight and Polovina, 1993)

### 1.3.2. REPRODUCTION

Female fecundity increases with both carapace length and tail-width (Honda, 1980; DeMartini *et al.,* 2003). Female lobsters have between 114,000 and 782,000 eggs per brood, and may have multiple broods per spawning season (DeMartini *et al.,* 2003). A 36% increase in average fecundity and a 5% increase in egg diameter was observed over a 30-year period and attributed to a compensatory response to decreased lobster densities and increased per capita food resources as a result of either natural cyclic declines in productivity and/or high exploitation rates from the commercial fishery (DeMartini *et al.,* 1993; DeMartini *et al.,* 2003). This increase in fecundity and egg size coincided with compensatory declines in size at maturity (DeMartini *et al.,* 2003).

Hawaiian spiny lobsters are dioecious and fertilization occurs externally (Uchida, 1986). Mature males will deposit a spermatophore on a mature females' abdomen (Uchida, 1986). Females then release the ova from the oviduct and simultaneously scratch and break the spermatophore open to release spermatozoa, which fertilize the eggs (WPRFMC, 1983). Females attach the fertilized eggs to setae of the female's pleopod. The eggs are visible and females carrying fertilized eggs on the pleopod are referred to as 'berried'. Females carry fertilized eggs for 30-40 days until they hatch into planktonic, pelagic larvae (Morris, 1968). Brooded eggs are orange when first extruded and change to a brown color before hatching (DeMartini *et al.,* 2003).

The spawning season of *P. marginatus* appears to vary within the NWHI chain. Around Nihoa, Necker Island, and French Frigate Shoals, ovigerous females occur in late summer and early winter; toward the northwestern end of the chain, ovigerous females are more abundant in early summer (Uchida *et al.,* 1980). Off O'ahu spawning has been throughout the year and peak activity is concentrated in May-August and low activity is apparent in November-January (McGinnis, 1972).

### 1.3.3. LARVAE AND RECRUITMENT

After hatching, pelagic phyllosoma larvae, drift in the ocean currents for 12 months and pass through 11 stages of development (MacDonald, 1986; Polovina and Moffitt, 1995). Larval phyllosoma make diurnal movements from 80-100 m during the day, to 10-20 m at night, and are found in high abundance on the surface at night during the new moon (Polovina and Moffitt 1995). Abundance of late stage phyllosomes are higher offshore (up to 25 nmi from 200 m contour) relative to the 200-m contour, which may be explained by either oceanographic currents and nearshore topography pushing larvae offshore and/or higher predation in nearshore areas (Polovina and Moffitt 1995). Although spiny lobsters have a long pelagic duration, banks differ substantially in the proportion of larvae they retain from resident spawners, as well as the portion of larvae they receive from other banks (Polovina *et al.,* 1999). Oceanographic processes such as the strength of the Subtropical Counter Current (SCC) at 26° N latitude, where it intersects with the Hawaiian Ridge and sea level height, play a large role in determining larval retention rates and survival of the pelagic phyllosoma. A high abundance of late stage larvae are found at 26° N suggesting recruitment is linked to the strength of the SCC (Polovina and Moffit, 1995).

This relationship is especially clear at Maro Reef in the NWHI, where a clear trend exists between sea level height and recruitment to the fishery 4 years later (Polovina *et al.,* 1995).

After 12 months, phyllosoma metamorphose into free swimming post-larval pueruli (Polovina and Moffitt, 1995). Pueruli actively swim to shallow, nearshore waters in preparation for settlement (MacDonald, 1986). Settlement is generally higher at the center of the Hawaiian Archipelago relative to the ends, and higher in the NWHI than the MHI (MacDonald, 1986). Other species of spiny lobster pueruli are capable horizontal, directed swimming of up to 40-60 km, but it is unknown how far pueruli of Hawaiian spiny lobster are able to move horizontally before settling (Pearce and Phillips, 1994). Large pulses in larvae settlement occur during new moon and first quarter lunar phase (MacDonald, 1986). However, seasonal, interannual, and geographic patterns of recruitment vary, which are determined to some extent by larval availability resulting from oceanographic conditions such as the strength of the subtropical counter current (MacDonald, 1986; Mitchum and Polovina, 1992; Polovina and Mitchum, 1994; Polovina and Moffitt, 1995; Polovina *et al.,* 1999).

Pueruli settle in depths between 1 and 30 m, and at low densities relative to other spiny lobster species (MacDonald, 1989; Polovina and Moffitt, 1995). While other *Panulirus* sp. use shallow nearshore algal, seagrass, and mangrove roots as nurseries, these types of habitats are poorly represented in Hawaii (MacDonald and Stimson, 1980). In the NWHI, there was no correlation found between shallow habitat and fishery production, suggesting that lobster pueruli may recruit directly to deeper waters from the pelagic habitat relative to other tropical lobster species (Parrish and Polovina, 1994). Upon settling, puerulus molts into the postpuerulus stage, typically around the time of the full moon (Macdonald, 1986).

### 1.3.4. JUVENILE STAGE

Although post-larval recruitment is influenced by the abundance of pueruli in the banks surrounding waters, differences in adult production between banks in the NWHI is also driven by availability of juvenile habitat (Parrish and Polovina, 1994; Polovina *et al.,* 1995). The habitat requirements of juvenile spiny lobsters are believed to be the bottleneck for adult lobster abundance (Parrish and Polovina, 1994). Observations of small lobsters between 1 and 30 m provide evidence that 30 m is the deepest that lobster larvae are able to settle (Polovina and Moffit, 1995). The highest abundances of juveniles are found in benthic habitat with intermediate (5-30 cm) vertical relief (Parrish and Polovina, 1994). Lower densities of juvenile lobster are found in habitats with low vertical relief (< 5 cm) and high vertical relief (>30 cm) (Parrish and Polovina, 1994). Intermediate vertical relief is provided by scattered coral colonies and algal fields, which are common habitats in the 2 most historically productive fishing grounds at Necker Island and Maro Reef (Parrish and Polovina, 1994). The intermediate vertical relief benthic habitat likely represents a compromise between shelter and abundance of predators; it is enough relief to provide some shelter, but in habitats with relief > 30 cm predatory reef fish such as sharks and jacks that prey on juvenile lobsters are more abundant.

Not only do benthic algae provide shelter, it may also play a role in the trophic ecology of lobsters (MacDiarmid *et al.,* 1991). Macroalgae that provide intermediate vertical relief found in the NWHI include *Dictopterus* sp., *Sargassum* sp., and *Padina* sp. Algal presence and growth is closely associated with temperature, thus northerly banks may be more susceptible to cooling and loss of algae cover resulting in reduced recruitment, increased natural predation, and potentially a reduction in food available to lobsters (Parrish and Polovina, 1994).

### 1.3.5. ADULT STAGE

Adult lobsters recruit to the fishery approximately 3 years after settling on to benthic habitat, which is slightly larger than the onset of sexual maturity (MacDonald 1985; Polovina and Mitchum, 1992). Generally adult lobsters are found in depths between 20 and 150 m at banks with summits less than 30 m deep, and do not move between banks, which can have depths over 4,000 m (Parrish and Polovina, 1994; Polovina *et al.,* 1995). The depth with highest abundance of lobsters varies with latitude and is likely a result of temperature (Uchida and Tagami, 1984). In the southern portion of the NWHI highest abundances were found in depths from 37 and 64 m, but north of Gardener Pinnacles higher abundances were found in depths of 10 to 36 m. Commercial fishers frequently fish in depths between 20 and 70 m (Polovina, 1993).

Vertical relief of habitat is not found to be correlated with adult lobster abundance (Parrish and Polovina, 1994). Perhaps this is because adult lobsters are less vulnerable to predators (Parrish and Polovina, 1994). Adult lobsters are often found in cracks and crevices of reefs, have been observed moving across open sandy areas between reef patches in pairs (MacDonald 1984), and are also found on the banks of deep slopes that are characterized by 'heavy seas, strong bottom surge, and swift currents' (Parrish and Kazama, 1994).

Unlike other *Panulirus* sp., adult lobsters do not undergo significant migrations. Tag and recapture studies in the NWHI found that the majority of lobsters moved < 1 km after over a year at liberty (O'Malley and Walsh, 2013). Limited movement patterns are likely because juvenile and adult lobster habitats are the same, offshore currents are within reach of newly hatched larvae, and the NWHI do not experience large seasonal shifts in water temperature (O'Malley and Walsh 2013).

*P. marginatus* are nocturnal predators (FAO, 1991) and are regarded as omnivorous, opportunistic scavengers (Pitcher, 1993). Food items reported from the diets of *Panulirus sp*. include echinoderms, crustaceans, mollusks (primarily gastropods), algae, and seagrass (Pitcher 1993). Catchability of spiny lobsters does not appear to be related to seasonal or lunar changes (MacDonald and Stimson, 1980)

### 1.4. SUMMARY OF HABITAT USE

| Stage | Stage Duration | Diet | Depth Distribution | General Distribution | Benthic Habitat | Oceanographic Features |
|---|---|---|---|---|---|---|
| **Egg** | 30-40 days (Morris,1968) | N/A | benthic (brooded by females) | N/A | N/A | N/A |
| **Larvae (phyllosoma)** | 12 months (Polovina and Moffit, 1995) | N/A | 80-100 m (daytime) 10- 20 m (night) (Polovina and Moffit, 1995). | Offshore (25 nmi from 200 nm contour) (Polovina and Moffit, 1995) | N/A | strength of the Subtropical Counter Current (SCC) at 26° N latitude and sea level height (Polovina, 1999) |
| **Post-pueruli and Juvenile** | ~3 years (Polovina and Moffit, 1989) | N/A | 1-30 m (Polovina and Moffit, 1995) | Settlement higher at center of Archipelago and in NWHI (MacDonald, 1986) | benthic habitat with intermediate (5-30 cm) vertical relief (Parrish and Polovina, 1994) | Temperature** (Polovina and Parrish, 1994) |
| **Adult** | Up to 20 years (Butler and MacDiarmid, 2011)* | echinoderms, crustaceans, mollusks, (primarily gastropods) algae, and seagrass (Pitcher, 1993) | between 20 and 150 m at banks with summits < 30 m deep (Polovina *et al.*, 1995) | Highest abundances in NWHI Maro Reef and Necker Island (Lacchei *et al.*, 2014) | Slopes of banks with rocky substrate or found in cracks and crevices in coral reef habitat (Polovina, 1989; Pitcher, 1993) | High abundance found in areas with heavy seas (4-6 ft.), strong bottom surge, and swift currents (1-2 knots) (Parrish and Kazama 1994) Also found in calm lagoon areas in the NWHI(Lacchei and Toonen, 2013) |

*Based on other species of spiny lobster.
**Algal cover that provides intermediate relief habitat utilized by juveniles is impacted by temperature.

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# 2. RED SPINY LOBSTER (*PANULIRUS PENCILLATUS*)

## 2.1. SPECIES DESCRIPTION AND DISTRIBUTION

*Panulirus pencillatus* also known as the ula, red spiny lobster, and proghorn spiny lobsters, is found from the Indo-West to the Eastern Pacific, the widest known geographic distribution of any spiny lobster species (Cockcroft *et al.,* 2011). Two genetically distinct populations have been identified between the western/central and eastern Pacific (Abdullah *et al.,* 2014). The common name of the species comes from the body color of individuals found in the eastern Pacific, which is less fitting for *P. pencillatus* with a greenish body color that are found in the western/central Pacific (Abdullah *et al.,* 2014).

## 2.2. FISHERIES

Red spiny lobster is targeted by lobster fisheries throughout its range, and is considered overexploited in many regions (Cockcroft *et al.,* 2011). Due to its relatively shallow depth preference, it most typically is targeted using hands from spearfishers, or fishers who walk along the reef flat at night (Coutures, 2003). In the Western Pacific region, fisheries exist for the red spiny lobster in American Samoa, CNMI, Guam, and the MHI (McGinnis, 1972; Coutures, 2003; Porter *et al.,* 2005). It is the most abundant lobster species in American Samoa, one of the top landed invertebrate species in CNMI and has been heavily exploited in the MHI. Although not targeted in the NWHI lobster fishery, red spiny lobsters were landed in low numbers (DiNardo and Moffit, 2007).

## 2.3. LIFE HISTORY

### 2.3.1. GROWTH, MATURITY, NATURAL MORTALITY, AND MOVEMENT

Like other lobster species, *P. pencillatus* growth is step-wise and body size increases by molting (Coutures, 2003). Reported growth rates vary substantially by region and are likely affected by local factors such as temperature and growth. Growth rates are generally high in juveniles and decrease with age, specifically at the onset of maturity, when more energy is devoted towards reproductive growth and molting becomes less frequent (Courtes, 2003).

*P. pencillatus* are sexually dimorphic, males reach larger sizes and grow faster than females (Coutures, 2003). Size at 50% sexual maturity in the Western Pacific region is estimated at 6 cm CL, approximately 2-3 years after settling in benthic habitat (Ebert and Ford, 1986; Coutures, 2003). The largest male is reported as 16 cm carapace length (Richer de Forges and Laboute, 1995).

Although natural mortality rates (*M*) vary with size and age, an average *M* of 0.25 per year was estimated for lobsters in CNMI (Ebert and Ford, 1986). Large males may be more vulnerable to predation due to difficulty finding large dens (Coutures, 2003). Large males may be absent on reefs where large dens are not available due to high predation rates. Although specific mortality rates have not been reported for this species, other spiny lobsters lived up to 20 years (Butler and MacDiarmid, 2011).

### 2.3.2. REPRODUCTION

Spawning season varies by location. For example, Enewetak Atoll in the Marianas has a peak in berried females during the spring, while the presence of berried females in another nearby atoll peaked in the fall (Ebert and Ford, 1986). In Hawaiʻi, berried females are found throughout the year (MacDonald, 1971). The drivers behind seasonality of spawning are not known, but may be related to environmental factors such as temperature (Ebert and Ford 1986).

The relationship between size and fecundity of females is exponential, and females may spawn 2-3 times per year (MacDonald, 1971; Pitcher, 1992). Like other spiny lobster species, fertilization is external and occurs when the male deposits a spermatophore on the abdomen of the female which she scratches off to fertilize extruded eggs. Eggs are brooded for approximately one month before hatching as pelagic larvae (Chubb, 1994). Females release eggs in areas that allow the pelagic larvae to quickly drift offshore (Coutures, 2000).

### 2.3.3. LARVAE AND RECRUITMENT

Phyllosoma larvae drift in the pelagic environment for up to 8-9 months before settling (Matsuda *et al.,* 2006) where they are carried up to 3,700 km by ocean currents and gyres (Johnson, 1974). In larval tows across the Hawaiian archipelago, *P. pencillatus* phyllosoma were found in high abundance near Oʻahu, but were not present in any tows east of French Frigate or off of Midway Atoll (Johnson, 1968).

Limited information is available about *P. pencillatus* recruitment in the Western Pacific region, but they are believed to settle in the same benthic habitat utilized by adults, near the outer reef break (Coutures, 2003). In French Polynesia, *P. pencillatus* post-larvae make active settlement choices, with highest preference towards dead coral (Lecchini *et al.,* 2010). Recruitment also occurred on live coral, macroalgae, and sand (Lecchini *et al.,* 2010).

### 2.3.4. JUVENILE STAGE

No juvenile specific information was found in the literature, but they are thought to inhabit the same areas as adult lobster (Coutures, 2003).

### 2.3.5. ADULT STAGE

Red spiny lobsters occupy relatively shallow depths from 1-16 m deep on small islands or near arid coasts (Holthuis, 1991). In the Western Pacific adults are found in clear waters near fringing or reefs slopes that are exposed to high wave energy, habitat that is typically found on the windward exposure of islands in depths up to 5 m (George, 1992; Ebert and Ford, 1986). *P. pencillatus* are nocturnal, hiding in protected caves and corals, or under boulders during the day that are present in lagoons and the outer reef slope (George, 1972; MacDonald, 1979; Coutures, 2003). At night, lobster move up the spurs and grooves of surge channels at the reefs edge and into shallow reef flats to forage (Coutures, 2003).

*P. pencillatus* have a robust pereiopod, which may be an advantageous adaption that allows foraging in shallow, high energy wave environments where rates of foraging competition and predation may be lower (MacDonald, 1988). Spiny lobster feed on algae, crustaceans, echinoderms, polychaets, and mollusks found in reef flats (Graham, 1993). Females migrate further up the reef flat (closer to shore) than males at night, which may make them more susceptible to fishers walking on reef flats (Ebert and Ford, 1986).

In Hawaii, historical exploitation rates are higher in the MHI than in the NWHI due to the >18 m depth restriction that was used to manage the NWHI lobster fishery (Lacchei *et al.,* 2014). However, in general, abundances of spiny lobster are much higher in the MHI compared to the NWHI because of the larger area of available shallow habitat (Lacchei *et al.,* 2014). In Tutuila, American Samoa the total area of *P. pencillatus* habitat is small, a narrow ban that has a 20-25 m width around the reef edge. In CNMI the estimated density of lobsters per linear km is on average 126 (Ebert and Ford, 1986).

**2.4. SUMMARY OF HABITAT USE**

| Stage | Stage Duration | Diet | Depth Distribution | General Distribution | Benthic Habitat | Oceanographic Features |
|---|---|---|---|---|---|---|
| **Egg** | 1 month (Chubb, 2000) | N/A | Benthic (brooded by females) | N/A | N/A | Eggs hatched in areas accessible to currents (Coutures, 2003) |
| **Larvae** | 8-9 months (Matsuda *et al.*, 2006) | N/A | Pelagic | Offshore | N/A (pelagic) | Oceanic gyres and currents (Johnson, 1997) |
| **Juvenile** | 2-3 years (Ebert and Ford, 1986) | N/A | N/A | N/A | Dead coral, live coral, macroalgae, sand (Lecchini *et al.*, 2010) | N/A |
| **Adult** | Up to 20 years (Butler and MacDiarmid, 2011)* | Algae, crustaceans, echinoderms, polychaetes, mollusks (Hothuis, 1991) | 0-5 m (George, 1972) | Most common on outer reef slopes of fringing reefs moving at night up surge channels at the reef edge and onto shallow reef flats (Coutures, 2003) | Reef or rocky areas with high vertical structure (Coutues, 2003) | Clear oceanic waters and high energy wave action typical of windward exposure (Holthuis, 1991) |

*Based on other species of spiny lobster.

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# 3. SLIPPER LOBSTER (*SCYLLARIDES SQUAMOSUS*)

## 3.1. SPECIES DESCRIPTION AND FISHERIES

The scaly slipper lobster (*Scyllarides squamosus*), or ulu papapa, is found throughout the Indo-Pacific from east Africa to Japan, Hawaiʻi, Melanesia, and Australia (Butler *et al.,* 2011). In the NWHI *S. squamosus* is assumed to make up a single meta-population (DiNardo and Moffit, 2007).

*S. squamosus* made up a minor portion of catch in the NWHI from the 1970s to 1996 in fishers primarily targeting *P. marginatus*. From 1997-1999 several commercial vessels began targeting slipper lobster at Maro Reef (DeMartini and Kleiber, 1998), During the time that the NWHI lobster fishery was active, because little was known about the life history of the scaly slipper lobster, life history parameters were borrowed from the spiny lobster species that was also targeted in the fishery (O'Malley, 2011). However, recent studies on *S. squamosus* reveal life history characteristics between the two species are very different than previously thought (O'Malley, 2011). The NWHI was closed in 2000 due to uncertainty in assessment results and population status of both lobster species. Recent fishery independent surveys indicate that abundance of scaly slipper lobsters has not increased since that time (O'Malley, 2011).

In the MHI, the slipper lobster is managed with 7 cm tail width minimum size regulations.

## 3.2. LIFE HISTORY

### 3.2.1. GROWTH, MATURITY, NATURAL MORTALITY, AND MOVEMENT

Growth of *S. squammosus* varies by location. Growth is best described by the Schnute model; juveniles experience faster growth rates, which decline with the onset of maturity (O'Malley, 2011). In the NWHI, growth rates vary by bank; however, individual variation in growth at each bank is minimal (O'Malley, 2011).

Size at sexual maturity also varies by location, but has been reported occurring around 6.6-6.7 cm (Hearn *et al.,* 2007, Lavalli *et al.,* 2009). Adults can reach sizes up to 20 cm CL (Holthuis, 1991). Natural mortality varies by location and year (O'Malley, 2009), and adults do not move large distances (< 1 km; O'Malley and Walsh, 2013).

### 3.2.2. REPRODUCTION

In Hawaiʻi, ovigerous females are found throughout the year and peak in abundance during May and July when water is warmer (O'Malley 2011). Fecundity increases with size and ranges between 54,000 and 227,000 eggs per female (DeMartini and Williams, 2001; DiNardo and Moffitt 2007; Sekiguchi *et al.,* 2007).

### 3.2.3. LARVAE AND RECRUITMENT

The pelagic larvae duration of *S. squamosus* is between 3 - 6 months (DiNardo and Moffitt, 2007). Larvae have been found up to 20 km of coast of southwest Oʻahu (Phillips and McWilliam, 1989) and in midwater trawls around the Marianas (Sekiguchi, 1990).

### 3.2.4. JUVENILE STAGE

There is no information on the juvenile stage of *S. squammosus*.

### 3.2.5. ADULT STAGE

*S. squammosus* are found in reefs and rocky areas (Holthuis, 1991). The reported depth range of this species varies by location. In Hawai'i, the reported depth range is 30 – 120 m (DiNardo and Moffit, 2007). In other areas it is reported as 5-80 m with highest abundances at 20-50 m (Chan, 1998). Adult *S. squammosus* are found in very high densities in banks making them very vulnerable to trap fisheries (Clarke and Yoshimoto, 1990).

The scaly slipper lobster reaches sexual maturity between a 66-67 mm carapace length (DeMartinit and Kleiber, 1998) and can reach a maximum size of 15 cm carapace length (Holthuis, 1991) shelters during the day, and forages at night where it feeds mainly on bivalves (Chan, 1998; Lavalli and Spanier, 2007). Adults are known to feed on bivalves (Chan, 1998; Lavalli and Spanier, 2007).

### 3.3. SUMMARY OF HABITAT USE

| Stage | Stage Duration | Diet | Depth Distribution | General Distribution | Benthic Habitat | Oceanographic Features |
|---|---|---|---|---|---|---|
| **Egg** | | | benthic (brooded by females) | | | |
| **Larvae** | 3-6 month (DiNardo and Moffit, 2007) | | pelagic | Offshore (at least 20 km) (Phillips and McWilliam, 1989) | N/A (pelagic) | Optimal temperature 25-29 C (Minagawa, 1990) |
| **Juvenile** | | | | | | |
| **Adult** | | Bivalves (Chan 1998, Lavalli *et al.,* 2007) | 1-120 m (DiNardo and Moffit, 2007) | Most common on outer reef slopes of fringing reefs moving at night up surge channels at the reef edge and onto shallow reef flats (Courtes, 2003) | Reef and rocky areas (Holthuis, 1991) | |

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# 4. KONA CRAB (*RANINA RANINA*)

## 4.1. GENERAL SPECIES DESCRIPTION AND DISTRIBUTION

The kona crab (*Ranina ranina*), also known as frog crab, red frog crab, papa'i kua loa, krab ziraf, and spanner crab is a large marine brachyuran which is targeted by both commercial and recreational fishers in Hawai'i. While Hawai'i represents the easternmost point of the Kona crab's range (Brown, 1985) commercial fisheries also exist in Australia, Japan, Philippines, Thailand, Seychelles Islands and Hawai'i (Brown, 1985; Tahil, 1983; Boulle, 1995; Krajangdara and Watanabe, 2005). The largest fishery for Kona crabs is found in Queensland, Australia where annual landings can reach over six million pounds making it the largest single species fishery in the State (Dichmont and Brown, 2010). No genetic information is currently available to determine the connectivity of Kona crabs across the Hawaiian Archipelago.

## 4.2. FISHERIES

A small commercial fishery for Kona crabs has operated continuously in the MHI since 1938, with an annual peak in landings of 70,000 lbs. occurred in 1972 (Vansant 1978). Additionally, a small number of crabs were landed in the NWHI and Kona crab were taken incidentally in the NWHI spiny lobster fishery (closed in 2000) (Brown 1985). Historically, the majority of Kona crab landings in Hawai'i have come from either Penguin Bank, located off the southwest coast of Moloka'i, or from the northwest coast of Ni'ihau (Onizuka, 1972). Several fishermen also operate off the north coast of O'ahu (Onizuka, 1972). Kona crab is thought to be a popular target for recreational fishers (Smith, 1993) however, the extent of the recreational fishery is not known.

Currently the State of Hawai'i Department of Aquatic Resources (HDAR) manages the MHI Kona crab stock as one management unit. The fishery is currently managed using four regulations: (1) seasonal closure May-August, (2) a minimum legal size of 4 inch carapace length, (3) no taking/killing of female crabs and (4) no spearing of crabs. The same regulations apply to recreational fishers. The WPRFMC does not have species-specific management measures applicable to federal waters.

## 4.3. LIFE HISTORY

### 4.3.1. GROWTH, MATURITY, MOVEMENT, AND NATURAL MORTALITY

Definitive growth rates of Kona crabs are not known but some partial information is available. In Australia two opposing hypotheses for the growth rates of Kona crabs have been proposed. The fast growth hypothesis estimates that crabs will reach a minimum legal size (4 inches) within 18 months will be 5.5 inches in 4 years and will attain maximum size within 8 to 9 years (Brown, 1986; Boullé, 1995). The slow growth hypothesis estimates that male crabs would take 4 years to reach minimum legal size (4 inches), nine years to attain 5.51-inch size and 14 - 15 years to attain maximum size found in this species (de Moussac, 1988; Chen and Kennelly, 1999; Brown *et al.,* 1999; Kirkwood *et al.,* 2005). Aquarium-reared Kona crabs were found to grow approximately 0.25 inches per week from the time they settle, until the time they have reached the ninth instar (Brown *et al.,* 2008).

The growth rates of Kona crabs are difficult to assess as their hard parts are lost during molting, and growth rates are stepwise between molts (Brown *et al.,* 1999). Catch and recapture methods to determine growth provide an overestimation of time between molts as time since last molt of recaptured crabs cannot be determined (Chen and Kennelly, 1999) and tagging can negatively affect growth rates (Brown *et al.,* 1999). An attempt at analyzing lipofuscin in the brain and eyestalks of the crabs to determine age was unsuccessful (Brown *et al.,* 2008) although this technique has been successful in other crustaceans (Sheehy and Prior, 2008). Due to high mortality rates of Kona crabs in captivity future attempts using this technique must begin with a larger sample size (Brown *et al.,* 2008). Overall, male Kona crabs grow faster than females and grow more per molt (Chen and Kennelly 1999; Brown *et al.,* 1999). Smaller crabs molt much more often than larger crabs. However, larger crabs experience more growth per molt (Chen and Kennelly, 1999). In Hawai‘i males grow on average 0.39 inches per molt and females grown an average of 0.30 inches per molt (Onizuka, 1972). The growth rates found in Kona crabs vary by region, as is typical for many crustaceans (Kruse, 1993). Factors such as temperature and food availability are correlated with the number of molts a crab experiences and how quickly a crab is able to grow (Brown *et al.,* 1999).

The size at which Kona crabs reach sexual maturity varies by region and sex. Color of Kona crabs may be a general indicator of their sexual maturity; immature crabs are white and turn orange as they mature (Fielding and Haley, 1976). In Hawai‘i, the majority of males were found to have mature spermatozoa at a 2.9 inch carapace length (Fielding and Haley, 1976). In Hawai‘i, over 87% of females were sexually mature with a 2.6 inch carapace length (Onizuka, 1972).

Natural mortality rates for Kona crabs in Hawai‘i are unknown (Onizuka, 1972). A preliminary estimate of natural mortality using the length converted catch curve was completed in the Seychelles Islands in the Indian Ocean. Natural mortality rates (M) in the Seychelles were estimated to be 0.8-0.9 $yr^{-1}$ for female crabs and 1.0 $yr^{-1}$ for males (de Moussac, 1988).

### 4.3.2. REPRODUCTION

Berried females (i.e., crabs that are bearing eggs) are found from May through September (Onizuka, 1972). The highest frequency of egg bearing females occurs in June and July. Ovarian growth for female Kona crabs occurs from February to May resulting in increased feeding during these months (Fielding and Haley, 1976). Feeding rates and thus emergence time in females has been found to be greatly correlated with their reproduction cycle (Kennelly and Watkins, 1994). Berried females rarely emerge from the sand causing catch rates for females to drop dramatically during certain times of the year (Skinner and Hill, 1987; Kennelly and Watkins, 1994). In months prior to breeding, emergence of females increases, as they search for food (Skinner and Hill, 1986).

In Kona crabs fertilization is external (Onizuka, 1972). Large brachyuran male crabs may be able to fertilize multiple females (Kruse, 1993). However, small male crabs may not be all of a female's eggs. A unique characteristic of brachyuran crabs is the ability of females to store sperm in the abdominal receptacle and successfully fertilize their eggs up to two years after copulation (Kruse, 1993). Male Kona crabs must be large enough to dig female crabs out of the sand and copulate (Skinner and Hill, 1986; Minagawa, 1993). The eggs are orange in color until a few days before hatching, when they turn brown (Onizuka, 1972). Eggs are brooded until they hatch 24 to 35 days after being fertilized (Onizuka, 1972).

### 4.3.3. LARVAE AND RECRUITMENT

Newly settled Kona crabs have been observed in the shallow waters of the surf break on a beach in west Maui (Layne Nakagawa, pers. comm.). Kona crab larvae spend several weeks as planktonic larvae which is their primary mechanism for dispersal (Brown, 1985). The first molt, when the larvae develop into a zoea I stage, is typically 7-8 days after the larvae hatch (Fielding, 1974). Six to seven days later a second molt occurs and the larvae develop into the zoea II stage. Prey density greatly affects the time between molts and the growth of these larval crabs (Minagawa and Murano, 1993a). Larvae begin to settle on the bottom 5-6 weeks after they have hatched (Brown *et al.,* 2008). The newly settled crabs typically have around a 0.40 inch carapace length (Brown *et al.,* 2008). The settlement cue for the larvae is unknown but they are presumed to settle in sandy substrata (Brown *et al.,* 2008). Larvae feed mostly during the day but little is known about the food preference of the larvae making aquaculture-rearing attempts unsuccessful to date (Minagawa and Murano, 1993b). Changes in temperature will affect the feeding habits of the larvae as water temperature is correlated with feeding rates (Minagawa and Murano, 1993b).

### 4.3.4. JUVENILE STAGE

The habitat of small juveniles is unknown but assumed to be similar to the adult habitat (Brown, 2001).

### 4.3.5. ADULT STAGE

Adult Kona crabs can reach up to 5.5-10.4 inches in length, and live up to 10 years (Pecl *et al.,* 2011). Adult Kona crabs are found in sandy substrata adjacent to coral reefs in areas subject to strong currents across the tropical and subtropical Indo-Pacific in depths ranging from 6 to 650 feet (Vansant, 1978). Most commercial Kona crab fishing in Hawaiʻi occurs from 50 to 150 feet (Vansant, 1978)

The crabs spend a majority of time buried in the sand to avoid predators which include sharks, rays, loggerhead turtles, large fish, and occasionally marine mammals (Skinner and Hill, 1986; Kennelly *et al.,* 1990). Kona crabs emerge from the sand to feed and mate (Skinner and Hill, 1986). Kona crabs are opportunistic scavengers but also feed on small fish and invertebrates (Onizuka, 1972).

### 4.4. SUMMARY OF HABITAT USE

| Stage | Stage Duration | Diet | Depth Distribution | General Distribution | Benthic Habitat | Oceanographic Features |
|---|---|---|---|---|---|---|
| **Egg** | 24-35 days (Onizuka, 1972) | N/A | benthic (brooded by females) | N/A | N/A | |
| **Larvae** | 5-6 weeks (Brown *et al.*, 2008) | | pelagic | Offshore | N/A (pelagic) | Temperature* (Minagawa and Murano, 1993b) |
| **Juvenile** | | Similar to adults (Brown *et al.*, 2008) | Shallower than juveniles (pers. comm.) | | Sandy substrata adjacent to coral reefs (Brown, 2008) | |
| **Adult** | | Opportunistic scavengers but also feed on small fish and invertebrates (Onizuka, 1972) | 2 – 200 m (Vansant, 1978) | Wide islands shelves (Thomas *et al.*, 2013) | Sandy substrata adjacent to coral reefs (smooth soft bottoms) (Brown, 2008) | Areas subject to strong currents (Vansant, 1978) |

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