

ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT: FISHERY ECOSYSTEM PLAN FOR THE AMERICAN SAMOA ARCHIPELAGO

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 fishery, 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 appeared to be stable. On a short-term average, total catch of all species caught with the bottomfishing gear have increased by 9%, though total landings sold have continued to decline but are within the 10-year variations in catch. When considering only BMUS on a short-term basis, total estimated landings increased by 52% while the commercial landings decreased by 31%; 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 a decrease. The amount of effort in the bottomfish fishery (measured in gear-hours) increased by 35% in 2017 relative to 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 in 2017 was higher in the mixed bottomfishing and trolling methods than in the spearfishing method. Trolling CPUE had decreased 72% in 2017 in the midst of a 10-year increasing trend. The shore-based hook-and-line and rod-and-reel fisheries showed a lower estimated CPUE, whereas the spear, gleaning, and gillnetting fisheries had higher CPUE (deemed statistically significant for spear and gillnet). Fishing effort was lower for five coral reef fishery methods; 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 (96%) to just two total gear-hours.

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 section.

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 165th Council meeting; specifically, it identifies the various social and economic groups within the region’s fishing communities and their interconnections. The section begins with an overview of the socioeconomic context for the region, and then provides a summary of relevant studies and data for American Samoa, followed by summaries of relevant studies and data for each fishery within American Samoa, and concludes with relevant socioeconomic data trends including commercial pounds sold, revenues, and prices. There were no new data reported for neither the crustacean nor the precious coral fisheries in the archipelago. Considering the American Samoan bottomfish fishery, the price for BMUS reached a high of \$5/lb. in 2017, while the average cost of a bottomfish trip was similar to 2016 at approximately \$120. For the coral reef fishery in the region, the price of CREMUS remained steady at around \$3/lb. in 2017, while 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 recognize patterns and trends. The atmospheric concentration of carbon dioxide (CO₂) trend, for example, is 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 on the species distribution, fisheries in the Western Pacific Region, and life history is summarized. The annual report also addresses any Council directives toward its plan team, however there were no directives 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 are included for the first time in 2017 before suggested revisions at the request of the Plan Team for inclusion in the 2018 reports. The noncommercial coral reef fishery in American Samoa generally showed no association with

the environmental parameters assessed here. Members of the Scaridae family showed a negative relationship with SST, while species in the family Mullidae displayed a positive relationship. No statistically significant relationship was uncovered between the fishery and chlorophyll-*a* concentrations (including the incorporation of phase lag). A non-metric multidimensional scaling analysis showed that, while the evaluation was not able to identify any significant levels of association between expanded creel catch data and a swath 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 forward with associated 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 associated with this 2017 annual 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.

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

Regarding the improvement of identifying precious coral essential fish habitat, the Archipelagic Plan Team endorses the Plan Team Precious Coral Working Group Report, and they recommend

that the Council direct staff to develop an analysis of options to redefine EFH/HAPC for Council consideration for an FEP amendment.

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

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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° 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 km²) and most populated island, is the most eroded with the most extensive shelf area and has banks and barrier reefs. Aunu'u is a small island very close to Tutuila. Ofu and Olosega (together as 13 km²) 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 km²) 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 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 bottomfish 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 18th 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 Lau'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
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)	46,015 [▲9%] 	46,015 [▲26%] 
	Estimated total lbs. (all species) Commercial Purchase Data	4,492 [▼31%] 	4,492 [▼39%] 
Bottomfish MUS only	Total Creel Data Estimated (expanded) total lbs. (all BF trips)	20,420 [▲52%] 	20,420 [▲77%] 
	Estimated total lbs. (all species) Commercial Purchase Data	1,000 [▼31%] 	1,000 [▼44%] 
	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	46985		46985	
1990	14509	22937	37446	
1991	18388	37291	55679	3423
1992	14395	20901	35296	3059
1993	17293	13211	30504	7418
1994	47918	6511	54429	9296
1995	37641	6471	44112	15833
1996	38299	12384	50683	7550
1997	46118		46118	4559
1998	20540		20540	5182
1999	22330		22330	8165
2000	31373		31373	10865
2001	48916		48916	7462
2002	45343		45343	4454
2003	26234		26234	5517
2004	23155	447	23602	6381
2005	14421	4364	18785	5011
2006	7780	8611	16391	4501
2007	24870	14679	39549	9840
2008	46108	8769	54877	8679
2009	75015	2792	77807	8949
2010	16060	3985	20045	2294
2011	27366	5271	32637	1428
2012	6645	1777	8422	3195
2013	14286	7966	22252	2714
2014	30346	3677	34023	6539
2015	44047	7691	51738	6314
2016	35240	10253	45493	8983
2017	32059	5739	37798	3652
10-year avg.	32717	5792	38509	5275
10-year SD	18533	2650	18978	2806
20-year avg.	29607	6144	33908	6006
20-year SD	15926	3645	16157	2607

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	12115		12115	
1990	3332	2328	5660	
1991	6256	194	6450	2066
1992	4260	2287	6547	1819
1993	8131	766	8897	2845
1994	16639	594	17233	2422
1995	14519	297	14816	3662
1996	16079	1039	17118	1445
1997	18042		18042	1151
1998	9814		9814	1149
1999	11644		11644	2498
2000	7917		7917	2560
2001	18008		18008	2659
2002	12875		12875	483
2003	5023		5023	1797
2004	6703	167	6870	2565
2005	6806	1382	8188	2116
2006	2330	1088	3418	2980
2007	8670	1097	9767	2295
2008	16144	309	16453	4267
2009	22390	196	22586	2330
2010	4231	24	4255	709
2011	8087	32	8119	480
2012	1113	214	1327	734
2013	4161	374	4535	630
2014	12938	130	13068	2354
2015	17143	363	17506	1403
2016	18137	1342	19479	543
2017	15047	552	15599	1000
10-year avg.	11939	354	12293	1445
10-year SD	6745	364	6900	1150
20-year avg.	10459	519	10823	1778
20-year SD	5806	472	5813	1019

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 $\sum \text{catch} / \sum (\text{hours fished} * \text{number of fishers})$ for boat-based and $\sum \text{catch} / \sum (\text{hours fished} * \text{number of gears used})$ 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 2007-2017.

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 bottomfish MUS.

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY} B}{c B_{MSY}} \quad \text{for } B \leq c B_{MSY}$ $F(B) = F_{MSY} \quad \text{for } B > c B_{MSY}$	$c B_{MSY}$	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 time 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 ($F_{RO-REBUILD}$) 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.

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

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 American 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.)
<i>Selar crumenophthalmus</i> – atulai or 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
Serranidae – groupers	30,500
Siganidae – rabbitfish	200
All Other CREMUS Combined - Other CRE-finish - Other invertebrates - Misc. bottomfish - Misc. reef fish - Misc. shallow bottomfish	28,500
<i>Cheilinus undulatus</i> – humphead (Napoleon) wrasse	N.A.
<i>Bolbometopon muricatum</i> – 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 160th Council meeting on June 25 to 27, 2014. The specification covers fishing year 2015, 2016, 2017, and 2018 for the coral reef MUS complexes. A P* and SEEM analysis was performed for this multiyear specification (NMFS, 2015). For the bottomfish, it was a roll over from the previous specification since an assessment update was not available for fishing year 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	<i>S. crumenophthalmus</i>	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-mulletts	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
	<i>Cheilinus undulatus</i>	N.A.	N.A.	N.A.	3
	<i>Bolbometopon muricatum</i>	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 which:

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

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

The Council recognizes that MSY and OY are long-term values whereas the ACLs are yearly snapshots based on the level of fishing mortality at F_{MSY} . There are situations when the long-term means around MSY are going to be lower than ACLs especially if the stock is known to be productive or relatively pristine or lightly fished. One can have catch levels and catch rates exceeding that of MSY over short-term enough to lower the biomass to a level around the estimated MSY and still not jeopardize the stock. 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 (fishing year landings relative to the ACL or OY) and the harvest capacity (remaining portion of the ACL or OY that could potentially still be harvested in a given fishing year).

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 coral	Black coral	790	N.A.F.	0.0	100.0
	Precious coral in AS expl. area	2,205	N.A.F.	0.0	100.0
Coral Reef	<i>Selar crumenophthalmus</i>	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.
	<i>Cheilinus undulatus</i>	N.A.	3	N.A.	N.A.
	<i>Bolbometopon muricatum</i>	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.

1.16 REFERENCES

- Cook, R., 2014. Report on the Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.
- Fricke, H. and Meischner, D., 1985. Depth limits of Bermudan scleractinian corals: a submersible survey. *Marine Biology*, 88(2), pp. 175-187.
- Haddon, M., 2014. Center for Independent Experts (CIE) Peer Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.
- Hart, S.R., Coetzee, M., Workman, R.K., Blusztajn, J., Johnson, K.T.M., Sinton, J.M., Steinberger, B. and Hawkins, J.W., 2004. Genesis of the Western Samoa seamount province: age, geochemical fingerprint and tectonics. *Earth and Planetary Science Letters*, 227(1), pp. 37-56.
- Humphreys, R. and Moffitt, R., 1999. Unit 17-Western Pacific Bottomfish and Armorhead Fisheries. DOC, NOAA, NMFS Our Living Oceans—Report on the Status of US Living Marine Resources, pp. 189-192.
- Jones, C., 2014. Biomass Augmented Catch---MSY Model for Pacific Island Coral Reef Ecosystem Resources. Report submitted to the Center for Independent Experts.
- Kahng, S.E. and Maragos, J.E., 2006. The deepest, zooxanthellate scleractinian corals in the world? *Coral Reefs*, 25(2), pp. 254-254.
- Konter, J.G. and Jackson, M.G., 2012. Large volumes of rejuvenated volcanism in Samoa: Evidence supporting a tectonic influence on late-stage volcanism. *Geochemistry, Geophysics, Geosystems*, 13(6).
- Lang, J.C., 1974. Biological Zonation at the Base of a Reef: Observations from the submersible Nekton Gamma have led to surprising revelations about the deep fore-reef and island slope at Discovery Bay, Jamaica. *American Scientist*, 62(3), pp. 272-281.

- Martell, S. and Froese, R., 2013. A simple method for estimating MSY from catch and resilience. *Fish and Fisheries*, 14(4), pp. 504-514.
- Meyer, R. and Millar, R.B., 1999. Bayesian stock assessment using a state–space implementation of the delay difference model. *Canadian Journal of Fisheries and Aquatic Sciences*, 56(1), pp. 37-52.
- Moffitt, R.B., Brodziak, J., and Flores, T., 2007. Status of the Bottomfish Resources of American Samoa, Guam, and Commonwealth of the Northern Mariana Islands, 2005. NOAA Pacific Islands Fisheries Science Center Administrative Report H-07-04.
- Nadon, M.O., Ault, J.S., Williams, I.D., Smith, S.G. and DiNardo, G.T., 2015. Length-based assessment of coral reef fish populations in the main and northwestern Hawaiian Islands. *PLoS one*, 10(8), p.e0133960.
- Neall, V.E. and Trewick, S.A., 2008. The age and origin of the Pacific islands: a geological overview. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1508), pp. 3293-3308.
- NMFS, 2015. Specification of Annual Catch Limits and Accountability Measures for Pacific Island Coral Reef Ecosystem Fisheries in Fishing Years 2015 through 2018. Honolulu, HI 96813. RIN 0648-XD558. 228 p.
- Oram, R., TuiSamoa, N., Tomanogi, J., Sabater, M., Quach, M., Hamm, D., Graham, C., (in press). American Samoa Shore-Based Creel Survey Documentation. NOAA, National Marine Fishery Service, Pacific Island Fishery Science Center, Administrative Report x-xx-xx.
- Oram, R., TuiSamoa, N., Tomanogi, J., Sabater, M., Quach, M., Hamm, D., Graham, C., (in press). American Samoa Boat-Based Creel Survey Documentation. NOAA, National Marine Fishery Service, Pacific Island Fishery Science Center, Administrative Report x-xx-xx.
- Restrepo, V.R., Thompson, G.G., Mace, P.M., Gabriel, W.L., Low, L.L., MacCall, A.D., Methot, R.D., Powers, J.E., Taylor, B.L., Wade, P.R. and Witzig, J.F., 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31, pp. 1-54.
- Sabater, M. and Kleiber, P., 2014. Augmented catch-MSY approach to fishery management in coral-associated fisheries. *Interrelationships between Corals and Fisheries*. CRC Press, Boca Raton, FL, pp. 199-218.
- Williams, I. 2010. U.S. Pacific Reef Fish Estimates Based on Visual Survey Data. NOAA Pacific Islands Fisheries Science Center Internal Report IR-10-024.
- WPRFMC, 2011. Omnibus Amendment for the Western Pacific Region to Establish a Process for Specifying Annual Catch Limits and Accountability Measures. Honolulu, HI 96813.

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



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.

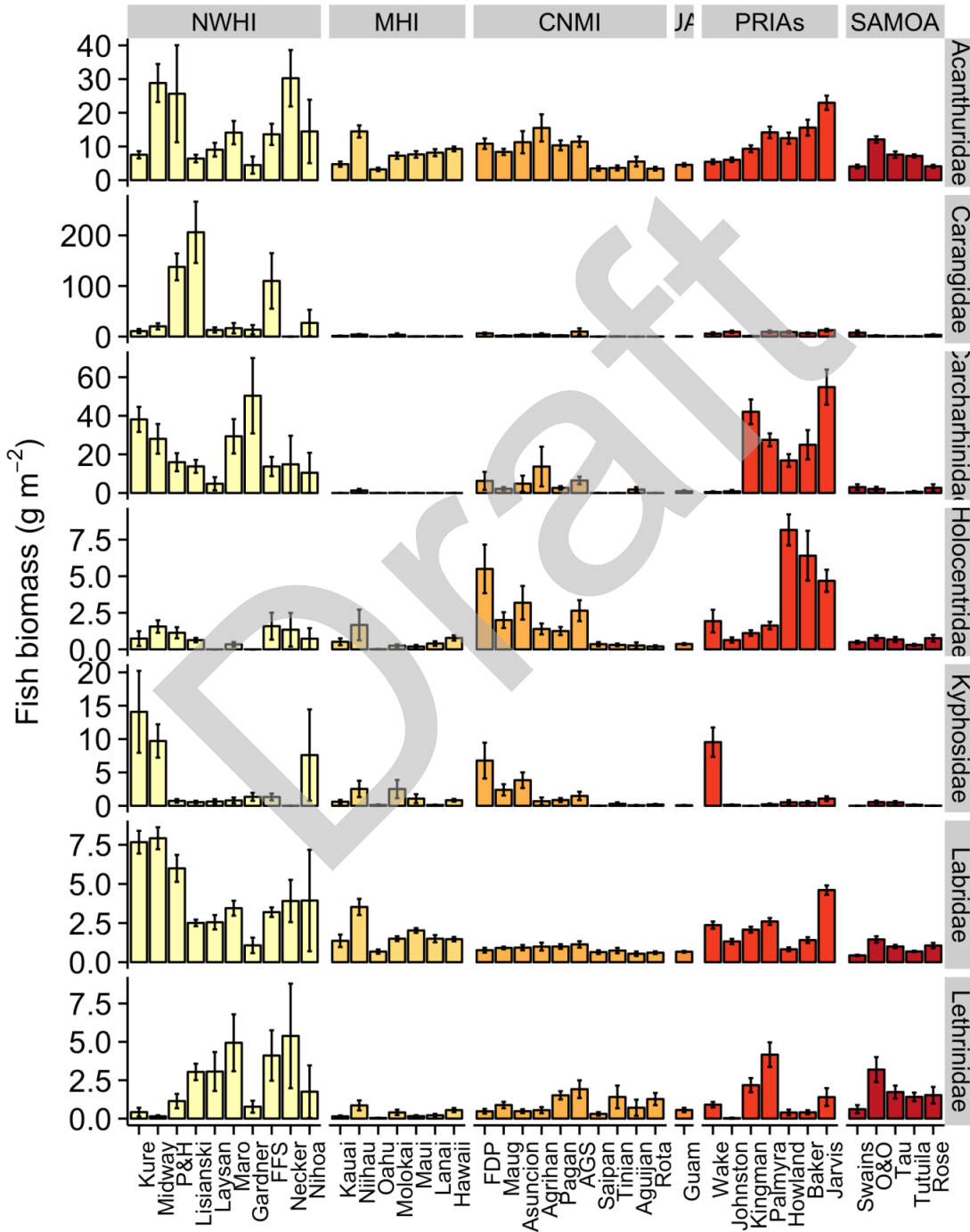
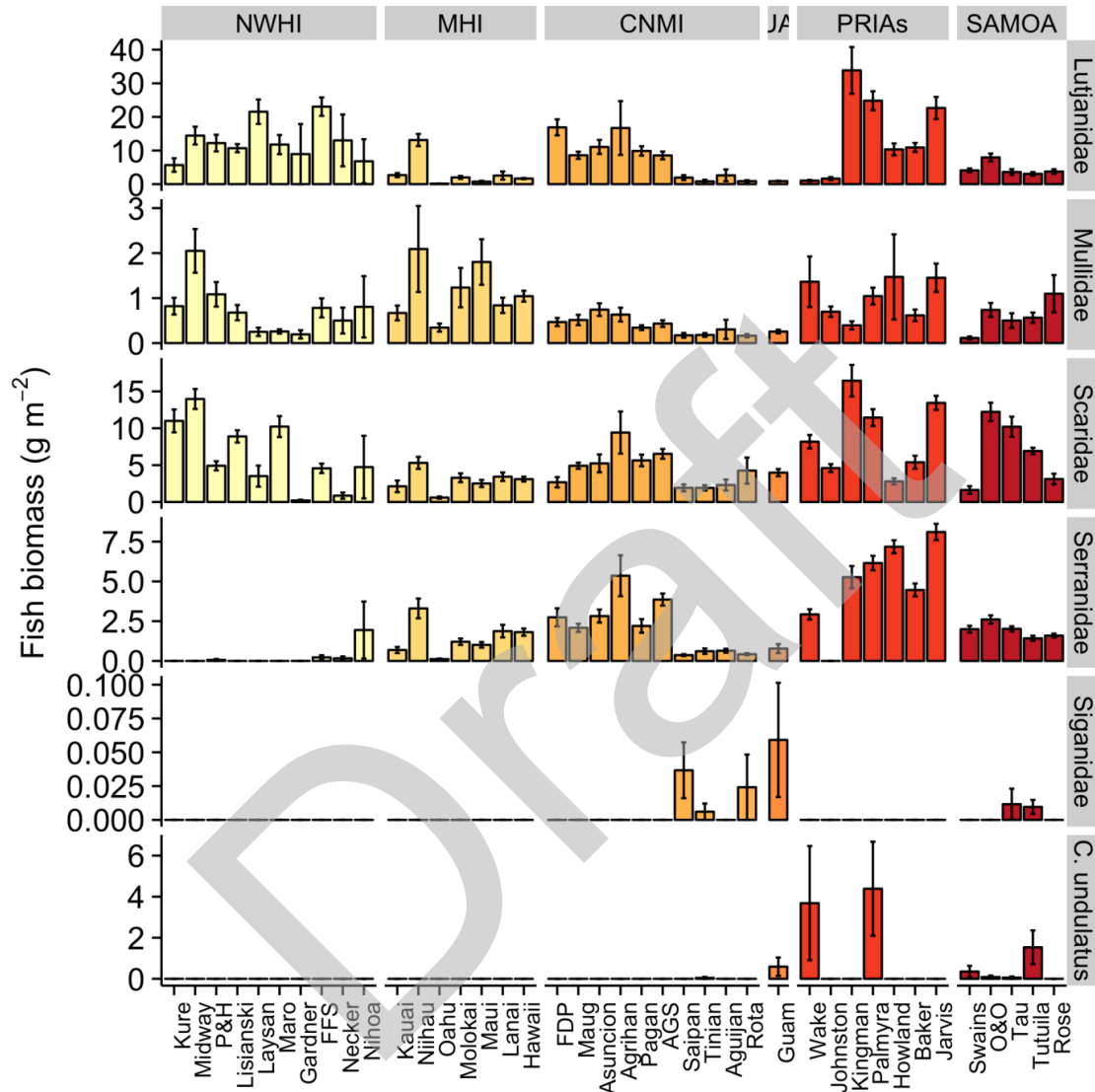


Figure 1. Mean fish biomass ($\text{g m}^{-2} \pm$ standard error) of Coral Reef Management Unit Species (CREMUS) grouped by U.S. Pacific reef area from the years 2009-2015. Islands are ordered within region by latitude. Figure continued from previous page.



2.1.2 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.

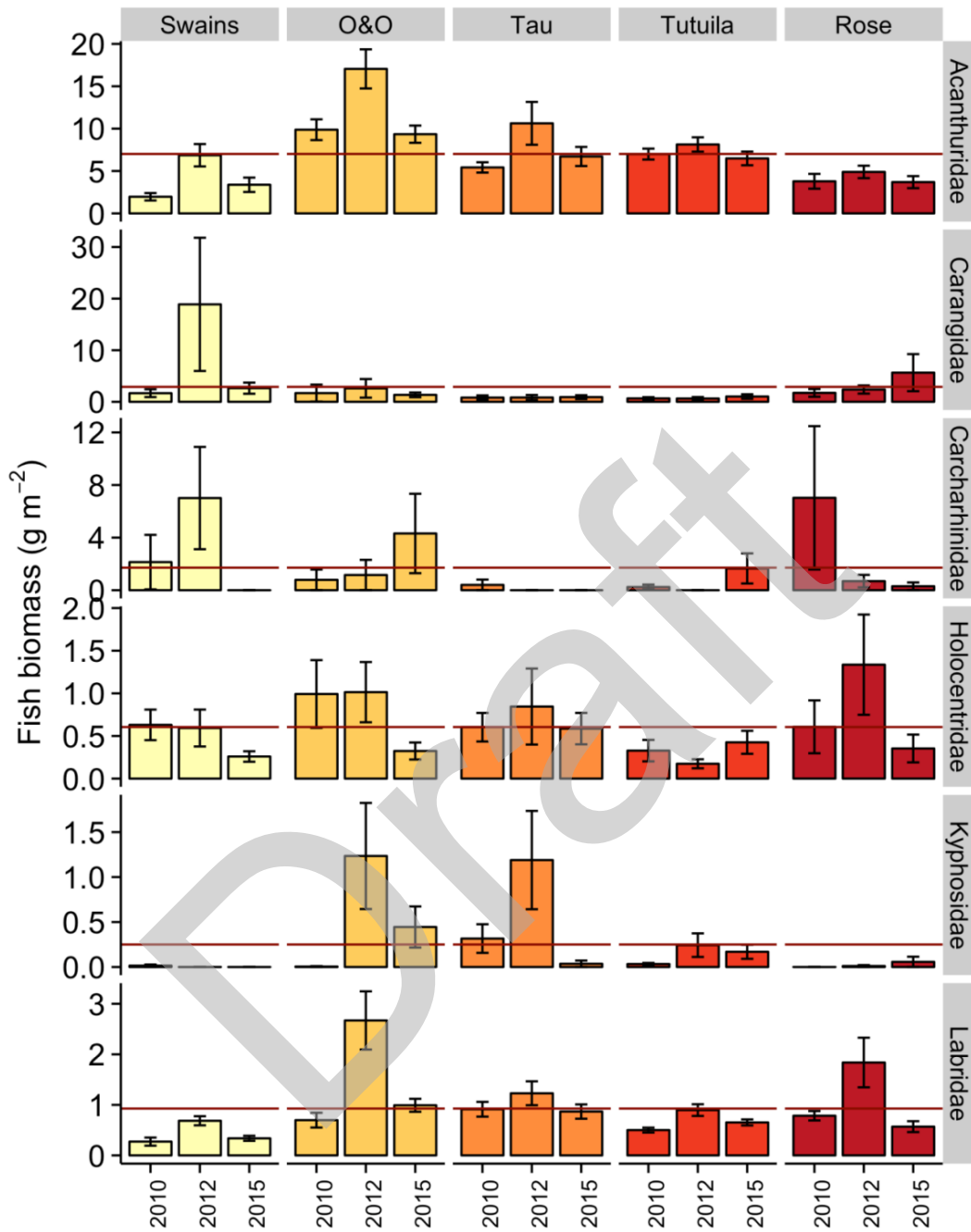
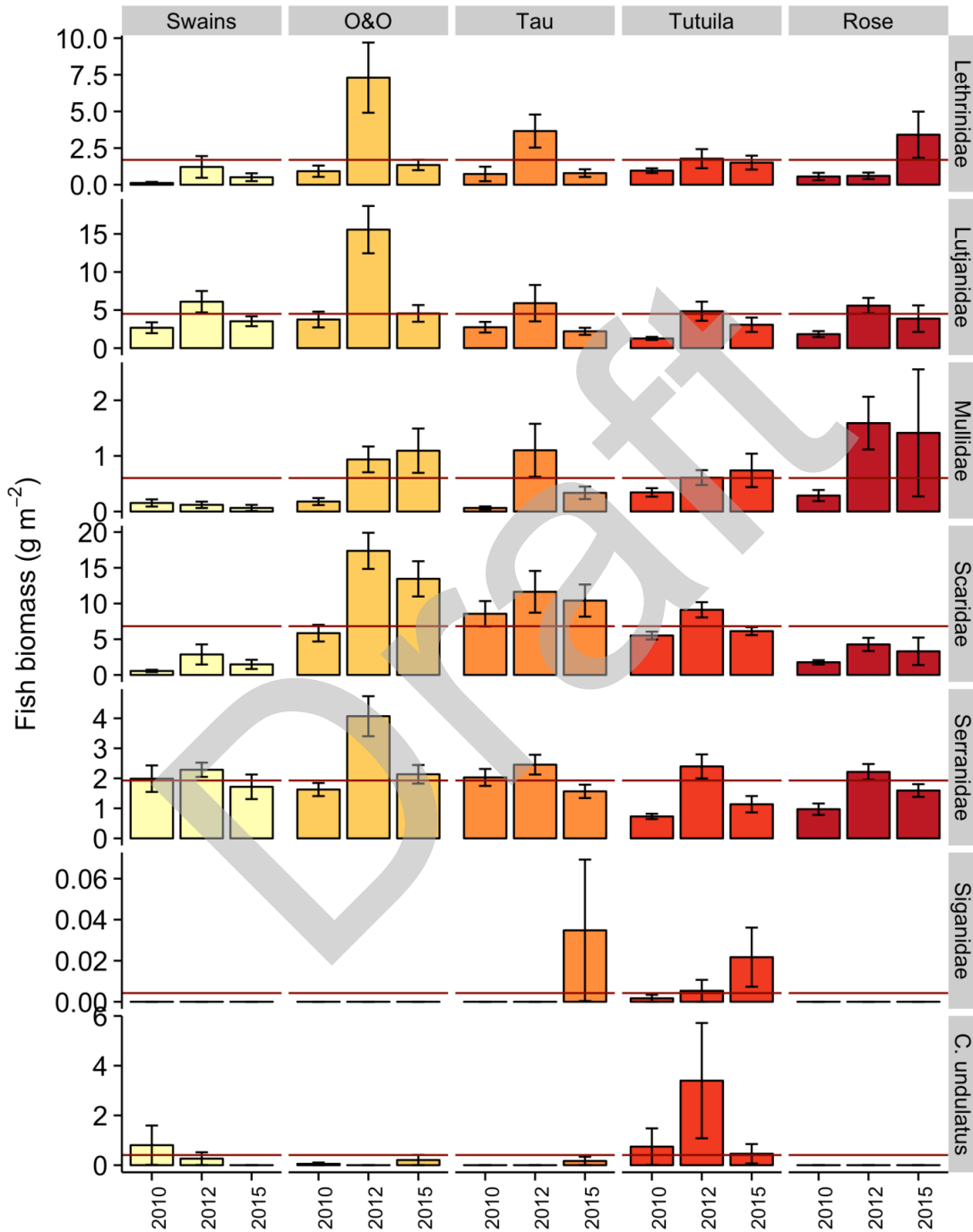


Figure 2. Mean fish biomass ($\text{g/m}^2 \pm$ standard error) of American Samoa CREMUS from 2009-2015. The American Samoa archipelago mean estimates are represented by the red line. Figure continued from previous page.



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.

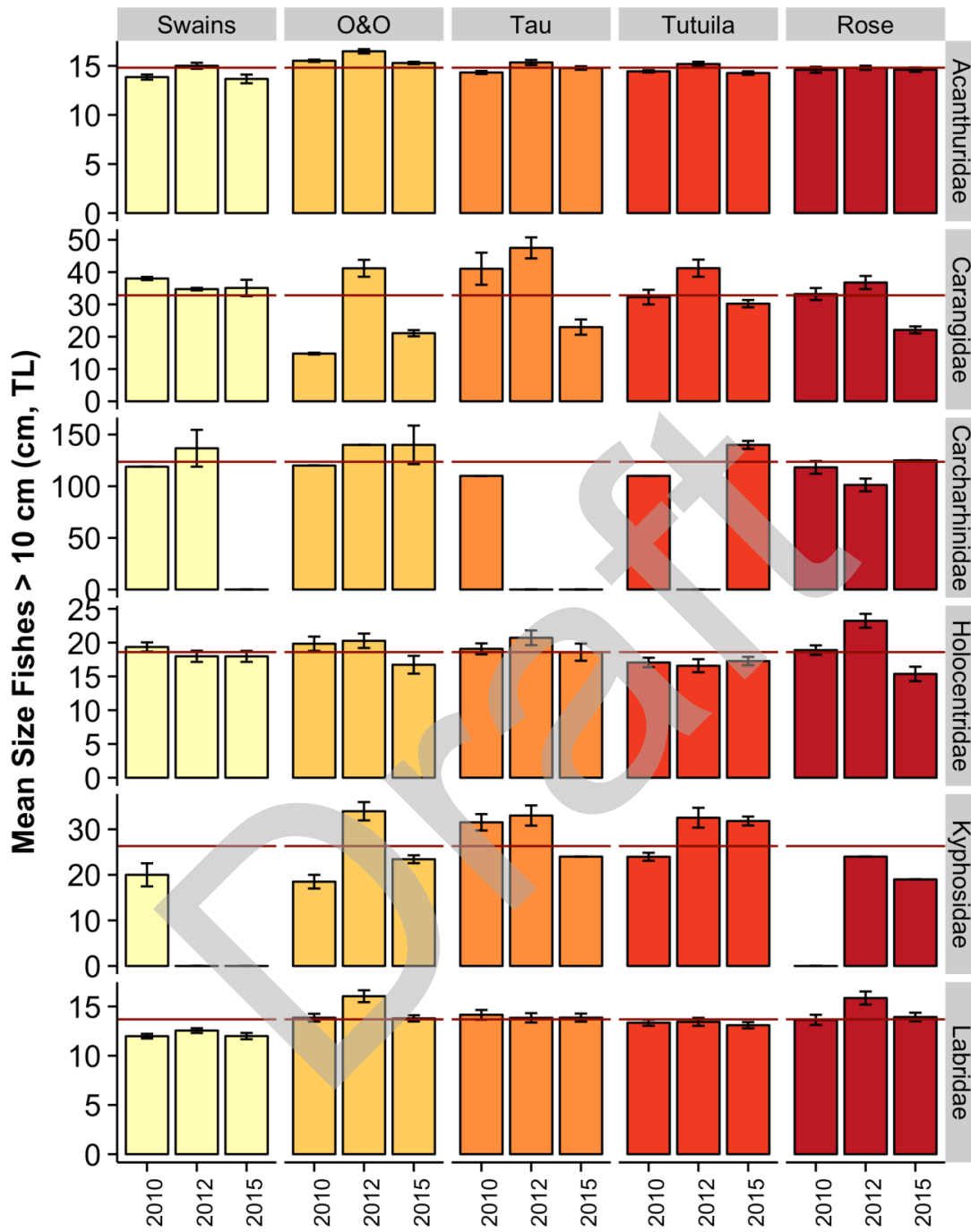
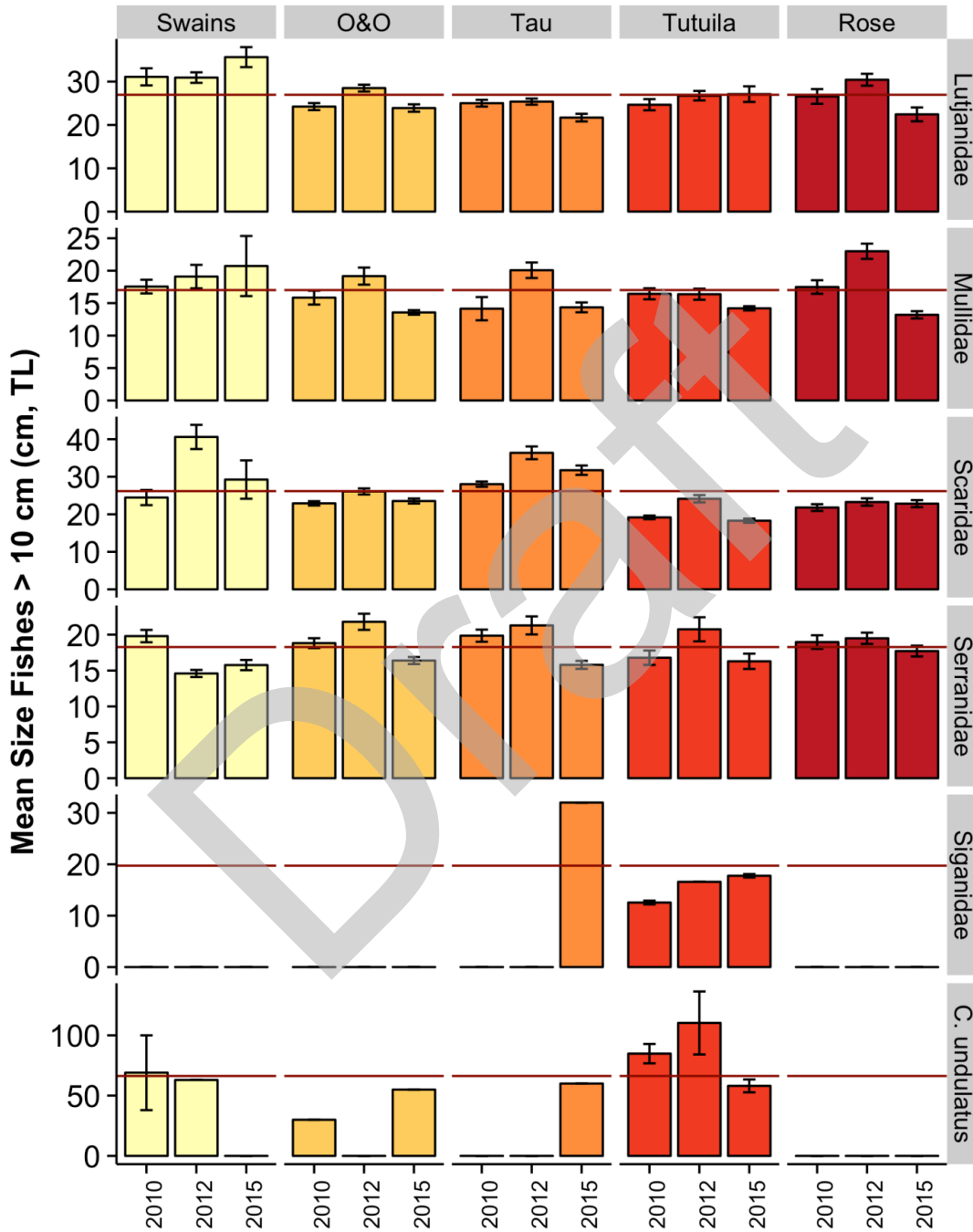


Figure 3. Mean fish size (cm, TL \pm standard error) of American Samoa CREMUS from the years 2009-2015. The American Samoa archipelago mean estimates are plotted for reference (red line). Figure continued from previous page.



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/m²) 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)	<i>N</i>	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)	<i>N</i>	Estimated population biomass (metric tons) in survey domain of < 30 m hard bottom					
			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 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 BioSampling Program allows for significant collection of life history samples like otoliths and gonads from priority species in the bottomfish and coral reef fisheries. These life history samples, once processed and data extracted, will contribute to the body of scientific information for the two data-poor fisheries in the region. The life history information available from the region will be monitored by the Fishery Ecosystem Plan Team and will be tracked through this section of the report.

This section will be divided into two fisheries: 1) coral reef; and 2) bottomfish. Within each fishery, the available life history information will be described under the age, growth, & 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_{∞} , 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_{∞} (asymptotic length) – One of three coefficients of the von Bertalanffy growth function (VBGF) that measures the mean maximum length at which the growth curve plateaus and no longer increases in length with increasing age. This coefficient reflects the mean maximum length and not the observed maximum length.

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

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

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

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

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

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

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

Rationale: These nine life history parameters provide basic biological information at the species level to evaluate the productivity of a stock - an indication of the capacity of a stock to recover once it has been depleted. Currently, the assessment of coral reef fish resources in 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.

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_{∞} , 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.

Species	Age, growth, reproductive maturity parameters									Reference
	T_{max}	L_{∞}	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
<i>Lethrinus xanthochilus</i>	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 <i>et al.</i> , in review
<i>Lutjanus gibbus</i>	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 <i>et al.</i> , in review
<i>Lutjanus</i>	12 ^c	21.8	0.86	-0.20	0.35 ^c	16.4				Taylor <i>et al.</i> ,

<i>rufolineatus</i>		(f) 23.3 (m) ^c	(f) 0.80 (m) ^c	(f), -0.20 (m) ^c	(f) ^c				in review
<i>Myripristis amaena</i>						NA		NA	
<i>Myripristis berndti</i>						NA	166 ^b	NA	
<i>Myripristis murdjan</i>						NA		NA	
<i>Naso unicornis</i>	X ^a	X ^a	X ^a	X ^a	X ^a	NA	X ^a	NA	
<i>Sargocentron caudimaculatum</i>						NA		NA	
<i>Sargocentron spiniferum</i>						NA		NA	
<i>Sargocentron tiere</i>						NA	150 ^b	NA	
<i>Scarus rubrovioaceus</i>	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).

2.2.1.2 Fish Length Derived Parameters

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

- Broad scale look at commercial landings (by fisher/trip, gear, 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 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-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	
<i>Acanthurus lineatus</i>	24.5	18.8	1955	0.87	0.068	2.68	
<i>Ctenochaetus striatus</i>	25.2	18.0	424	0.87	0.043	2.83	
<i>Naso lituratus</i>	47.4	22.2	8752	0.93	0.022	3.02	
<i>Sargocentron tiere</i>	25.0	18.0	3002	0.85	0.069	2.62	
<i>Chlorurus japanensis</i>	46.2	26.4	6852	0.97	0.018	3.07	
<i>Naso unicornis</i>	55.0	32.3	5042	0.99	0.033	2.85	
<i>Scarus rubroviolaceus</i>	54	34.9	4556	0.99	0.012	3.17	
<i>Panulirus penicillatus</i>	15.8	9.1	3365	0.94	2.614	2.41	
<i>Scaru oviceps</i>	44.5	23.6	3987	0.97	0.013	3.17	
<i>Myripristis berndti</i>	27.2	17.8	4228	0.89	0.100	2.53	
<i>Acanthurus nigricans</i>	36.0	16.9	3003	0.79	0.171	2.42	
<i>Lutjanus gibbus</i>	56.8	30.9	2291	0.96	0.04	2.8	
<i>Lethrinus xanthochilus</i>	54.5	36.8	2186	0.97	0.028	2.85	
<i>Epinephelus melanostigma</i>	54.9	26.5	2653	0.95	0.012	3.10	
<i>Myripristis amaena</i>	22.5	16.9	2849	0.82	0.149	2.39	
<i>Acanthurus guttatus</i>	24.5	16.8	1872	0.87	0.084	2.69	
<i>Panulirus sp.</i>	15.3	8.6	3331	0.91	5.755	2.06	
<i>Myripristis murdjan</i>	27.5	17.0	1707	0.84	0.72	1.83	
<i>Scarus frenatus</i>	44.5	26.9	1777	0.98	0.014	3.14	
<i>Selar crumenophthalmus</i>	32.7	19.3	298	0.96	0.007	3.30	
<i>Parupeneus bifasciatus</i>	34.5	22.6	1413	0.96	0.015	3.12	
<i>Variola albimarginatus</i>	43.6	27.0	965	0.89	0.122	2.42	
<i>Scarus globiceps</i>	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_{∞} , 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_{∞} (asymptotic length) – One of three coefficients of the von Bertalanffy growth function (VBGF) that measures the mean maximum length at which the growth curve plateaus and no longer increases in length with increasing age. This coefficient reflects the mean maximum length and not the observed maximum length.

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

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

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

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

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

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

$L\Delta_{50}$ (length of sex switching) – Length (usually in terms of fork length) at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal; this is the length associated with $A\Delta_{50}$ estimates. This parameter is derived using a logistic function to fit the percent sex reversal data by length class with sex reversal status best determined via microscopic analyses of gonad histology preparations. $L\Delta_{50}$ information is typically more available than $A\Delta_{50}$ since $L\Delta_{50}$ estimates do not require knowledge of age 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_{∞}	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
<i>Aphareus rutilans</i>							NA		NA	
<i>Aprion virescens</i>							NA		NA	
<i>Etelis carbunculus</i>							NA		NA	
<i>Etelis coruscans</i>							NA		NA	
<i>Lethrinus amboinensis</i>										
<i>Lethrinus xanthochilus</i>										
<i>Lutjanus gibbus</i>							NA		NA	
<i>Pristipomoides auricilla</i>							NA		NA	
<i>Pristipomoides filamentosus</i>							NA		NA	
<i>Pristipomoides flavipinnis</i>	X ^a	X ^a	X ^a	X ^a	X ^a		NA		NA	O'Malley <i>et al.</i> , in prep.
<i>Pristipomoides sieboldii</i>							NA		NA	
<i>Pristipomoides zonatus</i>							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

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

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

In 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-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	
<i>Lutjanus kasmira</i>	35.0	22.3	459	0.92	0.017	3.02	
<i>Lethrinus rubrioperculatus</i>	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 need 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).

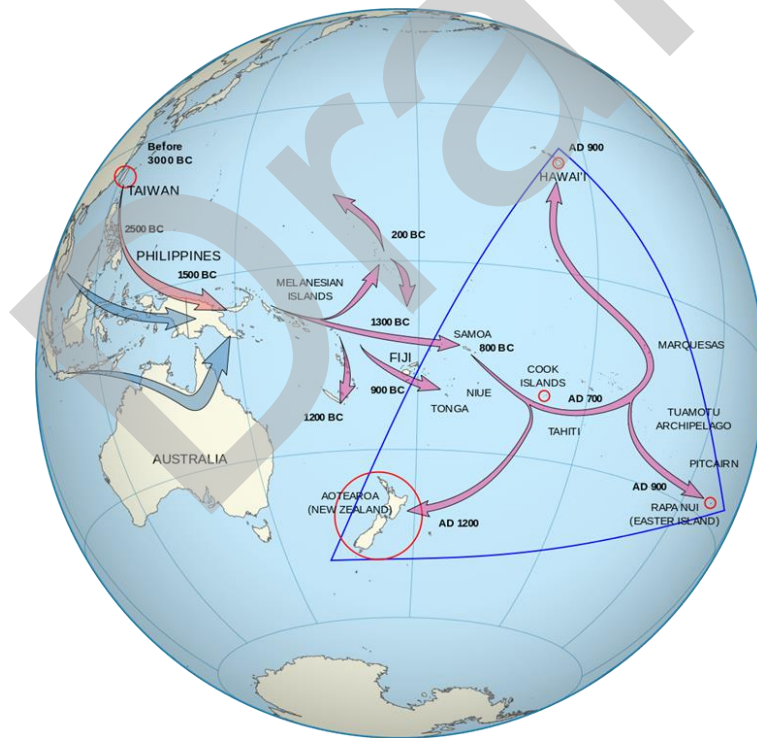


Figure 4. Settlement of the Pacific Islands, courtesy Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg.

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 km² 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.

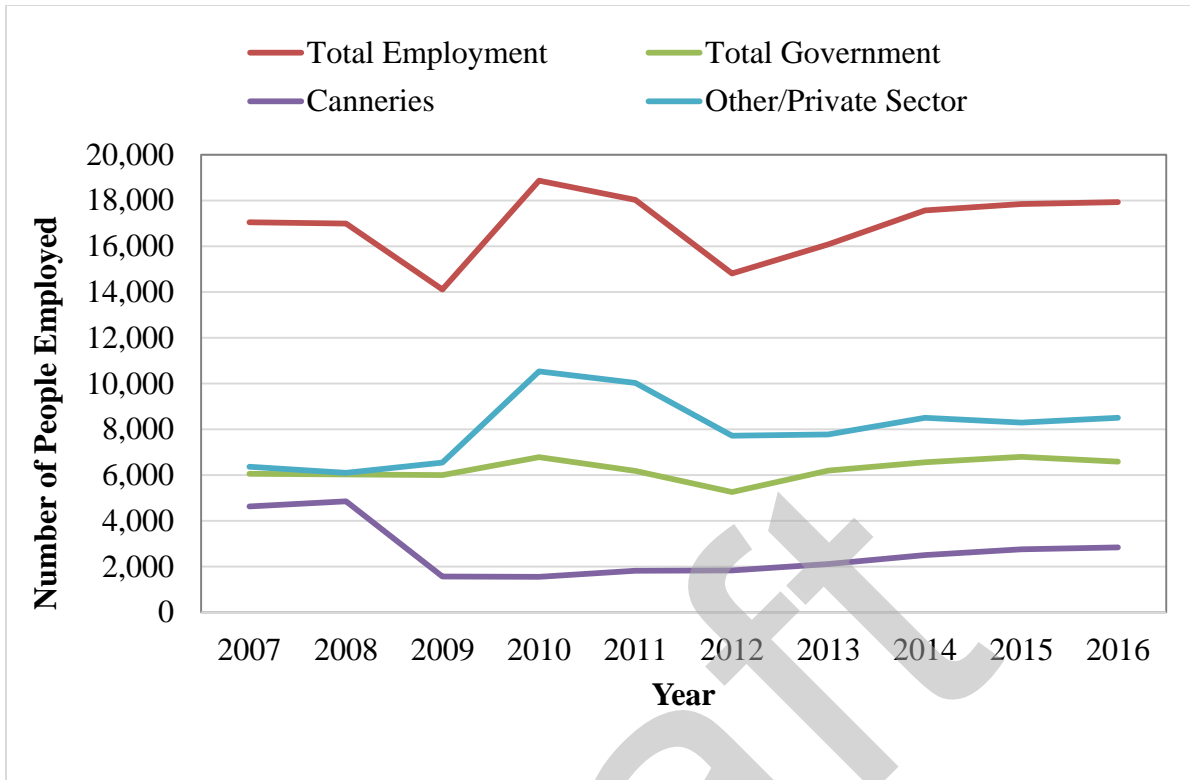


Figure 5. American Samoa Employment Estimates from 2007-2016. Data from American Samoa Statistical Yearbook 2016, American Samoa Government (2016).

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 Fishery

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. Alia 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, Prices

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

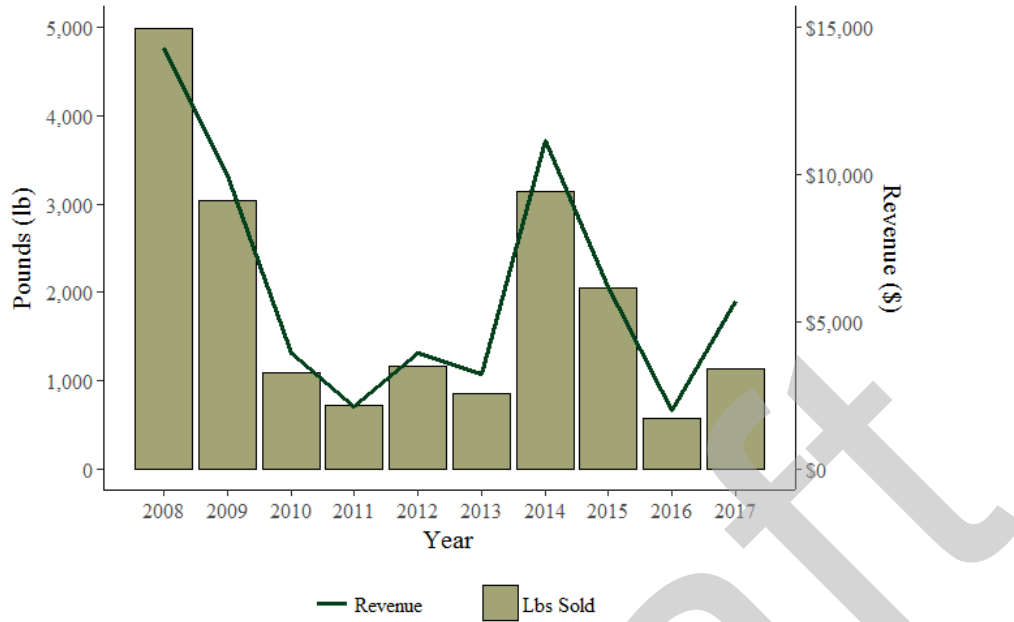
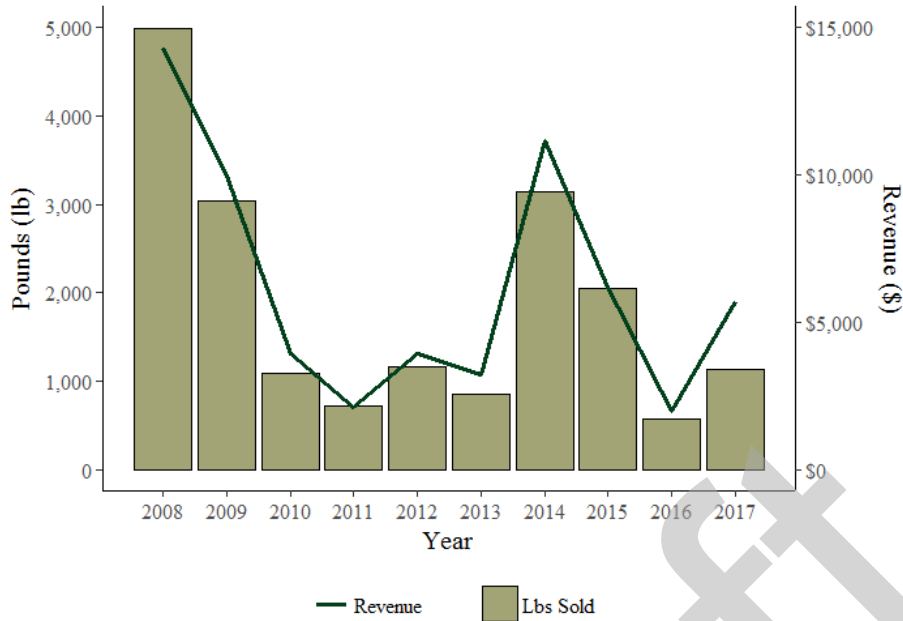


Figure 6 presents the trends of commercial pounds sold and revenues of bottomfish fishery



during 2008-2017 and

Figure 7 presents the trend of fish price of bottomfish sold during 2008-2017. Supporting data



for



Figure 6 and

Figure 7 are shown in Table 31. Table 31 also includes fish price and the % of pounds sold to the total pounds caught of the bottomfish fishery. In addition, the table also includes both nominal and adjusted values.

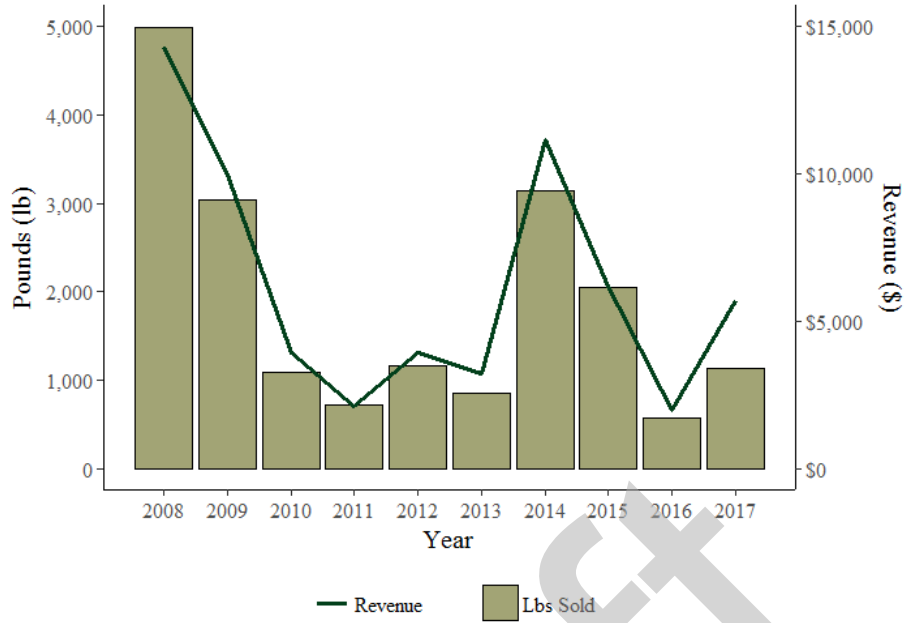


Figure 6. Pounds sold and revenue (adjusted to 2017 dollars) for the American Samoa bottomfish fishery from 2008-2017.



Figure 7. Price of BMUS (adjusted to 2017 dollars) for the American Samoa bottomfish fishery from 2008-2017.

Table 31. Commercial landings and revenue (adjusted to 2017 dollars) from the American Samoa bottomfish fishery from 2008-2017.

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue (\$)	Estimated revenue (\$ adjusted)	% of pounds sold	Fish price (\$)	Fish price (\$ adjusted)	CPI adjustor
2008	30,519	4,996	11,396	14,304	16%	2.28	2.86	1.255
2009	43,272	3,035	8,208	9,973	7%	2.7	3.29	1.215
2010	9,247	1,084	3,398	3,939	12%	3.13	3.63	1.159
2011	17,260	711	1,949	2,090	4%	2.74	2.94	1.072
2012	3,499	1,161	3,796	3,942	33%	3.27	3.40	1.038
2013	11,022	855	3,176	3,233	8%	3.71	3.78	1.018
2014	16,163	3,140	11,051	11,171	19%	3.52	3.56	1.011
2015	27,647	2,047	6,074	6,195	7%	2.97	3.03	1.020
2016	24,819	566	1,948	1,989	2%	3.44	3.51	1.021
2017	17,425	1,137	5,688	5,688	7%	5.00	5.00	1

2.3.4.2 Costs of Fishing

Since 2009, the PIFSC Socioeconomics Program has 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 8 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 8 are presented in Table 32.

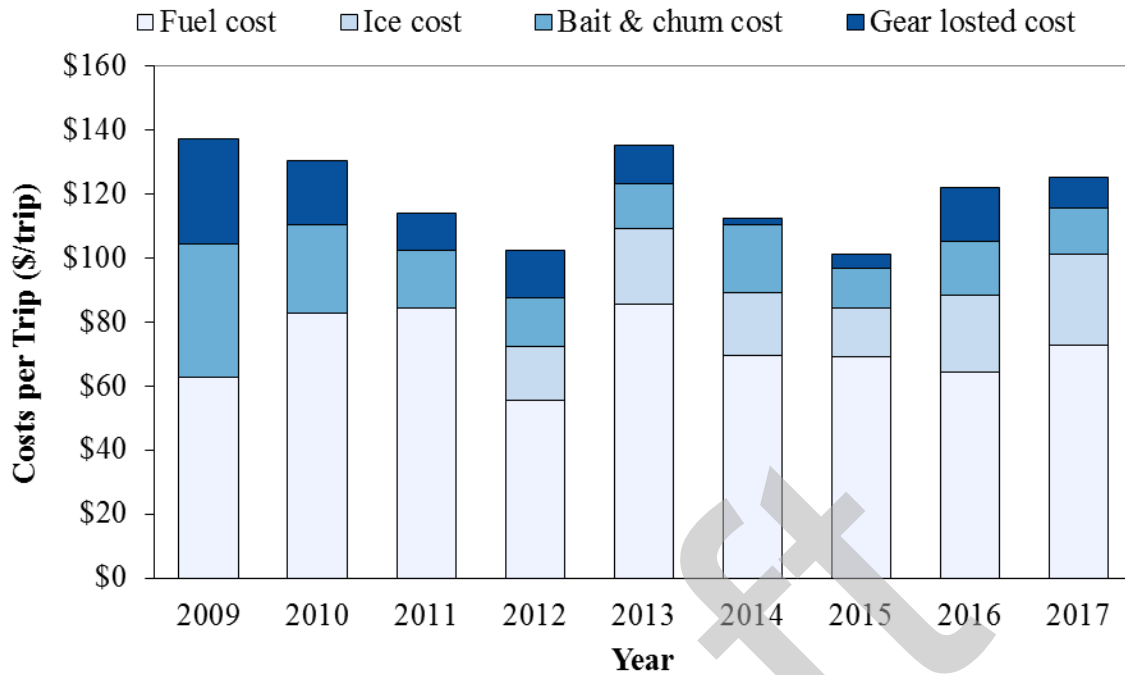


Figure 8. Average costs (adjusted to 2017 dollars) for American Samoa coral reef fishing trips from 2009–2017.

Table 32. Average and itemized costs (adjusted to 2017 dollars) for American Samoa bottomfish trips from 2009–2017. Data source: Chan and Pan Tech Memo (2018; in review).

Year	Total trip costs (\$)	Total trip costs (adjusted)	Fuel cost (\$)	Fuel cost (adjusted)	Ice cost (\$)	Ice cost (adjusted)	Gear lost cost (\$)	Gear lost 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

2.3.5 Crustacean Fishery

In American Samoa, spiny lobsters constitute the bulk of the crustacean fishery (see Markrich and Hawkins, 2016 for description of this fishery). 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.

2.3.5.1 Commercial Participation, Landings, Revenues, Prices

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

2.3.6 Coral Reef Fishery

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 were not sold, but were shared with others or distributed amongst the community. Many American Samoans still believe that some species such as the palolo should not be sold, as this will ruin 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 these mass spawning events and share fewer, as they can be stored for longer periods.

The American Samoa Department of Marine and Wildlife Resources (DMWR) has 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 decade despite the increase in the human population over the same time period.

Studies that have examined how residents value coral reef resources have found that most people perceive coral reefs as an important source of food, as well as providing nonuse benefits related to social, cultural, and biodiversity aspects (Levine and Allen, 2009; Levine *et al.*, 2016). Less importance was placed on 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 is estimated to be somewhat lower than other islands in the Western Pacific; an analysis in 2004 estimated their value at \$5 million per year (Grace-McCaskey, 2014).

2.3.6.1 Commercial Participation, Landings, Revenues, Prices

This section describes trends in commercial pounds sold, revenues, and prices for the American Samoa coral reef fishery. Figure 9 presents the trends of commercial pounds sold and revenues of coral reef fishery from 2008 to 2017, and

Figure 10 presents the trend of fish price in coral reef fishery from 2008 to 2017. Supporting data for Figure 9 and

Figure 10 are shown in Table 33. Table 33 also includes fish price and the percentage of pounds sold to the total pounds caught of the coral reef fishery. In addition, the table also includes both nominal and adjusted values. Most of the reef fish were caught by spear fishing gear (using boat or in shore). Figure 11 shows the average trip costs for American Samoa boat-base spear fishing trips during 2009–2017. In 2017, the average trip costs of boat base spear trips were \$55, \$1 less (nominal value) compared to 2016. Supporting data for Figure 11 are presented in Table 34.

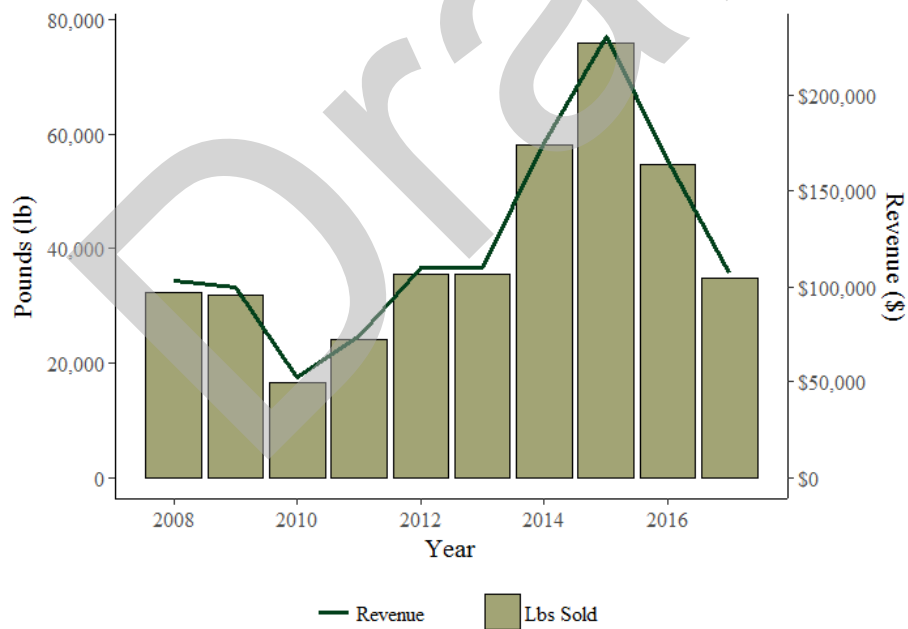


Figure 9. Pounds sold and revenue (adjusted to 2017 dollars) for the American Samoa coral reef fishery from 2008-2017.

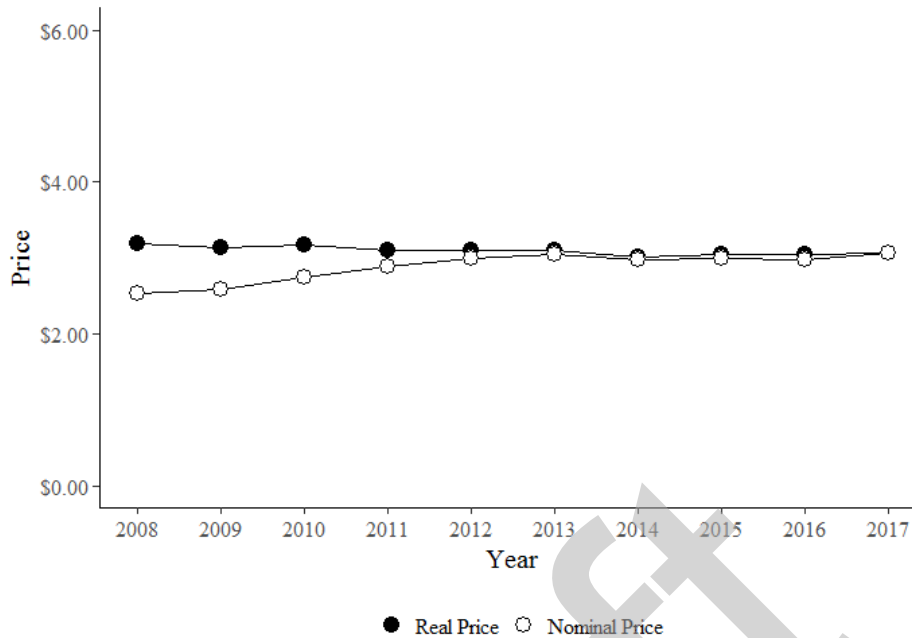


Figure 10. Prices (adjusted to 2017 dollars) for the American Samoa coral reef fishery from 2008-2017.

Table 33. Commercial landings and revenue (adjusted to 2017 dollars) for the American Samoa coral reef fishery from 2008-2017.

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue (\$)	Estimated revenue (\$ adjusted)	% of pounds sold	Fish price (\$)	Fish price (\$ adjusted)	CPI adjustor
2008	75,738	32,412	82,165	103,129	43%	2.54	3.18	1.255
2009	65,426	31,935	82,279	99,973	49%	2.58	3.13	1.215
2010	101,418	16,597	45,467	52,713	16%	2.74	3.18	1.159
2011	103,686	24,091	69,407	74,439	23%	2.88	3.09	1.072
2012	42,421	35,502	106,202	110,263	84%	2.99	3.11	1.038
2013	83,786	35,483	108,173	110,108	42%	3.05	3.10	1.018
2014	53,815	58,102	173,091	174,964	108%	2.98	3.01	1.011
2015	71,141	76,001	226,946	231,481	107%	2.99	3.05	1.020
2016	91,389	54,674	162,908	166,332	60%	2.98	3.04	1.021
2017	37,602	34,928	107,009	107,009	93%	3.06	3.06	1

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

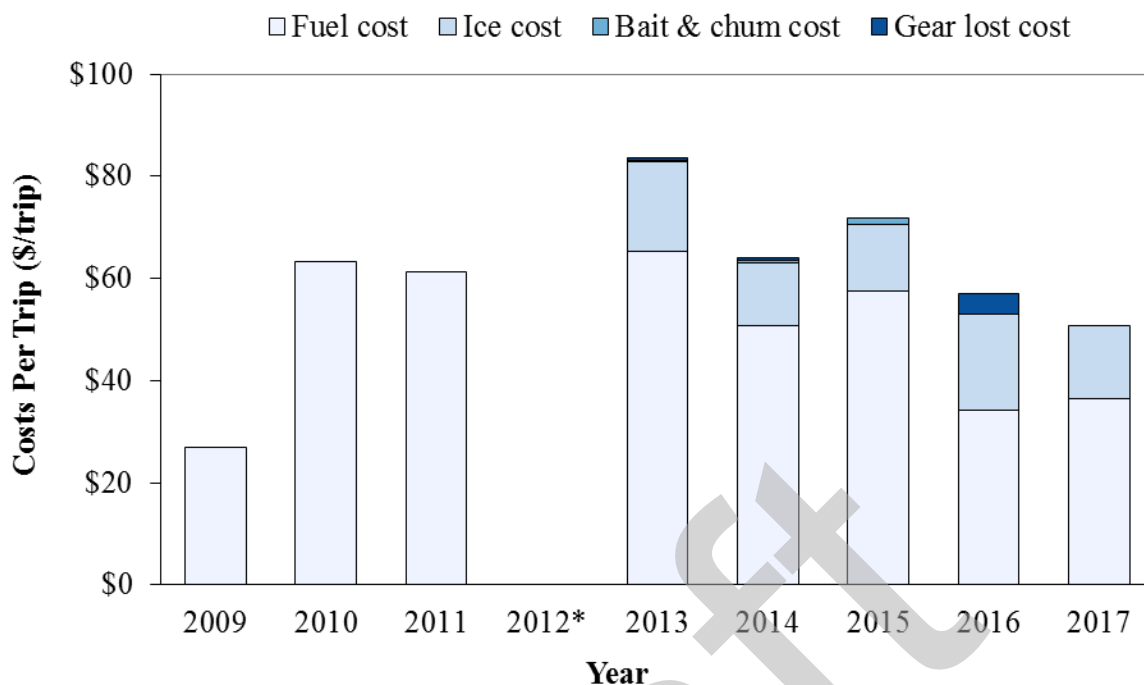


Figure 11. Average costs (adjusted to 2017 dollars) for American Samoa spearfishing trips from 2009–2017. Data for 2012 are not presented due to less than three observations).

Table 34. Average trip costs and itemized costs (adjusted to 2017 dollars) for American Samoa coral reef trips from 2009–2017. Data sourced from Chan and Pan Tech. Memo (2018, in review).

Year	Total trip costs (\$)	Total trip costs (\$ (adjusted))	Fuel cost (\$)	Fuel cost (\$ (adjusted))	Ice cost (\$)	Ice cost (\$ (adjusted))	Gear lost cost (\$)	Gear lost 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

2.3.7 Precious Coral Fishery

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, Prices

This section will describe trends in commercial participation, landings, revenues, and prices, as data allows, 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

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

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

2.3.10 References

American Samoa Government, 2016. American Samoa Statistical Yearbook 2016. American Samoa Government Department of Commerce Statistics Division. Pago Pago, American Samoa. 194 p.

Arita, S., and Pan, M., 2013. Cost-Earnings Study of the American Samoa Longline Fishery Based on Vessel Operations in 2009. PIFSC Working Paper WP-13-009, issued 12 July 2013. <https://dx.doi.org/10.7289/v5/ar-pifsc-h-17-01>

Armstrong, K., Herdrich, D.J., and Levine., A., 2011. Historic fishing methods in American Samoa. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-24, 70 p. + Appendices.
https://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_24.pdf.

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

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.

- Pacific Islands Fish. Sci. Cent. Admin. Rep. H-15-04, 30 p.
https://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_15-04.pdf
- Honolulu Star Advertiser, 2016. Tuna cannery in American Samoa to halt production. October 13, 2016. Business Breaking Top News.
<http://www.staradvertiser.com/2016/10/13/business/business-breaking/tuna-cannery-in-american-samoa-to-halt-production/>
- Kilarski, S., Klaus, D., Lipscomb, J., Matsoukas, K., Newton, R. and Nugent, A., 2006. Decision support for coral reef fisheries management: community input as a means of informing policy in American Samoa. The Donald Bren School of Environmental Science and Management, University of California, Santa Barbara.
- Levine, A., and Allen, S., 2009. American Samoa as a fishing community. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-19, 74 p.
https://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_19.pdf
- Levine, A.S., Dillard, M.K., Loerzel, J., and Edwards, P.E.T., 2016. National Coral Reef Monitoring Program Socioeconomic Monitoring Component. Summary Findings for American Samoa, 2014. U.S. Dep. Commerce., NOAA Technical Memorandum CRCP 24, 80 p. + Appendices.
- Markrich, M. and Hawkins, C., 2016. Fishing Fleets and Fishery Profiles: Management – Vessels – Gear – Economics. Pacific Islands Fishery Monographs NO. 5 September 2016. Western Pacific Regional Fishery Management Council. Honolulu, HI. 34 p.
- Pacific Islands Report, 2016. American Samoa Cannery yo Scale Back Operations Due To Fish Shortages. September 28, 2016. <http://www.pireport.org/articles/2016/09/28/american-samoa-cannery-scale-back-operations-due-fish-shortages>
- Pacific Islands Report, 2017. Tri Marine Has 'No Plans' To Reopen Tuna Cannery In American Samoa. April 20, 2017. <http://www.pireport.org/articles/2017/04/20/tri-marine-has-no-plans-reopen-tuna-cannery-american-samoa>
- PIFSC Socioeconomics Program, 2016. CNMI, American Samoa, and Guam Small Boat Fishery Trip Expenditure (2009 to present). Pacific Islands Fisheries Science Center,
<https://inport.nmfs.noaa.gov/inport/item/20627>
- Pan, M., 2015. Economic performance and status of American Samoa longline fishery, 2014. Pacific Islands Fisheries Science Center, PIFSC Internal Report, IR-15-015, 9 p.
<https://www.pifsc.noaa.gov/library/pubs/IR-15-015.pdf>
- Polovina, J. and Dreftak, K. (Chairs), Baker, J., Bloom, S., Brooke, S., Chan, V., Ellgen, S., Golden, D., Hospital, J., Van Houtan, K., Kolinski, S., Lumsden, B., Maison, K., Mansker, M., Oliver, T., Spalding, S., Woodworth-Jefcoats, P., 2016. Pacific Islands Regional Action Plan: NOAA Fisheries climate science strategy. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-59, 33 p. doi:10.7289/V5/TM-PIFSC-59.

Richmond, L., and Levine, A., 2012. Institutional analysis of community-based marine resource management initiatives in Hawaii and American Samoa. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-35, 48 p. + Appendices.

https://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_35.pdf

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.

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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 in the American Samoa FEP Fisheries

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 35.

Table 35. 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.

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.

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.

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).

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

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.

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.

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.

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 36). 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 36. 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	<i>Carcharhinus longimanus</i>	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	<i>Thunnus orientalis</i>	Positive (81 FR 70074, 10/11/2016)	In progress, expected 6/2017	N/A	N/A	N/A
Chambered nautilus	<i>Nautilus pompilius</i>	Positive (81 FR 58895, 8/26/2016)	In progress, expected 5/2017	N/A	N/A	N/A
Giant manta ray	<i>Manta birostris</i>	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	<i>Manta alfredi</i>	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	<i>Chelonia mydas</i>	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.

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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.

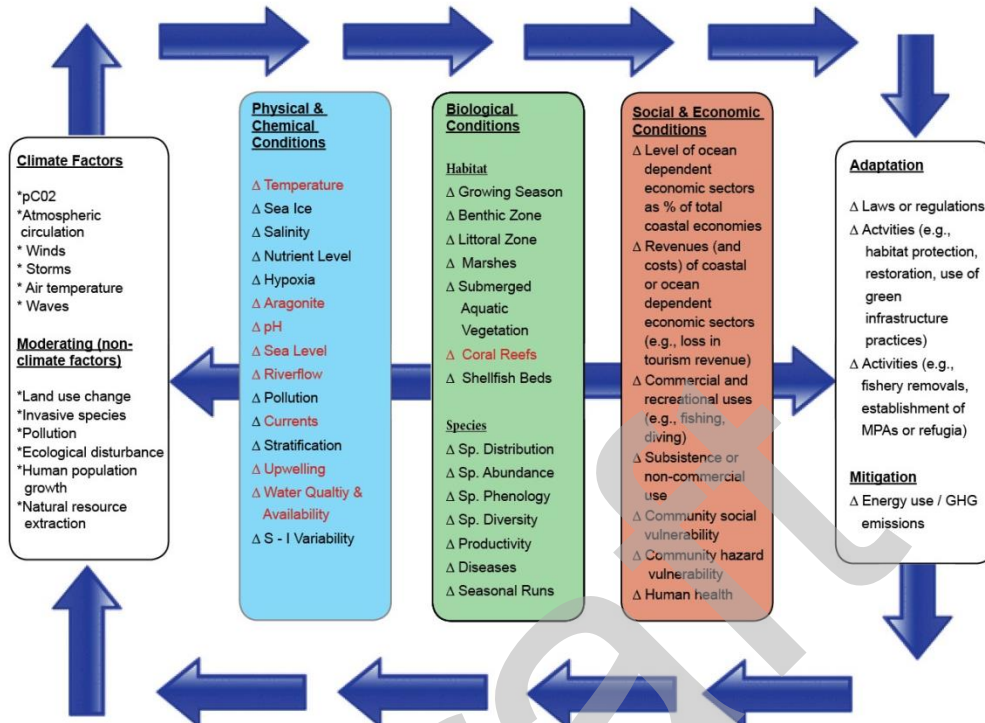
Starting with the 2015 Report, the Council and its partners have provided continuing descriptions of changes in a series of climate and oceanic indicators that will grow and evolve over time as they become available and their relevance to Western Pacific fishery resources becomes clear.

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:

Indicators of Change to Archipelagic Coastal and Marine Systems*
(Items in red to be monitored for 2015 Annual Reports of the Archipelagic Fishery Ecosystem Plans for the Western Pacific Region)



**Adapted from National Climate Assessment and Development Advisory Committee. February 2014. National Climate Indicators System Report. B-59.*

Figure 12. 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 CO₂ 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.

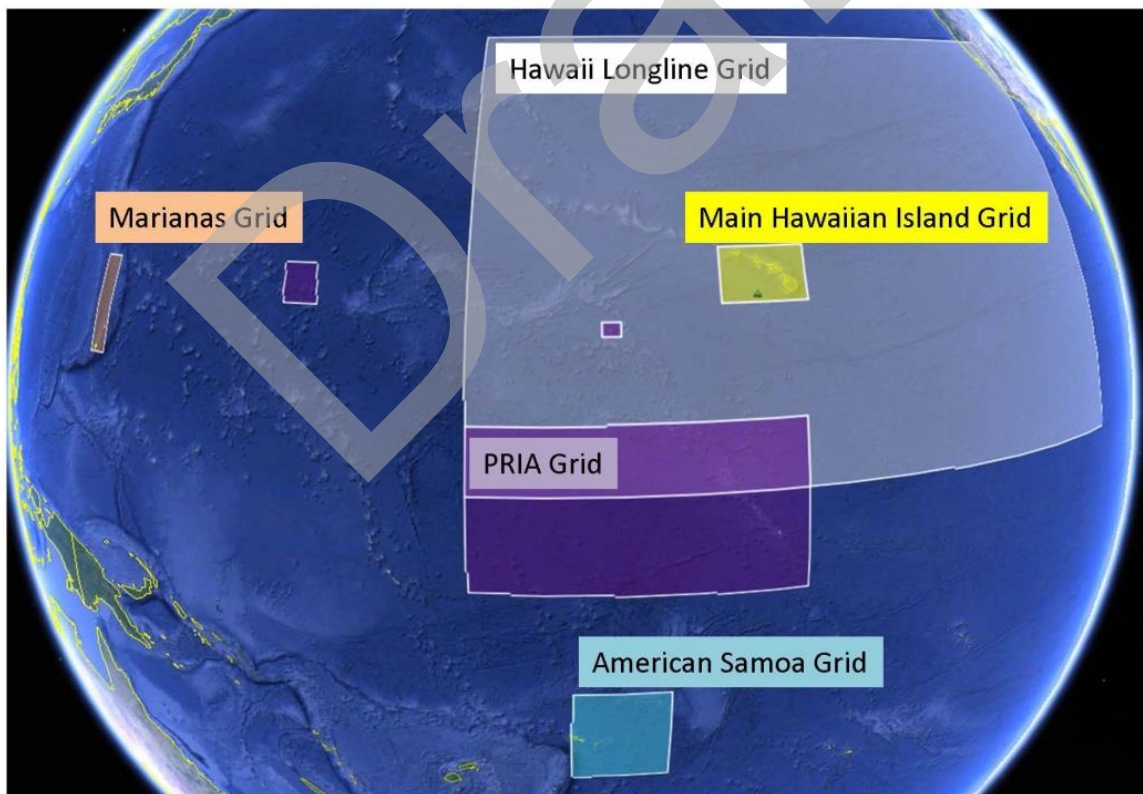


Figure 13. Regional spatial grids representing the scale of the climate change indicators being monitored.

Table 37. Climate and Ocean Indicator Summary.

Indicator	Definition and Rationale	Indicator Status
Atmospheric Concentration of Carbon Dioxide (CO ₂)	Atmospheric concentration CO ₂ at Mauna Loa Observatory. Increasing atmospheric CO ₂ is a primary measure of anthropogenic climate change.	Trend: increasing exponentially 2017: time series mean 406.53 ppm
Oceanic pH	Ocean surface pH at Station ALOHA. Ocean pH provides a measure of ocean acidification. Increasing ocean acidification limits the ability of marine organisms to build shells and other hard structures.	Trend: pH is decreasing at a rate of 0.039 pH units per year, equivalent to 0.4% increase in acidity per year
Oceanic Niño Index (ONI)	Sea surface temperature anomaly from Niño 3.4 region (5°N - 5°S, 120° - 170°W). This index is used to determine the phase of the El Niño – Southern Oscillation (ENSO), which has implications across the region, affecting migratory patterns of key commercial fish stocks which in turn affect the location, safety, and costs of commercial fishing.	2017: ENSO Neutral
Pacific Decadal Oscillation (PDO)	PDO can be thought of as a long-lived, multi-decadal ENSO cycle that has well-documented fishery implications related to ocean temperature and productivity.	2017: positive (warm) from Jan – June, negative (cool) from Jul – Dec
Sea Surface Temperature* (SST)	Satellite remotely-sensed sea surface temperature. SST is projected to rise, and impacts phenomena ranging from winds to fish distribution.	SST in waters surrounding most of PRIA ranged between 27-30° C with 2017 showing anomalies dependent on latitude: along the equator, 2017 showed a negative anomaly, while at ~4 deg N, the 2017 anomaly moves positive.
Coral Thermal Bleaching Exposure (DHW)	Satellite remotely-sensed metric of time and temperature above thresholds relevant for coral bleaching. Metric used is Degree Heating Weeks (DHW).	The equatorial PRIA showed prolonged, substantial DHW stress in 2015-2016, in which DHW values exceeded the range in which mass mortality is expected (DHW>8). Wake Atoll showed more regular, but less prolonged heating events ('14, '15, '17).
Chlorophyll-A (Chl-A)	Satellite remotely-sensed chlorophyll-a. Chl-A is projected to drop over much of the central Pacific, and is directly linked ecosystem productivity.	The Chl-A around the PRIA ranges from 0.08 to 0.35 mg/m ³ , with 2017 showing a near-zero and spatially

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

2.5.3.1 Atmospheric Concentration of Carbon Dioxide (CO₂) 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 CO₂ is increasing exponentially. In 2017, the annual mean concentration of CO₂ 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.

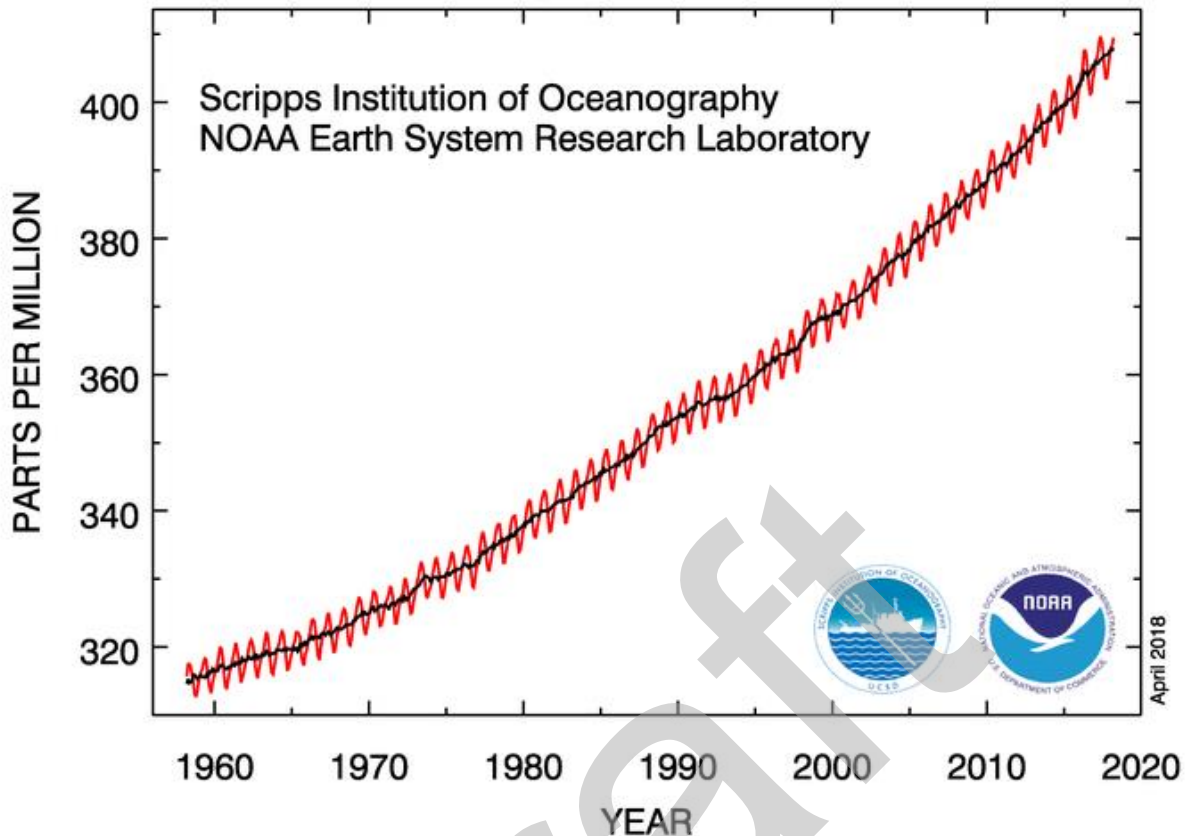


Figure 14. Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawai`i. Note: The red line shows monthly averages and the black line shows seasonally-corrected data.

Description: Monthly mean atmospheric carbon dioxide (CO₂) 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 CO₂ 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 CO₂ is removed from the atmosphere, whereas outside the growing season respiration exceeds photosynthesis and CO₂ 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 CO₂ record" available at <https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html>. Data from additional monitoring stations, including the Tutuila, American Samoa station are available at <https://www.esrl.noaa.gov/gmd/dv/iadv/>.

Measurement Platform: *In-situ* station

References:

Keeling, C.D., Bacastow, R.B., Bainbridge, A.E., Ekdahl, C.A., Guenther, P.R., Waterman, L.S., 1976. Atmospheric carbon 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 as pteropods and other prey for commercially-valuable fish species are already being negatively impacted by increasing acidification (Feely *et al.*, 2016). The full impact of ocean acidification on the pelagic food web is an area of active research (Fabry *et al.*, 2008).

Status: 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).

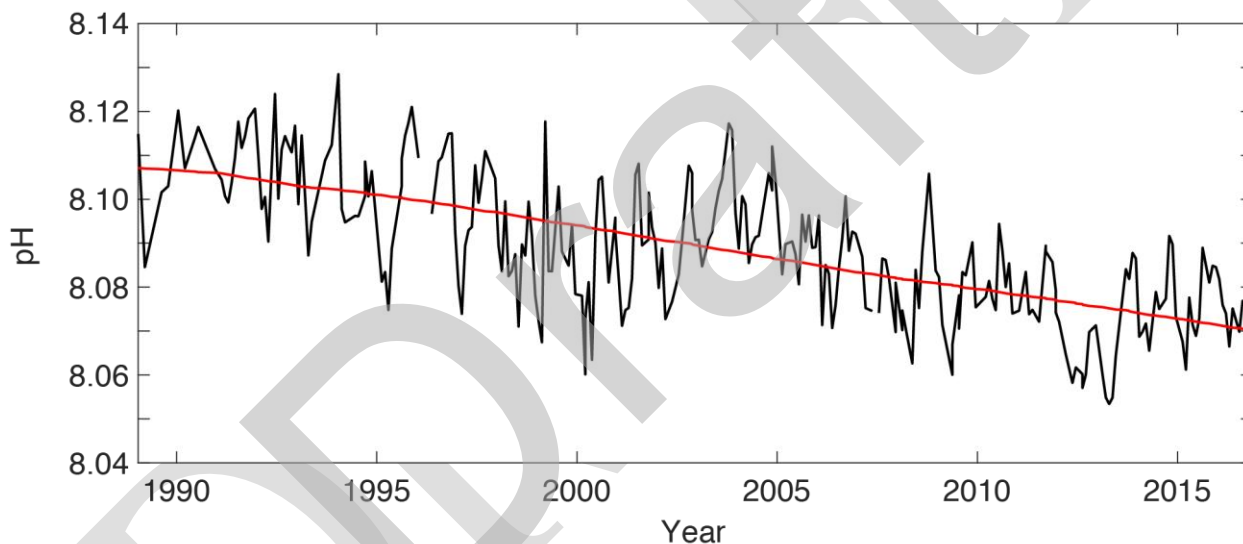


Figure 15. pH Trend at Station ALOHA, 1989 – 2016. Note: Measured pH values are plotted in black. The linear fit to this time series is shown in red.

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

Timeframe: Monthly

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

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

Measurement Platform: *In-situ* station

References:

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

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

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

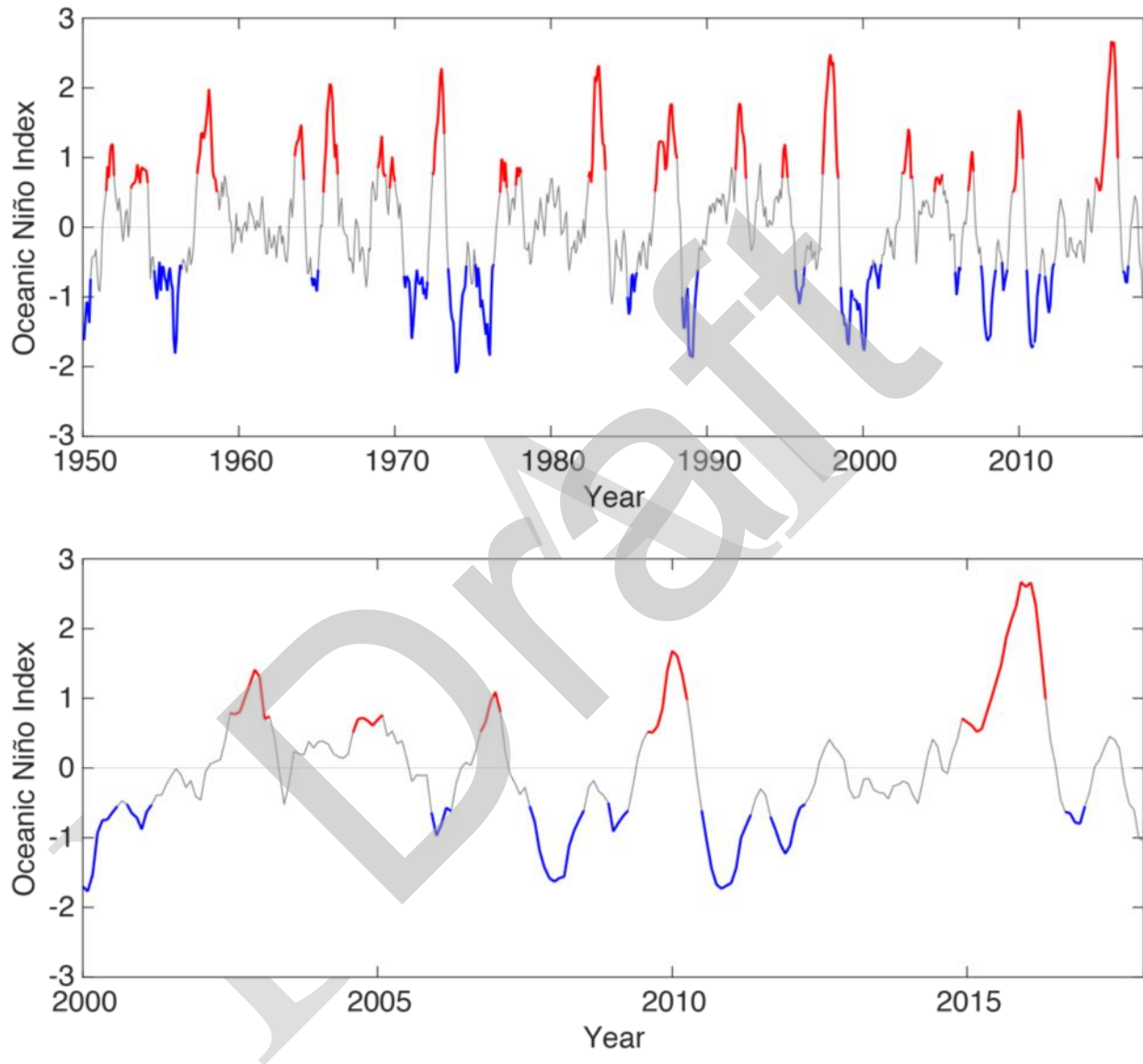


Figure 16. Oceanic Niño Index, 1950-2017 and 2000–2017. Note: Monthly time series of the Oceanic Niño Index for 1950 – 2017 (top) and 2000 – 2017 (bottom). El Niño periods are highlighted in red. La Niña periods are highlighted in blue.

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

Timeframe: Every three months

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

Data Source: NOAA NCEI at

<https://www.ncdc.noaa.gov/teleconnections/enso/indicators/sst.php>.

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

References:

A full description of ENSO and its global impacts can be found at:

<https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-and-la-ni%C3%B1a-frequently-asked-questions>

2.5.3.4 Pacific Decadal Oscillation

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

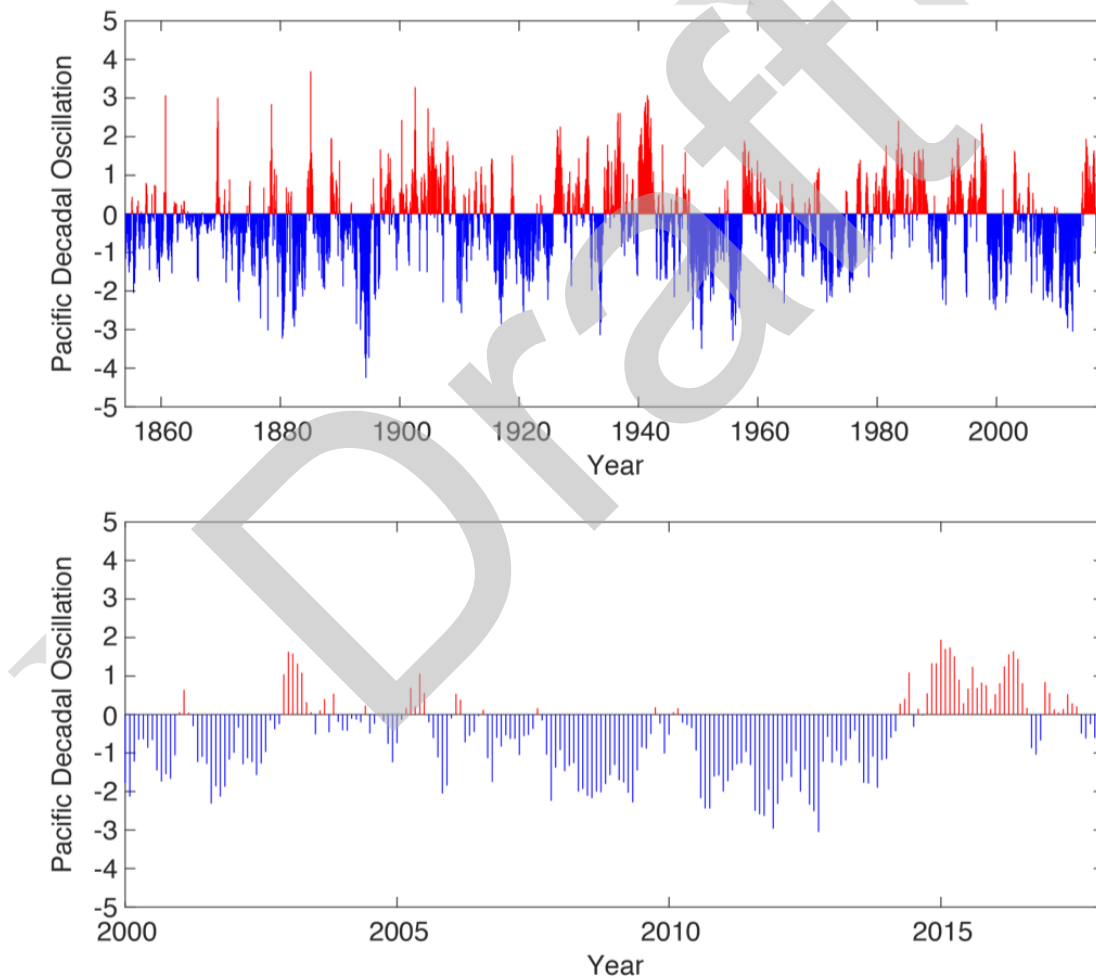


Figure 17. Pacific Decadal Oscillation, 1854–2017 and 2000–2017. Note: Monthly values of the Pacific Decadal Oscillation for 1854 – 2017 (top) and 2000 – 2017 (bottom). Positive, or warm, phases are plotted in red. Negative, or cool, phases are plotted in blue.

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

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

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

Timeframe: Annual, monthly

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

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

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

References:

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

2.5.3.5 Sea Surface Temperature & Anomaly

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

Short Descriptions:

Text from the OceanWatch Central Pacific Node:

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

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

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

Technical Summary:

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

The 4 km Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Version 5 sea surface temperature (SST) dataset is a reanalysis of historical AVHRR data that have been improved using extensive calibration, validation and other information to yield a consistent research quality time series for global climate studies. This SST time series represents the longest continual global ocean physical measurement from space. Development of the Pathfinder dataset is sponsored by the NOAA National Oceanographic Data Center (NODC) in collaboration with the University of Miami Rosenstiel 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 an average value and the data from only every third scan line are processed, yielding an effective 4 km resolution at nadir. The collection of NOAA satellite platforms used in the AVHRR Pathfinder SST time series includes NOAA-7, NOAA-9, NOAA-11, NOAA-14, NOAA-16, NOAA-17, and NOAA-18. These platforms contain "afternoon" orbits having a daytime ascending node of between 13:30 and 14:30 local time (at time of launch) with the exception of NOAA-17 that has a daytime descending node of approximately 10:00 local time. SST AVHRR Pathfinder includes separate daytime and nighttime daily, 5 day, 8 day, monthly and yearly datasets. This particular dataset represent nighttime monthly averaged observations.

GOES-POES dataset - Text from:

https://www.star.nesdis.noaa.gov/sod/mech/blended_validation/background.php

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

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

The GOES-11 and 12 imagers observe both northern and southern hemisphere every half an hour. These 5-band (0.6, 3.9, 6.7, 10.7, 12 or 13.3 micron) and 4-band (0.6, 3.9, 6.7, 10.7. or 13.3 micron) images are processed to retrieve SST retrievals at 4-km resolution. The window infrared channels determine the SST, and all channels (except the 6.7 and 13.3 μm) determine the cloud contamination. These retrievals are remapped, averaged, and composited hourly and posted to a server for user access. The retrievals are available approximately 90 minutes after the nominal epoch of the SST determinations. Three-hour and 24-hour averages are also made available. CoastWatch Regional Imagery is generated every three hours by combining the 1hourly SST images for these areas.

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

Region/Location: Global.

Data Source:

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

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

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

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

References:

- Li, X., 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.
- Li, X., Pichel, W.G., Clemente-Colón, P., Krasnopolsky, V., and Sapper J.F., 2001b. Validation of coastal sea and lake surface temperature measurements derived from NOAA/AVHRR Data, *Int. J. Remote Sens.*, 22(7), pp. 1285-1303.
- 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.

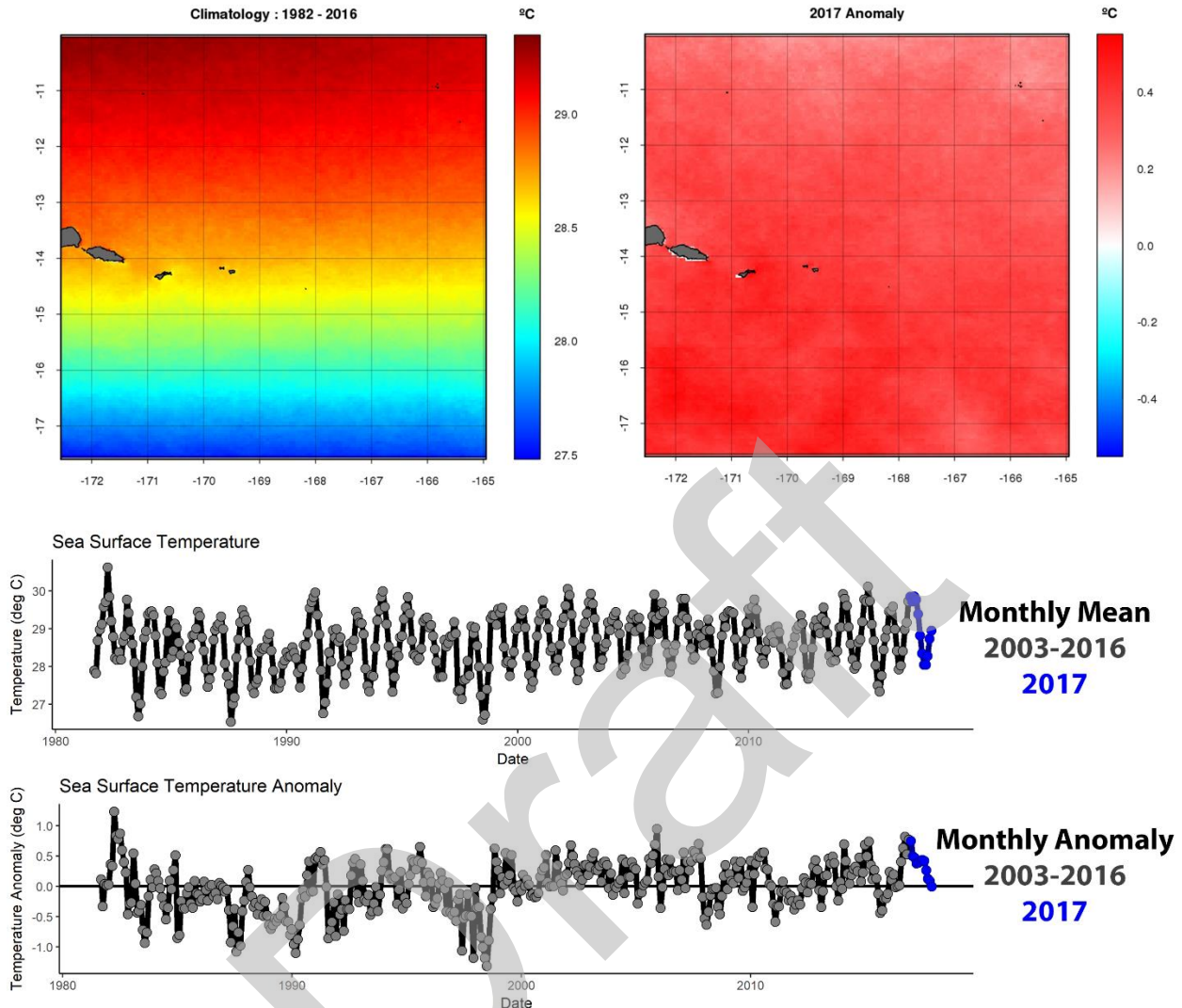


Figure 18. Sea surface temperature (SST) and SST Anomaly from 2003-2017.

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

Short Description:

Text inserted from the NOAA [Coral Reef Watch](https://www.coralreefwatch.noaa.gov/) website.

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

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

Technical Summary:

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

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

A significantly improved climatology was introduced in the Version 3 products. It was derived from a combination of NOAA/NESDIS' 2002-2012 reprocessed daily global 5km Geo-Polar Blended Night-only SST Analysis and the 1985-2002 daily global 5km SST reanalysis, produced by the United Kingdom Met Office, on the Operational SST and Sea Ice Analysis (OSTIA) system. The near-real-time OSTIA SST was recently incorporated into the generation of NESDIS' operational daily 5km Blended SST that CRW's 5km coral bleaching heat stress monitoring product suite is based on. Hence, the 2002-2012 reprocessed 5km Geo-Polar Blended SST that has just become available, extended with the 1985-2002 portion of the 5km OSTIA SST 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.

Timeframe: 2013-2017, Daily data.

Region/Location: Global.

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

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

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

References:

Liu, 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.

Coral Thermal Stress Exposure: Samoa 2013-2018

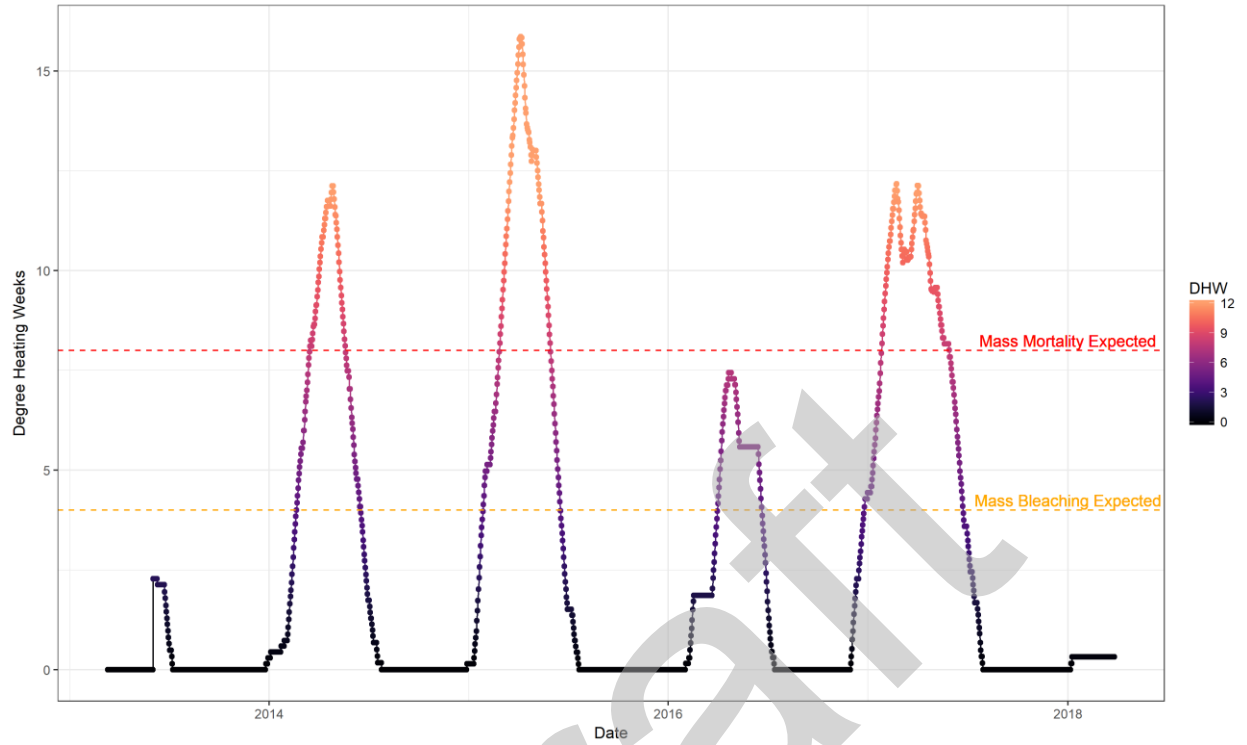


Figure 19. Coral Thermal Stress Exposure measured at Samoa Virtual Station 2013-2017 (Coral Reef Watch Degree Heating Weeks).

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:

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

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

Technical Summary:

Text inserted from:

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

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

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

Region/Location: Global.

Data Source:

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

Measurement Platform: *MODIS sensor on NASA Aqua Satellite*

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

References:

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

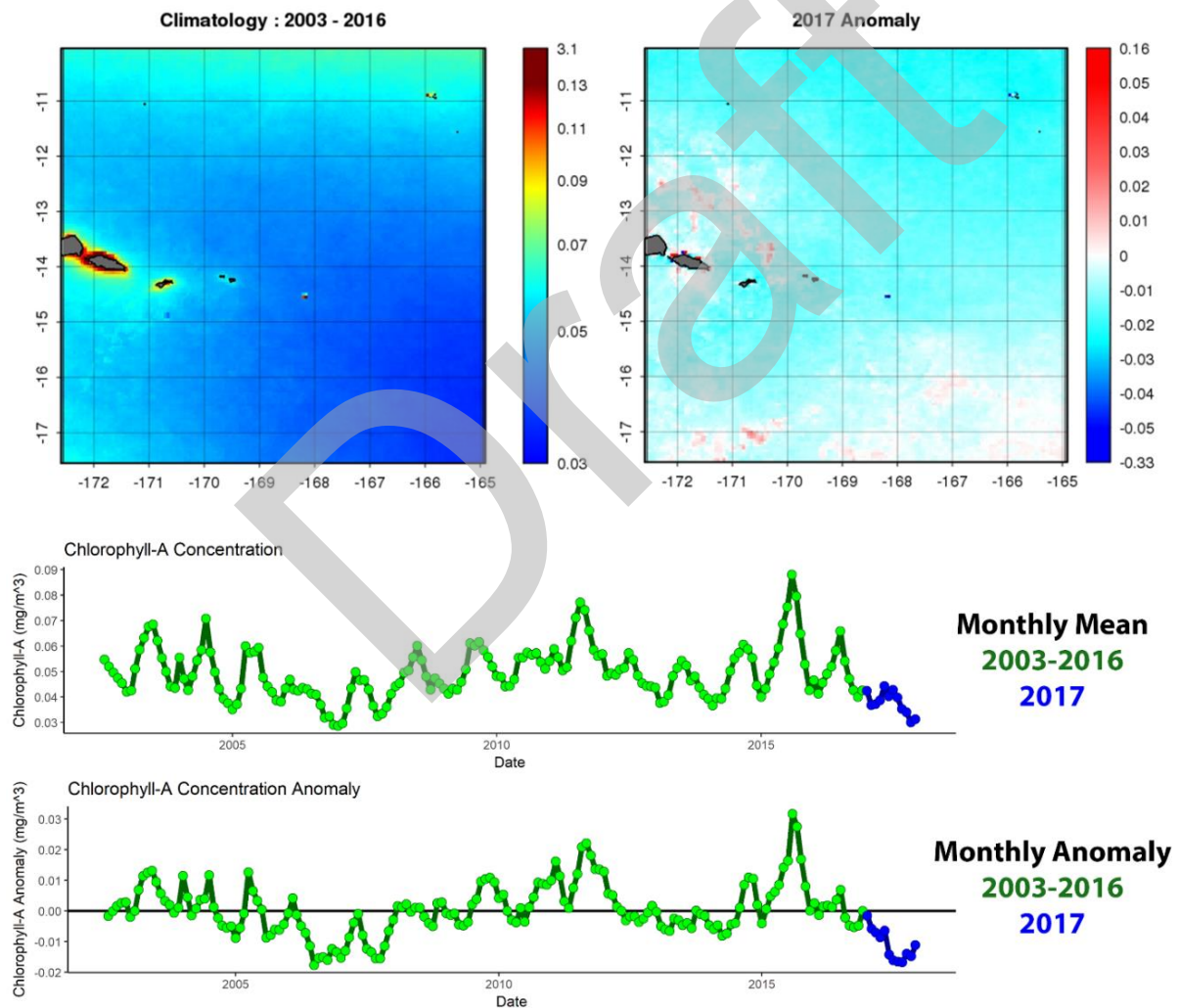


Figure 20. Chlorophyll-A (Chl-A) and Chl-A Anomaly from 2003-2017.

2.5.3.6 Heavy Weather (Tropical Cyclones & Storm-Force Winds)

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

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

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

In addition, we also plot the percentage occurrence of "storm-force" winds, wind occurrences greater than, or equal to, 34 knots since 1980 in the three sub-regions. The value of 34 knots represents "Gale, fresh gale" on the Beaufort scale, which corresponds to 5-8 m wave heights and boating becomes very challenging. Characterizing the percent occurrence of these gale-force winds gives an indication of storminess 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 ($\times 10^4$ knots²), which is below the 1981-2010 average of 132 ($\times 10^4$ knots²), and the lowest since 2013.” Inserted from: <https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713>.

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](https://doi.org/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.

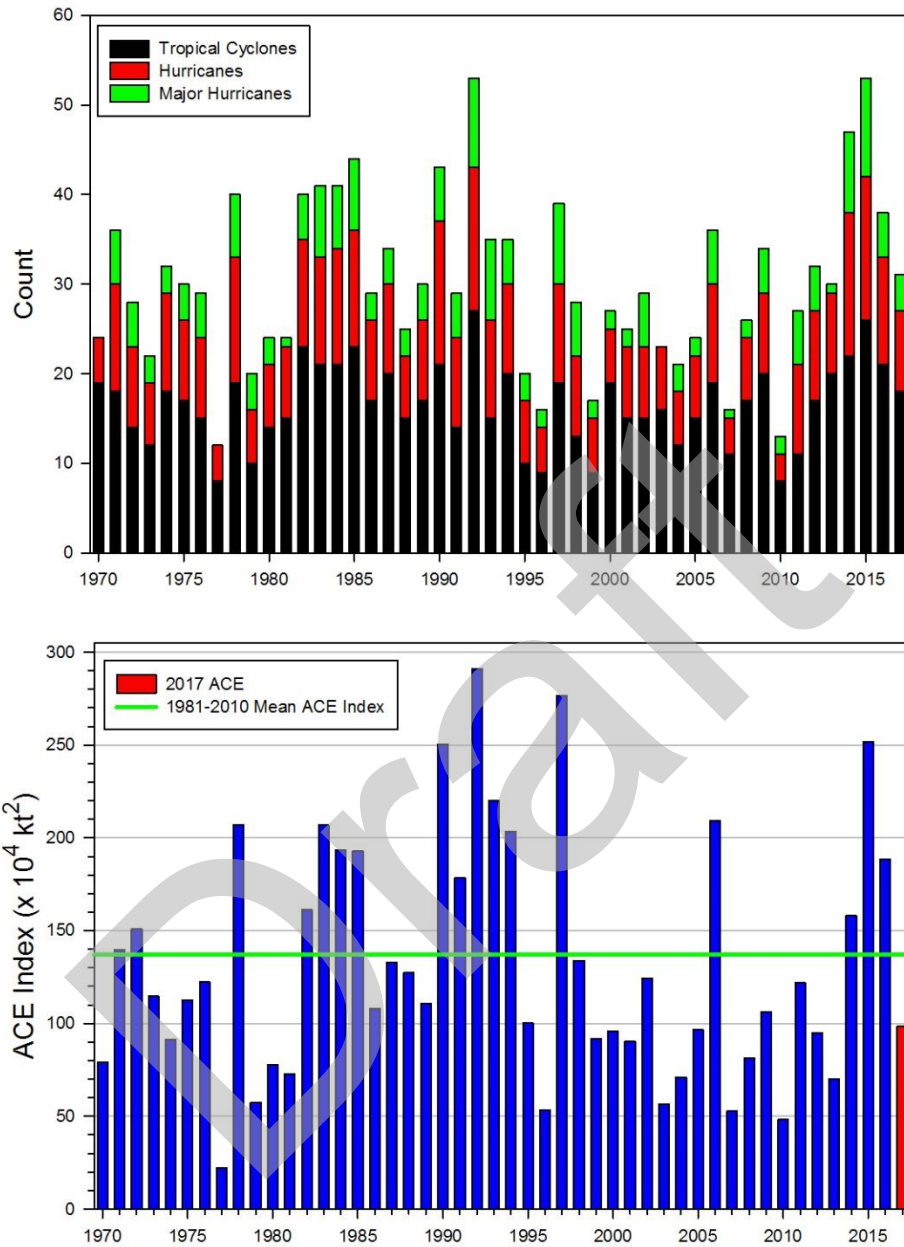


Figure 21. Annual Patterns of Tropical Cyclones in the Eastern Pacific from 1970-2017 with 1981-2010 mean superimposed (sourced from NOAA's National Hurricane Center).

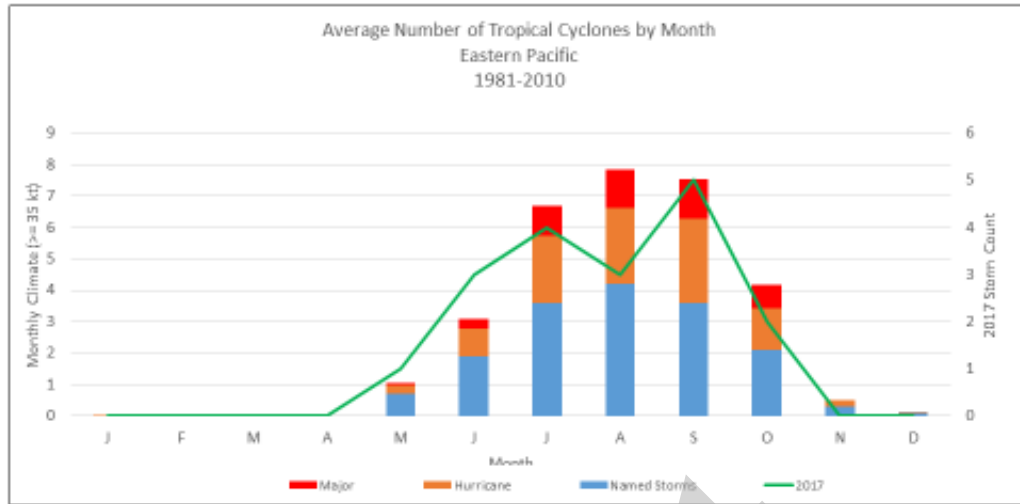


Figure 22. Seasonal Climatology of Tropical Cyclones in the Eastern Pacific from 1981-2010 with 2017 storms superimposed (sourced from NOAA's National Hurricane Center).

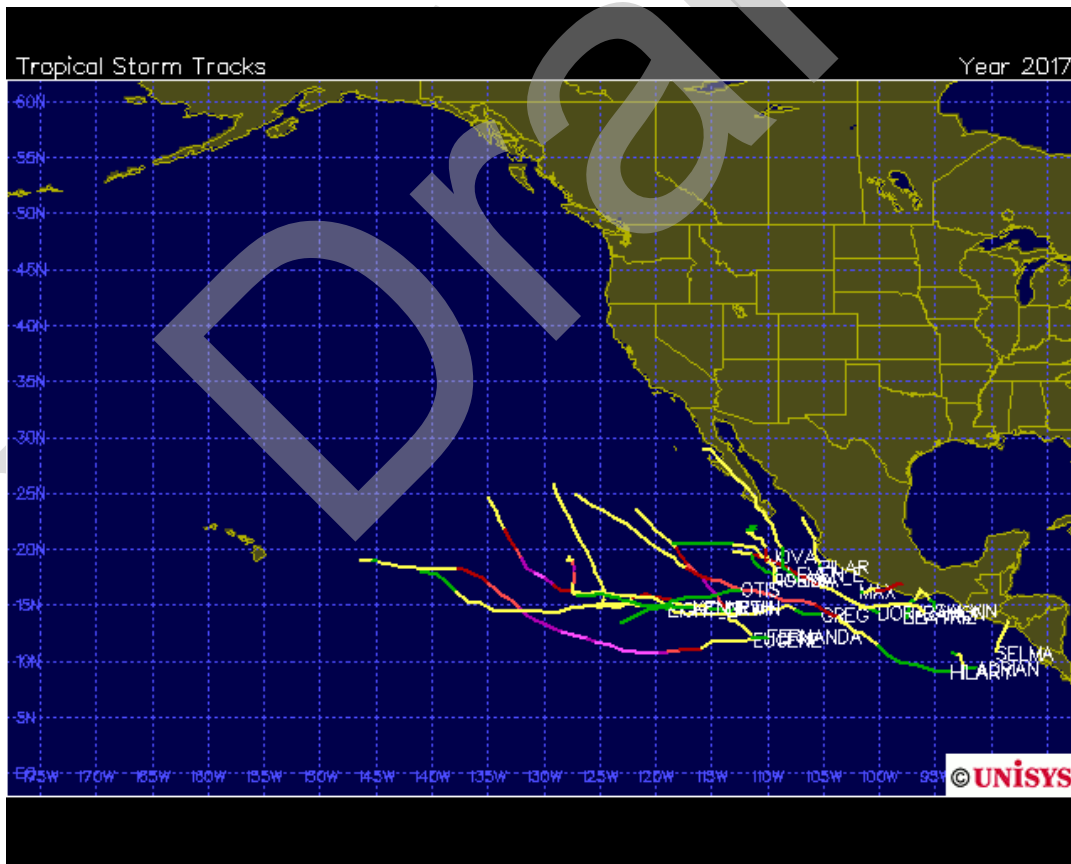


Figure 23. Eastern Pacific Cyclone Tracks in 2017.

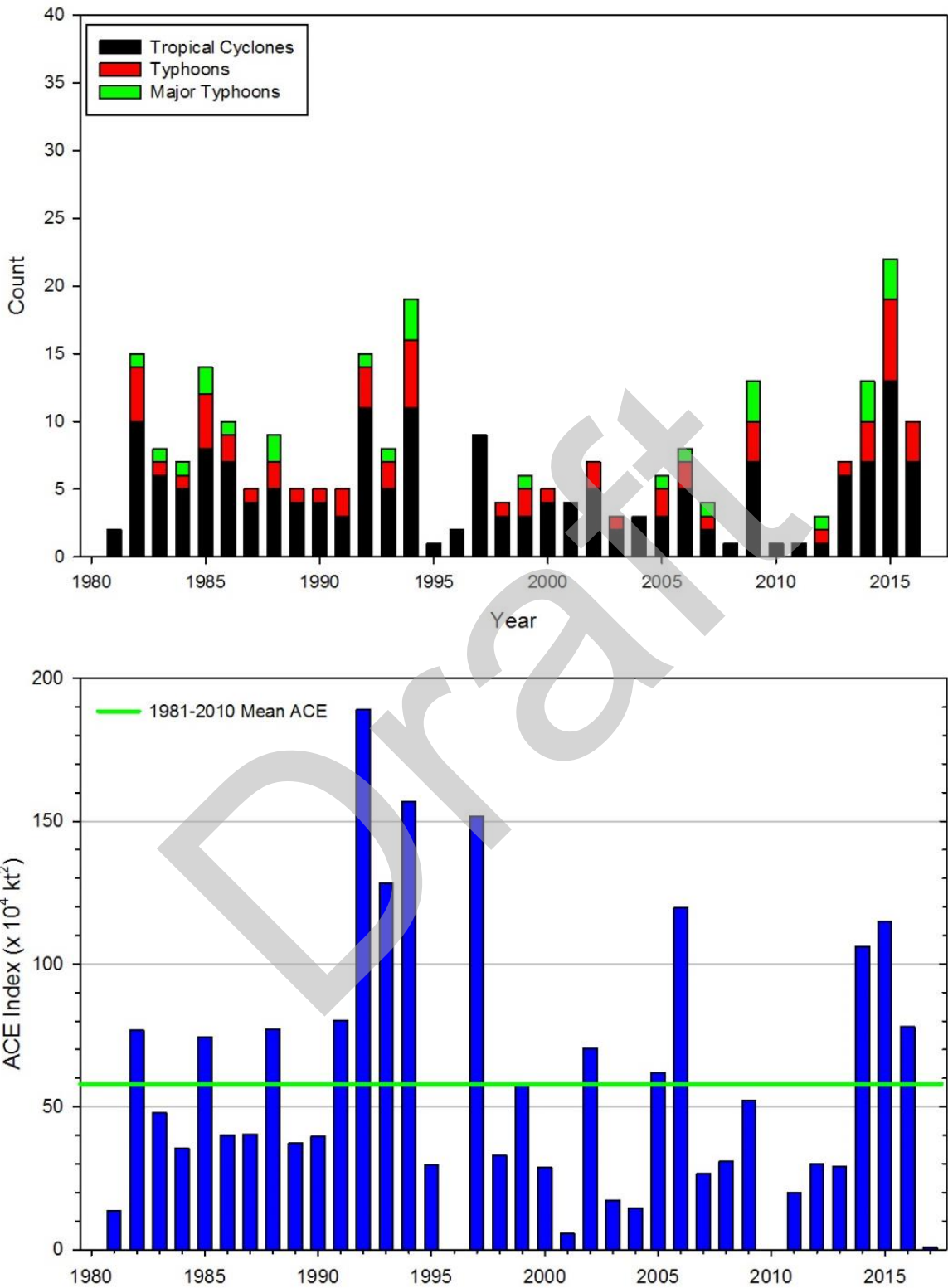


Figure 24. Annual Patterns of Tropical Cyclones in the Central Pacific, 1980-2017, with 1981-2010 mean superimposed (sourced from NOAA's National Hurricane Center).

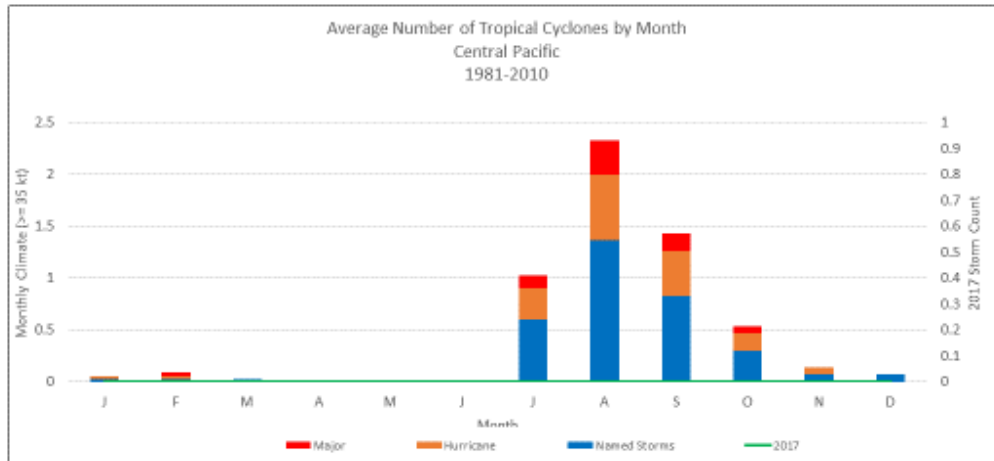


Figure 25. Seasonal Climatology of Tropical Cyclones in the Central Pacific, 1981-2010, with 2017 storms (zero) superimposed (sourced from NOAA's National Hurricane Center).

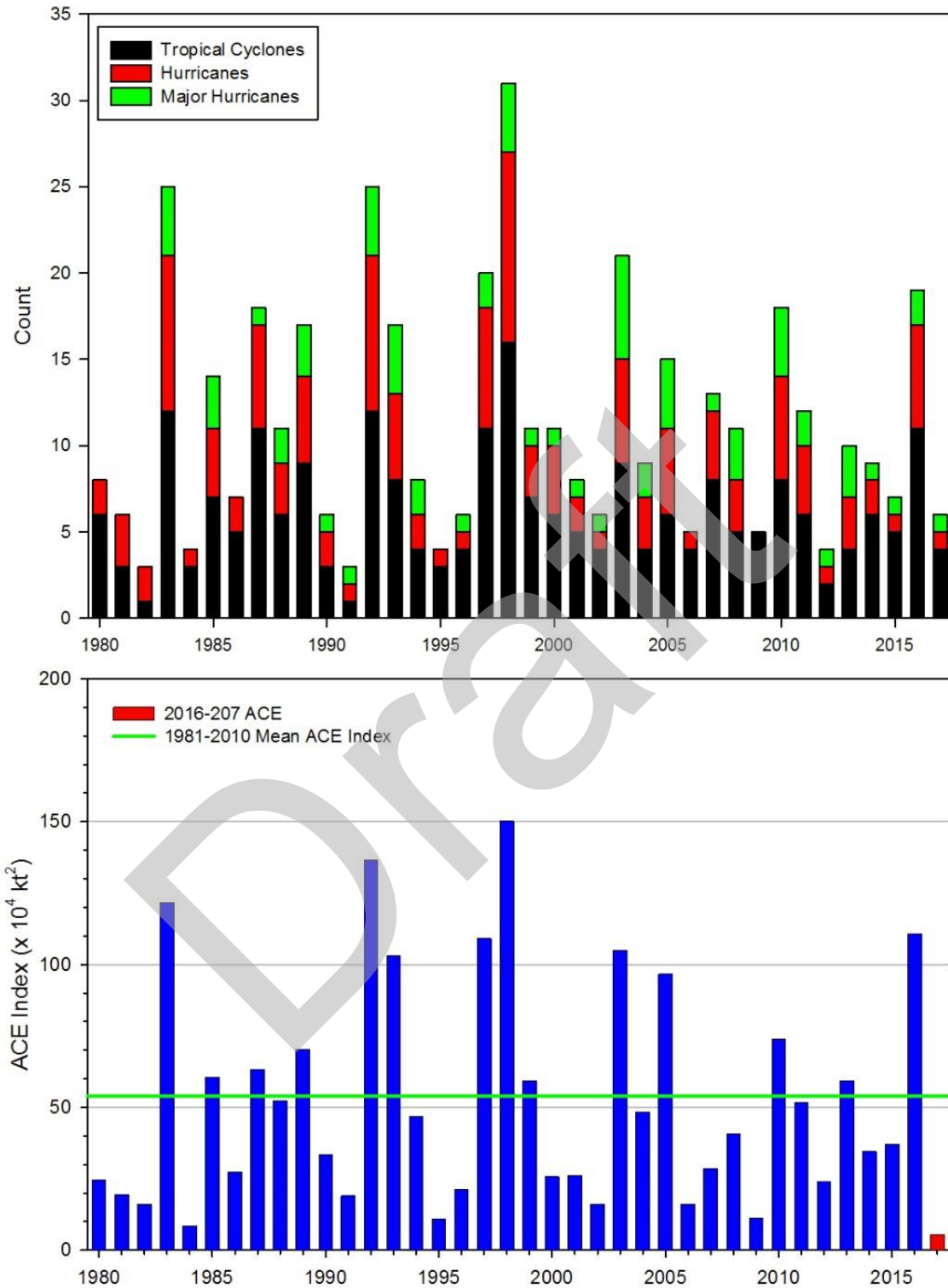


Figure 26. Annual Patterns of Tropical Cyclones in the South Pacific, 1980-2017, with 1981-2010 mean superimposed. Source: NOAA's National Hurricane Center.

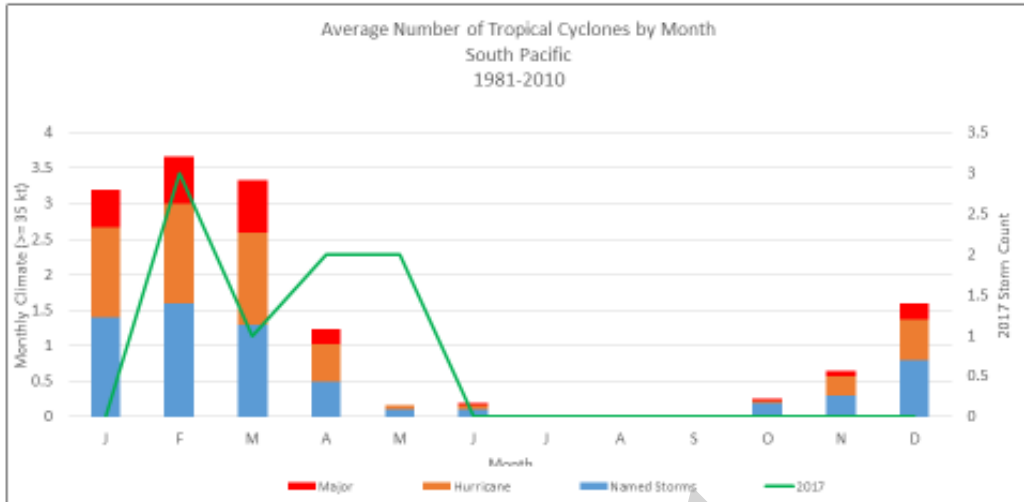


Figure 27. Seasonal Climatology of Tropical Cyclones in the South Pacific, 1981-2010, with 2017 storms (zero) superimposed. Source: NOAA's National Hurricane Center.

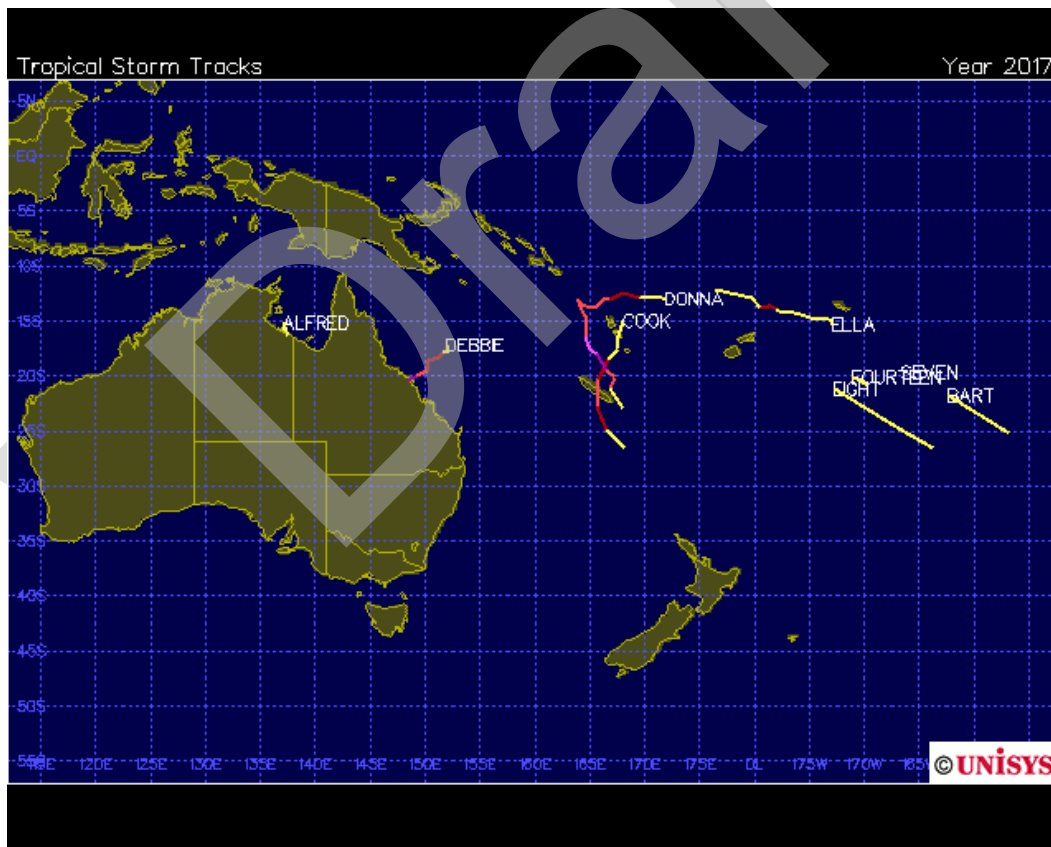


Figure 28. South Pacific Cyclone Tracks in 2017.

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

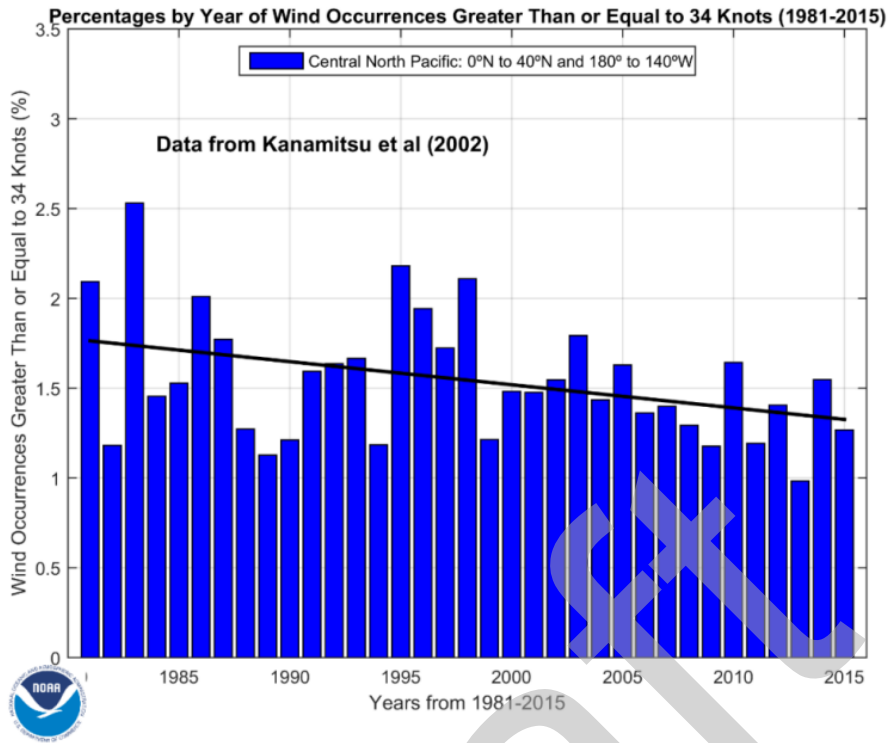


Figure 29. Storm-Force Wind in the Central North Pacific from 1981-2015.

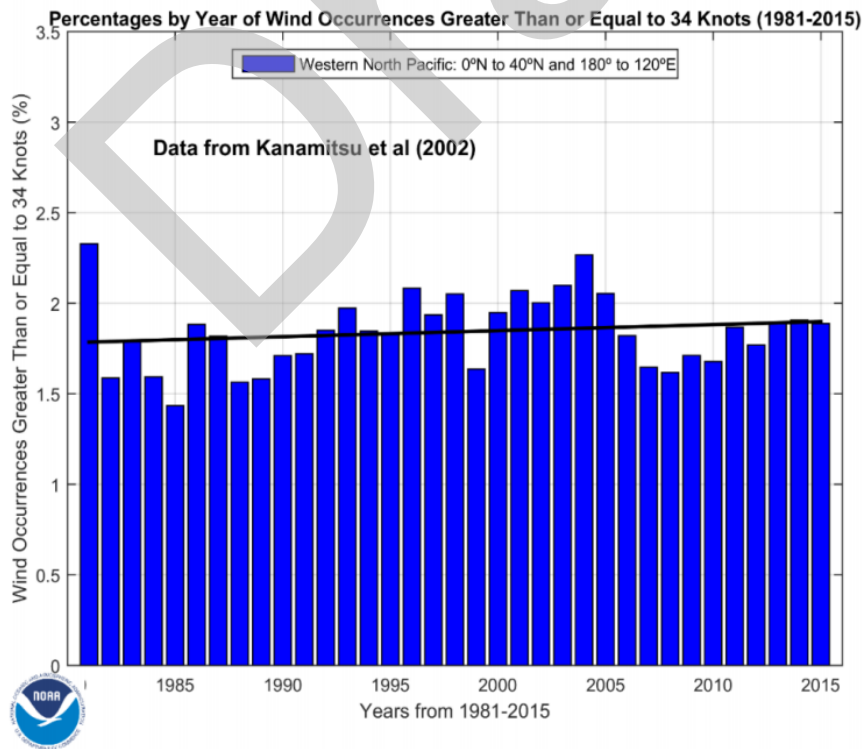


Figure 30. Storm-Force Wind in the Western North Pacific from 1981-2015.

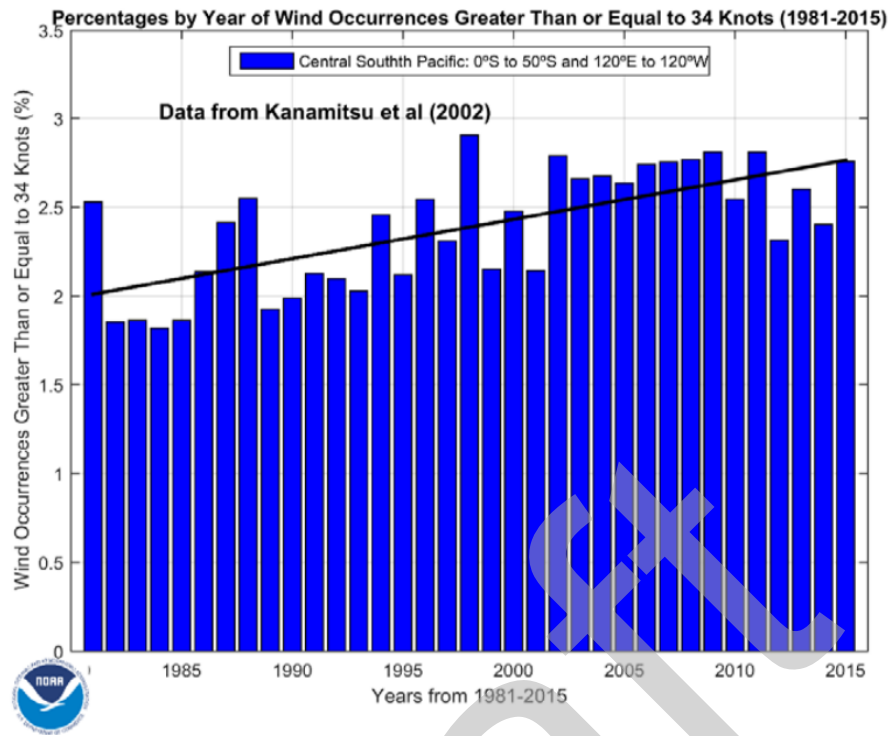


Figure 31. Storm-Force Wind in the Central South Pacific from 1981-2015.

2.5.3.8 Rainfall (CMAP Precipitation)

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

Description: The CPC Merged Analysis of Precipitation ("CMAP") is a technique which produces pentad and monthly analyses of global precipitation in which observations from 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.

Monthly and pentad CMAP estimates back to the 1979 are available from [CPC ftp server](#).

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

The monthly data set consists of two files containing monthly averaged precipitation rate values. Values are obtained from 5 kinds of satellite estimates (GPI, OPI, SSM/I scattering, SSM/I emission and MSU) and gauge data. The enhanced file also includes blended NCEP/NCAR Reanalysis Precipitation values.

Text taken from: <https://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html#detail>

Timeframe: Monthly

Region/Location: Global

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

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

References:

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.

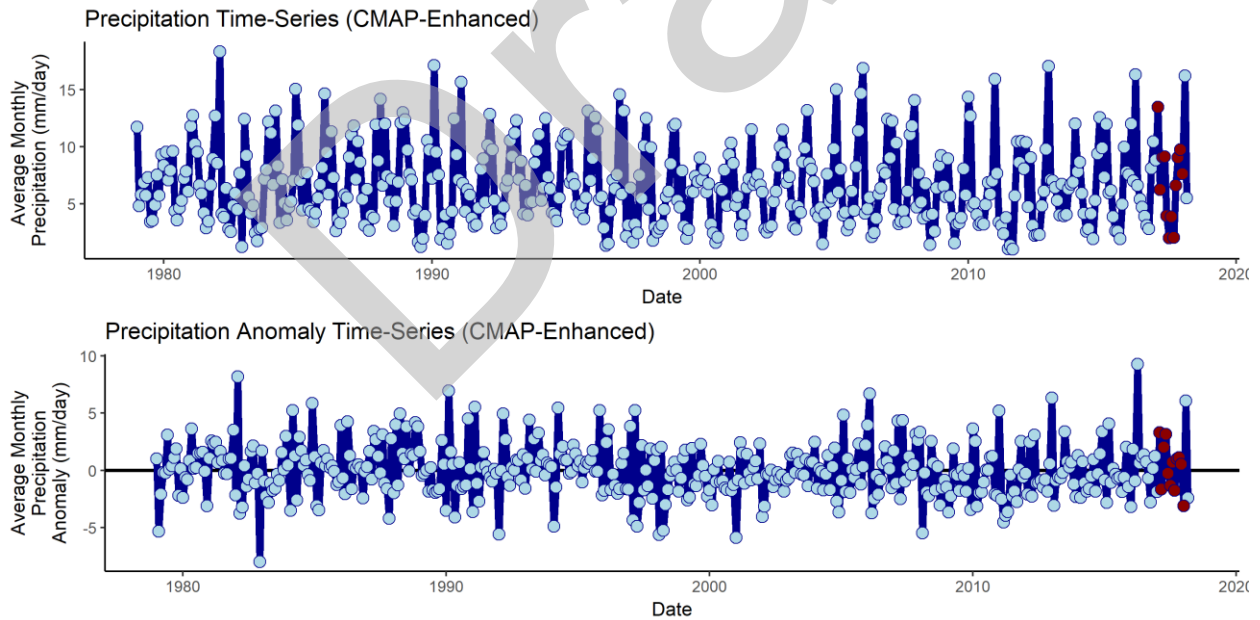


Figure 32. CMAP precipitation across the American Samoa Longline Grid. 2017 values are in red.

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.)

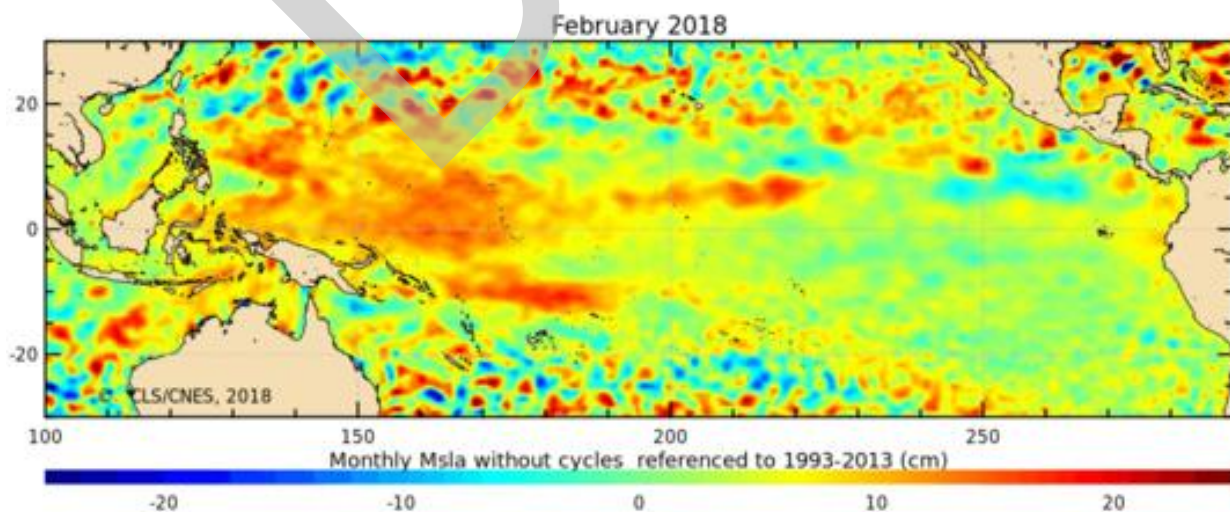


Figure 33a. Sea surface height and anomaly.

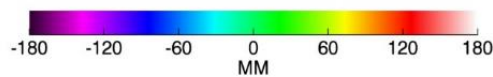
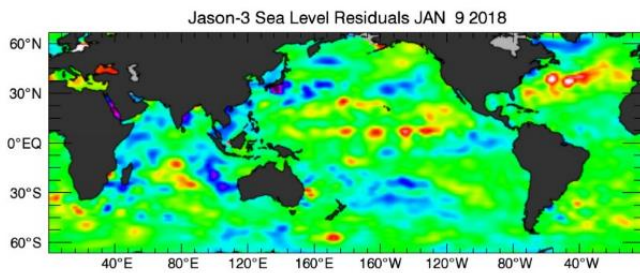
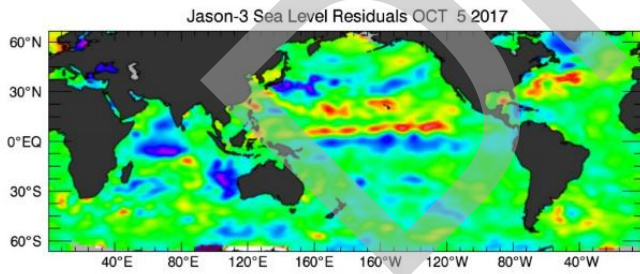
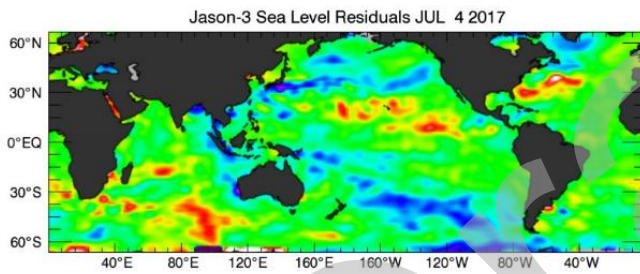
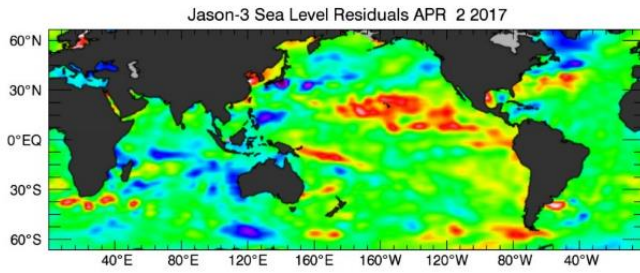
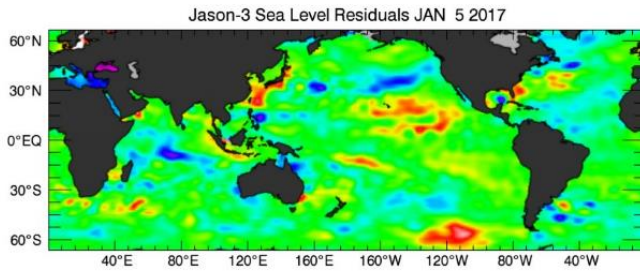
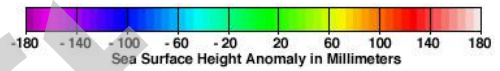


Figure 33b. Quarterly time series of mean sea level anomalies during 2017 show no pattern of El Niño throughout the year according to satellite altimetry measurements of sea level height (unlike 2015).

<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 34 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.

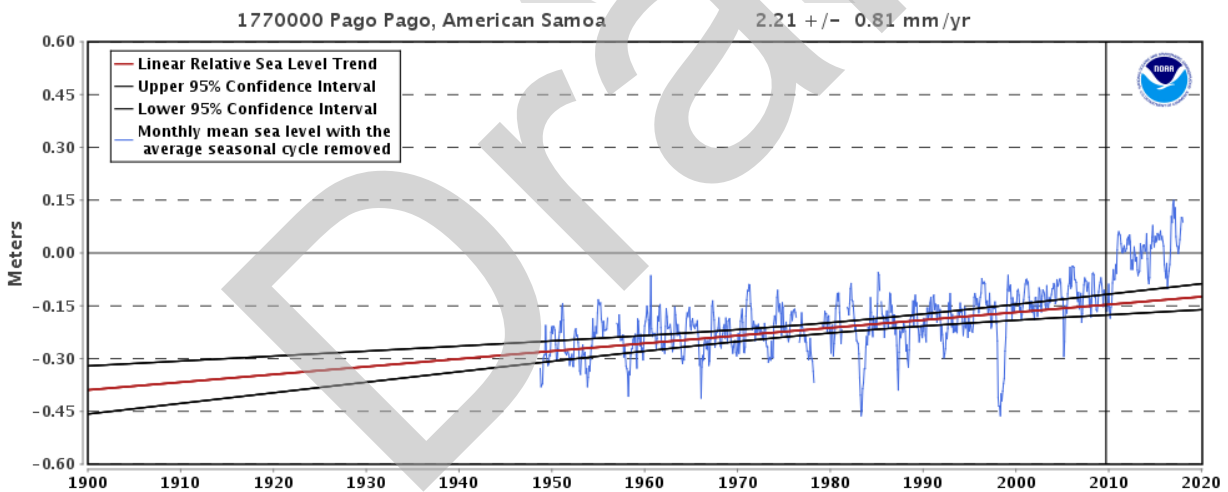


Figure 34. Monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents.

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

At its 170th meeting, the Council directed staff to scope the non-fishing impacts review, from the 2016 SAFE reports, through its advisory bodies. The 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 35). 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 (Neill and Trewick, 2008). Rose Atoll's geological origin is not well studied.

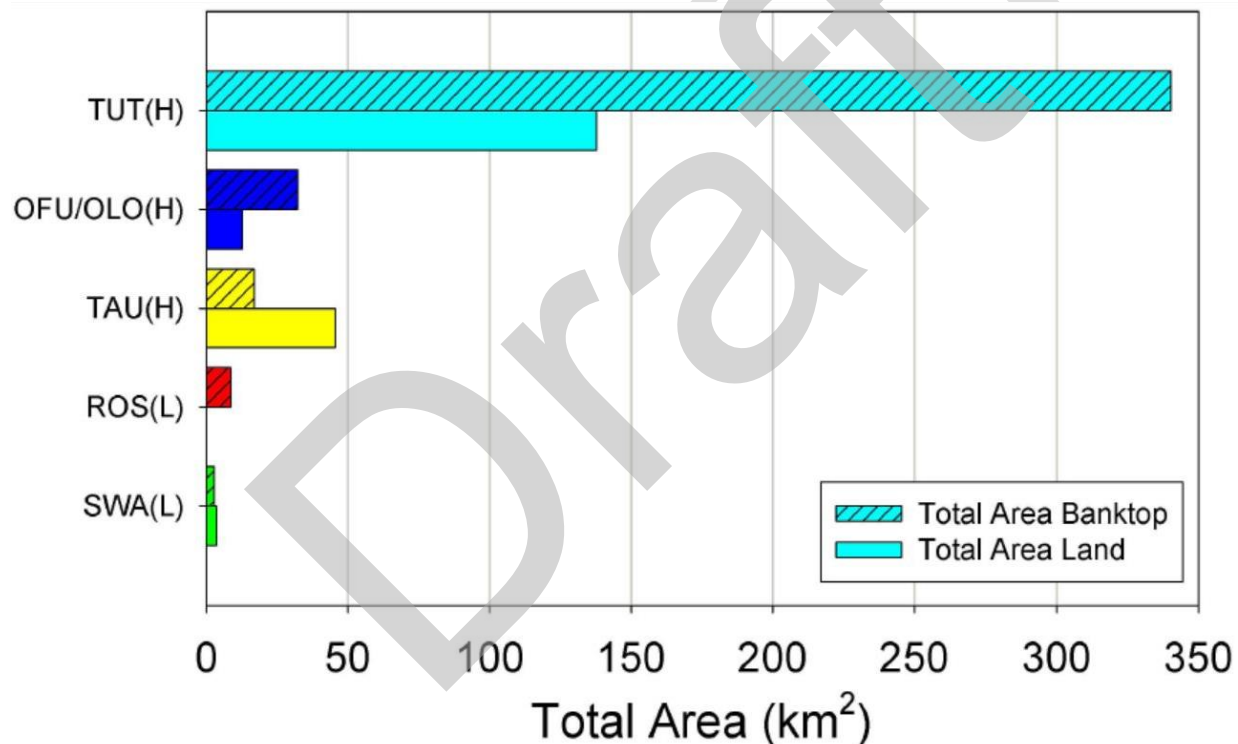


Figure 35. Total banktop area and total terrestrial land area of Tutuila and Aunu'u (TUT), Ofu and Olosega (OFU/OLU), Ta'u (TAU), Rose (ROS), and Swains (SWA). High volcanic islands are denoted with the letter 'H', low carbonate islands/atolls with the letter 'L'.

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 36). 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.

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). CREP 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.

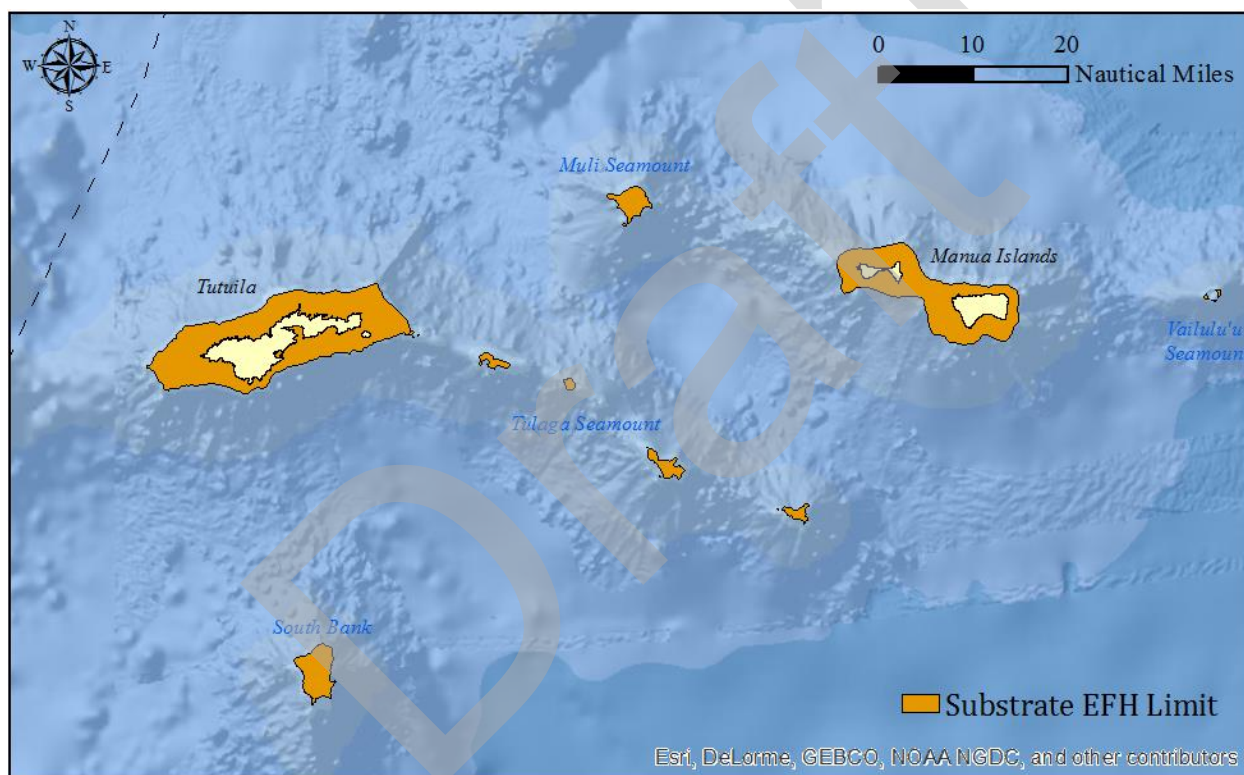


Figure 36. Substrate EFH limit of 700 m isobath around the high islands and surrounding banks of American Samoa. Sourced from GMRT.

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 38. 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 37.

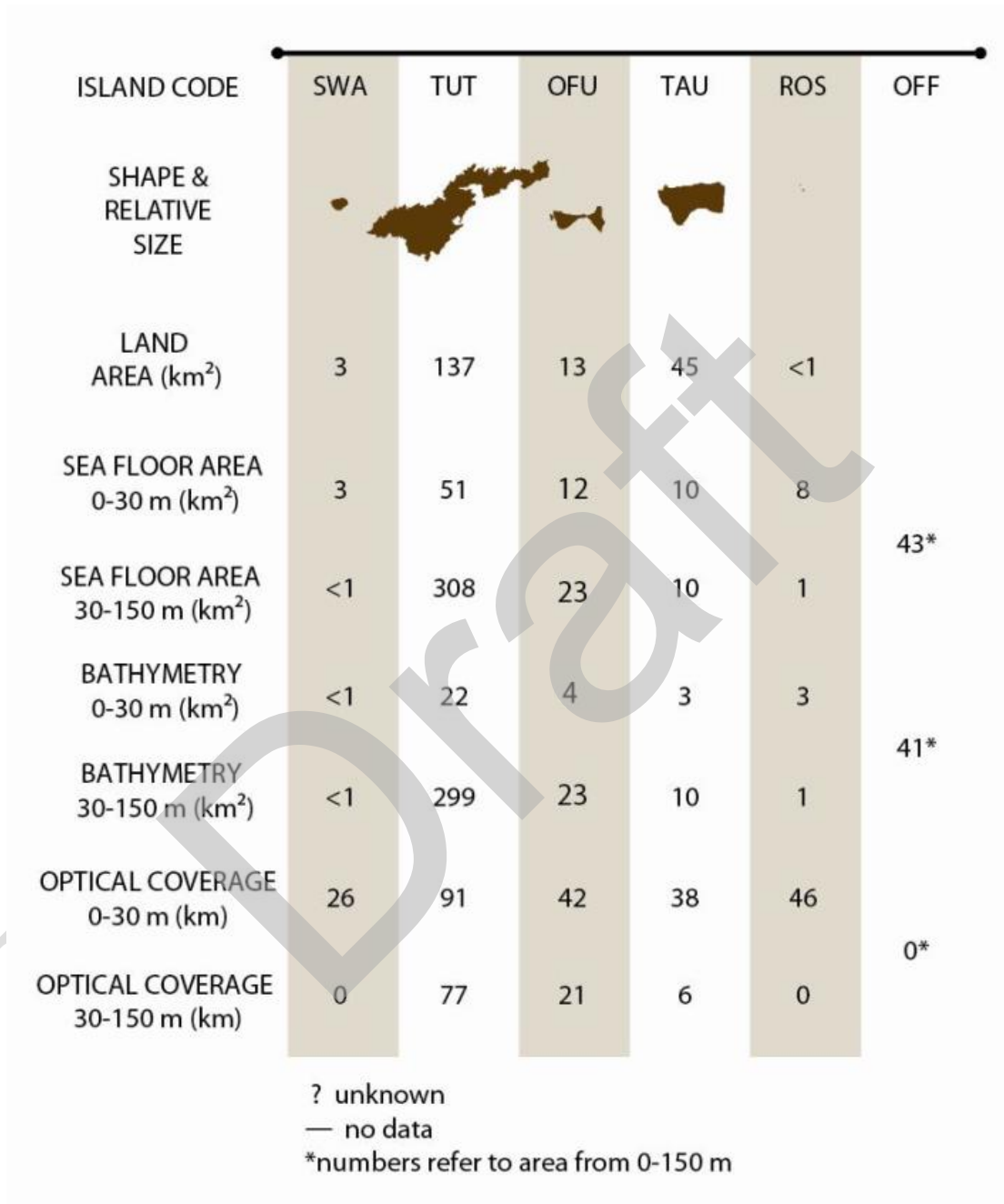


Figure 37. American Samoa Land and Seafloor Area and Primary Data Coverage (from CRCP, 2011).

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 39 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 39. 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 seastars, sea cucumbers, free and boring urchins, and giant clams).

Towed-diver surveys are typically 50 min long and cover about two to three km of habitat. Each survey is divided into five-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 40. 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 41. 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 42. 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 Hawai'i Undersea Research Laboratory (HURL) is a center operating under the School of Ocean and Earth Sciences and Technology at the University of Hawai'i 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 43. Level of EFH information available for Western Pacific precious corals management unit species. Note that all observations are from the Hawaiian Islands.

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

2.6.4.2 Bottomfish and Seamount Groundfish

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

Table 44. 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)				
<i>Aphareus rutilans</i> (red snapper/silvermouth)	0	0	0	2
<i>Aprion virescens</i> (gray snapper/jobfish)	0	0	1	2
<i>Caranx ignobilis</i> (giant trevally/jack)	0	0	1	2
<i>C. lugubris</i> (black trevally/jack)	0	0	0	2
<i>Epinephelus faciatus</i> (blacktip grouper)	0	0	0	1

Life History Stage	Eggs	Larvae	Juvenile	Adult
<i>E. quernus</i> (sea bass)	0	0	1	2
<i>Etelis carbunculus</i> (red snapper)	0	0	1	2
<i>E. coruscans</i> (red snapper)	0	0	1	2
<i>Lethrinus amboinensis</i> (ambon emperor)	0	0	0	1
<i>L. rubrioperculatus</i> (redgill emperor)	0	0	0	1
<i>Lutjanus kasmira</i> (blueline snapper)	0	0	1	1
<i>Pristipomoides auricilla</i> (yellowtail snapper)	0	0	0	2
<i>P. filamentosus</i> (pink snapper)	0	0	1	2
<i>P. flavipinnis</i> (yelloweye snapper)	0	0	0	2
<i>P. seiboldi</i> (pink snapper)	0	0	1	2
<i>P. zonatus</i> (snapper)	0	0	0	2
<i>Pseudocaranx dentex</i> (thicklip trevally)	0	0	1	2
<i>Seriola dumerili</i> (amberjack)	0	0	0	2
<i>Variola louti</i> (lunartail grouper)	0	0	0	2
Seamount Groundfish:				
<i>Beryx splendens</i> (alfonsin)	0	1	2	2
<i>Hyperoglyphe japonica</i> (ratfish/butterfish)	0	0	0	1
<i>Pseudopentaceros richardsoni</i> (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 45. Level of EFH information available for the CMUS complex.

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

- Annette DesRochers. "Benthic Habitat Mapping." NOAA Fisheries Center, Honolulu, HI. Presentation. April 6, 2016.
- Brainard, R. and Balwani, S., 2008. Coral Reef Ecosystem Monitoring Report for American 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.
- Miller, J., Battista, T., Pritchett, A., Rohmann, S., and Rooney, J., 2011. Coral Reef Conservation Program Mapping Achievements and Unmet Needs. US Department of Commerce, National Oceanic and Atmospheric Administration, Coral Reef Conservation Program. March 14, 2011. 68 p.
- Neall, V.E. and Trewick, S.A., 2008. The age and origin of the Pacific islands: a geological overview. *Phil. Trans. R. Soc.*, 363(1508), pp. 3293-3308.
- PIFSC, 2011. Coral reef ecosystems of American Samoa: a 2002–2010 overview. NOAA Fisheries Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-11-02, 48 p.
- Pacific Islands Fisheries Science Center Ecosystem Sciences Coral Reef Ecosystem Survey Methods. Benthic Monitoring. http://www.pifsc.noaa.gov/cred/survey_methods.php. Updated April 1, 2016. Accessed April 5, 2016.

2.7 MARINE PLANNING

2.7.1 Introduction

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

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

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

In order to monitor implementation of this objective, this annual report includes the Council's spatially-based fishing restrictions or marine managed areas (MMAs), the goals associated with those, and the most recent evaluation. Council research needs are identified and prioritized through the 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 147th 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 162nd 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 46 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 38.

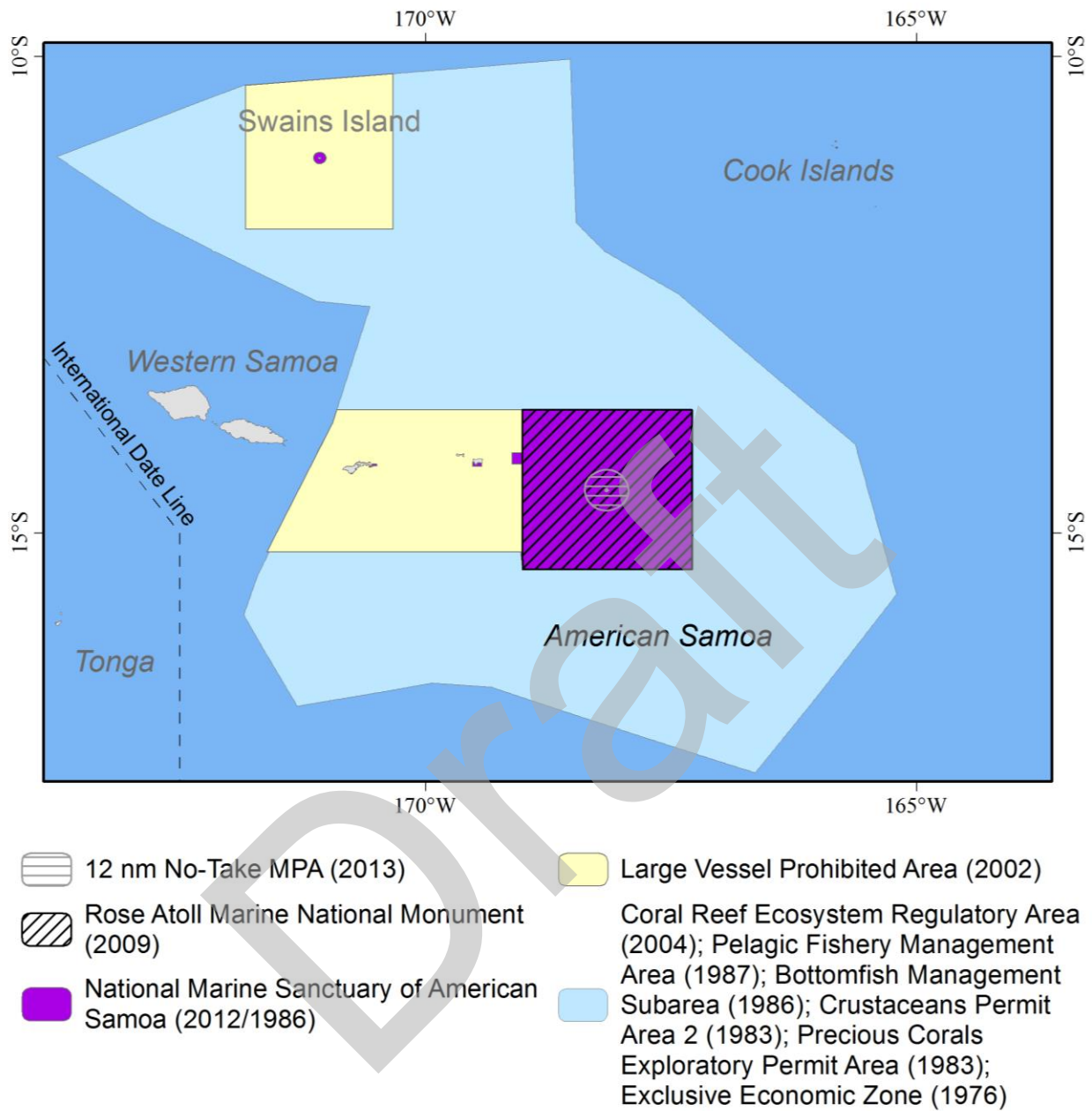


Figure 38. Regulated fishing areas of American Samoa.

Table 46. 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 Archipelago/ 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&=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>.
- Pacific Island Pelagic Fisheries; Exemption for Large U.S. Longline Vessels to Fish in Portions of the American Samoa Large Vessel Prohibited Area, Final Rule. *Federal Register* 81 (3 February 2016): 5619-5626. Downloaded from <https://www.gpo.gov/fdsys/pkg/FR-2016-02-03/pdf/2016-01891.pdf>.
- Pelagic Fisheries of the Western Pacific Region, Final Rule. *Federal Register* 56 (18 October 1991): 52214-52217. Downloaded from <http://www.wpcouncil.org/pelagic/Documents/FMP/Amendment3-FR-FinalRule.pdf>.
- Pelagic Fisheries of the Western Pacific Region, Final Rule. *Federal Register* 57 (4 March 1992): 7661-7665. Downloaded from <http://www.wpcouncil.org/pelagic/Documents/FMP/Amendment5-FR-FinalRule.pdf>.
- Western Pacific Fisheries; Fishing in the Marianas Trench, Pacific Remote Islands, and Rose Atoll Marine National Monuments, Final Rule. *Federal Register* 78 (3 June 2013): 32996-33007. Downloaded from <http://www.wpcouncil.org/precious/Documents/FMP/Amendment5-FR-FinalRule.pdf>.
- Western Pacific Regional Fishery Management Council. Fishery Management Plan and Fishery Ecosystem Plan Amendments available from <http://www.wpcouncil.org/>.

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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 47.

Table 47. 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 48) 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 48. 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- <i>a</i> (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- <i>a</i> (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 lowered 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 2.5.3 in 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 39. 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.

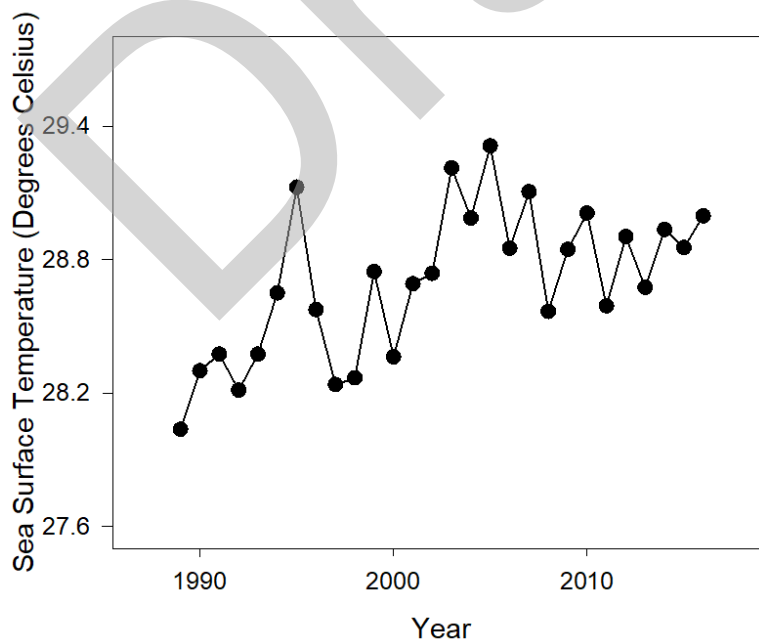


Figure 39. Average annual SST ($^{\circ}\text{C}$) in American Samoa from 1985-2016 ($CV = 1.15$).

3.4.1 Evaluating relationship for entire recreational reef fishery

Figure 40 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 40).

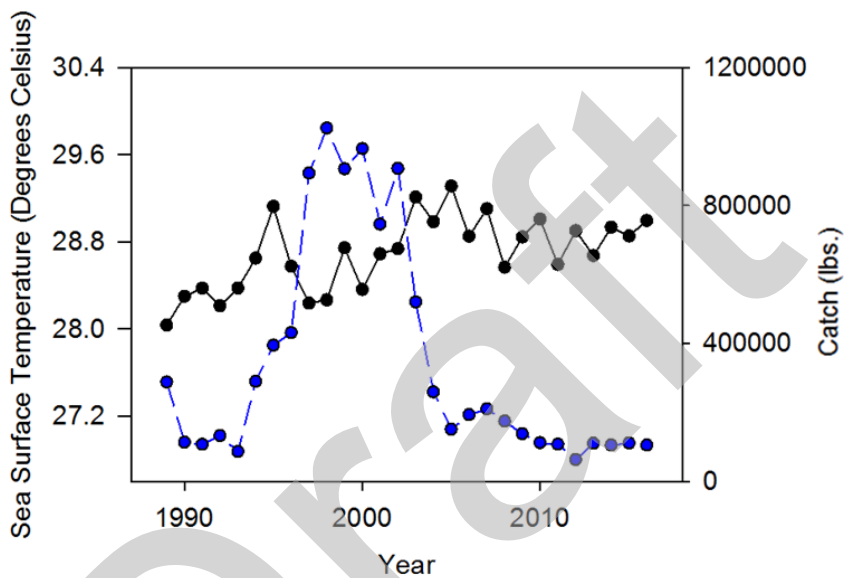


Figure 40. Total annual catch (lbs.; blue) for the American Samoa recreational coral reef fishery plotted with average annual SST (°C; black) from 1989-2016.

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 49 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 49. 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 50). 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 50; Figure 41). The observed association between the two parameters appeared to associate negatively over time despite the lack of a statistically significant trend (Figure 41).

Table 50. Correlation coefficients (r) between recreational coral reef fishery catch (lbs.) and SST ($^{\circ}\text{C}$) in American Samoa for 12 taxa harvested from 1989-2016. Significant correlations are indicated in bold ($\alpha=0.05$).

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

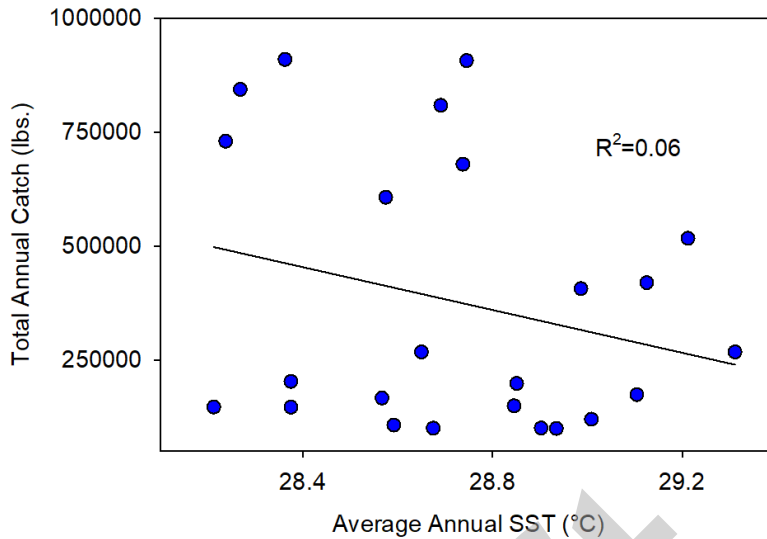


Figure 41. Linear regression showing the correlation between total annual catch (lbs.) for the recreational coral reef fishery and average annual sea surface temperature (°C) in American Samoa from 1989-2016.

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 50). 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 50; Figure 42a). 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 50; Figure 42b) 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 50; Figure 42c). 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.

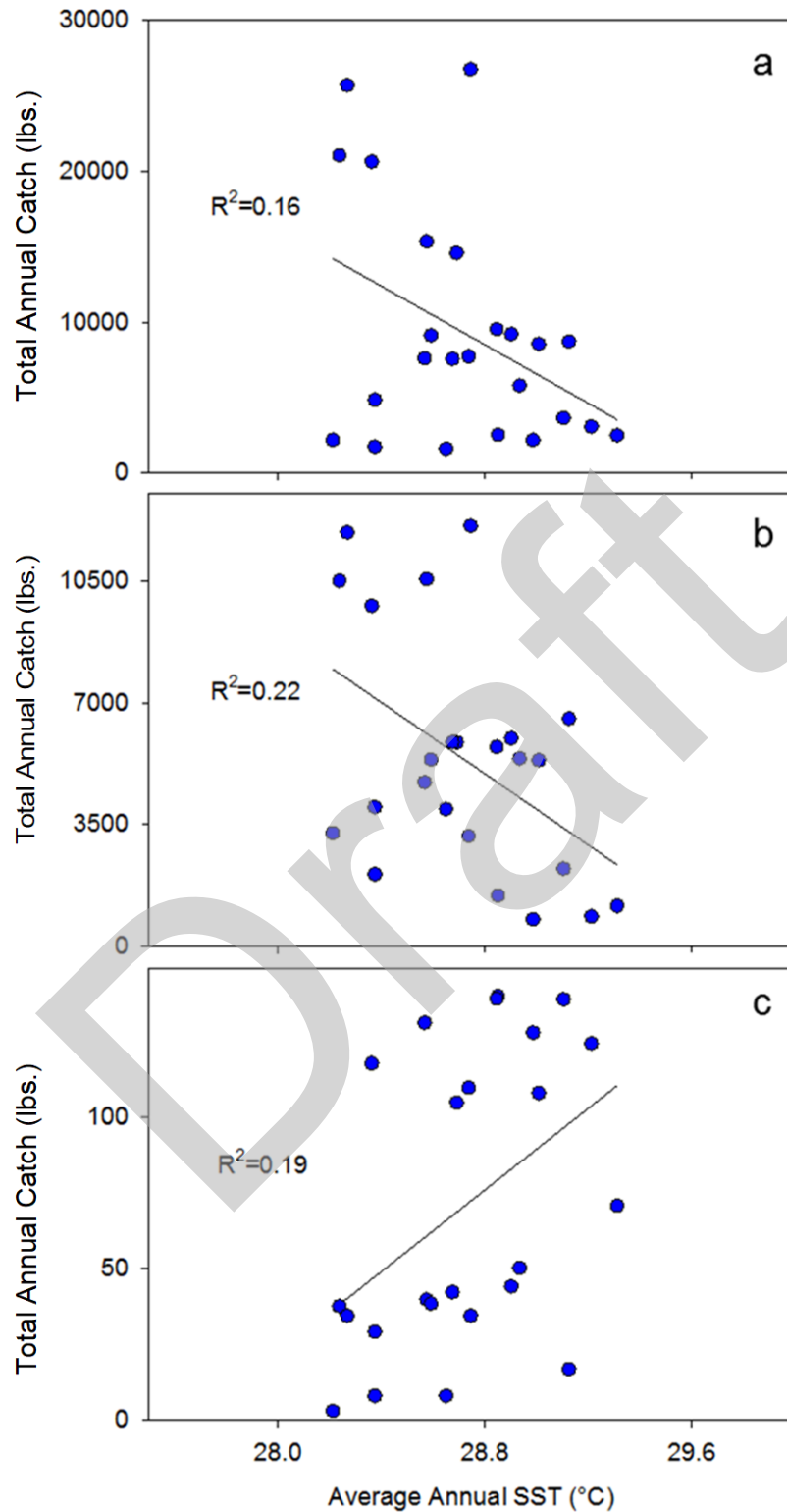


Figure 42. Linear regressions showing the three top correlations between total annual catch (lbs.) for the recreational coral reef fishery and average annual SST (°C) in American Samoa for (a) Acanthurids, (b) Scarids, and (c) Mullids from 1989-2016.

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 physiochemistry 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 Initiative 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 43. The chlorophyll levels had relatively low variability over the course of evaluated data ($\text{CV} = 4.90$; Figure 43). 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 $0.039 \text{ mg}/\text{m}^3$, and the lowest recorded level was seen at the inception of the time series in 2005 at $0.036 \text{ mg}/\text{m}^3$ (Figure 43).

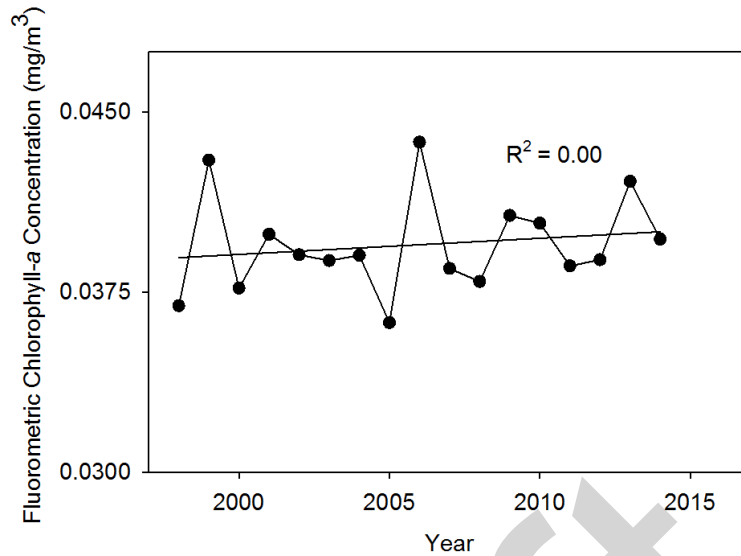


Figure 43. Fluorometric chlorophyll-a concentrations (mg/m^3) from 1998–2016 (CV = 4.90).

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 44).

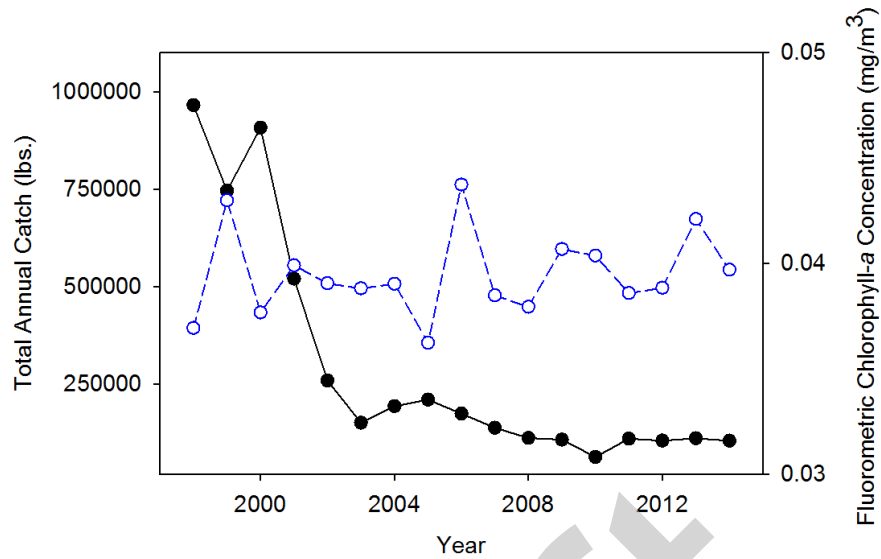


Figure 44. Comparison of American Samoa recreational reef fish catch (lbs.; black) and chlorophyll-*a* concentrations (mg/m³; blue) from 1998 – 2014 and two years of time lag.

The linear regressions performed between noncommercial reef catch in American Samoa and fluorometric chlorophyll-*a* concentrations (mg/m³) are shown in Figure 45. 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 51; Figure 45). 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 51. Correlation coefficients (*r*) from comparisons of time series of American Samoa recreational coral reef fishery annual catch (lbs.) and fluorometric chlorophyll-*a* concentrations (mg/m³) 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													
<i>p</i>	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
<i>r</i>	-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
<i>R</i> 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

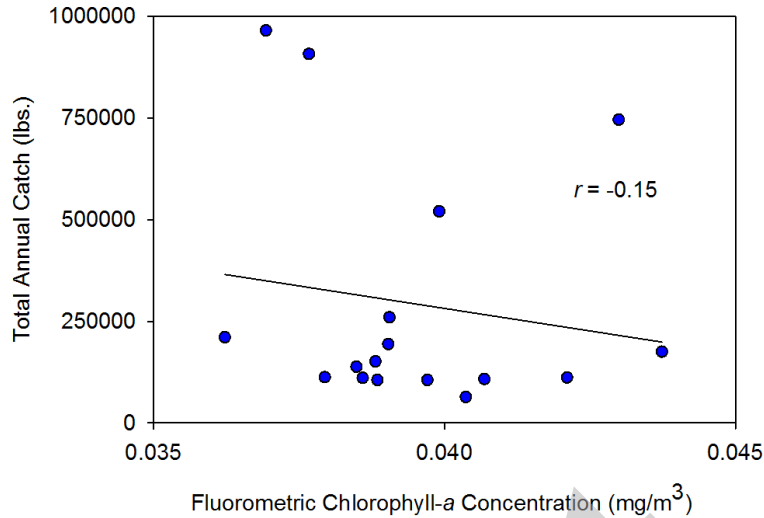


Figure 45. Linear regression showing between total annual catch (lbs.) for the American Samoa recreational coral reef fishery with phase lag (t+2 years) and fluorometric chlorophyll-a concentrations (mg/m³) from 1998-2014.

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 51). 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 51; Figure 46a-c).

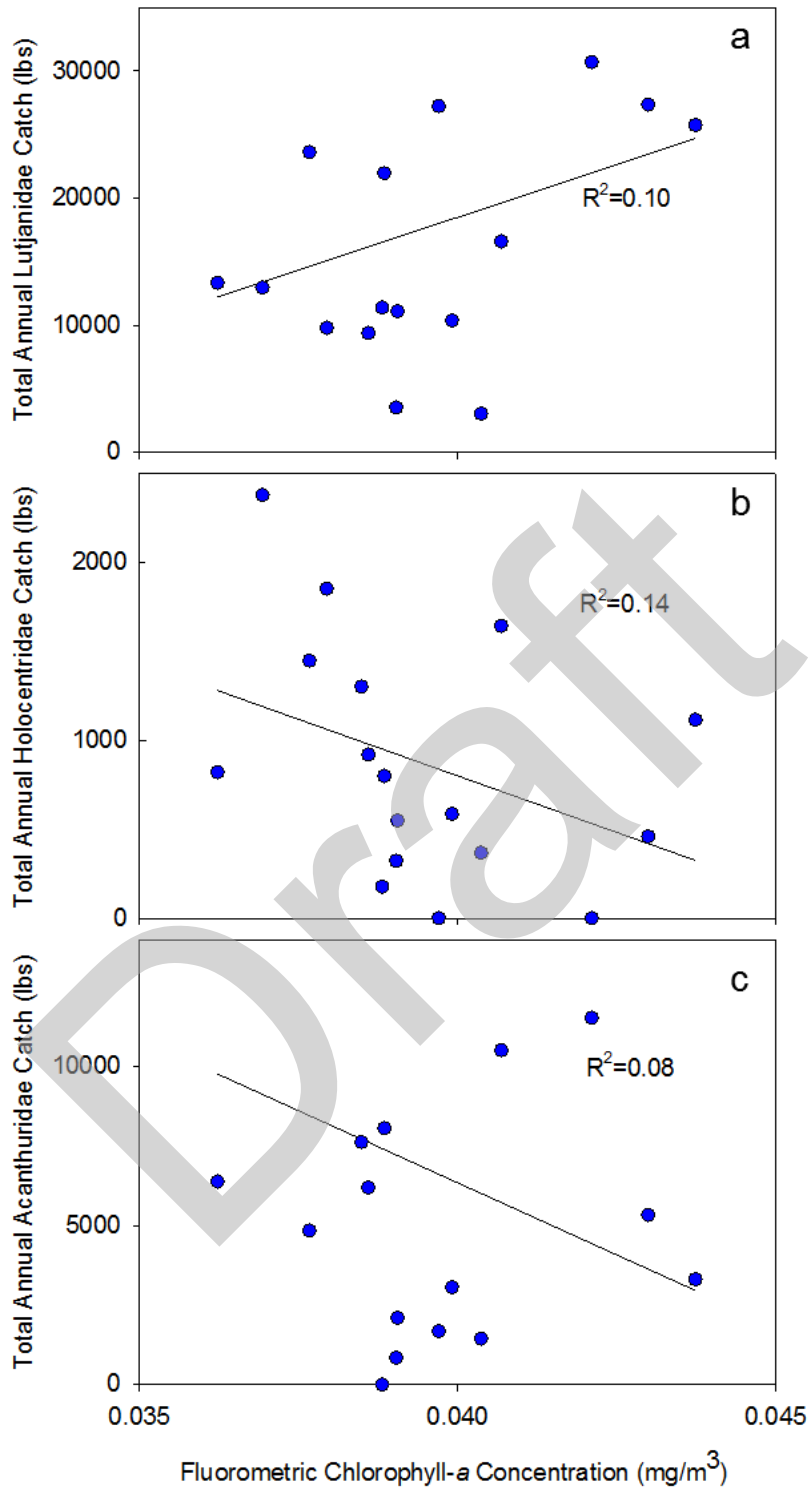


Figure 46. Linear regressions showing three correlations between total annual catch (lbs.) for the American Samoa recreational coral reef fishery and fluorometric chlorophyll-*a* concentrations (mg/m³) for (a) Lutjanids, (b) Holocentrids, and (c) Acanthurids from 1998–2014 with phase lag (t+2 years).

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 through 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 47). 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 47).

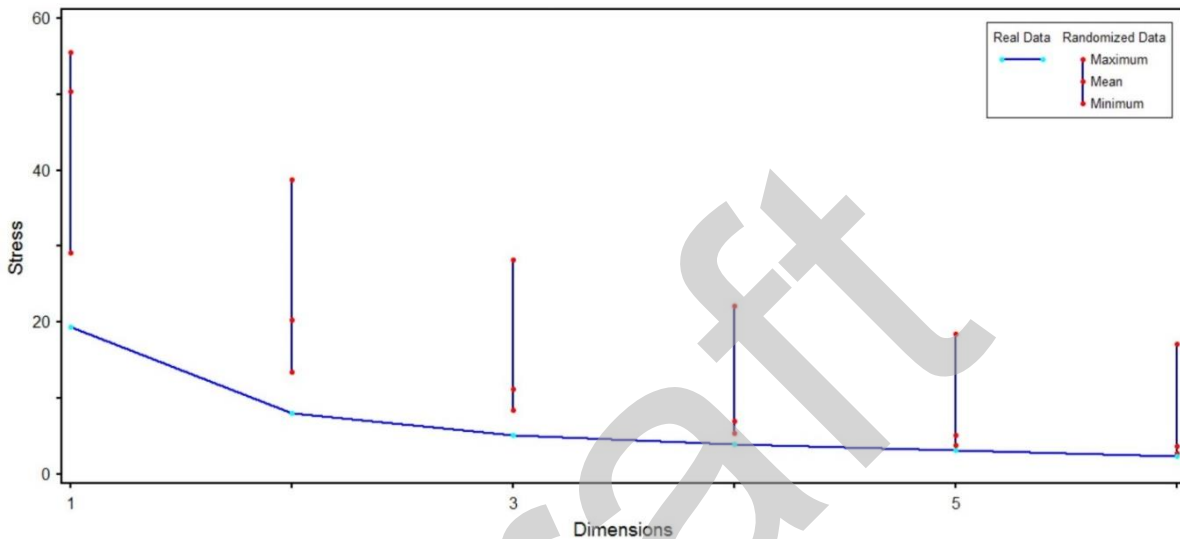


Figure 47. NMS scree plot showing the stress test to determine dimensionality for the final solution for the American Samoa multivariate analysis.

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 48). 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 48). Analyses including time series of precipitation levels in American Samoa may be useful going forward.

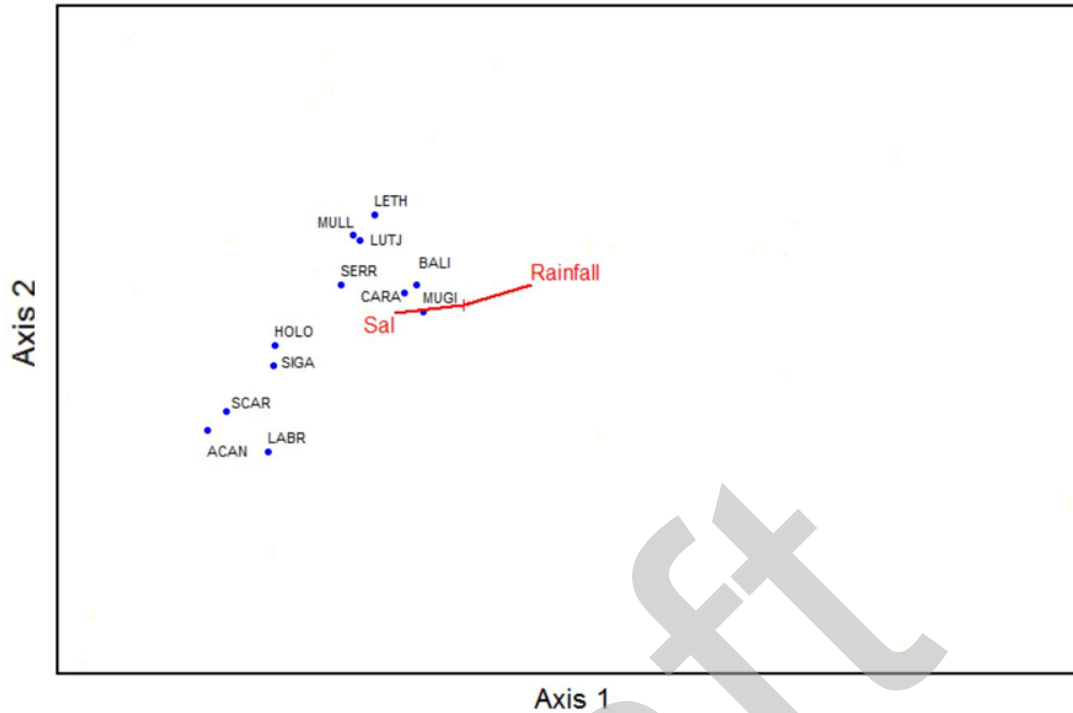


Figure 48. Two-dimensional scatterplot overlaid with a joint biplot depicting ordination scores resulting from an NMS analysis on creel survey expanded catch data and prominent environmental parameters in American Samoa from 1989-2014.

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

- Carton, J.A. and Giese B.S., 2008. A Reanalysis of Ocean Climate Using Simple Ocean Data Assimilation (SODA), *Mon. Weather Rev.*, 136, pp. 2999-3017.
- Climate Prediction Center Internet Team, 2015. Cold and warm episodes by season. NOAA Center for Weather and Climate Prediction, Maryland, United States. Accessed March 2017. Available from http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml.
- Hawhee, J.M., 2007. Western Pacific Coral Reef Ecosystem Report. Report prepared for the Western Pacific Regional Fishery Management Council, Honolulu, HI 96813 USA, 185.
- Islam, M.S., and Tanaka, M., 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine pollution bulletin*, 48(7), pp. 624-649.
- Kitiona, F., Spalding, S., and Sabater, M., 2016. The impacts of climate change on coastal fisheries in American Samoa. University of Hawaii at Hilo, HI 96720 USA, 18 p.
- McClanahan, T.R., Graham, N.A., MacNeil, M.A., Muthiga, N.A., Cinner, J.E., Bruggemann, J.H., and Wilson, S.K., 2011. Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries. *Proceedings of the National Academy of Sciences*, 108(41), pp.17230-17233.
- Messié, M. and Radenac, M.H., 2006. Seasonal variability of the surface chlorophyll in the western tropical Pacific from SeaWiFS data. *Deep Sea Research Part I: Oceanographic Research Papers*, 53(10), pp. 1581-1600.
- NOAA/NESDIS/OceanWatch – Central Pacific, n.d. OceanWatch – Sea-surface Temperature, AVHRR Pathfinder v5.0 + GAC – Monthly. NOAA, Maryland, USA. Accessed March 2017. Available from <<http://oceanwatch.pifsc.noaa.gov/thredds/dodsC/pfgac/monthly>>.
- NOAA/NOS/CO-OPS, n.d. Observed Water Levels. NOAA, Maryland, United States. Accessed March 2017. Available from <<https://tidesandcurrents.noaa.gov/waterlevels.html>>.
- NOAA PDO, n.d. Pacific Decadal Oscillation Index. NOAA, Maryland, United States. Accessed March 2017. Available from <<http://research.jisao.washington.edu/pdo/PDO.latest>>.
- NWS-AS, n d. National Weather Service Forecast Office, Pago Pago, American Samoa. NOAA National Weather Service. Accessed March 2017. Available from <<http://w2.weather.gov/climate/xmacis.php?wfo=samoa>>.
- Ocean Colour Climate Change Initiative dataset, Version 3.1, European Space Agency. Accessed August 2017. Available from <<http://www.esa-oceancolour-cci.org/>>.
- Ochavillo, D., 2012. Coral Reef Fishery Assessment in American Samoa. Department of Marine and Wildlife Resources, Pago Pago, American Samoa 96799 USA, 29 p.

- Peck, J.E., 2016. *Multivariate Analysis for Ecologists: Step-by- Step*, Second edition. MjM Software Design, Gleneden Beach, OR. 192 p.
- Remington, T.R. and Field, D.B., 2016. Evaluating biological reference points and data-limited methods in Western Pacific coral reef fisheries. Report prepared for the Western Pacific Regional Fishery Management Council, Honolulu, HI 96813 USA, 134 p.
- Roemmich, D. and McGowan, J., 1995. Climatic warming and the decline of zooplankton in the California Current. *Science: New York then Washington*, pp. 1324-1324.
- Richards B.L., Williams I.D., Vetter O.J., and Williams G.J., 2012. Environmental factors affecting large-bodied coral reef fish assemblages in the Mariana Archipelago. *PLoS ONE* 7(2), e31374.
- Weng, K.C. and Sibert, J.R., 2000. Analysis of the Fisheries for two pelagic carangids in Hawaii. Joint Institute for Marine and Atmospheric Research, University of Hawaii at Manoa, Honolulu, HI 96822 USA, 78 p.
- Williams, I.D., Baum, J.K., Heenan, A., Hanson, K.M., Nadon, M.O., and Brainard, R.E., 2015. Human, Oceanographic and Habitat Drivers of Central and Western Pacific Coral Reef Fish Assemblages. *PLoS ONE* 10(5): e0129407.