



# Annual Stock Assessment and Fishery Evaluation Report: 2020

## American Samoa Archipelago Fishery Ecosystem Plan

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

Phone: 808-522-8220

Website: [www.wpcouncildata.org](http://www.wpcouncildata.org)



*The ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT for the AMERICAN SAMOA FISHERY ECOSYSTEM PLAN 2020 was drafted by the Fishery Ecosystem Plan Team. This is a collaborative effort primarily between the Western Pacific Regional Fishery Management Council (WPRFMC), National Marine Fisheries Service (NMFS)-Pacific Island Fisheries Science Center (PIFSC), Pacific Islands Regional Office (PIRO), Hawaii Division of Aquatic Resources (HDAR), American Samoa Department of Marine and Wildlife Resources (DMWR), Guam Division of Aquatic and Wildlife Resources (DAWR), and Commonwealth of the Mariana Islands (CNMI) Division of Fish and Wildlife (DFW).*

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

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

**Edited By:** Thomas Remington, Contractor & Marlowe Sabater and Asuka Ishizaki, WPRFMC.

**Cover image:** WPRFMC.

**This document can be cited as follows:**

*WPRFMC, 2021. Annual Stock Assessment and Fishery Evaluation Report for the American Samoa Archipelago Fishery Ecosystem Plan 2020. Remington, T., Sabater, M., Ishizaki, A. (Eds.) Western Pacific Regional Fishery Management Council. Honolulu, Hawaii 96813 USA. 147 pp. + Appendices.*

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

**American Samoa Department of Marine and Wildlife Resources:** Domingo Ochavillo.

**NMFS Pacific Islands Fisheries Science Center:** Marc Nadon, Felipe Carvalho, Ashley Tomita, Reka Domokos-Boyer, Joseph O'Malley, Michael Parke, Thomas Oliver, Melanie Abecassis, Frank Parrish, Keith Bigelow, Robert Ahrens, T. Todd Jones, Minling Pan, Danika Kleiber, Justin Hospital, and Kirsten Leong.

**NMFS Pacific Islands Regional Office:** Brett Schumacher.

The Council also acknowledges the staff of the **NMFS PIFSC Fisheries Research and Monitoring Division data programs** for providing the technical support to generate the data summaries.

The Council would like to thank the following individual for their contributions to the report: Samuel Kahng.

This page was intentionally left blank.

## EXECUTIVE SUMMARY

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

The Fishery Performance chapter of this report first presents a general description of the local fisheries within American Samoa, focusing on the bottomfish management unit species (MUS), particularly bottomfish MUS (BMUS), accompanied by monitoring of ecosystem component species (ECS). The fishery data collection system is explained, encompassing creel surveys and commercial receipt books. Fishery meta-statistics for BMUS and ECS are organized into summary dashboard tables showcasing the values for the most recent fishing year and a comparison to short-term (10-year) and long-term (20-year) averages. Time series for catch and effort statistics are also provided along with annual catch limit (ACL) determinations.

For 2020 in American Samoa, there was no ACL for BMUS, but there was an interim catch limit (ICL) of 13,000 lb implemented associated with an interim management measure for the American Samoa bottomfish fishery (85 FR 73003, November 16, 2020) due to the stock complex being determined to be overfished and experiencing overfishing according to the most recent benchmark stock assessment (Langseth et al. 2019). American Samoa BMUS total estimated catch in 2020 and the three-year average catch from 2018 to 2020 did not exceed this ICL. There are no other MUS in American Samoa, as an amendment to the American Samoa Archipelago FEP in early 2019 reclassified most of the MUS as ECS except for bottomfish (84 FR 2767, February 8, 2019). ECS do not require management under ACLs or accountability measures but are still to be monitored regularly in the annual SAFE report through a one-year snapshot of the ten most-caught ECS, complete catch time series of prioritized ECS as selected by the American Samoa Department of Marine and Wildlife Resources (DMWR), as well as trophic and functional group biomass estimates from fishery independent surveys.

American Samoa bottomfish fishery performance declined in 2020, which may be partially attributed to direct and indirect impacts of the novel coronavirus (COVID-19) pandemic. Total BMUS catch was 8,040 lb estimated from the creel survey data, a 35% reduction from the short-term (10-year) trend and 44% reduction from the long-term (20-year) trend. BMUS catch from commercial purchase data totaled just 307 lb in 2020, which was a substantial decrease from both the 10-year average (-75%) and 20-year average (-84%). Catch-per-unit-effort (CPUE) for BMUS in 2020 was lower than 10- and 20-year averages for both metrics presented, pounds per trip and pounds per gear hour. There were 26 lb/trip of BMUS harvested by bottomfish fishing, which was a 43% reduction from the short-term trend and 53% reduction from the long-term trend. The estimated 1.1515 lb/gear hour of BMUS harvested by bottomfish fishing was a 4% decrease from the 10-year average and 25% decrease from the long-term average. There were 37 tallied fishing trips that harvested BMUS in 2020, which was a 36% decrease from the 10-year trend and a 42% decrease from the 20-year trend. Tallied gear hours bottomfish fishing for

BMUS were estimated to be 871, a 72% and 68% decrease from the short- and long-term trends, respectively. Participation in the bottomfish fishery also decreased in 2020, with just six unique vessels recorded as harvesting BMUS (a decrease of 40% and 50% from 10- and 20-year averages, respectively). There was an estimated average of two fishermen per bottomfish trip, though historically there have been three fishermen per trip. There was no recorded bycatch in American Samoa boat-based non-pelagic fisheries in 2020.

For the top ten landed ECS in American Samoa in 2020, available data streams showed that humpback snapper (*Lutjanus gibbus*) had the most catch in the creel surveys, while the blue-banded surgeonfish (*Acanthurus lineatus*) had the most catch from commercial invoice data. The second most caught species in the boat-based creel surveys was the redlip parrotfish (*Scarus rubroviolaceus*), while a generic group of unknown reef fishes was second highest in the commercial purchase data. Several other species had notable catch estimates in the creel survey data, including the bigeye barracuda (*Sphyraena fosteri*) and bluespine unicornfish (*Naso unicornis*). For commercial data, the striped bristletooth (*Ctenochaetus striatus*) ranked third. Many remaining top ten ECS from commercial purchase data were multi-species or family groups (e.g., *Scarus* spp. and inshore groupers) due to how the species are organized during data collection.

For prioritized ECS (i.e., those selected by DMWR) in American Samoa, 2020 creel survey catch estimates for four of the six species were zero. *Panulirus penicillatus* (307 lb) and *Epinephelus melanostigma* (110 lb) were the only species with catch recorded in the boat-based creel surveys for the year. In American Samoa commercial purchase data, five of the six species had zero recorded catch. The only species with catch data for 2020 was *P. penicillatus*, whose landings showed declines of 83% and 87% from its 10- and 20-year averages, respectively.

For the first time in 2020, summaries of catch and effort from commercial federal logbook data for lobster and deepwater fisheries in American Samoa were added to the annual SAFE report. No federal permits, catch, or effort were reported in 2020.

An Ecosystem Considerations chapter was added to the annual SAFE reports following the Council's review of its FEPs and revised management objectives. Fishery independent ecosystem survey data, socioeconomic, protected species, climate and oceanographic, essential fish habitat, and marine planning information are included in this chapter. For the first time in the 2020 annual SAFE report, a section on fishermen observations was added, detailing on-the-water observations from bottomfish fishermen in the Territory for the year. In addition, a special section was also added describing the impacts of COVID-19 on American Samoa archipelagic fisheries and fishing communities.

Fishery independent ecosystem data were acquired through visual surveys conducted by the National Marine Fisheries Service (NMFS) Pacific Islands Fisheries Science Center (PIFSC) Reef Assessment and Monitoring Program (RAMP) under the Ecosystem Sciences Division (ESD) in CNMI, the Pacific Remote Island Areas (PRIA), American Samoa, Guam, the Main Hawaiian Islands (MHI), and the Northwestern Hawaiian Islands (NWHI). This report describes mean fish biomass of functional, taxonomic, and trophic groups for coral reefs as well as habitat condition using mean coral coverage per island for each of these locations, however, there were no new data reported for 2020 because surveys were cancelled due to restrictions associated with COVID-19. Coral coverage at locations in American Samoa ranged from just over 3% (at South Bank) to nearly 30.5% (at Swains Island) averaged from 2010 to 2019, however there were only

two surveys done at South Bank in that period. Total estimated fish biomass in American Samoa averaged from 2010 to 2019 was lowest at South Bank and highest at Ofu and Olosega, which also had the highest biomass for mid-large target surgeonfish, species of the family Scaridae, herbivores, and mobile invertebrate feeders. Biomass of non-planktivorous butterflyfish was highest at Tau, while Tutuila had the highest biomass for corallivores. Swains Island had the highest observed biomass for planktivores, and Rose Atoll had the highest biomass for species of the families Serranidae and Lutjanidae.

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 length-weight regression, and length-weight coefficients. Values for six reef-associated species and 11 species of bottomfish are presented for American Samoa where available. For American Samoa, age, growth, and reproduction parameters for *Lethrinus rubrioperculatus* were added to the report this year.

The socioeconomics section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of the FEP for the American Samoan Archipelago. It meets the objective “Support Fishing Communities” adopted at the 165<sup>th</sup> Council meeting; specifically, it identifies the various social and economic groups within the region’s fishing communities and their interconnections. The section begins with an overview of the socioeconomic context for the region, provides a summary of relevant studies and data for American Samoa, gives summaries of relevant data and studies for American Samoan fisheries, presents available socioeconomic data (including annual data for revenue, fish price, and cost of fishing), and lists relevant studies for American Samoa. In the American Samoan bottomfish fishery in 2020, there was an estimated total of 307 lb sold for \$1,067, which is a substantial reduction from recent years. In 2020, the average cost for a bottomfish fishing trip was consistent with 2019 at \$150 despite the relative increase in fuel cost. The top ten harvested ECS in American Samoa had 14,516 pounds sold for \$45,666 in revenue in 2020. The only priority ECS in 2020 with data was the green spiny lobster, with 171 pounds sold for \$690.

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 ecosystem component 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. In 2020, NMFS published a proposed rule to designate critical habitat for threatened coral species in the Western Pacific region (85 FR 76262, November 27, 2020).

The climate change section of this report includes indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Council has 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 considering changing climate, provide historical context, and identify patterns and trends.

The trend of atmospheric concentration of carbon dioxide (CO<sub>2</sub>) is increasing exponentially with a time series maximum at 414 ppm in 2020. Since 1989, the oceanic pH at Station ALOHA in Hawaii has shown a significant linear decrease of -0.043 pH units, or roughly a 9.4% increase in acidity ([H<sup>+</sup>]) and was 8.06 in 2019. The Oceanic Niño Index, which is a measure of the El Niño – Southern Oscillation (ENSO) phase, transitioned from neutral to La Niña conditions in fall 2020. The Pacific Decadal Oscillation (PDO) was negative in 2020. Tropical cyclone activity was average in the South Pacific in 2019, with 10 named storms, five hurricanes, and one major hurricane. Annual mean sea surface temperature (SST) was 29.95° C in 2020, and over the period of record, annual SST has increased at a rate of 0.023° C/year. The annual anomaly was 0.40 °C hotter than average with wide spatial variability. American Samoa experienced a coral heat stress event that began in March 2020 and reached its maximum in June. Annual mean chlorophyll-*a* was 0.045 mg/m<sup>3</sup> in 2020, and the annual anomaly was 0.0007 mg/m<sup>3</sup> lower than average. Precipitation anomalies were relatively positive over the course of the year. The local trend in sea level rise is 2.41 millimeters/year, equivalent to a change of 0.79 feet in 100 years.

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, and the 2020 annual SAFE report fulfills these requirements. The guidelines also require a report on the condition of the habitat. In the 2017 annual reports, a literature review of the life history and habitat requirements for each life stage for four species of reef-associated crustaceans that are landed in commercial fisheries Western Pacific region was presented, including information on two species of spiny lobster (*Panulirus marginatus* and *Scyllarides squammosus*), scaly slipper lobster (*Scyllarides squammosus*), and Kona crab (*Ranina ranina*). In 2019, an EFH review was completed for reef-associated crustaceans, but study locations were focused on the MHI and Guam. The National Standard guidelines also require a report on the condition of the habitat. In the 2020 annual report, data on benthic cover are included as indicators, pending development of habitat condition indicators for the Mariana Archipelago not otherwise represented in other sections of this report. The annual report is also meant to address any Council directives toward its Plan Team, and at its 182<sup>nd</sup> meeting in June 2020, the Council requested that NMFS work with the Council to determine “non-essential” fish habitat to look at ways to remove areas that are degraded from being considered EFH.

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 in 2020. The status of the Large Vessel Prohibited Area (LVPA) underwent litigation over the reduction of the LVPA in territorial waters. NMFS appealed Hawaii Federal District Court’s 2017 decision that invalidated



the 2016 LVPA reduction to the U.S. Ninth Circuit Court of Appeals. Oral arguments were in February 2020 in Honolulu, Hawaii, and the decision was reversed in a September 2020 ruling.

The Data Integration chapter of this report is under development. The chapter explores the potential association between fishery parameters and ecologically-associated variables that may be able to explain a portion of the variance in fishery-dependent data. A contractor completed preliminary evaluations in 2017, and results of exploratory analyses were included for the first time in the 2017 annual SAFE report. Going forward with the data integration analyses and presentation of results for Chapter 3 of the annual SAFE reports, the Council's Archipelagic Fishery Ecosystem Plan Team (Plan Team) suggested several improvements to implement in the future: standardizing and correcting values in the time series, incorporating longer stretches of phase lag, completing comparisons on the species-level and by dominant gear types, incorporating local knowledge on shifts in fishing dynamics over the course of the time series, and utilizing the exact environmental data sets presented in the Ecosystem Consideration chapter of this annual SAFE report. Many of these recommendations were applied to a revisited analysis in the Hawaii annual SAFE report in 2018 with similar plans for American Samoa data integration analyses in future report cycles. Implementation of these suggestions will allow for the preparation of a more finalized version of the data integration chapter in coming years. The chapter will be updated in the future as resources allow. For the 2020 report, several recent relevant abstracts from primary publications related to data integration were added to the Data Integration chapter.

Regarding the revisions to the 2020 annual SAFE reports, the 2021 Archipelagic Plan Team generated several work items relevant to the American Samoa report:

- In finalizing the annual SAFE reports, the Annual SAFE Report Coordinator to incorporate the fishermen observations as a separate section of the Ecosystem Considerations chapter for each archipelago and explicitly note the source of the information.
- DMWR to add caveats in terms of the limitations in the data for 2020 associated with COVID restrictions in their respective narratives. PIFSC will provide technical support for the individual agencies.
- The Plan Team to provide clarification on what it means and how to manage ECS.
- PIFSC Fisheries Research and Monitoring Program and the PIFSC Socioeconomics Program to work with the territorial management agencies in documenting the COVID impacts to the fishery performance data and fishing communities for inclusion in the new special COVID section of the annual SAFE reports.
- Council and Pacific Islands Regional Office (PIRO) staff to continue to work with PIFSC, the State of Hawaii, and territories to ensure that the bycatch summaries in the annual SAFE reports are consistent with standardized bycatch reporting methodology.

**TABLE OF CONTENTS**

Executive Summary .....	v
Acronyms and Abbreviations .....	xvii
1 Fishery Performance .....	1
1.1 Fishery Descriptions.....	1
1.1.1 Bottomfish Fishery.....	2
1.1.2 Ecosystem Component Fishery.....	2
1.2 Fishery Data Collection System.....	3
1.2.1 Boat-Based Creel Survey .....	3
1.2.2 Shore-Based Creel Survey .....	4
1.2.3 Commercial Receipt Book System .....	4
1.2.4 Boat Inventory .....	4
1.3 Meta-Data Dashboard Statistics .....	5
1.3.1 Creel Survey Meta-Data Statistics .....	5
1.3.2 Commercial Receipt Book Statistics .....	6
1.4 Fishery Summary Dashboard Statistics.....	8
1.5 Catch Statistics .....	9
1.5.1 Catch by Data Stream .....	10
1.5.2 Expanded Catch Estimates by Fishing Method .....	11
1.5.3 Top and Prioritized Species in Boat-Based Fishery Catch .....	12
1.6 Catch-per-Unit-Effort (CPUE) Statistics .....	16
1.7 Effort Statistics .....	19
1.8 Participants .....	22
1.9 Bycatch Estimates .....	24
1.10 Federal Logbook Data .....	26
1.10.1 Number of Federal Permit Holders.....	26
1.10.2 Summary of Catch and Effort for FEP Fisheries .....	27
1.11 Status Determination Criteria.....	28
1.11.1 Bottomfish Fishery.....	28
1.11.2 Current Stock Status .....	30
1.12 Overfishing Limit, Acceptable Biological Catch, and Annual Catch Limits.....	31
1.12.1 Brief Description of the ACL Process .....	31
1.12.2 Current OFL, ABC, ACL, and Recent Catch .....	31
1.13 Best Scientific Information Available.....	32
1.13.1 Bottomfish fishery .....	32
1.14 Harvest Capacity and Extent.....	32
1.15 Administrative and Regulatory Actions.....	33
2 Ecosystem Considerations .....	35
2.1 2020 COVID-19 Impacts .....	35
2.1.1 Social Impacts .....	35
2.1.2 Community Impacts.....	35
2.1.3 Fisheries Impacts .....	36
2.1.4 Data Collection Impacts.....	36
2.2 2020 Fishermen Observations.....	37
2.3 Coral Reef Fish Ecosystem Parameters .....	38
2.3.1 Regional Reef Fish Biomass and Habitat Condition .....	38

2.3.2	Archipelagic Reef Fish Biomass and Habitat Condition .....	41
2.4	Life History Information and Length-Derived Variables .....	43
2.4.1	American Samoa Coral Reef Ecosystem – Life History .....	43
2.4.2	American Samoa Ecosystem – Management Unit Species Life History .....	48
2.5	Socioeconomics .....	53
2.5.1	Response to Previous Council Recommendations .....	54
2.5.2	Introduction .....	54
2.5.3	People Who Fish .....	58
2.5.4	Fishery Economic Performance .....	61
2.5.5	Ongoing Research and Information Collection .....	67
2.5.6	Relevant PIFSC Economics and Human Dimensions Publications: 2020 .....	69
2.6	Protected Species .....	71
2.6.1	Indicators for Monitoring Protected Species Interactions in the American Samoa FEP Fisheries .....	71
2.6.2	Status of Protected Species Interactions in the American Samoa FEP Fisheries ...	74
2.6.3	Identification of Emerging Issues .....	74
2.6.4	Identification of Research, Data, and Assessment Needs .....	76
2.7	Climate and Oceanic Indicators .....	78
2.7.1	Introduction .....	78
2.7.2	Response to Previous Plan Team and Council Recommendations .....	79
2.7.3	Conceptual Model .....	79
2.7.4	Selected Indicators .....	80
2.8	Essential Fish Habitat .....	103
2.8.1	Introduction .....	103
2.8.2	Habitat Use by MUS and Trends in Habitat Condition .....	104
2.8.3	Report on Review of EFH Information .....	111
2.8.4	EFH Levels .....	111
2.8.5	Project Updates .....	112
2.8.6	Research and Information Needs .....	113
2.9	Marine Planning .....	114
2.9.1	Introduction .....	114
2.9.2	Response to Previous Council Recommendations .....	114
2.9.3	Marine Managed Areas established under the FEPs .....	116
2.9.4	Fishing Activities and Facilities .....	117
2.9.5	Non-Fishing Activities and Facilities .....	118
2.9.6	American Samoa Spatial Planning Tools .....	118
3	Data Integration .....	119
3.1	Introduction .....	119
3.1.1	Potential Indicators for Insular Fisheries .....	119
3.1.2	2018 Recommendations and Direction for Chapter Development .....	120
3.2	Past Work .....	121
3.3	Sea Surface Temperature .....	122
3.3.1	Evaluating relationship for entire coral reef fishery .....	123
3.3.2	Evaluating relationships for dominant taxa .....	125
3.4	Primary Productivity .....	127
3.4.1	Evaluating relationship for entire coral reef fishery .....	128

3.4.2	Evaluating relationships with dominant taxa.....	130
3.5	Multivariate Assessments of Additional Environmental Variables .....	132
3.5.1	Non-Metric Multidimensional Scaling .....	132
3.6	Recent Relevant Abstracts .....	134
4	References.....	139
	Appendix A: List of Species .....	A-1
	Appendix B: List of Protected Species and Designated Critical Habitat.....	B-1

**TABLE OF TABLES**

Table 1. Summary of American Samoa boat-based creel survey meta-data .....	5
Table 2. Summary of American Samoa commercial receipt book meta-data .....	7
Table 3. Annual indicators for American Samoa bottomfish fisheries describing performance and comparing 2020 estimates with short- (10-year) and long-term (20-year) averages .....	8
Table 4. Annual indicators for American Samoa ECS fisheries describing performance and comparing 2020 estimates with short- (10-year) and long-term (20-year) averages .....	9
Table 5. Summary of American Samoa BMUS total catch (lb) from expanded boat-based and shore-based creel surveys and the commercial purchase system for all gear types .....	10
Table 6. Total catch time series estimates (lb) for all species and BMUS only using American Samoa expanded boat-based creel survey data for bottomfish fishing gears .....	11
Table 7a. Top ten landed ECS in American Samoa from boat-based creel survey data in 2020 .	13
Table 8a. Catch (lb) from boat-based creel survey expansion data for prioritized species in American Samoan ECS fisheries .....	14
Table 9. CPUE (lb/trip and lb/gear hour) for bottomfish fishing gears in the American Samoa boat-based fishery for all species and BMUS only .....	17
Table 10. Effort (trips and gear hours) for bottomfish fishing gears in the American Samoa boat-based fishery for all species and BMUS only .....	20
Table 11a. Estimated number of unique vessels for bottomfish fishing gears in the American Samoa boat-based fishery for all species and BMUS only .....	22
Table 12. Time series of catch and bycatch in the American Samoa boat-based BMUS and non-BMUS fisheries .....	25
Table 13. Number of federal permit holders in American Samoa crustacean fisheries .....	27
Table 14. Summary of available federal logbook data for lobster fisheries in American Samoa	27
Table 15. Summary of available federal logbook data for deepwater shrimp fisheries in American Samoa .....	28
Table 16. Overfishing threshold specifications for BMUS .....	29
Table 17. Recruitment overfishing control rule specifications for BMUS .....	30
Table 18. Stock assessment parameters for the BMUS complex (from Langseth et al. 2019) ....	30
Table 19. American Samoa 2020 ACL table with three-year recent average catch (lb) .....	31
Table 20. American Samoa ACL proportion of harvest capacity and extent in 2020 .....	33
Table 21. Available age, growth, and reproductive maturity information for prioritized coral reef ecosystem component species in American Samoa .....	46
Table 22. Available length-derived information for prioritized coral reef ecosystem component species in American Samoa .....	47
Table 23. Available age, growth, and reproductive maturity information for BMUS targeted for otoliths and gonads sampling in American Samoa .....	50
Table 24. Available length-derived information for BMUS in American Samoa .....	51
Table 25. Supporting data for Figure 6. ....	57
Table 26. The commercial landings and revenue from bottomfish fishery for American Samoa, 2011-2020 .....	63
Table 27. Average and itemized costs for American Samoa bottomfish trips from 2011–2020 adjusted to 2020 dollars .....	65
Table 28. Top 10 ECS commercial landings, revenue, and price 2019 and 2020 .....	67
Table 29. Priority ECS commercial landings, revenue, and price 2019 and 2020 .....	67
Table 30. Pacific Islands Region 2020 Commercial Fishing Economic Assessment Index .....	68

Table 31. Pacific Islands Region 2021 Commercial Fishing Economic Assessment Index .....	68
Table 32. Summary of ESA consultations for American Samoa FEP Fisheries .....	72
Table 33. Status of candidate ESA species, recent ESA listing processes, and post-listing activities .....	75
Table 34. Summary of habitat mapping in American Samoa .....	106
Table 35. Occurrence of EFH by feature .....	108
Table 36. Mean percent cover of live coral from RAMP sites collected from belt transect surveys using updated methodology in American Samoa .....	109
Table 37. Mean percent cover of macroalgae from RAMP sites collected from belt transect surveys using updated methodology in American Samoa .....	109
Table 38. Mean percent cover of crustose coralline algae from RAMP sites collected from belt transect surveys using updated methodology in American Samoa .....	110
Table 39. Level of EFH information available for American Samoa BMUS .....	111
Table 40. EFH and HAPC for American Samoa BMUS .....	112
Table 41. MMAs established under FEPs from 50 CFR § 665 .....	117
Table 42. Families recorded in creel survey data in the U.S. Western Pacific evaluated in these analyses .....	124
Table 43. Correlation coefficients ( $r$ ) between the coral reef fishery catch (lb) and SST (°C) in American Samoa for 12 taxa harvested from 1989-2016; significant correlations are indicated in bold ( $\alpha=0.05$ ) .....	124
Table 44. Correlation coefficients ( $r$ ) from comparisons of time series of American Samoa coral reef fishery annual catch (lb) and fluorometric chlorophyll- $a$ concentrations (mg/m <sup>3</sup> ) for 12 top taxa harvested from 1998–2014 .....	129

## TABLE OF FIGURES

Figure 1. Mean coral cover (%) per U.S. Pacific island averaged over the years 2010-2020 by latitude.....	39
Figure 2. Mean fish biomass ( $\text{g/m}^2 \pm$ standard error) of functional, taxonomic, and trophic groups by U.S. Pacific reef area from the years 2010-2020 by latitude. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can be hyper-abundant in some regions). Similarly, the bumphead parrotfish, <i>Bolbometopon muricatum</i> , has been excluded from the corallivore group – as high biomass of that species at Wake Island overwhelms corallivore biomass at all other locations. The group ‘MI Feeder’ consists of fishes that primarily feed on mobile invertebrates .....	40
Figure 3. Mean coral cover (%) per island averaged over the years 2010-2020 by latitude with American Samoa archipelago mean estimates plotted for reference (red line) .....	41
Figure 4. Mean fish biomass ( $\text{g/m}^2 \pm$ standard error) of American Samoa functional, taxonomic, and trophic groups from the years 2010-2020 by island. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can be hyper-abundant in some regions). Similarly, the bumphead parrotfish, <i>Bolbometopon muricatum</i> , has been excluded from the corallivore group. The group ‘MI Feeder’ consists of fishes that primarily feed on mobile invertebrates; with American Samoa archipelago mean estimates plotted for reference (red line) .....	42
Figure 5. Settlement of the Pacific Islands, courtesy Wikimedia Commons, <a href="https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg">https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg</a> . ....	53
Figure 6. American Samoa Employment Estimates from 2008-2017; sourced from the American Samoa Statistical Yearbook 2017, American Samoa Government (2018) .....	57
Figure 7. The pounds sold and revenues, for the American Samoa bottomfish fishery, 2011-2020 (adjusted to 2020 dollars).....	62
Figure 8. The prices of BMUS for the American Samoa bottomfish fishery, 2011-2020.....	63
Figure 9. Average costs adjusted for American Samoa bottomfish trips from 2011–2020 adjusted to 2020 dollars.....	65
Figure 10. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability .....	80
Figure 11. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability .....	81
Figure 12. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of anthropogenic climate change .....	82
Figure 13. Regional spatial grids representing the scale of the climate change indicators being monitored .....	82
Figure 14. Monthly mean (black) and seasonally corrected (blue) atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii .....	84
Figure 15. Time series and long-term trend of oceanic pH measured at Station ALOHA from 1989-2019 .....	85
Figure 16. Oceanic Niño Index from 1950-2020 (top) and 2000-2020 (bottom) with El Niño periods in red and La Niña periods in blue .....	86
Figure 17. Pacific Decadal Oscillation from 1950-2020 (top) and 2000-2020 (bottom) with positive warm periods in red and negative cool periods in blue .....	88
Figure 18. 2020 Pacific basin tropical cyclone tracks .....	91
Figure 19. 2020 tropical storm totals by region.....	91

Figure 20. Sea surface temperature climatology and anomalies from 1985-2020 .....	93
Figure 21. Coral Thermal Stress Exposure measured at Samoa Virtual Station 2014-2020 (Coral Reef Watch Degree Heating Weeks) .....	95
Figure 22. Chlorophyll- <i>a</i> and Chlorophyll- <i>a</i> Anomaly from 1998-2020 .....	97
Figure 23. CMAP precipitation (top) and anomaly (bottom) across the American Samoa Longline Grid with 2020 values in blue.....	99
Figure 24a. Sea surface height and anomaly .....	100
Figure 25. Monthly mean sea level without regular seasonal variability due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents .....	102
Figure 26. Bank top and terrestrial land area on high (H) or low (L) islands of Tutuila and Aunu'u (TUT), Ofu and Olosega (OFU/OLU), Ta'u (TAU), Rose (ROS), and Swains (SWA) .....	105
Figure 27. American Samoa land and seafloor area and primary data coverage (from Miller et al. 2011) .....	107
Figure 28. Regulated fishing areas of American Samoa.....	116
Figure 29. Average annual SST (°C) in American Samoa from 1985-2016 (CV = 1.15).....	122
Figure 30. Total annual catch (lb; blue) for the American Samoa coral reef fishery plotted with average annual SST (°C; black) from 1989-2016.....	123
Figure 31. Linear regression showing the correlation between total annual catch (lb) for the coral reef fishery and average annual sea surface temperature (°C) in American Samoa from 1989-2016 .....	125
Figure 32. Linear regressions showing the three top correlations between total annual catch (lb) for the coral reef fishery and average annual SST (°C) in American Samoa for (a) Acanthurids, (b) Scarids, and (c) Mullids from 1989-2016.....	126
Figure 33. Fluorometric chlorophyll- <i>a</i> concentrations (mg/m <sup>3</sup> ) from 1998–2016 (CV = 4.90). 128	
Figure 34. Comparison of American Samoa reef fish catch (lb; black) and chlorophyll- <i>a</i> concentrations (mg/m <sup>3</sup> ; blue) from 1998 – 2014 and two years of time lag.....	129
Figure 35. Linear regression showing between total annual catch (lb) for the American Samoa coral reef fishery with phase lag (t+2 years) and fluorometric chlorophyll- <i>a</i> concentrations (mg/m <sup>3</sup> ) from 1998-2014 .....	130
Figure 36. Linear regressions showing three correlations between total annual catch (lb) for the American Samoa coral reef fishery and fluorometric chlorophyll- <i>a</i> concentrations (mg/m <sup>3</sup> ) for (a) Lutjanids, (b) Holocentrids, and (c) Acanthurids from 1998–2014 with phase lag (t+2 years) .....	131
Figure 37. NMS scree plot showing the stress test to determine dimensionality for the final solution for the American Samoa multivariate analysis .....	133
Figure 38. 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 .....	134



## ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
A <sub>50</sub>	Age at 50% Maturity
AΔ <sub>50</sub>	Age at 50% Sex Reversal
ABC	Acceptable Biological Catch
ACE	Accumulated Cyclone Energy
ACL	Annual Catch Limits
ACT	Annual Catch Target
AM	Accountability Measure
AS	American Samoa
ASCA	American Samoa Code Annotated
ASG	American Samoa Government
ASOP	American Samoa Ocean Plan
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
B	Biomass
B <sub>FLAG</sub>	Reference point indicating low biomass
BiOp	Biological Opinion
BMUS	Bottomfish Management Unit Species
BOEM	Bureau of Ocean Energy Management
BSIA	Best Scientific Information Available
CFEAI	Commercial Fishing Economic Assessment Index
CFMP	Community-Based Fishery Management Program
CFR	Code of Federal Regulations
CMAF	Merged Analysis of Precipitation (CPC)
CMUS	Crustacean Management Unit Species
CNMI	Commonwealth of the Northern Mariana Islands
CO-OPS	Center for Operational Oceanographic Products and Services (NOAA)
CPC	Climate Prediction Center (NOAA)
CPI	Consumer Price Index
CPUE	Catch per Unit Effort
CRED	Coral Reef Ecosystem Division (PIFSC)
CREP	Coral Reef Ecosystem Program (PIFSC)
CREMUS	Coral Reef Ecosystem Management Unit Species
CRW	Coral Reef Watch (NOAA)
CV	Coefficient of Variation
DAR	Division of Aquatic Resources (Hawaii)
DAWR	Division of Aquatic and Wildlife Resources (Guam)
DFW	Division of Fish and Wildlife (CNMI)
DGI	Daily Growth Increments
DHW	Degree Heating Weeks
DIC	Dissolved Inorganic Carbon
DMWR	Department of Marine and Wildlife Resources (American Samoa)
DPS	Distinct Population Segment
E	Effort

<b>Acronym</b>	<b>Meaning</b>
EA	Environmental Assessment
ECS	Ecosystem Component Species
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
ENSO	El Niño - Southern Oscillation
EO	Executive Order
ESA	Endangered Species Act
ESRL	Earth Systems Research Laboratory (NOAA)
F	Fishing Mortality
FL	Fork Length
FR	Federal Register
FAO	Food and Agriculture Organization
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FONSI	Finding of No Significant Impact
GLM	General Linear Modeling
GOES	Geostationary Operational Environmental Satellite (NOAA)
GPS	Global Positioning System
H	Harvest
HAPC	Habitat Area of Particular Concern
HOT	Hawaii Ocean Time Series (UH)
HURL	Hawaii Undersea Research Laboratory (NOAA and UH)
ICL	Interim Catch Limit
k	von Bertalanffy Growth Coefficient
L <sub>50</sub>	Length at 50% Maturity
L $\Delta$ <sub>50</sub>	Length at 50% Sex Reversal
L <sub>∞</sub>	Asymptotic Length
L <sub>bar</sub>	Mean Fish Length
L <sub>max</sub>	Maximum Fish Length
LAA	Likely to Adversely Affect
LOC	Letter of Concurrence
LOF	List of Fisheries
LVPA	Large Vessel Prohibited Area
M	Natural Mortality
MBTA	Migratory Bird Treaty Act
MFMT	Maximum Fishing Mortality Threshold
MHI	Main Hawaiian Islands
MMA	Marine Managed Area
MMPA	Marine Mammal Protection Act
MNM	Marine National Monument
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA)
MPA	Marine Protected Area
MPCC	Marine Planning and Climate Change
MPCCC	MPCC Committee (WPRFMC)
MSA	Magnuson-Stevens Fishery Conservation and Management Act

<b>Acronym</b>	<b>Meaning</b>
MSL	Mean Sea Level
MSST	Minimum Stock Size Threshold
MSU	Microwave Sounding Unit
MSY	Maximum Sustainable Yield
MUS	Management Unit Species
n	Sample Size
N <sub>L-W</sub>	Sample Size for Length-Weigh Regression
N/A	Not Applicable
NAF	No Active Fishery
NASA	National Aeronautics and Space Administration
NCADAC	National Climate Assessment and Development Advisory Committee
NCDC	National Climatic Data Center (NOAA)
ND	Not Detected
NEPA	National Environmental and Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NLAA	Not Likely to Adversely Affect
NMFS	National Marine Fisheries Service (NOAA)
NMS	Non-metric Multidimensional Scaling
NMSAS	National Marine Sanctuary of American Samoa
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service (NOAA)
NS	National Standard
NWHI	Northwestern Hawaiian Islands
NWS	National Weather Service
OEO	Office of Economic Opportunity (American Samoa)
OFL	Overfishing Limits
ONI	Ocean Niño Index
OPI	OLR Precipitation Index (NOAA)
OLR	Outgoing Longwave Radiation
OY	Optimum Yield
PacIOOS	Pacific Islands Ocean Observing System
PCMUS	Precious Coral Management Unit Species
PDO	Pacific Decadal Oscillation
Pelagic FEP	Fishery Ecosystem Plan for the Pacific Pelagic Fisheries
PIBHMC	Pacific Island Benthic Habitat Mapping Center (UH)
PIFSC	Pacific Island Fisheries Science Center (NMFS)
PIRCA	Pacific Islands Regional Climate Assessment
PIRO	Pacific Islands Regional Office (NMFS)
PMEL	Pacific Marine Environmental Laboratory (NOAA)
PMUS	Pelagic Management Unit Species
POES	Polar Operational Environmental Satellite (NOAA)
PRIA	Pacific Remote Island Areas
RAMP	Reef Assessment and Monitoring Program (CRED)

<b>Acronym</b>	<b>Meaning</b>
ROV	Remotely Operated Underwater Vehicle
RPB	Regional Planning Body
SAFE	Stock Assessment and Fishery Evaluation
SBRM	Standardized Bycatch Reporting Methodologies
SD	Standard Deviation
SEEM	Social, Economic, Ecological, Management (Uncertainty)
SFA	Sustainable Fisheries Act
SODA	Simple Ocean Data Assimilation
SPC	Stationary Point Count
SSC	Scientific and Statistical Committee (WPRFMC)
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
SSBPR	Spawning Stock Biomass Proxy Ratio
$t_0$	Hypothetical Age at Length Zero
$T_{max}$	Maximum Age
TA	Total Alkalinity
TALFF	Total Allowable Level of Foreign Fishing
TBA	To Be Assigned
TBD	To Be Determined
UH	University of Hawaii
USFWS	United States Fish and Wildlife Service
VBGF	von Bertalanffy Growth Function
VFP	Visual Fox Pro
WPacFIN	Western Pacific Fishery Information Network
WPR	Western Pacific Region
WPRFMC	Western Pacific Regional Fishery Management Council
WPSAR	Western Pacific Stock Assessment Review

# 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 Hawaii in the central South Pacific Ocean and is divided into two political entities: Independent Samoa and American Samoa. The Independent Samoa has two large islands, Upolu and Savaii, and eight islets. American Samoa is comprised of five volcanic islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'u), one low-island (Swains Island), and a coral atoll (Rose Atoll). The five volcanic islands that are part of the American Samoa territory are very steep with mountainous terrain and high sea cliffs and of various sizes. Tutuila Island, the largest (137 km<sup>2</sup>) 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 close to Tutuila. Ofu and Olosega (13 km<sup>2</sup> together) are twin volcanic islands separated by a strait which is a shallow and narrow break in the reef flat between the islands. Ta'u is the easternmost island (45 km<sup>2</sup>) with a more steeply sloping bathymetry.

The Samoa archipelago was formed by a series of volcanic eruptions from the “Samoa hotspot” (Hart et al. 2000). Based on the classic hotspot model, Savaii Island (the westernmost) in Samoa would be the oldest and Ta'u 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 Ta'u about 100,000 years old. Swains and Rose are built on much older volcanoes, they but are not part of the Samoan volcanic chain (Hart et al. 2004). The geological age and formation of Rose Atoll is not well known, and Swains is part of the Tokelau hot-spot chain which is anywhere from 59 to 72 million years old (Neall and Trewick 2008; Konter et al. 2008). There are numerous banks in the archipelago, the origins of which are not well known. The South Bank near Tutuila Island, for instance, is of another geological origin.

American Samoa experiences occasional cyclones due to its geographic location in the Pacific. Cyclones occur on one- to 13-year intervals, with the six strong occurrences happening over the last 40 years (Esau in 1981; Tusi in 1987; Ofa in 1990; Val in 1991; Heta in 2004; Olaf in 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 bottomfish fishermen mainly targeting snappers, emperors, and groupers. Bottomfish fishing utilizing traditional canoes by the indigenous residents of American Samoa has been a subsistence practice since the Samoans settled on the Tutuila, Manu'a, 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 deep-water 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 the bottomfish fishery occurred as many skilled and full-time commercial fishermen converted to trolling. Additionally, profits and revenue in bottomfish fishing suffered from four separate hurricanes, Tusi in 1987, Ofa in February of 1990, Val in December of 1991, and Heta in January of 2004, as well as 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 recent 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 percent of coolers imported from the independent state of Samoa on the Lady Naomi Ferry were designated for commercial sale, and 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 bottomfish fishing to trolling. In recent years, the dominant fishing method has been longlining (by weight). Bottomfish fishing 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, and the fuel price has lowered since then.

### **1.1.2 Ecosystem Component 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 deep water and pelagic fisheries have traditionally used wooden canoes, hand-woven sennit lines with shell hooks and stone sinkers, and lures made of wood and shell pieces.

Presumably, the change from traditional to present-day fishing methods started with Western contact in the 18<sup>th</sup> 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). Bottomfish fishing is a combination of mesophotic reef fishing (i.e., spearfishing) 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 in 1998, and finally banned in 2002 following recommendations by biologists from the DMWR and local scientists.

In 2018, the Council drafted an Amendment 4 to the American Samoa FEP that reclassified a large number MUS as Ecosystem Component Species (ECS; WPRFMC 2018). The final rule was posted in the Federal Register in early 2019 (84 FR 2767, February 8, 2019). This amendment reduces the number of MUS from 205 species/families to 11 in the American Samoa FEP. All former coral reef ecosystem management unit species (CREMUS) were reclassified as ECS that do not require ACL specifications or accountability measures but are still to be monitored regularly to prioritize conservation and management efforts and to improve efficiency of fishery management in the region. All existing management measures, including reporting and record keeping, prohibitions, and experimental fishing regulations apply to the associated ECS. If an ECS stock becomes a target of a federal fishery in the future, NMFS and the Council may consider including that stock as a MUS to actively manage it. These species are still regularly monitored via other means (see Sections 1.5.3 and 2.1.3).

## **1.2 FISHERY DATA COLLECTION SYSTEM**

American Samoa has been regularly conducting fishery-dependent monitoring since 1982 for its boat-based fisheries. The boat-based fisheries mostly involve trolling for tuna, skipjacks, and trevally, and bottomfish fishing mostly targets snappers, emperors, and groupers. Boat-based data collection involve two runs: first is the participation run used to determine the number of boats/fishermen out to fish and identify the type of gear being used, and the second is the interview run where the fishermen are interviewed for 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. Boat-based data collection is also being conducted in Manu'a. Boat-based data collection in both Ofu-Olosega and Ta'u is 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, which documents catch composition, 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. (2011).

### **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 Lauuli'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. (2011).

### **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 16<sup>th</sup> 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 were enough samples to run the expansion algorithm. The trends of these parameters over time may infer survey performance. Monitoring the survey performance is critical for explaining the reliability of the expanded information.

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

#### 1.3.1 Creel Survey Meta-Data Statistics

Calculations:

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

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

**Table 1. Summary of American Samoa boat-based creel survey meta-data**

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
1986	186	532	1
1987	110	338	0
1988	158	366	0
1989	160	389	0
1990	160	191	0
1991	134	169	0
1992	127	137	0
1993	140	126	0
1994	209	234	0
1995	239	333	0
1996	222	389	3
1997	226	888	1
1998	229	852	1
1999	207	659	0
2000	206	457	0
2001	205	249	2
2002	194	212	0
2003	220	489	0

Year	# Sample Days	# Catch Interviews	
		Regular	Opportunistic
2004	239	485	5
2005	238	330	0
2006	238	319	7
2007	251	484	6
2008	225	303	11
2009	165	174	9
2010	188	168	2
2011	240	203	1
2012	269	285	14
2013	262	245	0
2014	236	353	27
2015	233	247	26
2016	224	165	47
2017	222	139	33
2018	215	176	11
2019	218	166	12
2020	230	164	2
<b>10-year avg.</b>	<b>235</b>	<b>214</b>	<b>17</b>
<b>10-year SD</b>	<b>17</b>	<b>64</b>	<b>15</b>
<b>20-year avg.</b>	<b>226</b>	<b>268</b>	<b>11</b>
<b>20-year SD</b>	<b>24</b>	<b>110</b>	<b>13</b>

In summary, the number of sample days doubled from the 1980s to the 1990s, but there has been a general decline in regular interviews over the years. The number of opportunistic interviews increased from 2014 until 2019. The variability of opportunistic interviews is related to natural disasters, program staff changes, the fuel subsidy program, and COVID-19 restrictions in 2020.

### 1.3.2 Commercial Receipt Book Statistics

Calculations:

# Vendors: Count of the number of unique buyer codes found in the commercial purchase header data from the Commercial Receipt Book, BMUS vendors are only from vendors that landed BMUS species.

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

**Table 2. Summary of American Samoa commercial receipt book meta-data**

<b>Year</b>	<b># Vendors</b>	<b># Invoices Collected</b>	<b># BMUS Vendors</b>	<b># BMUS Invoices Collected</b>
1992	11	445	8	51
1993	17	695	11	88
1994	21	1,425	13	145
1995	39	2,410	16	193
1996	17	1,755	8	83
1997	18	1,763	2	5
1998	22	1,741	6	17
1999	19	1,525	8	63
2000	19	1,169	7	61
2001	32	1,372	13	158
2002	27	1,076	9	127
2003	31	1,263	13	123
2004	28	937	14	118
2005	68	1,000	14	93
2006	60	1,201	13	109
2007	65	1,355	10	135
2008	47	1,020	11	100
2009	45	806	14	114
2010	34	620	9	54
2011	30	776	7	28
2012	30	827	11	28
2013	34	777	4	19
2014	42	1,126	9	37
2015	45	1,577	6	53
2016	50	1,395	6	18
2017	58	1,372	6	21
2018	62	1,342	3	16
2019	64	1,491	6	41
2020	58	657	3	7
<b>10-year avg.</b>	<b>47</b>	<b>1,134</b>	<b>6</b>	<b>27</b>
<b>10-year SD</b>	<b>12</b>	<b>327</b>	<b>2</b>	<b>13</b>
<b>20-year avg.</b>	<b>46</b>	<b>1,100</b>	<b>9</b>	<b>70</b>
<b>20-year SD</b>	<b>14</b>	<b>284</b>	<b>4</b>	<b>48</b>

In summary, the number of engaged vendors has increased over time, but the number of invoices has declined. In addition, the number of vendors selling BMUS has declined through the years. This suggests a decline in bottomfish and BMUS commerce. Finally, COVID-19 restrictions seem to have also negatively affected fish commerce and BMUS commerce.

## 1.4 FISHERY SUMMARY DASHBOARD STATISTICS

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

Legend Key:



- increasing trend in the time series



- above 1 standard deviation



- decreasing trend in the time series



- below 1 standard deviation



































- no trend in the time series









- within 1 standard deviation

























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

**Table 3. Annual indicators for American Samoa bottomfish fisheries describing performance and comparing 2020 estimates with short- (10-year) and long-term (20-year) averages**

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
<b>Bottomfish</b>	<b>Total estimated catch (lb)</b>		
All gears (BMUS only)	All BMUS from creel survey data	8,040[▼35%]  	11,040[▼44%]  
	All BMUS from commercial purchase data	307[▼75%]  	307[▼84%]  
	<b>Catch-per-unit-effort (from boat-based creel surveys)</b>		
Bottomfish fishing (BMUS only)	Bottomfish lb/trip	26[▼43%]  	26[▼53%]  
	Bottomfish lb/gr-h.	1.1515[▼4%]  	1.1515[▼25%]  
	<b>Fishing effort (from boat-based creel surveys)</b>		
Bottomfish fishing (BMUS only)	Tallied bottomfish trips	39[▼36%]  	39[▼42%]  
	Tallied bottomfish gear hours	871[▼72%]  	871[▼68%]  
	<b>Fishing participation (from boat-based creel surveys)</b>		
Bottomfish fishing (BMUS only)	Tallied number of bottomfish vessels	6[▼40%]  	6[▼50%]  
	Estimated average number of fishermen per bottomfish trip	2[▼33%]  	2[▼33%]  

	Bycatch		
Bottomfish fishing (BMUS only)	# fish caught	404[▼75%] 	404[▼85%] 
	# fish discarded/released	0[no change] 	0[no change] 
	% bycatch	0[no change] 	0[no change] 

**Table 4. Annual indicators for American Samoa ECS fisheries describing performance and comparing 2020 estimates with short- (10-year) and long-term (20-year) averages**

Fishery	Fishery statistics	Short-term (10 years)	Long-term (20 years)
ECS	Total estimated catch (lb)		
Prioritized ECS	<i>Sargocentron tiera</i> from creel survey data	NA[▼100%] 	NA[▼100%] 
	<i>Sargocentron tiera</i> from commercial purchase data	NA[no change] 	NA[no change] 
	<i>Crenimugil crenilabis</i> from creel survey data	NA[▼100%] 	NA[▼100%] 
	<i>Crenimugil crenilabis</i> from commercial purchase data	0[no change] 	0[no change] 
	<i>Panulirus penicillatus</i> from creel survey data	307[▼58%] 	307[▼80%] 
	<i>Panulirus penicillatus</i> from commercial purchase data	171[▼83%] 	171[▼87%] 
	Clams from creel survey data	NA[no change] 	NA[no change] 
	Clams from commercial purchase data	NA[no change] 	NA[no change] 
	<i>Octopus cyanea</i> from creel survey data	NA[no change] 	NA[no change] 
	<i>Octopus cyanea</i> from commercial purchase data	NA[no change] 	NA[no change] 
	<i>Epinephelus malanostigma</i> from creel survey data	110[▲38%] 	110[▲175%] 
	<i>Epinephelus malanostigma</i> from commercial purchase data	NA[no change] 	NA[no change] 

“NA” = no data available.

## 1.5 CATCH STATISTICS

The following section summarizes the catch statistics for bottomfish, a one-year snapshot of the top ten landed species, and the top six prioritized species (and species groups) in American Samoa as determined by DMWR. The six species are the bluelined squirrelfish (*Sargocentron tiera*), fringelip mullet (*Crenimugil crenilabis*), green spiny lobster (*Parulirus penicillatus*), clams, day octopus (*Octopus cyanea*), and one-blotch grouper (*Epinephelus melanostigma*). 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 bottomfish fisheries in addition to the top ten landed species and top six prioritized species.

### 1.5.1 Catch by Data Stream

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

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

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

Year	Boat-Based Creel Survey Estimates	Shore-Based Creel Survey Estimates	Total Creel Survey Estimates	Commercial Landings
1992	8,050	1,132	9,182	1,895
1993	9,675	403	10,078	3,464
1994	24,195	560	24,755	2,375
1995	22,246	262	22,508	5,112
1996	22,477	1,040	23,517	1,082
1997	26,812	NA	26,812	419
1998	10,501	NA	10,501	851
1999	12,687	NA	12,687	3,197
2000	13,850	NA	13,850	3,693
2001	30,064	NA	30,064	3,447
2002	23,621	NA	23,621	1,448
2003	12,971	NA	12,971	2,511
2004	11,000	10	11,010	3,233
2005	8,226	46	8,272	2,490
2006	3,051	343	3,394	2,203
2007	10,913	161	11,074	4,001
2008	22,095	256	22,351	3,171
2009	34,388	194	34,582	3,035
2010	7,044	4	7,048	1,084
2011	14,083	3	14,086	711
2012	2,099	7	2,106	1,161
2013	5,732	1	5,733	882
2014	13,984	NA	13,984	3,140
2015	21,528	8	21,536	2,047

Year	Boat-Based Creel Survey Estimates	Shore-Based Creel Survey Estimates	Total Creel Survey Estimates	Commercial Landings
2016	19,307	6	19,313	566
2017	14,791	190	14,981	1,131
2018	11,957	283	12,240	838
2019	11,082	551	11,633	1,749
2020	7,751	289	8,040	307
<b>10-year avg.</b>	<b>12,231</b>	<b>149</b>	<b>12,365</b>	<b>1,253</b>
<b>10-year SD</b>	<b>5,621</b>	<b>184</b>	<b>5,597</b>	<b>802</b>
<b>20-year avg.</b>	<b>14,284</b>	<b>147</b>	<b>14,402</b>	<b>1,958</b>
<b>20-year SD</b>	<b>8,362</b>	<b>159</b>	<b>8,346</b>	<b>1,089</b>

“NA” = no data available.

In summary, non-commercial BMUS landings comprise roughly 90% of total catch, and only 10% of BMUS is sold. Variability in BMUS landings is likely due to natural disturbances and the government fuel subsidy. BMUS landings have steadily declined since 2015, with a steeper decline in 2020 due to COVID-19 restrictions. There was a 30% decline in BMUS landings due to COVID-19, and an 80% decline in commercial BMUS.

### 1.5.2 Expanded Catch Estimates by Fishing Method

Catch information is provided for boat-based fishing methods that contribute most of the annual catch for American Samoa.

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

**Table 6. Total catch time series estimates (lb) for all species and BMUS only using American Samoa expanded boat-based creel survey data for bottomfish fishing gears**

Year	Bottomfish Fishing		Bottom-Troll Mixed		Spearfishing	
	All	BMUS	All	BMUS	All	BMUS
1986	59,512	1,648	61,310	2,194	33,451	NA
1987	9,161	316	35,676	309	32,884	NA
1988	28,798	16,528	35,990	7,645	53,616	45
1989	20,556	12,075	42,483	14,022	40,828	584
1990	8,308	4,754	11,829	4,651	1,441	NA
1991	14,439	7,328	14,004	3,734	833	NA
1992	14,941	8,050	NA	NA	NA	NA
1993	18,535	7,984	5,277	1,647	734	NA
1994	52,382	22,395	8,812	1,674	32,996	NA
1995	20,900	11,442	37,078	10,699	6,531	2
1996	39,932	18,110	13,626	4,348	6,369	19
1997	37,784	21,621	10,131	4,870	85,169	320

Year	Bottomfish Fishing		Bottom-Troll Mixed		Spearfishing	
	All	BMUS	All	BMUS	All	BMUS
1998	10,759	7,280	6,542	3,102	77,443	119
1999	15,009	9,896	8,142	2,616	63,509	176
2000	25,104	12,045	3,888	1,746	42,922	60
2001	53,374	28,692	3,756	1,373	9,841	NA
2002	47,689	22,852	1,774	768	8,562	NA
2003	28,119	12,364	1,599	607	5,557	NA
2004	29,591	9,526	3,517	1,470	4,405	NA
2005	17,911	6,723	4,066	1,500	416	2
2006	12,028	2,539	1,169	494	2,589	19
2007	36,093	10,228	1,273	580	19,249	105
2008	54,674	21,495	1,809	575	8,030	25
2009	81,909	34,113	1,175	275	17,208	NA
2010	16,307	6,917	272	83	60,110	44
2011	29,834	12,973	5,355	1,091	33,210	19
2012	13,515	1,834	1,646	259	15,950	1
2013	27,126	5,240	1,853	437	31,784	51
2014	32,471	13,165	4,006	801	17,695	4
2015	43,173	20,110	5,715	1,197	25,756	203
2016	28,363	14,435	15,300	4,398	7,272	474
2017	29,940	12,697	8,594	1,980	8,759	114
2018	18,763	11,145	3,550	658	6,140	121
2019	18,426	10,507	2,773	482	8,514	47
2020	13,636	5,790	6,812	1,453	7,193	318
<b>10-year avg.</b>	<b>25,525</b>	<b>10,790</b>	<b>5,560</b>	<b>1,276</b>	<b>16,227</b>	<b>135</b>
<b>10-year SD</b>	<b>8,889</b>	<b>5,004</b>	<b>3,860</b>	<b>1,153</b>	<b>10,011</b>	<b>147</b>
<b>20-year avg.</b>	<b>31,647</b>	<b>13,167</b>	<b>3,801</b>	<b>1,024</b>	<b>14,912</b>	<b>77</b>
<b>20-year SD</b>	<b>17,024</b>	<b>8,264</b>	<b>3,359</b>	<b>918</b>	<b>13,711</b>	<b>121</b>

“NA” = no data available.

In summary, BMUS landings closely track landings for all bottomfish, and account for 40% of the bottomfish landings. However, the mixed bottomfish-trolling gear classification shows a different trend with a decline in BMUS landings. There were hurricane impacts to the fishery in 1987, 1990, 2004, and 2005, as well as in 2009 due to the tsunami. The 26% decline in bottomfish landings and 45% decline in BMUS landings in 2020 are attributed to impacts associated with COVID-19. However, landings from bottomfish-trolling increased in 2020.

### 1.5.3 Top and Prioritized Species in Boat-Based Fishery Catch

Catch time series can act as indicators of fishery performance. Variations in the catch can be attributed to various factors, and there is no single explanatory variable for the observed trends.



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

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

**Table 7a. Top ten landed ECS in American Samoa from boat-based creel survey data in 2020**

Common Name	Scientific Name	Catch (lb)
Humpback snapper	<i>Lutjanus gibbus</i>	2,784
Redlip parrotfish	<i>Scarus rubroviolaceus</i>	1,453
Bigeye barracuda	<i>Sphyrna forsteri</i>	1,127
Bluespine unicornfish	<i>Naso unicornis</i>	1,058
Blue-banded surgeonfish	<i>Acanthurus lineatus</i>	1,010
Twinspot snapper	<i>Lutjanus bohar</i>	871
Orangespot emperor	<i>Lethrinus erythracanthus</i>	681
Bigeye trevally	<i>Caranx sexfasciatus</i>	561
Bluefin trevally	<i>Caranx melampygus</i>	541
Redtail parrotfish	<i>Chlorurus japanensis</i>	509

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

**Table 7b. Top ten landed ECS in American Samoa from estimated commercial landings data in 2020**

Common Name	Scientific Name	Catch (lb)
Blue-banded surgeonfish	<i>Acanthurus lineatus</i>	4,822
Reef fishes (unknown)	Multi-genera multi-species	2,403
Striped bristletooth	<i>Ctenochaetus striatus</i>	2,094
Parrotfishes	<i>Scarus</i> spp.	1,792
Unicornfishes	<i>Naso</i> spp.	1,624
Pacific sailfin tang	<i>Zebrasoma veliferum</i>	694
Swai*	<i>Pangasianodon hypophthalmus</i>	354
Squirrelfishes	<i>Sargocentron</i> spp.	300
Inshore groupers	Multi-species	262
Spiny lobster	<i>Parulirus penicillatus</i>	171

\* Swai is a non-native fish in American Samoa waters, so the reported landings are likely from imported fish that were not indicated as imported in the commercial receipt book data.

In summary, species groupings and catch are expectedly different for ECS between the creel surveys and commercial invoices. *Lutjanus gibbus* was the top ECS in the creel surveys, but not on the top list from commercial data. *Acanthurus lineatus* was top ECS from commercial invoices but was in the middle of the list from creel surveys.

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

**Table 8a. Catch (lb) from boat-based creel survey expansion data for prioritized species in American Samoan ECS fisheries**

<b>Year</b>	<b><i>Sargocentron tiere</i></b>	<b><i>Crenimugil crenilabis</i></b>	<b><i>Parulirus penicillatus</i></b>	<b>Clams (multi- species)</b>	<b><i>Octopus cyanea</i></b>	<b><i>Epinephelus melanostigma</i></b>
1986	NA	NA	1,903	NA	NA	NA
1987	NA	NA	2,545	NA	NA	NA
1988	NA	NA	5,973	NA	NA	NA
1989	NA	NA	4,212	NA	NA	NA
1990	NA	NA	186	NA	NA	NA
1991	NA	NA	146	NA	NA	NA
1992	NA	NA	NA	NA	NA	NA
1993	NA	NA	47	NA	NA	NA
1994	NA	NA	1,375	NA	NA	NA
1995	NA	NA	269	NA	NA	NA
1996	NA	NA	379	NA	NA	NA
1997	NA	NA	4,885	NA	NA	NA
1998	NA	NA	3,924	NA	NA	NA
1999	NA	NA	2,065	NA	NA	NA
2000	NA	NA	1,762	NA	NA	NA
2001	NA	NA	1,544	NA	NA	NA
2002	NA	NA	753	NA	NA	NA
2003	NA	NA	910	NA	NA	NA
2004	NA	NA	560	NA	NA	NA
2005	NA	NA	29	NA	NA	NA
2006	NA	NA	225	NA	NA	NA
2007	NA	3	1,618	NA	NA	NA
2008	NA	NA	1,113	NA	NA	NA
2009	NA	NA	2,759	NA	NA	NA
2010	NA	NA	14,305	NA	NA	NA
2011	NA	NA	3,135	NA	NA	NA
2012	NA	NA	566	NA	NA	NA
2013	79	4	1,727	NA	NA	13
2014	9	NA	140	NA	NA	52
2015	NA	NA	7	NA	NA	52
2016	18	42	249	NA	NA	71
2017	32	NA	1,042	NA	NA	174
2018	20	143	148	NA	NA	182
2019	29	181	NA	NA	NA	146
2020	NA	NA	307	NA	NA	110
<b>10-yr avg.</b>	<b>19</b>	<b>37</b>	<b>732</b>	<b>NA</b>	<b>NA</b>	<b>80</b>

Year	<i>Sargocentron tiere</i>	<i>Crenimugil crenilabis</i>	<i>Parulirus penicillatus</i>	Clams (multi- species)	<i>Octopus cyanea</i>	<i>Epinephelus melanostigma</i>
<b>10-yr SD</b>	<b>25</b>	<b>68</b>	<b>1,003</b>	<b>NA</b>	<b>NA</b>	<b>69</b>
<b>20-yr avg.</b>	<b>9</b>	<b>19</b>	<b>1,557</b>	<b>NA</b>	<b>NA</b>	<b>40</b>
<b>20-yr SD</b>	<b>19</b>	<b>50</b>	<b>3,130</b>	<b>NA</b>	<b>NA</b>	<b>63</b>

“NA” = no data available.

Calculations: Catch tallied from commercial purchase data for species identified as priority ECS (Appendix A).

**Table 8b. Catch (lb) from commercial purchase data for prioritized species in American Samoan ECS fisheries**

Year	<i>Sargocentron tiere</i>	<i>Crenimugil crenilabis</i>	<i>Parulirus penicillatus</i>	Clams (multi- species)	<i>Octopus cyanea</i>	<i>Epinephelus melanostigma</i>
1996	NA	NA	3,104	NA	NA	NA
1997	NA	NA	4,262	NA	NA	NA
1998	NA	NA	3,088	NA	NA	NA
1999	NA	NA	2,255	NA	NA	NA
2000	NA	NA	808	NA	NA	NA
2001	NA	NA	1,105	NA	NA	NA
2002	NA	NA	762	NA	NA	NA
2003	NA	NA	779	NA	NA	NA
2004	NA	NA	506	NA	NA	NA
2005	NA	NA	3,238	NA	NA	NA
2006	NA	NA	5,380	NA	NA	NA
2007	NA	NA	1,649	NA	NA	NA
2008	NA	NA	1,417	NA	NA	NA
2009	NA	NA	680	NA	NA	NA
2010	NA	NA	1,464	NA	NA	NA
2011	NA	NA	974	NA	NA	NA
2012	NA	NA	621	NA	NA	NA
2013	NA	NA	899	NA	NA	NA
2014	NA	NA	1,292	NA	NA	NA
2015	NA	NA	989	NA	NA	NA
2016	NA	NA	2,203	NA	NA	NA
2017	NA	NA	767	NA	NA	NA
2018	NA	3	743	NA	NA	NA
2019	NA	NA	1,256	NA	NA	NA
2020	NA	NA	171	NA	NA	NA
<b>10-yr avg.</b>	<b>NA</b>	<b>0</b>	<b>992</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>
<b>10-yr SD</b>	<b>NA</b>	<b>1</b>	<b>533</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>

Year	<i>Sargocentron tiere</i>	<i>Crenimugil crenilabis</i>	<i>Parulirus penicillatus</i>	Clams (multi- species)	<i>Octopus cyanea</i>	<i>Epinephelus melanostigma</i>
<b>20-yr avg.</b>	NA	0	1,345	NA	NA	NA
<b>20-yr SD</b>	NA	1	1,162	NA	NA	NA

“NA” = no data available.

In summary, the priority ECS for American Samoa are the soldierfish (*Sargocentron tiere*), the giant clams (*Tridacna*), the nearshore grouper (*Epinephelus melanostigma*), the nearshore mullet (*Crenimugil crenilabis*), the octopus (*Octopus cyanea*), and the spiny lobster (*Parulirus penicillatus*). All of these priority ECS have more catch data in recent years likely due to sampling changes. However, only the spiny lobster has substantial data throughout the years. Lobster landings were affected by previous hurricanes but not by the 2009 tsunami. Lobster landings were also not correlated with the government alia fishing subsidy. However, COVID-19 restrictions seem to have led to 86% decline in commercial catch.

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

This section summarizes the estimates for CPUE in the boat-based fisheries both for all species and for BMUS only. The boat-based fisheries include bottomfish fishing (handline gear), spearfishing (snorkel), and bottom-trolling mixed that comprise a majority of the total bottomfish catch. Trolling is primarily a pelagic fishing method but also catches coral reef fishes including jacks and gray jobfish. CPUE is reported as both pounds per gear hour and pounds per trip in the boat-based methods.

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

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

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

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

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

In summary, CPUE as reflected in lb/gr-hr has declined for bottomfish overall, BMUS, bottomfish-trolling overall, and bottomfish-trolling for BMUS over the years.

**Table 9. CPUE (lb/trip and lb/gear hour) for bottomfish fishing gears in the American Samoa boat-based fishery for all species and BMUS only**

Year	Bottomfish Fishing				Bottom-Troll Mixed				Spearfishing			
	All		BMUS		All		BMUS		All		BMUS	
	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr
1986	136	3.1629	189	3.4249	217	5.0818	130	2.1	257	5.0789	NA	NA
1987	138	4.8346	13	0.5778	210	5.1237	61	1.2039	191	5.2366	NA	NA
1988	175	6.6497	107	4.0791	285	6.0957	96	2.3959	215	5.442	13	0.325
1989	159	6.8703	103	4.2144	326	4.5561	107	1.499	332	7.0243	66	0.9381
1990	127	4.1244	83	2.6035	248	4.3152	95	1.6559	170	5.2713	NA	NA
1991	121	2.9885	69	1.5836	219	5.6877	81	1.986	358	6.2807	NA	NA
1992	139	3.9978	80	2.2854	NA	NA	NA	NA	NA	NA	NA	NA
1993	124	2.7464	62	1.3932	255	4.9038	100	1.9295	70	NA	NA	NA
1994	125	2.6166	53	1.1048	193	3.3716	30	0.5322	247	2.4015	NA	NA
1995	121	3.1105	67	1.5048	160	3.4249	49	0.9954	NA	NA	NA	NA
1996	143	5.5806	61	2.2653	283	6.6927	72	1.6676	NA	NA	NA	NA
1997	139	5.0745	79	2.8703	151	6.4212	63	2.6545	294	10.4707	10	0.6145
1998	175	4.8339	116	3.1987	35	1.4583	NA	NA	393	10.9028	NA	NA
1999	151	5.1222	103	3.4378	103	8.5833	NA	NA	186	7.1635	NA	NA
2000	122	4.1111	61	2.0792	36	3	5	0.4167	NA	NA	NA	NA
2001	140	5.5835	76	2.9408	NA	NA	NA	NA	164	6.2363	NA	NA
2002	81	2.6203	40	1.2748	NA	NA	NA	NA	177	3.7455	NA	NA
2003	105	5.262	50	2.5331	157	6.5657	61	2.0101	179	5	NA	NA
2004	77	1.5414	32	1.0551	151	6.2438	73	2.8781	154	6.9104	NA	NA
2005	97	4.7214	53	2.8239	138	7.6418	53	2.9253	30	3	NA	NA
2006	81	3.4699	32	1.0303	97	4.2978	41	1.8162	86	2.1136	4	NA
2007	147	4.2018	50	1.4061	87	3.6797	49	2.0853	104	2.9904	4	0.1011
2008	191	4.4263	82	1.8302	107	2.9317	32	0.8661	106	3.4339	2	0.0581

Year	Bottomfish Fishing				Bottom-Troll Mixed				Spearfishing			
	All		BMUS		All		BMUS		All		BMUS	
	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr	lb/trip	lb/gr-hr
2009	320	5.711	135	2.3881	278	4.1685	65	0.9738	330	9.2102	NA	NA
2010	190	3.7284	94	1.6112	507	7.6818	308	4.6667	246	6.2103	17	0.5156
2011	194	4.6544	89	2.0253	292	8.2155	68	1.7891	326	8.4875	10	0.1852
2012	54	4.6563	61	2.6506	227	2.8736	55	2.1905	123	11.9337	0	NA
2013	81	1.9066	34	0.5237	162	3.9398	49	1.131	247	7.4339	5	0.1287
2014	118	3.4964	56	1.5382	153	5.2539	31	1.0654	124	2.8798	1	0.0125
2015	109	2.9842	51	1.3638	140	0.6288	31	0.137	147	3.4904	14	0.2842
2016	87	0.5867	41	0.2754	166	3.2375	46	1.0297	49	1.3187	9	0.2632
2017	91	1.128	36	0.4372	145	0.3066	58	0.1873	45	0.1348	3	0.0034
2018	65	1.7273	35	0.9424	75	3.5179	19	0.8353	32	0.9214	2	0.0587
2019	66	2.3901	33	1.1076	138	4.2227	27	0.8384	31	0.8313	1	0.0696
2020	58	2.8195	26	1.1515	114	5.0616	25	1.0678	59	1.4646	4	0.0726
<b>10-year avg.</b>	<b>92</b>	<b>2.635</b>	<b>46</b>	<b>1.2016</b>	<b>161</b>	<b>3.7258</b>	<b>41</b>	<b>1.0272</b>	<b>118</b>	<b>3.8896</b>	<b>5</b>	<b>0.1198</b>
<b>10-year SD</b>	<b>39</b>	<b>1.3016</b>	<b>18</b>	<b>0.6999</b>	<b>57</b>	<b>2.1647</b>	<b>16</b>	<b>0.5931</b>	<b>95</b>	<b>3.7992</b>	<b>4</b>	<b>0.0975</b>
<b>20-year avg.</b>	<b>118</b>	<b>3.3808</b>	<b>55</b>	<b>1.5455</b>	<b>174</b>	<b>4.4705</b>	<b>61</b>	<b>1.583</b>	<b>138</b>	<b>4.3873</b>	<b>5</b>	<b>0.1461</b>
<b>20-year SD</b>	<b>63</b>	<b>1.4829</b>	<b>27</b>	<b>0.7756</b>	<b>99</b>	<b>2.1528</b>	<b>62</b>	<b>1.0794</b>	<b>90</b>	<b>3.1139</b>	<b>5</b>	<b>0.1408</b>

“NA” = no data available.

## **1.7 EFFORT STATISTICS**

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

Calculations: Effort estimates (in both trips and gear hours) are calculated from boat-based interview data. Trips are tallied according to the interview data in boat-based creel surveys. Gear hours are generated by summing the data on number of gears used\*number of hours fished collected from interviews by gear type. For the boat-based estimates, data collection started in 1982, but is reported here from 1986.

All - Trips: All trips tallied by gear type.

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

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

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

In summary, the number of bottomfish fishing trips increased, but the number of bottomfish-trolling trips declined over the years. There was a 60% decline in bottomfish-trolling trips and 40% decline in bottomfish and BMUS gear hours, likely due to impacts associated with COVID-19.

**Table 10. Effort (trips and gear hours) for bottomfish fishing gears in the American Samoa boat-based fishery for all species and BMUS only**

Year	Bottomfish Fishing				Bottom-troll Mixed				Spearfishing			
	All		BMUS		All		BMUS		All		BMUS	
	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr
1986	135	5,341	13	346	80	3,385	5	260	39	1,976	NA	NA
1987	19	544	4	90	57	2,337	3	152	51	1,860	NA	NA
1988	41	1,082	37	974	34	1,589	22	879	73	2,887	1	40
1989	30	694	28	681	34	2,435	34	2,435	40	1,893	3	210
1990	19	587	16	512	15	863	15	863	8	258	NA	NA
1991	32	1,300	29	1,256	19	730	14	571	2	114	NA	NA
1992	26	902	24	841	NA	NA	NA	NA	NA	NA	NA	NA
1993	38	1,719	33	1,475	3	156	3	156	1	NA	NA	NA
1994	40	1,917	37	1,784	9	514	8	451	4	411	NA	NA
1995	23	896	19	842	25	1,165	22	1,090	NA	NA	NA	NA
1996	37	949	34	916	10	423	8	343	NA	NA	NA	NA
1997	46	1,261	45	1,241	14	330	14	330	31	871	5	83
1998	17	614	17	614	2	48	NA	NA	2	72	NA	NA
1999	15	442	14	418	1	12	NA	NA	4	104	NA	NA
2000	10	297	9	265	1	12	1	12	NA	NA	NA	NA
2001	37	886	35	878	NA	NA	NA	NA	9	237	NA	NA
2002	44	1,343	44	1,343	NA	NA	NA	NA	7	330	NA	NA
2003	83	1,103	82	1,103	10	99	10	99	7	110	NA	NA
2004	103	4,882	92	2,631	20	484	19	484	3	67	NA	NA
2005	56	743	53	687	29	455	28	455	1	10	NA	NA
2006	88	1,779	56	1,451	12	272	12	272	7	88	1	NA
2007	127	4,147	121	4,085	13	306	11	258	71	2,282	10	366
2008	105	4,349	102	4,311	10	366	10	366	35	1,051	6	241



Year	Bottomfish Fishing				Bottom-troll Mixed				Spearfishing			
	All		BMUS		All		BMUS		All		BMUS	
	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr	Trips	Gr-hr
2009	109	6,046	107	6,032	8	534	8	534	27	961	NA	NA
2010	42	2,132	36	2,086	1	66	1	66	94	3,533	2	64
2011	55	2,173	52	2,135	18	608	16	569	58	2,158	1	54
2012	99	1,088	14	269	5	277	2	42	55	513	1	NA
2013	75	3,160	36	2,276	11	399	8	252	68	2,171	6	202
2014	125	4,081	107	3,818	22	642	22	642	64	2,761	2	160
2015	122	4,045	116	3,997	27	5,542	25	5,498	26	1,093	4	190
2016	63	8,127	62	8,119	46	1,785	46	1,785	35	1,230	7	228
2017	73	5,650	72	5,650	18	7,420	13	3,780	35	10,195	9	7,117
2018	58	2,083	57	2,083	16	280	11	249	46	1,577	10	392
2019	58	1,469	57	1,469	7	229	7	229	41	1,446	6	115
2020	43	881	39	871	17	357	16	339	48	1,933	14	675
<b>10-year avg.</b>	<b>77</b>	<b>3,276</b>	<b>61</b>	<b>3,069</b>	<b>19</b>	<b>1,754</b>	<b>17</b>	<b>1,339</b>	<b>48</b>	<b>2,508</b>	<b>6</b>	<b>913</b>
<b>10-year SD</b>	<b>27</b>	<b>2,164</b>	<b>29</b>	<b>2,265</b>	<b>11</b>	<b>2,439</b>	<b>12</b>	<b>1,755</b>	<b>13</b>	<b>2,633</b>	<b>4</b>	<b>2,076</b>
<b>20-year avg.</b>	<b>78</b>	<b>3,008</b>	<b>67</b>	<b>2,765</b>	<b>15</b>	<b>1,006</b>	<b>13</b>	<b>796</b>	<b>37</b>	<b>1,687</b>	<b>4</b>	<b>490</b>
<b>20-year SD</b>	<b>29</b>	<b>2,021</b>	<b>30</b>	<b>2,023</b>	<b>11</b>	<b>1,885</b>	<b>11</b>	<b>1,362</b>	<b>26</b>	<b>2,182</b>	<b>4</b>	<b>1,530</b>

“NA” = no data available.

## 1.8 PARTICIPANTS

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

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

All: Total unique vessels by gear type.

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

**Table 11a. Estimated number of unique vessels for bottomfish fishing gears in the American Samoa boat-based fishery for all species and BMUS only**

Year	Bottomfish Fishing		Bottom-Troll Mixed		Spearfishing	
	All	BMUS	All	BMUS	All	BMUS
1986	20	5	20	3	7	NA
1987	11	3	14	3	8	NA
1988	12	12	11	9	9	1
1989	14	13	13	13	4	1
1990	5	4	6	6	2	NA
1991	13	12	9	7	1	NA
1992	9	9	NA	NA	NA	NA
1993	10	9	3	3	1	NA
1994	8	7	6	6	2	NA
1995	10	8	12	12	NA	NA
1996	15	14	8	6	NA	NA
1997	13	12	8	8	4	3
1998	9	9	1	NA	2	NA
1999	9	8	1	NA	1	NA
2000	8	7	1	1	NA	NA
2001	12	11	NA	NA	5	NA
2002	13	13	NA	NA	3	NA
2003	14	14	4	4	4	NA
2004	21	21	7	6	3	NA
2005	13	12	5	5	1	NA
2006	20	14	1	1	2	1
2007	21	19	6	4	3	3
2008	18	16	8	8	3	2
2009	14	14	4	4	3	NA
2010	11	8	1	1	5	1
2011	8	7	5	5	2	1

Year	Bottomfish Fishing		Bottom-Troll Mixed		Spearfishing	
	All	BMUS	All	BMUS	All	BMUS
2012	11	6	4	2	2	1
2013	13	10	5	3	3	2
2014	16	13	9	9	4	1
2015	14	14	10	9	4	2
2016	15	15	10	10	3	2
2017	11	11	8	7	6	3
2018	9	9	6	5	3	3
2019	6	6	3	3	5	2
2020	7	6	6	6	3	3
<b>10-year avg.</b>	<b>11</b>	<b>10</b>	<b>7</b>	<b>6</b>	<b>4</b>	<b>2</b>
<b>10-year SD</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>1</b>	<b>1</b>
<b>20-year avg.</b>	<b>13</b>	<b>12</b>	<b>5</b>	<b>5</b>	<b>3</b>	<b>1</b>
<b>20-year SD</b>	<b>4</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>1</b>	<b>1</b>

“NA” = no data available.

In summary, the number of operating vessels has been affected by natural disasters and access to the government subsidy over the years but has also been on a declining trend.

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

All: Average fishers from all trips by gear type.

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

**Table 11b. Estimated number of fishermen per trip for bottomfish fishing gears in the American Samoa boat-based fishery for all species and BMUS only**

Year	Bottomfish Fishing		Bottom-Troll Mixed		Spear	
	All	BMUS	All	BMUS	All	BMUS
1986	3	2	2	2	5	NA
1987	3	2	2	2	5	NA
1988	2	2	3	3	4	4
1989	3	3	4	4	5	6
1990	2	2	3	3	4	NA
1991	3	3	3	3	5	NA
1992	2	2	NA	NA	NA	NA
1993	2	2	3	3	5	NA
1994	2	2	3	3	4	NA
1995	3	2	2	3	NA	NA

Year	Bottomfish Fishing		Bottom-Troll Mixed		Spear	
	All	BMUS	All	BMUS	All	BMUS
1996	3	3	3	2	NA	NA
1997	3	3	3	3	5	3
1998	3	3	3	NA	6	NA
1999	2	2	3	NA	4	NA
2000	3	3	3	3	NA	NA
2001	3	3	NA	NA	3	NA
2002	3	3	NA	NA	5	NA
2003	3	3	3	3	4	NA
2004	3	3	3	3	6	NA
2005	3	3	3	3	5	NA
2006	3	4	3	3	4	6
2007	3	3	3	3	5	5
2008	3	3	3	3	4	5
2009	4	4	4	4	6	NA
2010	3	4	3	3	6	5
2011	3	3	3	3	7	9
2012	2	3	5	3	5	NA
2013	3	3	4	4	6	6
2014	3	3	3	3	6	7
2015	3	3	3	3	5	5
2016	3	3	3	3	5	4
2017	6	6	7	4	7	14
2018	3	3	3	2	5	5
2019	3	3	3	3	5	4
2020	2	2	2	2	5	5
<b>10-year avg.</b>	<b>3</b>	<b>3</b>	<b>4</b>	<b>3</b>	<b>6</b>	<b>6</b>
<b>10-year SD</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>3</b>
<b>20-year avg.</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>5</b>	<b>4</b>
<b>20-year SD</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>4</b>

“NA” = no data available.

## 1.9 BYCATCH ESTIMATES

This section focuses on Magnuson-Stevens Fishery Conservation and Management Act (MSA) § 303(a)(11), which requires that all fishery management plans (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 BMUS individuals found in the raw data including bycatch. The number kept is the total number of BMUS individuals in the raw data that are not marked as bycatch. The number released is number caught minus the number kept. Percent bycatch is the sum of all released divided by the number caught.

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

Year	BMUS			Non-BMUS			BMUS + Non-BMUS		
	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch
1992	1,803	0	0.00	637	0	0.00	2,440	0	0.00
1993	1,534	0	0.00	860	0	0.00	2,394	0	0.00
1994	5,447	0	0.00	2,210	0	0.00	7,657	0	0.00
1995	2,397	0	0.00	1,008	0	0.00	3,405	0	0.00
1996	3,940	0	0.00	2,059	0	0.00	5,999	0	0.00
1997	2,910	0	0.00	2,283	0	0.00	5,193	0	0.00
1998	998	0	0.00	846	0	0.00	1,844	0	0.00
1999	3,213	0	0.00	2,417	0	0.00	5,630	0	0.00
2000	3,386	0	0.00	3,052	0	0.00	6,438	0	0.00
2001	3,499	0	0.00	2,703	0	0.00	6,202	0	0.00
2002	3,362	0	0.00	3,597	0	0.00	6,959	0	0.00
2003	3,778	0	0.00	4,019	1	0.02	7,797	1	0.01
2004	2,970	0	0.00	3,764	0	0.00	6,734	0	0.00
2005	1,807	0	0.00	1,877	0	0.00	3,684	0	0.00
2006	1,573	0	0.00	4,260	0	0.00	5,833	0	0.00
2007	2,752	0	0.00	4,184	0	0.00	6,936	0	0.00
2008	4,616	0	0.00	3,972	0	0.00	8,588	0	0.00
2009	11,080	0	0.00	8,441	0	0.00	19,521	0	0.00
2010	2,902	0	0.00	2,119	0	0.00	5,021	0	0.00
2011	4,229	0	0.00	3,130	0	0.00	7,359	0	0.00
2012	775	0	0.00	4,362	0	0.00	5,137	0	0.00
2013	1,031	0	0.00	3,494	0	0.00	4,525	0	0.00
2014	3,123	0	0.00	3,504	0	0.00	6,627	0	0.00
2015	3,602	0	0.00	3,666	0	0.00	7,268	0	0.00
2016	888	0	0.00	1,234	0	0.00	2,122	0	0.00
2017	926	0	0.00	1,425	0	0.00	2,351	0	0.00
2018	630	0	0.00	742	0	0.00	1,372	0	0.00
2019	771	0	0.00	823	0	0.00	1,594	0	0.00

Year	BMUS			Non-BMUS			BMUS + Non-BMUS		
	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch	# Caught	# Discard or Release	% Bycatch
2020	404	0	0.00	632	0	0.00	1,036	0	0.00
10-yr avg.	1,638	0	0.00	2,301	0	0.00	3,939	0	0.00
10-yr SD	1,351	0	0.00	1,377	0	0.00	2,411	0	0.00
20-yr avg.	2,736	0	0.00	3,097	0	0.00	5,833	0	0.00
20-yr SD	2,322	0	0.00	1,751	0	0.01	3,883	0	0.00

## 1.10 FEDERAL LOGBOOK DATA

### 1.10.1 Number of Federal Permit Holders

In American Samoa, the following federal permits are required for fishing in the exclusive economic zone (EEZ) under the Hawaii FEP. Regulations governing fisheries under the Hawaii FEP are in the Code of Federal Regulations (CFR), Title 50, Part 665.

#### 1.10.1.1 Special Coral Reef Ecosystem Permit

Regulations require the special coral reef ecosystem fishing permit for anyone fishing for coral reef ecosystem management unit species in a low-use marine protected area (MPA), fishing for species on the list of Potentially Harvested Coral Reef Taxa or using fishing gear not specifically allowed in the regulations. NMFS will make an exception to this permit requirement for any person issued a permit to fish under any fishery ecosystem plan who incidentally catches American Samoa coral reef ECS while fishing for bottomfish MUS, crustacean MUS or ECS, western Pacific pelagic MUS, precious coral, or seamount groundfish. Regulations require a transshipment permit for any receiving vessel used to land or transship potentially harvested coral reef taxa, or any coral reef ECS caught in a low-use MPA.

#### 1.10.1.2 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.

#### 1.10.1.3 Western Pacific Crustacean Permit

Regulations require a permit for the owner of a U.S. fishing vessel used to fish for lobster (now ECS) or deepwater shrimp in the EEZ around American Samoa, Guam, Hawaii, and the Pacific Remote Islands Areas (PRIA), and in the EEZ seaward of three 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 13. Table 13 provides the number of permits issued to American Samoa FEP fisheries between 2011 and 2020. Data are from the Pacific Islands Regional Office (PIRO) Sustainable Fisheries Division (SFD) permits program.

**Table 13. Number of federal permit holders in American Samoa crustacean fisheries**

<b>Crustacean Fishery<sup>1</sup></b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>
Lobster	0	0	0	1	0	0	0	0	0	0
Shrimp	0	0	0	1	0	0	0	0	0	0

<sup>1</sup> Source: PIRO SFD unpublished data.

### 1.10.2 Summary of Catch and Effort for FEP Fisheries

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

Federal permits are not required to fish for bottomfish in American Samoa; NMFS has never issued a federal permit for precious coral or coral reef fishing in federal waters around American Samoa. Therefore, catch and effort data is not presented for these fisheries.

#### 1.10.2.1 Spiny and Slipper Lobster

**Table 14. Summary of available federal logbook data for lobster fisheries in American Samoa**

<b>Year</b>	<b>No. of Federal Lobster Permits Issued<sup>1</sup></b>	<b>No. of Federal Lobster Permits Reporting Catch</b>	<b>No. of Trips in AS EEZ</b>	<b>Total Reported Logbook Catch (lb)</b>		<b>Total Reported Logbook Release/Discard (#)</b>	
				<i>Spiny lobster ECS<sup>2</sup></i>	<i>Slipper lobster ECS<sup>2</sup></i>	<i>Spiny lobster ECS<sup>2</sup></i>	<i>Slipper lobster ECS<sup>2</sup></i>
2004	0						
2005	0						
2006	2	0					
2007	2	0					
2008	7	0					
2009	0						
2010	0						
2011	0						

2012	0						
2013	0						
2014	1	0					
2015	0						
2016	0						
2017	0						
2018	0						
2019	0						
2020	0						

<sup>1</sup> Source: PIRO SFD unpublished data.

<sup>2</sup> On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify all crustacean MUS in American Samoa as ECS.

### 1.10.2.2 Deepwater Shrimp

**Table 15. Summary of available federal logbook data for deepwater shrimp fisheries in American Samoa**

Year	No. of Federal Shrimp Permits Issued <sup>1</sup>	No. of Federal Shrimp Permits Reporting Catch	No. of Trips in American Samoa EEZ	Total Reported Logbook Shrimp ECS <sup>2</sup> Catch (lb)	Total Reported Logbook Shrimp ECS <sup>2</sup> Release/Discard (lb)
2009	0				
2010	0				
2011	0				
2012	0				
2013	0				
2014	1	0			
2015	0				
2016	0				
2017	0				
2018	0				
2019	0				
2020	0				

<sup>1</sup> Source: PIRO SFD unpublished data.

<sup>2</sup> On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify all crustacean MUS in American Samoa as ECS.

Note: Federal permit and reporting requirements for deepwater shrimp fisheries became effective on June 29, 2009 (74 FR 25650, May 29, 2009).

## 1.11 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. Instead, the control rules are applied to each stock complex as a whole.

The maximum sustainable yield (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 section. The latest estimate published annually in the stock assessment and fishery evaluation (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 16.

**Table 16. Overfishing threshold specifications for BMUS**

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

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

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

Since the MSY control rule specified here applies to multi-species stock complexes, it is important to ensure that no 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 17. Again,  $E_{MSY}$  is used as a proxy for  $F_{MSY}$ .

**Table 17. Recruitment overfishing control rule specifications for BMUS**

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

### 1.11.2 Current Stock Status

#### 1.11.2.1 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 CPUE for the multi-species complexes as a whole. At this time, it is not possible to partition these effort measures among the various bottomfish MUS. The most recent stock assessment (Langseth et al. 2019) for the American Samoa bottomfish MUS complex (comprised of 11 species of shallow and deep species of snapper, grouper, jacks, and emperors) was based on estimates of total catch and an abundance index derived from the nominal CPUE generated from the creel surveys. The assessments used a state-space Bayesian surplus production model within the modeling framework Just Another Bayesian Biomass Assessment (JABBA), which included biological information and fishery-dependent data through 2017. Determinations of overfishing and overfished status can then be made by comparing current biomass and harvest rates to  $MSY$ -level reference points. The American Samoa BMUS were determined to be both undergoing overfishing and in an overfished state (Table 18).

**Table 18. Stock assessment parameters for the BMUS complex (from Langseth et al. 2019)**

Parameter	Value	Notes	Status
$MSY$	28.8 (16.4-55.9)	Expressed in 1000 lb (with 95% confidence interval)	
$H_{2017}$	0.15	Expressed in percentage	
$H_{CR}$	0.107 (0.044-0.228)	Expressed in percentage (with 95% confidence interval)	
$H/H_{CR}$	2.75		Overfishing occurring
$B_{2017}$	102.6	Expressed in thousand pounds	
$B_{MSY}$	272.8 (120.8-687.4)	Expressed in 1000 lb (with 95% confidence interval)	
$B/B_{MSY}$	0.38		Overfished

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

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

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

No ACLs were implemented by NMFS for American Samoa MUS in 2020. However, NMFS did implement an interim catch limit (ICL) of 13,000 lb for 2020 associated with an interim management measure for the American Samoa bottomfish fishery (85 FR 73003, November 16, 2020). Consistent with Magnuson-Stevens Act sections 304(e)(6) and 305(c), the Council requested that NMFS implement this interim measure to reduce overfishing of BMUS while the Council develops management measures to end overfishing and rebuild the American Samoa bottomfish stock complex. The catch shown in Table 19 takes the average of the most recent three years as recommended by the Council at its 160<sup>th</sup> meeting to avoid large fluctuations in catch due to high interannual variability in estimates.

**Table 19. American Samoa 2020 ACL table with three-year recent average catch (lb)**

Fishery	MUS	OFL*	ABC	ACL**	Catch
Bottomfish	Bottomfish multi-species complex	8,000	N.A.	13,000	10,638

\* OFL derived from the stock assessment (Langseth et al. 2019) with 2025 as the terminal year.

\*\* The catch limit for 2020 was an ICL implemented by NMFS as an interim measure (85 FR 73003, November 16, 2020).

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

#### 1.13.1.2 Stock Assessment Updates

Updates to the 2007 benchmark stock assessment were done in 2012 (Brodziak et al. 2012) and 2015 (Yau et al. 2016). These included a two-year stock projection table used for selecting the level of risk the fishery will be managed under ACLs. Yau et al. (2016) was considered the best scientific information available for the Territory BMUS complexes after undergoing a Western Pacific Stock Assessment Review (WPSAR) Tier 3 panel review (Franklin et al. 2015) prior to the Langseth et al. (2019) benchmark stock assessment. This was the previous basis for P\* and SEEM analyses that determined the risk levels to specify past 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](#).

PIFSC and the Council conducted a workshop with various stakeholders in CNMI to identify factors and quantify uncertainties associated with the social, economic, ecological, and management of the coral reef fisheries (Sievanen and McCaskey 2014). This was the basis for the SEEM analyses that determine the risk levels to specify ACLs. However, species targeted by coral reef fisheries in American Samoa are no longer classified as MUS.

## 1.14 HARVEST CAPACITY AND EXTENT

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

- Will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and considering the protection of marine ecosystems.

- Is prescribed on the basis of the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor.
- In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery [50 CFR §600.310(f)(1)(i)].

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

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

The harvest extent, in this case, is defined as the level of catch harvested in a fishing year relative to the ACL or OY. The harvest capacity is the level of catch remaining in the annual catch limit that can potentially be used for the total allowable level of foreign fishing (TALFF). Table 20 summarizes the harvest extent and harvest capacity information for American Samoa using three-year average catch against the ACL, but no ACL was implemented by NMFS for American Samoa BMUS in 2020. However, NMFS did implement an ICL of 13,000 lb for 2020 associated with an interim management measure for the American Samoa bottomfish fishery (85 FR 73003).

**Table 20. American Samoa ACL proportion of harvest capacity and extent in 2020**

Fishery	MUS	ACL*	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	Bottomfish multi-species complex	13,000	10,638	81.8	18.2

\* The catch limit for 2020 was an ICL implemented by NMFS as an interim measure (85 FR 73003, November 16, 2020).

## 1.15 ADMINISTRATIVE AND REGULATORY ACTIONS

This summary describes management actions NMFS implemented for insular fisheries in American Samoa during calendar year 2020.

November 16, 2020. Final rule: **Interim measures for American Samoa Bottomfish**. This temporary rule implemented an interim catch limit (ICL) of 13,000 lb of American Samoa bottomfish for fishing years 2020 and 2021 during the effective period of the rule. NMFS will monitor catches, and if the fishery reaches the ICL within a fishing year, they will close the fishery in federal waters through the end of the fishing year, or through the end of the effective period of this rule, whichever comes first. These interim management measures are necessary to reduce overfishing of American Samoa bottomfish while minimizing socioeconomic impacts to fishing communities. This temporary rule supports the long-term sustainability of American Samoa bottomfish. This rule is effective from November 16, 2020 through May 17, 2021.

This page was intentionally left blank.

## **2 ECOSYSTEM CONSIDERATIONS**

### **2.1 2020 COVID-19 IMPACTS**

This section on impacts associated with COVID-19 in the Western Pacific region was added to the annual SAFE report this year given the distinctive effects that the pandemic had on both fishing communities and fisheries in the Pacific Islands. The section is not meant to be a permanent fixture in the annual SAFE report, and it will only be included in the future as long as the impacts from COVID-19 remain relevant for the region's fisheries.

#### **2.1.1 Social Impacts**

The Pacific Islands Region has experienced a number of unique risks from COVID-19 as well as measures put in place to stop its spread. While the number of COVID-19 cases in the Pacific Island Region have been comparatively few, restrictions on travel and local restrictions on gathering and commerce have had profound effects on local economies, livelihoods, and human well-being. Since March 2020, airlines have significantly limited flights across the Pacific Islands Region, impacting the ability of people to see their loved ones, travel off island for medical treatments, as well as reshaping economies heavily reliant on tourism. Measures to limit community spread such as curfews, limitations on gatherings, and stay-at-home orders have also had a heavy impact on local businesses, and often shifted subsistence practices.

Through it all fisheries communities in the Pacific Islands Region have played a vital role in supporting local food systems, nutrition, food security, and community social cohesion. COVID-19 has amplified these critical roles of fishing in island communities and there is a shared hope for an increased understanding and value of all local fisheries to island communities, economy, and food security for the future.

#### **2.1.2 Community Impacts**

American Samoa implemented early and strict protective measures to prevent the spread of the novel coronavirus. The first measures were designed to stop community spread of the virus and included social distancing, a cancellation of public gatherings associated with a public emergency declaration (March 18), and an island-wide stay-at-home work-at-home order (March 24; Department of Legal Affairs 2020). Perhaps most significantly, on March 30, all flights between Hawaii and American Samoa were suspended for 30 days (Sagapolutele 2020). Those flight restrictions were later broadened and extended, resulting in no commercial flights throughout the rest of 2020, effectively closing the island (Office of the Governor 2020). In early 2021, repatriation flights began to allow residents stranded off-island to begin to come home (Samoa News Staff 2021). There has also been increased regulation of foreign vessels in Pago Pago harbor. The American Samoa Government imposed a 15-day quarantine on foreign vessels that have visited other ports, met up with another vessel, or fueled via a tanker. These vessels supply the StarKist Samoa cannery. Cannery staff and stevedores are allowed onboard to offload product, but the crew are not allowed to depart vessels. The Department of Health has maintained diligence to ensure crew are safe and limiting exposure to local populations. Given ongoing travel restrictions, many skippers and crews have not been able to return home for over

six months. Given ongoing travel restrictions, many skippers and crews were not able to return home during 2020.

In November, the first three cases of COVID-19 were reported in three crew members of a container ship in the port of Pago Pago. However, steps were taken to contain the cases, and there was no community spread (Samoa News Staff 2020). In January 2021, the first vaccines were made available to American Samoan residents. To date, there are no reported cases of COVID-19 across the islands of American Samoa.

### **2.1.3 Fisheries Impacts**

American Samoa shore-based, alia, and small boat fisheries are a mix of subsistence, cultural, recreational, and quasi-commercial fishers. Fish and fishing are an integral part of the culture and important components of the social fabric in American Samoa. In addition to social importance, most fishermen consider the fish they catch to be an important source of food for their families. Fishing is critically important in terms of building and maintaining social and community networks, perpetuating fishing traditions, and providing fish to local communities as a source of food security.

Shore-based and small-boat fisheries on Tutuila and the Manu'a Islands continued throughout 2020. While fish was still widely available to the local population throughout the year, revenue from commercial fisheries fell (see Section 2.5). From March to May 2020, opportunities to fish were impacted by curfews, which restricted night fishing, and by school closures that increased the need for childcare. Curfews also had an indirect impact on the sale of fish due to the limited business hours of restaurants, bars, and nightclubs, which are primary destinations for island seafood. Furthermore, these businesses could only serve 10 or fewer customers at a time. Taken together, these restrictions meant many of these businesses were unable to cover payroll, rent, utilities, and other fixed costs, causing many to shut down entirely.

### **2.1.4 Data Collection Impacts**

The American Samoa Government shutdown all entry into the Territory on March 23, 2020. Data collection continued throughout the pandemic; however, staff working hours were reduced to 20 hours a week, which resulted in reduced survey days for the shore-based creel survey. Staff resumed full working hours on July 1, 2020, and PIFSC received the first data submission from American Samoa in early August. According to data submitted, reduced shore-based data collection occurred in April, however, shore-based fishing effort increased by 50% compared to the first five months of 2019. Total boat-based survey days were not affected by the reduction in working hours, but fishing effort decreased by 10% compared to the first six months of 2019. Data submission of commercial receipts declined by 50% compared to the first six months of 2019 as well.

Due to COVID-19, a health proclamation was imposed on all government agencies at the end of March 2020. There were various changes in the proclamation, but the time spent on fisheries data collection was decreased. Creel surveys were no longer conducted at a minimum of 8 hours per day. Instead, surveys were conducted at a minimum of 4 hours a day. In addition, there were no surveys conducted on Saturdays (weekend type of day in the creel survey stratification) through June 2020. In July 2020, a change in the COVID-19 health proclamation allowed all



program activities to resume as usual: surveys were conducted eight to 16 hours a day for three to five days a week and two weekends a month.

Commercial invoice collection is conducted four days a month. There are two dedicated days for vendor pre-visit where staff visits commercial vendors to train new vendor representatives, review invoice logs, and remind vendors to make their monthly submission on or before the 16<sup>th</sup> of every month. Two other days are dedicated to review and collect invoices. Due to COVID-19, there was a decrease in business hours and crowds were hard to avoid. An official letter from DMWR was distributed to all registered commercial vendors to inform them that there will be one monthly visit to their place of business to ensure the safety and health of employees. In addition, they were reminded that it is mandated by law that they need to make their monthly submissions. Therefore, they were encouraged to drop off their invoices at the DMWR office. Vendor representatives made their monthly submissions from April to July. Commercial invoice collection days increased to three days per month after a change in the COVID-19 health proclamation in July 2020.

## **2.2 2020 FISHERMEN OBSERVATIONS**

Fishers from American Samoa met with the Council's American Samoa Advisory Panel on Tuesday, February 9, 2021, to discuss their observations on fisheries during 2020. Bottomfish fishing in American Samoa was difficult in 2020 with more rain, high winds, and rough currents, making it difficult for smaller boats to fish. Fishermen noticed a strong shark presence in November and December. There was also an increase in sports fishermen engaging in bottomfish fishing. While bottomfish fishing was spotty around Tutuila island, fishermen reported high productivity around the Manu'a islands. Onaga catches were good for some fishermen, landing 100 to 200 lb per trip. This section will be expanded in future annual SAFE reports as resources allow.

## 2.3 CORAL REEF FISH ECOSYSTEM PARAMETERS

### 2.3.1 Regional Reef Fish Biomass and Habitat Condition

**Description:** ‘Reef fish biomass’ is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2020. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new survey occurred in 2020 due to COVID-19, and the numbers presented here are identical to last year’s report.

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

**Data Category:** Fishery-independent

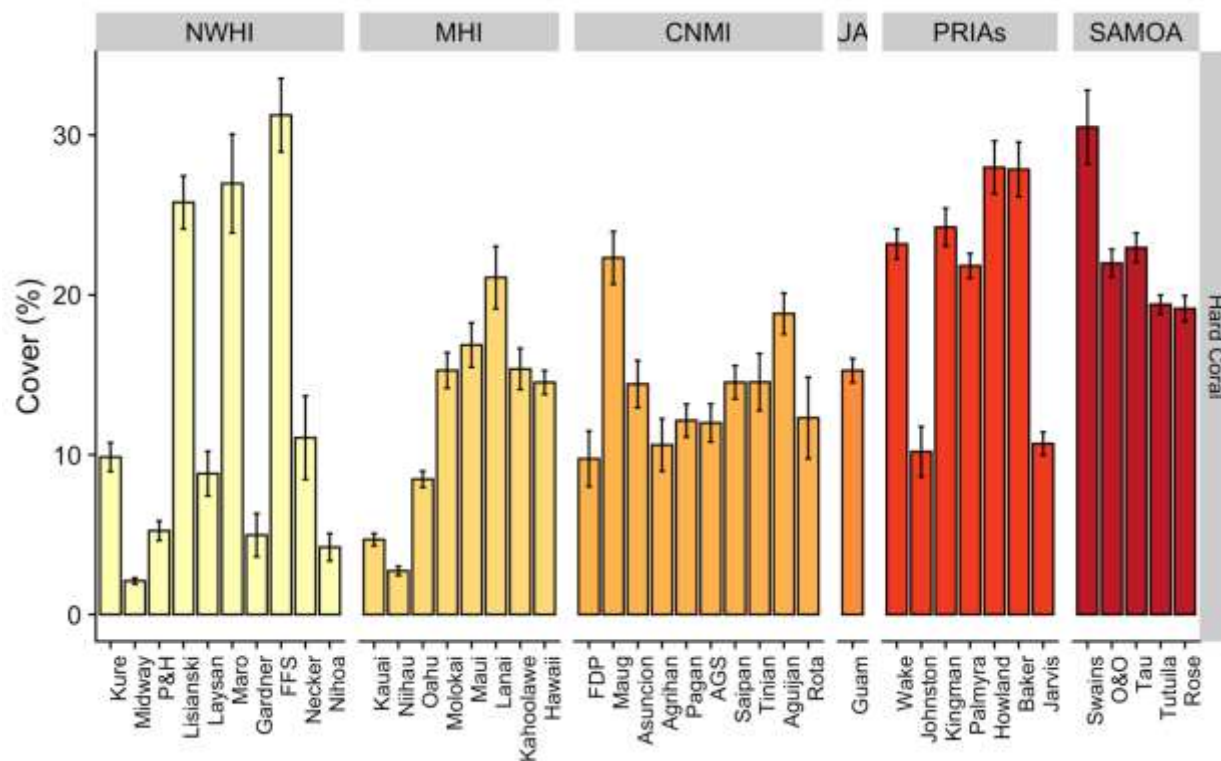
**Timeframe:** Triennial

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

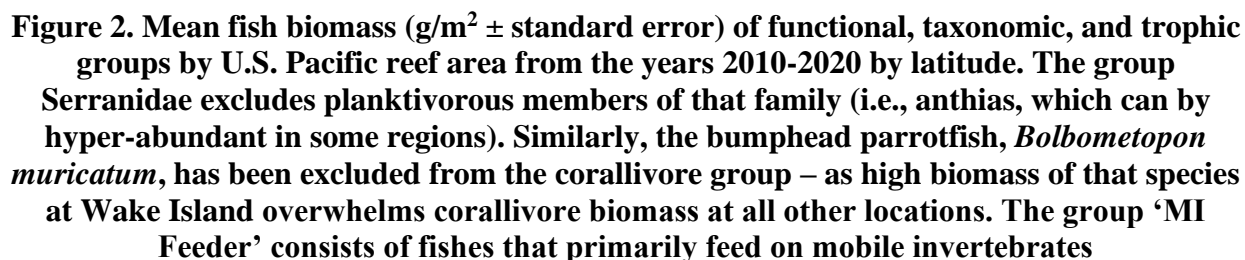
**Spatial Scale:** Regional

**Data Source:** Data used to generate cover and biomass estimates come from visual surveys conducted by the National Marine Fisheries Service (NMFS) Pacific Island Fisheries Science Center (PIFSC) Ecosystem Sciences Division (ESD) and their partners as part of the Pacific Reef Assessment and Monitoring Program ([RAMP](#)). Survey methods are described in detail in Ayotte et al. (2015). In brief, they involve teams of divers conducting stationary point count cylinder (SPC) surveys within a target domain of < 30 meter hard-bottom habitat at each island, stratified by depth zone and, for larger islands, by section of coastline. For consistency among islands, only data from forereef habitats are used. At each SPC, divers record the number, size, and species of all fishes within or passing through paired 15 meter-diameter cylinders over the course of a standard count procedure.

Fish sizes and abundance are converted to biomass using standard length-to-weight conversion parameters, taken largely from [FishBase](#) and converted to biomass per unit area by dividing by the area sampled per survey. Site-level data were pooled into island-scale values by first calculating mean and variance within strata, and then calculating weighted island-scale mean and variance using the formulas given in Smith et al. (2011) with strata weighted by their respective sizes.



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



### 2.3.2 Archipelagic Reef Fish Biomass and Habitat Condition

**Description:** ‘Reef fish biomass’ is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2020. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new survey occurred in 2020 due to COVID-19 and the numbers presented here are identical to last year’s report.

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

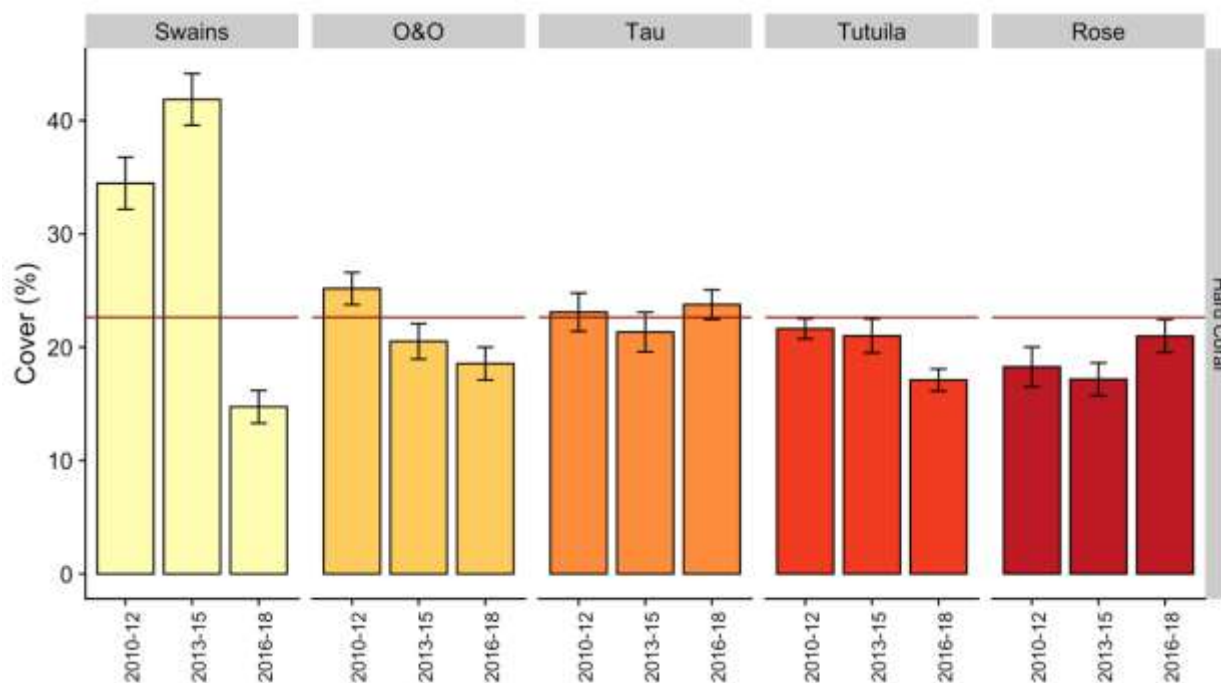
**Data Category:** Fishery-independent

**Timeframe:** Triennial

**Jurisdiction:** American Samoa

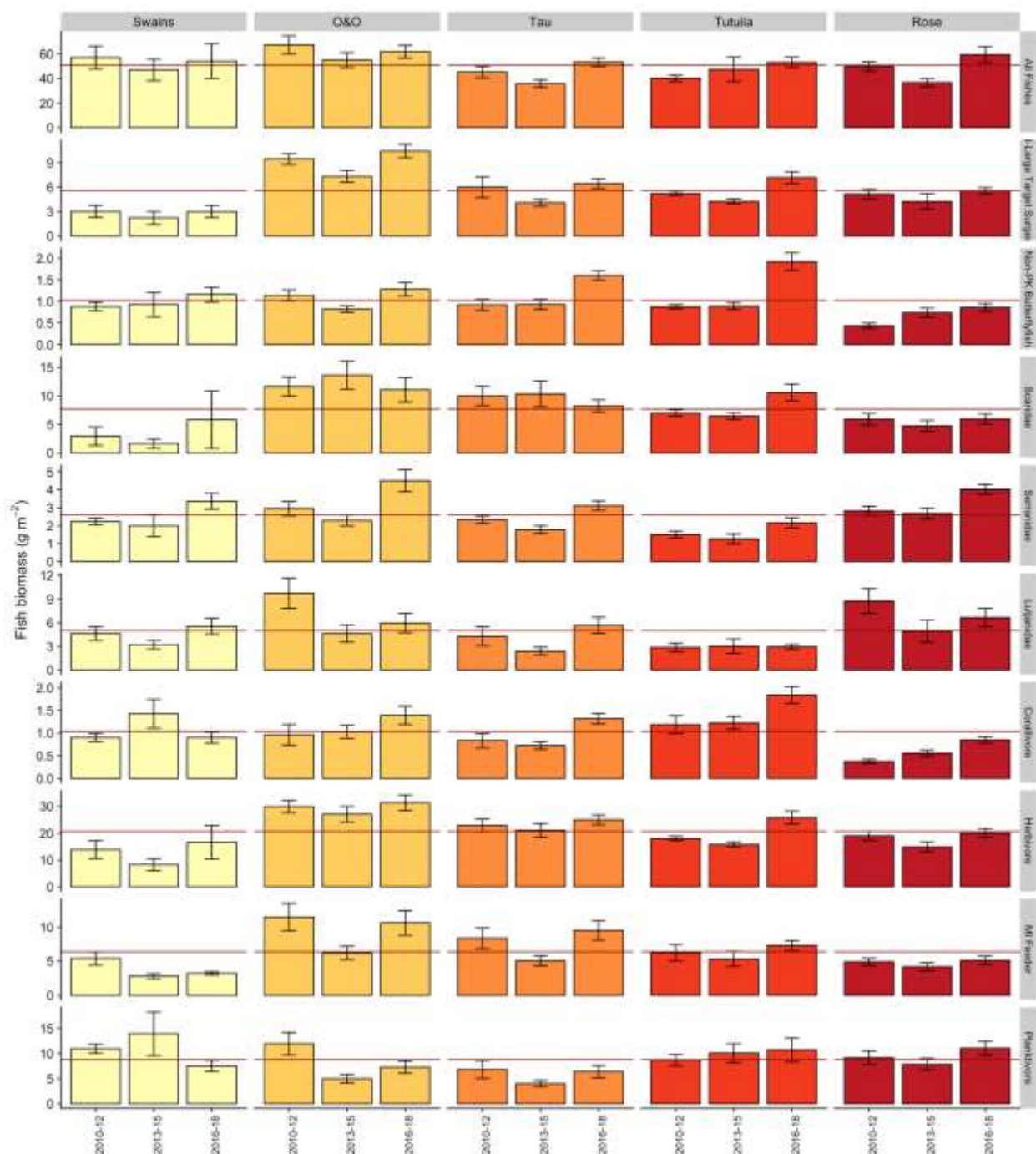
**Spatial Scale:** Island

**Data Source:** Data used to generate biomass and cover estimates comes from visual surveys conducted by NMFS PIFSC ESD and partners, as part of the Pacific RAMP. Survey methods and sampling design, and methods to generate reef fish biomass are described in Section 2.3.1.



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





**Figure 4. Mean fish biomass (g/m² ± standard error) of American Samoa functional, taxonomic, and trophic groups from the years 2010-2020 by island. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can be hyper-abundant in some regions). Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group. The group ‘MI Feeder’ consists of fishes that primarily feed on mobile invertebrates; with American Samoa archipelago mean estimates plotted for reference (red line)**

## 2.4 LIFE HISTORY INFORMATION AND LENGTH-DERIVED VARIABLES

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

The NMFS PIFSC Bio-Sampling Program allows for the collection of life history samples like otoliths and gonads from priority species in the bottomfish and coral reef fisheries. A significant number of samples are also collected during research cruises. These life history samples, once processed and examined, will contribute to the body of scientific information for the two data poor fisheries in the region (coral reef fish and bottomfish). The life history information available from the region will be monitored by the Fishery Ecosystem Plan Team and will be tracked through this section of the report.

This section will be divided into two fisheries: 1) prioritized coral reef ecosystem component species (ECS), and 2) bottomfish management unit species (BMUS). The prioritized coral reef species list was developed by the American Samoa Department of Marine and Wildlife Resources (DMWR) in 2019. The BMUS are the species that are listed in the federal ecosystem plan and are managed on a federal level. Within each fishery, the available life history information will be described under the age, growth, and reproductive maturity section. The section labelled “Fish Length Derived Parameters” summarizes available information derived from sampling the fish catch or the market. Length-weight conversion coefficients provide area-specific values to convert length from fishery-dependent and fishery-independent data collection to weight or biomass.

### 2.4.1 American Samoa Coral Reef Ecosystem – Life History

#### 2.4.1.1 Age, Growth, and Reproductive Maturity

**Description:** Age determination is based on counts of yearly growth marks (annuli) and/or daily growth increments (DGIs) internally visible within transversely cut, thin sections of sagittal otoliths. Validated age determination is based on several methods including an environmental signal (bomb radiocarbon  $^{14}\text{C}$ ) 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  $^{14}\text{C}$  values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the  $^{14}\text{C}$  otolith core values back in time from its capture date to where it intersects with the known age  $^{14}\text{C}$  coral reference series. Fish growth is estimated by fitting the length-at-age data to a von Bertalanffy growth function (VBGF). This function typically uses three coefficients ( $L_{\infty}$ ,  $k$ , and  $t_0$ ), which together characterize the shape of the length-at-age growth relationship.

Length-at-reproductive maturity is based on the histological analyses of small tissue samples of gonad material that are typically collected along with otoliths when a fish is processed for life history studies. The gonad tissue sample is preserved, cut into five-micron sections, stained, and

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

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

**Data Category:** Biological

**Timeframe:** N/A

**Jurisdiction:** American Samoa

**Spatial Scale:** Archipelagic

**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 (LHP). Refer to the “Reference” column in Table 21 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 ( $^{14}\text{C}$ ) analysis of otolith core material. Units are years.

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



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

**$t_0$  (hypothetical age at length zero)** – One of three coefficients of the VBGF whose measure is highly influenced by the other two VBGF coefficients ( $k$  and  $L_{\infty}$ ) and typically assumes a negative value when specimens representing early growth phases) are not available for age determination. This parameter can be fixed at 0. Units are years.

**$M$  (natural mortality)** – This is a measure of the mortality rate for a fish stock and is considered to be directly related to stock productivity (i.e., high  $M$  indicates high productivity and low  $M$  indicates low stock productivity).  $M$  can be derived through use of various equations that link  $M$  to  $T_{max}$  and the VBGF coefficients ( $k$  and  $L_{\infty}$ ) or by calculating the value of the slope from a regression fit to a declining catch curve (regression of the natural logarithm of abundance versus age class) derived from fishing an unfished or lightly fished population.

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

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

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

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

**Rationale:** These nine life history parameters provide basic biological information at the species level to evaluate the productivity of a stock - an indication of the capacity of a stock to recover once it has been depleted. These parameters are also used as direct inputs into stock assessments. Currently, the assessment of coral reef fish resources in American Samoa is data limited. Knowledge of these life history parameters support current efforts to characterize the resilience

of these resources and provide important biological inputs for future stock assessment efforts and enhance our understanding of the species' likely role and status as a component of the overall ecosystem. Furthermore, knowledge of life histories across species at the taxonomic level of families or among different species that are ecologically or functionally similar can provide important information on the diversity of life histories and the extent to which species can be grouped (based on similar life histories) for future multi-species assessments.

**Table 21. Available age, growth, and reproductive maturity information for prioritized coral reef ecosystem component species in American Samoa**

Species	Age, growth, reproductive maturity parameters									Reference
	$T_{max}$	$L_{\infty}$	$k$	$t_0$	$M$	$A_{50}$	$A\Delta_{50}$	$L_{50}$	$L\Delta_{50}$	
<i>Crenimugil crenilabis</i>										
<i>Epinephelus melanostigma</i>										
<i>Octopus cyanea</i>										
<i>Panulirus penicillatus</i>										
<i>Sargocentron tere</i>										
<i>Tridacna maxima</i>										

Parameter estimates are for females unless otherwise noted (f=females, m=males). Parameters  $T_{max}$ ,  $t_0$ ,  $A_{50}$ , and  $A\Delta_{50}$  are in years;  $L_{\infty}$ ,  $L_{50}$ , and  $L\Delta_{50}$  are in mm fork length (FL);  $k$  is in units of year<sup>-1</sup>; 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 (<sup>d</sup>) are shown in the "Reference" column.

#### 2.4.1.2 Fish Length Derived Parameters

**Description:** The NMFS Commercial Fishery Bio-Sampling Program started in 2010 and ended in 2015. This program had two components: first was the Field/Market Sampling Program and the second was the Lab Sampling Program, details of which are described in a separate section of this report. The goals of the Field/Market Sampling Program were to:

- Broad scale looks 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; and
- Develop accurate local length-weight curves.

In American Samoa, the Bio-Sampling Program 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.

**Data Category:** Biological

**Timeframe:** N/A

**Jurisdiction:** American Samoa

**Spatial Scale:** Archipelagic

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

**Parameter Definitions:**

*n* – **sample size** is the total number of samples accumulated for each species recorded in the Bio-Sampling Program database from the commercial spear fishery.

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

*N<sub>L-W</sub>* – **sample size for L-W regression** is the number of samples used to generate the *a* and *b* coefficients.

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

**Rationale:** Length-derived information is an important component of fisheries monitoring and data poor stock assessment approaches. Maximum length (*L<sub>max</sub>*) is used to derive missing species- and location-specific life history information (Nadon et al. 2015; Nadon and Ault 2016; Nadon 2019). The length-weight coefficients (*a* and *b* values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length is typically recorded but weight is the factor being used for management. This section of the report presents the best available information for the length-derived variables for the American Samoa coral reef ecosystem component fisheries.

**Table 22. Available length-derived information for prioritized coral reef ecosystem component species in American Samoa**

Species	Length-derived parameters					Reference
	<i>n</i>	<i>L<sub>max</sub></i>	<i>N<sub>L-W</sub></i>	<i>a</i>	<i>b</i>	
<i>Crenimugil crenilabis</i>	380	48.2	380	0.0388	2.73	Matthews et al. (2019)
<i>Epinephelus melanostigma</i>	2,662	54.9	2,662	0.0109	3.10	Matthews et al. (2019)
<i>Octopus cyanea</i>						
<i>Panulirus penicillatus</i>	3,384	15.8	3,384	2.6004	2.41	Matthews et al. (2019)
<i>Sargocentron tiere</i>	3,002	25.0	3,002	0.069	2.62	Matthews et al. (2019)
<i>Tridacna maxima</i>						

## 2.4.2 American Samoa Ecosystem – Management Unit Species Life History

### 2.4.2.1 Age, Growth, and reproductive Maturity

**Description:** Age determination is based on counts of yearly growth marks (annuli) and/or DGIs internally visible within transversely cut, thin sections of sagittal otoliths. Validated age determination is based on several methods including an environmental signal (bomb radiocarbon  $^{14}\text{C}$ ) 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  $^{14}\text{C}$  values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the  $^{14}\text{C}$  otolith core values back in time from its capture date to where it intersects with the known age  $^{14}\text{C}$  coral reference series. Fish growth is estimated by fitting the length-at-age data to a VBGF. This function typically uses three coefficients ( $L_{\infty}$ ,  $k$ , and  $t_0$ ), which together characterize the shape of the length-at-age growth relationship.

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

Age at 50% maturity ( $A_{50}$ ) and age at 50% sex reversal ( $A\Delta_{50}$ ) is typically derived by referencing the 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 and growth and reproductive maturity are concurrently determined, estimates of  $A_{50}$  and  $A\Delta_{50}$  are derived directly by fitting the percent of mature samples for each age (i.e., one-year) interval to a three- or four-parameter logistic function using statistical analyses. The mid-point of this fitted logistic function provides a direct estimate of the age at which 50% of fish of a species have achieved reproductive maturity ( $A_{50}$ ) and sex reversal ( $A\Delta_{50}$ ).

**Category:** Biological

**Timeframe:** N/A

**Jurisdiction:** American Samoa

**Spatial Scale:** Archipelagic

**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 LHP. Refer to the “Reference” column in Table 23 for specific details on data sources by species.

**Parameter definitions:** Identical to Section 2.4.1.1.

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

Parameter estimates are for females unless otherwise noted (f=females, m=males). Parameters  $T_{max}$ ,  $t_0$ ,  $A_{50}$ , and  $AA_{50}$  are in years;  $L_{\infty}$ ,  $L_{50}$ , and  $LA_{50}$  are in mm FL;  $k$  is in units of  $\text{year}^{-1}$ ; 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; NA=not applicable. Superscript letters indicate status of parameter estimate (see footnotes below table). Published or in press publications (<sup>d</sup>) are shown in the “Reference” column.

**Table 23. Available age, growth, and reproductive maturity information for BMUS targeted for otoliths and gonads sampling in American Samoa**

Species	Age, growth, and reproductive maturity parameters									Reference
	$T_{max}$	$L_{\infty}$	$k$	$t_0$	$M$	$A_{50}$	$A\Delta_{50}$	$L_{50}$	$L\Delta_{50}$	
<i>Aphareus rutilans</i>							NA		NA	
<i>Aprion virescens</i>							NA		NA	
<i>Caranx lugubris</i>							NA		NA	
<i>Etelis carbunculus</i> <sup>1</sup>							NA		NA	
<i>Etelis coruscans</i>							NA		NA	
<i>Lethrinus rubrioperculatus</i>	f=10 <sup>d</sup> m=10 <sup>d</sup>	f=27.3 <sup>d</sup> m=29.1 <sup>d</sup>	f=0.74 <sup>d</sup> m=0.71 <sup>d</sup>	f=-0.16 <sup>d</sup> m=-0.15 <sup>d</sup>				f=21.2 <sup>d,e</sup>		Pardee et al. (2020)
<i>Lutjanus kasmira</i>							NA		NA	
<i>Pristipomoides filamentosus</i>							NA		NA	
<i>Pristipomoides flavipinnis</i>	28 <sup>d</sup>	41.15 <sup>d</sup>	0.47 <sup>d</sup>		0.22 <sup>d</sup>		NA		NA	O'Malley et al. (2019)
<i>Pristipomoides zonatus</i>							NA		NA	
<i>Variola louti</i>										

<sup>1</sup> *E. carbunculus* is now known to be comprised of two distinct, non-interbreeding lineages (Andrews et al. 2016). Both species occur in the Samoa Archipelago and were likely both captured by fishermen in the 1980s but reported as one species.

<sup>a</sup> signifies estimate pending further evaluation in an initiated and ongoing study.

<sup>b</sup> signifies a preliminary estimate taken from ongoing analyses.

<sup>c</sup> signifies an estimate documented in an unpublished report or draft manuscript.

<sup>d</sup> signifies an estimate documented in a finalized report or published journal article (including in press).

<sup>e</sup>  $L_{50}$  was derived from the published literature based on the relationship between  $L_{\infty}$  and  $L_{50}$

### 2.4.2.2 Fish Length Derived Parameters

**Description:** The NMFS Commercial Fishery Bio-Sampling Program started in 2010 and ended in 2015. This program had two components: first was the Field/Market Sampling Program and the second was the Lab Sampling Program, details of which are described in a separate section of this report. The goals of the Field/Market Sampling Program were:

- Broad scale looks 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; and
- Develop accurate local length-weight curves.

In American Samoa, the Bio-Sampling 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 was 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:** Biological

**Timeframe:** N/A

**Jurisdiction:** American Samoa

**Spatial Scale:** Archipelagic

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

**Parameter Definition:** Identical to Section 2.4.1.2

**Rationale:** Length-derived information is an important component of fisheries monitoring and data poor stock assessment approaches. Maximum length ( $L_{max}$ ) is used to derive missing species- and location-specific life history information (Nadon et al. 2015; Nadon and Ault 2016; Nadon 2019). The length-weight coefficients ( $a$  and  $b$  values) are used to convert length to weight for fishery-dependent and fishery-independent data collection where length is typically recorded but weight is the factor being used for management. This section of the report presents the best available information for the length-derived variables for the American Samoa BMUS fishery.

**Table 24. Available length-derived information for BMUS in American Samoa**

Species	Length derived parameters					Reference
	$n$	$L_{max}$	$N_{L-w}$	$a$	$b$	
<i>Aphareus rutilans</i>	173	85.0	173	0.0395	2.73	Matthews et al. (2019)
<i>Aprion virescens</i>	952	73.4	952	0.0157	2.99	Matthews et al. (2019)
<i>Caranx lugubris</i>	164	86.0	164	0.0404	2.80	Matthews et al. (2019)
<i>Etelis carbunculus</i> <sup>1</sup>						
<i>Etelis coruscans</i>	106	89.5	106	0.0322	2.81	Matthews et al. (2019)
<i>Lethrinus rubrioperculatus</i>	2,349	57.0	2,349	0.0287	2.86	Matthews et al. (2019)
<i>Lutjanus kasmira</i>	461	35.0	461	0.0176	3.01	Matthews et al. (2019)

Species	Length derived parameters					Reference
	$n$	$L_{max}$	$N_{L-W}$	$a$	$b$	
<i>Pristipomoides flavipinnis</i>	262	56.5	262	0.0249	2.90	Matthews et al. (2019)
<i>Pristipomoides zonatus</i>						
<i>Pristipomoides filamentosus</i>						
<i>Variola louti</i>		50.5	365	0.0135	3.08	Matthews et al. (2019)

<sup>1</sup> *E. carbunculus* is now known to be comprised of two distinct, non-interbreeding lineages (Andrews et al. 2016). Both species occur in the Samoa Archipelago and were likely both captured by fishermen in the 1980s but reported as one species.



## 2.5 SOCIOECONOMICS

This section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of the Fishery Ecosystem Plan for the American Samoan Archipelago (WPRFMC 2009). It meets the objective “Support Fishing Communities” adopted at the 165<sup>th</sup> 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, 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.

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 5).



**Figure 5. Settlement of the Pacific Islands, courtesy Wikimedia Commons, [https://commons.wikimedia.org/wiki/File:Polynesian\\_Migration.svg](https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg).**

Polynesian voyagers relied on the ocean and marine resources on their long voyages in search of new islands, as well as in sustaining established island communities. Today, the population of the region also represents many Asian cultures from Pacific Rim countries, which reflect similar importance of marine resources. Thus, fishing and seafood are integral local community ways of life. This is reflected in the amount of seafood eaten in the region in comparison to the rest of the United States, as well as the language, customs, ceremonies, and community events. It can also affect seasonality in prices of fish. Because fishing is such an integral part of the culture, it is difficult to cleanly separate commercial from non-commercial fishing, with 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, if not more, important. Due to changing economies and westernization, recruitment of younger fishermen is becoming a concern for the sustainability of fishing and fishing traditions in the region.

### **2.5.1 Response to Previous Council Recommendations**

At its 181<sup>st</sup> meeting held in Honolulu, Hawaii in March 2020, the Council requested NMFS PIFSC to engage fishermen user groups throughout the stock assessment process. Workshops and other forms of engagement should be held with a sample of local fishermen in each island group to inform any pending stock assessments. Throughout the process, fishermen can speak to their knowledge of the stocks, stock condition, and to data collection and data quality issues. The council also directed staff to work with NMFS and the territory agencies to develop a coordinated plan to conduct targeted outreach on the importance of accurate and robust data collection and the management efforts for the bottomfish fisheries in American Samoa, Guam, and CNMI.

PIFSC and Joint Institute for Marine and Atmospheric Research (JIMAR) have begun work on a stakeholder engagement plan for the Guam bottomfish fishery. Due to the COVID-19 pandemic and associated travel restrictions, this project has been delayed until 2021. PIFSC social science staff intend to work closely with PIFSC Stock Assessment Program staff to provide expertise to support future community engagement and data workshop activities. In 2020, JIMAR supported two social scientists to receive training in conservation conflict transformation which will prove relevant to these efforts.

### **2.5.2 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 (WPRFMC 2009). 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; Kleiber and Leong 2018; Levine and Allen 2009; Richmond and Levine 2012). These studies describe the importance of marine resources in cultural, economics, and subsistence aspects of American Samoan village life. Fishing was held in high esteem in traditional Samoan culture, with fishing skill bringing high social status and fishing activities figuring prominently in mythology. The basic components of Samoan social structure are the family and village, with the family acting as the central unit. The village leadership decides,

according to season, what sort of community fishing should take place. The tautai, or master fishermen, of the village were key decision makers who were awarded higher status than others who might otherwise outrank him when it came to matters of fishing. Village-level systems of governance and resource tenure are still largely intact, and American Samoan cultural systems and representation are formally incorporated into the Territorial Government. Reciprocity is emphasized over individual accumulation. Gifts of food, especially fish and other marine resources, mark every occasion and are a pivotal part of American Samoan social structure to this day.

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

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

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

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

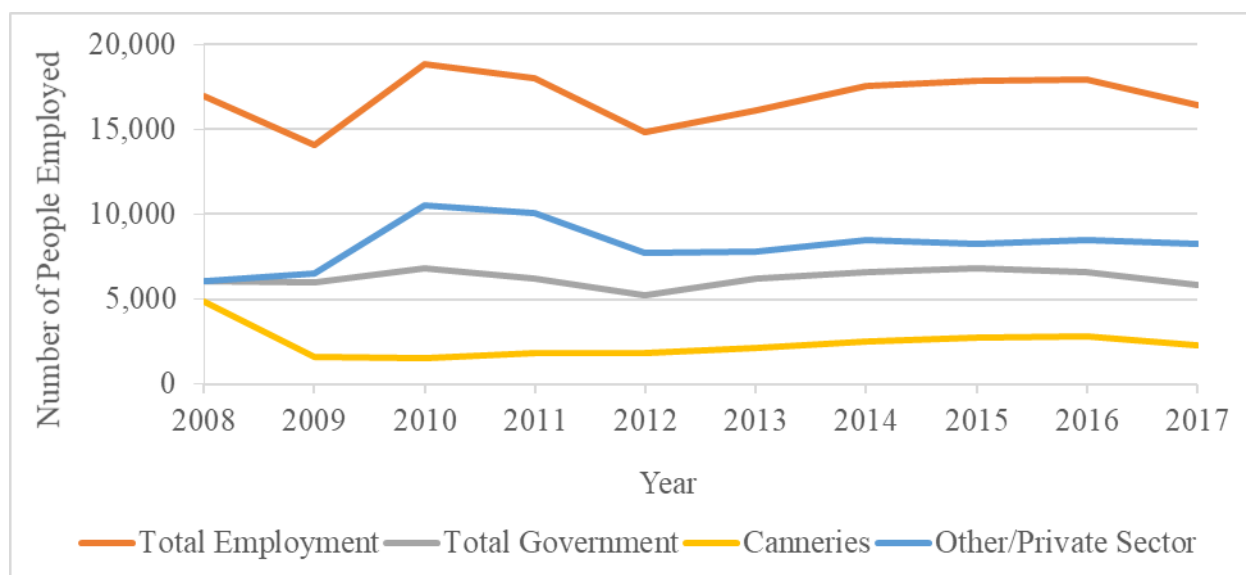
Unlike other areas of the Western Pacific region, American Samoa also experienced the development of domestic industrial-scale fisheries, including tuna processing, transshipment, and home port industries. These domestic industrial fisheries came about due to the harbor at Pago Pago, 390,000 km<sup>2</sup> 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 last published Statistical Yearbook, main imports include fish brought in for processing (American Samoa Government, 2018). Exports are primarily canned tuna and by-products, including fish meal and pet food. In 2017, domestic exports (including re-exports) from American Samoa were valued at \$309,221,000, of which \$307,732,000 (over 99%) came from canned tuna sale (American Samoa Government, 2018). Private business and commerce comprise a third sector. Unlike some of their neighbors in the South Pacific, American Samoa has never been known for having a robust tourist industry.

In 2017, the ASG employed 5,849 people accounting for 36% of the total workforce in the Territory (American Samoa Government, 2018), and the private sector employed 8,247 people (Figure 6). The canneries employed 2,312 people, accounting 14% of the workforce. Ancillary businesses involved in re-provisioning the fishing fleet also generated a notable number of jobs and income for 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 principal 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 6. American Samoa Employment Estimates from 2008-2017; sourced from the American Samoa Statistical Yearbook 2017, American Samoa Government (2018)**

**Table 25. Supporting data for Figure 6.**

Labor force status	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total Employment	16,990	14,108	18,862	18,028	14,806	16,089	17,565	17,853	17,930	16,408
Total Government	6,035	6,004	6,782	6,177	5,258	6,198	6,556	6,804	6,585	5,849
Canneries	4,861	1,562	1,553	1,815	1,827	2,108	2,500	2,759	2,843	2,312
Other/Private Sector	6,094	6,542	10,527	10,036	7,721	7,783	8,509	8,290	8,502	8,247

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 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, 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 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. A study examining dimensions of cultural fishing for the small and large longline fleets found that these fisheries play an important role in maintaining cultural practices, primarily through sharing of catch (Kleiber and Leong 2018).

### **2.5.3 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, many 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 is still tightly tied to fishing activities.

As described in the Fishery Ecosystem Plan (FEP), American Samoans have been discouraged from working on foreign longline vessels delivering tuna to the canneries for several 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).

### **2.5.3.1 Bottomfish**

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

In the early 1970s, the American Samoa Office of Economic Opportunity (OEO) funded the Dory Project, which provided easy credit and loans to fishermen to develop offshore fisheries. Records indicate that 70% of these dories were engaged in bottomfish fishing 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 bottomfish fishing, and

spearfishing, netting, and vertical longlining were used on occasion. Bottomfish fishing 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.

### 2.5.3.2 Reef Fish

American Samoa's nearshore fishing is focused on the narrow fringing coral reef that partially surrounds the islands (Levine and Allen 2009; Richmond and Levine 2012). A diverse array of fish and shellfish is harvested by 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 offshore. 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 several traditional fisheries associated with seasonal runs of certain species. Atule, or bigeye scad (*Selar crumenophthalmus*), is a coastal migratory species that spawns in mass near shore. Atule are caught through a village-wide effort in some areas where they spawn, with villagers driving the fish to a central location to be harvested. I'asina (juvenile goatfish) are caught in hand-woven funnel traps called enu. Thousands of i'asina may appear along sandy shorelines during the months of October–April. The palolo worm (*Palola viridis*), a coral-dwelling polychaete worm, is another unique species that is caught in large numbers in the Samoa Islands during spawning events. Palolo generally emerge once a year, one week after the full moon in October or November, to release their reproductive segments (epitokes) into nearshore waters. These epitokes are a local delicacy, and Samoans will gather in the thousands at midnight on the predicted spawning event to collect them in hand nets and screens.

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



fish during mass spawning events and share fewer, as they can be stored for longer periods for personal use.

The American Samoa 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 decades despite the increase in the human population over the same time period.

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

### **2.5.3.3 Crustaceans**

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

### **2.5.3.4 Precious Corals**

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

## **2.5.4 Fishery Economic Performance**

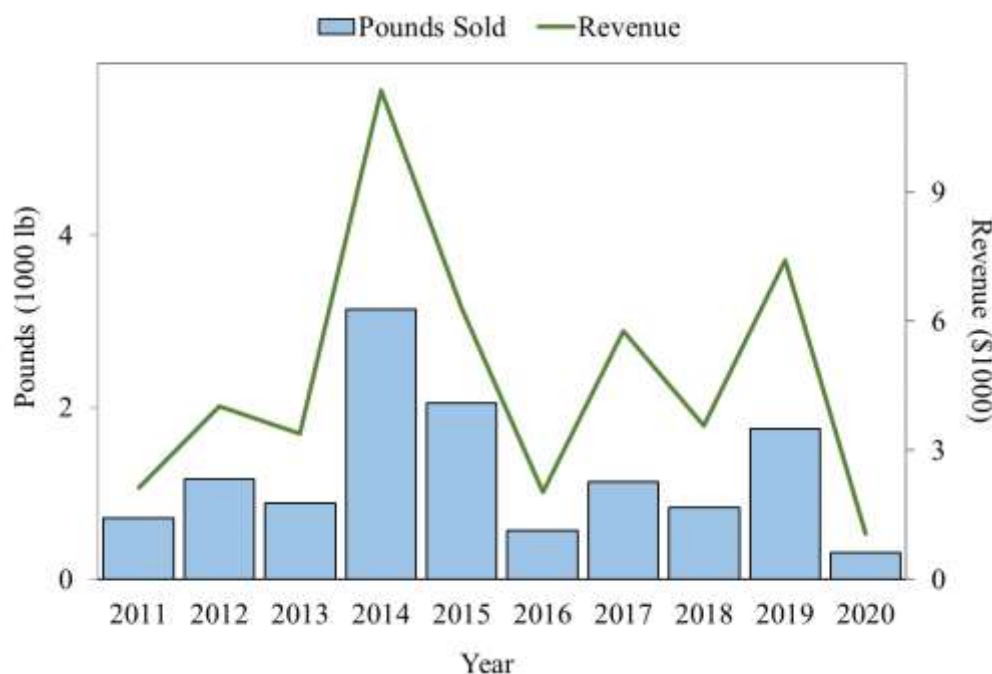
### **2.5.4.1 Bottomfish Fishery Commercial Landings, Revenues, Price**

This section will describe trends in commercial pounds sold, revenues and prices, for the American Samoa bottomfish fishery. Figure 7 presents the trends of commercial pounds sold and revenues of bottomfish fishery (for BMUS only) during 2011-2020 and Figure 8 presents the trend of fish price for bottomfish sold during 2011-2020. Supporting data for Figure 7 and Figure 8 are shown in Table 26. The table also includes the percentage of pounds sold relative to estimates of total pounds landed for the bottomfish fishery. Both nominal and adjusted values are included.

The total pounds sold of bottomfish reported in 2020 were only 307 pounds, 4% of the estimated total landings, while the average percentage sales to total landings in the past 10 years were 17%. Revenue trends follow a similar pattern as pounds sold. The BMUS commercial bottomfish landings and revenue were up and down within a certain range during the period of 2011-2019, but in 2020 both revenue and pounds sold went down considerably. Pounds sold went down 82% and revenue down 86%, compared to 2019, probably due to the impacts of the pandemic.

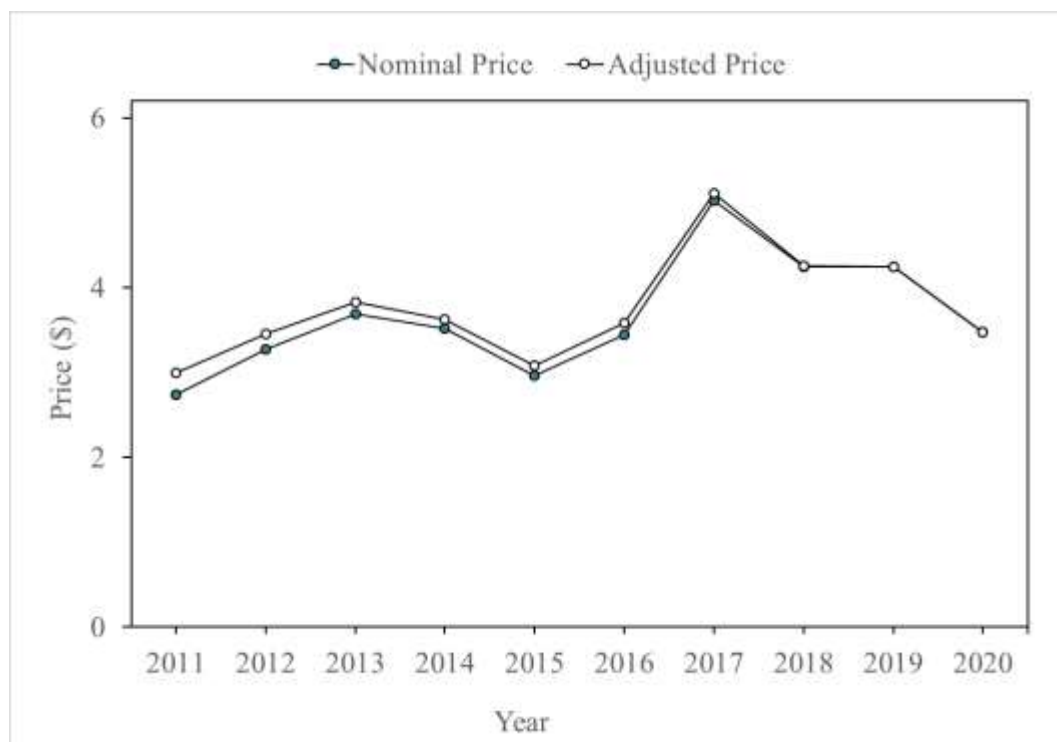
Bottomfish (BMUS) price was steady over most of the time period, but it went up substantially in 2017 then decreased after. The bottomfish price in 2020 was down from \$4.24 in 2019 to \$3.48 per pound in 2020. Low commercial landings and low fish prices resulted in a historical low for bottomfish revenue in 2020.

It is worth noting that the data for pounds caught and pounds sold are collected by two different data collection methods. The data of pounds sold are collected through the Commercial Sales Receipt Books Program, while the data of pounds caught are collected through [Boat- and Shore-Based Creel Surveys](#). Both data series are generated from an expansion algorithm built on a non-census data collection program, and the survey coverage rates of two data collection methods may change independently across individual years. Therefore, the two time series may not move coherently to each other. For example, the low percentage of pounds sold compared to pounds caught could be due to low coverage of dealer participation in the Commercial Receipt Books Program.



**Figure 7. The pounds sold and revenues, for the American Samoa bottomfish fishery, 2011-2020 (adjusted to 2020 dollars<sup>1</sup>)**

<sup>1</sup> The CPI 2020 for American Samoa was not available and assumed it was the same as 2019 as a preliminary estimate.



**Figure 8. The prices of BMUS for the American Samoa bottomfish fishery, 2011-2020**

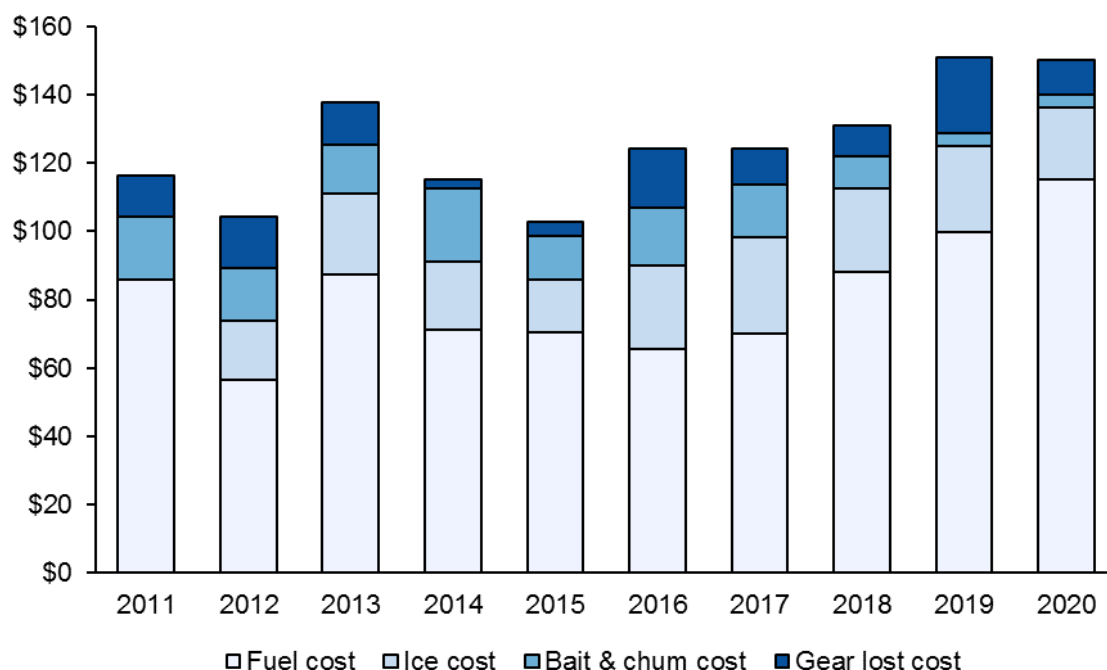
**Table 26. The commercial landings and revenue from bottomfish fishery for American Samoa, 2011-2020**

Year	Estimated pounds caught (lb)	Estimated pounds sold (lb)	Estimated revenue (\$)	Estimated revenue (\$ adjusted)	% of pounds sold	Fish price (\$)	Fish price (\$ adjusted)	CPI adjustor
2011	14,082	711	1,949	2,128	5%	2.74	2.99	1.092
2012	2,099	1,162	3,797	4,013	55%	3.27	3.45	1.057
2013	5,731	882	3,258	3,375	15%	3.69	3.83	1.036
2014	13,982	3,140	11,051	11,371	22%	3.52	3.62	1.029
2015	21,528	2,048	6,073	6,304	10%	2.97	3.08	1.038
2016	19,308	565	1,948	2,024	3%	3.45	3.58	1.039
2017	14,790	1,130	5,676	5,778	8%	5.02	5.11	1.018
2018	11,958	838	3,558	3,565	7%	4.25	4.25	1.002
2019	11,082	1,749	7,423	7,423	16%	4.24	4.24	1
2020	7,750	307	1,067	1,067	4%	3.48	3.48	1

#### 2.5.4.2 Bottomfish Costs of Fishing

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

collected from same subset of fishing trips as the boat-based creel survey carried out by the local fisheries management agencies and WPacFIN. Figure 9 shows the average trip costs for American Samoa bottomfish trips during 2011–2020. In 2020, the average trip costs of bottomfish trips were \$150, similar to 2019, as fuel cost were key cost item and the fuel price in 2020 was similar to 2019. Supporting data for Figure 9 are presented in Table 27. The cost data summaries were generated by excluding outliers (the cases with >10 gallons/hour fished).



**Figure 9. Average costs adjusted for American Samoa bottomfish trips from 2011–2020 adjusted to 2020 dollars**

**Table 27. Average and itemized costs for American Samoa bottomfish trips from 2011–2020 adjusted to 2020 dollars**

Year	Total trip costs (\$)	Total trip cost adj. (\$)	Fuel cost adj. (\$)	Ice cost adj. (\$)	Bait cost adj. (\$)	Gear lost adj. (\$)	Fuel price adj. (\$/gallon)	CPI Adjustor
2011	106	116	86	0	18	12	4.43	1.092
2012	99	110	57	17	15	15	4.43	1.057
2013	133	143	87	24	14	12	4.44	1.036
2014	112	119	71	20	21	2	2.62	1.029
2015	99	107	70	15	13	4	2.07	1.038
2016	119	129	65	24	17	17	2.29	1.039
2017	122	127	70	28	15	11	2.33	1.018
2018	131	131	88	25	10	9	3.19	1.002
2019	151	151	100	25	4	22	3.26	1
2020	150	150	115	21	3	10	3.15	1

Data source: PIFSC Continuous Cost Data Collection Program (Chan and Pan 2019).

#### 2.5.4.3 Ecosystem Component Species

Based on new guidelines for the archipelagic SAFE report from the Council, this section highlights the top 10 ECS (sorted by landings) and the priority ECS (recommended by the local fishery management agency) caught by small boats or shoreline fishing. Please note the top 10

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

Table 28 shows the commercial landings and revenue of the top 10 ECS in American Samoa. The total pounds sold of the top 10 species/species groups was 14,516 pounds (valued at \$45,666) in 2020. The commercial landings of the top 10 species dropped substantially, only 22% of the 2019 level. Revenue also went down significantly, only 23% of the 2019 level. While the total pounds caught/landed for the two years were similar, it seems that the pandemic had more negative impacts on fish trading activities (commercial landings) than fishing activities themselves. Compared to the pounds caught of the top 10 species (presented in the fishery module), the total pounds sold were near five times higher pounds caught (10,255 pounds) in 2019. The sum of top 10 commercial landings was higher than the sum of top 10 landings in previous years, because the commercial landings (pounds sold) were collected through the commercial receipt book program where species were often lumped into species group or family and the data of pounds caught were collected through creel survey where species was more specifically defined. Table 29 shows the priority ECS. Six fish species are suggested as priority species (species of interests) for the area. Only one species (green spiny lobster) of the six showed up in the commercial receipt books in 2020.

**Table 28. Top 10 ECS commercial landings, revenue, and price 2019 and 2020**

	2020			2019		
<b>Top 10 ECS Species</b>	<b>Estimated Pounds Sold</b>	<b>Estimated Revenue</b>	<b>Price per Pound</b>	<b>Estimated Pounds Sold</b>	<b>Estimated Revenue</b>	<b>Price per Pound</b>
Blue-banded surgeonfish	4,822	14,726	3.05	19,974	59,834	3.00
Reef fishes (unknown)	2,403	7,327	3.05	13,561	40,876	3.01
Striped bristletooth	2,094	6,319	3.02	10,318	30,955	3.00
Parrotfishes	1,792	6,264	3.5	8,946	28,145	3.15
Unicornfishes	1,624	4,971	3.06	6,509	19,502	3.00
Pacific sailfin tang	694	2,803	4.04			
Squirrelfishes	300	934	3.11	1,865	5,748	3.08
Swai	354	825	2.33			
Inshore groupers	262	807	3.08	1,461	4,397	3.01
Spiny Lobster	171	690	4.04	1,256	4,040	3.22
Emperors				619	1,856	3.00
Bottomfishes (unknown)				879	2,695	3.07
Total	14,516	45,666	3.15	65,388	198,048	3.03

Data source: WPacFIN, commercial receipt books

**Table 29. Priority ECS commercial landings, revenue, and price 2019 and 2020**

	2020			2019		
<b>Priority Species</b>	<b>Pounds Sold</b>	<b>Revenue (\$)</b>	<b>Price \$/lb</b>	<b>Pounds Sold</b>	<b>Revenue (\$)</b>	<b>Price \$/lb</b>
Green spiny lobster	171	690	4.04			

Data source: WPacFIN commercial receipt books

### 2.5.5 Ongoing Research and Information Collection

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

The table below represents the most recent data available for CFEAI metrics for select regional commercial fisheries for 2020. Entries for American Samoa insular fisheries are bolded in red. These values represent the most recent year of data for key economic data monitoring parameters (fishing revenues, operating costs, and fixed costs). The assessment column indicates the most recent publication year for specific economic assessments (returns above operating cost, profit), where available.

**Table 30. Pacific Islands Region 2020 Commercial Fishing Economic Assessment Index**

	2020 CFEAI				
	2020 Reporting Year (e.g. 1/2020-12/2020)				
	Data			Assessment	
Pacific Islands Fisheries	Fishing Revenue Most Recent Year	Operating Cost Most Recent Year	Fixed Cost Most Recent Year	Returns Above Operating Costs (Quasi Rent) Assessment Most Recent Year	Profit Assessment Most Recent Year
HI Longline	2020	2020	2013	2020	2016
ASam Longline	2020	2020	2016	2020	2019
HI Offshore Handline	2020	2014	2014	2019	2019
HI Small Boat (pelagic)	2020	2014	2014	2017	2019
HI Small Boat (bottomfish)	2020	2014	2014	2017	2019
HI Small Boat (reef)	2020	2014	2014	2017	2019
Guam Small boat	2020	2020	2019	2019	
CNMI Small boat	2020	2020	2019	2019	
<b>ASam Small boat</b>	<b>2020</b>	<b>2020</b>	<b>2015</b>	<b>2020</b>	

PIFSC also generates projections for upcoming fiscal years, and the table below provides the projected CFEAI report for 2021 (*all projected activities and analyses are subject to funding*). Based on early projections PIFSC intends to maintain ongoing economic data collections in American Samoa for both the longline fishery (Pan 2018) and small boat fisheries (Chan and Pan, 2019) during 2021. PIFSC intends to conduct a cost-earnings survey of the American Samoa small boat fishery in 2021. This survey will provide updated data on fishing revenues, operating costs, and fixed costs, as well as numerous elements related to fishing behavior, market participation, and fishery demographics for American Samoa bottomfish and boat-based reef fisheries.

**Table 31. Pacific Islands Region 2021 Commercial Fishing Economic Assessment Index**

	2021 Projected CFEAI				
	2021 Reporting Year (e.g. 1/2021-12/2021)				
	Data			Assessment	
Pacific Islands Fisheries	Fishing Revenue Most Recent Year	Operating Cost Most Recent Year	Fixed Cost Most Recent Year	Returns Above Operating Costs (Quasi Rent) Assessment Most Recent Year	Profit Assessment Most Recent Year
HI Longline	2021	2021	2013	2021	2016
ASam Longline	2021	2021	2016	2021	2019
HI Offshore Handline	2021	2021	2021	2019	2019
HI Small Boat (pelagic)	2021	2021	2021	2017	2019
HI Small Boat (bottomfish)	2021	2021	2021	2017	2019
HI Small Boat (reef)	2021	2021	2021	2017	2019
Guam Small boat	2021	2021	2019	2021	
CNMI Small boat	2021	2021	2019	2021	
<b>ASam Small boat</b>	<b>2021</b>	<b>2021</b>	<b>2021</b>	<b>2021</b>	

Community social indicators have been generated for American Samoa (Kleiber *et al.*, 2018) in accordance with a national project to describe and evaluate community well-being in terms of environmental justice, economic vulnerability, and gentrification pressure (<https://www.fisheries.noaa.gov/national/socioeconomics/social-indicators-coastal->



[communities](#)). However, these indicators rely on Census data, and cannot be updated until 2020 Census data becomes available.

## 2.5.6 Relevant PIFSC Economics and Human Dimensions Publications: 2020

<b>Publication</b>	<b>MSRA Priority</b>
Ayers A, Leong K. 2020. Stories of Conservation Success: Results of Interviews with Hawai'i Longline Fishers. Pacific Islands Fisheries Science Center, PIFSC Administrative Report, H-20-11, 43 p. <a href="https://doi.org/10.25923/6bnn-m598">https://doi.org/10.25923/6bnn-m598</a>	PS1.4.2 PS2.1 PS2.4 HC3.2.2
Ingram RJ, Leong KM, Gove J, Wongbusarakum S. 2020. Including Human Well-Being in Resource Management with Cultural Ecosystem Services. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC112, 95 p. <a href="https://doi.org/10.25923/q8ya-8t22">https://doi.org/10.25923/q8ya-8t22</a>	IF8.1.1 HC2.1.1
Leong KM, Decker DJ. 2020. Human Dimensions Considerations in Wildlife Disease Management: U.S. Geological Survey Techniques and Methods. Book 15, chap. C8, 21 p. <a href="https://doi.org/10.3133/tm15C8">https://doi.org/10.3133/tm15C8</a>	HC3.2.3 HC3.2.4
Leong KM, Gramza AR, Lepczyk CA. 2020. Understanding conflicting cultural models of outdoor cats to overcome conservation impasse. Conservation Biology. 34(5):1190-1199. <a href="https://doi.org/10.1111/cobi.13530">https://doi.org/10.1111/cobi.13530</a>	HC3.2.3 HC3.2.4
Leong KM, Torres A, Wise S, Hospital J. 2020. Beyond recreation: when fishing motivations are more than sport or pleasure. Pacific Islands Fisheries Science Center, PIFSC Administrative Report, H-20-05, 57 p. <a href="https://doi.org/10.25923/k5hk-x319">https://doi.org/10.25923/k5hk-x319</a>	HC1.2 HC3.1.1 HC3.2.1
National Marine Fisheries Service (NMFS). 2020. NOAA Fisheries Initial Impacts Assessment of the COVID-19 Crisis on the U.S. Commercial Seafood and Recreational For-Hire/Charter Industries. 32p. <a href="https://media.fisheries.noaa.gov/2021-02/Initial-COVID-19-ImpactAssessment-webready.pdf">https://media.fisheries.noaa.gov/2021-02/Initial-COVID-19-ImpactAssessment-webready.pdf</a>	HC1
Oliver TA, Hospital J, Brainard RE. 2020. Spatial Prioritization under Resilience Based Management: Evaluating Trade-offs among Prioritization Strategies. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFSPIFSC-105, 47 p. <a href="https://doi.org/10.25923/xd2-t259">https://doi.org/10.25923/xd2-t259</a>	HC2.1.2 HC2.2.1
Oliver TA, Kleiber D, Hospital J, Maynard J, Tracey D. 2020. Coral Reef Resilience and Social Vulnerability to Climate Change: American Samoa. Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-20-002d, 6 p. <a href="https://doi.org/10.25923/t9tm-pa91">https://doi.org/10.25923/t9tm-pa91</a>	HC2.1.2 HC2.2.1

<b>Publication</b>	<b>MSRA Priority</b>
Pacific Islands Fisheries Science Center. 2020. Fishery Ecosystem Analysis Tool (FEAT). <a href="https://origin-apps-pifsc.fisheries.noaa.gov/FEAT/#/">https://origin-apps-pifsc.fisheries.noaa.gov/FEAT/#/</a>	HC1.1.1 HC3.1.3
Pacific Islands Fisheries Science Center. 2020. Pacific Islands Fisheries Impacts from COVID-19: Pacific Islands Snapshot, March-July 2020. 10p. <a href="https://media.fisheries.noaa.gov/2021-02/Pacific-Islands-COVID-19-ImpactSnapshot-webready.pdf">https://media.fisheries.noaa.gov/2021-02/Pacific-Islands-COVID-19-ImpactSnapshot-webready.pdf</a>	HC1
Sterling EJ, Pascua P, Sigouin A, Gazit N, Mandle L, Betley E, Aini J, Albert S, Caillon S, Caselle JE, Wongbusarakum S, et al. 2020. Creating a space for place and multidimensional well-being: lessons learned from localizing the SDGs. Sustainability Science. 15(4):1129-47. <a href="https://doi.org/10.1007/s11625-020-00822-w">https://doi.org/10.1007/s11625-020-00822-w</a>	HC2.1.1 HC2.2.2
Wongbusarakum S, Kindinger T, Gorstein M. 2020. Assessing socio-economic indicators to improve their usefulness for resource management in the US Pacific islands. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-98, 67 p. <a href="https://doi.org/10.25923/27jh-pm07">https://doi.org/10.25923/27jh-pm07</a>	HC1.1.7 HC1.1.9 HC2.1.2

## **2.6 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.

### **2.6.1 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.

#### **2.6.1.1 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 prohibitions benefit protected species by preventing potential interactions with non-selective fishing gear.

#### **2.6.1.2 ESA Consultations**

ESA consultations were conducted by NMFS and the U.S. Fish and Wildlife Service (USFWS; 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 ESA-listed species or adversely modifying critical habitat. The results of these consultations conducted under section 7 of the ESA are briefly described below and summarized in Table 32.

NMFS concluded in an informal consultation dated April 9, 2015 that all fisheries managed under the American Samoa FEP are not likely to adversely affect the Indo-West Pacific distinct population segment (DPS) of scalloped hammerhead shark or ESA-listed reef-building corals.

**Table 32. Summary of ESA consultations for American Samoa FEP Fisheries**

<b>Fishery</b>	<b>Consultation date</b>	<b>Consultation type<sup>a</sup></b>	<b>Outcome<sup>b</sup></b>	<b>Species</b>
Bottomfish	3/3/2002	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
	Initiated 6/5/2019	<i>Consultation ongoing</i>		Oceanic whitetip shark, giant manta ray, chambered nautilus
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
	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.
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
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
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
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
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
All fisheries	4/9/2015	LOC	NLAA	Reef-building corals, scalloped hammerhead shark (Indo-West Pacific DPS)

<sup>a</sup> BiOp = Biological Opinion; LOC = Letter of Concurrence

<sup>b</sup> 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).

On June 5, 2019, NMFS reinitiated consultation for the American Samoa bottomfish fisheries due to the listing of the oceanic whitetip shark, giant manta ray, and chambered nautilus under the ESA. On June 6, 2019 (extended on August 11, 2020), NMFS determined that the conduct of the American Samoa bottomfish fisheries during the period of consultation will not violate ESA Section 7(a)(2) and 7(d).

#### *Crustacean Fishery*

In an informal consultation completed on September 28, 2007, NMFS 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).

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

#### *Coral Reef Ecosystem Fishery*

In an informal consultation completed on March 7, 2002, NMFS 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).

On May 22, 2002, the USFWS concurred with the determination of NMFS that the activities conducted under the Coral Reef Ecosystems FMP are not likely to adversely affect listed species under USFWS's exclusive jurisdiction (i.e., seabirds) and listed species shared with NMFS (i.e., sea turtles).

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

#### *Precious Coral Fishery*

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

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

### **2.6.1.3 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 2020 LOF (86 FR 3028, January 14, 2021) 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).

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

### *Bottomfish and Coral Reef Fisheries*

There are no observer data available for the American Samoa bottomfish or coral reef fisheries. However, based on the information in the 2002 BiOp for fisheries operating under the American Samoa FEP, bottomfish fisheries are not expected to interact with any ESA-listed species in federal waters around American Samoa. Based on current ESA consultations, coral reef 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 and coral reef commercial fisheries will not affect marine mammals in any manner not considered or authorized under the MMPA.

As described in Section 2.6.1.2, ESA consultation for newly listed elasmobranch species in the American Samoa bottomfish fishery is ongoing. There are no known interactions with oceanic whitetip shark or giant manta rays in this fishery.

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

### *Crustacean and Precious Coral Fisheries*

There are currently no crustacean or precious coral fisheries operating in federal waters around 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 and precious coral commercial fisheries will not affect marine mammals in any manner not considered or authorized under the MMPA.

## 2.6.3 Identification of Emerging Issues

Table 33 summarizes current candidate ESA species, recent listing status, and post-listing activity (critical habitat designation and recovery plan development). Impacts from FEP-managed fisheries on any new listings and critical habitat designations will be considered in future versions of this report.

**Table 33. Status of candidate ESA species, recent ESA listing processes, and post-listing activities**

Species		Listing Process			Post-Listing Activity	
Common Name	Scientific Name	90-Day Finding	12-Month Finding / Proposed Rule	Final Rule	Critical Habitat	Recovery Plan
<b>Oceanic whitetip shark</b>	<i>Carcharhinus longimanus</i>	Positive (81 FR 1376, 1/12/2016)	Positive, threatened (81 FR 96304, 12/29/2016)	Listed as threatened (83 FR 4153, 1/30/2018)	Designation not prudent; no areas within U.S. jurisdiction that meet definition of critical habitat (85 FR 12898, 3/5/2020)	In development; recovery planning workshops convened in 2019.
<b>Chambered nautilus</b>	<i>Nautilus pompilius</i>	Positive (81 FR 58895, 8/26/2016)	Positive, threatened (82 FR 48948, 10/23/2017)	Listed as threatened (83 FR 48876, 9/28/2018)	Designation not prudent; no areas within U.S. jurisdiction that meet definition of critical habitat (85 FR 5197, 01/29/2020)	TBA
<b>Giant manta ray</b>	<i>Manta birostris</i>	Positive (81 FR 8874, 2/23/2016)	Positive, threatened (82 FR 3694, 1/12/2017)	Listed as threatened (83 FR 2916, 1/22/2018)	Designation not prudent; no areas within U.S. jurisdiction that meet definition of critical habitat (84 FR 66652, 12/5/2019)	Recovery outline published 12/4/19 to serve as interim guidance until full recovery plan is developed; recovery planning workshop planned for 2021.
<b>Corals</b>	N/A	Positive for 82 species (75 FR 6616, 2/10/2010)	Positive for 66 species (77 FR 73219, 12/7/2012)	20 species listed as threatened (79 FR 53851, 9/10/2014)	Critical habitat proposed (85 FR 76262, 11/27/2020), comment period extended through 5/26/2021 (86 FR 16325)	In development, interim recovery outline in place; recovery workshops convened in May 2021.
<b>Cauliflower coral</b>	<i>Pocillopora meandrina</i>	Positive (83 FR 47592, 9/20/2018)	Not warranted (85 FR 40480, 7/6/20)	N/A	N/A	N/A

Species		Listing Process			Post-Listing Activity	
Common Name	Scientific Name	90-Day Finding	12-Month Finding / Proposed Rule	Final Rule	Critical Habitat	Recovery Plan
<b>Giant clams</b>	<i>Hippopus</i> , <i>H. porcellanus</i> , <i>Tridacna costata</i> , <i>T. derasa</i> , <i>T. gigas</i> , <i>T. Squamosa</i> , and <i>T. tevoroa</i>	Positive (82 FR 28946, 06/26/2017)	TBA (status review ongoing)	TBA	N/A	N/A
<b>Green sea turtle</b>	<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 TBA	TBA
<b>Leatherback sea turtle</b>	<i>Dermochelys coriacea</i>	Positive 90-day finding on a petition to identify the Northwest Atlantic leatherback turtle as a DPS (82 FR 57565, 12/06/2017)	7 populations qualify as DPS, but DPS listing not warranted due to all populations meeting existing endangered classification; no changes proposed to existing global listing (85 FR 48332, 8/10/20)	N/A	N/A	N/A

<sup>a</sup> NMFS and USFWS have been tasked with higher priorities regarding sea turtle listings under the ESA, and do not anticipate proposing green turtle critical habitat designations in the immediate future.

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

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

- Improve species identification of commercial and non-commercial fisheries data (e.g., outreach, use FAO species codes) to improve understanding of potential protected species impacts.
- Define and evaluate innovative approaches to derive robust estimates of protected species interactions in insular fisheries.



- Conduct genetic and telemetry research to improve understanding of population structure and movement patterns for listed elasmobranchs.
- Estimates of post release survival for incidental protected species.

## **2.7 CLIMATE AND OCEANIC INDICATORS**

### **2.7.1 Introduction**

Over the past few years, the Council has incorporated climate change into the overall management of the fisheries over which it has jurisdiction. This 2020 annual SAFE report includes a now standard chapter on indicators of climate and oceanic conditions in the Western Pacific region. These indicators reflect global climate variability and change as well as trends in local oceanographic conditions.

The reasons for the Council's decision to provide and maintain an evolving discussion of climate conditions as an integral and continuous consideration in their deliberations, decisions, and reports are numerous:

- Emerging scientific and community understanding of the impacts of changing climate conditions on fishery resources, the ecosystems that sustain those resources, and the communities that depend upon them;
- Recent Federal Directives including the 2010 implementation of a National Ocean Policy that identified Resiliency and Adaptation to Climate Change and Ocean Acidification as one of nine National priorities as well as the development of a Climate Science Strategy by NMFS in 2015 and the subsequent development of the Pacific Islands Regional Action Plan for climate science; and
- The Council's own engagement with NOAA as well as jurisdictional fishery management agencies in American Samoa, CNMI, Guam, and Hawaii as well as fishing industry representatives and local communities in those jurisdictions.

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

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

Beginning with the 2015 report, the Council and its partners began providing continuing descriptions of changes in a series of climate and oceanic indicators. The MPCCC was disbanded in early 2019, re-allocating its responsibilities among its members already on other committees or teams, such as the Fishery Ecosystem Plan Teams.

This annual report focuses previous years' efforts by refining existing indicators and improving communication of their relevance and status. Future reports will include additional indicators as the information becomes available and their relevance to the development, evaluation, and revision of the FEPs becomes clearer. Working with national and jurisdictional partners, the Council will make all datasets used in the preparation of this and future reports available and easily accessible.

### **2.7.2 Response to Previous Plan Team and Council Recommendations**

There were no Council recommendations relevant to the climate and oceanic indicators section of the annual SAFE report for the American Samoa Archipelago in 2020.

### **2.7.3 Conceptual Model**

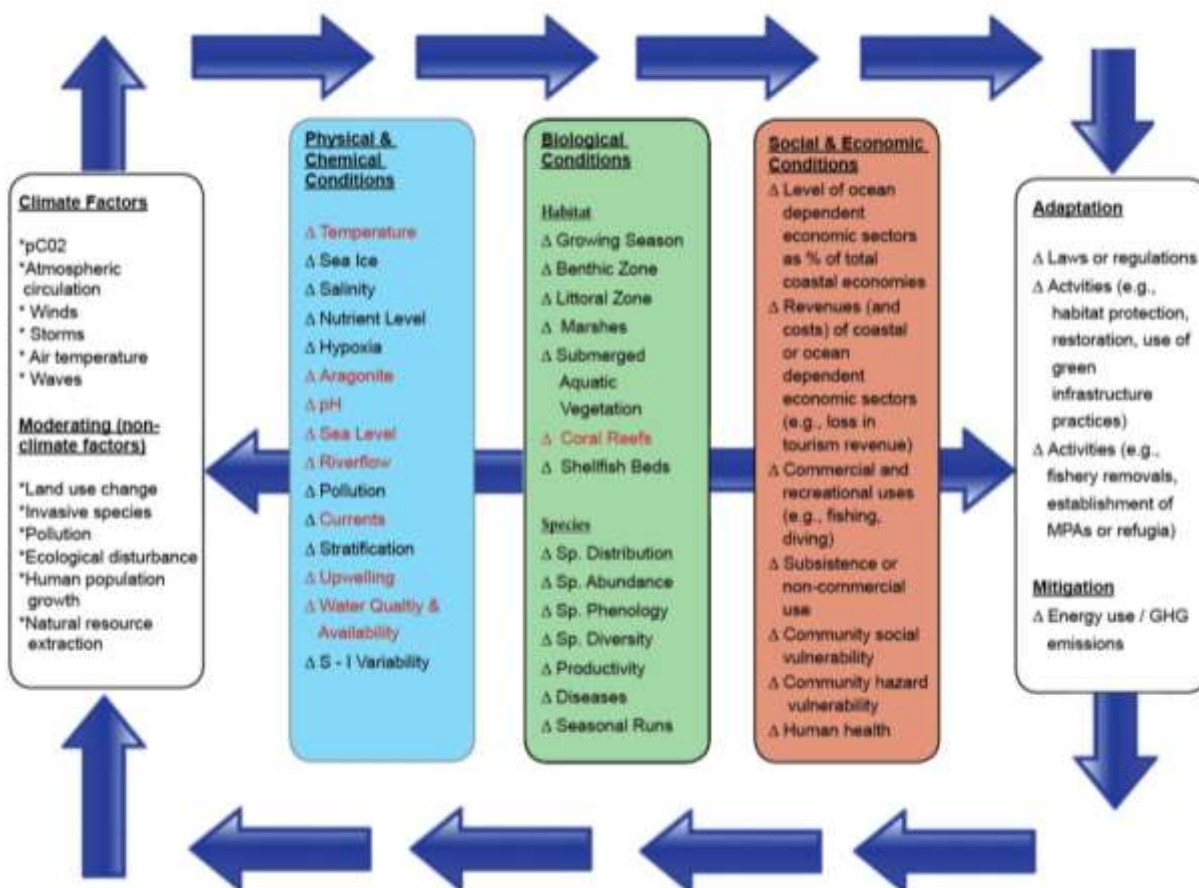
In developing this chapter, the Council relied on a number of recent reports conducted in the context of the U.S. National Climate Assessment including, most notably, the 2012 Pacific Islands Regional Climate Assessment (PIRCA) and the Ocean and Coasts chapter of the 2014 report on a Pilot Indicator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

The Advisory Committee Report presented a possible conceptual framework designed to illustrate how climate factors can connect to and interact with other ecosystem components to impact ocean and coastal ecosystems and human communities. The Council adapted this model with considerations relevant to the fishery resources of the Western Pacific region (Figure 10).

As described in the 2014 NCADAC report, the conceptual model presents a “simplified representation of climate and non-climate stressors in coastal and marine ecosystems.” For the purposes of this Annual Report, the modified Conceptual Model allows the Council and its partners to identify indicators of interest to be monitored on a continuing basis in coming years. The indicators shown in red were considered for inclusion in the Annual SAFE Reports, though the final list of indicators varied somewhat. Other indicators will be added over time as data become available and an understanding of the causal chain from stressors to impacts emerges.

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

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

## 2.7.4 Selected Indicators

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

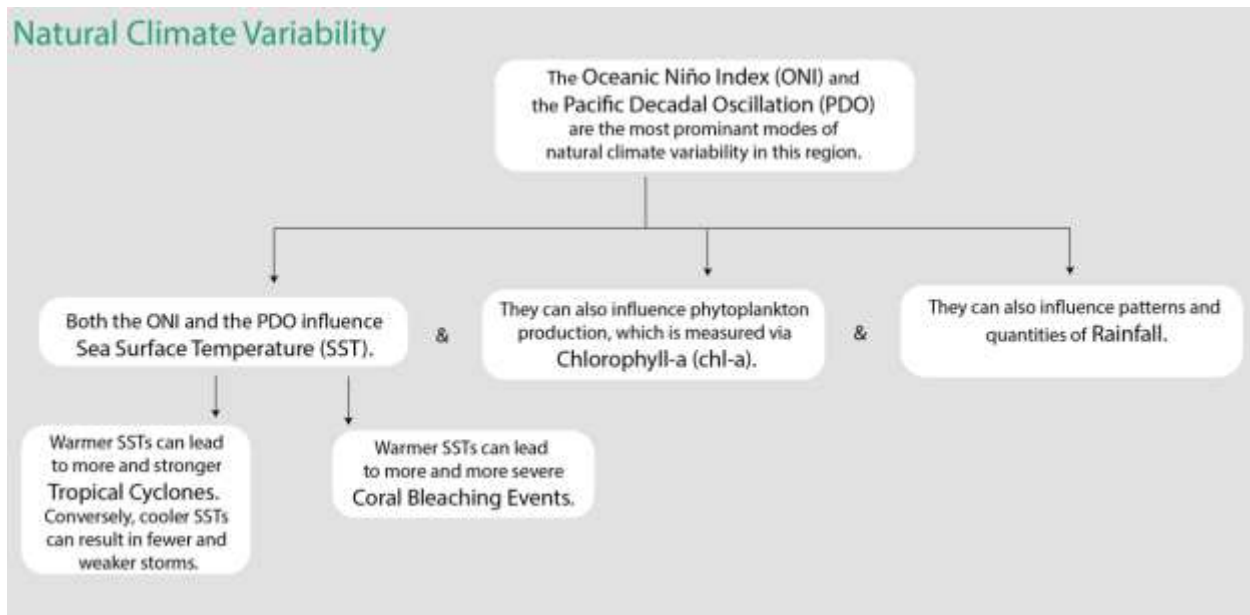
- Be fisheries relevant and informative;
- Build intuition about current conditions considering changing climate;
- Provide historical context; and
- Recognize patterns and trends.

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

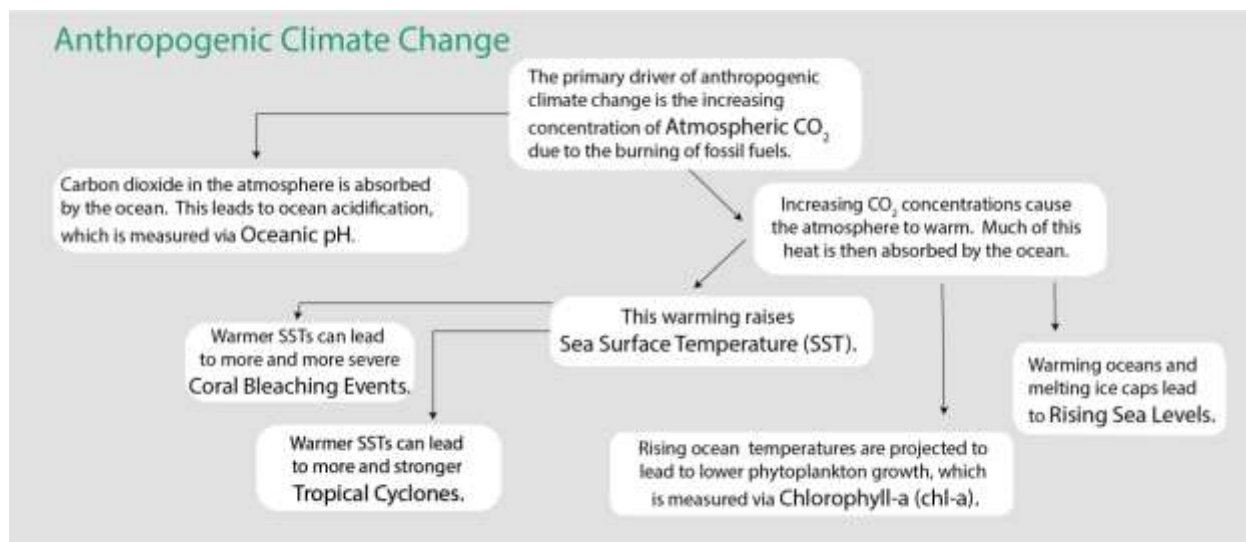
- Atmospheric concentration of carbon dioxide (CO<sub>2</sub>)
- Oceanic pH at Station ALOHA;

- Oceanic Niño Index (ONI);
- Pacific Decadal Oscillation (PDO);
- Tropical cyclones;
- Sea surface temperature (SST);
- Coral Thermal Stress Exposure
- Chlorophyll-A
- Rainfall
- Sea Level (Sea Surface Height)

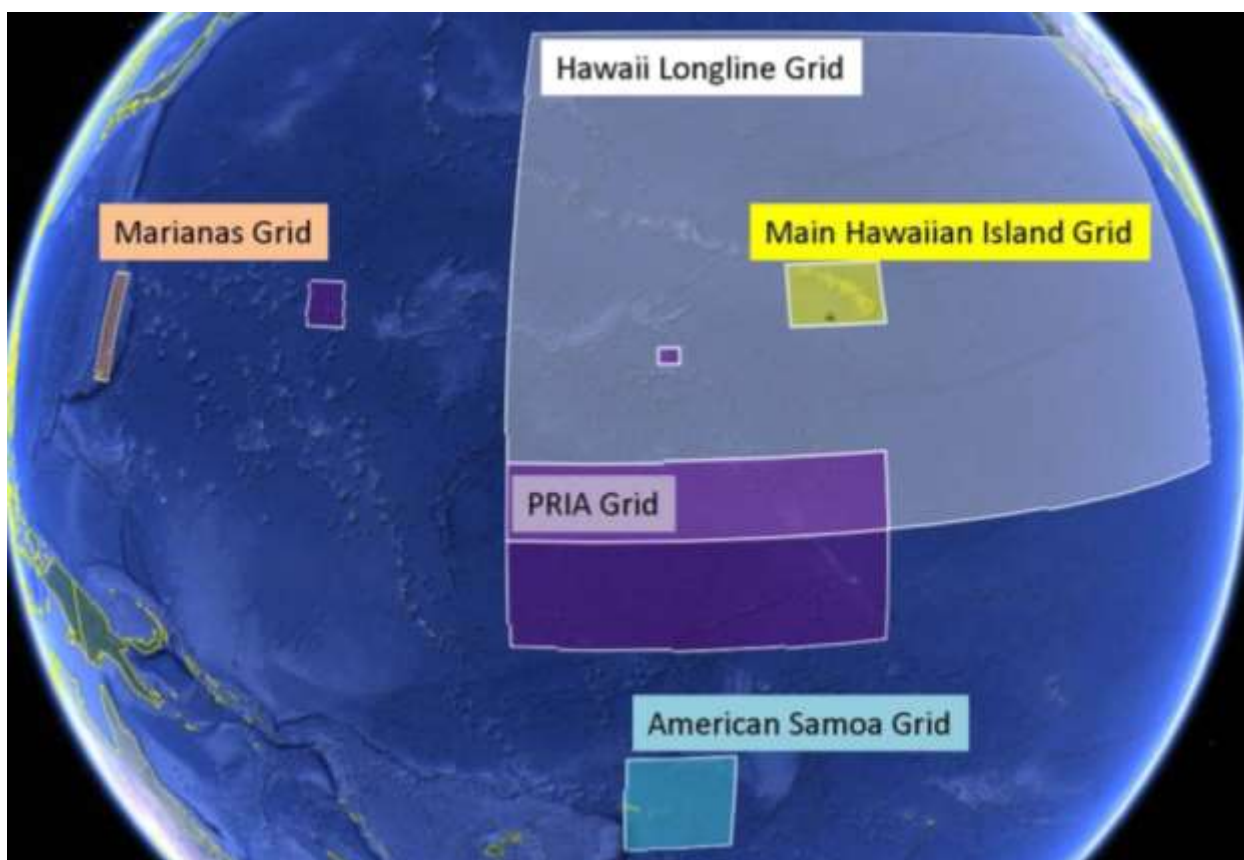
Figure 11 and Figure 12 provide a description of these indicators and illustrate how they are connected to each other in terms of natural climate variability and anthropogenic climate change.



**Figure 11. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability**



**Figure 12 Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of anthropogenic climate change**



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

#### 2.7.4.1 Atmospheric Concentration of Carbon Dioxide at Mauna Loa

**Rationale:** Atmospheric carbon dioxide (CO<sub>2</sub>) is a measure of what human activity has already done to affect the climate system through greenhouse gas emissions. It provides quantitative information in a simplified, standardized format that decision makers can easily understand. This indicator demonstrates that the concentration (and, in turn, warming influence) of greenhouse gases in the atmosphere has increased substantially over the last several decades.

**Status:** Atmospheric CO<sub>2</sub> is increasing exponentially. This means that atmospheric CO<sub>2</sub> is increasing at a faster rate each year. In 2020, the annual mean concentration of CO<sub>2</sub> was 414 parts per million (ppm). In 1959, the first year of the time series, it was 316 ppm. The annual mean passed 350 ppm in 1988, and 400 ppm in 2015.

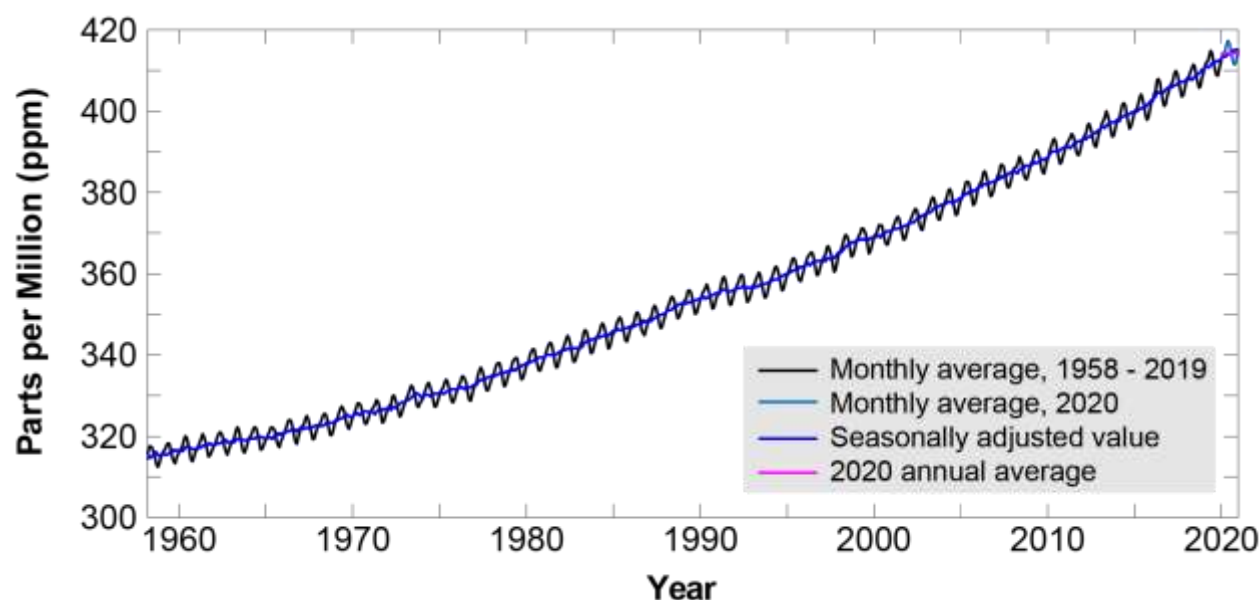
**Description:** Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawai‘i in ppm from March 1958 to present. The observed increase in monthly average carbon dioxide concentration is primarily due to CO<sub>2</sub> emissions from fossil fuel burning. Carbon dioxide remains in the atmosphere for a long time, and emissions from any location mix throughout the atmosphere in approximately one year. The annual variations at Mauna Loa, Hawai‘i are due to the seasonal imbalance between the photosynthesis and respiration of terrestrial plants. During the summer growing season, photosynthesis exceeds respiration, and CO<sub>2</sub> is removed from the atmosphere. In the winter (outside the growing season), respiration exceeds photosynthesis, and CO<sub>2</sub> is returned to the atmosphere. The seasonal cycle is strongest in the northern hemisphere because of its larger land mass.

**Timeframe:** Annual, monthly.

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

**Measurement Platform:** *In-situ* station.

**Sourced from:** Keeling et al. (1976), Thoning et al. (1989), and NOAA (2021a).



**Figure 14. Monthly mean (black) and seasonally corrected (blue) atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii**

#### 2.7.4.2 Oceanic pH

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

**Status:** The ocean is roughly 9.4% more acidic than it was 30 years ago at the start of this time series. Over this time, pH has declined by 0.043 at a constant rate. In 2019, the most recent year for which data are available, the average pH was 8.06. Additionally, small variations seen over the course of the year are outside the range seen in the first year of the time series for the third year in a row. The highest pH value reported for the most recent year (8.077) is lower than the lowest pH value reported in the first year of the time series (8.081).

**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 2019 (2020 data are not yet available). Oceanic pH is a measure of ocean acidity, which increases as the ocean absorbs carbon dioxide from the atmosphere. Lower pH values represent greater acidity. Oceanic pH is calculated from total alkalinity (TA) and dissolved inorganic carbon (DIC). Total alkalinity represents the ocean's capacity to resist acidification as it absorbs CO<sub>2</sub> and the amount of CO<sub>2</sub> absorbed is captured through measurements of DIC. The multi-decadal time series at Station ALOHA represents the best available documentation of the significant downward trend in oceanic pH since the time series began in 1988. Oceanic pH varies over both time and space, though the conditions at Station ALOHA are considered broadly representative of those across the Western and Central Pacific's pelagic fishing grounds.

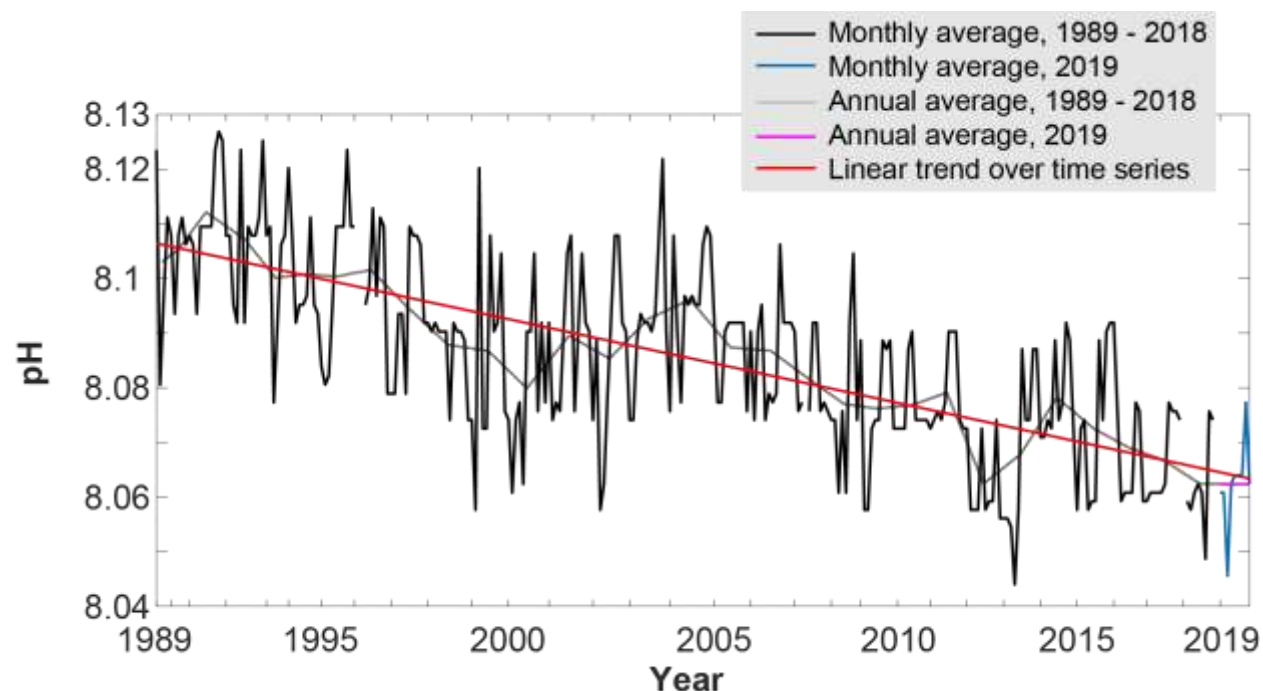


Timeframe: Monthly.

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

Measurement Platform: *In-situ* station.

Sourced from: Fabry et al. (2008), Feely et al. (2016), and the Hawai‘i Ocean Time Series as described in Karl et al. (1996) and on its website (HOT 2021).



**Figure 15. Time series and long-term trend of oceanic pH measured at Station ALOHA from 1989-2019**

### 2.7.4.3 Oceanic Niño Index

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

Status: In autumn of 2020, the ONI transitioned from neutral to La Niña conditions. Over the year, the ONI ranged from 0.5 to -1.3. This is within the range of values observed previously in the time series.

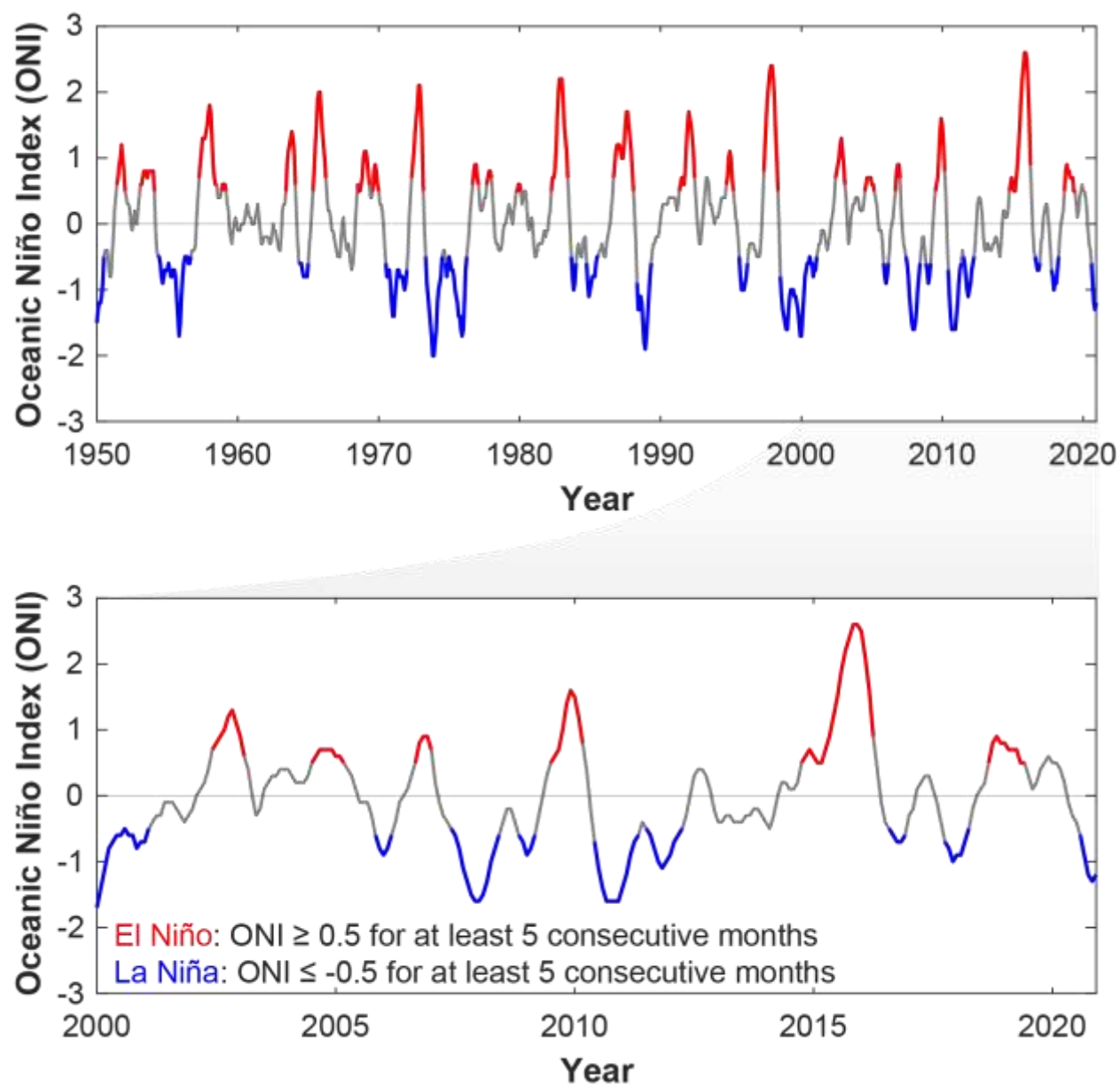
Description: The three-month running mean of satellite remotely-sensed sea surface temperature (SST) anomalies in the Niño 3.4 region (5°S – 5°N, 120° – 170°W). The ONI is a measure of the ENSO phase. Warm and cool phases, termed El Niño and La Niña respectively, are based in part on an ONI threshold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

Timeframe: Every three months.

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

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

Sourced from NOAA CPC (2021).



**Figure 16. Oceanic Niño Index from 1950-2020 (top) and 2000-2020 (bottom) with El Niño periods in red and La Niña periods in blue**

#### 2.7.4.4 Pacific Decadal Oscillation

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

**Status:** The PDO was negative in 2020. The index ranged from -0.51 to -1.75 over the course of the year. This is within the range of values observed previously in the time series.

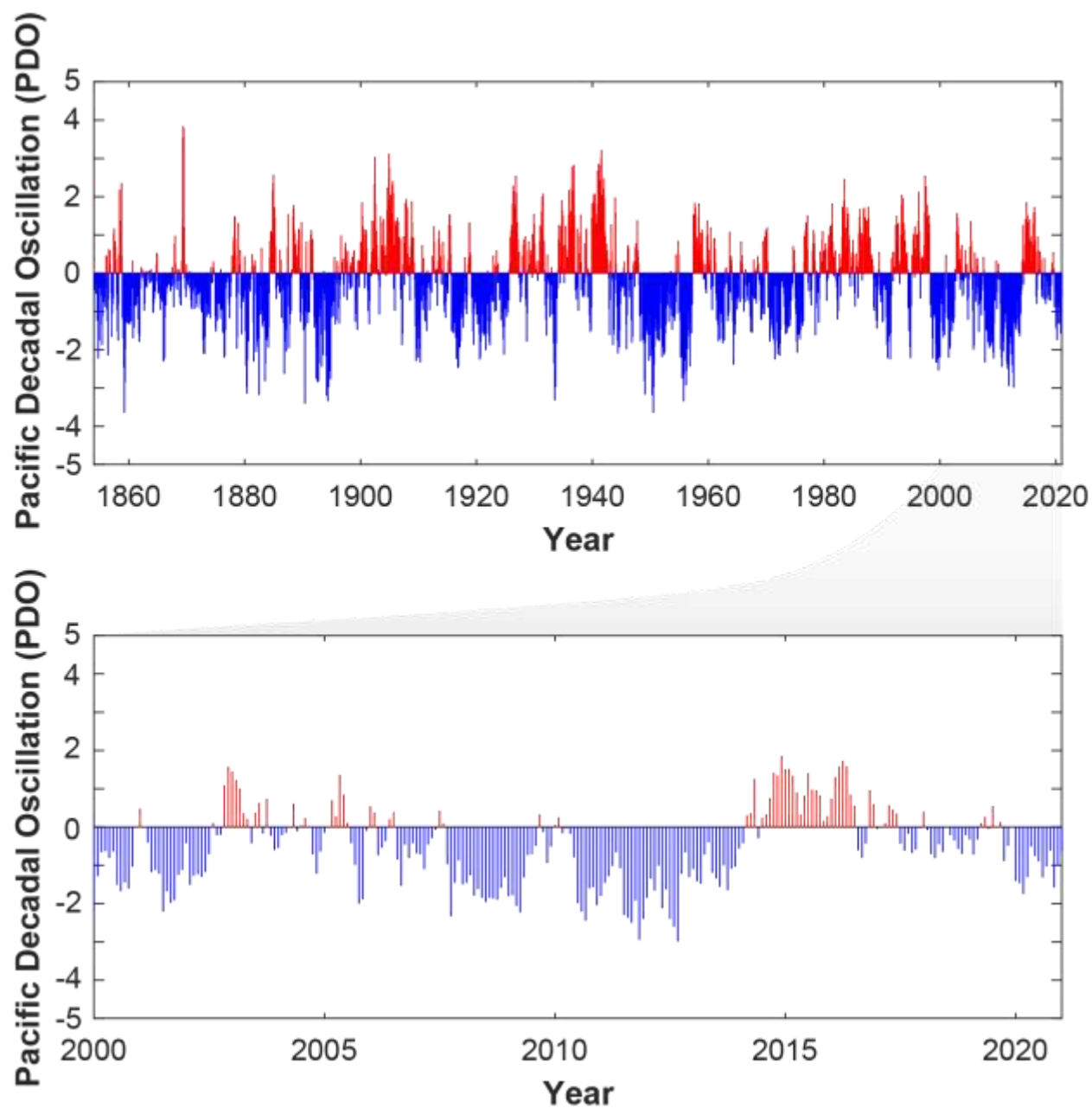
**Description:** The PDO is often described as a long-lived El Niño-like pattern of Pacific climate variability. As seen with the better-known ENSO, extremes in the PDO pattern are marked by widespread variations in the Pacific Basin and the North American climate. In parallel with the ENSO phenomenon, the extreme cases of the PDO have been classified as either warm or cool, as defined by ocean temperature anomalies in the northeast and tropical Pacific Ocean. When SST is below average in the interior North Pacific and warm along the North American coast, and when sea level pressures are below average in the North Pacific, the PDO has a positive value. When the climate patterns are reversed, with warm SST anomalies in the interior and cool SST anomalies along the North American coast, or above average sea level pressures over the North Pacific, the PDO has a negative value. (NOAA ESRL 2021a).

**Timeframe:** Annual, monthly.

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

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

**Sourced from:** NOAA (2021b), Mantua (2017).



**Figure 17. Pacific Decadal Oscillation from 1950-2020 (top) and 2000-2020 (bottom) with positive warm periods in red and negative cool periods in blue**

#### 2.7.4.5 Tropical Cyclones

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

**Status:**

*Eastern North Pacific.* Overall, the 2020 eastern Pacific hurricane season featured an average number of named storms, but below average hurricane and major hurricane activity. There were sixteen named storms, of which four became hurricanes and three became major hurricanes - category 3 or higher on the Saffir-Simpson Hurricane Wind Scale. This compares to the long-term averages of fifteen named storms, eight hurricanes, and four major hurricanes. There were also five tropical depressions that did not reach tropical storm strength. Two tropical storms, Odalys and Polo, formed in the basin in November. Although the long-term (1981-2010) average is one tropical storm forming in the basin every second or third year, this is the third straight November with at least one named storm forming. In fact, named storms have formed in November in six of the past seven years in the basin. In terms of Accumulated Cyclone Energy (ACE), which measures the strength and duration of tropical storms and hurricanes, activity in the basin for 2020 was below normal, more than 40 percent below the long-term average.

Summary inserted from <https://www.nhc.noaa.gov/text/MIATWSEP.shtml>.

*Central North Pacific.* Tropical cyclone activity in the central Pacific in 2020 was slightly below average. While there was only one named storm, which is below the 1981 – 2010 average of three, this storm was particularly noteworthy. July's hurricane Douglas reached category 4 strength, making it a major hurricane. Its intensity fell prior to its passage just north of the main Hawaiian Islands. On average, the central Pacific sees three named storms, two hurricanes, and no major hurricanes. The 2020 ACE index was about an order of magnitude below the 1981 – 2010 average.

*Western North Pacific.* Tropical cyclone activity was below average in the western Pacific in 2020. There were 23 named storms, compared to an average of 26. Twelve of these developed into typhoons, and seven of these typhoons were major. An average year would see 17 typhoons, nine of which would be major. The West Pacific was unusually quiet in 2020 with less than half its normal ACE (third lowest since 1981). The West Pacific did have the strongest storm of 2020, Super Typhoon Goni, which made landfall in the Philippines as a powerful category 5 storm. The initial estimates of 195-mph winds during its landfall would be the strongest on record. Portions of the summary inserted from <https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202013>.

*South Pacific.* Tropical cyclone activity in the south Pacific region was roughly average in 2020. There were ten named storms, five of which developed into cyclones and one of which – Harold – was major. The long-term average in this region is nine named storms, five cyclones, and two major cyclones. The strongest cyclone of the Southern Hemisphere season was category-5 Tropical Cyclone Harold. Harold alone accounted for more than half of the Southwest Pacific's ACE for 2020 (overall, the region's ACE index was below average in 2020). It was the first

category 5 storm in the Southern Hemisphere since Tropical Cyclone Gita in 2018. Harold caused widespread damage throughout the South Pacific Islands, particularly in Vanuatu where it achieved its peak intensity. Portions of the summary inserted from <https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202013>.

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

The annual frequency of storms passing through each basin is tracked and a bar plots shows the representative breakdown of Saffir-Simpson hurricane categories.

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

Timeframe: Annual.

Region/Location:

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

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

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

South Pacific: south of the equator.

Measurement Platform: Satellite.

Sourced from: Knapp et al. (2010), Knapp et al. (2018), NOAA (2021c).

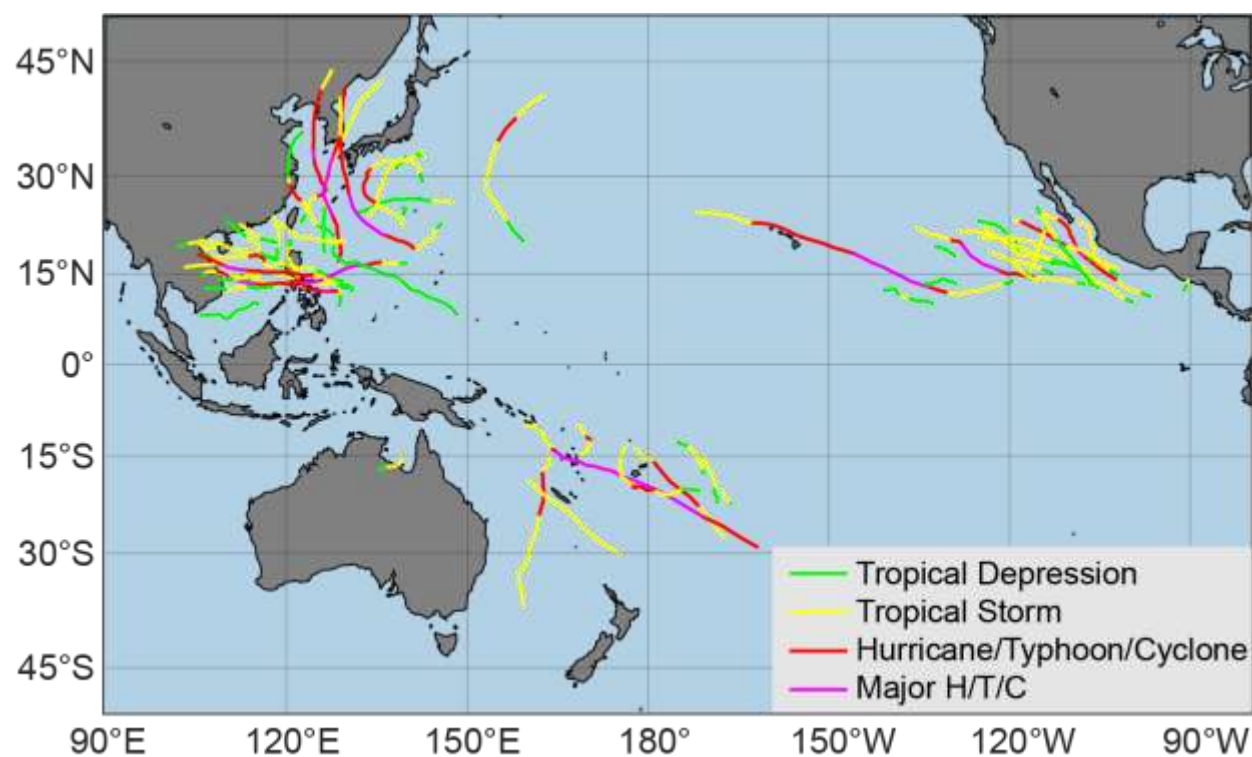


Figure 18. 2020 Pacific basin tropical cyclone tracks

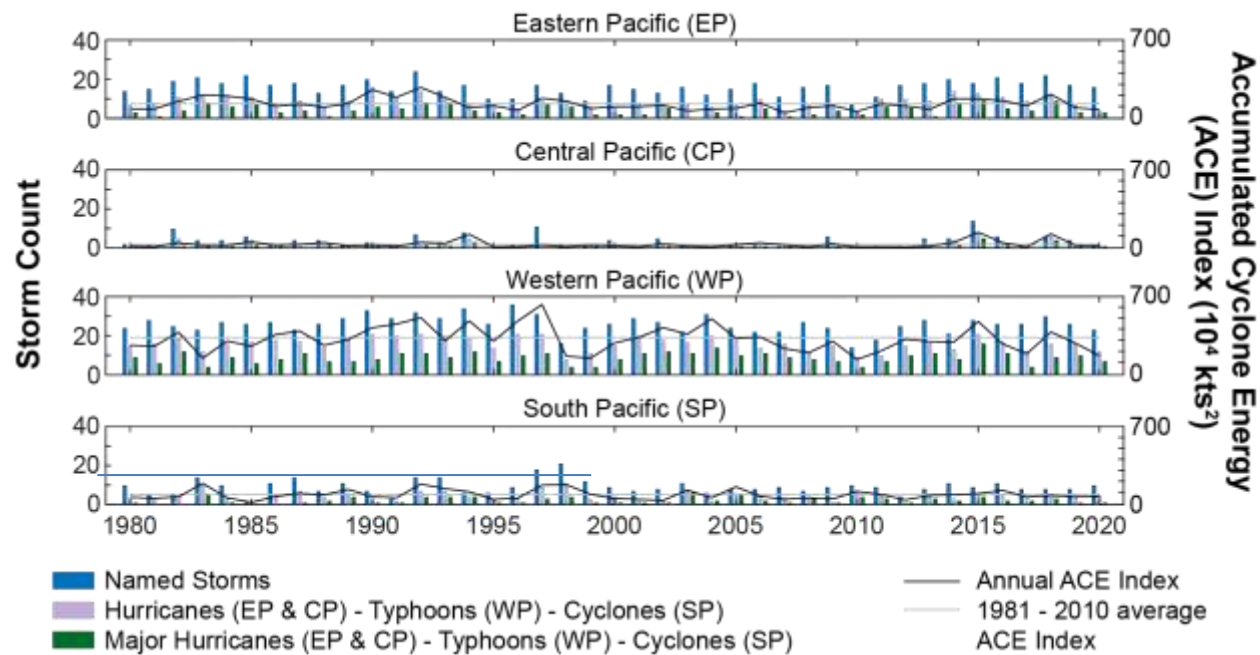


Figure 19. 2020 tropical storm totals by region



#### **2.7.4.6 Sea Surface Temperature and Anomaly**

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

**Status:** Annual mean SST was 28.95°C in 2020. Over the period of record, annual SST has increased at a rate of 0.023° C yr<sup>-1</sup>. Monthly SST values in 2020 ranged from 28.23 – 29.96 ° C, exceeding the climatological range of 26.55 – 29.90 °C. The annual anomaly was 0.40° C hotter than average, with wide spatial variability.

Note that from the top to bottom in Figure 20, panels show climatological SST (1985-2019), 2020 SST anomaly, time series of monthly mean SST, and time series of monthly SST anomaly. The white box in the upper panels indicates the area over which SST is averaged for the time series plots.

**Description:** Satellite remotely-sensed monthly sea surface temperature (SST) is averaged across the American Samoa Grid (10° – 17.5°S, 165° – 172°W). A time series of monthly mean SST averaged over the American Samoa Grid Region is presented. Additionally, spatial climatology and anomalies are shown.

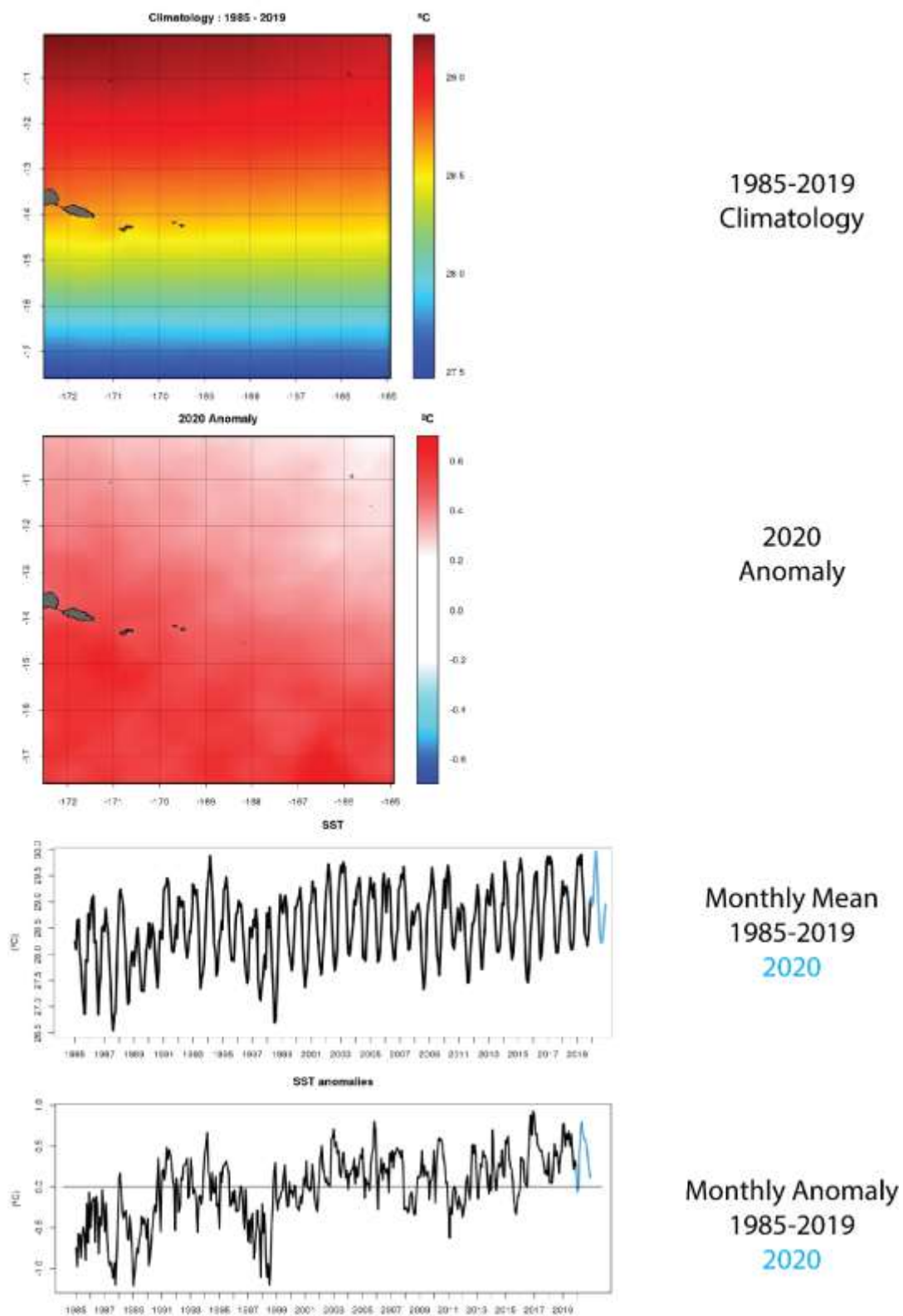
**Timeframe:** Monthly.

**Region/Location:** American Samoa Grid (10° – 17.5°S, 165° – 172°W).

**Measurement Platform:** Satellite.

**Sourced from:** NOAA Coral Reef Watch v3.1 (2021).





**Figure 20. Sea surface temperature climatology and anomalies from 1985-2020**

#### **2.7.4.7 Coral Thermal Stress Exposure: Degree Heating Weeks**

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

**Status:** After a series of stress events in 2014, 2015, 2016, 2017 and 2019, the Samoas experienced another coral heat stress event that began in March 2020 and reached its maximum in June 2020.

**Description:** Here we present a metric of exposure to thermal stress that is relevant to coral bleaching. DHW measures time and temperature above a reference ‘summer maximum’, presented as rolling sum weekly thermal anomalies over a 12-week period. Higher DHW measures imply a greater likelihood of mass coral bleaching or mortality from thermal stress.

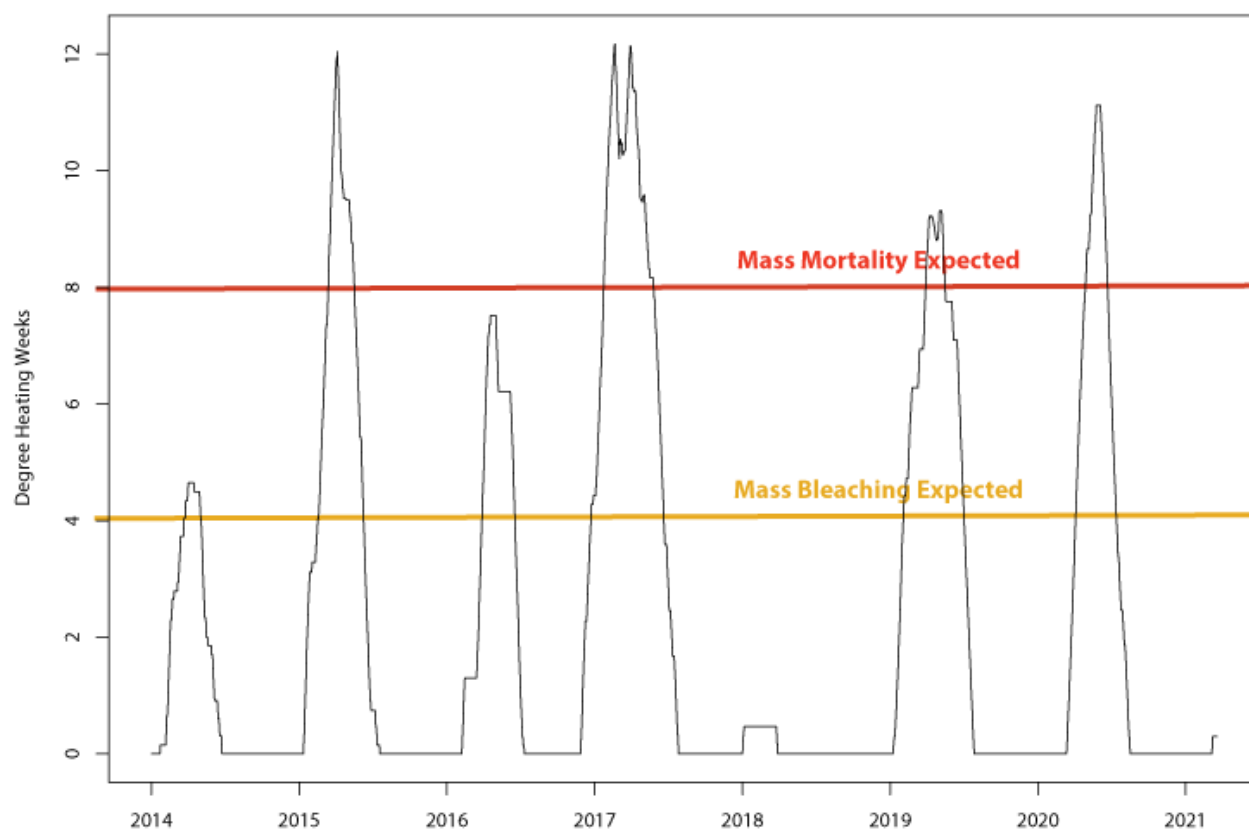
The NOAA Coral Reef Watch program uses satellite data to provide current reef environmental conditions to quickly identify areas at risk for [coral bleaching](#). Bleaching is the process by which corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached,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

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

**Timeframe:** 2013-2018, Daily data.

**Region/Location:** Global.

**Sourced from:** NOAA Coral Reef Watch v3.1 (2021).



**Figure 21. Coral Thermal Stress Exposure measured at Samoa Virtual Station 2014-2020 (Coral Reef Watch Degree Heating Weeks)**

#### **2.7.4.8 Chlorophyll-*a* and Anomaly**

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

**Status:** Annual mean chlorophyll-*a* was 0.045 mg/m<sup>3</sup> in 2020. Over the period of record, annual chlorophyll-*a* has shown no significant temporal trend. Monthly chlorophyll-*a* values in 2020 ranged from 0.045-0.072 mg/m<sup>3</sup>, within the climatological range of 0.036 – 0.090 mg/m<sup>3</sup>. The annual anomaly was 0.0007 mg/m<sup>3</sup> lower than average, with some intensification in the southern section of the region.

**Description:** Chlorophyll-*a* concentrations from 1998-2020 were derived from the ESA Ocean Color Climate Change Initiative dataset, v5.0. A monthly climatology was generated across the entire period (1982-2019) to provide both a 2020 spatial anomaly and an anomaly time series.

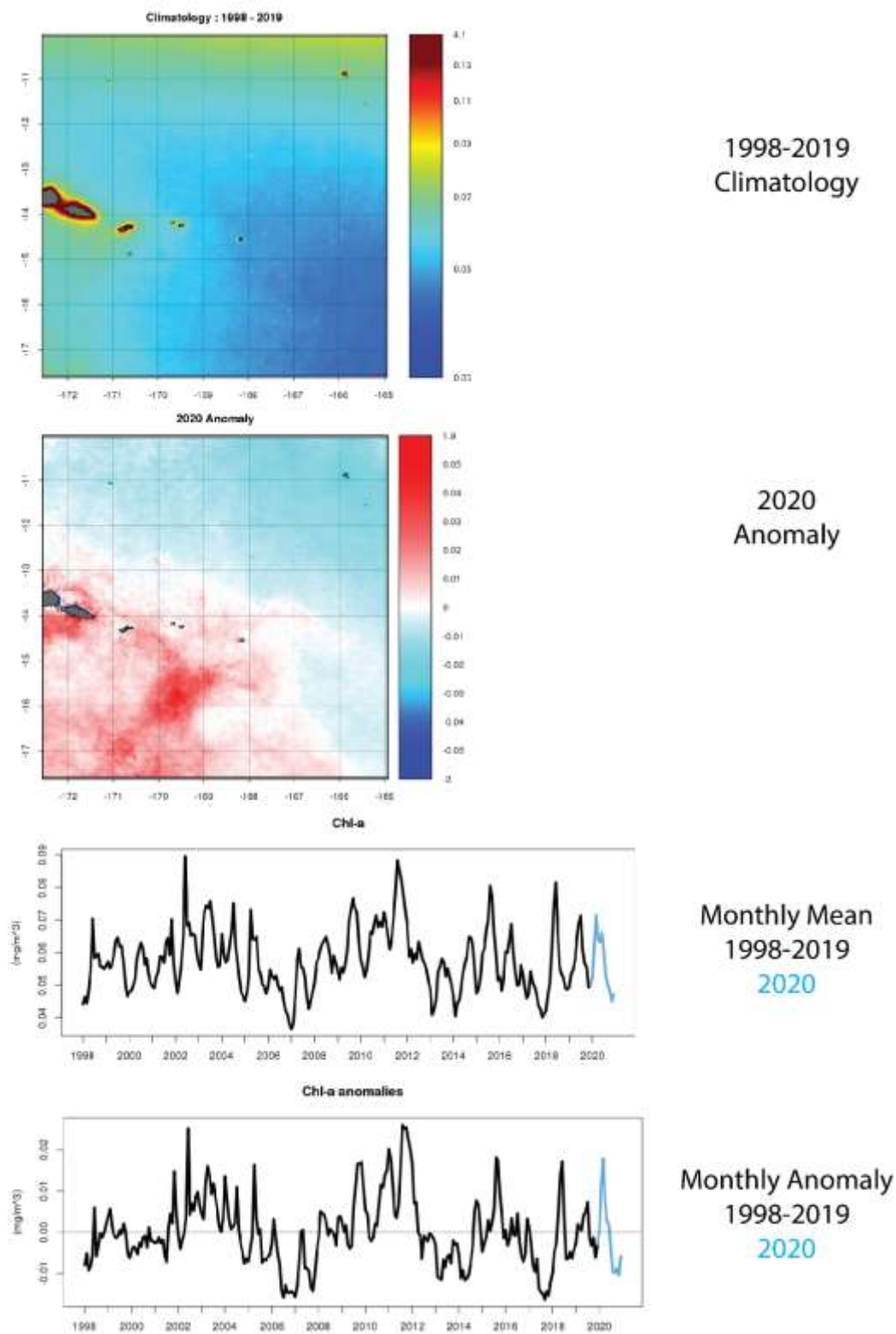
ESA Ocean Color Climate Change Initiative dataset is a merged dataset, combining data from SeaWIFS, MODIS-Aqua, MERIS, and VIIRS to provide a homogeneous time-series of ocean color. Data was accessed from the OceanWatch Central Pacific portal.

**Timeframe:** 1998-2020, daily data available, monthly means shown.

**Region/Location:** Global.

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

**Sourced from:** NOAA OceanWatch (2021).



**Figure 22. Chlorophyll-*a* and Chlorophyll-*a* Anomaly from 1998-2020**

#### 2.7.4.9 Rainfall

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

**Description:** The Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) is a technique which produces pentad and monthly analyses of global precipitation in which observations from rain gauges are merged with precipitation estimates from several satellite-based algorithms, such as infrared and microwave (NOAA 2002). The analyses are on a 2.5 x 2.5-degree latitude/longitude grid and extend back to 1979. CMAP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, from their Web site at <https://www.esrl.noaa.gov/psd/>. The data are comparable (but should not be confused with) similarly combined analyses by the Global Precipitation Climatology Project described in Huffman et al. (1997).

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

The merging technique is thoroughly described in Xie and Arkin (1997). Briefly, the methodology is a two-step process. First, the random error is reduced by linearly combining the satellite estimates using the maximum likelihood method, in which case the linear combination coefficients are inversely proportional to the square of the local random error of the individual data sources. Over global land areas the random error is defined for each time period and grid location by comparing the data source with the rain gauge analysis over the surrounding area. Over oceans, the random error is defined by comparing the data sources with the rain gauge observations over the Pacific atolls. Bias is reduced when the data sources are blended in the second step using the blending technique of Reynolds (1988).

Text inserted from

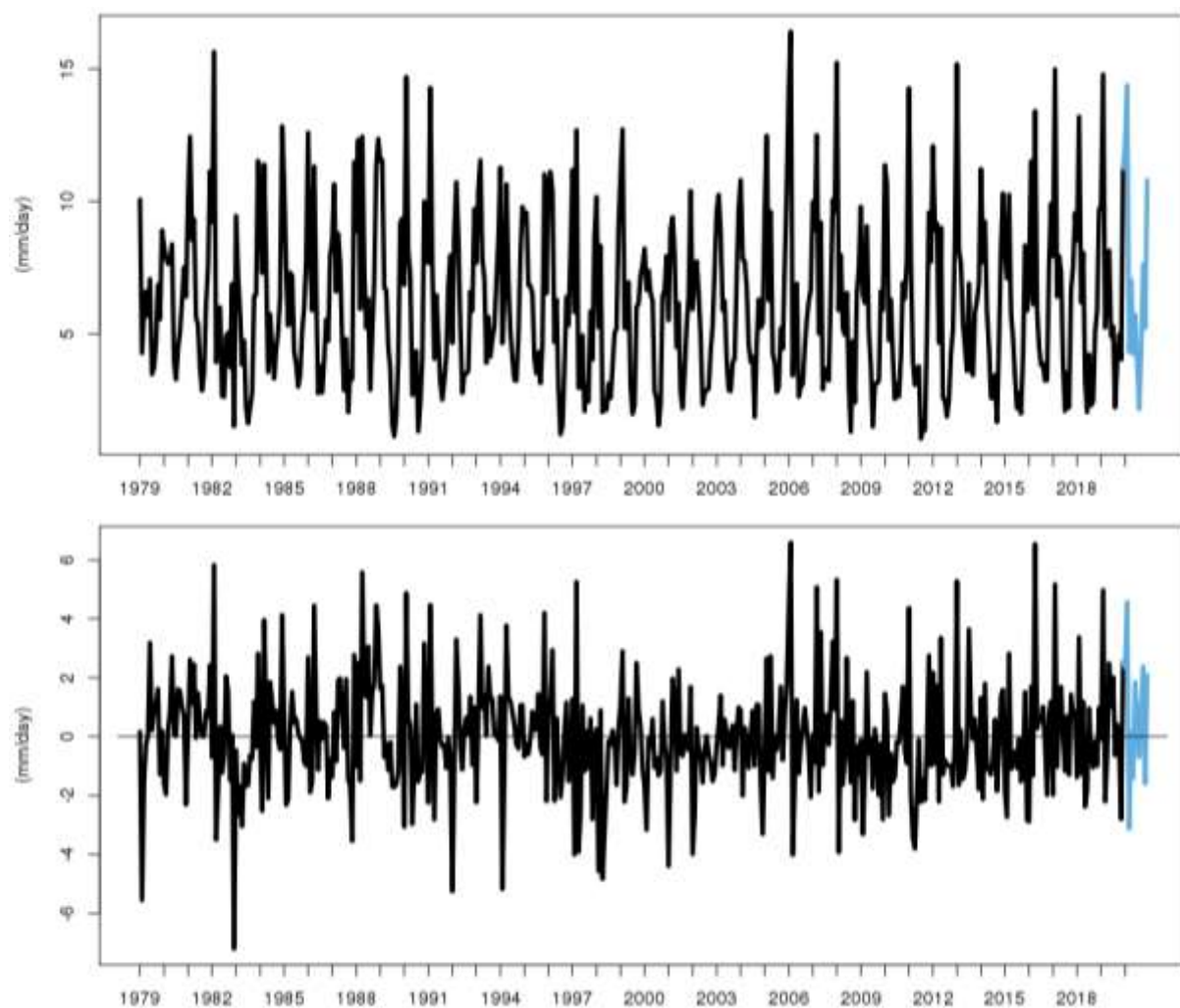
[https://www.cpc.ncep.noaa.gov/products/global\\_precip/html/wpage.cmap.shtml](https://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.shtml).

Timeframe: Monthly.

Region/Location: Global.

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

Sourced from: CMAP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, from their Web site at <https://www.esrl.noaa.gov/psd/>; NOAA (2021d).



**Figure 23. CMAP precipitation (top) and anomaly (bottom) across the American Samoa Longline Grid with 2020 values in blue**



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

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

**Description:** Monthly mean sea level time series of local and basin-wide sea surface height and sea surface height anomalies, including extremes.

**Timeframe:** Monthly.

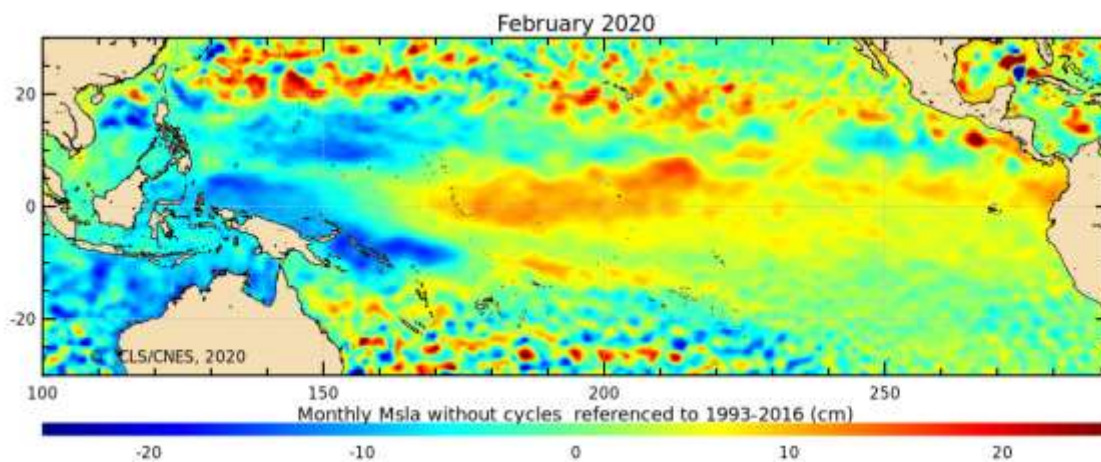
**Region/Location:** Observations from selected sites within the Samoan Archipelago.

**Measurement Platform:** Satellite and *in situ* tide gauges.

**Sourced from:** Aviso (2021) and NOAA (2021e).

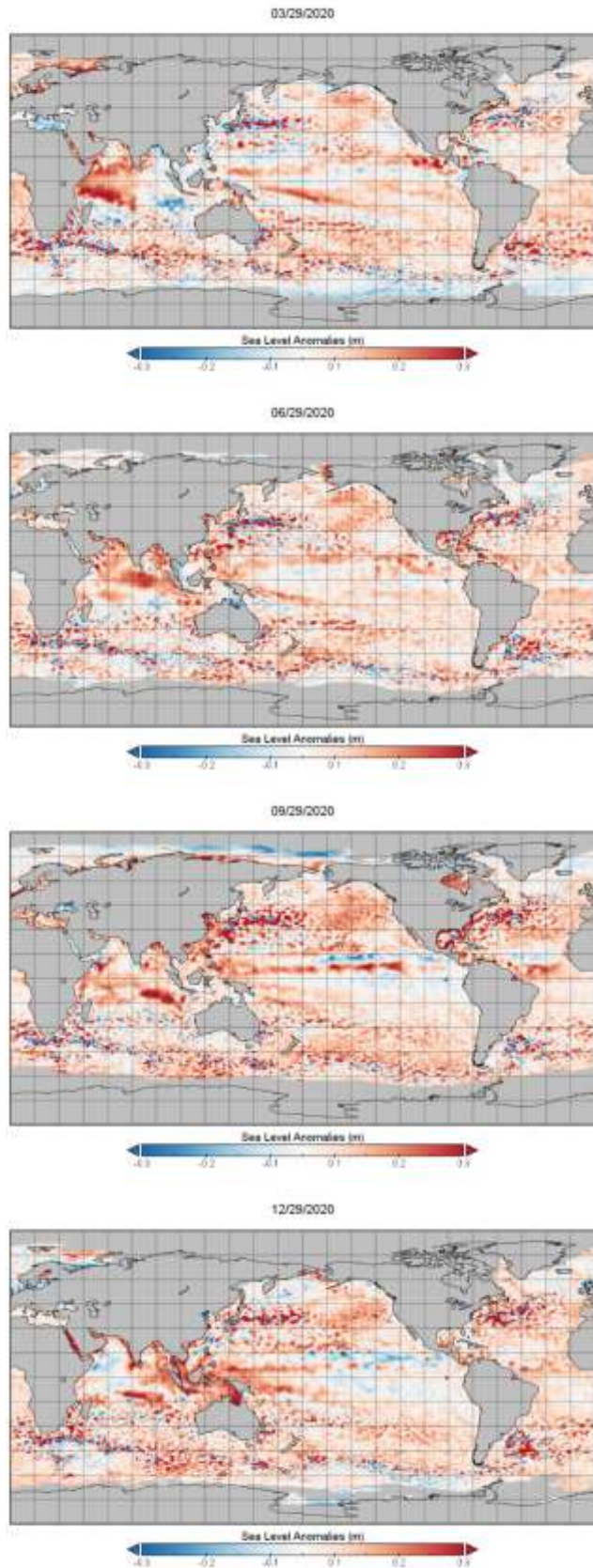
#### 2.5.3.9.1 Basin-Wide Perspective

This image of the mean sea level anomaly for February 2020 compared to 1993-2013 climatology from satellite altimetry provides a glimpse into how the 2020 neutral ENSO conditions affected sea level across the Pacific Basin. The image captures the fact that sea level is slightly lower in the Western Pacific and slightly higher in the Central and Eastern Pacific (this basin-wide perspective provides a context for the location-specific sea level/sea surface height images that follow).



**Figure 24a. Sea surface height and anomaly**





**Figure 24b. Quarterly time series of mean sea level anomalies during 2020 show no pattern of El Niño throughout the year according to satellite altimetry measurements of sea level height**

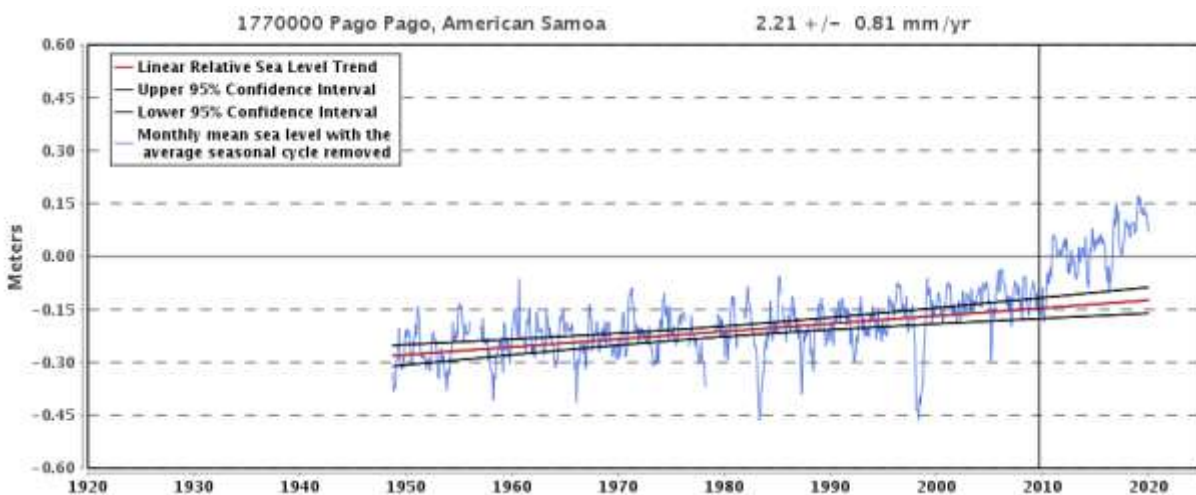
Altimetry data are provided by the NOAA Laboratory for Satellite Altimetry, accessed from NOAA CoastWatch (2021).

### 2.5.3.9.2 Local Sea Level

These time-series from *in situ* tide gauges provide a perspective on sea level trends within each Archipelago (Tide Station Time Series from NOAA Center for Operational Oceanographic Products and Services, or CO-OPS).

The following figures and descriptive paragraphs were inserted from the [NOAA Tides and Currents website](#). Figure 25 shows the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent [Mean Sea Level datum established by CO-OPS](#). The calculated trends for all stations are available as a [table in millimeters/year and in feet/century](#). If present, solid vertical lines indicate times of any major earthquakes in the vicinity of the station and dashed vertical lines bracket any periods of questionable data or datum shift.

The relative sea level trend is 2.41 millimeters/year with a 95% confidence interval of  $\pm 0.8$  mm/yr based on monthly mean sea level data from 1948 to 2009 which is equivalent to a change of 0.79 feet in 100 years. The trend is based only on data before September 2009 earthquake.



**Figure 25. Monthly mean sea level without regular seasonal variability due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents**

## **2.8 ESSENTIAL FISH HABITAT**

### **2.8.1 Introduction**

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

NMFS and the regional fishery management councils must describe and identify EFH in fishery management plans (FMPs) or fishery ecosystem plans (FEPs), minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. Federal agencies that authorize, fund, or undertake actions that may adversely affect EFH must consult with NMFS, and NMFS must provide conservation recommendations to federal and state agencies regarding actions that would adversely affect EFH. Councils also have the authority to comment on federal or state agency actions that would adversely affect the habitat, including EFH, of managed species. Fishery management actions must be evaluated for impacts to all EFH and HAPC in the area of effect and not just the EFH and HAPC for the fishery to which the management action applies.

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

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

#### **2.8.1.1 EFH Information**

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

The Council has described EFH for five management unit species (MUS) under its management authority, most of which are no longer MUS: pelagic (PMUS), bottomfish (BMUS), crustaceans (CMUS), former coral reef ecosystem species (CREMUS), and precious corals (PCMUS). Only bottomfish remain designated as MUS after Amendment 4 to the American Samoa FEP that reduced the number of MUS from 205 species/families to 11, with the other species being classified as ECS (84 FR 2767, February 8, 2019).

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

- Updated species descriptions, which can be found appended to the SAFE report. These can be used to directly update the FEP;
- Updated EFH levels of information tables, which can be found in Section 0;
- Updated research and information needs, which can be found in Section 0. These can be used to directly update the FEP; and
- An analysis that distinguishes EFH from all potential habitats used by the species, which is the basis for an options paper for the Council. This part is developed if enough information exists to refine EFH.

#### **2.8.1.2 Habitat Objectives of FEP**

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

- Review EFH and HAPC designations every five years based on the best available scientific information and update such designations based on the best available scientific information, when available; and
- Identify and prioritize research to assess adverse impacts to EFH and HAPC from fishing (including aquaculture) and non-fishing activities, including, but not limited to, activities that introduce land-based pollution into the marine environment.

#### **2.8.1.3 Response to Previous Council Recommendations**

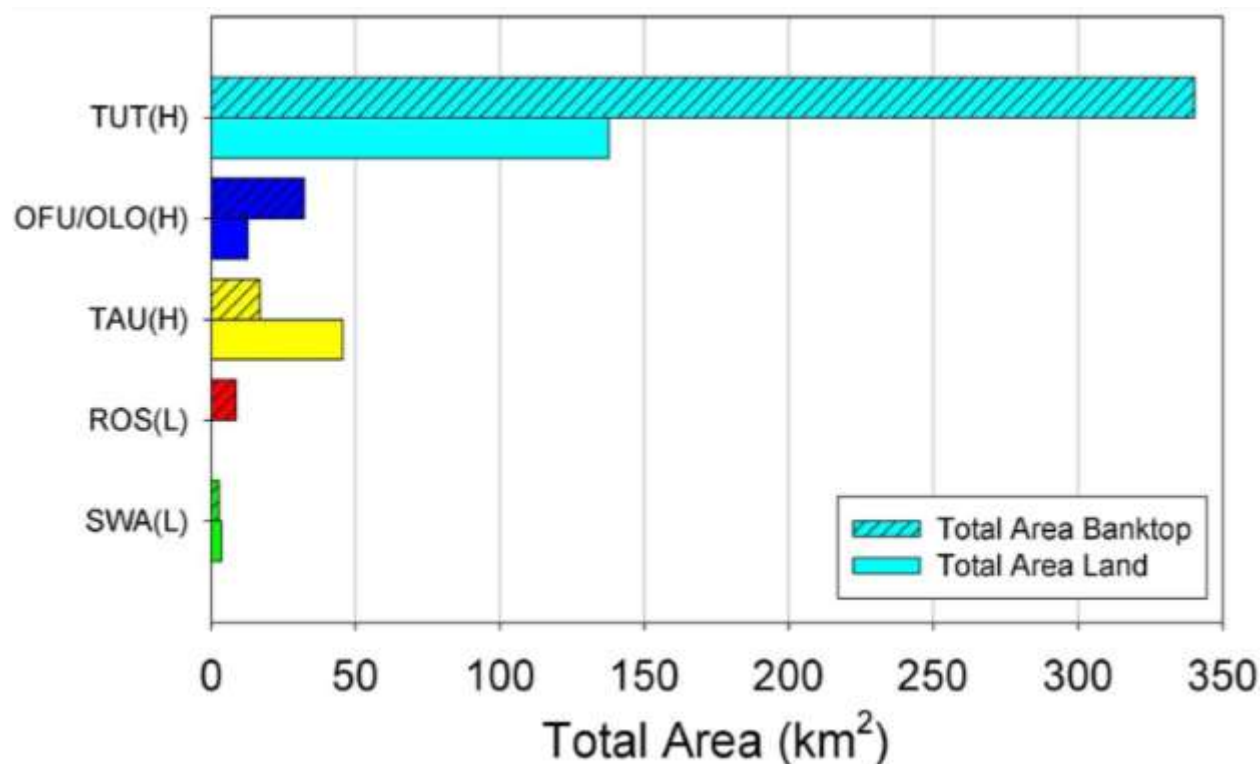
At its 172<sup>nd</sup> meeting in March 2018, the Council recommended that staff develop an omnibus amendment updating the non-fishing impact to EFH sections of the FEPs, incorporating the non-fishing impacts EFH review report by Minton (2017) by reference. An options paper was developed.

At its 182<sup>nd</sup> meeting in June 2020, the Council requested that NMFS work with the Council to determine “non-essential” fish habitat to look at ways to remove areas that are degraded from being considered EFH.

### **2.8.2 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 2011). Tutuila is the largest island in the territory and has banks (320 km<sup>2</sup>) surrounding

the island that extend between one and nine km offshore (according to the PIBHMC) and extends more than three km from shore in most places (PIFSC 2011). The islands of Ofu, Olosega, and Ta'u make up the Manu'a Islands group, which have more limited shallow submerged banks (Figure 26). The nearshore habitat consists of narrow reef flat lagoons and fringing coral reefs (PIFSC 2011). While the five high, volcanic islands are part of the hot-spot chain that also includes the surrounding seamounts of Muli, Vailulu'u, South Bank and independent Samoa, Swains Island is part of the Tokelau hot-spot chain (Neall and Trewick 2008). Rose Atoll's geological origin is not well studied.



**Figure 26. Bank top and terrestrial land area on high (H) or low (L) islands of Tutuila and Aunu'u (TUT), Ofu and Olosega (OFU/OLU), Ta'u (TAU), Rose (ROS), and Swains (SWA)**

While the coral reef ecosystems surrounding the islands in the American Samoa archipelago have been the subject of a comprehensive monitoring program through the PIFSC Coral Reef Ecosystem Division (CRED) biennially since 2002, surveys are focused on the nearshore environments surrounding the islands, atolls, and reefs and the offshore banks and pelagic environment in which MSA-managed fisheries operate have been less studied. However, American Samoa's Territorial Monitoring Program has been monitoring bleaching in two backreef lagoon pools on Tutuila from December 2003 to present.

PIFSC CRED is now the Coral Reef Ecosystem Program (CREP) within the PIFSC Ecosystem Sciences Division (ESD), whose mission is to conduct multidisciplinary research, monitoring, and analysis of integrated environmental and living resource systems in coastal and offshore waters of the Pacific Ocean. This mission includes field research activities that cover near-shore island ecosystems such as coral reefs to open ocean ecosystems on the high seas. The ESD research focus includes oceanography, coral reef ecosystem assessment and monitoring, benthic habitat mapping, and marine debris surveys and removal. This broad focus enables ESD to

analyze not only the current structure and dynamics of marine environments, but also to examine potential projections of future conditions such as those resulting from climate change impacts. Because humans are a key part of the ecosystem, our research includes the social, cultural, and economic aspects of fishery and resource management decisions ([PIFSC 2020](#)). The CREP continues to “provide high-quality, scientific information about the status of coral reef ecosystems of the U.S. Pacific islands to the public, resource managers, and policymakers on local, regional, national, and international levels” (PIFSC 2011). CREP conducts comprehensive ecosystem monitoring surveys at about 50 islands, atolls, and shallow bank sites in the Western Pacific Region on a rotating schedule, based on operational capabilities. CREP coral reef monitoring reports provide the most comprehensive description of nearshore habitat quality in the region.

### 2.8.2.1 Habitat Mapping

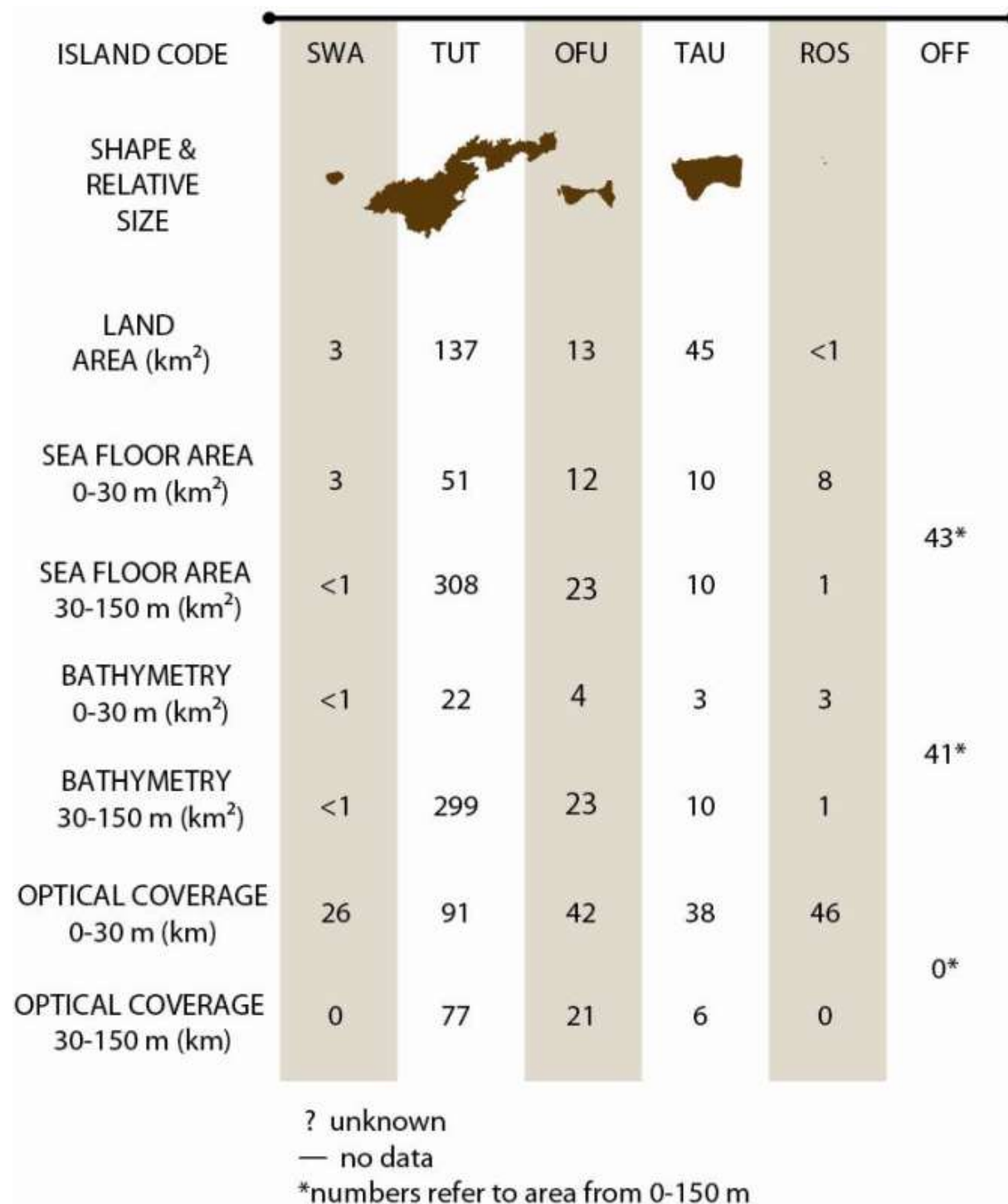
Interpreted IKONOS benthic habitat maps in the 0-30 m depth range have been completed for all islands in American Samoa (Miller et al. 2011). Between the Pacific Islands Benthic Habitat Mapping Center (PIBHC) and academically collected data, there is nearly 100% multibeam coverage of the Territory between 20 and 3,000 m depths.

**Table 34. 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	<a href="#">NCCOS Data Collections: Territory Benthic Habitat Maps</a>
	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% coverage	<a href="#">Pacific Islands Benthic Habitat Mapping Center</a>



The land and seafloor area surrounding the islands of American Samoa as well as primary data coverage are reproduced from Miller et al. (2011) in Figure 27.



**Figure 27. American Samoa land and seafloor area and primary data coverage (from Miller et al. 2011)**

### 2.8.2.1.1 Benthic Habitat

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

Table 35 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 35. Occurrence of EFH by feature**

<b>Feature</b>	<b>Summit Minimum Depth</b>	<b>Bottomfish</b>	<b>Long Term Monitoring</b>
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		

### 2.8.2.1.2 RAMP Indicators

Benthic percent cover of coral, macroalgae, and crustose coralline algae are surveyed as a part of the Pacific Reef Assessment and Monitoring Program (RAMP) led by the PIFSC ESD.

Previously, Pacific RAMP surveys had benthic cover data collected by towed-diver survey and summarized by island. These data were shown in previous reports but have since been replaced by more recent data using different collection methods.

More recently, the surveys began focusing on geographic sub-regions of islands for a more fine-scale summary of benthic cover; these data are shown in Table 36 through Table 38. A stratified random sampling design is used to determine status, trends, and variability of benthic communities at Rapid Ecological Assessment (REA) sites. Starting in 2018, surveys at each REA site were conducted with one 10-meter squared belt transects, whereas two belt transects were used from 2013 to 2017. The survey domain encompasses the majority of the mapped area of reef and hard bottom habitats from 0 to 30 m depth. The stratification scheme includes (1) three depth categories (shallow: 0 to 6 m; mid-depth: >6 to 18 m; and deep: >18 to 30 m); (2) regional sub-island sectors; (3) reef zone components, including back reef, lagoon, and fore reef.

Coral colonies and their morphology are identified before measuring the colony size and assessing colony condition. Photoquadrats are used to derive estimates of benthic cover. The photoquadrat consists of a high-resolution digital camera mounted on a photoquadrat pole. Photoquadrat images are collected along the same two transects used for coral surveys at one-meter intervals, starting at 1 m and progressing to the 15-meter mark (images are not collected at



the 0 m mark). This provides a total of 15 images per transect and 30 per site. In 2018, a single stage sampling scheme was implemented, which designates primary sample units (referred to sites) as grid cells containing >10% hard-bottom reef habitats. Also in 2018, a new method of determining survey effort was used by first determining the number of days spent at each island then by strata area and variance of target species at the island level (Swanson et al. 2018; Winston et al. 2019).

**Table 36. Mean percent cover of live coral from RAMP sites collected from belt transect surveys using updated methodology in American Samoa**

Island	Island Area	2010	2015	2015-16	2016	2018
Ofu & Olosega	Ofu & Olosega	24.48		32.37	24.25	28.73
Rose Atoll	Rose Atoll Lagoon	1.27		7.55		7.45
Rose Atoll	Rose Atoll (NMS)	15.95	14.32	20.06	21.63	16.67
South Bank	South Bank	2.28				
Swains	Swains (Open)			68.58		5.92
Swains	Swains (NMS)			37.64		23.78
Swains	Swains (Both)	34.47				
Tau	Tau (Both)	24.96				
Tau	Tau (Open)			33.84	33.21	35.09
Tau	Tau (NMS)			29.36	19.59	12.63
Tutuila	Aunu'u (NMS)			7.53		
Tutuila	Fagatele Bay (NMS)			39.65	28.24	33.05
Tutuila	Northeast (NMS)	19.62				
Tutuila	Northeast (Open)			28.65	32.33	27.73
Tutuila	Northwest (NMS)	29.92				
Tutuila	Northwest (Open)			24.64	22.40	18.61
Tutuila	Southeast (NMS)	21.12				
Tutuila	Southeast (Open)			18.39		8.60
Tutuila	Southwest (Open)	39.07		35.91	33.64	32.16

Note: "NMS" means the survey area was within the National Marine Sanctuary of American Samoa; "Open" means the survey area was outside the National Marine Sanctuary boundary; "Both" means the survey area was both within and outside the National Marine Sanctuary boundary.

**Table 37. Mean percent cover of macroalgae from RAMP sites collected from belt transect surveys using updated methodology in American Samoa**

Island	Island Area	2010	2015	2015-16	2016	2018
Ofu & Olosega	Ofu & Olosega	0.78		1.65	0.70	0.62
Rose Atoll	Rose Atoll Lagoon	0.27		0.35		0.34
Rose Atoll	Rose Atoll (NMS)	5.50	0.36	7.65	0.52	1.97
South Bank	South Bank	24.17				
Swains	Swains (Open)			3.06		3.50
Swains	Swains (NMS)			10.20		6.59
Swains	Swains (Both)	7.33				
Tau	Tau (Both)	0.15				
Tau	Tau (Open)			0.86	0.25	0.36

Island	Island Area	2010	2015	2015-16	2016	2018
Tau	Tau (NMS)			0.44	0.10	0.47
Tutuila	Aunu'u (NMS)			2.17		
Tutuila	Fagatele Bay (NMS)			2.42	0.83	0.69
Tutuila	Northeast (NMS)	0.44				
Tutuila	Northeast (Open)			2.67	1.72	0.77
Tutuila	Northwest (NMS)	0.95				
Tutuila	Northwest (Open)			2.84	0.43	1.67
Tutuila	Southeast (NMS)	2.40				
Tutuila	Southeast (Open)			6.69		3.97
Tutuila	Southwest (Open)	0.79		2.35	0.79	0.87

Note: “NMS” means the survey area was within the National Marine Sanctuary of American Samoa; “Open” means the survey area was outside the National Marine Sanctuary boundary; “Both” means the survey area was both within and outside the National Marine Sanctuary boundary.

**Table 38. Mean percent cover of crustose coralline algae from RAMP sites collected from belt transect surveys using updated methodology in American Samoa**

Island	Island Area	2010	2015	2015-16	2016	2018
Ofu & Olosega	Ofu & Olosega	38.29		22.86	20.75	24.68
Rose Atoll	Rose Atoll Lagoon	12.34		3.51		5.34
Rose Atoll	Rose Atoll (NMS)	44.64	48.69	41.36	45.65	51.20
South Bank	South Bank	2.63				
Swains	Swains (Open)			10.27		70.00
Swains	Swains (NMS)			19.93		36.71
Swains	Swains (Both)	17.03				
Tau	Tau (Both)	28.46				
Tau	Tau (Open)			15.02	15.40	18.90
Tau	Tau (NMS)			13.00	22.36	16.40
Tutuila	Aunu'u (NMS)			2.85		
Tutuila	Fagatele Bay (NMS)			24.28	26.08	26.97
Tutuila	Northeast (NMS)	14.90				
Tutuila	Northeast (Open)			9.80	12.78	14.82
Tutuila	Northwest (NMS)	17.20				
Tutuila	Northwest (Open)			7.90	13.90	12.62
Tutuila	Southeast (NMS)	33.29				
Tutuila	Southeast (Open)			19.42		25.31
Tutuila	Southwest (Open)	31.14		23.28	23.14	24.76

### 2.8.2.2 Oceanography and Water Quality

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

### 2.8.3 Report on Review of EFH Information

There were no EFH reviews completed in 2020 for American Samoa, however a habitat analysis of the biological components of crustacean EFH in Guam and Hawaii was finalized in 2019 and can be found in the 2019 Archipelagic SAFE Reports for the Mariana and Hawaii Archipelagos. Non-fishing and cumulative impacts to EFH were reviewed in 2016 through 2017, which can be found in Minton (2017).

### 2.8.4 EFH Levels

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

- Level 1: Distribution data are available for some or all portions of the geographic range of the species.
- Level 2: Habitat-related densities of the species are available.
- Level 3: Growth, reproduction, or survival rates within habitats are available.
- Level 4: Production rates by habitat are available.

The Council adopted a fifth level, denoted Level 0, for situations in which there is no information available about the geographic extent of a managed species' life stage. The existing level of data for individual MUS in each fishery are presented in tables per fishery.

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

#### 2.8.4.1 Bottomfish

EFH for bottomfish was originally designated in Amendment 6 to the Bottomfish and Seamount Groundfish FMP (64 FR 19067, April 19, 1999), and the levels of EFH information available for American Samoa BMUS are shown in Table 39. The designated areas of EFH and HAPC for American Samoa FEP bottomfish by life stage are summarized in Table 40. To analyze the potential effects of a proposed fishery management action on EFH, one must consider all designated EFH.

**Table 39. Level of EFH information available for American Samoa BMUS**

Life History Stage	Eggs	Larvae	Juvenile	Adult
<i>Aphareus rutilans</i> (red snapper/silvermouth)	0	0	0	1
<i>Aprion virescens</i> (gray snapper/jobfish)	0	0	1	1

Life History Stage	Eggs	Larvae	Juvenile	Adult
<i>Caranx lugubris</i> (black trevally/jack)	0	0	0	1
<i>Etelis carbunculus</i> (red snapper)	0	0	1	1
<i>E. coruscans</i> (red snapper)	0	0	1	1
<i>Lethrinus rubrioperculatus</i> (redgill emperor)	0	0	0	1
<i>Lutjanus kasmira</i> (blueline snapper)	0	0	1	1
<i>Pristipomoides filamentosus</i> (pink snapper)	0	0	1	1
<i>P. flavipinnis</i> (yelloweye snapper)	0	0	0	1
<i>P. zonatus</i> (snapper)	0	0	0	1
<i>Variola louti</i> (lunartail grouper)	0	0	0	1

Table 40. EFH and HAPC for American Samoa BMUS

American Samoa BMUS	EFH	HAPC
<i>Aphareus rutilans</i> (red snapper/silvermouth) <i>Aprion virescens</i> (gray snapper/jobfish) <i>Caranx lugubris</i> (black trevally/jack) <i>Etelis carbunculus</i> (red snapper) <i>E. coruscans</i> (red snapper) <i>Lethrinus rubrioperculatus</i> (redgill emperor) <i>Lutjanus kasmira</i> (blueline snapper) <i>Pristipomoides filamentosus</i> (pink snapper) <i>P. flavipinnis</i> (yelloweye snapper) <i>P. zonatus</i> (snapper) <i>Variola louti</i> (lunartail grouper)	<p><b>Eggs and larvae:</b> the water column extending from the shoreline to the outer limit of the EEZ down to a depth of 400 m (200 fm).</p> <p><b>Juvenile/adults:</b> the water column and all bottom habitat extending from the shoreline to a depth of 400 m (200 fm)</p>	<p>All slopes and escarpments between 40–280 m (20 and 140 fm)</p>

### 2.8.5 Project Updates

No field work related to EFH was conducted in American Samoa in 2020. A land-based sources of pollution project was completed that identified nearshore coastal areas that were most subject to sediment runoff. This project completed an assessment of actions in the watershed of Faga'alu and provides baseline surveys of the Aua watershed. It supports efforts to reduce land-based sources of pollution impacts in priority watersheds and to contextualize spatio-temporal benthic community change with physical drivers. Results of this study were presented and delivered to American Samoa management agencies and are available in GIS format through the Pacific Islands Ocean Observing System (PacIOOS).

A collaborative effort between the PIFSC Life History Program and Am. Samoa was planned for Tutuila and the Manu'a Islands for 2020 but was delayed due to COVID-19. In 2021, they plan to conduct shore-based bottomfish research to provide life history (e.g., growth rate, size-at-maturity), population dynamics (e.g., mortality rate), and ecological (e.g., how the life history and population dynamics vary over space and time) information for a large variety of economical, recreational, and subsistence valued coral reef fishes, deepwater snappers and groupers, and pelagic fishes. Parts of this work should contribute to the understanding of bottomfish habitats in American Samoa. Other recent and ongoing research in the Samoa Archipelago by the Life History Program includes:

- Giant ruby snapper/palu malau (*Etelis* sp.) age, growth, size-at-maturity. In review.
- Yelloweye snapper/palu-sina (*Pristipomoides flavipinnis*) age, growth, and mortality differences (O'Malley et al. 2019).
- Eight bar grouper (*Hyporthodus octofasciatus*) age, growth, genetics (DiBattista et al. 2018).
- Humpback red snapper/mala'i (*Lutjanus gibbus*), yellow-lined snapper/savane-ulasama (*Lutjanus rufolineatus*), yellow-lip emperor (*Lethrinus xanthurus*) age, growth, size-at-maturity (Taylor et al. 2018)
- Red-lip parrotfish/laea-mala (*Scarus rubroviolaceus*) age, growth, size-at-maturity (Taylor and Pardee 2017).
- Blue-striped snapper/savane (*Lutjanus kasmira*) age and growth. Cooperative research between the PIFSC Life History Program and DMWR. In progress.
- Lehi/palu-gutusaliva (*Aphareus rutilans*) population genetics. Cooperative research between the PIFSC Life History Program and DMWR. In progress.

## 2.8.6 Research and Information Needs

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

### 2.8.6.1 All FMP Fisheries

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

### 2.8.6.2 Bottomfish Fishery

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

## **2.9 MARINE PLANNING**

### **2.9.1 Introduction**

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

At its 165<sup>th</sup> meeting in March 2016, in Honolulu, Hawaii, 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; and
- d. As needed, periodically evaluate the management effectiveness of existing spatial-based fishing zones in federal waters.

To monitor implementation of this objective, this annual report includes the Council's spatially based fishing restrictions or MMAs, the goals associated with those, and the most recent evaluation. Council research needs are identified and prioritized through the Five-Year Research Priorities and other processes and are not tracked in this report.

To meet the EFH and National Environmental Policy Act (NEPA) mandates, this annual SAFE report tracks activities that occur in the ocean that are of interest to the Council, and incidents or facilities that may contribute to cumulative impact. NMFS is responsible for NEPA compliance, and the Council must assess the environmental effects of ocean activities for the FEP's EFH cumulative impacts section. These are redundant efforts; therefore, this report can provide material or suggest resources to meet both mandates.

### **2.9.2 Response to Previous Council Recommendations**

There are no standing Council recommendations indicating review deadlines for American Samoa MMAs.

At its 147<sup>th</sup> meeting in March 2010, the Council recommended a no-take area from 0-12 nautical miles around Rose Atoll Marine National Monument (MNM) with the Council to review the no-take regulations after three years. The most recent review took place in 2013, with the

subsequent review previously scheduled for 2016. PIRO received no requests for non-commercial permits to fish within the Rose Atoll MNM. Further, inquiries in American Samoa showed that there was no indication that the 12 nm closure around Rose Atoll MNM has been limiting fishing. Thus, there is no interest to fish within the monument boundaries. The Pelagic Plan Team deferred decision on Rose Atoll in May 2017 until after the Administration reviews to make any decision on the monument provisions. At its 172<sup>nd</sup> meeting in March 2018, the Council requested that NOAA and USFWS provide a report to the Council at its following meeting to review resultant benefits to fish populations, protected species, and coral reef, deep-slope, and pelagic ecosystems from the establishment of the Rose MNM. USFWS presented this report to the Council at its 173<sup>rd</sup> meeting in June 2018, from which no recommendations were generated. No further action was taken on the Rose Atoll MNM.

At its 162<sup>nd</sup> meeting in March 2015, 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 50 ft. in length. The Council would 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. In 2016, NMFS published a final rule that allowed large, federally-permitted U.S. longline vessels to fish in specific areas of the LVPA (81 FR 5619, February 3, 2016). In July 2016, American Samoa sued NMFS and the Council in the Hawaii Federal District Court, claiming that NMFS did not consider the 1900 and 1904 Deeds of Cession with respect to the protection of the cultural fishing rights of the people of American Samoa. In 2017, the Hawaii Federal District Court deemed the final rule invalid and ordered NMFS to vacate the LVPA exemption rule (82 FR 43908, September 20, 2017).

At its 173<sup>rd</sup> meeting in June 2018, regarding the LVPA applicable to the American Samoa limited entry vessels, the Council recognized the LVPA rule has led to disagreement within the American Samoa fishing community and was the subject of litigation. The Council noted that last year's court decision requires the consideration and protection of American Samoa cultural fishing. To this end, the Council requested PIFSC conduct research on American Samoa cultural fishing practices to facilitate understanding and potential impacts of opening some restricted fishing areas within the U.S. EEZ for American Samoa vessels that primarily target albacore. PIFSC presented the results of this research at the Council's 172<sup>nd</sup> meeting in March 2018, which indicate that all fishing in American Samoa has cultural importance, whether commercial longline, commercial alia vessels, troll, or other fishing sectors, because catch from all locally-based fishing sectors flows into the American Samoa community for cultural purposes. The Council also recommended a regulatory amendment to provide a four-year exemption for vessels permitted under the American Samoa longline limited entry program to fish within the LVPA seaward of 12 nm around Tutuila, 12 nmi around Manu'a, 12 nm around Swains, and 2 nmi around the offshore banks, and recommended annual monitoring of the American Samoa longline and troll catch rates, small vessel participation, and local fisheries development.

NMFS appealed Hawaii Federal District Court's 2017 decision that invalidated the 2016 LVPA reduction to the U.S. Ninth Circuit Court of Appeals. Oral arguments were in February 2020 in Honolulu, Hawaii, and the decision was reversed in a September 2020 ruling.

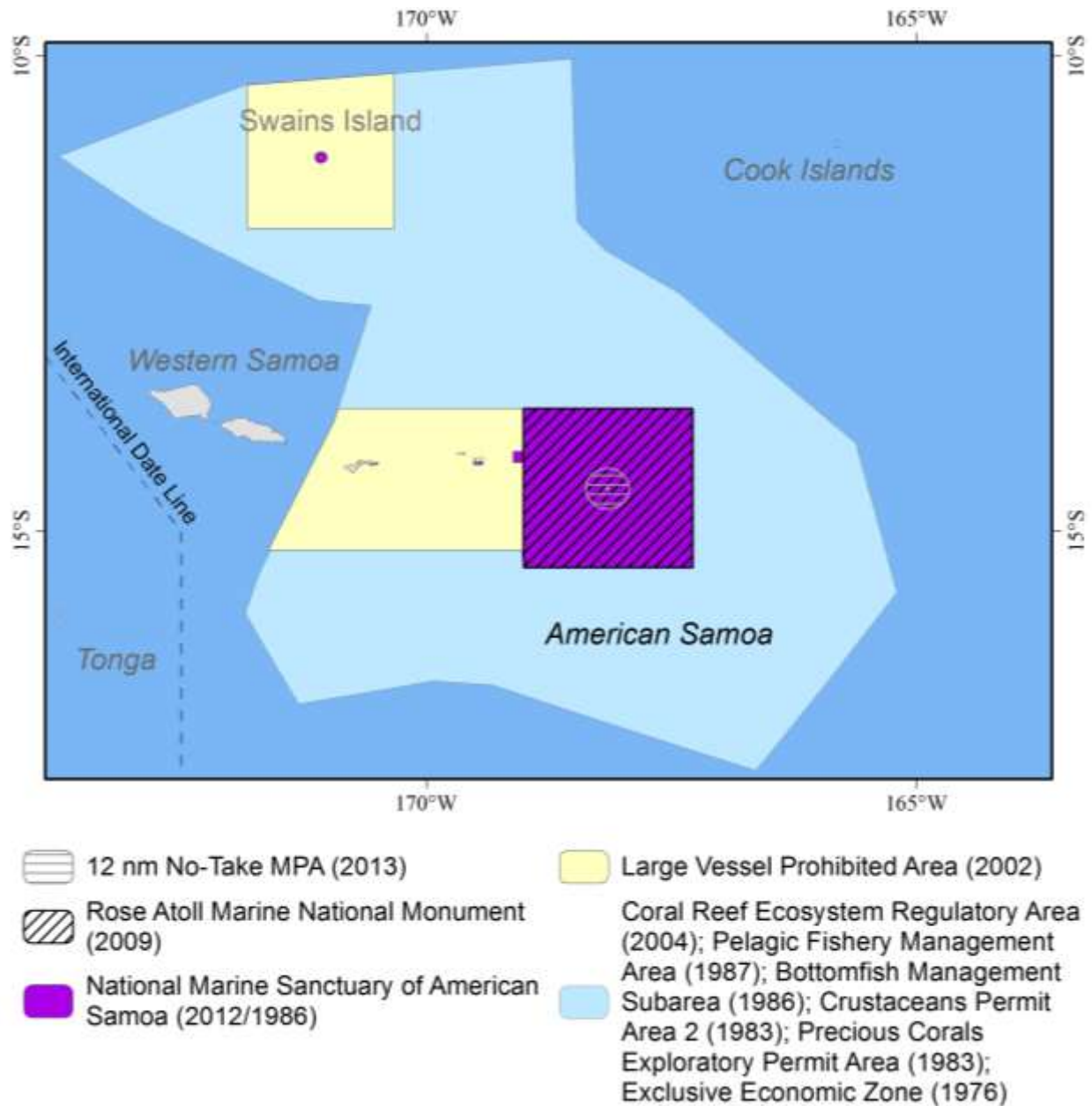
At its 184<sup>th</sup> meeting in December 2020, the Council directed staff to monitor the fishing operation and fishery performance of the American Samoa longline and alia fisheries and report back to the Council at its September 2021 meeting. Based on this performance review, the Council may reconsider its 2017 LVPA modification action at that meeting.

### **2.9.3 Marine Managed Areas established under the FEPs**

Council-established MMAs are compiled in



Table 41 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 28.



**Figure 28. Regulated fishing areas of American Samoa**

**Table 41. MMAs established under FEPs from [50 CFR § 665](#)**

Name	FEP	Island	50 CFR / FR / Amendment Reference	Marine (km <sup>2</sup> ) 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) <a href="#">81 FR 5619</a> <a href="#">82 FR 43908</a>	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) <a href="#">81 FR 5619</a> <a href="#">82 FR 43908</a> <a href="#">Pelagic FEP</a>	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) <a href="#">69 FR 8336</a> <a href="#">Coral Reef Ecosystem FMP</a> <a href="#">78 FR 32996</a> <a href="#">American Samoa FEP Am. 3</a>	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nm	June 3, 2013	June 3, 2016

## 2.9.4 Fishing Activities and Facilities

There are no aquaculture activities currently occurring in the offshore waters of American Samoa.

### **2.9.5 Non-Fishing Activities and Facilities**

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

### **2.9.6 American Samoa Spatial Planning Tools**

In June 2018, President Trump signed the EO 13840 *Regarding the Ocean Policy to Advance Economic, Security, and Environmental Interests of the United States*, which established a policy focused on public access to marine data and information and requires federal agencies to 1) coordinate activities regarding ocean-related matters and 2) facilitate the coordination and collaboration of ocean-related matters with governments and ocean stakeholders. To that end, the [American Samoa Coastal and Marine Spatial Planning Data Portal](#) was created by [Marine Cadastre](#) to share information and data for coastal and marine spatial planning in American Samoa.

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

To support the development of Chapter 3 of the annual SAFE report, staff from the Council, National Marine Fisheries Service (NMFS), Pacific Islands Fisheries Science Center (PIFSC), Pacific Islands Regional Offices (PIRO), and Triton Aquatics (consultants), held a SAFE Report Data Integration Workshop (hereafter, “the Workshop”) convened on November 30, 2016 to identify potential fishery ecosystem relationships relevant to local policy in the WPR and determine appropriate methods to analyze them. The archipelagic fisheries group developed nearly 30 potential fishery ecosystem relationships to examine across bottomfish, coral reef, and crustacean fisheries based on data reliability, suitability of methodology, repeatability on an annual basis, and how well analyses could potentially inform management decisions.

Brief introductory analyses, presented in this section and initially introduced in the 2017 report, were intended to be “proof of concept” such that similar evaluations could be carried out on remaining fishery data for American Samoa in the future. However, the Fishery Ecosystem Plan Team determined that the quantitative analyses were not enough to act as a model for future evaluations. Using the direction from the Plan Team, the data integration module was updated for the Hawaii Archipelagic Annual SAFE Report, but each of the remaining archipelagic reports still contain data integration assessments from 2017. The Annual SAFE Report for the Mariana Archipelago will be updated in the following year similar to the Annual SAFE Report for the Hawaii Archipelago pending PPT approval.

Going forward, relationships deemed potentially relevant will be emphasized and recommended for further analysis. In subsequent years, this chapter will be updated with these analyses through the SAFE report process as the strength of certain fishery ecosystem relationships relevant to advancing ecosystem-based fishery management are determined.

To begin, this chapter described feedback from the Plan Team, SSC, and Council members on the initial drafts of the data integration module. Next, the chapter includes brief descriptions of past work on fishery ecosystem relationship assessment in coral reefs of the U.S. Western Pacific, followed by initial evaluations of relationships previously recommended for evaluation by participants of the Workshop using current data streams from American Samoa. The evaluations completed were exploratory in nature, being the first step of analyses to know which comparisons may be more useful to focus on going forward.

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

### **3.1.2 2018 Recommendations and Direction for Chapter Development**

At the FEP Team Meeting held on April 30<sup>th</sup> and May 1<sup>st</sup>, 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;
- 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; and
- Spatial specificity and precision should be increased for analyses of environmental variables in relation to areas commonly fished.

The analyses presented in the data integration chapter of the 2018 Hawaii Annual SAFE Report reflect a thoughtful re-approaching to these data integration evaluations based on this feedback. Additional data can be added to either time series as they are made available. Incorporating such recommendations into the American Samoa 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.

### **3.2 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 of climate and/or ecosystem change on coral reefs fish stocks of American Samoa using climate and oceanic indicators (see Section 2.7.4). The evaluation of environmental variables showed that certain climate parameters (e.g., SST anomaly, sea level height, precipitation, and tropical storm days) are likely linked to fishery performance. It was also noted that larger natural disturbances in recent decades, such as cyclones and tsunamis, negatively impacted reef fish assemblages and lowered reef fishery CPUE in American Samoa (Ochavillo et al. 2012).

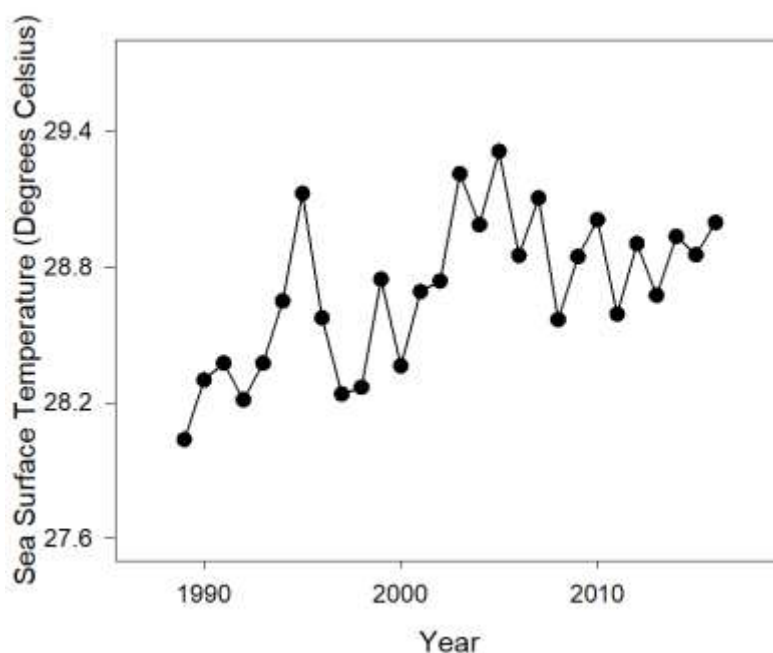
On a larger spatial scale, an analysis of various drivers on coral reef fish populations across 37 U.S.-affiliated islands in the Central and Western Pacific was performed by Williams et al. (2015) and evaluated relationships between fish biomass in these reefs with human and environmental factors. Again, 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., 2011). Hawhee (2007) adapted this idea, generating biological reference points in the form of CPUE-based proxies to be used as indicators for reef fish stocks in the WPR. However, the devised method was determined to be inappropriate for application in management of reef stocks in the U.S. Western Pacific due to the lack of a historical CPUE to use as a baseline for the reference points and their limit thresholds (Remington and Field, 2016).

### 3.3 SEA SURFACE TEMPERATURE

Sea surface temperature (SST) is a commonly used diagnostic tool in monitoring climate change and its affects both regionally and globally, as it is representative of changes in ocean temperatures over time that can affect coastal fisheries (see Section 2.7.4). The potential influence of temperature-derived variables in fishery ecosystem relationships for U.S. Western Pacific coral reef stocks was deemed to be among the highest priority by the participants of the Workshop. Data for SST was gathered from the NOAA's Advanced Very High Resolution Radiometer (AVHRR) Pathfinder v5.0 through the OceanWatch program in the Central Pacific (NOAA/National Environmental Satellite, Data, and Information Service [NESDIS]/OceanWatch). Future work will utilize time series of SST described in Section 2.7.4 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.

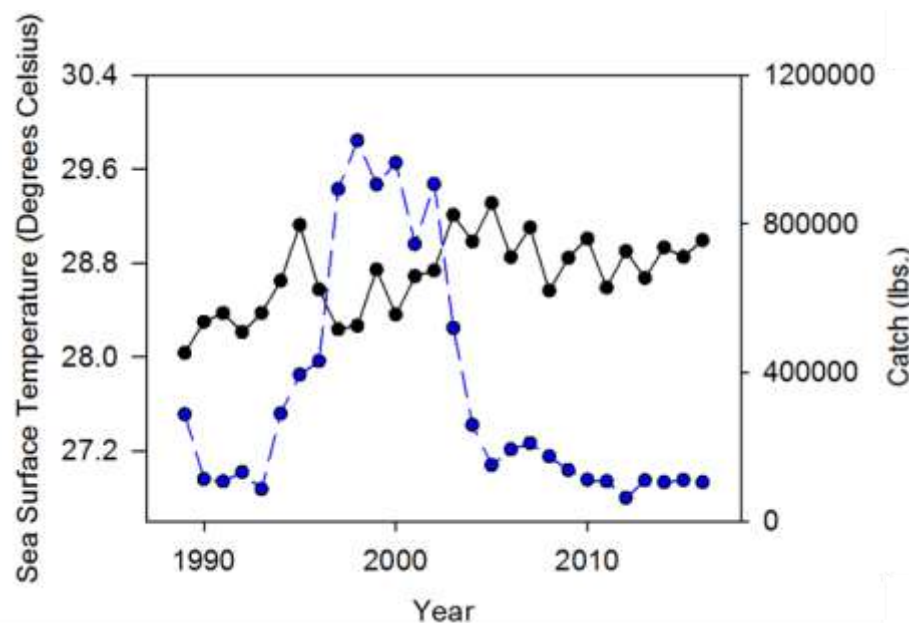
A time series of SST for American Samoa from 1989-2016 is shown in Figure 29. The SST for American Samoa over this period had relatively little variability ( $CV = 1.15$ ). SST has been seemingly increasing over the course of available data, though its variability appeared to be decreasing in the last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



**Figure 29. Average annual SST ( $^{\circ}\text{C}$ ) in American Samoa from 1985-2016 ( $CV = 1.15$ )**

### 3.3.1 Evaluating relationship for entire coral reef fishery

Figure 30 shows a plot depicting the relationship between SST and catch time series for the 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 lb). Recent recorded catch levels (i.e., 2016) are among the lowest for the fishery through the available time series of data (~105,000 lb; Figure 30).



**Figure 30. Total annual catch (lb; blue) for the American Samoa 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 42 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.



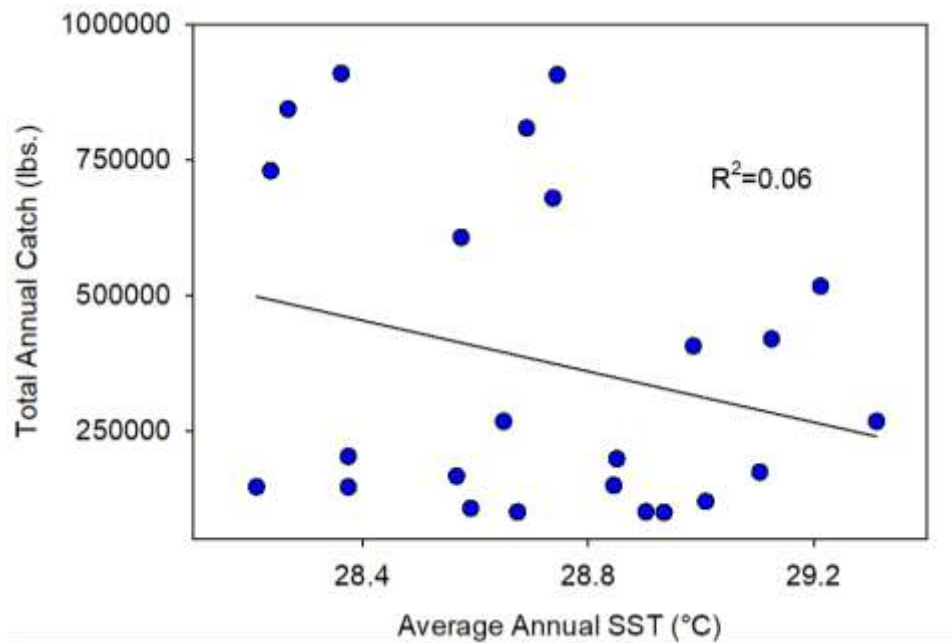
**Table 42. Families recorded in creel survey data in the U.S. Western Pacific evaluated in these analyses**

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 coral reef fishery catch and annual mean SST from American Samoa were performed (Table 43). Assessments measuring this potential relationship for the entirety of the coral reef fishery catch in American Samoa showed no general relationship between 1989 and 2016 ( $R^2 = 0.06$ ,  $p = 0.20$ ; Table 43; Figure 31). The observed association between the two parameters appeared to associate negatively over time despite the lack of a statistically significant trend (Figure 31).

**Table 43. Correlation coefficients ( $r$ ) between the coral reef fishery catch (lb) 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
<b>n = 24</b>													
<b><math>p</math></b>	0.20	0.43	0.24	0.96	0.052	0.30	0.78	<b>0.02</b>	<b>0.03</b>	0.22	0.78	0.15	0.17
<b><math>r</math></b>	-0.25	0.17	0.25	0.01	-0.40	-0.22	-0.06	<b>-0.47</b>	<b>0.44</b>	0.26	-0.06	-0.30	0.29
<b><math>R^2</math></b>	0.06	0.03	0.06	0.00	0.16	0.05	0.00	<b>0.22</b>	<b>0.19</b>	0.07	0.00	0.09	0.09

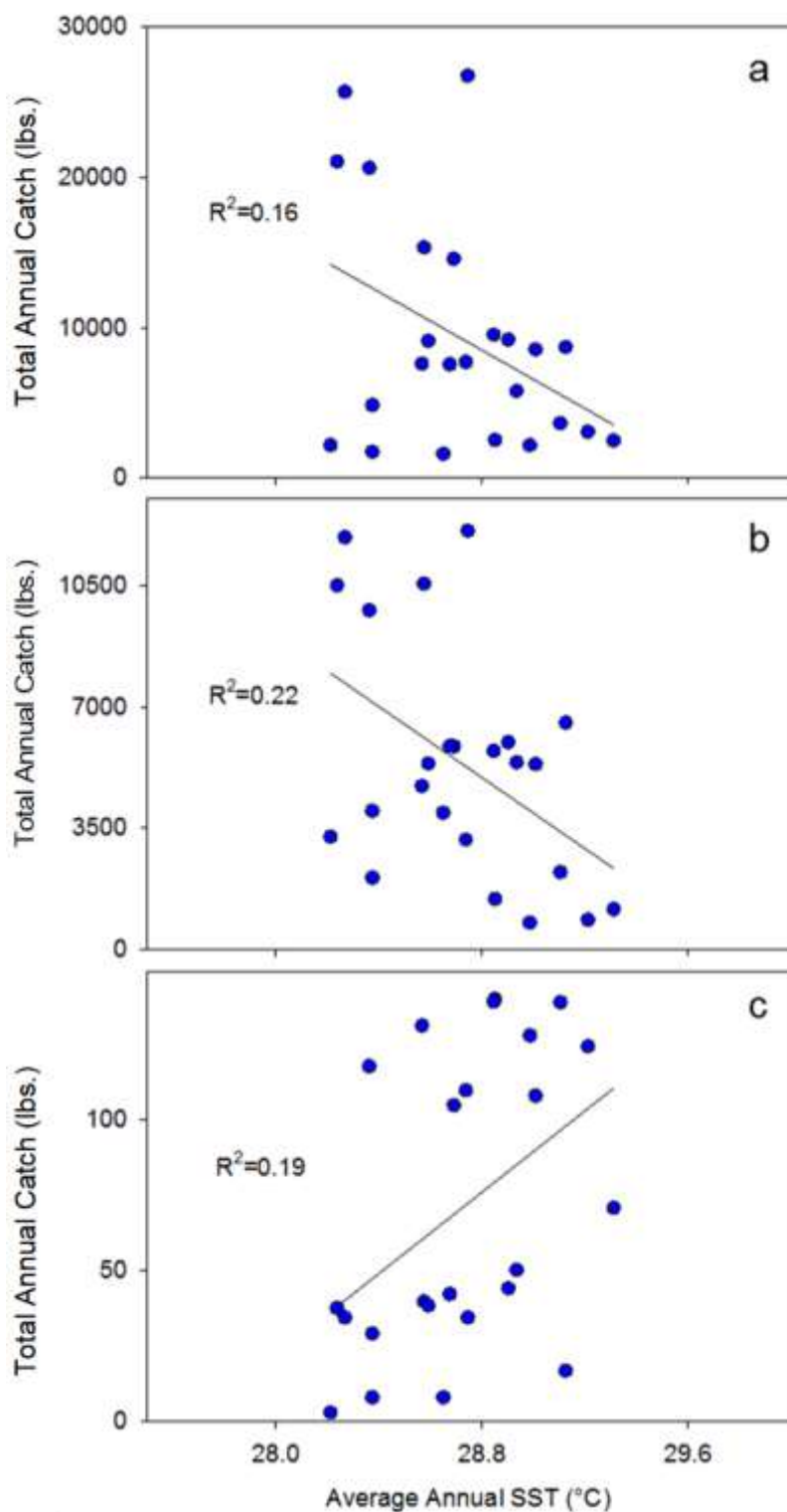


**Figure 31. Linear regression showing the correlation between total annual catch (lb) for the coral reef fishery and average annual sea surface temperature (°C) in American Samoa from 1989-2016**

### 3.3.2 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 43). 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 lb ( $R^2 = 0.22$ ,  $p = 0.02$ ; Table 43; Figure 32a). 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 lb (~67 lb;  $R^2 = 0.19$ ,  $p = 0.03$ ; Table 43; Figure 32b). 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 43; Figure 32c). 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 lb for every 1°C increase temperature.



**Figure 32. Linear regressions showing the three top correlations between total annual catch (lb) for the coral reef fishery and average annual SST (°C) in American Samoa for (a) Acanthurids, (b) Scarids, and (c) Mullids from 1989-2016**

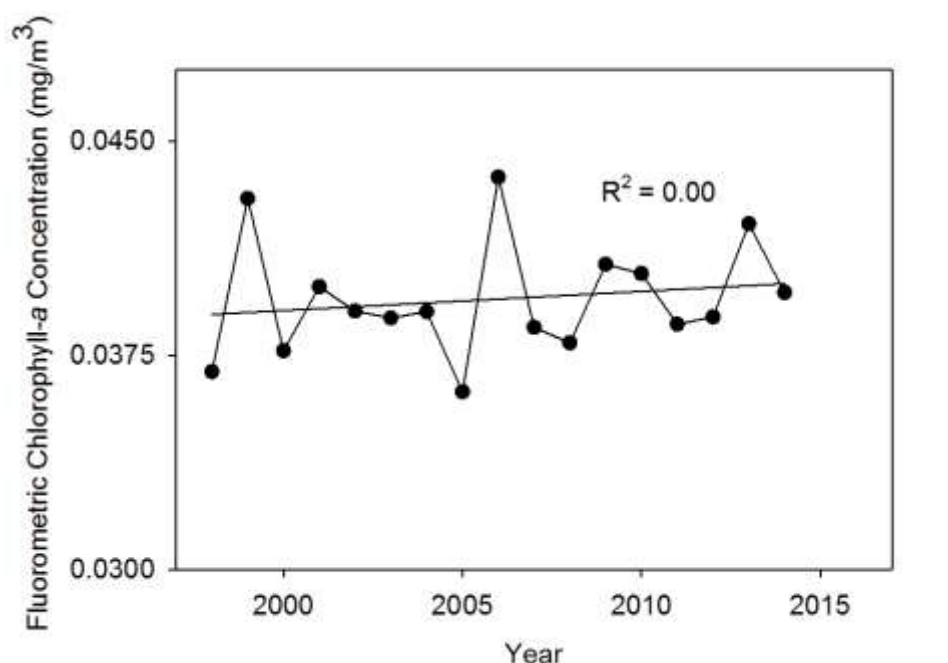
### 3.4 PRIMARY PRODUCTIVITY

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 (Kitona 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 (Behrenfeld et al. 2006; Messié and Radenac 2006). Data for the study at hand were gathered from the ESA Ocean Colour Climate Change Initiative dataset version 3.1.

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.

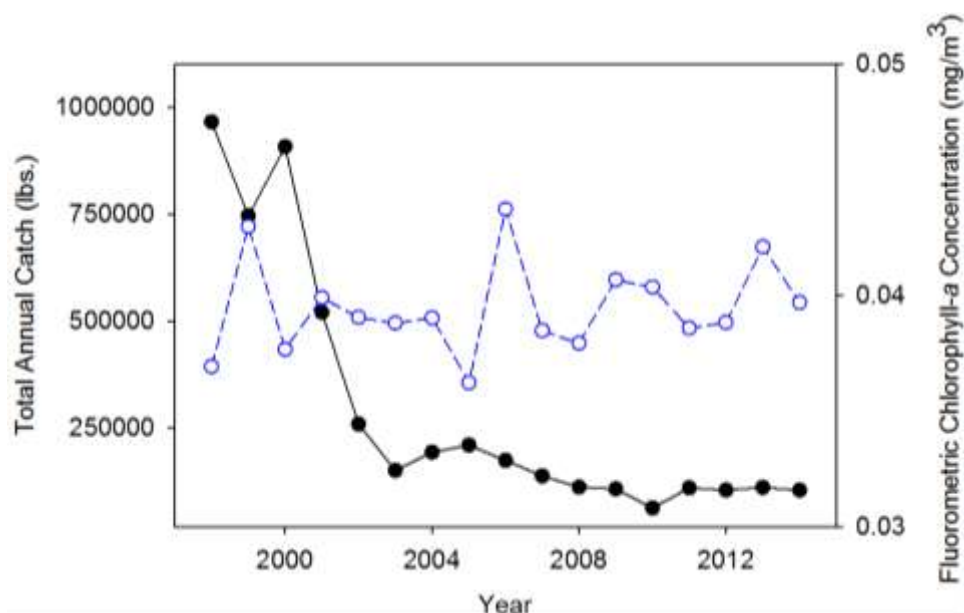
Time series of fluorometric chlorophyll-*a* concentrations ( $\text{mg}/\text{m}^3$ ) from 1998 to 2016 in American Samoa is shown in Figure 33. The chlorophyll levels had relatively low variability over the course of evaluated data ( $\text{CV} = 4.90$ ; Figure 33). Local chlorophyll-*a* concentrations 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 33).



**Figure 33. Fluorometric chlorophyll-a concentrations (mg/m<sup>3</sup>) from 1998–2016 (CV = 4.90)**

### 3.4.1 Evaluating relationship for entire coral reef fishery

A comparison plot depicting the relationship between chlorophyll-*a* concentrations and catch time series gathered through creel surveys measuring American Samoa's 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 lb), 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 lb; Figure 34).

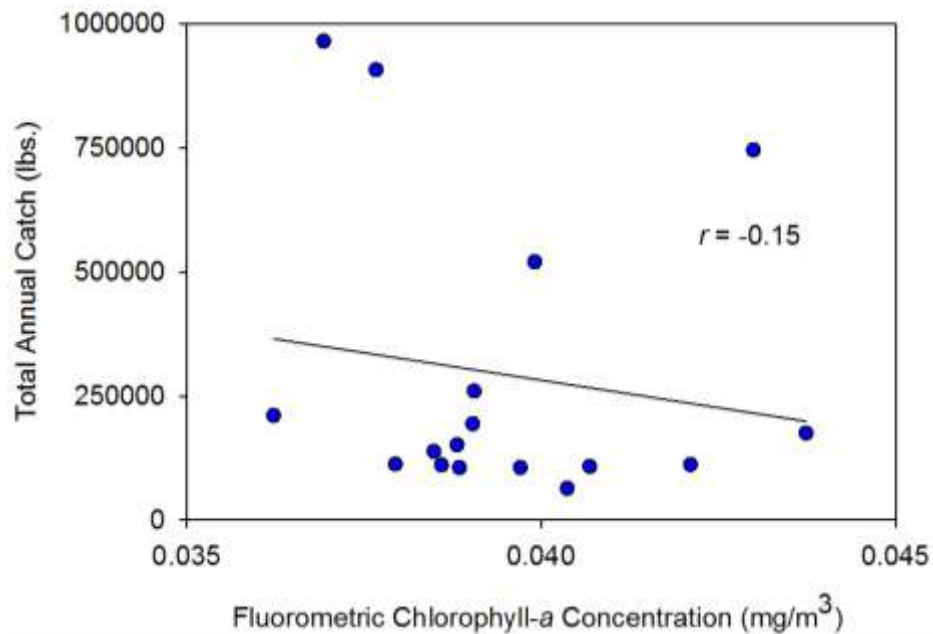


**Figure 34. Comparison of American Samoa reef fish catch (lb; black) and chlorophyll-*a* concentrations (mg/m<sup>3</sup>; blue) from 1998 – 2014 and two years of time lag**

The linear regressions performed between noncommercial reef catch in American Samoa and fluorometric chlorophyll-*a* concentrations (mg/m<sup>3</sup>) are shown in Figure 35. 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 44; Figure 35). 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 44. Correlation coefficients ( $r$ ) from comparisons of time series of American Samoa coral reef fishery annual catch (lb) and fluorometric chlorophyll-*a* concentrations (mg/m<sup>3</sup>) for 12 top taxa harvested from 1998–2014**

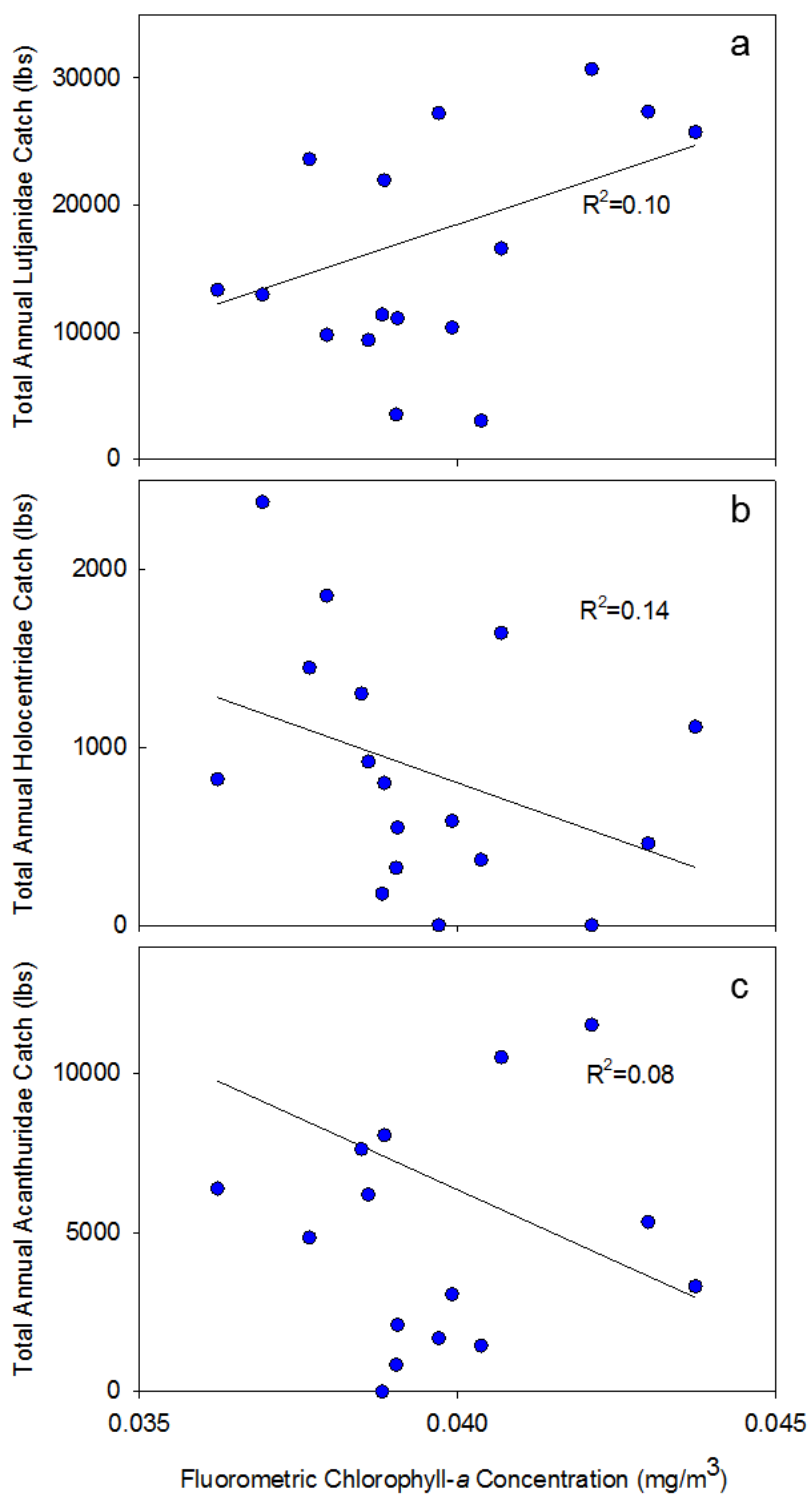
Taxa Code	Total Catch	LUTJ	LETH	CARA	ACAN	SERR	SIGA	SCAR	MULL	MUGI	LABR	HOLO	BALI
<b>n = 17</b>													
<b><i>p</i></b>	0.57	0.25	0.29	0.62	0.28	0.99	0.17	0.54	0.82	0.65	0.37	0.13	0.09
<b><i>r</i></b>	-0.15	0.32	0.27	-0.13	-0.28	0.00	0.35	-0.16	0.06	0.12	-0.23	-0.38	-0.42
<b><i>R</i><sup>2</sup></b>	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 35. Linear regression showing between total annual catch (lb) for the American Samoa coral reef fishery with phase lag (t+2 years) and fluorometric chlorophyll-a concentrations (mg/m<sup>3</sup>) from 1998-2014**

### 3.4.2 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 44). 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 44; Figure 36a-c).



**Figure 36. Linear regressions showing three correlations between total annual catch (lb) for the American Samoa coral reef fishery and fluorometric chlorophyll-*a* concentrations (mg/m<sup>3</sup>) for (a) Lutjanids, (b) Holocentrids, and (c) Acanthurids from 1998–2014 with phase lag (t+2 years)**



### 3.5 MULTIVARIATE ASSESSMENTS OF ADDITIONAL ENVIRONMENTAL VARIABLES

#### 3.5.1 Non-Metric Multidimensional Scaling

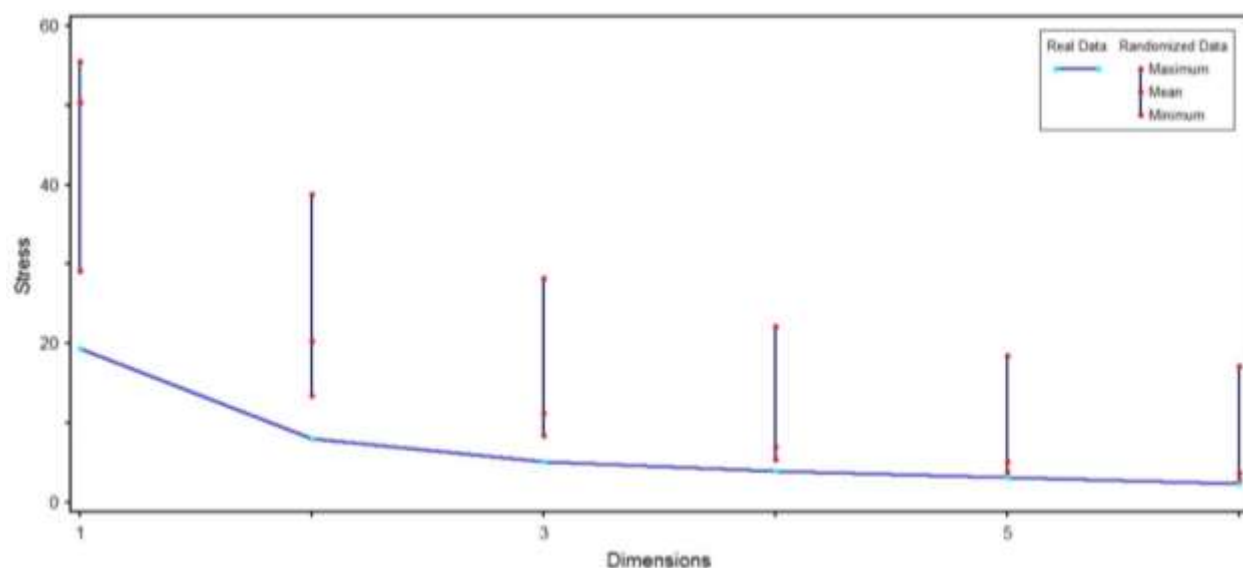
There were several other prioritized fishery ecosystem relationships for coral reefs in the American Samoa involving environmental parameters that were not to be addressed in this initial evaluation including: the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), sea level height, pH, dissolved oxygen, and salinity. Further descriptions of these climate and oceanic indicators are available in Section 2.7.4. Sea surface height data were aggregated from the Ocean Service, Tides, and Currents, and Sea Level database operated (NOAA/NOS/CO-OPS). Basin-wide data ONI were taken from NOAA's Nation Centers for Environmental Information- Equatorial Pacific Sea Surface Temperature Database (Climate Prediction Center Internet Team 2015). Similarly, PDO data were obtained from NOAA's Earth System Research Laboratory Physical Sciences Division originally derived from OI.v1 and OI.v2 SST parameters (NOAA PDO). Salinity data for American Samoa were gathered from Simple Ocean Data Assimilation (SODA) version 3.3.1 (Carton and Giese 2008). Rainfall estimates were obtained through the local National Weather Service in American Samoa (NWS-AS).

Non-metric multidimensional scaling (NMS), a form of multivariate analysis that orders sample units along synthetic axes to reveal patterns of composition and relative abundance, is most commonly utilized when looking to identify patterns in heterogenous species response data (Peck 2016). For this study, NMS was used to help identify associations between coral reef fishery parameters and ecological/environmental factors using the program PC-ORD 7. To ensure the same length of time series for all catch and environmental variables considered thus allowing for the general inclusion of more parameters, data was analyzed from 1989 to 2015. The generated axes represented the best fit of patterns of redundancy in the catch data used as input, and the resulting ordination scores were a rank-order depiction of associations in the original dataset.

NMS produces robust results even in the presence of outliers by avoiding parametric and distributional assumptions (Peck, 2016). The only assumption to be met in NMS is that the relationship between the original rank ordered distances between sample units and the reduced distances in the final solution should be monotonic; that is, the slope of the association between the two is flat or positive, as determined by the stress statistic. In the most general terms, interpretable and reliable ordination axes have stress less than 10 up to 25 for datasets with large sample size, but large stress scores (i.e., greater than 30) may suggest that the final ordination results have little association with the original data matrix. Additionally, NMS ordination scores vary depending on the number of dimensions/axes designated to be solved (Peck, 2016). Dimensionality (i.e., number of axes for the final solution) for each test was identified though PC-ORD result recommendations based on final stress being lower than that for 95% of randomized runs (i.e.,  $p \leq 0.05$ ). Tau is a statistic that represents the rank correlations of the ordination scores to the original data matrices and was used to identify explanatory variables with associations to the ordination axes. For the American Samoa test, data from 12 families from 1989-2014 (26 years) were included along with eight variables of environmental data collected during the same time period.

The resulting ordination scores from the NMS analysis performed on boat-based expanded creel survey catch records and the previously mentioned environmental parameters selected two

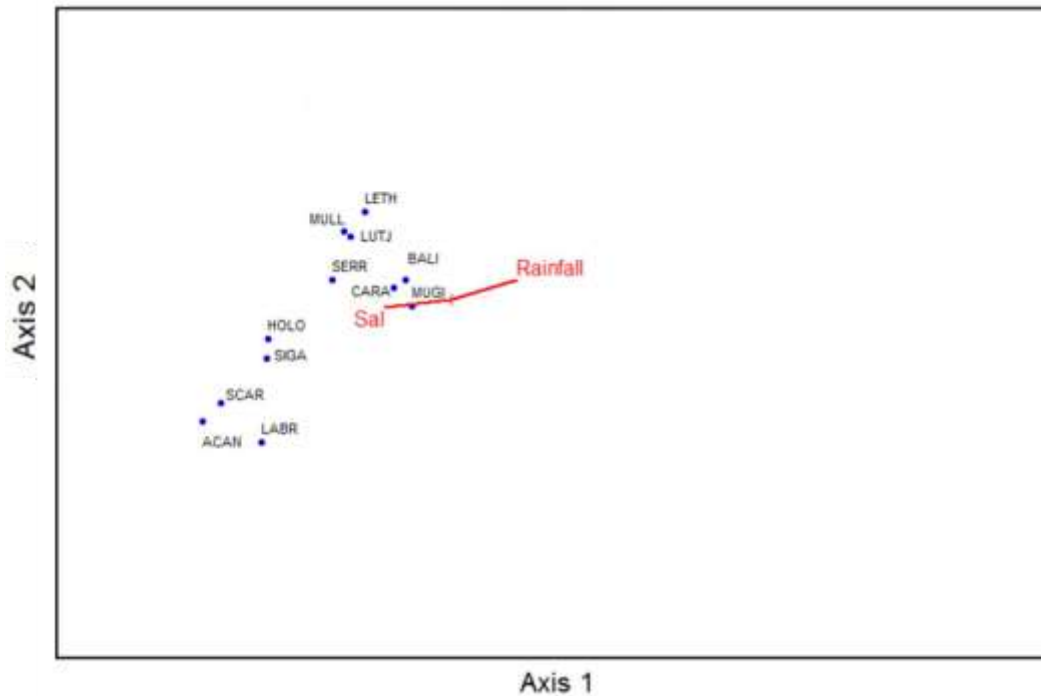
completely orthogonal ordination axes in the final solution, accounting for 94.7% of variance observed in the American Samoa boat-based creel survey data (Figure 37). The NMS final stress was low for the real runs (8.05) relative to stress from the randomization runs (15.1), suggesting interpretable results (Figure 37).



**Figure 37. 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 38). 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 38). Analyses including time series of precipitation levels in American Samoa may be useful going forward.

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.



**Figure 38. 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**

### 3.6 RECENT RELEVANT ABSTRACTS

In this section, abstracts from primary journal articles published in 2020 and relevant to data integration are compiled. Collecting the abstracts of these articles is intended to further the goal of this section being used to guide adaptive management.

**Arostegui MC, Braun CD, Woodworth-Jefcoats PA, Kobayashi DR, Gaube P. 2020. Spatiotemporal segregation of ocean sunfish species (Molidae) in the eastern North Pacific. *Mar Ecol Prog Ser* 654:109-125. <https://doi.org/10.3354/meps13514>**

Ocean sunfishes or molas (Molidae) are difficult to study as a result of their extensive movements and low densities in remote waters. In particular, little is known of the environmental niche separation and differences in the reproductive or movement ecology of molids in sympatry. We investigated spatiotemporal dynamics in the distribution of the common mola *Mola mola*, sharptail mola *Masturus lanceolatus*, and slender mola *Ranzania laevis* in the eastern North Pacific. We used observer data from a commercial fishery consisting of 85000+ longline sets spanning 24 yr, >50° in longitude, and >45° in latitude. Satellite altimetry analysis, species distribution modeling, and multivariate ordination revealed thermal niche separation, spatiotemporal segregation, and distinct community associations of the 3 molid species. Our quantitative findings suggest that the common mola is a more temperate species, while slender and sharptail mola are more (sub)tropical species, and that slender (and possibly also sharptail) mola undergo spawning migrations to the region around the Hawaiian Islands. In addition, we identified potential effects of fishing gear type on molid catch probability, an increasing trend in catch probability of a vulnerable species perhaps related to a shift in the distribution of fishing

effort, and the possible presence in the fishery of a fourth molid species being misidentified as a congener, all of which are important conservation considerations for these enigmatic fishes.

**Guo C, Fu C, Olsen N, Xu Y, Grüss A, Liu H, Verley P, Shin Y-J. 2020 Incorporating environmental forcing in developing ecosystem-based fisheries management strategies, *ICES Journal of Marine Science*, Volume 77, Issue 2, Pages 500–514, <https://doi.org/10.1093/icesjms/fsz246>.**

This study incorporated two pathways of environmental forcing (i.e. “larval mortality forcing” and “somatic growth forcing”) into an end-to-end ecosystem model (Object-oriented Simulator of Marine ecOSystEms, OSMOSE) developed for the Pacific North Coast Integrated Management Area (PNCIMA) off western Canada, in order to evaluate alternative fisheries management strategies under environmental changes. With a suite of ecosystem-level indicators, the present study first compared the ecosystem effects of different pathways of environmental forcing scenarios; and then evaluated the alternative fisheries management strategies which encompassed a series of fishing mortality rates relative to FMSY (the fishing mortality rate that produces maximum sustainable yield) and a set of precautionary harvest control rules (HCRs). The main objectives of this study were to (i) explore the ecosystem effects of different environmental forcing scenarios; (ii) identify the impacts of different fishing mortality rates on marine ecosystem structure and function; and (iii) evaluate the ecosystem-level performance of various levels of precautionary HCRs. Results indicated that different pathways of environmental forcing had different ecosystem effects and incorporating appropriate HCRs in the fisheries management process could help maintain ecosystem health and sustainable fisheries. This study provides important information on future fisheries management options within similar marine ecosystems that are facing global changes.

**Heck N, Agostini V, Reguero B, Pfliegner K, Mucke P, Kirch L, Beck MW. 2020. Fisheries at Risk – Vulnerability of Fisheries to Climate Change. Technical Report. The Nature Conservancy, Berlin.**

Fishing is vital to the lives and livelihoods of coastal communities and countries around the world. Yet marine fish and fishers face growing challenges from coastal hazards and climate change. Many coastal countries and communities need support to build resilience and adapt to these changes. This study examines the impacts of climate change on fish and fishers and informs strategies to support adaptation and risk reduction for fishing communities. It refines previous global fisheries risk assessments by: (i) focusing on overall risk (not just vulnerability) and (ii) separately examining multiple aspects of coastal hazards (e.g., waves, storms) and climate change (warming, acidification) that differentially affect fish and fishing communities. We show that these differences in exposure of fish and fishers to climate change affect the strategies to reduce these risks. We provide an assessment of nearterm and future risk based on expected changes in sea surface temperature, ocean acidification, and sea level rise.

**Holsman KK, Haynie AC, Hollowed AB *et al.* 2020. Ecosystem-based fisheries management forestalls climate-driven collapse. *Nat Commun* 11, 4579. <https://doi.org/10.1038/s41467-020-18300-3>.**

Climate change is impacting fisheries worldwide with uncertain outcomes for food and nutritional security. Using management strategy evaluations for key US fisheries in the eastern Bering Sea we find that Ecosystem Based Fisheries Management (EBFM) measures forestall future declines under climate change over non-EBFM approaches. Yet, benefits are species-specific and decrease markedly after 2050. Under high-baseline carbon emission scenarios (RCP 8.5), end-of-century (2075–2100) pollock and Pacific cod fisheries collapse in >70% and >35% of all simulations, respectively. Our analysis suggests that 2.1–2.3 °C (modeled summer bottom temperature) is a tipping point of rapid decline in gadid biomass and catch. Multiyear stanzas above 2.1 °C become commonplace in projections from ~2030 onward, with higher agreement under RCP 8.5 than simulations with moderate carbon mitigation (i.e., RCP 4.5). We find that EBFM ameliorates climate change impacts on fisheries in the near-term, but long-term EBFM benefits are limited by the magnitude of anticipated change.

**Kurota H, Szuwalski CS, Ichinokawa M. 2020. Drivers of recruitment dynamics in Japanese major fisheries resources: Effects of environmental conditions and spawner abundance. *Fisheries Research*, 221. <https://doi.org/10.1016/j.fishres.2019.105353>.**

Identifying driving factors of recruitment dynamics is essential for understanding population dynamics of fisheries resources and managing them sustainably. Spawner abundance and environmental conditions have been assumed as driving factors of recruitment, and the relative influence of these two drivers in fish populations has been debated for a long time. We addressed this issue by applying cross-correlation analysis to the time series of recruitment and spawner abundance of 28 Japanese fisheries stocks. The analysis showed that spawner abundance was significantly related to recruitment in 18 of the 28 stocks, but in many stocks, particularly for small pelagic species, recruitment influenced the later spawner abundance more strongly, suggesting a strong influence of the environment. We also detected temporal shifts of recruitment levels corresponding to shifts of wide-area climatic and oceanographic conditions. These results indicate that both spawner abundance and environment might drive recruitment in many stocks, but the apparent effect of spawner abundance might be a by-product of long-term recruitment changes caused by environmental conditions in some cases. Considering our observations, efficient management strategies are needed that are robust to uncertainties of environmental impacts on fish dynamics and spawner-recruitment relationships and match life-history characteristics of managed stocks.

**McGowan DW, Goldstein ED, Arimitsu ML, Deary AL, Ormseth O, De Robertis A, Horne JK, Rogers LA, Wilson MT, Coyle KO, Holderied K. 2020. Spatial and temporal dynamics of Pacific capelin *Mallotus catervarius* in the Gulf of Alaska: implications for ecosystem-based fisheries management. *Marine Ecology Progress Series*, 637, pp.117-140.**

Pacific capelin *Mallotus catervarius* are planktivorous small pelagic fish that serve an intermediate trophic role in marine food webs. Due to the lack of a directed fishery or monitoring of capelin in the Northeast Pacific, limited information is available on their distribution and abundance, and how spatio-temporal fluctuations in capelin density affect their availability as prey. To provide information on life history, spatial patterns, and population dynamics of capelin in the Gulf of Alaska (GOA), we modeled distributions of spawning habitat and larval dispersal, and synthesized spatially indexed data from multiple independent sources from 1996 to 2016. Potential capelin spawning areas were broadly distributed across the GOA. Models of larval drift

show the GOA's advective circulation patterns disperse capelin larvae over the continental shelf and upper slope, indicating potential connections between spawning areas and observed offshore distributions that are influenced by the location and timing of spawning. Spatial overlap in composite distributions of larval and age-1+ fish was used to identify core areas where capelin consistently occur and concentrate. Capelin primarily occupy shelf waters near the Kodiak Archipelago, and are patchily distributed across the GOA shelf and inshore waters. Interannual variations in abundance along with spatio-temporal differences in density indicate that the availability of capelin to predators and monitoring surveys is highly variable in the GOA. We demonstrate that the limitations of individual data series can be compensated for by integrating multiple data sources to monitor fluctuations in distributions and abundance trends of an ecologically important species across a large marine ecosystem.

**Sandoval-Lugo A, Espinosa-Carreón T, Seminoff J, Hart C, Ley-Quinónez C, Aguirre A, Jones TT, and Zavala-Norzagaray A. 2020. Movements of loggerhead sea turtles (*Caretta caretta*) in the Gulf of California: Integrating satellite telemetry and remotely sensed environmental variables. *Journal of the Marine Biological Association of the United Kingdom*, 100(5), 817-824. doi:10.1017/S0025315420000636.**

The loggerhead turtle (*Caretta caretta*) is a circumglobal species and is listed as vulnerable globally. The North Pacific population nests in Japan and migrates to the Central North Pacific and Pacific coast of North America to feed. In the Mexican Pacific, records of loggerhead presence are largely restricted to the Gulf of Ulloa along the Baja California Peninsula, where very high fisheries by-catch mortality has been reported. Records of loggerhead turtles within the Sea of Cortez also known as the Gulf of California (GC) exist; however, their ecology in this region is poorly understood. We used satellite tracking and an environmental variable analysis (chlorophyll-*a* (Chl-*a*) and sea surface temperature (SST)) to determine movements and habitat use of five juvenile loggerhead turtles ranging in straight carapace length from 62.7–68.3 cm (mean: 66.7 ± 2.3 cm). Satellite tracking durations ranged from 73–293 days (mean: 149 ± 62.5 days), transmissions per turtle from 14–1006 (mean: 462 ± 379.5 transmissions) and total travel distance from 1237–5222 km (mean: 3118 ± 1490.7 km). We used travel rate analyses to identify five foraging areas in the GC, which occurred mainly in waters from 10–80 m deep, with mean Chl-*a* concentrations ranging from 0.28–13.14 mg m<sup>-3</sup> and SST ranging from 27.8–34.4°C. This is the first study to describe loggerhead movements in the Gulf of California and our data suggest that loggerhead foraging movements are performed in areas with eutrophic levels of Chl-*a*.

**Weijerman M, Oyafuso ZS, Leong KM, Oleson KLL, Winston M. 2020. Supporting Ecosystem-based Fisheries Management in meeting multiple objectives for sustainable use of coral reef ecosystems, *ICES Journal of Marine Science*, <https://doi.org/10.1093/icesjms/fsaa194>.**

Ecosystem-based Fisheries Management is a holistic management approach that integrates the dynamics of an entire ecosystem, including societal dimensions. However, this approach seldom lives up to its promise because economic and social objectives are rarely specified. To fill this gap, we explored how an ecosystem model could better integrate economic and social objectives, using the coral reef ecosystem around Hawai'i as a case study. After meeting with stakeholders and conducting a literature review of policy/strategy documents, we identified societal and ecological objectives and associated performance indicators for which data existed. We

developed a social–ecological system conceptual framework to illustrate the relationships between ecological and social state components. This framework was the foundation for the development of the final social–ecological system model which we simulated using an Ecopath with Ecosim model. We simulated four gear/species restrictions for the reef-based fishery, two fishing scenarios associated with the opening of hypothetical no-take Marine Protected Areas for the deepwater-based fishery, and a Constant Effort (No Action) scenario. Despite limitations in the model, our approach shows that when social and economic objectives and social–ecological relationships are defined, we can quantify the trade-offs among the identified societal objectives to support managers in choosing among alternative interventions.

**Vargas-Ángel B, Huntington B. 2020. Status and trends assessments for land-based sources of pollution impacts on benthic reef communities in Faga‘alu Bay, American Samoa. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-109, 38 p. doi:10.25923/0gvj-zm69.**

This report provides a summary of key findings for work completed between 2012 and 2020 to assess the effectiveness of management actions conducted at the Samoa Maritime quarry in Faga‘alu, American Samoa. Collectively, these data offer a contrast between the 2012/2013 pre-intervention and 2015–2020 post-intervention status, and examine how benthic and coral community response variables differed across factors of year (2012/2013, 2015, 2020) and reef stratum (backreef north, backreef south, forereef north, and forereef south).

## 4 REFERENCES

- American Samoa Government, 2018. American Samoa Statistical Yearbook 2017. American Samoa Government Department of Commerce Statistics Division. Pago Pago, American Samoa. 211 pp.
- Andrews, K.R., Williams, A.J., Fernandez-Silva, I., Newman, S.J., Copus, J.M., Wakefield, C.B., Randall, J.E. and B.W. Bowen, 2016. Phylogeny of deepwater snappers (Genus *Etelis*) reveals a cryptic species pair in the Indo-Pacific and Pleistocene invasion of the Atlantic. *Molecular Phylogenetics and Evolution*, 100, pp. 361-371.
- Ansell, A.D., Gibson, R.N., Barnes, M., and U.C.L. Press, 1996. Coastal fisheries in the Pacific Islands. *Oceanography and Marine Biology: an annual review*, 34(395), p. 531.
- Armstrong, K., Herdrich, D.J., and A. Levine, 2011. Historic fishing methods in American Samoa. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-24, 70 pp. + Appendices. [https://www.pifsc.noaa.gov/library/pubs/tech/NOAA\\_Tech\\_Memo\\_PIFSC\\_24.pdf](https://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_24.pdf).
- Aviso, 2021. Ocean Bulletin. ENSO Maps, Centre National D'études Spatiales. Accessed from [https://bulletin.aviso.altimetry.fr/html/produits/indic/enso/welcome\\_uk.php](https://bulletin.aviso.altimetry.fr/html/produits/indic/enso/welcome_uk.php).
- Ayotte, P., McCoy, K., Heenan, A., Williams, I., and J. Zamzow, 2015. Coral Reef Ecosystem Division standard operating procedures: data collection for Rapid Ecological Assessment fish surveys. PIFSC Administrative Report H-15-07. 33 p. Retrieved from <https://repository.library.noaa.gov/view/noaa/9061>.
- Behrenfeld, M.J., O'Malley, R.T., Siegel, D.A., McClain, C.R., Sarmiento, J.L., Feldman, G.C., Milligan, A.J., Falkowski, P.G., Letelier, R.M. and E.S. Boss, 2006. Climate-driven trends in contemporary ocean productivity. *Nature*, 444(7120), pp.752-755.
- Brodziak, J., O'Malley, J., Richards, B., and G. DiNardo, 2012. Stock assessment update of the status of the bottomfish resources of American Samoa, the Commonwealth of the Northern Mariana Islands and Guam, 2012. PIFSC Cent Admin Rep H-12-04, 124 pp.
- Carton, J.A. and B.S. Giese, 2008. A Reanalysis of Ocean Climate Using Simple Ocean Data Assimilation (SODA), *Mon. Weather Rev.*, 136, pp. 2999-3017.
- Chan, H.L. and M. Pan, 2019. Tracking economic performance indicators for small boat fisheries in America Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-79, 76 pp. <https://doi.org/10.25923/8etp-x479>.
- Chan, H.L., 2020. Potential Economic Impacts from the 2018 Amendment to the Billfish Conservation Act of 2012. Pacific Islands Fisheries Science Center, PIFSC Internal Report, IR-20-004, 9 p.
- 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. Accessed from [http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ensoyears.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml).



- Department of Legal Affairs, 2020. Public Notices. American Samoa Government. Accessed from <https://www.legalaffairs.as.gov/blog>.
- DesRochers, A., 2016. "Benthic Habitat Mapping." NOAA Fisheries Center, Honolulu, HI. Presentation. 6 April 2016.
- DiBattista, J.D., Wakefield, C.B., Moore, G.I., Bunce, M., Williams, A.J., O'Malley, J.M., Humphreys Jr, R.L., Halafihi, T., Williams, A., Green, M.A. and K. Graham. 2018. Genomic and life-history discontinuity reveals a precinctive lineage for a deep-water grouper with gene flow from tropical to temperate waters on the west coast of Australia. *Ecological Genetics and Genomics*, 9, pp. 23-33.
- Fabry, V.J., Seibel, B.A., Feely, R.A., and J.C. Orr, 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., and L. Juranek, 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.
- Figueroa, D.F. and A.R. Baco, 2014. Complete mitochondrial genomes elucidate phylogenetic relationships of the deep-sea octocoral families Coralliidae and Paragorgiidae. *Deep Sea Research Part II: Topical Studies in Oceanography*, 99, pp. 83-91.
- Franklin, E., Caloupka, M. and D.R. Kobayashi, 2015. WPSAR Tier 3 Panel Review of 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. Prepared for Pacific Islands Fisheries Science Center, NOAA/NMFS, and the Western Pacific Regional Fishery Management Council. 15 pp.
- Fricke, H. and D. Meischner, 1985. Depth limits of Bermudan scleractinian corals: a submersible survey. *Marine Biology*, 88(2), pp. 175-187.
- Grace-McCaskey, C.A, 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 pp. [https://www.pifsc.noaa.gov/library/pubs/admin/PIFSC\\_Admin\\_Rep\\_14-01.pdf](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 pp. Accessed from [http://cynthiagracemccaskey.com/wp-content/uploads/2017/01/AmericanSamoaFishingCommunityProfile\\_PIFSC\\_Admin\\_Rep\\_15-04.pdf](http://cynthiagracemccaskey.com/wp-content/uploads/2017/01/AmericanSamoaFishingCommunityProfile_PIFSC_Admin_Rep_15-04.pdf).
- Hart, S. R., Staudigel, H., Koppers, A. A. P., Blusztajn, J., Baker, E. T., Workman, R., Jackson, M., Hauri, E., Kurz, M., Sims, K., Fornari, D., Saal, A., and Lyons, S., 2000. Vailulu'u undersea volcano: The New Samoa, *Geochem. Geophys. Geosyst.*, 1, 1056 pp. doi:10.1029/2000GC000108.
- 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.
- 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 pp.
- 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/>.
- HOT, 2021. Hawaii Ocean Time Series. School of Ocean and Earth Science and Technology, University of Hawaii Manoa. Accessed from <https://hahana.soest.hawaii.edu/hot/hot-dogs/bseries.html>.
- Huffman, G.J., Adler, R.F., Arkin, P., Chang, A., Ferraro, R., Gruber, A., Janowiak, J., McNab, A., Rudolf, B., and U. Schneider, 1997. The global precipitation climatology project (GPCP) combined precipitation dataset. *Bulletin of the American Meteorological Society*, 78(1), pp. 5-20.
- Islam, M.S. and M. Tanaka, 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.
- Karl, D.M., and R. Lukas. 1996. The Hawaii Ocean Time-series program: Background, rationale and field implementation. *Deep-Sea Res II*, 43, pp. 129-156.
- Keeling, C.D., Bacastow, R.B., Bainbridge, A.E., Ekdahl, C.A., Guenther, P.R., and L.S. Waterman, 1976. Atmospheric carbon dioxide variations at Mauna Loa Observatory, Hawaii. *Tellus*, 28, pp. 538-551.
- Kahng, S.E. and J.E. Maragos, 2006. The deepest, zooxanthellate scleractinian corals in the world? *Coral Reefs*, 25(2), pp. 254-254.
- Kitiona, F., Spalding, S., and M. Sabater, 2016. The impacts of climate change on coastal fisheries in American Samoa. University of Hawaii at Hilo, HI 96720 USA, 18 pp.
- Kleiber, D., and K. Leong, 2018. Cultural fishing in American Samoa. Pacific Islands Fisheries Science Center, PIFSC Administrative Report, H-18-03, 21 pp. doi:10.25923/fr4m-wm95.
- 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.
- Knapp, K. R., H. J. Diamond, J. P. Kossin, M. C. Kruk, and C. J. Schreck, 2018: International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4. NOAA National Centers for Environmental Information. <https://doi.org/10.25921/82ty-9e16>
- Konter, J.G. and M.G. Jackson, 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.
- Langseth, B., Syslo, J., Yau, A., and F. Carvalho, 2019. Stock assessments of the bottomfish management unit species of Guam, the Commonwealth of the Northern Mariana Islands, and American Samoa, 2019. NOAA Tech Memo. NMFS-PIFSC-86, 177 pp. + supplement, 165 pp. doi:10.25923/bz8b-ng72.
- Leong K.M., Torres, A., Wise, S., and J. Hospital, 2020. Beyond recreation: when fishing motivations are more than sport or pleasure. NOAA Admin Rep. H-20-05, 57 p. doi:10.25923/k5hk-x319
- Levine, A., and S. Allen, 2009. American Samoa as a fishing community. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-19, 74 pp. [https://www.pifsc.noaa.gov/library/pubs/tech/NOAA\\_Tech\\_Memo\\_PIFSC\\_19.pdf](https://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_19.pdf).
- Levine, A.S., Dillard, M.K., Loerzel, J., and P.E.T. Edwards, 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 pp. + Appendices.
- Mantua, N., 2017. The Pacific Decadal Oscillation. Accessed from <http://research.jisao.washington.edu/pdo/>.
- Markrich, M. and C. Hawkins, 2016. Fishing Fleets and Fishery Profiles: Management – Vessels – Gear – Economics. Pacific Islands Fishery Monographs N0. 5 September 2016. Western Pacific Regional Fishery Management Council. Honolulu, HI. 34 pp.
- Matthews, T., Ochavillo, D., Felise, S., Letalie, T., Letuane, M., Schuster, E., Soonaolo, A., Tofaeono, S., Tua, A., and F. Tuilagi, 2019. Length-weight relationships for 71 reef and bottomfish species from Tutuila and Aunu'u, American Samoa. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96818-5007. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-19-03, 9 p.
- McClanahan, T.R., Graham, N.A., MacNeil, M.A., Muthiga, N.A., Cinner, J.E., Bruggemann, J.H., and S.K. Wilson, 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 M.H. Radenac, 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.
- Miller, J., Battista, T., Pritchett, A., Rohmann, S., and J. Rooney, 2011. Coral Reef Conservation Program Mapping Achievements and Unmet Needs. NOAA Coral Reef Conservation Program, Silver Spring, MD, 68 pp.
- Minton, D. 2017. Non-fishing effects that may adversely affect essential fish habitat in the Pacific Islands region, Final Report. NOAA National Marine Fisheries Service, Contract AB-133F-15-CQ-0014. 207 pp.

- Nadon, M.O., Ault, J.S., Williams, I.D., Smith, S.G., and G.T. DiNardo, 2015. Length-based assessment of coral reef fish populations in the main and northwestern Hawaiian Islands. *PloS one*, 10(8), p.e0133960.
- Nadon, M.O. and J.S. Ault, 2016. A stepwise stochastic simulation approach to estimate life history parameters for data-poor fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*. <https://doi.org/10.1139/cjfas-2015-0303>.
- Nadon, M.O., 2019. Stock Assessment of Guam Coral Reef Fish, 2019. NOAA Technical Memorandum NMFS-PIFSC-82, 107 p. doi: 10.25923/pyd6-7k49.
- Neall, V.E. and S.A. Trewick, 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.
- NOAA, 2002. CPC Merged Analysis of Precipitation. National Weather Service, National Centers for Environmental Prediction, Climate Prediction Center. Available at [https://www.cpc.ncep.noaa.gov/products/global\\_precip/html/wpage.cmap.html](https://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.html). Updated 25 September 2002.
- NOAA, 2016. 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. 50 CFR Part 665. *Federal Register*. Vol. 81, No. 22. pp. 5619-5626.
- NOAA, 2017. Pacific Island Pelagic Fisheries; Exemption for Large U.S. Longline Vessels To Fish in Portions of the American Samoa Large Vessel Prohibited Area; Court Order; Final Rule. 50 CFR Part 665. *Federal Register*. Vol. 82, No. 181. pp. 43908-43909.
- NOAA, 2021a. Full Mauna Loa CO<sub>2</sub> Record. Trends in Atmospheric Carbon Dioxide. Earth System Research Laboratory, Global Monitoring Division. Accessed from <https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html>.
- NOAA, 2021b. Climate Indices: Monthly Atmospheric and Oceanic Time-Series. Earth System Research Laboratory, Physical Sciences Division. Accessed from <https://www.ncdc.noaa.gov/teleconnections/pdo/>.
- NOAA, 2021c. Tropical Cyclones – Annual 2020. National Centers for Environmental Information. Accessed from <https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202013>.
- NOAA, 2021d. CPC Merged Analysis of Precipitation (CMAP). National Centers for Environmental Prediction. Accessed from <https://www.esrl.noaa.gov/psd/>
- NOAA, 2021e. Sea level Trends. NOAA Tides & Currents. Available at [https://tidesandcurrents.noaa.gov/datum\\_options.html](https://tidesandcurrents.noaa.gov/datum_options.html).
- NOAA Climate Prediction Center (CPC), 2021. Oceanic Niño Index. Accessed from [https://origin.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ONI\\_v5.php](https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php).
- NOAA CoastWatch, 2021. Sea level Anomaly and Geostrophic Currents, multi-mission, global, optimal interpolation, gridded. Accessed from <https://coastwatch.noaa.gov/cw/satellite-data-products/sea-surface-height/sea-level-anomaly-and-geostrophic-currents-multi-mission-global-optimal-interpolation-gridded.html>.

- NOAA Coral Reef Watch v3.1, 2021. NOAA Satellite and Information Service. Accessed from <https://coralreefwatch.noaa.gov/product/vs/>.
- NOAA OceanWatch, 2021. OceanWatch Central Pacific. OceanWatch Central Pacific Node. Accessed from <https://oceanwatch.pifsc.noaa.gov/>.
- NWS-AS, n.d. National Weather Service Forecast Office, Pago Pago, American Samoa. NOAA National Weather Service. Accessed March 2017.
- O'Malley, J.M., Wakefield, C.B., Oyafuso, Z., Nichols, R.S., Taylor, B.M., Williams, A.J., Sapatu, M., and M. Marsik, 2019. Effects of exploitation evident in age-based demography of 2 deepwater snappers, the goldeneye jobfish (*Pristipomoides flavipinnis*) in the Samoa Archipelago and the goldflag jobfish (*P. auricilla*) in the Mariana Archipelago. *Fisheries Bulletin*, 117, pp. 322-336. doi: 10.7755/FB.117.4.5.
- 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 pp.
- Office of the Governor, 2020. Declaration of Ongoing Public Health and Emergency State of Emergency. American Samoa Government. Accessed from [https://4307e575-0744-4fa0-bcca-68011612de53.filesusr.com/ugd/4bfff9\\_209244296662496c949e0f42d4749b57.pdf](https://4307e575-0744-4fa0-bcca-68011612de53.filesusr.com/ugd/4bfff9_209244296662496c949e0f42d4749b57.pdf).
- Opresko, D.M., 2009. A New Name for the Hawaiian Antipatharian Coral Formerly Known as *Antipathes dichotoma* (Cnidaria: Anthozoa: Antipatharia) 1. *Pacific Science*, 63(2), pp. 277-292.
- Oram, R., TuiSamoa, N., Tomanogi, J., Sabater, M., Quach, M., Hamm, D., and C. Graham, 2011. American Samoa Boat-Based Creel Survey Documentation. NOAA, National Marine Fishery Service, Pacific Island Fishery Science Center, Administrative Report. 14 pp.
- Pacific Islands Benthic Habitat Mapping Center. Pacific Remote Island Areas. School of Ocean and Earth Science and Technology, University of Hawaii at Manoa. Accessed from <http://www.soest.hawaii.edu/pibhmc/cms/data-by-location/pacific-remote-island-area/>.
- Pacific Islands Report, 2016. American Samoa Cannery to 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>.
- Pardee, C., Taylor, B.M., Felise, S., Ochavillo, D., and J. Cuertos-Bueno, 2020. Growth and maturation of three commercially important coral reef species from American Samoa. *Fisheries Science*, 86, pp. 985-993. <https://doi.org/10.1007/s12562-020-01471-9>.
- 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 pp.



- PIFSC, 2020. Pacific Islands Fisheries Science Center. About Us. Ecosystem Sciences. <https://www.fisheries.noaa.gov/about/pacific-islands-fisheries-science-center>.
- Peck, J.E., 2016. Multivariate Analysis for Ecologists: Step-by-Step, Second edition. MjM Software Design, Gleneden Beach, OR. 192 pp.
- Remington, T.R. and D.B. Field, 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 pp.
- 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 J.F. Witzig, 1998. Technical Guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA-TM-NMGS-F/SPO-31.
- Richards B.L., Williams I.D., Vetter O.J., and G.J. Williams, 2012. Environmental factors affecting large-bodied coral reef fish assemblages in the Mariana Archipelago. *PLoS ONE* 7(2), e31374.
- Richmond, L. and A. Levine, 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 pp. + Appendices. [https://www.pifsc.noaa.gov/library/pubs/tech/NOAA\\_Tech\\_Memo\\_PIFSC\\_35.pdf](https://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_35.pdf).
- Roemmich, D. and J. McGowan, 1995. Climatic warming and the decline of zooplankton in the California Current. *Science: New York then Washington*, pp. 1324-1324.
- 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 J.F. Witzig, 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.
- Reynolds, R.W., 1988. A real-time global sea surface temperature analysis. *Journal of Climate*, 1(1), pp. 75-87.
- Sagapolutele, F., 2020. Update: Hawaiian Air Service to American Samoa Suspended. Samoa News. Accessed from <https://www.samoanews.com/update-hawaiian-air-service-american-samoa-suspended>.
- Samoa News Staff, 2020. Update: Three crew on container vessel test positive for COVID-19. Samoa News. Accessed from <https://www.samoanews.com/local-news/update-three-crew-container-vessel-test-positive-covid-19>.
- Samoa News Staff, 2021. ASG releases further repat flight dates and need for cost sharing. Samoa News. Accessed from <https://www.samoanews.com/local-news/asg-releases-further-repat-flight-dates-and-need-cost-sharing>.
- Sievanen, L. and C.A. Grace-McCaskey, 2014. Saipan Fisheries Workshop Data for Use in Reef Fishery SEEM Analysis. Invited presenter at Western Pacific Regional Fishery Management Council SEEM Working Group Meeting. Honolulu, HI.

- Sinniger, F., Ocana, O.V., and A.R. Baco, 2013. Diversity of zoanthids (Anthozoa: *Hexacorallia*) on Hawaiian seamounts: description of the Hawaiian gold coral and additional zoanthids. *PloS one*, 8(1), p.e5260.
- Smith, S.G., Ault, J.S., Bohnsack, J.A., Harper, D.E., Luo, J., and D.B. McClellan., 2011. Multispecies survey design for assessing reef-fish stocks, spatially explicit management performance, and ecosystem condition. *Fisheries Research*, 109(1), pp. 29-41.
- 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.
- Swanson, D., Bailey, H., Schumacher, B., Ferguson, M., and B. Vargas-Ángel, 2018. Ecosystem Science Division Standard Operating Procedures: Data Collection for Rapid Ecological Assessment Benthic Surveys. NOAA Tech. Memo NMFS-PIFSC-71. 63 pp. <https://doi.org/10.25923/39jh-8993>.
- Taylor, B.M. and C. Pardee. 2017. Growth and maturation of the redlip parrotfish *Scarus rubroviolaceus*. *Journal of Fish Biology*, 90(6), <https://doi.org/10.1111/jfb.13309>.
- Taylor, B.M., Oyafuso, Z.S., Pardee, C.B., Ochavillo, D., and S.J. Newman. 2018. Comparative demography of commercially-harvested snappers and an emperor from American Samoa. *PeerJ* 6:e5069 <https://doi.org/10.7717/peerj.5069>.
- Thoning, K.W., Tans, P.P., and W.D. Komhyr, 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.
- Williams, I.D., Baum, J.K., Heenan, A., Hanson, K.M., Nadon, M.O., and R.E. Brainard, 2015. Human, Oceanographic and Habitat Drivers of Central and Western Pacific Coral Reef Fish Assemblages. *PLoS ONE* 10(5): e0129407.
- Winston, M., Couch, C., Ferguson, M., Huntington, B., Swanson, D., and B. Vargas-Ángel, 2019. Ecosystem Sciences Division Standard Operating Procedures: Data Collection for Rapid Ecological Assessment Benthic Surveys, 2018 Update. NOAA Tech. Memo. NOAA-TM-NMFS-PIFSC-92, 66 p.
- WPRFMC. Fishery Management Plan and Fishery Ecosystem Plan Amendments. Available from <https://www.wpcouncil.org/fishery-ecosystem-plans-amendments/>.
- WPRFMC, 2009a. Fishery Ecosystem Plan for the American Samoan Archipelago. Honolulu, HI. 202 pp.
- WPRFMC, 2011. Omnibus Amendment for the Western Pacific Region to Establish a Process for Specifying Annual Catch Limits and Accountability Measures. Honolulu, HI 96813.
- WPRFMC, 2018. Amendment 4 to the Fishery Ecosystem Plan for American Samoa – Ecosystem Components. PIRO, NMFS, Honolulu, HI. RIN 0648-BH63. 171 pp.
- WPRFMC, 2020. Annual Stock Assessment and Fishery Evaluation Report for the American Samoa Archipelago Fishery Ecosystem Plan 2019. Remington, T., Sabater, M., Ishizaki, A. (Eds.) Western Pacific Regional Fishery Management Council. Honolulu, Hawaii 96813 USA.

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



**APPENDIX A: LIST OF SPECIES****AMERICAN SAMOA MANAGEMENT UNIT SPECIES****1. Bottomfish Multi-species Stock Complex (FSSI)**

<b>DMWR Creel Species Code</b>	<b>Species Name</b>	<b>Scientific Name</b>
247	red snapper, silvermouth (lehi) (silverjaw jobfish)	<i>Aphareus rutilans</i>
239	grey snapper, jobfish	<i>Aprion virescens</i>
111	black trevally, jack	<i>Caranx lugubris</i>
229	lunar tail grouper (yellow edge lyretail)	<i>Variola louti</i>
249	red snapper	<i>Etelis carbunculus</i>
248	longtail snapper	<i>Etelis coruscans</i>
267	redgill emperor	<i>Lethrinus rubrioperculatus</i>
231	blueline snapper	<i>Lutjanus kasmira</i>
242	pink snapper (paka)	<i>Pristipomoides filamentosus</i>
241	yelloweye snapper	<i>Pristipomoides flavipinnis</i>
245	flower snapper (gindai)	<i>Pristipomoides zonatus</i>

**MONITORED ECOSYSTEM COMPONENT SPECIES****1. Species Selected for Monitoring by DMWR**

<b>DMWR Creel Species Code</b>	<b>Species Name</b>	<b>Scientific Name</b>
3511	Bluelined squirrelfish	<i>Sargocentron tiere</i>
1301	Fringelip mullet	<i>Crenimugil crenilabis</i>
504	Green spiny lobster	<i>Parulirus penicillatus</i>
None	Small giant clam	<i>Tridacna maxima</i>
5061	Day octopus	<i>Octopus cyanea</i>
208	One-blotch grouper	<i>Epinephelus melanostigma</i>

## 2. Species Monitored by Trophic, Taxonomic, and Functional Groups

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

Family	Scientific Name	Trophic Group	Functional Group
Acanthuridae	<i>Naso lituratus</i>	H	Browsing Surgeons
Acanthuridae	<i>Naso tonganus</i>	H	Browsing Surgeons
Acanthuridae	<i>Naso unicornis</i>	H	Browsing Surgeons
Acanthuridae	<i>Naso brachycentron</i>	H	Browsing Surgeons
Acanthuridae	<i>Ctenochaetus cyanocheilus</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Ctenochaetus strigosus</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Acanthurus nigroris</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Ctenochaetus hawaiiensis</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Ctenochaetus striatus</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Ctenochaetus marginatus</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Acanthurus lineatus</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Acanthurus blochii</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Acanthurus dussumieri</i>	H	Mid-Large Target Surgeons
Acanthuridae	<i>Acanthurus xanthopterus</i>	H	Mid-Large Target Surgeons
Chaetodontidae	<i>Chaetodon flavocoronatus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon multicinctus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon punctatofasciatus</i>	MI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon mertensii</i>	H	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon citrinellus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon pelewensis</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon lunulatus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon melannotus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon rafflesii</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon ulietensis</i>	MI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon fremblii</i>	SI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon quadrimaculatus</i>	Cor	Non-PK Butterflyfish

Chaetodontidae	<i>Chaetodon meyeri</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon reticulatus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon trifascialis</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Heniochus chrysostomus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon bennetti</i>	MI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon tinkeri</i>	SI	Non-PK Butterflyfish
Chaetodontidae	<i>Heniochus varius</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon ornatissimus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon unimaculatus</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon lunula</i>	SI	Non-PK Butterflyfish
Chaetodontidae	<i>Forcipiger longirostris</i>	MI	Non-PK Butterflyfish
Chaetodontidae	<i>Forcipiger flavissimus</i>	SI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon ephippium</i>	MI	Non-PK Butterflyfish
Chaetodontidae	<i>Heniochus monoceros</i>	MI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon auriga</i>	SI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon vagabundus</i>	SI	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon semeion</i>	H	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodontidae</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Heniochus singularius</i>	Cor	Non-PK Butterflyfish
Chaetodontidae	<i>Chaetodon lineolatus</i>	SI	Non-PK Butterflyfish
Caracanthidae	<i>Caracanthus typicus</i>	MI	No Group
Gobiidae	<i>Eviota</i> sp.	MI	No Group
Pomacentridae	<i>Chrysiptera traceyi</i>	H	No Group
Apogonidae	<i>Ostorhinchus luteus</i>	Pk	No Group
Caracanthidae	<i>Caracanthus maculatus</i>	MI	No Group
Pseudochromidae	<i>Pseudochromis jamesi</i>	MI	No Group
Pomacentridae	<i>Chromis acares</i>	Pk	No Group
Serranidae	<i>Luzonichthys whitleyi</i>	Pk	No Group
Pomacentridae	<i>Pomachromis guamensis</i>	Pk	No Group
Pomacentridae	<i>Pomachromis richardsoni</i>	Pk	No Group
Gobiidae	<i>Fusigobius duospilus</i>	MI	No Group
Pomacentridae	<i>Plectroglyphidodon imparipennis</i>	MI	No Group
Microdesmidae	<i>Nemateleotris helfrichi</i>	Pk	No Group
Pomacentridae	<i>Chromis leucura</i>	Pk	No Group
Syngnathidae	<i>Doryrhamphus excisus</i>	Pk	No Group
Pomacentridae	<i>Pomacentrus coelestis</i>	Pk	No Group
Clupeidae	<i>Spratelloides delicatulus</i>	Pk	No Group
Pomacentridae	<i>Chrysiptera biocellata</i>	H	No Group

Pseudochromidae	<i>Pictichromis porphyreus</i>	MI	No Group
Pomacanthidae	<i>Centropyge fisheri</i>	H	No Group
Cirrhitidae	<i>Cirrhitops hubbardi</i>	MI	No Group
Gobiidae	<i>Amblyeleotris fasciata</i>	Pk	No Group
Pomacentridae	<i>Chromis lepidolepis</i>	Pk	No Group
Pomacentridae	<i>Chromis margaritifer</i>	Pk	No Group
Pomacentridae	<i>Chromis ternatensis</i>	Pk	No Group
Pomacentridae	<i>Chromis viridis</i>	Pk	No Group
Pomacentridae	<i>Chrysiptera cyanea</i>	Pk	No Group
Pomacentridae	<i>Dascyllus aruanus</i>	Pk	No Group
Pomacentridae	<i>Dascyllus reticulatus</i>	Pk	No Group
Engraulidae	<i>Encrasicholina purpurea</i>	Pk	No Group
Pomacentridae	<i>Neopomacentrus metallicus</i>	Pk	No Group
Pomacentridae	<i>Chromis amboinensis</i>	H	No Group
Pomacentridae	<i>Chromis iomelas</i>	H	No Group
Pomacentridae	<i>Chrysiptera glauca</i>	H	No Group
Pomacentridae	<i>Chrysiptera taupou</i>	H	No Group
Labridae	<i>Labroides pectoralis</i>	MI	No Group
Labridae	<i>Pseudocheilinus hexataenia</i>	MI	No Group
Labridae	<i>Pseudocheilinus tetrataenia</i>	MI	No Group
Scorpaenidae	<i>Sebastapistes cyanostigma</i>	MI	No Group
Labridae	<i>Wetmorella nigropinnata</i>	MI	No Group
Pseudochromidae	<i>Pseudochromis</i> sp.	MI	No Group
Monacanthidae	<i>Pervagor marginalis</i>	Om	No Group
Pomacentridae	<i>Chromis alpha</i>	Pk	No Group
Pomacentridae	<i>Plectroglyphidodon phoenixensis</i>	H	No Group
Gobiidae	<i>Amblyeleotris guttata</i>	Pk	No Group
Atherinidae	<i>Atherinomorus insularum</i>	Pk	No Group
Pomacentridae	<i>Chromis caudalis</i>	Pk	No Group
Pomacentridae	<i>Chromis hanui</i>	Pk	No Group
Labridae	<i>Cirrhilabrus katherinae</i>	Pk	No Group
Microdesmidae	<i>Nemateleotris magnifica</i>	Pk	No Group
Apogonidae	<i>Ostorhinchus angustatus</i>	Pk	No Group
Serranidae	<i>Pseudanthias bartlettorum</i>	Pk	No Group
Tetraodontidae	<i>Canthigaster jactator</i>	H	No Group
Tetraodontidae	<i>Canthigaster janthinoptera</i>	H	No Group
Tetraodontidae	<i>Canthigaster valentini</i>	H	No Group
Pomacanthidae	<i>Centropyge shepardi</i>	H	No Group

Pomacentridae	<i>Chrysiptera brownriggii</i>	H	No Group
Monacanthidae	<i>Oxymonacanthus longirostris</i>	Cor	No Group
Cirrhitidae	<i>Amblycirrhitus bimacula</i>	MI	No Group
Cirrhitidae	<i>Cirrhitichthys falco</i>	MI	No Group
Labridae	<i>Labroides rubrolabiatus</i>	MI	No Group
Cirrhitidae	<i>Neocirrhites armatus</i>	MI	No Group
Labridae	<i>Pseudojuloides splendens</i>	MI	No Group
Apogonidae	<i>Ostorhinchus novemfasciatus</i>	Pk	No Group
Labridae	<i>Pteragogus cryptus</i>	MI	No Group
Scorpaenidae	<i>Sebastapistes</i> sp.	Pisc	No Group
Scorpaenidae	<i>Taenianotus triacanthus</i>	Pisc	No Group
Pomacentridae	<i>Amphiprion perideraion</i>	Pk	No Group
Pomacentridae	<i>Chromis fumea</i>	Pk	No Group
Labridae	<i>Cirrhilabrus jordani</i>	Pk	No Group
Blenniidae	<i>Ecsenius bicolor</i>	Pk	No Group
Blenniidae	<i>Ecsenius midas</i>	Pk	No Group
Blenniidae	<i>Ecsenius opsifrontalis</i>	Pk	No Group
Pomacentridae	<i>Lepidozygus tapeinosoma</i>	Pk	No Group
Blenniidae	<i>Meiacanthus atrodorsalis</i>	Pk	No Group
Apogonidae	<i>Ostorhinchus apogonoides</i>	Pk	No Group
Pomacentridae	<i>Plectroglyphidodon lacrymatus</i>	Pk	No Group
Pomacentridae	<i>Pomacentrus brachialis</i>	Pk	No Group
Pomacentridae	<i>Pomacentrus nigriradiatus</i>	Pk	No Group
Pomacentridae	<i>Pomacentrus philippinus</i>	Pk	No Group
Pomacentridae	<i>Pomacentrus vaiuli</i>	Pk	No Group
Serranidae	<i>Pseudanthias dispar</i>	Pk	No Group
Serranidae	<i>Pseudanthias hawaiiensis</i>	Pk	No Group
Tetraodontidae	<i>Canthigaster bennetti</i>	H	No Group
Pomacanthidae	<i>Centropyge bispinosa</i>	H	No Group
Pomacanthidae	<i>Centropyge heraldi</i>	H	No Group
Pomacanthidae	<i>Centropyge loricula</i>	H	No Group
Blenniidae	<i>Cirripectes obscurus</i>	H	No Group
Blenniidae	<i>Cirripectes polyzona</i>	H	No Group
Blenniidae	<i>Cirripectes</i> sp.	H	No Group
Blenniidae	<i>Cirripectes springeri</i>	H	No Group
Blenniidae	<i>Cirripectes stigmaticus</i>	H	No Group

Blenniidae	<i>Cirripectes variolosus</i>	H	No Group
Callionymidae	<i>Callionymidae</i>	MI	No Group
Labridae	<i>Labroides phthiophagus</i>	MI	No Group
Pomacanthidae	<i>Paracentropyge multifasciata</i>	MI	No Group
Blenniidae	<i>Plagiotremus ewaensis</i>	MI	No Group
Blenniidae	<i>Plagiotremus goslinei</i>	MI	No Group
Scorpaenidae	<i>Sebastapistes coniota</i>	MI	No Group
Monacanthidae	<i>Pervagor melanocephalus</i>	Om	No Group
Blenniidae	<i>Plagiotremus laudandus</i>	Par	No Group
Blenniidae	<i>Plagiotremus rhinorhynchus</i>	Par	No Group
Blenniidae	<i>Plagiotremus tapeinosoma</i>	Par	No Group
Labridae	<i>Pseudocheilinus ocellatus</i>	MI	No Group
Pomacanthidae	<i>Centropyge flavissima &amp; vroliki</i>	H	No Group
Pomacentridae	<i>Amblyglyphidodon curacao</i>	Om	No Group
Pomacentridae	<i>Amphiprion melanopus</i>	Pk	No Group
Pomacentridae	<i>Chromis agilis</i>	Pk	No Group
Gobiidae	<i>Istigobius</i> sp.	Pk	No Group
Pomacentridae	<i>Pomacentrus pavo</i>	Pk	No Group
Apogonidae	<i>Pristiapogon fraenatus</i>	Pk	No Group
Tetraodontidae	<i>Canthigaster epilampra</i>	H	No Group
Tetraodontidae	<i>Canthigaster solandri</i>	H	No Group
Blenniidae	<i>Cirripectes vanderbilti</i>	H	No Group
Pomacentridae	<i>Stegastes albifasciatus</i>	H	No Group
Pomacentridae	<i>Stegastes aureus</i>	H	No Group
Pomacentridae	<i>Stegastes marginatus</i>	H	No Group
Pomacentridae	<i>Plectroglyphidodon dickii</i>	Cor	No Group
Cirrhitidae	<i>Paracirrhites xanthus</i>	MI	No Group
Monacanthidae	<i>Paraluteres prionurus</i>	MI	No Group
Microdesmidae	<i>Microdesmidae</i>	Pk	No Group
Scorpaenidae	<i>Sebastapistes ballieui</i>	MI	No Group
Apogonidae	<i>Apogon kallopterus</i>	Pk	No Group
Pomacentridae	<i>Chromis weberi</i>	Pk	No Group
Labridae	<i>Cirrhilabrus exquisitus</i>	Pk	No Group
Syngnathidae	<i>Corythoichthys flavofasciatus</i>	Pk	No Group
Pomacentridae	<i>Dascyllus albisella</i>	Pk	No Group
Microdesmidae	<i>Gunnellichthys curiosus</i>	Pk	No Group

Apogonidae	<i>Pristiapogon kallopterus</i>	Pk	No Group
Serranidae	<i>Pseudanthias olivaceus</i>	Pk	No Group
Ptereleotridae	<i>Ptereleotris heteroptera</i>	Pk	No Group
Ptereleotridae	<i>Ptereleotris zebra</i>	Pk	No Group
Pomacanthidae	<i>Centropyge vrolikii</i>	H	No Group
Pomacentridae	<i>Plectroglyphidodon leucozonus</i>	H	No Group
Pomacentridae	<i>Plectroglyphidodon johnstonianus</i>	Cor	No Group
Labridae	<i>Anampses melanurus</i>	MI	No Group
Apogonidae	<i>Cheilodipterus quinquelineatus</i>	MI	No Group
Cirrhitidae	<i>Cirrhitichthys oxycephalus</i>	MI	No Group
Cirrhitidae	<i>Cirrhitops fasciatus</i>	MI	No Group
Labridae	<i>Halichoeres biocellatus</i>	MI	No Group
Labridae	<i>Labroides dimidiatus</i>	MI	No Group
Labridae	<i>Labropsis micronesica</i>	MI	No Group
Labridae	<i>Macropharyngodon negrosensis</i>	MI	No Group
Labridae	<i>Pseudojuloides cerasinus</i>	MI	No Group
Labridae	<i>Pseudojuloides polynesica</i>	MI	No Group
Blenniidae	<i>Aspidontus taeniatus</i>	Par	No Group
Tetraodontidae	<i>Torquigener randalli</i>	MI	No Group
Pomacentridae	<i>Plectroglyphidodon sindonis</i>	H	No Group
Pomacanthidae	<i>Centropyge potteri</i>	H	No Group
Cirrhitidae	<i>Oxycirrhites typus</i>	Pk	No Group
Serranidae	<i>Pseudanthias bicolor</i>	Pk	No Group
Ptereleotridae	<i>Ptereleotris microlepis</i>	Pk	No Group
Pomacentridae	<i>Stegastes lividus</i>	H	No Group
Labridae	<i>Cirrhilabrus punctatus</i>	MI	No Group
Labridae	<i>Halichoeres margaritaceus</i>	MI	No Group
Labridae	<i>Pseudojuloides atavai</i>	MI	No Group
Holocentridae	<i>Sargocentron punctatissimum</i>	MI	No Group
Monacanthidae	<i>Pervagor janthinosoma</i>	Om	No Group
Pomacentridae	<i>Amphiprion clarkii</i>	Pk	No Group
Serranidae	<i>Anthias</i> sp.	Pk	No Group
Blenniidae	<i>Blenniella chrysospilos</i>	Pk	No Group
Chaetodontidae	<i>Chaetodon kleinii</i>	Pk	No Group
Pomacentridae	<i>Dascyllus trimaculatus</i>	Pk	No Group

Apogonidae	<i>Ostorhinchus maculiferus</i>	Pk	No Group
Serranidae	<i>Pseudanthias cooperi</i>	Pk	No Group
Gobiidae	<i>Amblygobius phalaena</i>	H	No Group
Tetraodontidae	<i>Canthigaster amboinensis</i>	H	No Group
Tetraodontidae	<i>Canthigaster coronata</i>	H	No Group
Pomacanthidae	<i>Centropyge flavissima</i>	H	No Group
Pomacentridae	<i>Stegastes nigricans</i>	H	No Group
Labridae	<i>Halichoeres melanurus</i>	MI	No Group
Labridae	<i>Halichoeres melasmapomus</i>	MI	No Group
Labridae	<i>Labroides bicolor</i>	MI	No Group
Labridae	<i>Labropsis xanthonota</i>	MI	No Group
Cirrhitidae	<i>Paracirrhites arcatus</i>	MI	No Group
Labridae	<i>Pseudocheilinus evanidus</i>	MI	No Group
Labridae	<i>Pseudocheilinus octotaenia</i>	MI	No Group
Monacanthidae	<i>Pervagor aspricaudus</i>	Om	No Group
Ostraciidae	<i>Lactoria fornasini</i>	SI	No Group
Labridae	<i>Pseudojuloides</i> sp.	MI	No Group
Pomacentridae	<i>Abudefduf sexfasciatus</i>	Pk	No Group
Pomacentridae	<i>Chromis vanderbilti</i>	Pk	No Group
Pomacentridae	<i>Chromis xanthura</i>	Pk	No Group
Labridae	<i>Cirrhilabrus</i> sp.	Pk	No Group
Pomacanthidae	<i>Genicanthus watanabei</i>	Pk	No Group
Labridae	<i>Thalassoma amblycephalum</i>	Pk	No Group
Pomacanthidae	<i>Centropyge bicolor</i>	H	No Group
Serranidae	<i>Belonoperca chabanaudi</i>	MI	No Group
Labridae	<i>Coris centralis</i>	MI	No Group
Labridae	<i>Halichoeres ornatissimus</i>	MI	No Group
Malacanthidae	<i>Hoplolatilus starcki</i>	MI	No Group
Labridae	<i>Macropharyngodon meleagris</i>	MI	No Group
Labridae	<i>Oxycheilinus bimaculatus</i>	MI	No Group
Labridae	<i>Pteragogus enneacanthus</i>	MI	No Group
Labridae	<i>Stethojulis balteata</i>	MI	No Group
Labridae	<i>Stethojulis strigiventer</i>	MI	No Group
Labridae	<i>Stethojulis trilineata</i>	MI	No Group
Pomacentridae	<i>Stegastes</i> sp.	H	No Group
Apogonidae	<i>Apogon</i> sp.	Pk	No Group
Apogonidae	<i>Apogonidae</i>	Pk	No Group
Chaetodontidae	<i>Chaetodon miliaris</i>	Pk	No Group



Pomacentridae	<i>Dascyllus auripinnis</i>	Pk	No Group
Labridae	<i>Pseudocoris yamashiroi</i>	Pk	No Group
Labridae	<i>Stethojulis bandanensis</i>	Pk	No Group
Monacanthidae	<i>Cantherhines verecundus</i>	H	No Group
Pomacanthidae	<i>Centropyge interrupta</i>	H	No Group
Pomacentridae	<i>Stegastes fasciolatus</i>	H	No Group
Blenniidae	<i>Exallias brevis</i>	Cor	No Group
Labridae	<i>Labrichthys unilineatus</i>	Cor	No Group
Labridae	<i>Halichoeres prosopeion</i>	MI	No Group
Labridae	<i>Macropharyngodon geoffroy</i>	MI	No Group
Gobiidae	<i>Valenciennea strigata</i>	MI	No Group
Ostraciidae	<i>Ostracion whitleyi</i>	SI	No Group
Scorpaenidae	<i>Dendrochirus barberi</i>	MI	No Group
Blenniidae	<i>Blenniidae</i>	Pk	No Group
Synodontidae	<i>Synodus binotatus</i>	Pisc	No Group
Pomacentridae	<i>Amphiprion chrysopterus</i>	Pk	No Group
Serranidae	<i>Pseudanthias pascalus</i>	Pk	No Group
Acanthuridae	<i>Ctenochaetus flavicauda</i>	H	No Group
Labridae	<i>Cheilinus oxycephalus</i>	MI	No Group
Holocentridae	<i>Sargocentron diadema</i>	MI	No Group
Holocentridae	<i>Sargocentron xantherythrum</i>	MI	No Group
Labridae	<i>Thalassoma quinquevittatum</i>	MI	No Group
Labridae	<i>Iniistius umbrilatus</i>	MI	No Group
Labridae	<i>Thalassoma</i> sp.	MI	No Group
Pomacentridae	<i>Pomacentridae</i>	Om	No Group
Pomacentridae	<i>Abudefduf notatus</i>	Pk	No Group
Chaetodontidae	<i>Hemitaurichthys polylepis</i>	Pk	No Group
Ptereleotridae	<i>Ptereleotris evides</i>	Pk	No Group
Labridae	<i>Anampses twistii</i>	MI	No Group
Apogonidae	<i>Cheilodipterus</i> sp.	MI	No Group
Labridae	<i>Cymolutes lecluse</i>	MI	No Group
Labridae	<i>Halichoeres hartzfeldii</i>	MI	No Group
Labridae	<i>Halichoeres marginatus</i>	MI	No Group
Pinguipedidae	<i>Parapercis clathrata</i>	MI	No Group
Pinguipedidae	<i>Parapercis schauinslandii</i>	MI	No Group
Labridae	<i>Choerodon jordani</i>	Om	No Group
Monacanthidae	<i>Pervagor</i> sp.	Om	No Group
Monacanthidae	<i>Pervagor spilosoma</i>	Om	No Group

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

Synodontidae	<i>Synodontidae</i>	Pisc	No Group
Pomacentridae	<i>Chromis verater</i>	Pk	No Group
Pempheridae	<i>Pempheridae</i>	Pk	No Group
Serranidae	<i>Pseudanthias thompsoni</i>	Pk	No Group
Balistidae	<i>Xanthichthys auromarginatus</i>	Pk	No Group
Acanthuridae	<i>Ctenochaetus binotatus</i>	H	No Group
Labridae	<i>Anampses meleagrides</i>	MI	No Group
Labridae	<i>Iniistius aneitensis</i>	MI	No Group
Mullidae	<i>Parupeneus chrysonemus</i>	MI	No Group
Balistidae	<i>Sufflamen chrysopterum</i>	MI	No Group
Cirrhitidae	<i>Paracirrhites forsteri</i>	Pisc	No Group
Synodontidae	<i>Saurida gracilis</i>	Pisc	No Group
Holocentridae	<i>Myripristis kuntze</i>	Pk	No Group
Pempheridae	<i>Pempheris oualensis</i>	Pk	No Group
Pomacentridae	<i>Abudefduf septemfasciatus</i>	H	No Group
Acanthuridae	<i>Acanthurus nigricans</i>	H	No Group
Acanthuridae	<i>Acanthurus nigrofusus</i>	H	No Group
Holocentridae	<i>Neonippon aurolineatus</i>	MI	No Group
Pinguipedidae	<i>Parapercis</i> sp.	MI	No Group
Labridae	<i>Bodianus sanguineus</i>	Om	No Group
Synodontidae	<i>Synodus dermatogenys</i>	Pisc	No Group
Synodontidae	<i>Synodus variegatus</i>	Pisc	No Group
Pomacentridae	<i>Abudefduf sordidus</i>	H	No Group
Holocentridae	<i>Myripristis earlei</i>	MI	No Group
Pomacentridae	<i>Abudefduf abdominalis</i>	Pk	No Group
Pomacanthidae	<i>Genicanthus personatus</i>	Pk	No Group
Chaetodontidae	<i>Heniochus acuminatus</i>	Pk	No Group
Holocentridae	<i>Myripristis chryseres</i>	Pk	No Group
Holocentridae	<i>Myripristis woodsi</i>	Pk	No Group
Labridae	<i>Thalassoma lunare</i>	Pk	No Group
Acanthuridae	<i>Acanthurus achilles</i>	H	No Group
Acanthuridae	<i>Acanthurus achilles &amp; nigricans</i>	H	No Group
Acanthuridae	<i>Acanthurus leucopareius</i>	H	No Group
Acanthuridae	<i>Acanthurus pyroferus</i>	H	No Group
Monacanthidae	<i>Cantherhines pardalis</i>	H	No Group
Labridae	<i>Bodianus diana</i>	MI	No Group
Balistidae	<i>Rhinecanthus rectangulus</i>	MI	No Group

Holocentridae	<i>Sargocentron caudimaculatum</i>	MI	No Group
Holocentridae	<i>Sargocentron ensifer</i>	MI	No Group
Labridae	<i>Thalassoma duperrey</i> & <i>quinquevittatum</i>	MI	No Group
Labridae	<i>Thalassoma lutescens</i>	MI	No Group
Pomacanthidae	<i>Apolemichthys griffisi</i>	SI	No Group
Pomacanthidae	<i>Apolemichthys trimaculatus</i>	SI	No Group
Pomacanthidae	<i>Apolemichthys xanthopunctatus</i>	SI	No Group
Pomacanthidae	<i>Pygoplites diacanthus</i>	SI	No Group
Serranidae	<i>Epinephelus hexagonatus</i>	Pisc	No Group
Acanthuridae	<i>Acanthurus nubilus</i>	Pk	No Group
Muraenidae	<i>Gymnothorax melatremus</i>	MI	No Group
Labridae	<i>Pseudodax moluccanus</i>	MI	No Group
Labridae	<i>Thalassoma duperrey</i>	MI	No Group
Acanthuridae	<i>Acanthurus triostegus</i>	H	No Group
Serranidae	<i>Grammistes sexlineatus</i>	MI	No Group
Labridae	<i>Halichoeres hortulanus</i>	MI	No Group
Labridae	<i>Halichoeres trimaculatus</i>	MI	No Group
Serranidae	<i>Cephalopholis urodeta</i>	Pisc	No Group
Cirrhitidae	<i>Paracirrhites hemistictus</i>	Pisc	No Group
Acanthuridae	<i>Acanthurus thompsoni</i>	Pk	No Group
Siganidae	<i>Siganus spinus</i>	H	No Group
Balistidae	<i>Rhinecanthus lunula</i>	MI	No Group
Balistidae	<i>Sufflamen bursa</i>	MI	No Group
Ostraciidae	<i>Ostracion meleagris</i>	SI	No Group
Acanthuridae	<i>Acanthurus guttatus</i>	H	No Group
Cirrhitidae	<i>Cirrhitidae</i>	MI	No Group
Serranidae	<i>Cephalopholis spiloparaea</i>	Pisc	No Group
Labridae	<i>Oxycheilinus digramma</i>	Pisc	No Group
Scorpaenidae	<i>Scorpaenopsis diabolus</i>	Pisc	No Group
Scorpaenidae	<i>Scorpaenopsis</i> sp.	Pisc	No Group
Synodontidae	<i>Synodus ulae</i>	Pisc	No Group
Caesionidae	<i>Caesio lunaris</i>	Pk	No Group
Balistidae	<i>Canthidermis maculata</i>	Pk	No Group
Hemiramphidae	<i>Hyporhamphus acutus</i>	Pk	No Group
Caesionidae	<i>Pterocaesio lativittata</i>	Pk	No Group
Caesionidae	<i>Pterocaesio tile</i>	Pk	No Group

Carangidae	<i>Selar crumenophthalmus</i>	Pk	No Group
Balistidae	<i>Xanthichthys mento</i>	Pk	No Group
Acanthuridae	<i>Ctenochaetus</i> sp.	H	No Group
Acanthuridae	<i>Naso thynnoides</i>	H	No Group
Balistidae	<i>Balistapus undulatus</i>	MI	No Group
Cirrhitidae	<i>Cirrhitus pinnulatus</i>	MI	No Group
Labridae	<i>Coris ballieui</i>	MI	No Group
Lethrinidae	<i>Gnathodentex aureolineatus</i>	MI	No Group
Malacanthidae	<i>Malacanthus brevirostris</i>	MI	No Group
Mullidae	<i>Mulloidichthys mimicus</i>	MI	No Group
Holocentridae	<i>Myripristis violacea</i>	MI	No Group
Labridae	<i>Novaculichthys taeniourus</i>	MI	No Group
Balistidae	<i>Rhinecanthus aculeatus</i>	MI	No Group
Synodontidae	<i>Saurida flamma</i>	Pisc	No Group
Acanthuridae	<i>Paracanthurus hepatus</i>	Pk	No Group
Caesionidae	<i>Caesionidae</i>	Pk	No Group
Holocentridae	<i>Holocentridae</i>	MI	No Group
Priacanthidae	<i>Heteropriacanthus carolinus</i>	Pk	No Group
Holocentridae	<i>Myripristis adusta</i>	Pk	No Group
Holocentridae	<i>Myripristis amaena</i>	Pk	No Group
Labridae	<i>Cheilinus chlorourus</i>	MI	No Group
Labridae	<i>Gomphosus varius</i>	MI	No Group
Lethrinidae	<i>Lethrinus harak</i>	MI	No Group
Holocentridae	<i>Neoniphon sammara</i>	MI	No Group
Serranidae	<i>Epinephelus melanostigma</i>	Pisc	No Group
Serranidae	<i>Epinephelus merra</i>	Pisc	No Group
Holocentridae	<i>Myripristis berndti</i>	Pk	No Group
Priacanthidae	<i>Priacanthus hamrur</i>	Pk	No Group
Priacanthidae	<i>Priacanthus meeki</i>	Pk	No Group
Acanthuridae	<i>Acanthurus albipectoralis</i>	H	No Group
Tetraodontidae	<i>Arothron nigropunctatus</i>	Cor	No Group
Mullidae	<i>Parupeneus insularis</i>	MI	No Group
Mullidae	<i>Parupeneus pleurostigma</i>	MI	No Group
Holocentridae	<i>Sargocentron tiere</i>	MI	No Group
Labridae	<i>Thalassoma trilobatum</i>	MI	No Group
Mullidae	<i>Upeneus taeniopterus</i>	MI	No Group
Balistidae	<i>Melichthys vidua</i>	H	No Group
Serranidae	<i>Epinephelus spilotoceps</i>	Pisc	No Group

Lutjanidae	<i>Lutjanus semicinctus</i>	Pisc	No Group
Serranidae	<i>Pogonoperca punctata</i>	Pisc	No Group
Caesionidae	<i>Caesio caeruleaurea</i>	Pk	No Group
Carangidae	<i>Decapterus macarellus</i>	Pk	No Group
Holocentridae	<i>Myripristinae</i>	Pk	No Group
Caesionidae	<i>Pterocaesio marri</i>	Pk	No Group
Balistidae	<i>Xanthichthys caeruleolineatus</i>	Pk	No Group
Labridae	<i>Iniistius pavo</i>	MI	No Group
Holocentridae	<i>Neoniphon opercularis</i>	MI	No Group
Holocentridae	<i>Neoniphon</i> sp.	MI	No Group
Mullidae	<i>Parupeneus crassilabris</i>	MI	No Group
Labridae	<i>Anampses cuvier</i>	MI	No Group
Labridae	<i>Cheilinus fasciatus</i>	MI	No Group
Siganidae	<i>Siganus punctatus</i>	H	No Group
Gobiidae	<i>Gobiidae</i>	MI	No Group
Scorpaenidae	<i>Pterois volitans</i>	Pisc	No Group
Balistidae	<i>Melichthys niger</i>	Pk	No Group
Priacanthidae	<i>Priacanthus</i> sp.	Pk	No Group
Monacanthidae	<i>Monacanthidae</i>	H	No Group
Siganidae	<i>Siganidae</i>	H	No Group
Diodontidae	<i>Diodon holocanthus</i>	MI	No Group
Mullidae	<i>Mulloidichthys vanicolensis</i>	MI	No Group
Mullidae	<i>Parupeneus multifasciatus</i>	MI	No Group
Balistidae	<i>Sufflamen fraenatum</i>	MI	No Group
Monacanthidae	<i>Cantherhines dumerilii</i>	Om	No Group
Pomacanthidae	<i>Pomacanthus imperator</i>	SI	No Group
Lethrinidae	<i>Lethrinus rubrioperculatus</i>	MI	No Group
Caesionidae	<i>Caesio teres</i>	Pk	No Group
Balistidae	<i>Odonus niger</i>	Pk	No Group
Acanthuridae	<i>Acanthurus nigricauda</i>	H	No Group
Acanthuridae	<i>Acanthurus olivaceus</i>	H	No Group
Acanthuridae	<i>Zebrasoma veliferum</i>	H	No Group
Labridae	<i>Bodianus loxozonus</i>	MI	No Group
Labridae	<i>Coris gaimard</i>	MI	No Group
Labridae	<i>Hologymnosus annulatus</i>	MI	No Group
Labridae	<i>Hologymnosus doliatus</i>	MI	No Group
Mullidae	<i>Mulloidichthys flavolineatus</i>	MI	No Group
Acanthuridae	<i>Acanthurus maculiceps</i>	H	No Group

Kyphosidae	<i>Kyphosus hawaiiensis</i>	H	No Group
Cheilodactylidae	<i>Cheilodactylus vittatus</i>	SI	No Group
Ostraciidae	<i>Ostraciidae</i>	SI	No Group
Siganidae	<i>Siganus argenteus</i>	H	No Group
Labridae	<i>Anampses caeruleopunctatus</i>	MI	No Group
Serranidae	<i>Epinephelus fasciatus</i>	Pisc	No Group
Labridae	<i>Thalassoma ballieui</i>	MI	No Group
Labridae	<i>Thalassoma purpureum</i>	MI	No Group
Serranidae	<i>Cephalopholis miniata</i>	Pisc	No Group
Hemiramphidae	<i>Hemiramphidae</i>	Pk	No Group
Acanthuridae	<i>Acanthurus leucocheilus</i>	H	No Group
Ostraciidae	<i>Ostracion cubicus</i>	H	No Group
Bothidae	<i>Bothus mancus</i>	MI	No Group
Labridae	<i>Cheilinus</i> sp.	MI	No Group
Labridae	<i>Cheilinus trilobatus</i>	MI	No Group
Malacanthidae	<i>Malacanthus latovittatus</i>	MI	No Group
Labridae	<i>Oxycheilinus unifasciatus</i>	Pisc	No Group
Labridae	<i>Oxycheilinus</i> sp.	MI	No Group
Serranidae	<i>Epinephelus retouti</i>	Pisc	No Group
Mullidae	<i>Mulloidichthys pfluegeri</i>	MI	No Group
Serranidae	<i>Cephalopholis sexmaculata</i>	Pisc	No Group
Serranidae	<i>Cephalopholis sonnerati</i>	Pisc	No Group
Serranidae	<i>Gracila albomarginata</i>	Pisc	No Group
Mullidae	<i>Parupeneus cyclostomus</i>	Pisc	No Group
Belonidae	<i>Platybelone argalus</i>	Pisc	No Group
Acanthuridae	<i>Acanthurus mata</i>	Pk	No Group
Tetraodontidae	<i>Arothron meleagris</i>	Cor	No Group
Balistidae	<i>Balistoides conspicillum</i>	MI	No Group
Labridae	<i>Hemigymnus fasciatus</i>	MI	No Group
Lethrinidae	<i>Lethrinus obsoletus</i>	MI	No Group
Mullidae	<i>Mullidae</i>	MI	No Group
Mullidae	<i>Parupeneus barberinus</i>	MI	No Group
Holocentridae	<i>Sargocentron</i> sp.	MI	No Group
Ephippidae	<i>Platax orbicularis</i>	Om	No Group
Serranidae	<i>Epinephelus macrospilos</i>	Pisc	No Group
Scorpaenidae	<i>Scorpaenopsis cacopsis</i>	Pisc	No Group
Kyphosidae	<i>Kyphosus cinerascens</i>	H	No Group
Labridae	<i>Cheilio inermis</i>	MI	No Group

Mullidae	<i>Parupeneus porphyreus</i>	MI	No Group
Serranidae	<i>Epinephelus socialis</i>	Pisc	No Group
Tetraodontidae	<i>Arothron hispidus</i>	MI	No Group
Holocentridae	<i>Sargocentron spiniferum</i>	MI	No Group
Carangidae	<i>Trachinotus bailloni</i>	Pisc	No Group
Labridae	<i>Epibulus insidiator</i>	MI	No Group
Serranidae	<i>Epinephelus howlandi</i>	Pisc	No Group
Labridae	<i>Bodianus albotaeniatus</i>	MI	No Group
Labridae	<i>Bodianus bilunulatus</i>	MI	No Group
Acanthuridae	<i>Acanthurus</i> sp.	H	No Group
Serranidae	<i>Aethaloperca rogaa</i>	Pisc	No Group
Serranidae	<i>Anyperodon leucogrammicus</i>	Pisc	No Group
Serranidae	<i>Cephalopholis argus</i>	Pisc	No Group
Serranidae	<i>Cephalopholis</i> sp.	Pisc	No Group
Serranidae	<i>Epinephelus maculatus</i>	Pisc	No Group
Holocentridae	<i>Myripristis murdjan</i>	Pk	No Group
Acanthuridae	<i>Naso brevirostris</i>	Pk	No Group
Acanthuridae	<i>Naso maculatus</i>	Pk	No Group
Acanthuridae	<i>Naso vlamingii</i>	Pk	No Group
Kyphosidae	<i>Kyphosus vaigiensis</i>	H	No Group
Muraenidae	<i>Gymnothorax eurostus</i>	MI	No Group
Labridae	<i>Hemigymnus melapterus</i>	MI	No Group
Balistidae	<i>Pseudobalistes flavimarginatus</i>	MI	No Group
Lethrinidae	<i>Lethrinus xanathochilus</i>	Pisc	No Group
Acanthuridae	<i>Naso caesius</i>	Pk	No Group
Lethrinidae	<i>Monotaxis grandoculis</i>	MI	No Group
Serranidae	<i>Variola albimarginata</i>	Pisc	No Group
Labridae	<i>Coris flavovittata</i>	MI	No Group
Tetraodontidae	<i>Arothron mappa</i>	Om	No Group
Carangidae	<i>Carangoides ferdau</i>	Pisc	No Group
Carangidae	<i>Carangoides orthogrammus</i>	Pisc	No Group
Carangidae	<i>Scomberoides lysan</i>	Pisc	No Group
Acanthuridae	<i>Acanthuridae</i>	H	No Group
Lethrinidae	<i>Lethrinus amboinensis</i>	MI	No Group
Lethrinidae	<i>Lethrinus erythracanthus</i>	MI	No Group
Ephippidae	<i>Platax teira</i>	Om	No Group
Serranidae	<i>Plectropomus areolatus</i>	Pisc	No Group



Carangidae	<i>Gnathanodon speciosus</i>	Pisc	No Group
Serranidae	<i>Epinephelus polyphekadion</i>	Pisc	No Group
Serranidae	<i>Epinephelus tauvina</i>	Pisc	No Group
Muraenidae	<i>Gymnothorax breedeni</i>	Pisc	No Group
Acanthuridae	<i>Naso hexacanthus</i>	Pk	No Group
Acanthuridae	<i>Naso</i> sp.	Pk	No Group
Kyphosidae	<i>Kyphosus sandwicensis</i>	H	No Group
Kyphosidae	<i>Kyphosus</i> sp.	H	No Group
Balistidae	<i>Balistidae</i>	MI	No Group
Balistidae	<i>Balistoides viridescens</i>	MI	No Group
Muraenidae	<i>Echidna nebulosa</i>	MI	No Group
Haemulidae	<i>Plectorhinchus gibbosus</i>	MI	No Group
Balistidae	<i>Balistes polylepis</i>	MI	No Group
Tetraodontidae	<i>Tetraodontidae</i>	MI	No Group
Monacanthidae	<i>Aluterus scriptus</i>	Om	No Group
Ophichthidae	<i>Myrichthys magnificus</i>	MI	No Group
Aulostomidae	<i>Aulostomus chinensis</i>	Pisc	No Group
Muraenidae	<i>Enchelycore pardalis</i>	Pisc	No Group
Sphyrinae	<i>Sphyrinae helleri</i>	Pisc	No Group
Muraenidae	<i>Gymnothorax rueppelliae</i>	MI	No Group
Oplegnathidae	<i>Oplegnathus fasciatus</i>	MI	No Group
Serranidae	<i>Variola louti</i>	Pisc	No Group
Haemulidae	<i>Plectorhinchus picus</i>	MI	No Group
Haemulidae	<i>Plectorhinchus vittatus</i>	MI	No Group
Lethrinidae	<i>Lethrinidae</i>	MI	No Group
Lethrinidae	<i>Lethrinus</i> sp.	MI	No Group
Oplegnathidae	<i>Oplegnathus punctatus</i>	MI	No Group
Carangidae	<i>Caranx papuensis</i>	Pisc	No Group
Muraenidae	<i>Gymnothorax steindachneri</i>	Pisc	No Group
Diodontidae	<i>Diodon hystrix</i>	MI	No Group
Labridae	<i>Labridae</i>	MI	No Group
Belonidae	<i>Belonidae</i>	Pisc	No Group
Carangidae	<i>Caranx lugubris</i>	Pisc	No Group
Carangidae	<i>Caranx sexfasciatus</i>	Pisc	No Group
Scombridae	<i>Euthynnus affinis</i>	Pisc	No Group
Scombridae	<i>Grammatorcynus bilineatus</i>	Pisc	No Group
Lethrinidae	<i>Lethrinus olivaceus</i>	Pisc	No Group
Acanthuridae	<i>Naso annulatus</i>	Pk	No Group

Ophidiidae	<i>Brotula multibarбата</i>	MI	No Group
Dasyatidae	<i>Urogymnus granulatus</i>	MI	No Group
Scombridae	<i>Sarda orientalis</i>	Pisc	No Group
Congridae	<i>Congridae</i>	Pisc	No Group
Congridae	<i>Heterocongrinae</i>	Pisc	No Group
Scombridae	<i>Katsuwonus pelamis</i>	Pisc	No Group
Echeneidae	<i>Echeneis naucrates</i>	Pk	No Group
Carangidae	<i>Trachinotus blochii</i>	MI	No Group
Carangidae	<i>Caranx melampygus</i>	Pisc	No Group
Muraenidae	<i>Gymnothorax meleagris</i>	Pisc	No Group
Tetraodontidae	<i>Arothron stellatus</i>	Cor	No Group
Labridae	<i>Coris aygula</i>	MI	No Group
Carangidae	<i>Pseudocaranx dentex</i>	Pisc	No Group
Muraenidae	<i>Scuticaria tigrina</i>	Pisc	No Group
Serranidae	<i>Plectropomus laevis</i>	Pisc	No Group
Serranidae	<i>Epinephelus</i> sp.	Pisc	No Group
Serranidae	<i>Serranidae</i>	Pisc	No Group
Belonidae	<i>Tylosurus crocodilus</i>	Pisc	No Group
Carangidae	<i>Alectis ciliaris</i>	Pisc	No Group
Muraenidae	<i>Enchelynassa canina</i>	Pisc	No Group
Muraenidae	<i>Gymnothorax undulatus</i>	Pisc	No Group
Muraenidae	<i>Gymnomuraena zebra</i>	MI	No Group
Carangidae	<i>Carangidae</i>	Pisc	No Group
Fistulariidae	<i>Fistularia commersonii</i>	Pisc	No Group
Carangidae	<i>Caranx ignobilis</i>	Pisc	No Group
Carangidae	<i>Caranx</i> sp.	Pisc	No Group
Sphyraenidae	<i>Sphyraena qenie</i>	Pisc	No Group
Carangidae	<i>Elagatis bipinnulata</i>	Pisc	No Group
Chanidae	<i>Chanos chanos</i>	H	No Group
Dasyatidae	<i>Taeniurops meyeri</i>	MI	No Group
Dasyatidae	<i>Dasyatidae</i>	MI	No Group
Carangidae	<i>Seriola dumerili</i>	Pisc	No Group
Carcharhinidae	<i>Carcharhinus melanopterus</i>	Pisc	No Group
Sphyraenidae	<i>Sphyraena barracuda</i>	Pisc	No Group
Scombridae	<i>Thunnus albacares</i>	Pisc	No Group
Carcharhinidae	<i>Triaenodon obesus</i>	Pisc	No Group
Labridae	<i>Cheilinus undulatus</i>	MI	No Group
Carcharhinidae	<i>Carcharhinus amblyrhynchos</i>	Pisc	No Group

Muraenidae	<i>Gymnothorax flavimarginatus</i>	Pisc	No Group
Scombridae	<i>Scombridae</i>	Pisc	No Group
Scombridae	<i>Gymnosarda unicolor</i>	Pisc	No Group
Muraenidae	<i>Muraenidae</i>	Pisc	No Group
Carcharhinidae	<i>Carcharhinus limbatus</i>	Pisc	No Group
Muraenidae	<i>Gymnothorax javanicus</i>	Pisc	No Group
Muraenidae	<i>Gymnothorax</i> sp.	Pisc	No Group
Ginglymostomatidae	<i>Nebrius ferrugineus</i>	Pisc	No Group
Myliobatidae	<i>Aetobatus ocellatus</i>	MI	No Group
Carcharhinidae	<i>Carcharhinus galapagensis</i>	Pisc	No Group
Sphyrnidae	<i>Sphyrna lewini</i>	Pisc	No Group
Sphyrnidae	<i>Sphyrnidae</i>	Pisc	No Group
Myliobatidae	<i>Mobula</i> sp.	Pk	No Group
Scaridae	<i>Scarus fuscocaudalis</i>	H	Parrotfish
Scaridae	<i>Calotomus zonarchus</i>	H	Parrotfish
Scaridae	<i>Chlorurus japanensis</i>	H	Parrotfish
Scaridae	<i>Scarus globiceps</i>	H	Parrotfish
Scaridae	<i>Scarus spinus</i>	H	Parrotfish
Scaridae	<i>Scarus psittacus</i>	H	Parrotfish
Scaridae	<i>Scarus dubius</i>	H	Parrotfish
Scaridae	<i>Scarus oviceps</i>	H	Parrotfish
Scaridae	<i>Scarus schlegeli</i>	H	Parrotfish
Scaridae	<i>Chlorurus spilurus</i>	H	Parrotfish
Scaridae	<i>Scarus niger</i>	H	Parrotfish
Scaridae	<i>Scarus festivus</i>	H	Parrotfish
Scaridae	<i>Scarus frenatus</i>	H	Parrotfish
Scaridae	<i>Chlorurus frontalis</i>	H	Parrotfish
Scaridae	<i>Scarus dimidiatus</i>	H	Parrotfish
Scaridae	<i>Calotomus carolinus</i>	H	Parrotfish
Scaridae	<i>Scarus forsteni</i>	H	Parrotfish
Scaridae	<i>Scarus tricolor</i>	H	Parrotfish
Scaridae	<i>Scarus xanthopleura</i>	H	Parrotfish
Scaridae	<i>Hipposcarus longiceps</i>	H	Parrotfish
Scaridae	<i>Scarus altipinnis</i>	H	Parrotfish
Scaridae	<i>Chlorurus perspicillatus</i>	H	Parrotfish
Scaridae	<i>Scaridae</i>	H	Parrotfish
Scaridae	<i>Scarus rubroviolaceus</i>	H	Parrotfish
Scaridae	<i>Chlorurus microrhinos</i>	H	Parrotfish

Scaridae	<i>Cetoscarus ocellatus</i>	H	Parrotfish
Scaridae	<i>Scarus ghobban</i>	H	Parrotfish
Scaridae	<i>Chlorurus</i> sp.	H	Parrotfish
Scaridae	<i>Scarus</i> sp.	H	Parrotfish
Scaridae	<i>Bolbometopon muricatum</i>	Cor	Parrotfish
Lutjanidae	<i>Lutjanus fulvus</i>	MI	Snappers
Lutjanidae	<i>Lutjanus kasmira</i>	MI	Snappers
Lutjanidae	<i>Lutjanus gibbus</i>	MI	Snappers
Lutjanidae	<i>Lutjanus monostigma</i>	Pisc	Snappers
Lutjanidae	<i>Macolor macularis</i>	Pk	Snappers
Lutjanidae	<i>Aphareus furca</i>	Pisc	Snappers
Lutjanidae	<i>Macolor niger</i>	Pk	Snappers
Lutjanidae	<i>Macolor</i> sp.	Pk	Snappers
Lutjanidae	<i>Lutjanus bohar</i>	Pisc	Snappers
Lutjanidae	<i>Lutjanus argentimaculatus</i>	MI	Snappers
Lutjanidae	<i>Aprion virescens</i>	Pisc	Snappers

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

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

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

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

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

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Risso's Dolphin	<i>Grampus griseus</i>	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Perrin <i>et al.</i> , 2009
Rough-Toothed Dolphin	<i>Steno bredanensis</i>	Not Listed	Unknown	Found in tropical to warm-temperate waters worldwide. Common in A. Samoa waters.	Perrin <i>et al.</i> , 2009, Craig, 2005
Sei Whale	<i>Balaenoptera borealis</i>	Endangered	Strategic	Generally found in offshore temperate waters.	35 FR 18319, Barlow, 2003, Bradford <i>et al.</i> , 2013
Short-Finned Pilot Whale	<i>Globicephala macrorhynchus</i>	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Shallenberger, 1981, Baird <i>et al.</i> , 2013, Bradford <i>et al.</i> , 2013
Sperm Whale	<i>Physeter macrocephalus</i>	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the region.	35 FR 18319, Rice, 1960, Barlow, 2006, Lee, 1993, Mobley <i>et al.</i> , 2000, Shallenberger, 1981
Spinner Dolphin	<i>Stenella longirostris</i>	Not Listed	Unknown	Common in American Samoa, found in waters with mean depth of 44 m.	Reeves <i>et al.</i> , 1999, Johnston <i>et al.</i> , 2008
Striped Dolphin	<i>Stenella coeruleoalba</i>	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world.	Perrin <i>et al.</i> , 2009
<b>Elasmobranchs</b>					
Giant manta ray	<i>Manta birostris</i>	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles, and seamounts, and on shallow reefs.	Dewar <i>et al.</i> , 2008, Marshall <i>et al.</i> , 2009, Marshall <i>et al.</i> , 2011.
Oceanic whitetip	<i>Carcharhinus longimanus</i>	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C	Bonfil <i>et al.</i> , 2008, Backus <i>et al.</i> , 1956, Strasburg, 1958, Compagno, 1984



Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Scalloped Hammerhead	<i>Sphyrna lewini</i>	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m.	Compagno, 1984, Schulze-Haugen & Kohler, 2003, Sanches, 1991, Klimley, 1993
<b>Corals</b>					
N/A	<i>Acropora globiceps</i>	Threatened	N/A	Occur on upper reef slopes, reef flats, and adjacent habitats in depths from 0 to 8 m	Veron, 2014
N/A	<i>Acropora jacquelineae</i>	Threatened	N/A	Found in numerous subtidal reef slope and back-reef habitats, including but not limited to, lower reef slopes, walls and ledges, mid-slopes, and upper reef slopes protected from wave action, and its depth range is 10 to 35 m.	Veron, 2014
N/A	<i>Acropora retusa</i>	Threatened	N/A	Occur in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons. Depth range is 1 to 5 m.	Veron, 2014
N/A	<i>Acropora speciosa</i>	Threatened	N/A	Found in protected environments with clear water and high diversity of <i>Acropora</i> and steep slopes or deep, shaded waters. Depth range is 12 to 40 meters and have been found in mesophotic habitat (40-150 m).	Veron, 2014
N/A	<i>Euphyllia paradivisa</i>	Threatened	N/A	Found in environments protected from wave action on at least upper reef slopes, mid-slope terraces, and lagoons in depths ranging from 2 to 25 m depth.	Veron, 2014
N/A	<i>Isopora crateriformis</i>	Threatened	N/A	Found in shallow, high-wave energy environments, from low tide to at least 12 meters deep, and have been reported from mesophotic	Veron, 2014

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
				depths (less than 50 m depth).	

<sup>a</sup> These species have critical habitat designated under the ESA. See Table B-2.

Table B-2. ESA-listed species' critical habitat in the Pacific Ocean<sup>a</sup>

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

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

## REFERENCES

- Backus, R.H., Springer, S., and Arnold, E.L., 1956. A contribution to the natural history of the white tip shark, *Pseudomius kmgimurus* (Poey). *Deep-Sea Res.* 3, pp. 178- 188.
- Baird, R.W., McSweeney, D.J., Bane, C., Barlow, J., Salden, D.R., Antoine, L.R.K., LeDuc, R.G. and Webster, D.L., 2006. Killer Whales in Hawaiian Waters: Information on Population Identity and Feeding Habits 1. *Pac Sci*, 60(4), pp.523-530.
- Baird, R.W., Webster, D.L., Aschettino, J.M., Schorr, G.S. and McSweeney, D.J., 2013. Odontocete cetaceans around the main Hawaiian Islands: Habitat use and relative abundance from small-boat sighting surveys. *Aquat Mamm*, 39(3) pp. 253-269.

- Balazs, G.H., Craig, P., Winton, B.R. and Miya, R.K., 1994, March. Satellite telemetry of green turtles nesting at French Frigate Shoals, Hawaii, and Rose Atoll, American Samoa. *In*: Bjorndal, K.A., Bolten, A.B., Johnson, D.A., and Eliazar, P.J. [eds.]. Proceedings of the fourteenth annual symposium on sea turtle biology and conservation, pp. 184-186).
- Barlow, J., 2003. Preliminary Estimates of the Abundance of Cetaceans Along the US West Coast, 1991-2001. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.
- Barlow, J., 2006. Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. *Mar Mamm Sci*, 22(2), pp. 446-464.
- Bonfil, R., Clarke, S., Nakano, H., Camhi, M.D., Pikitch, E.K., and Babcock, E.A., 2008. The biology and ecology of the oceanic whitetip shark, *Carcharhinus longimanus*. *In*: Camhi, M.D., Pikitch, E.K., and Babcock, E.A. [eds.]. Sharks of the Open Ocean: Biology, Fisheries, and Conservation, pp. 128-139.
- Bradford, A.L., Oleson, E.M., Baird, R.W., Boggs, C.H., Forney, K.A., and Young, N.C., 2015. Revised stock boundaries for false killer whales (*Pseudorca crassidens*) in Hawaiian waters. NOAA Tech. Memo. NMFS-PIFSC-47.
- Caldwell, D.K. and Caldwell, M.C., 1989. Pygmy sperm whale *Kogia breviceps* (de Blainville, 1838) & dwarf sperm whale *Kogia simus* Owen, 1866. *Handbook of marine mammals*, 4, pp. 235-260.
- Compagno, L.J.V., 1984. FAO Species Catalogue. Vol. 4. Sharks of the World. An Annotated and Illustrated Catalogue of Shark Species Known to Date. Carcharhiniformes. *FAO Fish. Synop.*, 124(4), Part 2.
- Craig, P., 2005. Natural history guide to American Samoa. National Park of American Samoa, Department of Marine and Wildlife Resources, American Samoa Community College.
- Dalebout, M.L., Baker, C.S., Anderson, R.C., Best, P.B., Cockcroft, V.G., Hinsz, H.L., Pegg, V. and Pitman, R.L., 2003. Appearance, distribution, and genetic distinctiveness of Longman's beaked whale, *Indopacetus pacificus*. *Mar Mamm Sci*, 19(3), pp. 421-461.
- Dewar, H., Mous, P., Domeier, M., Muljadi, A., Pet, J., and Whitty, J., 2008. Movements and site fidelity of the giant manta ray, *Manta birostris*, in the Komodo Marine Park, Indonesia. *Mar Biol*, 155, pp. 121-133.
- Dodd, C.K., 1990. *Caretta* (Linnaeus) Loggerhead Sea Turtle. *Catalogue of American Amphibians and Reptiles*, 48, pp. 1-483.7.
- Garrigue, C., Franklin, T., Russell, K., Burns, D., Poole, M., Paton, D., Hauser, N., Oremus, M., Constantine, R., Childerhouse, S., Mattila, D., Gibbs, N., Franklin, W., Robbins, J., Clapham, P., and Baker, C.S., 2007. First assessment of interchange of humpback whales between Oceania and the east coast of Australia. International Whaling Commission, Anchorage, Alaska. SC/59/SH15 (available from the IWC office).
- Grant, G.S. 1994. Juvenile leatherback turtle caught by longline fishing in American Samoa. *Marine Turtle Newsletter*, 66, pp. 3-5.

- Hamilton, T.A., Redfern, J.V., Barlow, J., Ballance, L.T., Gerrodette, T., Holt, R.S., Forney, K.A., and Taylor, B.L., 2009. Atlas of Cetacean Sightings for Southwest Fisheries Science Center Cetacean and Ecosystem Surveys, 1986-2005.
- Heyning, J.E., 1989. Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. In: S.H. Ridgway and R. Harrison [eds.]. Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales. Academic Press, London and San Diego. 442 pp.
- Johnston, D.W., Robbins, J., Chapla, M.E., Mattila, D.K. and Andrews, K.R., 2008. Diversity, habitat associations and stock structure of odontocete cetaceans in the waters of American Samoa, 2003-2006. *J Cetacean Res Manag.*, 10(1), pp. 59-66.
- Klimley, A.P., 1993. Highly directional swimming by scalloped hammerhead sharks, *Sphyrna lewini*, and subsurface irradiance, temperature, bathymetry, and geomagnetic field. *Mar Biol*, 117(1), pp. 1-22.
- Leatherwood, J.S. and Dahlheim, M.E., 1978. Worldwide distribution of pilot whales and killer whales. Naval Ocean System Center Technical Report, 443, pp. 1-39.
- Marshall, A., Compagno, L.J.V., and Bennett, M.B., 2009. Redescription of the genus *Manta* with resurrection of *Manta alfredi* (Krefft, 1868) (Chondrichthyes; Myliobatoidei; Mobulidae). *Zootaxa*, 2301, pp. 1-28.
- Marshall, A., Bennett, M.B., Kodja, G., Hinojosa-Alvarez, S., Galvan-Magana, F., Harding, M., Stevens, G., and Kashiwagi, T., 2011. *Manta birostris*. The IUCN Red List of Threatened Species 2011: e.T198921A9108067.
- Mead, J.G., 1989. Beaked whales of the genus *Mesoplodon*. In: Ridgeway, S. H. and Harrison, R. [eds.]. Handbook of marine mammals. Volume 4. River dolphins and the larger toothed whales. Academic Press Ltd: London, 452 p.
- Mitchell, E. 1975. Report on the meeting on smaller cetaceans, Montreal, Apr 1-11, 1974. *J Fish Res Bd Can*, 32(7), pp. 914-16
- Mobley Jr., J.R., Spitz, S.S., Forney, K.A., Grotenfendt, R., and Forestell, P.H., 2000. Distribution and abundance of odontocete species in Hawaiian waters: preliminary results of 1993-98 aerial surveys. Administrative Report LJ-00-14C. Available from the NOAA Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 26 p.
- Nagorsen, D., 1985. *Kogia simus*. Mammalian Species, 239, pp. 1-6.
- Olson, P.A., Ensor, P., Olavarria, C., Bott, N., Constantine, R., Weir, J., Childerhouse, S., van der Linde, M., Schmitt, N., Miller, B.S. and Double, M.C., 2015. New Zealand Blue Whales: Residency, Morphology, and Feeding Behavior of a Little-Known Population. *Pac Sci*, 69(4), pp. 477-485.
- Perrin, W.F., Wursig, B., and Thewissen J.G.M. [eds.], 2009. Encyclopedia of marine mammals. Academic Press.
- Perryman, W.L., Au, D.W.K., Leatherwood, S., and Jefferson, T.A., 1994. Melon-headed whale *Peponocephala electra* Gray, 1846. In: Ridgway, S. H. and Harrison, R. [eds.].

- Handbook of marine mammals. Volume 5. The first book of dolphins. Academic Press, London, U.K.
- Rice, D.W., 1960. Distribution of the bottle-nosed dolphin in the leeward Hawaiian Islands. *J Mamm*, 41(3), pp. 407-408.
- Ross, G.J.B. and Leatherwood, S., 1994. Pygmy killer whale *Feresa attenuata* (Gray, 1874). *Handbook of marine mammals*, 5, pp. 387-404.
- Schulze-Haugen, M. and Kohler, N.E. [eds.], 2003. Guide to Sharks, Tunas, & Billfishes of the U.S. Atlantic and Gulf of Mexico. RI Sea Grant/National Marine Fisheries Service.
- Shallenberger E.W., 1981. The status of Hawaiian cetaceans. Marine Mammal Commission Report No. MMC-77/23 (NTIS PB82-109398).
- Strasburg, D.W., 1958. Distribution, abundance, and habits of pelagic sharks in the central Pacific Ocean. *Fisheries*, 1, 2S.
- Tuato'o-Bartley, N., Morrell, T.E., and Craig, P., 1993. Status of sea turtles in American Samoa in 1991. *Pac Sci*, 47(3), pp. 215-221.
- Utzurum, R., 2002. Sea turtle conservation in American Samoa. In: Kinan, I. [ed.]. Proceedings of the western Pacific sea turtle cooperative research and management workshop.
- Veron, J.E.N., 2014. Results of an update of the Corals of the World Information Base for the Listing Determination of 66 Coral Species under the Endangered Species Act. Report to the Western Pacific Regional Fishery Management Council, Honolulu.