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National Marine Sanctuary of American Samoa: 202_ Condition Report: Status and Trends 2007–2020

Commented [1]: Mageo: The Introduction Section of the Report is concise, simple and self-explanatory in regards to the Report's overall Objective(s)/Intentions.

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Office of National Marine Sanctuaries

The Office of National Marine Sanctuaries (ONMS), part of the National Oceanic and Atmospheric Administration (NOAA), serves as the trustee for a system of underwater parks encompassing more than 620,000 square miles of ocean and Great Lakes waters. The 15 national marine sanctuaries and two marine national monuments within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migration corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to thousands of unique or endangered species and are important to America's cultural heritage. Sanctuaries range in size from less than one square mile to more than 582,000 square miles and serve as natural classrooms, cherished recreational spots, and are home to valuable commercial industries.

National Marine Sanctuary of American Samoa

The National Marine Sanctuary of American Samoa comprises six protected areas covering 13,581 square miles of nearshore coral reef and offshore open ocean waters across the archipelago. Of these, three areas located on and near Tutuila are relatively accessible: Fagatele Bay and Fagalua/Fogamaʻa are along the southwest coast of the island, and Aunuʻu is just southeast of Pago Pago Harbor. The other areas, Taʻu, Swains and Muliāva, are remote and accessible only by boat. The sanctuary includes deep water reefs, hydrothermal vents, some of the world's oldest and largest *Porites* coral heads, rare archaeological resources, and also encompasses important fishing grounds. It is also the only true tropical reef within the National Marine Sanctuary System.

Framework for Condition Reports

Sanctuary condition reports are used by NOAA to assess the condition and trends of national marine sanctuary resources and ecosystem services. Condition reports provide a standardized summary of resources in NOAA's sanctuaries, drivers and pressures on those resources, and current conditions and trends for resources and ecosystem services. These reports also describe existing management responses to pressures that threaten the integrity of the marine environment. Condition reports include information on the status and trends of water quality, habitat, living resources, and maritime heritage resources, and the human activities that affect them. They present responses to a set of questions posed to all sanctuaries (Appendix A). The reports also rate the status and trends of ecosystem services (Appendix B). Resource and ecosystem service status are assigned ratings ranging from good to poor, and the timelines used for comparison vary from topic to topic. Trends in the status of resources and ecosystem services are also reported, and are generally based on observed changes in status since the prior condition report, unless otherwise specified.

Sanctuary condition reports are structured around two frameworks: 1) a series of questions posed to all national marine sanctuaries; and 2) a management-logic model called the Drivers-Pressure-State-Ecosystem Services-Response (DPSER) framework (detailed below). The questions are derived from a conceptual, generic model of a marine ecosystem. The DPSER framework defines the structure of the condition reports themselves.

Although the National Marine Sanctuary System's 15 national marine sanctuaries and two marine national monuments are diverse in many ways, including size, location, and resources, condition reports allow ONMS to consistently analyze the status and trends of abiotic and biotic factors in each site's ecosystem to inform place-based management. To that end, each unit in the sanctuary system is asked to answer the same set of questions, located in Appendix A, during the preparation of each condition report. Additional details about how the condition report process has evolved over time are below.

DPSER Framework

In 2019, ONMS began restructuring sanctuary condition reports based on a model that describes the interactions between driving societal forces (Drivers), resulting threats (Pressures), their influence on resource conditions (State), the impact to derived societal benefits (Ecosystem services), and management responses (Response) to control or improve them. The DPSER framework recognizes that human activities, the primary target of management actions, are linked to demographic, economic, social, and/or institutional values and conditions (collectively called drivers). Changes in these drivers affect the nature and level of pressures placed on both natural and heritage resources, which determines their condition (e.g., the quality of natural resources or aesthetic value). This, in turn, affects the availability of benefits that humans receive from the resources (ecosystem services[1]), which prompts targeted

[1] For the purposes of this report, ecosystem services are defined as benefits that humans desire from the environment (e.g., recreation, food). They are what link humans to ecosystems, can be goods (e.g., food) or services (e.g., coastal protection), are valued to varying degrees by various types of users, and can be regulated directly by the environment or managed by controlling human activities or ecosystem components (e.g., restoring habitats). Whether or not specific services are rendered can be evaluated directly or indirectly based on attributes of the

management responses intended to prevent, reduce, or mitigate undesirable changes (see Figure FCR.1).

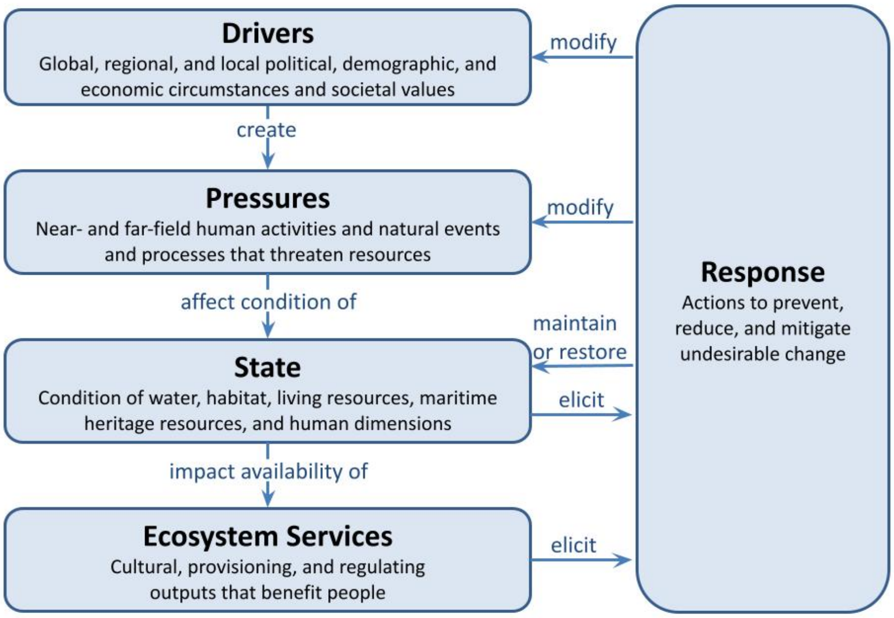

Figure FCR.1. This diagram of the DPSER framework illustrates the functional connections between compartments and the targets of management responses designed to modify drivers, pressures, and resource conditions. Image: NOAA

About This Report

The purpose of a condition report is to use the best available science and most recent data to assess the status and trends of various parts of the sanctuary's ecosystem. The first condition report was released in 2007 (NOAA Office of National Marine Sanctuaries, 2007) and assessed the condition and trends of Fagatele Bay National Marine Sanctuary; ratings from that report are provided in Appendix C. This updated condition report marks an updated and comprehensive description of the status and trends of resources and ecosystem services in the expanded sanctuary – the National Marine Sanctuary of American Samoa. The findings in this condition report document status and trends in water quality, habitat, living resources, maritime heritage

natural ecosystem that people care about. For example, recreational scuba divers care about water clarity and visibility in coral reef ecosystems. These are attributes that can be measured and factored into status and trend ratings to assess ecosystem services.

resources, and ecosystem services from 2007–2020, unless otherwise noted[2]. The report helps identify gaps in current monitoring efforts, as well as causal factors that may require monitoring, and potential remediation, through management actions in coming years. The data discussed will not only enable sanctuary resource managers and stakeholders to acknowledge and have a shared perspective on prior changes in resource status, but will also inform management efforts to address challenges stemming from pressures, such as increasing coastal populations and climate change.

The findings in this condition report will provide critical support for identifying high-priority sanctuary management actions, and will specifically help to shape updates to the NMSAS management plan. The management plan helps guide future work and resource allocation decisions at NMSAS by describing strategies and activities designed to address priority issues and advance core sanctuary programs. The next update to the sanctuary management plan will begin in 202_. The process will involve significant public input, agency consultation, and environmental compliance work, and, depending on the complexity of actions proposed, may take one to three years to complete.

The State of Resources section of this document reports the status and trends of water quality, habitat, living resources, and maritime heritage resources from 2007–2020, unless otherwise noted. The State of Ecosystem Services section includes an assessment of human benefits derived from non-consumptive recreation, consumptive recreation, science, education, heritage and sense of place, commercial harvest, subsistence harvest, and coastal protection within the sanctuary.

In order to rate the status and trends of resources, human activities, and ecosystem services, sanctuary staff consulted with a group of non-ONMS experts familiar with resources, activities, and services in the sanctuary. These experts also had knowledge of previous and current scientific efforts in the sanctuary (Appendix D). Evaluations of status and trends were based on the interpretation of quantitative and, when necessary, qualitative assessments, as well as observations of scientists, managers, and users.

Two other important changes to the condition report process since 2007 should be noted. First, in response to feedback provided to ONMS, the process used to generate the current condition report is more quantitatively robust and repeatable. This was achieved by using the NOAA Integrated Ecosystem Assessment (IEA) framework (NOAA, 2020), which takes a literature-based approach to developing indicators for key components of the ecosystem. Status and trend assessments can then be made for the selected indicators over time. This approach ensures that, whenever possible, the expert community has quantitative data representative of core ecosystem components available to them as they contribute to assessment ratings. These indicators continue to be tracked over time, and updated time series data can be used in subsequent assessments.

The second improvement pertains to communication of confidence, which was not done in a consistent way in earlier reports. Determination of confidence is now based on an evaluation of the quality and quantity of data used to determine the rating (e.g., peer-reviewed literature vs. expert opinion) and the level of agreement among experts (Appendix D). The new approach allows for a consistent and standardized characterization of confidence. The symbols used for

[2] The COVID-19 pandemic and its impacts to both the state of the resources and ecosystem services are not included in this assessment as it was a newly evolving situation during the time of the expert workshops.

status and trend ratings have been modified to depict levels of confidence as judged by the expert panel.

This condition report meets the aforementioned standardized format and framework prescribed for all ONMS condition reports. To the extent possible, authors have attempted to make each section's narrative consistent and comparable in terms of content, detail, and length; however, it is important to understand that each section contains different types and amounts of information given the realities and confines of datasets and expert opinions that were available during this process. In addition, this report is the result of a multi-year, collaborative effort across multiple authors, contributors, and reviewers and thus contains stylistic writing differences across some sections. These differences do not detract from the validity or quality of this report but, rather, reflect the diversity of voices and cultures involved in report generation. Finally, ratings reflect the collective interpretation of sanctuary staff and outside experts based on their knowledge and perception of local conditions. When the group could not agree on a rating, sanctuary staff determined the final rating with an acknowledgement of the differences in opinion noted in the report. The interpretation, ratings, and text in this condition report are final and the responsibility of ONMS. To emphasize this important point, authorship of the report is attributed to ONMS; subject matter experts are not authors, though their efforts and affiliations are acknowledged in the report. This report has been peer reviewed and complies with the White House Office of Management and Budget's peer review standards, as outlined in the Final Information Quality Bulletin for Peer Review (White House Office of Management and Budget, 2004).

Text box:

It is important to consider, when reading this report, that the people in the Samoa archipelago were presented with significant challenges from 2019–2021, including a measles outbreak in the fall of 2019, followed by the global pandemic that began in early 2020. These health crises had significant impacts on the territory, including the distribution of many services and programs that are provided by NMSAS. However, the COVID-19 pandemic and its impacts to both the state of the resources and ecosystem services are not included in this assessment as it was a newly evolving situation during the time of the expert workshops.

Literature Cited

National Oceanic and Atmospheric Administration. (2020, January 7). *The Integrated Ecosystem Assessment approach*. https://www.integratedecosystemassessment.noaa.gov/national/IEA-approach

White House Office of Management and Budget. (2004). *Final information quality bulletin for peer review*. https://georgewbush-whitehouse.archives.gov/omb/memoranda/fy2005/m05-03.pdf

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To be drafted after Peer Review

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National Marine Sanctuary of American Samoa Summary of Resource Conditions

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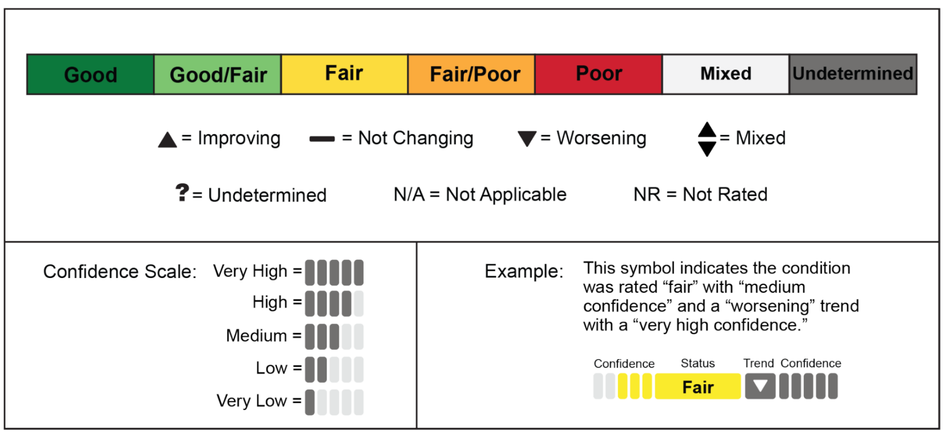
The various resource status and trend evaluations presented in this report are summarized below. Each question used to rate the condition and trends sanctuary resources is listed, followed by:

1) A set of rating symbols that display key information. The first symbol includes a color and term to indicate status. The next symbol indicates trend. A shaded scale adjacent to both symbols indicates confidence (see key for example and definitions).

2) The status description, which is a statement that best characterizes resource status and corresponds to the assigned color rating and definition as described in Appendix A. The status description statements are customized for all possible ratings for each question.

3) The rationale: a short statement or list of criteria used to justify the rating.



Question 1: What is the eutrophic condition of sanctuary waters and how is it changing?

Status: Good, Confidence - Medium; **Trend**: Not Changing, Confidence - Medium
Status Description: Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.
Rationale: Data on eutrophication are limited, but available data suggest that nitrogen, phosphorus, and chlorophyll a (Chl-a) concentrations remain below recommended threshold levels in sanctuary waters. However, dissolved inorganic nitrogen (DIN) may be increasing in Fagatele Bay based on the most recent data. Macroalgae cover has been variable over the reporting period, but remains low overall within sanctuary units.

Question 2: Do sanctuary waters pose risks to human health and how are they changing?

Status: Good, Confidence - Medium; **Trend**: Undetermined, Confidence - Medium
Status Description: One or more water quality indicators suggest the potential for human health impacts, but human health impacts have not been reported.
Rationale: There are currently no known human health risks from sanctuary waters, however, data are limited and no trend data are available. Contaminants were detected in Fagatele Bay, but only nickel concentrations exceeded toxicology screening levels. Coliform bacteria have been detected in Fagatele Bay and there is a sewage outfall in the Aunu'u Multipurpose Zone, but sanctuary units are not part of regular recreational water sampling efforts, so potential health impact is unknown. No ciguatera poisoning has been reported from fish caught in the sanctuary.

Question 3: Have recent, accelerated changes in climate altered water conditions and how are they changing?

Status: Fair, Confidence - High; **Trend**: Declining, Confidence - High
Status Description: Climate-related changes have caused measurable, but not severe, degradation in some attributes of ecological integrity.
Rationale: Increasing sea surface temperatures have caused more frequent and more severe coral bleaching events. Ocean acidification is affecting water quality worldwide, however, aragonite saturation state and calcification rates have remained high in sanctuary units.

Question 4: Are other stressors, individually or in combination, affecting water quality, and how are they changing?

Status: Good/Fair, Confidence - Medium; **Trend**: Not changing, Confidence - Low
Status Description: Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Rationale: Non-point source pollution from the landfill activity, agriculture, and development was raised as a concern for Tutuila and Aunu'u units, however, managers have not detected major impacts to the ecological integrity of these sites during this reporting period. Accelerated coastal erosion caused by subsidence has not caused significant deposition. Iron enrichment at a vessel grounding site continues to be a problem at Rose, but has improved. The bird populations at Rose Atoll have had some variability due to storms, but these fluctuations did not appear to disturb nutrient cycles around the atoll.

Question 5: What are the levels of human activities that may adversely influence water quality and how are they changing?

Status: Good / Fair, Confidence - Low; **Trend**: Undetermined, Confidence - Medium
Status Description: Some potentially harmful activities exist, but they have not been shown to degrade water quality.
Rationale: There are measurable contaminant and nutrient inputs within sanctuary units, particularly in Fagatele Bay. Contaminants and nutrients from the landfill and agricultural activities have been documented at low levels in Fagatele Bay and it is likely that they have also reached Fagalua / Fogama'a. No measurable impact on water quality or biological communities has been detected. There is a sewage outfall in the Aunu'u Multipurpose Zone A Unit that may

also discharge contaminants and nutrients to the shallow reef zone. Limited data prevents full assessment of these impacts and no trend data were available to assess changes over time.

Question 6: What is the integrity of major habitat types and how are they changing?

Rating: Good/Fair, Confidence - High; Trend: Declining, Confidence - High
Status Description: Selected habitat loss or alteration is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.
Rationale: Habitats within the sanctuary have demonstrated resilience to disturbances from coral bleaching events, sea level rise, crown-of-thorns sea stars, and cyclones. These ecosystems have adapted to or recovered from these events. The damage from a vessel grounding in Aunu'u has had lasting impacts, but is constrained to a small area, and marine debris continues to be a chronic, but minor problem across all habitats. Data for pelagic and deep sea habitats are limited, and no immediate threats were identified.

Question 7: What are contaminant concentrations in sanctuary habitats and how are they changing?

Rating: Good/Fair, Confidence - Medium; **Trend**: Undetermined, Confidence - Medium
Status Description: Selected contaminants are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Rationale: Data on contaminants within the sanctuary are limited. Heavy metals, hydrocarbons, pesticides, and pharmaceuticals were detected in water and sediment in Fagatele Bay in 2018, but only nickel was observed at concentrations above recommended screening levels. Iron contamination from the 1993 grounding at Rose Atoll persists but is limited in scope and continues to improve. As the Fagatele data are from a single point in time and no recent data are available for other sanctuary units, the expert confidence in this rating is medium and experts were unable to determine a trend rating.

Question 8. What are the levels of human activities that may adversely influence habitats and how are they changing?

Status: Fair, Confidence - High; **Trend**: Undetermined, Confidence - Medium
Status Description: Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Rationale: Vessel groundings have had localized effects on coral reef habitat in the Aunu'u and Muliava units. Destructive fishing practices have not been observed recently, but abandoned fishing gear has been removed from sites on Tutuila. Marine debris is widespread across the sanctuary, but documented habitat impacts have been limited. Deep-sea surveys detected significant marine debris accumulations in the deep sea around Tutuila, but did not detect marine debris in the Muliava unit. Limited data are available for all sites, particularly for pelagic, mesophotic, and deep-sea habitats.

Question 9: What is the status of keystone and foundation species and how is it changing?

Status: Mixed[1] (high confidence); **Trend**: Not Changing (medium confidence)
Status Description: The status of keystone or foundation species is mixed.

Fish species	Fair/Poor	The status of keystone and foundation species suggests severe degradation in some but not all attributes of ecological integrity.
Benthic species	Good / Fair	The status of keystone or foundation species may preclude full community development and function, but has not yet led to measurable degradation.

Rationale: The status of keystone and foundation species varies across taxa. Experts noted that benthic foundation species warrant a Good/Fair ranking, but considering the low abundance of certain fish species that play critical ecological roles , the rating was downgraded to Fair/Poor. Overall fish abundance is low and the lack of large predators and large herbivores in shallow coral reef habitats may decrease ecosystem resilience. Benthic foundation species such as corals and crustose coralline algae have fluctuated but have consistently recovered following coral bleaching events, starfish outbreaks, and storms. Data for mesophotic and deep sea species are limited, but do not indicate degradation of these habitats.

Question 10: What is the status of other focal species and how is it changing?

Status: Mixed[2], Confidence - High; **Trend**: Undetermined, Confidence - Medium
Status Description: The status of keystone or foundation species is mixed.

Fish species Giant Clams	Fair/Poor	Selected focal species are at substantially reduced levels and prospects for recovery are uncertain.
Giant Porites	Good	Selected focal species appear to reflect near-pristine conditions.
Sea Turtles Humpback Whales	Fair	Selected focal species are at reduced levels, but recovery is possible.

Rationale: Experts noted that the abundances of giant clams (Tridacna sp.), targeted food fish species, and humphead wrasse (Cheilinus undulatus) are low and that recovery is uncertain due to continued harvesting and life cycle characteristics. The continued low abundance of these species drove the overall rating down to Fair / Poor. Data on sea turtles suggests that regional populations are stable and may be slowly recovering, but are still at risk. Sea turtle nesting activity is still limited and may be affected by coastal development and climate change. Humpback whale populations may be increasing, but data are limited and increasing ocean temperatures may be shifting their habitat preferences away from American Samoa.

[1] Experts assigned a rating of Fair/Poor at the workshop, but recommended splitting the status rating. Following the workshop, a new “mixed” status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

[2] Experts assigned a rating of Fair/Poor at the workshop, but recommended splitting the status rating. Following the workshop, a new “mixed” status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

Question 11: What is the status of non-indigenous species and how is it changing?

Status: Good/Fair, Confidence - High; **Trend**: Not Changing, Confidence - High
Status Description: Non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.
Rationale: Non-indigenous species have been observed in American Samoa, but have not exhibited invasive characteristics within NMSAS units.

Question 12: What is the status of biodiversity and how is it changing?

Status: Fair, Confidence - High; **Trend**: Not Changing, Confidence - High
Status Description: Selected biodiversity loss or change has caused measurable but not severe degradation in some attributes of ecological integrity.
Rationale: Diversity continues to be high in the sanctuary, additional species have been documented, and new species are still being discovered. Shallow scleractinian coral populations have fluctuated over time due to predation, cyclone, and coral bleaching events, but have proven resilient. Many large, ecologically important fish species are rare throughout the sanctuary and fish biomass in Tutuila units is below island averages and below estimated biological potential in all units except for Swains Island. Impaired fish community structure may affect overall coral reef ecosystem function and resilience and was a primary driver for this rating.

Question 13. What are the levels of human activities that may adversely influence living resources and how are they changing?

Status: Fair, Confidence - High; **Trend**: Undetermined, Confidence - High
Status Description: Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Rationale: Fishing appears to be a significant pressure on living resources in the sanctuary. Experts believe that Fagatele Bay may deserve a Fair/Poor rating due to low fish biomass observed at the site. Fishing pressure appears to be decreasing, but fish biomass has not increased during the reporting period. Clam populations continue to decline. Sea turtle populations are stable or increasing. Vessel groundings reduced species diversity and abundance at the impact sites in Aunu'u and Rose Atoll. Limited data is available for pelagic, mesophotic, and deep-sea habitats.

Question 16: What is the condition of known maritime heritage resources and how is it changing?

Status: Fair, Confidence - High; **Trend**: Worsening, Confidence - High.
Status Description: The diminished condition of selected maritime heritage resources has reduced, to some extent, their aesthetic, cultural, historical, archaeological, scientific, or educational value, and may affect the eligibility of some sites for listing in the National Register of Historic Places.
Rationale: Maritime heritage resources have not been subject to human impacts that might otherwise diminish their aesthetic, cultural, historical, archaeological, scientific, or educational value. They have been subject to natural deterioration, erosion and high-energy shoreline events, yet remain substantially without assessment, documentation or monitoring efforts. Therefore, their condition is rated Fair. However, the trend is worsening because they are

subject to continuing natural forces like erosion and high-energy shoreline events, leading to concern regarding future conditions. Maritime heritage resources like submerged shipwrecks and aircraft, which likely exist within the sanctuary, are presumed to be slowly degrading, primarily due to natural processes.

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National Marine Sanctuary of American Samoa Summary of Ecosystem Services

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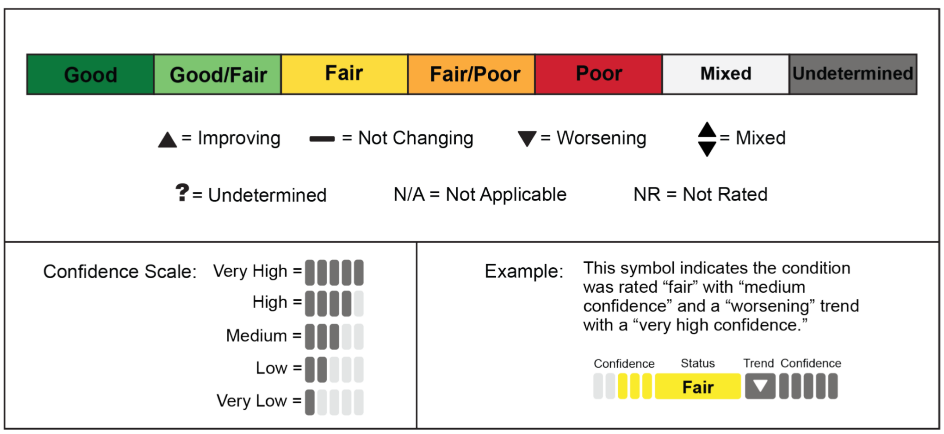
The various resource ecosystem service evaluations presented in this report are summarized below. Each ecosystem service is listed, followed by

1) A set of rating symbols that display key information. The first symbol includes a color and term to indicate status, the next symbol indicates trend, and a shaded scale adjacent to both symbols indicates confidence (see key for example and definitions).

2) The status description, which is a statement that best characterizes status and corresponds to the assigned color rating and definition as described in Appendix B.

3) The rationale, a short statement or list of criteria used to justify the rating.



Non-Consumptive Recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Status: Fair (High Confidence), **Trend:** Improving (High Confidence)
Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Rationale: Though it is clear that both physical conditions and infrastructure limit access for non-consumptive recreation activities in the sanctuary, the levels of existing activities are not well understood or quantified. The improving trend reflects sanctuary and partner outreach and education activities that highlight recreational opportunities in the sanctuary. These create interest among residents and tourists to use the sanctuary.

Consumptive Recreation — Recreational activities that result in the removal of or harm to natural or cultural resources

Status: Good/Fair with Low Confidence (Limited evidence, Medium agreement)
Trend: Improving with Medium Confidence (Limited evidence, High agreement)
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Rationale - The status of good/fair was based primarily on the fact that recreational opportunities have not been significantly reduced by changes in resource availability or access restrictions. The expansion of the sanctuary restricted fishing access in two sites, but was expected to have minimal impact on recreational fishing activities. People were still able to access resources for enjoyment and the sanctuary worked to increase awareness of responsible recreational fishing practices. Consumptive recreation in the sanctuary likely decreased after the expansion in 2012 and then increased after subsequent outreach to enhance recreation fishing activities. There is insufficient data to determine the extent of these changes, therefore, the ratings for this service are based primarily upon expert opinion.

Science - The capacity to acquire and contribute information and knowledge

Status: Good/ Fair with High Confidence **Trend**: Increasing with High Confidence
Status Description: Demand for the service is not fully met, but performance is acceptable and may not warrant enhanced management.
Rationale: Science activity has been increasing at NMSAS throughout the reporting period and current levels are rated as good/fair. During this time, research activities, publications, science capacity, and partnerships have all increased. Experts noted that there are still limitations due to access to large research vessels and science staff capacity, and the program will need more support in the future, given the large sanctuary expansion in 2012. The incorporation of traditional knowledge and more student programs were highlighted as areas for future improvement.

Education - The capacity to acquire and provide educational programs

Status: Good, Confidence – Very High
Trend: Improving, Confidence – Very High
Status Description: The capacity to provide the ecosystem service has remained unaffected or has been restored.
Rationale: Education programs have strengthened the NMSAS mission to continue to restore and protect marine ecosystems. The sanctuary has a very robust education program that includes pre-K through higher education programs for teachers and students that has reached over 3500 students and over 100 teachers, yearly; immersive summer programs that have reached over 850 participants; a wide range of community outreach events; and approximately 40,000 individuals have toured the well-regarded visitor center that serves both the local community and tourists. The number of programs has expanded during the reporting period with new offerings added each year.

Heritage & Sense of Place — Recognition of History, Heritage Legacy, Cultural Practices, Aesthetic Attraction, Spiritual Significance & Location Identity

Specific ratings were not assigned for the Heritage and Sense of Place Ecosystem Service because to measure these services in that manner in American Samoa would be culturally inappropriate. Note: the physical condition of heritage resources and sites (distinct from heritage services or ecosystem benefits) was given a rating in Section 3d “Maritime Heritage Resources”.

Rationale: Cultural traditions and values, inherent to the ecosystem services of Heritage and Sense of Place, currently thrive in American Samoa where one people, one language, and one common set of cultural practices continue to be perpetuated. The Ali’i or chiefs who were engaged in the workshop process stated that cultural values are too important and too complex to be captured in a rating scheme. This is an indication of the enhanced significance of these benefits. Therefore, there are no status or trend assessments for Heritage and Sense of Place. Furthermore, the Heritage and Sense of Place are so similar in American Samoa that they can only be understood as a single, interrelated topic (as presented here). ONMS places a high value on partnerships with sanctuary communities and maintains great respect for fa’a-Samoa. Fa’a-Samoa, the traditional Samoan way of life, provides the cultural context for all sanctuary activities and functions.

Though not rated, the cultural aspects of Heritage and Sense of Place have been a large part of the work that NMSAS has completed to date and since the sanctuary expanded. Workshop participants acknowledged the priority that NMSAS places on cultural traditions and values, and felt that these should continue to be included as a core emphasis for NMSAS programs and activities. The matai’s also stated their preference that NMSAS capture the importance of cultural information discussed during the workshop in a narrative format rather than in a rating scheme. Respecting the sensitive nature of cultural heritage information and accommodating a narrative format is an option supported by the condition report process and the marine sanctuary system.

Commercial Harvest — The capacity to support commercial market demands for seafood products

Status: Undetermined with Medium Confidence **Trend**: Undetermined with Medium Confidence.
Status Description: Not Applicable
Rationale: Throughout the study period (2008-2018) the number of commercial fishing vessels has declined. Additionally, there is limited information specific to NMSAS and regulations vary across sites within the sanctuary. Ecosystem changes linked to climate change may have impaired the ability of the ecosystem to provide commercial harvest.

Subsistence Harvest — The capacity to support non-commercial harvesting of food and utilitarian products

Status: Good/Fair with Medium Confidence **Trend**: Worsening with Medium Confidence
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Rationale - Although evidence is limited to rate this service, the agreement was high that the status is good/fair. In a 2014 survey, roughly one-third of respondents reported fishing at least two to three times per month. Additionally, several respondents indicated that they gathered other marine resources (such as shells, octopus, lobster, sea cucumber and other non-fish

species). The most common reasons for fishing include feeding themselves and family, giving to extended family and friends, giving to pastors and village leaders and for special occasions and cultural services. There is a shift towards residents fishing less frequently, likely because of the increased convenience of storing and purchasing food. The worsening trend was attributed to surveys showing respondents believing fishing is worse now than when people were younger (Levine & Sauafea-Leau 2013).

Coastal Protection — Natural features that control water movement and/or wind energy, thus protecting habitat, property, heritage resources and coastlines

Status: Mixed[1], Medium Confidence **Trend:** Worsening with High Confidence.
Status Description: The status of coastal protection services is mixed.

Aunu'u Unit	Fair/Poor	The capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it.
Muliava Unit	Good / Fair	The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Other Units	Fair	The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: Although coastal protection is rated as fair in most sanctuary units, Rose Atoll is considered to be good/fair and Aunu'u is fair/poor. The overall fair rating was driven by sea level rise threats to the health of corals and crops grown in coastal areas, and because vessel groundings and storms have damaged natural coastal protection defenses, such as corals and mangroves, in localized areas. The worsening trend is the result of the combined effects of sea level rise and subsidence. Experts noted that subsidence on the island is about 7-9mm/year, making the island's relative sea level rise rate about 5 times the global average. In addition to deepening reefs, this causes coastal and inland flooding, which threatens reef growth, and coastal habitats, crops, and infrastructure.

[1] Experts assigned a rating of Fair at the workshop, but noted that status varied across individual sites. Following the workshop, a new "mixed" status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Sanctuary Setting

Commented [1]: Mageo: The Sanctuary Setting Section is a bit lengthy but justifiably so given the context of the contents, including graphics/chart & photos, therein.
Excellent work on the brief and informative narrative of the Territory, Culture and Political affiliations; as well as the inclusion of the
Fa'a-Samoa, Our Samoan People's input in regards to the Sanctuary and respect of communal lands that Sanctuary Units are on.
Interesting note of the European/Western influence on the Islands because it's the cause of various challenges that threatens the Sanctuary
Units and its Management since its inception.
Enjoyed the brief, yet informative, description of each Sanctuary Unit within NMSAS and the impressive photos (especially the underground
Vailulu'u volcano).

Overview

American Samoa is an unincorporated territory of the United States consisting of the eastern part of the Samoan archipelago, located in the south-central Pacific Ocean. It is located approximately 1,600 miles (2,600 km) northeast of New Zealand and 2,200 miles (3,500 km) southwest of Hawai´i. American Samoa includes the inhabited islands of Tutuila, Manu´a islands (Ta´u, Olosega, Ofu), and Aunu´u, along with Rose Atoll, an uninhabited coral atoll, and Swains Island, a formerly inhabited coral atoll. The capital of American Samoa is Pago Pago, on Tutuila. In 2020, ,the population of America Samoa was 49,710 (U.S. Census Bureau, 2010 Census of American Samoa and 2020 Census of American Samoa), with the majority of residents living on Tutuila. The total land area is 199 square kilometers (76.8 sq. mi), slightly more than the size of Washington, D.C. American Samoa is the southernmost territory in the U.S. and one of two U.S. territories (the other is the uninhabited Jarvis Island) south of the Equator (ONMS 2012).

National Marine Sanctuary of American Samoa (NMSAS) is composed of six protected areas covering 13,581 square miles of nearshore coral reef and offshore ocean waters across the Samoan Archipelago (Figure SS.1). It was formerly known as Fagatele Bay National Marine Sanctuary (FBNMS), established in 1986 to protect 0.25 square miles of coral reef habitat in Fagatele Bay. In 2012, the sanctuary expanded to include Fagalua/Fogama´a on Tutuila Island, as well as areas surrounding Aunu'u, Ta'u, and Swains Island, and Muliāva, a unit that overlays Rose Atoll Marine National Monument and includes nearby Vailulu'u Seamount.

NMSAS is located in the cradle of Polynesia's oldest culture. It is home to a great diversity of marine life, including corals and other invertebrates, fish, turtles, marine plants, and marine mammals. It also includes some of the oldest and largest *Porites* coral colonies in the world, along with deep-water reefs, an undersea volcano, and important fishing grounds.

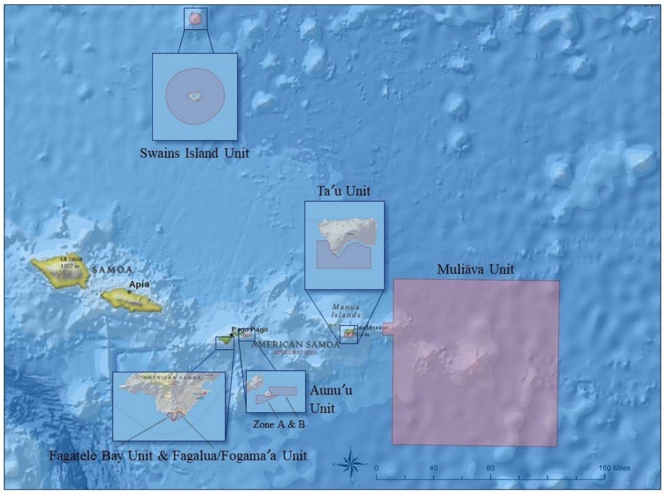


Figure SS.1. National Marine Sanctuary of American Samoa is comprised of six protected areas (Swains Island, Ta'u, Aunu'u, Fagalua/Fogama´a, Muliāva, and Fagatele Bay), covering 13,581 square miles of nearshore coral reef and offshore open ocean waters across the Samoan Archipelago. Image: NOAA

Designation of the Sanctuary

In 1982 the governor of American Samoa proposed Fagatele Bay to the National Oceanic and Atmospheric Administration (NOAA) as a candidate for marine sanctuary designation. After a lengthy public process, the Fagatele Bay National Marine Sanctuary (FBNMS) was designated on April 29, 1986 by an act of Congress. The Fagatele Bay sanctuary became part of American Samoa's conservation strategy, which includes the National Park of American Samoa (NPSA) and a community-based marine protected area program coordinated by the Department of Marine and Wildlife Resources (DMWR) (Raynal et al 2016).

On January 6, 2009, President George W. Bush established the Rose Atoll Marine National Monument under the Antiquities Act (Proclamation 8337, 74 FR 1577). The proclamation ordered the Department of Commerce to initiate a process to add the marine areas of the monument to the FBNMS. In 2008, NOAA initiated a process to expand FBNMS. ONMS worked closely with the American Samoan government and local communities, who wanted to protect these special places for future generations, to evaluate areas for proposed inclusion in the sanctuary. Through a series of public meetings that engaged both the American Samoan government and local communities, public input on the proposed areas was solicited and reviewed based on the metrics of ecological, cultural, and scientific importance. Eventually, from an initial list of 11 proposed sites, five areas were selected for final evaluation: Swains Island, Ta'u, Aunu'u, Fagalua/Fogama´a, and Muliāva.

On July 26, 2012, five new areas were added to the existing Fagatele Bay National Marine Sanctuary, for a total of six discrete management units, and the name of the sanctuary was changed to the National Marine Sanctuary of American Samoa (77 FR 43942). NOAA also amended existing sanctuary regulations and applied these regulations to activities in the expanded sanctuary. These final regulations took effect on October 15, 2012 (77 FR 65815).

NOAA co-manages the sanctuary with the American Samoa Government and works closely with communities adjacent to the sanctuary to support Samoan cultural traditions and practices.

Fa'asamoa- The Samoan Way

American Samoans hold on to ancient traditions tightly (U.S. Department of Labor 2010). ~~After~~ Despite decades of foreign influence, most Samoans are still fluent in their native language and practice fa'asamoa, the traditional communal Samoan lifestyle, or way of life. Fa'asamoa is the foundation of Polynesia's oldest culture – dating back 3,000 years~~. It places great importance on the dignity and achievements of the group rather than on individual achievements.~~ It ~~also~~ emphasizes reciprocity rather than individual accumulation, and similarly, prestige is gained through generous distribution (not accumulation) of wealth. While it holds on to these traditions, Samoan culture has inherent flexibility, allowing ceremonial and traditional customs to be modified to suit modern situations (U.S. Department of Commerce 1984). One key factor in the integrity of Samoan culture is the endurance of the Samoan language. Samoan is spoken in the workplace, including in the offices of the sanctuary and the American Samoa Department of Commerce. Samoans take pride in the tenets of respect, humility, and service as guiding principles of their culture. In this regard, as a courtesy and sign of respect, permission from families is required to cross or enter family lands. This includes beach areas that may be access points to the sanctuary (Figure SS.2).

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Figure SS.2. Reaching Fagatele Bay from Futiga requires permission, and sometimes a fee, from the local family. The site warden is responsible for unlocking the gate at the entrance to the Fagatele Bay Trail, which traverses private family land. Photo: Sarah Kinsfather

The sanctuary team places a high value on partnerships with sanctuary communities and maintains great respect for fa'aSamoa. The relationship between sanctuary staff and the matai (chiefs) is critical to successful resource management. The American Samoa Office of Samoan Affairs helps facilitate the sanctuary's community consultations in a culturally appropriate and respectful manner of fa'aSamoa. This work includes consultations with saofa´iga a le nuu (village council meeting) and individual matai (ONMS, 2012).

Human Settlement and Political History

Human history in American Samoa dates back about 3,000 years (Craig, 2009; Linnekin et al., 2006). Polynesian culture developed following the voyaging discovery and settlement of the Fiji/Tonga/Samoa region. The settlement of the Pacific islands millennia ago was guided by ancient seafarer navigation using the stars and other natural cues and observations -- a vehicle for cultural renewal and pride to this day. This voyaging and settlement of the Pacific has been called the greatest ocean-borne human migration in history.

The first European contacts came in 1722 (Davidson, 1969; Linnekin et al., 2006). The subsequent wave of outside visitors included European missionaries and explorers. The Wilkes Expedition from the U.S. in 1839 conducted the first systematic natural history and cultural surveys of Samoa. This expedition, along with the arrival of Christian missionaries, established the Western influence over Samoan society that continues today (Figure SS.3).

During the 1800's, three colonial powers, Germany, England, and the U.S. laid claim to the Samoan Islands, nearly coming to war before signing a tripartite agreement in 1899 that granted control of Upolu and Savai'i to Germany and control of Tutuila, Aunu'u, and Manu'a to the U.S. That year, the U.S. Department of the Navy assumed administration of "Tutuila Station" (Enright et al. 1997) (Figure SS.4). The family chiefs, or matais, of Tutuila and Aunu'u ceded these islands to the U.S. on April 17, 1900. Tui Manu'a and other Manu'a Chiefs ceded the Manu'a islands to the U.S. four years later on July 16, 1904. Several years later, the Navy began to refer to the region as "American Samoa" (Linnekin et al. 2006). On March 4, 1925, Olohega, or Swains Island, was annexed by the U.S. and became part of American Samoa. In 1951, per Executive Order 10264, administration of American Samoa transferred from the Department of the Navy to the Department of the Interior (DOI).

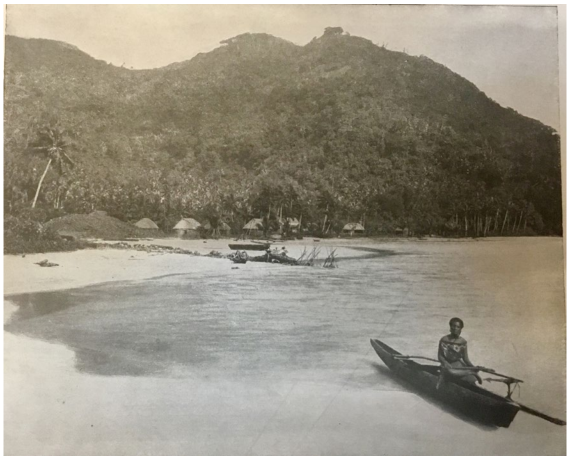

Figure SS.3. Fagatogo (Tutuila) during the time of European settlement. Note the pile of coal stored on the beach. Image: Our Islands and their People, 1899

Today, American Samoa is an unincorporated, unorganized, and self-governing territory of the U.S. and remains administered by the Office of Insular Affairs (DOI). Congress gave plenary authority over the territory to the President of the U.S., who then delegated that authority to the DOI. The Secretary of the Interior enabled American Samoans to draft a constitution under

Commented [2]: All of the background sections below seem to be about American Samoa in general, vs. the sanctuary specifically. While it is important to have the broader context to understand the sanctuary setting, it is unclear what specifically is relevant to the sanctuary portions.

Having a paragraph like the last paragraph in the Fa'a Samoa section that links back to the sanctuary context would be good to include in each section. If there isn't a specific link, then you might think about how much is necessary (since you were looking for places to streamline) which the American Samoa Government functions (Office of Insular Affairs 2010, U.S. Department of Labor 2010). American Samoans are classified as U.S. nationals rather than as full citizens. Consequently, they cannot vote in national elections, but have freedom of entry into the United States. American Samoa has had an elected, non-voting Member of Congress in the U.S. House of Representatives since 1981 (U.S. Department of Labor, 2010).

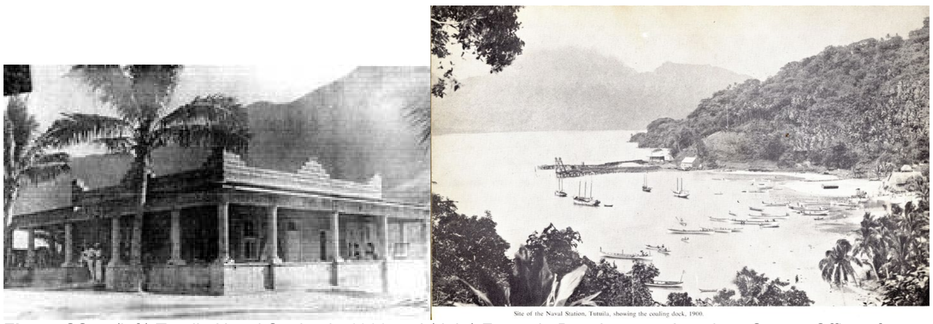

Figure SS.4. (left) Tutuila Naval Station in 1900 and (right) Fagatele Bay. Images: American Samoa Office of Archives and Records Management

Commerce

Today, the territorial government and tuna processing plants are the territory's largest employers and the mainstay of the economy. The government employs 36.9% of the local workforce (American Samoa Statistical Yearbook, 2018-2019). Two large U.S. tuna canneries once formed the basis of an industry that employed more than 3,000 Samoan and foreign workers. In 2016, one of the canneries closed due to economic difficulties. The industry has struggled due to staffing and supply chain issues associated with the global coronavirus pandemic. International fishing fleets supply catches to the canneries for export, while small-scale artisanal fisheries supply the local market for fish.

Retail trade and services dominate the rest of the territory's economy. Small-scale agriculture on the islands of American Samoa mainly supply the local markets. The most important crops include taro, coconuts, bananas, oranges, pineapples, papayas, breadfruit, and yams. Tourism is not well developed in American Samoa, with only a handful of small hotels on Tutuila. However, short visits by cruise ships provide a periodic addition to the economy. Cruise traffic ceased during the 2019 measles outbreak and global coronavirus pandemic.

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Geology

The Samoan archipelago's geologic features are the result of plate tectonics, volcanism, and reef accretion. The archipelago is 200 km (124 miles) north of the convergence of the Australian and Pacific Plates. A geologic hotspot (a stationary source of molten rock) located 50 km (31 miles) east of Ta'u created the main islands in the archipelago as the Pacific plate moved over the hotspot in a westwardly direction at about 7 centimeters (3 inches) per year (Craig, 2009). Consequently, the age of the islands increases to the west (Thornberry-Ehrlich, 2008). Tutuila is about 1.5 million years old, Ofu and Olosega are about 300,000 years old, and Ta'u is about 100,000 years old (PIFSC, 2008). Vailulu'u seamount, which sits on top of the hotspot, is constantly forming, collapsing, and reforming due to the volcanic activity. Swains Island and

Rose Atoll arose from much older volcanoes and are geographically separate from the Samoan volcanic chain (Hart et al., 2004).

Climate

The American Samoa climate is characterized by warm, relatively stable air temperatures, variable precipitation, high humidity, predominant southeast tradewinds, and periodic tropical cyclone activity (ONMS, 2012). Rainfall and tradewinds in American Samoa are influenced by the South Pacific Convergence Zone, a low-pressure area that seasonally moves over and around the archipelago, resulting in a long rainy season from October–May, and a slightly cooler and drier period, with higher southeasterly trade wind activity, from June–September (Finucane et al., 2012, ONMS, 2012). Average air temperature is 80.6°F (1967-2020) and has been increasing (Keener et al., 2021). The averaged monthly mean sea surface temperatures ranges from 82-84°F (NOAA CRW, 2021).

The Pacific Islands region experiences high inter-annual and inter-decadal climate variability as a result of the El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Inter-decadal Pacific Oscillation (IPO) (Finucane et al., 2012; ONMS, 2012; Cheng and Gaskin, 2011). ENSO events – including La Niña (cold phase) and El Niño (warm phase) – influence a variety of regional climate factors, including tradewind activity, rainfall, storm tracks, and ocean temperature (Finucane et al., 2012; ONMS, 2012).

Currents, Tides, and Waves

Ocean currents transport, among other things, nutrients, marine life, heat, oxygen, and carbon dioxide. At the broadest scale, the Samoan archipelago lies along the northern edge of the South Pacific Gyre, a series of connected ocean currents with a counter-clockwise flow that spans the Pacific basin (Figure SS.5; Alory & Delcroix; 1999, Tomczak & Godfrey, 2003; Craig, 2009). At a regional scale centered on the Samoan Archipelago, the major surface currents and eddies that affect the archipelago are the westward flowing South Equatorial Current, which occurs all year between 5° and 15° S; the South Equatorial Counter Current, which interrupts the South Equatorial Current between 9° and 12° S during the summer; and the Tonga Trench Eddy, that regularly occurs between September and December south of the archipelago (Kendall and Poti 2011). Of these, the South Equatorial Counter Current is the most prominent current feature in the region, occurring at approximately 200 m depth, and strongest in January and February (Kessler & Taft, 1987; Chen & Qui, 2004).

In addition to surface currents, deep sea currents plan an important role in regulating conditions in the deep sea. American Samoa lies along the Pacific Meridional Overturning Circulation (Voet et al., 2015), commonly referred to as the global ocean conveyor belt. The Circumpolar Deep Water flow is a deep thermohaline current that originates in Antarctica, flows along the Kermadec and Tonga Trenches and past American Samoa before entering a region known as the Samoan Passage just to the north of the EEZ. This current carries oxygen and nutrients to deep sea areas and is believed to be an important mechanism for dispersal for deep sea species across the tropical central Pacific.

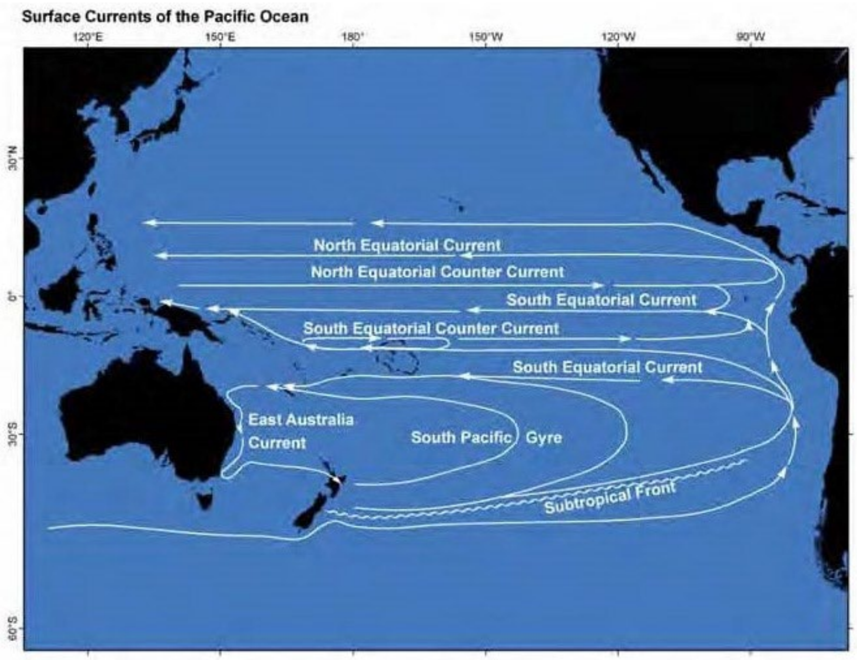

Figure SS.5. Major surface currents of the Southern Pacific Ocean. EEZs of Samoa and American Samoa are outlined in the center of the map. Image: Kendall and Poti 2011

Tides in the archipelago consist of two daily highs and lows with a mean range of 0.78 m (as measured at Pago Pago) with extremes of 0.9 m and -0.84 m (http://tidesandcurrents.noaa.gov/) during king tides and ENSO events. Tides may influence nearshore currents. Extreme high tides may flood low lying areas and extreme low tides can expose reef flat areas to the air. NOAA maintains one tidal station in American Samoa, within Pago Pago harbor.

Wave height and power are highest on average on the eastern- and southern-facing coasts of Samoan islands but can vary seasonally and among years (Barstow and Haug, 1994). Seasonally, ocean swells from the south are highest during May to September (2 to 3 m [6.5 to 9.8 ft] wave height is common) due to the increased intensity and frequency of the trade winds at higher latitudes (Barstow & Haug, 1994, PIFSC, 2008). November to March is a period often characterized by shorter period waves, lower wave heights (about 2 m), and more variable directionality (PIFSC 2008). Large anomalous wave events occur when cyclones pass (e.g., wave heights larger than 8 m were recorded during Cyclone Ofa in 1990 and Heta in 2004). Storms in the north Pacific can even cause unusually large swells on the usually more calm northern coasts of the islands (Barstow & Haug 1994; PIFSC, 2008).

Habitat and Living Resources

American Samoa is an oceanic archipelago with a small insular shelf. Therefore, shallow water habitats, such as rocky shore, reef flat, and coral reef, generally only occur within 0.5 to 2 miles

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from shore because of the steep slope of the seafloor (Craig, 2009, Figure SS.6). Pelagic (open-ocean) waters constitute the primary habitat within the archipelago. The sanctuary also includes overlaying banks, deep ocean floor, hydrothermal vents, and seamounts (Figure SS.7).

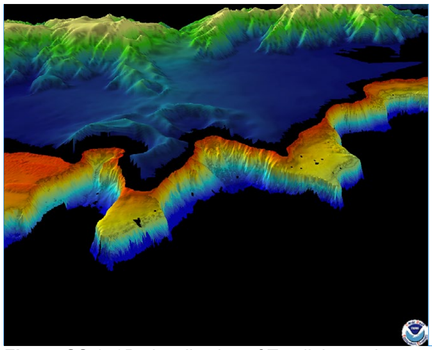

Figure SS.6. 3D visualization of Tutuila's southwestern shore, mountain to seafloor (top to bottom) view of Fagatele Bay, Larsen Bay, and Coconut Point (from left to right). Note the steep slope into the deep sea (red down to black). Photo: NOAA.

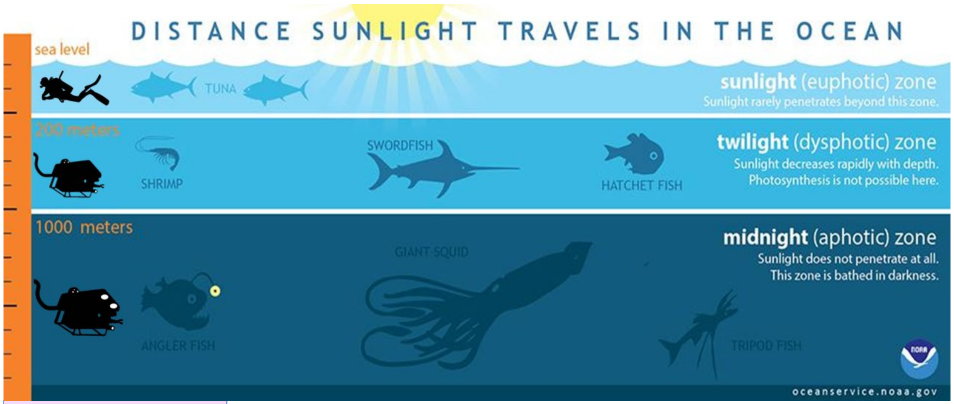

Figure SS.7. Image: NOAA

Nearshore benthic (bottom) habitats include coral reefs (reef flats and reef slopes), seagrass beds, mangrove forests, and sandy, hard, and rubble substrates in the subtidal and intertidal zones (see Fenner et al., 2008b, PIFSC, 2008, Kendall & Poti, 2011 for habitat characterizations and benthic habitat maps for the entire archipelago). Each sanctuary unit contains shallow coral reefs (<30 meters) and mesophotic reefs (30-150 meters), with Aunu'u containing the largest zone of known bottomfish habitat, and Fagatele Bay and Fagalua/Fogama´a containing submarine canyons. The Muliāva unit contains the greatest area of pelagic and deep-sea habitat, including Vailulu'u and Malulu seamounts (ONMS, 2012).

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Intertidal

Intertidal habitats in the sanctuary include rocky cliffs and terraces, caves, beaches, and reef flats. These habitats experience frequent changes from changing tides and wave action. Rocky intertidal fauna include limpets, chitons, blennies, and crabs that have specialized features to help them survive in these dynamic environments. Seabirds and shorebirds may use the area for resting and foraging. Intertidal reef flat areas and tide pools have more diversity and may support corals, macroalgae, fish, and a wide variety of invertebrates, but community development is limited by low tide exposure and the community may be disturbed by cyclones and large wave events.

Coral Reefs

Coral reef ecosystems extend from sea level down to approximately 150 meters and include both shallow coral reefs (SCR < 30m) and mesophotic coral ecosystems (MCE 30-150m) (Figure SS.8). Shallow coral reefs are some of the most diverse habitats on the planet. Within NMSAS, fringing coral reefs extend from shore, often including reef flat terraces and shallow reef crests where waves break, and then create extensive fore reef slope habitats (Table SS.1). These reefs house a high diversity of framework-building species, such as scleractinian corals and coralline algae. Below 30 meters light is diminished and the species composition shifts to corals, sponges, and algae that can tolerate low light conditions in this “twilight zone” (Figure SS.11). The MCE may have high levels of endemism, and recent work suggests that MCEs in American Samoa have distinct coral community assemblages compared to shallow reefs (Montgomery et al., 2019). Both SCR and MCE serve as essential fish habitat for some economically and ecologically important fish species, which use these areas for spawning, breeding, feeding, and growth to maturity.

Table SS.1. Geodesic area (km^2) and reef slope (m) for each NMSAS management area. SCR = shallow coral reef, MCE = mesophotic coral ecosystem. MCE zones are upper (30–70 m), mid (70–110 m), and lower (110–150 m). Source: Montgomery et al., 2019

		Aunu’u Island A	**Aunu’u Island B**	**Fagalua/Fogāma´a**	**Fagatele Bay**	**Ta’u**	**Swains Island**	**Muliāva/Rose Atoll**
Habitat area (km^2)	SCRs	2.60	2.53	0.45	0.42	1.23	1.68	1.10
	MCEs	2.34	6.94	0.49	0.27	1.70	0.48	1.31
	Upper	1.26	6.08	0.22	0.12	0.71	0.23	0.75
	Mid	1.08	0.67	0.10	0.07	0.54	0.18	0.43
	Lower	0.00	0.18	0.17	0.07	0.45	0.07	0.13
Slope (m)(mean ± sd)	Upper	10.5 ± 8.8	3.8 ± 4.2	29.7 ± 15.1	29.5 ± 14.2	15.6 ± 8.0	50.9 ± 6.5	30.9 ± 13.8
	Mid	4.9 ± 5.1	8.1 ± 6.5	35.1 ± 14.3	29.0 ± 17.1	22.7 ± 9.8	56.1 ± 7.2	42.2 ± 17.2

	Lower	-	29.8 ± 16.2	31.7 ± 17.6	27.1 ± 17.6	30.9 ± 12.3	73.7 ± 8.1	70.5 ± 8.9

Figure SS.8. A rebreather diver surveys the mesophotic habitat in NMSAS at approximately 90 meters depth. Photo: Dan Wagner, NOAA

A total of 342 stony coral species are present or possibly present in American Samoa (Montgomery et al., 2019, Figure SS.9). Corals are part of the taxonomic group called Cnidaria, and are related to jellyfish. Coral colonies are made up of a collection of individual animals known as coral polyps. Each polyp secretes a hard calcium carbonate skeleton that attaches to the skeletons of other polyps to build the colony. The slowest growing corals add between 0.2-1 inch per year and the fastest can add up to 8 inches per year (Gladfelter et al., 1978). Growth rates vary with light, temperature, nutrients, and aragonite saturation state (the measure of available calcium carbonate ions in seawater). Corals may extend their tentacles to actively feed on plankton in the water column, however in most shallow reef habitats, suspension feeding does not supply enough energy to sustain coral growth. Instead, these coral species rely on a highly productive symbiotic relationship between the coral polyp and a type of single celled algae called zooxanthellae. These algae live inside the coral polyps, converting sunlight, carbon dioxide, and water into food for the coral. Most stony corals above a depth of 200 m have zooxanthellae. This relationship is sensitive to temperature, and most reef building corals prefer temperatures between 73-84° F. If temperatures exceed a coral's preferred range for too long, the corals may have to expel the algae, a process known as coral bleaching. The combined loss of the algae and heat stress may result in coral death if temperatures exceed a coral's temperature threshold for too long.


Figure SS.9. Coral reef at Fagatele Bay. Photo: Wendy Cover, NOAA

Algae found on the coral reefs in American Samoa include zooxanthellae, microalgae, macroalgae, filamentous algae (turf), and coralline algae (both crustose and branching forms). Algae play different roles in ecosystem function and are important to the coral reef environment. Macroalgae and filamentous algae provide food for herbivorous fish, and shelter for juvenile fish and invertebrates but also compete for space with corals. Skelton and South (2007) described 243 species of benthic macroalgae in American Samoa. Since their extensive survey, further species have been identified (e.g., Kraft and Saunders, 2014). While corals are the primary reef-builders on coral reefs, other calcifiers, such as crustose coralline algae (CCA) are also very important to the ecosystem because they bind the reef together (Skelton, 2003; Craig, 2009) and provide substrate for coral larvae settlement (Craig, 2009). Rose Atoll is known for its high CCA cover which gives its slopes an incredible purple coloration. Unique to Rose Atoll are the distinctive formations built by CCA on the reef slopes (Figure SS.10).

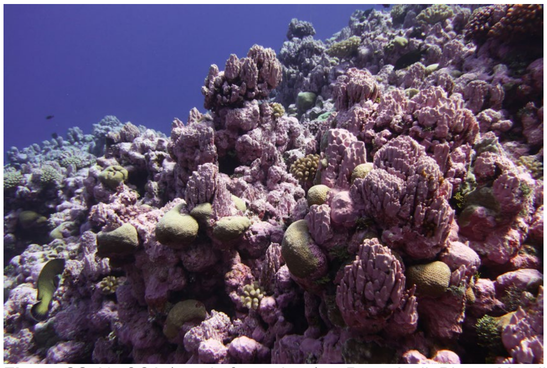
Figure SS.10. CCA (purple formations) at Rose Atoll. Photo: Mareike Sudek, NOAA

Coral reefs provide habitat for over 900 species of reef fish (Waas, 1984; Montgomery et al., 2019) and over 1,000 invertebrate species (ONMS, 2012). This includes a variety of species harvested for food including surgeonfish, jacks, snappers, parrotfish, groupers, lobsters, octopus, sea cucumbers, and giant clams. Fish and invertebrate biomass is generally higher in the more remote islands due to the lack of human fishing pressure. Large fish like reef sharks, humphead wrasse, and groupers are rare throughout the territory (Fenner, 2008b). Rose Atoll is known for an exceptionally high density of giant clams (Green & Craig, 1999). Endangered green and hawksbill sea turtles are found on reefs throughout the territory. Coral reefs also serve as resting areas for resident spinner dolphin pods, and humpback whales with their newborn calves are frequently observed near reefs from June to November.

Pelagic Zone

Most of American Samoa's marine habitat is pelagic. Even though the pelagic habitat consists entirely of water hundreds of kilometers wide and thousands of meters deep, it should not be considered without structure and associated ecosystem zones. There are four distinct zones: epipelagic (<200m), mesopelagic (200-1000m), bathypelagic (1000-4,000m), and abyssopelagic (<4,000m). Pelagic species are closely associated with their physical and chemical environments, and thus their habitat range and distribution may be significantly altered by oceanographic variability, like ENSO events. Some organisms migrate through pelagic zones, or between pelagic and benthic habitats, during life cycle phases. Others are found in different zones during different activities such as migration, foraging, and reproduction (Garrison 1999).

The epipelagic zone is highly dynamic, affected by the South Equatorial Current and the South Equatorial Countercurrent which display seasonal and interannual variability. These currents, and their resultant eddies, are affected by ENSO events (Domokos et al., 2007; Domokos, 2009). Only 45 pelagic fish species have been identified in this zone (Waas, 1984), including important pelagic fishery targets such as albacore (*Thunnus alalunga*) and yellowfin tuna (*T. obesus),* blue marlin (*Makaira nigricans*), wahoo (*Acanthocybium solandri*), masimasi (*Coryphaena hippurus*), and skipjack tuna (*Katsuwonus pelamis*). Seabirds forage in these upper layers and marine mammals spend most of their time in this zone.

Thirteen species of marine mammals have been observed in American Samoan waters (Craig, 2009). There are two mysticetes (baleen whales): humpback, and minke whale (Utzurrum et al., 2006). There are 11 odontocetes (toothed cetaceans): sperm whale, killer whale, short finned pilot whale, common bottlenose dolphin, spinner dolphin, pan-tropical spotted dolphin, striped dolphin, rough toothed dolphin, Cuvier's beaked whale, dwarf sperm whale, and false killer whale (Utzurrum et al., 2006; Johnston et al. 2008). Each year, from July through October, humpbacks use the waters around American Samoa for breeding and calving (Lindsey et al., 2016).

The darker mesopelagic zone is a haven during the daylight hours for micronekton organisms that comprise the deep scattering layer (small fish, crustacean, and cephalopods), but these animals migrate to the epipelagic zone each night to feed on phytoplankton and smaller zooplankton found there (Domokos et al., 2007). Little is known about the bathypelagic and abyssopelagic zones in American Samoa.

Seamounts and Deep-Sea

Deep ocean benthic habitat includes hard, soft, and biogenic habitats at water depths below 150 meters, and are by far the largest benthic habitat in American Samoa. Soft sediments are made up mostly of mud and sand and are generally low in biological productivity. Deep sea corals are found on hard bottom substrate in dark waters where temperatures range from 4-12° C. For this reason, these corals are known as “cold-water” or “deep-sea” corals. Cold-water corals are also part of the taxonomic group Cnidaria, and they are related to shallow corals. However, these corals lack the symbiotic algae that inhabit and help color shallow corals. Instead, cold-water corals feed by waiting for small food particles to flow past, and then use their stinging cells to capture them. They also provide habitat for other species. Some reefs are several thousand years old, and some individual corals live several hundred years. Cold-water corals have been poorly studied. However, increasing knowledge and evidence shows that cold-water corals are important as fish habitat and are hotspots of biodiversity. The deep sanctuary units support a diverse biological community that includes deep-sea corals, crinoids, octocorals, and sponges (Kennedy et al., 2019, NOAA DSCRTP, 2020).

Biological hot spots may be found on ridgelines, near hydrothermal vents, and around seamounts. Seamounts are underwater volcanic mountains, rising from the seafloor, and occur throughout all ocean basins (Wessel et al., 2010). Generally, seamounts are highly productive and support a rich biodiversity of organisms. Some species of bottomfish found on seamounts are important to commercial fisheries, such as snappers (Lutjanidae), groupers (Serranidae), jacks (Carangidae), and emperors (Lethrinidae). Most bottomfish are associated with hard substrates, holes, ledges, or caves and are believed to not migrate between isolated seamounts. In comparison, highly migratory species, including bigeye and yellowfin tuna, traverse across the entire south Pacific basin andare also attracted to geological features such as seamounts and islands (Morato et al, 2010).

There are 48 seamounts within the American Samoa EEZ (Kendall and Poti, 2011) rising from as deep as 13,000 ft (4,000 m) (WPFMC 2009a). Vailulu’u Seamount (Figure SS.11) is located in between Manu’a and Rose Atoll and is the only hydrothermally active seamount within the EEZ (Koppers et al., 2010). Discovered in 1975 and first mapped in 1999, Vailulu'u is the active volcanic hotspot that created the Samoan archipelago. The caldera of Vailulu’u has risen and collapsed repeatedly over time and currently sits at about 708 meters below the water's surface. Between 2001 and 2005, a new cone formed in the middle of the crater and was named Nafanua (after the Samoan goddess of war). Researchers have estimated that if activity continues at the current growth rate, the seamount could eventually breach the surface within decades, forming a new island in the Samoan island chain (Staudigel et al., 2006). Vailulu’u supports a diverse biological community including polychaetes, crinoids, octocorals, sponges, and cutthroat eels (Staudigel et al., 2006). Malulu Seamount is located near Vailulu’u, but much less is known about this seamount. It is very deep, lying from 2,400 meters to 4,800 meters in depth (Seamount Biogeosciences Network, 2022).

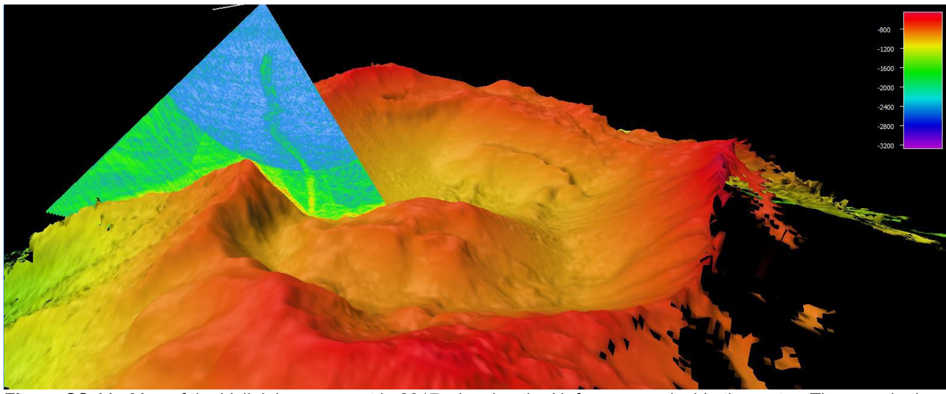

Figure SS.11. Map of the Vailulu'u seamount in 2017, showing the Nafanua cone inside the crater. The cone in the image is the beam fan of the water column backscatter data from the multibeam. The ~~green~~ feature snaking up from the bottom of the cone is a gaseous plume emanating from the volcano's crater floor. The legend in the multibeam image is depth in meters for the bathymetry shown. Image: NOAA

Commented [8]: @kathy.broughton@noaa.gov This color ramp is not accessible. If possible, it would be great to change to a red to blue ramp (without any green, similar to the bathymetry in SS.6). That being said, if it cannot be easily changed, I think we can leave it with some added description (e.g., restate the average depth of the crater in the caption), since the main purpose of this image seems to be illustrating the plume/hydrothermal activity (and that is visible w/filters due to the blue background of the cone).

Maritime Heritage Resources

Maritime heritage resources can capture specific portions of American Samoan history and serve as windows on the past, though few specific surveys for heritage sites have been conducted. In general, known and potential maritime heritage resources in American Samoa fall into five categories: 1) historical shipwrecks (35 reported lost, two located/assessed); 2) World War II naval aircraft (43 lost between 1942-1944, none located); 3) World War II fortifications, gun emplacements, and coastal pillboxes (multiple sites assessed, but none reported in the sanctuary); 4) archaeological sites (Addison et al., 2010 identified more than fifty coastal/nearshore archaeological sites or features following the 2009 tsunami, from coastal settlements, stone tool manufacturing sites, and isolated artifacts scatters); and 5) marine/coastal natural resources associated with the legends and folklore of American Samoa (described by the American Samoa Historic Preservation Office as sites "of extraordinary significance to Samoan culture", see Volk et al. (1992).

Sanctuary Units

The sanctuary includes six discrete units that have unique habitats and varying regulations (see Table ___ in the Response section for further information): Fagatele Bay, Fagalua/Fogama´a, Aunu'u, Ta'u, Swains Island, and Muliāva units.

Fagatele Bay

The Fagatele Bay unit is a 0.25 square mile (0.65 square km) coastal embayment that extends from Fagatele Point to Steps Point along the southwestern coast of Tutuila Island (Figures SS.12-13). This naturally protected bay was formed by a collapsed volcanic crater and is surrounded by steep, forested cliffs. It was designated as a National Marine Sanctuary in 1986 to protect its extensive coral reef ecosystem. In 2012, Fagatele Bay was declared a no-take marine protected area (ONMS 2012) and as such, fishing and other extractive uses are not allowed. Activities that are allowed include non-extractive research, education, and recreation (see Table ___ in the Response section for further information). The shore of Fagatele Bay was the site of a historical coastal village from prehistoric times to the 1950s, but at present, no human settlement exists near the shoreline.

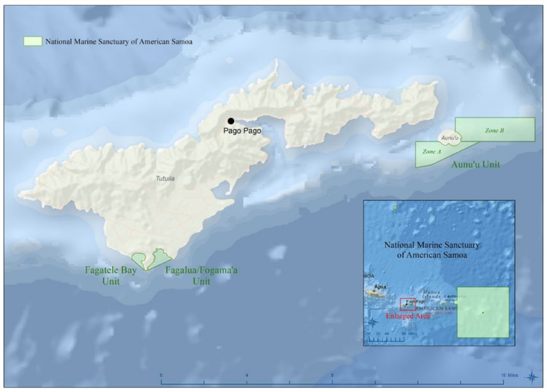

Figure SS.12. The Fagatele Bay and Fogāma´a/Fagalua units are located on the island of Tutuila. Aunu'u is approximately 1.2 miles southeast of Tutuila and includes two zones – a Multiple Use Zone (A) and a Research Zone (B). Map: Tony Reyer/NOAA

Figure SS.13. In 1986, NOAA established the Fagatele Bay as a National Marine Sanctuary in order to protect and preserve the 0.25 square miles of coral reef ecosystem within the bay. Photo: Matt McIntosh/NOAA

Fagalua/Fogama´a

Fagalua/Fogama´a unit is a 0.46 square mile (1.2 square km) bay on the southwest shore of Tutuila, just east of Fagatele Bay (Figure SS.14). Fagalua and Fogama´a coves make up the inner western portion of the entire bay area, which extends from Steps Point to Sail Point Rock. Like Fagatele Bay, Fagalua/Fogama´a was formed by a flooded volcanic crater and is surrounded by steep, forested cliffs. The importance of the relationship between this bay and the surrounding environment is comparable to Fagatele Bay, with both bays having high coral coverage, as well as many different types of coral and fish species. Because of this similarity, the area provides a replicate habitat for increased protection, scientific research, and overall increased resilience of coral reef ecosystems (U.S. Department of Commerce 2012). A variety of activities are allowed in the Fagalua/Fogama´a unit, including research, education, recreation, hook-and-line fishing, cast nets, spearfishing (non-scuba assisted), and traditional methods used for sustenance and cultural purposes such as gleaning, enu and ola (traditional basket fishing) (see Table ___ in the Response section for further information). The Turtle and Shark Lodge is found on the cliffs of Fogāma´a alongside a few scattered houses and plantations, but otherwise no settlements are found on the shore of Fagalua/Fogama´a bay.

Figure SS.14. Fagalua/Fogama´a was formed by a flooded volcanic crater and is surrounded by steep, forested cliffs. Photo: MAJ

Aunu'u

Aunu'u Island is a small, volcanic island approximately 1.2 miles (2 km) southeast of Tutuila with a land area of 0.58 square miles. The Aunu'u unit encompasses 5.8 square miles (15 sq km) and borders the island on three sides. The unit consists of coral reef, pelagic, and deep seas habitat, including extensive mesophotic habitat. Based on limited survey data, the coral cover and number of species present in the Aunu'u units is generally moderate compared to other areas around Aunu'u.

The Aunu'u unit includes two zones – a Multiple Use Zone (1.9 sq miles) and a Research Zone (3.9 sq miles) (Figure SS.15). The multiple use zone is located on the southern side of the island near the village. Allowed activities in the multiple use zone include research, education, and recreation. Hook-and-line fishing, casting nets, spearfishing (non-scuba assisted), and other non-destructive fishing methods including those traditionally used for sustenance and cultural purposes, such as gleaning,enu and ola' (traditional basket fishing), are also permitted (see Table ___ in the Response section for further information). The research zone is located on the eastern side of the island. Allowed activities in the research zone include research, education, recreation, and surface fishing for pelagic species, including fishing by trolling. Bottom fishing, trawling, and fishing for bottom-dwelling species are prohibited in the Research Zone (see Table ___ in the Response section for further information).

The island of Aunu'u is home to one small village with a population of 402 (Source: U.S. Census Bureau, 2020 Census of American Samoa). The sanctuary unit is of high ecological and cultural significance for the local residents who commonly use the area for subsistence fishing.

Figure SS.15. Photo: Ed Lyman/NOAA

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Ta'u

Ta'u, part of the Manu`a island group, is a volcanic island located approximately 70 miles east of Tutuila Island (Figure SS.16). Ta'u is ringed by extremely steep sea cliffs and a steeply dropping seafloor. The island has a south-facing embayment, the result of collapse and landslides off the remnants of a southern caldera similar to the Fagatele Bay formation. The Ta'u unit encompasses 14.6 square miles and includes waters from Vaita Point to Si`ufa`alele Point along the western coast, and from Si`ufa`alele Point to Si`u Point along the southern coast (Figure SS.17). The inner sanctuary boundary along the southern coast is adjacent to, but does not include, the nearshore waters of National Park of American Samoa, which extend 0.25 nautical miles from shore.

The Ta'u unit includes the "Valley of the Giants," home to many large *Porites* corals, including the Fale Bommie, also known as Fale Bommie, or Big Momma coral, which is more than 500 years old and over 6 meters high, and has a circumference of 41 meters (Figure SS.18, Tangri et al., 2018, Brown et al., 2009). It is one of the largest recorded coral colonies in the world.

Activities allowed in the Ta'u unit include research, education, recreation, hook-and-line fishing, cast nets, spearfishing (non-scuba assisted) and other non-destructive fishing methods including those traditionally used for sustenance and cultural purposes (see Table ___ in the

Response section for further information). The island of Ta’u is home to 553 people (Source: U.S. Census Bureau, 2020 Census of American Samoa).

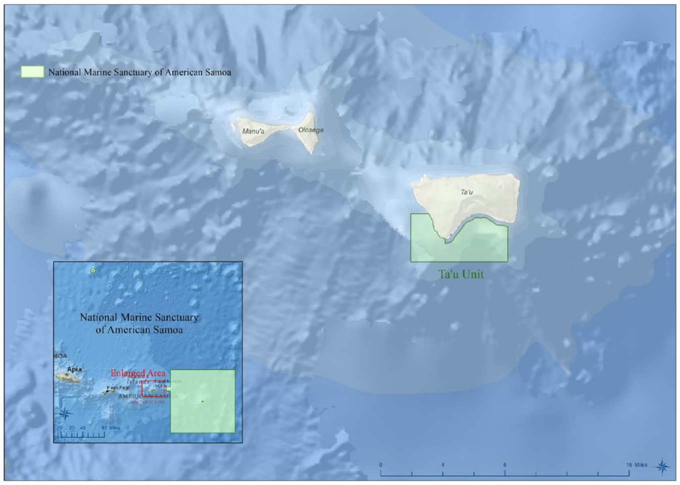

Figure SS.16. The Ta’u unit. Map: Tony Reyer/NOAA


Figure SS.17. The coast of Ta’u island. Photo: Nerelle Que Moffitt/NOAA


Figure SS.18. Giant *Porites* coral, also known as Fale Bommie, or Big Momma coral is located in the waters off of Ta’u, American Samoa. Photo: XL Catlin Seaview Survey

Swains Island

Swains Island is a privately owned low-lying emergent seamount and coral atoll located about 200 miles (350 km) northwest of Tutuila. It is geologically part of the Tokelau volcanic island group and not the Samoan volcanic chain. The Swains unit encompasses 52.3 square miles (135.5 sq km) of territorial waters (Figures SS.19-20). Swains Island is approximately 1.5 miles in diameter, with approximately 1 square mile of highly vegetated land that has a maximum elevation of 6 feet above sea level. The coral reef area is small and has a steep slope. The reef is dominated by *Pocillopora* and plating *Montipora* corals and large schools of predators, mostly barracudas, jacks and snappers, can be encountered.

Activities allowed in the Swains Island unit include research, education, recreation, hook-and-line fishing, cast nets, spearfishing (non-scuba assisted) and other non-destructive fishing methods including those traditionally used for sustenance and cultural purposes such as gleaning (fagota savali), enu, and ola' (see Table ___ in the Response section for further information). Swains Island, initially known as Olosega, has a unique history of human occupation, but the island has been uninhabited since 2008 (Van Tilburg et al., 2013). In 2013, NOAA's Office of National Marine Sanctuaries, along with partner agencies and institutions, conducted an eight-day on-island multidisciplinary survey of Swains Island. The fieldwork focused on the unique environmental setting (including a survey of the geomorphology of the atoll) and past cultural heritage resources of the island (including a maritime archaeology survey to identify historic and prehistoric maritime heritage resources) (Van Tilburg et al., 2013).

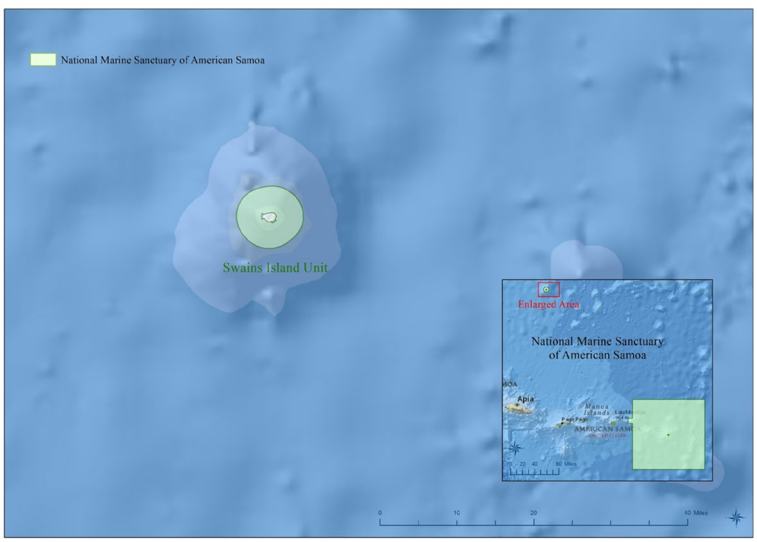

Figure SS.19. The Swains unit. Map: Tony Reyer/NOAA

Figure SS.20. Swains Island is a low-lying coral atoll and is the most remote of the sanctuary units. Photo: Nerelle Que/NOAA

Muliāva

The Muliāva unit is the largest and encompasses 13,507.8 sq miles (34,985 sq km). It includes the marine waters of the Rose Atoll Marine National Monument as well as the waters surrounding the Vailulu'u Seamount, a submerged volcanic cone and the only hydrothermally active seamount within the EEZ. The Rose Atoll National Wildlife Refuge lies within the center of this unit and includes the lagoon and islands within Rose Atoll. The refuge is managed by the U.S. Fish and Wildlife Service and is not part of the sanctuary. The sanctuary begins at the mean low water mark on the outside of the lagoon and includes the outer reef slopes and deep sea habitat around the atoll(Figures SS.21-23). Rose Atoll is approximately 150 miles (240 km) east-southeast of Tutuila Island's Pago Pago Harbor. It is the easternmost Samoan island and the southernmost point of the United States. One of the smallest atolls in the world, Rose Atoll consists of about 0.03 square miles of land and 2.5 square miles of lagoon surrounded by a narrow reef flat (ONMS, 2012).

Commented [10]: From Bert: To avoid confusion, it's worth clarifying what Muliava is referring to in this document. Most people including the Manuans refers to Rose Atoll as "Nu'u o Manu" (village of the birds) and/or "Muliava or Mulia'au".

Commented [11]: I agree, there is a lot of misunderstanding what is what so it would be good to expand here a bit and try to explain the complicated layout of Rose Atoll, Sanctuary and Monument.

Commented [12]: @mareike.sudek@noaa.gov do you think we should add this to a call to discuss?

Commented [13]: yes I think it would be helpful to agree on language here. Maybe we can edit this part together on a call.

Commented [14]: @mareike.sudek@noaa.gov what was the final decision on editing this language?

Commented [15]: @kathy.broughton@noaa.gov & @mareike.sudek@noaa.gov "Muliava" is the sanctuary designation of waters within the Marine National Monument.. ROSE ATOLL is MOTU O MANU (YES) - the body of LAND. But the WATERS "Muliava" is translated - the end of the current... (water)

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YES

Rose Atoll, also known as *Motu o Manu* (island of the birds) or *Nu'u o Manu* (village of the birds) is a distinct environment within the archipelago. The lagoon at Rose Atoll supports the highest densities of faisua (giant clams) in the Samoan Archipelago, and Rose Island is an important site for green turtle and seabird nesting in American Samoa. The outer reefs of the atoll are characterized by very high CCA cover and large numbers of fish. The atoll is positioned upstream in the south equatorial current relative to the rest of the Samoan Archipelago and therefore, may be an important larval source for the territory (Kendall & Poti, 2011). The name "*Muliāva*" means "the end of the current" and refers to the marine waters around Rose Atoll. In addition to Rose Atoll, the Muliāva unit also includes vast deep sea areas as well as the submerged volcanic Vailulu'u Seamount, which is outside of the monument boundaries but within the sanctuary boundaries (Figure SS.23).

Fishing in the Rose Atoll Marine National Monument is regulated by the NOAA National Marine Fisheries Service (NOAA Fisheries), US Fish and Wildlife Service, and the American Samoa Government. Commercial fishing is prohibited within the monument and in 2013, NOAA Fisheries enacted additional regulations that prohibited all fishing within 12 nautical miles of Rose Atoll unless authorized by a permit for sustenance or recreational fishing (78 FR 32996). Activities allowed in the area include research, education, recreation, and limited fishing with a permit (see Table ___ in the Response section for further information).

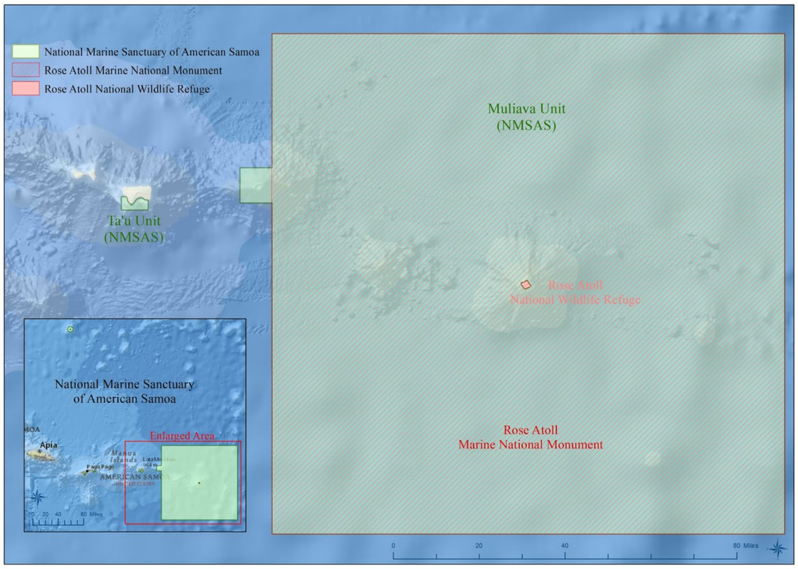

Figure SS.21. The Muliāva unit includes the marine waters of the Rose Atoll Marine National Monument and the Vailulu'u Seamount. Map: Tony Reyer/NOAA

Figure SS.22. Aerial view of Rose Island, surrounded by shallow sandy lagoon and deep fringing reef. Photo: Tamiano Gurr/American Samoa Visitors Bureau

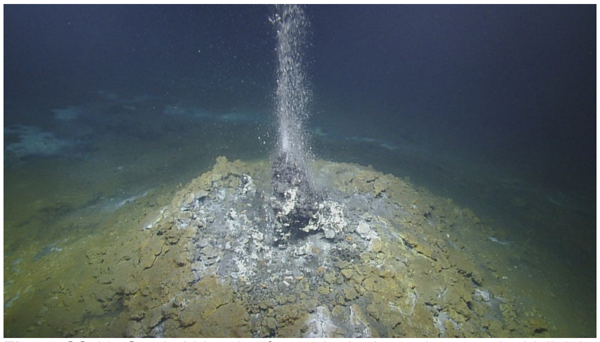

Figure SS.23. Gas bubbles rise from a hydrothermal vent at the Vailulu'u Seamount observed by Ocean Exploration Trust E/V *Nautilus* in July 2019. Photo: OET/Nautilus

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Drivers

For purposes of condition reports, driving forces, or drivers, are defined as societal values, policies, and socioeconomic factors that influence different human uses of the ecosystem. Drivers can influence the condition, or state, of the environment, creating both negative results, considered pressures, and positive results that benefit the environment. Drivers can result in pressures that affect the condition, or state, of the environment. They help us understand the forces behind pressures and are the ultimate cause of anthropogenic changes in ecosystems. Further, drivers may be local, regional, national, or international in scale. Because the most influential drivers originate and operate at large geographic scales, this section begins with a broad focus on drivers, followed by a more locally focused discussion of pressures that directly affect sanctuary water, habitat, living resources, and maritime heritage resources. Trends in drivers and pressures support the assessment of these resources and can aid in forecasting the direction and influence of future pressures.

Pressures may be affected by one or more driving forces, which often affect multiple pressures. The most influential drivers of pressures at NMSAS are shown in Table DP.DF.1 and integrated into discussions of each pressure. Table DP.DF.1 shows the relationships between drivers and pressures.

Table DF.1. Driving forces and their relationship to pressures that affect NMSAS resources. For each row, the bullets indicate the range of influence of drivers across pressures. For each column, the bullets indicate drivers affecting individual pressures. The geographic scales at which different drivers originate to affect pressures are also shown (I=international, N=national, R=regional, L=local). See text below for explanations of specific drivers and pressures.

		PRESSURES									
Drivers	**Scale**	**Accelerated Climate Change**	**Fishing**	**Coastal Development & Nearshore Construction**	**Non-Point Source Pollution**	**Point Source Pollution**	**Marine Debris**	**Vessel Groundings**	**Visitation**	**Nuisance Species Outbreaks**	**Research Activities (and consider sanctuary operations)**
Gov't Relationships	N, R, L		•	•	•	•			•		•
Traditional Management	L		•	•					•		•
Population	G, N, R, L	•	•	•	•	•	•	•	•	•	•
Per-capita Income	G, N, R, L	•	•	•	•	•	•	•	•	•	

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Various Pressures from Coastal Developments to Non-Point/Point Source Pollutions (to name a few) to natural phenomena such as
Climate Change and Nuisance Species Outbreaks are largely impacted by Drivers derived from human behavior/actions according to the
this Section of the Report.

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Arguably, it's the human behaviors that you're trying to affect, so it makes sense to focus on the drivers of human behaviors.

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Fuel Prices	G, N, R, L	•	•				•	•	•		
Demand for Seafood	G, N, R, L	•	•		•	•	•	•	•	•	
Technological Advancement	G, N, R, L		•		•	•	•	•			
Societal Values /Conservation Ethic	N, R, L	•	•	•	•	•	•		•	•	•
Ocean Policy	N, R, L	•	•	•	•	•	•		•	•	•

Drivers operate at different, and sometimes multiple, scales ranging from international, national, regional, and local. Most affect demand for resources (e.g., government relationships, per-capita income, fuel prices, etc.) and, thus, levels of activities (e.g., coastal development, fishing, visitation) that alter resource conditions. Some, like the gross domestic product (GDP) of foreign countries, have global influence. Among other things, GDP affects global demand for seafood and the pressure of commercial fishing. Local drivers, on the other hand, are those that originate from and influence the NMSAS "local economy" (sometimes called the "study area" or "sanctuary economy"). This area is identified by first including villages, then working with NMSAS leadership to determine the spatial footprint of localized socioeconomic contributions stemming from the use of sanctuary resources. These contributions include income, jobs and economic output, all of which respond to changes in resource conditions that are influenced by changing pressures. Further, this section provides an overview of several key drivers, and the discussion below is not an exhaustive list of all drivers affecting NMSAS.

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Some drivers influence the supply of or access to resources. These stem mostly from management and policy actions, whether local, state, tribal, national, or international, and may increase or decrease the pressures on resources. Some, such as relationships established and dictated through treaties, create cooperative management approaches that can preempt pressures (e.g., cooperative fisheries management, preparation of oil spill response plans). Importantly, these drivers also exemplify a concept frequently expressed by Indigenous peoples, namely the reciprocal relationship between people and the environment. This originates from Indigenous peoples' sense of oneness with nature and emphasizes the mutual roles of both in supporting each other. Advocates of the modern conservation movement will recognize this as a foundational aspect of their efforts as well. In this way, both can be considered "positive" drivers.

Before discussing other drivers, it is important to consider NOAA and ONMS mandates as institutional drivers. Starting with federal agencies' basic obligation of public service, each employee has an oath-bound responsibility to the United States government and its citizens to display loyalty to the Constitution, laws, and ethical principles (5 CFR § 2635.101). This includes fulfilling the responsibilities outlined in the the National Marine Sanctuaries Act (NMSA; 16 U.S.C. § 1431), which:

> "establishes areas of the marine environment [that] have special conservation, recreational, ecological, historical, cultural, archeological, scientific, educational, or esthetic qualities as national marine sanctuaries managed as the National Marine Sanctuary System will—(A) improve the conservation, understanding, management, and

wise and sustainable use of marine resources; (B) enhance public awareness, understanding, and appreciation of the marine environment; and (C) maintain for future generations the habitat, and ecological services, of the natural assemblage of living resources that inhabit these areas."

This guiding language ensures that the sanctuary acts in a manner to improve conservation and management for generations to come.

The expansion of NMSAS was in response to the American Samoa Governors in 2000 and 2008 committing to the goal of setting aside 20% of coral reef habitat within the territory for long-term protection. Additionally, Presidential Proclamation 8337 (in 2009) states that "[t]he Secretary of Commerce shall initiate the process to add the marine areas of the [Rose Atoll Marine National] monument to the Fagatele Bay National Marine Sanctuary in accordance with the National Marine Sanctuary Act" (74 FR 5631).

Government Relationships

Samoans are known as people who share a common language and a 3,000-year-old cultural code. A significant difference between Samoa and American Samoa is how the people are governed. Samoa is an independent nation with its Head of State, while American Samoa is a self-governing territory of the U.S. American Samoans are classified as U.S. nationals rather than as full citizens.

American Samoa has an intergovernmental relationship with the Samoa Government to collaborate effectively on shared environmental concerns. As part of a shared environmental agenda, the leaders of these two jurisdictions hold an annual forum to discuss areas of common interest (e.g., trade, health, education, communication and technology, fisheries, agricultural, food security, enforcement, etc.). This partnership allows both governments to collaborate and share information. This cooperation amongst peoples to ensure the continued conservation, stewardship, and adaptation to environmental challenges may be a positive driver.

Traditional Management and Governance Structure of American Samoa

American Samoa Government is based on the United States party system which honors the Fa'a Samoa traditional village protocol, or the matai system (council of chiefs). This takes place at all levels of the Samoan structure – from the family, to the village, to the government. The matai (chiefs) are elected by consensus within the fono of the extended family and village(s) concerned. The matai and the fono (made of matai) decide on the distribution of family exchanges and the tenancy of communal lands. The majority of lands in American Samoa are communal. A matai can represent a small family group or a great extended family that reaches across islands and to both American Samoa and Samoa.

Fa'asamoa, the Samoan way of life, emphasizes loyalty to family, respect for one's elders, and a commitment to serving the community, which is considered all-important. For example, a seasonal village MPA may be guided and overseen by the council of chiefs. The village MPA is allowed to open for a short period to support village events or special occasions. The government is also informed of these arrangements and they provide science and technical support by analyzing data. Since the local people control communal lands and waters, conservation and stewardship are entrusted with those who have an extended relationship with these areas across generations and space. This approach promotes more responsive and localized monitoring of the resources, promoting community well being, continued cultural engagement, and environmental health of the sanctuary and surrounding waters.

Population and Per Capita Income

International and domestic demand for goods and services, at all scales ranging from local to global, is directly tied to changes in population and real per capita income. It is and will remain a ubiquitous, primary driver of pressures on sanctuary resources. For example, as income or population increases, demand increases for normal goods like clothes, technology, and other consumer goods. Because the majority of these goods are imported to American Samoa, higher demand can increase vessel traffic. On the other hand, declines in income or population may have the opposite effect.

From 2010 to 2020, the population of American Samoa decreased by 10.5% from 55,519 to 49,710 people (U.S. Census Bureau, 2010 Census of American Samoa and 2020 Census of American Samoa. In 2010, the annual per capita income in American Samoa was $6,311 and the poverty rate was 57.8% (U.S. Census Bureau, 2010 Census, in American Samoa Statistical Yearbook, 2017). A relatively high poverty rate in a place with strong cultural linkages to ancestral practices may result in higher reliance on subsistence harvest to meet nutritional needs. If not managed sustainably, subsistence harvest could become a significant pressure on resources.

Fuel Prices

Fuel prices are an important, and often an immediate, driver of many ocean activities. Ocean users consider fuel prices in their decisions about whether to conduct activities like commercial fishing, to buy and register boats for ocean recreation, or to explore for offshore oil and gas (and in the longer term, install offshore renewable energy facilities). Figure DP.1 shows the average annual fuel price from 2007 to 2017. Since 2014 gasoline prices have been declining, indicating that the cost of recreational and commercial activities within the sanctuary that utilize fuel are also likely declining. Lower activity cost may result in increased activities and thus pressure on sanctuary resources.

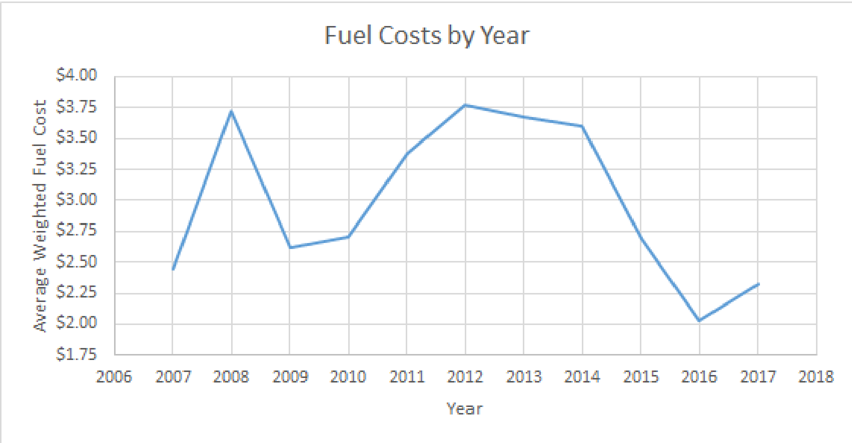

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Figure DP.1. Average annual fuel prices from 2007 to 2017. Image: American Samoa Statistical Yearbook, 2017

Demand for Seafood

As global and domestic demand for seafood grows, effective management of wild-caught fish and continued increases in the growth of aquaculture will be required (NOAA Fisheries, 2020b). Yet, while these approaches are needed to meet demand, they may also lead to increased pressures on resources and ecosystems. While this section considers global and national demand, local and regional markets are likely to be affected and face increased pressures to meet global and national demands. Further, as prices fluctuate locally, this may change the willingness of commercial fishermen to expend time and resources targeting specific species. For example, if the price of tuna increases while the price of surgeonfish stays the same, more effort may be spent harvesting tuna. For more information on harvest revenue and landings of species within the sanctuary, see the Commercial Harvest section of this report.

The tuna cannery in American Samoa is significant to both import and export vessel traffic. American Samoa exported roughly $428 million worth of goods in 2016 (CIA World Factbook, 2020). Canned tuna is the primary commodity exported from American Samoa (93.0% in 2017) and the tuna harvesting and processing industries are key elements of the private sector (CIA, 2020).

American Samoa's tuna canning industry faces multiple challenges, including increased competition and minimum wage increases, which led to cannery closures in 2018. Impact of the canneries completely closing would be significant, as it provides 30 percent of American Samoa’s workforce. Additionally, transportation, energy and utility costs would rise because the canneries would no longer be available to share those costs.

Technological Advancement

Technological advancement may be viewed as either a positive and negative driver depending on the technology and what it promotes. For example, requirements for seafloor mapping may act as a positive driver by increasing knowledge and awareness of sensitive habitats and refining our understanding of species distributions. Significant efforts to increase seafloor mapping in NMSAS by vessels, such as the NOAA Ship Okeanos Explorer and E/V *Nautilus*, have taken place in the past decade. Seafloor mapping may identify previously unknown deposits of resources, which could increase pressures to extract those resources. Advancements in fishing technology in the past have resulted in increased harvests while decreasing the effort needed to catch fish. Improvements in fishing gear technologies can also reduce bycatch of sensitive species. Advancements in autonomous vehicles have helped to estimate fish abundance to promote sustainable fishing while reducing the risks to human health and fish (NOAA Fisheries, 2020a).

Societal Values and Practices

Public access to the beaches, and consequently the marine ecosystem, is under the purview of the village or individual families that reside adjacent to the water and public places. One must obtain permission or approval for access out of respect and courtesy. These families are the caretakers of these special places and help to maintain and safeguard them for current and future generations. Given the caretakers of the ocean resources in American Samoa are also part of the community, this approach to resource management helps to reduce pressures and identify improving and/or degrading conditions more rapidly.

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The relationship between the peoples of Samoa and American Samoa may also provide a mix of positive and negative influences on drivers. This relationship exemplifies the longstanding connections between Samoa and American Samoa through trading fish and the exportation of foods based upon need (e.g., as a result of a tsunami or other disasters). As a societal value, the desire to ensure food security across the region is a driver, as is the sharing of knowledge. As an example, as a consequence of climate change, Aunu'u is experiencing salt water intrusion in wetlands and swamps. Certain species of native grasses in Samoa have a high tolerance to climate change and could be planted in American Samoa to reduce and/or delay climate change impacts. In this example, the two nations support one another and are sharing knowledge regarding food security in order to ensure survival.

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Another example of societal values that reduce fishing pressure is the belief that one does not play with their food. Participation in recreational reef activities is not a common activity amongst native Samoans (2016 Levine et al). . In addition, NMSAS promotes awareness of allowable and responsible fishing practices within the sanctuary by bringing together and educating local fishing groups.

For places like American Samoa that have long-standing and vibrant indigenous cultures, the associated cultural practices of communities are, collectively, a driver that may exert positive and/or negative impacts on resources. Religion significantly influences the Samoan way of life, where God is first in all facets of society. Therefore, it is not uncommon for anyone who starts an activity or event; prayer is, in fact, respectfully practiced to this day. For example, ceremonial events such as a church dedication or a death in the family may result in temporary pressures caused by more people fishing within the community. Most cultural practices in indigenous cultures tend to reflect deep connections between people and the resources they depend on, and care is generally taken to moderate impacts while still respecting long-held traditions.

Ocean Policy

The United States is party to numerous agreements that establish international entities composed of member governments that focus on various topics, ranging from managing shipping (International Maritime Organization), global whale stocks (International Whaling Commission), fisheries (Inter-American Tropical Tuna Commission, Western and Central Pacific Fisheries Commission, etc.), and oil spill response (Pacific Ocean Pollution Prevention Programme).

Since 2010, the United States has had an ocean policy, first through Executive Order 13547 (2010) and later replaced with Executive Order 13840 (2018). While the primary focus differs between these policies, both emphasize improving cross-agency coordination on management of the ocean and its resources and access to data. Mapping the seafloor of our nation's waters is a priority under the current ocean policy to enhance navigation and development of the blue economy. Furthermore, in 2019, a Presidential Memorandum on "Ocean Mapping of the United States Exclusive Economic Zone (EEZ) and the Shoreline and Nearshore of Alaska" set forth a strategy for mapping, exploring, and characterizing the EEZ through enhanced collaboration. The American Samoa Ocean Plan 2018 was an outcome of this executive order as the first spatial plan to be completed by the United States for its jurisdictions in the Pacific Ocean.

In 2009, President George W. Bush established the Rose Atoll Marine National Monument through Presidential Proclamation 8337. The proclamation banned commercial fishing within the monument, but does allow for limited subsistence and recreational fishing with a permit from NMFS. This proclamation also directed the Secretary of Commerce to initiate the process to add the marine areas of the monument to the Fagatele Bay National Marine Sanctuary. These areas were part of the sanctuary expansion in 2012 and provide an example of ocean policy contributing towards conservation and stewardship.

Pressures on Sanctuary Resources

Human activities and natural processes both affect the condition of natural, cultural, and maritime heritage resources in national marine sanctuaries. The following section discusses the nature and extent of the most prominent human influences upon NMSAS, including impacts from accelerated climate change, fishing, pollution, marine debris, vessel groundings, visitor use, scientific and management activities, and nuisance species outbreaks.

Accelerated climate change and ocean acidification

Rising ocean temperatures associated with climate change were recognized as a pressure on coral reef ecosystems in Fagatele Bay in the 2007 condition report (ONMS 2007). Ocean temperatures have continued to increase, but we now recognize that ocean acidification and stratification, increasing storm intensity, and rising sea levels may affect marine ecosystems across the entire sanctuary. Pacific Islands are among the most vulnerable areas in the world to the predicted effects of climate change (Mimura et al., 2007, Howes et al., 2018).

Since the 1970s, sea surface temperatures in the Pacific Islands region have been increasing and are projected to continue increasing over the next century (Howes et al., 2018; NOAA CRW, 2020; Keener et al. 2021; Figure DP.2). Elevated water temperature is a well-known trigger for coral bleaching, a phenomenon where corals lose their colorful symbiotic algae, revealing their white skeleton and making them look “bleached.” Bleaching can be caused by a short-term exposure (1-2 days) to temperature elevations of 3 to 4 ^{o}C above ambient conditions, or by long-term exposure (weeks) to elevations of only 1 to 2 ^{o}C. Depending on the severity of bleaching, the symbiotic algae may repopulate and corals can survive. However, when high temperature stress occurs over extended periods, corals suffer high mortalities, as observed during several mass bleaching events throughout the tropics (Glynn, 1984; Eakin et al., 2010; Eakin et al., 2019; Skirving et al., 2019). In American Samoa, mass mortalities of staghorn corals were documented in the airport pools on Tutuila during the 2015 bleaching event (DMWR unpublished data, Catlin XL Seaview Survey). Since 2005, bleaching in American Samoa has been documented in shallow backreef pools nearly every summer (DMWR unpublished data), but until 2015 it had only caused minimal mortalities (D. Fenner pers. comm.) Widespread bleaching events were documented in 2015, 2016, 2017, and again in 2020 (CRAG, ESD).

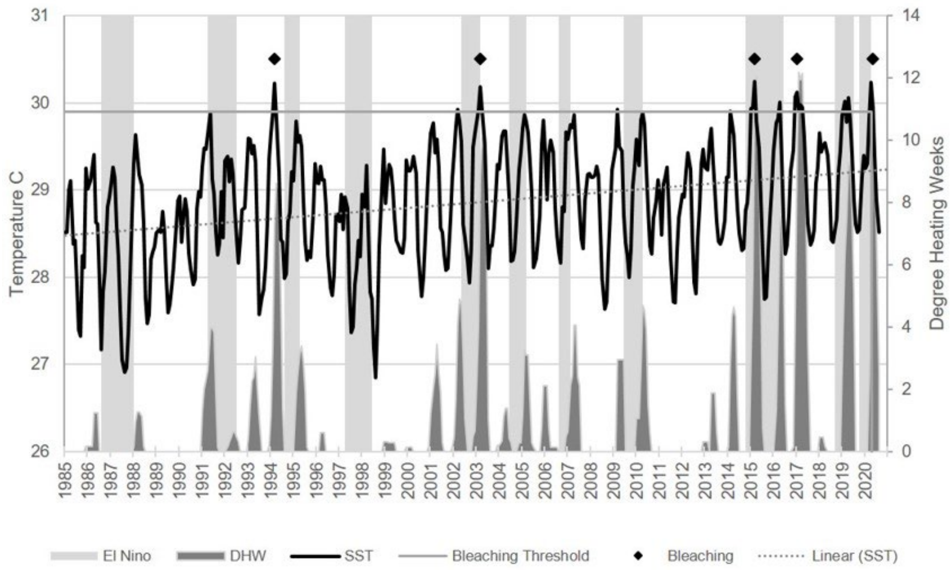

Figure DP.2. Sea surface temperature and degree heating weeks (the number of weeks the temperature remains above the bleaching threshold) from 1985-2020. Widespread bleaching events are noted by black diamonds (NOAA CRW 2020, NOAA PSL 2015). The 2016 bleaching event was limited to Swains Island and was not added to this figure.

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Disease epizootics are also predicted to increase with climate warming (Harvell et al., 2002) and many coral diseases have been linked to increasing ocean temperatures (Randall & Van Woesik 2015; Howells et al., 2020; Aeby et al., 2020). Even on a small scale, disease can alter community structure, reduce reproductive output, and decrease coral cover (Hughes 1994; Kim & Harvell 2004). Several diseases of corals and CCA have been documented in the sanctuary. Coralline lethal orange disease (CLOD), a bacterial infection that affects CCA (Littler & Littler 1995), was found to be more prevalent in Fagatele Bay than in other sites examined around Tutuila (Aeby et al., 2008; Vargas-Angel 2019). A black fungal infection affecting CCA has also been reported in American Samoa (Littler & Littler 1998). White syndrome, a general term used to describe coral disease lesions characterized by rapid tissue loss and a distinct lesion boundary between apparently healthy tissue and exposed white skeleton (Sussman et al., 2008), is one of the most common coral diseases around Tutuila (Aeby et al., 2008). This disease can be very virulent and can result in acute tissue loss (Roff et al., 2011). *Acropora* table corals in American Samoa can display growth anomalies (Hyperplasia), with distorted, tumor-like growths on the surface of the coral (Work et al., 2008a). This disease affects numerous table corals in Fagatele Bay. A cyanobacterial disease has been reported in the Ofu Pools, Manu'a Islands, since 2019, but appears to be slow, and temperature influenced (CRAG, pers. comm.).

Corals and other calcifying organisms, including certain types of phytoplankton, crustaceans, mollusks, echinoderms, and other taxa, are threatened by ocean acidification, which results in a reduction of the pH of ocean water due to uptake of increased atmospheric carbon dioxide (Caldeira & Wickett 2003, Figure DP.3). Acidified waters compromise carbonate accretion and therefore, directly affect the ability of these organisms to secrete their calcareous skeletal structures (Orr et al., 2005; Fabry et al., 2008). Directly linked to this is aragonite saturation. Carbonate accretion (i.e. coral calcification) declines at aragonite saturation values below 3.3 (Hoegh-Guldberg et al., 2007). In 2018, NMFS PIFSC ESD reported near-optimum aragonite saturation states across the American Samoa archipelago (Vargas-Angel et al., 2019). However, ocean acidification scenarios predict detrimental conditions for calcifying organisms that could lead to widespread changes of marine ecosystems (Orr et al., 2005; Hoegh-Guldberg et al., 2007; Fabry et al., 2008). Ocean acidification does not just affect calcifying organisms. Lowered pH may alter the behavior of larval fish and invertebrates, influence settlement success due to changes in suitable settlement substrate, and alter larval development or larval energy budgets (Espinel-Velasco, 2018).

Figure DP.3. Time series of staghorn corals in the airport pool on Tutuila. Photos: XL Catlin Seaview Survey

Rising temperatures are also shifting oceanographic processes that control ocean currents and mixing at both local and global scales. One potential impact is water column stratification. As surface temperatures increase and the ocean absorbs more heat energy, the upper layers warm more quickly and create sheets of warm water that reduce mixing between layers and block cycling of oxygen, carbon, nutrients, and heat within the water column. Stratification globally has increased by 5.3% since 1960 (Li et al. 2020). Most of the increase (~71%) occurred in the upper 200 m of the ocean. This was largely influenced by temperature changes (>90%).

Salinity changes may play an important role at a local scale. Ocean regions are connected by large thermohaline currents that transfer oxygen and nutrients from the poles towards the equator. American Samoa lies within the Pacific meridional overturning circulation (PMOC).

North of American Samoa, the geological feature known as the Samoan Passage is an important conduit and mixing zone for these currents that move from Antarctica to the North Pacific (Roemmich et al., 1996; Voet et al., 2015). Recent studies have indicated that the PMOC is changing both in strength and temperature as surplus heat associated with climate change is reaching the deep ocean. Voet et al. (2016) assessed the abyssal flow through the Samoan Passage in 2012-2013. The data indicated a slightly weakened volume transport by about 0.6 Sv, or 10%, and a significant warming of 10-3 C/yr over the past two decades. This is consistent with numerical simulations that demonstrate the possibility of a slowing meridional overturning circulation due to climate change impacts (Schmittner et al., 2005). It is unknown if this shift is already affecting deep-sea communities, but it could have significant implications for deep-sea habitats throughout NMSAS and the broader region in the coming years.

American Samoa is susceptible to tropical cyclones during the austral (southern) summer from November to April. In 1990, 1991, 2004, 2005, and 2018 cyclones caused damage to coral reefs in American Samoa (Figure DP.4). Impacts included large amounts of coral rubble and redistributed sediments in shallow water in affected areas. With climate change, storms are predicted to decrease in frequency, but increase in intensity (Howes et al., 2018; Knutson et al., 2020, Keener et al., 2021), providing an additional challenge to maintaining high coral cover in the future. In addition, rainfall is expected to increase by up to 10%, particularly during episodic heavy rain events such as cyclones and monsoons (ONMS, 2020). These processes are influenced by a number of factors including the ENSO and other complex ocean-atmospheric interactions, so it is difficult to determine if these have been affected by climate change. Fifty-three tropical cyclones have passed within 200 nm of Tutuila since 1959 (NOAA Digital Coast, 2020).

While only a few tangible heritage properties have been located within sanctuary boundaries, intangible heritage resources including practices, traditions, belief systems, and Samoan knowledge related to the marine environment exist within the sanctuary. These practices are threatened by climate change impacts including ocean acidification, sea level rise, increased water temperatures, and increased storm frequency and intensity. Culturally valued species (e.g. corals, fish, and invertebrates) threatened by changing environmental conditions may negatively impact community valuation of offshore areas and the local environment, while increased storm activity has the potential to limit everyday human on-water activities such as boating, fishing, or gathering.

Cultural heritage and sense of place are intertwined; social roles and customs rely on strong attachments to specific locations. Climate change threatens these attachments in many ways including direct destruction of coastal sites, weakening of social bonds as people relocate to avoid climate impacts, and loss of traditions as coastal access and resources change (Peau et al. 2021). The fautasi race held on flag day in April, for example, may be threatened by increased storm activity during the cyclone season, resulting in an altered race or change to the racing season. Novel weather patterns and altered seasonality as a whole present similar concerns as they may alter or limit pre-existing practices such as the timing of cultural events, such as akule fishing or the palolo harvest, or the ability to apply traditional knowledge and skillsets to localized resource management (McMillen 2014). Further identification and documentation of intangible heritage resources will provide a better understanding of the impact of climate change to these resources.

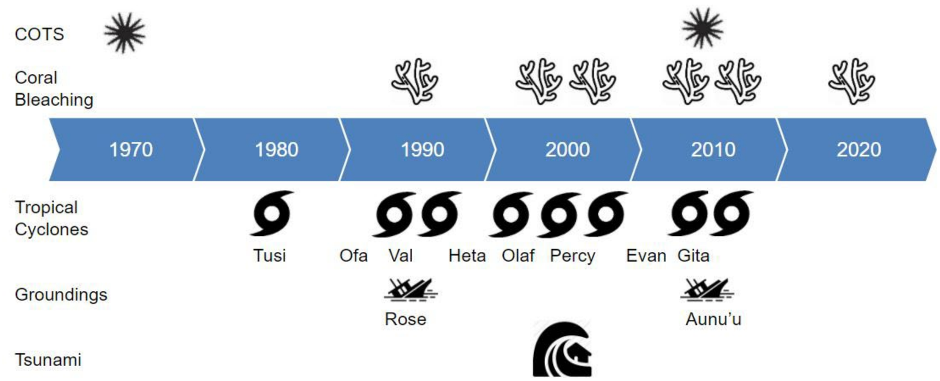

Figure DP.4. Timeline of major disturbance events in American Samoa from 1970-2020.

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Fishing

Worldwide, there is heavy pressure on fish assemblages from fishery activities, and assessments have demonstrated declines in reef fish abundance across the Pacific Islands (Kaylyn, et al. 2018). These results suggest that the current level of harvest of reef fish and invertebrates is unsustainable in many locations (SPC, 2013). Assessment of the US Pacific islands indicated that reefs in American Samoa had only a quarter of the fish biomass seen in remote areas (Williams et al., 2011) and that reef fish populations in all islands except for Swains are well below the biological potential for these systems (Williams et al., 2015). Destructive fishing methods, including explosives, bleach and cyanide, that affect corals and non-target species are also a concern. Fishing with explosives has occurred in Fagatele Bay as recently as 2004 (NMSP 2007). Although there has been no recent evidence of this practice, the damage to the reef structure is still visible. Anchoring boats within fishing areas can also cause mechanical damage to reefs. Evidence of anchor damage, in the form of numerous flipped tabletop corals, was found on towboard surveys along the SW Aunu'u bank and Nafanua bank in 2014 (J. Paulin, pers. comm.). Anchor damage and two illegal moorings have also been found in Fagatele Bay (J. Paulin, pers. comm.).

A 2019 assessment of the Bottomfish Management Unit Species complex in American Samoa determined that the area is in an overfished state (Langseth et al. et al 2019). This includes shallow coral reef fish species such as bluestripe snapper (*Lutjanus kasmira),* green jobfish

(Aprion virescens), yellow-edged lyretail *(Variola louti),* black jack *(Caranx lugubris),* and spotcheek emperor *(Lethrinus rubrioperculatus),* as well as deeper species including deepwater snappers (*Etelis coruscans* and *E. carbunculus)*. Pelagic resources appear to be more resilient to fishing pressure, but it is unclear how climate change may affect pelagic species distributions across the region (SPC, 2013).

Fishing is prohibited in Fagatele Bay, and limited in Aunu'u Zone B and Muliāva, however, direct observation and enforcement of fishing activity in these areas is difficult. Fishing may quickly reduce the population of commercial reef fish species in constrained bays like Fagatele Bay and remote sites like Rose Atoll with limited fish recruitment. Several large species of reef fishes, characteristic of unfished reefs in the Indo-Pacific region, are conspicuously absent or are small in size in Fagatele Bay, and found in lower abundance at Rose Atoll than oceanographic and habitat conditions would predict (Williams et al., 2015). These include species such as humphead wrasse (*Cheilinus undulatus*), sharks, and large species of grouper and parrotfish, all of which are known to be particularly vulnerable to fishing pressure.

Coastal Development & Nearshore Construction

Due to the island's small size, all terrestrial areas within American Samoa are considered "coastal." Development can significantly affect coastal habitats because of the small watershed size and short distances from ridge to reef. On Tutuila, developed areas increased by 5.8% from 2004–2010, despite a decline in population during this period (OCM, 2021). Additional development has taken place since 2010, but has not been quantified. Due to rising sea levels, many coastal areas have been armored with seawalls to protect valuable infrastructure and homes. In some areas, coastal protection structures have resulted in the loss of coastal and marine habitat, including benthic organisms, and ecological function associated with these habitats. This may in turn reduce larval connectivity through habitat fragmentation and the loss of brood stock (Hughes et al., 2005). Coastal armoring also disrupts the movement of sand and beach development which may affect both terrestrial and marine resources. The continued development and coastal armoring have reduced nesting habitat for sea turtles in Tutuila and Manu'a and may impair the recovery of sea turtles in the region (Tuato'o-Bartley et al., 1993; Saili, 2005). Based on data collected from 2007–2013, Seminoff et al. (2015) estimated that 105 female green sea turtles nest at Rose Atoll, 23 at Swains Island, but only three in Tutuila. As of 2020, the only new development directly adjacent to NMSAS waters is a small seawall built on the south side of Aunu'u. It was built by the village from available debris following storm waves that inundated the Aunu'u power plant in 2019.

Agriculture in American Samoa is still largely at subsistence scale with mostly traditional staple food crops, chickens, and pigs. With shifting land use patterns, American Samoa is likely to experience increased agricultural development, including the land surrounding sanctuary management areas. Such development may threaten water quality, habitat integrity, and the biological health of the reefs, particularly if fertilizer and pesticide use increase and erosion are not controlled. Heavy sedimentation is currently not a problem in the sanctuary management areas, but this could change with increasing coastal development and agricultural demand.

Non-point source pollution

Land-based sources of pollution, including nutrients, sedimentation, and chemical contaminants, are major threats to coral reefs worldwide and can promote algae growth, cause stress to corals, and increase the likelihood of disease and bleaching (Vega-Thurber et al., 2014). Pollutants can be an issue in American Samoa, primarily in areas adjacent to populated coastal areas and industries (Houk et al., 2005). All sanctuary management areas in American Samoa are remote and not near highly populated coastal areas. However, pollutants could drift into the Sanctuary and affect the condition of sanctuary resources.

Human sewage/cesspool outflows, runoff of agricultural fertilizers, and animal waste can increase nutrient loads in nearshore waters, primarily nitrogen and phosphorus. Nutrient inputs from surface run-off and submarine groundwater discharge contribute to eutrophication and algal blooms, which can hinder coral growth or recovery following disturbance (D'Angelo & Wiedenmann, 2014). Nutrients are also implicated in promoting crown-of-thorns sea star outbreaks (Brodie et al., 2005; Fabricius et al., 2010). Available data indicate that nutrient levels in sanctuary units are below recommended thresholds, but in Fagatele Bay there is evidence nutrient input may be increasing, likely due to the landfill and increased agriculture in the surrounding watershed.

The Fagatele Bay and Fagalua/Fogāma'a sanctuary management areas lie within one mile of the main landfill for the island of Tutuila. Although separated from Fagatele Bay by the high ridge that surrounds the bay, the Futiga landfill is unlined and contaminants such as heavy metals, petrochemicals, and pharmaceuticals may leach into groundwater that flows into the bay through ocean seeps. Heavy metals, hydrocarbons, pesticides, and pharmaceuticals were detected in low levels in water and sediment in Fagatele Bay in 2019 (NCCOS in prep). Aunu'u and Ta'u Island have their own landfills, but these are smaller.

Point source pollution

Point source pollution originates from single identifiable sources from which pollutants are discharged, such as a stream mouth. The sanctuary units are far from major point source pollution sources, including the large sewage and cannery outfalls on Tutuila, but there are small point source pollution sources in the Aunu'u and Muliāva units. For instance, the sewage outfall in Aunu'u discharges in shallow waters just outside the reef margin and may be a source of contamination, but the chemical composition of the effluent is unknown and no testing has been conducted. The discharge zone is highly mixed and accumulation is unlikely. In Muliāva, there may be waste, ballast, and bilge discharges from ships transiting in or near the area.

Marine debris

Trash in its many forms has long been a problem on the shorelines and coastal waters of American Samoa, especially plastic trash, which persists and accumulates in the environment. Another problem is derelict fishing gear, which snags on reefs and can entangle marine mammals and turtles. Marine debris has a comparatively lower presence underwater in the sanctuary, but it does accumulate on adjacent shorelines in some locations. The Fagalua/Fogama'a unit has persistent accumulation of both ocean and shore based debris, including abandoned fishing gear and discarded trash left by visitors. Recent deep sea exploration cruises noted significant accumulations of marine debris in the deep-sea near Tutuila, but presence was low in sanctuary units (Amon, 2020). When plastic debris breaks down as microplastics in the marine environment, the potential environmental impact has become a growing concern worldwide (Cole et al., 2011; Wright et al., 2013; Huang et al., 2021). It is currently unknown to what extent microplastics are a concern in American Samoa and if food-fish are negatively impacted through trophic accumulation.

Vessel groundings

Ship groundings on coral reefs can cause extensive physical damage to the reef structure and can release toxic petrochemicals along with harmful cargo, killing reef organisms. Any wreckage left on the reef can continue to cause physical damage and may release iron into nearby waters. Iron inputs are thought to be especially damaging on atolls, because unlike high volcanic islands, these systems do not have natural inputs of iron. Iron can contribute to blooms of cyanobacteria on the already damaged reef, preventing recovery of corals and other reef organisms, turning them into “black reefs” (Kelly et al., 2012). Other unanticipated consequences can occur, such as the corallimorph outbreak on Palmyra Atoll following a ship grounding in 1991 (Work et al., 2008b).

On Rose Atoll, the grounding of a 135-foot Taiwanese long-line tuna-fishing vessel in October 1993 released diesel lube oil into refuge waters. Prevailing currents carried these contaminants across the reef flat and into the lagoon, killing invertebrates and algae. The grounding itself physically damaged the reef when the ship hit the upper portion of the outer reef slope and moved across the reef before coming to rest (Green et al., 1997). Extensive removal efforts were undertaken over many years by USFWS, but some iron debris remains. Subsequent monitoring and assessment studies indicate that the reef has suffered ongoing injury from iron being released from the decaying ship debris (Schroeder et al., 2008). In April 2016, the 62 ft. F/V *No.1 JiHyun* lost its main engines and grounded off the west side of Aunu'u Island in the Multiple Use Zone. This area is of ecological and cultural significance for the local residents. using hook-and-line, casting nets, spearfishing (non-scuba assisted) and other non-destructive fishing methods, including those traditionally used for sustenance and cultural purposes, such as gleaning. After a number of unsuccessful attempts the vessel was removed in August 2016. The grounding impaired 1,641 m^2 of reef habitat, leaving a large rubble field with low complexity and rugosity that has not recovered (Symons et al., 2017).

Visitation

There is relatively little tourism in American Samoa and it is likely to be some years before the territory enters the mainstream of South Pacific tourism. Due to the remote location of the sanctuary management areas, even on the main island of Tutuila, visitation numbers are low compared to other South Pacific island destinations. For example, in 2017, 5,579 tourists arrived in American Samoa (American Samoa Statistical Yearbook, 2017) compared with 869,000 and 199,000 total visitor arrivals in Fiji and Papua New Guinea, respectively (Cheer et al., 2018). Access to Fagatele is limited, as the adjacent land is privately owned and requires a small fee for access, but it is visited by eco-tours associated with cruise ship visits. The beach at Fogāma'a is becoming more popular with local residents and visitors and is used for both day access and overnight camping. However, visitor numbers remain fairly low (< 20 people on busy days). The Aunu'u and Ta'u units are used by local residents, but are not currently significant tourist destinations. There are no maintained trails to reach the Ta'u unit, so access by land is limited. Swains Island and Rose Atoll are occasionally visited by researchers but are not accessible for tourists.

There are few locally owned pleasure or charter boats. Local alia and sportfishing boats visit the Fagalua/Fogama'a, Aunu'u Multiple Use Zone, and Ta'u units to engage in fishing activities, including bottom fishing and spearfishing. Sportfishing for pelagic tuna, masimasi and marlin is popular, and occasional fishing tournaments are held. The Aunu'u and Ta'u units are visited for pelagic fishing but most pelagic fishing activity takes place in offshore waters outside sanctuary management areas. There are currently two commercial SCUBA diving operations in the territory, but recreational diving is infrequent due to lack of demand. Yachts occasionally enter Pago Pago Harbor to buy provisions and find shelter during the cyclone season and may visit the sanctuary units, but the sanctuary's anchoring prohibitions and lack of mooring buoys make this difficult for yacht operators.

Potential impacts to sanctuary management areas due to visitation include unregulated fishing, illegal collection of invertebrates, and damage to the reef from boat anchors and walking on the reef flat.

Nuisance Species Outbreaks

American Samoa has not identified any significant marine invasive species threats, but there are a number of species that experience outbreaks that are detrimental to ecosystem health. These include the crown-of-thorns sea stars (CoTS), (*Acanthaster cf. solaris; alamea* in the Samoan language), a tunicate (*Diplosoma similis*), and a green bubble algae (*V. fasciculata*)

The most serious of these is CoTS, which are coral-eating echinoderms whose populations periodically increase to outbreak levels and cause widespread coral mortality. The starfish eat the soft tissues of corals, often killing the coral colony, and each CoTS consumes 5 to 13 sq. m of coral each year (Dixon, 1996).

CoTS are a natural component of Indo-Pacific coral reef ecosystems. Under normal conditions, CoTS prefer fast growing coral species (e.g. *Acropora* and *Montipora*) and open up space for slower growing coral species (e.g. *Porites*) to recruit. As long as other aspects of the ecosystem are intact such as the prevalence of CoTS predators, and disturbances are infrequent, CoTS outbreaks are relatively rare. Consequently, new coral recruitment and growth will replace the damage caused by the sea star.

At outbreak levels, however, these animals can have severe impacts on reef ecosystems. In the late 1970's, a major outbreak of CoTS around Tutuila destroyed 80 to 90 percent of corals in Fagatele Bay (Birkeland et al., 1987). This massive amount of destruction in one of the most pristine and coral-rich bays in American Samoa propelled the designation of Fagatele Bay as a national marine sanctuary, which would promote the future protection of this special place. More recently, another CoTS outbreak in 2014-2017 threatened corals around the island of Tutuila.

There is increasing evidence that overfishing of CoTS natural predators and eutrophication associated with land based sources of pollution contributes to the increased frequency of outbreaks throughout the Pacific (Brodie et al., 2005; Fabricius et al., 2010; Cowan et al., 2017 & 2020). Management agencies across the Pacific, including NMSAS and NPSA, are increasingly taking direct action, such as physical removal or injections, to reduce problematic populations of CoTS.

In 2008, a tunicate (*Diplosoma similis*) was observed overgrowing live coral and benthic substrate along the north-northwest side of Swains Island (Vargas-Angel et al., 2009). This raised concern about a potential shift in the reef habitat, but the outbreak subsided by 2010. More recently, CRAG and NPSA have been following an outbreak of a green bubble algae (*Valonia fastigiata*) in the Ofu pools. This algae has spread from a small patch to an extensive area and is now overgrowing corals in the area. No outbreaks have been reported in NMSAS. Corallivorous snails (*Drupella* and *Coralliophila*) can also form smaller outbreaks and impact corals (Cumming, 2009; Hamman, 2018). Managers are concerned that shifts in land based sources of pollution and changes in ocean conditions related to climate change may increase outbreaks or introduce invasive species.

Research Activities

The sanctuary science program is growing and research is encouraged within the sanctuary units. Projects often require the installation of scientific instruments, markers, or buoys. This has included the placement of two oceanographic buoys (the Moored Autonomous Partial Pressure of Carbon Dioxide [MAPCO2] buoy in Fagatele Bay, and the wave buoy in the Aunu'u Research Zone), a climate station in Fagatele Bay with oceanographic instruments and settlement structures, an ecological acoustic recorder in Fagatele, monitoring markers, and contaminant and sediment monitoring devices. NMSAS evaluated the value of each project and worked with the researchers to minimize impacts to sanctuary resources. Although there is a potential for impacts, no significant damage has been observed from research activities.

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State of Sanctuary Resources

This section provides summaries of resource status and trends within four areas: water quality, habitat, living resources, and maritime heritage resources. Virtual workshops were convened with subject matter experts from August to November, 2020 to discuss and evaluate the series of questions about each resource area. It is important to note that, in general, the assessments of the status and trends in NMSAS are for the period from 2007–2020. However, in some cases, data series extend into 2021. Answers for each question are supported by data and the rationale is provided at the end of each section for each resource area. Where published or additional information exists, the reader is provided with appropriate references and web links. Workshop discussions and ratings were based on data available at the time (e.g., through 2020). However, in some instances, sanctuary staff later incorporated newly available data in order to more accurately describe the current status and trends of resources. Situations where data were used by sanctuary staff to support a rating, but were not presented or discussed during the workshop, are noted in the text. More information about the questions can be found in Appendix A and additional information about the methods to complete the assessments can be found in Appendix D.

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Water Quality (Questions 1 – 5)

The following information provides an assessment of the status and trends of water quality indicators in NMSAS for the period of 2007–2020.

Question 1 focuses on eutrophication and its impacts on Sanctuary resources. Eutrophication is usually caused by an excess amount of nutrients (primarily nitrogen and phosphorus) entering the ocean and leading to an increase in the growth of algae, including microalgae (phytoplankton), macroalgae (seaweed), and filamentous algae (turf).

Question 2 focuses on parameters affecting public health. Human health concerns can arise from water, beach, and/or seafood contamination (bacteria or chemical).

Question 3 focuses on shifts in water quality due to climate drivers. Climate indicators include water temperature, ocean acidification and calcification rates, and sea level rise. Increases in water temperature cause coral bleaching and increased susceptibility to disease. Acidification can affect organism survival, growth, and reproduction. Sea level rise causes increased erosion.

Question 4 assesses other biotic and abiotic stressors, individually or in combination, that may influence sanctuary water quality, but were not addressed in the above questions, such as turbidity and iron pollution from ship groundings.

Human activities that adversely impact water quality are the focus of Question 5. These include terrestrial point source discharges, commercial and recreational vessel-based activities and coastal development.

Question 1: What is the eutrophic condition of sanctuary waters and how is it changing?

Status*: Good, Confidence - Medium;* ***Trend****: Not Changing, Confidence - Medium*

Status Description: *Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.*

Rationale: *Data on eutrophication are limited, but available data suggest that nitrogen, phosphorus, and chlorophyll a (Chl-a) concentrations remain below recommended threshold levels in sanctuary waters. However, dissolved inorganic nitrogen (DIN) may be increasing in Fagatele Bay based on the most recent data. Macroalgae cover was evaluated as a proxy for* *nutrients and has been variable over the reporting period, but remains low overall within sanctuary units.*

Question 1 Indicator Table. Summaries for the key indicators related to eutrophication that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Nutrients	Nearshore Habitats	Comeros-Raynal et al., 2017, 2019; NCCOS study 2019; Comeros-Raynal et al 2021;; Shuler and Comeros-Raynal, 2020; CRED, 2010	Sampling has been limited, but all samples taken during the reporting period met EPA's water quality standard levels ("median not to exceed".) In 2019, DIN in a set of water samples from Fagatele approached the recommended maximum threshold value, though previous samples indicated much lower levels. Recent modeling suggests that Fagatele and Fagalua/Fogama'a should have low nutrient loading. The other units were last sampled in 2010.
	Pelagic		No nutrient data were available for pelagic waters.
	MCE		No nutrient data were available for MCE.
Chl-a	Nearshore Habitats	PMEL /PacIOOS; CRED, 2010	Automated sampling of Chl-a in Fagatele suggests that levels are variable, but consistently below recommended levels for open ocean waters. The other units were last sampled in 2010. Chl-a was low at all sites, but approached EPA water quality limits in Ta'u.
	Pelagic Habitats	NOAA STAR	Satellite data indicates that Chl-a levels are low across the territory, and there is low seasonal variation.
Macroalgae	Nearshore Habitats	MARC, 2020; Vargas-Angel et al., 2019	Local and federal monitoring programs have recorded low (<10%) macroalgae abundances across all sanctuary units throughout the reporting period..
	MCE	Bare et al., 2010	Benthic camera tows along the Tutuila Insular Shelf in 2002, 2004, and 2008 indicated that macroalgae is low in the upper and lower mesophotic zones, but higher (15-20%) in the 50-79m depth zone (Bare et al 2010).

Quantitative data on eutrophication within the sanctuary boundaries are limited. Data collection has been intermittent and focused on nearshore habitats, particularly streams, sandy shores, and coral reefs. Fagatele Bay is the exception, as its designation as a "pristine" watershed by the American Samoa Environmental Protection Agency made it an ideal control site for studies throughout the reporting period. Data for pelagic areas are limited to satellite derived datasets and no recent data are available for mesophotic and deep sea habitats.

Recent modeling efforts suggest that DIN nutrient loading in Fagatele Bay and Fogama'a/Fagalua units are likely low compared to other coastal areas in Tutuila (Shuler and Comeros-Raynal 2020). Fagatele Bay had the lowest nutrient concentration out of 28 watersheds sampled by Comeros-Raynal et al. (2017, 2019) throughout Tutuila. Fagalua/Fogama'a, Aunu'u, Ta'u, Rose Atoll, and Swains Island were not included in the analysis. Overall, nutrient levels were below the EPA water quality standard for embayments ("median not to exceed") but recent nutrient measurements in Fagatele were higher than previous studies, suggesting either fluctuating or increasing nutrient levels in the bay or perhaps other sources such as from submarine groundwater discharge (NCCOS study 2019, Comeros-Raynal et al. 2021) (Figure S.WQ.1.1). Experts noted that discharge from the landfill and agricultural activities in the nearby watershed may be influencing nutrient dynamics within both Fagatele Bay and Fagalua/Fogama'a units and recommended continued monitoring of nutrients in these units. The high proportion of nitrate in DIN measurements from Fagatele suggests these are possible sources of nitrogen enrichment. In 2010, NMFS collected and analyzed water samples from coral reef habitats around all of the islands in American Samoa (CRED 2010). The results indicated that phosphate, nitrate, nitrite, and total nitrogen across all islands of American Samoa are below EPA recommended levels for Open Ocean waters (Figure S.WQ.1.2). However, these samples were limited to one point in time and no recent data are available, therefore it is not possible to determine any trends in open water nutrient levels.

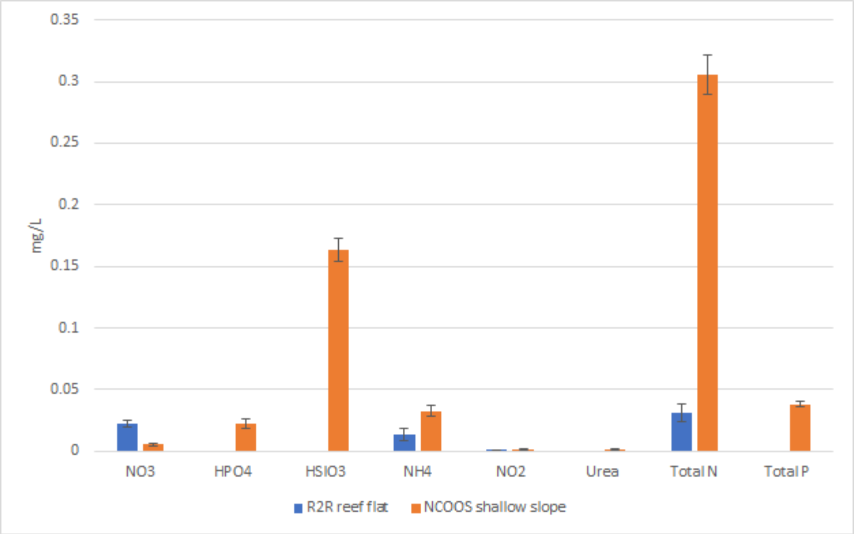

Figure S.WQ.1.1. Comparison of R2R (sampled in 2016) and NCCOS (sampled in 2019) nutrient data for Fagatele Bay (average +/- SE). R2R study did not evaluate HPO_4, $HSiO_3$, Urea, and total P. Source: NCCOS study 2019; Comeros-Raynal et al., 2021

Commented [1]: @kathy.broughton@noaa.gov Y axis title is incomplete. I would suggest something like "Average Concentration (mg/L)".

X axis title is missing. I would suggest something like "Type of Nutrient," "Nutrient," or something to that effect.

For x axis labels, please ensure chemical compounds are written with subscript numbers. I believe HSIO3 should also be HSiO3 if I am not mistaken...silicon rather than sulfur and iodine? Please have authors double check, will edit in caption to indicate suggested change.

Please spell out "R2R" acronym in legend, as this is not previously defined. NCCOS can stay since it will be defined and presumably used frequently, however it is misspelled in the legend.

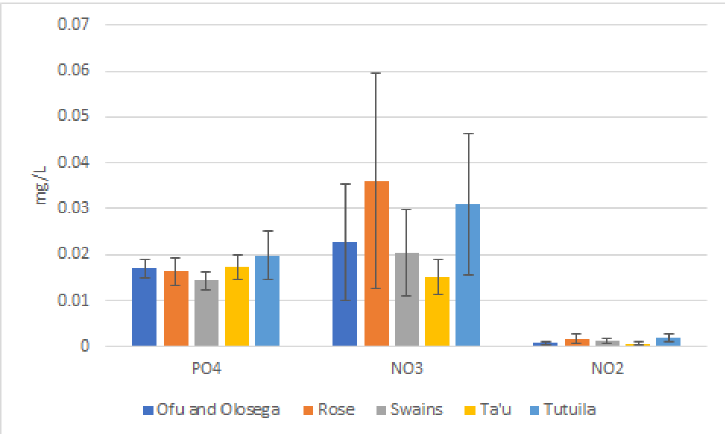

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Figure S.WQ.1.2. Nutrient data collected in 2010 around all islands in American Samoa. Data haves been converted to mg/L (average +/- SD) to compare with ASEPA standards. Source: CRED, 2010

Chlorophyll a is a useful indicator of eutrophication, as it measures the amount of primary production in the water column. Data on Chl-a concentrations in sanctuary units are sparse for most of the reporting period, so no trend data are available. Data from grab samples in 2010 and 2012 indicated that Chl-a levels were within the AS EPA water quality standards for open coastal waters (NOAA ESD?, ASEPA 2018; Figure S.WQ.1.3). Since May 2019, Chl-a has been measured consistently by a sensor on the MapCO2 buoy located in Fagatele Bay (PMEL 2020, PacIOOS 2020). The buoy has recorded low Chl-a levels throughout the year, with slightly higher values from October to May; however this data has not been verified and is insufficient to evaluate long term trends. No other in-situ data are available for any of the other sanctuary units. Satellite monitoring of the waters around American Samoa (NOAA STAR), indicates that Chl-a concentrations are generally low across the territory (<0.1mg/m2) with some slight seasonal fluctuations (Figure S.WQ.1.4). Based on these limited data, Chl-a levels do not indicate there is eutrophication in sanctuary units.

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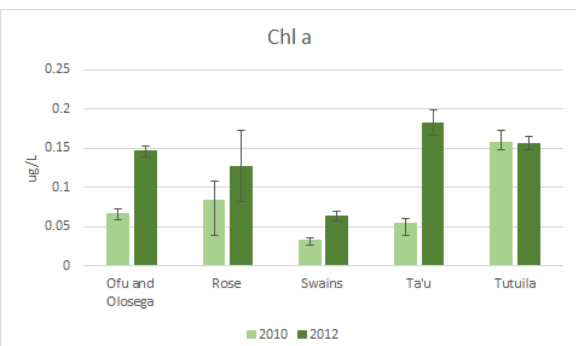

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I also recommend deleting the "Chl a" title for consistency with the graphs above. As a general heads up, I will probably also spell out "chlorophyll a" when I copy edit since it's not used that many times.

Figure S.WQ.1.3. Average Chl a values (+/- SE) from grab samples at all islands in American Samoa in 2010 and 2012. All values are below the AS water quality standard of 0.25 ug/L for open ocean coastal waters (ASEPA 2018). Source: NOAA ESD?.

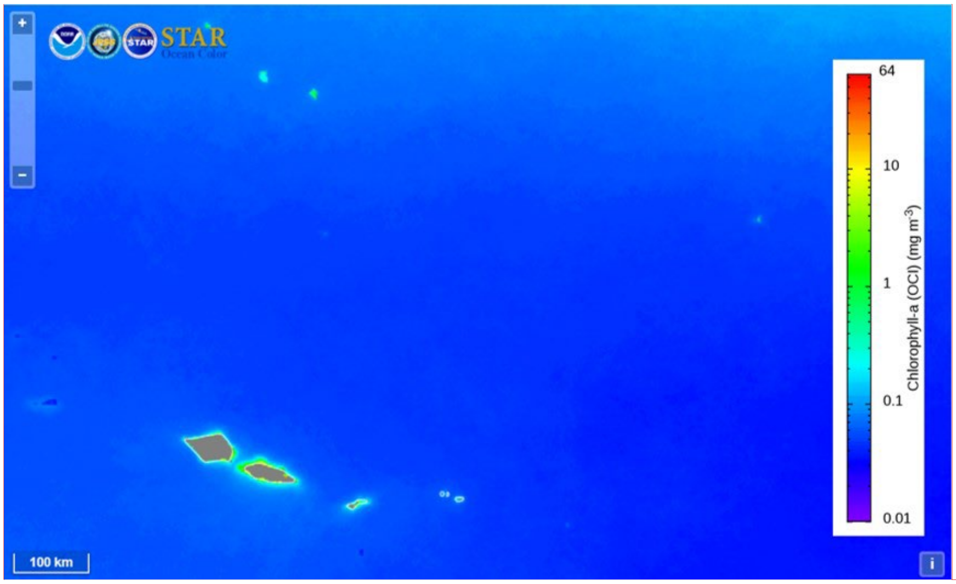

Figure S.WQ.1.4. NOAA STAR Ocean Color Science Team monitors Chl a concentrations using satellite derived datasets. The long term climatology indicates that Chl a concentrations are low in the waters surrounding the Samoan Archipelago with some enrichment around populated islands. Source: NOAA STAR 2022

Macroalgae are another indicator of eutrophication, as macroalgal cover tends to increase with nutrient inputs. Local and federal monitoring programs have recorded low macroalgae abundances across all sanctuary units throughout the reporting period (MARC 2020, Vargas-Angel et al 2019). There are some temporal fluctuations observed with a drop in cover in 2018 (Figure S.WQ.1.5.) but generally macroalgae cover has remained low throughout the years (averages <10%). Benthic camera tows along the Tutuila Insular Shelf in 2002, 2004, and 2008 indicated that macroalgae is low in the upper and lower mesophotic zones, but higher (15-20%) in the 50-79m depth zone (Bare et al 2010). However, there was considerable variation across sites and these surveys have not been repeated, so this may not reflect current mesophotic conditions in NMSAS.

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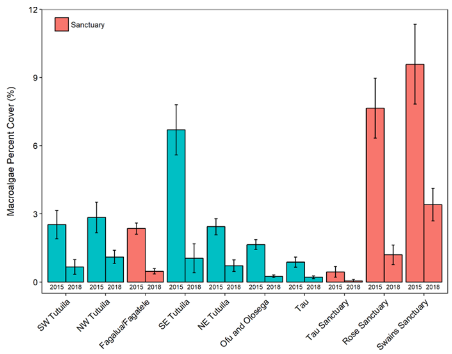

Figure S.WQ.1.5. Macroalgae cover in sanctuary units between 2015 and 2018. Source: Vargas-Ángel et al., 2019

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Conclusion

Quantitative data on eutrophication within the sanctuary boundaries are limited. Data for Fagatele Bay are more robust and indicate that nutrient levels are below recommended thresholds, but may be increasing, likely due to the landfill and increased agriculture in the surrounding watershed. Macroalgae cover remains low within shallow coral reef habitats, and satellite data for Chl-a indicate low concentrations throughout the sanctuary. Quantitative in-situ data are not available for pelagic, mesophotic and deep sea habitats and experts recommended more frequent and expanded sampling across the sanctuary units to address these gaps.

Question 1 Literature Cited

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Question 2: Do sanctuary waters pose risks to human health and how are they changing?

***Status**: Good, Confidence - Medium; **Trend**: Undetermined, Confidence - Medium*

***Status Description:** One or more water quality indicators suggest the potential for human health impacts, but human health impacts have not been reported.*

***Rationale:** There are currently no known human health risks from sanctuary waters, however, data are limited and no trend data are available. Contaminants were detected in Fagatele Bay, but only nickel concentrations exceeded toxicology screening levels. Coliform bacteria have been detected in Fagatele Bay and there is a sewage outfall in the Aunu'u Multipurpose Zone, but sanctuary units are not part of regular recreational water sampling efforts, so potential health impact is unknown. No ciguatera poisoning has been reported from fish caught in the sanctuary.*

Question 2 Indicator Table. Summaries for the key indicators related to sanctuary waters posing a risk to human health that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Heavy metals	Nearshore Habitats	NCCOS, in prep	In 2019, 16 metals (Ag, Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Se, Si, Sn, Zn) were measured in sediment samples from Fagatele Bay. Ag, As, Cd, Cr, Cu, Hg, Pb, Zn were detected, but were at levels below the Effects Range Low (ERL - a measure of possible toxicity to benthic infauna). Nickel was the only metal that exceeded ERL values at 3 out of 5 sites within the bay and exceeded the Effects Range Median (ERM) value at one site which may indicate probable toxicity to benthic infauna (Ni measurements = 69.6, 23.9, 24.1 ppm, ERL = 20.9 ppm; ERM = 51.6 ppm). The team noted that the concentration of As, Cr, Ni, and Se at some stations in Fagatele was higher than the mean values observed at Faga'alu (a more impacted watershed on Tutuila). ERL values are not available for some metals (Al, Fe, Mn, Sb, Se, Si, Sn), but all values from Fagatele Bay were below mean values previously measured in Faga'alu except for Se.
Chemical pollutants	Nearshore Habitats	NCCOS, in prep	In 2019, water samples were screened for over 400 compounds. Only a small number were detected and all were below published toxicity screening levels (i.e. LC50 - single exposure concentration that kills 50% of test animals). The compounds included PAHs, pesticides, other organic compounds, and pharmaceuticals. While these chemicals were found in low concentrations, there is some concern that some compounds may have sublethal effects (e.g. endocrine disruption) even at very low concentrations.
Coliform bacteria/*E. Coli*	Nearshore Habitats	NCCOS, in prep ASEPA	In 2019, NCCOS analyzed water collected at eight sites within Fagatele Bay and the inflowing stream for coliform bacteria and *E. coli* (NCCOS study 2019). All samples tested positive for coliform bacteria and over half the samples tested positive for *E. coli*, indicating that mammalian (e.g. bats, pigs, human) wastes are entering the waters. Raw sewage is discharged in the Aunu'u Multipurpose Zone, but no quantitative data were available on volume or bacteria in receiving waters. Recreational water quality at beaches near NMSAS units is generally good (ASEPA.)
Ciguatera	Nearshore Habitats	Clemes, 1997	Ciguatera poisoning has been reported from Tutuila (Clemes 1997) but is unclear if there have been recent cases. There is no available information on affected fish species or high risk locations in American Samoa.

Heavy metals, pesticides, bacteria, and harmful algae blooms can have detrimental impacts on human health through direct contact or bioaccumulation in organisms used for food. Some of these are linked to human activities through runoff, groundwater contamination, or sewer outfalls. Two known sources of potential contamination include the Futiga Sanitary Landfill located north of the Fagatele Bay and Fagalua/Fogama'a units and the sewage outfall on the western side of Aunu'u (see Human Dimensions section for more information). Incidents of ciguatera poisoning from *Gambierdiscus* blooms have been reported in American Samoa, but there is no clear link to human activities. As most of the sanctuary has been perceived as "pristine," quantitative data on these indicators within the sanctuary boundaries are very limited.

The Futiga Landfill has been used as a municipal waste disposal site since the 1960s. The landfill was recompacted in 2018 to extend its lifespan, but is nearing its capacity. The lack of a liner and leachate collection system has caused concern about potential contamination to adjacent waters. In 2019, NCCOS scientists tested the presence of contaminants in Fagatele

Bay. They collected sediment samples at eight sites across the bay to screen for the presence of heavy metals (Figure S.WQ.2.1). Values were compared to known toxicity ratings originally assembled by Long et al (1995). In total, 17 metals were detected, but only nickel was present in concentrations above the Effects Range Low value, indicating that it may be toxic to benthic infauna (Figure S.WQ.2.1). All values from Fagatele Bay were below values previously recorded from other sites in Tutuila (NCCOS study 2019).

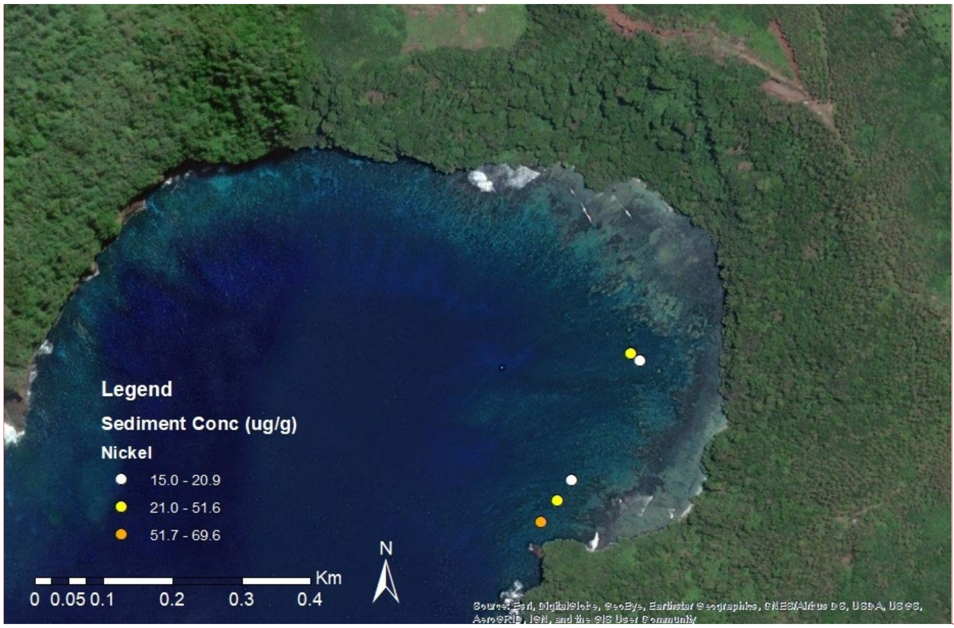

Figure S.WQ.2.1. The concentration of nickel in sediment samples taken from three sites in Fagatele Bay was above the ERL, indicating possible toxicity to benthic infauna. At one site (shown in orange), the concentration was above the ERM which may indicate probable toxicity to benthic infauna. Source: NCCOS, 2019

Commented [7]: @kathy.broughton@noaa.gov The yellow and orange colors are very difficult to distinguish with colorblindness filters. I recommend varying shapes as well as color (e.g., circle, square, triangle) or updating to colorblindness-friendly colors.

I recommend changing the legend to state "Concentration of nickel in sediment (ug/g)". Please also change "u" to "µ". The "k" in "Km" should also be lower case.

To detect pesticides, hydrocarbon derivatives (PAHs), and pharmaceutical compounds, the same study deployed CLAMs (Continuous Low-Level Aquatic Monitoring) at eight sites within the bay (Figure S.WQ.2.2). CLAMs are in-situ submersible field extraction units that are able to continuously sample by filtering the water at a known flow rate. Results indicate that the vast majority of the 400 tested compounds were not detectable. However, 30 organic compounds were detected. None of these exceeded the published LC50 values (where available), defined as the lethal concentration required to kill 50% of tested organisms. Of the compounds that were detected in Fagatele Bay, most were orders of magnitude below the LC50 values. However, LC50s are not available for nine of the detected PAHs and two of the detected organic compounds due to their water solubility or recent invention. While no immediate threats to human health were detected, there may be sublethal effects (e.g., endocrine disruption) from these compounds. The fact that pesticides, PAHs, and pharma compounds were detected in Fagatele Bay is concerning and should be further investigated (D. Whitall, pers. comm.).

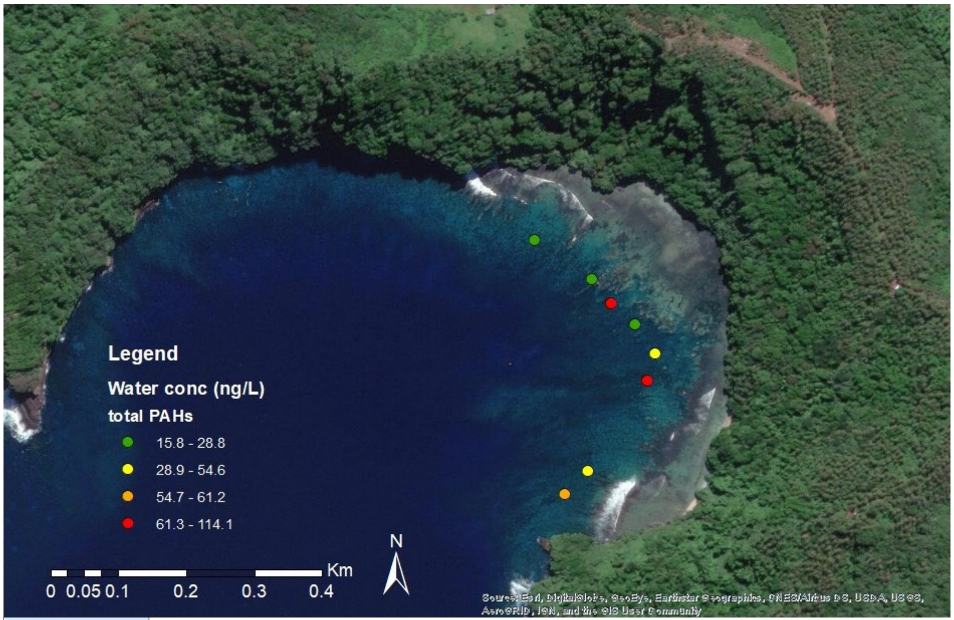

Figure S.WQ.2.2. In 2019, NCCOS collected water samples using Continuous Low-Level Aquatic Monitoring devices at 8 sites in Fagatele Bay to evaluate the concentration of contaminants in the water. Thirty organic compounds were detected in low quantities. Source: NCCOS, 2019

The American Samoa Environmental Protection Agency (ASEPA) monitors popular recreational beaches around Tutuila for the presence of enterococci bacteria which may indicate fecal contamination from animals or humans (ASEPA 2021ab, ASEPA 2018). However, none of their beach monitoring sites are within NMSAS boundaries. Monitoring sites in villages closest to the sanctuary (Leala-Taputimu Sliding Rock, Aunu'u Wharf, Ta'u Beach) generally have low incidence of advisories but do occasionally recommend no swimming (mostly for Leala-Taputimu) (ASEPA 2021ab, ASEPA 2018). The ASEPA integrated monitoring reports note that Fagatele-Larson watershed was listed as impaired and was assigned a "Not Supporting (fair)" status for aquatic life in ocean shoreline waters in 2014 for an undetermined nonpoint source stressor". Subsequent reports list the watershed as "Fully Supporting" (ASEPA 2021b). In 2019, NCCOS analyzed water sampled at around 10 feet depth at eight sites within Fagatele Bay and the inflowing stream for coliform bacteria and *E. coli* (NCCOS study 2019). All samples tested positive for coliform bacteria and over half of the samples tested positive for *E. coli*, indicating that mammalian (e.g., bats, pigs, human) wastes are entering the bay. However, this was a limited sampling effort and additional sampling is needed to evaluate whether this is a human health risk.

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Colors are very inaccessible, please vary symbols or change to colorblindness friendly palette.

Please change legend description to something like "Concentration of total PAHs in Water (ng/L)".

Please change "k" in "Km" to lower case.

Experts noted that a sewage outfall in the Aunu’u Multipurpose Zone, may be a potential source of contamination. The wastewater collection system for the village consists of a wet well with a grinder pump, which is discharged as untreated sewage through ocean outfall in shallow water on a fringing coral reef. It was constructed by the American Samoa Power Authority (ASPA) to protect shallow groundwater resources impacted by septic tanks and leach fields. Surveys conducted prior to 2007 indicate that the bacterial counts for the waters in the area around the sewage outfall meet American Samoa water quality standards for recreational beaches, although the location and depth of the outfall indicate a potential for unacceptable bacterial levels along these beaches. In 2007, the AS-EPA and U.S. EPA developed a wastewater facilities plan for the village and island of Aunu’u, but it was not implemented (AS-EPA 2007) due to other ASPA priorities.

Ciguatera poisoning is caused by eating reef fish that are contaminated with ciguatoxin, a chemical produced by a microorganism, the dinoflagellate *Gambierdiscus toxicus*, which grow on algae that are eaten by herbivorous fish and bioaccumulate in larger fish through the food web. Ciguatera poisoning rarely causes death, but symptoms can last for months. It has been reported from Tutuila (Clemes 1997) but there is limited data on the incidence of ciguatera in American Samoa and which species of fish or areas pose the greatest risk. No cases of ciguatera poisoning from fish caught in the sanctuary have been reported.

Conclusion

Contaminants have been detected in Fagatele Bay, which poses some concern, but levels are below documented thresholds for human health risks. Additional testing is necessary to determine if there is bacterial contamination of sanctuary waters, particularly Fagatele Bay, Fagalua / Fogama’a and Aunu’u, based on identified threats. Human contact with pelagic and remote areas is limited, but risks should be evaluated in the future.

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NCCOS study 2019

Question 3: Have recent, accelerated changes in climate altered water conditions and how are they changing?

***Status**: Fair, Confidence - High; **Trend**: Declining, Confidence - High*

***Status Description:** Climate-related changes have caused measurable, but not severe, degradation in some attributes of ecological integrity.*

***Rationale**: Increasing sea surface temperatures have caused more frequent and more severe coral bleaching events. Ocean acidification is affecting water quality worldwide, however, aragonite saturation state and calcification rates have remained high in sanctuary units.*

Question 3 Indicator Table. Summaries for the key indicators related to climate change that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Temperature	Nearshore Habitats	NOAA Coral Reef Watch, 2020; Vargas-Angel et al., 2019; CRAG unpub. data	Sea surface temperature has steadily increased over the past decades causing an increase in thermal stress events, including widespread coral bleaching (Coral Reef Watch). NMFS *in situ* data loggers confirmed that temperatures at 15m exceeded the bleaching threshold in 2015, 2016, and 2017 across all islands (Vargas-Angel et al. 2019). *In situ* temperatures exceeding 34°C were recorded on reef flats during the 2015- 2016 thermal stress event (CRAG unpub .data). In 2016, Swains Island experienced the greatest thermal anomalies with water temperatures of almost 31°C (NCRMP 2018, Vargas-Angel et al. 2019).
	Pelagic	PacIOOS, 2020	*In situ* pelagic water temperatures at the PacIOOS wave buoy off of Aunu'u showed similar trends to the satellite based sea surface temperature data.
	MCE, Deep sea	NOAA, OET	Temperature data from CTD casts and ROV instrumentation during cruises are available, but have not been analyzed for comparisons or trends.
OA Indicators (CO2, pH, aragonite saturation, calcification)	Nearshore Habitats	PMEL, 2020	The MAPCO2 buoy located in Fagatele Bay measured CO2 and pH every three hours starting in May 2019. The CO2 concentration and pH are highly variable due to natural diurnal fluxes in the semi-enclosed Fagatele Bay. Data have not been finalized by PMEL, but all pH measures are below the 8.1 global ocean average. ESD has recorded pH periodically during cruises since 2010, but the data are not robust enough to detect temporal trends. Values ranged from 8.02-8.08. ESD also noted that American Samoa has some of the highest aragonite saturation state values in the US Pacific Islands. Rose has the highest levels (3.91-4.35) with a slight decrease in values moving towards Tutuila (3.49-3.99). Fagatele and Fagalua/Fogama'a are lower, but this may be due to biological demand

			(ESD). Calcification rates are some of the highest measured in the Pacific and follow the same spatial pattern as aragonite (NCRMP 2018).
	Pelagic Habitats	NOAA GML, USEPA, WHOI	Atmospheric carbon dioxide concentration has continued to rise and measurements at the NOAA American Samoa Baseline Observatory reached 410 μmol/mol in 2020. WHOI compiled global data on changes in aragonite saturation from 1880-2015. The data indicate that aragonite saturation has declined by approximately 0.5-0.6 in American Samoa's pelagic areas during that time.
	MCE, Deep sea		No ocean acidification data were found for MCE or deep sea habitats.
Sea level rise	Nearshore Habitats	NOAA CO-OP, 2020; Han et al., 2019	Relative sea level increased 2.41 millimeters/year based on monthly mean sea level data from 1948 to 2009 (95% confidence interval of +/- 0.8 mm/yr). Since 2009, continued subsidence following the *Mw* 8.1 Samoa-Tonga earthquake doublet (megathrust + normal faulting) in September 2009 has effectively increased the rate of sea level rise in the Samoan Archipelago to 7-9 mm/yr, or approximately 5 times the global average. So far, relative sea level has increased by 25 cm (9 inches) since the earthquake and this trend is expected to continue for decades (Han et al 2019). It is unclear how much of the current sea level rise is due to climate change.
Cyclones	Nearshore Habitats	NOAA Digital Coast, 2020	53 tropical cyclones have passed within 200 nm of Tutuila since 1959. 69% of the strong cyclones passed through the area since 2000, which suggests a slight increase in storm intensity, but the sample size is too small for further analysis.
Rainfall	Nearshore Habitats	NOAA WSO Pago Pago	There is a slight increasing trend in rainfall, but totals are highly variable and are heavily influenced by ENSO and cyclone activity. 2020 set a record for annual rainfall with 191.68 inches recorded for the year. The previous record from 1981 (167.32 inches) was surpassed on November 11, 2020.
Currents	Nearshore Habitats, Pelagic Habitats, MCE, Deep sea	Kendall and Poti, 2011	A biogeographic assessment used drifter data from 2004-2009 to validate a hydrographic model for the region and investigate current patterns, but no newer analyses or comparisons are available to assess changes.
Stratification and Thermohaline Circulation	MCE, Deep sea	NOAA, OET	Temperature data from CTD casts and ROV instrumentation during cruises are available, but have not been analyzed for comparisons or trends. Experts did note that there appeared to be a lack of recruitment, but it is not clear if this is an emerging impact of changing conditions, or just a normal pattern in deep sea succession.

Climate change is a global pressure that is expected to increase sea surface and air temperatures, raise sea levels, make oceans more acidic, shift cyclone and rainfall patterns, and eventually impact oceanic currents, ocean stratification, and thermohaline circulation. The widespread effects of climate change are likely to affect all sanctuary waters from the surface to the deep sea, but shallow ecosystems, such as coral reefs, are expected to be the first affected.

Satellite-derived sea surface temperature (SST) data indicate a steady increase in SST across American Samoa over the last few decades (NOAA CRW 2020, Figure SS.WQ.3.1). Shallow coral reef habitats are particularly susceptible to rising temperatures as corals live very close to their upper thermal tolerances (Jokiel and Coles 1990). Temperature increases of just 1-2 ℃ persisting for several weeks can cause widespread bleaching in the coral community. As water temperatures have increased, so have the frequency and intensity of bleaching events (NOAA CRW 2020). Significant bleaching events were documented in 2015, 2017, and again in 2020 (CRAG, ESD). *In situ* temperature measurements indicate that the timing and magnitude of temperature patterns are similar across all of the islands. However, mean temperatures at Swains Island are 0.4°C higher in the summer (Dec-Mar) and 0.8°C higher in the winter (Jul-Oct) than the other islands and, in 2016, Swains Island experienced an unprecedented high water temperature of almost 31°C. Experts believe this was the cause of a staggering decline (>60%) in the number of *Pocillopora* coral colonies at Swains Island between 2015 and 2018 (Vargas-Ángel et al 2019, Figure SS.WQ.3.2). Detailed data on bleaching prevalence and associated mortality in sanctuary units were not collected during these events.

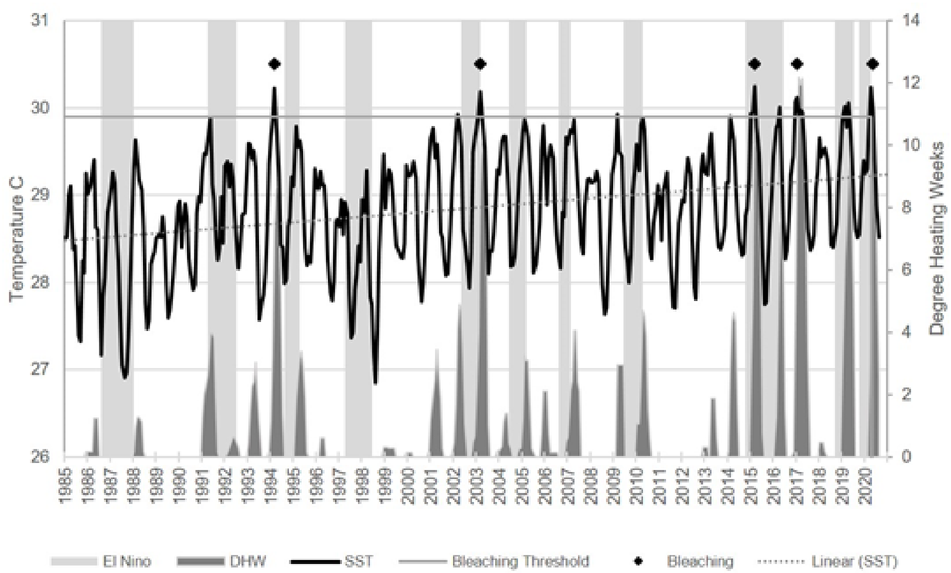

Figure SS.WQ.3.1. Sea surface temperature and degree heating weeks (the number of weeks the temperature remains above the bleaching threshold) from 1985-2020 from NOAA Coral Reef Watch. Widespread bleaching events are noted by black diamonds. The 2016 bleaching event was limited to Swains Island and was not added to this figure. Source: NOAA CRW 2020

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Figure SS.WQ.3.2. Healthy and thriving *Pocillopora* community at Swains island in 2013 (left) and widespread dead *Pocillopora* overgrown by CCA in 2017 (right), likely caused by the bleaching events in 2015-2016. PC: left Wendy Cover, NOAA; right Mareike Sudek, DMWR

Detailed water temperature data are limited to surface waters. It is not known if temperatures in mesophotic and deep sea habitats are also changing. While NOAA does collect temperature data throughout the water column during research cruises, they are limited in spatial and temporal scale and have not been analyzed.

Global sea level has also been rising over the past century, and the rate has increased in recent decades. In American Samoa, data from the NOAA Tide Gauge indicated that sea level was increasing by 2.41 millimeters/year up until 2009 (Figure SS.WQ.3.3). However, continued subsidence following the Mw 8.1 Samoa-Tonga earthquake doublet (megathrust + normal faulting) in September 2009 has effectively increased the rate of sea level rise in the Samoan Archipelago to 16 mm/yr, or approximately five times the global average. So far, relative sea level may have increased by 21 cm (8.4 inches) since the earthquake and this trend is expected to continue for decades (Han et al 2019). Consequences of this dramatic trend are increased coastal erosion and inundation, which has already led to widespread coastal armoring to protect important infrastructure. This armoring may negatively impact adjacent intertidal and coral reef habitats, as well as cause shifts in sediment dynamics, affecting natural beach replenishment. Coastal inundation has been most noticeable adjacent to the Aunu'u unit and the village started armoring the upper shoreline along the southwestern coastline in 2020.

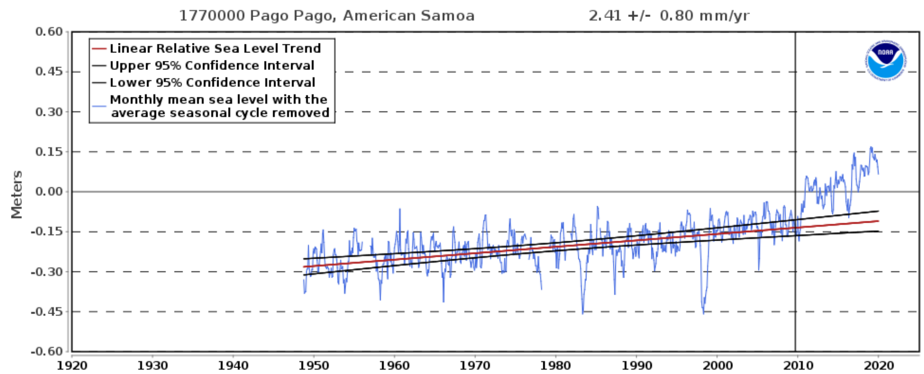

Figure SS.WQ.3.3. Sea level height in American Samoa from 1950-2020. The black bar denotes the 2009 earthquake and tsunami. Note that sea level rise accelerated after the 2009 event due to subsidence. Source: NOAA CO-OP 2020

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If possible, please change legend descriptions such that they are all sentence case rather than a mix of sentence case and title case.

Data from the NOAA Tula Observatory indicate that atmospheric carbon dioxide (CO2) has been increasing rapidly since 1975 and is now above 400ppm (NOAA 2020). Rising CO2 levels in the atmosphere result in increased CO2 absorption by the ocean, forming carbonic acid, which lowers the pH, a process known as ocean acidification (OA). Acidification is expected to decrease calcification rates in organisms such as corals and giant clams and may affect larval development for fish and other animals. The MAPCO2 buoy installed in Fagatele Bay in May 2019 measures pH and seawater CO2 concentration (PMEL 2020, PacIOOS 2020) and may provide more insight on these trends in the coming years. Initial data indicate that CO2 concentration and pH appear to be quite variable, likely due to biological processes and the longer residence time of water in the semi-enclosed bay. ESD has measured pH intermittently across the territory since 2010, but the data are not robust enough to detect temporal trends. pH values varied across time and location, but measures (pH= 8.01 to 8.08) were consistently lower than the global ocean average of 8.07 +/- 0.02 (Jiang et al. 2019). Despite this, values for another OA indicator, aragonite saturation state, are still near optimal levels for coral growth and remain some of the highest recorded in the US Pacific Islands. The highest aragonite values were recorded at Rose Atoll and values decreased slightly moving towards Tutuila (Figure SS.WQ.3.4). Fagatele and Fagalua/Fogama'a have lower values, but this may be due to biological demand (Vargas-Ángel et al 2019). High aragonite saturation likely facilitates the relatively high calcification rates observed in American Samoa, which follow the same spatial trend as aragonite saturation (Rose>Swains>Manu'a>Tutuila) (Figure SS.WQ.3.5; Barkley et al. 2021). Calcification rates around the island of Tutuila are among the lowest in American Samoa and the Pacific Remote Island Marine National Monument area, but are higher than other islands monitored by NCRMP in the Pacific Islands Region (NOAA ESD 2017). Vargas-Angel et al (2015) suggest that these lower values in Tutuila may be due to anthropogenic influences that reduce calcification.

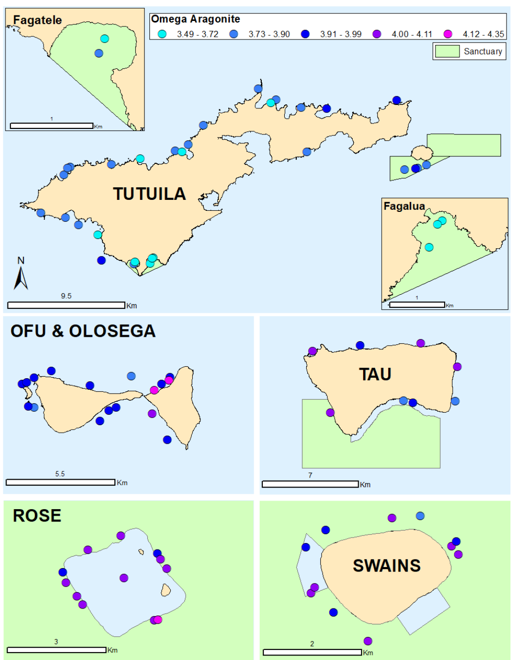

Figure SS.WQ.3.4. Aragonite saturation state values in American Samoa in 2018. Source: Vargas-Ángel et al., 2019

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Please increase legend font size.

Please change "Omega Aragonite" to "Aragonite saturation state".

I would also prefer "NMSAS" over "Sanctuary" for the boundary shading label, but it can stay as-is if needed.

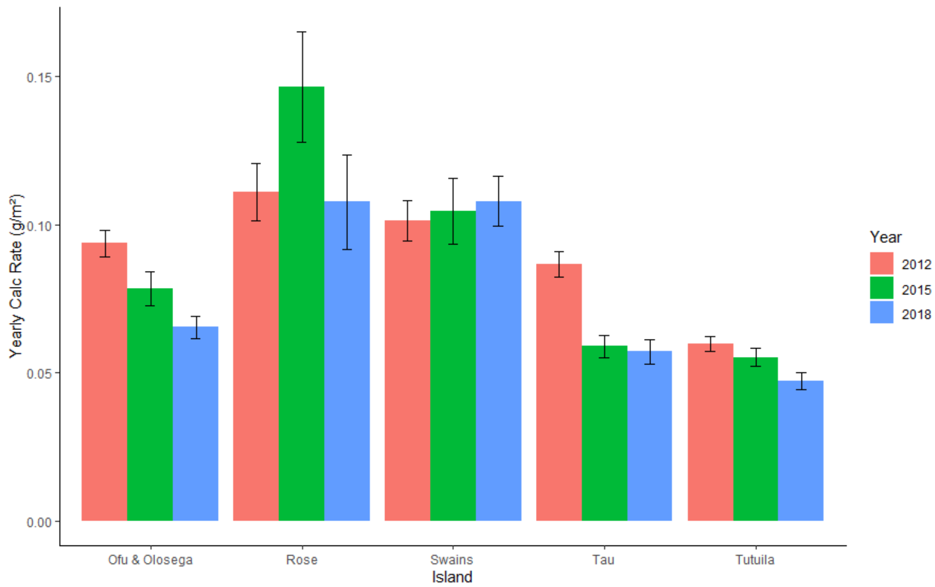

Figure SS.WQ.3.5. Carbonate accretion rate (g/cm2yr) for all CAU sites in 2012, 2015 and 2018. Accretion was highest at Rose Atoll and Swains Island and lowest in Tutuila. Source: NOAA ESD unpub data

Commented [13]: @kathy.broughton@noaa.gov There is a mismatch between the units in the caption and the y axis label (g/m2) vs (g/cm2). Please ensure units match. I also recommend using the same terminology in the axis label and in the caption, either "Yearly Calcification Rate" (please spell out "Calc") or "[Annual] Carbonate Accretion Rate".

Climate change is expected to decrease the number of cyclones in this region, but storms are expected to be stronger and rainfall is expected to increase by up to 10%, particularly during episodic heavy rain events such as cyclones and monsoons (ONMS 2020). Cyclones and precipitation are influenced by a number of factors including the El Niño Southern Oscillation and other complex ocean-atmospheric interactions, so it is difficult to determine if these have been affected by climate change. Fifty-three tropical cyclones have passed within 200 nm of Tutuila since 1959 (NOAA Digital Coast 2020). Sixteen of those became strong hurricanes (Category 3-5) and most of these strong storms (69%) occurred between 2000-2020, which suggests a slight increase in storm intensity. Rainfall has also been variable, but the National Weather Service announced that a new annual precipitation record was set for Tutuila in November 2020. The final total for 2020 was 191.68 inches, 26.2 inches above the previous record set in 1981 (NOAA WSO Pago Pago 2020). These data appear to align with the climate change projections, but are not definitive.

At this time, there are no available data for mesophotic or deep sea habitats. Monitoring is needed to determine climate change impacts on these deeper environments.

Conclusion

Although climate change has not yet caused severe degradation within NMSAS ecosystems, there are clear indications of increasing sea surface temperature, and rising sea levels. Rising temperatures have led to widespread coral bleaching events in 2015, 2017, and 2020, and a smaller event at Swains Island in 2016, but limited data are available from these events to evaluate mortality, sublethal impacts, and extent of the events. Despite decreasing regional pH levels, aragonite saturation and calcification remain high in American Samoa, but carbonate dynamics are not well understood. Data are even more limited for pelagic, MCE, and deep sea habitats, consisting of a few discrete sampling events and no long term trend data. Climate change is likely to have a significant influence on the status and trends of sanctuary resources in the future, and it is important that NMSAS work with partners to address data gaps moving forward.

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Question 4: Are other stressors, individually or in combination, affecting water quality, and how are they changing?

***Status**: Good/Fair, Confidence - Medium; **Trend**: Not changing, Confidence - Low*

***Status Description:** Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.*

***Rationale:** Non-point source pollution from the landfill activity, agriculture, and development was raised as a concern for Tutuila and Aunu'u units, however, managers have not detected major impacts to the ecological integrity of these sites during this reporting period. Accelerated coastal erosion caused by subsidence has not caused significant deposition. Iron enrichment at a vessel grounding site continues to be a problem at Rose, but has improved. The bird populations at Rose Atoll have had some variability due to storms, but these fluctuations did not appear to disturb nutrient cycles around the atoll.*

Question 4 Indicator Table. Summaries for the key indicators related to other stressors that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Non- Point Source Pollution: Land Use Change	Nearshore Habitats	OCM, 2021	The NOAA C-CAP land use change data indicate that forest cover declined in the watersheds of Fagatele Bay and Fogama'a between 2005 and 2010. This loss is related to a quarry, landfill activities, and agricultural clearing within the watersheds. On Swains Island, 0.01 square miles of forest shifted to scrub and on Rose Island, 0.01 square miles of scrub switched to forest. No changes were observed adjacent to the sanctuary unit in Ta'u and there were only minor changes in forest and wetland cover in Aunu'u.
Non- Point Source Pollution: Turbidity	Nearshore Habitats	Comeros-Raynal et al. 2021; PMEL, 2020; PacIOOS, 2020	Sediment traps were deployed for one year (2018-2019) in Fagatele Bay and six other sites.. Average sediment collection rates in Fagatele were comparatively low (<2 (1.42) mg/day/cm^3) and the researchers noted that there was little terrigenous sediment collected in the trap, suggesting that most of the sediment collected were resuspended reef sediments (Comeros-Raynal et al 2021). The MAPCO2 buoy recorded turbidity data from May 2019-August 2020 (NOAA PMEL 2020). Overall NTU measures were low, but data indicate a slight increase in turbidity from December through March that may warrant further investigation.
Coastal Erosion	Nearshore Habitats	Han et al., 2019	Since 2009, continued subsidence following the *Mw* 8.1 Samoa-Tonga earthquake doublet (megathrust + normal faulting) in September 2009 has effectively increased the rate of sea level rise in the Samoan Archipelago to 7-9 mm/yr, or approximately 5 times the global average. So far, sea level has increased by 25 cm or 9 inches since the earthquake and this trend is expected to continue for decades (Han et al 2019).
Point-source Pollution	Nearshore Habitats	Schroeder et al., 2008; Google Earth	The metal remains of the Jin Shiang Fa are still releasing iron into the water at Rose Atoll, which appears to support a persistent cyanobacteria bloom around the wreck site (Schroeder et al 2008). The extent of the cyanobacteria bloom has decreased over time, but still produces visible impacts to the reef flat habitat.
Seabird Populations	Nearshore Habitats	USFWS; Titmus., 2016	Rose Atoll is the only rat free island in American Samoa and is used by a large proportion of the territory's seabirds. Minor fluctuations in bird populations took place during the reporting period, but it is not clear if the change in nutrient levels affected marine resources. Seabird levels are depressed at Swains due to rat infestation (Titmus 2016)..

Other processes known to affect water quality in sanctuary habitats include non-point source pollution, particularly sediment conveyed by run-off from entire watersheds, sedimentation from accelerated coastal erosion linked to subsidence, iron enrichment from the grounding at Rose Atoll, and fluctuations in seabird populations and resultant nutrient enrichment at Rose Atoll.

The sanctuary units have long been considered "pristine" areas as they are located in areas with little or no human population and there has been limited paving and physical disturbance within their watershed catchment areas. There is no disturbed or paved land adjacent to units at Ta'u, Rose Atoll, and Swains Island. However, the village of Aunu'u is in close proximity to the sanctuary units, and there is a landfill, an active quarry and some agricultural activity above the Fagatele Bay and Fagalua/Fogama'a units (Figure SS.WQ.4.1). On Tutuila, developed areas increased by 5.8% from 2004-2010, and forest cover in the area surrounding Fagatele and Fagalua / Fogama'a decreased (OCM, 2021). To evaluate sedimentation rates in Fagatele Bay, sediment traps were deployed for one year (2018-2019). Sediment collection rates in Fagatele were comparatively low with an average of 1.42 mg/cm2/day (Figure S.WQ.4.2), and the researchers noted that there was little terrigenous sediment collected in the trap, suggesting that most of the sediment collected were resuspended reef sediments (Comeros-Raynal et al 2021). In addition to the sediment data, the MAPCO2 buoy recorded turbidity data from May 2019-August 2020 (PMEL 2020). Overall NTU measures were low, but the data indicate a slight increase in turbidity from December through March that may warrant further investigation.

Figure SS.WQ.4.1. Land use has shifted in Fagatele Bay during the reporting period.

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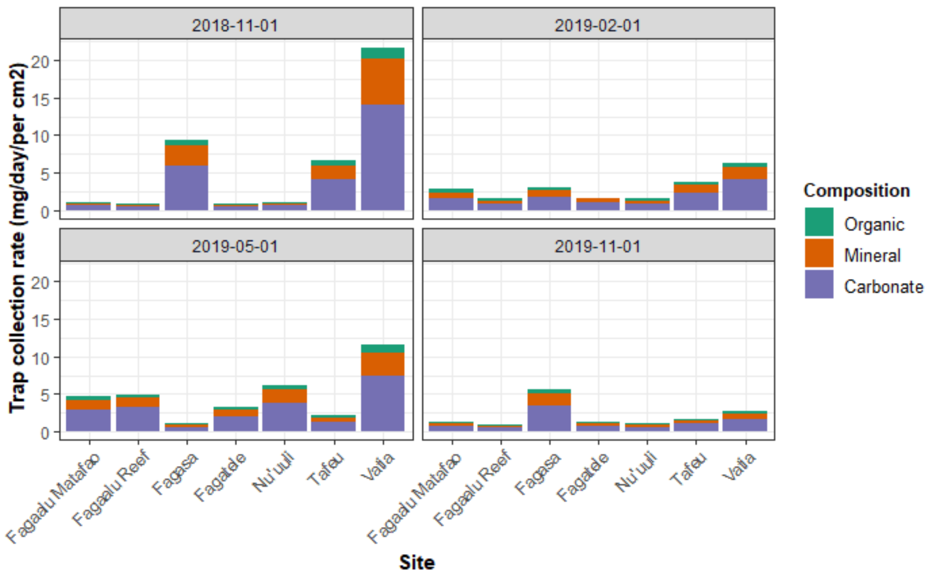

Figure S.WQ.4.2. Sediment accumulation in Fagatele Bay compared to other study sites around the island of Tutuila. Source: Camerors-Raynal et al 2021.

Sea level rise has increased coastal erosion and may also contribute to higher sedimentation rates. Global sea level rise attributed to climate change increased sea level in American Samoa by 2.41 millimeters/year from 1950 to 2009 (NOAA CO-OP 2020; see Figure S.WQ.3.3). However, continued subsidence following the September 2009 earthquake has effectively increased the rate of sea level rise by 16 mm/yr. So far, relative sea level may have increased by up to 21 cm (8.4 inches) since the earthquake (Han et al 2019), leading to increased coastal erosion and inundation. Within NMSAS, coastal inundation has been most noticeable adjacent to the Aunu'u unit, where storm waves overflowed the road and damaged the village generator. The village began armoring the upper shoreline along the southwestern coastline in 2020. It is not known if this inundation affected marine habitats and it is not clear what effects, if any, the new coastal armoring will have.

The 1993 grounding of the longline fishing vessel, *Jin Shiang Fa*, on the southwest edge of Rose Atoll left iron debris scattered across the reef. Most of the vessel debris was removed by 2005, but remaining metal is still releasing iron into the water and appears to support a persistent cyanobacteria bloom around the wreck site (Figure S.WQ.4.3, Schroeder et al 2008). The extent of the cyanobacteria bloom has decreased over time, but still produces visible impacts to the reef flat habitat. Please see the question addressing how human activities influence water quality for more details on the grounding.

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Figure SS.WQ.4.3. The FV *Jin Shiang Fa* ran aground on Rose atoll in 1993. Fuel and oil discharged from the vessel affected nearby reef flats and the remaining metal continues to cause cyanobacteria outbreaks. Photo: Green et al., 1997

Recent research has shown that coral reefs thrive next to rat-free islands because the seabirds play a critical role in depositing nutrients in their guano that leach into the surrounding waters (Graham at all 2018). Seabird populations may also change with storm impacts and shifts in forage fish. Rose Atoll is the only rat free island in American Samoa and is a key migratory stopover that provides vital nesting and roosting habitat for 12 federally-protected seabird species (USFW 2014). USFWS Refuge Manager, Brian Peck, noted that populations have fluctuated during the report period, and while birds have always used the island, there are no data available on nutrient production. Titmus et al (2016) noted that rats likely pose a threat to seabird populations at Swains Island. The DMWR has identified rat control as an important step to reduce pressure on bird populations on Swains Island, but this project has not yet started and it is unclear if the depressed bird populations affect marine resources in sanctuary units.

Conclusion

Non-point source pollution from the landfill activity, agriculture, and development was raised as a concern for the Fagatele Bay, Fagalua/Fogam’a and Aunu’u units, but managers have not detected significant impacts to the ecological integrity of these sites during this reporting period. Subsidence has accelerated coastal erosion and the island has experienced 25 cm of sea level rise since 2009. This is starting to affect human communities adjacent to the sanctuary, but has not caused detectable impacts on marine habitats. Iron enrichment continues to occur at a vessel grounding site on Rose, but has improved over time and should further improve after a planned remediation project takes place. The bird populations at Rose Atoll have experienced some variability due to storms, but these fluctuations did not appear to disturb nutrient cycles around the atoll. Bird populations are still depressed by rat predation on Swains Island. Experts recommended that NMSAS continue to track these impacts and support remediation and mitigation efforts. Additional focus may be required to address changes linked to sea level rise in Aunu’u.

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Question 5: What are the levels of human activities that may adversely influence water quality and how are they changing?

***Status:** Good / Fair, Confidence - Low; **Trend**: Undetermined, Confidence - Medium*

***Status Description:** Some potentially harmful activities exist, but they have not been shown to degrade water quality.*

***Rationale:** There are measurable contaminant and nutrient inputs within sanctuary units, particularly in Fagatele Bay. Contaminants and nutrients from the landfill and agricultural activities have been documented at low levels in Fagatele Bay and it is likely that they have also reached Fagalua / Fogama'a. No measurable impact on water quality or biological communities has been detected. There is a sewage outfall in the Aunu'u Multipurpose Zone A Unit that may also discharge contaminants and nutrients to the shallow reef zone. Limited data prevents full assessment of these impacts and no trend data were available to assess changes over time.*

The cumulative impacts of multiple anthropogenic activities, such as changing land use within the watersheds, sewage discharge, and continued presence of vessel wreckage at Rose Atoll, have the potential to impact NMSAS water quality. These activities generally do not seem to be adversely influencing water quality, however, data on many of these human activities are limited. Terrestrial contaminant sources such as the landfill, agricultural chemicals, and sewage discharges, could influence water quality in the future. Few data are available on human activity impacts on water quality in pelagic, mesophotic and deep-sea habitats.

There are few human activities taking place within NMSAS that directly impair water quality, but land based sources of pollution from adjacent watersheds may affect nearshore sanctuary habitats (see Figure SS.WQ.4.1). Quarrying and agricultural activities take place in the watersheds adjacent to the Fagatele Bay and Fagalua/ Fogama'a units and the Futiga landfill is also located within close proximity to both units. The landfill has been operating since the 1960s and is the only municipal landfill facility on Tutuila. The site was recompacted in 2018 to extend the life of the site after experts warned it would fill by 2020 (BBC News 2018). It is unlined and does not have a leachate collection system to prevent contaminants from reaching groundwater (Figure SS.WQ.5.1). The hydrology of this area is not well documented, but experts believe that landfill contaminants could enter sanctuary units via submarine groundwater discharge. Soil samples taken near the Futiga landfill showed high levels of lead, malathion (pesticide), PAHs, and phthalates (Polidoro et al 2016). Even though NMSAS units were not specifically sampled the results could give an indication of possible contaminants that could enter Fagatele and Fogama'a/Fagalua via overland flow or groundwater discharge from these human activities.

<<IMAGE TO BE INSERTED>>

Figure SS.WQ.5.1. The Futiga landfill was recompacted in 2015 to make additional space for solid waste on Tutuila. The site is unlined and groundwater hydrology has not been studied. Photo: NMSAS

A study in 2019 analyzed water samples from Fagatele Bay for various contaminants (NCCOS in prep). Most of the chemicals were not detected or detected in very low concentrations. Polycyclic aromatic hydrocarbons (PAHs) and other organic compounds were detected but did not exceed published screening levels. The recorded levels were low enough that there are likely no significant adverse biological results at this time. Pharmaceuticals were also detected, but there is a lack of information about the potential ecological impacts of these chemicals. Some pharmaceuticals may act as endocrine disruptors in marine animals at very low concentrations. Further monitoring of these pollutants is highly recommended as changes in hydrology, types of landfill input, and landfill decomposition processes could cause these values to increase.

The study also tested marine sediment samples from Fagatele Bay for 17 different metals and found that most were below the Effects Range Low (ERL) value, which is considered the threshold for possible toxicity to benthic infauna. Nickel was the only metal that exceeded ERL values (at three of five sites within the bay) but did not exceed the Effects Range Medium (ERM), the threshold for probable toxicity to benthic infauna. These elevated nickel concentrations could be natural or caused from landfill discharge through groundwater, and could indicate possible toxicity to sediment infauna.

Nutrient sampling in Fagatele indicates that levels are below the EPA threshold for water quality (Figure SS.WQ.5.2 Cameros-Raynal et al 2017) but recent sampling (NCCOS in prep) has raised some concern for potential increases in nutrient concentrations in the bay (See Water Quality Section).

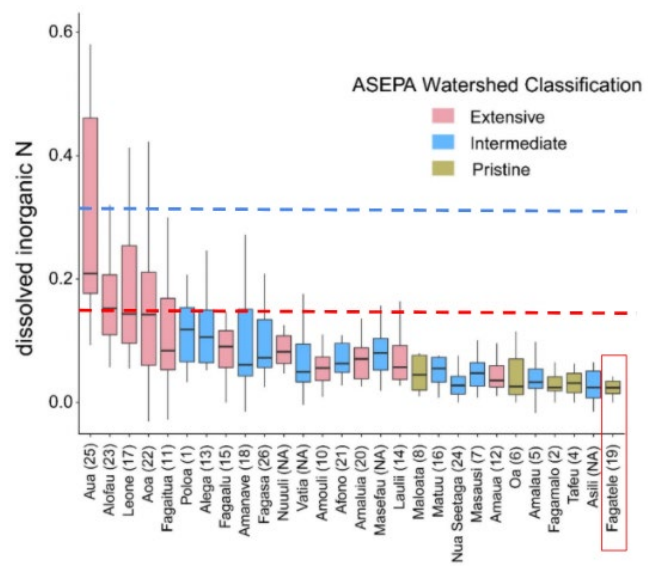

Figure SS.WQ.5.2. The distribution of monthly DIN concentrations (mg/L) over the course of the study year with respect to ASEPA watershed classifications showing all sampled watersheds (streams). Black lines show median values, boxes show 25th and 75th percentile, and lines show 5th and 95th percentile of the data. Colors indicate varying ASEPA watershed categories. DIN is shown in mg/l. Blue line: Current DIN threshold 0.3mg/l (EPA 2013). Red line: DIN threshold of 0.15mg/l (Houk et al 2019) (Comeros-Raynal et al 2017)

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A sewage outfall in the Aunu'u Multipurpose Zone A Unit discharges a small amount of untreated raw sewage from the village directly into the shallow reef zone. This discharge may contain contaminants as well as nutrients that could impact water quality. Limited data are available for this outfall.

No water quality impairments are currently known from the Ta'u and Swains Island units as the areas adjacent to these units are sparsely populated and have low levels of visitation. The Muliava unit is relatively pristine due to its distance from human populations, however, a section of the reef suffers from long term iron enrichment associated with the grounding of the Taiwanese longline fishing vessel, FV *Jin Shiang Fa*.

In 1993, the vessel ran aground on the seaward edge of the southwest side of Rose Atoll. Four months after the grounding, a large amount of wreckage and debris was still present on the reef slope, covering an area of approximately 3,500 m^2. In subsequent years most of the iron was removed from the reef but some remains (Green et al 1997). The metal sections of the vessel are corroding and releasing iron into the water, causing a persistent cyanobacteria bloom near the wreck site (Schroeder et al 2008) that is still impacting the reef in 2020. Although iron is not normally considered a limiting nutrient on coral reefs, in the iron poor waters of Rose Atoll, it promotes cyanobacterial growth that has prevented the recovery of the reef ecosystem in the grounding site. The extent of the cyanobacteria bloom has decreased over time, but managers recommend the removal of the remaining pieces to facilitate full recovery.

Conclusion

Quantitative data on contaminants and eutrophication within the sanctuary boundaries are limited. Data for Fagatele Bay are more robust and indicate that nutrient levels are below recommended thresholds, but may be increasing, likely due to the landfill and increased agriculture in the surrounding watershed. The cyanobacteria bloom associated with the grounding of the Jin Shiang Fa remains at Rose Atoll, but has decreased in size over time. Quantitative *in-situ* data are not available for pelagic, mesophotic and deep sea habitats and experts recommended more frequent and expanded sampling across the sanctuary units to address these gaps.

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This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Habitat (Questions 6 – 8)

The following information provides an assessment of the status and trends of key habitat indicators in NMSAS for the period of 2007–2020.

Question 6 focuses on the integrity of major habitats within the sanctuary, including shallow coral reef, MCE and deep sea. The integrity of habitat structuring benthic organisms that create structures used by other living marine resources, such as corals and sponges, is assessed as well as disturbances to these habitats. Changes to habitat integrity can significantly alter the diversity of living marine resources and ecosystem services.

Question 7 examines concentrations and variability of contaminants in major sanctuary habitats.

Question 8 covers human activities that may adversely influence habitats. Human activities often have structural impacts (e.g., removal or mechanical alteration) to habitats. Fishing activities that physically disrupt the seafloor (e.g., trawls and dredges), anchoring, commercial dredging, and pipe and cable installation are described as resulting in structural impacts.

Question 6: What is the integrity of major habitat types and how are they changing?

Rating*: Good/Fair, Confidence - High; Trend: Declining, Confidence - High*

Status Description*: Selected habitat loss or alteration is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.*

Rationale*: Habitats within the sanctuary have demonstrated resilience to disturbances from coral bleaching events, sea level rise, crown-of-thorns sea stars, and cyclones. These ecosystems have adapted to or recovered from these events. The damage from a vessel grounding in Aunu'u has had lasting impacts, but is constrained to a small area, and marine debris continues to be a chronic, but minor problem across all habitats. Data for pelagic and deep sea habitats are limited, and no immediate threats were identified.*

Question 6 Indicator Table. Summaries for the key indicators related to the integrity of major habitat types that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Sea Level	Intertidal Habitats: Rocky Shores, Sandy Shores and Reef Flats	Han et al. 2019	Since 2009, continued subsidence following the *Mw* 8.1 Samoa-Tonga earthquake doublet (megathrust + normal faulting) in September 2009 has effectively increased the rate of sea level rise in the Samoan Archipelago to 7-9 mm/yr, or approximately 5 times the global average. So far, sea level has increased by 25 cm or 9 inches since the earthquake and this trend is expected to continue for decades (Han et al. 2019). This increase has likely shifted intertidal habitats, but there are limited data on intertidal habitats within the sanctuary. Corals on the reef flats at Fagatele and Fogama'a have been impacted by subaerial exposure during extreme low tides in 2020.
Coral cover	Shallow Coral Reef Ecosystem	NOAA PIFSC ESD 2018, C. Birkeland pers comm 2020; Green et al., in prep.; A. Green pers comm 2020, Vargas-Angel et al. 2019, CRAG unpublished data 2020, Houk unpublished data 2020	Data derived from towed diver surveys suggest that coral cover in American Samoa was relatively stable from 2002 - 2015, with Swains island having the highest coral cover (NOAA PIFSC ESD 2018). Bleaching events in 2015-2017 were documented, but not quantified. Dr. Charles Birkeland and Dr. Alison Green conducted reef surveys in 1994/5, 2002, and 2018. Dr. Birkeland noted that he felt that the coral communities looked better in 2018 than he had ever seen them, particularly in Fagatele Bay. The preliminary data from this effort indicate that coral cover declined slightly around Tutuila from 2002 to 2018, but increased around Ta'u and Rose. He noted that community structure was more robust with both recruits and older size classes (C. Birkeland pers comm, Green et al., in prep.). NOAA PIFSC ESD reported that the average coral cover for the territory dropped from 28.7% ± 2.6 in 2015 to 18.2% ± 2.0 in 2018, representing a 36% decline. The 2018 sampling effort was greatly reduced due to weather and this may have affected these results and prevented site based analysis. The team did note that at Swains island, the density of *Pocillopora* corals declined by over 60% and there is strong evidence that this was associated with the 2015-2017 bleaching events (Vargas-Angel et al. 2019). CRAG's site based monitoring data from Fagatele Bay and Aunu'u are not directly comparable across the reporting period due to staff changes and a methods change in 2015. The data from 2015 to 2018, suggests that coral cover has increased in Fagatele during that time. The limited data available for Fagalua/Fogama'a suggest that coral cover increased from 2007 (average 27%) to 2013 (average 49%) (Houk unpublished data?).
CCA cover	Shallow Coral Reef Ecosystem	Vargas-Angel et al. 2019, CRAG unpublished data 2020, Houk	CCA cover in American Samoa is generally high. NOAA PIFSC ESD recorded significant increases in CCA cover at all NMSAS areas between 2015 and 2018. The 2018 levels of CCA at Swains were historically high (around 44%) and close to those recorded at Rose Atoll (around 49%). The 2018 sampling effort was greatly reduced due to weather and this may have affected these results and prevented site based analysis (Vargas-Angel et al. 2019). In contrast,

		unpublished data 2020	CRAG reports that CCA cover at their fixed monitoring site in Fagatele was the lowest in 2018 (28%). Their data records fluctuations in cover throughout the years but overall remain fairly high (averaging between 30-60%). CRAG reports that CCA cover at their fixed monitoring site in Aunu'u did not change between 2015 (average 35%) and 2018 (average 34.5%) and generally appeared to be fairly stable across the monitoring years (averaging between 30-45%) (CRAG unpub data 2020). There are fewer data available for Fagalua/Fogama'a but the data from Peter Houk suggest that CCA decreased from 2007 (average 42%) to 2013 (average 27%) (Houk unpublished data 2020).
Algae cover	Shallow Coral Reef Ecosystem	Vargas-Angel et al. 2019, CRAG unpublished data 2020, Houk unpublished data 2020	Macroalgae (MA) cover at all sanctuary sites is low (below 10%). NOAA PIFSC ESD recorded significant declines in MA cover at all NMSAS areas between 2015 and 2018, with the greatest decrease occurring at Swains Island (from 10% to 3%) and Rose Atoll (from 7% to 1%) (Vargas-Angel et al. 2019). CRAG reports that MA cover at their fixed monitoring site in Fagatele shows fluctuations throughout the years but remains low with a spike in 2016 (average 5.5%) following a significant decline in 2018 (average 0.7%). CRAG reports that MA cover at their fixed monitoring site in Aunu'u has remained low across the monitoring years with slight increases starting in 2012 (from 0% to 1.2%) (CRAG unpublished data 2020). There are fewer data available for Fagalua/Fogama'a but data from Peter Houk suggests that MA cover was stable from 2007 (average 1.1%) to 2013 (average 1.6%) (Houk unpublished data 2020). Turf algae cover in NMSAS is generally low. NOAA PIFSC ESD recorded that turf algae cover has remained fairly stable at all NMSAS management areas (averaging around 20%) and is highest at Ta'u (averaging around 40%), the only NMSAS management areas, where an increase was recorded (Vargas-Angel et al. 2019). CRAG reports that turf cover at their fixed monitoring site in Fagatele shows fluctuations throughout the years but remains low (<8%) with a slight spike in 2018 (average 12%). CRAG data for their fixed monitoring site in Aunu'u suggest a slight increase in turf cover across the monitoring years with the highest record in 2015 (average 15%) (CRAG unpublished data 2020). There are fewer data available for Fagalua/Fogama'a, but data from Peter Houk suggest that turf cover has remained very low between 2007 to 2013 (<0.3%).
Noise	Shallow Coral Reef Ecosystem	PIFSC 2011	In 2006/2007 an EAR was deployed in Fagatele Bay. The recording shows strong diel variability. Fish scrapes were the most common event-triggered noises recorded but there was also evidence for presence of cetaceans and motorized vessels, but the amount of noise created by motorized vessels was low. In 2008/2009 an EAR was

			deployed at Rose atoll. Interestingly, the day versus night sound pressure levels are not as pronounced as in Fagatele Bay. Cetaceans were the most common event-triggered noises recorded, but there was also evidence for fish scrapes and motorized vessels. Vessel noise was detected at both sites, with 21 distinct events recorded at Fagatele and 20 events at Rose Atoll (PIFSC 2011).
Disturbance	Nearshore Habitats	NMSAS, USGS, Schroeder et al. 2008, Green et al., 2009; NOAA Digital Coast, 2020.	A number of cyclones, bleaching events, CoTS outbreaks, ship groundings, and a tsunami have impacted the sanctuary units in recent years. Since 1959, 53 tropical cyclones have passed within 200 nm of Tutuila (NOAA Digital Coast 2020). In 2018, Cyclone Gita damaged forests surrounding Fagatele Bay, dropping significant amounts of debris into the bay and damaging corals. The storm also toppled table corals and caused other physical damage to the reef in Fagatele Bay. Approximately 20% of the corals on the eastern side of the bay were damaged, and 3-5% in other areas. A CoTS outbreak in 2014-2017 mostly affected Taema bank and the north side of Tutuila but also caused some impacts to the south side and sanctuary units. A ship grounding at Rose Atoll in 1993 caused considerable physical damage to the reef and a persistent cyanobacteria bloom remains due to iron enrichment from remaining debris. In 2016 a ship grounding at Aunu'u caused considerable physical damage at the grounding site. The grounding and removal efforts impaired 1,641 m^2 of reef habitat. Restoration was not possible due to the exposed conditions and the site has not recovered. The 2009 tsunami was devastating to Tutuila, but appeared to have only minor impacts in NMSAS units due to their orientation in relation to the waves.
Habitat Structuring Benthic Organisms	MCE	Montgomery et al. 2019, Bare et al. 2010	NMSAS includes 13.53 km2 of mesophotic coral ecosystems compared to only 10.01 km2 of shallow coral reef ecosystems (Table X) and much of it remains unexplored and undocumented. The Aunu'u and Ta'u units have the highest proportion of hard substrate suitable for coral and sponge communities in the mesophotic zone (Figure X; Montgomery et al. 2019). A mesophotic habitat assessment of the Tutuila insular shelf (30-110m) found that scleractinian coral cover decreased with depth and that plate-like and encrusting corals dominated the upper zones, with branching corals becoming more common in the middle mesophotic zone. Massive coral cover decreased with depth and dropped to zero below 80m. Macroalgae was observed down to 100m, but was most abundant in the mid-range depths (50-80m) (Bare et al. 2010).
	Deep sea	OET unpub data	NOAA Office of Exploration and Research (NOAA OER) and the Ocean Exploration Trust (OET) led expeditions to American Samoa in 2017 and 2019 respectively. Analysis

		2019, HURL unpub data 2020, NOAA DSCRTP 2020	conducted by HURL indicates that the deep ridges along Swains Island supported the highest density of corals and sponges (1732 counts/km) documented by the OET expedition, and the outer slope of Aunu'u and a deep ridge along Rose Atoll also supported relatively high densities (1559 counts/km and 1319 counts/km respectively). All three communities are considered moderate density communities as they contain 1,000-2,999 coral and sponge counts per kilometer. The Ta'u site adjacent to the sanctuary had few sponges, but 693 corals per kilometer, while the young Vailulu'u seamount site only had 6 sponges per kilometer and no corals (OET 2019, HURL unpublished data 2020). Densities were not calculated for the NOAA OER dives. Habitat forming benthic organisms observed during these two expeditions included black, gorgonian, lace, soft, Stoloniferan, and stony corals; sea pens; demosponges; and glass sponges (NOAA DSCRTP 2020) .
Habitat Variation	Hydrothermal Vent	Koppers et al. 2010, NOAA OER, OET/HURL, Staudigel et al. 2006	The Nafanua cone at the center of the seamount formed between 2001 and 2004 (Koppers et al. 2010). Multibeam sonar surveys conducted by the Okeanos Explorer in 2017 detected major depth changes in the summit caldera of Vailulu'u since the 2005 expedition, and comparisons of the data indicated that the cone grew in both height and width. The crater is by nature a very unstable environment but appears to have four distinct habitats that are closely linked spatially but contrast sharply in their biota (Staudigel et al. 2006). The 2019 OET expedition did not detect any notable changes in the crater's bathymetry, but did locate a new hydrothermal vent on the east side of the crater. The water temperature was 202.7°C at the top of the plume outflow and 114°C at the base. Around the peak of the plume, a high abundance of crabs (Bythograeidae), shrimp, and isopods were present. Near the active plume there was a field of dormant chimneys, ranging from 0.5 to about 2 meters in height. Some of the chimneys still released warm water, but no bubbles were present.
Marine debris	All Habitats	NMSAS, Ammon et al. 2020	Marine debris is affecting all major habitat types of NMSAS, but has had minor detectable impacts. Marine debris accumulation surveys on the beaches of Fogama'a/Fagalua and Aunu'u showed that styrofoam and hard plastics are the main contributors. Occasional marine debris items have been observed on dives in Fagatele Bay and Fogama'a/Fagalua. In the deep sea, the highest estimates of marine debris were within the United States EEZ (not within protected areas) around American Samoa and the main Hawaiian Islands. However, NMSAS areas had small amounts of marine debris mostly consisting of fishing gear (Ammon et al. 2020)

NMSAS covers 13,581 square miles and includes habitats from intertidal zones to 3,500m below the surface. Habitats include intertidal habitats such as rocky shores, sandy shores and reef flats; shallow coral reef ecosystems (SCR); mesophotic coral ecosystems (MCE); deep slopes; pelagic; deep-sea coral and sponge communities; hydrothermal vents and abyssal plain habitats. This question addresses the change in habitats since 2007, with a particular focus on those that may have been impacted by human activities.

Intertidal Habitats

Due to their close proximity to human activities and the surface of the ocean, intertidal habitats and coral reefs are the habitats most likely to experience change. Surprisingly, little is known about NMSAS intertidal habitats along rocky cliffs, in caves, and on sandy beaches. The intertidal zone has shifted due to the nine inch increase in sea level in the region over the last decade (Han et al. 2019), but no quantitative data are available to evaluate the effects of this shift. Coral reef habitats have been better studied. Key components of coral reef habitats include habitat-forming organisms such as corals, crustose coralline algae (CCA), and macroalgae. These three components provide the foundation for coral reef habitats, providing structure, shelter, and food for other reef organisms, but are sensitive to environmental variation. Substrates such as rocky cliffs, boulders, and pavement also provide structure, but can be more stable and less sensitive and changes take place across longer time scales. In deeper waters, corals and sponges are the most common habitat-forming organisms, but other organisms also create habitat around hydrothermal vents at the Vailulu'u Seamount.

Shallow Coral Reefs

Corals are sessile colonial animals that accrete calcium carbonate to build their skeletons, which contribute to the creation of the geologic reef framework, while also providing shelter and food for other reef organisms. Coral skeletons form the foundation of coral reefs, and healthy live corals support diverse and highly interdependent faunal communities that depend on them (Idjadi and Edmunds 2006, Pratchet et al. 2012).

Corals are highly vulnerable to temperature extremes, pollution, and physical damage, so these animals are an important indicator of ecosystem health and impacts for sanctuary managers. Percent cover is a standard metric for coral habitat and has been monitored for decades in Fagatele Bay and was collected on an island scale from 2002-2015 (Figure S.H.6.1, NOAA CRCP 2018). There have been fluctuations in cover throughout the years, but American Samoa's reefs have so far demonstrated resilience in the face of natural disturbances and recovered after CoTS predation, cyclones (Green et al., 2009), and most recently, repeated coral bleaching events in 2015, 2016 (Swains only) and 2017.

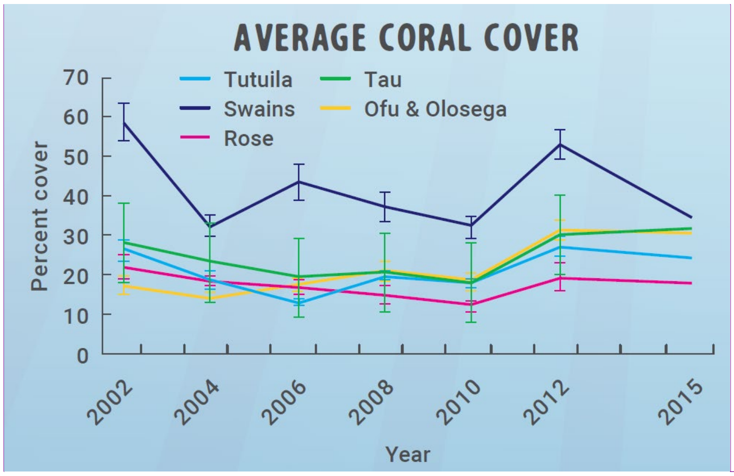

Figure S.H.6.1. Average coral cover observed during towed divers surveys from 2002-2015 across all islands of American Samoa (NOAA CRCP 2018)

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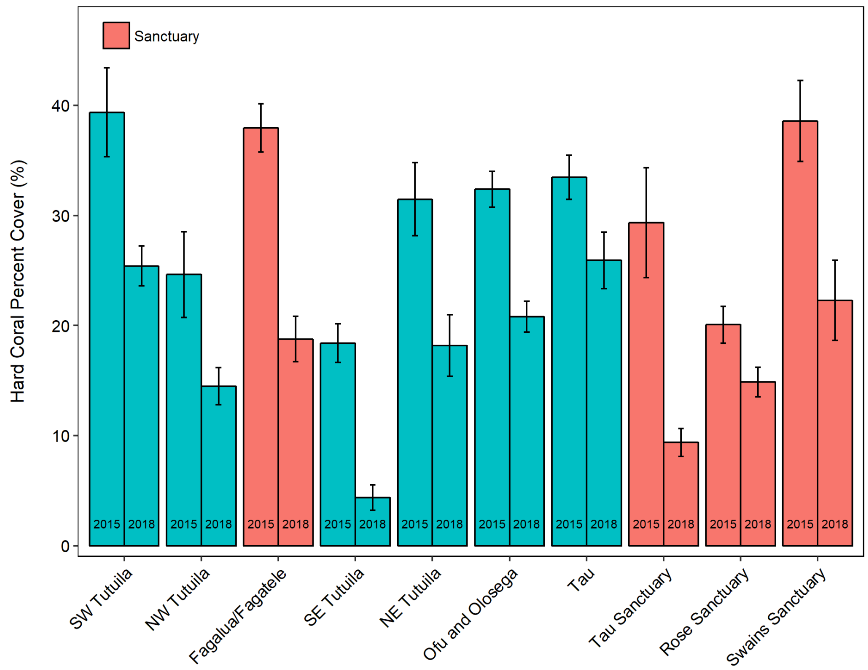
Coral bleaching events have affected reefs across American Samoa in different ways. ESD reported a significant (α = 0.05) decline in coral cover between 2015 and 2018 at all sites that had sufficient sample sizes for analysis, including Rose Atoll and Ta'u Island. However, Fagatele/Fagalua, and Swains, were omitted from the analysis due to insufficient sample size (Vargas-Ángel et al. 2019, Figure S.H.6.2). Coral cover data from CRAG's Fagatele and Aunu'u monitoring sites (Figure S.H.6.3) indicates possible changes in coral cover during the reporting period, however, there were several changes in staff and a significant methods change in 2015, so the values may not be directly comparable. Data collected since 2015, indicates that coral cover has increased or remained relatively stable in Fagatele and many other sites around Tutuila from 2015 to 2019 (Coward, 2021). Dr. Charles Birkeland also reported that in 2018, the coral at Fagatele Bay was the best that he had observed in the past 40 years (C. Birkeland pers. Comm., 2020, Green et al., in prep.). Limited observations at Swains Island suggest that coral bleaching in 2015, 2016, and 2017 may have had more significant effects on corals there and ESD calculated that over 60% of the *Pocillopora* colonies at study sites around Swains were lost between 2015 and 2018 (Vargas-Ángel et al. 2019, CRAG).



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Commented [3]: @kathy.broughton@noaa.gov As with similar graph in the water quality section, please include labels for both categories in legend (e.g., "Within NMSAS boundaries" and "Outside NMSAS boundaries"). Please add x axis label (e.g., "Sampling Location" or "Site").

Figure S.H.6.2. Percent hard coral cover recorded by NOAA ESD in 2015 and 2018. ESD reported a significant (α = 0.05) decline in coral cover between 2015 and 2018 at all sites that had sufficient sample sizes for analysis. Fagatele/Fagalua, SW Tutuila, SE Tutuila, and Swains, were omitted from the analysis due to insufficient sample size. (Vargas-Ángel et. al, 2019)

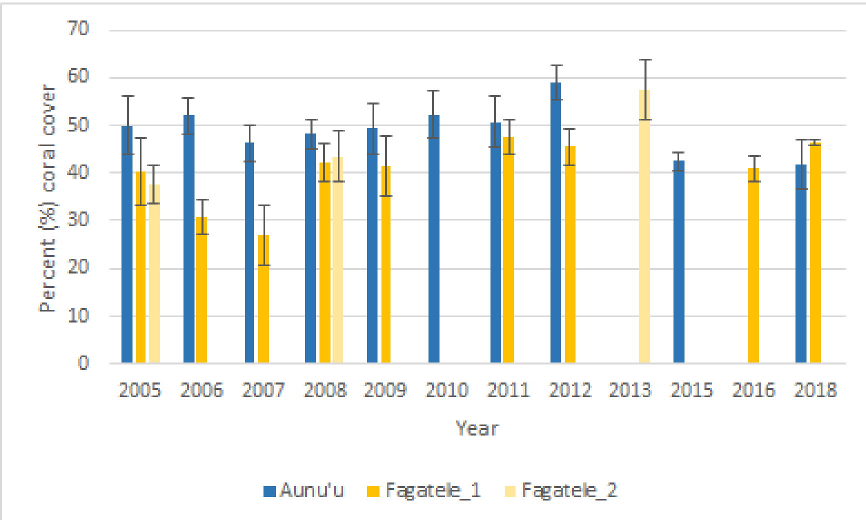

Figure S.H.6.3. Coral cover at CRAG monitoring sites in Fagatele Bay (Fagatele_1) and Aunu'u from 2005 - 2018 (CRAG 2020) and at Peter Houks AS-EPA monitoring site in Fagatele (Fagatele_2). (CRAG & Houk/ASEPA monitoring data)

Commented [4]: @mareike.sudek@noaa.gov update graph to reflect correct years for Fagatele data. I think you said 2016 should be 2017 (R2R). Were you able to confirm if 2018 data was QC'd? It is not in the CRAG database submitted to NCEI. We may want to use the figure in the latest report that Georgia sent, although they only show 2018 for Aunu'u. _Assigned to Mareike Sudek - NOAA Affiliate_

Commented [5]: Tash just send me the CPCe output Excel sheets for Fagatele and Aunu'u. If her CPC analysis was QC'd I don't know. You said there was an issue with that data so might be better to just use Georgias graph

Commented [6]: @kathy.broughton@noaa.gov Please change y axis label to title case and put (%) at the end (although it could also be removed as "percent" is already stated in the title). Also, should this be "Average Percent Coral Cover" since error bars are present? Also, what do error bars denote (assuming SE?), as I'm not seeing this in the caption.

Crustose coralline algae (CCA) is another important component of reef habitat. CCA are important calcifiers that maintain reef structure and integrity, but some species also provide habitat for fish and invertebrates, and many induce larval settlement for benthic organisms, particularly corals. In American Samoa, CCA cover remains high, but is variable across spatial and temporal scales (Vargas-Angel et al. 2019). ESD reported a significant ($\alpha = 0.05$) increase in CCA cover between 2015 and 2018 at Rose Atoll, Ta'u Island, and Northern Tutuila. Further, in 2018 CCA cover at Swains island was historically high (44.6 ± 4.6%), approaching levels observed at Rose Atoll (Vargas-Ángel et al. 2019). The historic level of CCA cover at Swains is likely attributable to the mortality event of *Pocillopora* corals, which created space for the proliferation of CCA over the dead coral skeletons. In contrast, CRAG observed slight increases in CCA cover at permanent monitoring sites at Aunu'u in 2015 and Fagatele Bay in 2016, it remained stable in Aunu'u in 2018, but declined in Fagatele Bay (CRAG).

Algae is also a valuable part of reef habitats, providing food for herbivorous fish, and shelter for juvenile fish and invertebrates. But due to rapid growth rates, it can easily overwhelm corals and CCA, disrupting ecosystem functions (e.g., food web structure and space competition) and altering productivity (Kuffner et al. 2006, Birrell et al. 2008). Algae often increase following significant coral or CCA mortality events, when the system is exposed to high levels of nutrients, or when herbivory declines due to overharvest or lack of fish recruitment (Mumby et al. 2007, Soatka et al. 2009, Vermeij et al. 2010). Local and federal monitoring surveys have documented temporal fluctuations in macroalgae and turf algae cover but overall, it remains very low (<15%) within all sanctuary units (CRAG, Vargas-Angel et al. 2019). Turf algae cover was higher, but quite variable across time and space. Turf algae cover was highest in the Ta'u unit (Vargas-Angel et al. 2019).

Noise can affect the integrity of ocean habitats, but data on noise pollution in sanctuary units are sparse. An ecological acoustic recorder (EAR) was deployed for one year in both Fagatele Bay (August 2006- July 2007) and Rose Atoll (March 2008 - July 2009). Sound profiles from both sites are dominated by natural sounds, including snapping shrimp, whales, dolphins, fish, and rain. The data from Fagatele Bay demonstrate strong diel (day/night) variability. Interestingly, the differences were not as pronounced at Rose atoll and the two sites appeared to have different seasonal patterns. Although minimal, vessel noise was detected at both sites, with 21 distinct events recorded at Fagatele and 20 events at Rose Atoll (PIFSC 2009, 2010, 2011).

Disturbance frequency and relative impacts can be important habitat indicators, as both natural and human disturbance events dramatically impact sanctuary resources. While ecosystems may have adapted to periodic natural disturbance events over time, changes in disturbance frequency and intensity, particularly those linked to climate change and human activities may cause lasting impacts such as phase shifts. A number of disturbance events, including cyclones, bleaching, CoTS outbreaks, ship groundings, and a tsunami, have impacted the sanctuary in recent years. Since 1959, 53 tropical cyclones have passed within 200 nm of Tutuila. In 2018, Cyclone Gita damaged forests surrounding Fagatele Bay, which released significant amounts of debris into the bay, damaging corals. The storm also toppled table corals and caused other physical damage to the reef in Fagatele Bay. Approximately 20% of the corals on the eastern side of the bay were damaged, and approximately 3-5% in other areas of the bay (NMSAS 2018). A crown-of-thorns sea star outbreak in 2014-2017 mostly affected the north side of Tutuila but also caused some impacts to sanctuary units. The ship groundings at Rose atoll in 1993, and Aunu'u in 2016, caused considerable physical damage. Long-term changes to the reef, while limited in areal extent, will have long term impacts (please refer to the human dimensions section for more information). The 2009 tsunami was devastating to Tutuila, but based on wave exposure models (USGS, PMEL) and visual inspections, the tsunami appeared to have only minor impacts in NMSAS units. This is likely due to their orientation in relation to the tsunami waves. With the exception of the physical damage from the vessel grounding in Aunu'u , workshop participants felt that shallow nearshore habitats have proven resilient to acute impacts and are in good condition. Cyclones, groundings, and the tsunami all caused an influx of marine debris into nearshore habitats (see the human dimensions section), but had limited lasting effects.

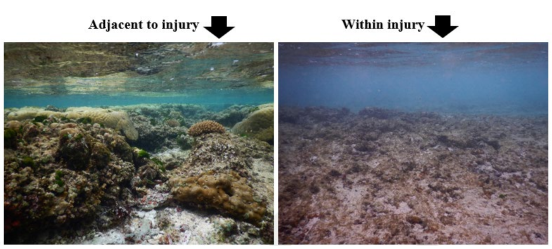

Figure S.H.6.4. Ship grounding site in the Aunu'u Sanctuary unit in 2018 (two years after the grounding). No recovery within the injury site was seen.

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Mesophotic Coral Ecosystems

Mesophotic coral ecosystems (MCE) are found in every NMSAS unit (Table S.H.6.1). There are more MCEs in NMSAS than shallow coral reeefs (SCR) (Montgomery et al. 2019) and most of them remain unexplored and undocumented. The Aunu'u and Ta'u units have the highest proportion of hard substrate in the mesophotic zone (Figure S.H.6.5). These substrates are most likely to support habitat structuring benthic organisms such as corals and sponges, but hard substrate appears to decrease with depth, shifting to predominantly unconsolidated substrate in the lower mesophotic zone (Montgomery et al. 2019). A mesophotic habitat assessment of the Tutuila insular shelf (30-110m) found that scleractinian coral cover decreased with depth and that plate-like and encrusting corals dominated the upper zones, with branching corals more common in the middle mesophotic zone. Massive coral cover decreased with depth and dropped to zero below 80m. Macroalgae was observed down to 100m, but was most abundant in the mid-range depths (50-80m) (Bare et al. 2010).

Table S.H.6.1a. Geodesic area and reef slope for each NMSAS management area. The mesophotic zones are upper (30–70 m), mid (70–110 m), and lower (110–150 m). SCR = shallow coral reef, MCE = mesophotic coral ecosystem (Montgomery et al. 2019). Habitat area (km2)

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	Aunu'u Island A	Aunu'u Island B	Fagalua/Fogama'a	Fagetele Bay	Ta'u Island	Swains Island	Muliāva/Rose Atoll
SCRs	2.60	2.53	0.45	0.42	1.23	1.68	1.10
MCEs	2.34	6.94	0.49	0.27	1.70	0.48	1.31
Upper	1.26	6.08	0.22	0.12	0.71	0.23	0.75
MId	1.08	0.67	0.10	0.07	0.54	0.18	0.43
Lower	0.00	0.18	0.17	0.07	0.45	0.07	0.13

Table S.H.6.1b. Geodesic area and reef slope for each NMSAS management area. The mesophotic zones are upper (30–70 m), mid (70–110 m), and lower (110–150 m). SCR = shallow coral reef, MCE = mesophotic coral ecosystem (Montgomery et al. 2019). Slope (mean ±sd)

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	Aunu'u Island A	Aunu'u Island B	Fagalua/Fogama'a	Fagetele Bay	Ta'u Island	Swains Island	Muliava/Rose Atoll
Upper	10.5 ± 8.8	3.8 ± 4.2	29.7 ± 15.1	29.5 ± 14..2	15.6 ± 8.0	50.9 ± 6.5	30.9 ± 13.8
Mid	4.9 ± 5.1	8.1 ± 6.5	35.1 ± 14.3	29.0 ± 17.1	22.7 ± 9.8	56.1 ± 7.2	42.2. ± 17.2

Lower	-	29.8 ± 16.2	31.7 ± 14.2	27.1 ± 17.6	30.9 ± 12.3	73.7 ± 8.1	70.5 ± 8.9

		Aunu‘u Island A	Aunu‘u Island B	Fagalua/ Fogama‘a	Fagatele Bay	Ta‘ū Island	Swains Island	Muliava/ Rose Atoll[a]
Habitat area (km^2)	SCRs	2.60	2.53	0.45	0.42	1.23	1.68	1.10
	MCEs	2.34	6.94	0.49	0.27	1.70	0.48	1.31
	Upper	1.26	6.08	0.22	0.12	0.71	0.23	0.75
	Mid	1.08	0.67	0.10	0.07	0.54	0.18	0.43
	Lower	0.00	0.18	0.17	0.07	0.45	0.07	0.13
Slope (mean ± sd)	Upper	10.5 ± 8.8	3.8 ± 4.2	29.7 ± 15.1	29.5 ± 14.2	15.6 ± 8.0	50.9 ± 6.5	30.9 ± 13.8
	Mid	4.9 ± 5.1	8.1 ± 6.5	35.1 ± 14.3	29.0 ± 17.1	22.7 ± 9.8	56.1 ± 7.2	42.2 ± 17.2
	Lower	–	29.8 ± 16.2	31.7 ± 14.2	27.1 ± 17.6	30.9 ± 12.3	73.7 ± 8.1	70.5 ± 8.9

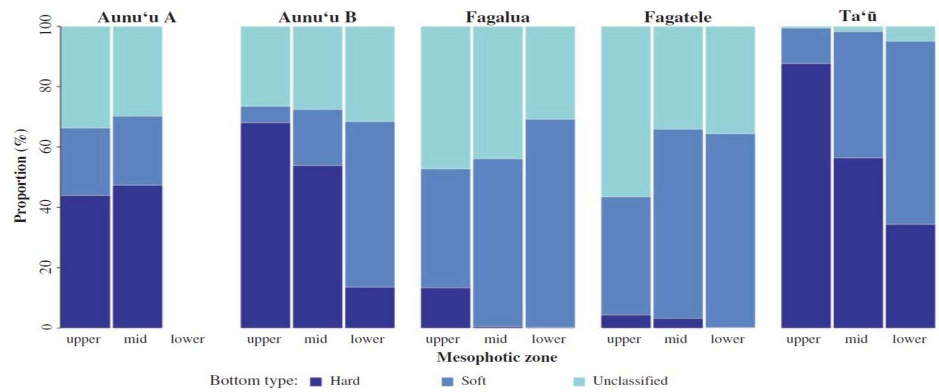

Figure S.H.6.5. Proportion of bottom types in NMSAS mesophotic coral ecosystems. Hard bottom types support corals and sponge communities that attract fish and invertebrates. MCE in the Muliava and Swains Island units were not classified due to the steep topographies along these atolls (Montgomery et al. 2019).

In 2017, divers using rebreathers conducted deep dives in Fagatele, Fagalua/Fogama’a, and Aunu’u. The divers documented mesophotic habitats in these units and sampled antipatharian and gorgonian corals, but were unable to collect quantitative data on habitat status (unpublished data). In 2019, the EV *Nautilus* supported a short exploration of the deep mesophotic zone in the Aunu’u unit. Video taken from the ROV *Hercules* shows a thriving mesophotic ecosystem extending to approximately 175m. The deep mesophotic zone supported coralline algae, large sea fans and black corals. At depths above 105 m the coral community shifts and there are more scleractinian corals. Sharks, trevallies, and schools of snappers and dogtooth tuna were observed at approximately 100 m. Though sparse, these data indicate the presence of

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significant mesophotic habitats within NMSAS and minimal direct human impact. Detailed data on habitat structure, status, and long-term trends for all indicators are lacking.

Pelagic and Deep Sea

Pelagic and deep-sea habitats make up the majority of NMSAS habitats, but are the least well studied. NOAA Office of Exploration and Research (NOAA OER) and the Ocean Exploration Trust (OET) led expeditions to American Samoa in 2017 and 2019, respectively. The expedition teams made great strides in mapping and exploring deep sea habitats across NMSAS using multibeam sonar, remotely operated vehicles, and other specialized tools. The surveys conducted with the ROVs significantly expanded the knowledge of deep sea habitats in American Samoa, including those along island ridges, seamounts, and active hydrothermal vents at the Vailulu'u Seamount. Areas with hard substrate and steady currents were targeted, as they are most likely to support cnidarian and sponge communities that create habitat for other organisms. Although the data from these sites are not directly comparable, as they cover a wide range of depths, slopes, and substrates, and were of varying length, the density of organisms observed can provide insight into their habitat functions.

The Hawaii Undersea Research Laboratory (HURL) analyzed the footage from the OET expedition and calculated densities for each dive (OET / HURL unpublished). The deep ridges along Swains Island supported the highest density of corals and sponges (1732 counts / km) documented by the OET expedition, and the outer slope of Aunu'u and a deep ridge along Rose Atoll also supported relatively high densities (1559 counts /km and 1319 counts /km respectively). All three communities are considered moderate density communities as they contain 1,000-2,999 coral and sponge counts per kilometer. The Ta'u site adjacent to the sanctuary had few sponges, approximately 693 corals per kilometer, while the young Vailulu'u seamount site only had six sponges per kilometer and no corals. Densities were not calculated for the NOAA OER dives. Habitat forming benthic organisms observed during these two expeditions included black, gorgonian, lace, soft, Stoloniferan, and stony corals; sea pens; demosponges; and glass sponges. The HURL analysis also noted that both sponges and corals serve as habitat for a wide range of organisms including echinoderms, arthropods, cnidarians, and mollusks. Ctenophores used sponges but not corals. The expeditions also noted marine debris even at substantial depths (see Question 3), but these did not appear to cause significant habitat disturbance. These expeditions provide a glimpse of deep-sea habitat, however, detailed data and long-term trends for integrity indicators are lacking.

Vailulu'u Seamount is located between the Manu'a islands and Rose Atoll and is the only hydrothermally active seamount within the American Samoa Exclusive Economic Zone (Koppers et al. 2010). It was discovered in 1975 and first mapped in 1999. Vailulu'u volcano is seismically and hydrothermally active, with frequent earthquakes and hydrothermal fluxes (Konter et al., 2004, Staudigel et al. 2006). The Nafanua cone at the center of the seamount formed between 2001 and 2004 (Koppers et al. 2010). Multibeam sonar surveys conducted by the Okeanos Explorer in 2017 detected major depth changes in the summit caldera of Vailulu'u since the 2005 expedition, and comparisons of the data indicated that the cone grew in both height and width (Figure S.H.6.6). The 2019 OET expedition did not detect any notable changes in the crater's bathymetry, but did locate a new hydrothermal vent on the east side of the crater. The crater is by nature a very unstable environment but appears to have four distinct habitats that include the Nafanua summit's iron oxide mats and cutthroat eel habitat, the hostile "Moat of Death", intermediate zones with variable conditions, and rocky bottoms on the outside of the crater. These zones are contiguous, but contrast sharply in their biota (Staudigel et al. 2006). The hydrothermal vent discovered in 2019 supported a high abundance of organisms including crabs, shrimp, and isopods around the plume. A field of dormant chimneys, ranging from 0.5 to about 2 meters in height was located nearby. Some of the chimneys still released warm water, but no bubbles were present (Sudek et al. 2020). The expeditions did not observe any human activity or unnatural alteration of the seamount.

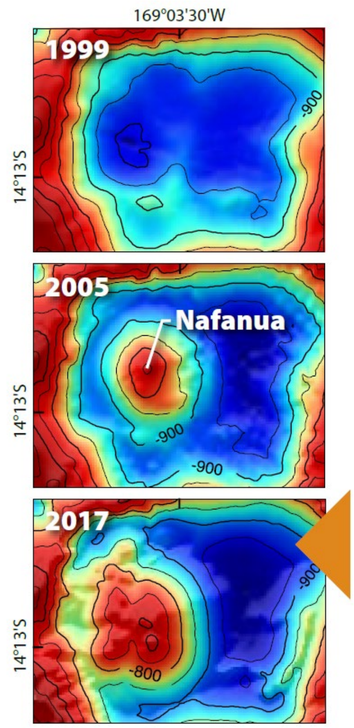

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Figure S.H.6.6. Multibeam bathymetry of the crater at Vailulu'u Seamount (in meters), showing growth of the central cone over time. The map combines data from three different bathymetric surveys. Graphic credit: Jasper Konter, University of Hawai'i at Mānoa; NOAA OER

Conclusion

Despite some minor declines, indicators for habitat integrity suggest that sanctuary habitats are in good/fair condition. Shallow nearshore habitats were exposed to frequent disturbances including cyclones, coral bleaching events, and CoTS, yet these habitats, particularly coral reefs, have demonstrated resilience to these events. However, shallow nearshore habitats are also exposed to direct anthropogenic impacts. For example, the damage from a vessel grounding in Aunu'u has had lasting impacts, but is constrained to a small area. Marine debris continue to be a chronic, but minor problem across all habitats. Data for habitats in the mesophotic and pelagic zones are limited, but do not indicate any substantial impacts to habitats in these areas. Recent deep-sea expeditions did not identify any recent impacts or immediate threats to these habitats, but data are extremely limited and no previous data are available for comparison.

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Question 7: What are contaminant concentrations in sanctuary habitats and how are they changing?

***Rating**: Good/Fair, Confidence - Medium; **Trend**: Undetermined, Confidence - Medium*

***Status Description**: Selected contaminants are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.*

***Rationale**: Data on contaminants within the sanctuary are limited. Heavy metals, hydrocarbons, pesticides, and pharmaceuticals were detected in water and sediment in Fagatele Bay in 2018, but only nickel was observed at concentrations above recommended screening levels. Iron contamination from the 1993 grounding at Rose Atoll persists but is limited in scope and continues to improve. As the Fagatele data are from a single point in time and no recent data are available for other sanctuary units, the expert confidence in this rating is medium and experts were unable to determine a trend rating.*

Question 7 Indicator Table. Summaries for the key indicators related to contaminants that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Non-point Source Pollution: Contaminants	Nearshore Habitats	Polidoro et al. 2017, NCCOS in prep	Soil samples taken near the Futiga landfill in American Samoa showed high levels of lead, malathion (pesticide), PAHs, and phthalates (Polidoro et al. 2016). A study in 2019 collected water and sediment samples in Fagatele Bay for contaminant screening. The water samples were screened for 400 compounds, including heavy metals, hydrocarbons, pesticides, pharmaceuticals and other organic compounds. Overall, the results indicate that Fagatele Bay, while not pristine, is a relatively clean marine environment. Most of the target compounds were not detected or were present in very low concentrations. No PAHs or organic compounds exceeded the available LC50 levels. Pharmaceuticals that could cause endocrine disruption at higher concentrations were detected. Sediment samples were tested for 16 different metals. Silver, arsenic, cadmium, chromium, copper, mercury, lead, and zinc were all below the Effects Range Low (ERL) indicating possible toxicity to benthic infauna. The team noted that the concentration of arsenic, chromium, nickel, and selenium at some stations in Fagatele was higher than the mean values observed at Faga'alu (a more impacted watershed on Tutuila). Nickel was the only metal that exceeded ERL values at 3 out of 5 sites within the bay and exceeded the Effects Range Median (ERM) value at one site which may indicate probable toxicity to benthic infauna (Ni measurements = 69.6, 23.9, 24.1 ppm, ERL = 20.9 ppm; ERM = 51.6 ppm). ERL values are not available for

			some metals (aluminum, iron, manganese, antimony, selenium, silicon, tin), but all values from Fagatele Bay were below values previously measured in Faga'alu except for selenium.
Point-source Pollution: Iron	Nearshore Habitats	Green et al. 1997, Schroeder et al. 2008	The Jin Shiang Fa grounded at Rose Atoll in 1993 and scattered metal debris over a 3,500 m^2 area (Green et al. 1997). Most of the metal was removed, but approximately 1 ton of metallic debris remains. Iron is a limiting nutrient at Rose Atoll and these remaining metal pieces are releasing iron into the water, supporting a persistent cyanobacteria bloom on the reef flat surrounding the wreck site (Schroeder et al. 2008) that is still present in 2020. The conditions appear to be improving and most of the impacts are outside of the sanctuary on the reef flat. Note: Iron is normally considered a nutrient, but as Rose Atoll is an iron limited habitat and this is a discrete anthropogenic impact, it is also treated as a contaminant in this case.
Point source Pollution: Chemical	Nearshore Habitats	Green et al. 1997, ASEPA	The Jin Shiang Fa was carrying an estimated 100,000 gallons of diesel fuel (# 2 fuel oil), 500 gallons of lube oil, and 2,500 pounds of refrigeration system ammonia when it struck the reef at Rose Atoll in 1993. All of these contaminants were discharged into the marine environment at the wreck site on the southwest arm, where they subsequently spread over the reef flat and into the lagoon. Responders noted that oil was pounded into the reef structure and sediments by waves. Petroleum products persisted in the sediment at the wreck site for at least 22 months after the spill (Green et al. 1997). It is not known if these chemicals persist. Pollution from the No. 1 Ji Hyun wreck off of Aunu'u in 2016 were quickly removed and any that may have reached the water likely dissipated rapidly in the high energy environment. No data were available regarding the effluent released by the Aunu'u sewage outfall, but ASEPA noted that the discharge zone is highly mixed.

Contaminants have been found even in some of the world's most remote marine habitats (Jamieson et al. 2017), so it is likely that contaminants are present in remote parts of NMSAS. Known sources of contamination include the Futiga landfill, vessel grounding sites at Rose Atoll and Aunu'u, and the sewage outfall at Aunu'u (see Question 2 and 3).

Polidoro et al. (2017) confirmed the presence of lead, malathion (pesticide), PAHs, and phthalates in soils around the Futiga landfill on Tutuila. NMSAS partnered with NCCOS in 2019 to sample water and sediment in Fagatele Bay to determine if contaminants have reached the marine environment. The team screened the samples for over 400 compounds including heavy metals, hydrocarbons, pesticides, pharmaceuticals and other organic compounds. Many of these were not detected or were present in very low concentrations. Nickel was the only metal that exceeded Effects Range Low screening levels, indicating possible toxicity to benthic infauna in the bay (see Figure S.WQ.2.1). This elevated nickel concentration may be natural or a sign that contaminants from the landfill are reaching the bay. The concentrations of other metals and compounds were below established regulatory and screening levels, but there are no recommendations for many of these compounds. Dr. Whitall noted that nothing alarming has been observed in Fagatele and it is a relatively clean system compared to other sites around the country. The concentration of As, Cr, Ni, and Se at some stations in Fagatele was higher than the mean values observed at Faga'alu (a more impacted watershed on Tutuila). He did note that there may be sub-lethal effects, such as endocrine disruption in marine animals, at concentrations below the available screening levels for some contaminants. More work needs to be conducted to determine if the contaminants are from the landfill or other anthropogenic impacts such as agriculture. The adjacent bay, Fagalua/ Fogama’a, may also be affected by the landfill and agricultural practices and should be evaluated. Experts agreed that further monitoring of these pollutants is essential as these values could increase over time with landfill use and changes in hydrology.

In 1993, the Taiwanese longline fishing vessel *Jin Shiang Fa* ran aground on the seaward edge of the southwest arm of Rose Atoll (see Question 2 and Figure S.H.7.1). The wreck resulted in the release of fuel, oil, and refrigerant, and petroleum products were detectable in the sediments at the wreck site for at least 22 months after the spill. Most of the vessel was removed, but some metal debris remains embedded in the reef (Green et al. 1997). The metal sections are corroding and releasing iron into the water and have caused a persistent cyanobacteria bloom near the wreck site (Schroeder et al. 2008). Although iron enrichment and cyanobacteria blooms are normally considered a form of eutrophication, in this case, ONMS is treating it as a contaminant at Rose Atoll as it is naturally a limiting element in this remote ecosystem and was introduced through a discrete event. USFWS is evaluating a project to remove the remaining metal debris, but the project will be difficult as the debris is embedded in the reef matrix. Pollution from the No. 1 *Ji Hyun* wreck off of Aunu’u in 2016 was quickly removed and any pollutants that may have reached the water likely dissipated rapidly in the high energy environment (see Question 3 for more information on the grounding event).

Figure S.H.7.1. The extent of the 1993 vessel grounding impacts at Rose Atoll can be observed through satellite imagery over time. A persistent cyanobacteria bloom is still visible near the site of the grounding (TBD).

Commented [14]: Working on obtaining a better set of satellite images available to NOAA.

Commented [15]: And will also circle grounding site on image.

Data is not available regarding effluent released by the Aunu'u sewage outfall. While there is no industry on Aunu'u, household sewage may contain pharmaceuticals and other contaminants. ASEPA stated that the discharge zone is highly mixed and accumulations are therefore unlikely.

Conclusion

Contaminants have been observed in Fagatele Bay and Rose Atoll, but are present in low levels and have not caused measurable degradation to sanctuary resources. Potential sources of contamination have been identified that may affect Fagalua/Fogama'a and Aunu'u units as well, but contaminant screening has not been conducted at these locations. Heavy metals, hydrocarbons, pesticides, and pharmaceuticals were detected in water and sediment in Fagatele Bay in 2019, but only nickel was observed at concentrations above recommended screening levels. Experts agreed that further monitoring of these pollutants is essential as these values could increase over time with changes in landfill use and hydrology. The 1993 grounding of the *Jin Shiang Fa* at Rose Atoll released fuel, oil, and refrigerant into the water. Petroleum products were detectable in the sediments at the wreck site for at least 22 months after the spill, but it is not clear if there is lasting contamination from these chemicals. Iron pollution from the grounding persists but the impacts to the sanctuary are limited in scope and continue to improve. USFWS is evaluating a project to remove remaining metal debris from the site. In Aunu'u, responders quickly removed pollution from the 2016 vessel grounding and any contaminants released from the vessel likely dissipated quickly. The sewage outfall in Aunu'u may be a source of contamination, but the chemical composition of the effluent is unknown and no testing has been conducted. The discharge zone is highly mixed and accumulation is unlikely.

Question 7 Cited Resources

Green, A., Burgett, J., Molina, M., Palawski, D., Gabrielson, P. (1997) The impact of a ship grounding and associated fuel spill at Rose Atoll National Wildlife Refuge, American Samoa. Report to US Fish and Wildlife Service, Pacific Islands Ecoregion, Honolulu, Hawaii

Jamieson, A., Malkocs, T., Piertney, S., Toyonobu, F., and Zhang, Z. (2017) Bioaccumulation of persistent organic pollutants in the deepest ocean fauna. *Nat Ecol Evol* 1, 0051. https://doi.org/10.1038/s41559-016-0051

NCCOS study ------- INSERT IF REPORT BECOMES AVAILABLE BEFORE CR IS PUBLISHED

Polidoro B A, Comeros-Raynal M T, Cahill T, Clement C (2017) Land-based sources of marine pollution: Pesticides, PAHs and phthalates in coastal stream water, and heavy metals in coastal stream sediments in American Samoa, Marine Pollution Bulletin 116:501-507. https://doi.org/10.1016/j.marpolbul.2016.12.058

Schroeder R, Green A, DeMartini E, Kenyon J (2008) Long-Term Effects of a Ship-Grounding on Coral Reef Fish Assemblages at Rose Atoll, American Samoa. Bulletin of Marine Science 82:345-364

Question 8. What are the levels of human activities that may adversely influence habitats and how are they changing?

Status: *Fair, Confidence - High;* ***Trend****: Undetermined, Confidence - Medium*

Status Description: *Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.*

Rationale: *Vessel groundings have had localized effects on coral reef habitat in the Aunu'u and Muliava units. Destructive fishing practices have not been observed recently, but abandoned fishing gear has been removed from sites on Tutuila. Marine debris is widespread across the sanctuary, but documented habitat impacts have been limited. Deep-sea surveys detected significant marine debris accumulations in the deep sea around Tutuila, but did not detect marine debris in the Muliava unit. Limited data are available for all sites, particularly for pelagic, mesophotic, and deep-sea habitats.*

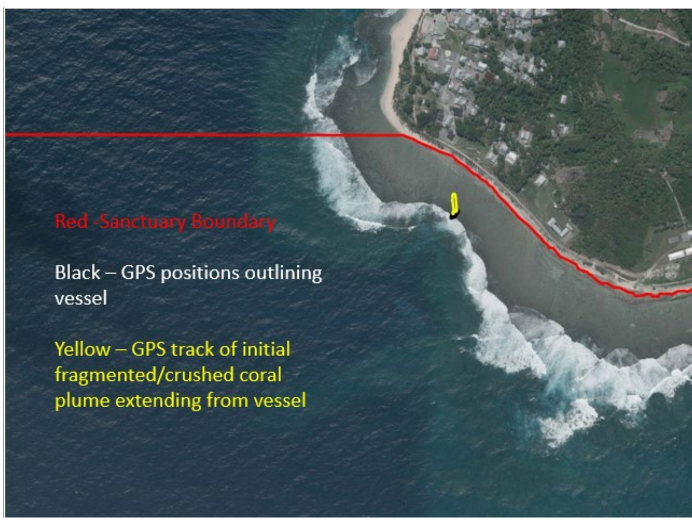
Human activities can impact the structural (physical), biological, oceanographic, acoustic, and/or chemical characteristics of the habitat. Structural impacts, such as removal or mechanical alteration of habitat, can result from various destructive fishing methods (e.g., drag nets, chemicals, and explosives), and anchoring. Marine debris, including abandoned fishing gear, nets, and buoys, can damage fragile corals in the shallow coral reefs. Ship groundings on coral reefs can cause extensive physical damage to the reef structure and can release toxic petrochemicals, killing reef organisms. Any wreckage left on the reef can continue to cause physical damage and may release iron into nearby waters, disrupting natural nutrient cycles.

Destructive fishing methods, particularly dynamite fishing, were documented in the previous condition report, but no evidence of dynamite fishing has been detected since 2007 in any of the units. Fishing lines, hooks, and weights have been removed from the reef at multiple sites and anchor damage has been observed in Aunu'u, Fagatele and Fagalua/Fogama'a, but damage has been limited and localized.

Marine debris has been documented along the beaches in all NMSAS units. Surveys in Fagalua / Fogama'a indicated that polystyrene foam and plastic are the biggest contributors at these sites. A piece of abandoned net damaged a large table coral in Fagalua in 2019 and a drifter drogue that hung up in Fagatele Bay in 2020 broke a large table coral and killed three additional corals from shading and abrasion. Based on deep sea surveys conducted in 2017 across the US Pacific Islands, Tutuila was noted as a hot spot for deep-sea marine debris, likely due to cyclones and the 2009 tsunami. Marine debris in NMSAS was mostly associated with fishing debris (Amon et al 2020).

Two vessel groundings have caused lasting habitat impacts to NMSAS coral reef habitats. On Rose Atoll, the grounding of a Taiwanese 135-foot long-line tuna-fishing vessel in October 1993 released 100,000 gallons of diesel and 500 gallons of lube oil into refuge waters. Prevailing currents carried these contaminants across the reef flat and into the lagoon. The diesel and oil killed giant clams, sea cucumbers, reef-boring urchins, and a large area of coralline algae. The grounding itself physically damaged the reef when the ship hit the upper portion of the outer reef slope and moved across the reef before coming to rest (Green et al. 1997). Extensive removal efforts were undertaken over many years by USFWS, but some iron debris remains. Subsequent monitoring and assessment studies indicate that the high concentration of iron has led to algal blooms that further inhibit repopulation of CCA and filter feeding marine organisms (Schroeder et al. 2008).

In Aunu'u, the 62 ft. F/V *No.1 JiHyun* lost its main engines and grounded off the west side of the island in the NMSAS Multiple Use Zone on April 14, 2016 (Figure S.WQ.8.1). Severe weather (Category 3 Tropical Cyclone Amos), high winds and surf, limitations on site access, daylight high tides and availability of resources including tugs, tow lines and trained personnel made the response challenging. Three unsuccessful removal attempts occurred under Oil Pollution Act (OPA) authorization under the leadership of the US Coast Guard. An additional three removal efforts occurred, in consultation with USCG, under the authority of the National Marine Sanctuaries Act (NMSA) and leadership of the NOAA ONMS, eventually resulting in the successful removal of the F/V No.1 JiHyun on August 19, 2016.



Commented [16]: @kathy.broughton@noaa.gov I recommend redoing this legend with squares to show each color category and text descriptions in the same color. The black category is particularly confusing, as the text color is white, whereas the other two match the color they are describing. Please use sentence case for all legend descriptions.

Figure S.WQ.8.1. Map of the reef area affected by the grounding of the F/V *No.1 JiHyun* on August 19, 2016 in the Aunu'u multipurpose zone.

Because of the severe weather the wreck shifted several times before it could be removed, resulting in significant scouring injuries. The grounding and removal efforts impaired 1,641 m^2 of reef habitat (Figure S.WQ.8.2), leaving a large rubble field with low complexity and rugosity (Figure X). Subsequent monitoring showed that two years after the removal no coral recruitment had occurred within the scouring injury and most of the substrate was covered with turf and small, low profile macroalgae. The decreased reef complexity and rugosity does not provide appropriate habitat for most reef organisms and the site has not recovered. Due to the intensity of wave action in that area, restoration of the grounding site is not feasible.

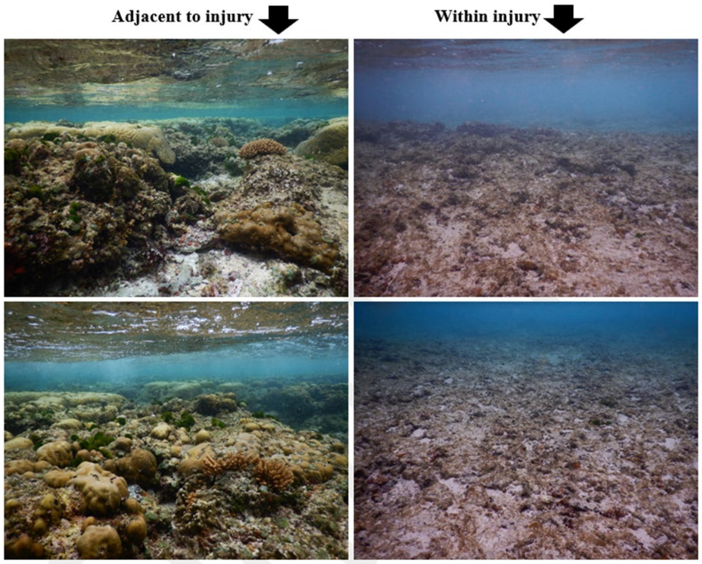


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Figure S.WQ.8.2. Pictures of the reef adjacent to the grounding site and within the grounding injury footprint. Due to shifting rubble and reduced habitat complexity, this area has not recovered from the injury.

Anthropogenic noise is an increasing concern in marine habitats. Ecological acoustic recorders (EARs) were deployed in Fagatele and Rose Atoll in 2006-2007 to assess noise. The data collected from these devices indicated that anthropogenic noise is limited in these areas and appears to be associated with infrequent vessel visits to the sites. A new recorder was installed in Fagatele Bay in 2019, but data have not been analyzed yet.

Conclusion

Vessel groundings have had severe localized effects on coral reef habitat in the Aunu’u and Muliava units. Destructive fishing practices have not been observed recently, but abandoned fishing gear has been removed from sites on Tutuila. Marine debris is widespread across the sanctuary, but documented habitat impacts have been limited. Deep-sea surveys detected significant marine debris accumulations in the deep sea around Tutuila, but did not detect marine debris in the Muliava unit. Limited data are available for all sites, but particularly for pelagic, mesophotic, and deep-sea habitats.

Question 8 Literature Cited

Amon D J., Kennedy B R. C., Cantwell K, Suhre K, Glickson D, Shank T M., Rotjan R D. (2020) Deep-Sea Debris in the Central and Western Pacific Ocean. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2020.00369

Green, A., Burgett, J., Molina, M., Palawski, D., Gabrielson, P., 1997. The impact of a ship grounding and associated fuel spill at Rose Atoll National Wildlife Refuge, American Samoa. Report to US Fish and Wildlife Service, Pacific Islands Ecoregion, Honolulu, Hawaii

Schroeder RE, Green AL, DeMartini EE, Kenyon JC (2008) Longterm effects of a ship grounding on coral reef fish assemblages at Rose Atoll, American Samoa, Bulletin of Marine Science 82(3):345-364

This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Living Resources (Questions 9 – 13)

The following information provides an assessment of the status and trends of key living resource indicators in NMSAS for the period 2007–2020.

Question 9 evaluates the status of keystone and foundation species. Both are important components of the ecosystem. A "keystone" species has a disproportionately large effect on its environment relative to its abundance (Cottee-Jones and Whittaker 2012). "Foundation" species are those that define much of the structure of a community by creating locally stable conditions, such as providing primary prey for local predators or serving as biogenic habitat (sensu Dayton 1972).

Commented [1]: is there a reference for who/how the species to rate were selected? Is this based on whatever was chosen the last time this was done?

Question 10 focuses on "other focal species". These include culturally important species such as giant clams and food fish, large charismatic species such as sea turtles and humpback whales, indicator species, and species that are of interest for other reasons.

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Question 11 assesses the impacts of non-indigenous species. Also called alien, exotic, non-native, or introduced species, and invasive species when they cause environmental or economic impacts, these are animals or plants living outside their endemic geographical range.

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Question 12 addresses the status of biodiversity, which is defined as variation of life at all levels of biological organization, and commonly encompasses diversity within species (genetic diversity), among species (species diversity), and comparative diversity among ecosystems (ecosystem diversity). Biodiversity can be measured in many ways. The simplest measure is to count the number of species found in a certain habitat or ecosystem, termed species richness. Other indices of biodiversity couple species richness with relative abundance to provide a measure of evenness and heterogeneity. Whether measured or not, changes in biodiversity can be inferred through assessments of functionally important species, altered food web structure, and using other proxies that reflect changes in relative abundance.

Human activities that have the potential to negatively impact living resources are the focus of Question 13. These include activities that remove plants or animals as well as activities that have the potential to injure or degrade the condition of living resources. Activities that can facilitate the introduction or spread of non-indigenous species are also relevant to this question.

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Question 9: What is the status of keystone and foundation species and how is it changing?

***Status**: Mixed[1], Confidence - High; **Trend**: Not Changing, Confidence - Medium*

***Status Description:** The status of keystone or foundation species is mixed.*

Fish species	*Fair/Poor*	*The status of keystone and foundation species suggests severe degradation in some but not all attributes of ecological integrity.*
Benthic species	*Good / Fair*	*The status of keystone or foundation species may preclude full community development and function, but has not yet led to measurable degradation.*

***Rationale**: The status of keystone and foundation species varies across taxa. Experts noted that benthic foundation species warrant a Good/Fair ranking, but considering the low abundance of certain fish species that play critical ecological roles , the rating was downgraded to Fair/Poor. Overall fish abundance is low and the lack of large predators and large herbivores in shallow coral reef habitats may decrease ecosystem resilience. Benthic foundation species such as corals and crustose coralline algae have fluctuated but have consistently recovered following coral bleaching events, starfish outbreaks, and storms. Data for mesophotic and deep sea species are limited, but do not indicate degradation of these habitats.*

Question 9 Indicator Table. Summaries for the key indicators related to keystone and foundation species that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Zooxanthellate Scleractinian Corals: Demographics, Acute Impacts	Nearshore Habitats	Charles Birkeland pers. comm, Vargas-Angel et al. 2019	Corals in American Samoa have substantial recruitment and well-filled size classes, good signs for healthy coral communities (Charles Birkeland pers comm). In 2018, adult coral density was highest in the mid-depth strata and adult coral density was greater than juvenile density across all reporting units and depth strata. At Ta'u and Rose, the deep strata had higher adult coral density than other islands in American Samoa. This may reflect the impacts of coral bleaching events from 2015-2017. At Ta'u, the density of juvenile coral was high in the deep strata and almost equal to adult density. Throughout NMSAS, adult and juvenile coral density did not change significantly between 2015 and 2018. Disease prevalence remained low in all units. (Vargas-Angel et al. 2019). NMSAS noted that white syndrome prevalence appears to increase during warming events and warrants further study. Dr. Charles Birkeland (pers. comm.) noted that *Acropora* communities in Fagatele Bay remained in

[1] Experts assigned a rating of Fair/Poor at the workshop, but recommended splitting the status rating. Following the workshop, a new “mixed” status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

			good condition between 1995 and 2018 and the coral community was in the best condition he has observed in the past 40 years.
Crustose Coralline Algae: Cover, Disease Prevalence	Nearshore Habitats	Vargas-Angel et al. 2019	CCA cover remains high and increased at many sites between 2015 and 2018. Coralline Lethal Orange Disease (CLOD) has been observed in Fagatele Bay at low levels of occurrence. In 2018, an increase in disease prevalence was observed in Fagatele Bay (ESD) and NMSAS staff noted a further spike in 2020. Elevated water temperatures are critical to infection and propagation of CLOD (Cervino et al. 2005). It is therefore reasonable to consider that recent warming events (2015 onwards) and increased CCA cover contributed to the proliferation of CLOD. This disease has not been documented at Rose or Swains but was also recorded at a low level in the Ta'u Sanctuary in 2015 (ESD).
Reef Sharks: Biomass	Nearshore Habitats	Nadon et al 2012, MacNeil et al 2020	Nadon et al (2012) recorded grey reef, whitetip, black tip, and nurse sharks in American Samoa. White tip reef sharks had the highest abundance of these species. Using a simulation, they estimated that unexploited shark densities would be between 1.2 sharks/ha and 2.4 sharks/ha; current densities are at 4–8% of these estimates. Recent BRUVS surveys also recorded very low shark densities in American Samoa compared to some other islands in the South Pacific (MacNeil et al 2020).

Large Parrotfish: Fish Biomass, Size Structure	Nearshore Habitats	Comeros-Raynal et al. 2019, Comeros-Raynal 2021, MARC 2020, Kobayashi et al. 2011, McCoy et al. 2018, Vargas-Angel et al. 2019	On Tutuila, parrotfish biomass in the 10-30cm size class has remained stable since 2010, with a slight increase in 2018. Biomass of large parrotfish (>30cm) was more variable with a slight increase in 2018. In Ta'u, parrotfish biomass is dominated by larger parrots and is well above the American Samoa average. Swains had few parrotfish in the 10-30cm size class, and biomass of larger parrotfish is variable. Rose had more small parrotfish, but relatively low parrotfish biomass. It is not clear what is driving these patterns. (McCoy et al. 2018, Vargas-Angel et al. 2019). Large-bodied parrotfish account for approximately 10% of the target reef fish community in Aunu'u and Fagatele Bay, while small bodied parrotfish account for approxmately 50%. Parrotfish abundances at both sites were below the average for Tutuila (Comeros-Raynal et al. 2019, MARC 2020). Surveys in Fagatele Bay in 2019 recorded very low recruitment of parrotfish on the reef flat and reef slope compared to other sites on Tutuila (i.e., sites adjacent to intermediate and extensive watersheds) (Mia Comeros-Raynal 2021). Bumphead parrotfish (*Bolbometopon muricatum*) were observed at Ta'u (1.08 fish per km2) and at Tutuila (0.41 fish per km2) during towed diver surveys (NOAA Status Report 2011). No recent sightings have been reported and this species is considered by many to be functionally extinct in American Samoa.
Surgeonfish and Unicornfish: Fish Biomass, Size structure	coral reef	Comeros-Raynal et al. 2019, Comeros-Raynal 2021, MARC 2020, WPRFMC 2019	In Aunu'u, small surgeonfish make up about 10 % of the target reef fish community and large-bodied surgeons (orangespine unicornfish) were not observed during surveys. In Fagatele, small surgeonfish make up about 12 % of the fish community and large-bodied surgeons (orangespine unicornfish) are approximately 10% of the target reef fish community (Comeros-Raynal et al. 2019, MARC 2020). The mean size of surgeonfish is approximately 15cm across all islands (WPRFMC 2019), which may be cause for concern. Surgeonfish recruitment on the reef flat and reef slope in Fagatele Bay was moderate in 2019 and comparable to other surveyed sites in American Samoa. In general, fish recruitment was higher on the reef flat compared to the reef slope (Comeros-Raynal pers. comm.).

Corals: Species presence and richness	Mesophotic Coral Ecosystems	Bare et al 2010, Montgomery et al. 2019, Wagner 2017	Approximately 110 species of scleractinian corals have been observed at mesophotic depths in American Samoa (Montgomery et al. 2019). Encusting and plate-like coral are the most common growth forms across depths. Branching corals appear to be most abundant at deeper depth ranges. Massive corals are more common at shallower depths (Bare et al. 2010). In 2019, the ROV Hercules aboard the E/V Nautilus captured video of *Leptoseris* corals as deep as 148m in Aunu'u. Sea fans (*Anella* sp.) and unidentified antipatharian corals were observed in the deep mesophotic zone (OET 2019). During rebreather surveys in Fagatele and Fogama'a/Fagalua, a variety of gorgonian and black coral specimens were documented and samples collected for taxonomic ID purposes (Wagner 2017). Data are insufficient to evaluate trends.
Corals and Sponges: Cover, density	Deep Sea	Kennedy et al 2019, NOAA DSCRTP 2020, OET / HURL unpub. Data	Two expeditions documented a large number of black, gorgonian, lace, soft, stoloniferan, and stony corals; sea pens; demosponges; and glass sponges (Kennedy et al 2019, NOAA DSCRTP 2020). In 2019, moderate-density communities (1,000 - 2,999 combined counts per km) were observed at Swains, Aunu'u, and Rose Atoll. Footage from the 2019 E/V Nautilus expedition showed over 1,500 animals including echinoderms, arthropods, cnidarians, and mollusks associated with either a coral or sponge (OET / HURL unpublished).

Shallow coral reefs in NMSAS are diverse, complex systems and many species are highly specialized, making it difficult to select single keystone and foundation species for evaluation. In the sanctuary's mesophotic and deep-sea ecosystems, too little is known about ecological interactions and individual species' roles in the ecosystem to identify individual keystone or foundation species at this time. So for this question, groups of ecologically important species are evaluated for their combined contributions to the ecological integrity of their respective ecosystems.

Zooxanthellate Scleractinian Corals

Scleractinian corals are important foundation species for shallow coral reef ecosystems, providing structure and food for many other reef organisms. Over 150 species of coral have been documented in NMSAS, but species-specific data are limited. Coral communities were affected by coral bleaching events in 2015, 2016, 2017, and 2020, a crown-of-thorns sea stars outbreak in 2014-2017, and Cyclone Gita in 2018. Coral diseases have been observed, but prevalence has remained low. Despite these episodic events, overall coral cover has remained stable since 2007 (See Habitat section), and expert opinion is that the corals in Fagatele Bay are doing better than in the recorded past.

Coral cover provides a good metric of reef habitat quality, but coral community demographics provide deeper insight into the ecology of these foundational species. Dr. Charles Birkeland noted that despite frequent disturbances, reefs in American Samoa, and particularly in Fagatele Bay, seem to have substantial coral recruitment and well-filled size classes. These are signs of healthy coral communities, indicating the presence of robust older corals that have been resilient to disturbance and the successful recruitment of new corals into the ecosystem. Dr. Birkeland noted that *Acropora*, in particular, exhibited these trends in Fagatele Bay. In 1995 the *Acropora* community was dominated by small to mid-size colonies and by 2018 the community had shifted to more mid-sized corals and had full upper size classes, including a number of colonies greater than 160cm across(C.Birkeland pers comm).

NOAA PIFSC ESD noticed similar patterns in their 2015 and 2018 surveys, with evidence of recent recruitment and stable juvenile and adult colony densities observed across all sites despite repeated bleaching events (Figure S.LR.9.1). ESD noted that adult coral density in 2018 was highest in the mid-depth strata, which may reflect adult mortality in the shallow depth zone from repeated coral bleaching events. At Swains Island, observers noted that the bleaching events had a visible effect on coral community demographics, and further analysis indicated that the density of *Pocillopora* colonies declined by over 60% between 2015 to 2018. Deep reefs in Ta'u appear to have experienced higher mortality than other deep sites, but both adult and juvenile colony density were higher there in 2018 than most other sites and depth strata. Rose also had a relatively high proportion of adult colonies in the deep depth strata. Disease prevalence was low (1-2%) at all sites and did not change significantly between years (Vargas-Angel et al. 2019).

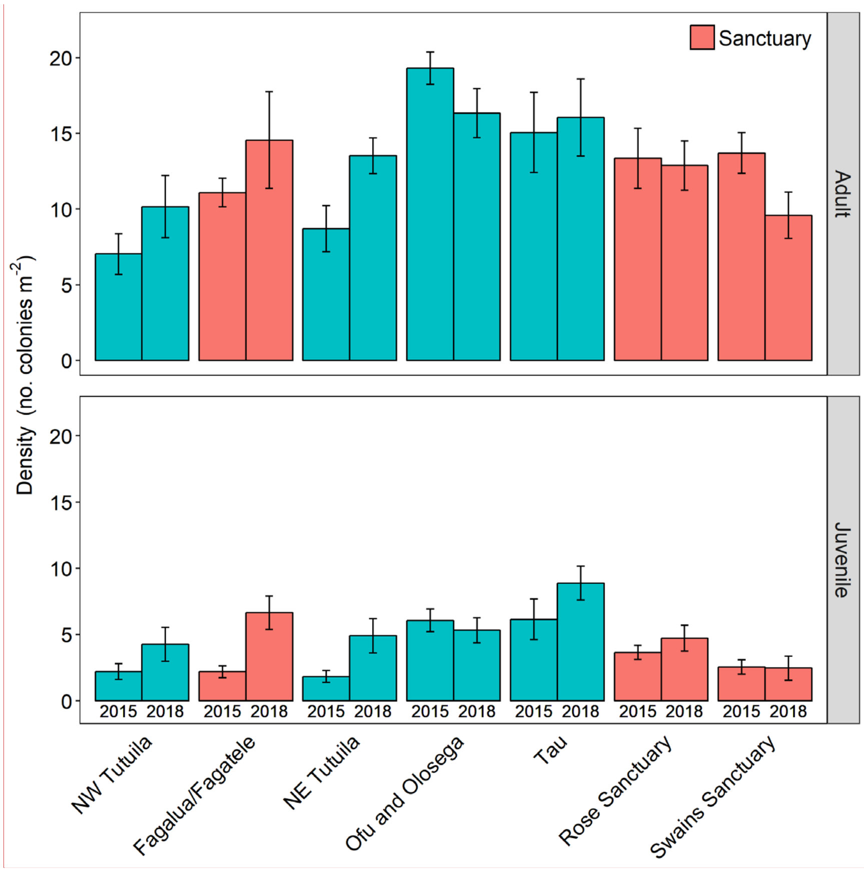

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Figure S.LR.9.1. The density of adult and juvenile coral colonies (# of colonies / m2) was stable from 2015 to 2018 across American Samoa despite repeated bleaching events (Vargas-Angel et al. 2019).

Coralline Algae

Coralline algae are an important component of the reef in American Samoa, cementing the reef substrate together, stabilizing rubble after disturbances, building algal ridges along high energy reef margins, creating habitat for fish and invertebrates, and attracting coral larvae to settle on reefs (Littler and Littler 2013). Video taken from the ROV Hercules off of Aunu'u in 2019 documented coralline algae as deep as 175m (OET 2019). At Rose Atoll, coralline algae is a major component of the reef framework and large knob forming coralline algae are common. Percent cover on shallow reefs increased temporarily after coral bleaching events, but has remained relatively stable/high since 2007 (See Habitat section). No quantitative data exist for mesophotic coralline algae. Coralline Lethal Orange Disease has been observed consistently in Fagatele Bay, and prevalence appears to increase with sea surface temperature anomalies. Overall, mean CLOD occurrence was low (<0.2) across survey years. CLOD was not observed at Swains Island or Rose Atoll (Vargas-Angel et al. 2019).

Reef Sharks
Sharks are an important component of coral reef ecosystems. Whitetip, gray reef, black tip, and nurse sharks are the most common reef sharks encountered in American Samoa. The status of sharks was listed as critical in the 2018 CRCP status report on reef condition in American Samoa (CRCP 2018). This measure was based on reef fish monitoring data from NOAA PIFSC ESD from 2002-2015 compared with a model-generated estimate of baseline shark abundance in American Samoa (Nadon et al. 2012). The model estimated that baseline reef shark densities should be between 1.2 sharks/ ha and 2.4 sharks/ ha. The observed reef shark density is currently at 4-8% of these calculated baseline levels (Nadon et al. 2012). Large fish biomass is low across the territory. Remote Swains Island has the highest abundance of large fish, including sharks. A school of juvenile gray reef sharks (<1m) was encountered there in 2012, which is a promising sign. Surveys in Ta'u in 2021 noted frequent encounters with reef sharks (G. Coward pers.comm.). A recent global assessment of baited underwater video system deployments also concluded that American Samoa's reef shark populations are depleted and have low conservation potential (MacNeil et al. 2020). This may have impacts on reef fish populations and long term resilience of shallow coral reef ecosystems.

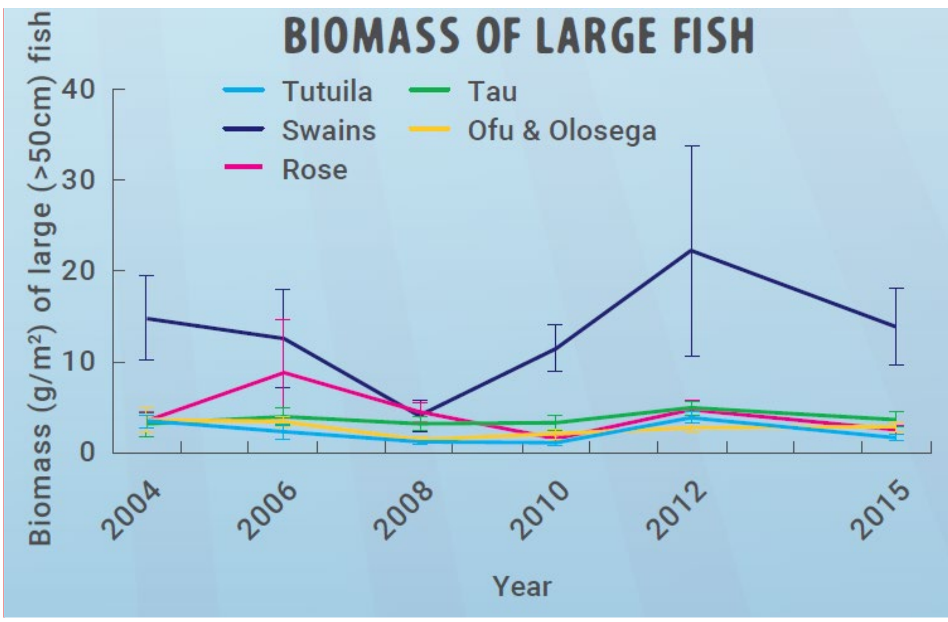

Figure S.LR.9.2. Biomass of large fish (>50cm) observed during towed diver surveys in American Samoa 2004-2015. (CRCP 2018, NOAA PIFSC ESD 2018, CREP 2017)

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Large Parrotfish
Large parrotfish (Family: Labridae: Scarini) such as *Bolbometopon muricatum*, *Chlorurus microrhinos*, *Scarus rubroviolaceus*, *Hipposcarus longiceps*, *S. forsteni*, *S. altipinnis*, and

Cetoscarus ocellatus, through their diverse feeding strategies, play an important role in coral reef ecosystem dynamics by removing algae, opening up substrate for coral settlement, and keeping fast growing coral species in check (Green & Bellwood, 2009). These species are also desirable food fish and are common targets for spearfishing. Large parrotfish were particularly impacted by SCUBA spearfishing practices in American Samoa in the 1990s (Page 1998). Page noted that some of these large species were harvested before reaching sexual maturity and that SCUBA spearfishing accounted for up to 89% of the total annual yield. The report recommended an immediate ban on the practice and this was supported by the work of Dr. Alison Green and Dr. Chuck Birkeland (Gillet and Moy 2006). SCUBA spearfishing was banned in 2002, but these species are still harvested by free divers and have not fully recovered. For instance, the Bumphead Parrotfish, *Bolbometopon muricatum,* is now considered functionally extinct in American Samoa by local experts as there have only been two observations of this species since 2002, one in Tutuila and one in Ta'u (Kobayashi et al. 2011). The other species have been observed, but large individuals are still rare around most islands (NOAA ESD 2018).

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NOAA PIFSC ESD began survey efforts for large fish (>50cm) in 2004. Since that time, large fish biomass has remained low across the territory (Figure S.LR.9.2; CRCP 2018, NOAA PIFSC ESD 2018, CREP 2017). In Tutuila, parrotfish communities are skewed towards smaller individuals (10-30cm), but large parrotfish (>30cm) biomass increased in 2018 (Figure S.LR.9.3; Vargas-Angel et al. 2019, McCoy et al. 2018). These small parrotfish accounted for over 50% of food fish biomass at CRAG's Aunu'u and Fagatele Bay monitoring sites, but large parrotfish only account for 10% of fish biomass (Comeros-Raynal et al. 2019, MARC 2020). A recent recruitment survey noted that parrotfish recruitment in Fagatele Bay is very low relative to sites adjacent to intermediate and disturbed watersheds. The emerging complexity of parrotfishes' nutritional ecology, as microphages that target cyanobacteria or protein-rich autotrophs on calcareous substrata [Clements et al. 2016], suggests a mechanism for driving the spatial pattern of parrotfish recruit densities (Comeros-Raynal pers. comm.). Ta'u consistently had the highest biomass of large parrotfish during these survey efforts and the biomass of large parrotfish was greater than small parrotfish biomass. Swains Island also had a higher proportion of large parrotfish to small parrotfish, but overall parrotfish abundance is low. This may be due to Swains Island's remote location and position relative to major larval sources in the region (Kendall and Poti 2011). Rose Atoll also had a low abundance of large parrotfish, but the biomass for small parrotfish was comparable to Tutuila. This could indicate a lack of recruitment for large bodied parrotfish species due to the atoll's location relative to major larval sources (Kendall and Poti 2011), or unreported fishing activity.

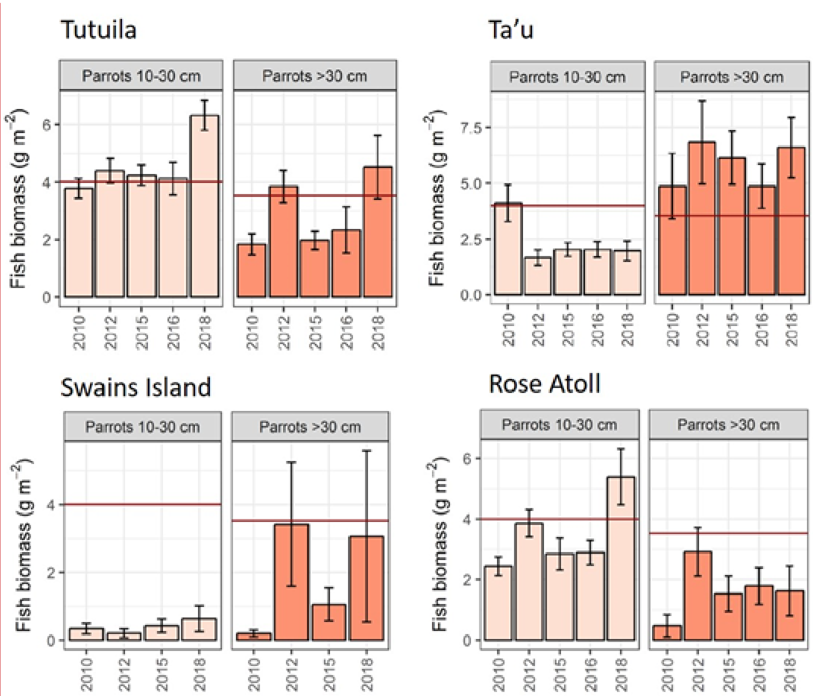

Figure S.LR.9.3. Average parrotfish biomass (g/m2) per island from 2010-2018 for small (10-30 cm) and large parrots (>30 cm) (Vargas-Angel et al. 2019, McCoy et al. 2018).

Surgeonfish and Unicornfish

Surgeonfish and unicornfish (Family Acanthuridae) play an important role in coral reef ecosystem dynamics filling a number of functional roles from grazers and browsers, to detritivores and planktivores (add citations). Small surgeonfish are the second most abundant functional group at CRAG's fixed monitoring site in Aunu'u, accounting for about 10% of total fish biomass. No unicornfish were observed during the survey. At CRAG's site in Fagatele, small surgeonfish make up about 12% of the fish community and large-bodied surgeons (orangespine unicornfish) were about 8% of the fish community (Comeros-Raynal et al., 2019, MARC 2020). In 2019, there was moderate surgeonfish recruitment on the reef flat and reef slope in Fagatele Bay. This was comparable to other surveyed sites in American Samoa (Comeros-Raynal pers comm). NOAA PIFSC ESD included data for one heavily exploited species, *Acanthurus lineatus*, the blue lined surgeonfish in the 2019 report. This territorial species is a preferred species for harvest. Overall *A. lineatus* biomass was highly variable between 2015 and 2018 but biomass increased at a number of sites, and increased slightly in most sanctuary units. The 2018 data may not provide an accurate picture of species status, however, as these fish prefer shallow reef habitats, and weather limited shallow surveys on the southern exposures in 2018 (Vargas-Angel et al., 2019).

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Surgeonfishes are also valued for human consumption and some species are easily exploited by spearfishing due to nocturnal resting behavior. Like parrotfish, these species may have also been targeted by the SCUBA spearfishing practices in the 1990s. Based on visual surveys in 2010, 2012, and 2015, the mean size for adult (>10cm) surgeonfish and unicornfish in American Samoa was approximately 15cm total length (WPRFMC, 2019). This is just above the size at first maturity for the small surgeonfish species such as *Ctenochaetus striatus (Ochavillo et al. 2011*). It is well below the size at first maturity for larger fisheries target species such as *A. lineatus* (Craig at al., 1997) and *Naso unicornis* (Taylor et al., 2014). It may indicate that the harvest practices for some species in this complex are not sustainable.

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Mesophotic Corals

Approximately 110 species of scleractinian corals are found at mesophotic depths in American Samoa (Montgomery et al. 2019). Bare et al. (2010) described coral ecosystems down to 110m. They noted that encusting and plate-like coral are the most common growth forms across the upper and mid-mesophotic zones and branching corals appear to be most abundant from 80-110m. Massive corals are more common at shallower depths (Bare et al. 2010). More recently, ROV Hercules captured video of *Leptoseris* corals as deep as 148m off the coast of Aunu'u during the 2019 EV Nautilus expedition to American Samoa (OET 2019). *Anella* sp. sea fans and unidentified Antipatharian corals were also observed in the deep mesophotic zone. Rebreather surveys in Fagatele and Fogama'a/Fagalua, documented and collected a variety of gorgonian and black coral specimens, but did not provide detailed information about scleractinian corals (Wagner 2017). These habitats are still being explored and there is insufficient data to evaluate trends.

Deep-sea Corals and Sponges

Corals and sponges provide important habitat for echinoderms and other organisms in the deep sea habitats. The 2017 Okeanos Explorer and 2019 EV Nautilus expeditions provided unprecedented access to the deep sea and the data and specimens from these expeditions are still being analyzed. The two expeditions documented a large number of corals and sponges including black, gorgonian, lace, soft, stoloniferan, and stony corals; sea pens; demosponges; and glass sponges (Kennedy et al 2019, NOAA DSCRTP 2020, OET/HURL unpub. data).. In 2019, moderate-density communities (1,000 - 2,999 combined counts per kilometer) were observed at Swains, Aunu'u, and Rose Atoll. Analysis of footage from the 2019 expedition aboard the EV Nautilus found that over 1,500 animals including echinoderms, arthropods, cnidarians, and mollusks were associated with either a coral or sponge (Figure S.LR.9.4). In fact, most of the echinoderms (96%) observed on the expedition were associated with a coral or sponge host (OET / HURL unpub. data). As these expeditions were the first to explore these deep-sea areas, it is not possible to evaluate the status or trends of these systems in this report.

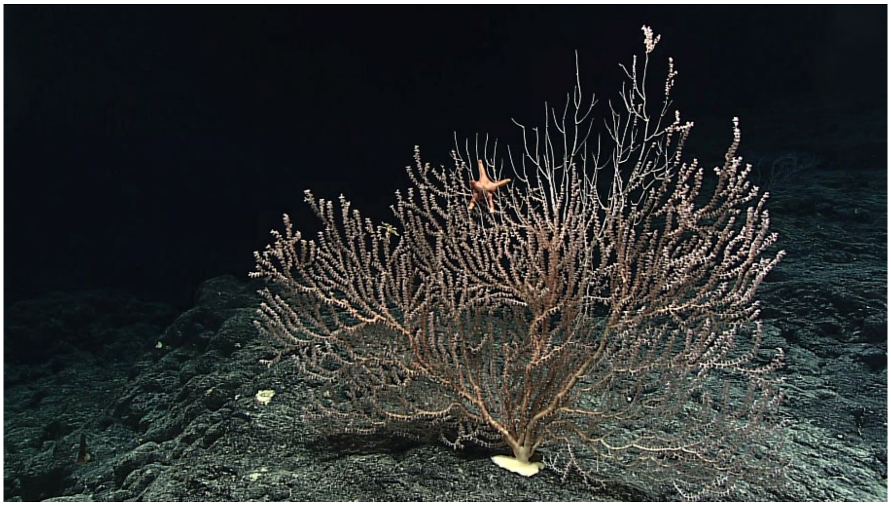

Figure S.LR.9.4. Deep sea corals and sponges provide habitat for other animals such as sea stars, brittle stars, snails, shrimp, and crabs. (NOAA OER)

Conclusion

The scleractinian corals in the shallow reef ecosystems of the NMSAS are robust and include healthy populations of both large, old corals and recruits. Although repeated bleaching has affected these communities, particularly at Swains, they remain resilient. The limited information on mesophotic coral ecosystems and deep-sea corals and sponges suggests that these species are in good condition. Experts did note that coral recruitment seemed low for deep-sea species, but coral recruitment data are limited in these areas, precluding comparisons at this time. The continued low abundance of large fish, particularly sharks, large parrotfish, and surgeonfish which provide important ecological services, is of great concern. Sharks are at 4-8% of their potential biomass, bumphead parrotfish are now functionally extinct, the low biomass estimates and mean size of surgeonfish and unicornfish may indicate unsustainable fishing pressure, and biomass for other large parrotfish species remains low despite the implementation of the SCUBA spearfishing ban in 2002. The continued lack of large predators and large herbivores in shallow coral reef habitats may compromise ecosystem resilience. This drove the overall rating down to Fair/Poor.

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Question 10: What is the status of other focal species and how is it changing?

***Status**: Mixed[2], Confidence - High; **Trend**: Undetermined, Confidence - Medium*

***Status Description:** The status of keystone or foundation species is mixed.*

Fish species *Giant Clams*	*Fair/Poor*	*Selected focal species are at substantially reduced levels and prospects for recovery are uncertain.*
Giant Porites	*Good*	*Selected focal species appear to reflect near-pristine conditions.*
Sea Turtles *Humpback Whales*	*Fair*	*Selected focal species are at reduced levels, but recovery is possible.*

***Rationale:** Experts noted that the abundances of giant clams (Tridacna sp.), targeted food fish species, and humphead wrasse (Cheilinus undulatus) are low and that recovery is uncertain due to continued harvesting and life cycle characteristics. The continued low abundance of these species drove the overall rating down to Fair / Poor. Data on sea turtles suggests that regional populations are stable and may be slowly recovering, but are still at risk. Sea turtle nesting activity is still limited and may be affected by coastal development and climate change. Humpback whale populations may be increasing, but data are limited and increasing ocean temperatures may be shifting their habitat preferences away from American Samoa.*

Question 10 Indicator Table. Summaries for the key indicators related to other focal species that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Giant *Porites* Corals	Coral Reefs	Brown et al., 2009; Tangri et al., 2017; Coward et al., 2020.	NMSAS Ta’u unit is home to one of the largest and oldest reef building corals ever documented. Known as Big Momma, the large *Porites lutea* colony is over 7 m high and 41 m around (Brown et al., 2009). Tangri et al. (2017) estimate that the coral is at least 500 years old based on a 6.1m core taken from the center of the colony in 2011. The colony has one large growth anomaly and several smaller anomalies. There were no noticeable effects from the recent coral bleaching events and extensive pufferfish bites do not appear to affect the colony's health. Tow surveys in the Ta’u unit documented a total of 28 *Porites* corals that were over 10m diameter. The surveys also noted 123 5-10m colonies and another 128 2-5m colonies (Coward et al. 2020, unpub. data). Large *Porites* colonies have also been observed in Fagatele and Fagalua/Fogama’a units, but have not been measured.

[2] Experts assigned a rating of Fair/Poor at the workshop, but recommended splitting the status rating. Following the workshop, a new “mixed” status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

Giant Clam Abundance and Size	Nearshore Habitats	AS-EPA/CRAG R2R unpub. data; Green and Craig 1999; Brainard et al 2008; NOAA PIFSC 2021.	Giant clam populations have declined over the past few decades. Historically, Rose Atoll had a high abundance of giant clams (1995/6: Lagoon = 3,000clams/ha, Fore-reef = 100 clams/ha (Green and Craig, 1999)), but those numbers have declined precipitously (B. Peck pers.comm.). Towed diver surveys of adult clams in 2006 noted that Rose Lagoon had the highest mean density of giant clams (~45/ha), followed by Ta'u (~8/ha), Tutuila and Aunu'u (~1/ha), Ofu Olosega (~1/ha), Rose Atoll Forereef (~0.25/ha) and Swains (no sightings) (Brainerd et al., 2008). Repeat surveys conducted in 2015 found lower densities at most sites. The highest density was in Ta'u (~7/ha), then a slight increase in density on the Rose Atoll Forereef (~0.5/ha), followed by Ofu-Olosega (~0.8/ha), Tutuila and Aunu'u (~0.3/ha), and Swains (no sightings). No surveys were conducted in Rose Lagoon in 2015 (NOAA PIFSC 2021). Belt transects conducted by ASEPA and CRAG in 2017 surveyed all size classes. These surveys noted that overall giant clam abundance at 31 sites in Tutuila was low and most were small to medium sized. The largest clam observed in Tutuila was a 42cm individual in Fagasa. No clams were observed within the transects at Fagatele and 12 other sites, but a maximum of 10 clams per $300m^3$ site (~330 clams / ha) were observed at Fagamalo. Giant clam abundance in Aunu'u (~267 clams / ha) was the second highest recorded by the project, but the site was outside of the sanctuary (Ridge to Reef Project unpub. data). NMSAS staff have documented clams in Fagatele Bay, Fagalua/Fogama'a and Aunu'u in 2020, but all were outside of monitoring transects.
Food Fish Abundance	Nearshore Habitats	MARC, 2020; Dr. Alison Green pers. comm.,	Results of the Ridge to Reef Project indicate that targeted food fish biomass in Fagatele Bay and Aunu'u was below both the Tutuila average and the average for southern reefs. It also noted that there were very few large fish, with most fish (70% in Fagatele Bay, 58% in Aunu'u) falling in the 0-10cm size class. No fish larger than 30cm were observed in Fagatele, and in Aunu'u fish from 20-50 cm were present, but in very low abundances. According to this report, herbivores make up almost 90% of the targeted reef fish biomass at Fagatele Bay, but only about 75% at Aunu'u. Predator abundance was low at both sites. The project report concluded that Fagatele's reef fish assemblage suggested a disturbed and degraded site. Dr. Alison Green found that fish biomass, abundance, and richness in Fagatele decreased between 2002 and 2018 and noted that the disturbing lack of large fish species may impact the resilience of the reef ecosystem.
Humphead Wrasse Abundance	Nearshore Habitats	NOAA PIFSC ESD unpub data 2020,	This species is still observed around American Samoa, but numbers are very low. NOAA PIFSC ESD towed diver data from 2002 to 2015 suggest that numbers are variable, ranging from 0-19 individuals observed on each island. NMSAS staff observed sub-adults in Fagatele Bay in 2020 and 2021.

Commented [10]: what does this mean and how does it relate to the species already considered in the previous section? who decided which species to include? how?

		CRAG 2020, NMSAS	
Sea Turtle Abundance	Nearshore Habitats, Pelagic	Maison et al. 2010, Tagarino et al. 2008; Tagarino and Utzurrum 2010; Seminoff et al., 2015; Craig et al. 2004; Craig et al. 2019; Becker et al. 2019; B. Peck pers. comm.	Both hawksbill (*Eretmochelys imbricata*) and green (*Chelonia mydas*) sea turtles are now listed as endangered under the US Endangered Species Act (FWS & NOAA, 2015). Sea turtle nesting surveys indicate that sea turtle nesting abundance remains low around Tutuila, Ofu, Olosega, Ta`u and Swains Island (Maison et al. 2010, Tagarino et al. 2008; Tagarino and Utzurrum 2010, Craig et al. 2019). Green sea turtle nesting abundance is stable to increasing at Rose Atoll and Swains Island, and Rose Atoll has the highest level of nesting activity with an estimated 105 nesters based on observations from 2007-2013 (Seminoff et al., 2015). Tagging data indicate that most green sea turtles nesting at Rose Atoll migrate to feeding grounds in Fiji and hawksbills nesting in Tutuila and Manu'a dispersed across the region (Craig et al. 2004, Craig et al., 2019). Hawksbill nesters dispersed across the region. Rose Atoll is an important nesting ground for turtles but as they are a long-lived species it would take a long time to detect trends in abundance (B. Peck pers. comm.). Becker et al. (2019) evaluated in-water surveys of both species from 2002-2015 across the US Pacific islands. The analysis indicated that turtle densities are stable to increasing and modeling identified SST and productivity as the highest-ranked drivers of sea turtle densities. In American Samoa, juveniles are the most common size class observed followed by subadults, but Rose Atoll had a relatively high proportion of green sea turtle adults compared to the other islands. The study also noted that hawksbill sea turtles remain rare across a broad portion of the Pacific and that American Samoa, specifically Ta'u and Tutuila, may be important areas for hawksbills.
Humpback Whale Presence	Pelagic	Robbins et al 2011, Riekkola et al. 2018 Derville et al 2019, J. Robbins pers. comm.	Humpback whales travel from the waters around Antarctica to American Samoa from June to October to mate and raise their calves (Robbins et al 2011, Riekkola et al. 2018). 159 unique individuals were observed around Tutuila between 2003 and 2008 (Robbins et al. 2011). Tutuila has a higher encounter rate than many other islands in the South Pacific (Derville et al. 2019). Whales use all of the shelf waters around Tutuila, including an area just outside Fagatele Bay (Robbins pers. comm., Lindsay et al. 2016). Occasional sightings have also been recorded in the Aunu'u Research Zone. An EAR at Rose Atoll recorded a large number of humpback whale vocalizations indicating that Rose may be an important habitat as well. Topography and SST are important drivers of humpback whale distribution and climate change may affect habitat suitability in a great part of current breeding grounds in Oceania (Derville et al 2019). The seawater temperatures around American Samoa are now right at the edge of what

			is considered suitable SST for humpback whales. (Derville et al. 2019).

Focal species may or may not have ecologically important roles in sanctuary ecosystems, but are deemed important for their value to humans. These include culturally important species such as giant clams and food fish that are harvested for subsistence and cultural purposes. It can also include large charismatic species such as humphead wrasse, sea turtles, and humpback whales that may be valued both for cultural purposes, but also as potential economic resources for tourism.

Commented [11]: who/how did you decide which species to include, why, what process?

Giant Porites Corals
NMSAS is home to one of the world's largest known coral colonies, a *Porites* colony, known as Big Momma or Fale Bommie, located in the Ta'u Unit. It was first brought to scientific attention by Fale Tuilage and Dr. Alison Green in 1995. The coral was 7 m tall and 41m in circumference when evaluated by Brown et al (2009) and they estimated that the colony is made up of approximately 200 million polyps. Morphological characteristics and genetic analysis of tissue samples suggest that the colony is a *Porites lutea.* In 2011, a 6.01m continuous core was removed from the coral and scanned by X-ray computer-automated tomography to reveal the coral's growth bands (Tangri et al., 2017). Based on this information the coral is believed to be at least 500 years old. The coral was surveyed in 2021 and appeared to be in good health despite high ocean temperatures in 2020. There is still a large growth anomaly on one side, and several smaller anomalies in other locations. Pufferfish (*Arothron nigropunctatus* and *A. meleagris*) predation leaves small tissue scars all over the colony, but these seem to heal over. There is no lasting sign of the coral coring activity from 2011.

This is not the only large *Porites* coral in the territory. Brown et al. (2009) noted that at least twelve other colonies were located within 1 km of the site and along the northeast corner of Ta'u. Tow-board surveys in 2019 found that large *Porites* corals (>10m across) were found on the western, northern, and eastern sides of Ta'u, with a large proportion of those colonies found within the NMSAS Ta'u Unit (Coward et al., 2020, Figure S.LR.10.1). CRAG assessed a subset of these colonies in 2021 and reported that they appear to be in good health and support robust fish communities (Coward pers. comm.). Large *Porites* colonies have also been observed in Fagatele Bay and Fagalu'a / Fogama'a, but they are smaller. Some of the large *Porites* in Fagatele Bay suffered partial mortality during the 2020 coral bleaching event, but most have resheeted tissue and appear to be doing well (V. Brown pers. comm.).

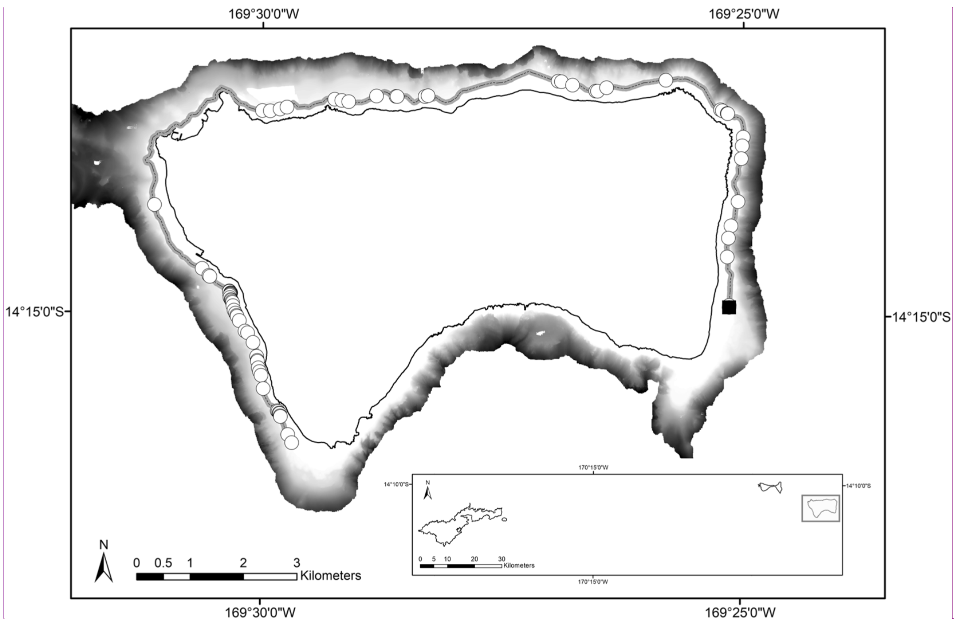

Figure S.LR.10.1. Tow-board surveys conducted by CRAG, NMSAS, and NPSA revealed that there are numerous large *Porites* colonies over 10 m in diameter around Ta'u. Many are located within NMSAS (Coward et al., 2020).

Giant Clams

Giant clams (*Tridacna* sp.) have both social and ecological value in American Samoa. Clams are a favored food item for residents and shells have been used for tools and ornamentation. Clams also provide shelter and food for other reef species and may act as a reservoir and distributor of zooxanthellae (Neo et al. 2015, Umeki et al. 2020). Historically, Rose Atoll had a high abundance of giant clams (1995/6: Lagoon = 3,000clams/ha, Fore-reef = 100 clams/ha (Green and Craig, 1999)), but those numbers have declined precipitously (B. Peck pers.comm.). Towed diver surveys of adult clams conducted by NOAA PIFSC from 2006-2015 indicated a decline in adult giant clam densities across most sites. In 2015, the highest island scale density was in Ta'u (~7/ha), followed by Ofu-Olosega (~0.8/ha), Rose Atoll Forereef (~0.5/ha), Tutuila and Aunu'u (~0.3/ha), and Swains (no sightings) (NOAA PIFSC 2021). No towed diver surveys were conducted in Rose Lagoon in 2015, but recent monitoring efforts by USFWS reported a further decline in giant clam densities inside the lagoon and the pinnacles (B. Peck pers. comm.).

More recently, the Ridge to Reef Project evaluated the abundance and size of giant clams on belt transects at 31 watersheds (ASEPA, CRAG unpublished data), including Aunu'u and Fagatele Bay. Overall giant clams were found to be in low abundances around Tutuila (Figure S.LR.10.2). More giant clams were observed at the site just outside of the Aunu'u unit (~267 clams/ha) than at most other sites. No giant clams were recorded in Fagatele, though giant clams have been observed there during other projects. This emphasizes the difficulty in monitoring low abundance organisms using transects and suggests that separate survey efforts

Commented [12]: @kathy.broughton@noaa.gov This needs a legend, I'm assuming the black square is the start of the towed survey, the gray/dotted line is the track of the survey, and open circles are individual Porites spp. colonies >10 m in diameter, but this is not explicit from either the figure or the caption.

Commented [13]: This map will be updated to include the location of Big Momma and the NMSAS boundaries for the final version.

may be warranted for this species. Craig et al. (2008) noted that approximately 35% of the giant clam harvest was composed of undersized animals (<15.2cm). There is no clear indication of what has caused the decline in giant clams over the past two decades, but clams may be affected by high temperature anomalies and ocean acidification in addition to harvesting pressures.

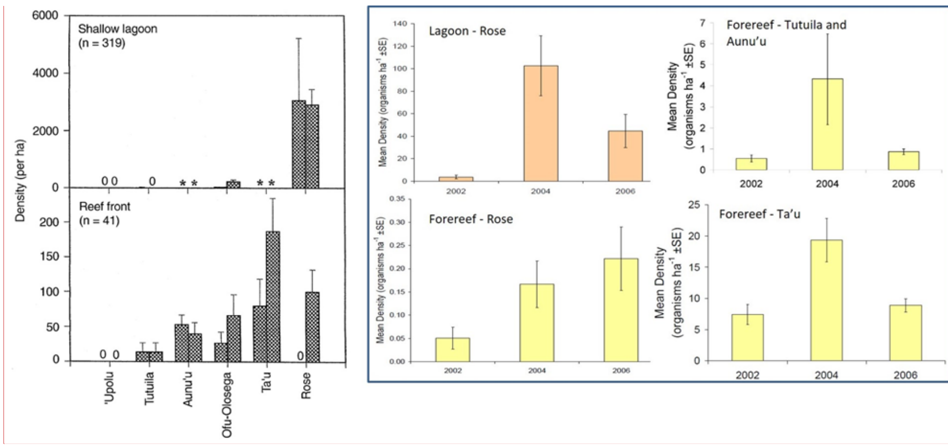

Figure S.LR.10.2. Giant Clam density was much higher in 1994-95 (left) than in 2002-2006 (right). (Green and Craig 1999, Brainard et al. 2008)

Commented [14]: @kathy.broughton@noaa.gov Is the raw data available for these? It is a little tough to interpret side-by-side since the scale is so different. At the very least, I would recommend stacking these vertically and making them S.LR.10.2a and S.LR.10.2b.

Should the left figure also be "Mean Density (per ha)" similar the right one? Please also add x axis labels.

Food Fish

Reef fish have historically been an important source of sustenance for human communities in American Samoa. Targeted species include parrotfish, surgeonfish, snappers, groupers, emperors, and goatfish (Craig et al., 2008). Many of these fish also have important ecological roles. CRAG monitors these species at sites in Fagatele Bay and just outside the sanctuary in Aunu'u. In the past, food fish biomass at these sites was relatively high, but it declined in 2015 and 2017 to less than half of previous measures (MARC 2020, Figure S.LR.10.3) In 2017, CRAG and AS-EPA conducted an island wide assessment of reef health. This assessment found that target fish biomass in Fagatele Bay and Aunu'u was below both the Tutuila average and the average for southern reefs. It also noted that there were very few large fish, with most (70% in Fagatele Bay, 58% in Aunu'u) falling in the 0-10cm size class (Comeros-Raynal et al. 2019, MARC 2020). No fish larger than 30cm were observed in Fagatele, and in Aunu'u fish from 20-50 cm were present, but in very low abundances. According to this report, herbivores make up almost 90% of the targeted reef fish biomass at Fagatele Bay, but only about 75% at Aunu'u. Predator abundance was low at both sites. An analysis of the reef fish community in Fagatele Bay suggested a disturbed and degraded site (CRAG 2018). NOAA ESD surveys in 2018 also noted that there were few fish over 30cm in Fagatele (only 1% of 956 fish surveyed). The largest fish was a 48cm parrotfish (McCoy 2018).

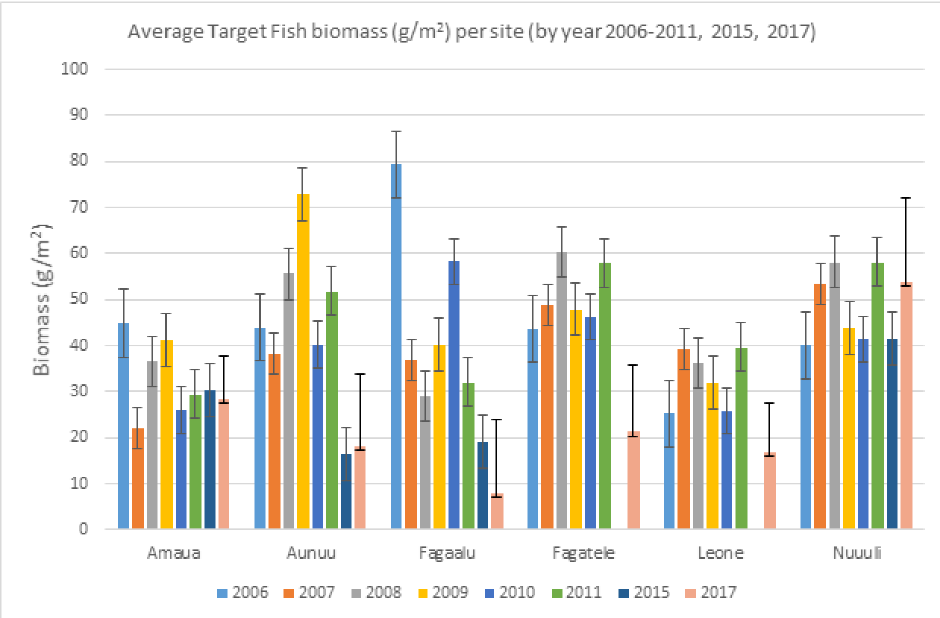

Figure S.LR.10.3. Average target fish biomass (g/m2) from 2006-2017 at sites in Tutuila (CRAG 2018).

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Please also add x axis label.

Dr. Alison Green surveyed Fagatele in 1994, 1998, 2001, 2004, 2007 and 2018. These surveys indicate that fish biomass is low compared to many other sites throughout the Territory, particularly for most fisheries families. The exception is small parrotfish species (particularly *Chlorurus spilurus*) that increased significantly in both biomass and density from 2002 to 2018 (probably due to the ban on scuba spearfishing in 2001). She noted that fish biomass values are below what is expected for a no take MPA. Species richness has declined from 34 to 20 species per transect due to unknown causes and rare and threatened species (e.g, sharks, large groupers, wrasses and parrotfishes) are rare throughout American Samoa, including in Fagatele Bay (Green et al., in prep.) Dr. Green recommended stronger enforcement of the no-take regulations as the bay's small size makes it vulnerable to fishing pressure.

Humphead Wrasse

Humphead wrasse (*Cheilinus undulatus*) are large, charismatic fish that are a favored attraction for sport divers. While regulations are in place for this species, it has historically been harvested for food, and large males are sometimes regarded as trophies of free dive spearfishing. These fish may also play an important role as a predator of crown of thorns starfish. It is also highly mobile and may not be properly assessed by standard fish monitoring techniques. Due to their slow growth rate, late sexual maturation, and sex reversal, the species is particularly vulnerable to exploitation.

This species is still observed around American Samoa, but numbers are very low. Sabeter et al., (2010) found that juvenile humphead wrasses were mostly observed in wide sheltered reef flats with small patches of sand bordered with branching corals. This juvenile habitat comprises only 1.6% of the shallow reef habitat around Tutuila. Their models based on underwater visual census and habitat maps estimated that these habitats may support approximately 350 individuals and suggested that this species may be limited by the availability of juvenile habitat. Towed diver data from 2002 to 2015 suggest that numbers are variable, ranging from 0-19 individuals observed on each island (Figure S.LR.10.4; NOAA PIFSC ESD 2018), but must be interpreted with caution as tow surveys sometimes lapped small islands and individual fish around Rose Atoll and Swains Island may have been counted more than once (Tye Kindiger pers. comm.). CRAG observed humphead wrasse in Aunu'u in 2009 and 2011 (A. Lawrence pers. comm.), NMSAS staff observed one large subadult humphead wrasse in Fagatele Bay in 2020, and three smaller individuals in 2021 (V. Brown pers. comm.), and in 2018, NOAA PIFSC ESD observed humphead wrasse during SPC surveys in Ta'u (Tye Kindiger pers. comm.).

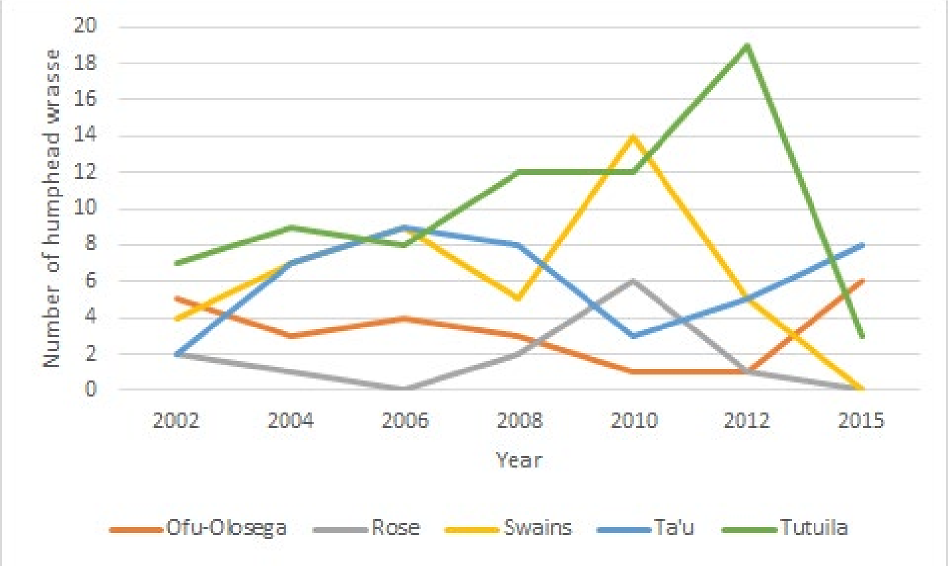

Figure S.LR.10.4. Humphead wrasse (*Cheilinus undulatus*) observed during towed diver surveys. Note that smaller islands may be surveyed twice in a given year, so numbers may be inflated by repeat observations of the same individual (NOAA PIFSC ESD 2018, Tye Kindinger pers. comm.)

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Sea Turtles

Sea turtles, particularly green (*Chelonia mydas*) and hawksbill sea turtles (*Eretmochelys imbricata*) are found throughout NMSAS. These animals were historically harvested for both sustenance and ornamentation and numbers in the region are quite low. Turtles have also been impacted by coastal development, particularly seawalls that remove nesting habitat, and the animals may also be disoriented during nesting and hatching times by land based lights. Both species are now listed as endangered under the Endangered Species Act.

In American Samoa, sub-adult and adult green turtles occur in low abundance in nearshore waters around Tutuila, Ofu, Olosega, Ta`u and Swains Islands, with sporadic, low-level green turtle nesting on Tutuila and Swains Islands (Maison et al. 2010, Tagarino et al. 2008; Tagarino and Utzurrum 2010, Craig et al. 2019). A 2019 study by Becker et al. evaluated sea turtle data from thirteen years of towed diver data in the Pacific. The work confirmed the scarcity of the hawksbill sea turtles across a broad portion of the Pacific and identified American Samoa, specifically Ta'u and Tutuila, as a population of significance for hawksbills. Regional trends indicate that turtle densities are stable to increasing and modeling identified SST and productivity as the highest-ranked drivers of sea turtle densities. The study found that juveniles were most common, then subadults and adults, and Rose Atoll had a relatively high proportion of green sea turtle adults compared to the other islands in American Samoa (Becker et al. 2019, Figure S.LR.10.5). Green turtle nesting has been observed on Tutuila, Ofu and Swains Islands from August to March. Tagging data show that most green sea turtles nesting at Rose Atoll migrate to feeding grounds in Fiji and are then vulnerable to harvest there (Craig et al. 2004). Rose Atoll is an important nesting ground for turtles but as they are a long-lived species it would take a long time to detect trends in abundance (B. Peck pers. comm.).

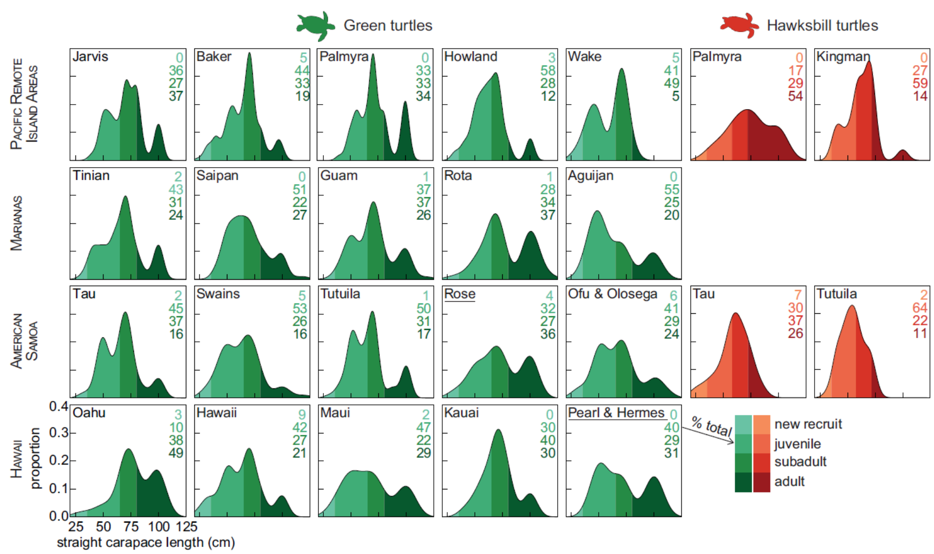

Figure S.LR.10.5. Sea turtle populations in the US Pacific Islands based on thirteen years of in-water observations (Becker et al. 2019).

Humpback Whales

Humpback whales come to American Samoa from June to October to mate and raise their calves. Topography and SST appear to be important drivers of humpback whale distribution in Oceania (Derville et al. 2019). Climate change is predicted to impact habitat suitability across most of the current breeding grounds in Oceania (Derville et al. 2019).

Oceania has smaller populations of humpback whales than other Southern Hemisphere areas (Constantine et al. 2012); but within Oceania, American Samoa appears to be an attractive site (Derville et al. 2019). However, American Samoa's water temperatures are now right at the edge of this species' preferred temperature range and the whales may shift to cooler sites in the future (Derville et al. 2019). Robbins et al. (2011) identified 159 individual whales in American

Samoa's waters between 2003 and 2008, and over 400 have been identified through 2019 (J. Robbins pers. comm). These animals travel from feeding grounds in the Southern Ocean, including near the Antarctic Peninsula (Robbins et al. 2011, Riekkola et al. 2018). Whales were observed near the Aunu'u and Fagatele Bay units in 2019 and 2020. An EAR at Rose Atoll also picked up a large number of whale vocalizations, indicating Rose Atoll may also be an important habitat for these visiting whales.

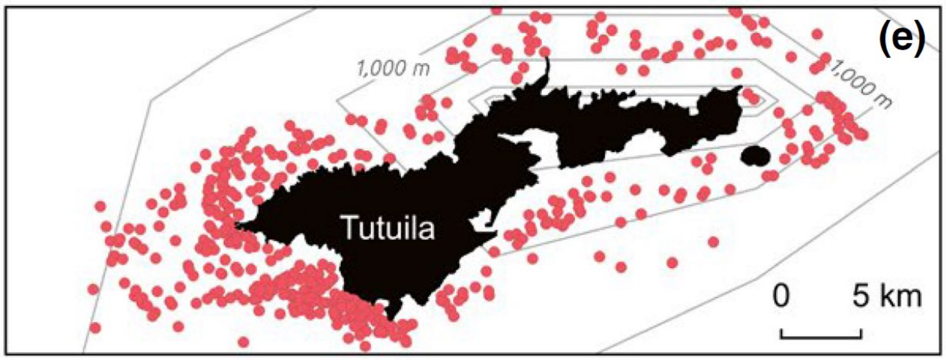

Figure S.LR.10.6. Humpback whale sightings around Tutuila. Whales are found in the Aunu'u unit and adjacent to the Fagatele Bay unit (Derville et al. 2019)

Commented [17]: @kathy.broughton@noaa.gov A legend would be helpful here, but since it's just one category, we can just add "each point denotes an individual whale" or whatever the case is, just a little more specificity would help here.

Also, the caption does not denote a time period over which these sightings were made, I recommend adding that info to the caption to aid in interpretation.

Conclusion

Experts noted that monitoring data for these species are limited and that additional efforts may be necessary to accurately assess population trends. The abundance of harvested species, including giant clams (*Tridacna* sp.), targeted food fish species, and humphead wrasse (*Cheilinus undulatus*), is low and recovery is uncertain due to continued harvesting and life cycle characteristics. The decline in giant clams from 1996 to 2006 is particularly worrisome to resource managers and there is some concern that ocean acidification and elevated seawater temperatures may be affecting these species. The continued low abundance of harvested focal species drove the overall rating down to Fair / Poor. Data on sea turtles suggest that resident populations may be slowly recovering, but nesting activity is still limited. Humpback whale populations may also be increasing, but data are limited and increasing ocean temperatures may shift their habitat preferences away from American Samoa. More specific survey efforts for giant clams, humphead wrasse, and rare food fish species are recommended as well as expanded survey efforts for sea turtles and humpback whales.

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Question 11: What is the status of non-indigenous species and how is it changing

Status: Good/Fair, Confidence - High; ***Trend****: Not Changing, Confidence - High*

Status Description: Non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.

Rationale: Non-indigenous species have been observed in American Samoa, but have not exhibited invasive characteristics within NMSAS units.

Question 11 Indicator Table. Summaries for the key indicators related to non-indigenous species that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Invasive Species Presence	Nearshore Habitats	Coles et al. 2003, Fenner 2019	Coles et al. (2003) reported two non-indigenous species (a tube forming annelid worm (*Salmacina dysteri*) and a bryozoan (*Savignyella lafontii*)) and three cryptogenic species in Fagatele Bay. The team noted that Fagatele Bay had high species diversity but low numbers of non-indigenous species (Coles 2003). Most introduced species are currently found in Pago Pago harbor (Fenner 2019).
Non-native Species Abundance	Nearshore Habitats	Purcell et al. 2020, NMSAS	In 2003 and 2006 trochus (*Rochia nilotica*) were introduced to reefs in Samoa for fishery purposes. A survey in 2018 revealed high densities of this species on the reefs there (Purcell et al 2020). Although no specific surveys have been carried out in American Samoa to determine population levels, this species has been observed in the territory (NMSAS).

Non-indigenous species exist in the sanctuary, but their abundance and distribution is poorly documented. Also called alien, exotic, nonnative, or introduced species, these are animals or plants living outside their endemic geographical range that have been brought there intentionally or unintentionally by human activities. They are called invasive species once they cause ecological or economic harm. Species may be introduced through ballast water or fouling on hulls or other equipment (e.g., fishing nets) and in other forms of trade. In addition, climate change may increase the number of, or susceptibility to introductions due to habitat alteration, warming waters, and changes in ocean circulation patterns.

Twenty-eight non-indigenous and cryptogenic species were documented in American Samoa in 2002 (Coles 2003). Two non-indigenous and three cryptogenic species were found in Fagatele Bay, but none have exhibited invasive growth patterns. No invasive species surveys have been conducted since that time.

In 2003 and 2006 trochus (*Rochia nilotica*) were introduced to reefs in Samoa for fishery purposes. A survey in 2018 revealed high populations of this species on the reefs with no apparent negative impacts to the coral communities (Purcell and Ceccarelli 2020). Although no specific surveys have been carried out in American Samoa to determine population levels there, this species is present on the reefs (NMSAS).

Two native species, a tunicate (*Diplosoma similis*) and a green alga (*Valonia sp*.) have exhibited invasive behavior, forming outbreaks at Swains Island and Ofu Island respectively, but because these are believed to be native species, they will be addressed in the biodiversity section (such species are usually called “nuisance” species).

No information on non-indigenous species is available for pelagic, mesophotic, and deep-sea habitats at this time.

Conclusion

Non-indigenous species have been observed in American Samoa, but have not exhibited invasive characteristics within NMSAS units. Trochus has been introduced but has not displayed any invasive characteristics. A tunicate and a green alga have recently exhibited invasive behavior, but are believed to be native species. No recent surveys have been conducted specifically to look for invasive species and this is an important biosecurity gap that needs to be addressed.

Question 11 Cited Resources

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Question 12: What is the status of biodiversity and how is it changing?

***Status**: Fair, Confidence - High; **Trend**: Not Changing, Confidence - High*

***Status Description**: Selected biodiversity loss or change has caused measurable but not severe degradation in some attributes of ecological integrity.*

***Rationale**: Diversity continues to be high in the sanctuary, additional species have been documented, and new species are still being discovered. Shallow scleractinian coral populations have fluctuated over time due to predation, cyclone, and coral bleaching events, but have proven resilient. Many large, ecologically important fish species are rare throughout the sanctuary and fish biomass in Tutuila units is below island averages and below estimated biological potential in all units except for Swains Island. Impaired fish community structure may affect overall coral reef ecosystem function and resilience and was a primary driver for this rating.*

Question 12 Indicator Table. Summaries for the key indicators related to biodiversity that were discussed during the 2020 status and trends workshop.

Indicator	Habitat	Source	Summary
Coral: Species Richness	Nearshore Habitats	ESD, Charles Birkeland	Limited data are available on species richness in sanctuary management areas. Generic richness is highest at Ta'u and lowest at Swains. Corals in American Samoa have substantial recruitment and well-filled size classes - good signs for healthy coral communities.
Macroalgae: Species Richness	Nearshore Habitats	Brainard et al. 2008, Diaz-Ruiz et al. 2018, Kraft and Saunders 2014, Skelton and South 2007, Tribollet et al. 2010, Tsuda et al. 2011, Kraft and Saunders 2014.	At least 240 species have been documented across American Samoa (Skelton and South 2007), including 59 species at Swains Island (Tsuda et al. 2011), 45 species at Rose Atoll (Diaz-Ruiz et. al. 2018), and at least 24 species in Ta'u (Brainard et al. 2008). Macroalgal assemblages are distinct at all islands and Swains Island has the greatest dissimilarity from other islands (Tribollet et al. 2010). A new species, *Dissimularia tauensis*, was described by Kraft and Saunders (2014).

Mobile Invertebrates: Species Richness	Nearshore Habitats	Coles et al. 2003, CREP 2017	At least 299 non-coral invertebrate species have been recorded in Fagatele Bay (Coles et al. 2003). Sampling in other sites has been limited. An assessment of cryptic reef diversity of colonizing marine invertebrates using Autonomous Reef Monitoring Structures included sites in Fagatele Bay, Fogama'a, Aunu'u, Ta'u, and Rose Atoll units from 2013-2018. Species richness was variable across the sites and ranged from 119 to 205, with the highest number recorded at Ta'u (CREP 2017).
Reef Fish: Biomass, Size, Species Richness	Nearshore Habitats	Comeros-Raynal et al. 2019, Comeros-Raynal 2021, MARC 2020, Green unpub data, McCoy et al. 2018, Nadon et al. 2012, NOAA CRCP 2018, Vargas-Angel et al. 2019, Williams et al. 2011, Williams et al. 2015	Fish biomass is well below potential levels at Tutuila (-56%) and Ta'u (-42%). Biomass at Swains Island is within the estimated potential range, but biomass at Rose Atoll is slightly below its potential (Williams et al. 2015). Biomass of large fishes (>50 cm) and piscivores is low across the territory, but is highest at Swains and Rose. Biomass of small fish is relatively high and primary consumers (herbivores) are a major contributor to biomass to all islands, but primary consumer biomass is lowest at Swain Island (McCoy et al. 2018). Total fish biomass increased significantly (α = 0.05) between 2015 and 2018 in the Fagatele Bay and Rose Atoll units and for the island of Ta'u (Vargas-Angel et al. 2019). Despite this increase, CRAG found that biomass is still lower than the Tutuila average at Fagatele and Aunu'u (MARC 2020, Comeros-Raynal et al. 2019). Dr. Alison Green noted that fish biomass and species richness remains unexpectedly low at Fagatele Bay despite improvements in coral since the 1980s, but biomass increased in Ta'u and Rose (unpub data). Recruitment surveys indicated relatively low recruitment on the reef flat and reef slope at Fagatele compared to other sites (Comeros-Raynal 2021).

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Nuisance species: CoTS, *Drupella* / Coralliophila, Tunicates, *Rhodactis* abundance	Nearshore Habitats	NPSA, NOS, NMSAS, Vargas-Angel et al. 2009, D. Fenner pers.comm.	From 2011-2017 an outbreak of crown-of-thorns sea stars (CoTS; *Acanthaster planci*) devastated reefs around Tutuila. CoTS were observed in low numbers in Fagatele Bay, Fogama'a/Fagalua, and Aunu'u in 2013 and 2014. Diver interventions around the island removed over 25,000 starfish using ox bile and sodium bisulfite and coral cover has started to recover in many places (NPSA, NOS, NMSAS). Low numbers of CoTS have been recorded from Fagatele Bay, Fogama'a/Fagalua and Aunu'u since then (NMSAS unpub data). Predation on corals by *Drupella* and *Coralliophila* snails has been observed. No data are available on snail abundance, but damage has been minor and is likely within normal levels (NMSAS unpub data). In 2008, a didemnid tunicate overgrew corals and reef habitat on the north-northwest side of Swains Island, affecting up to 76.5% at one site. The outbreak subsided by 2010 and coral cover has recovered (Vargas-Angel et al. 2009, D. Fenner pers. comm.).
Marine Mammal: Species richness	Pelagic	Craig 2009, Johnston et al. 2008, Dave Mattila pers. Comm., Reeves et al. 1999	Eight whale and five dolphin species have been reported in American Samoa (Craig 2009). Three other whale and two dolphin species have been observed in the region (Reeves et al. 1999). There is a variety of whale and dolphin species reported from American Samoa. Johnston et al. (2008) suggest some level of site fidelity for rough-toothed and spinner dolphins. Rough toothed dolphins and spinner dolphins have been observed near Fagatele and Aunu'u (D. Matilla pers. comm.). Humpback whales have been observed adjacent to the sanctuary units (NMSAS unpub data) and were captured on ecological acoustic recorders in Fagatele Bay and Rose Atoll in 2006-2007 (NMFS).
Seabird: Species Richness	Pelagic	Brian Peck pers. comm, Titmus et al. 2016, VanderWerf and Swift 2017, Wegmann and Holzwarth 2006	Seabirds are common in all sanctuary units. Six species are regularly observed at the Aunu'u, Fagatele, and Fagalua/Fogama'a units (VanderWerf and Swift 2017). Up to 15 species roost and nest at Rose Atoll and forage in sanctuary waters (Wegmann and Hozwarth 2006). Four species were observed roosting and breeding at Swains Island (Titmus et al. 2016).

Pelagic Fish: Catch and Species Richness	Pelagic	WPRFMC 2020	Total pelagic catch and catch per unit effort for albacore tuna in American Samoa have declined over the past decade along with fishing effort. No data are available specifically from the sanctuary, but trolling methods are used in the Aunu’u units and may also be used in the Ta’u unit. Species reported from the troll fishery in 2019 were limited to skipjack tuna, yellowfin tuna, kawakawa, blue marlin, mahimahi, wahoo, dogtooth tuna, sailfish, and rainbow runner (WPRFMC 2020).
Coral: Species Richness	MCE	Montgomery et al. 2019, Daniel Wagner pers. comm.	Rebreather surveys in 2016 identified 110 scleractinian coral species in the 30-60m zone at eight sites around Tutuila. Six were new records for American Samoa. One corallimorpharian, 28 alcyonaceans (including 13 gorgonians), two milleporids, one stylasterid, two zoanthids, and four antipatharians were found (Montgomery et al. 2019). Rebreather dives conducted surveys in Fagatele and Fogama'a/Fagalua in 2015 and 2017. Gorgonian and black coral specimens were collected for taxonomic ID (16 gorgonian genera, five families of black corals) (Daniel Wagner pers. comm.).
Fish: Species Richness, Harvest Status, and Age Structure	MCE	HURL 2020, Montgomery et al. 2019, O'Malley et al. 2018	A total of 244 species among 118 genera have been recorded during rebreather surveys. 168 species (69%) were from shallow reefs and 56 (23%) from mesophotic depths (30–200 m). The remaining 20 species occur in both depth ranges. Rebreather surveys in 2017 including Fagatele Bay and Fagalua/Fogama'a found 61 species, including five new records, and four possible new species (Montgomery et al. 2019). NMFS determined that the Bottomfish Management Unit Species complex is undergoing overfishing and is in an overfished state (Langseth et al. 2019). *Etelis* and *Pristipomoides* species were observed in Aunu'u and Ta'u during the E/V Nautilus expedition in 2019 (HURL 2020). A recent assessment of *P. flavipinnis* suggests that fishing has had significant impacts on the age structure of this species (O'Malley et al. 2018).

Coral and Sponge: Species Richness, Relative Density	Deep sea	Kennedy et al. 2019, OET / HURL unpub. Data	The top three genera observed in American Samoa were all corals: *Enallopsammia*, *Stichopathes*, and *Scleronephthya*, which combined represented 79.5% of genera observed. Anthozoan diversity was low (Shannon-Wiener Diversity Index H'=1.47) and the American Samoa Region had the least even distribution (J'=0.40) of the areas surveyed (Kennedy et al. 2019). Anthozoan sightings in 2017 were highest at Swains Island (486) and Rose Atoll (148, 75). Poriferan sightings were highest at Swains Island (82), Malulu Seamount (77), and Ta'u (41) (NOAA DSCRTP 2020). Surveys conducted by the Ocean Exploration Trust in 2019 found the highest relative density (# observed/km) of corals and sponges at Swains Island (1732/km), Aunu'u (1559/km), and Rose Atoll (1319/km) and are considered moderate-density communities. The dynamic nature of the Vailulu'u Seamount appears to have an effect on sessile fauna as observations were low in these areas (OET / HURL unpublished data).
Mobile Invertebra te: Species Richness	Deep sea	Kennedy et al. 2019, OET / HURL unpub. data, OET unpub. data	Across the Pacific echinoderm genera appear to be highly specific at shallow depths (200–500 m). The highest degree of under-sampled diversity was noted in the 3,000–4,000 m depth range. Mobile invertebrate data are limited but the American Samoa Region displayed the most unique taxonomic assemblage of the areas surveyed by the Okeanos Explorer from 2015-2017. (Kennedy et al. 2019). At Vailulu'u Seamount, OET observed echinoderms including asteroids, comatulid and isocrinid crinoids, and euryalid ophiuroids. High abundances of crabs (Bythograeidae), shrimp, and isopods were observed at a newly discovered vent in 2019 (OET unpublished data).
Fish: Species Richness	Deep sea	OER website, OET/HURL unpub data, OET website	Fish from 48 families were observed during the 2019 expedition aboard the E/V Nautilus (OET / HURL unpub data). In 2017, small cutthroat eels (*Dysommina rugosa*) were observed in large numbers near low-temperature vents (OER); ROV dives in 2019 sighted significantly fewer in the crater (OET unpublished data)

Biodiversity is defined as variation of life at all levels of biological organization. The simplest measure is to count the number of species found in a certain habitat or ecosystem, termed species richness. Other indices of biodiversity couple species richness with relative abundance. In this section, the species richness and abundance of key species groups were considered in each of the sanctuary ecosystems ranging from shallow nearshore habitats to the deep sea.

<u>Near-shore (Sandy Shores, Rocky Shores, Coral Reef)</u>

Habitat Structuring Organisms

Coral abundance was evaluated in previous sections (climate change and keystone / foundation species). Over 150 species of coral have been documented in NMSAS, but there are limited data on species richness in individual sanctuary units. The 2018 surveys by NOAA PIFSC ESD found that generic richness was highest at Ta'u and lowest at Swains. The surveys detected a slight decrease in generic richness across most sites in 2018, but this was not significant ($p<0.05$) (Vargas-Angel et al. 2019). However, this survey method may not detect changes within highly diverse, bleaching sensitive genera such as *Acropora*, *Montipora*, and *Pocillopora*. Dr. Charles Birkeland (pers. comm.) noted that corals in American Samoa seem to generally have substantial recruitment and well-filled size classes, which are good signs for healthy coral communities. He noted that in Fagatele Bay, *Acropora* recruitment has declined slightly since 1996, but the upper size classes have filled, which is a good indicator of a robust reef community.

Few studies have been conducted on the algae of American Samoa. At least 240 species have been documented across American Samoa (Skelton and South 2007). Tsuda et al. (2011) reported 59 species of marine benthic algae from Swains Island, Diaz-Ruiz et al. (2018) documented a total of 45 species at Rose Atoll, and at least 24 species were observed in Ta'u (Brainard et al. 2008) and a new species, *Dissimularia tauensis*, was described by Kraft and Saunders (2014). The highest species and generic richness has been documented from Tutuila. Tribollet et al. (2010) found that macroalgal assemblages at all islands in American Samoa were significantly different from each other, with Swains Island having the most dissimilarity from other islands, likely due to its geographic separation from the other islands. They noted that cyclone activity appeared to decrease macroalgae abundance and hypothesize that storms may have a significant effect on the macroalgae community there. One algal species, *Valonia sp.,* has recently begun to overgrow coral reefs in the Ofu Pools and become a nuisance species. This species is present in the sanctuary, but has only been observed in low abundances.

Mobile Invertebrates

There is limited data on the recent status of marine invertebrates within the sanctuary. Surveys have focused on giant clams, crown-of-thorns sea stars, and introduced species. At least 299 non-coral invertebrate species have been recorded in Fagatele Bay (Coles et al. 2003), but other sites have not been intensively sampled. From 2013-2018, NOAA PIFSC assessed cryptic reef diversity of colonizing marine invertebrates in the sanctuary using Autonomous Reef Monitoring Structures (ARMS). These devices were developed in collaboration with scientists from the Census of Marine Life and mimic the complexity of a coral reef in a systematic manner. The ARMS were colonized by eleven invertebrate phyla (Table X). Arthropoda was the most diverse phylum (55-107 species per site), followed by Mollusca (16-70 species per site), and Echinodermata (3-16 species per site). Species composition varied by site with 119 to 205 species identified at each site. Aunu'u and Ta'u had the most diverse assemblages (CREP 2017, Table S.LR.12.1).

Table S.LR.12.1. Cryptic reef diversity of colonizing marine invertebrates in NMSAS units assessed by NOAA PIFSC using Autonomous Reef Monitoring Structures (ARMS) from 2013-2018. Each ARMS was in place for three years. (CREP 2017).

Phylum	Fagatele Bay Site TUT-22	Fagatele Bay Site TUT-75	Fogama'a Site TUT-11	Aunu'u Site TUT-73	Ta'u Site TAU-12	Rose Atoll Site ROS-4	Rose Atoll Site ROS-19	Rose Atoll Site ROS-25
Annelida	3	5	2	14	7	3	3	5
Arthrophoda	65	50	55	106	85	107	87	78
Chordata	2	5	7	5	1	-	2	3
Cnidaria	-	2	1	-	-	-	-	-
Echinodermata	4	3	8	16	4	4	3	5
Mollusca	42	45	48	61	70	16	36	28
Nematoda	-	-	-	-	1	-	-	-
Nemertea	-	1	2	1	-	-	2	-
Platyhelminthes	1	-	-	-	-	-	-	-
Protozoa	-	-	-	2	-	-	-	-
Sipuncula	2	2	1	-	2	-	2	-
Unknown	1	-	1	-	-	1	-	-
Grand Total	**120**	**122**	**125**	**205**	**170**	**131**	**135**	**119**

Fish
A number of surveys and experts have noted the lack of large fish, including sharks, groupers, and parrotfish throughout American Samoa, particularly in Tutuila (Williams et al. 2011, Nadon et al. 2012, Green per.comm., McCoy et al. 2018, Vargas-Angel et al. 2019, NOAA CRCP 2018). While the biomass of small fish (0-20cm) is relatively high when compared to other sites across the Pacific (Figure S.LR.12.1; McCoy et al. 2018.), overall fish biomass is below the calculated unfished baseline levels at all sites except for Swains Island (Williams et al., 2015). In 2016-2017 surveys, Comeros-Raynal et al. (2019) found that fish biomass for targeted food fish species in the Fagatele unit and just outside of the Aunu'u Zone A unit is below average for the island of Tutuila (MARC 2020).

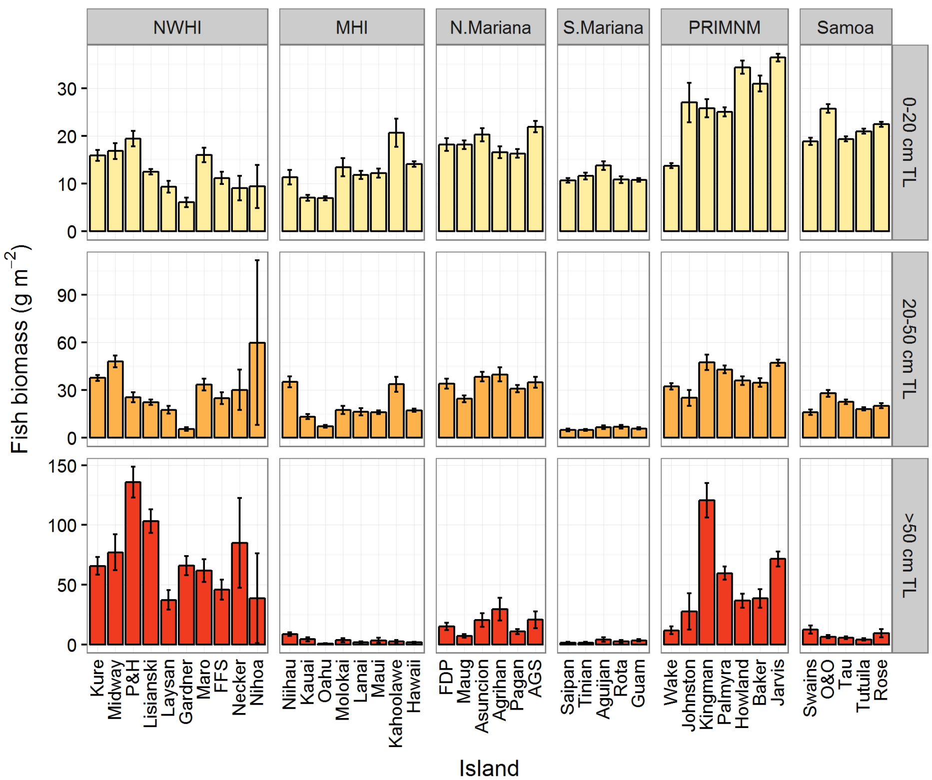

Figure S.LR.12.1. Fish biomass by size class across the U.S. Pacific Islands. Experts noted the low abundance of large fish (>50 cm total length [TL]) and relatively high abundance of small fish (0-20 cm TL) across the islands of American Samoa. Image: McCoy et al., 2015

NOAA PIFSC ESD noted an increase in fish biomass in Fagatele, Ta'u, and Rose and increases in species richness across all sites between 2015 and 2018, but stated that diver bias may be responsible for the increase in species richness as it was consistent across sites. No fish larger than 50cm were observed in Fagatele, Fagalua/ Fogama'a, or Ta'u in 2018, but large fish were observed in Rose and Swains. Aunu'u was not sampled in 2018 and sampling along southern exposures was limited due to weather (Vargas-Angel et al. 2019). In 2018, fish biomass was highest in Rose, Ta,u and Swains. Piscivore biomass has been very low across all islands during the reporting period and small herbivores are a major contributor to biomass (McCoy et al. 2018). Towed-diver surveys from 2004 to 2015 consistently found that the average biomass of large fish (>50cm) was below 10g/m^2 at all sites except for Swain's Island (NOAA CRCP 2018). Dr. Alison Green, who has been surveying fish in Fagatele Bay since the 1990s, found that while fish density increased, due to an increase in coral associated damselfish, biomass values in 2018 were low compared to many other sites sampled throughout the territory, particularly for food fish species. Fish biomass is lower than expected for a no take MPA. She also noted that species richness in Fagatele Bay has declined over time from 34 to 20 species per transect. Rare and threatened species (e.g., sharks, large

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groupers, wrasses and parrotfishes) were rare throughout American Samoa, including in Fagatele Bay (Green et al., in prep).

A 2019 assessment of the Bottomfish Management Unit Species complex in American Samoa determined that the complex is undergoing overfishing and is in an overfished state (Langseth et al. 2019). This includes shallow coral reef ecosystem species such as *Lutjanus kasmira*, *Aprion virescens*, *Variola louti*, *Caranx lugubris*, and *Lethrinus rubrioperculatus* as well as deeper species including *Etelis coruscans and E. carbunculus*. Research on the comparative demography of two other snappers and an emperor species (*Lutjanus gibbus, Lutjanus rufolineatus*, and *Lethrinus xanthochilus*) indicated a low level of prevailing exploitation for these shallow species (Taylor et al. 2018).

Nuisance species

Acanthaster planci, or crown-of-thorns sea stars (CoTS), are voracious coral predators that normally exist in low abundances on reefs throughout the Indo-Pacific. However, from 2011 to 2017, this species experienced a rapid increase in population that threatened corals around the island of Tutuila. CoTS were observed in Fagalua/Fogama'a in 2013 and 2014 and in low numbers in Fagatele and Aunu'u. The National Park of American Samoa and other sites on the north side were severely infested and efforts were undertaken to stop the outbreak through diver interventions (NPS 2014). Over 25,000 starfish were removed from across the island using injections of sodium bisulfite and ox bile salts and coral cover has recovered in many places. Surprisingly, coral cover remained stable within the Tutuila unit of NSPA before, during, and after the outbreak (NPS, unpublished data). Low level CoTS predation and two adult CoTS were observed in Fagatele in 2019. Limited surveys in 2020 observed continued low level predation, but did not directly observe any CoTS.

Predation on corals by snails in the genera *Drupella* and *Coralliophila* has also been documented during surveys. No quantitative data on these mollusks are available, but the damage has been minor and suggests that populations are in the normal range. In 2008, a tunicate (*Diplosoma similis*) was observed overgrowing live coral and benthic substrate along the north-northwest side of Swains Island. Surveys documented *D. similis* cover as high as 76.5% at one site and 35% at a second site within this area, raising concern that it may overwhelm the reef (Vargas-Angel et al. 2009). Biologists with NMFS noted that this outbreak may have been linked to impacts from Hurricane Heta in 2004, which may have allowed the tunicate to spread. By 2010, the species had subsided back to normal levels (Doug Fenner pers. comm.).

<u>Pelagic/Open water</u>

Marine Mammals

Eight whale and five dolphin species have been reported in American Samoa (Craig 2009). However, more recently two species of baleen whale and 11 odontocete species have been verified (Robbins pers. comm.) Three other whale and two dolphin species have been observed in the region (Reeves et al. 1999). Based on resighting data, Johnston et al. (2008) suggested that rough-toothed (*Steno bredanensis*) and spinner dolphins (*Stenella longirostris*) appear to exhibit some level of site fidelity in American Samoa. Rough toothed dolphins and spinner dolphins have been observed near Fagatele and Aunu'u (D. Matilla pers. comm.). The EAR installed at Fagatele in 2019 will shed more light on marine mammal activity in the bay in the future, but data have not been analyzed. Research suggests that marine mammal diversity in American Samoa is similar to other island nations in this region. There is a need for more expansive and regular surveys as well assessments of marine mammals throughout the territory.

Seabirds
Seabirds are common in all sanctuary units. At Aunu'u, Fagatele and Fagalua / Fogama'a a variety of sea birds use sanctuary waters to feed and roost on the adjacent cliffs. Species observed in these areas include brown boobies (*Sula leucogaster*), blue-gray noddies (*Procelsterna cerulea*), brown noddies (*Anous stolidus*), bridled terns (*Onychoprion anaethetus*), white terns (*Gygis alba*), and white tailed tropic birds (*Phaethon lepturus*) (VanderWerf and Swift 2017). Further research is needed to document species abundance in the sanctuary, identify what sanctuary resources these species rely on and evaluate the effect they have on nutrient cycling in these areas.

Rose Atoll is a key migratory stopover for seabird species and is an important roosting spot for resident seabirds. The waters of the sanctuary provide important foraging. It is believed that the majority of seabird nesting in American Samoa takes place on Rose Island. Red tailed tropic birds (*Phaethon rubricauda*), frigatebirds (*Fregata aerial* and *F. minor*), three species of boobies (*Sula sula, S. leucogaster, S. dactylatra*), white terns (*Gygis alba*), sooty terns (*Onychoprion fuscatus)*, gray backed tern (*Onychoprion lunatus)* and noddies (*Anous stolidus, A. minutus)* all nest within the Rose Atoll National Wildlife Refuge. Shearwaters (*Puffinus pacificus*, *P. navitatus*), white tailed tropicbirds, and blue noddies have been observed at Rose Atoll, but breeding status is uncertain (Wegmann and Holzwarth 2006). It is believed that sooty terns and red tailed tropic birds may nest exclusively at Rose Island. Nesting is highly variable and may depend on foraging conditions in the waters around Rose Atoll. Seabird numbers increased after rats were eradicated from the island in 1992, but suffered losses from Cyclone Victor in 2016 (Brian Peck pers. comm.).

In 2012, Titmus et al. (2016) surveyed the seabird community at Swains Island. The team noted that the seabird community was dominated by Black Noddy (*Anous minutus*), White Tern (*Gygis alba*), and Brown Noddy (*Anous stolidus*). Inland surveys revealed four roosting or breeding species: Black Noddy, White Tern, Brown Noddy, and Red-footed Booby (*Sula sula*). The researchers noted that the presence of rats and limited amount of preferred roosting vegetation (i.e. Pisonia and Pandannus) may limit seabird populations at the island.

Fish
There is limited information about the pelagic fish communities within the sanctuary. Pelagic fisheries in American Samoa are monitored by NOAA Fisheries, but data are pooled and can not be used to assess a specific geographic location. The Western Pacific Regional Fisheries Management Council’s Annual Stock Assessment and Fishery Evaluation Report (2020) indicates that four tuna species - albacore, yellowfin, skipjack, and bigeye - make up most of the pelagic landings in American Samoa. Other species, in order of decreasing catch are, blue marlin, wahoo, swordfish, spearfish, mahimahi, sailfish, striped marlin, thresher sharks, moonfish, dogtooth tuna, barracuda, pomfret, oilfish, and rainbow runner. This includes catch from longline (>50 miles from shore), trolling and other methods. The longline fishery also caught and released silky sharks, white tip oceanic sharks, blue sharks, and shortfin mako sharks. No data is available specifically from the sanctuary, but trolling methods are used in the Aunu’u units and may also be used in the Ta’u unit. Species reported from the troll fishery in 2019 were limited to skipjack tuna, yellowfin tuna, kawakawa, blue marlin, mahimahi, wahoo, dogtooth tuna, sailfish, and rainbow runner. Catch per unit effort for albacore and total pelagic catch in American Samoa has declined over the past decade along with fishing effort (Figure S.LR.12.2). The decrease in catch could be linked to decreased effort or could indicate declines

in the fish populations. Harvesting, climate change, and marine debris may all affect the abundance and distribution of pelagic fish. Fishery independent data is not available for these species, so it is difficult to assess the status of pelagic fish communities.

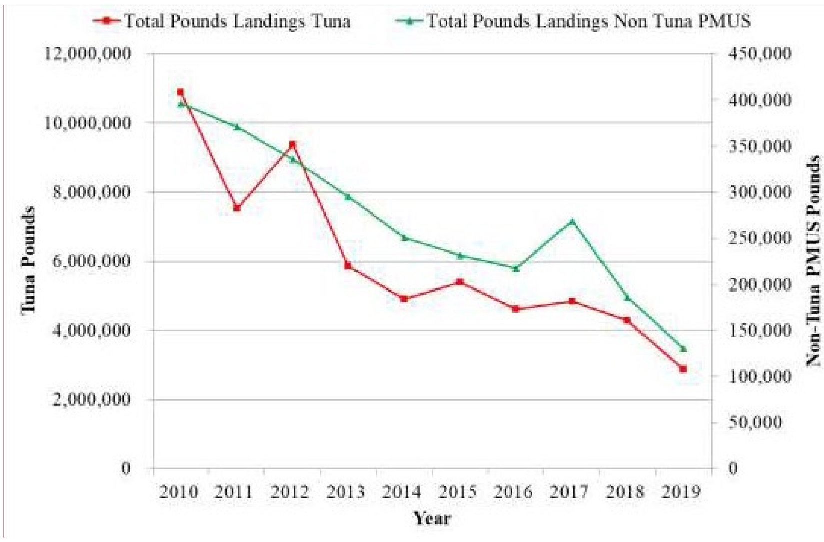

Figure S.LR.12.2. Estimated total landings of tuna and non-tuna Pelagic Management Unit Species from 2010 to 2019 (WPRFMC 2020).

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Left y axis title: "Tuna Landings (lbs)"

Right y axis title: "Non-Tuna Pelagic Management Unit Species Landings (lbs)"

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Mesophotic (MCE)

Habitat structuring organisms

Island-wide surveys of mesophotic habitats around Tutuila and the Manu'a islands were conducted by NOAA Fisheries using a towed optical assessment device (TOAD) from 2002-2008 (Bare et al. 2010). Benthic habitat was categorized into scleractinian coral, macroalgae, other colonizers, unconsolidated hard bottom, and sand (Table X). Percent cover of scleractinian coral was further classified by growth form. Encusting and plate-like coral were the most common growth forms across mesophotic depths. Massive corals were more common in the upper (30-60m) mesophotic zone (Table S.LR.12.2; Bare et al., 2010), presumably due to light requirements. Branching corals that require less light were most abundant at deeper depths. Columnar and free-living corals were also observed, but in much lower numbers.

Table S.LR.12.2. Substrate type and % living cover in mesophotic coral ecosystem habitats around American Samoa (2002-2008), using a towed optical assessment device. (Bare et al. 2010)

Depth Interval (m)	Frames Analyzed (n)	Scleractinian Coral - mean (SD)	Macroalgae - mean (SD)	Other Colonizers - mean	Unconsolidated Hard	Sand - mean (SD)	Total Hard Bottom - mean (SD)

				(SD)	Bottom - mean (SD)		
30–39.9	543	15.5 (26.00)	3.1 (11.60)	14.7 (26.20)	24.1 (34.90)	32.3 (38.20)	67 (38.30)
40–49.9	1,181	8.8 (20.70)	7.5 (18.90)	13.4 (23.20)	11.3 (22.20)	53.4 (41.20)	44.9 (41.00)
50–59.9	1,678	4.7 (14.60)	20.3 *29.10)	17 (25.90)	11.8 (23.00)	45 (39.90)	54.4 (39.90)
60–69.9	978	6.6 (16.50)	16.9 (28.20)	19.6 (28.70)	9.9 (21.70)	40/9 (44.10)	54.6 (44.70)
70–79.9	359	6.7 (16.20)	15.4 (29.10)	14.1 (26.40)	4.1 (11.60)	56 (44.90)	41.40 (44.50)
80–89.9	114	1.9 (7.50)	3.2 (11.50)	5.8 (17.60)	3.5 (12.50)	82.50 (30.70)	14.6 (28.10)
90–99.9	87	4.8 (14.60)	3 (11.60)	5.3 (18.70)	12.6 (27.00)	47.8 (46.80)	48.7 (46.80)
100–109.9	18	3.3 (7.70)	0 (-)	4.40 (14.60)	12.20 (19.60)	- (-)	100 (-)

Rebreather surveys in 2016 identified 110 scleractinian coral species in the 30-60m zone at eight sites around Tutuila. Six of these were new records for American Samoa. One corallimorpharian, 28 alcyonaceans (including 13 gorgonians), 2 milleporids, 1 stylasterid, 2 zoanthids, and 4 antipatharians were found (Montgomery et al. 2019). During NOAA NOS rebreather surveys in Fagatele and Fogama'a/Fagalua in 2015 and 2017, divers documented the diversity of fish, gorgonians, and antipatharians. Gorgonian and black coral specimens were collected for taxonomic ID purposes (16 gorgonian genera, 5 families of black corals) (Daniel Wagner pers. comm.).

Data on macroalgae are limited in this zone, but Bare et al. (2010) documented vast swaths of *Halimeda* algae around Tutuila, particularly on deep reef slopes. Overall, data on mesophotic habitats are limited and insufficient to determine trends.

Mobile invertebrates

Knowledge of the invertebrate fauna populating the MCE of American Samoa is extremely scarce.

Fish

Very little data has been published on reef fish diversity in the MCEs of American Samoa. In American Samoa, a total of 244 reef fish species among 118 genera have been recorded during rebreather surveys. 168 species (69%) were from shallow coral reefs (SCR) and 56 (23%) from MCEs or deeper (30–200 m). The remaining 20 species occur on both SCRs and MCEs. This pattern of reef fish species richness in American Samoa is generally consistent with that of coral reef fish families elsewhere. Surveys conducted by PMNM rebreather divers in 2017 around Fagatele Bay and Fagalua / Fogama’a detected 61 fish species in mesophotic depths. Five of these were new records for American Samoa and four may be new species (Montgomery et al. 2019). This highlights the need for further study of MCE within NMSAS.

Many of the species in the Bottomfish Management Unit Species complex utilize mesophotic habitats. NMFS determined that the complex is undergoing overfishing and is in an overfished state (Langseth et al. 2019) The deeper species, including *Etelis coruscans, E. carbunculus,* and *Pristipomoides flavipinnis,* are long lived species that may be more sensitive to fishing pressure than other shorter lived species. O'Malley et al. (2019) examined the age and size composition, growth, and mortality of *P. flavipinnis* in both fished and unfished areas in the Samoan Archipelago. The results suggest that fishing has had significant impacts on the age structure of this species in fished areas and raised concerns about stock assessment models based on a species complex instead of individual species. Video taken during the 2019 cruise aboard the E/V Nautilus and analyzed by the Hawai'i Undersea Research Laboratory documented the presence of *Etelis* and *Pristipomoides* species in the Aunu'u unit and near the Ta'u unit, but did not assess abundance (HURL 2020).

Deep sea

Habitat structuring organisms

Knowledge of the cnidarian fauna populating the deep waters of American Samoa is extremely limited. From 2015-2017, NOAA Vessel Okeanos Explorer conducted surveys throughout the Pacific Island Region, including thirteen sites across American Samoa. The results indicate that American Samoa's deep sea communities are distinct from the other regions sampled, including the nearby South-Central Pacific region. This may be due to ocean circulation patterns linked to the Samoan Passage or location. The top three genera observed in American Samoa were corals: *Enallopsammia*, *Stichopathes*, and *Scleronephthya*, which accounted for 79.5% of genera observed. Despite the high level of representation, overall anthozoan diversity was low (Shannon-Wiener Diversity Index H=1.47) and the American Samoa Region had the least even distribution (*J*'=0.40) of the areas surveyed (Kennedy et al. 2019). Anthozoan sightings were highest at Swains Island (486), followed by Rose Atoll (148, 75), and Aunu'u (41). Poriferan sightings were highest at Swains Island (82), Malulu Seamount (77), and Ta'u (41) (NOAA DSCRTP 2020). The ten most abundant families observed are listed in Table S.LR.12.3.

Table S.LR.12.3. Top ten most abundant families observed during the Okeanos Explorer expedition in American Samoa to evaluate deep sea habitats. Source: Kennedy et al., 2019

Family	Common Name	Total #	Total for Region (%)
Dendrophylliidae	Stony coral	5508	39.30
Antipathidae	Black coral	3655	26.08
Nephtheidae	Soft coral	1660	11.85
Chrysogorgiidae	Soft coral	642	4.58

Schizopathidae	Black coral	293	2.09
Euplectellidae	Glass sponge	272	1.94
Epigonidae	Cardinalfish	181	1.29
Amphianthidae	Sea anemone	157	1.12
Isididae	Bamboo coral	137	0.98
Myxillidae	Demosponge	104	0.74

The Ocean Exploration Trust's EV *Nautilus* conducted additional deep sea surveys in 2019 using it's ROV's Argos and Hercules. The highest numbers of benthic fauna sighted were at Swains Island (1310), Aunu'u (758), and Ta'u (639). HURL converted these observations into a count/ kilometer estimate of relative density. The highest density of corals and sponges were observed at Swains Island (1732/km), Aunu'u (1559/km), and Rose Atoll (1319/km) and are considered moderate-density communities (Table S.LR.12.4) (OET/HURL unpublished data).

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Table S.LR.12.4. Summary of coral and sponge densities and environmental parameters observed during the 2019 EV Nautilus expedition to American Samoa (OET / HURL unpublished data).

Dive #	Location	Depth (m)	Porifera #/km	Cnidaria #/km	Combined #/km	Avg Depth (m)	Avg Temp (°C)	Avg O2 (mg/l)
H1764	Swains Island	1264-2432	164	1568	1732	1644	2.7	3.31
H1768	Tutuila - Aunu'u	112-1003	196	1363	1559	315	18.2	4.78
H1772	Rose Atoll	325-981	133	1185	1319	412	12.9	4.14
H1767	Ta'u Unit West	214-611	3	693	696	275	18.5	4.52
H1765	Ofu-Olosega	1748-1832	51	244	295	1771	2.5	3.52
H1766	Ta'u Unit East	452-769	6	24	30	602	6.8	4.05
H1770	Vailulu'u Seamount	728-734	6	0	6	729	5.5	3.85
H1773	Vailulu'u Seamount	N/A	0	0	0	N/A	N/A	N/A

At Vailulu'u Seamount, the strong environmental fluctuations in the crater have a particular effect on sessile habitat structuring organisms, such as corals and sponges. Community assemblages and abundances appear to shift constantly in response to the ever-changing habitat conditions. Outside the crater, rocky bottoms not affected by hydrothermal activity support an epifauna dominated by octocorals (e.g., *Anthomastus* sp., *Iridogorgia* sp.) and hexactinellid sponges (Staudigel et al. 2006).

Mobile invertebrates
Knowledge of the invertebrate fauna populating the deep waters of American Samoa is also extremely limited. Available data from the Okeanos Explorer surveys suggest that at shallow depths (200–500 m) specific echinoderm genera are only present in a very narrow depth range, whereas in deep water (3,000–6,000 m) echinoderm genera were observed across a much broader depth range. The American Samoa Region displayed the most unique taxonomic assemblage (Kennedy et al. 2019).

At Vailulu'u seamount, echinoderms including asteroids, comatulid and isocrinid crinoids, and euryalid ophiuroids were present. At a newly discovered hydrothermal vent a high abundance of crabs (Bythograeidae), shrimp, and isopods were observed in 2019 (EV Nautilus unpublished data).

Fish
Deep-sea fish communities in American Samoa appear to be structured by depth. Overall, fish from forty-eight families were observed during the 2019 expedition aboard the EV Nautilus (OET / HURL unpub. data). These data include fish observations from surveys conducted over a wide range of depth strata (110 – 2432 m) and additional analysis is needed to evaluate species richness and relative density across sites and depth zones.

More research and monitoring is needed to shed light on fish diversity across the sanctuary's deep-sea habitats. One area of particular interest is the dynamic hydrothermal vent habitats located around the Nafanua Cone on Vailulu'u Seamount. Environmental fluctuations appear to have a strong impact on fish distribution and abundance at these sites. In 2017, small cutthroat (synaphobranchid) eels (*Dysommina rugosa)*, were observed in large numbers near low-temperature vents (OER website), however, ROV dives in 2019 sighted significantly fewer cutthroat eels in the crater (OET unpublished data)

Conclusion
Overall, biological diversity remains high in the sanctuary. Shallow scleractinian coral populations have fluctuated over time due to predation, cyclone, and coral bleaching events, but have proven resilient to these stressors. Experts felt that many large, ecologically important fish species are rare throughout the sanctuary. Fish biomass in the Fagatele Bay and Aunu'u units is below island averages and fish biomass at all units, except for Swains Island, is below estimated biological potential. This impaired fish community structure may affect overall coral reef ecosystem function and resilience and was a primary driver for this rating. Limited data suggest that marine mammals are steady or increasing and that resident sea turtle populations, while still low, may be slowly increasing. Data for mesophotic, pelagic, and deep-sea habitats are limited and there are no data on trends. Mesophotic and deep-sea expeditions have expanded the species list for the sanctuary. New species are still being discovered and there is a need for further research.

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Question 13. What are the levels of human activities that may adversely influence living resources and how are they changing?

Status: *Fair, Confidence - High;* ***Trend****: Undetermined, Confidence - High*

Status Description: *Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.*

Rationale: *Fishing appears to be a significant pressure on living resources in the sanctuary. Experts believe that Fagatele Bay may deserve a Fair/Poor rating due to low fish biomass observed at the site. Fishing pressure appears to be decreasing, but fish biomass has not increased during the reporting period. Clam populations continue to decline. Sea turtle populations are stable or increasing. Vessel groundings reduced species diversity and abundance at the impact sites in Aunu'u and Rose Atoll. Limited data is available for pelagic, mesophotic, and deep-sea habitats.*

Data on human visitation and use in the sanctuary are limited, but sanctuary sites are used for recreation and fishing activities on a regular basis. Human activities can impair living resources through breakage, harvesting, or harassment. Fishing is not allowed in Fagatele Bay and is limited in the Aunu'u research zone, but enforcement is difficult. Commercial fishing is prohibited in most of the Muliava unit, but subsistence fishing is allowed with a permit. Vessel groundings have impaired living resources at Aunu'u and Rose Atoll.

Fishing is an important activity in American Samoa. Fish are harvested to feed families, support extended families and friends, and to support cultural practices (Levine et al 2016). Data suggest that fishing activity has declined over the reporting period, with 46% of households in Aunu'u reporting that they fish less frequently (Levine et al 2016) and declines in the number of registered boats and fishermen and overall harvest (AS Statistical Yearbook 2018). Despite this decline in effort, fish biomass in the territory remains far below the potential biomass (Williams et al 2015), and total fish biomass values in Aunu'u and Fagatele are lower than island averages (MARC 2020) (Figure S.LR.13.1). Large fish such as sharks, large parrotfish, and large groupers are rare, and bumphead parrotfish (*Bolbometopon muricatum*) are believed to be functionally extinct (Fenner pers comm).

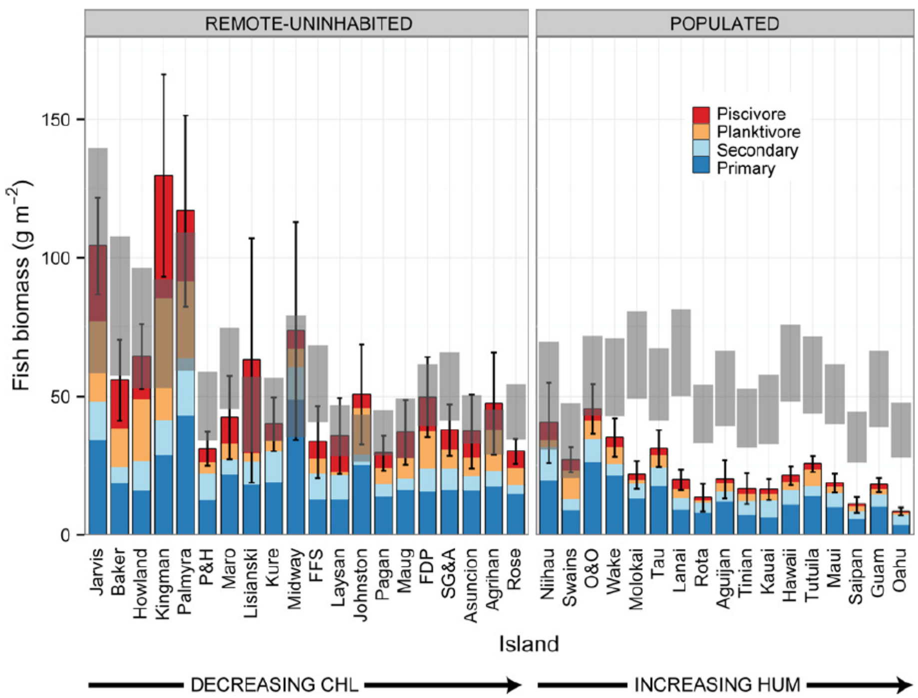

Figure S.LR.13.1. Colored bars are fish biomass (+95% CI per island). Gray bars are model predictions in absence of humans. Williams et al (2015)

A 2019 assessment of the Bottomfish Management Unit Species complex in American Samoa determined that the complex is undergoing overfishing and in an overfished state (Langseth et al. 2019). This includes shallow coral reef ecosystem species as well as deeper species. Pelagic resources appear to be more resilient to fishing pressure for now.

Giant clams (*Tridacna sp.*) are also harvested for food and cultural requirements. Abundances of these invertebrates have declined significantly over the past two decades (Green and Craig 1999 and Brainard et al 2008) and small to medium sizes are now most prevalent (Figure S.LR.13.2). Around Tutuila, harvesting may be a factor, but further study is needed to determine the cause of this decline.

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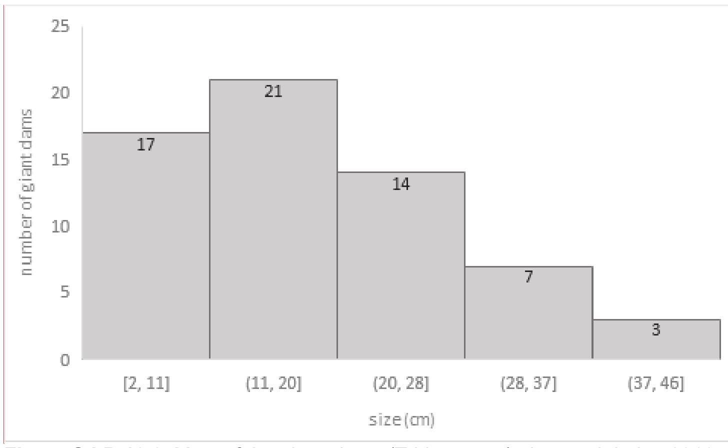

Figure S.LR.13.2. Most of the giant clams (Tridacna sp.) observed during 2016 surveys around Tutuila were less than 20cm in size. The low number of individuals in larger size classes suggests that disturbance events or harvesting pressure may affect survival. (Ridge to Reef Project; EPA, CRAG)

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Please:

-Change x and y axis titles to title case
-Clarify what's going on w/x axis labels - should these be ranges? If so, please use en dashes rather than commas and remove parentheses/brackets
-Remove data labels on columns
-Increase resolution

Sea turtles have been protected by the Endangered Species Act since the 1980s. Seminoff et al. (2015) noted that legal and illegal harvest of green sea turtles and sea turtle eggs for human consumption continues to be a significant threat to green turtles in the region. Limited in-water surveys began in 2002. Since that time resident sea turtle populations in American Samoa have remained stable or increased (Becker et al. 2019).

Vessel groundings in Aunu'u and Rose Atoll have had significant effects on habitat within the impact footprint of these events. This loss of habitat has led to declines in species diversity and abundance within the impact sites as described in the previous section. These sites are limited in size and do not affect the overall rating.

Conclusion

Fishing appears to be a significant pressure on living resources in the sanctuary, particularly reef fish, bottomfish, and giant clams. Experts believe that Fagatele Bay and Fagalua / Fogama'a may deserve a Fair/Poor rating due to low fish biomass observed at the site. Other sites are doing better, but are still below the potential fish biomass estimates. Data on fishing pressure suggest that effort appears to be decreasing, but fish biomass has not increased during the reporting period. Clam populations continue to decline, but it is not clear if this is linked to human activities such as harvesting or pollution. Sea turtle populations are stable or increasing. Vessel groundings reduced species diversity and abundance at the impact sites in Aunu'u and Rose Atoll. Limited data are available for pelagic, mesophotic, and deep-sea habitats.

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This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Maritime Heritage Resources (Questions 14 – 15)

The following information provides an assessment of the status and trends of maritime heritage resource indicators in NMSAS for the period of 2007–2020.

The Maritime Heritage Resources section of this report addresses the condition and threats to heritage resources in the sanctuary. Maritime heritage can encompass a wide variety of cultural, archaeological, and historical resources. Archaeological and historical resources are material evidence of past human activities and include vessels, aircraft, structures, habitation sites, and objects created or modified by humans. Cultural resources may include specific locations associated with traditional beliefs or where a community has traditionally carried out economic, artistic, or other cultural practices important to maintaining its historic identity. In the past, heritage preservation studies usually focused on the land, so currently the majority of available site information for the marine environment describes shipwreck (archaeological/historical) resources. Question 14 assesses the integrity of known maritime heritage resources in the sanctuary. The integrity of a heritage resource refers to its ability to convey information about the past, and can be impacted by both natural events and human activities. Archaeological integrity is generally linked to the condition of the resource, whereas historical significance may rely on other factors. The sanctuary system as a whole is working towards increasing consideration for non-shipwreck heritage resources. Human activities that adversely impact maritime heritage resources are the focus of Question 15.

Commented [1]: Mageo: Credit to authors of this Section in its ample description, examples, explanation, trends and rationale of the State of Maritime Heritage Resources (Archaeological, Historical & Cultural) with the impact of natural processes in the decaying conditions of these Resources while the effects of human activities has yet to be studied or determined. Also, the Report stated ONMS/NOAA has yet to conduct a full survey of the submerged areas of all six of its Sanctuary Units. However, desk-based assessment efforts, case studies outside of sanctuary areas (yet a microcosm of the Sanctuary), experience and opinion of subject matter experts will suffice in bridging this crucial gap of the State of MHR's trends, integrity, conditions, ratings and services in managing the Sanctuary.

Question 14: What is the condition of known maritime heritage resources and how is it changing?

***Status**: Fair, Confidence - High; **Trend**: Worsening, Confidence - High.*

***Status Description:** The diminished condition of selected maritime heritage resources has reduced, to some extent, their aesthetic, cultural, historical, archaeological, scientific, or educational value, and may affect the eligibility of some sites for listing in the National Register of Historic Places.*

***Rationale:** Maritime heritage resources have not been subject to human impacts that might otherwise diminish their aesthetic, cultural, historical, archaeological, scientific, or educational value. They have been subject to natural deterioration, erosion and high-energy shoreline events, yet remain substantially without assessment, documentation or monitoring efforts. Therefore, their condition is rated Fair. However, the trend is worsening because they are subject to continuing natural forces like erosion and high-energy shoreline events, leading to concern regarding future conditions. Maritime heritage resources like submerged shipwrecks and aircraft, which likely exist within the sanctuary, are presumed to be slowly degrading, primarily due to natural processes.*

Maritime Heritage Resources Studies

Following the completion of the 2007 Fagatele Bay Condition Report, the initial *American Samoa Maritime Heritage Inventory* report was finalized by the ONMS Maritime Heritage Program, categorizing types of maritime heritage resources within the sanctuary and across the Territory. In following years, other maritime heritage related studies were completed by ONMS, partners, and experts (included in References below):

- *American Samoa Maritime Heritage Inventory* (Van Tilburg, 2007)
- *Historic Fishing Methods in American Samoa* 2008
- *American Samoa as a Fishing Community* 2009
- "Damage to Archaeological Sites on Tutuila Island (American Samoa) Following the 29 September 2009 Tsunami" 2010
- *Unlocking the Secrets of Swains Island: a Maritime Heritage Resources Survey* 2013
- "Fautasi: the Race for Flag Day" (ONMS Stories from the Blue video) 2014
- "Row as One! A History of the Development and Use of the Sāmoan Fautasi" 2018
- *Fautasi Heritage of American Samoa* 2020 (2021)

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Importantly, the 2012 transition of Fagatele Bay National Marine Sanctuary to the National Marine Sanctuary of American Samoa expanded the original sanctuary area from 0.25 to 13,581 square miles, incorporating six protected areas ranging from the intertidal zone to the deep-sea. Additionally, the focus on maritime archaeological resources in the previous condition report process was expanded to include maritime heritage (archaeological, cultural, historical) resources, more fully reflecting the federal preservation mandates defined within the National Historic Preservation Act and the National Marine Sanctuary Act.

Key Data Sets

Current ONMS knowledge of the nature, location, and significance of maritime heritage resources within the sanctuary is limited. Descriptive resource inventories have been compiled mainly through desk-based assessment efforts. Field archeological surveys of submerged sanctuary areas, with the exception of Swains Island, have yet to be conducted. Due to limited formal studies and reports, the majority of evidence discussed below includes case studies from outside of sanctuary boundaries (as examples relevant to conditions within the sanctuary) and relies heavily on the experience and opinion of subject matter experts.

Shipwrecks

There are at least 35 vessel losses recorded for American Samoa (Van Tilburg 2007: 8). These losses historically connect the Territory to British colonization efforts in the Pacific, whaling heritage, fishing activities, inter island transportation, and to naval activities in World War II. Some of these losses are modern, such as fishing vessels that grounded during Cyclone Val in 1991 and were later disposed intentionally at sea, and several other groundings in more recent years. Approximately ten lost ships, wrecked between 1828-1949, are potentially more historically significant (Table 1). However, field survey data is scarce. Two shipwrecks, of the 25 that have been located, have been systematically assessed: 1) USS *Chehalis*, scuttled in Pago Pago Harbor following an onboard explosion/fire (outside sanctuary boundaries); and 2) *Jin Shiang Fa*, a longline fishing vessel grounded at Rose Atoll (within the Marine National Monument).

The naval gasoline tanker USS *Chehalis* AOG-48 (Figure S.MH.14.1) burned, exploded and sank on October 7th, 1949 in Pago Pago Harbor, with the loss of six crewmen (four bodies recovered). In 2007 the American Samoa EPA completed an investigation of the site, confirming the presence of gasoline cargo, as well as the possibility of unexploded ordnance. In April 2009, the U.S. Navy conducted preliminary site investigations, and cargo fuel removal actions (60,000 gallons) were completed in April 2010 (Goldstein 2013).

Figure S.MH.14.1. The Patapsco-class gasoline tanker USS *Chehalis*, prior to loss at Pago Pago Harbor through explosion/fire. (Photo US Navy)

In October 1993, a 137-foot Taiwanese flagged longline fishing vessel, the *Jin Shiang Fa* (Figure S.MH.14.2), ran aground on the western reef of Rose Atoll. In 1999 the Taiwanese government funded the removal of the majority of the wreck. Over the next 14 years, the remaining debris was removed by the U.S. Coast Guard (USCG), U.S. Fish and Wildlife Service (USFWS), American Samoan Government, NOAA, and other partners (Roberson 2017: 18). In addition to the mechanical damage to the reef and coralline algae, long-term impacts from the leaching of iron (overgrowth of cyanobacteria) into the ecosystem have been studied.

Figure S.MH.14.2. The longline fishing vessel *Jin Shiang Fa* aground on the reef at Rose Atoll in 1993. (Photo USFWS 1997)

Aircraft

Between 1900 and 1950 American Samoa was under the administration of the Department of the Navy, and during the years of World War II Tutuila supported a naval air station. As a consequence of intensive wartime training and patrols, 43 naval aircraft are recorded as having ditched or crashed into American Samoan waters between 1942 and 1944, mainly in the vicinity of Tutuila. Discussants agreed that none of these aircraft have been located/identified in the sanctuary or Territory.

Tutuila may also possess one of the most famous commercial aircraft crashes in Pacific history. On January 12th, 1939, Captain Edwin C. Musick, along with his six-man aircrew, suffered a fatal explosion and crashed into the ocean approximately 12 miles northwest of Pago Pago. Musick had inaugurated the Panamerican Flying Clipper service in the Pacific, the first trans-oceanic air link in the region. A 2019 deep ocean acoustic survey for the Samoan Clipper NC16734 (Figure S.MH.14.3) was conducted by the Air/Sea Heritage Foundation and Ocean Exploration Trust, but the site was not located/identified (Matthews 2020).

Figure S.MH.14.3. The Sikorsky S42 is the type of flying boat aircraft flown by PanAmerican/Edwin Musick and lost north of Tutuila Island in 1939. (Photo Library of Congress)

Contemporary losses can also have significant cultural impacts. In 2014 a father and son team (Babar and Haris Suleman) were attempting an around-the-world flight, when their Beech A36 Bonanza aircraft developed problems and crashed shortly after takeoff from Pago Pago. The father's body was never recovered (Barbash 2014).

Coastal Archaeological Sites/features

As of 2002, the American Samoa Historic Preservation Office's archaeological sites database maintained a record of 691 sites throughout the Territory. As the largest and most populous island in American Samoa, there are numerous archaeological sites on Tutuila. However, only a few are known within or adjacent to marine and coastal/shoreline locations. These include features such as whetstones, petroglyphs, grinding holes/bait cups (Figure S.MH.14.4), and certain archaeological sites of coastal villages.

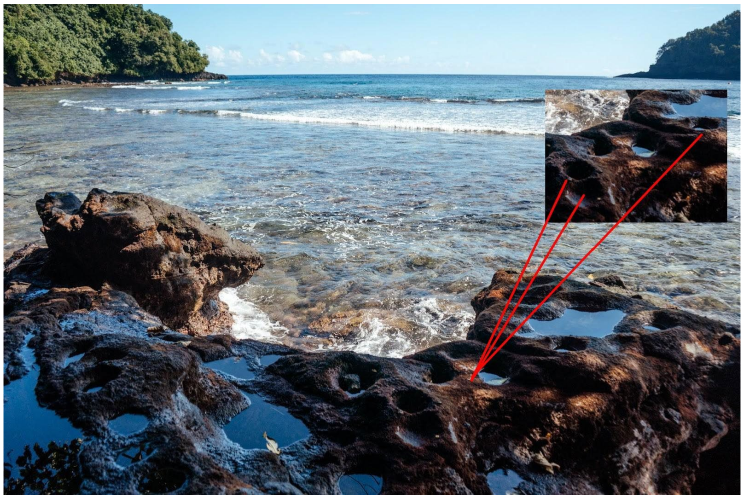

Figure S.MH.14.4. Foaga (grinding stone holes or bait cups) found at Fagatele Bay are indicative of early Sāmoan settlement in ancient times. Carved into the shoreline along the reef edge, the stone holes may have been used to sharpen basalt stone tools or to collect sea water to make sea salt. (Photo Nerelle Que/NOAA)

The 2010 article "Damage to Archaeological Sites on Tutuila Island (American Samoa) Following the 29 September 2009 Tsunami" (Addison et al) assesses post-tsunami impacts to shoreline cultural resource sites. More than fifty nearshore sites were identified during the survey. They range in size from whole coastal settlements (e.g., Fagafue, Aoloau Tuai) to single isolated artifacts and include major lithic manufacture sites, exposed stratigraphy with cultural layers, and a variety of other archaeological remains. The authors found:

> The presence of exposed stratigraphy with cultural strata at several locations around the island suggests that Tutuila's coasts are eroding and that archaeological deposits are being lost in coastal areas. Global climate change and sea-level rise should inspire a sense of urgency for the excavation and detailed study of these deposits before they are completely gone.

The potential for increasing impacts associated with climate change was noted during the workshop. The suggestion was made during discussion that there should be a follow up to the Addison et al. (2010) report in light of new understanding about climate change.

In 2013, ONMS, along with partner agencies, conducted a multidisciplinary survey of Swains Island, American Samoa (Van Tilburg et al. 2013). The fieldwork involved three areas of inter-related research: 1) the geomorphology survey revealed the previous channel (now a filled swale) leading into the brackish lake; 2) the maritime archaeology survey of the lake and nearshore marine locations identified historic and prehistoric maritime heritage resources; and 3) the terrestrial archaeology on land identified 19th century historic and possible prehistoric cultural artifacts from previous habitation phases. The project also resulted in the 2014 documentary, "Swains Island - One of the Last Jewels of the Planet" by the Ocean Futures Society.

Shoreline Pillboxes

The remnants of numerous concrete pillboxes along the shoreline, as well as gun emplacements, bunkers, naval buildings, foundations, etc. are the more visible reminders of the World War II period in American Samoa (Kennedy et al. 2005). A National Register of Historic Places (NRHP) multiple property nomination for many of these World War II sites was prepared in 2005. The nearshore coastal pillbox sites are associated with the US Marines and with the local Fitafita Samoan Marines (Figure S.MH.14.5). None were identified within sanctuary boundaries, but the general condition for these sites was discussed during the workshop. Individual pillboxes in the surf zone are subject to continuing erosion and change, and some have been knocked down, broken or displaced. Still, these resources are robust, and even when impacted by erosion, may still be considered eligible for nomination to the NRHP, as they are close enough to their original position and still retain their historic and educational value.

Figure S.MH.14.5. WWII pillbox defensive structures are located along the shorelines of Tutuila, slowly being impacted by coastal erosion. (Photo Hans van Tilburg/NOAA)

Geo-cultural Features

There are a number of legends and stories represented by natural features or specific locations within the coastal and marine context. Even specific locations underwater, such as freshwater springs or passages in the reef, can be associated with cultural folklore (Van Tilburg 2007: 27). Features of the landscape and seascape are visible touchstones of oral history. According to Volk et al. (1992):

> These sites are of extraordinary significance to Samoan culture. Compared to all of the archaeological and historic sites that the HPO [Historic Preservation Office] tries to protect, these sites are seen as the most significant to local residents.

Examples of geo-cultural locations include Turtle and Shark Cove, which is listed on the National Register of Historic Places. No negative impacts, or obstacles to access these cultural locations, are obvious. The Heritage discussion in the Ecosystem Services section also describes geo-cultural locations in the sanctuary.

Other Types of Resources

Workshop discussions raised additional resources and topics, enhancing our understanding of maritime heritage within the Territory and advancing possible topics for future research both within and beyond the sanctuary boundaries:

- WWII-era disposal of lots of vehicles, equipment, and even ammunition reportedly located at Faga`alu bay over the reef near the elementary school (outside NMSAS boundaries);
- Reports from fishermen about ammunition (Unexploded Ordnance UXO? Disposed Military Munitions DMM?) located on Taema Bank and also at deeper locations off the north side of Tutuila Island (outside NMSAS boundaries);
- UXO at Rose Atoll (within NMSAS boundaries);
- Deterioration of the Rose Atoll concrete monument (USFWS jurisdiction);
- Basalt stones/boulders recorded at Rose Atoll both by 19th century observers and on recent surveys by archaeologists (outside NMSAS boundaries)…possible "cultural artifacts" as there is no natural source of basalt at Rose Atoll (Sachet 1954; Pickering 1876; Kramer 1995).

Conclusion

Maritime heritage resources are those tangible and intangible properties (archaeological, cultural, historical resources) that capture our human connections to our Great Lakes and ocean areas. Current ONMS knowledge of the nature, location, and significance of maritime heritage resources within the National Marine Sanctuary of American Samoa is limited. Significant data gaps exist for field assessments of submerged shipwrecks and aircraft, the updated condition of nearshore/coastal archaeological sites and features (post-2010 article/assessment), and the identification of geo-cultural locations, including associated folklore and Samoan place names. The most relevant information for addressing the condition of maritime heritage resources in the sanctuary comes from the existing desk-based assessment of heritage resources for the whole Territory of American Samoa, which includes the sanctuary. Therefore, resources outside the immediate boundaries must sometimes be considered in order to estimate possible conditions of potential resources within the sanctuary itself. In general, the collective condition of maritime heritage resources is Fair, as many known sites are in somewhat degraded conditions even though many have not been subject to human impacts that might otherwise diminish their aesthetic, cultural, historical, archaeological, scientific, or educational value. Maritime heritage resources have been subjected, however, to damaging natural forces like erosion and high-energy shoreline events, which are also cause for concern regarding trends and future conditions. Resources like submerged shipwrecks and aircraft, which likely exist within the sanctuary, are presumed to be slowly degrading, primarily due to natural processes.

Table S.MH.14.1. Selected Potentially Historic Shipwreck Losses in American Samoa

name	*year lost*	*type*	*location*	*comment*
Phoebe	1828	Brig	Tutuila	Vessel stolen by Australian convicts, arrived (wrecked) at Tutuila via Huahine.
Friendship	1849	Schooner	Rose Atoll	British schooner lost at Rose Atoll, cargo saved.
Speculateur	1849	Schooner	At sea	Lost in storm and abandoned at sea. Crew reaches American Samoa.
Wakulla	1853	Schooner	Rose Atoll	Went onto the rocks, vessel stripped.
Metacom	1860	Whaler	Pago Pago	Dragged anchor in gale while provisioning, went ashore on reef.
Good Templar	1868	Schooner	Rose Atoll	En route from San Francisco, all hands but two perished.
Mary Winkelman	1923	Barkentine	Pago Pago	Drifted onto reef while departing harbor.
Tutuila	1940	Steamer	Leone Bay	31 children from Apia saved, two perished. Local divers report debris and anchor in bay.
USS *O'Brien*	1942	Destroyer	Vicinity Tutuila	Torpedoed during war, sank while underway for repairs at Pago Pago.
USS *Chehalis*	1949	Tanker	Pago Pago	Scuttled following explosion and fire near inner harbor fuel dock. ASEPA site report completed.

Commented [3]: Where should this be referenced in text?

Commented [4]: This is referenced as Table 1 on Page 2 and just needs reference to match the Table #.

Question 14 Cited Resources

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Van Tilburg, H.K., Herdrich, D., Howells, M., Sesepasara, Va'amua H., Ausage, Telei'ai C., Coszalter, M. 2018. Row as One! A History of the Development and Use of the Samoan 'fautasi'. *Journal of the Polynesian Society* 127(1): 111-136.

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Question 15: What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing?

***Status**: Good/Fair, Confidence - High; **Trend**: Not Changing, Confidence - High.*

***Status Description:** Some potentially damaging activities may exist, but they have not been shown to degrade maritime heritage resource condition.*

***Rationale:** The question addresses human activities that may have adverse impacts, and is not meant to consider deterioration primarily due to natural processes. Based on observations by participating experts, few activities, either within the sanctuary boundaries or adjacent to those boundaries, are known to have the potential for adverse impacts to maritime heritage resources. Additionally, there is agreement that this low level of adverse activity has not changed since the previous condition report.*

Maritime Heritage Resources

Maritime heritage resources are those tangible and intangible properties (archaeological, cultural, historical resources) that capture our human connections to our Great Lakes and ocean areas. Archaeological and historical resources are material evidence of past human activities and significant events, and include vessels, aircraft, structures, habitation sites, and objects created or modified by humans. Cultural resources may include specific locations associated with oral traditions or where a community has traditionally carried out economic, artistic, or other cultural practices important to maintaining its cultural identity. While there may be a broad array of tangible and intangible resources, condition report resource assessments are based on known heritage resources that are measurable and appropriate for rating. References and web links are provided here where published or additional information exists. Where data may be lacking, conclusions are best estimates, based on expert consensus and experience in the heritage preservation field.

Key Data Sets

The National Marine Sanctuary of American Samoa is not subject to many human activities that adversely impact maritime heritage resources. In order to facilitate discussions with subject matter experts, a description of the general types of activities that could have adverse impacts was provided (not necessarily associated with NMSAS):

- Anchor damage to submerged historic properties;
- Dredging channels/dumping dredge spoils;
- Trawling/fishing impacts of nets and lines to submerged properties;
- Illegal salvage of or damage to submerged shipwrecks and aircraft;

- Nearshore development including landfill, harbor/breakwater, pipeline or submarine cable infrastructure, or coastal armoring;
- Offshore development including submarine pipelines or cables, or renewable energy sources like wind turbines;
- Obstructing public or practitioner access to culturally significant locations/features;
- Obstructing cultural view sheds by nearshore development or development of offshore wind turbines;
- Indirect impacts (e.g. sedimentation from land runoff or development).

There were no indications of permissible human activities that might adversely affect maritime heritage resources within the sanctuary, but workshop discussion included some activities that could have general impacts to areas outside or adjacent to sanctuary boundaries (see below). Evidence supporting this question relies heavily on personal experience of the experts attending the workshop, due to limited formal studies and reports.

Nearshore Activities and Development

Sand removal, or sand "mining", may be a cause of increased coastal erosion, but it is not known to be occurring in the sanctuary. Sand mining for traditional use has been ongoing for years in the Fatu ma Futi area (e.g. beautification of the front yard during ceremonial events). Over the years, American Samoa has also experienced severe erosion problems at Utulei beach as a result of climate change. It is a great concern that the removal of sand in public places may be causing erosion. Palm trees once standing along the shoreline are now falling into the ocean. An area on Aunu`u may possibly be mined for sand (across from the sanctuary boundary), but that has not been confirmed.

Shoreline armoring could impact maritime heritage resources or locations, but there are no current plans proposed for the sanctuary. When under threat of erosion, it is common to consider a seawall as the fastest and most effective way to stabilize the coastline. These often bring other problems, with the loss of the high-tide beach and their tendency to accelerate erosion on adjacent land.

Commented [6]: Is this based on observation or is there an engineering reference that could support this statement?

Offshore Activities and Development

There are no offshore development activities that may impact maritime heritage resources within the sanctuary. A fiber optic submarine cable was recently installed outside of sanctuary boundaries. This project required that a compliance sidescan sonar survey (a National Historic Preservation Act Section 106 mandate) be conducted and potential historic properties within the area of potential effect were not identified (TeleGeography 2020).

Access to Cultural Resources

There are no known activities that might obstruct access to culturally significant locations or features (e.g., Turtle and Shark Cove).

Other Activities and Impacts

In 2016 the longliner fishing vessel, *No. 1 JiHyun*, grounded on the western reef of Aunu`u Island (Figure S.MH.15.1). No historic properties, like submerged shipwrecks or aircraft, are known to be present in the affected area, but the reef itself is culturally important to the community of Aunu`u as a viewshed and a location for fishing, gathering, subsistence and traditional practices. The grounding assessment report (Peau 2018) states: "This area is of ecological and cultural significance for local residents using hook-and-line, casting nets, spearfishing (non-scuba assisted) and other non-destructive fishing methods, including those traditionally used for sustenance and cultural purposes such as gleaning." The 2016 grounding represents the one activity that has degraded a location with heritage significance within the sanctuary; this event and its impact to the reef ecosystem is discussed further in the Habitat and Living Resources sections). The grounding highlighted the need for greater response capabilities and supplies, and to create clearer processes for accountability from vessel owners who ground within the sanctuary waters (Weinberg 2016).

Figure S.MH.15.1. The fishing vessel *No. 1 Ji Hyun* grounded on the western reef of Aunu`u Island (within the sanctuary), April 2016. (Photo NOAA)

Conclusion

Current ONMS knowledge of the nature, location, and significance of maritime heritage resources within the sanctuary is limited, and this data gap in recording and understanding tangible heritage resources and culturally significant locations within sanctuary boundaries affects the assessment of potential adverse impacts to those resources from human activities. Nevertheless, it is clear from the sanctuary input and workshop discussion that the site and community places high priority on cultural traditions and practices, and that few human activities within the Territory of American Samoa have obvious adverse impacts to heritage resources or locations. Due to limited formal studies and reports, this assessment relies heavily on the experience of subject matter experts. Therefore, the status is rated

Good/Fair. Additionally, there is agreement that this low level of adverse activity has not changed since the previous condition report.

Question 15 Cited Resources

Addison, D.J., Filomoehala, C., Quintus, S.J., Sapienza, T. 2010. Damage to Archaeological Sites on Tutuila Island (American Samoa) Following the 29 September 2009 Tsunami. *Rapa Nui Journal* 24(1): 34-44.

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Commented [7]: Citations not found in Q15

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This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

State of Ecosystem Services

This section provides summaries of status and trends for nine ecosystem services: non-consumptive recreation, consumptive recreation, science, education, heritage, sense of place, commercial harvest, subsistence harvest, and coastal protection. Virtual workshops were convened with subject matter experts from August to November, 2020 to discuss and evaluate these ecosystem services. It is important to note that, in general, the assessments are for the period from 2007–2020. However, in some cases, data series extend into 2021. Assessment for each service are supported by data and the rationale is provided at the end of each section. Where published or additional information exists, the reader is provided with appropriate references and web links. Workshop discussions and ratings were based on data available at the time (e.g., through 2020). However, in some instances, sanctuary staff later incorporated newly available data in order to more accurately describe the current status and trends of resources. Situations where data were used by sanctuary staff to support a rating, but were not presented or discussed during the workshop, are noted in the text. The definitions for each ecosystem service can be found in Appendix B and additional information about the methods to complete the assessments can be found in Appendix D.

Commented [1]: Mageo: Ecosystem Services are clearly defined and described with its Categories; thus, including the Types of Indicators to determine the trends,
status and ratings of each Ecosystem Service, particularly, the Category of Final Ecosystem Services.

Ecosystem services are the benefits that humans receive from natural and cultural resources. Generally, the taxonomy of the Millennium Ecosystem Assessment (2005) is used in ONMS condition reports. The Millennium Ecosystem Assessment (2005) was an initiative of the United Nations to assess ecosystem services, including cultural, provisioning, regulating, and supporting services. Categories of ecosystem services include “final” services, which are directly valued by people, and “intermediate” services, which are ecological functions that support final services (Boyd & Banzhaf, 2007). In ONMS condition reports, only final ecosystem services are rated, which is consistent with the anthropogenic focus of the reports and highlights priority management successes and challenges in sanctuaries. The complete definitions of ecosystem services considered by ONMS are included in Appendix B.

Text Box 1.:
There are two categories of ecosystem services: intermediate and final. Ecosystem services that are evaluated in condition reports are final ecosystem services. Intermediate services support other ecosystem services, whereas a good/service must be directly enjoyed by a person to be considered a final ecosystem service. For example, nutrient balance leads to clearer water and higher visibility for snorkeling and scuba diving. Nutrient balance is an intermediate service that supports the final ecosystem service of non-consumptive recreation via snorkeling and scuba diving.

Text Box 2.:

Thirteen final ecosystem services may be rated in ONMS condition reports

Cultural (non-material benefits)

1. Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources

2. Non-consumptive recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources
3. Science — The capacity to acquire and contribute information and knowledge
4. Education — The capacity to acquire and provide intellectual enrichment
5. Heritage — Recognition of historical and heritage legacy and cultural practices
6. Sense of Place — Aesthetic attraction, spiritual significance, and location identity

Provisioning (material benefits)

7. Commercial harvest — The capacity to support commercial market demands for seafood products
8. Subsistence harvest — The capacity to support non-commercial demands for harvesting of food and utilitarian products
9. Water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash
10. Ornamentals — Resources collected for decorative, aesthetic, or ceremonial purposes
11. Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use
12. Energy — Use of ecosystem-derived materials or processes for the production of energy

Regulating (buffers to change)

13. Coastal protection — Flow regulation that protects habitats, property, coastlines, and other features

Notably, some consider consumptive recreational fishing as a provisioning service, but it is included here as a cultural ecosystem service. Also, even though biodiversity was listed as an ecosystem service by the Millennium Ecosystem Assessment (2005), ONMS decided to remove it, recognizing that biodiversity is an attribute of the ecosystem on which many final ecosystem services depend (e.g., recreation, harvest); therefore, it is addressed in the State section of this report. Lastly, although ONMS listed climate stability as an ecosystem service in 2015, it is no longer considered an ecosystem service in ONMS condition reports, because national marine sanctuaries are not large enough to influence climate stability (Fisher et al., 2008, 2011).

For NMSAS, ten of the 13 final ecosystem services were rated during the 2020 workshops: non-consumptive recreation, consumptive recreation, science, education, heritage, sense of place,commercial harvest, subsistence harvest, and coastal protection. The other three ecosystem services were evaluated by staff, but were determined to not be applicable to the sanctuary.

Commented [2]: the odd separation of material and non-material culture into provisioning and cultural categories has always bothered me about the MEA classification scheme. You see that very clearly in this category. Why would ceremonial purposes not be a cultural benefit? This is just an observation, I don't think there is much you can do about it since this is the framework you're using. You might consider whether "cultural" and "provisioning" are really any more helpful than relabeling to "material" and "non-material", which is what they actually represent according to the parentheses anyway.

Commented [3]: why? what is the rationale for both and why did you decide it was better to put it under non-material? I'm not advocating for one or the other, just pointing out that the rationale should be included.

Ecosystem Services Indicators

The status and trends of ecosystem services are best evaluated using a combination of three types of indicators: economic, non-economic, and resource. Economic indicators may include direct measures of use (e.g., person-days of recreation, catch levels) that result in spending, income, jobs, gross regional product, and tax revenues, or non-market economic values (the difference between what people pay to use a good/service and what they would be willing to pay). Non-economic indicators can be used to complement economic indicators and include importance-satisfaction ratings for natural and cultural resources, facilities and services for recreation uses, limits of acceptable change for resource conditions, social values and preferences, social vulnerability indicators, perceptions of resource conditions in the present and expectations for the future, and access to resources. Finally, resource indicators are considered in determining status and trend ratings for each ecosystem service. Resource indicators are used to determine if current levels of use are sustainable or are causing degradation to resources. If resources cannot support current levels of use, this may downgrade a rating that may otherwise be higher based on economic and non-economic indicators alone. Together, these three types of indicators are considered when assessing the status and trends of ecosystem services in national marine sanctuaries.

Non-Consumptive Recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Rating: *Fair (High Confidence) and Improving Trend (High Confidence)*

Status Description: *The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.*

Rationale: *Though it is clear that both physical conditions and infrastructure limit access for non-consumptive recreation activities in the sanctuary, the levels of existing activities are not well understood or quantified. The improving trend reflects sanctuary and partner outreach and education activities that highlight recreational opportunities in the sanctuary. These create interest among residents and tourists to use the sanctuary.*

Non-consumptive recreation services within NMSAS include activities such as swimming, snorkeling, SCUBA diving, and boating, beach recreation, and beach camping that do not result in the intentional removal of or damage to natural and heritage resources. Sanctuaries are directed to facilitate recreational activities to the extent compatible with resource protection. The goals of NMSAS are to increase awareness of responsible use in the sanctuary and minimize user impacts. The status of non-consumptive recreation is "Fair" (high confidence) as these activities are limited in most of the NMSAS units due to the remote nature and limited or difficult access into these areas. Direct impacts to sanctuary resources from non-consumptive recreation appear to be minimal. The trend is "Improving" (high confidence) as the sanctuary has implemented efforts to improve access during the reporting period.

To access Fagatele Bay, most of Fagalua/Fogama'a, the Aunu'u Research Zone, and Ta'u visitors must either hike across rough terrain or access the site by boat. There are no facilities at the sites and land access to Fagatele Bay is controlled by the traditional landowners. Limited area for beach camping is available adjacent to the Fagalua/Fogama'a unit and campers often swim and fish within the sanctuary. Rowing, kayaking, and paddling in these areas are impractical due to the access constraints and reef structure. Residents of Aunu'u can easily access the Aunu'u Multipurpose Zone which abuts the southern side of the village, however, the waves along this coast can be treacherous making shore access to deeper waters dangerous at times. Visitors have to take a ferry from Tutuila to reach Aunu'u. Rose Atoll and Swains Island have restricted access and require a lengthy boat trip making recreational access impractical. The remote nature of the units also makes it difficult to evaluate visitor use, so no data is available to directly assess this service.

Although there are no studies available that look specifically at non-consumptive recreational activities within the sanctuary itself, there have been studies that analyze marine-related activities and uses of the waters in American Samoa. For example, the National Coral Reef Monitoring Program conducted

Commented [1]: Mageo: Placing the Assessments (Rating, Status Description, Rationale) of each Ecosystem Service to begin each sub-Section is appropriate and
helpful to the reader. Appropriate because it's easily accessible instead of a graphic/chart display in another Appendix at the end of the Report. It's also helpful because it summarizes the contents of the whole section in its entire context. Non-Consumptive Recreational Activities, although access is very limited to Sanctuary Units, is one of the Services with a significant cultural, historical and natural value if/when it's utilized.

socioeconomic survey in 2014 (2016, Levine, et al.).The most common non-consumptive recreational activities taking place in American Samoa are swimming, beach recreation, and beach camping (primarily Fagalua and Fogama'a) The 2014 survey of American Samoan residents (n=448) showed that 47% reported swimming more than once/month, 21% reported beach recreation at least once in the past month, and 16% reported beach camping at more than once per month. Less common activities include snorkeling, diving, boating, canoeing, and surfing.

Outside of this survey, there is little evidence and/or documentation of visitation to the sanctuary. However, sign-in sheet data maintained by the landowners showed that 297 individuals visited Fagatele Bay in 2010 (Cheng and Gaskin 2011). Data are not available for other years. A trail was constructed in 2007 that leads from the ridge to the beach adjacent to the bay, thus allowing for increased access to Fagatele Bay. Public access to the beaches, and consequently the water, is under the purview of the village or individual families that reside adjacent to the water and public places. One must obtain permission or approval for access out of respect and courtesy. In some places landowners charge an access fee (that does not go to the sanctuary). These families are the caretakers of these special places and help to maintain and safeguard them for current and future generations.

The only available data regarding the number of snorkeling trips by visitors are from 2004, when roughly 2,750 snorkel trips in Fagatele Bay occurred. Data regarding diving activities are also limited. In 2004 there were 15 active divers living in American Samoa and they completed approximately a total of 450 dives in the sanctuary (Spurgen et al. 2004). In a more recent study conducted in 2014 of 448 residents of American Samoa reported that 70% never went snorkeling and 93% never went diving (Levine, et al., 2016). Five percent of respondents reported snorkeling four or more times a month and two percent reported diving four or more times a month.

Humpback whales can be seen in the waters of American Samoa from mid July to November, although exact arrival and departure times vary from year to year. There were no commercial whale watching operators in American Samoa from 1991-1998, but in 2005 and 2008 there may have been minimal commercial whale watching operations (Connor et al. 2009). Anecdotally, experts at the workshop noted they were unaware of any current commercial whale watching operations. However, it is possible that those on cruise ships, yachts or along the shore engage in whale watching, but there is no information on these user groups relative to wildlife viewing.

Pago Pago Harbor is one of the deepest harbors in the Pacific and an increasingly popular stop for cruise ships. The number of cruise ships visiting American Samoa has increased since 2006, with the number of incoming cruise ships more than doubling from six in 2006 to 14 in 2017 (Table App.NCR.1). Each ship carries hundreds of visitors. Cruise ship arrivals were cancelled from December 2019- February 2020 due to a measles epidemic in neighboring Samoa, and ceased in March 2020 due to the global pandemic. Arrivals by yachts are variable from year to year with a low of 50 arrivals in 2009 and a peak of 113 in 2011 (ASSY, 2016 & 2017).

The number of tourist arrivals by plane has also been variable (American Statistical Yearbooks of 2016 and 2017) (Table App.NCR.2). Starting at a high point of roughly 7,500 arrivals in 2007, arrivals showed a declining trend until 2015. There was a rebound in 2016 and 2017 with 2,501 and 5,579 arrivals, respectively. The majority of tourist arrivals are from the United States and New Zealand. Tourists visit the nearby National Park of American Samoa. From 2008-2018 there was a steady increase of visitors to the park (Figure ES.NCR.1). A notable peak occurred in 2017, with roughly 70,000 visitors entering the park. Although these data sources provide information on the total number of visitors to the island, it is

Commented [2]: how does the sanctuary management coordinate with these landowners? is this an area of opportunity? Do the landowners live within the sanctuary or adjacent and just provide access? is there any federal land from which people access the sanctuary? is it preferred that people access from certain areas? This dynamic isn't clear.

Is there a management plan with objectives that can be related to these indicators? It's hard to tell what is the desired status.

Commented [3]: how was this measured, by who, and why hasn't it been done since then?

unclear how many actually visit the sanctuary. Cruise, yacht and airplane arrivals abruptly ended in 2020 due to the global pandemic and it is unknown how long this industry will take to recover. Arrivals and departures by vessel type are conveyed in Table App.NCR.1 (American Samoa Statistical Year 2016 & 2017).

During the workshop experts also noted educational programs being implemented by the sanctuary have likely increased awareness, and perhaps visitation and recreation to NMSAS. The sanctuary has also supported efforts to increase awareness around ocean swimming and science. From 2011-2015 the Ocean Swimming/Ocean Science course offered 1 credit to Samoana High School students that were taught how to swim. The total number of students who took the course from 2012-2015 was 160 students (50 students in 2012, 50 students in 2013, 30 students in 2014 and 30 students in 1025). In the summer, Ocean Star was targeted toward elementary school students to learn about coral reefs and swimming. Thirty-five students participated in 2013, 35 participated in 2014 and 40 participated in 2015. A more complete list of educational programs is provided in the Education Ecosystem Service.

Further, because of these outreach efforts there is more awareness of the various locations within the sanctuary, thus leading to more visitation. Despite this additional awareness, experts noted there is limited access to many sites within the sanctuary due to a lack of infrastructure and/or distance of many locations to the marinas and boat ramps. The sanctuary does not control land access to many sites, requiring either permission from landowners or chartering a boat to reach the sites. It is not within the sanctuary's ability to improve infrastructure related to accessing the marine environment since the surrounding lands are either community or privately owned. Anchoring is prohibited in all sanctuary units and the site has not maintained mooring buoys during this period which may limit boat access. There is a limited number of for-hire and tour guide businesses that take snorkelers and boat-riders out to Tutuila, including Aunu'u and Fagatele, but the industry is not well developed. These businesses have begun taking visitors to the Ta'u unit to snorkel or dive around the large *Porites* colonies there, but the number of trips is limited. The lack of access and limited capacity to provide this service may restrict the overall non-consumptive use within the sanctuary.

The condition of natural resources is probably not significantly affected by non-consumptive recreation and, therefore, did not influence this rating. As described in the State Section, the status of water quality was rated good. According to the AS EPA, the open coastal waters in Fagatele Bay, Ta'u, and Aunuu are fully supporting recreational use. Coral communities remain robust, though they may be experiencing impacts from climate change. Antarctic humpback whales continue to journey to American Samoa for calving and breeding, with high densities observed near Fagatele Bay and Aunu'u. Lastly, the decreased biomass potential, particularly for larger parrotfish, groupers and sharks, is unrelated to non-consumptive recreation.

Conclusion

Although there have been no studies specific to non-consumptive recreation in NMSAS, there have been studies that look at participation rates across the entire region. This proxy data show that swimming and beach recreation are some relatively common activities in American Samoa. Although the number of cruise ship arrivals has been increasing, the number of overall tourist arrivals to American Samoa has decreased from 2007-2015 (although there has been some increases in recent years). Visitation to the national park has been increasing since 2008, with a peak visitation occurring in 2017 (Figure ES.NCR.1.1). . Yet, despite increasing awareness of the sanctuary and the recreational opportunities available, a lack of infrastructure to promote access continues to be a limiting factor. Expert opinion along with the measurable proxy indicators lead to a status rating of fair with an improving trend.

Figures

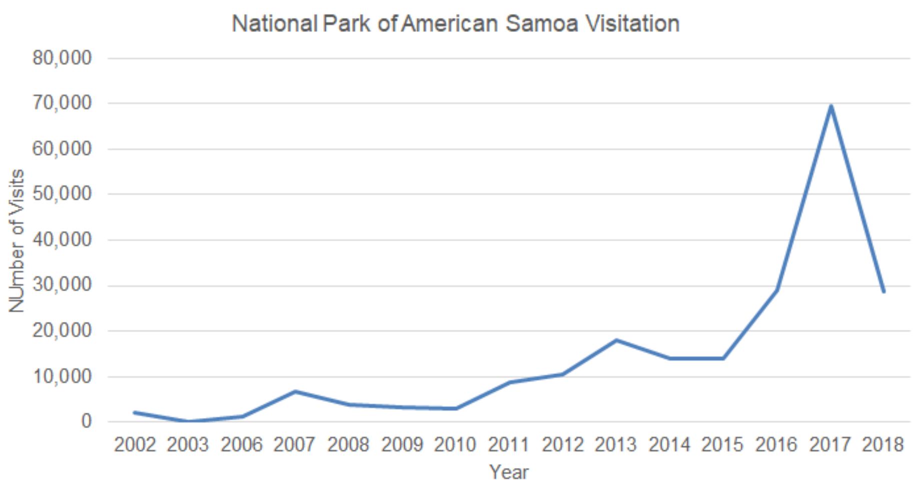

Figure ES.NCR.1. Number of visits to the National Park of American Samoa. From 2008-2018 visitors have shown a steady increase. A notable peak occurred in 2017 with roughly 70,000 visitors entering the park.

Commented [4]: @kathy.broughton@noaa.gov I recommend removing the embedded title if possible.

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https://corporate.southpacificislands.travel/humpback-whales-returning-american-samoa/

Appendix - Non-Consumptive Recreation

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Table App.NCR.1. Vessel Traffic at Pago Pago Harbor: FY 2006-2017. Sources: American Statistical Yearbook, 2016 and 2017

Type	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Incoming vessels	849	742	639	710	731	693	845	527	811	878	746	666
Cruise ships	6	5	8	10	8	7	26	10	21	13	16	14
Government boats	4	-	-	-	-	-	-	-	-	-	-	
Freighters	172	146	114	124	111	96	66	93	106	121	121	146
Tankers	33	29	24	30	31	31	30	17	27	30	29	31
Fishing boats	276	152	137	83	75	-	-	-	-	529	-	344
Yachts	84	69	95	50	84	113	60	64	96	101	102	56
Local boats		-	-	-	-	-	-	-	-	-	-	
Military/ naval ships	1	1	-	-	-	-	3	1	2	7	-	4
Barges/tugs		3	-	-	-	1	-	-	-	-	-	
Reefers	17	18	13	15	18	15	9	3	15	18	8	

Commented [6]: Eric Brown: What are "Reefers"?

Commented [7]: Generally, cargo vessels (refrigerated) for perishables. Need to confirm with site staff as I am not familiar with American Samoa vessels

Others	253	322	248	398	403	431	651	339	544	59	470	68
Outgoing vessels	817	744	621	819	702	630	785	553	813	925	771	666
Cruise ships	6	5	8	10	8	8	26	10	21	13	16	14
Government boats		2	-	-	-	-	-	-	-	-	-	
Freighters	171	147	114	124	101	96	66	93	106	122	123	146
Tankers	33	29	24	29	31	28	30	17	31	28	29	31
Fishing boats	250	160	140	95	76	-	-	-	-	573	-	344
Yachts	77	71	75	60	79	79	62	55	69	102	99	56
Local boats		-	-	-	-	-	-	-	-	-	-	
Military/ naval ships	1	1	-	-	-	-	3	1	2	11	-	4
Barges/tugs		2	-	-	-	1	-	-	-	-	-	
Reefers	18	15	14	11	13	13	7	3	13	18	6	3
Others	257	316	246	490	393	406	591	374	571	58	498	68

Table App.NCR.2. Tourist Arrivals by Month: 2006-2017. Sources: American Statistical Yearbook, 2016 and 2017

Month	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017

January	837	648	688	642	544	559	459	460	488	454	445	495
February	450	411	362	409	371	402	319	308	264	298	292	302
March	639	505	533	531	468	482	372	385	365	395	366	425
April	512	551	428	452	492	402	392	379	382	398	477	527
May	567	613	584	482	508	400	603	451	387	364	363	471
June	810	759	668	592	538	698	566	490	511	476	611	622
July	837	928	1,197	712	707	559	838	766	440	451	567	677
August	698	638	620	476	471	491	420	476	261	254	356	465
September	508	629	455	408	402	352	368	295	386	336	332	383
October	622	477	502	607	415	270	331	309	429	350	371	376
November	420	473	392	429	356	383	285	315	361	345	340	321
December	862	889	655	734	854	684	610	496	538	534	531	515
Total	7,762	7,521	7,084	6,474	6,126	5,682	5,563	5,130	4,812	4,655	5,051	5,579

This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Consumptive Recreation — Recreational activities that result in the removal of or harm to natural or cultural resources

Status: Good/Fair with Low Confidence (Limited evidence, Medium agreement)
Trend: Improving with Medium Confidence (Limited evidence, High agreement)

Status Description: *The capacity to provide the ecosystem service is compromised, but performance is acceptable.*

Rationale - *The status of good/fair was based primarily on the fact that recreational opportunities have not been significantly reduced by changes in resource availability or access restrictions. The expansion of the sanctuary restricted fishing access in two sites, but was expected to have minimal impact on recreational fishing activities. People were still able to access resources for enjoyment and the sanctuary worked to increase awareness of responsible recreational fishing practices. Consumptive recreation in the sanctuary likely decreased after the expansion in 2012 and then increased after subsequent outreach to enhance recreation fishing activities. There is insufficient data to determine the extent of these changes, therefore, the ratings for this service are based primarily upon expert opinion.*

Consumptive recreation is a term used to describe recreational activities that may result in the death or disturbance of wildlife, or the destruction of natural habitats. In many places, this includes recreational fishing, sport fishing, and beachcombing. Within the sanctuary system, sites try to balance access to these activities with resource protection to maintain this ecosystem service. Evaluating this service in the Pacific islands is difficult as island communities rely on fishing for subsistence and do not view it as a recreational activity. The National Coral Reef Monitoring Program found that In American Samoa, 24% of survey respondents did report 'for fun' as being a 'frequent' or 'sometimes' reason they fish, but this was almost always coupled with other reasons related to providing food or fulfilling cultural obligations (Levine et al., 2016). When residents fish, it is primarily to support their families and communities, which is discussed further in the subsistence harvest section.

Due to the traditional marine tenure system, residents usually fish in their home village and do not require a license, special gear, or for-hire operations. This makes it difficult to track fishing activities in the territory, so there are limited data to assess the level of direct use of consumptive recreation as a stand-alone activity. Non-residents (e.g. tourists or contract workers) may engage in recreational fishing activities, however, opportunities are limited, as only a few companies offer charter fishing services and the cruise ship tourists usually do not have enough time to engage in fishing activities during their short (<12 hours) visit to the island. Experts noted that they do not see much recreational fishing, even by visitors to the island, and fishing tournaments (Figure ES.CR.1) are one of the few truly recreational fishing activities in American Samoa. Therefore, consumptive recreation is likely to be a small portion of total fishing when compared to commercial and subsistence harvests. What is known about the level of recreational fishing effort data is summarized here.

During the expansion process, NMSAS worked with village councils to evaluate fisheries regulations for each unit. The Futiga Village Council requested that fishing activity be restricted in Fagatele Bay and in

Commented [1]: Mageo: Similar comments as to the beginning of the aforementioned Section(5a). It's only appropriate that there is no survey being conducted, data or evidence collected in regards to Consumptive Recreation Activities/Services because it's mostly utilized by local residents mainly for fun and sustenance. It's part of life in the Territory/Islands; therefore, local water activity experiences and opinions will suffice as stated.
Also, commendation to ONMSAS/NOAA in its efforts with educational outreach through various activities in regards to benefits and
cautioned in awareness to Consumptive Recreation.

Aunu'u, the Village Council requested that some fishing be allowed within the research zone of the Aunu'u unit.   Fagatele Bay is now a no-take marine protected area and only surface fishing for pelagic species is allowed in the Aunu'u research zone. These units are difficult to access for fishing, requiring either a boat or a hike across rough terrain. Fishing is allowed in the Aunu'u multipurpose zone, which is the only NMSAS unit that is close to a village and considered an important fishing ground.
In 2013, NOAA Fisheries designated a no-take zone for 12 nm around Rose Atoll, however, recreational fishing is allowed in this zone with a permit. Fishing access was not altered in Fagalua/Fogma'a, Ta'u, and Swains Island. The sanctuary expansion may have affected consumptive recreation by restricting fishing in Fagatele and the Aunu'u research zone, but the impact was expected to be minimal due to their location and access constraints (DOC 2012). Residents also were confused about fishing access after the expansion and this may have curtailed activity immediately after the expansion. To counter this, and to correct misperceptions related to the new units, NMSAS conducted outreach to educate the public about fishing access in the sanctuary, and hosts an annual fishing tournament to encourage pelagic fishing (Figure ES.CR.1).

Figure ES.CR.1. Local fishing community participants at the 2019 Fagota Mo Taeao Open Fishing Tournament. Photo: Nerelle Que/NOAA

Tourism is still limited in American Samoa, but cruise ship visits have increased over the reporting period, doubling from six in 2006 to 14 in 2017 (Table App.NCR.1). Each ship carries hundreds of visitors. Pago Pago Harbor is one of the deepest harbors in the Pacific, making it an ideal stop for cruise ships and yachts. Although this may change in the future, at present cruise ships and other tourist arrivals do not appear to be relevant to consumptive recreation (Table App.NCR.2). One reason is because the cruise ships only dock for a limited time, often after peak fishing hours and not long enough for passengers to engage in fishing charters. Also, due to the limited tourism market, there are only a few for-hire operations that take visitors to the sanctuary on tours. These businesses must rely on other activities (e.g. inter-island transport, commercial diving, etc.) throughout the year to sustain operations. Companies that coordinate cruise ship visits in American Samoa, do not promote many water recreation tours due to the lack of capable companies to provide these tours. There are no fishing, whale watching, or island cruises listed as tour options for any of the ships.

Yachts often visit for longer periods and may engage in consumptive recreation activities during their stay, or during transit before or after their visit to Pago Pago. However, there are no data on how many yachters fish and if they fish within the sanctuary; it is believed to be minimal. Workshop experts noted that the National Park of American Samoa is closer to the airport and easier to access, and is a more established destination for tourists. It also tracks visitor use. This data may be helpful in evaluating this service in the future, as it is likely that the same visitors that use the park also recreate in NMSAS. However, more research would be needed to confirm this (Figure ES.NCR.1). A full discussion of cruise ship, yacht, and other tourist arrivals is provided in the non-consumptive recreation section (American Samoa Statistical Year 2016 & 2017).

The annual Fagota Mo Taeao Open Fishing Tournament, started in 2016, is hosted by the Sanctuary Advisory Council Fishing Committee, and is co-managed by NMSAS and Department of Marine & Wildlife Resources. The purpose of the tournament is to increase awareness of sustainable fishing practices in the sanctuary and bring traditional fishermen and recreational anglers together. It is open to both residents and non-residents. The tournament receives extensive local sponsorship and provides donations of fish to a local charity. The tournament not only supports and is supported by locals, but also provides an opportunity to learn about sustainable fishing. Prizes are awarded to the three heaviest fish caught in six different species categories and awards are also provided for outstanding sportsmanship and participation. In 2019, the two-day tournament had a total of 16 boats registered and participation included 80 local ‘alia and recreational anglers, with the youngest being nine years old. The number of reported catches has increased since the tournament's inception. The most commonly kept fish caught were yellowfin, dogtooth and skipjack tuna. Participants reported some catches from both Aunu’u and Ta’u, but most were~~was~~ from outside of the sanctuary.

Conclusion

There is limited evidence related to consumptive recreation within NMSAS. At present, the majority of those who benefit from consumptive recreation in American Samoa are local residents, but they generally do not conduct the activity solely for recreational purposes, but do so in conjunction with other responsibilities, such as providing food. Cruise ships, yachts and tourist arrivals have not been significant participants in these activities, and are not useful indicators for this service at this time.

Commented [2]: are there any plans to try to collect any evidence in the future? How would recommendations like that fit in with this report?

Citations

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Office of National Marine Sanctuaries. 2012. Fagatele Bay National Marine Sanctuary Final Management Plan / Final Environmental Impact Statement. Silver Spring, MD.

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This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Science - The capacity to acquire and contribute information and knowledge

Commented [1]: Mageo: Science appears to be the most viable and utilized Service in studying, maintaining and in managing the NMSAS Ecosystems. It has the greatest capacity for expansion with multiple functions in sustaining and managing NMSAS.

Status: *Good/ Fair with High Confidence* ***Trend:*** *Increasing with High Confidence*

Status Description: *Demand for the service is not fully met, but performance is acceptable and may not warrant enhanced management.*

Rationale: *Science activity has been increasing at NMSAS throughout the reporting period and current levels are rated as good/fair. During this time, research activities, publications, science capacity, and partnerships have all increased. Experts noted that there are still limitations due to access to large research vessels and science staff capacity, and the program will need more support in the future, given the large sanctuary expansion in 2012. The incorporation of traditional knowledge and more student programs were highlighted as areas for future improvement.*

Science as an ecosystem service is defined as the capacity to acquire and contribute information and knowledge. This information and knowledge can come in many forms, from quantitative data on ecological parameters such as fish biomass and coral cover to traditional knowledge about seasonal trends and cycles. Science services often involve scientists, but can also be generated by students and community members. The information generated from these programs feeds directly into the adaptive management process at NMSAS.

Science capacity at NMSAS falls into three main categories, science conducted by the sanctuary, science conducted by research partners, and science conducted by students and the community. NMSAS had limited scientific capacity during this reporting period, but has recently added a full time research coordinator, a research scientist, and marine operations coordinator to support scientific field operations. The lack of NMSAS science capacity limited sanctuary lead research activities in the past, but NMSAS has acquired funding and technical capacity to initiate a research program including a long term coral reef monitoring program, which began in 2020. The program will address the priorities established in the Marine Conservation Science and Climate Change Action Plans, including monitoring, characterization, climate science, and improving public science outreach.

Most of the science conducted at NMSAS from 2007 to 2020 was implemented by partner organizations, including ONMS MHP, NOAA PIFSC ESD, NOAA NOS NCCOS, NOAA CRCP, NOAA OER, NOAA OAP, ASHPO, the Bishop Museum, the Ocean Exploration Trust, Catlin Sea View, the Ocean Futures Society, agencies associated with the AS CRAG, and a number of academic institutions. Projects include shallow coral reef monitoring, ocean acidification monitoring, mesophotic reef characterization and exploration, bathymetric mapping, deep sea exploration, targeted research on contaminants and coral disease, and archaeological and social science research to evaluate maritime heritage resources.

NMSAS has tracked the effort and outcomes of these projects. Figure ES.S.1 illustrates the increase in scientific permits within NMSAS since 2007. Prior to 2007, the highest number of permits in any given year was three, but this increased to nine in 2018. This activity decreased slightly in 2020 due to the global pandemic, but is expected to increase once travel resumes. Figure ES.S.2 shows the number of publications related to NMSAS. Publications have increased significantly since 2007, with seven publications specific to NMSAS and over thirty publications related to sanctuary units in some way.

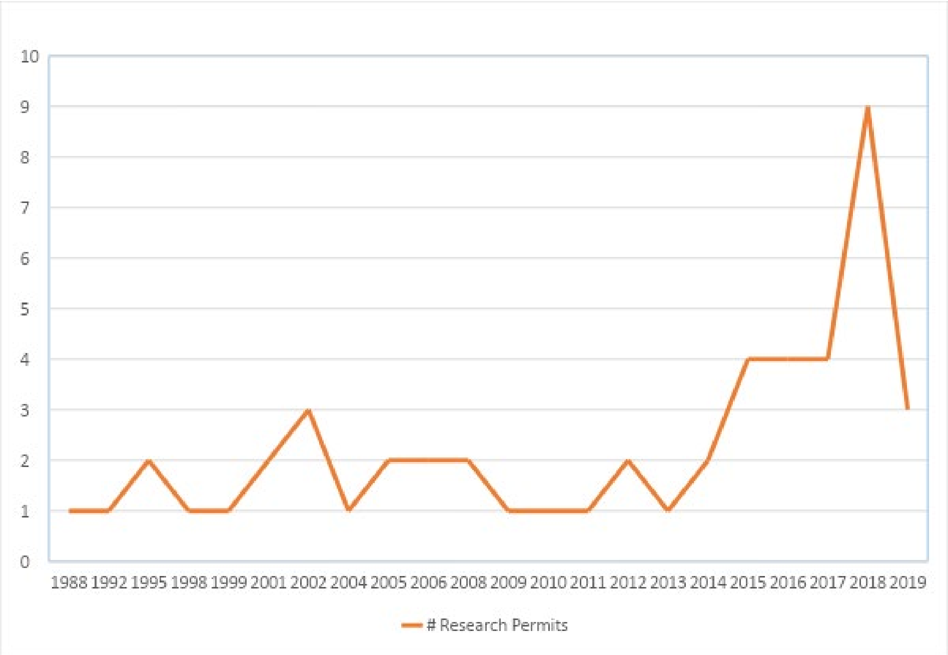

Figure ES.S.1. Number of research permits issued by NMSAS from 1988 to 2019. Source: NMSAS data

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Commented [3]: @kathy.broughton@noaa.gov Just catching random other things as a I go...if this is a specific database/data set, it needs a full citation with a year. If not, it can just be changed to "Source: NMSAS."

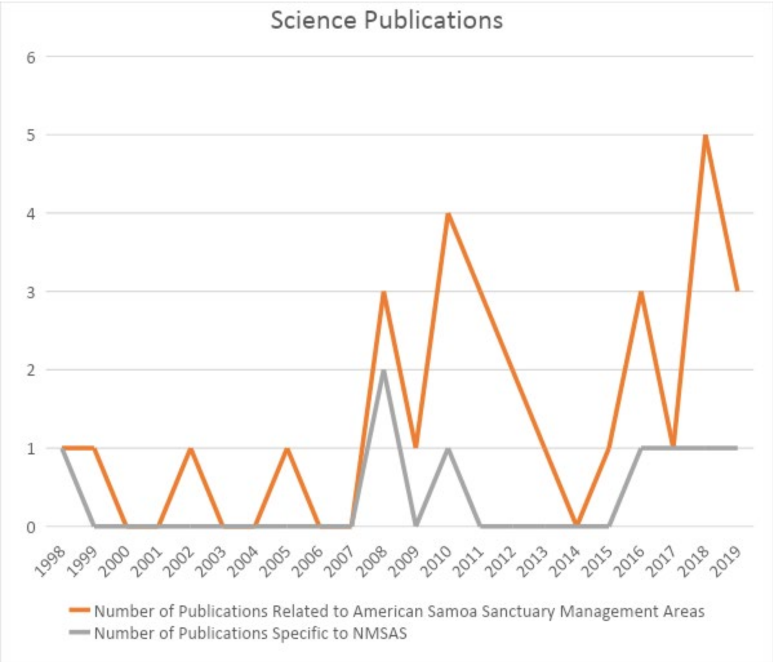

Figure ES.S.2. Number of scientific publications either related to NMSAS units or specific to NMSAS from 1998 to 2019. Note the significant increase after 2007. Source: NMSAS data

Major partner efforts include the AS Reef Assessment and Monitoring Program cruises cruises funded by NOAA CRCP in 2008, 2010, 2012, 2015, and 2018 (Brainard et al. 2008, NOAA CREP 2016, Vargas-Angel et al. 2018), which collected data on shallow coral reef ecosystems (0-30m) around all the islands within the territory using a stratified random sampling design. This program is now part of the National Coral Reef Monitoring Program and monitors benthic habitat, coral demographics, fish biomass and diversity, and oceanographic parameters. Later cruises increased sampling in NMSAS units to improve data availability for the sanctuary. Divers from NOAA NOS PMNM, NPSA, UH, and Bishop Museum conducted exploration dives in Fagatele Bay, Fagalua/Fogama'a, and Aunu'u using rebreathers from 2015-2018. Another significant effort was the CAPSTONE project conducted by the Okeanos Explorer in 2017. This project assessed deep sea habitats within NMSAS as part of its exploration efforts and data are publicly accessible via the NOAA Deep-Sea Coral Program portal and a number of publications, including Kennedy et al 2019 and Amon 2020. The ship is well equipped for outreach and conducted telepresence activities for the local community. This was followed by the Ocean Exploration Trust's 2019 cruise aboard the EV Nautilus, which also included telepresence opportunities and included local agency staff and students as part of the science team (OET 2019). Also in 2019, a MAPCO2 buoy was installed in Fagatele Bay to monitor ocean acidification and general oceanographic conditions as part of a

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Please:

-Add x and y axis titles in title case
-Remove embedded title
-Change legend descriptions to sentence case (only first word and proper nouns capitalized); "number of" can be removed from these descriptions since y axis title should be something like "Number of Publications".

partnership between NMSAS, OAP, and CRCP. The buoy transmits real-time data, which is available at PMEL and PacIOOS websites.

NMSAS also supports capacity building and stakeholder engagement through internships, including Kupu interns, Hollings Scholars, Nancy Foster Scholars, and NERTO interns, and provides science information to the public through the visitor center and ocean literacy efforts.

Experts noted that the science capacity at NMSAS is limited by access to vessels capable of supporting operations at Swains Island and Rose Atoll, the limited staff capacity at NMSAS for scientific operations, the lack of entry level positions for emerging local scientists, and the lack of dedicated lab space, research facilities, and affordable housing for visiting researchers. They noted that science capacity in NMSAS has increased, but given the enormous expansion of the sanctuary in 2012, it will need more support to meet the needs for monitoring and other conservation science. The NOAA Ship Hi'ialakai In addition, experts would like to see more traditional knowledge incorporated into sanctuary science activities and more opportunities for students to be engaged.

Conclusion

Science is an important ecosystem service for NMSAS and activity has been increasing throughout the reporting period. Current levels are rated as good/fair. During this time, research activities, publications, science capacity, and partnerships have all increased. NMSAS has successfully worked with partners to support research cruises for shallow coral reef ecosystems and deep sea exploration, exploration of mesophotic systems, investigation of contaminants in Fagatele Bay, and installation of a buoy to monitor ocean acidification in Fagatele Bay. College interns and fellows have supported science efforts and outreach staff have incorporated science into ocean literacy efforts. Experts noted that there are still limitations due to vessel access and science staff capacity and suggested that the program would benefit from more support. The incorporation of traditional knowledge and more student programs were highlighted as targets for improvement.

Citations

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Brainard et al (2008) Coral Reef Ecosystem Monitoring Report for America Samoa: 2002–2006. NOAA Special Report NMFS PIFSC

Kennedy BRC, Cantwell K, Malik M, Kelley C, Potter J, Elliott K, Lobecker E, Gray LM, Sowers D, White MP, France SC, Auscavitch S, Mah C, Moriwake V, Bingo SRD, Putts M and Rotjan RD (2019) The Unknown and the Unexplored: Insights Into the Pacific Deep-Sea Following NOAA CAPSTONE Expeditions. Front. Mar. Sci. 6:480. doi: 10.3389/fmars.2019.00480

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Ocean Exploration Trust. (2019). Exploring the National Marine Sanctuary of American Samoa. https://nautiluslive.org/blog/2019/07/22/exploring-national-marine-sanctuary-american-samoa. Accessed 8/16/2020.

Vargas-Angel et al (2018) Coral Reef Ecosystem Monitoring Report for the National Marine Sanctuary of American Samoa. Pacific Islands Fisheries Science Center. Ecosystem Sciences Division. NOAA Technical Report

This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Education - The capacity to acquire and provide educational programs

Commented [1]: Mageo: Education is the most active of all the NMSAS Ecosystem Services in providing programs to inform the public through open forums, presentations, conferences, schools and ONMSAS/NOAA sponsored Community or Government Outreach/Activities. This Service is the most invaluable in raising public awareness as to the status of the NMSAS Units, Ecosystems and its management of various Responses.

Status: *Good, Confidence – Very High*

Trend*: Improving, Confidence – Very High*

Status Description*: The capacity to provide the ecosystem service has remained unaffected or has been restored.*

Rationale: *Education programs have strengthened the NMSAS mission to continue to restore and protect marine ecosystems. The sanctuary has a very robust education program that includes pre-K through higher education programs for teachers and students that has reached over 3500 students and over 100 teachers, yearly; immersive summer programs that have reached over 850 participants; a wide range of community outreach events; and approximately 40,000 individuals have toured the well-regarded visitor center that serves both the local community and tourists. The number of programs has expanded during the reporting period with new offerings added each year.*

Commented [2]: do you have any metrics of outcomes (e.g., knowledge gain, attitude or behavior change) vs. outputs (e.g., how many people reached, how many programs delivered, how many brochures produced)

Education Indicator Table. Summaries for the key indicators related to education that were discussed during the 2020 status and trends workshop.

Non-Economic Indicators	Source	Data Summary
Pre-K to 12 Education Programs	ONMS Knack System, and I.Halatuituia, personal communication, October 2020	The data shows the number of students participated in school presentations; career day, presentations, guest speakers, etc.
Summer Programs	NMSAS Summer Program Report, one-pagers,2016, 2017, 2018, 2019; I.Halatuituia, personal communication October 2020	The data shows the number of participants in different summer programs; Ocean Swimming Ocean Science, Ocean Star, and Sanctuary Summer Science in the Village (SSSV)
Capacity Building for teachers and students	NMSAS one-pager/flyer, 2017, 2018, 2019; Knack	Through teacher's orientation, school professional development, and partnership workshops, this table indicates the number of participants.

	system, and I. Halatuituia, personal communication October 2020	
Community Outreach	NMSAS, 2012-2020 & Nerelle Que, personal communication, October 2020	NMSAS has had various outreach programs that target local and global communities. While the number of programs has decreased, the number of engagements has increased overall.
Visitor Center	NMSAS, 2012-2020, & Iosefa Siatu'u, personal communication, October 2020	The frequency of walk-in visitors to the Tauese P.F. Sunia Ocean Center has decreased, but the quality of exhibits, multimedia, and visitor information has increased.

Education is the process by which individuals develop their knowledge, values, and skills. Education encompasses both teaching and learning. NMSAS provides unique opportunities that attract educators at many levels for both formal and informal education. Further, through the sanctuary and partners, students have opportunities to learn both on-shore and within the sanctuary. The section provides information on both the formal and informal educational opportunities provided. Indicators include a number of teachers and students benefiting from various programs and the programs of partners.

Education

Since the 2007 Condition Report, NMSAS has developed a wide range of education and outreach programs to advance the sanctuary's mission. NMSAS offers a variety of education and outreach programs that have evolved and improved with time (Table ES.E.1). The educational programs have provided the following: 1) Helpful resources for both students and teachers 2) Classroom visits 3) Summer Programs and 4) Capacity building opportunities. Teachers and students from pre-K through college and community outreach have all benefited from these educational programs. School presentations have been the foundation of the NMSAS education program throughout the reporting period, reaching over 4,000 students from 2012-2020 (Figure ES.E.1). School presentations include data and visuals, engaging discussions, and virtual technology (Figure ES.E.2). NMSAS also facilitates opportunities for students to interact directly with experts face-to-face or through virtual learning platforms (Figures ES.E.3). These experiences are meaningful and rewarding opportunities for students learning about real-world science applications and different perspectives. NMSAS education team continues to present or share important and specific topics that may be forgotten or not elaborated on enough in a regular classroom setting, providing an improved learning experience for the students and teachers. Often, classes visit the Ocean Center, sanctuary units, or tour visiting research and exploration vessels as a culminating event.

Table ES.E.1. NMSAS education and outreach programs.

Program Name	Years	Target Audience	# Participants	Location
On-going School Visits / Presentations	2011-present	K5-college	4,000+	Schools
Tauese P.F. Sunia Ocean Center Tour	2012-present	ALL	2015-2020: 39,688	Ocean Center
Youth Ocean Summit	2012, 13, 15 & 17:	High School students/Teachers	2012, 13, 15 & 17: 750+	2012: Lee Auditorium 2013, 15 & 17: Ocean Center
Ocean Swimming Ocean Science (Samoana HS course)	2012-2014	High School students	100	Samoana High School & Utulei Beach Park
Ocean Star	2013-2015	Middle School students	110	Ocean Center, Utulei Beach
Ocean Swimming Ocean Science (Summer)	2014-2015	High School students	60	Ocean Center Utulei Beach
Voyaging STEM	2014-2016	Teachers	50	DOE office, Ocean Center Schools
Taiala o le Sami (Stewards of the Ocean)	2015-2018	ALL	1850+	Schools
2019 Summer Sanctuary Science in the Village (SSSV) --- 2020 SSSV kits	2016 - present	Students age 5-15; specifically those in sanctuary adjacent villages --- Community borrow kits	508 --- 2020:49	Ta'u, Vaitogi, Aunu'u, Leone , Faleniu, Aunu'u, STEAM Academy
Teacher Professional Development Works hops	2016-present	Teachers	180	Ocean Center
Virtual Reality Tours	2017-present	K5-adults	2,200	Schools, Ocean Center

Remotely Operated Vehicles Program	2018 - present	High School students, Teachers/Mentors	280+	All High Schools Ocean Center Community Pool
Student Film Workshop	2020	High School students	30	Ocean Center Fagatele Bay
Sanctuary Resource Library	2019 - present	Teachers/Students	376	Schools

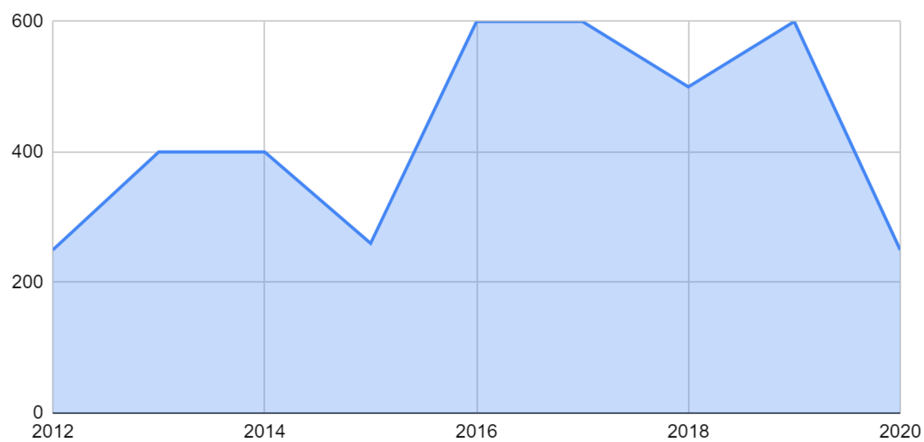

Figure ES.E.1. Number of students reached through in-school presentations. In 2015, the number of school presentations decreased because more outreach programs were implemented, and supported schools through the year-long Get Into Your Sanctuary campaign. During this year there were more competitions, and schools pledged to do class-based projects (Taiala O le Sami). This has boosted NMSAS presence in schools ever since. Image: NOAA

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Figure ES.E.2. Tafuna Elementary students enjoying the virtual tour to the National Marine Sanctuaries. Photo: Isabel Halatuituia/NOAA


Figure ES.E.3. Samoana H.S and ASCC touring NOAA's E/V *Oceanos Explorer*. Photo: NOAA/NMSAS

Summer programs allow for additional opportunities for students to learn about NMSAS, ocean literacy, and the effects of human impact on the environment. Since 2013, over 850 students have participated in NMSAS's summer programs (Figure ES.E.4). The sanctuary has worked collaboratively with partners, such as the Le Tausagi group, to host the annual Environ-Discovery summer camp, which includes guest speakers from the sanctuary's Sanctuary Summer Science in the Village (SSSV) program. The SSSV program focuses on sanctuary communities, exposing participants to ocean conservation (Figure ES.E.5), allowing them to implement new skill sets, and exposing them to STEAM subject areas (science, technology, engineering, the arts, and mathematics, Figure ES.E.6). STEAM programs provide an important opportunity for local students to enhance skill sets that could lead to advancement in the workforce and being prepared for rapid changes in the global economy. Some of these students also participate in other sanctuary education programs such as Underwater Remotely Operated Vehicle (ROV), Taiala o le Sami, and Zero Waste Week.

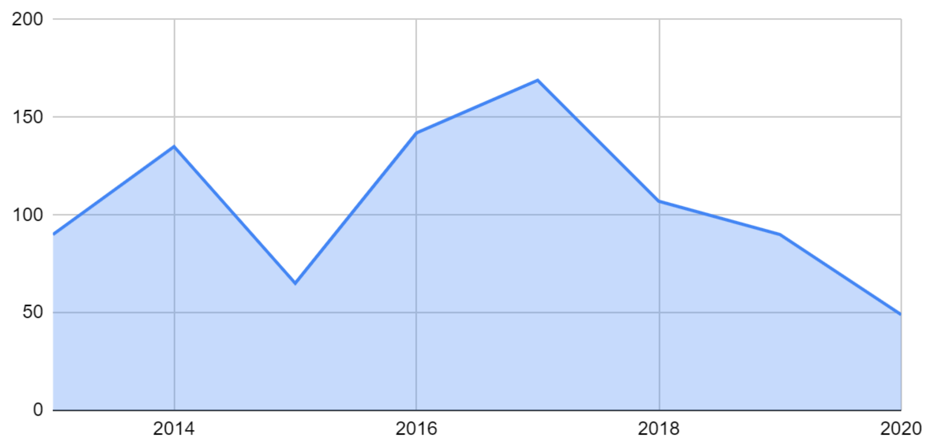

Figure E.S. E4. Number of participants in summer programs by year. Numbers declined in 2015 and 2019 due to a decline in the number of summer programs held within the sanctuary communities. Normally, NMSAS would hold summer programs in four villages/islands. In 2015 and 2019, the team only went to the most remote sanctuary community (Ta'u) due to limited available funds. Image: NOAA/NMSAS

Figure ES.E.5. Students collecting marine debris near Turtle & Shark look out in Vaitogi in 2015 as part of Sanctuary Summer Science in the Village.(Photo: Isabel Halatuituia/NOAA)

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Figure ES.E.6. Students building cars using rubber bands, wheels, and popsicle sticks as part of Sanctuary Summer Science in the Village in Aunu'u in 2018 (Photo:Isabel Halatuituia/NOAA)

Education is an on-going process, and teachers are continually encouraged to improve their craft, become more proficient at their jobs, and learn new learning and teaching styles that may be more effective and appropriate for their students. As such, NMSAS provides teacher development workshops to build teacher capacity, particularly in STEAM fields (Figures ES.E.7-8). Workshop content has included ocean exploration, Voyaging STEM, and most recently through a partnership with the MATE program and the Stockbridge InvenTeam (from the Thunder Bay NMS community), underwater remotely operated vehicles (ROV). These workshops challenge teachers, taking them out of their comfort zone, and build confidence in unfamiliar subjects. The development of the underwater ROV program is a great example of this process. Teachers were first exposed to ROVs and ocean exploration through workshops and ship tours in cooperation with the NOAA Office of Ocean Exploration and Research (OER) and the NOAA Ship *Okeanos Explorer* in 2016 and 2017. ROV workshops followed and after an intensive teacher workshop in 2019 (Figure ES.E.9) the program became more established and the local Department of Education applied to host an official ROV competition through MATE in 2020. NMSAS continues to support local teachers by hosting Professional Development and workshops.

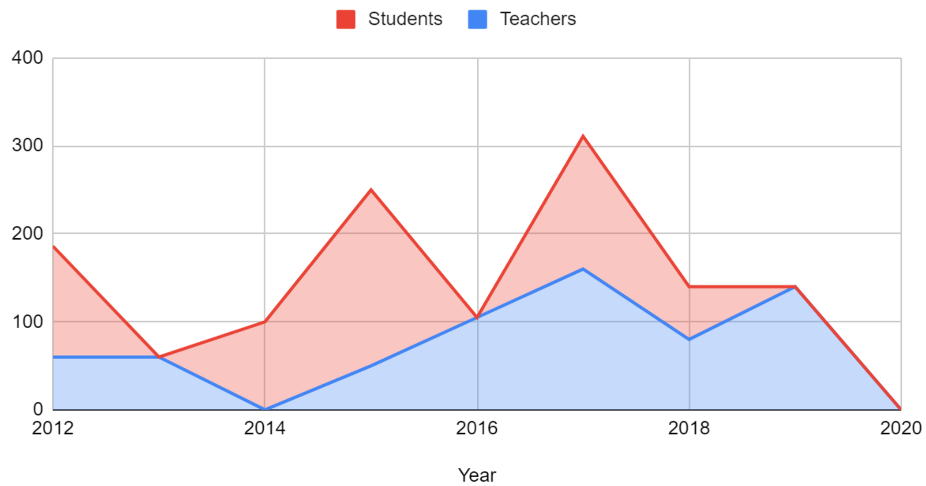

Figure ES.E.7. Number of teachers and students participating in various workshops over the years.

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Figure ES.E.8. Teachers demonstrating Ocean Acidification activity during the 2017 Why do we explore workshop. Photo: NOAA/NMSAS

Figure ES.E.9. 2019 Underwater ROV Teacher 5-day workshop. Photo: Iosefa Siatu'u/NOAA

NMSAS could not accomplish all of this alone. Over the years, NMSAS has fostered many local, federal, and national partnerships in order to achieve common goals. Partnerships offer various perspectives for problem solving and innovation, while reducing the cost and manpower for specific projects. Most of NMSAS's programs and projects are a success because of the support and contributions from partners.

Outreach

Community engagement and outreach connects conservation and culture by bringing people to place and place to people. NMSAS outreach programs are designed in conjunction with science and education initiatives. As an example, between 2007 and 2012, NMSAS worked with the National Park of American Samoa and stakeholders to develop the Fagatele Bay trail. Murals, exhibits, and kiosks were installed in high traffic areas including the Lyndon Baines Johnson Tropical Medical Center, Fagatogo Marketplace, and the Pago Pago International Airport.

Throughout the years, NMSAS has established outreach programs to target local communities, implemented recreation & tourism activities as well as reached global audiences (Figure ES.E.10). Outreach programs, infrastructure, and virtual telepresence have evolved since the last condition report and includes a diverse range of audiences and participant numbers (Table ES.E.2). In alignment with goals and priorities, outreach has been fine-tuned each year to focus efforts and build upon past results to be more effective. Additionally, NMSAS is prominently featured in 15 films produced by ONMS, Ocean Future's Society, PBS Broadcasting etc. that highlight the sanctuary's ecological, cultural, and recreational resources . Many of these films have been viewed and shared beyond American Samoa, expanding NMSAS' reach.

Figure ES.E.10. Visitors explore unique offerings hosted by sanctuary-adjacent villages at the Festival of Sites. Photo: NOAA/NMSAS

Table ES.E.2a. NMSAS community outreach events from 2007–2020. A blank cell indicates data is not available.

Outreach events	Years	Target Audience	# Participants	Location
ONMS 40th event	2012	General public	100	Ocean Center
Festival of sites	2013-2017	Cruise ship visitors, Sanctuary village communities	3,000	Ocean Center
Jean-Michel Cousteau presents at the Ocean Center	2013	General public	130	Ocean Center

Le Tausagi Summer Camps	2013	Students	20	Various locations
CoTS Threat Outreach Presentation on removal	2013	Science partners; affected coastal communities	75	Ocean Center
Sanctuary Wellness	2013-2015	General public	9,200	Ocean Center
Malama Honua Worldwide Voyage (Three month outreach program)	2014	General public	2100	Ocean Center & Malaloa Dock
Healthy People Healthy Ocean	2014	General public	250	Ocean Center
Google Streetview & XL Catlin Seaview Survey	2014	General public	150	Ocean Center
Get Into Your Sanctuary (GIYS)	2015-2020	General public	2015 - 2019: 2,482 2020 -2021 (virtual): 5500	Various Locations
Care for your Sanctuary	2015	Students (Lupele & A.P Lutali school)	40	Fagatele & Aunu'u
Launch of Virtual Experience - 2015	2015	General public	300	Ocean Center
Fagota Mo Taeao Open Fishing Tournament (formerly known as Buds and Suds)	2016-2019	Fishing communities	626	Malaloa Marina; and sanctuary sites
Rain Garden	2016	Students	50	Aunu'u Elementary
Photo Fishing Contest	2016	Students	60	Aunu'u, Fogama'a
NPS Centennial Celebration VR and education outreach	2016	General public	200	Utulei Beach Park
Sanctuary Outreach at American Samoa Community College (ASCC)	2016	Students	18	American Samoa Community College
Coast Weeks Family Day	2017	General public	250	Utulei Beach Park

Fautasi Heritage Symposium three day event	2019	General public	173	Ocean Center
American Samoa and Hawaii Student Cultural Exchange program	2014	Students	5	Hawaii

Table ES.E.2b. Outreach publications created by NMSAS, 2007–2020. A blank cell indicates data is not available.

Outreach Publication Title	Years	Target Audience		Location
Okeanos Expedition of American Samoa	2018	General public	-	
Unlocking the Secrets of Swains Island: A Maritime Heritage Resources Survey	2013	General public	-	Swains Island
Dive Magazine	2017	General public	-	
Fautasi Heritage of American Samoa Magazine	2021	General public	-	Ocean Center
NMSAS Front cover of Islandtime magazine	2013	General public	-	
Swains Island Poster	2014	Swains community; General public	-	

Table ES.E.2c. Infrastructure that supports NMSAS community outreach, 2007–2020. A blank cell indicates data is not available.

Outreach infrastructure	Years	Target Audience	# Participants	Location
Hiking Trail Developed for Fagatele	2007	Visitors to Fagatele Bay	-	Futiga village
Sanctuary Exhibits at Convention Center	2007	General public	-	
PPG Airport and LBJ murals and kiosks launched	2011	Tourism industry; returning residents; general public	-	Pago Pago International Airport; and LBJ Tropical Medical Center
Hyperbaric Treatment Chamber Center at LBJ	2011	Science partners	20	LBJ Hospital
Mural at Marketplace	2011	General public	-	Fagatogo Market

Tauese P.F. Sunia Ocean Center Opening Day	2012	General public	190	Utulei
Aunu'u Rest Fale	2012	Visitors to Aunu'u	30	Aunu'u wharf
Dive Exhibit opens	2014	General public	30	Ocean Center
Wyland Mural at OC and Painting Project	2014	ASCC art students; General public	85	Ocean Center
Google Street View Launches for Ocean and Landscapes of NMSAS	2015	General public	150	Ocean Center
Fautasi Heritage Exhibit at Ocean Center rotunda launches	2019	General public	75	Ocean Center
NMSAS website revamp launch	2019	General public	-	Online

Table ES.E.2d Exploration vessels and virtual telepresence that supports NMSAS community outreach, 2007–2020. A blank cell indicates data is not available.

Exploration Vessels and Virtual Telepresence	Years	Target Audience	# Participants	Location
Okeanos Explorer Village Program with OSA	2016	Office of Samoan Affairs	50	Office of Samoan Affairs
Okeanos Explorer expedition ship tours and ship-to-shore telepresence	2017	General public	488	Pago Pago Harbor Dock; and online
Okeanos Explorer live telepresence online	2017	General public	33,000	Online
NOAA Research Vessel Hi'ialakai - Rapid Assessment and Monitoring Program (RAMP) cruise and Outreach Ship Tour	2018	General public	120	Pago Pago Harbor Dock
E/V Nautilus deep sea research expedition in NMSAS: telepresence at OC	2019	General public	42	Ocean Center
E/V Nautilus deep sea research expedition live telepresence online	2019	General public	66129	Online

Exploring by the Seat of Your Pants NMSAS telepresence	2020	General public	400	Online

Table ES.E.2e. Workshops and in-reach meetings that NMSAS sponsored, 2007–2020. A blank cell indicates data is not available.

Workshop / In-Reach Meetings	Years	Target Audience	# Participants	Location
Dive training and drill	2013, 2016	DPS, EMS, LBJ, AS Dive Network Group (Govt & Private Sector) partners	80	Ocean Center
Village Tour Guide Interpretive Training	2013	Village residents adjacent to sites	20	Ocean Center & Out in the field
Media Coffee chats	2014	Media partners	12	Ocean Center
The Two Samoas Exchange Visit meeting	2013	Government partners	60	Ocean Center
Future Leaders of the Pacific Forum	2013	Government Partners	20	OCean Center
In-reach briefing with tour operators, hotels, airlines on NMSAS	2013	Tourism industry	10	Ocean Center
In-reach briefings with OSA & Village Pulenu'u on NMSAS	2013	Office of Samoan Affairs; and village pulenu'u	60	Ocean Center
Special Places meeting with DMWR, DOC, OSA	2013	Government partners	25	Ocean Center
Samoa Tourism Exchange (2 Staff represented NMSAS in Samoa)	2014	Tourism	1000	Samoa
NOAA Vessel Training	2014	Science partners	20	Ocean Center
CoTS Mission Presentations	2014	Science & Village Pulenu'u as partners	40	Ocean Center
Hyperbaric Training for LBJ	2014	Science partners	10	LBJ

Business Exchange Program to Hawaii	2014	Tourism	10	In Hawaii
CPR, First Aid, and AED capacity building	2015	Training led by NOAA Corp Officer for Partners	75	Ocean Center
Eco-Tourism Workshops	2015, 2016	Tourism industry	20	Ocean Center
Certified Interpretive Training	2015	Outreach	6	Ocean Center
Mesophotic Coral Presentation at OC	2016	Students & Science partners	75	Ocean Center
Rapid Vulnerability Assessment Workshop	2016	Science partners	15	Ocean Center
Interpretive Student Guide Training	2016	Students	15	Ocean Center & Field
In-reach briefings with NOAA OLE, US Congressionals, etc	2017	Government partners	25	Ocean Center
Bishop Museum AS Deep Water Coral and Fish Survey Project presentation	2017	Schools & Science partners	75	Ocean Center
Ocean Literacy Working Group meeting	2019	Educators	25	Ocean Center
Pacific Islanders in Communication film grant opportunities workshop	2019	Local filmmakers	24	Ocean Center
In-reach with NPSA on social media opportunities	2020	Science partners	5	Remotely
Sanctuary Student Film Workshop and Competition	2020	Students	30	Ocean Center and Fagatele Bay
Virtual Presentations for kids with NMSAS	2020	Students	31	Remotely
In-Reach with Visitor's Bureau Trade Show Coordinator	2020	Tourism industry	3	Ocean Center

Table ES.E.2f. Films that feature NMSAS, 2007–2020. A blank cell indicates data is not available.

Films	Years	Target Audience	# Participants	Location

Penina Tutasi Amerika Samoa video (1st film on NMSAS)	2013	General public	150	Ocean Center
"Sanctuary of the South Seas" Film Festival	2013	General public	-	
Swains Island Expedition with Jennings Family, and filming crew	2013	Swains community	-	Swains Island
“Swains Island – One of the Last Jewels of the Planet” Film wins award at Blue Ocean Film Festival	2014	General public	-	
Ocean Future's Society & NMSAS Launches 5 short cultural films internationally	2015	General public	-	
Screening of "Chasing Coral"	2017	General public	60	Ocean Center
Stories from the Blue with 4 films on NMSAS	2017	General public	-	Virtual
PBS Changing Seas "American Samoa's Resilient Coral Reefs" episode premiere online and live virtual screening	2020	General public	12566	Virtual
Get Into Your Sanctuary: Connecting Conservation & Culture with National Marine Sanctuary of American Samoa	2020	General public	4,000+	Virtual (Facebook)
Get Into Your Sanctuary: Sense of Place and Siva Samoa	2021	General public	1500	Virtual (Facebook and GoTo Webinar)

Table ES.E.2c. Other programs that support NMSAS community outreach, 2007–2020. A blank cell indicates data is not available.

Other	Years	Target Audience	# Participants	Location
Student volunteer / internship programs	2012-2014	Students	18	Ocean Center

Cruise ship tours	2012-2019	Tourism industry	18,120	Ocean Center
Visitor center visits	2012-2020	General public	58,123	Ocean Center
In reach briefings	2012	Government partners	-	Ocean Center
Culture and Voyaging Camp Program	2016		30	
Aunu'u Grounded Vessel Removal	2016	Aunu'u community	13	Aunu'u
NMSAS Featured in ASVB Talk Show	2016	General public	-	KVZK TV
Ocean Exploration Tours	2017	General public	150	On Board Okeanos Explorer
"Get In Your Sanctuary" radio jingle airs on South Seas Broadcasting 93KHJ	2017, 2019	General public	7,000+ active listeners daily	Local radio station
Federal Pathway Open House	2018	Students	400+	
USCRTF Disaster Response Workshop – Vessel Grounding	2018	Government partners	60	
Aunu'u Marine Debris Survey led by KUPU intern	2018	Aunu'u community	100	Aunu'u

Figure ES.E.11 shows total participation in outreach programs by year. This data indicator does not include recreational visitors to the individual sites, for which there is no visitor log data available. The dip in participation in 2016 was due to more focused outreach, and limitation with school field trips to the Ocean Center. In 2017 and 2019, NMSAS worked with NOAA *Okeanos Explorer* and Ocean Exploration Trust's EV *Nautilus* and hosted live ship-to-shore telepresence interactions which garnered increased participation from a global audience online. In 2020, outreach programs shifted to virtual platforms. While the quantity of visitations to the Ocean Center decreased, the quality of the exhibits were improved with new upgrades & additions, multimedia was expanded, and visitor information also increased with social media. Participation data is not available for all activities, as indicated by blank cells.

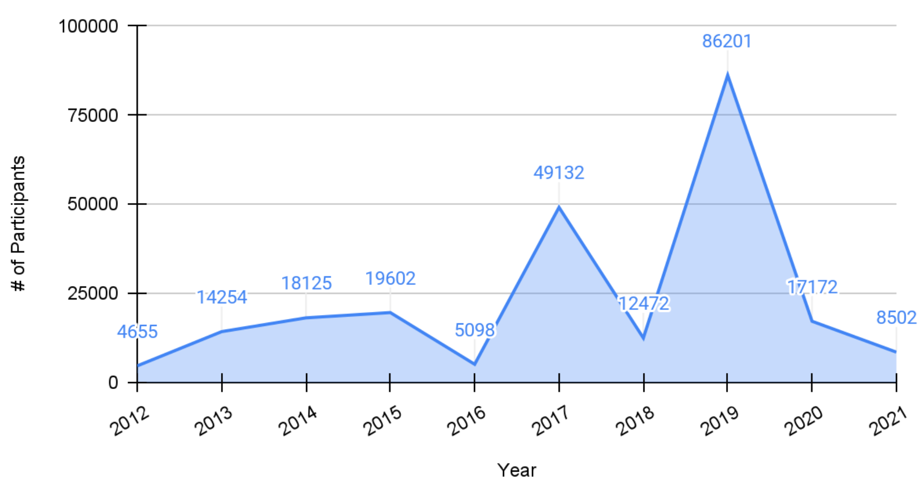

Figure ES.E.11. Outreach participants from 2012 - 2020. Image: NOAA

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The Tauese P.F. Sunia Ocean Center was established in 2012 as NMSAS' hub of sanctuary information and research, as well as for education and outreach programs (Figures ES.E.12-14). The Ocean Center has two display areas available to the public. The main rotunda includes a Science on a Sphere® (currently being upgraded to the Science on a Sphere® Explorer system) with two wall panel exhibit options highlighting 1.) American Samoa's marine resources, issues, and threats, and 2.) fautasi maritime cultural heritage displays, added in 2019 as part of the Fautasi Heritage Symposium at the Ocean Center. The smaller sanctuary room has displays on each of the six sanctuary units. Recent health crises including a measles outbreak in 2019 and the global pandemic in 2020 reduced visitor numbers during these years as cruise ships were not permitted to visit and student activities were constrained. Figure ES.E.15 shows the total visitor count to the Ocean Center from 2012 to 2020. This count is based on sign-ins and may reflect multiple visits to the center by the same individual.

Figure ES.E.12. Young students highly engaged in a tour at the Tauese P.F. Sunia Ocean Center. Photo: Nerelle Que/NOAA

Figure ES.E.13. Aerial view of Tauese P.F. Sunia Ocean Center during the Fautasi Heritage Symposium in April 2019. [Photo: Nonito Que]

Figure ES.E.14. Samoan elders experiencing sanctuary sites through virtual reality goggles during a Get Into Your Sanctuary outreach event. Photo: Nerelle Que/NOAA

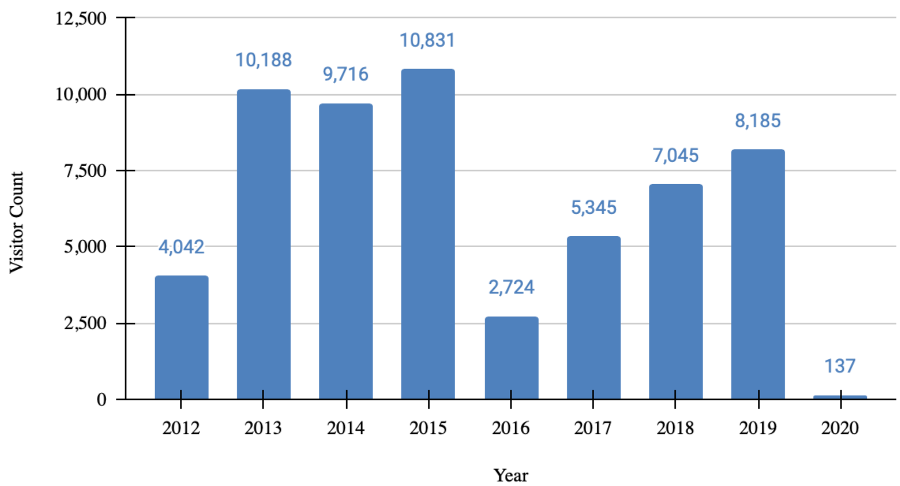

Figure ES.E.15. Number of annual visitors to the Tauese P.F.Sunia Ocean Center from 2012 - 2020. Image: NOAA

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Conclusion

Education and outreach is an important ecosystem service for NMSAS that has benefitted a wide range of audiences, participants, partners, communities and networks locally, regionally, nationally, and internationally. The education and outreach efforts consistently grew throughout the reporting period and, in some cases, included collaborating with partners in order to gain a wider reach. Many programs that were implemented throughout the years were evaluated, adapted, and adjusted to ensure effectiveness. A significant success has been harnessing support and building capacity for local residents, including students, teachers, village communities, and partners. Ensuring residents were the first to benefit from training, programs, activities, or other opportunities aimed at building pride in protecting sanctuary resources and enhancing skills was essential. Current levels are rated as Good. Additionally, NMSAS has collaborated with wonderful local, regional, national, and international partners to project the place, people, special resources, and ecosystems of the sanctuaries via films, publications, and expeditions.

This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Heritage & Sense of Place — Recognition of History, Heritage Legacy, Cultural Practices, Aesthetic Attraction, Spiritual Significance & Location Identity

Rating: *Specific ratings were not assigned for the Heritage and Sense of Place Ecosystem Service because to measure these services in that manner in American Samoa would be culturally inappropriate. Note: the physical condition of heritage resources and sites (distinct from heritage services or ecosystem benefits) was given a rating in Section 3d "Maritime Heritage Resources."*

Status Description: *Not Applicable*

Rationale: *Cultural traditions and values, inherent to the ecosystem services of Heritage and Sense of Place, currently thrive in American Samoa where one people, one language, and one common set of cultural practices continue to be perpetuated. The Ali'i or chiefs who were engaged in the workshop process stated that cultural values are too important and too complex to be captured in a rating scheme. This is an indication of the enhanced significance of these benefits. Therefore, there are no status or trend assessments for Heritage and Sense of Place. Furthermore, the Heritage and Sense of Place are so similar in American Samoa that they can only be understood as a single, interrelated topic (as presented here). ONMS places a high value on partnerships with sanctuary communities and maintains great respect for fa'a-Samoa. Fa'a-Samoa, the traditional Samoan way of life, provides the cultural context for all sanctuary activities and functions.*

Though not rated, the cultural aspects of Heritage and Sense of Place have been a large part of the work that NMSAS has completed to date and since the sanctuary expanded. Workshop participants acknowledged the priority that NMSAS places on cultural traditions and values, and felt that these should continue to be included as a core emphasis for NMSAS programs and activities. The matai's also stated their preference that NMSAS capture the importance of cultural information discussed during the workshop in a narrative format rather than in a rating scheme. Respecting the sensitive nature of cultural heritage information and accommodating a narrative format is an option supported by the condition report process and the marine sanctuary system.

Background for Heritage and Sense of Place Services in American Samoa:

Assessing the cultural benefits of Heritage and Sense of Place requires an understanding of the historical and cultural background in American Samoa. Approximately 3,500 years before Columbus came to America, ancestors of the earliest Polynesians discovered a group of islands that became known as Samoa. In the ensuing 2,000 years, descendants created and established Samoa's culture and way of life known as "fa'a-Samoa." Samoans practice fa'a-Samoa or traditional and cultural living everyday with pride as a normal way of life (Craig 2009; Linnekin et al. 2006).

Through a set of treaties between the U.S. Navy and local chiefs in 1900 and 1904, American Samoa became an unincorporated territory of the United States and has maintained that status, reflecting the persistence of local identity (Enright et al. 1997). American Samoa's forefathers had incredible vision and foresight when they signed the Deed of Cession in 1900 ceding the islands to the United States. The founding fathers and traditional leaders understood that cultural values and traditions needed to be

Commented [1]: Mageo: "I couldn't have done, said or even written it better myself", is the popular American idiom that comes to mind with this Section of the Report. The authors have captured in its totality the intrinsic value (which is infinitely immeasurable) of the Fa'aSamoa to the Islands,
its People and NMSAS Resources, Services and Management as well. As stated by the authors of the Report, the ONLY numerical rating or value (condition, status, scientific, etc,) if there really needs to be one as to Heritage and Sense of Place Services is ONE…as in ONE People, ONE Language, ONE Core set of Values that is intricately woven into the very fabric of our existence with Our Lands and Environment which is the Fa'aSamoa, the Samoan Way of Life. The authors have notably expressed in no uncertain terms that the success, improvement and maintaining of the NMSAS's Units relies heavily on the Fa'aSamoa because the Sanctuary is part of the Fa'aSamoa OR IS the Fa'aSamoa long before its designation as National Marine Sanctuary Units/Monument.

Commented [2]: it would be useful to also include objectives for the role of the sanctuary specifically related to heritage and sense of place in this section. How is having a sanctuary designation meant to contribute or support or maintain the concepts that are described below any differently than without having a sanctuary designation? Isn't the point of a condition assessment to see whether the sanctuary is achieving what is meant to be achieved in each of these categories? And if it's not appropriate to think that it will be able to serve these concepts, then it seems odd to include them. I understand that for this round, people were asked to rate them, so you need to document that rating them was deemed inappropriate. But then it seems like they should be excluded earlier on as a category that is part of the monitoring scheme.

I know that including these concepts as a narrative has been done in other sanctuaries as well, but I worry that this further sidelines them as "too different to think about". I would like to see further discussion and thought to how to include more qualitative assessments by the appropriate people (e.g., chiefs) of how well sanctuary management is contributing to perpetuating these concepts, rather than trying to come up with a quantitative assessment of the quality of heritage or sense of place within the sanctuary. The latter is definitely inappropriate, but also seems unhelpful in terms of understanding how to improve management sustained within social, economic, and political spheres by the people for many generations. These small islands are not just unique because of their natural environment, but also because one culture, one heritage and one language continue to survive and thrive, while some other Pacific peoples are facing cultural disintegration. As of the 2000 census, about 90 percent of the population in American Samoa speak Samoan at home and 78 percent speak another language more frequently than English at home (data from U.S. Census Bureau 2003). American Samoan heritage and culture provide a distinct identity, whether Samoans live on island or abroad.

Commented [3]: What about more recent Census data since 2010 and 2020 have both been conducted.

Another key to the fortitude of Samoan culture is the commitment to maintaining fa'a-Samoa, the Samoan way of life, which is protected by Article 3 of the Bill of Rights in the American Samoa Revised Constitution:

> "It shall be the policy of the Government of American Samoa to protect persons of Samoan ancestry against alienation of their lands and the destruction of the Samoan way of life and language…." (U.S. Department of Labor 2010)

To understand Heritage and Sense of Place, it is important to describe tenets of Samoan culture by recognizing that it is about one people, one language, and a communal core of values that make it the only indigenous site within the sanctuary system. To capture heritage, one must delve into two key units of social organization in Samoa, the aiga (extended family) or clan and the nu'u or village. The aiga consist of a group of people by blood, marriage, or adoption. At the head of each aiga is the matai. The matai is an individual who holds a chiefly title, which can be either an Ali'i (Chief) or Tulafale (Orator). At the core of the family organization are the rights to land use, which is dependent on two factors: genealogy and service. A genealogical tie must link a person to the group's founding ancestor. Those links can be traced through either male or female lines or both. The name or the title of this ancestor identifies the kin group and is the chiefly title that the group gives to its leader (matai), chosen through consensus of the group. Because genealogical links may be traced through both female and male lines or both, an individual may potentially belong to many kin groups. The innate principles of respect and service to the group or family is recognized by contributions of labor, goods, and money.

Commented [4]: Papahānaumokuākea doesn't count?

A matai brings family prestige, and the matai must uphold that prestige within the village and to a larger extent, the district and country. Within the extended family itself, the matai is responsible for maintaining family unity and harmony, promoting participation in religious or church related activities and village priorities. The matai serves as the family spokesman in the village council of chiefs, or fono, thereby providing the family with a voice in all the village matters and public affairs. One of the most important responsibilities of any matai is serving as trustee of family land. In Samoan society, land tenure is an integral part of the social organization and is tied to both the kinship system and village organization (Shaffer 2018). Where family disputes over title holder or land have occurred in recent times, the Office of Samoan Affairs arbitrates matters to reach amicable outcomes to protect family and village relations. The Office of Samoan Affairs is directed by a high ranking Ali'i who is appointed by the Governor of American Samoa.

In every Samoan village, the fabric of culture and tradition recognizes the division of labor between men and women, and the young and old. Women are known for the art of "siapo" or making special designed cloth and crafting, in addition to skills at reef fishing. A woman's group known as "aualuma" existed to support young women who were primed to become "taupou" or village princesses (high chief's daughters). Over the years aualuma changed considerably as they were a handpicked select group of women who served the taupou . By the 1900's as village taupou disappeared, the need to have an aualuma did as well. Instead, women were identified with roles within the family rather than for the village. Conversely, the men's group of "aumaga" or untitled men to this day have a prominent role in village structure that aligns with implementing the directions and tasks from the village council. The aumaga performed several duties that still exist today such as fishing for the family and ceremonial events, policing the villages during daily village curfews or "sa", and farming the land for traditional starches like taro, breadfruit and bananas to provide food for families.

Samoans divided much of their time between subsistence agriculture and fishing. Prior to 1900, before European or canned food was readily available, villagers spent roughly equal amounts of time on the land or harvesting the resources of the sea. Cooking and food preparation, especially ceremonial cooking, remains an important aspect of life where the aumaga cook traditional foods for the chiefs and women prepare newer "foreign foods". The distinction is that women will cook additional food items for the feast in stoves or ovens. While the traditional form of Samoan cooking takes place in the "umu" (an earthen oven, built over a pile of hot stones where meat, breadfruit, taro, bananas and palusami or bundles of taro leaves with coconut milk are placed before banana leaves and piled over to retain the heat from the stones and cook the food). In pre-European contact times, Samoa fishermen spent significant time at sea to fish for the Sunday feast preparation or for ceremonial events. Samoans favor fish over other protein sources, the one exception being "pua'a" or pork. For the reef, wooden traps for capturing shellfish and eels, different kinds of throwing nets for capturing larger fish, and spear guns that resembled slingshots, were used. At sea fishermen used long, three-man canoes, called "va'aalo" (nearly 30 feet in length) to fish for bonito.

Today, following some 120 years of affiliation with the US, the resident population take pride in the gift of becoming an integral part of the American family, but more importantly, still value the privilege of being an American Samoan. Honoring the passage over time of this relationship is the annual celebration of "Flag Day," with festivities that include "siva ma pese" (song & dance) and the reputable "fautasi" (long boat) regalia race. The connection to the ocean through "fautasi" is an important historical landmark as first traditional watercraft used for transport then became long boats rowed by up to 50-member crews as a village community to support the months of training prior to the Flag Day race. Participation in the "fautasi" race each year for the crew and villages meant more than the physical strength of areas but more importantly the unity, spirit and village pride.

Commented [5]: Use of the word 'gift' mischaracterizes the formally negotiated relationship between US and AS; see description on Page 1

Despite western influences, Samoan heritage is perpetuated in all facets of life through family, village, activity, place, by Samoan people with a strong hold to ongoing cultural traditions. In addition to practices that occur even today, spoken Samoan as the first language in American Samoa is an important attribute that makes NMSAS strikingly unique in comparison to all the sites across the National Marine Sanctuary system. It is a norm for NMSAS staff to interpret and implement education, outreach, and community engagement programs in Samoan.

The Samoan way of life is an everyday practice. Samoans who have migrated overseas for family, school, sports, and military opportunities take with them their heritage wherever they go. If and when they return home, the immersion into village and family life allows them to re-integrate into Samoan culture. Practices such as the "Ava Ceremony", one of the most significant traditional events within Samoan culture, set the stage for ceremonial proceedings with the formal serving of the "ava" (kava), village council debate and oratorical rituals. During the management plan review process in 2009-2012, NMSAS was commended by the Secretary of the Office of Samoan Affairs for embodying respect and recognition of Samoan culture with engagement and consultation of village leaders in all steps of the process.

The recognition of cultural arts and their revival has also been embraced recently with the establishment of programs led by the Territorial Office of Aging (TAOA), American Samoa Community College (ASCC) Fine Arts & Samoan Studies Departments and other agencies. Skills such as weaving numerous kinds of mats, including the highly valuable "fine mat", involve a long, arduous process and months to complete. The fine mat was, and still is, an integral part of many of Samoan formal ceremonies. Additionally, cooking and food preparation, especially ceremonial cooking, has remained an important part of village life, where men play a major role in preparation and cooking of food . Growing local crops such as taro, breadfruit and bananas that can be harvested for the Sunday to'onai (family feast) is part of this traditional practice. Young men are assigned to prepare the to'onai, while skilled fishermen go out to fish for this feast as a means to provide for the family.

Workshop Discussion of Heritage and Sense of Place:

Content presented during the workshop highlighted examples of how local knowledge and the participation of traditional leaders are critical to the understanding of marine resources and ecosystem benefits in American Samoa. This section briefly summarizes their perspectives during this workshop.

Customary lands dominate the total landmass in American Samoa. Without our land tenure system, there is no Samoa. Our land (including the marine environment) is our inheritance. It is the connection we have with our past, present and our future. Land is our fa'asinomaga (identity), it is what gives our matai titles meaning. Without a connection to the fanua (land), we are outsiders to this special place.

Fa'asamoa (traditional way of life) places great importance on the dignity and achievements of the group rather than on individual gain as a cultural grounding that perseveres through generational time to present.

During the workshop, traditional leaders and clergy voiced the importance of acknowledging the Samoan culture, history, and people as essential for the success of the sanctuary program. They also reaffirmed that the condition report ranking system is not appropriate to place value on Samoan cultural ecosystem services. Also through consultation, they reminded the participants that the Fa'a-Samoa traditional way of life is alive and real. It is the foundation of Polynesia's oldest culture, which dates back some 3,000 years.

From their~~a~~ traditional standpoint, putting an economic value on heritage or place diminishes the cultural values of belonging or association with the place. Therefore, many of the more familiar economic methods for assessing Sense of Place, particularly those based on compilation of individual gains, might not convey proper value. Local knowledge, discussion of resources and activities and the relationship between sanctuary and community, and non-market value data are of greater importance. Traditional leaders see the connection with Sense of Place as an obligation as Samoans are stewards of their native lands. It is their responsibility to safeguard the land for future generations.

The traditional leaders also felt it was difficult to quantify Sense of Place with direct measures. Furthermore, it was determined that some aspects of Sense of Place may simply not be ratable using the standard rating scheme of condition reports.

Commented [6]: The perspectives summarized in this section are slightly confusing as they bounce between first-person participant, third-person participant and third-party summary without a clear break between the 'speakers'. Aside from that, the section encapsulates the voices of the traditional leaders and clergy regarding their decision not to support the use of conditions report ranking to heritage and sense of place.

Commented [7]: This perspective is specific to American Samoa leaders

Commented [8]: why were they asked to put an economic value on this?

Commented [9]: I agree that economic valuation, or even non-market valuation might not be appropriate. What about qualitative assessment by key stakeholders (e.g. those invited to the workshop) to assess the degree to which the sanctuary is contributing to whatever sense of place or heritage objectives were deemed within its purview? i.e., to what degree is it meeting those objectives related to sense of place or heritage?

Commented [10]: I would have liked to see an attempt to use conditions ranking to heritage and sense of place in order to gain an understanding of what type of ranking system could be developed in the future to appropriately address the content of this section particularly in terms of mapping dynamic change within the culture. However, it is recognized that if the local traditional leaders deem it inappropriate, it is only proper to agree to their request.

Key Heritage & Sense of Place Resources and Activities:

Since the establishment of NMSAS in 2012, the Sanctuary has embodied the importance of heritage and fa'a-Samoa in a number of programs and events. Common to all these activities, NMSAS provides bilingual exhibits and translated materials in recognition of the significance of the Samoan language. These events and programs provide examples of how the Sanctuary has worked to enhance the cultural services of Heritage and Sense of Place; they include the following:

Working Directly with Sanctuary Village Communities:

Removal of Fishing Vessel No. 1 Ji Hyun in Aunu'u – Village Council involvement from start to finish. The 2016 vessel grounding on the western reef of Aunu'u Island, and the removal efforts that followed, highlighted just how important community collaboration is for protecting the marine ecosystem of American Samoa. Greater collaboration emerged between NMSAS, agencies and, especially with Aunu'u, where high talking chief Fonoti attended all the briefings and was on site for the removal attempts. His role was critical in guiding the efforts, sharing his concerns on behalf of the families and informing the community. Fa'a-Samoa, the foundation of Samoan culture, places importance on the achievements of the group rather than the individual (Weinberg 2016).

Festival of Sites - Direct involvement of village communities adjacent to sanctuaries who participated in 2013-2016 events, showcasing unique traditions and cultural practices special to these areas. Village members participated in the festival at the Ocean Center to share special foods, crafts, artifacts and performances as a celebration of cultural heritage and connections with Samoans and the environment. It was a way to bring the people to the place where residents experienced and celebrated as a festival.

Fagota Mo Taeao Fishing Tournament – An annual event since 2015; recreational anglers on board alia (traditional fishing vessels) compete together as a way to increase awareness among fishing communities of allowable and prohibited fishing methods in sanctuary sites.

Ta'iala ole Sami – An educational program launched in one school adjacent to Fagatele & Fagalua & Fogama'a sanctuary management units to preserve and protect ocean resources, with curriculum in coral reef conservation and ecology that was taught in Samoan and English from 2014-17.

Outreach Films on Culture & Heritage:

The National Marine Sanctuary of American Samoa has also shown the importance of place, people and culture in the Territory with the various outreach films since 2013. These include the following;

Penina Tutasi o Amerika Samoa – 2013 first film depiction of the importance of place and people through a journey of how culture is vibrant and thriving in the new National Marine Sanctuary of American Samoa.

Swains Island Heritage Survey & Documentary– In the fall of 2013, NMSAS, along with partner agencies and institutions, conducted a multidisciplinary survey of Swains Island, American Samoa. The fieldwork focused on the unique ecosystem setting and past cultural heritage of the island, and led to a featured publication and award-winning Ocean Futures Society 2014 documentary *Swains Island: One of the Last Jewels of the Planet* (Van Tilburg et al. 2013).

Jean Michel Cousteau American Samoa Culture & Conservation Film Series – highlighting the importance of diversity the film series captures the connections between the cultural tenets practiced by people in American Samoa, with themes that center around the community caretakers, serving your village, church, and family, parts of the culture that pull us together rather than show our differences.

Get Into Your Sanctuary Film 2021: Sanctuary Sense of Place and Siva Samoa
A film completed by the National Marine Sanctuary of American Samoa for the annual Office of National Marine Sanctuaries Get Into Your Sanctuary Event all across the sanctuary system! From the rolling waves to the swaying trees, there are many stories that can be shared through Samoan song and dance (pese ma siva). At the same time, explore the teeming life underwater, learn about the rich Samoan culture, and take the pledge to protect wildlife!

Get Into Your Sanctuary Film 2020: Connecting Conservation and Culture with National Marine Sanctuary of American Samoa
A film to showcase the National Marine Sanctuary of American Samoa through a virtual tour for the Get Into Your Sanctuary annual event! The film allows you to learn about responsible recreation in the sanctuary, local culture, and ocean stewardship. You get to dive underwater in Fagatele Bay to take a look at the fish and coral that live there. Plus, learn about local food through a cooking demonstration of fa'ausi from Aunu'u! Interact with the hosts in the comments and learn more about the beautiful American Samoa.

Outreach Programs & Symposia:

Fautasi Heritage Symposium & Magazine -- In April 2019, NMSAS and the American Samoa Historic Preservation Office co-sponsored one of the most important sanctuary efforts to preserve our maritime connections to the ecosystem: the inaugural Fautasi Heritage Symposium. The workshop's goal was to share the cultural heritage and history of fautasi racing in American Samoa. Fautasi heritage and the results of the symposium are presented in the featured publication *Fautasi Heritage of American Samoa: Fa'aga I Le Tai: O Ala O Le Vavau A Samoa* (NOAA 2020).

Non-Market Data Related to Heritage and Sense of Place:

Studies addressing elements of Heritage and Sense of Place were reviewed and presented during the workshop. Data from Levine (2016), Severance (2013) and others, were presented to workshop participants. These sources highlight the importance of non-market data for the qualitative discussion of Sense of Place benefits of coral reefs, and heritage benefits of traditional fishing practices (catch use). Territorial data serves as a general proxy for sanctuary-specific analysis. The following figures highlight the unique culture and history of American Samoa and the communal resource values related to Sense of Place and Heritage:

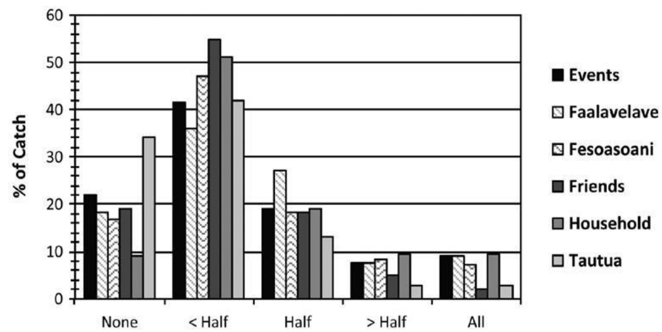
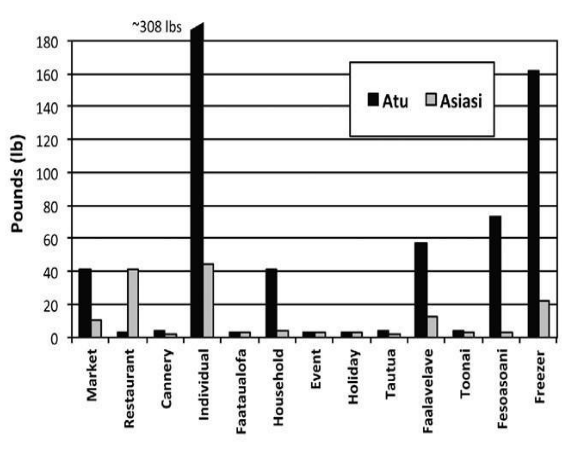


Figure ES.HSP.1. Percentage of catch distributed to cultural categories 1997. Source: Severance et al. 2013

Samoans place a great deal of importance on the cultural context of fishing. Figure ES.HSP.1 shows the percentage of catch used for the following non-market purposes- events, “fa’alavelave” (or family function or ceremony), “feasoasoani” (help) , friends, household, and “tautua” (service gifts for village chief or clergy). Gifts of fish are part of the reciprocal relations and constant circulation of food and gifts that maintain Samoan social structure to this day. The amount of effort we clearly see from this illustration speaks volumes of the importance of our communal values as a people, where we place the importance of the greater good over individual gain. This is a cultural value that cannot be accurately captured in numbers derived from monetary assessments.

Figure ES.HSP.2 illustrates the distribution of catch for selected species. In this instance, total consumption is communal (freezer, household, market, fa'alavelave etc., about 370+ pounds), exceeding “individual” (about 308 pounds) distribution as recorded. The 1997 data show that individual catch was very high for “atu” (skipjack tuna), though this may reflect roadside sales that occurred later.



Commented [11]: @kathy.broughton@noaa.gov Please add an x axis title if possible.

Figure ES.HSP.2. Pounds of atu and asiasi distributed by event mode 1997. Source: Severance et al. 2013

Figure ES.HSP.3 shows the breakdown of reasons for fishing for the 53% of people who engage in the activity in American Samoa. Notably, giving the catch to extended family, village leaders and pastors, and fishing for special cultural events (all non-market activities) are strongly represented.

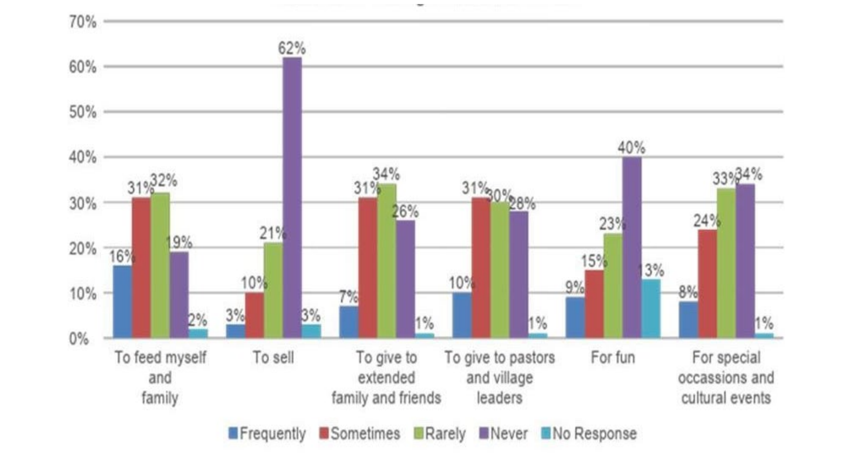


Figure ES.HSP.3: Reasons for fishing in American Samoa. Source: Levine et al. 2016

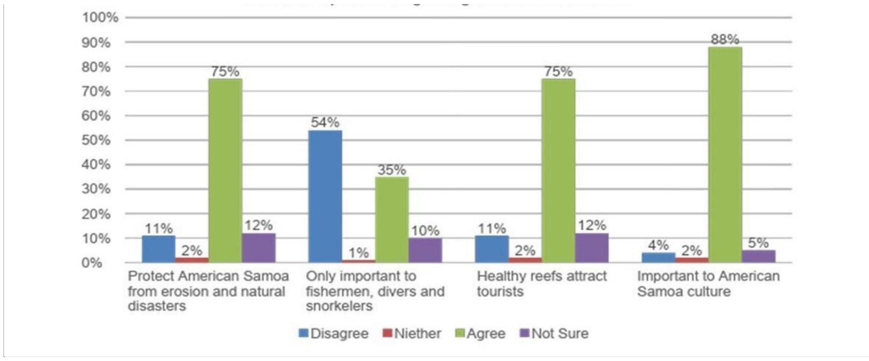


Figure ES.HSP.4: Resident opinions regarding coral reef services. Levine et al. 2016

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-"Frequently" and "Never" are somewhat difficult to distinguish with filters. I recommend changing colors and/or adding patterns if possible.

-Please and x and y axis titles in title case. For y axis title, specify unit as "(%)" and remove % symbols from y axis labels.

-Please remove data labels.

-Please change legend categories to sentence case (not a huge deal, just one..."No response", but might as well since other edits need to be made anyway).

Commented [13]: @kathy.broughton@noaa.gov All of the same comments as above. Please also note "neither" is misspelled in the legend. Please add Oxford comma to second category, i.e. "Only important to fishermen, divers, and snorkelers".

A 2016 survey (Figure ES.HSP.4) polled residents to rate the importance of coral reef services to them. 88% of the respondents said coral reefs were very important to the culture, are a way to attract tourists, and protect communities from storm surge and natural disasters. Clearly, the marine environment is recognized as a large cultural ecosystem benefit in American Samoa.

Conclusion:
Cultural traditions and values currently thrive in American Samoa where one people, one language, and one common set of cultural practices are perpetuated. The ecosystem services of Heritage and Sense of Place supported by NMSAS are unique to the cultural setting of American Samoa; the relationship between the sanctuary and community is therefore unlike other marine sanctuaries. NMSAS prioritizes cultural traditions and values as core emphases for programs and activities. The Chiefs who were engaged in the workshop process stated that culture is too important and too complex to capture in a rating. Therefore, there are no formal graded assessments for Heritage and Sense of Place, as to do so would be considered inappropriate. Instead, the value of cultural heritage is presented here in narrative form, including historical and cultural background in American Samoa and a summary of related resources and activities, such as engagement and education and outreach events. These events highlight the cultural traditions and values of family, village, ecosystem, and fa'asamoa. Heritage and Sense of Place, therefore, should be understood as shared and strongly supported by NMSAS and by the community of American Samoa.

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Commented [14]: couldn't find citation

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This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Commercial Harvest — The capacity to support commercial market demands for seafood products

Status: *Undetermined with Medium Confidence* ***Trend:*** *Undetermined with Medium Confidence.*
Status Description: *Not Applicable*
Rationale: *Throughout the study period (2008-2018) the number of commercial fishing vessels has declined. Additionally, there is limited information specific to NMSAS and regulations vary across sites within the sanctuary. Ecosystem changes linked to climate change may have impaired the ability of the ecosystem to provide commercial harvest.*

Commercial harvest is defined as the capacity to support commercial market demand for seafood products. These products may include fish, shellfish, other invertebrates, roe and algae. Artisanal fishing, which tends to be conducted by individuals or small groups who live near their harvest sites and use small scale, low technology, low cost fishing practices is also included in commercial harvest. Commercial fishing is prohibited within the Rose Atoll Marine National Monument and the Fagatele Bay Management Area. Additionally, throughout the sanctuary there are various zones that prohibit specific gears or require a permit (NMSAS Factsheet, 2019). Commercial fisheries data specific to sanctuary areas is not available, therefore aggregate data for the territory was evaluated to address this question, with the assumption that activities within the Sanctuary follow overall territorial trends. S~~However,~~ ~~s~~everal indicators from territorial datasets suggest a decline in commercial fisheries effort and harvest across the territory. The number of fishing vessels and fishermen in American Samoa has declined over the past ten years (American Samoa Statistical Yearbook, 2017). In 2019, the total estimated pelagic landings were approximately 2.9 million lbs., the lowest in the past decade (*WPRFMC, 2020a*) and a benchmark stock assessment determined that the bottomfish complex is overfished and experiencing overfishing (Langseth et al. 2019). Catch-per-unit-effort (CPUE) for bottomfish in 2019 was lower than 10- and 20-year averages (*WPRFMC, 2020).* In contrast, commercial data for the top five species based on cumulative harvest values from 2007-2019 (lined/blue-banded surgeonfish, yellowfin tuna, wahoo, parrotfish, and broadbill swordfish) remained variable, showing no clear trend over the study period (WPacFin - Commercial Dealer Data, 2020). Experts noted that people who use the resources have noticed declines in various fish stocks, including reef fish. For these reasons, the status and trend of commercial harvest are undetermined.

The most common form of commercial harvest taking place in American Samoa is fishing. In a 2014 survey of American Samoa residents 32% of respondents reported fishing more than once per month and 20% reported gathering marine resources more than once per month (Levine et al. 2016). However, this study did not differentiate between commercial and subsistence harvest. Of those surveyed who stated that they engaged in fishing or harvesting marine resources, 62% reported never fishing to sell, 21% reported rarely fishing to sell, 10% reported sometimes fishing to sell, and 3% reported frequently fishing to sell. And while it is not known what percentage of catch individuals sell for income, the data available suggest that the majority fish for subsistence purposes for themselves or others and not for commercial purposes.

Commented [1]: Mageo: This Section aptly define, describe and disseminate the benefits and concerns about this Service; it appears there is no immediate threat to the Management of NMSAS and its Resources. Thus, the use of aggregated data for the Territory due to unavailable data that is specific to the Sanctuary in assessing the Commercial Harvest Services. However, NMSAS management ought to look into Coastal development and off-shore Commercial harvest and its proximity to the protected zones of the Sanctuary in assessing its impact on Sanctuary Units. Nonetheless, it is duly noted that overfishing continues to be an area of major concern in providing this vital Service; although, there seemed to be less fishing activities and boats during this reporting cycle than previous ones based on the data gathered on fishing practices in the Territory.

Commented [2]: it would be helpful to emphasize what is allowed (rather than prohibited) in the sanctuary, to demonstrate that this category is relevant to examine

Commented [3]: does this mean that you are assuming that there is a decline in commercial fisheries activities within sanctuary waters, specifically?

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Another study conducted in 2014 looked at how Aunu'u residents depend on and value sources of food and income (Levine & Kilarski, 2015). Most respondents felt that boat transport is "very important" for food/income (89%), followed by farming (77%), government (73%), and fishing (52%). The least important sources of food/income are tourism, with 78% reporting it was "not at all important", the cannery (71%), private business (70%), and the off island remittances (70%). As stated above, the survey did not differentiate between subsistence and commercial use, so it is not clear if the 52% of people felt fishing was important for food (subsistence) or income (commercial).

When asked about the frequency of fishing and harvesting to generate income, 71% of Aunu'u respondents reported they never engaged in this activity for income, 15% reporting sometimes, and 13% reporting frequently. Further, 64% reported fishing for food frequently and 36% reported fishing sometimes for food, suggesting that the primary reason as to why 52% of respondents reported fishing is very important is because it provides them with food and income. In a follow-up survey of data collected in 2017, Levine & Kilarski (2018) found that Aunu'u households reported solely fishing for food and not to sell. Using data collected in 2017, respondents from Aunu'u stated the cannery (42%), government jobs (34%) and fishing (19%) were the most important sources of income. The survey implemented in 2017 did not include a question about boat transport as a source of income. Therefore, those that reported fishing as being important likely rely on the cannery for income, and thus find fishing to be important. The most common types of seafood targeted by Aunu'u households was fish from the reef flat (31%) followed by invertebrates (25%), fish from the reef slope (24%), and pelagic fish (20%) (Levine & Kilarski, 2015). Further, the study found the most frequent fishing methods include rod/reel/handline, and pole and line from shore. The second most common way of fishing is gleaning/gathering, followed by spearfishing.

In American Samoa (not specific to sanctuary units) from 2006-2016 the gear that landed the most pounds was longlining, followed by bottom fishing and spearfishing (American Samoa Statistical Yearbook 2017). Levine & Sauafea-Leau (2013), using survey data collected in 2008, found that 61% of respondents thought reef fishing was worse in 2008 than when they were younger. On Manu'a, roughly 15% thought it was worse and in Tutuilla roughly a third thought fishing was worse. Trolling has seen a decline since 2006, as has longlining. Spearfishing (which may be done on the reef) and bottom fishing have increased, with variation over time (American Samoa Statistical Yearbook 2017). (Table App. CH.1).

The Yearbook (2017) also provides data on the number of boats, fishermen and pounds landed. Figure ES.CH.1 and Table App.CH.2 show how these indicators have changed over time. From 2008-2010 there was a sharp decline in catch. To a lesser extent, the number of boats and fishermen also declined. In 2016 there were roughly one-third the number of fishermen as in 2006. Possible explanations for this decline include the 2009 tsunami that destroyed several of the Alia (local fishing boats). Additionally, experts noted that the cost per fish at the cannery has declined, meaning commercial fishing for species processed at the cannery has become less profitable. More specifically, the retail price of a 6.5 ounce of canned tuna declined from $1.92 in 2007 to a low of $1.34 in 2011, with the price recovering some in 2017 to $1.90 (American Samoa Statistical Yearbook, 2017).

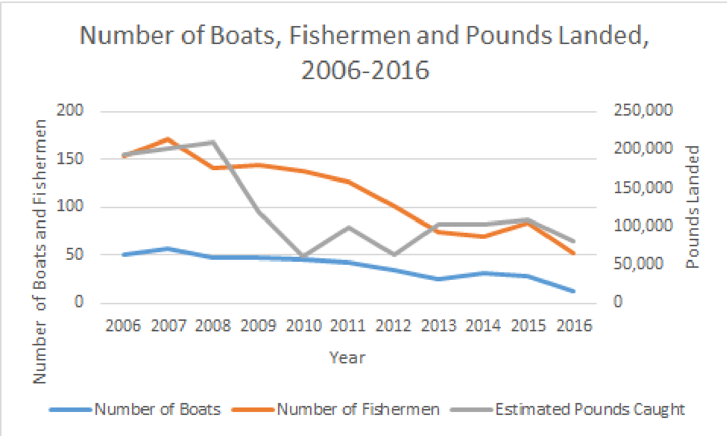

Figure ES.CH.1. Changes in fishing effort and participation between 2006 and 2016 Source: American Samoa Statistical Yearbook, 2017

This decline is further evidenced by a reduction in the number of permitted longline vessels from 2008 to 2018 (PIFSC, 2018; Figure ES.CH.2). Additionally, declines have been seen in commercial landings from the boat-based creel survey. Vehicle landings from commercial dealer data have remained stable, as have shore-based creel surveys (Figure ES.CH.3).

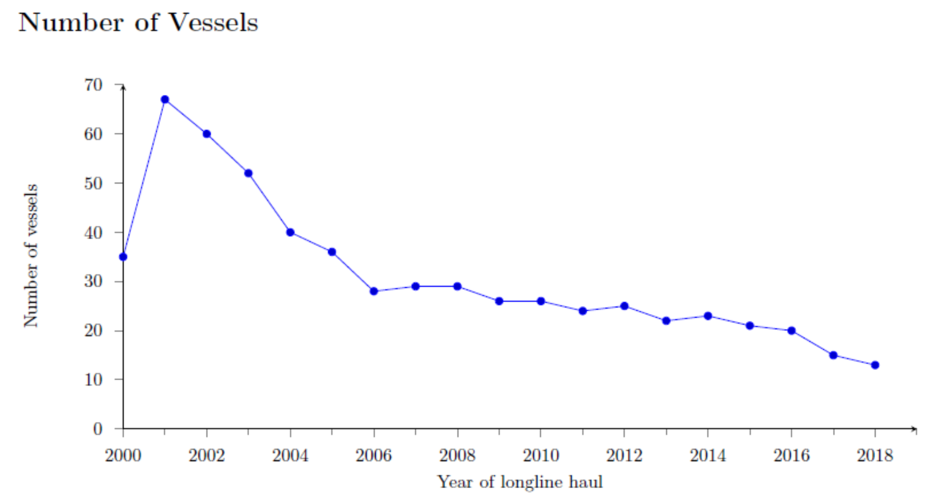

Figure ES.CH.2. Number of active longline vessels based in American Samoa, by year, 2000-2018. Source: PIFSC, 2018

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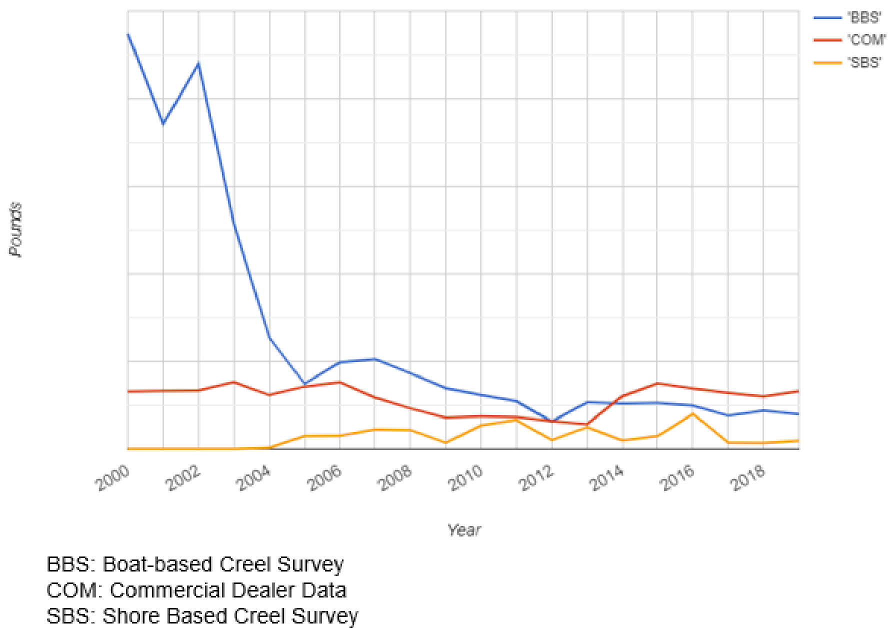

Figure ES.CH.3. Comparison of commercially sold seafood in American Samoa 2000-2019. Source: WPacFin, 2020

Using data from the Western Pacific Fisheries Information Network (WPacFin), 2020, the top five species in cumulative value from 2007-2019 were lined/blue-banded Surgeonfish, yellowfin tuna, wahoo, parrotfish, and broadbill swordfish (Figure ES.CH.4). Yellowfin tuna shows variation across the study period, with low catches from 2009-2013, and high catches from 2015-2018. There was no clear trend over time for wahoo, but the data reveal a low point in both catch and value for 2013. Broadbill swordfish showed variation over the study period, with no clear trends in either pounds or value. The catch and harvest value for two reef species, blue lined surgeonfish and parrotfish, increased over the reporting period with a peak in 2015, but then declined. Experts in the condition report workshop noted that coral bleaching in 2015 and later years may have affected reef species.

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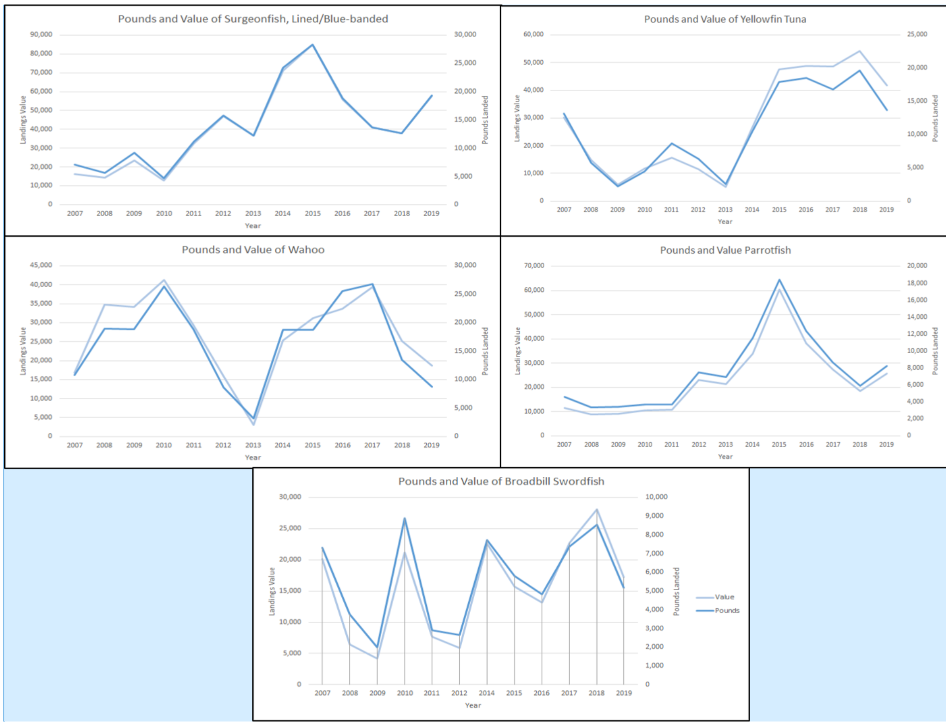

Figure ES.CH.4. Catch and value in American Samoa between 2007 and 2019 of the top five commercially harvested species by value. Source: WPacFin - Commercial Dealer Data, 2020

The total monetary benefits of coral reefs for artisanal fishermen working in the nearshore is roughly $44,000 per year (Spurgeon et al. 2004). When evaluating consumptive or potentially damaging ecosystem services, it is important to consider the sustainability of resource impacts. Data on fish in the State section of this report indicate a lack of larger parrotfish, groupers and sharks in NMSAS. Further, biomass of preferred fish species is low in Fagatele Bay and Aunu'u. Although the resource indicators and the number of commercial boats indicate a decline, there is limited to no data about what occurs within the sanctuary. All data available were collected for American Samoa and the data cannot be analyzed specific to the sanctuary or specific areas of the sanctuary. There are also several independent and interacting natural and socioeconomic factors that may explain variation in landings, including natural weather events and ecosystem changes associated with climate change. Additionally, gear types and the fishery rules vary by area and village, and data are limited overall. For these reasons, the status and trend were rated as undetermined.

Conclusion

Sanctuary specific data on commercial harvest was not available, so aggregate data for the territory was evaluated to address this question. The number of fishing vessels and fishermen have declined over time and in 2019 pelagic catches were the lowest in the past decade and NMFS determined that the bottomfish fishery was overfished and experiencing overfishing. Commercial fish sales data indicated

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that the commercial catch for the three top pelagic species was variable and the two reef species showed a general increase in harvest with a peak in 2015 followed by a decline. Experts noted that a coral bleaching event in 2015 may have affected these species. Respondents to social surveys noted that reef shark populations have improved, but octopus, giant clams, atule, and palolo declined or remained the same. Fishery independent data suggest that shallow reef fish biomass and giant clam abundance has declined. For these reasons the trend and status of commercial harvest is undetermined.

Commercial Harvest Indicator Table. Summaries for the key indicators related to commercial harvest that were discussed during the 2020 status and trends workshop.

Indicator	Source	Data Summary
Harvest participation	Levine et al., 2016	Status: Majority of respondents reported fishing in the past month and slightly less than half reported gathering marine resources in the past month.
Reasons for fishing	Levine et al., 2016	Only 3% sell fish frequently, the majority of respondents cited subsistence.
Reasons for fishing/harvest Aunu'u	Levine & Kilarski, 2015	Everyone said they either frequently or sometimes fish for food. The overwhelming majority said they provide fish to their pastor or village leaders.
Frequency of Fishing in Aunu'u	Levine & Kilarski, 2015	Only 21% of households reported that no one fished in their household. Most people fished at least once per month, with 18% reporting more than once per week. The most common fish targeted are reef flat fish (31%) and invertebrates (25%). Fishing from the shore and gathering/gleaning are the most reported modes of fishing. Further, 46% of respondents reported fishing less frequently over the past 10-years, while 28% fish about the same. Other data was only collected in 2014.
Fishing Gear observed	Craig et al., 2008	The most common gear observed in Manu'a was rod/reel followed by big-eye scad weir.
Fishing compare now to when you were young	Levine & Sauafea-Leau 2013	61% of respondents stated fishing is worse now than when they were young. Only 1% responded it was better. Reef sharks and sea turtles were identified as improving, but octopus, giant clams, atule, and palolo were identified as being worse or the same.

Number of boats, fishermen and pounds landed	American Samoa Statistical Yearbook, 2017	The number of boats, fishermen and pounds landed declined from 2006 – 2017, with notable declines observed in years 2010 and 2016.
Number of Active Longline Vessels	PIFSC, 2018	The number of longline vessels in American Samoa has been declining since 2001. The rate of decline slowed beginning in 2006.
Boat-based creel and shore-based creel survey data and commercial dealer data	WPacFin, 2020	Although, there was some variation in pounds landed by all data collection methods remained stable during the study period (2007-2019).
Value and pounds landed of commercial fish species	WPacFin, 2020	The top five species in cumulative value from 2007-2019 are lined/blue-banded Surgeonfish, yellowfin tuna, wahoo, parrotfish, and broadbill swordfish. Parrotfish showed an increasing trend in value and pounds, the other four species showed no clear trend over the study period.
Fish	Williams et al., 2015	Shallow coral reef fish biomass is lower than the potential biomass estimates. There is a lack of larger parrots, groupers, sharks, and at least one keystone species is functionally extinct.
Giant clams	Green and Craig, 1999; Brainard et al., 2008; NOAA PIFSC, 2021	Shallow coral reef clam communities have declined across most sites. Decline in Rose Atoll is dramatic and troubling.
Food fish	MARC, 2020	Shallow coral reef biomass for targeted food fish species is low in Fagatele and Aunu'u.

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Appendix - Commercial Harvest

Table App.CH.1 Pounds Landed by Gear Type, 2006-2016. Source: American Samoa Statistical Year, 2017

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Year	Total	Trolling	Bottom Fishing	Spear Fishing	Longlining
2006	194,395	19,254	11,433	13,691	149,935
2007	189,552	14,225	43,350	24,858	105,726
2008	210,442	40,064	103,959	9,357	53,529
2009	111,736	4,293	68,812	14,251	23,397
2010	61,020	2,205	23,146	31,971	2,711
2011	98,906	30,131	30,113	24,281	8,780
2012	63,945	20,724	19,689	18,003	2,081
2013	102,735	16,894	29,890	25,529	29,256
2014	102,122	19,178	31,799	27,548	18,936
2015	109,087	16,635	43,946	25,131	20,215
2016	80,353	8,444	22,228	33,022	4,658
Total	1,324,293	192,047	428,365	247,642	419,224

Table App.CH.2: Number of Boats, Fishermen and Pounds Landed, 2006-2016. Source: American Samoa Statistical Year, 2017

Year	Number of Boats	Number of Fishermen	Estimated Pounds Caught
2006	51	153	194,395
2007	57	171	202,043
2008	47	141	210,442
2009	48	144	117,736
2010	46	138	61,020
2011	42	126	98,906
2012	34	102	63,945
2013	25	75	102,735
2014	32	69	102,122
2015	28	84	109,087
2016	13	52	80,353

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Subsistence Harvest — The capacity to support non-commercial harvesting of food and utilitarian products

Status: *Good/Fair with Medium Confidence* ***Trend:*** *Worsening with Medium Confidence*

Status Description: *The capacity to provide the ecosystem service is compromised, but performance is acceptable.*

Rationale - *Although evidence is limited to rate this service, the agreement was high that the status is good/fair. In a 2014 survey, roughly one-third of respondents reported fishing at least two to three times per month. Additionally, several respondents indicated that they gathered other marine resources (such as shells, octopus, lobster, sea cucumber and other non-fish species). The most common reasons for fishing include feeding themselves and family, giving to extended family and friends, giving to pastors and village leaders and for special occasions and cultural services. There is a shift towards residents fishing less frequently, likely because of the increased convenience of storing and purchasing food. The worsening trend was attributed to surveys showing respondents believing fishing is worse now than when people were younger (Levine & Sauafea-Leau 2013).*

Subsistence harvest is defined as the capacity to support non-commercial harvesting of food and utilitarian products. Subsistence is conducted principally for personal and family use, and sometimes for community use, and may be distributed through ceremony, sharing, gifting, and bartering. Data sources used in this section are primarily surveys that ask about the importance of fishing for food and how fish are used and perceptions on how subsistence harvest species have changed over time. The data presented here represents fishing activities in village communities of American Samoa and although some of these villages may be along sanctuary waters, the data are not specific to the sanctuary.

Although limited data are available, a study conducted in 2014 provides multiple data points related to subsistence fishing in American Samoa (Levine et al., 2016). Unfortunately, the data was not specific to fishing activity in the sanctuary itself. The study of American Samoa residents reported the majority of respondents fishing within the prior month, with slightly less than half of the respondents gathering marine resources during that time. Further, only 3% of participants reported selling fish; the majority cited fishing for subsistence. In total, 46% of respondents reported fishing to feed themselves, 41% to give to pastors and village friends, and 38% to give to extended family and friends either frequently or sometimes. In addition, 62% of respondents reported never fishing to sell, suggesting that the majority of fishing is to support a communal way of life with personal and village consumption prioritized over commercial purposes.

A report published in 2015 by Levine & Kilarski looked specifically at households on Aunu'u. Only 21% of respondents reported that no one in their household engaged in fishing and/or harvesting marine resources. All Aunu'u households that engaged in fishing reported that they either fished frequently or sometimes for food, while 98% of respondents reported providing food for their pastor or village leader. Further, 88% of Aunu'u households reported fishing/harvesting of marine resources at least 1-3 times per month. When asked about the frequency of fishing over the past ten years, 28% of respondents

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However, fishing activities in utilizing this service through recent years has somewhat fluctuated to downright diminishing based on recent studies and collected data. According to the Report, the reduction in fishing activities using the Subsistence Harvest Service is due to both tangible and intangible factors impacting the Samoan Way of Life but not the lack of the Sanctuary's Resources in providing the aforementioned Services. In spite of recent findings, I believe with many other natives that this Service will continue to be an integral part of our Sanctuary system and plays a crucial role in sustaining our traditional/customary practices with Our Way of Life.

Commented [2]: will you be able to get the results from the 2021 survey before this report is finalized? https://www.coris.noaa.gov/monitoring/socioeconomic_samoa_survey.html indicated they fish about the same while 46% stated they fish less frequently (Levine & Kilarski, 2015). One of the reasons for less fishing compared to the past years is the shift to a cash economy. It is more convenient for people nowadays to purchase food than to fish and farm. The local population relies heavily on imported goods and services which began in the early 1970s.

A possible reason for the limited fishing may be that traditionally, Samoans fish for subsistence and not for sale. In the past, there was no electricity or means of refrigeration at most of the outer villages therefore, fishermen only fished for what the family could consume in a 1-2 day period. With westernization, people are able to store their catch in the refrigerator for a longer period of time, but this does not appear to have resulted in increasing subsistence catch. This may explain why 46% of surveyed residents fish less frequently (Levine and Kilarski 2015). The most common type of fish targeted by Aunu'u households was from the reef flat (31%), the reef slope (24%), and pelagic fish (20%). Invertebrates were also harvested (25%). The most frequent fishing methods included rod/reel/handline pole (67% reported using these methods frequently) and from the shore via gleaning and gathering (57% reported using these methods frequently).

Levine & Sauafea-Leau (2013), using survey data collected in 2008 from across American Samoa, found that 61% of surveyed residents thought reef fishing was worse in 2008 compared to when they were younger. On Manu'a roughly 15% thought it was worse and in Tutuila roughly a third thought fishing was worse. Survey respondents thought that sea turtles (25%) and reef sharks (22%) were better compared to when they were young, but 50%, 43% and 41% considered atule, palolo, and giant clams to be worse, respectively. Octopus were reported by 50% of respondents as being the same.

Lastly, Spurgeon et al., 2004 found the direct consumer surplus of subsistence fishing to be $73,000. Consumer surplus can be thought of as the benefit to residents from fishing minus any monetary expenditure the fishermen incur. Although this is a dated estimate, it demonstrates that subsistence fishing does provide a market value to households in addition to the non-market value of maintaining a connection to heritage and continuing cultural practices.

Conclusion

Subsistence fishing is important to the American Samoan community, to ensure that families have food on the table, have a healthy diet, and maintain a connection to the past through traditional and sustainable fishing methods. Data show that most households have at least one member fishing. Further, the most common reasons for fishing are for themselves, followed by giving to pastors and village leaders (Levine et al., 2016). But while most continue to participate in subsistence harvesting, many residents believe reef fishing is worse now than when they were young, including for the traditional harvest of species such as palolo, goatfish (i'asina), and bigeye scad (akule) (Levine and Sauafea-Leau 2013). Experts also noted that more people may be engaged in subsistence harvest, but the frequency of harvesting per person has decreased. This is supported by information from the State section of the report indicating declines in clam communities, a low abundance of large parrotfish, groupers, and sharks, and at least one functionally extinct species (humphead parrotfish). However, sea turtles and reef sharks were considered to be better than when respondents were young.

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Coastal Protection — Natural features that control water movement and/or wind energy, thus protecting habitat, property, heritage resources and coastlines

Status: *Mixed*[1]*, Medium Confidence* ***Trend:*** *Worsening with High Confidence.*

Status Description: *The status of coastal protection services is mixed.*

Aunu'u Unit	*Fair/Poor*	*The capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it.*
Muliava Unit	*Good / Fair*	*The capacity to provide the ecosystem service is compromised, but performance is acceptable.*
Other Units	*Fair*	*The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.*

Rationale: *Although coastal protection is rated as fair in most sanctuary units, Rose Atoll is considered to be good/fair and Aunu'u is fair/poor. The overall fair rating was driven by sea level rise threats to the health of corals and crops grown in coastal areas, and because vessel groundings and storms have damaged natural coastal protection defenses, such as corals and mangroves, in localized areas. The worsening trend is the result of the combined effects of sea level rise and subsidence. Experts noted that subsidence on the island is about 7-9mm/year, making the island's relative sea level rise rate about 5 times the global average. In addition to deepening reefs, this causes coastal and inland flooding, which threatens reef growth, and coastal habitats, crops, and infrastructure.*

Coastal protection is defined as the flow regulation that protects habitats, property, coastlines and other features. Coral reefs, mangroves and wetlands around American Samoa protect coastlines by dissipating wave energy, resulting in smaller, less destructive waves reaching the shore. These natural buffers help protect against erosion, which may threaten coastal properties and resources. It is important to note that coastal protection is evaluated based on the ability of natural features (not man-made infrastructure) to provide protection. Although there is limited data available for this service, there was a robust discussion amongst experts that is summarized below.

In American Samoa, relative sea level has increased by 25 cm (9 inches) since 2009 due to a combination of global sea level rise and subsidence linked to the 2009 earthquake along the Tongan trench (Han et al 2019). The rate of relative sea level rise in the Samoan Archipelago is now 7-9 mm/yr, or approximately five times the global average. This has led to increased coastal erosion and inundation and widespread

[1] Experts assigned a rating of Fair at the workshop, but noted that status varied across individual sites.. Following the workshop, a new "mixed" status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

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Hopefully, a concerted effort by the island Community in conjunction with NOAA, Government Agencies and Private Sector Partners, Village Councils, Villages and Churches to elicit a formidable RESPONSE in combating the challenges/threats confronting our Sanctuary and Management. I'm confident that it's not only feasible and possible but achievable because it is the Samoan Way of Life (Fa'aSamoa) and This is How We Do It!

coastal armoring to protect important infrastructure across Tutuila. Coral reefs play an important role in coastal protection within all sanctuary units. Coral reef cover in the sanctuary has remained relatively stable from 2002-2018 with some declines due to bleaching events in 2015-2017 and 2020 (NOAA PIFSC ESD 2018). Gilman, et al., 2007 found that there were no mangrove stands in the sanctuary to provide coastal protection, other than a small stand adjacent to Aunu'u multipurpose zone. They noted that these mangroves were retreating even before the rapid increase in sea level after the earthquake.

A study funded by USGS (Storlazzi et al. 2019, Gibbs et al. 2019) looked at the annual value of hazard risk mitigation provided by coral reefs for the islands of American Samoa. The study considered what the damage to the island would be with and without the existing coral reefs for several different flooding scenarios. The results are presented in Table ES.CP.1. Coral reefs protect a total of $25.9 million in buildings and $7.3 million in economic activity (2010 dollars). The analysis indicates that beaches in the Fagatele, Fagalua/Fogama'a, and Ta'u units would be impacted by the loss of reefs, but only assessed values for buildings and economic activity which are very low in these areas (Gibbs et al. 2019). The analysis suggests that the loss of reefs in these units could have significant impacts on beaches and intertidal biological communities, increase erosion impacts on reefs, submerge historic sites, and decrease recreational use values. The study did not include Aunu'u, Rose Atoll, or Swains Island.

Table ES.CP.1 Annual value of flood protection provided by coral reefs by island. Source: Storlazzi et al., 2019

Location	Buildings (U.S. dollars, 2010)	Economic Activity (U.S. dollars, 2010)
Tutuila	25,019,327	7,074,370
Ofu and Olosega	77,852	41,228
Ta'u	753,845	148,637
Total	25,851,024	7,264,235

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A previous study by Spurgeon et al., 2004 found that the indirect value of shoreline protection to American Samoa residents was $447,000 from coral reefs and $135,000 from mangroves. These benefits were assessed using replacement cost (how much it would cost to build an equivalent man-made protection system). The shoreline protection evaluated considered both shoreline resources and assets protected from erosion and flooding by waves and storm surges. The study stated that there was low accuracy for current and future values, but used the best available data. The value in 2004 was relatively low because tourism and recreational access to corals were limited and there were already extensive man-made shoreline revetment structures in Tutuila and at marinas in Ofu and Ta'u.

Updated economic values for coastal protection in Rose Atoll and Swains Island are not available as these sites were not prioritized for analysis in the USGS study due to the lack of human inhabitants. These low lying atolls provide important habitat for numerous species, but are particularly vulnerable to coastal hazards and sea level rise due to their low elevation. In 2016, Cyclone Victor hit Rose Atoll with

30 foot waves and 60 miles per hour winds. The storm eroded large swaths of the beach, disturbed sea turtle nests, and killed hundreds of seabirds (NMFS 2018), but the reefs prevented more extensive damage and the beach is rebuilding. Coral cover at Rose Atoll did decline from 2015 to 2018 (NOAA PIFSC ESD 2018), likely due to coral bleaching, but crustose coralline algae increased. Based on this information experts noted that the coastal protection services at Rose Atoll are still Good/Fair. This indicates that the capacity to provide the ecosystem service is compromised, but performance is acceptable. Coral reefs at Swains Island experienced the greatest decreases between 2015 and 2018 (NOAA PIFSC ESD 2018). This is unlikely to have affected coastal protection in the short term, but may lead to cumulative effects to coastal protection due to the loss of reef building corals.

The island of Aunu'u was also excluded from the USGS study. Aunu'u is considered to be more vulnerable to sea level rise as most of the island's infrastructure, housing, and agricultural resources lie in low lying areas. Coral reefs are likely an important defense for coastal areas on this island, but these services may have been impaired by the 2016 grounding of the fishing vessel, *No. 1 JiHyun*, along the southwest coast of Aunu'u. The vessel pulverized 468 square meters of coral along the reef margin where conditions were too rough to allow restoration actions (Symons et al. 2017). In August 2019, large swells pushed coral rubble onto shore in this area blocking the only road to the island's electrical generator and elementary school and flooding the generator building. While rubble naturally washes ashore during storm events (and actually is an essential process for many islands), these incidents exemplify how human degradation of reefs can exacerbate the impact and inconvenience they cause. The coastal inundation in this area may be exacerbating salt water intrusion into the island's taro patches and drinking water associated with sea level rise (Pacific RISA, 2013; McIntosh, 2013). A KUPU internship project hosted by NMSAS documented brackish conditions in some areas within the taro patches on Aunu'u in 2019 and 2020 (S. Ta'ala unpub. data). Experts noted that the coastal protection services at Aunu'u are Fair/Poor. This indicates that the capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it.

Coral reefs provide protection to existing infrastructure and support economic activity. Stable conditions of natural resources help to ensure the benefits to the island continue. Experts noted that the status of coastal protection services varied significantly across the sanctuary units, but settled on an overall rating of Fair. Experts emphasized that the status of Rose Atoll was good / fair as the reefs are in good condition with significant crustose coralline algae growth and documented recovery after a major storm. Aunu'u was rated lower (fair/poor) because there have been significant negative impacts to infrastructure as a result of a vessel grounding and sea level rise. Experts felt there was limited evidence available on this service, but had high agreement on the rating, leading to a medium confidence rating. Experts noted that the trend is worsening for all sites as sea level rise and coral bleaching have both increased over the reporting period, threatening coastal protection services provided by coral reefs. There was medium evidence to support the trend rating and high agreement leading to a high confidence score for this trend.

Conclusion

Coral reefs provide protection to existing infrastructure and support economic activity. Stable conditions of natural resources help to ensure the benefits to the island continue. Coral reefs and mangroves help to reduce flooding and wave energy as it approaches the shoreline. Rapidly rising relative sea level rise is driving the worsening trend, as it affects a large number of sites currently protected by these habitats and can itself directly degrade these habitats further reducing their ability to provide protection. Experts also noted that increased development, erosion and sedimentation in addition to coral bleaching events have led to declines in coral populations. Although different ratings were prescribed for different sites within the sanctuary, across all units, the rating is fair.

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Response to Pressures

The Drivers Forces and Pressures section of this report describes a variety of issues and human activities occurring within and beyond the sanctuary that warrant attention, tracking, study, and in some cases, specific management action. Addressing any of these issues requires participation by and coordination with a variety of agencies and organizations. The Office of National Marine Sanctuaries (ONMS) is fortunate to be able to work with many entities that contribute to managing human activities and addressing marine conservation issues. Central to that collaborative approach is the NMSAS Sanctuary Advisory Council (SAC), a community-based advisory body established to provide advice and recommendations to the NMSAS superintendent on issues including management, science, service, and stewardship (see text box).

NMSAS is co-managed with the American Samoa Government (ASG) and works closely with communities to manage sanctuary resources within the context of Samoan cultural traditions and practices. Since the designation of the Fagatele Bay National Marine Sanctuary in 1986, local administration of the Sanctuary has been conducted through a cooperative agreement with ASG. In 2002, a memorandum of agreement became the instrument for the relationship between ONMS and ASDOC. The programs and presence of the newly established NMSAS expanded in scope with the co-development of a world class visitor and learning facility known as the Tauese P.F Sunia Ocean Center and further collaboration on several efforts with ASDOC. In 2013, ASG shifted co-management from ASDOC to the AS DMWR. With this change, NMSAS continued to engage AS DMWR on a regular basis and collaborated on opportunities that benefit the territory such as CoTS removal and the Fagota mo Taeao Fishing Tournament.

ONMS and NMSAS place a high value on partnerships with sanctuary communities and maintain great respect for fa`a-Samoa. In American Samoa, the relationship between the sanctuary and the village council is critical to the success of this partnership. In 2009-2012 ONMS staff and Office of Samoan Affairs helped facilitate the sanctuary's community engagement, public meetings and individual consultations in a manner that is culturally appropriate and respectful of fa`a-Samoa. This work included following traditional protocols with meaningful community engagement with saofa'iga a le nuu (village councils) and consultation with the Office of Samoan Affairs. These relationships then helped facilitate shore based access to Fagatele Bay, CoTS removal, and the response to a vessel grounding in Aunu'u.

For each of the main issues and human activities presented in the Driving Forces and Pressures section of this report, a summary is provided below of related activities and management actions that ONMS has led or coordinated since 2007. The most significant action was the expansion of the sanctuary in 2012. During this process, ONMS worked with stakeholders to evaluate the issues affecting the sanctuary and this led to regulatory changes including the establishment of a no-take area in Fagatele Bay and prohibitions on damaging activities like anchoring throughout the sanctuary (Tables R.1-2). Eight action plans were developed through this process to guide sanctuary management. The Resource Protection and Enforcement (RP&E), Climate Change, Cultural Heritage and Community Engagement, and Ocean Literacy Action Plans all include strategies to reduce pressures on sanctuary resources. The activities described below are not exhaustive of all the ways the sanctuary serves the community and the marine ecosystems surrounding NMSAS, but highlights significant contributions that are responsive to known or emerging pressures.

Recommended future response actions are not presented in this section; however, in 2022, ONMS will begin updating the sanctuary's management plan, and the findings of this condition report will serve as an important foundation for recommendations of new action plans designed to address priority needs.

Table R.1. Allowed fishing methods (indicated by "x" or text) in the NMSAS units. Source: Final DEIS & Management Plan for the National Marine Sanctuary of American Samoa (2012)

Examples of Allowable Fishing Methods	Fagatele Bay (No-take area)	Aunu'u Multiple Use Zone (Zone A)	Aunu'u Research Zone (Zone B)	Fagalua/Fogama`a	Ta'u	Swains Island	Muliāva (No-take area out to 12 miles from Rose Atoll)
Hook-and-line fishing		x	Surface fishing for pelagics only (bottom fishing is not allowed)	x	x	x	
Cast nets		x		x	x	x	
Spear fishing (non-SCUBA assisted)		x		x	x	x	
Gleaning		x		x	x	x	
'enu and ola (traditional basket fishing)		x		x	x	x	
Sustenance, subsistence, and traditional		x	Surface fishing for pelagics only (bottom fishing is not allowed)	x	x	x	NOAA Permit Required*
Recreational		x	Surface fishing for	x	x	x	NOAA Permit

			pelagics only (bottom fishing is not allowed)				Required*

Table R.2. The following activities are prohibited within any unit of the National Marine Sanctuary of American Samoa except the Muliāva Unit.

§ 922.104 Prohibited or otherwise regulated activities – Sanctuary-wide except in the Muliāva Unit.	Fagatele Bay (No-take area)	Aunu'u Multiple Use Zone (Zone A)	Aunu'u Research Zone (Zone B)	Fagalua/ Fogama`a	Ta'u	Swains Island	Muliāva (No-take area out to 12 miles from Rose Atoll)
Gathering, taking, breaking, cutting, damaging, destroying, or possessing any giant clam [*Tridacna* spp.], live coral, bottom formation including live rock and crustose coralline algae.	x	x	x	x	x	x	
Possessing or using poisons, electrical charges, explosives, or similar environmentally destructive methods of fishing or harvesting.	x	x	x	x	x	x	
Possessing or using spearguns, including such devices known as Hawaiian slings, pole spears, arbaletes, pneumatic and spring-loaded spearguns, bows and arrows, bang sticks, or any similar taking device while utilizing SCUBA equipment.	x	x	x	x	x	x	
Possessing or using a seine, trammel, drift gill net, or any type of fixed net.	x	x	x	x	x	x	
Disturbing the benthic community by bottom trawling.	x	x	x	x	x	x	
There shall be a rebuttable presumption that any items listed in paragraph (a) of this section found in the possession of a person within the Sanctuary have been used, collected, or removed within or from the Sanctuary.	x	x	x	x	x	x	

Text Box:

Advisory Council

The Fagatele Bay National Marine Sanctuary Advisory Council was established in 2005 to assure continued public participation in management of the sanctuary. Since its establishment, the council has played a vital role in the decisions affecting the sanctuary, bringing valuable community advice and expertise to the task of assuring effective sanctuary management. The council provides a public forum for consultation and deliberation on resource management issues affecting the waters within the sanctuary and surrounding areas. In 2012, NMSAS was designated and the advisory council was expanded to include members representing tourism, business, diving, community at large seats (for Fagatele, Fagalu'a/Fogama'a, Aunu'u, Ta'u/Manu'a, and Swains) recreational fishing, commercial fishing, non-consumptive recreation, education, research, conservation and local, state and federal government agencies. The council meets in public sessions of up to three meetings a year.

Accelerated climate change

The 2007 condition report recognized that rising ocean temperatures associated with climate change were a growing pressure on the coral reef ecosystems in Fagatele Bay. Further assessments have clearly indicated that rising temperatures are just one component of climate change. Sea level rise, ocean acidification, changes in storm intensity and rainfall will also affect the sanctuary's ecosystems. In 2011, ONMS developed a climate profile for Fagatele Bay (Cheng and Gaskin, 2011). The report compiled existing information on climate change and potential impacts on Fagatele Bay, including the ecosystems, ecosystem services, and maritime heritage resources. As part of the management review and expansion, ONMS developed a Climate Change Action Plan that guides the sanctuary's response to climate change pressures.

Efforts described in the action plan aim to understand and characterize climate change drivers and impacts in the sanctuary, suggest "green" sanctuary operations, identify habitats vulnerable and resilient to climate change, conduct and prioritize climate change research and monitoring, and promote public awareness about the problem. As part of these efforts, NMSAS conducted initial assessments of greenhouse gas emissions for sanctuary operations and initiated efforts to reduce emissions. In 2016, NMSAS partnered with the NMSF and Eco Adapt to conduct a rapid vulnerability assessment and development of adaptation strategies for NMSAS and the territory. This effort included two workshops and resulted in a report (Score, 2017). This was an important first step to evaluate climate threats and vulnerabilities to marine resources. Adaptation strategies were developed for ten focal resources.

In order to evaluate climate change effects, NMSAS has worked to increase the site's conservation science program. In 2019, a Moored Autonomous Partial Pressure of Carbon Dioxide (MAPCO2) buoy was installed in Fagatele Bay. The sensors on this buoy monitor ocean acidification and are part of a national array of moored carbon dioxide buoys across the Pacific, Atlantic, and Caribbean. The buoy is funded by the NOAA Ocean Acidification Program and involves many partners including NOAA's Ocean Acidification Program, Pacific Marine Environmental Laboratory, Atlantic Oceanographic and Meteorological Laboratory, Coral Reef Conservation Program, Pacific Integrated Ocean Observing System, and NMSAS. In 2020, NMSAS initiated an annual monitoring program for coral reefs in Fagatele, Fagalua / Fogama'a, Aunu'u, and Ta'u. The program is monitoring key indicators such as coral cover, demographics, and diversity; fish biomass and species richness; and macroinvertebrates.

ONMS also worked with NOAA OAR and OET to conduct deep sea expeditions in 2017 and 2019, respectively. These expeditions collected valuable information on deep sea habitats in the sanctuary, providing a baseline for evaluating changes in deep sea fauna and habitats in the future.

Ocean Literacy programs hosted by NMSAS have included outreach to build comprehension of ocean science concepts, including efforts to raise awareness of climate change impacts in American Samoa. A full list of these activities was included in the Ecosystem Services section on Education. These programs extended far beyond American Samoa, with media partnerships with Jean-Michel Cousteau and the Ocean Futures Society to create a film about Swains Island, partnership with Catlin-XL Seaview to create virtual reality imagery that is used in tours and shows an iconic coral bleaching photo at Fatumafuti, and the South Florida PBS program Changing Seas. These efforts reached global audiences and helped raise awareness of the threat climate poses to these special places.

In 2020 ONMS completed a NMSAS Climate Change Impacts Profile and created a SAC Climate Change Working Group to provide input on NMSAS climate change efforts.

Fishing

Fishing is an integral part of Samoan culture, but it also can impair ecosystem functions and resilience if not properly managed. For many years, scientists have noted that fish populations in Fagatele Bay are lower than they should be and the 2007 condition report documented the use of destructive fishing practices, including dynamite fishing, within the bay. As part of the management review and expansion, NMSAS worked with local communities to evaluate management options. In the end, fishing activities in Fagatele Bay and the Aunu'u Research Zone were restricted to improve fish biomass (Table X).

The RP&E Action Plan was developed during the expansion to guide efforts to improve compliance with fisheries restrictions and improve enforcement. Efforts included the production and dissemination of outreach materials to alert the fishing community of the new sanctuary regulations and improved partnership with the NOAA Fisheries Office of Law Enforcement and DMWR Law Enforcement through their Joint Enforcement Agreement. DMWR conducts regular patrols of sanctuary areas to support compliance with sanctuary regulations.

In 2016, NMSAS and partners initiated an annual fishing tournament to improve communications with the local fishing community and encourage pelagic fishing as a way to reduce pressures on reef fish populations. And in 2020, NMSAS initiated efforts to improve monitoring of reef fish communities in the sanctuary.

Coastal Development & Nearshore Construction

As noted in the Water Quality section, land use changes can have detrimental impacts to sanctuary resources. NMSAS does not have regulatory oversight over coastal development, but continued to actively participate in the CRAG to support efforts to improve watershed management and collaborated with the ASDOC on coastal planning near sanctuary areas.

Some development is necessary to maintain vital services for local communities. This includes the need for improved vessel access to Swains Island. During the expansion, ONMS worked with the Jennings family to establish boundaries for the sanctuary that would take these needs into account, while protecting the island's marine ecosystems.

Non-point source pollution

Most sanctuary areas are considered pristine, located away from development and dense human settlements. However, they are not immune from contamination. The RP&E Action Plan includes a strategy to facilitate research on land based sources of pollution and develop outreach materials. NMSAS worked cooperatively with researchers at ASEPA, NOAA NCCOS, and other organizations to assess land based pollution and contaminants in Fagatele Bay. The results of these efforts were shared at the expert workshops and are incorporated into the State of Ecosystem Resources sections in this report. These projects provide important information about non-point source pollution in the sanctuary and lay the groundwork for future management efforts. Information about land based sources of pollution are also included in ocean literacy efforts discussed in the Ecosystem Services – Education section in this report.

Point source pollution

Point source pollution sources are limited to the Aunu'u sewage outfall located in the Aunu'u Zone A and discharges from vessels passing through the Muliāva unit. In 2007, the AS-EPA and U.S. EPA developed a wastewater facilities plan for the village and island of (AS-EPA 2007). The sanctuary encouraged EPA to implement this plan, but it is a low priority due to the lack of detectable human health impairments.

Marine debris

Completely preventing marine debris from entering sanctuary boundaries is virtually impossible, as debris has a mix of ocean-based and land-based sources. NMSAS implements the marine debris strategy in the RP&E Action Plan through routine monitoring of marine debris through towed snorkel surveys and beach surveys. This has allowed sanctuary staff to evaluate and minimize marine debris within the sanctuary. Through these efforts abandoned nets, a tire, a damaged drifter drogue, ropes, buoys, and many smaller debris items were removed from coral reef areas in Fagalua and Fagatele Bay and beach cleanups were conducted in multiple sites. NMSAS has supported internships focused on marine debris and the topic is included in Ocean Literacy programs and many of the other education and outreach efforts listed in the Ecosystem Services – Education section of this report.

Vessel groundings

The RP&E Action Plan also includes a strategy to minimize damage through coordinated emergency preparedness and contingency planning. These strategies were implemented when a fishing vessel grounded on the reef in the Aunu'u unit in 2016. NMSAS worked with the US Coast Guard and others to immediately respond to the grounding and removed the vessel under the authority of the NMSA as quickly as possible. Similar groundings in other areas have lingered for many years, compounding the damage to fragile reef ecosystems. Lessons learned from this response have been incorporated into response strategies. NMSAS also obtained funding to support capacity building for coral restoration activities and a pilot coral nursery that should facilitate improved mitigation for future events.

Visitation

Due to the remote location of the sanctuary management areas, even on the main island of Tutuila, visitation numbers are thought to be low. However, visitors can cause physical damage, leave marine debris, or introduce invasive species or disease from other locations. NMSAS has developed education and outreach programs to encourage responsible use of the sanctuary, including ocean etiquette and student interpretation tour training. In 2015, the sanctuary initiated the annual Get Into Your Sanctuary program, which is now conducted nationwide. Signs were maintained along the Fagatele Bay access trail to educate visitors about sanctuary resources. Visitors are also encouraged to visit the Ocean Center to learn more about sanctuary resources and visitation guidelines. NMSAS has continuously improved outreach capacity during the reporting period. This includes Science on a Sphere, SOS Explorer, and outside signage. In addition, NMSAS has created radio, television, and social media content to remind the community and visitors to care for sanctuary resources. In 2013-2014, NMSAS and NPSA partnered to conduct a tour guide training program to enhance interpretation and resource protection capacity.

Nuisance Species Outbreaks

From 2011 to 2017, *Acanthaster planci*, or crown-of-thorns sea stars (CoTS) experienced a rapid increase in population that threatened corals around the island of Tutuila. CoTS were observed in low numbers at Fagatele and Aunu'u. More were observed in Fagalua/Fogama'a and along the Vaitogi coastline just outside of the sanctuary, however these numbers were much lower than northern sites where thousands of starfish were observed. Sites on the north side of the island were severely infested and efforts were undertaken by NPSA to stop the outbreak through diver interventions (NPS 2014). NPSA estimates that over 25,000 CoTS were culled using injections of sodium bisulfite or ox bile salts. As part of this effort, NMSAS brought rebreather dive teams to American Samoa in 2014 and 2015 to implement control measures during the "CoTS Blitz". Sanctuary divers surveyed 29 miles of reef, spent 307 hours underwater, and culled over 1,600 starfish during this effort. NMSAS has continued to monitor CoTS as part of its resource protection program and is prepared to implement control measures should an outbreak be observed within the sanctuary.

Research Activities

The sanctuary conservation science program has grown with the sanctuary and research is encouraged within the sanctuary units. Projects often require the installation of scientific instruments, markers, or buoys. NMSAS carefully reviews permit applications and requires researchers to implement best practices to avoid damage to sanctuary resources. Permitted activities included the placement of two oceanographic buoys, the MAPCO2 buoy in Fagatele Bay and the PacIOOS wave buoy in the Aunu'u Research Zone, a climate station in Fagatele Bay with oceanographic instruments and settlement structures, an ecological acoustic recorder in Fagatele, monitoring markers, and contaminant and sediment monitoring devices. No significant damage has been observed from these research activities. In response to the outbreak of stony coral tissue loss disease in the Caribbean, NMSAS initiated decontamination procedures for staff, partners and outside researchers in 2020 to minimize the potential transfer of invasive species and diseases. Gear must now be decontaminated between islands.

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Cited in text, but missing here: Final DEIS & Management Plan for the National Marine Sanctuary of American Samoa (2012)

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To be drafted after Peer Review

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Acknowledgements

This report would not have been possible without the participation and contributions of many state and federal agencies, tribal members and tribal staff, academic and non-governmental organizations, consortia, partners, funders, and researchers. With gratitude we recognize these individuals, who participated in meetings and workshops, contributed information, reviewed drafts, and/or provided general support to this effort: List to be pulled from here. (don't forget Meme Lobecker - NOAA OE helped with map question)

ONMS is indebted to the thoughtful peer reviewers of this document: __________.

Finally, we are also grateful to Kathryn Lohr for providing copy edits and Dayna McLaughlin for design and layout of the final report.

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Literature Cited

To be compiled from each section at the conclusion of the Peer Review.

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Appendix A:
Questions and Rating Schemes for State of Sanctuary Resources

The purpose of this rating scheme is to clarify the questions and possible responses used to report the condition of sanctuary resources in condition reports for all national marine sanctuaries. ONMS and subject matter experts used this guidance, as well as their own understanding of the condition of resources, to make judgments about the status and trends of sanctuary resources.

The questions derive from the National Marine Sanctuary System's mission, and a system-wide monitoring framework developed to ensure the timely flow of data and information to those responsible for managing and protecting resources in the ocean and coastal zone, and to those that use, depend on, and study sanctuary resources. The questions are being used to guide ONMS and its partners at each of the sanctuary system's 14 units in the development of periodic sanctuary condition reports. Evaluations of status and trends were based on interpretation of quantitative and, when necessary, non-quantitative assessments and observations of scientists, managers, and users.

In 2012, ONMS led an effort to review and edit the set of questions and their possible responses that were developed for the first round of condition reports (drafted between 2007 and 2014) (National Marine Sanctuary Program, 2004). The questions that follow are revised and improved versions of those original questions. Although all questions have been edited to some degree, both in their description and status ratings, the nature and intent of most questions have not changed. Five questions, however, are either new or are significantly altered and therefore, are not directly comparable to the original questions. For these, a new baseline will need to be established.

- Among the Water Quality questions, one was added on climate change. This was necessary to address the constantly increasing awareness and attention to the issue following the original design of the condition report process, which began in 2002. It also removed the need to combine climate change discussions with other questions.
- Two Habitat Quality questions were combined due to feedback received during the development of the first round of reports. A single question regarding the "integrity of major habitat types" has been created and combines prior questions that separately inquired about non-biogenic and biogenic habitats. Our experience showed that species constituting biogenic habitat (e.g., kelp, corals, seagrass, etc.) were considered adequately within questions about living resources, and need not be covered twice in the reports.
- Among the Living Resource Quality questions, one used in the first round of condition reports was removed entirely. It asked about "the status of environmentally sustainable fishing." It was removed for a variety of reasons—it

was the only question focused on a single, specific human activity and because fishing activity discussions were already included in the question regarding “human activities that may influence living resource quality.” In addition, living resource quality that would provide a basis for judgement for this question was typically considered as part of other living resource questions, and need not be covered twice. Another change to the Living Resource Quality questions pertains to the question about the “health of key species” which was previously addressed in a single question, but is now split into two. The first asks specifically about the status of “keystone and foundation” species, the second about “other focal species.” In either case, the health of any species of interest can be considered in judgement of status and trends.

- One of the initial maritime archaeology questions addressed potential environmental hazards presented by heritage resources like shipwrecks. While the assessment of such threats is important, it was decided that the question should actually address environmental hazards in general rather than apply specifically to historic maritime properties. Therefore, the question was removed from the maritime heritage resources section of the report and the subject is discussed in the context of other questions.

Ratings for a number of questions depend on judgments of the “ecological integrity” within a national marine sanctuary. This is because one of the foundational principles behind the establishment of sanctuaries is to protect ocean ecosystems. The term ecological integrity is used to imply “the presence of naturally occurring species, populations and communities, and ecological processes functioning at appropriate rates, scales, and levels of natural variation, as well as the environmental conditions that support these attributes” (modified from the National Park Service’s Vital Signs Monitoring Program). Sanctuaries have ecological integrity when they have their native components intact, including abiotic components (i.e., the physical forces and chemical elements, such as water), biotic elements (such as habitats), biodiversity (i.e., the composition and abundance of species and communities), and ecological processes (e.g., competition, predation, symbioses). For purposes of this report, the level of integrity that is judged to exist is based on the extent to which humans have altered specific components of the system, and the effect of that change on the ability of an ecosystem to resist continued change and recover from it. The statements for many questions are intended to reflect this judgment. Reference is made in the rating system to “near-pristine” conditions, for which this report would imply a status as near to an unaltered ecosystem as can reasonably be presumed to exist, recognizing that there are virtually no ecosystems on Earth completely free from human influence.

Not all questions, however, use ecological integrity as a basis for judgment. One focuses on the impacts of water quality factors on human health. Two questions rate the status of keystone and key species compared with that expected in an unaltered ecosystem. One rates maritime heritage resources based on their historical, archaeological, scientific, and educational value. Finally, four ask specifically about the levels of ongoing human activities (i.e., Pressures) that could affect resource condition.

During workshops in which status and trends are rated, subject matter experts discuss each question and available data, literature (e.g., published scientific studies, reports), and experience associated with the topic. They then discuss the statements provided as options for judgments about status; these statements have been customized for each question. Once a particular statement is agreed upon, a color code and status rating (e.g., good, fair, poor) is assigned. Experts can also decide that the most appropriate rating is “N/A” (i.e., the question does not apply), “Undetermined” (i.e., resource status is undetermined due to a paucity of relevant information), or “Mixed” (i.e., resource status across a number of indicators is mixed).

A subsequent discussion is then held about the trend. Conditions are determined to be improving, remaining the same, or worsening in comparison to the results found in the first round of condition reports. Symbols used to indicate trends are the same for all questions: “**▲”**—conditions appear to be improving; “**▬”**—conditions do not appear to be changing; “**▼”**—conditions appear to be worsening; “▲▼” —conditions appear to be mixed; and “**?”**—trend is undetermined.

Water Quality

1. What is the eutrophic condition of sanctuary waters and how is it changing?

Eutrophication is the accelerated production of organic matter, particularly algae, in a water body. It is usually caused by an increase in the amount of nutrients (largely nitrogen and phosphorus) being discharged to the water body. As a result of accelerated algal production, a variety of interrelated impacts may occur, including nuisance and toxic algal blooms, depleted dissolved oxygen, and loss of submerged aquatic vegetation (Bricker et al., 1999). Indicators commonly used to detect eutrophication and associated problems include nutrient concentrations, chlorophyll content, rates of water column or benthic primary production, benthic algae cover, algae bloom frequency and intensity, oxygen levels, and light penetration.

Eutrophication of sanctuary waters can impact the condition of other sanctuary resources. Nutrient enrichment often leads to plankton and/or algae blooms. Blooms of benthic algae can affect benthic communities directly through space competition. Indirect effects of overgrowth and other competitive interactions (e.g., accumulation of algal-sediment mats) often lead to shifts in dominance in the benthic assemblage, oxygen depletion, etc. Disease incidence and frequency can also be affected by algae competition and changes in the chemical environment along competitive boundaries. Blooms can also affect water column conditions, including light penetration and plankton availability, which can alter pelagic food webs. HABs, some of which are exacerbated by eutrophic conditions, often affect other living resources, as biotoxins are consumed or released into the water and air, or decomposition depletes oxygen concentrations.

Good	Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.

Good/Fair	Eutrophication is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.
Fair	Eutrophication has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Eutrophication has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Eutrophication has caused severe degradation in most if not all attributes of ecological integrity.

2. Do sanctuary waters pose risks to human health and how are they changing?

Human health concerns are generally aroused by evidence of contamination (usually bacterial or chemical) in bathing waters or seafood intended for consumption. They also arise when harmful algal blooms are reported or when cases of respiratory distress or other disorders attributable to harmful algal blooms increase dramatically. Any of these conditions should be considered in the course of judging the risk to humans posed by waters in a marine sanctuary.

Some sanctuaries may have access to specific information about beach closures and seafood contamination. In particular, beaches may be closed when criteria for water safety are exceeded. Shellfish harvesting and fishing may be prohibited when contaminant or biotoxin loads or infection rates exceed certain levels. Alternatively, seafood advisories may also be issued, recommending that people avoid or limit intake of particular types of seafood from certain areas (e.g., when ciguatera poisoning is reported). Any of these conditions, along with changing frequencies or intensities, can be important indicators of human health problems and can be characterized using the descriptions below.

Good	Water quality does not appear to have the potential to negatively affect human health.
Good/Fair	One or more water quality indicators suggest the potential for human health impacts but human health impacts have not been reported.

Fair	Water quality problems have caused measurable human impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Water quality problems have caused severe impacts that are either widespread or persistent.
Poor	Water quality problems have caused severe, persistent, and widespread human impacts.

3. Have recent, accelerated changes in climate altered water conditions and how are they changing?

The purpose of this question is to capture shifts in water quality, and associated impacts on sanctuary resources, due to climate change. Though temporal changes in climate have always occurred on Earth, evidence is strong that changes over the last century have been accelerated by human activities. Indicators of climate change in sanctuary waters include water temperature, acidity, sea level, upwelling intensity and timing, storm intensity and frequency, changes in erosion and sedimentation patterns, and freshwater delivery (e.g., rainfall patterns). Climate-related changes in one or more of these indicators can impact the condition of habitats, living resources, and maritime archaeological resources in sanctuaries.

Increasing water temperature has been linked to changing growth rates, reduced disease resistance, and disruptions in symbiotic relationships (e.g., bleaching on coral reefs), and changes in water temperature exposure may affect a species' resistance or the capacity to adapt to disturbances. Acidification can affect the survival and growth of organisms throughout the food web, as well as the persistence of skeletal material after death (through changes in rates of dissolution and bioerosion). Recent findings also suggest acidification impacts at sensory and behavioral levels, which can alter vitality and species interactions. Sea level change alters habitats, as well as their use and persistence. Variations in the timing and intensity of upwelling is known to change water quality through factors such as oxygen content and nutrient flow, further disrupting food webs and the natural functioning of ecosystems. Changing patterns and intensities of storms alter community resistance and resilience within ecosystems that have, over long periods of time, adapted to such disturbances. Altered rates and volumes of freshwater delivery to coastal ecosystems affects salinity and turbidity regimes and can disrupt reproduction, recruitment, growth, disease incidence, phenology, and other important processes.

Good	Climate-related changes in water conditions have not been documented or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Climate-related changes are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Climate-related changes have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Climate-related changes have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Climate-related changes have caused severe degradation in most if not all attributes of ecological integrity.

4. Are other stressors, individually or in combination, affecting water quality, and how are they changing?

The purpose of this question is to capture shifts in water quality due to anthropogenic stressors not addressed in other questions. For example, localized changes in circulation or sedimentation resulting from coastal construction or dredge spoil disposal can affect light penetration, salinity regimes, oxygen levels, productivity, waste transport, and other aspects of water quality that in turn influence the condition of habitats and living resources. Human inputs, generally in the form of contaminants from point or non-point sources, including fertilizers, pesticides, hydrocarbons, heavy metals, and sewage, are common causes of environmental degradation. When present in the water column, any of these contaminants can affect marine life by direct contact or ingestion, or through bioaccumulation via the food chain.

(Note: Over time, accumulation in sediments can sequester and concentrate contaminants. Their effects may manifest only when the sediments are resuspended during storm or other energetic events. In such cases, reports of status should be made under in the habitat/contaminants question.)

Good	Other stressors on water quality have not been documented, or do not appear to have the potential to negatively affect ecological integrity.

Good/Fair	Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Selected stressors have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected stressors have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected stressors have caused severe degradation in most if not all attributes of ecological integrity.

5. What are the levels of human activities that may adversely influence water quality and how are they changing?

Among the human activities in or near sanctuaries that affect water quality are those involving direct discharges and spills (vessels, onshore and offshore industrial facilities, public wastewater facilities), those that contribute contaminants to groundwater, stream, river, and water control discharges (agriculture, runoff from impermeable surfaces through storm drains, conversion of land use), and those releasing airborne chemicals that subsequently deposit via particulates at sea (vessels, land-based traffic, power plants, manufacturing facilities, refineries). In addition, dredging and trawling can cause resuspension of contaminants in sediments. Many of these activities can be controlled through management actions in order to limit their impact on protected resources.

Good	Few or no activities occur that are likely to negatively affect water quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade water quality.
Fair	Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.

Poor	Selected activities have caused severe, persistent, and widespread impacts.

Habitat

6. What is the integrity of major habitat types and how are they changing?

Ocean habitats can be categorized in many different ways, including water column characteristics, benthic assemblages, substrate types, and structural character. There are intertidal and subtidal habitats. The water column itself is one habitat type (Federal Geographic Data Committee, 2012). There are habitats composed of substrates formed by rocks or sand that originate from purely physical processes. And, there are certain animals and plants that create, in life or after their death, substrates that attract or support other organisms (e.g., corals, kelp, beach wrack, drift algae). These are commonly called biogenic habitats.

Regardless of the habitat type, change and loss of habitat is of paramount concern when it comes to protecting marine and terrestrial ecosystems. Of greatest concern to sanctuaries are changes to habitats caused, either directly or indirectly, by human activities. Human activities like coastal development alter the distribution of habitat types along the shoreline. Changes in water conditions in estuaries, bays, and nearshore waters can negatively affect biogenic habitat formed by submerged aquatic vegetation. Intertidal habitats can be affected for long periods by oil spills or by chronic pollutant exposure. Marine debris, such trash and lost fishing gear, can degrade the quality of many different marine habitats including beaches, subtidal benthic habitats, and the water column. Sandy seafloor and hard bottom habitats, even rocky areas several hundred meters deep, can be disturbed or destroyed by certain types of fishing gear, including bottom trawls, shellfish dredges, bottom longlines, and fish traps. Groundings, anchors, and irresponsible diving practices damage submerged reefs. Cables and pipelines disturb corridors across numerous habitat types and can be destructive if they become mobile.

Integrity of biogenic habitats depends on the condition of particular living organisms. Coral, sponges, and kelp are well known examples of biogenic habitat-forming organisms. The diverse assemblages residing within these habitats depend on and interact with each other in tightly linked food webs. They may also depend on each other for the recycling of wastes, hygiene, and the maintenance of water quality. Other communities that are dependent on biogenic habitat include intertidal communities structured by mussels, barnacles, and algae and subtidal hard-bottom communities structured by bivalves, corals, or coralline algae. In numerous open ocean areas drift algal mats provide food and cover for juvenile fish, turtles, and other organisms. The integrity of these communities depends largely on the condition of species that provide structure for them.

This question is intended to address acute or chronic changes in both the extent of habitat available to organisms and the quality of that habitat, whether non-living or biogenic. It asks about the quality of habitats compared to those that would be expected in near-pristine conditions (see definition above).

Good	Habitats are in near-pristine condition.
Good/Fair	Selected habitat loss or alteration is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.
Fair	Selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected habitat loss or alteration has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected habitat loss or alteration has caused severe degradation in most if not all attributes of ecological integrity.

7. What are contaminant concentrations in sanctuary habitats and how are they changing?

Habitat contaminants result from the introduction of unnatural levels of chemicals or other harmful material into the environment. Contaminants may be introduced through discrete entry locations, called point sources (e.g., rivers, pipes, or ships) and those with diffuse origins, called non-point sources (e.g., groundwater and urban runoff). Chemical contaminants themselves can be very specific, as in a spill from a containment facility or vessel grounding, or a complex mix, as with urban runoff. Familiar chemical contaminants include pesticides, hydrocarbons, heavy metals, and nutrients. Contaminants may also arrive in the form of materials that alter turbidity or smother plants or animals, therefore affecting metabolism and production.

This question is focused on risks posed primarily by contaminants within benthic formations, such as soft sediments, hard bottoms, or structure-forming organisms (see notes below). Not only are contaminants within benthic formations consumed or absorbed by benthic fauna, but resuspension due to benthic disturbance makes the contaminants available to water column organisms. In both cases contaminants can be passed upwards through the food chain. While the contaminants of most common concern to sanctuaries are generally pesticides, hydrocarbons, and nutrients, the specific concerns of individual sanctuaries may differ substantially.

Notes: 1) Contaminants in the water column addressed in the water quality section of this report should be cited, but details need not be repeated here; 2) many consider noise a pollutant, but in the interest of focusing here on more traditional forms of habitat degradation caused by contaminants, ONMS recommends addressing the impacts of acoustic pollution within the living resource section, most likely as it impacts key species.

Good	Contaminants have not been documented, or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Selected contaminants are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Selected contaminants have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected contaminants have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected contaminants have caused severe degradation in most if not all attributes of ecological integrity.

8. What are the levels of human activities that may adversely influence habitats and how are they changing?

Human activities that degrade habitat quality do so by affecting structural (physical), biological, oceanographic, acoustic, or chemical characteristics of the habitat. Structural impacts, such as removal or mechanical alteration of habitat, can result from various fishing methods (e.g., trawls, traps, dredges, longlines, and even hook-and-line in some habitats), dredging of channels and harbors, dumping dredge spoil, grounding of vessels, anchoring, laying pipelines and cables, installing offshore structures, discharging drill cuttings, dragging tow cables, and placing artificial reefs. Removal or alteration of critical biological components of habitats can occur due to several of the above activities, most notably trawling, groundings, and cable drags. Marine debris, particularly in large quantities (e.g., lost gill nets and other types of fishing gear), can degrade both biological and structural habitat components. Changes in water circulation often occur when channels are dredged, fill is added, coastlines are armored or other construction takes place. Management actions such as beach wrack removal or sand replenishment on high public-use beaches, may impact the integrity of the natural ecosystem. Alterations in circulations can lead to changes in food delivery, waste removal, water quality (e.g., salinity, clarity and sedimentation), recruitment patterns, and a host of other ecological processes. Chemical alterations most commonly occur following spills and can have both acute and chronic impacts. Many of these activities can be controlled through management actions in order to limit their impact on protected resources.

Good	Few or no activities occur that are likely to negatively affect habitat quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade habitat quality.
Fair	Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

Living Resources

9. What is the status of keystone and foundation species and how is it changing?

Certain species are defined as "keystone" within ecosystems, meaning they are species on which the persistence of a large number of other species in the ecosystem depends (Paine, 1966). They are the pillars of community stability (among other things, they strongly affect both resistance and resilience) and their contribution to ecosystem function is disproportionate to their numerical abundance or biomass. Their impact is therefore important at the community or ecosystem level. Keystone species are often called "ecosystem engineers" and can include habitat creators (e.g., corals, kelp), predators that control food web structure (e.g., Humboldt squid, sea otters), herbivores that regulate benthic recruitment (e.g., certain sea urchins), and those involved in critical symbiotic relationships (e.g., cleaning or co-habitating species).

"Foundation" species are single species that define much of the structure of a community by creating locally stable conditions for other species, and by modulating and stabilizing fundamental ecosystem processes (Dayton, 1972). These are typically dominant biomass producers in an ecosystem and strongly influence the abundance and biomass of many other species. Examples include krill and other zooplankton, kelp, forage fish, such as rockfish anchovy, sardine, and coral. Foundation species exhibit similar control over ecosystems as keystone species, but their high abundance distinguishes them.

Changes in either keystone or foundation species may transform ecosystem structure through disappearances of or dramatic increases in the abundance of dependent species. Not only do the abundances of keystone and foundation species affect ecosystem integrity, but measures of condition can also be important to determining the likelihood that these species will persist and continue to provide vital ecosystem functions. Measures of condition may include growth rates, fecundity, recruitment, age-specific survival, contaminant loads, pathologies (e.g., disease incidence, tumors, deformities), the presence and abundance of critical symbionts, or parasite loads.

Good	The status of keystone and foundation species appears to reflect near-pristine conditions and may promote ecological integrity (full community development and function).
Good/Fair	The status of keystone or foundation species may preclude full community development and function, but has not yet led to measurable degradation.
Fair	The status of keystone or foundation species suggests measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	The status of keystone and foundation species suggests severe degradation in some but not all attributes of ecological integrity.
Poor	The status of keystone and foundation species suggests severe degradation in most if not all attributes of ecological integrity.

10. What is the status of other focal species and how is it changing?

This question targets other species of particular interest from the perspective of sanctuary management. These “focal species” may not be abundant or provide high value to ecosystem function, but their presence and health is important for the provision of other services, whether conservation, economic, or strategic. Examples include species targeted for special protection (e.g., threatened or endangered species), species for which specific regulations exist to minimize perturbations from human disturbance (e.g., touching corals, riding manta rays or whale sharks, disturbing white sharks, disturbing nesting birds), or indicator species (e.g., common murres as indicators of oil pollution). This category could also include so-called “flagship” species, which include charismatic or iconic species associated with specific locations, ecosystems or are in need of specific management actions, are highly popular and attract visitors or business, have marketing appeal, or represent rallying points for conservation action (e.g., humpback and blue whales, Dungeness crab).

Status of these other focal species can be assessed through measures of abundance, relative abundance, or condition, as described for keystone species. In contrast to keystone and foundation species, however, the impact of changes in the abundance or condition of focal species is more likely to be observed at the population or individual level, and less likely to result in ecosystem or community effects.

Good	Selected focal species appear to reflect near-pristine conditions.
Good/Fair	Reduced abundances in selected focal species are suspected but have not yet been measured.
Fair	Selected focal species are at reduced levels, but recovery is possible.
Fair/Poor	Selected focal species are at substantially reduced levels, and prospects for recovery are uncertain.
Poor	Selected focal species are at severely reduced levels, and recovery is unlikely.

11. What is the status of non-indigenous species and how is it changing?

This question allows sanctuaries to report on the threat posed and impacts caused by non-indigenous species. Also called alien, exotic, non-native, or introduced species, these are animals or plants living outside their native distributional range, having arrived there by human activity, either deliberate or accidental. Activities that commonly facilitate invasions include vessel ballast water exchange, restaurant waste disposal, and trade in exotic species for aquaria. In some cases, climate change has resulted in water temperature fluctuations that have allowed range extensions for certain species.

Non-indigenous species that have damaging effects on ecosystems are called “invasive” species. Some can be extremely destructive, and because of this potential, non-indigenous species are usually considered problematic and warrant rapid response after invasion. For those that become established, however, their impacts can sometimes be assessed by quantifying changes in affected native species. In some cases, the presence of a species alone constitutes a significant threat (e.g., certain invasive algae and invertebrates). In other cases, impacts have been measured, and may or may not significantly affect ecosystem integrity.

Evaluating the potential impacts of non-indigenous species may require consideration of how climate change may enhance the recruitment, establishment, and/or severity of impacts of non-indigenous species. Altered temperature or salinity conditions, for example, may facilitate the range expansion, establishment and survival of non-indigenous species while stressing native species, thus reducing ecosystem resistance. This will also make management response decisions difficult, as changing conditions will make new areas even more hospitable for non-indigenous species targeted for removal.

Good	Non-indigenous species are not suspected to be present or do not appear to affect ecological integrity (full community development and function).
Good/Fair	Non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.
Fair	Non-indigenous species have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Non-indigenous species have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Non-indigenous species have caused severe degradation in most if not all attributes of ecological integrity.

12. What is the status of biodiversity and how is it changing?

Broadly defined, biodiversity refers to the variety of life on Earth, and includes the diversity of ecosystems, species and genes, and the ecological processes that support them (United Nations Convention on Biological Diversity). This question is intended as an overall assessment of biodiversity compared to that expected in a near-pristine system (one as near to an unaltered ecosystem as people can reasonably expect, given that there are virtually no ecosystems completely free from human influence). It may include consideration of measures of biodiversity (usually aspects of species richness and evenness) and the status of functional interactions between species (e.g., trophic relationships and symbioses). Intact ecosystems require that all parts not only exist, but that they function together, resulting in natural symbioses, competition, predator-prey relationships, and redundancies (e.g., multiple species capable of performing the same ecological role). Intact structural elements, processes, and natural spatial and temporal variability are essential characteristics of community integrity and provide a natural adaptive capacity through resistance and resilience.

The response to this question will depend largely on changes in biodiversity that have occurred as a result of human activities that cause depletion, extirpation or extinction, illness, contamination, disturbance, and changes in environmental quality. Examples include collection of organisms, excessive visitation (e.g., trampling), industrial activities, coastal development, pollution, activities creating noise in the marine environment, and those that promote the spread of non-indigenous species.

Loss of species or changing relative abundances can be mediated through selective mortality or changing fecundity, either of which can influence ecosystem shifts. Human activities of particular interest in this regard are commercial and recreational harvesting. Both can be highly selective and disruptive activities, with a limited number of targeted species, and often result in the removal of high proportions of the populations, as well as large amounts of untargeted species (bycatch). Extraction removes biomass from the ecosystem, reducing its availability to other consumers. When too much extraction occurs, ecosystem stability can be compromised through long-term disruptions to food web structure, as well as changes in species relationships and related functions and services (e.g. cleaning symbioses). This has been defined as “ecologically unsustainable” extraction (Zabel et al., 2003).

Good	Biodiversity appears to reflect near-pristine conditions and promotes ecological integrity (full community development and function).
Good/Fair	Selected biodiversity loss or change is suspected and may preclude full community development and function, but has not yet caused measurable degradation.
Fair	Selected biodiversity loss or change has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected biodiversity loss or change has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected biodiversity loss or change has caused severe degradation in most if not all attributes of ecological integrity.

13. What are the levels of human activities that may adversely influence living resources and how are they changing?

Human activities that degrade the condition of living resources do so by causing a loss or reduction of one or more species, by disrupting critical life stages, by impairing various physiological processes, or by promoting the introduction of non-indigenous species or pathogens. (Note: Activities that impact habitat and water quality may also affect living resources. These activities are dealt with in the following human activity questions, and some may be repeated here as they also directly affect living resources).

For most sanctuaries, recreational or commercial fishing and collecting have direct effects on animal or plant populations, either through removal or injury of organisms. Related to this, lost fishing gear can cause extended periods of loss for some species through entanglement and “ghost fishing.” In addition, some fishing techniques are size-selective, resulting in impacts to particular life stages. High levels of visitor use in some places also cause localized depletion, particularly in intertidal areas or on shallow coral reefs, where collecting and trampling can be chronic problems.

Mortality and injury to living resources has also been documented from cable drags (e.g., towed barge operations), dumping spoil or drill cuttings, vessel groundings, or repeated anchoring. Contamination caused by acute or chronic spills or increased sedimentation to nearshore ecosystems from road developments in watersheds (including runoff from coastal construction or highly built coastal areas), discharges by vessels, or municipal and industrial facilities can make habitats unsuitable for recruitment or other ecosystem services (e.g., as nurseries or spawning grounds). And while coastal armoring and construction can increase the availability of surfaces suitable for hard bottom species, the activity may disrupt recruitment patterns for other species (e.g., intertidal soft bottom animals), and natural habitat may be lost.

Oil spills (and spill response actions), discharges, and contaminants released from sediments (e.g., by dredging and dumping) can all cause physiological impairment and tissue contamination. Such activities can affect all life stages by direct mortality, reducing fecundity, reducing disease resistance, loss as prey and disruption of predator-prey relationships, and increasing susceptibility to predation. Furthermore, bioaccumulation results in some contaminants moving upward through the food chain, disproportionately affecting certain species.

Activities that promote the introduction of non-indigenous species include bilge discharges and ballast water exchange, commercial shipping and vessel transportation. Intentional or accidental releases of aquarium fish and plants can also lead to introductions of non-indigenous species.

Many of these activities are controlled through management actions in order to limit their impact on protected resources.

Good	Few or no activities occur that are likely to negatively affect living resource quality.

Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade living resource quality.
Fair	Selected activities have caused measurable living resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

Maritime Heritage Resources

14. What is the condition of known maritime heritage resources and how is it changing?

Maritime heritage resources are the wide variety of tangible and intangible elements (archaeological, cultural, historical properties) that reflect our human connections to Great Lakes and ocean areas.

Maritime heritage resources include archaeological and historical properties, and material evidence of past human activities, including vessels, aircraft, structures, habitation sites, and objects created or modified by humans. The condition of these resources in a marine sanctuary significantly affects their value for science and education, as well as the resource's eligibility for listing in the National Register of Historic Places. The "integrity" of archaeological/historical resources, as defined within the National Register criteria, refers to their ability to help scientists answer questions about the past through archaeological research. Historical significance of an archaeological resource depends on its integrity and/or its representativeness of past events that made a significant contribution to the broad patterns of history, its association with important persons, or its embodiment of a distinctive type or architecture.

Maritime heritage resources also include certain culturally significant resources, locations and viewsheds, the condition of which may change over time. Such resources, often more intangible in nature, may still be central to traditional practices and maintenance of cultural identity. The integrity of both cultural resources and cultural locations are included within the National Register criteria.

Section 110 of the National Historic Preservation Act requires federal agencies to inventory, assess, and nominate appropriate maritime heritage resources (“historic properties”) to the National Register. The Maritime Cultural Landscape approach, adopted by the sanctuary system, provides a comprehensive tool for the assessment of archaeological, historical and cultural (maritime heritage) resources.

Assessments of heritage resources include evaluation of the apparent condition, which results from deterioration caused by human and natural forces (unlike questions about water, habitat, and living resources, the non-renewable nature of many heritage resources makes any reduction in integrity and condition, even if caused by natural forces, permanent). While maritime heritage resources have intrinsic value, these values may be diminished by changes to their condition.

Good	Known maritime heritage resources appear to reflect little or no unexpected natural or human disturbance.
Good/Fair	Selected maritime heritage resources exhibit indications of natural or human disturbance, but there appears to have been little or no reduction in aesthetic, cultural, historical, archaeological, scientific, or educational value.
Fair	The diminished condition of selected maritime heritage resources has reduced, to some extent, their aesthetic, cultural, historical, archaeological, scientific, or educational value, and may affect the eligibility of some sites for listing in the National Register of Historic Places.
Fair/Poor	The diminished condition of selected maritime heritage resources has substantially reduced their aesthetic, cultural, historical, archaeological, scientific, or educational value, and is likely to affect their eligibility for listing in the National Register of Historic Places.
Poor	The degraded condition of known maritime heritage resources in general makes them ineffective in terms of aesthetic, cultural, historical, archaeological, scientific, or educational value, and precludes their listing in the National Register of Historic Places.

15. What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing?

Maritime heritage resources are the wide variety of tangible and intangible elements (archaeological, cultural, historical properties) that reflect our human connections to Great Lakes and ocean areas.

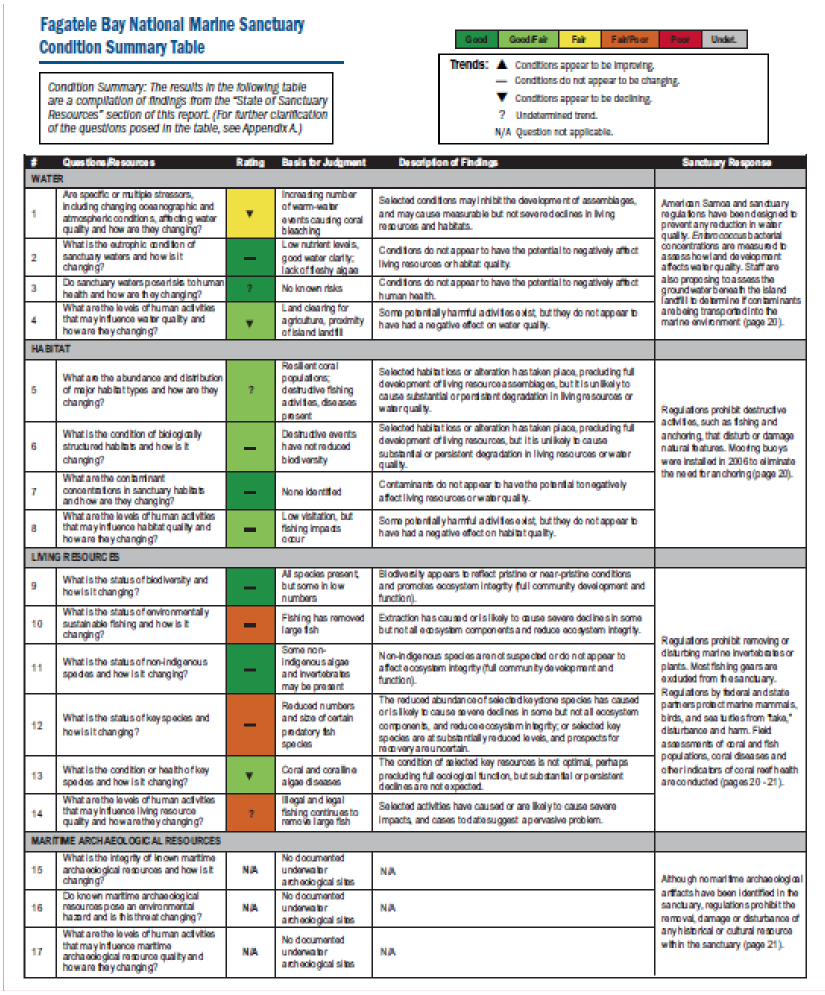
Some human activities threaten the archaeological or historical condition of maritime heritage resources. Archaeological or historical condition is compromised when elements are moved, removed, or otherwise damaged. Threats come from looting, inadvertent damage by recreational divers, improper research methods, vessel anchorings and groundings, and commercial and recreational fishing activities, among others. Other human activities may alter or damage heritage resources by impacting the landscape or viewshed of culturally significant places or locations. Many of these activities can be controlled through management actions in order to limit their impact to maritime heritage resources.

Good	Few or no activities occur at maritime heritage resource sites that are likely to adversely affect their condition.
Good/Fair	Some potentially damaging activities exist, but they have not been shown to degrade maritime heritage resource condition.
Fair	Selected activities have caused measurable impacts to maritime heritage resources, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Appendix C: Fagatele Bay National Marine Sanctuary 2007 Condition Report Ratings

The following table summarizes the condition and trend ratings as presented in the 2007 Fagatele Bay National Marine Sanctuary Condition Report.



Fagatele Bay National Marine Sanctuary Condition Summary Table

Condition Summary: The results in the following table are a compilation of findings from the "State of Sanctuary Resources" section of this report. (For further clarification of the questions posed in the table, see Appendix A.)

Good | Good/Fair | Fair | Fair/Poor | Poor | Undet.

Trends:
▲ Conditions appear to be improving.
— Conditions do not appear to be changing.
▼ Conditions appear to be declining.
? Undetermined trend.
N/A Question not applicable.

#	Questions/Resources	Rating	Basis for Judgment	Description of Findings	Sanctuary Response
WATER					
1	Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality and how are they changing?	Fair ▼	Increasing number of warm-water events causing coral bleaching	Selected conditions may inhibit the development of assemblages, and may cause measurable but not severe declines in living resources and habitats.	American Samoa and sanctuary regulations have been designed to prevent any reduction in water quality. Enterococcus bacterial concentrations are measured to assess how land development affects water quality. Staff are also proposing to assess the groundwater beneath the island landfill to determine if contaminants are being transported into the marine environment (page 20).
2	What is the eutrophic condition of sanctuary waters and how is it changing?	Good —	Low nutrient levels, good water clarity; lack of fleshy algae	Conditions do not appear to have the potential to negatively affect living resources or habitat quality.	
3	Do sanctuary waters pose risks to human health and how are they changing?	Good ?	No known risks	Conditions do not appear to have the potential to negatively affect human health.	
4	What are the levels of human activities that may influence water quality and how are they changing?	Good/Fair ▼	Land clearing for agriculture, proximity of island landfill	Some potentially harmful activities exist, but they do not appear to have had a negative effect on water quality.	
HABITAT					
5	What are the abundance and distribution of major habitat types and how are they changing?	Good/Fair ?	Resilient coral populations; destructive fishing activities, diseases present	Selected habitat loss or alteration has taken place, precluding full development of living resource assemblages, but it is unlikely to cause substantial or persistent degradation in living resources or water quality.	Regulations prohibit destructive activities, such as fishing and anchoring, that disturb or damage natural features. Mooring buoys were installed in 2006 to eliminate the need for anchoring (page 20).
6	What is the condition of biologically structured habitats and how is it changing?	Good/Fair —	Destructive events have not reduced biodiversity	Selected habitat loss or alteration has taken place, precluding full development of living resources, but it is unlikely to cause substantial or persistent degradation in living resources or water quality.	
7	What are the contaminant concentrations in sanctuary habitats and how are they changing?	Good —	None identified	Contaminants do not appear to have the potential to negatively affect living resources or water quality.	
8	What are the levels of human activities that may influence habitat quality and how are they changing?	Good/Fair —	Low visitation, but fishing impacts occur	Some potentially harmful activities exist, but they do not appear to have had a negative effect on habitat quality.	
LIVING RESOURCES					
9	What is the status of biodiversity and how is it changing?	Good —	All species present, but some in low numbers	Biodiversity appears to reflect pristine or near-pristine conditions and promotes ecosystem integrity (full community development and function).	Regulations prohibit removing or disturbing marine invertebrates or plants. Most fishing gears are excluded from the sanctuary. Regulations by federal and state partners protect marine mammals, birds, and sea turtles from "take," disturbance and harm. Field assessments of coral and fish populations, coral diseases and other indicators of coral reef health are conducted (pages 20 - 21).
10	What is the status of environmentally sustainable fishing and how is it changing?	Fair/Poor —	Fishing has removed large fish	Extraction has caused or is likely to cause severe declines in some but not all ecosystem components and reduce ecosystem integrity.	
11	What is the status of non-indigenous species and how is it changing?	Good —	Some non-indigenous algae and invertebrates may be present	Non-indigenous species are not suspected or do not appear to affect ecosystem integrity (full community development and function).	
12	What is the status of key species and how is it changing?	Fair/Poor —	Reduced numbers and size of certain predatory fish species	The reduced abundance of selected keystone species has caused or is likely to cause severe declines in some but not all ecosystem components, and reduce ecosystem integrity; or selected key species are at substantially reduced levels, and prospects for recovery are uncertain.	
13	What is the condition or health of key species and how is it changing?	Good/Fair ▼	Coral and coralline algae diseases	The condition of selected key resources is not optimal, perhaps precluding full ecological function, but substantial or persistent declines are not expected.	
14	What are the levels of human activities that may influence living resource quality and how are they changing?	Fair/Poor ?	Illegal and legal fishing continues to remove large fish	Selected activities have caused or are likely to cause severe impacts, and cases to date suggest a pervasive problem.	
MARITIME ARCHAEOLOGICAL RESOURCES					
15	What is the integrity of known maritime archaeological resources and how is it changing?	N/A	No documented underwater archeological sites	N/A	Although no maritime archaeological artifacts have been identified in the sanctuary, regulations prohibit the removal, damage or disturbance of any historical or cultural resource within the sanctuary (page 21).
16	Do known maritime archaeological resources pose an environmental hazard and is this threat changing?	N/A	No documented underwater archeological sites	N/A	
17	What are the levels of human activities that may influence maritime archaeological resource quality and how are they changing?	N/A	No documented underwater archeological sites	N/A	

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This is the Peer Review copy of the NMSAS Condition Report and was locked for additional editing on 25March2022.

Appendix D: Consultation with Experts, Documenting Confidence, and Document Review

The process for preparing condition reports involves a combination of accepted techniques for collecting and interpreting information gathered from subject matter experts. The approach varies somewhat from sanctuary to sanctuary in order to accommodate different styles for working with partners. NMSAS's approach was closely related to the Delphi Method, a technique designed to organize group communication among a panel of geographically dispersed experts by using questionnaires, ultimately facilitating the formation of a group judgment. This method can be applied when it is necessary for decision makers to combine the testimony of a group of experts, whether in the form of facts, informed opinion, or both, into a single useful statement. The Delphi Method requires experts to respond to questions with a limited number of choices to arrive at the best-supported answers. Feedback to the experts allows them to refine their views, gradually moving the group toward the most agreeable judgment.

In order to assess the standardized state of the resources questions and ecosystem services that are addressed in condition reports (see Appendices A and B), throughout the condition report process, ONMS selected and consulted outside experts familiar with water quality, habitat, living resources, maritime heritage resources, and socioeconomics in the sanctuary. A list of experts who have participated in the NMSAS condition report process is available in the Acknowledgements section of this report.

First, a series of virtual workshops were held from August to November, 2020 to discuss and evaluate the series of questions about each resource and ecosystem service: human activities, water quality, habitat, living resources, maritime heritage resources, and ecosystem services (non-consumptive recreation, consumptive recreation, science, education, heritage, sense of place, commercial harvest, subsistence harvest, and coastal protection). During the virtual workshops, experts were introduced to the questions and ecosystem services, relevant indicators were presented, and experts were provided with time series datasets ONMS had collected from experts prior to the meeting. Attendees were then asked to review the datasets, identify data gaps or misrepresentations, and suggest any additional datasets that may be relevant. Once all datasets were reviewed, experts were asked to provide status and trend recommendations and supporting arguments. In order to ensure consistency with the Delphi Method, a critical role of the facilitator was to minimize dominance of the discussion by a single individual or opinion (which often leads to "follow the leader" tendencies in group meetings) and to encourage the expression of honest differences of opinion. As discussions progressed, the group converged on an opinion for each rating that most accurately described the resource or ecosystem service condition. After an appropriate amount of time, the facilitator asked whether the group could agree on a rating for the question or ecosystem service, as defined by specific language linked to each rating (see Appendices A and B). If an agreement was reached, the result was recorded and the group moved on to consider the trend in the same manner. If agreement was not reached, the facilitator recorded the vote of individuals for each rating category and that information helped to inform the confidence scoring process.

After assigning status ratings and trends, experts were asked to assign a level of confidence for each value by: (1) characterizing the sources of information they used to make judgments; and (2) their agreement with the selected status and trend ratings. The evidence and agreement ratings were then combined to determine the overall confidence ratings, as described in Table AppC.1 below.

Table AppC.1. Criteria used to determine confidence levels for condition report status and trend ratings.

Step 1: Rate Evidence

Consider three categories of evidence typically used to make status or trend ratings: (1.) data,(2.) published information and(3.) personal experience.

Evidence Scores		
Limited	**Medium**	**Robust**
Limited data or published information, and little or no substantive personal experience.	Data available, some peer reviewed published information, or direct personal experience.	Considerable data, extensive record of publication, or extensive personal experience.

Step 2: Rate Agreement

Rate agreement among those participating in determining the status and trend rating, or if possible, within the broader scientific community. Levels of agreement can be characterized as *"low," "medium"* or *"high."*

Step 3: Rate Confidence

Using the matrix below, combine ratings for both evidence and agreement to identify a level of confidence. Levels of confidence can be characterized as *"very low," "low," "medium," "high" or "very high."*

Agreement ↑			
	"Medium" High agreement Limited evidence	*"High"* High agreement Medium evidence	*"Very High"* High agreement Robust evidence
	"Low" Medium Agreement Limited evidence	*"Medium"* Medium agreement Medium evidence	*"High"* Medium agreement Robust evidence
	"Very Low" Low agreement Limited evidence	*"Low"* Low agreement Medium evidence	*"Medium"* Low agreement Robust evidence

Evidence (type, amount, quality, consistency) ⟶

An initial draft of the report, written by ONMS, summarized new information, expert opinions, and levels of confidence expressed by the experts. Comments, data, and citations received from the experts were included, as appropriate, in text supporting the ratings and compiled in three appendices. This initial draft was made available to contributing experts and data providers, which allowed them to review the content and determine if the report accurately reflected their input, identify information gaps, provide comments, or suggest revisions to the ratings and text.

Following the expert review, the document was sent to representatives of partner agencies for a second review. These representatives were asked to review the technical merits of resource ratings and accompanying text, as well as to point out any omissions or factual errors. Upon receiving reviewer comments, ONMS revised the text and ratings as appropriate.

In January 2022, a draft final report was sent to three regional science experts for a required external peer review. External peer review became a requirement when the White House Office of Management and Budget (OMB) issued a Final Information Quality Bulletin for Peer Review (OMB Bulletin) that established peer review standards to enhance the quality and credibility of the federal government's scientific information (OMB, 2004). Along with other information, these standards apply to "influential scientific information," which is information that can reasonably be determined to have a "clear and substantial impact on important public policies or private sector decisions" (OMB, 2004, p. 11). Condition reports are considered influential scientific information and are subject to the review requirements of both the Information Quality Act and the OMB Bulletin guidelines; therefore, every condition report is reviewed by a minimum of three individuals who are considered to be experts in their field, were not involved in the development of the report, and are not ONMS employees. Comments and recommendations of the peer reviewers were considered and incorporated, as appropriate, into the final text of this report. Furthermore, OMB Bulletin guidelines require that reviewer comments, names, and affiliations be posted on the agency website, http://www.cio.noaa.gov/. Reviewer comments, however, are not attributed to specific individuals. Comments by the external peer reviewers are posted at the same time as the formatted final document.

In all steps of the review process, experts were asked to review the technical merits of resource ratings and accompanying text, as well as to point out any omissions or factual errors; however, the interpretation, ratings, and text in the condition report are the responsibility of, and receive final approval by, ONMS. To emphasize this important point, authorship of the report is attributed to ONMS; subject matter experts are not authors, though their efforts and affiliations are acknowledged in the report.

National Marine Sanctuary of American Samoa
Confidence Ratings from August - November, 2020 Virtual Expert Workshops

Table AppC.2. A summary of confidence levels for NMSAS condition report ratings. Note that an additional virtual workshop was held on August 25, 2020 with experts regarding deep sea corals. This information was compiled and considered in a number of questions and ecosystem services where appropriate.

Question	Virtual Workshop Date	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)

Commented [1]: Reminder to check with Val regarding any ratings that changed after the workshop. If so, footnotes need to be added.

Commented [2]: @kathy.broughton@noaa.gov reminder to remove question numbers

1. Water/Eutrophic Condition	August 24, 2020	Status: Good	Limited	High	Medium
		Trend: Not Changing	Limited	High	Medium
2. Water/Human Health	August 24, 2020	Status: Good	Limited	Medium	Low
		Trend: Undetermined	Limited	?	?
3. Water/Climate Change	August 31, 2020	Status: Fair	Medium	High	High
		Trend: Worsening	Medium	High	High
4. Water/Other Stressors	August 24, 2020	Status: Good/Fair	Limited	High	Medium
		Trend: Not Changing	Limited	Medium	Low
5. Water/Human Activities	November 17, 2020	Status: Good/Fair	Limited	Medium	Low
		Trend: Undetermined	Limited	High	Medium

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6. Habitat/Integrity	August 31, 2020	Status: Good/Fair	Medium	High	High
		Trend: Worsening	Medium	High	High
7. Habitat/Contaminants	August 24, 2020	Status: Good/Fair	Limited	High	Medium
		Trend: Undetermin ed	Limited	High	Medium
8. Habitat/Human Activities	November 17, 2020	Status: Fair	Medium	High	High
		Trend: Undetermin ed	Limited	High	Medium
9. Living Resources/Keystone and Foundation Species	September 1, 2020	Status: Fair/Poor[1]	Medium	HIgh	High
		Trend: Not Changing	Medium	Medium	Medium

[1] Experts assigned a rating of Fair/Poor at the workshop, but recommended splitting the status rating. Following the workshop, a new "mixed" status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

10. Living Resources/Other Focal Species	September 1, 2020	Status: Fair/Poor[2]	Medium	High	High
		Trend: Undetermined	Limited	High	Medium
11. Living Resources/Non-Indigenous Species	September 2, 2020	Status: Good/Fair	Medium	High	High
		Trend: Not Changing	Medium	High	High
12. Living Resources/Biodiversity	September 2, 2020	Status: Fair	Medium	High	High
		Trend: Not Changing	Medium	High	High
13. Living Resources/Human Activities	November 17, 2020	Status: Fair	Medium	High	High
		Trend: Undetermined	Medium	High	High
		Status: Fair	Medium	High	High

[2] Experts assigned a rating of Fair/Poor at the workshop, but recommended splitting the status rating. Following the workshop, a new "mixed" status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

14. Maritime Heritage Resources/Condition	September 15, 2020	Trend: Worsening	Medium	High	High
15. Maritime Heritage Resources/Human Activities	September 15, 2020	Status: Good/Fair	Medium	High	High
		Trend: Not Changing	Medium	High	High

Ecosystem Services	**Virtual Workshop Date**	**Rating**	**Evidence** (Limited, Medium, Robust)	**Agreement** (Low, Medium, High)	**Confidence** (Very Low, Low, Medium, High, Very High)
Non-Consumptive Recreation	September 28, 2020	Status: Fair	Medium	High	High
		Trend: Improving	Medium	High	High
Consumptive Recreation	October 2, 2020	Status: Good/Fair	Limited	?	?
		Trend: Improving	Limited	?	?
Science	September 28, 2020	Status: Good/Fair	Medium	High	High

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Commented [5]: Will do a writeup and send it out for additional expert review/input.

		Trend: Improving	Medium	High	High
Education	September 28, 2020	Status: Good	Robust	High	Very High
		Trend: Improving	Robust	High	Very High
Heritage	September 18, 2020	Not rated			
Sense of Place	September 18, 2020	Not rated			
Commercial Harvest	October 2, 2020	Status: Undetermined	Limited	High	Medium
		Trend: Undetermined	Limited	High	Medium
Subsistence Harvest	October 2, 2020	Status: Good/Fair	Limited	High	Medium
		Trend: Worsening	Medium	Medium	Medium

Coastal Protection	September 14, 2020	Status: Fair[3]	Limited	High	Medium
		Trend: Worsening	Medium	High	High

[3] Experts assigned a rating of Fair at the workshop, but noted that status varied across individual sites. Following the workshop, a new "mixed" status was introduced to the condition report rating scheme. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the expert discussions and available data.

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Appendix ___: Glossary of Terms

Commented [1]: Mageo: It's ALL good and great!

Aiga – extended family

Commented [2]: @kathy.broughton@noaa.gov This might work better as a table with one column for "Samoan Language Term" and one for "English Translation" or something to that effect.

Alamea – crown-of-thorns starfish
Alia – fishing vessels based on traditional design 'Alia and Alia are both correct with same meaning but the most common spelling is Alia - ~~'Alia~~
Ali'i – high chief
Asiasi – yellowfin tuna
Asoama, Utu – green jobfish (*Aprion Virescens*)
Atu – skipjack tuna
Aualuma – women's group
Aumaga – untitled men
Ava – kava (it's important we use the most common spelling Ava) ~~-'Ava~~
Enu and ola – traditional basket for juvenile fishing (Enu) ~~-'Enu~~
Fa'afetai – thanks
Fa'alavelave – family function/ceremony
Fa'a Samoa – traditional Samoan way of life
Fa'asinomaga – identity as Samoan
~~Fale Bommie –~~ "Big Momma" coral The village council has not given a Samona name therefore, all NMSAS documents and publications should use "Big Momma" until such time the Village council gives an official Samoan name.
Foāga – grinding stone holes or bait cups
Saofa'iga a le Nu'u – village council
Fautasi – Samoan long boat
Feasoasoani – resource help
Saofa'iga a le Nu'u – legislature or village council
Matai – chief
Motu o Manu - Island of Birds (Rose Atoll)
Muliāva - end of the current (waters surrounding Rose Atoll)
Nafanua – Samoan goddess of war
Nu'u o Manu - Village of Birds (Rose Atoll)
Pala Atu – flame snapper (*Etelis Coruscans*)
Pala Loa – flame snapper (*Etelis Coruscans*)
Pala Mamalu – flame snapper (*Etelis Coruscans*)
Papa Tuauli – juvenile coronation trout (*Variola Louti*)
Papa – adult coronation trout (*Variola Louti*)
Pese ma siva – Samoan song and dance
Pua'a – pig
Fasi pua'a – piece of pork
Sa/Vavao – village curfew
~~Fono a le Nu'u - village council meeting~~
Savane – bluestripe seaperch (*Lutjanus Kasmira*)
Siapo – Samoan cloth made from bark of the paper mulberry tree
Siva ma pese – song and dance
Tafauli – black trevally (*Caranx Lugubris*)

Taupou – village princesses
Tautua – service
To’onai – Sunday family feast
Tulafale – orator
Umu – above ground hot stones oven
Va’aalo – three-man canoes
Velo – subadult coronation trout (*Variola Louti*)

Place names:
Samoa -(replace any Sāmoa)
Ta’u - (replace any Taʻū)
Fogama’a - (replace any Fogāma'a)
Muliāva - end of the current (waters surrounding Rose Atoll)
Nu’u o Manu - Village of Birds (Rose Atoll)
Motu o Manu - Island of Birds (Rose Atoll)

THIS CHAPTER HAS BEEN FORMATTED. PLEASE MAKE ANY EDITS IN SUGGESTION MODE ONLY AND TAG DAYNA

Definitions and Rating Scheme for Status and Trends of Ecosystem Services

The following describes the ecosystem services and possible responses that ONMS considers in condition reports for all national marine sanctuaries. ONMS and subject matter experts use this guidance to make judgments about the status and trends of sanctuary ecosystem services.

ONMS defines ecosystem services in a slightly more restrictive way than some other experts. Specifically, ecosystem services are defined herein as the benefits people obtain from nature through use, consumption, enjoyment, and/or simply knowing these resources exist (non-use). The descriptions below reflect this definition, and therefore, only these ecosystem services are evaluated in sanctuary conditions reports. Intermediate services are not evaluated in the Status and Trends of Ecosystem Services chapter of these reports. Intermediate services, while critical to ecosystem function, are not directly used, consumed, or enjoyed by humans and thus do not meet the ONMS condition report definition of ecosystem services. In other words, these intermediate services support ecosystems but are not final ecosystem services in and of themselves. As an example, biodiversity is often considered as an ecosystem service by experts in the field, but ONMS recognizes biodiversity as an intermediate service of the ecosystem on which many final ecosystem services depend (e.g., consumptive and non-consumptive recreation, commercial and subsistence harvest depend on the status and trend of biodiversity). For this reason, biodiversity is considered an intermediate ecosystem service and it is evaluated in the Status and Trends of Sanctuary Resources chapter of the report. Decomposition and carbon storage are examples of other intermediate services.

In addition, ONMS does not consider climate regulation or stabilization as ecosystem services in condition reports. The impacts of climate change on water quality, habitat, and living resources are considered separately in the Status and Trends of Sanctuary Resources chapter of the report. While sanctuaries are not large enough to influence climate stability, they may locally buffer climate-related factors, such as temperature change and ocean acidity; thus, the extent to which they may locally buffer climate-related factors is reflected in resource conditions in the Status and Trends of Sanctuary Resources chapter.

Finally, some ecosystem services may not be assessed by individual sanctuaries because the activities required to achieve them are prohibited (e.g., collection of ornamentals), the sanctuary is not mandated to manage a specific resource that provides a particular service (e.g., management of fisheries), or there is simply no related activity underway or expected (e.g., renewable energy production).

Below are brief descriptions of the ecosystem services that could be considered within each sanctuary condition report (more complete descriptions are provided below the list).

***Cultural* (non-material benefits)**

1. Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources
2. Non-consumptive recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources
3. Science — The capacity to acquire and contribute information and knowledge
4. Education — The capacity to acquire and provide intellectual enrichment
5. Heritage — Recognition of historical and heritage legacy and cultural practices
6. Sense of Place — Aesthetic attraction, spiritual significance, and location identity

***Provisioning* (material benefits)**

7. Commercial Harvest — The capacity to support commercial market demands for seafood products
8. Subsistence Harvest — The capacity to support non-commercial harvesting of food and utilitarian products
9. Drinking water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash
10. Ornamentals — Resources collected for decorative, aesthetic, ceremonial purposes
11. Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use
12. Renewable energy — Use of ecosystem-derived materials or processes for the production of energy

***Regulating* (buffers to change)**

13. Coastal protection — Flow regulation that protects habitats, property, coastlines, and other features

Sanctuaries vary with regard to the ecosystem services they support. To rate the status and trend for each relevant ecosystem service, the following can be considered:

- the best available indicators for each ecosystem service (e.g., economic, human dimension non-economic, resource, traditional ecological knowledge)
- the status and direction of change of each ecosystem service

- the prioritization of each indicator
- whether economic indicators send a false signal about the status and trend of an ecosystem service (namely, conflicting ecological and economic indicators, suggesting that people are sacrificing natural capital for short-term economic gain)

The steps used to rate ecosystem services were adapted from a multi-year study, *Marine and Estuarine Goal Setting for South Florida*, of three south Florida marine ecosystems, including Florida Keys National Marine Sanctuary (Kelble et al., 2013). The study used integrated conceptual ecosystem models for each ecosystem under the DPSER Model (Nuttle & Fletcher, 2013) and evaluation of three types of indicators for each ecosystem service: 1) economic; 2) human dimension non-economic (Lovelace et al., 2013); and 3) resource.

The evaluation of ecosystem services should consider whether economic and non-economic indicators yield the same conclusions as resource indicators; this will enable consideration of the sometimes conflicting relationship between economic gain and the preservation of natural capital. For example, economic indicators (e.g., dive operator income) may suggest improving recreational services, while resource indicators (e.g., anchor damage to benthic habitat) suggest that natural resources are being sacrificed for short-term gain, thus making the activity unsustainable.

ONMS recognizes that the ecosystem services model is intentionally anthropocentric, designed to elicit a selected type of service-oriented rating useful in resource management decision-making. Connections between ecosystems, culture and heritage, and resource management are often complex, beyond the scope of the condition report. Collectively, stakeholders may have multiple worldviews and ecosystem values equally important to consider, and some ecosystem elements may not be appropriate to rate in the ecosystem services approach (e.g., aspects of heritage and sense of place). Sanctuaries may want to consider the option of including a “context-specific perspective” or narrative (as proposed in Diaz et al., 2018), without assigning a status or trend rating, for the purpose of providing appropriate information for management purposes. Cultural (non-material) ecosystem services are particularly intricate and have been undervalued in the past. Evaluators should remember that deliberative processes engaging local stakeholders and subject matter experts are critical, and adherence to the process demands both flexibility and creativity.

During workshops in which status and trends are determined, subject matter experts discuss each ecosystem service and relevant indicators, available data, literature (e.g., published scientific studies, reports), and experience associated with the topic. They then discuss the statements provided (see table below) as options for judgments about status. Once a particular statement is agreed upon, a color code and status rating (e.g., good, fair, poor) is assigned. Experts can also decide that the most appropriate rating is “N/A” (i.e., the ecosystem service does not apply), “undetermined” (i.e., ecosystem service status is undetermined due to a paucity of relevant information), or “mixed” (i.e., variation across indicators prevents the selection of a single status rating). A subsequent discussion is then held about the trend. Conditions are determined to be improving, remaining the same, or worsening in comparison to the results found in the first round of condition reports. Symbols used to indicate trends are the same for all ecosystem services: "▲"—conditions appear to be improving; "▬"—conditions do not appear to be changing; "▼"—conditions appear to be worsening; "▲▼" —conditions appear to be mixed; and "**?**"—trend is undetermined; "N/A"—the ecosystem service does not apply.

Rating Scheme for Ecosystem Services

Rating	Status Description
Good	The capacity to provide the ecosystem service has remained unaffected or has been restored.
Good/Fair	The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Fair	The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Fair/Poor	The capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it.
Poor	The capacity to provide the ecosystem service is compromised, and it is doubtful that new or enhanced management would restore it.

Cultural (non-material benefits)

Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources

Perhaps the most popular activity that involves consumptive recreation is sport fishing from private boats and for-hire operations. Targeted species and bycatch are removed from the environment, and those that must be released due to regulations and prohibitions (e.g., undersized or out of season) sometimes die due to stress or predation. Nonetheless, fishing for consumptive purposes is a highly valued cultural tradition for many people, as well as a popular recreational activity. Other consumptive recreational activities include beachcombing, clam digs and shell collecting.

Indicators of status and trends for consumptive recreation often include levels of use (direct counts or estimates made from commercial vessel records and catch levels, and fishing license registrations) and production of economic value through job creation, income, spending, and tax revenue. Public polls can also be used to assess non-market indicators, such as importance and satisfaction, social values, willingness to pay, and facility and service availability.

Non-consumptive recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Recreational activities, including ecotourism and outdoor sports, are often considered a non-consumptive ecosystem service that provides desirable experiential opportunities. Non-consumptive recreational activities include those on shore or from private boats and for-hire operations, such as relaxing, exploring, diving and snorkeling, kayaking, birdwatching, surfing, sailing, and wildlife viewing. Activities that may have unintentional impacts on habitats or wildlife including catch-and-release fishing and tidepooling which could result in mortality or trampling, respectively, are also considered in this category.

It should be noted that private boating often includes both non-consumptive and consumptive recreational activities (e.g., snorkeling and fishing during a single trip). Thus, field and survey data can be ambiguous, reflecting the heterogeneous preferences of boaters. This also has implications for interpretations of data regarding attitudes and perceptions of management strategies and regulations to protect and restore natural and cultural resources.

Indicators used to assess status and trends in market values for recreation can include direct measures of use (e.g., person-days of use by type of activity) that result in spending, income, jobs, gross regional product, and tax revenues. They can also be non-market economic values (the difference between what people pay to use a good/service and what they would be willing to pay). The data can be used to estimate the value a consumer receives when using a good or service over and above what they pay to obtain the good or service. Indirect measures are also used. For example, populations and per capita incomes at numerous scales influence demand for recreational products and services. Fuel prices can even serve as indirect measures of recreational demand because the levels of use by some recreational users tracks fuel prices.

Science — The capacity to acquire and contribute information and knowledge

Sanctuaries serve as natural laboratories that can advance science and education. NOAA provides vessel support, facilities, and information that is valuable to the research community, including academic, corporate, non-governmental and government agency scientists, citizen scientists, and educators that instruct others using research.

Sanctuaries serve as long-term monitoring sites, provide minimally disturbed focal areas for many studies, and provide opportunities to restore or maintain natural systems.

Status and trends for science can be assessed by counting and characterizing the number of research permits and tracking the accomplishments and growth of partnerships, activity levels of citizen monitoring, and participation of the research community in sanctuary management. The number and types of research cruises and other expeditions conducted can also provide useful indicators. Indirect indicators, such as per capita income and gross regional or national product, may be helpful as higher incomes and better economic conditions often result in higher investments in research and monitoring.

Education — The capacity to acquire and provide intellectual enrichment

As with science, national marine sanctuaries' protected natural systems and cultural resources attract educators at many levels for both formal and informal education. Students and teachers often either visit sanctuaries or use curricula and information provided by sanctuary educators.

The status and trends for education can be tracked by evaluating the number of educators and students visiting the sanctuary and visitor centers, the number of teacher trainings, use of sanctuary-related curricula in the classroom, and levels of activity in volunteer docent programs. The number of outreach offerings provided during sanctuary research and education expeditions can also be a good indicator. Education can also follow trends in populations and per capita income locally, regionally, and nationally. Populations create demand for services, and higher incomes lead to investment, making these useful indirect indicators.

Heritage — Recognition of historical and heritage legacy and cultural practices

The iconic nature of many national marine sanctuaries or particular places within them generally means that they have long been recognized, used, and valued. Communities developed around them, traveled through them, and depended on their resources. This shared history and heritage creates the unique cultural character of many present-day coastal communities, and can also be an important part of the current economy. Recognition of the past, including exhibits, artifacts, records, stories, songs, and chants provide not only a link to the history of these areas, but a way to better understand the maritime and cultural heritage within the environment itself. Tangible and intangible aspects of heritage blend together to contribute to the history and legacy of the place.

For some marine sanctuaries, vibrant and active indigenous cultures remain a defining and dominant element of the cultural heritage of these places. Not only are they a direct and priceless connection to the past, but they frame and influence modern-day economies, cultural landscapes, and conservation ethics and practices. Their very existence is intrinsic to the heritage of these places.

Given this broad range of cultural expression, benefits of heritage may take many forms. Additionally, cultural heritage resources will often be part of, or overlap with, other ecosystem service categories, and may be understood from multiple perspectives (such as, a living resource keystone species that may also be identified as a "cultural" keystone species, one of exceptional significance to a culture or a people). The Heritage ecosystem service category defines benefits from resources primarily attached to historical and heritage legacy and culture. Heritage resources, including certain living resources and traditional medicines, may also provide other benefits that can be addressed in other ecosystem service categories.

Economic indicators that reflect status and trends for heritage value as an ecosystem service may include spending, income, jobs, and other revenues generated from visitation, whether it is to dive on wreck sites or patronize museums and visitor centers where artifacts are displayed and interpreted. Non-market indicators, such as willingness to pay for protection of resources, activity levels for training and docent interpretation, and changes in threat levels (looting and damage caused by fishing), may also be considered. Sites may determine that some aspects of Heritage may simply not be ratable using the framework of condition reports.

Sense of place — Aesthetic attraction, spiritual significance, and location identity

A wide range of intangible meanings can be attributed to a specific place by people, both individually and collectively. Aesthetic attraction, spiritual significance, and location identity all influence our recognition and appreciation for a place, as well as efforts to protect its iconic elements.

Marine environments serve as places of aesthetic attraction for many people, and inspire works of art, music, architecture, and tradition. Many people also value particular places as sources of therapeutic rejuvenation and to offer a change of perspective. Aesthetic aspects are often reflected as motifs in books, film, artworks, and folklore and as part of national symbols, architecture, and advertising efforts. These elements of "place attachment" may develop and change over the short and long term.

Many people, families, and communities consider places as defining parts of their "self identity," especially if they have lived there during or since childhood. The relationship between self/family/community and place can run very deep, particularly where lineage is place-based, with genealogy going back many generations. "Place identity" develops over the long term, and is often expressed in reciprocal human-ecosystem relationships, and locations associated with spiritual significance. The recognition of very long term place-based stewardship, sometimes in excess of 10,000 years, provides a unique aspect of place identity.

Many people even incorporate water or water-related activities as habitual or significant parts of their lives and cultures. Different factors are considered to measure/assess sense of place, including level of uniqueness, recognition, reputation, reliance, and appreciation for a place. Accounting for sense of place can provide strong incentives for conservation, preservation, and restoration efforts.

Despite its value as a cultural ecosystem service, it is difficult to quantify sense of place with direct measures. Examples of indicators may include the quality and availability of opportunities to support rituals, ceremonies and narratives and the level of satisfaction knowing that a place exists. Polls or surveys are often used to evaluate public opinions regarding economic and non-economic values of a place. Non-economic values may include existence or bequest value, which use surveys to estimate the value people would be willing to pay for resources to stay in a certain condition even though they may never actually use them. To comprehensively evaluate sense of place, sites may find it useful to consider subcategories such as place attachment and place identity. Furthermore, sites may determine that some aspects of Sense of Place may simply not be ratable using the framework of condition reports.

Provisioning (material benefits)

Commercial Harvest — The capacity to support commercial market demands for seafood products

Humans consume a large variety and abundance of products originating from the oceans and Great Lakes for nutrition or for use in other sectors. This includes fish, shellfish, other invertebrates, roe, and algae. Seafood is one of the largest traded food commodities in the world. Commercial fishing provides food for domestic and export markets, sold as wholesale and retail for household, restaurant and institutional meals. Seafood based industries include those that fish and harvest directly from wild capture and cultivated resources, as well as other businesses with functions throughout the supply chain including production of commercial gear, processors, storage facilities, buyers, transport and market outlets.

Within this category we also include what many call artisanal fishing, which can include commercial sale, but is also conducted by individuals or small groups who live near their harvest sites and use small scale, low technology, low cost fishing practices. Their catch is usually not processed (although it may be smoked or canned), and is mainly for local consumption or sale. Artisanal fishing uses traditional fishing techniques such as rod and tackle, fishing arrows and harpoons, cast nets, and sometimes small traditional fishing boats.

Fisheries located in national marine sanctuaries are usually encompassed by larger regional fisheries that are regulated by fisheries management plans. Fisheries management plans may include sanctuary-specific restrictions to protect sanctuary habitats, living resources, and archaeological resources, and to fulfill treaty obligations. Data that can be used to assess status and trends for this ecosystem service include: catch levels by species and species groups; and economic contributions in the form of sector-related jobs, income, sales, and tax revenue. Indirect measures include data on licensing, fleet size, fishing vessel types and sizes, days at sea, and commodity prices.

Subsistence Harvest — The capacity to support non-commercial harvesting of food and utilitarian products

Subsistence harvesting is the practice of collecting marine resources (e.g., fish, shellfish, marine mammals, seabirds, roe, and algae) either for food or for creating products that are utilitarian in nature (e.g., traditional medicine, shelter, clothing, fuel and tools) that are not for sale or income generation. Subsistence is conducted principally for personal and family use, and sometimes for community use, and may be distributed through ceremony, sharing, gifting, and bartering. Some people depend on subsistence fishing for food security and may have few other sources of income to provision their food and nutrition needs. Harvesting for subsistence is also a cultural or traditional practice for some people. It typically operates on a smaller and more local scale than commercial fishing. Natural resources that support subsistence harvest may also be used as ceremonial regalia or for cultural traditions, and therefore support other ecosystem services, including Heritage, Sense of Place, and Ornamentals. Data from surveys, tribal and indigenous knowledge and the status of fishery stocks can be used to assess the status and trends of this service.

Drinking water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash

Clean water is considered a final ecosystem service when the natural environment is improving water quality for human consumption or other direct use (e.g., irrigation). Although sanctuary ecosystems often function to improve water quality, most do not result in the final ecosystem service of clean water for human use. For most natural resources, improving water quality in a sanctuary is a supporting or intermediate ecosystem service that may, for example, result in better water quality for fish species that are then enjoyed by commercial or recreational anglers, safer water in which to swim, or improved water clarity for diving. These are aspects of other final ecosystem services and the water quality itself is an indicator that is inherently important to them; however, ONMS does not include this aspect of clean water in condition reports because it would result in a double counting of its ecosystem service value. Instead, ONMS evaluates clean water as a final ecosystem service, where the natural environment is improving water for human consumption, such as drinking water, or for irrigation (e.g., through filtration or suitability for desalination). In this way, the benefits of management policies and actions that improve water quality are captured separately, but in relation to the relevant final ecosystem services they support.

Ornamentals — Resources collected for decorative, aesthetic, or ceremonial purposes

In sanctuaries where the collection of ornamental products is not prohibited or is allowed under permit, they are taken for their aesthetic or material value for artwork, souvenirs, fashion, handicrafts, jewelry, or display. This includes live animals for aquaria and trade, pearls, shells, corals, sea stars, furs, feathers, ivory, and more. Some, particularly animals for the aquarium trade, are sold commercially and can be valued like other commodities; others cannot. Some products may be decorative and relatively non-functional, others culturally significant and specifically functional, such as ceremonial regalia. Status and trends for the use of ornamentals can also be evaluated using indicators such as the number of permitted or other collectors, frequency and intensity of collection operations, and sales.

Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use

Biochemical and genetic resources, medicines, chemical models, and test organisms are all potential products that can be derived or sourced from national marine sanctuaries. Biochemical resources include compounds extracted from marine animals and plants and used to develop or manufacture foods, pharmaceuticals, cosmetics, and other products (e.g., omega-3 fatty acids from fish oil, or microbes for spill or waste bioremediation). Genetic resources are the genetic content of marine organisms used for animal and plant breeding and for biotechnology. Natural resources can also be used as a model for new products (e.g., the development of fiber optic technology, based on the properties of sponge spicules). Items harvested for food consumption are evaluated in Commercial and Subsistence Harvest.

Collections of products for biotechnology applications may be allowed under permit, and sanctuary permit databases can also be used to gauge demand and collection activity within a given national marine sanctuary. The value of commercially sold products associated with biotechnology may also be available.

Renewable energy — Use of ecosystem-derived materials or processes for the production of energy

In the offshore environment, energy production sources are considered to be either non-renewable (oil and gas) or renewable (wind, solar, tidal, wave, or thermal). While oil and gas technically are ecosystem-sourced and may be renewable over a time frame measured in millions of years, as an ecosystem service, they are not subject to management decisions in human time frames; therefore, they are not considered an ecosystem service in this section. The activities and management actions related to hydrocarbon production are, however, considered elsewhere in condition reports, primarily with regard to resource threats, impacts, and protection measures.

In contrast, “renewable” forms of energy that depend on ecosystem materials and processes operating over shorter time periods are evaluated. Indicators of status and trends for these energy sources include the types and number of permitted or licensed experimental or permanent operations, energy production, revenues generated, and jobs created. Indirect indicators that inform trends and provide some predictive value include social and market trends, energy costs, and expected demand based on service market populations trends.

Regulating (buffers to change)

Coastal protection — Natural features that control water movement and/or wind energy, thus protecting habitat, property, heritage resources and coastlines

Coastal and estuarine ecosystems can buffer the potentially destructive energy of environmental disturbances, such as floods, tidal surges and storm waves, and wind. Wetlands, kelp forests, mangroves, seagrass beds, and reefs of various types all absorb some of the energy of local disturbances, protecting themselves, submerged habitats closer to shore, intertidal ecosystems, and emergent land masses. They also can trap sediments and promote future protection through shoaling. They can also become sources of sediments for coastal dunes and beaches that control flooding and protect coastal properties from wave energy and the impacts of sea-level rise.

The value of coastal protection can be estimated by evaluating the basis of the value of vulnerable coastal properties and infrastructure and modeled estimates of losses expected under different qualities of coastal ecosystems (replacement cost). Levels of historical change under different energy scenarios can be used to support these estimates. Public polls can also reveal information on willingness to pay that is used to value this service.