Rapid Vulnerability Assessment and Adaptation Strategies for the National Marine Sanctuary and Territory of American Samoa



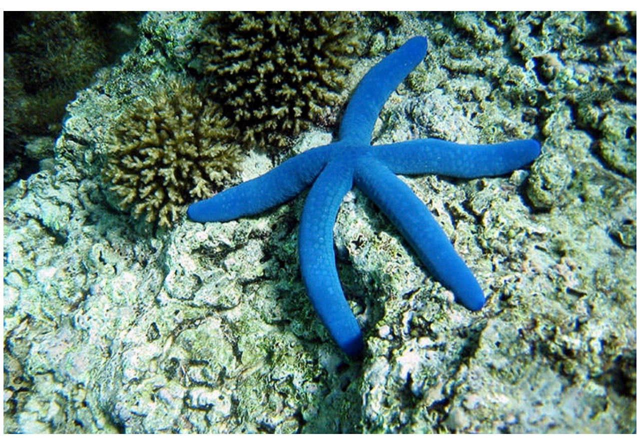


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Table of Contents

List of Figures

List of Tables

Executive Summary

The ocean systems and the interdependent lives and economies that are protected by the National Marine Sanctuary of American Samoa are affected by diverse and compounding anthropogenic factors. These range from marine debris and pollution, to human development and fishing practices, to climate change and ocean acidification. Sanctuary planning and management help to ensure that the natural systems on which marine, wildlife and human communities depend are healthy and sustainable for generations to come despite these far-reaching stressors. For emerging threats such as climate change and ocean acidification, marine and coastal resource managers often recognize the threats climate change poses to the resilience, health, and ecosystem services of the special coastal and ocean places they protect, yet are still struggling with how to develop appropriate management options.

This report summarizes the results of a rapid vulnerability assessment (July 2016) and adaptation strategy planning (September 2016) workshops for 10 focal resources in the Territory and National Marine Sanctuary of American Samoa by engaging with stakeholders, including village leaders, community members, resource managers, local government representatives, and business owners that rely on the resources with the goal of increasing climate resilience in the region.

Vulnerability Assessment Results

Rankings for each vulnerability component (i.e., sensitivity, exposure, adaptive capacity) were combined into an overall vulnerability score. The table below depicts the results of the vulnerability of the ten focal resources over the next 20 years[1] as well as confidence scores**.** Overall the vulnerability assessment of the 10 focal resources was moderate to low-moderate with mostly high and moderate confidence scores. This is likely due to the 20-year timeframe that participants chose to use rather than a more standard long-term timeframe of 50-100 years. If the standard climate change timeframe would have been used for this vulnerability assessment, one would have probably expected higher vulnerability and lower confidence scores.

FOCAL RESOURCE	VULNERABILITY	CONFIDENCE SCORE
Coral Reef Habitat	Moderate	High
Mangrove Habitat	Low-Moderate	High
Water Quality	Moderate	High
Giant Clam	Moderate	High
Herbivore Reef Fish	Low-Moderate	High
Charismatic Reef Fish	Low-Moderate	High
Reef Piscivores	Low-Moderate	High
Pelagic Fish	Moderate	High
Sharks and Rays	Low-Moderate	Moderate
Sea Turtles	Moderate	Moderate

[1] Participants identified a 20-year timeframe under which to assess the resources' vulnerability. A longer timeframe would have yielded much lower confidence scores for the rankings, and participants wanted to provide

Adaptation Strategy Development Results

For each resource, participants generated a list of adaptation strategies and actions. The table below presents the top ranked current and future climate-informed recommended actions.

RESOURCE	CLIMATE-INFORMED ACTIONS
Coral Reef Habitat	• Support sewer upgrades and expansions, new wastewater treatment plants, proper septic tank installation, and cesspool removal • Plant more trees/vegetation in coastal areas and in villages to reduce runoff • Select corals that are resilient to bleaching for restoration projects
Mangroves	• Increase use of stream catchments to catch debris
Water Quality	• Improve sewage effluent quality and sewage treatment (secondary treatment and UV lights) • Increase public education and outreach • Pass and enforce anti-littering bill (Keep American Samoa Beautiful Act) • Find alternatives to untreatable/disposable pollutants
Giant Clam	• Create hatchery for clam stocking and genetic study of giant clams between different islands to diversify seed source • Increase public education and outreach • Enforce and develop new harvest regulations to avoid overharvesting
Reef Fish	• Utilize fishing regulations and ensure enforcement
Sharks & Rays	• Increase research to identify breeding/rearing critical habitat
Sea Turtles	• Engage village councils to enforce laws • Monitor turtles/eggs; satellite tagging to track migration routes • Create citizen science program to track turtle/nest presence • Increase education (importance of beaches and light use) • Use turtle-friendly street lights

Chapter 1 An Overview of Climate Change in American Samoa

Overview and Background

Office of National Marine Sanctuaries Perspective

The Office of National Marine Sanctuaries serves as the trustee for a network of underwater parks encompassing more than 600,000 square miles (1,553,993 sq. km.) of marine and Great Lakes waters from Washington State to the Florida Keys, and from Lake Huron to American Samoa. The network includes a system of 13 national marine sanctuaries and Papahānaumokuākea Marine National Monument. National marine sanctuaries operate at the heart of coastal communities where local marine resources provide jobs, recreational opportunities and a sense of identity. Each sanctuary works closely with its local, state and federal level stakeholders in managing the site to create a shared vision that integrates human uses with the primary mandate of resource protection.

National marine sanctuaries play a significant role in understanding the influence of climate change. While climate change threatens marine resources and the communities that rely on them, national marine sanctuaries are working with partners to educate the public and to systematically integrate climate change in management and day-to-day operations. In addition, sanctuaries provide coastal communities with natural defenses against climate change impacts. They protect and restore critical blue carbon habitats, such as salt marshes, mangroves and seagrass beds, that help mitigate climate change by capturing and storing carbon from the atmosphere. By being on the frontline, sanctuaries are ideal places to focus climate research and monitoring and to find practical ways to build resilience to climate change.

American Samoa

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 lies about 1,600 miles (2,600 km) northeast of New Zealand and 2,200 miles (3,500 km) southwest of the U.S. state of Hawai´i.

American Samoa includes the inhabited islands of Tutuila, Manu´a islands (Ta´u, Olosega, Ofu), and Aunu´u, along with an uninhabited coral atoll named Rose Island. Swains Island, a formerly inhabited coral atoll, about 280 miles (450 km) northwest of Tutuila and physiographically separate from the archipelago, was made a part of American Samoa in 1925. The capital of American Samoa is Pago Pago, on Tutuila.

The 2010 census showed a total population of 55,519 people. The total land area is 199 square kilometers (76.8 sq. mi), slightly more than Washington, D.C. American Samoa is the southernmost territory of the U.S. and one of two U.S. territories (with the uninhabited Jarvis Island) south of the Equator (US DOC NOAA ONMS 2012).

Fa´a-Samoa - The Samoan Way

While American Samoa is the place where the sanctuary is physically located, fa´a-Samoa is the cultural context for all sanctuary activities. Fa´a-Samoa is the traditional communal Samoan lifestyle, or way of life. It is the foundation of Polynesia's oldest culture - dating back some 3,000 years. It places great importance on the dignity and achievements of the group rather than on individual achievements. The traditional communal lifestyle revolves around the aiga, or extended family. Aiga are headed by leading matai (chief) or Sa´o, who manage the communal economy, protect and distribute family lands, are responsible for the welfare of all in their aiga, and represent the family in councils. Even after decades of foreign influence, most Samoans are fluent in their native language, but also speak English.

The sanctuary team places a high value on partnerships with communities and maintains great respect for fa´a-Samoa. In American Samoa, the sanctuary-matai relationship is critical to the success of this partnership. The American Samoa Office of Samoan Affairs helps facilitate the sanctuary's community consultations in a manner that is culturally appropriate and respectful of fa´a-Samoa. This work includes consultations with saofa´iga ale nuu (village council meeting) and individual matai (US DOC NOAA ONMS 2012).

Preparing for Climate Change

Islands in the Pacific region are among the most vulnerable areas in the world to impacts from climate change (Mimura et al. 2007). Given American Samoa's isolation, limited land area, and vulnerability to extreme weather events and coastal hazards, there is a critical need to prepare communities for environmental changes such as impacts from climate change. Due to the traditional land tenure system in American Samoa, where land is tied to chiefly, or matai, titles and not controlled by the government, it is necessary to engage the chiefs at the village level in order to create an effective resilience plan. The need to "integrate plans at the village level" was noted in the 2012 American Samoa Capacity Assessment (Page et al. 2012). In addition, the NOAA Coral Reef Conservation Program noted that there is a need to "Identify, understand, and communicate risks and vulnerability of US coral reef ecosystems, ecosystem services, and dependent human communities to climate change and ocean acidification" in its 2009 report entitled "NOAA Coral Reef Conservation Program Goals and Objectives 2010-2015." Despite these needs, little local planning and resource vulnerability assessments have been conducted to date.

Local climate change actions taken thus far include:

1) The Coral Reef Advisory Group (CRAG) was created in American Samoa in 1994 by three founding agencies (American Samoa Environmental Protection Agency, Department of Commerce and Department of Marine and Wildlife Resources) with two additional groups (National Park of American Samoa and the American Samoa Community College's Marine Science Program) joining in 2000. The CRAG identified four threats as "most devastating" to coral reefs in American Samoa—over-fishing, population growth, development pressure/unmanaged land use, and climate change. Local research was supported to explore these threats, including climate change, with territorial and federal funds, and workshops were held to build agency capacity on these issues, while working to develop response strategies.

2) In 2007 then Governor Tulafono signed an executive order entitled, "Climate Change Mitigation Executive Order," which mandated that the American Samoa Government (ASG) would make efforts to reduce its carbon footprint through such actions as: Increased minimum fuel efficiency for ASG vehicles; no longer buying 4-wheel drive vehicles unless needed; increase

the number of hybrid vehicles by 5% until 50% of new ASG vehicles are hybrid in 2017; banning the importation of vehicles made before 1999; require gas stations to install vapor recovery nozzles; use compact florescent bulbs, encouraging all ASG departments to set up a recycling program, purchasing only energy star appliances, and it banned the import of high phosphorus detergents to reduce nutrification in nearshore waters.

3) Several high level climate change workshops were held in American Samoa after the 2007 Executive Order, including one in April, 2010 entitled, "Planning for Climate Change in the Coastal and Marine Environment," and another in February, 2010 entitled, "Making Climate Change Local: Building Resilient Communities in the Pacific." Both of these workshops were in whole or part sponsored and organized by the then Fagatele Bay National Marine Sanctuary (now National Marine Sanctuary of American Samoa).

4) An ASG mandated Territorial Climate Change Adaptation Working Group was created in June, 2011.

5) In August of 2012, then Governor Tulafono signed an updated executive order (EO-03-2012) acknowledging and reaffirming the serious nature of the impacts of climate change to American Samoa, and even specifically noting the actions were taken from the recommendations of the "Making Climate Change Local: Building Resilient Communities in the Pacific" workshop. This executive order proposed to: ban import of vehicles older than ten years, requiring all newly purchased ASG vehicles to be hybrids, requiring all newly purchased ASG appliances to be Energy Star, banning the importation of any detergents containing phosphates, prohibiting the use of incandescent light bulbs and requiring new lighting to use light-emitting diode (LED) bulbs, or compact fluorescent bulbs if LEDs aren't an option, and requires all ASG departments to create their own recycling program.

6) A Territorial Climate Change Adaptation Framework and a Community Climate Change Resiliency Guide was created in August of 2012.

7) In 2012 air-born LiDAR-Light Detection and Ranging—a remote sensing method used to examine the surface of the Earth, was flown over the island of Tutuila; this critical data set is being used to develop sea level rise models for local villages.

8) In 2012, the village of Amouli created a village resiliency plan, as outlined in the resiliency guide. This was a result of a project driven by Co-Principle Investigators Dr. Arielle Levine and Fatima Sauafea Le'au, with technical assistance from Dr. Chip Fletcher.

9) In 2012, the Fagatele Bay National Marine Sanctuary Final Management Plan / Final Environmental Impact Statement, that included a Climate Change Action Plan, were completed (US DOC NOAA ONMS 2012).

Climate Change Impacts in American Samoa

American Samoa climate is characterized by warm, relatively stable air temperatures, variable precipitation, high humidity, persistent southeast trade winds, and periodic tropical cyclone activity (US DOC NOAA ONMS 2012). Rainfall and trade winds in American Samoa are influenced by the South Pacific Convergence Zone, a low-pressure area which seasonally moves over and around the archipelago, resulting in a long rainy season from October-May, and a slightly cooler and drier period from June-September with higher southeasterly trade wind activity (Finucane et al. 2012; US DOC NOAA ONMS 2012). Tropical cyclone activities bring heavy rainfall and high wave activity, with peak cyclone activity occurring from December to February (Finucane et al. 2012).

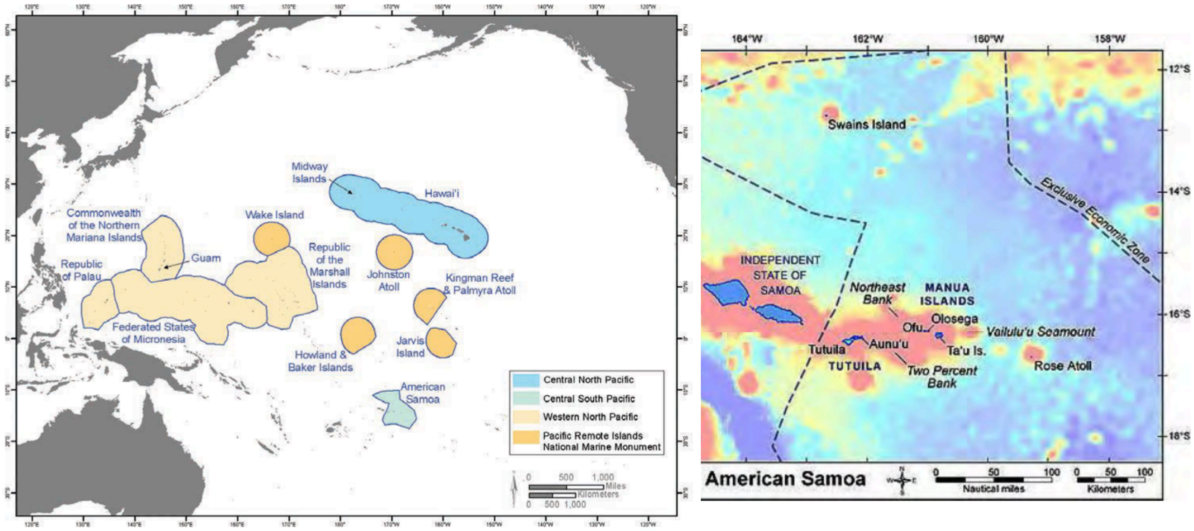


Figure 1. Map of the Pacific Islands sub-regions (left) and American Samoa (right) (Finucane et al. 2012; US DOC NOAA ONMS 2012).

The Pacific Islands region experiences high inter-annual and inter-decadal climate variability as a result of the El Nino Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Inter-decadal Pacific Oscillation (IPO) (Finucane et al. 2012; US DOC NOAA 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 trade wind activity, rainfall, storm tracks, and ocean temperature (Finucane et al. 2012; US DOC NOAA ONMS 2012). These events typically persist for 6-18 months and ENSO phase shifts occur every 3-7 years (Cane 2005). The PDO has similar effects because its warm and cold phases alter the relative dominance of El Niño and La Niña events. PDO phases typically cycle every 20-30 years (D'Aleo 2005), and it is believed that the Pacific Islands region has been in a cold PDO phase since 1999; this phase will likely persist for the next several decades. The IPO behaves similarly to the PDO, affecting the broader south Pacific, where American Samoa is located (Finucane et al. 2012).

Where possible, climate information specific to American Samoa is presented. In the absence of specific information for American Samoa, climate trends and projections for Samoa, the Central South Pacific, or the Pacific Islands region as a whole are presented.

Air Temperature

In nearby Samoa, average annual, minimum, and maximum air increased significantly from 1950-2009 (+0.25°F (+0.14°C), +0.07°F (+0.04°C), and +0.4°F (0.22°C) per decade, respectively), with the largest increases in maximum air temperatures (Young 2007; ABM and CSIRO 2011). Air temperatures are projected to continue increasing over the next century in the Central South Pacific (Young 2007; ABM and CSIRO 2011). Relative to temperatures from 1971-2000, average annual surface temperatures are projected to increase +1.1-1.3°F (+0.61-0.72°C) by 2030, +1.9-2.5°F (+1.06-1.39°C) by 2050, and +2.5-4.8 °F by 2090 (+1.39-2.67°C) (ABM and

CSIRO 2011). Additionally, extreme heat days are projected become more frequent and intense across the Pacific Islands region during the 21st century (Finucane et al. 2012).

Potential impacts of air temperature increases on American Samoa's marine and coastal resources include increased mangrove heat stress and altered mangrove forest species composition, distribution, growth rates, and phenology, altered tidal flat community composition, distribution, and productivity, increased evaporation, exacerbating drought stress, altered bird migration timing, and shifts in sea turtle hatchling sex ratios (more females) (Parker and Miller 2012; Leong et al. 2014).

Annual and Seasonal Precipitation

There are few stable precipitation monitoring records for American Samoa, but from what data are available, American Samoa has shown no significant trend in annual precipitation or winter one-day precipitation volume since 1965 (Leong et al. 2014). Similarly, annual and seasonal rainfall trends in Samoa showed no significant trends from 1950-2009 (ABM and CSIRO 2011). Future precipitation projections for the Central South Pacific are highly variable and display conflicting results (Young 2007; ABM and CSIRO 2011). However, future conditions may include no change to a slight increase in mean annual precipitation during the 21st century, with slight precipitation decreases during the dry season and slight precipitation increases during the wet season (ABM and CSIRO 2011; Keener et al. 2012).

Precipitation patterns are influenced by a variety of factors in addition to climate change, including shifts in ENSO, PDO, and IPO phases, and according to local topography and location on a given island (Finucane et al. 2012, Leong at al. 2014). For example, El Niño conditions can cause heavy rainfall or drought depending on event strength and island location (Finucane et al. 2012). A summary of general phase effects on rainfall and tropical cyclone activity are listed below.

Summary of phase event influences on precipitation and tropical cyclone activity in American Samoa (ABM and CSIRO 2011):

- El Niño:
  - Weak: reduced rainfall and tropical cyclone activity
  - Moderate: enhanced rainfall and tropical cyclone activity, extended rainy season
  - Strong: reduced rainfall
- La Niña:
  - Increased tropical cyclone activity and rainfall
- PDO/IPO:
  - Warm phases: generally increase El Niño activity
  - Cold phases: generally increase La Niña activity

Potential impacts of altered precipitation patterns on American Samoa's marine and coastal resources include: altered freshwater runoff magnitude and timing to coastal and nearshore environments (e.g., lagoons, reef adjacent bays), altering pollutant, sediment, and nutrient delivery and altered ocean salinity and stratification (Cheng and Gaskin 2011; Finucane et al. 2012; Parker 2012; Leong et al. 2014).

Drought

Drought events in Samoa are correlated with El Niño events, but drought frequency has not changed over the past 60 years in Samoa (Young 2007; ABM and CSIRO 2011) or American Samoa (Keener et al. 2012). Drought frequency in Samoa is unlikely to exhibit major change during the 21st century, but there is low confidence in this projection due to poor modeling of dry season precipitation patterns in the region (Young 2007).

Potential drought impacts on American Samoa's marine and coastal resources are reduced freshwater resources, particularly if drought is combined with enhanced saltwater intrusion and sea level rise, and the potential for decreased tourism (ABM and CSIRO 2011; Cheng and Gaskin 2011; Finucane et al. 2012; Parker 2012; Leong et al. 2014).

Extreme Precipitation and Tropical Cyclones

The Central South Pacific has shown no increase in the frequency of extreme rainfall events since 1965 (Keener et. al 2012). However, tropical cyclones are the primary source of extreme precipitation in the Central South Pacific, and the proportion of tropical storms escalating into tropical cyclones increased from 1991-2010 relative to 1970-1990 (Parker 2012). Extreme rainfall events are likely to increase in frequency and intensity during the 21st century, and will likely continue to be correlated with tropical cyclone activity (Young 2007; ABM and CSIRO 2011). Although region-specific projections are highly uncertain (Keener et al. 2012), tropical cyclone intensity across the Pacific Islands is projected to increase over the next 70 years (Diamond 2012), even while overall cyclone activity may decline in the Central South Pacific as storm tracks shift toward the Central North Pacific (ABM and CSIRO 2011; Seneviratne et al. 2012). In addition to responding to sea surface and atmospheric temperatures, cyclone activity is also correlated with ENSO, PDO, and IPO phase shifts, making future projections difficult (Keener et al. 2012).

More frequent and intense extreme precipitation events and more intense tropical cyclones can have a variety of impacts on American Samoa's marine and coastal resources, including 1) increased erosion, sedimentation, and pollution runoff during extreme precipitation events, reducing water quality and promoting algal blooms in mangrove and coral reef systems; 2) increased nutrient runoff and crown-of-thorns starfish outbreaks following storms; 3) increased risk of waterborne diseases; 4) altered geomorphology of mangroves forests, coral reefs, and seagrass beds, reducing critical habitat and protection for coastal communities; and increased coastal erosion, potentially affecting important cultural resources, nesting sea turtles, and tourism (Parker 2012; Leong et al. 2014; Cheng and Gaskin 2011; Finucane et al. 2012).

Streamflow

There is very little long-term, reliable streamflow data for American Samoa, but the limited data available from Tutuila indicate no significant trend in total streamflow, baseflow, or the number of extreme low- or high-flow days over a period of 35 years (1960-1995) (Keener et al. 2012). There are no concrete projections for streamflow in American Samoa, although streamflows are likely to be influenced by shifts in regional precipitation. Natural flow regimes are also influenced by human infrastructure and use (Keener et al. 2012).

Potential impacts of altered streamflows on American Samoa's marine and coastal resources include possibly reduced streamflow or increased streamflow dependent on precipitation events and drought events. Reduced streamflow can result in reduced nutrient delivery to nearshore and coastal ecosystems and reduced tourism opportunities by limiting freshwater availability. Increased streamflow can result in increased sedimentation and pollutant and nutrient delivery to nearshore ecosystems influencing tourism (Kenner et al. 2012; Parker 2012; Leong et al. 2014).

Sea Level Rise

Global sea levels have risen over the past century, although exact magnitude estimates vary (Cheng and Gaskin 2011; Yu and Hamilton 2010). Recent estimates indicate that global sea levels increased 3.4 (+/- 0.4 mm) per year from 1993-2009, representing a much faster rate of rise than during the 20th century (Emanuel 2005). Mean sea level rise was +2.07 mm per year from 1948-2006 in American Samoa, but exhibited annual variability (Cheng and Gaskin 2011).

There are no concrete projections for sea level rise in American Samoa (Cheng and Gaskin 2011). However, the Pacific Islands region will likely experience similar rates of sea level rise as global averages, with a potential increase between 0.2 to 2 m by 2100 depending on greenhouse gas emission scenarios and rates of ice sheet loss (Marra et al. 2012). Mirroring increases in mean sea level, the Pacific Islands region will likely experience an increased frequency of extreme sea level events. Based on past trends observed at Pago Pago, extreme sea level events will likely be driven by high tides (Marra et al. 2012) and extreme weather (e.g., cyclones).

Additionally, local rates of sea level rise will likely vary according to land dynamics (subsidence, uplifting), phase changes of ENSO and the PDO, wind patterns, and storm activity. For example, some communities in American Samoa (e.g., Pago Pago) may be subsiding, which will increase relative local rates of sea level rise (Li et al. 2010). Energetic ENSO phases can raise local sea levels by 6-12 inches (15-31 cm), and storm winds can raise water levels several inches to multiple feet (Keener et al. 2012). Additionally, shifts in trade wind activity can alter relative rates of sea level rise, and are thought to have contributed to the higher rates of sea level rise in the western Pacific relative to global trends from 1993-2010 (Nerem et al. 2010; Cheng and Gaskin 2011; Marra et al. 2012).

Potential impacts of sea level rise and extreme sea level events on American Samoa's marine and coastal resources include:

- Altered distribution and availability of coastal and nearshore habitats due to altered inundation timing and erosion, including sandy beaches, shallow coral reefs, seagrass beds, intertidal flats, and mangrove forests (Cheng and Gaskin 2011; Finucane et al. 2012; Leong 2014)
- Enhanced flooding and erosion of low-lying coastal areas, potentially affecting recreation, tourism, and important cultural resources (Parker and Miller 2012)
- Reduced mangrove forest extent and associated nursery habitat and ecosystem services (coastal protection, water purification) (Parker and Miller 2012; Leong et al. 2012)

- Reduced seabird breeding and sea turtle nesting habitat (Parker and Miller 2012; Leong et al. 2012)
- Enhanced saltwater intrusion in aquifers and groundwater storage areas, particularly on lower islands (Parker and Miller 2012; Leong et al. 2012)
- Increased salinity in freshwater and brackish wetlands (Parker and Miller 2012; Leong et al. 2012)
- Reduced upward coral growth (Cheng and Gaskin 2011; Finucane et al. 2012; US DOC NOAA ONMS 2012; Leong 2014)
- Enhanced erosion and re-suspension of seabed sediment, increasing sedimentation and turbidity among reefs (Cheng and Gaskin 2011; Finucane et al. 2012; US DOC NOAA ONMS 2012; Leong 2014)

Wave Height

Few long-term records of wave height exist for the Pacific Islands region (Young et al. 2011; Seneviratne et al. 2012). Future wave conditions are difficult to project due to the uncertainty underlying future storm patterns in a changing climate (Marra et al. 2012), but within the Pacific Islands region, annual mean wave heights are projected to increase in the southern tropical Pacific, and decrease in other Pacific areas (Hermer et al. 2010).

Potential impacts of shifting wave heights on American Samoa's coastal and marine resources include altered coral distribution, increased coral erosion, changes reef growth patterns, and increased coastal erosion (Parker and Miller 2012; Leong et al. 2014).

Sea Surface Temperature

Since the 1970s, sea surface temperatures in the Pacific Islands region have increased +0.13-0.41°F (+0.07-0.23°C) per decade depending on location (ABM and CSIRO 2011). American Samoa has also exhibited warming trends (although exact rates aren't available) and Samoa exhibited a temperature increase of +0.14°F (+0.08°C) per decade from 1970-2011 (ABM and CSIRO 2011; US DOC NOAA ONMS 2012). Sea surface temperature in the Pacific Islands region is projected to continue increasing over the next century, potentially increasing +1.1-1.7°F (+0.61-0.94°C) by 2030, +1.8-2.3°F (+1.0-1.28°C) by 2055, and +2.5-4.7°F (+1.39-2.61°C) by 2090, depending on emissions trajectories and phase changes of ENSO, the PDO, and the IPO (ABM and CSIRO 2011; Finucane et al. 2012; Marra et al. 2012).

Potential impacts of increased sea surface temperatures on American Samoa's coastal and marine resources include the following:

- More frequent and intense coral bleaching events (e.g., annual summer bleach events) and increased susceptibility to future bleaching episodes (Cheng and Gaskin 2011; Finucane et al. 2012; US DOC NOAA ONMS 2012; Leong at al. 2014);
- Increased coral mortality (larval and adult stages) and disease incidence (e.g., coral bleaching) (Cheng and Gaskin 2011; Finucane et al. 2012; US DOC NOAA ONMS 2012; Leong et al. 2014);
- Suppressed coral reef reproduction and altered population connectivity, potentially undermining recovery from bleaching events (Cheng and Gaskin 2011; Finucane et al. 2012; US DOC NOAA ONMS 2012; Leong et al. 2014);

- Potential shifts in coral distribution (e.g., shift toward deeper locations and areas with high water flow to ameliorate thermal stress) (Cheng and Gaskin 2011; Finucane et al. 2012; US DOC NOAA ONMS 2012; Leong et al. 2014);
- Altered distribution and reduced diversity, recruitment, and abundance of reef fishes;
- Increased reef fish disease vulnerability via suppressed immune system function (Cheng and Gaskin 2011; Finucane et al. 2012)
- Altered invertebrate larval development and transport (Cheng and Gaskin 2011; Finucane et al. 2012);
- Loss of ecosystem services provided by coral reefs (e.g., subsistence and commercial fisheries, tourism, coastal protection) (Leong et al. 2014);
- Range expansions of warm-water species (Parker and Miller 2012);
- Decline of seagrass systems, including shifts in species distribution, sexual reproduction, carbon dynamics, and growth rates (Cheng and Gaskin 2012; Leong et al. 2014);
- Decline of mangrove systems (Cheng and Gaskin 2012; Leong et al. 2014);
- Altered oceanic species distribution (including adults and larvae) and composition, potentially affecting fisheries (stock abundance and access) (Leong et al. 2014);
- Altered stratification, resulting in shifts in photic zone nutrient availability and phytoplankton size, abundance, and diversity, contributing oceanic food web shifts (Leong et al. 2014);
- Increased dominance of dinoflagellates over other phytoplankton and potential increase in toxic and non-toxic dinoflagellate blooms (Leong et al. 2014); and
- Increased vulnerability to marine invasive species (Cheng and Gaskin 2011; Finucane et al. 2012; US DOC NOAA ONMS 2012; Leong at al. 2014).

Ocean Acidification

Ocean acidification has been progressing across the Pacific Islands region over the past several centuries, and according to estimates for the Samoa region the aragonite saturation state in the late 18th century was 4.5, whereas it was measured at 4.1 in 2000 (ABM & CSIRO 2011). Coral formation occurs optimally at saturation states above 4.0, declining to extremely marginal production at levels at and below 3.0 (US DOC NOAA ONMS 2012). Regional ocean waters are projected to become more acidic in the future, and the aragonite saturation state is projected to fall below 3.5 in the region by 2060, and continue declining thereafter (ABM & CSIRO 2011).

Potential impacts of ocean acidification on American Samoa's coastal and marine resources include: reduced calcification in corals, crustaceans, mollusks, echinoderms, and other taxa, reduced coral formation, growth, diversity, abundance, health, and recruitment, shifts in competitive interactions amongst coral taxa, altering reef complexity, increased macroalgae (fleshy algae) growth, altered oceanic species distribution as phytoplankton productivity and distribution changes, potentially affecting fisheries, and reduced coastal protection from wave energy and overwash if reef structures decline (Cheng et al. 2011; Parker and Miller 2012; Leong et al. 2014).

Chapter 2 Vulnerability Assessment and Adaptation Planning: Methods and Workshop Activities

Overview

Climate change **vulnerability assessments** provide two kinds of information: (1) they identify which resources are likely to be most affected by changing climate conditions, and (2) they improve understanding as to why these resources are likely to be vulnerable. Knowing which resources are most vulnerable better enables managers to develop **adaptation strategies** and set priorities for conservation action (Glick et al. 2011).

This vulnerability assessment and adaptation strategy report is an initial science-based effort to identify how and why focal resources (habitats, species, and ecosystem services) across the American Samoa are likely to be affected by future climate conditions over the next **20 years** and what are some strategies and options for reducing those vulnerabilities. This report includes the results of two workshops to assess Step 1 through Step 3 of the Adaptation Planning Process (see Figure 2). Step 1 included the identification of conservations efforts for 10 focal resources, Step 2 included the assessment of the vulnerability of those focal resources, and Step 3 included the identification of management options to reduce those vulnerabilities that were identified in Step 2.

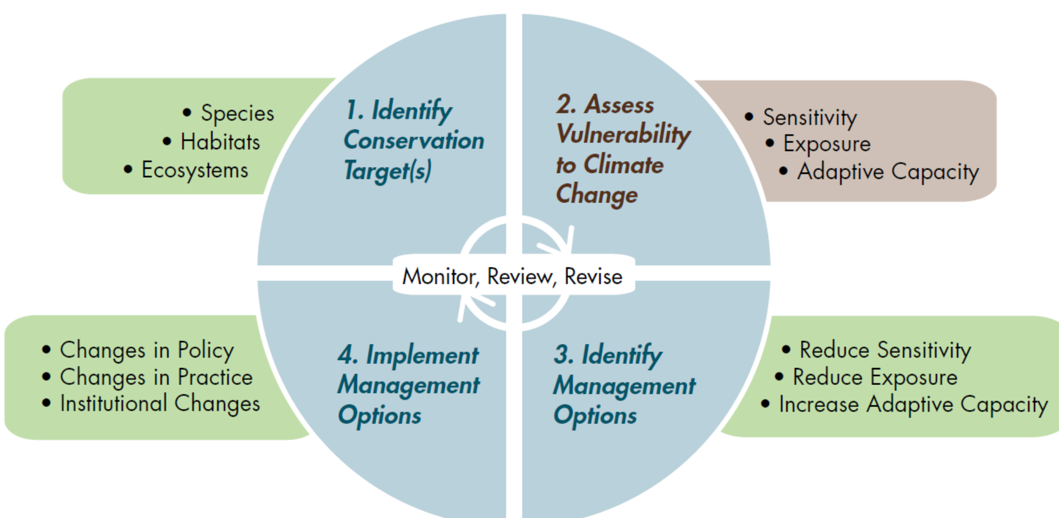


Figure 2. Adaptation planning process (Glick et al. 2011).

Developing resilient management options to decrease vulnerabilities requires implementing a variety of adaptation options. Most **adaptation options** fall into the following five main categories:

1. **Enhance Resistance.** Implementation of these strategies can help to prevent the effects of climate change from reaching or affecting a resource. Common resistance actions include those designed to reduce non-climate stressors.
2. **Promote Resilience**. These strategies can help a resource withstand the impacts of climate change by avoiding the effects of or recovering from changes.

3. **Facilitate Transition (or Response).** Transition or response strategies intentionally accommodate change and enable resources to adaptively respond to changing and new conditions.
4. **Increase Knowledge.** These strategies are aimed at gathering more information about climate changes, impacts, and/or the effectiveness of management actions in addressing the challenges of climate change.
5. **Engage Coordination**. Coordination strategies may help align budgets and priorities for programs of work across lands or establish or expand collaborative monitoring efforts or projects, among others.

STEP 1: Identify Conservation Targets - Focal Resource Selection

A total of **10 focal resources** were selected from a list of 6 habitats, 12 species, and 3 ecosystem services valued in American Samoa. Sanctuary staff, village leaders, advisory council members, scientists, and managers were asked eight questions to select the resources most impacted by climate change with a survey. The questions for considerations when picking the focal resources included:

1. Is the resource listed as threatened, endangered or sensitive?
2. Is the resource considered to be ecologically foundational, a dominant species, an ecosystem engineer, a keystone species, an umbrella species, an important indicator, or strong interactor?
3. Does the resource have substantial or significant management implications?
4. Does the resource have significant other stressors already affecting viability?
5. Does the resource have available data and information upon which to do the vulnerability assessment?
6. Is the resource considered to be controversial or rare?
7. Does the resource have socio-economic significance (for example, is it a flagship species or does it have cultural or economic value)?
8. Is the resource likely to be significantly impacted by climate change?

The final focal resources selected included 2 combined habitats, coral reef habitat (reef flat, reef crest, reef slope, mesophotic reefs) and mangrove/lagoon habitat; 7 species assemblages, charismatic fish, herbivorous fish, piscivorous fish, pelagic fish, sharks and rays, giant clams, and sea turtles; and 1 ecosystem service, water quality.

STEP 2: Vulnerability Assessment Workshop and Methods

The vulnerability assessment comprises three components: 1) sensitivity, 2) adaptive capacity, and 3) exposure, for focal resources, which are averaged by rankings for those components, and confidence scores for those rankings. The sensitivity, adaptive capacity, and exposure components each include multiple finer resolution elements that were addressed individually. **Sensitivity** involves factors that currently shape species, habitat, or ecosystem service to climate and climate driven factors (e.g., air and sea temperature, precipitation, drought, tropical storms, streamflow, coastal erosion, ENSO), sensitivity to disturbance regimes (e.g., disease, crown-of-thorns starfish), and sensitivity to non-climate stressors (e.g., land use change, overfishing, nutrient loading). **Adaptive capacity** elements include extent, status, and dispersal ability; species life history diversity, genetic diversity, behavioral plasticity, and phenotypic plasticity; species ability to resist and recover from stressors; and species management potential. To assess **exposure**, participants were asked to identify the climate and climate-driven changes most relevant to consider for the species, habitats, and ecosystem services and to evaluate how they would experience to those changes. A climate change trends and projections table was provided to participants to facilitate this evaluation (See Appendix III).

Vulnerability Terminology and Definitions:

1. **Vulnerability:** A function of the sensitivity of a particular resource to changes in climate changes, its exposure to those changes, and its capacity to adapt to those changes (IPCC 2007).
2. **Sensitivity:** The climate and climate-driven factors that currently shape the species, habitat or ecosystem services.
3. **Exposure:** Consideration of future changes in climate that could affect the species, habitat, or ecosystem service.
4. **Adaptive Capacity**: The ability of an individual, community, or ecosystem to respond or adapt to change; this reflects intrinsic traits (e.g., behavioral or physiological flexibility that allows individuals to respond to new situations) and extrinsic factors (e.g., degree of habitat fragmentation, management potential).

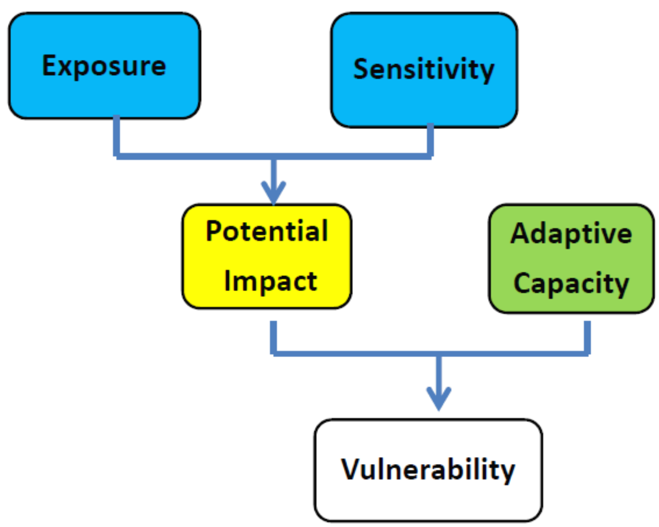


Figure 3. Visual representation of the vulnerability assessment process.

Habitat Vulnerability Assessment Criteria: Sensitivity, Exposure, and Adaptive Capacity

1. **Climate and Climate Drive Factors:** There are two ways to assess habitat sensitivity:
   a. whether habitat exists in a relatively narrow zone, and thus being more sensitive, or exists in a relatively broad climatic zone, thus being less sensitive;
   b. whether the habitat experiences large changes in composition or structure due to small changes in climate or climate-driven factors, and thus is more sensitive; or the habitat experiences small changes even with larger changes in climate or climate-driven factors, and this is less sensitive.
2. **Disturbance Regimes:** Natural disturbance regime is a concept that describes the pattern of disturbances that shape an ecosystem over a long time scale. It is distinguished from a single disturbance event because it describes a spatial disturbance

pattern, frequency and intensity of disturbances, and a resulting ecological pattern over space and time. More sensitive habitats will show larger changes in composition or structure in response to relatively small climate-driven changes in disturbance regimes. Conversely, it would take much larger climate-driven changes in disturbance regimes to elicit a substantial change in composition or structure in less sensitive habitats. Changes in disturbance regimes may be either good or bad for the habitat.

3. **Future Climate Exposure:** Exposure involves future climate changes that could affect the habitat and the likely degree of exposure to those changes, including increased air and sea temperatures, decreased pH, altered currents, and storms.
4. **Sensitivity and Current Exposure to Non-Climate Stressors:** Sensitivity of the habitat to climate change impacts may be highly influenced by the existence, extent of, and current exposure to non-climate stressors. Although a habitat may be sensitive to a non-climate stressor, if it is not currently exposed to it, the overall sensitivity of the habitat may be lower.
5. **Extent, Integrity, and Continuity:** Habitats that are currently widespread in their geographic extent, with high integrity and continuity may have greater adaptive capacity, may be more likely to withstand non-climate and climate stressors, and may persist into the future. Habitats that are degraded, isolated, limited in extent, or currently declining due to non-climate and climate stressors may have less adaptive capacity, and may be less likely to persist into the future.
6. **Resistance and Recovery:** Some habitats may be more resistant to changes, stressors, or maladaptive human responses, or are able to recover more quickly from stressors; these habitats likely exhibit higher adaptive capacity. This may include habitat diversity or diverse physical and topographical characteristics (e.g., variety in aspects), which may confer higher adaptive capacity.
7. **Management Potential:** Management potential reflects the ability to impact the adaptive capacity and resilience of a habitat to changes in climate through actions taken by the human community overseeing a habitat.

Species Vulnerability Assessment Criteria: Sensitivity, Exposure, and Adaptive Capacity

1. **Climate and Climate-Driven Factors:** Species sensitivity to climate and climate-driven factors may be direct (e.g., physiological, phenological) or indirect (e.g., ecological relationships).
    a. *Physiological sensitivity* refers to a species' physiological ability to tolerate changes that are higher or lower than the range that they have experienced or currently experience. Species that are able to tolerate a wide range of climatic factors may be considered less sensitive.
    b. *Phenological sensitivity* refers to a species' ability to phenologically track climate (e.g., timing of reoccurring thermal events). Species that cannot phenologically track environmental changes may be considered more sensitive.
    c. *Species' ecological relationships* may also be affected by climate or climate-driven factors. Ecological relationships can include: predator/prey, foraging, competition, habitat, pollination, dispersal, symbiont/mutualist/parasite, and others. Ecological relationships significantly affected by small changes in climate and climate-driven factors may have higher sensitivity.

2. **Disturbance Regime:** Natural disturbance regime is a concept that describes the pattern of disturbances that shape an ecosystem over a long time scale; it is distinguished from a single disturbance event because it describes a spatial disturbance pattern, a frequency and intensity of disturbances, and a resulting ecological pattern over space and time. Species may be at greater risk of decline or elimination even in response to small changes in disturbance regimes. For example, increasing water temperatures can alter bleaching and disease patterns in coral reefs which may cause shifts from coral to algal dominated systems. Changes in disturbance regimes may be either good or bad for the species.
3. **Future Climate Exposure:** Climate exposure involves projected future changes in climate that could affect the species and the likelihood that a species will experience those changes, including increased air and sea temperature, decreased pH, altered currents, and storms.
4. **Dependencies:** Species that use multiple habitats or utilize multiple prey or forage species may be less sensitive to climate change (e.g., generalists). Conversely, species with very narrow habitat needs or habitat specialization, single prey or forage species, or dependence on another sensitive species may have a higher likelihood of decline if climate change significantly affects the habitat or species they are dependent upon (e.g., specialists).
5. **Sensitivity and Current Exposure to Non-Climate Stressors**: Sensitivity of the species to climate change impacts may be highly influenced by the existence, extent of, and current exposure to non-climate stressors. Although a species may be sensitive to a non-climate stressor, if it is not currently exposed to it, the overall sensitivity of the species may be lower.
6. **Extent, Status, and Dispersal Ability:** Species that are currently widespread in their geographic extent, with a robust population status, connectivity, and a high ability to disperse may have higher adaptive capacity. These species may be more likely to withstand and persist into the future despite climatic and non-climatic stressors. Species that are endemic, threatened or endangered, occur as isolated or fragmented populations, and/or exhibit limited ability to disperse may have lower adaptive capacity.
7. **Intraspecific/Life History Diversity:**
    a. Life history diversity: Species with a diversity of life history strategies (e.g., variations in age at maturity, reproductive or nursery habitat use, or resource use) may be more resilient to climate change.
    b. Genetic diversity: Species with characteristics such as faster generation times, genetic diversity, heritability of traits, larger population size, or multiple populations with connectivity among them to allow for gene flow may exhibit higher adaptive capacity.
    c. Phenotypic and behavioral plasticity: Species with the capacity to express different traits (e.g., phenology, behavior, physiology) in response to environmental variation may have higher adaptive capacity. For example, many species exhibit phenotype plasticity in response to inter-annual variation in temperature and precipitation.
8. **Resistance:** Some species may be more resistant to changes, stressors, or maladaptive human responses; these species may exhibit higher adaptive capacity.

9. **Management Potential:** Management potential reflects the ability to enhance the adaptive capacity and resilience of a species to changes in climatic through actions taken by the human community overseeing a resource.

Ecosystem Service Vulnerability Assessment Criteria: Sensitivity, Exposure, and Adaptive Capacity

1. **Sensitivity** involves factors that currently shape ecosystem services; exposure involves future climate changes that could affect the ecosystem service, and is covered in another section below. Ecosystem service sensitivity may largely be determined by the sensitivities of those components (e.g., species, habitat, hydrology, etc.) that provide or support the service. For example, the sensitivity of "marine fisheries" as an ecosystem service is significantly determined by the sensitivity of the target species climate and climate-driven factors (e.g., pH or temperature). Similarly, the sensitivity of recreation as an ecosystem service is dependent on the sensitivity of target species (e.g., birds for bird-watching) or habitat (e.g., beaches for sunbathing).
2. **Disturbance Regime:** Natural disturbance regime is a concept that describes the pattern of disturbances that shape an ecosystem over a long time scale; it is distinguished from a single disturbance event because it describes a spatial disturbance pattern, a frequency and intensity of disturbances, and a resulting ecological pattern over space and time. More sensitive ecosystem services may show significant changes in their ability to be provided in response to relatively small climate-driven changes in disturbance regimes (e.g., increased diseases in shellfish leading to harvest restrictions and/or closures).
3. **Future Climate Exposure:** Climate exposure involves projected future climate changes that could affect the service and the likely degree of exposure to those changes.
4. **Sensitivity and Current Exposure to Non-Climate Stressors:** Sensitivity of the service to climate change impacts may be highly influenced by the existence, extent of, and current exposure to non-climate stressors. Although a service may be sensitive to a non-climate stressor, if it is not currently exposed to it/affected by it, the overall sensitivity of the service will be lower.
5. **Intrinsic Value and Management Potential:** Intrinsic value considers societal value of the service, including whether or not people would be willing to change behavior to continue access to and condition of the service. Management potential reflects our ability to affect the adaptive capacity and resilience of an ecosystem service to climatic changes through actions taken by the human community overseeing an ecosystem service.

Vulnerability Assessment Workshop Activities

During the July 2016 workshop,[2] participants were asked to evaluate the vulnerability for all 10 of the focal resources. The two-day workshop provided participants with baseline knowledge and understanding of climate trends (current, historic, projected future) for American Samoa

[2] http://ecoadapt.org/workshops/NMSAS-VA-workshop

and collectively assessed vulnerabilities of habitats, species, and ecosystem services to climate change including evaluating sensitivity, exposure, and adaptive capacity.

The vulnerability assessment model used in this process comprises three vulnerability components (i.e. sensitivity, adaptive capacity, and exposure), confidence evaluations for all components, and overall vulnerability and confidence for each focal resource. Sensitivity, exposure, and adaptive capacity components were broken down into specific elements better suited to assessing the vulnerability of particular resources for this assessment. Sensitivity elements for habitats and ecosystem services include: direct sensitivity to climate, climate-driven changes, and non-climate stressors. Disturbance regimes and non-climate stressors are also included in species sensitivity; however, several other elements are better suited to assessing species' sensitivity including: generalist/specialist, physiology, life history, ecological relationships, and dependence on sensitive habitats.

During the workshop, participants assigned a ranking (1-low to 5-high) to each finer resolution element for sensitivity, exposure, and adaptive capacity, and provided a corresponding confidence score (e.g., 1-low to 3-high) to the ranking for all focal resources. These individual rankings and confidence scores were then averaged to generate rankings and confidence scores for each vulnerability component (i.e., sensitivity, adaptive capacity, exposure score). Results presented in a range (e.g., from moderate to high) reflect variability assessed by participants. Please note that participants felt that it was best to focus on future climate and climate-driven changes for over the next **20 years** rather than 50-100 years because participants felt they needed more information to assess vulnerability over a longer timeframe.

Rankings for each vulnerability component (i.e., sensitivity, adaptive capacity, exposure) were then combined into an overall vulnerability score that was calculated as follows:

Vulnerability = (Climate Exposure + Climate Sensitivity) – (Adaptive Capacity)

STEP 3: Adaptation Planning Workshop and Methods

The adaptation strategy planning process consists of analysis of vulnerabilities of current management goals, strategies, and actions and an assessment on ways they can be more resilient and less vulnerable to climate and non-climate stressors. It also consisted of brainstorming new goals, strategies and actions that can help the resource become more resilient and less vulnerable to climate and non-climate stressors.

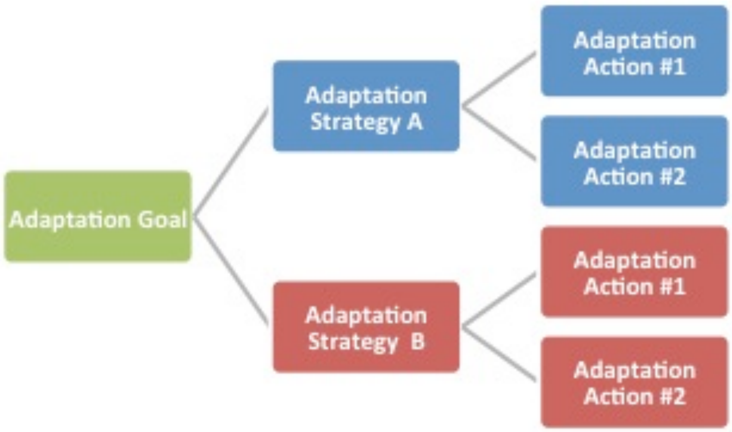


Figure 4. Visual representation of the relationship between adaptation goals, strategies, and specific actions.

Adaptation Terminology and Definitions

Adaptation Goal: A desired result for a given resource.

Adaptation strategy: General statements of how to reduce vulnerabilities or increase resilience of current management goals.

Adaptation actions: Specific activities that facilitate progress towards achieving an adaptation strategy.

Adaptation Strategy Workshop Activities

The September 2016 adaptation planning workshop[3] goals were to develop climate-informed adaptation strategies and actions to conserve priority resources in the National Marine Sanctuary and Territory of American Samoa. Participants identified both current and future management **goals** for each of the focal resources. The purpose of identifying current management goals is to provide a foundation for evaluating whether and how climate change might affect the ability to achieve a given goal, and to develop options for reducing vulnerabilities through revised management activities. For each management goal, participants identified potential climate change vulnerabilities. This activity was followed by the evaluation of current management actions, including whether, in their current form, they can help to reduce identified vulnerabilities and/or how they can be modified to better address climate challenges. Following the evaluation of potential vulnerabilities of current management goals and actions, participants explored potential future management goals and adaptation **strategies** and identified more specific adaptation **actions** designed to reduce vulnerabilities or increase resilience of the selected focal resources. For each adaptation action, participants then evaluated where, when, and how to implement those actions as well as collaboration and capacity needs.

[3] http://ecoadapt.org/workshops/NMSAS-AS-workshop

Current Management Goals and Potential Vulnerabilities

Workshop participants identified key current management goals and their potential climate and non-climate vulnerabilities. In response to these vulnerabilities, participants then evaluated whether or not existing management actions may be effective in reducing vulnerability; identified what, if any, climate and non-climate vulnerabilities the action helps reduce; and evaluated the feasibility of action implementation. Given action effectiveness and feasibility, participants then evaluated whether or not to continue implementation of the action. For those actions recommended for continued implementation, participants then identified both how and where to implement.

Future Management Goals and Adaptation Actions

Workshop participants also identified the possible future management goals and adaptation actions for each resource. They then evaluated action effectiveness and feasibility; identified the timeframe for action implementation; described where and how to implement the action; and identified collaboration and capacity needs. Timeframe, collaboration and capacity needs are defined below.

- **Implementation timeframe:** Identify when a particular action could feasibly be implemented.
    - *Near-term*: <5 years; *Mid-term*: 5-15 years; or *Long-term*: >15 years.
- **Collaboration:** Identify any other agencies, organizations, or people needed to collaborate with in order to implement an action.
- **Capacity needed**: Identify capacity needed for implementation such as data, staff time and resources, funding, or policy changes, among others.

These workshop activities generated a range of recommended adaptation actions that could be implemented both now and in the future. The resulting actions are not comprehensive, and users of this report are encouraged to explore additional adaptation actions that may help reduce vulnerabilities, increase resilience, or capitalize on opportunities presented by climate change.

Adaptation Action Feasibility

Participants were also asked to assess the effectiveness, feasibility, and implementation of all actions identified. These assessments help identify which actions can be easily implemented and those that might need more collaboration and longer time frames to help develop an implementation plan in STEP 4 of the Adaptation Planning Process. Participants were asked to identify the following:

- **Action effectiveness**: Identify the effectiveness of the action in reducing vulnerability.
    - High: action is very likely to reduce vulnerability and may benefit additional goals or habitats
    - Moderate: action has moderate potential to reduce vulnerability, with some limits to effectiveness
    - Low: action is unlikely to reduce vulnerability
- **Action feasibility**: Identify feasibility of implementing the action.

- High: there are no obvious barriers and it has a high likelihood of being implemented
    - Moderate: it may be possible to implement the action, although there may be challenges or barriers
    - Low: there are obvious and/or significant barriers to implementation that may be difficult to overcome
- **How to implement**: Identify how to apply this action given vulnerabilities. For example, consider planting native species that can cope with a range of future conditions or those best adapted to projected future conditions.
- **Where to implement**: Identify the management, ecological, or site conditions where the action could be most appropriately implemented. For example, is it best to implement in coral habitats that are resilient to bleaching.

Chapter 3 Vulnerability Assessment and Adaptation Planning Results

Summary

Overall the vulnerability assessment of the 10 focal resources was moderate to low-moderate with mostly high and moderate confidence scores. This is probably due to limited **20-year timeframe** that participants chose to use rather than considering multiple scenarios and time steps of 10, 20, 50, and 100 years (Glick et al. 2011). If longer timeframes were used for this vulnerability assessment, one would expect higher vulnerability and lower confidence scores.

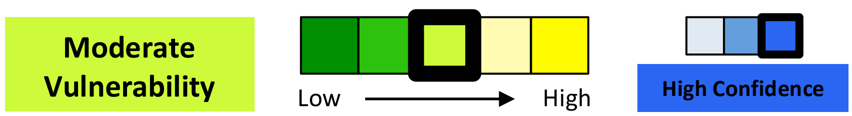
FOCAL RESOURCE	VULNERABILITY SCORE	CONFIDENCE SCORE
Coral Reef Habitat	Moderate	High
Mangrove Habitat	Low-Moderate	High
Water Quality	Moderate	High
Giant Clam	Moderate	High
Herbivore Reef Fish	Low-Moderate	High
Charismatic Reef Fish	Low-Moderate	High
Reef Piscivores	Low-Moderate	High
Pelagic Fish	Moderate	High
Sharks and Rays	Low-Moderate	Moderate
Sea Turtles	Moderate	Moderate

1. Coral Reef Habitat

Introduction

Coral reefs in American Samoa include three zones: reef flat, reef crest, and reef slope. Reef flats are shallow and narrow (50-500 m) systems extending from shore to the reef crest. Reef crests are shallow systems representing the highest point of the reef system and dividing reef flat from slope; they are occasionally exposed during low tides, as are reef flats. Reef slopes descend 20-30 m in depth on the oceanic side of the reef crest. Differences in temperature, salinity, wave action, water depth, and sedimentation between these three zones affects coral community composition. However, American Samoan coral reef communities are generally dominated by crustose coralline algae with live hard corals being less dominant, and brown macroalgae occasionally occurring on reef slopes and flats (Fenner et al. 2008; US DOC NOAA ONMS 2012). Unique coral communities occur at Rose Atoll and Swains Island (Kendall 2011; US DOC NOAA ONMS 2012). In general, coral reef systems harbor high biodiversity (US DOC NOAA ONMS 2012).

Vulnerability Assessment Results



Workshop participants evaluated coral reefs in American Samoa to have a moderate relative vulnerability to climate change due to moderate-high sensitivity to climate and non-climate stressors, moderate exposure to future climate changes, and moderate-high adaptive capacity. Coral reefs are sensitive to numerous climate stressors, including ocean acidification, sea surface temperature, tropical storms, runoff/stream flow, coastal erosion, and currents, mixing, and stratification. These stressors directly affect coral survival, recruitment, and growth, as well as alter water quality by affecting sediment, pollutant, and nutrient delivery. Climate stressors may also increase coral susceptibility to disturbance regimes, including disease and crown-of-thorns starfish outbreaks, which elevate coral mortality. Coral reefs are sensitive to several non-climate stressors, including dredging, land use change, overwater/underwater structures, nutrient loading, sedimentation, trampling, seawalls, and fishing. Non-climate stressors can directly degrade and destroy coral communities, and will likely compound declining water quality trends occurring with climate change. Coral reefs in American Samoa are generally healthy and continuous around islands, and have been able to recover from a variety of past environmental disturbances, although they are less resilient to human disturbances. High coral biodiversity enhances overall resilience, but future functional group shifts may occur as many reef-building coral species are vulnerable to climate change, which will impact overall reef stability. Coral reefs provide important commercial and subsistence fishing opportunities, as well as other ecosystem services such as biodiversity, coastal protection, and recreation. A variety of marine protected areas have been established; however, they cover only a small percentage of existing reef habitat, and protective regulations vary between sites.

Current Management Actions

Goal 1: Protect Coral Reef Habitat

- Water quality testing for bacteria and near shore nutrient input, sometimes resulting in beach closures
- Reduce litter and marine debris
- Federal, territorial, and village Marine Protected Areas (MPAs)
- No discharge and anchoring in the Sanctuary

Goal 2: Control crown-of-thorns starfish outbreaks

- Targeted crown-of thorns starfish eradication with ox bile
- Manual eradication of crown-of thorns starfish (spear or bash)
- Ban take of large reef fish (e.g., humphead wrasse), which are believed to be crown-of-thorns predators

Goal 3: Use education and outreach to protect coral reefs and bring the site to the people

- School programs such as Reef Check (geared toward any audience; provides education on coral fragility and importance of coral habitat so audience can become environmental steward)
- Virtual experience for students, allowing them to see changes, including climate change impacts with special goggles

Future Management Actions

Goal 1: Decrease nutrient input and sedimentation into coastal waters

- Ensure piggery compliance and enforce EPA regulations
- Support sewer expansions, new waste water treatment plants, proper septic tank installation, and cesspool removal
- Plant more trees/plants in coastal areas and in villages to reduce runoff
- Ensure compliance of coastal development setbacks
- Start a wetlands restoration project
- Education/outreach on strengthening village laws
- Remove all wastewater outfalls

Goal 2: Cooling for bleaching prevention and reduction

- Move deeper, cooler water to shallow, warmer areas

Goal 3: Develop resilient marine protected areas (MPAs) – design future MPAs in areas that are climate resilient and effective for multiple species (consider network of MPAs)

- Analyze what is already in place and what is working to identify priority areas for protection
- Allow easy exchange of data and accessibility of information to allow managers to assess changes over time

Goal 4: Assemble a coral reef database and develop sharing method for management and decision support

- Develop easy exchange and accessibility of information to allow managers to assess changes over time

Goal 5: Use coral nursery gardens for restoration

- Select corals that do not bleach for restoration projects

Feasibility and Effectiveness of Current and Future Management Actions

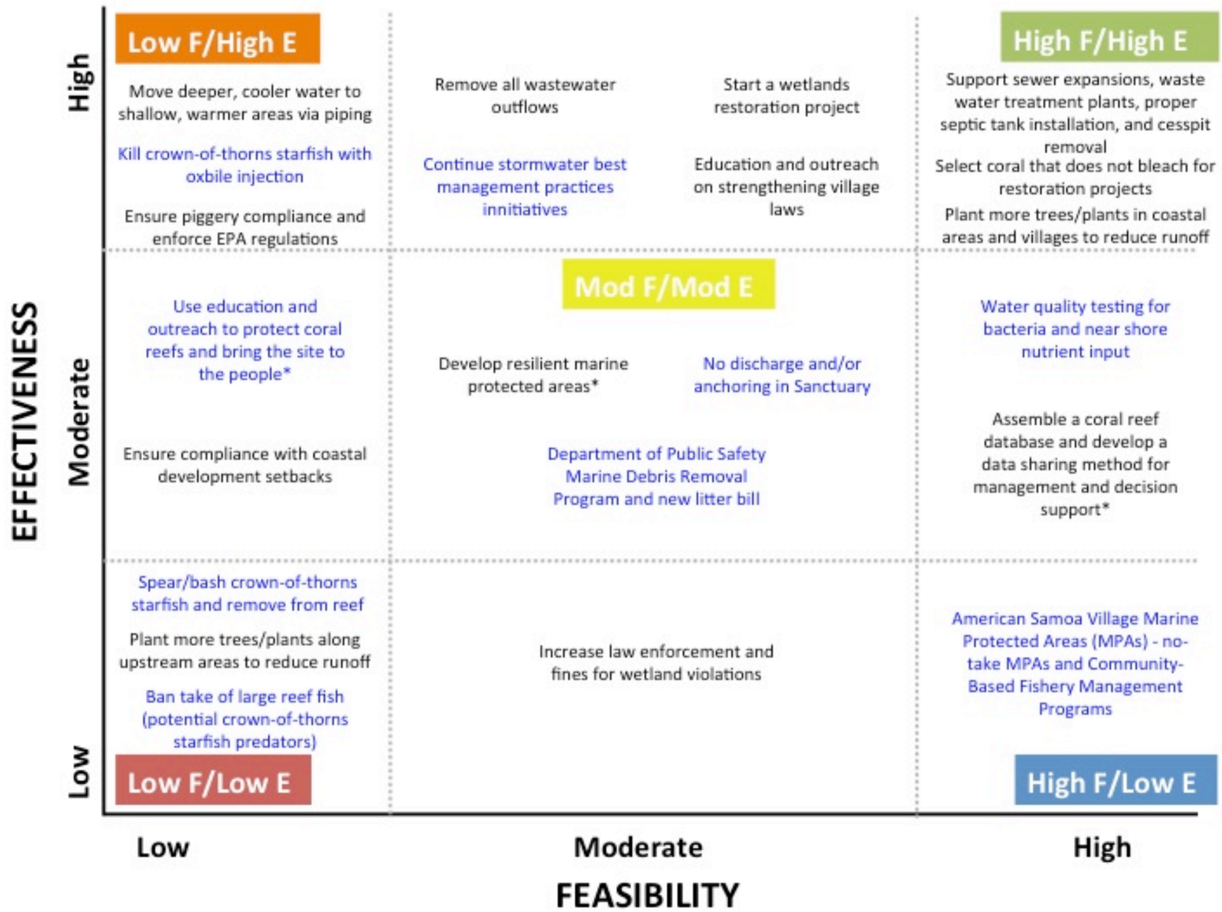


Figure 5. Feasibility and Effectiveness of Current (blue) and Future Adaptation Actions for Coral Reefs.

Note: Effectiveness and feasibility for coral reef current management actions includes, among other factors, workshop participants' perceptions of current acceptance and compliance. Engaging the community to create greater acceptance and compliance can lead to higher effectiveness. Additionally, one reviewer commented that it is good to select corals that are resilient to bleaching for restoration projects, but it is generally considered ineffective because of the scale of the process, i.e., the amount of work needed is large and the area of reef restored is small. Therefore, the reviewer suggested moving "select coral that does not bleach to restoration projects" from the upper right to the lower left.

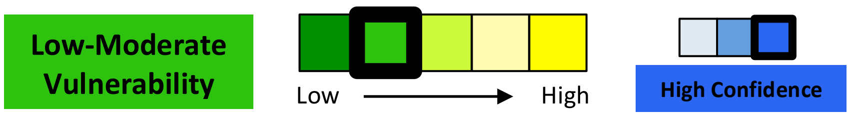
2. Mangroves and Lagoon Habitat

Introduction

Mangrove forests in American Samoa are found only on Tutulia and Aunu'u Islands, and include tidal fringing and interior/partially enclosed basin forests. They are typically found in sheltered coastal lagoons and protected areas near stream mouths (ASCCFP 2010). Three mangrove species occur: oriental mangrove (*Bruguiera gymnorrhiza*) is the dominant species, red mangrove (*Rhizophora mangle*) can be found along seaward margins, and the puzzlenut tree

(*Xylocarpus moluccensis*) is quite rare. Other mangrove forest associates include beach hibiscus (*Hibiscus tiliaceus*), fish-poison tree (*Barringtonia asiatica*), and Tahitian chestnut (*Inocarpus fagifer*) (Bardi and Mann 2004). Mangrove forests thrive in brackish water conditions, and provide critical habitat for a variety of fish, invertebrate, and mollusk species (US DOC NOAA ONMS 2012).

Vulnerability Assessment Results



Workshop participants evaluated American Samoan mangroves to have a low-moderate relative vulnerability to climate change due to moderate sensitivity to climate and non-climate stressors, moderate exposure to projected future climate changes, and moderate adaptive capacity. Mangrove forests are sensitive to coastal erosion and sea level rise, which cause landward retreat, potentially leading to habitat extirpation if retreat is impossible. Earthquakes contribute to sea level changes and tsunami risk; tsunamis and cyclones can severely damage mangrove systems and cause high tree mortality. Non-climate stressors play the largest role in American Samoan mangrove decline. Mangrove clearing changes the coastal hydrology resulting in debris, nutrient and pollutant build up. Additionally, roads/armoring can block landward mangrove migration, increasing habitat vulnerability to sea level rise. Significant portions of mangrove forests have been lost to human land use in American Samoa; only five stands across two islands remain, encompassing roughly 52 hectares (US DOC NOAA ONMS 2012). Mangroves may not recover from extensive alteration or mortality; when stands do recover naturally, recovery time ranges from 15-30 years. Facilitated rehabilitation has experienced varying success. As the key functional group, low mangrove diversity increases habitat vulnerability to climate change, although diversity amongst affiliate tree species is higher. Mangroves provide a variety of ecosystem services (e.g., biodiversity, fish nursery habitat, coastal protection), although there is low cultural recognition of these services. Mangroves are protected through several regulatory mechanisms, but a lack of enforcement undermines this legal protection.

Current Management Actions

Goal: Control residential/commercial development near mangroves to protect mangrove habitat

- Prevent building over mangroves through permitting process (Project Notification and Review System – PRNS)
- Enforcement of special management areas designed specifically to protect mangroves on Tutuila

Future Management Actions

Goal 1: Reduce non-climate stressors such as debris from streams that destroy/smother mangrove habitat

- Remove debris from mangrove habitats

- Educate people on the effect of debris on mangroves and enforce ban on debris thrown out upstream
- Increase use of stream catchments to catch debris

Goal 2: Increase public knowledge of importance of mangroves and increase local enforcement.

- Create mangrove education and outreach campaign to increase understanding of mangroves and understanding of existing guidelines in policies that protect mangroves
- Create targeted village education and outreach campaign to increase likelihood of regulation enforcement

Feasibility and Effectiveness of Current and Future Management Actions

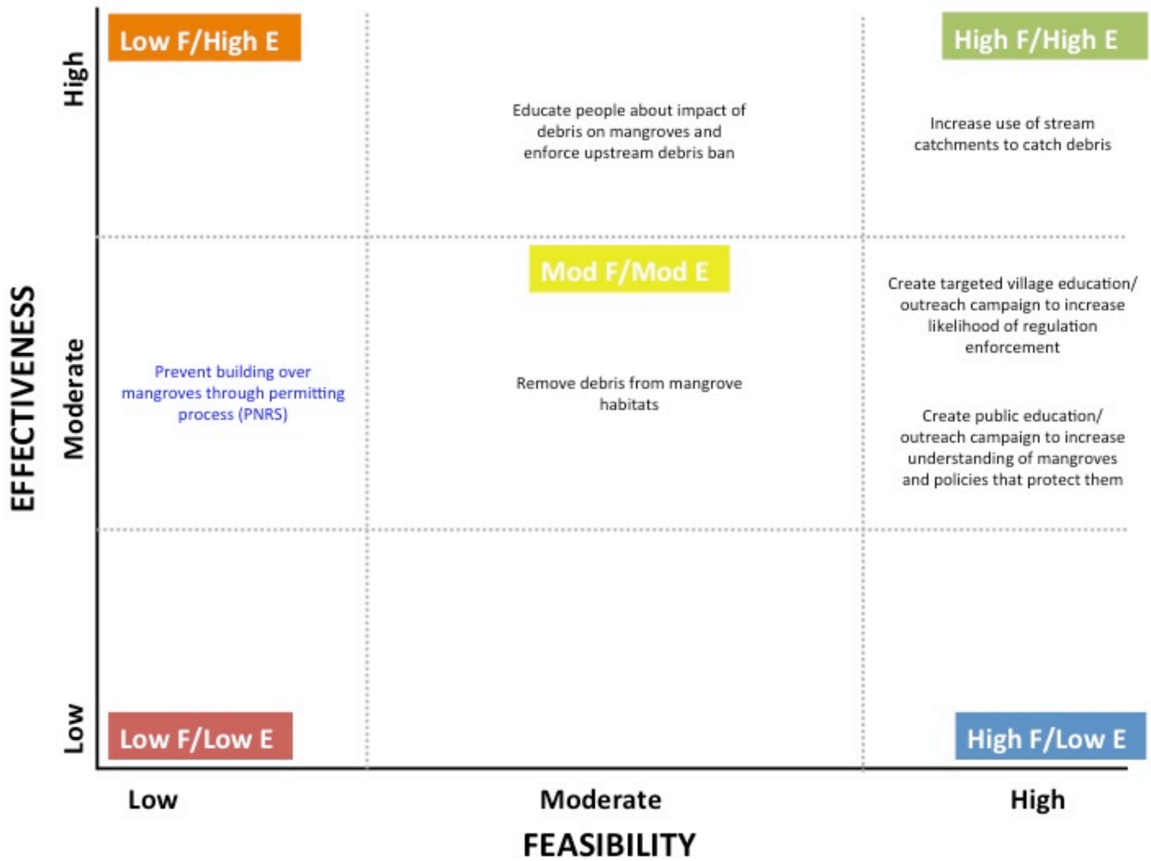


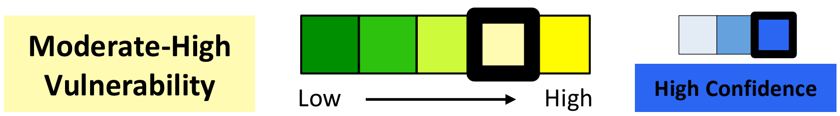
Figure 6. Feasibility and Effectiveness of Current (blue) and Future Adaptation Actions for Mangroves.

3. Water Quality

Introduction

Water quality in American Samoa is compromised by increased population growth, clearing for agriculture, and increased bacterial, pharmaceutical, pesticide, pathogen, and nutrient pollution from poorly constructed human and piggery waste disposal systems. Most of the wells and pumps for groundwater distribution are found in the Tafuna-Leone plain, which is also where most residents and businesses are located (ASEPA 2014). Since the Tutuila volcanic stratum is very permeable, it is also very vulnerable to contamination and pollution from rain events, causing runoff of pollutants such as oil and gas from automobiles, and pathogens and nutrient loading from poorly constructed humans and pig waste water systems. Stream water, which was traditionally used as the primary potable water, has also been compromised by development along streams causing sedimentation, increased erosion, and nutrient and bacterial loading from animal and human waste (ASEPA 2014). Along the coastal shoreline, poor water quality has been threatening nearby fringing reefs. Since the construction of the airport, which altered natural circulation patterns in the Pala Lagoon, the area has had poor water quality and low biodiversity (Craig 2009; ASEPA 2014). Pago Pago Harbor also has poor water quality due to degraded conditions from fuel/oil spills and toxins, and high eutrophication from nutrient loading from land-based sources of pollution (US DOC NOAA ONMS 2012). The fish and invertebrates in the harbor are even contaminated with heavy metals (US DOC NOAA ONMS 2012).

Vulnerability Assessment Results



The relative vulnerability of water quality in American Samoa was evaluated by workshop participants to be moderate-high due to high sensitivity to climate and non-climate stressors, high exposure to projected future changes, and moderate to high adaptive capacity. Water quality is sensitive to climate drivers that alter hydrology of rivers and streams, such as air temperature, tropical storms, precipitation, and drought, causing soil erosion, pollution, and nutrient loading. Other climate drivers, such as ocean acidification and increased ocean temperatures, will impact water quality of nearshore coastal waters. Water in American Samoa is a limited resource found in groundwater and streams, and is very vulnerable to increased demand due to development and population growth. Sea level rise and increased storms will increase saltwater intrusion into groundwater reserves (UGCRP 2009).

Current Management Actions

Goal: Improve water quality

- Improve sewage effluent quality and sewage treatment
    - Secondary treatment
    - UV lights
    - Fix leaking pipes
- Improve groundwater quality
    - Fix leaking pipes
    - Seal cesspools and convert to septic
    - Oil collection
    - Pesticide control
    - Identify resilient aquifers
    - Microfiltration plants
- Improve surface water quality and stormwater management
    - Nets at stream mouths to catch debris

- Rain gardens/soak beds
- Tamaligi tree removal
- Project Notification and Review System (PNRS) sediment permit requirement

- Enforce the Keep American Samoa Beautiful Act (The anti-littering bill was signed into law October 2016)

Future Management Actions

Goal: Develop and instill a sense of responsibility in protecting watersheds and disposing of waste and trash appropriately

- Increase public education and outreach
- Implement and enforce environmental disposal fee to assist with funding
- Find alternatives to pollutants for which American Samoa does not have the capacity to dispose of or treat (e.g., PFCs)

Feasibility and Effectiveness of Current and Future Management Actions

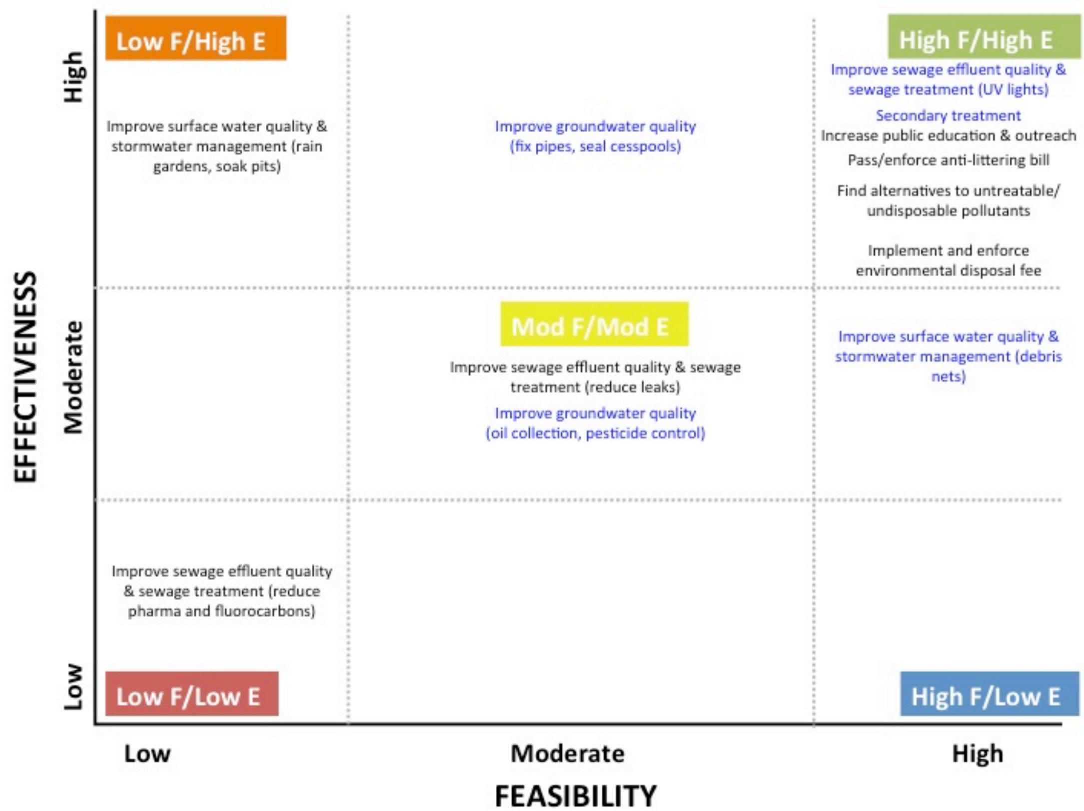


Figure 7. Feasibility and Effectiveness of Current (blue) and Future Adaptation Actions for Water Quality.

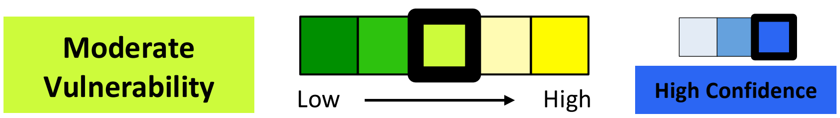
Note: The anti-littering bill was signed into law – Keep American Samoa Beautiful Act – now a current action.

4. Giant Clams

Introduction

Giant clams, including *Tridacna mxima, T.squamosa,* and *T. noae*, are generally found along reef tops and slopes of clear and shallow American Samoa waters. They are particularly abundant in the sanctuary Muliāva Management Area and Rose Atoll Marine National Monument, as well as the north and west sides of Ta’u. They have a special significance to American Samoa cultural heritage, the fa’a-Samoa thus are at risk to be overfished (US DOC NOAA ONMS 2012). Fa'alavelave, traditional gatherings among communities and extended families, include offerings of giant clams when available (Fenner et al. 2008). There have been some aquaculture efforts for *Tridacna sp.* in Tutuila and initiating grow-out facilities in Aunu’u and the Manu’a islands (US DOC NOAA ONMS 2012). Giant clams, *Tridacna sp.* were listed vulnerable on the IUCN red List in 2006 (IUCN 2014).

Vulnerability Assessment Results



Workshop participants and experts evaluated giant clams in American Samoa to have a moderate relative vulnerability to climate change due to moderate-high sensitivity to climate and non-climate stressors, moderate exposure to future climate changes, and moderate-high adaptive capacity. Giant clams are sensitive to several climate stressors, including ocean acidification, ocean temperature, currents, mixing, and stratification. These stressors can directly affect recruitment and growth of giant clams.

Current Management Actions

Goal: Increase giant clam populations

- Enforce harvest regulations to avoid over-harvest of this culturally important resource

Future Management Actions

Goal: Increase giant clam populations/stocks by supporting fisheries in shallow waters and stocking clams in deeper waters

- Support hatchery operations for stocking in shallow water to support fisheries and stocking clams in deep water beyond 100 ft. (30.5 m) for stock replenishment
- Conduct a genetic study of giant clams between islands to diversify seed source

Feasibility and Effectiveness of Current and Future Management Actions

Figure 8. Feasibility and Effectiveness of Current (blue) and Future Adaptation Actions for Giant Clams.

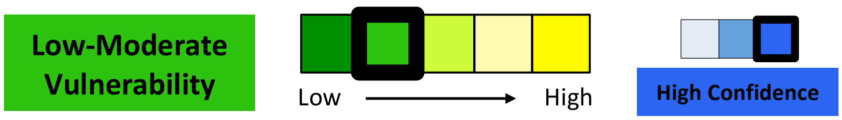
5. Reef Fish

A vulnerability assessment was conducted for reef herbivores, reef piscivores, and charismatic reef fish. During the vulnerability assessment workshops participant felt that each different type of reef fish assemblage should be considered independently since they have unique attributes. During the adaptation strategy workshops, participants felt that current and future management actions to reduce vulnerabilities and increase resilience would be the same for all reef dependent fishes, thus they should be considered as a reef fish assemblage and not differentiated by their attributes.

Reef Herbivores Introduction

Common reef herbivorous fish used for subsistence, artisanal, and recreational purposes include the surgeon fisheries such as the lined surgeonfish or alogo (*Acanthurus lineatus*) and manini and pone (*Acanthurus* sp.) (Craig 2009). Other reef herbivores include parrotfishes (Scaridae), soldierfishes/squirrelfishes (Holocentridae), wrasses (Labridae), and goatfishes (Mullidae). The alogo is a quite abundant and popular Samoan food fish and accounts for approximately 30% of reef fish caught for the subsistence fishery, while the manini and pone are also abundant and popular subsistence and artisanal fisheries (Craig 2009). Parrotfishes and surgeonfishes also have close association to the reef environment. Parrotfishes are known as bioeroders, feeding on detritus on reefs by scrapping reef surfaces, while surgeonfishes are more diverse and can feed on both plant and detrital matter. All reef herbivorous fishes contribute in limiting algal growth in coral reefs and helping to maintain diversity and coral reef health (Comeros-Raynal 2012). Globally these species assemblages are at low risk of extinction. However, they are regionally threatened due to increased harvest from subsistence fisheries. The bumphead parrotfish (*Bolbometapon muricatum*) is considered a prize catch and has been listed as a species of concern because of illegal spearfishing and habitat degradation (US DOC NOAA ONMS 2012).

Reef Herbivore Fish Vulnerability Assessment Results

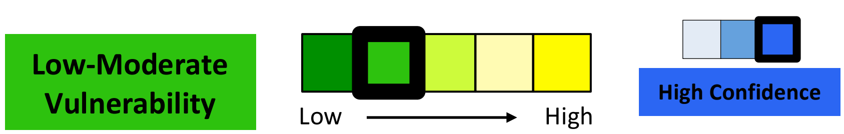


The relative vulnerability of herbivorous reef fish was evaluated by workshop participants to be low to moderate due to moderate sensitivity to climate and non-climate stressors, such as sea surface temperatures, habitat destruction by disease, and invasive species such as the crown-of-thorns starfish; moderate exposure to projected future climate changes in the next 20 years of increased nutrient runoff and sedimentation from precipitation and extreme storms; and high adaptive capacity. Reef fish tend to live near the upper end of their thermal tolerance limit and may experience physiological and developmental impacts and range shifts due to increases in sea temperature (Guidry and Mackenzie 2001; Leong et al. 2014).

Reef Piscivores Introduction

There are over 69 different species of reef fish and invertebrates species/assemblages consumed and sold in American Samoa. Of those targeted, reef-dependent piscivores include jacks (Carangidae), snappers (Lutjanidae), groupers (Serranidae), and emperor fish (Lethrinidae) (Levine and Allen 2009). Continued overfishing and declines in coral reef habitat will negatively impact reef fish populations, which are valuable to commercial, recreational, and subsistence fishermen (Gregg et al. 2016). Many reef-dependent fish that use coral reefs for spawning, foraging, protection, and feeding will likely experience population declines as corals degrade due to increased sea temperature, ocean acidifcation, and invasive species (Leong et a. 2014).

Reef Piscivores Vulnerability Assessment Results

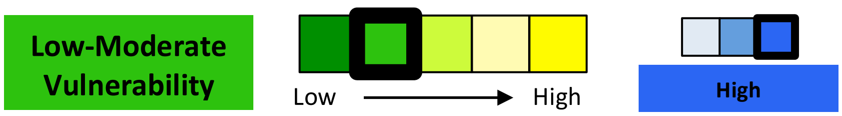


The relative vulnerability of reef-dependent piscivores was evaluated by workshop participants to be low to moderate due to moderate to high sensitivity to climatic and non-climatic stressors including ocean acidification and increased sea surface temperatures impacting reef habitat and biological processes, such as growth and reproduction. Reef-dependent piscivores also are impacted by high fishing pressure and nutrient loading/pollution but have high adaptive capacity with increased management of both habitat and species assemblages.

Charismatic Reef Fish Introduction

Reef fish (both piscivores and herbivores) are abundant and highly diverse with over 930 species (Craig 2009). Many coral reef fish are territorial algal eaters and habitat specialists, tending to only frequent certain habitats within the coral reef system with some taking permanent residence, such as damsels (Pomacentridae), mano'o blennies, and gobies (Gobiidae) (Wass 1984). Damselfish in particular are very territorial and aggressively protect their habitat. Butterflyfishes are fully dependent on feeding on live coral and are vulnerable to the overall decline in coral reefs worldwide (Cole et al. 2008). Charismatic reef species assemblages are also vulnerable to capture for aquaria and/or bioprospecting trade, although there is currently no harvest for the marine ornamental industry in American Samoa.

Charismatic Reef Fish Vulnerability Assessment Results



The relative vulnerability of charismatic reef fish was evaluated by workshop participants to be low to moderate due to moderate to high sensitivity to climatic and non-climatic factors such as ocean acidification, increased sea temperature, land use changes, and dredging that impacts coral reef habitat. Species assemblages will be impacted by future moderate exposure of increased sea surface temperature and erosion causing further sedimentation to the coral reef habitat.

Current Management Actions For All Reef Fish Assemblages

Goal: Protect reef fish populations and ensure sustainable fishing practices

- Fully utilize and enforce all fishing regulations
  - 2001 American Samoa Governor Executive Order banned SCUBA fishing due to depletion of reef piscivores and herbivores and increase in fishing efficacy
  - Minimum fishing net size, and nets cannot be left overnight; nets can only be left unattended 3-5 hours
  - Daily catch limits exist in federal water (3-200 miles) (5-322 km.)
  - Department of Marine and Wildlife Resources Community-Based Fisheries Management Program (0-3 miles) (0-5 km.)
  - Non- destructive fishing rule in territorial waters
  - Encourage true traditional and cultural fishing methods – the fa'a-Samoa "Samoan way"

Future Management Actions For All Reef Fish Assemblages

Goal: Promote diverse and healthy reef fish populations

- Set size limits – make sure they are over the reproductive age (greater number of years at reproductive age could increase the likelihood of recruitment success)
- Set catch limits – number of individual fish per day (if sold, commercial license still needed)

Feasibility and Effectiveness of Current and Future Management Actions for All Reef Fish Assemblages

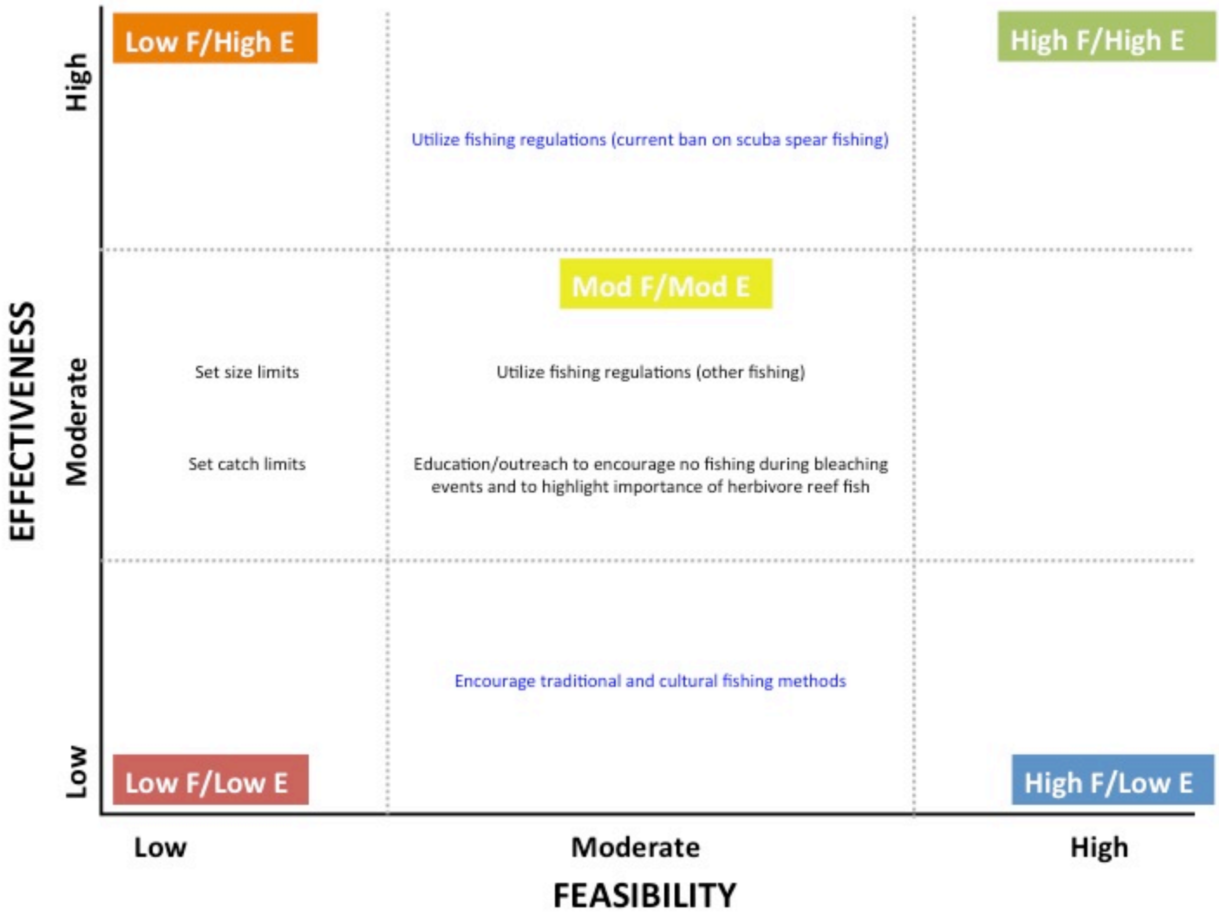


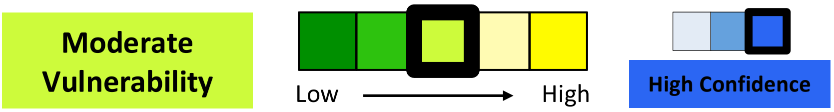
Figure 9. Feasibility and Effectiveness of Current (blue) and Future Adaptation Actions for Reef fish.

6. Pelagic Fish

Introduction

Pelagic fish species in the region are managed through the Western and Central Pacific Fisheries Commission and include migratory tunas such as the bigeye (*Thunnus obesus*), yellowfin or asiasi (*T. albacares*), albacore or apakoal (*T. alalunga*), dogtooth or tagi (*Gymnosarda unicolor*) and skipjack or atu (*Katsuwonus pelamis*) (Craig 2009). Other important species include billfish (*Tetrapturus auda, Makaira mazara, Xiphias gladius*), dolphinfish (*Coryphaena hippurus, C. equiselas*) and wahoo (*Acanthocybium solandri*) (Craig 2009). Most pelagic fish prefer open ocean area and seldom come close to shore; occasionally the dogtooth tuna is seen along reef areas. Although American Samoa has a large tuna packing cannery industry (Chicken of the Sea), tuna is not particularly abundant in the region and most of the tuna canned locally use fish caught in other areas (US DOC NOAA ONMS 2012).

Vulnerability Assessment Results



Commercially valuable pelagic fish species were evaluated to be moderately vulnerable by workshop participants due to changes in temperature, ocean circulation, and ocean acidification. Common migratory pelagic tunas have already shown responses to increased temperatures and changes in circulation patterns during El Niño Southern Oscillation (ENSO) events (Keener et al. 2012; Leong et al. 2014). Future changes in distribution and abundance of migratory species might result due to changes increased temperature and changes in currents affecting prey availability and thermal tolerance.

Current Management Actions /Future Management Actions

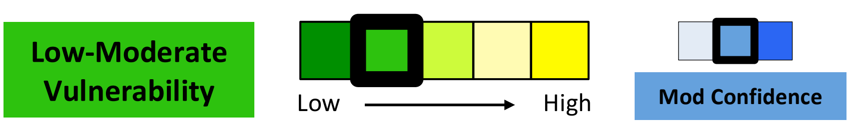
Participants did not evaluate current and future management actions for pelagic fish. They discussed pelagic fish along with sharks and rays but did not complete a full assessment (see below).

7. Sharks and Rays

Introduction

Common species of sharks in American Samoa include the blacktip reef shark (*Carcharhinus melanopterus*) and the whitetip reef shark (*Triaenodon obesus*). Other rarer species include hammerhead sharks, tiger sharks (*Galeocerdo cuvier*), and whale sharks (*Rhincodon typus*) (Craig 2009). The most common species of rays in American Samoa are Eagle rays (*Myliobatidae* sp.). Sharks and rays are generally rare across Indo-Pacific coral reef habitats, and have been protected from catch and possession since 2012 (Craig 2009; US DOC NOAA ONMS 2012). Although sharks are not typically targeted in American Samoa, violations have been observed. Blacktip and whitetip reef sharks are commonly found in nearshore waters and sighted while diving, snorkeling, and swimming. Hammerhead sharks are known to give birth in Pago Pago Harbor, while few tiger sharks have been caught around Tutuila (Craig 2009). Increased sea surface temperatures may affect shark and ray ranges, prey availability, and embryonic development (Hobday et al. 2009). Extreme precipitation events can also diminish their ability to effectively use their sense of smell and electroreception to locate prey (Hobday et al. 2009).

Vulnerability Assessment Results



Sharks and rays were evaluated have low to moderate vulnerability by workshop participants due to climate and non-climate stressors such as ocean acidification, sea surface temperature, and changes in currents and wind. Although sharks are protected, there are threats of harvest for shark fins. Sharks and rays are impacted by the same oceanographic conditions that affect pelagic fish, and as well as by land-based stressors including coastal erosion, sedimentation, and runoff.

Current Management Actions

Participants at the workshop were not familiar with current management actions for sharks and rays and were not comfortable addressing current management actions vulnerability to climate changes in this workshop. (Note: Shark fishing is prohibited by the American Samoa Government).

Future Management Actions

Goal: Increase research on sharks and rays

- Increase research to identify spawning/rearing critical habitat (most are protected)
- Increase research on climate change effects on sharks and rays
- Increased enforcement and court outreach and capacity to lead to convictions

Feasibility and Effectiveness of Current and Future Management Actions

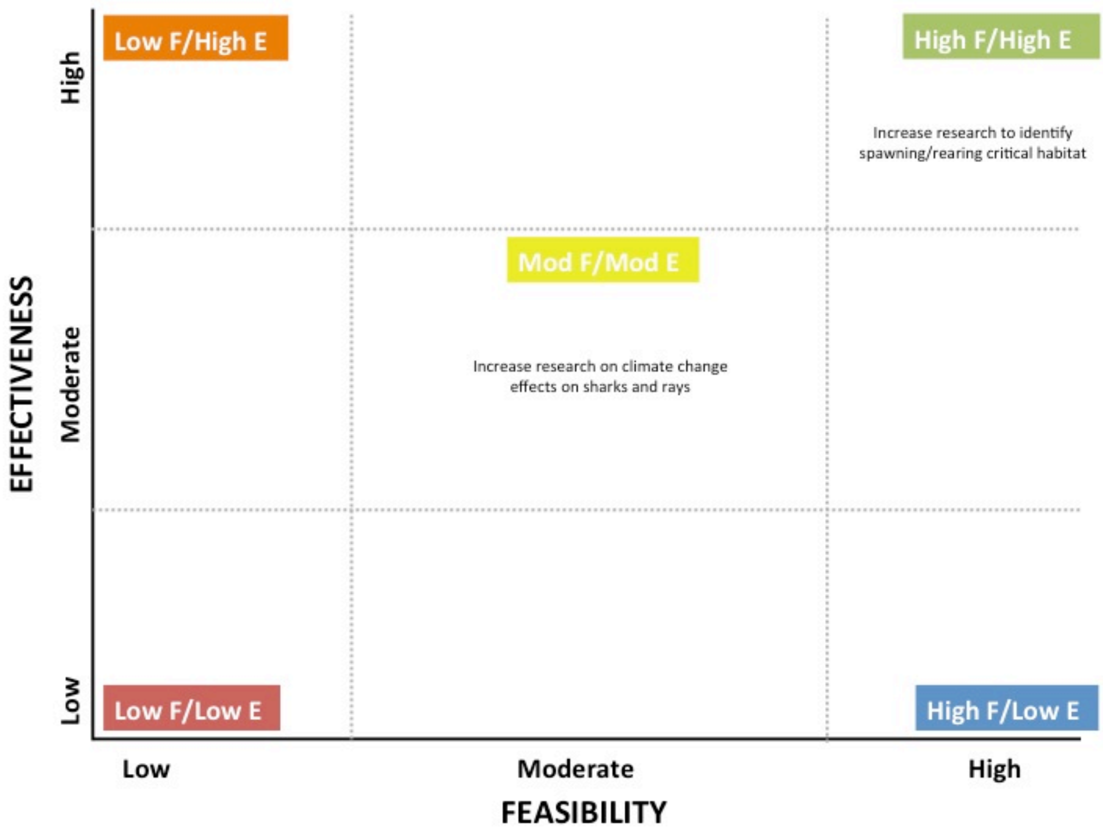


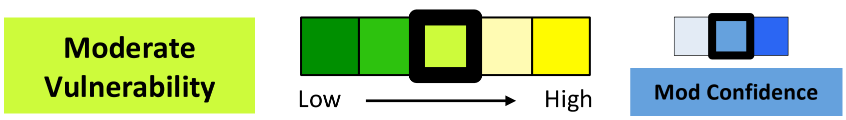
Figure 10. Feasibility and Effectiveness of Current (blue) and Future Adaptation Actions for Sharks and Rays.

8. Sea Turtles

Introduction

Sea turtles in American Samoa, also called Laumei (DMWR 2006), include the endangered hawksbill sea turtle (*Eretmochelys imbricata*) (US DOC NOAA ONMS 2012) and the endangered green sea turtle (*Chelonia mydas)* (81 FR 20058). Both species are globally distributed throughout tropical and sub-tropical zones. Locally, juveniles of both species are commonly found in near-shore coral reef habitats in American Samoa. It has been assumed that only hawksbills nest on beaches of Tutuila, Aunu'u and the Manua Islands (Craig 2009); however, recent tagging work by DMWR and the National Park of American Samoa have confirmed that substantial proportions of turtles nesting on Ofu are green turtles (per comm, M. MacDonald, DMWR) additional surveys are needed to determine if the same is true of other islands. There is a substantial nesting aggregation of green turtles at Rose Atoll. NMFS scientists estimate as many as 300 green turtles nest there (Oram et al 2016), making Rose Atoll, a significant source populations for the central South Pacific Distinct Population Segment of green turtles. Nesting turtles from Rose Atoll have been tracked returning to forage areas in Samoa, American Samoa, Fiji, Cook Islands, Vanuatu, Tahiti, Papua New Guinea, and French Polynesia (NMFS 2015).

Vulnerability Assessment Results



Overall sea turtle vulnerability was rated as moderate by workshop participants due to moderate sensitivity to climate and non-climate stressors, moderate exposure to projected future climate changes, and low to moderate adaptive capacity. Sea turtles are vulnerable to loss of habitat due to sea level rise and coastal erosion (Poloczanska et al. 2009). Increased air and sea temperatures also impact nest sex composition and nesting preference (Cheng and Gaskin 2011). Sea turtle habitat is also threatened by coastal development including coastal armoring, water quality, and light pollution (Cheng and Gaskin 2011). Other non-climatic threats to sea turtles include incidental fisheries catch and possible predation and poaching of eggs.

Current Management Actions

Goal: Protect nesting habitat

- Require permits for sand mining – not a lot of space for nesting on Tutuila
- Amend the Project Notification and Review System (PNRS) setback requirement – 100 ft. (30.48 m) from shoreline
- Monitoring and satellite tagging of nesting turtles

Future Management Actions

Goal 1: Protect turtle nesting habitat by preserving sand

- Create ban on sand mining (may require change in enforcement agency and need to include provisions to allow for cultural use)

- Increase education for why sand is critical for turtles

Goal 2: Protect turtle nests from heat stress

- Increase native grass/vegetation planting to provide shade

Goal 3: Protect turtles by increasing light management

- Use turtle-friendly street lights
    - Paint over lights; paint side that faces beaches
    - Use special types of light bulbs along shorelines
- Increase education for coastal residents and businesses to turn lights off during nesting season
    - Motion sensor lights may already be in use

Goal 4: Create education and outreach campaign about sea turtles and their habitat.

- Create widespread public awareness campaign
- Create a citizen science program for residents to report what they see
- Engage village councils to help protect and enforce laws

Feasibility and Effectiveness of Current and Future Management Actions

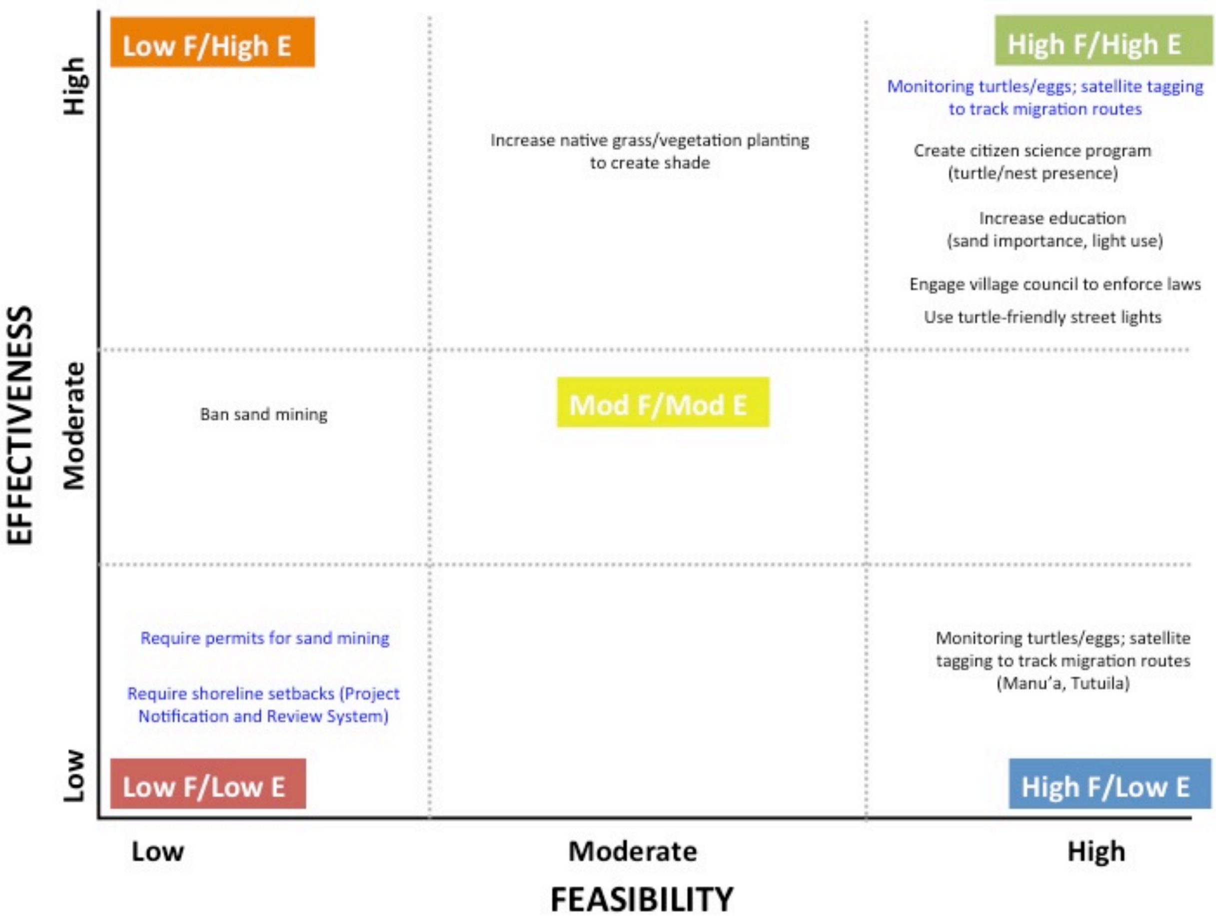


Figure 11. Feasibility and Effectiveness of Current (blue) and Future Adaptation Actions for Sea Turtles.

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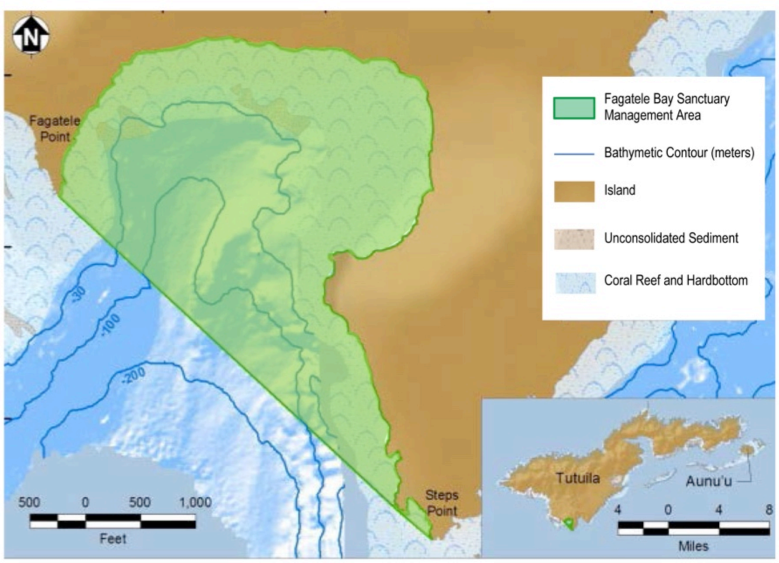
Appendices

Appendix I: National Marine Sanctuary of American Samoa

The National Marine Sanctuary of American Samoa is currently one of 14 sites of the **National Marine Sanctuary System** that includes a network of underwater parks encompassing more than 600,000 square miles (1,553,993 sq. km.) of marine and Great Lakes waters throughout the US mainland and Pacific Islands. Each having its own significance for marine life, cultural and historical phenomenon, economic value, tourism and the unique people and communities in which they are found; sanctuaries are places where people work together to conserve and protect special places (US DOC NOAA ONMS 2012).

On July 26, 2012, five discrete geographical areas were added to the existing Fagatele Bay National Marine Sanctuary 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).

Fagatele Bay Management Area
The Fagatele Bay is entirely no-take. Fishing and other extractive uses are not allowed.
Allowed – non-extractive research, education, and recreation.

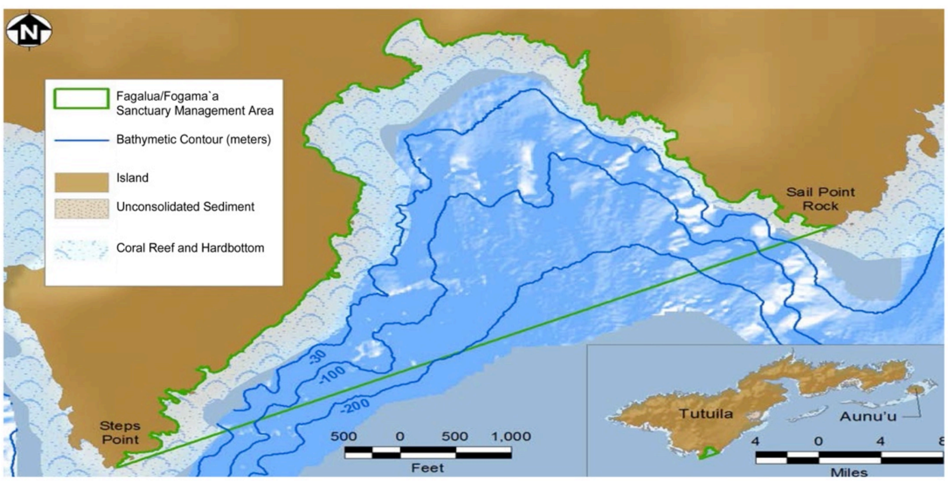


Fagatele Bay is a 0.25 square mile (0.65 sq. km.) treasure off the southwest coast of Tutuila. As of 2012, when the sanctuary expanded, it is now a no-take marine protected area to support what is one of the most biologically diverse areas in the National Marine Sanctuary System and the only sanctuary south of the Equator. The bay has proven to be more resilient than other reefs in the territory as was seen during the most recent, 2015 global coral bleaching event. The cultural significance of Fagatele Bay lies in its connection with a historic coastal village that occupied its shores from prehistoric times through the 1950s. The site has not been excavated, but foundations of structures and pathways remain beneath the overgrown vegetation. Fagatele Bay contains one of the few marine archaeological records in the territory: grinding holes or bait cups carved by Ancient Samoans into the shoreline along the reef edge (US DOC NOAA ONMS 2012).

Surveys have identified at least 200 species of corals in the bay that are thought to be the centerpiece of a community of more than 1,400 species of algae and invertebrates and more than 270 species of fish. Abundant groups include adult and juvenile damselfish, surgeonfish, wrasse, butterflyfish, and parrotfish. Herbivorous species can help decrease available sources of food for threats like juvenile crown-of-thorns starfish that once adults can decimate corals as seen during outbreaks around American Samoa in the 1970s as well as in recent years (US DOC NOAA ONMS 2012).

Fagalua/Fogāma'a Management Area

Allowed – 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, `enu and ola (traditional basket fishing).



Fagalua/Fogāma´a is roughly 0.46 square miles (1.19 sq. km.) of bay area on the southwest shore of Tutuila. The importance of the relationship between this bay and the surrounding environment is comparable to Fagatele Bay, located just over the ridge. Both coves are considered regional hotspots with high coral coverage and 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 resilience of coral reef ecosystems. Within this area, Fagalua is the site of two turtle images carved in a boulder, prehistoric fale foundations and may contain buried archeological deposits (US DOC NOAA ONMS 2012).

Aunu'u Management Areas

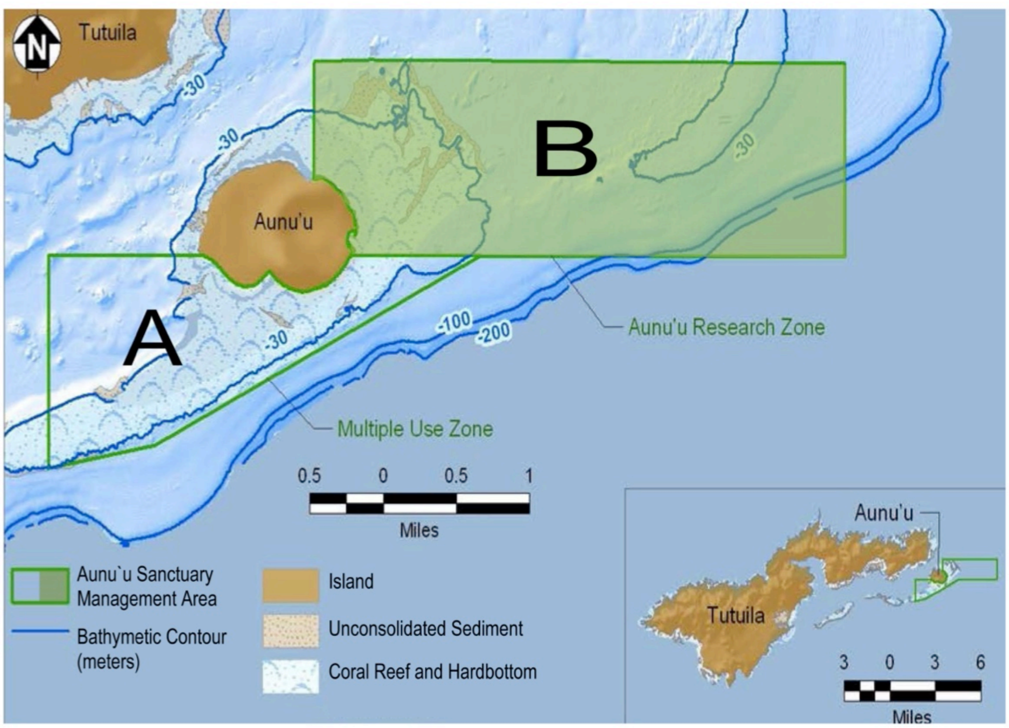
Zone A – Multiple Use Zone

Allowed – 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.

Zone B – Research Zone

Allowed – research, education, recreation and surface fishing for pelagic species – including fishing by trolling. Examples of pelagic fish include: dogtooth or white tuna, skipjack tuna, spearfish, billfish, wahoo, masimasi, rainbow runner and sailfish.

Not Allowed – fishing for bottom-dwelling species. Bottom fishing and trawling is prohibited.

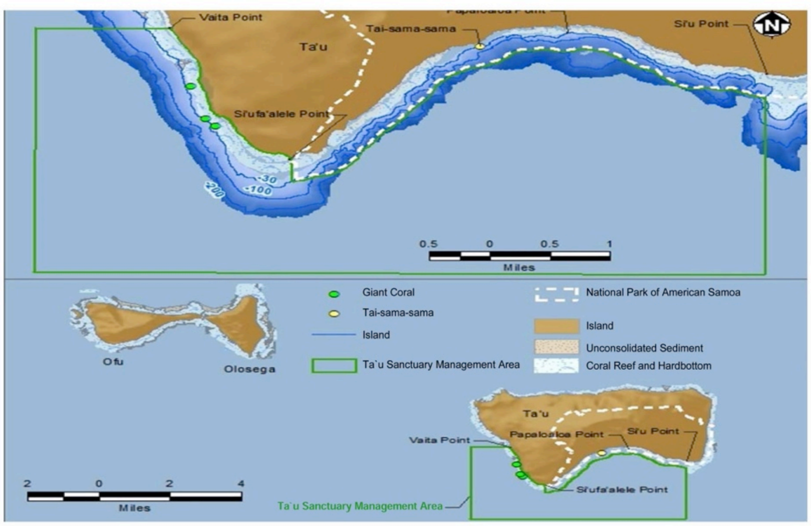


Aunu´u is a small, volcanic island with a land area of 0.58 square miles (1.50 sq. km.). Major features of the island include Aunu´u Crater, Pala Lake (a unique area of red quicksand), and Faimulivai Marsh, the largest freshwater wetland in American Samoa. The island is a National Park Service National Natural Landmark. The area surrounding the island overlaps with four distinct biogeographic regions, making it a highly diverse marine area that includes hot spots for coral cover, fish biomass, and fish richness (US DOC NOAA ONMS 2012).

A total of 5.8 square miles (15.02 sq. km.)of reef and offshore waters around Aunu´u have been included in the sanctuary, with 3.9 square miles (10.10 sq. km.) designated a research zone and allows surface fishing for pelagics only, and 1.9 square miles (4.92 sq. km.) multiple use zone that allows traditional and non-destructive fishing practices. The research and multiple use zones will allow for comparisons over time of an area that prohibits the take of reef fish and bottom dwelling species and benefits to an adjacent area of higher human uses that meets the needs of day-to-day living in sustainable ways (US DOC NOAA ONMS 2012).

The area off the coast of Aunu´u Island consists of marine habitats of varying depth including shallow water reefs to deep waters. The benthic habitats surrounding Aunu´u are very diverse and comprised mostly of coral reef and hardbottom formations. To the east of the island extends a coral bank with extensive aggregate patch reef on its western edge, descending into deeper waters that support mesophotic reefs. Turf algae dominate much of the bank habitat near the island, forming extensive algal plains. Together, these features create a diversity of habitat unique in American Samoa (US DOC NOAA ONMS 2012).

Ta’u Management Area
Allowed – 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, `enu and ola.

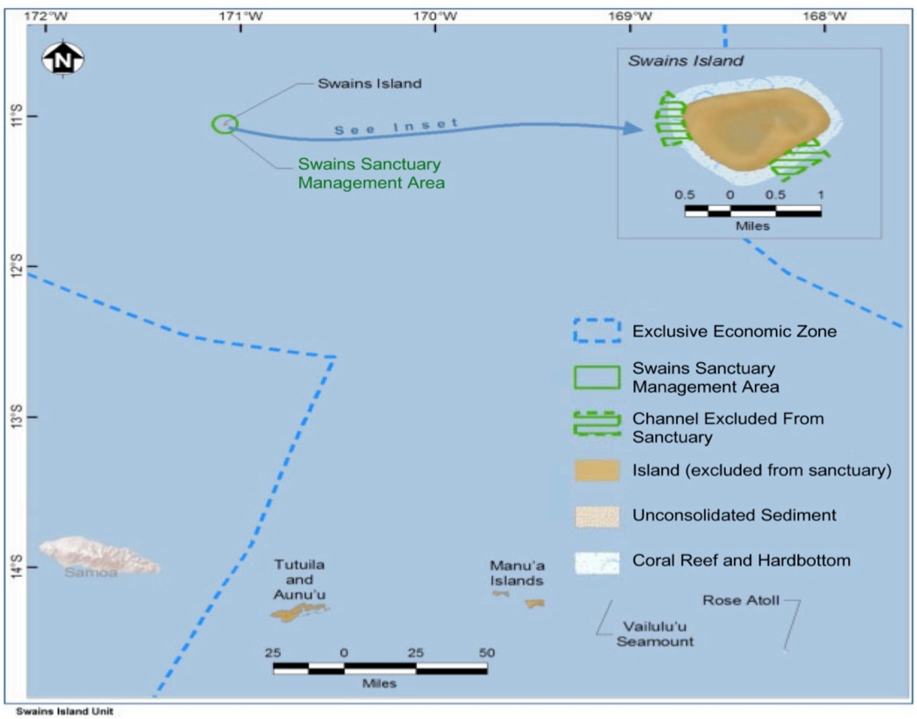


Ta’u Island, part of the Manu’a Island group, is located 70 miles (112.65 km.) east of Tutuila and 6.9 miles southeast of Olosega. The Ta’u Management Area is approximately 14.6 square miles (37.81 sq. km.) and includes both nearshore and deep waters from Si’ufa’alele Point south along the western coast, and includes deep waters beginning 0.25 miles (0.40 km.) offshore, adjacent to the nearshore waters of the National Park of American Samoa (NPSA), along the southern coast between Si’ufa’alele Point and Si’u Point. Located within the sanctuary are massive *Porites* corals in an area known as “Valley of the Giants.” This area is also home to what is believed to be possibly the oldest and largest *Porites* coral in the world. At over 500 years of age, “Big Momma” lies at a depth of 50 feet (15.24 m.), stands 21 feet (6.40 m.) tall, 42 feet (12.80 m.) wide and has a circumference of 135 feet (41.15 m.). This area has become an attraction for researchers as well as a destination for the developing dive tourism industry (US DOC NOAA ONMS 2012).

The western side of Ta’u’s southern coast is a regional hotspot for coral and fish diversity and possesses a distinct coral community. The sanctuary serves as a deep water buffer zone for the marine areas of the NPSA, as well as adding near shore and reef protection around the Porites coral heads (US DOC NOAA ONMS 2012).

Swains Management Area

Allowed – 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, `enu and ola.

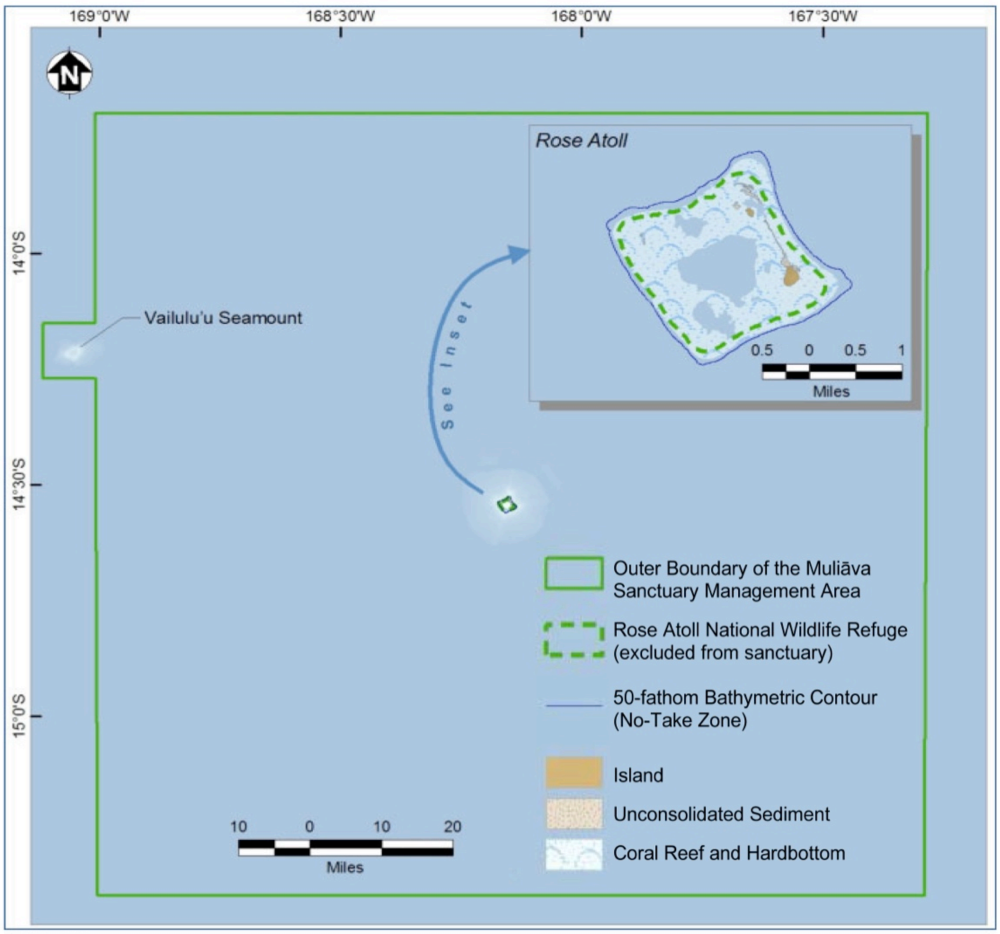


Swains Island is a privately owned low-lying coral atoll located about 200 miles (321.87 km.) northwest of Tutuila. It is approximately 1.5 miles (2.41 km.) in diameter, with approximately 1 square mile (2.59 sq. km.) of highly vegetated sand and coral with a maximum elevation of 6 feet (1.83 m.) above sea level. Swains Island has a high amount of coral cover and many different types of corals. Coral disease is low at Swains Island. Swains Island is characterized by large schools of predators, mostly barracudas, jacks and snappers. Overall, there are high amounts of large fish around Swains Island. This sanctuary area includes 52.3 square miles (135.46 sq. km.) of territorial waters (US DOC NOAA ONMS 2012).

Ocean explorer Jean-Michel Cousteau has referred to Swains Island as “one of the last jewels of the planet.” A 2013 expedition to the island that included offshore, maritime archeology and terrestrial surveys led to discoveries that have experts calling Swains a microcosm of cultural influences in the Pacific. The findings are now available through the NOAA National Marine Sanctuaries publication, “Unlocking the secrets of Swains Island: a Maritime Heritage Resources Survey” (Van Tilburg et al 2013).

Muliāva Management Area

Allowed – research, education, recreation, and fishing with a permit (*see below for additional information*).



Muliāva Unit

Muliāva, part of the Kingdom of Manu´a, means end of the channel. Culturally, the name remains a reference to traditional knowledge of the ocean. Rose, the name appropriate for the color of the corals surrounding Rose Island, has also been referred to as “Motu o Manu” or Island of Birds (US DOC NOAA ONMS 2012).

The Rose Atoll Marine National Monument was established in 2009 by Presidential Proclamation 8337 (74 FR 1577). In 2012, the sanctuary Muliāva management area that includes 13,507.8 square miles (34,985.04 sq. km.) of marine waters was overlayed on to the monument to bring increased protections, regulations, research and education and outreach capacity. At Muliāva, the sanctuary works with the NOAA National Marine Fisheries Service, US Fish and Wildlife Service and the American Samoa Government through an intergovernmental committee for the coordinated management of this incredible place. In 2013, at the recommendation of the Western Pacific Regional Fishery Management Council, NOAA National Marine Fisheries Service enacted additional regulations that prohibited all fishing within 12 nautical miles (22.22 km.) of Rose Island. Non-commercial fishing outside 12 nautical miles (22.22 km.) is prohibited unless authorized by a permit that allows for sustenance, traditional indigenous and recreational fishing (78 FR 32996).

Rose is an appropriate name for the atoll because of the rose-colored crustose coralline algae that dominate the area. Rose is located approximately 150 miles (241.40 km.) east of 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 consists of about .03 square miles (.08 sq. km.) of land and 2.5 square miles (6.47 sq. km.) of lagoon surrounded by a narrow barrier reef that are included in a United States Fish and Wildlife Service National Wildlife Refuge (US DOC NOAA ONMS 2012).

At Muliāva, scientists have chronicled a distinct environment within the archipelago with large numbers of fish and a unique coral community that includes over 270 species of reef fish. Rose has been referred to as a hotspot for fish biomass that supports especially high densities of small planktivorous damselfish (US DOC NOAA ONMS 2012).

Rose Atoll is the primary site for green sea turtle nesting in American Samoa and supports the highest densities of the giant clam *Tridacna maxima* in the Samoan archipelago. More than 93 percent of the adult brood stock of giant clams in the Samoan archipelago is within its protected lagoon. Although similar suitable habitat for the giant clam exists elsewhere in American Samoa, such as on Tutuila and Upolu in the Independent State of Samoa, these unprotected populations have been severely depleted. Elsewhere in the Pacific Islands (Fiji), the giant clam has been harvested to local extinction (US DOC NOAA ONMS 2012).

The sanctuary area also includes the submerged volcanic cone known as the Vailuluʹu Seamount that has a diverse biological community that includes crinoids, octocorals, sponges, and cutthroat eels. Since 2003, an 1100 foot (335.28 m.) tall volcanic cone, known as Nafanua, has grown in the seamount's crater. Scientists speculate that Nafanua will breach the sea surface within decades, forming a new island in the Samoan island group. The seamount cone has several types of hydrothermal vents that provide habitat for an unusual group of organisms, ranging from microbial mats to polychaete worms. A thriving population of the eel *Dysommina rugosa* occupies the summit of Nafanua, surviving on crustaceans imported to the system from the water column above (US DOC NOAA ONMS 2012).

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Appendix II: List of Acronyms

ASEPA: American Samoa Environmental Protection Agency
ASCC: American Samoa Community College
ASG: American Samoa Government
ASPA: American Samoa Power Authority
CRAG: Coral Reef Advisory Group
CRCP: Coral Reef Conservation Program
CZMP: Coastal Zone Management Program
DMWR: Dept. of Marine and Wildlife Resources
DOC: Department of Commerce
DOE: Department of Education
ENSO: El Nino Southern Oscillation
EPA: Environmental Protection Agency
FWS: Fish and Wildlife Service
IPO: Inter-decadal Pacific Oscillation
MPA: Marine Protected Area
NMFS: National Marine Fisheries Service
NMSAS: National Marine Sanctuary of American Samoa
NMSASAC: National Marine Sanctuary of American Samoa Advisory Council
NPSA: National Park Service of American Samoa
NOAA: National Oceanic Atmospheric Administration
OCI: Office of Curriculum and Instruction
ONMS: Office of National Marine Sanctuary
PDO: Pacific Decadal Oscillation
PFCs: Perfluorinated Chemicals
PNRS: Project Notification and Review System
SPREP: Secretariat of the Pacific Regional Environment Programme
USGS: United State Geological Survey
WRRC: Water Resources Research Center

Appendix III: Climate Impacts Summary Table

Climate Variable and Trend	Observed Change	Trend	Relative Change	Future Projections	Confidence	Uncertainty	Source(s)
Air temperature	**Samoa** From 1950-2009: > Average annual temperatures increased +0.25°F (+0.14°C) per decade > Average maximum air temperatures increased +0.4°F (+0.22°C) per decade > Average minimum air temperatures increased +0.07°F (+0.04°C) per decade	↑	High	**Central South Pacific** Annual surface air temperature (compared to 1971-2000) > By 2030: +1.1-1.3°F (+0.61-0.72°C) > By 2050: +1.9-2.5°F (+1.06-1.39°C) > By 2090: +2.5-4.8°F (+1.39-2.67°C) **Pacific Islands** **>** Extreme heat days will become more frequent and intense during the 21st century	> High confidence in trend direction > Medium confidence in trend magnitude	> Magnitude of change varies by greenhouse gas emission scenario: B1 (lower) and A2 (higher)	Australian Bureau of Meteorology and CSIRO 2011; Finucane et al. 2012; Young 2007
Sea surface temperature	**Pacific Islands** > Sea surface temperatures have increased regionally at a rate of 0.13-0.41°F (+0.07-0.23°C) per decade since 1970 **American Samoa and Samoa** > It is difficult to determine long-term trends due to regional variability > American Samoa has exhibited warming trends (exact rates aren't available) > Samoa experienced sea surface warming at a rate of +0.14°F (+0.08°C) per decade from 1970-2011	↑	High	**Pacific Islands** Sea surface temperatures (compared to 1990, ranges represent low [B1] and high [A2] emissions scenarios) 1 > By 2030: +1.1-1.7°F (+0.61-0.94°C) > By 2055: +1.8-2.3°F (+1-1.28°C) > By 2090: +2.5-4.7°F (+1.39-2.61°C)	> High confidence in trend direction > Medium confidence in trend magnitude	> Magnitude varies by emissions scenario: B1 (lower) and A2 (higher) > Shifts in sea surface temperature will also be affected by ENSO, the PDO, and the IPO	Australian Bureau of Meteorology and CSIRO 2011; Keener et al. 2012; Young 2007

Climate Variable and Trend	Observed Change	Trend	Relative Change	Future Projections	Confidence	Uncertainty	Source(s)
Extreme Precipitation Events	**Central South Pacific** > No significant trend in the frequency of extreme rainfall events since 1965	↑↓	Moderate	**Central South Pacific** > Extreme rainfall events will be correlated with tropical storm activity (see below), but are likely to increase in frequency and intensity during the 21st century	> Moderate confidence in trend direction > Low confidence in trend magnitude	> Extreme rainfall projections are highly variable, influenced by ENSO/PDO patterns, and other factors. > Extreme rainfall events that currently occur once every 20 years on average are generally simulated to occur four times per year, on average, by 2055.	Australian Bureau of Meteorology and CSIRO 2011; Keener et al. 2012; Young 2007
Precipitation and drought	**American Samoa** > No significant trends in annual precipitation or winter one-day precipitation volume since 1965 > No change in drought event frequency in 60 years **Samoa** > No significant trends in seasonal or annual rainfall from 1950-2009 or from 1890-2005	↑↓	Low	**Central South Pacific** > Projections are highly variable and display conflicting results > Future conditions may include no change or a slight increase in mean annual precipitation with slight decreases during the dry season and slight increases during the wet season during the 21st century **Samoa** > Drought frequency isn't likely to exhibit major change during the 21st century	> Low confidence in trend direction and magnitude	> Precipitation projections for the Pacific Region are highly variable depending on emissions scenario and are influenced by many factors (e.g., ENSO/PDO/IPO phases, island location and	Australian Bureau of Meteorology and CSIRO 2011; Cheng and Gaskin 2011; Keener et al. 2012; Young 2007

Climate Variable and Trend	Observed Change	Trend	Relative Change	Future Projections	Confidence	Uncertainty	Source(s)
	> No change in drought frequency from 1942-2005, but events are correlated with El Nino conditions					geography). > There is very little long-term annual precipitation data for American Samoa to derive trends and inform projections.	
Tropical storms	**Central South Pacific** > The number of tropical storms escalating to cyclones increased in 1991-2010 relative to 1970-1990.	↑	Low	**American Samoa and Samoa** **>** Potential reduction in cyclone activity as storm tracks shift toward the Central North Pacific **Pacific Islands** **>** Increased storm intensity over the next 70 years	> Low confidence in trend direction and magnitude	> Tropical storm tracks will be influenced by regional variability related to ENSO, the PDO, and the IPO > The region exhibits high inter-annual variability in storm activity	Australian Bureau of Meteorology and CSIRO 2011; Emanuel 2005; Li et al. 2010; Seneviratne et al. 2012; Yu et al. 2010
Streamflow	**American Samoa** > No trend in total streamflow, baseflow, or the number of extreme low- or high-flow days from 1960-1995	No trend	Low	**American Samoa** **>** No specific projections, but streamflow will likely fluctuate with precipitation patterns	> Low confidence in trend direction and magnitude	> There is very little long-term data for American Samoa to derive trends and inform projections. > Many streams in American Samoa experience	Keener et al. 2012

Climate Variable and Trend	Observed Change	Trend	Relative Change	Future Projections	Confidence	Uncertainty	Source(s)
						human modifications to streamflow.	
Sea level rise	**Global** > Global sea levels increased 3.4 mm (+/- 0.4 mm) per year from 1993-2009, representing a much faster rate of rise than the 20th century **Western Tropical Pacific** > Relative rates of sea level rise matched or exceeded global rates from 1993-2010 due to enhanced trade wind conditions **American Samoa** > Mean sea level increased 2.07 mm/year at Pago Pago from 1948-2006	↑	High	**Pacific Islands** Region will experience roughly same mean average sea level rise as global trends. > By 2100: - "Low" scenario: 0.2 m - "Intermediate-Low" scenario: 0.5 m - "Intermediate-High" scenario: 1.2 m - "High" scenario: 2.0 m > Increased frequency of extreme sea level events (linked with high tide events)	> High confidence in trend direction > Low confidence in trend magnitude	> Magnitude projections vary based on model used (climate model vs. semi-empirical model) and emissions scenario. Additionally, sea level rise could accelerate if ice-sheet discharge increases, which is likely given current trends. > Regional variations in sea level rise likely due to land dynamics (subsidence/uplift) and changes in ocean circulation (ENSO/PDO) and wind patterns.	Cheng and Gaskin 2011; Marra et al. 2012; Nerem et al. 2010

Climate Variable and Trend	Observed Change	Trend	Relative Change	Future Projections	Confidence	Uncertainty	Source(s)
Wave height	**Pacific Islands** > No trend in wave heights available	↑	Low	**Pacific Islands** > Increased annual mean wave height in the southern tropical Pacific, decreased wave heights in most other Pacific areas		Few long-term records exist	Hemer et al. 2013; Marra et al. 2012; Seneviratne et al. 2012; Young et al. 2011
Ocean acidification	**Samoa** > Aragonite saturation state declined from 4.5 to 4.1 between the 18th century and 2000	↓	High	**Samoa** > By 2060: aragonite saturation state will fall below 3.5, and continue declining thereafter	> High confidence in trend direction > Moderate confidence in trend magnitude	> Carbon cycles are difficult to model, and regional biases and downscaling challenges exist in current models	Australian Bureau of Meteorology and CSIRO 2011

Appendix IV: Current and Future Adaptation Strategies Tables

Table 1. Current management goals, potential vulnerabilities, and current management actions for coral reefs.

For each current management action participants evaluated its effectiveness (likely to reduce climate vulnerability) and feasibility (likelihood of implementation), and identified climatic and non-climatic stressors the action could help to ameliorate the effects of. Given action effectiveness and feasibility, participants then evaluated whether or not the action should continue to be implemented. If the action was recommended for continued implementation, participants detailed any changes regarding where and how to implement given climate vulnerabilities. Lastly, participants evaluated whether there were potential conflicts with or benefits to other resources from action implementation.

Current Management Goal: Protect coral reef habitat.

Potential vulnerabilities:

- Increased sea surface temperature
- Ocean acidification
- Changes in high precipitation events: increased nitrification

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Water quality testing for bacteria and near shore nutrient input, sometimes resulting in beach closures.	Moderate	High	Serves as an indicator for possible impacts to coral reef habitat	Yes	**Where**: Areas susceptible to bleaching or currently bleached areas **How**: - Implement visibility/light penetration measurements in and outside reef slopes during high precipitation events and poor water	**Other resources action benefits**: Better understanding of water quality pulses around coral reef habitats **Other resources with potential conflicts**: None

					quality measurement periods - More studies to understand what is making it's way into the bay (e.g., what medicines and tracers are found in nearshore water)	
Reduce litter and marine debris.	Moderate	Moderate/High (if enforced)	Yes	Yes, and fully enforce	**Where**: Territory-wide **How**: Ensure island-wide enforcement of regulations against littering	**Other resources action benefits**: - Water quality - Sea turtles (reduces plastics) - Sea birds - Coral habitats **Other resources with potential conflicts**: None
American Samoa Village Marine Protected Areas (MPAs): co-managed by communities and local government (Department of Marine and Wildlife Resources), includes No-Take MPAs and Community-Based Fisheries Management Programs. Each of these MPAs has different	Low Some villages are dependent on coral reef fish for subsistence and MPA effectiveness has not been proven Vulnerability could	High (by permit) Depends on willingness of villages to enact and enforce	Yes, increases coral reef habitat resilience by maintaining herbivore fish populations, which are good for corals	Yes, since MPAs help locally protect herbivore reef fish, but should consider more evaluations of effectiveness	**Where**: In the 11 Village MPAs **How**: - Ensure that openings do not happen during high stress conditions and coral bleaching events to allow for reef recovery	**Other resources action benefits**: All reef-dependent species **Other resources with potential conflicts**: Subsistence and cultural fisheries practices

opening/closure times and lengths.	be very high if MPA openings coincide with high stress conditions (e.g., high sea surface temperature periods, bleaching events)				- Incorporate a monitoring component to evaluate MPA effectiveness	
No discharge and anchoring in the Sanctuary	Moderate/ High Enforcement action by NOAA Fisheries Office of Law Enforcement and DMWR Enforcement through Joint Enforcement Agreement. Effective with proper resources and if more mooring buoys are installed.	Moderate	Yes, helps water quality and coral reef habitat if enforced	Yes, with possible expansion in other areas	**Where**: Coral reef areas, particularly in areas that are more prone to bleaching or other stressors (e.g., crown-of-thorns starfish) **How**: Require no discharge/no anchoring in other areas beyond the Sanctuary	**Other resources action benefits**: All reef dependent species. **Other resources with potential conflicts**: None

Current Management Goal: Control crown-of-thorns starfish outbreaks.

Potential vulnerabilities:

- Temperature changes – unknown how crown-of-thorns starfish will respond
- Temperature and pH – if these factors cause decreased corals, there may less outbreaks
- Nutrient input – may affect crown-of-thorns starfish larvae

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Target crown-of-thorns starfish eradication with oxbile	High Oxbile very efficient since it requires only a single injection, and starfish falls apart in 24 hours. Has been very effective on North Tutuila. Requires dedicated team of divers.	Low/ Moderate Very expensive, and requires large team to remove all starfish. Tow board surveys are very time consuming. Resource intensive and requires lots of infrastructure.	Indirectly; leaves more viable coral populations to repopulate/ recover from other stressors	Yes	**Where**: - NPSA survey at hot spots (previous efforts concentrated in Tutuila and north side of island to keep crown-of-thorns starfish out of the park; very little known about what happens on south shore of Tutuila, Aunu'u, and Swains, but likely outbreaks here have gone unchecked) - Deep reefs – may be refuge for crown-of-thorns starfish, need to learn more, but can be expensive, time consuming, and dangerous to explore – Office of National Marine Sanctuaries re-breather divers periodically survey around Tutuila and	**Other resources action benefits**: Saving corals from crown-of-thorns starfish preserves fish habitat **Other resources with potential conflicts**: - Divers may damage/break corals - Public trust may be undermined if actions/theory not communicated properly

					Aunu'u and will be conducting deep water surveys in 2017 **How**: - Obtain permission from/cooperate with local villages for water and reef access - Train volunteers to distinguish between crown-of-thorns starfish scars versus bleaching/disease impacts to inform biologists/response teams	
Manual eradication of crown-of thorns starfish (spear or bash)	Low/ Moderate Removal is effective at small scale, but very time consuming. Starfish can regenerate – must be removed from water to ensure death. More dangerous/	Low Time consuming and expensive	Indirectly; leaves more viable coral populations to repopulate/ recover from other stressors	Yes, but some concerns about starfish's ability to replicate/ regenerate	**Where**: - Deeper reefs where crown-of-thorns starfish may find refuge - South shore of Tutuila, Aunu'u, and Swains (little known about what's happening there) - Useful method for local village management, but not for large scale **How**:	**Other resources action benefits**: Saving corals from crown-of-thorns preserves fish habitat **Other resources with potential conflicts**: Divers may damage/break corals

	increased diver risk with more handling due to venomous spines.				- Train spearfishers to eradicate local populations (possibly cheaper) - Obtain permission from/cooperate with local villages for water and reef access - Train volunteers to distinguish between crown-of-thorns starfish scars versus bleaching/disease impacts to inform biologists/response teams	
Ban take of large reef fish (e.g., humphead wrasse), which are believed to be crown-of-thorns starfish predators	Low/Unknown Not known which fish may eat young crown-of-thorns starfish, need more information.	Low/Unknown Need more information on which reef fish to protect; need to identify effective predator. Scale also an issue; 50,000+ crown-of-thorns individuals present.	Indirectly; leaves more viable coral populations to repopulate/ recover from other stressors	Yes, but need more info	**Where**: Unknown; potential future management action once research is underway **How**: Research and identify crown-of-thorns starfish predators and effectiveness of predation on starfish populations	**Other resources action benefits**: Could help large fish populations recover (e.g., humphead wrasse) and eventually allow these species to be fished in the future **Other resources with potential conflicts**: None

Current Management Goal: Use education and outreach to protect coral reefs and bring the site to the people.						
Potential vulnerabilities: • Most climate changes will impact corals • Sedimentation • Reduced funds for education and outreach						
Current Management Action	**Current Effectiveness**	**Current Feasibility**	**Does Action Ameliorate Effects of Any Vulnerabilities?**	**Continue to Implement Action Given Climate Vulnerabilities?**	**Where/How to Implement Given Climate Vulnerabilities**	**Other Resource Considerations**
School programs such as Reef Check (geared toward any audience; provides education on coral fragility and importance of coral habitat so audience can become environmental stewards)	Moderate/ High Space limited, requires a lot of staff time	Low/ Moderate Space limited	Yes, helps improve understanding and support for reef protection and action to increase reef resilience	Yes	**Where**: Territory-wide **How**: - Merge and consolidate federal and local programs to reach more people - Combine Sanctuary knowledge with local knowledge; use local governments to help bridge connections territory-wide	**Other resources action benefits**: All reef-dependent species **Other resources with potential conflicts**: None
Have several education programs catered to different age groups that links connections between land and sea - Currently working on	Moderate/ High	Low/ Moderate Space is limited	Yes, helps improve understanding and support for reef protection and action to	Yes	**Where**: - All local schools - Beyond American Samoa (virtually)	**Other resources action benefits**: All reef-dependent species

school curriculum lessons - Sanctuary Summer Science in the Village programs: have school kids visit ocean center or take eco-tours to learn basic science and complement lessons learned during school year - Teacher trainings			increase reef resilience		**How**: - Merge and consolidate federal and local programs to reach more people	**Other resources with potential conflicts**: None
Virtual experience for students, allowing them to see changes, including climate change impacts with special goggles. - "Science of the Sphere" – has 3000 data sets, including climate change topics	Moderate/ High Visualization is a powerful tool	Low/ Moderate Space is limited	Yes, helps improve understanding and support for reef protection and action to increase reef resilience	Yes	**Where**: Ocean Center **How**: Use local climate data and make data more available for sharing	**Other resources action benefits**: All reef-dependent species **Other resources with potential conflicts**: None

Table 2. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for coral reefs.

Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

Future Management Goal: Decrease nutrient input and sedimentation into coastal waters.					
Adaptation action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Ensure piggery compliance and enforce EPA regulations	Low/ Moderate Initiative is already in place, needs regulatory compliance	High Need to follow through; augment through village structure, look at health angles	Near/Mid EPA dependent, needs more enforcement	**Where**: Island-wide: small piggeries, family-based piggeries, community piggeries like community gardens (although community piggeries may cause conflict – disease spreading; maybe work in smaller villages) **How**: - Subcontractor funding to help implement - Public campaign/outreach	**Collaboration**: EPA; Villages determine if family or community piggeries Internal: **Capacity needed**: Funding for public campaigns
Support sewer expansions and new waste water treatment plants; support proper septic tank installment in proper locations; remove existing cesspools	High	High	Near/Mid Long - New wastewater treatment	**Where**: Coastal area community septic systems; lease for the village septic system **How**: - Work with land owners; cesspool removal may have property rights issues	**Collaboration**: - External: EPA, ASPA **Capacity needed**: - New, updated inventory of existing cesspools - Funding (millions) for new central waste water and continued removal

Plant more trees/plants in coastal areas and in villages to reduce runoff. Plant vetiver grass by streams along with native trees. Ensure new construction projects are set back away from streams to prevent erosion.	High (coastal) Need to look at highly resistant coastal plants Low (upstream)	High (coastal) Low (upstream)	Near, as long as there is interest in villages and community-based groups	**Where**: Community villages **How**: - Work with villages – provide incentives through villages and other volunteer programs	**Collaboration**: - External: EPA, Village mayor or pastor - Internal: Community outreach **Capacity needed**: Public outreach and education
Ensure compliance of coastal development setbacks - Enforce 200 ft (60.96 m) for coastal development, 25 ft (7.62 m) from wetland, 50 ft (15.24 m) for commercial development - Increase setbacks and add a 25 ft (7.62 m) buffer from streams	Moderate/ High	Low Needs enforcement	Near/Mid, if there is a will	**Where**: Streams, wetlands, coastal areas **How**: Develop amendments	**Collaboration**: - External: EPA, villages, communities, ASAP - Internal: Coastal Zone Management **Capacity needed**: - Enforcement - Outreach - Funding
Start a wetlands restoration project	High Restoration plan	Moderate Plant mortality can be an issue (e.g., Coconut Point)	Near	**Where**: Coconut Point, Leone, Masefau, Vatia **How**: Monitor for success	**Collaboration**: - External: EPA, DMWR, school groups - Internal: Coastal Zone Management **Capacity needed**: More research to inform success

Increase law enforcement and fines for any violations (wetlands)	Low Damage has been done, but there are opportunities for improvement in the future	Moderate/ High	Near	**Where**: Island-wide **How**: Increase enforcement	**Collaboration**: - External: EPA, villages, ASPA - Internal: ASPA **Capacity needed**: More research to inform success
Education/outreach on strengthening village laws – strengthen village councils while respecting different laws of each village - Village anti-litter laws: enforcement for garbage and fishing, have issued fines in past - Gather evidence	High (education)	Moderate	Near	**Where**: Island-wide **How**: Work with villages and village councils	**Collaboration**: - External: EPA, villages, ASPA - Internal: Villages **Capacity needed**: - Funding - Staff
Continue stormwater best management practices initiative - Require that new development has permeable areas and rain gardens	High, if successfully implemented	Moderate (targeting stormwater outfalls)	Near	**Where**: Island-wide **How**: More education in garbage removal in drains not filled by dirt	**Collaboration**: - External: EPA, USGS, ASPA - Internal: Department of Public Works, ASPA **Capacity needed**: Funding

Remove all wastewater outfalls; upgrade raw sewage discharges to secondary treatment	High, if successfully implemented	Moderate	Near	**Where**: Where existing outfalls are found Aunu'u **How**: Remove outfalls	**Collaboration**: - External: EPA, ASPA - Internal: Department of Public Works, ASPA **Capacity needed**: Funding
Future Management Goal: Cooling for bleaching prevention and reduction.					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Move deeper, cooler water to shallow, warmer areas – pipe down to cold water, pump up, and pipe to distribute	High, but need to make sure it's stable in case of cyclones	Low, based on case study from Hawaiʻi and Great Barrier Reef	Long	**Where**: Hotspot by the airport, where there is a high temperature change and surface temperature. This site is favorable due to thermal dynamics and because it is close to shore, but there hasn't been a feasibility study for this site. ASPA looking at mainstream renewable wind and solar. **How**: - Pipes/infrastructure for thermal cooling - Permitting and infrastructure - Examine lessons learned from Hawaiʻi and Great Barrier Reef	**Collaboration**: - External: engineering, American Samoa Renewable Energy Committee, Ocean Thermal Energy Conversion technology - Internal: ASPA, DMWR **Capacity needed**: - Funding (expensive)

Future Management Goal: Develop resilient marine protected areas (MPAs) – design future MPAs in areas that are climate resilient and effective for multiple species (consider network of MPAs).					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
- Do a GAPS analysis on what is already in place and what is working to identify priority areas for protection and what changes/additions are needed - Explore developing land-connected MPAs and include habitat protection for all species (e.g., sea birds, sea turtles)	Moderate/ High	Moderate	Long (ongoing)	**Where**: - West side reefs, some bays on the North side - MPA with no take to help herbivore fish/locate in areas with good water quality - Look at MPAs of contiguous coral reef that has done well historically; look at areas that do well after coral reefs **How**: - Promote and increase community acceptance of new MPAs, which may take a long time; instill values of habitat importance - Shift from fishing-based MPAs (meant to rebuild fish stocks) to ecosystem-based MPAs and coral reef-focused MPAs	**Collaboration**: - External: federal, local, and territory - Internal: Contractor/DMWR, CRAG/Parks refuge **Capacity needed**: - Funding - Staff - Public support

Future Management Goal: Assemble a coral reef database and develop a data sharing method for management and decision support.					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Develop an easy exchange and accessibility of information to allow managers to assess changes over time	Moderate/ High	High (is available)	Near	**Where**: - American Samoa Coral Reef DATABASE (federal data archive) - Local survey data - Marine Protected Areas	**Collaboration**: - External: NOAA Coral Reef Ecosystem Division, universities, data sharing plans

- Currently, not all projects have one data access point in American Samoa; would be good to have a centralized data access point for information sharing				**How**: Make sure data are being made available to all	- Internal: DMWR/National Park Service **Capacity needed**: Key personnel in each agency that is responsible for sharing
Future Management Goal: Use coral nursery gardens for restoration. Target nurseries of bleaching resistant strands. Make sure to have control sites.					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Select coral that does not bleach (including historic bleaching). - Test *Acropora formosa* (Staghorn) in coral heat tanks before transplanting - Need to look at all physical parameters	High (if water quality is good)	High (at localized scale; larger scale would require more funding)	Near (more sites, more involvement from multiple people)	**Where**: Select sites where water quality is good and other disturbances are low. Pago Pago is not a good area (disturbed due to dredging). **How**: - Survey to identify corals that are not bleaching - Teach volunteers to propagate - Use resilient corals from Alafau, Alofau, Anouli, and Ofu; take multiple colonies for variation	**Collaboration**: - External: Universities (Stanford, Old Dominion, University of Hawai'i) - Internal: DMWR/National Park Service **Capacity needed**: - Volunteers – teach them how to propagate - ASCC Marine Science Program - Funding

Table 3. Current management goals, potential vulnerabilities, and current management actions for mangroves and Pala Lagoon. For each current management action participants evaluated its effectiveness (likely to reduce climate vulnerability) and feasibility (likelihood of implementation), and identified climatic and non-climatic stressors the action could help to ameliorate the effects of. Given action effectiveness and feasibility, participants then evaluated whether or not the action should continue to be implemented. If the action was recommended for continued implementation, participants detailed any changes regarding where and how to implement given climate vulnerabilities. Lastly, participants evaluated whether there were potential conflicts with or benefits to other resources from action implementation.

Current Management Goal: Control residential/commercial development near mangroves to protect mangrove habitat.

Potential vulnerabilities:
- Sea level rise (causes mangrove damage or mortality)
- Storms (causes mangrove damage or mortality)

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Prevent building over mangroves through permitting process (Project Notification and Review System – PRNS)	Moderate	Low-Moderate (enforcement)	Reduces effects of erosion and storm events	Yes	**Where**: Villages with shoreline ownership **How**: - Increase training on importance of mangroves - Increase knowledge of permitting process - Increase setbacks and buffers behind mangroves and integrate into permitting process – current setbacks are ~25-50 ft (7.62-15.24 m). Is this sufficient under sea level rise scenarios? Should it be increased?	**Other resources action benefits**: Healthy mangroves provide fish habitat and de-nitrification benefits. Also benefits crabs and reefs. **Other resources with potential conflicts**: Complications as coastal land owners are primarily villages but permitting is by agencies.

Table 4. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for mangroves and Pala Lagoon.

Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

Future Management Goal: Reduce non-climate stressors such as debris from streams that destroy/smother mangrove habitat.

Adaptation action	Effectiveness	Feasibility	Timeframe	Implementation (where/how)	Collaboration & Capacity
Remove debris from mangrove habitats	Moderate	Moderate	Near	**Where**: High priority watersheds and mangrove habitats such as those in Pala, Leone, and Vatia **How**: Engage volunteers and village residents	**Collaboration**: American Samoa Power Authority, Le Tausagi group (education coordinators from different agencies), villagers, American Samoa Coastal Management Program (lead coordinator of Permit Notification and Review System), DMWR, Governor's office, ASEPA **Capacity needed**: People on the ground – volunteers, staff
Educate people on the effect of debris on mangroves and enforce ban on debris thrown out upstream	High	Moderate	Near	**Where**: High priority watersheds and mangrove habitats such as those in Pala, Leone, and Vatia **How**: Engage volunteers and village residents	**Collaboration**: American Samoa Power Authority, Le Tausagi group (education coordinators from different agencies), villagers, American Samoa Coastal Management Program (lead coordinator of Permit Notification and Review System), DMWR, Governor's office, ASEPA **Capacity needed**: Funding, policy changes to create stricter regulations on debris
Increase use of stream catchments to catch debris	High	High	Near	**Where**: High priority watersheds and mangrove habitats such as those in Pala, Leone, and Vatia	**Collaboration**: American Samoa Power Authority, Le Tausagi group (education coordinators from different agencies), villagers, American Samoa Coastal Management Program (lead coordinator of

				How: Identify areas most suitable for placement of catchments	Permit Notification and Review System), DMWR, Governor's office, ASEPA **Capacity needed**: May need permits for placements of catchments, funding, permission from landowners for placement
Future Management Goal: Increase public knowledge of importance of mangroves and increase local enforcement.					
Adaptation action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Create mangrove education and outreach campaign to increase understanding of mangroves and understanding of existing guidelines in policies that protect mangroves	Moderate	High	Near	**Where**: All areas **How**: - Radio - School curriculum - Cheap/local TV programs (KVCK) - Newspapers	**Collaboration**: DMWR, EPA, CZMP (all have own education programs), Le Tausagi group **Capacity needed**: Funding
Create targeted village education and outreach campaign to increase likelihood of regulation enforcement	Moderate/ High	High	Near	**Where**: Villages **How**: Office of Samoan Affairs	**Collaboration**: Village chiefs **Capacity needed**: Funding

Table 5. Current management goals, potential vulnerabilities, and current management actions for water quality. For each current management action participants evaluated its effectiveness (likely to reduce climate vulnerability) and feasibility (likelihood of implementation), and identified climatic and non-climatic stressors the action could help to ameliorate the effects of. Given action effectiveness and feasibility, participants then evaluated whether or not the action should continue to be implemented. If the action was recommended for continued implementation, participants detailed any changes regarding where and how to implement given climate vulnerabilities. Lastly, participants evaluated whether there were potential conflicts with or benefits to other resources from action implementation.

Current Management Goal: Improve water quality.

Potential vulnerabilities:

- Heavier rain events – increased inflow to sewage lines and water volume needing treatment, increased groundwater infiltration, increased sediment and debris runoff
- Increased number of storms/increased storm strength – increased damage to infrastructure, increased Tamaligi tree toppling
- Increased cost of electricity
- Salt water intrusion due to rising groundwater
- Sea level rise – increased damage to infrastructure, groundwater impacts

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Improve sewage effluent quality and sewage treatment - UV lights - Fix leaking pipes	High (UV elimination of pathogens) Moderate (decreased effluent volume by reducing leaks) Low (managing nutrients, pharma and	High (UV) Moderate (decreased leaks – replacing pipes, ASPA offers free septic pumping as part of groundwater protection recovery fee)	- Pathogens removed by UV light - Reducing leaks moderately decreases effluent released into groundwater and surface water. - New diffuser helps spread	UV – yes Decrease leaks – yes New diffuser – yes	**Where**: - Low-lying communities - System-wide - Treatment plants and power plants may need to be moved **How**: - Move treatment plants in communities - Create leak-proof system - Increase renewables and energy efficiency	**Other resources action benefits**: - Decreased pathogens and nutrients benefits many resources - Leak proofing decreases costs and improves public health **Other resources with potential conflicts**: - Limited money and land

	fluorocarbons)	Low (pharma and fluorocarbons)	effluent and reduces nutrient concentrations			- Increased energy consumption would increase cost (need to speed up renewable energy)
Improve groundwater quality - Fix leaking pipes - Seal cesspools and convert to septic - Oil collection - Pesticide control - Identify resilient aquifers - Microfiltration plants	High (pipes, cesspool) Moderate (oil – high for all who use it) Moderate (pesticides – high if farmers comply) Aquifers are resilient; higher elevation and microfilters would add to capacity	Moderate (cesspool conversion requires management by families to work over long term)	Protect/improve groundwater quality	Yes	**Where**: - Farms (pesticides) - Low-lying communities **How**: - Move low-lying septic systems - Monitor because sea level rise may decrease aquifer volume - Create/enforce soil and pesticide protocols throughout watersheds	**Other resources action benefits**: - Increased water quality and quantity - Increased watershed habitat **Other resources with potential conflicts**: - Limited money and land
Improve surface and storm water quality - Nets at stream mouths to catch debris - Rain gardens/soak beds - Tamaligi tree removal - PNRS sediment requirement	Moderate (nets) High (rain gardens/soak pits – if placed correctly and in sufficient numbers) Low	High (nets – if there's a will, but really need to stop debris) Low (rain gardens/ soak pits)	Capture sediment and debris runoff	Yes	**Where**: By streams **How**: Place nets at stream mouths	**Other resources action benefits**: Debris/sediment capture benefits coral reefs and nearshore habitats/species **Other resources with potential conflicts**: No answer provided by participants

Table 6. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for water quality.

Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

<table>
<tr><th colspan="6">Future Management Goal: Develop and instill a sense of responsibility in protecting watersheds and disposing of waste and trash appropriately.</th></tr>
<tr><th>Adaptation action</th><th>Effectiveness</th><th>Feasibility</th><th>Timeframe</th><th>Implementation (where/how)</th><th>Collaboration & Capacity</th></tr>
<tr><td>Increase public education and outreach</td><td>High</td><td>High</td><td>Near (1-2 years)</td><td rowspan="4">Where:
- Project Notification and Review System (PNRS): public works enforcement of building codes
- Agency collaboration with villages

How:
- Issue tickets and fines</td><td rowspan="4">Collaboration: ASPA, ASEPA, PNRS, ASDOE, Public Works, Office of Samoan Affairs, National Oceanic and Atmospheric Administration, Parks and Recreation, FWS, WRRC, University of Hawaiʻi, Sea Grant, DOC

Capacity needed:
- Funding
- Policy change
- Increased political cooperation and will</td></tr>
<tr><td>Enforce anti-littering law</td><td>High</td><td>High</td><td>Near</td></tr>
<tr><td>Implement and enforce environmental disposal fee to assist with funding</td><td>High</td><td>High</td><td>Near</td></tr>
<tr><td>Find alternatives to pollutants we don’t have the capacity to dispose and treat (e.g., PFCs)</td><td>High</td><td>High</td><td>Near</td></tr>
</table>

Table 7. Current management goals, potential vulnerabilities, and current management actions for giant clams. For each current management action participants evaluated its effectiveness (likely to reduce climate vulnerability) and feasibility (likelihood of implementation), and identified climatic and non-climatic stressors the action could help to ameliorate the effects of. Given action effectiveness and feasibility, participants then evaluated whether or not the action should continue to be implemented. If the action was recommended for continued implementation, participants detailed any changes regarding where and how to implement given climate vulnerabilities. Lastly, participants evaluated whether there were potential conflicts with or benefits to other resources from action implementation.

Current Management Goal: Increase giant clam populations.

Potential vulnerabilities:

- Increased sea surface temperature
- Ocean acidification
- Erosion/Sedimentation (affects water clarity and quality)

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Enforce harvest regulations to avoid over-harvest of this culturally popular food Existing regulations: - Clams taken for consumption must be at least 6 inches in shell length - Clams taken for sale must be at least 7 inches in shell length	High/ Moderate	Low – enforcement requires funding	Helps maintain a healthy population. Does not really address climate vulnerabilities, but helps address the non-climate factor of over-fishing	Yes	**Where**: Territory-wide **How**: Need better law enforcement. Work with village councils to ensure minimum size limits are locally enforced.	**Other resources action benefits**: Less fishing generally protects coral reef habitats **Other resources with potential conflicts**: None known

- Prohibition on take of clams in the sanctuary						

Table 8. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for giant clams.

Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

Future Management Goal: Increase giant clam populations/stocks by supporting fisheries in shallow waters and stocking clams in deeper waters.

Adaptation action	Effectiveness	Feasibility	Timeframe	Implementation (where/how)	Collaboration & Capacity
- Support hatchery for stocking in shallow water to support fisheries and stocking clams in deep water beyond 100 ft (30.48 m). to support stock replenishment - Conduct a genetic study of giant clams between islands to diversify seed source	High (50,000 clams per year)	Low (funding dependent)	Near- to Mid-term (takes about 5 years for harvesting time)	**Where**: Work with village council to get permission and place in local villages with good bay and water quality **How**: Work with villages to enforce minimum size fishing; and the requirement to sell the giant clam with the shell (6” personal; 7” commercial)	**Collaboration**: - External: University Master student to work with local schools and local village to increase support for giant clams restocking efforts - Internal: National Park Service, American Conservation Experience (NGO) **Capacity needed**: - Graduate students for community outreach and studying impacts of thermal stress in hatchery - Funding

Table 9. Current management goals, potential vulnerabilities, and current management actions for reef fish.
For each current management action participants evaluated its effectiveness (likely to reduce climate vulnerability) and feasibility (likelihood of implementation), and identified climatic and non-climatic stressors the action could help to ameliorate the effects of. Given action effectiveness and feasibility, participants then evaluated whether or not the action should continue to be implemented. If the action was recommended for continued implementation, participants detailed any changes regarding where and how to implement given climate vulnerabilities. Lastly, participants evaluated whether there were potential conflicts with or benefits to other resources from action implementation.

Current Management Goal: Protect reef fish populations and ensure sustainable fishing practices.

Potential vulnerabilities:

- Stressed coral habitats will impact fish populations
- Climate changes may be temporarily beneficial for herbivore fish
- There may be abuse of subsistence fishing privileges for commercial use

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Fully utilize and enforce fishing regulations - 2001 American Samoa Governor Executive Order banned SCUBA fishing due to depletion of reef piscivores and herbivores and increase in fishing efficacy. - Minimum fishing net size, and nets	High (SCUBA spear fishing) – no more need for industry in filling SCUBA tanks for fishing, more controlled now Moderate/Low (other fishing) – need more regulation and enforcement	Moderate/ Low – Regulation feasibility/ enforcement issue	Yes, but limited	Yes	**Where**: Territory-wide **How**: Possible limits for reef fish including herbivores	**Other resources action benefits**: - More protection for herbivorous fish - Protects coral reef habitat **Other resources with potential conflicts**: None known

cannot be left overnight; nets can only be left unattended 3-5 hours. - Daily catch limits exist in federal water (3-200 miles) (5-322 km). - Community Fisheries Management Program (0-3 miles) (0-5 km.) - Non- destructive fishing rule in territorial waters - Existing no-take-areas						
Encourage traditional and cultural fishing methods – the fa'a-Samoa "Samoan way" –the following sanctuary areas encourage traditional and non-destructive fishing practices: Fagalua/Fogāma'a, Aunu'u Multipurpose Area, Ta'u, Swains Island	Low/Moderate	Moderate/ High	Yes, but limited	Yes, if truly traditional fishing	**Where**: All villages **How**: Make sure only true traditional fishing methods are allowed	**Other resources action benefits**: Benefits coral reef habitat by reducing fishing impacts **Other resources with potential conflicts**: None known

Table 10. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for reef fish.

Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

Future Management Goal: Promote diverse and healthy reef fish populations.

Adaptation action	Effectiveness	Feasibility	Timeframe	Implementation (where/how)	Collaboration & Capacity
Set size limits – make sure they are over the reproductive age	Moderate/ High (if enforced)	Low – lack of social or political support	Near/Mid – needs DMWR support	Where: Territory-wide How: New legislations and regulations as well as enforcement capacity Broad-reaching education on importance of herbivore fish, maybe through villages	Collaboration: External: Village councils Internal: DMWR Capacity needed: Social buy-in Policy change
Set catch limits – number of individual fish per day (if sold, commercial license still needed)	Moderate/ High (if enforced)	Low – complicated by many species present and different size	Near/Mid – needs DMWR support		
Educational outreach to encourage not to fish during bleaching events and to highlight the importance herbivore reef fish	Moderate/ Low (takes lots of time)	Moderate	Near		

Table 11. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for sharks and rays.
Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

Future Management Goal: Increase research on sharks and rays.

Adaptation action	Effectiveness	Feasibility	Timeframe	Implementation (where/how)	Collaboration & Capacity
Increase research to identify spawning/rearing critical habitat (most are protected)	High	High	Near	**Where**: Territory-wide; in harbors, Airport Lagoon, offshore Sailele **How**: Can be done but expensive - Pacific Islands Fishery Science Center cruises may present an opportunity - Interview fishermen to ask about historic vs. current presence	**Collaboration**: - DMWR - Outside academics - Hawaiʻi Institute of Marine Biology **Capacity needed**: - Funding - Staff
Increase research on climate change effects on sharks and rays	Moderate	Moderate	Near	**Where**: N/A **How**: Academia	**Collaboration**: Academia **Capacity needed**: - Funding - Staff

Table 12. Current management goals, potential vulnerabilities, and current management actions for sea turtles. For each current management action participants evaluated its effectiveness (likely to reduce climate vulnerability) and feasibility (likelihood of implementation), and identified climatic and non-climatic stressors the action could help to ameliorate the effects of. Given action effectiveness and feasibility, participants then evaluated whether or not the action should continue to be implemented. If the action was recommended for continued implementation, participants detailed any changes regarding where and how to implement given climate vulnerabilities. Lastly, participants evaluated whether there were potential conflicts with or benefits to other resources from action implementation.

Current Management Goal: Protect turtle nesting habitat.

Potential vulnerabilities:

- Erosion
- Sea level rise (Rose Atoll is a major nesting site for green turtles, and is only 10 feet above sea level)
- Seawalls and other physical barriers

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Require permits for sand mining – not a lot of space for nesting on Tutuila	Low – no enforcement	Low	New erosion of nesting habitat	Yes	**Where**: Territory-wide: areas within Tutuila, Ofu & Olosega where nesting is already high **How**: - Enforcement: possibly transition management authority from Parks and Recreation to another entity - Education: community taking sand to make concrete for village graves; increase education on cumulative impacts of everyone "taking a little bit" - Create low-cost opportunities	**Other resources action benefits**: Seabirds and shorebirds **Other resources with potential conflicts**: No answer provided by participants

					to reduce sand removal (e.g., possibly crush glass bottles to create "fake" sand that can be used for concrete; encourage green/brown burials) - Education on benefits of conserving sand in order to protect cultural uses; use to promote conservation - Create cultural designation of sand mining sites - Protect parrotfish to help create sand	
Amend the Project Notification and Review System (PNRS) setback requirement – 100 ft (30.48 m). from shoreline	Low	Low	New erosion of nesting habitat	Yes	**Where**: Territory-wide **How**: - Functionality: lots of development still happens very close to shoreline, so increase compliance and enforcement Education and knowledge of permitting process	**Other resources action benefits**: Seabirds and shorebirds **Other resources with potential conflicts**: No answer provided by participants
Monitor to detect number of turtles and eggs, satellite tagging to track migration routes	High (Rose Atoll – major nesting site) Low (Manu'a, Tutuila because not many turtles)	High	No answer provided by participants	Yes	**Where**: Territory-wide **How**: - Document locations, including changes: data could help inform future locations of development and designate critical habitat. - Track turtles that migrate to	**Other resources action benefits**: No answer provided by participants **Other resources with potential conflicts**: No answer provided by participants

					Fiji and French Polynesia (complex migrations) - Identify genetic structure of population - Increase education to decrease fishing during nesting seasons – create collaborations with news agencies to let public know when nesting occurs - Increase public knowledge to help report nests (“I Saved a Turtle” t-shirt or patch) - Get more temperature loggers out for tracking temperature - SPREP: tagging databases so you can track who has tagged what - Monitoring beach profiles at Rose Atoll to track changes from storms and cyclones – also LiDAR	

Table 13. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for sea turtles.

Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

Adaptation action	Effectiveness	Feasibility	Timeframe	Implementation (where/how)	Collaboration & Capacity
Future Management Goal: Protect turtle nesting habitat by preserving sand.					
Create ban on sand mining (may require change in enforcement agency and need to include provisions to allow for cultural use)	Moderate	Low	Mid	**Where**: Known nesting beaches **How**: May require change in enforcement agency dictated by Governor's Office. Lobby the Fono.	**Collaboration**: Parks and Recreation, Village Councils, Governor's Office, Fono, Office of Samoan Affairs **Capacity needed**: - Policy change - Funding - Staff
Increase education for why sand is critical for turtles	High	High	Near	**Where**: Territory-wide and Village Council meeting days (once a month) **How**: DOC/Coastal Zone Management/Incorporate into curriculum for DOE, ASCC	**Collaboration**: DOC, Coastal Zone Management Program, DOE, ASCC, ASEPA, DMWR, Office of Samoan Affairs **Capacity needed**: Funding
Future Management Goal: Protect turtle nests from heat stress.					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Increase native grass/vegetation planting to provide shade	High	Moderate	Near	**Where**: Known nesting beaches plus beaches with high potential for nests **How**: - Collect seeds/cuttings for propagation	**Collaboration**: Village Councils, DMWR, ASCC, Land Grant, Office of Samoan Affairs **Capacity needed**: - Staff

				near beaches - Villages should take initiative for local plantings Leverage and expand Territory coastal vegetation restoration efforts (living shorelines, coastal rain gardens) to protect turtles	- Funding - Land for nursery
Future Management Goal: Protect turtles by increasing light management.					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Use turtle-friendly street lights - Paint over lights; paint side that faces beaches - Use special types of light bulbs along shorelines	High	High	Near	**Where**: Along coastlines. **How**: Public Works, working with DMWR and village councils	**Collaboration**: Public Works, DMWR, Le Tausagi, Office of Samoan Affairs **Capacity needed**: Funding
Increase education for coastal residents and businesses to turn lights off during nesting season - Motion sensor lights may already be in use	High	High	Near	**Where**: Coastal villages. **How**: DMWR, Le Tuasagi school programs, outreach programs in villages	**Collaboration**: DMWR, Le Tausagi, Office of Samoan Affairs **Capacity needed**: Funding

Future Management Goal: Create education/outreach campaign about sea turtles and their habitat.					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Create widespread public awareness campaign	High	High	Near	**Where**: Territory-wide, village council re: nesting habitats **How**: - Build off of school programs - Targeted during peak nesting season - Media blitz – commercials, billboards, school programs	**Collaboration**: DMWR, Sanctuaries, National Park Service **Capacity needed**: - Staff - Funding
Create a citizen science program for residents to report what they see	High	High	Near	**Where**: Territory-wide **How**: - Create or find protocols for tracking and reporting turtle presence and nests - School programs - Make phone number to report presence and non-compliance; phone number should be catchy/in a jingle - Perhaps create volunteer-tourism opportunities (EarthWatch)	**Collaboration**: DMWR, Sanctuaries, National Park Service **Capacity needed**: - Volunteers - Protocols
Engage village councils to help protect and enforce laws	High (within village boundaries there is high enforcement and compliance)	High	Near	**Where**: Villages **How**: - Target villagers – there will be higher compliance if villagers can be enforcers. - Communication tool: demonstrate why protection is important and what will happen without protection	**Collaboration**: Village councils **Capacity needed**: Funding