AMERICAN SAMOA COASTAL RESILIENCE ASSESSMENT

2021

Greg Dobson, Ian Johnson, Virginia Kowal, Kim Rhodes
UNC Asheville's NEMAC
Kristen Byler
National Fish and Wildlife Foundation
Bridget Lussier
Lynker, on contract to NOAA Office for Coastal Management

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Report cover images: Vatia, Tutuila (© eddy23) (top); coral reef under crashing wave (bottom)

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Project Team and Partners

National Fish and Wildlife Foundation	Kristen Byler, Kaity Goldsmith, Chris Burdett, Mike Lagua
National Environmental Modeling and Analysis Center	Greg Dobson, Ian Johnson, Virginia A. Kowal, Kim Rhodes, Dave Michelson, Matthew Geiger
National Environmental Modeling and Analysis Center Student Interns	Lindsey Nystrom, Anitra Griffin
National Oceanic and Atmospheric Administration	Bridget Lussier*, Julia Royster, Elaine Vaudreuil, Laura Petes, Kim Penn

Advisory Committee

National Oceanic and Atmospheric Administration, Office for Coastal Management	Hideyo Hattori*
National Oceanic and Atmospheric Administration, National Marine Fisheries Service	Dr. Bernardo Vargas-Ángel
Office of Disaster Assistance and Petroleum Management	Lima Fiatoa
Coastal Management Program	Gina Faiga-Naseri
Hawaiʻi Sea Grant and American Samoa Community College	Kelley Anderson Tagarino
Department of Marine and Wildlife Resources	Maria Vaofanua
U.S. Fish and Wildlife Service	Chris Swenson

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** Contractor with Lynker Technologies*

GLOSSARY OF RELEVANT TERMS

The analysis was developed in adherence to the following terms and their definitions adapted from the U.S. Climate Resilience Toolkit and NFWF.

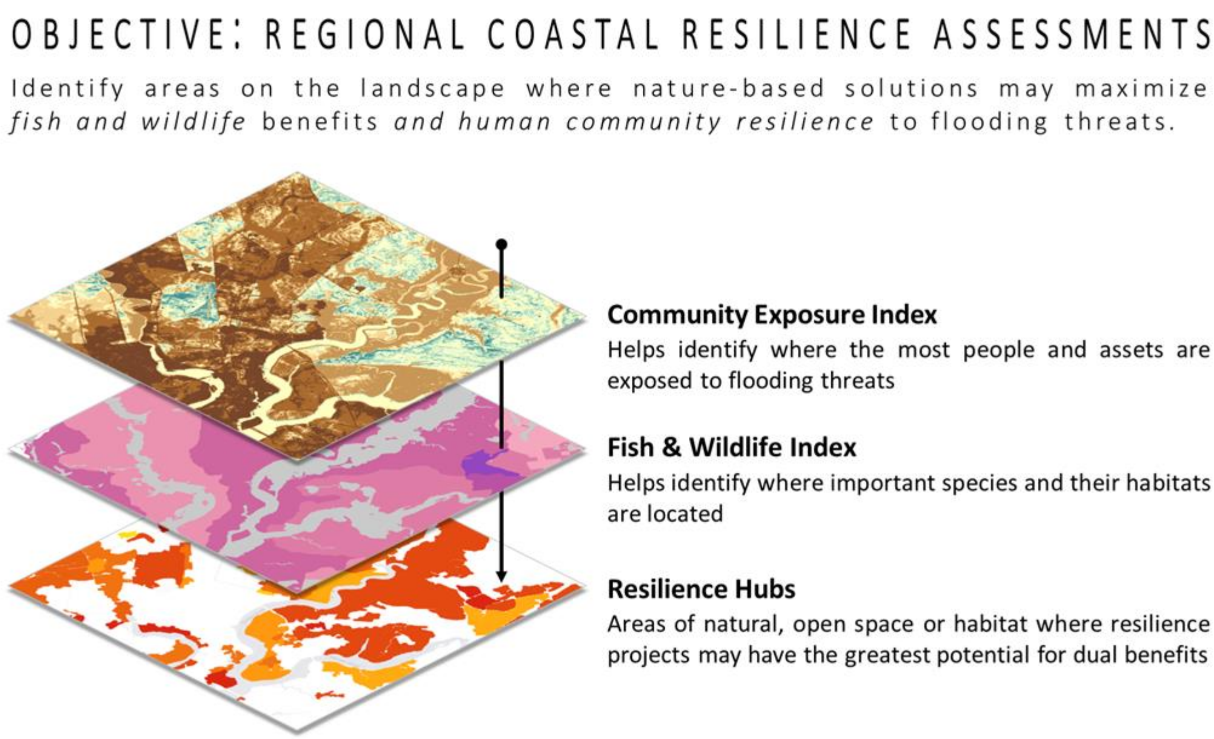
Term	Definition
Adaptive capacity	The ability of a person or system to adjust to a stressor, take advantage of new opportunities, or cope with change.
Ecosystem services	Benefits that humans receive from natural systems.
Exposure	The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards.
Impacts	Effects on natural and human systems that result from hazards. Evaluating potential impacts is a critical step in assessing vulnerability.
Natural features	Landscape features that are created and evolve over time through the actions of physical, biological, geological, and chemical processes operating in nature (Bridges et al. 2014).
Nature-based features	Features that may mimic characteristics of natural features, but are created by human design, engineering, and construction to provide specific services such as coastal risk reduction (Bridges et al. 2014).
Nature-based solutions	Actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (IUCN).
Resilience	The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.
Risk	The potential total cost if something of value is damaged or lost, considered together with the likelihood of that loss occurring. Risk is often evaluated as the probability of a hazard occurring multiplied by the consequence that would result if it did happen.
Sensitivity	The degree to which a system, population, or resource is or might be affected by hazards.
Threat	An event or condition that may cause injury, illness, or death to people or damage to assets.
Vulnerability	The propensity or predisposition of assets to be adversely affected by hazards. Vulnerability encompasses exposure, sensitivity, potential impacts, and adaptive capacity.
Community Assets	Critical infrastructure and facilities important to the character and function of a community immediately following a major flood event, including locations with dense populations and high social vulnerability.

EXECUTIVE SUMMARY

Coastal communities throughout the United States face serious current and future threats from natural events, and these events are predicted to intensify over the short and long term. Dynamic processes such as coastal erosion, storm surge flooding, and river runoff exacerbate the threat from sea level rise. Tropical systems and heavy precipitation events have the potential to devastate both human communities and fish and wildlife habitats. As communities prepare, decision-makers need tools and resources that allow for data-driven decision support to maximize available funding opportunities and other planning needs.

The American Samoa Coastal Resilience Assessment aims to support effective decision-making to help build resilience for communities facing flood-related threats. The National Fish and Wildlife Foundation (NFWF), in partnership with the National Oceanic and Atmospheric Administration (NOAA), is committed to supporting programs and projects that improve resilience by reducing communities' vulnerability to coastal storms, sea level rise, and flooding events through strengthening natural ecosystems and the fish and wildlife habitat they provide.

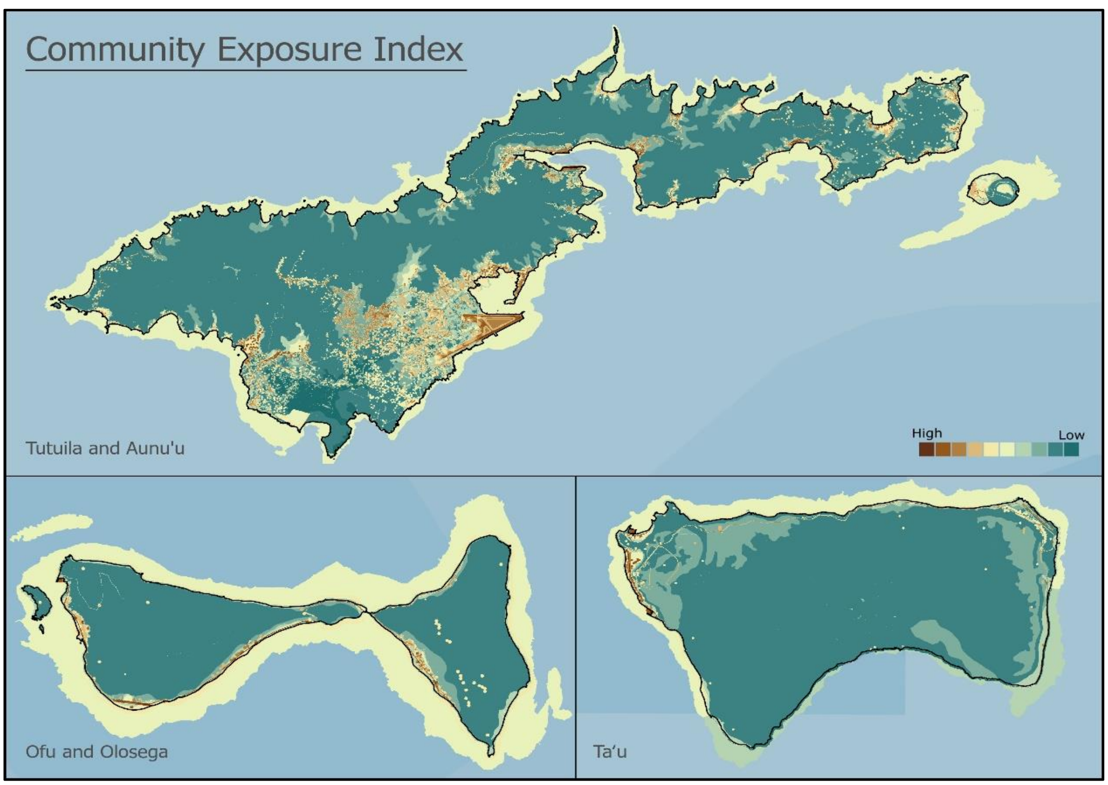
This Geographic Information System (GIS)-based Coastal Resilience Assessment combines spatial data related to land use, protected areas, human community assets, flooding threats, and fish and wildlife resources to identify and prioritize Resilience Hubs (see figure below). Resilience Hubs are large areas of natural, open space or habitat where, if investments are made in habitat conservation or restoration, there is potential to provide benefits to fish and wildlife and help build human community resilience to flooding threats.



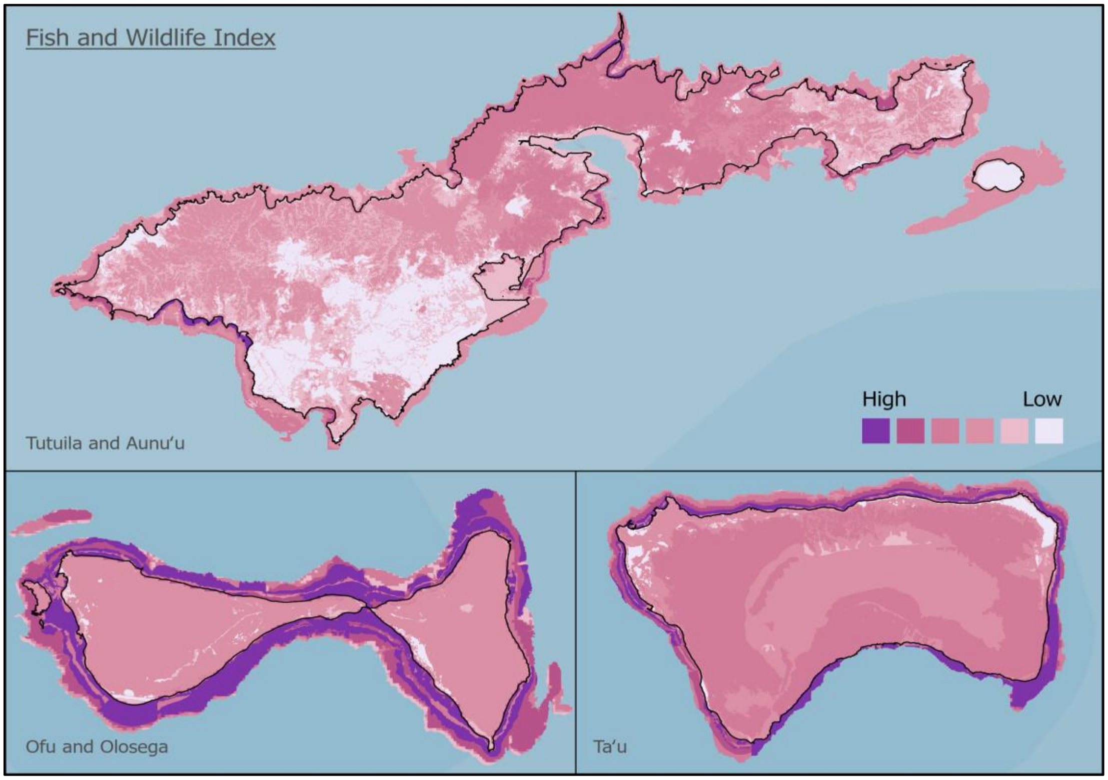
The Assessment identified areas throughout American Samoa that are not only exposed to a range of coastal-flood related threats, but also contain higher concentrations of community assets. In addition, through the development of habitat extent and suitability models, the analysis identified terrestrial and nearshore marine areas important for species of conservation concern. Together, the Assessment revealed natural areas of open space and habitat ideal for the implementation of resilience projects that may be capable of supporting both the people and wildlife of American Samoa. The primary mapping products from the American Samoa Assessment are shown below.

Local community planners, conservation specialists, and others can use the outputs of the American Samoa Assessment to help make informed decisions about the potential of restoration, conservation, or resilience projects to support fish and wildlife while also helping to build human community resilience to flooding threats. The Assessment is intended to be used as a screening-level tool designed to help identify areas that may be well suited for nature-based solutions. Before planning any resilience projects in American Samoa, it is important to first consult local matai, or chiefs, to explore opportunities in areas governed by traditional land tenure. As with all GIS analyses, site-level assessments are required to validate results and develop detailed design and engineering plans.

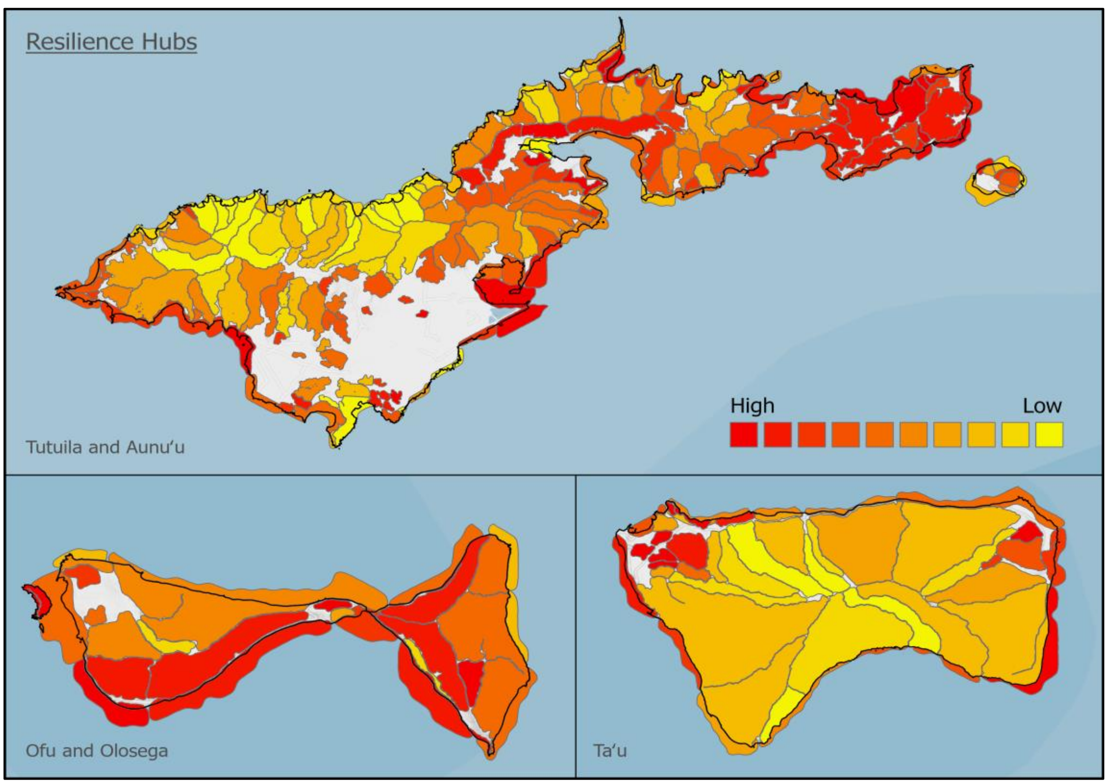
This American Samoa Coastal Resilience Assessment report provides a detailed discussion of the data and methods used for the three analyses (Community Exposure, Fish and Wildlife, and Resilience Hubs), regional results, and a case study. In addition to the results presented in this report, NFWF has developed the Coastal Resilience Evaluation and Siting Tool (CREST), an accompanying GIS-based web tool that allows users to view, download, and interact with the inputs and results of the American Samoa Assessment (available at resilientcoasts.org).



Community Exposure Index for the American Samoa Coastal Resilience Assessment. Higher values represent areas where a higher concentration of community assets are exposed to flooding threats.



Fish and Wildlife Index for the American Samoa Coastal Resilience Assessment. Higher values represent areas where numerous species of conservation concern and their habitats are located.



Resilience Hubs for the American Samoa Coastal Resilience Assessment. Higher values represent areas where resilience projects may have the greatest potential to benefit both human communities and wildlife.

INTRODUCTION

1.1 American Samoa

American Samoa has a rich natural and cultural history with extensive coral reefs, stunning beaches, rugged green mountains, and millennia of Polynesian history and culture. Located within the Samoan Islands archipelago in the mid-south Pacific, American Samoa has a total land area of approximately 200 square kilometers (77 square miles) covering five volcanic islands and two coral atolls. Tutuila is the largest island, home to over 90 percent of residents and the capital city of Pago Pago. Aunuʻu is a small, inhabited island off the eastern coast of Tutuila. Approximately 110 kilometers (70 miles) to the east lie the Manuʻa Islands consisting of the three sparsely populated volcanic islands of Ofu, Olosega, and Taʻu. The territory also includes two coral atolls: Rose Atoll, which is uninhabited and protected by a Marine National Monument, and the now unpopulated Swains Island.

Volcanic in origin, the main islands feature steep jagged mountains, lush paleotropical rainforests, and deeply chiseled stream valleys. Along the coast, habitats include rugged rocky shorelines, pristine sandy beaches, mangroves, and coral reefs. American Samoa's extensive coral reefs are among the most diverse and pristine in the United States, providing habitat for federally threatened and endangered species[1]. Protected areas such as the American Samoa National Park, American Samoa National Marine Sanctuary, and Rose Atoll National Monument were designated to help recognize and protect the territory's unique resources. For example, a large *Porites* sp. colony offshore Ta'u may be the largest and is one of the oldest coral colonies in the world (Coward et al. 2020).

American Samoa has been inhabited for over 3,000 years and has a rich cultural history that is strongly connected to the land and water. Polynesian culture and language are preserved to this day through the emphasis of fa'a Samoa or the "Samoan way." Land-tenure laws include a watershed-based management strategy, where matai (chiefs) manage watersheds from the mountain to the reef crest, determining the land and water use to steward resources responsibly. Due to the land tenure legal structure, unique Samoan culture, and many other considerations, any restoration and conservation project concepts must emphasize fa'a Samoa and include village engagement.

American Samoa's dynamic landscape faces numerous natural hazards ranging from tsunamis and earthquakes to cyclones and flash floods. Due to the rugged landscape, relatively little land can be developed, leaving much of the population restricted to low-lying coastal areas where communities are left exposed to threats such as sea level rise and storm surge. These effects are further compounded by significant land subsidence associated with an 8.1 magnitude earthquake that struck off the coast of American Samoa in 2009. As sea levels rise, the 2009 post-seismic event accelerated these effects, leaving American Samoa to face some of the greatest rates of relative sea level rise in the world (Han et al. 2019). The earthquake generated devastating tsunami waves up to 22 meters (72 feet). Thirty-four people were killed in American Samoa, leaving Pago Pago inundated and buildings flattened (Kong et al. 2015).

While the frequency of a tsunami event of this magnitude is low, American Samoa faces other threats associated with heavy rainfall events, tropical cyclones, shoreline erosion, and landslides. Extreme rainfall events are expected to increase in frequency and severity (Wang et al. 2016, Keener et al. 2021).

[1] For a list of threatened and endangered species in American Samoa listed under the U.S. Endangered Species Act, visit the U.S. Fish and Wildlife Service Environmental Conservation Online System (https://ecos.fws.gov/ecp/) and NOAA (https://www.fisheries.noaa.gov/pacific-islands/endangered-species-conservation/marine-protected-species-american-samoa).

Heavy rains cause regular flash flooding, leading to sanitary sewer overflows, pump station failure, and blocked roadways. Coastal erosion and flooding can damage infrastructure and roads, and squeeze beach and coastal habitat between the steep mountains and the advancing ocean. Rainfall, coastal flooding, and coastal erosion throughout the territory threaten tsunami evacuation routes, coastal roads, and other critical infrastructure. Tropical cyclones can also cause extreme flooding as was recently seen during 2012 Cyclone Evan and 2018 Cyclone Gita events.

In response to projected increases in sea level rise and the frequency of extreme rainfall events (Wang et al. 2016), numerous efforts have worked to better understand the threats, needs, gaps, and nature-based approaches that can be applied to build resilience in American Samoa. Recent efforts include the Pacific Islands Regional Climate Assessment for American Samoa (Keener et al. 2021), Multi-hazard Mitigation Plan for American Samoa (Caplan 2020), U.S. Army Corps of Engineer's Tafuna flood risk management study and American Samoa Post-Disaster Watershed Assessment[2], and efforts to promote green stormwater infrastructure (HWG 2019) and understand the relative resilience of coral reef ecosystems in American Samoa (Schumacher et al. 2018), among others.

As American Samoa takes steps to lower its exposure and plan for a more resilient future, resources such as this Coastal Resilience Assessment can equip decision-makers and stakeholders with valuable tools and information to help plan for future flood and storm events. The American Samoa Coastal Resilience Assessment provides a framework for a holistic approach that considers both fish and wildlife habitat and resilience for human communities facing growing flooding threats.

1.2 Overview of the Regional Coastal Resilience Assessments

The National Fish and Wildlife Foundation (NFWF) and the National Oceanic and Atmospheric Administration (NOAA) are committed to supporting projects and programs[3] that improve resilience by reducing communities' vulnerability to coastal storms, sea level rise, and flooding by strengthening natural ecosystems and the fish and wildlife habitat they provide. In response to growing coastal flooding threats, NFWF commissioned the University of North Carolina (UNC) Asheville's National Environmental Modeling and Analysis Center (NEMAC) to develop an assessment to identify coastal areas that are ideal for the implementation of nature-based solutions that build both human community resilience and fish and wildlife habitat. The resulting Regional Coastal Resilience Assessments (referred to from here forward as the Regional Assessments or Assessments) aim to identify and rank open space areas and habitat cores where targeted investments can implement resilience-building projects before devastating events occur and impact surrounding communities.

The American Samoa Coastal Resilience Assessment is part of a broader effort that seeks to evaluate regional resilience for all U.S. coastlines. Regional Assessments are already complete for the U.S. Atlantic, Gulf of Mexico, and Pacific coastlines, Hawaiʻi, Puerto Rico, the U.S. Virgin Islands, Guam, and the Commonwealth of the Northern Mariana Islands. Additional Assessments are underway for Alaska and the U.S. Great Lakes (Figure 1).

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[2] https://www.poh.usace.army.mil/Missions/Civil-Works/Project-Review-Plans/

[3] See the National Coastal Resilience Fund: https://www.nfwf.org/programs/national-coastal-resilience-fund.

Figure 1. The geographic extent of the Regional Coastal Resilience Assessments in dark gray and the American Samoa Assessment in orange. All Regional Assessments will be completed by 2022. Map not shown to scale.

Strategically implementing resilience projects can increase the ability of surrounding communities and habitats to withstand and recover from the impacts of coastal storms and flooding events (Narayan et al. 2017). Efforts to build resilience begin by determining the exposure of a community's assets to a hazard or threat. The Regional Assessments use a GIS-based approach to model landscape characteristics and their potential impacts to identify places throughout the United States where assets are potentially exposed to flood threats. They combine human community assets, flooding threats, and fish and wildlife resource spatial data to identify and rank Resilience Hubs. Resilience Hubs are large areas of natural, open space or habitat where, if investments are made in habitat conservation or restoration, there is potential to benefit fish and wildlife species while also helping to build human community resilience to flooding threats.

From a modeling standpoint, the Regional Assessments consist of three separate but interrelated analyses: (1) the Community Exposure Index, (2) the Fish and Wildlife Index, and (3) the Resilience Hubs (Figure 2). These three components make the Regional Assessments unique as they look at resilience potential through the lens of both human and fish and wildlife communities. Specifically, the Community Exposure Index can guide land use and hazard mitigation planners in identifying potential development constraints and improve the understanding of potential risks to critical infrastructure and human populations. The Fish and Wildlife Index can inform where important species and habitats occur. The Resilience Hubs then identify open spaces and habitat suitable for the implementation of projects expected to build communities' resilience to flood events while also benefiting fish and wildlife.

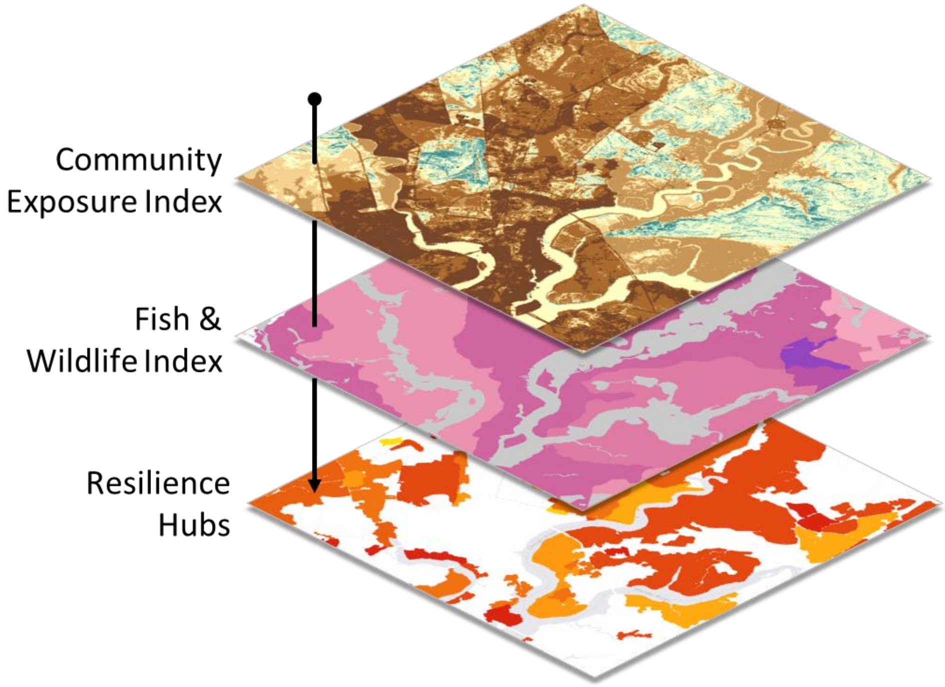

Figure 2. A conceptual model showing the separate, but interrelated components of the Regional Coastal Resilience Assessments.

While the Resilience Hubs are the primary output of the Regional Assessments, each component can be used individually or in combination to help community planners, conservation specialists, funding applicants, and others make informed decisions about the ability of potential restoration, conservation, or resilience projects to achieve dual benefits for both human community resilience and fish and wildlife species and habitats. The Assessment is intended to be used as a screening-level tool designed to help identify areas that may be well suited for nature-based solutions. Before planning any resilience projects in American Samoa, it is important to first consult local matai, or chiefs, to explore opportunities in areas governed by traditional land-tenure. As with all GIS analyses, site-level assessments are required to validate results and develop detailed design and engineering plans.

METHODS

2.1 Introduction

The foundation of the Regional Coastal Resilience Assessments is based on the coastal vulnerability research outlined in Gornitz et al. (1994). In 2011, the New Jersey Office of Coastal Management and Department of Environmental Protection adapted that research to assess existing and future hazard vulnerabilities on a local scale (NJ-DEP 2011). This research was integral to structuring the inputs and methodology of this analysis.

The following sections provide a brief overview of the methods used in the American Samoa Coastal Resilience Assessment. For more details about overarching methodology and data sources common across all Regional Coastal Resilience Assessments, please refer to Dobson et al. (2020). To the extent possible, the Regional Assessments aim to use the same methodology and data across all regions. However, given the unique geographic characteristics of each region and the fact that data availability varies, some regionally specific modifications were required. Given the geographic scale of American Samoa, all GIS modeling was completed at a three-meter resolution to best match the resolution common to the input data. The following sections briefly discuss pertinent methodological changes to the Community Exposure Index, Fish and Wildlife Index, and Resilience Hubs for American Samoa.

2.2 Study Area

The American Samoa Assessment focuses on the main islands of Tutuila, Aunuʻu, Ofu, Olosega, and Taʻu, and does not include Rose Atoll or Swains Island. American Samoa has a total population of less than 60,000 people, 95 percent of whom live on the largest island of Tutuila. With over 100 kilometers (60 miles) of coastline, the main islands possess a diversity of ecosystems, climates, terrain, and habitats ranging from volcanic craters to rainforests to coral reefs. Characterized by a steep and rugged topography, the highest peaks in American Samoa range from just over 650 meters (2,100 feet) at Matafao Peak in Tutuila to over 900 meters (2,950 feet) at Olotania Crater on the island of Taʻu.

The Assessment covers entire watersheds, from the mountains to sea, extending into the ocean to the 30-meter depth contour (Figure 3)[4]. This Assessment is unique in that it not only considers the immediate coastline, but it also focuses on inland areas that can often directly contribute to coastal flood-related issues. For instance, intense rainfall and overland flow in steep, montane environments can directly exacerbate coastal flooding events. In all regions, the boundaries of the Assessments follow the coastal watersheds designated by the U.S. Environmental Protection Agency (EPA), which are watersheds that drain directly to the ocean and are represented at a hydrologic unit code eight scale (HUC-8)[5]. For American Samoa, the HUC-8 watersheds cover all the islands, and thus the study area also overs the entirety of each island (Figure 3).

[4] A 30-meter depth contour was used for the Fish and Wildlife Index to allow for the inclusion of marine habitats with potential to host significant biodiversity. In contrast, the Resilience Hub analysis only considered habitats less than 10 meters in depth since shallow water habitats are expected to provide greater coastal protection benefits through the implementation of nature-based solutions.

[5] According to the Environmental Protection Agency's Coastal Wetlands Initiative: https://www.epa.gov/wetlands/coastal-wetlands.

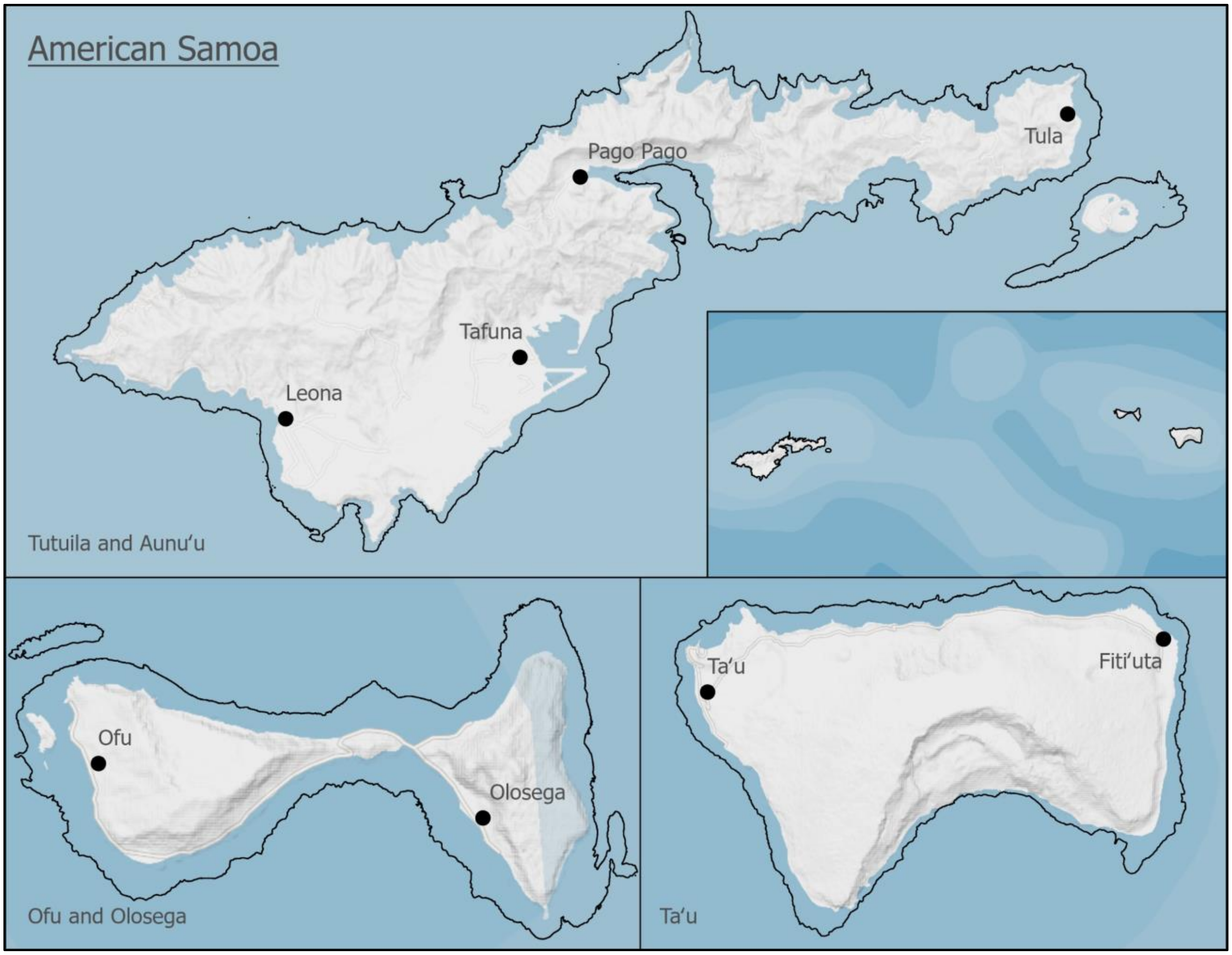

Figure 3. The American Samoa Coastal Resilience Assessment study area. The 30-meter depth contour is shown in black.

2.3 Data Collection and Stakeholder Engagement

The Project Team compiled an initial set of data from multiple national and regional data sources, including sea level rise data from NOAA and floodplain data from the Federal Emergency Management Agency (FEMA). In addition to reviewing publicly available data sources, the American Samoa Assessment relied on significant input from local and regional stakeholders to identify and inform the use of additional data sets.

To help guide the Assessment process, the Project Team established an Advisory Committee consisting of six members representing NOAA's Office for Coastal Management and NOAA Fisheries, the American Samoa Office of Disaster and Petroleum Management, the American Samoa Coastal Management Program, the American Samoa Department of Marine and Wildlife Resources, Hawaiʻi Sea Grant, American Samoa Community College, and the U.S. Fish and Wildlife Service. The Advisory Committee met regularly with the Project Team to:

1. Provide guidance to the Project Team at key decision points in the analyses, including recommendations on data to be included;
2. Help identify additional local stakeholders within federal agencies, local and territorial governments, universities, village mayors, non-governmental organizations, and others to provide input into the development of the American Samoa Assessment; and

3. Advise on final products and tools, including the effective dissemination of results.

With input from the Advisory Committee and building on initial data collection, the Project Team hosted a virtual workshop to allow local stakeholders to review and provide input on preliminary Assessment products. The Virtual Stakeholder Workshop was held over the week of March 15, 2021. The Project Team hosted three sessions to introduce the assessment and discuss preliminary results. All participants had access to written materials and an online GIS viewer to facilitate the review of draft models and provide comments during and after the workshop. The comment period remained open for several weeks following the virtual workshop.

Thirty people attended the workshop, representing local, federal, non-government, and academic organizations. For a complete list of all organizations invited to the workshop, see Appendix G. Workshop participants helped the Project Team:

1. Identify geographic features, flooding threats, cultural and socio-economic factors, and additional considerations that are unique to the region;
2. Identify, collect, and appropriately use GIS datasets related to flooding threats, community assets, and species and habitat;
3. Provide references and contact information for additional experts that may be able to contribute data or knowledge to the effort; and
4. Obtain overall buy-in to the Assessment process and solicit ways in which it can be used by local stakeholders in American Samoa.

Participants reviewed draft maps and data sources, providing important feedback and recommendations to improve the analyses. In addition, participants considered measures that local communities can take to enhance resilience, including management strategies, activities, and projects that restore habitats and install natural and nature-based features that reduce flood-related threats.

Following the stakeholder workshop, the Project Team reconvened with the Advisory Committee to assess the feedback, comments, and suggestions provided during the workshop and to determine which data to incorporate into the revised products. NEMAC then followed up individually with Committee members and other key stakeholders to further discuss data and methodology as needed. Results of the American Samoa Assessment were reviewed by the Advisory Committee and shared with local stakeholders via a public webinar.

2.4 Creating the Community Exposure Index

The Community Exposure Index was created by combining the Threat Index and Community Asset Index, depicting the spatial distribution of the potential exposure of assets to flood threats (Figure 4). The following equation calculates exposure:

Threat Index × Community Asset Index = Community Exposure Index

To accommodate local datasets and needs, the following text describes the specific methods used for the American Samoa Assessment. A complete list of datasets included can be found in Appendix A. See Appendix D for a description of the methodology used to calculate the Community Exposure Index.

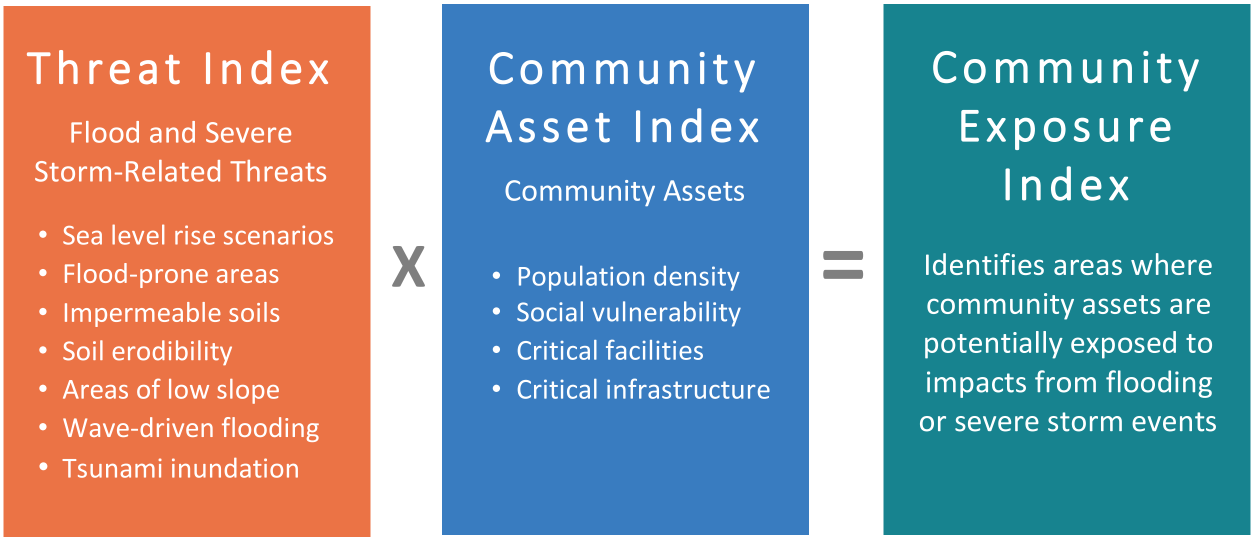

Figure 4. Elements of the Threat and Community Asset Indices used to create the Community Exposure Index.

2.4.1 Threat Index

Flood-related datasets are used to help communities understand what kind of threats are potentially present in their area. While other threats may exist, for the purposes of this analysis only those threats relevant to coastal flooding in American Samoa were included. Threats are defined as datasets that show coastal flood and severe storm hazards on the landscape. The Threat Index is a raster-based model with a cumulative scoring of inputs (Dobson et al. 2020). As in other Regional Assessments, the American Samoa analysis included data related to sea level rise, flood-prone areas, soil erodibility, impermeable soils, areas of low slope, landslide susceptibility, and tsunami inundation areas (Wood et al. 2019), each of which are described in detail in the Methodology and Data Report (Dobson et al. 2020). While post seismic land subsidence is a clear geologic stressor in American Samoa (Han et al. 2019), there were insufficient spatial data across the entire study area to include subsidence in the Threat Index. It is important to recognize that subsidence due to nearby seismic activity is likely a compounding factor that exacerbates the flood-related threats that were included in the Index. Storm surge, which is typically a Threat Index input used in other Regional Assessments, was unavailable for American Samoa at the time of modeling. An additional input—wave-driven flooding—was included to serve as a proxy for storm surge (see Appendix B.1 for details). For this input, the analysis utilized data from Storlazzi et al. (2019). These models used significant wave heights associated with the 10-, 50-, 100-, and 500-year storm return periods and inundation was modeled based on the presence or absence of coral reefs. For the purposes of this analysis, inundation models in the presence of coral reefs were used. Additional details on those data used to create the Threat Index for American Samoa can be found in Appendix A.1 and Appendix B.

2.4.2 Community Asset Index

The Community Asset Index includes data related to infrastructure and human population. The Index used datasets that quantify the number of assets present—not their magnitude of vulnerability or susceptibility to flood threats. The infrastructure and facilities that were incorporated into the Regional Assessments were chosen for their ability to help people respond to flood events.

In American Samoa, the Community Asset Index included population density, social vulnerability, and the full complement of critical facilities and infrastructure detailed in the Methodology and Data Report (Dobson et al. 2020). Unlike previous assessments, where critical infrastructure locations received a lower rank than critical facilities, in American Samoa these two categories of community assets were counted with equal weight. Based on feedback from the stakeholder workshop and Advisory Committee, critical infrastructure was given an equal rank to critical facilities since all assets are important in response to storm and flood events on remote islands. This approach is consistent with other existing methodologies to identify community assets that support recovery during an emergency, such as the FEMA Community Lifelines framework[6]. It was of utmost importance to include locally available data whenever possible. Therefore, based on feedback from the stakeholder workshop and Advisory Committee, some local datasets were incorporated from the National Marine Sanctuary of American Samoa GIS Data Archive and the American Samoa Department of Homeland Security, while others were digitized by NEMAC with guidance from the Advisory Committee. In addition, the analysis included cultural heritage sensitivity areas and historic sites within the study area. Although these sites may not directly assist in responding to flood events, their importance to local communities, as well as any economic value they may hold, were considered justification for including them as a type of critical infrastructure. The following types of critical infrastructure were included in the American Samoa Assessment:

- Primary roads
- Bridges
- Airports
- Ports
- Power plants and substations
- Petroleum terminals and refineries
- Hazardous sites
- Wastewater treatment facilities
- Cultural and historic resources

In addition, as with all other regions, the following list of critical facilities were included because of their relevance and widespread use following flood events or other disasters:

- Medical facilities (hospitals, nursing homes, etc.)
- Law enforcement (police, sheriff stations, etc.)
- Schools (public and private, universities)
- Fire stations

A detailed list of datasets used for all Community Asset Index inputs included in the American Samoa Assessment can be found in Appendix A.2. See Appendix C for a description of methods used to create the Community Asset Index.

2.5 Creating the Fish and Wildlife Index

The Fish and Wildlife Index, which consists of Marine and Terrestrial components, allows for a greater understanding of important habitats and fish and wildlife resources to aid in the identification of areas where implementing nature-based solutions may support coastal resilience and ecosystem benefits (Figure 5). The Index attempts to identify areas on the landscape where terrestrial, aquatic, and marine species of conservation concern and their habitats are located. For the American Samoa Assessment, only those species of concern with federal- or territory-level protection status and/or those included in resource management plans were considered. By nature, the Fish and Wildlife Index varies regionally; however, a detailed description of the general methods governing the Fish and Wildlife Index is available in the Methodology and Data Report (Dobson et al. 2020). Regional considerations for American Samoa are discussed below; a complete list of data can be found in Appendix A and a description of the methods used to create the Fish and Wildlife Index can be found in Appendix E.

[6] FEMA Community Lifeline: https://www.fema.gov/emergency-managers/practitioners/lifelines.

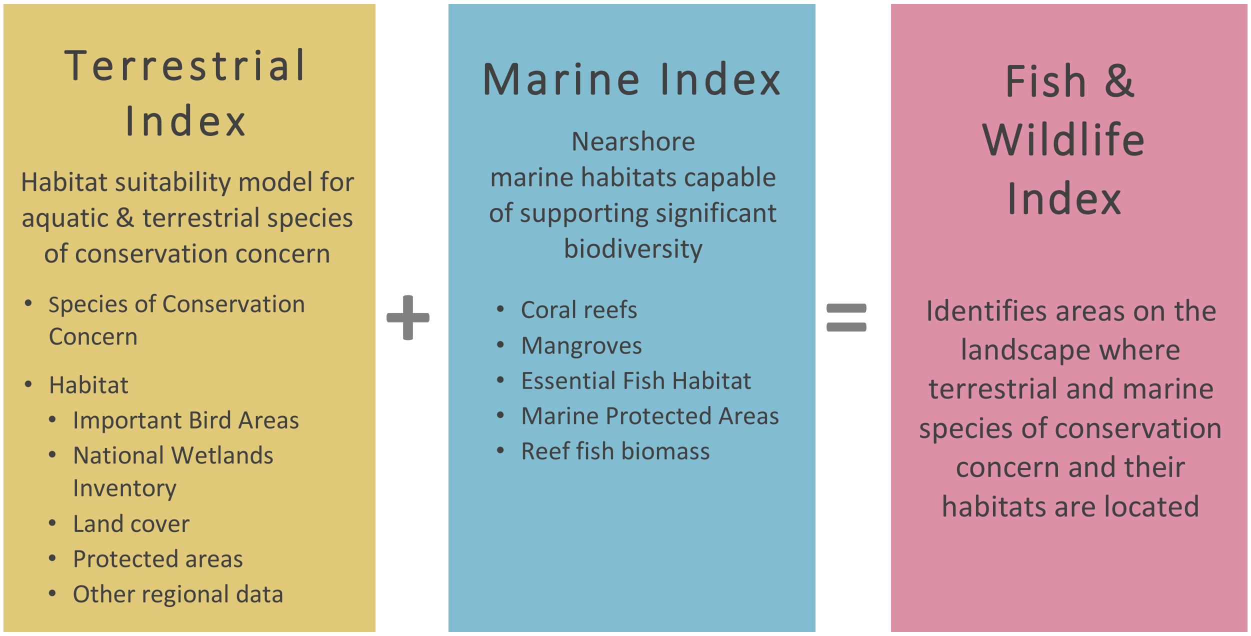

Figure 5. Elements of the Terrestrial and Marine Indices used to create the Fish and Wildlife Index.

2.5.1 Terrestrial Index

The Terrestrial Index aims to identify suitable habitats for major species groups using available land cover and habitat data. The Index is created relative to the habitat preferences and needs of the species of greatest conservation concern in the region, which were identified using the American Samoa Comprehensive Wildlife Conservation Strategy (DMWR 2016) and species listed as threatened or endangered under the U.S. Endangered Species Act. Broad taxonomic and species groupings were used to model habitat preferences throughout the region, including:

- Sea birds
- Land birds
- Reptiles
- Terrestrial mammals

Based on habitat preferences associated with each species group, the analysis modeled primary, secondary, and tertiary habitat suitability (for details see Dobson et al. 2020). A complete list of species (organized by taxonomic and species group) included in the American Samoa Assessment is available in Appendix E.1.

In addition to using the NOAA Coastal Change Analysis Program land cover data, U.S. Fish and Wildlife Service's National Wetlands Inventory, and USGS National Hydrography Dataset to identify habitat types, the analysis utilized vegetation maps from the U.S. Forest Service (Liu et al. 2011) and the high-resolution land cover map for American Samoa developed by Meyer et al. (2017) to identify areas of primary forest and intact rare forest types. BirdLife International Important Bird Areas (IBAs) were also included. A complete list of datasets and methods used to create the American Samoa Terrestrial Index can be found in Appendix A.3 and Appendix E.1, respectively.

2.5.2 Marine Index

The Marine Index aims to identify marine habitat types that can support significant biodiversity, such as coral reefs and mangroves. While other marine habitat types may support significant biodiversity, the American Samoa Assessment focused on those habitat types where restoration and resilience projects may offer the multiple benefits of species richness, ecosystem enhancement, and coastal protection.

The study area for the Marine Index was defined by the 30-meter depth boundary around each island according to bathymetric data. Inside this boundary, the spatial extent of coral reef habitat was estimated from live coral cover records using NOAA's National Coral Reef Monitoring Program, which regularly implements stratified random sample surveys throughout the islands. Based on surveys from 2018, areas with higher coral cover—and thus more likely to support higher numbers of reef associated species (Komyakova et al. 2013)—were ranked higher in the Marine Index. Due to ecosystem changes since the benthic habitats were mapped in 2007, it was recommended that survey data be used at the sector-level broken into three depth categories, known as the strata-level, using bathymetry (Tom Oliver, NOAA, personal communication). The coral cover data were pooled for each strata and then ranked across the islands. The three depth levels are as follows: shallow (0-6 meters), mid-depth (>6-18 meters), and deep (>18-30 meters). Data on mangrove extent were also incorporated using a presence/absence scoring to indicate their potential capability for supporting higher species richness.

In addition to the spatial extent and condition of these habitat types, the Marine Index calls upon several additional datasets including Essential Fish Habitat, Marine Protected Areas, and reef fish biomass data from NOAA. A complete list of datasets and methods used to create the American Samoa Marine Index can be found in Appendix A.4 and Appendix E.2.

2.6 Creating the Resilience Hubs

Resilience Hubs are areas of natural, undeveloped space that attempt to identify places that may be suitable for resilience-building conservation or restoration efforts that can help prepare for potential adverse impacts to infrastructure and communities, while also improving the habitats of fish and wildlife species. Therefore, Resilience Hubs represent open spaces and habitats that have a high potential to provide benefits to both human communities and fish and wildlife. Accounting for natural spaces on both inland areas and in the nearshore marine environment, Resilience Hubs are formed based upon undeveloped landscapes and habitat types to create two outputs: Green Habitat Cores (inland) and Blue Habitat Cores (marine) (Figure 6).

While the criteria differ between the Green and Blue Habitat Cores, both models rank Resilience Hubs according to the combined average values of the Community Exposure Index and the Fish and Wildlife Index (for a detailed description of methods see Appendix F and Dobson et al. 2020). To show variation within Resilience Hubs, the Habitat Cores are further subdivided and scored at a finer 4-hectare (10-acre) hexagon grid (Figures 7, 8, and 9). This scale was chosen to facilitate local decision-making commensurate with the size of potential nature-based projects and solutions.

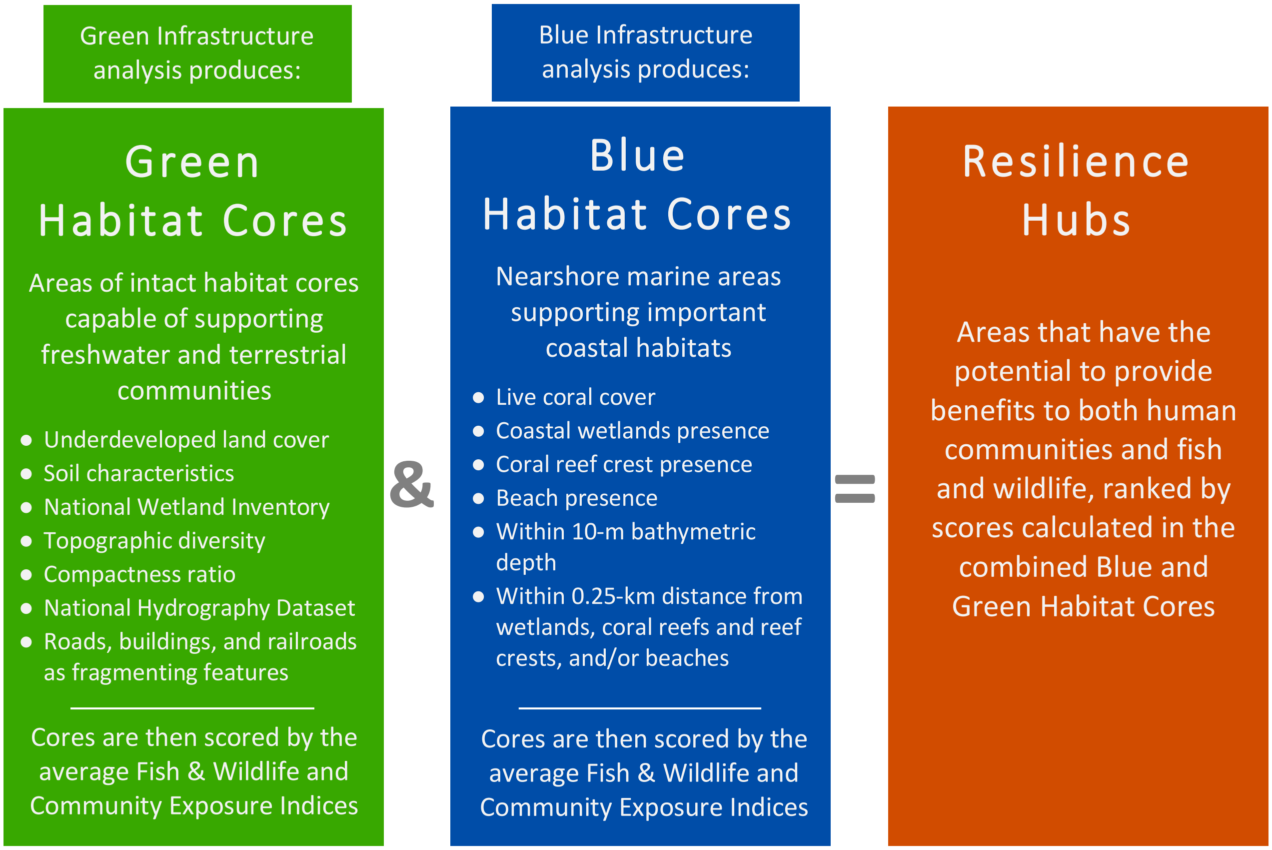

Figure 6. Elements of the Green and Blue Habitat Core outputs used to create the Resilience Hubs.

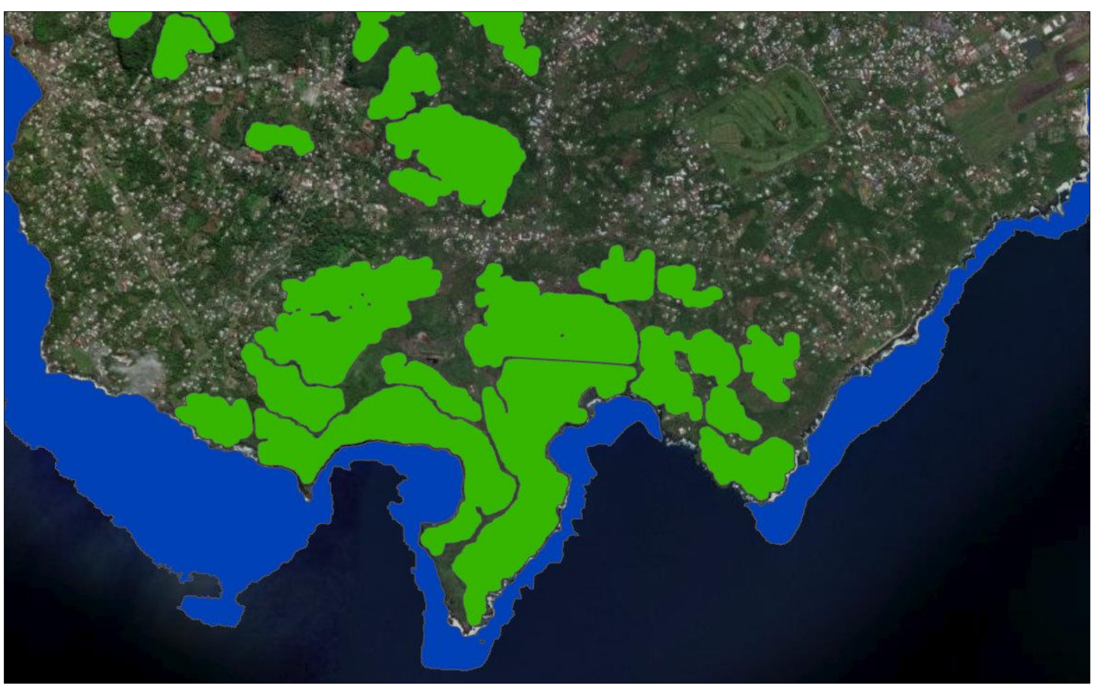

Figure 7. An initial step in creating the Green and Blue Habitat Cores. Note the Green Habitat Cores include both terrestrial and freshwater aquatic areas. The Blue Habitat data include coral cover, beaches, coastal wetlands, coral reef crests, and nearshore marine areas less than 10 meters in depth but have not yet been grouped into Cores.

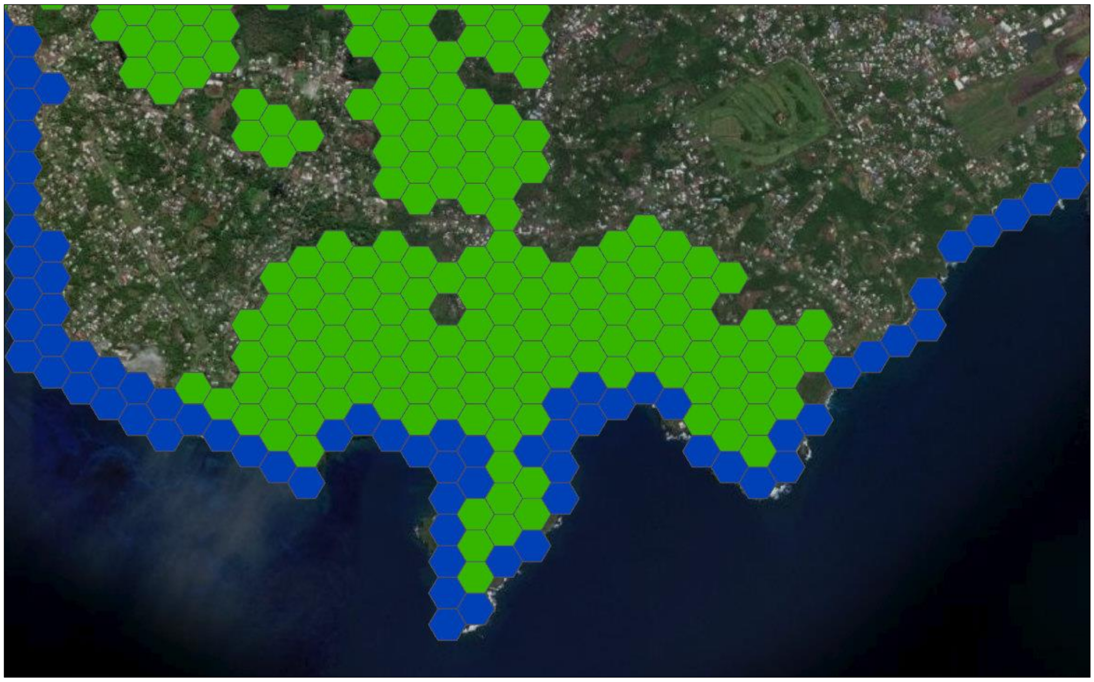

Figure 8. Green and Blue Habitat Cores converted to 4-hectare (10-acre) hexagons. As with each Habitat Core, each hexagon is later ranked to show variation within Resilience Hubs.

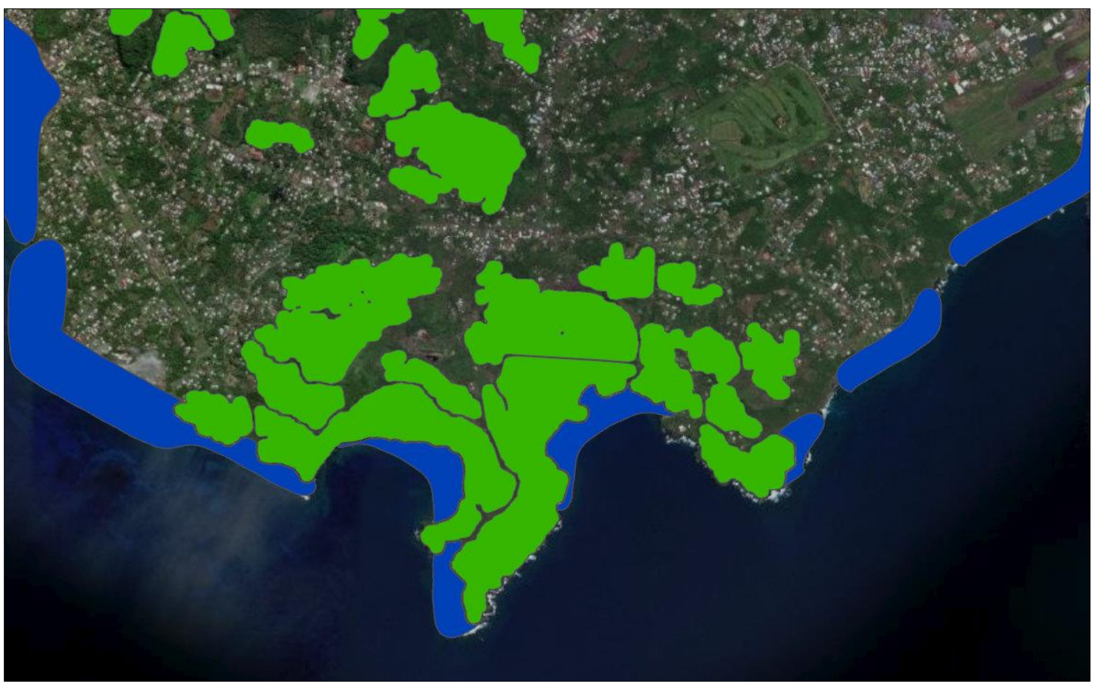

Figure 9. Final Green and Blue Habitat Cores. The Blue Habitat hexagons are grouped into Habitat Cores by bathymetric basin. The resulting Green and Blue Cores are then ranked to become Resilience Hubs.

2.6.1 Green Infrastructure

The Green Infrastructure[7] analysis used in the Regional Assessments builds upon methodology developed by the Green Infrastructure Center for the continental United States (Firehock & Walker 2019). Since these data were not available for American Samoa, NEMAC replicated the analysis to create this important layer for the American Samoa Assessment. The analysis identifies "intact habitat cores," or every natural area 4 hectares (10 acres) or greater, regardless of ownership or preservation status. The dataset is intended to guide local, regional, and urban planners in identifying important places to conserve prior to planning development projects. The dataset also helps to prioritize which landscapes to protect and connect—such as natural systems that mitigate flooding, provide recreational opportunities, and benefit air and water quality (Firehock & Walker 2019). Habitat cores also represent relatively intact habitat that considers fragmenting features that may disrupt the movement of wildlife species.

Applying these methods to American Samoa, the Green Infrastructure analysis resulted in the creation of Green Habitat Cores, or inland habitat cores encompassing both terrestrial and freshwater aquatic habitats. The resulting Green Habitat Core features are then converted into a 4-hectare (10-acre) hexagonal grid (Figure 8). The hexagonal grid helps to highlight variation in the Community Exposure Index and Fish and Wildlife Index scores associated with each habitat core to help facilitate fine-scale decision-making. For full documentation on how the Green Habitat Cores were created, please refer to Appendix F and Dobson et al. (2020).

In addition to scoring the Green Habitat Cores with the Community Exposure and Fish and Wildlife Indices, consideration was given to Cores that are nearest to the community assets identified within the Community Asset Index. This ensures that priority Green Habitat Cores are identified based on their potential to benefit the largest number of community assets that are nearest to each core.

In summary, the Green Infrastructure approach—in determining both Green Habitat Cores and their subsequent hexagons—identifies contiguous natural landscapes composed of similar landscape characteristics that are nearest to community assets. Lands identified have the potential to be of higher ecological integrity and thus may offer improved potential for both human and wildlife benefit. This allows for a more accurate determination of the boundaries of natural landscapes when forming and ranking the Resilience Hubs. See Appendix A.5 and Appendix F for more details.

2.6.2 Blue Infrastructure

Recognizing the prominence of valuable coastal marine habitats in American Samoa, the Assessment developed a Blue Infrastructure[8] analysis. Marine and coastal habitats, such as coral reefs, mangroves, wetlands, and beaches not only support significant biodiversity but are also important natural features that can protect human communities and infrastructure from flooding-related threats. Unlike the methodology used in the Green Infrastructure analysis, marine environments typically lack the fragmenting features that are necessary to delineate and form open spaces into inland habitat cores. As a result, the Project Team developed a different approach to identify Blue Habitat Cores, or marine and coastal areas represented by habitats that may be suitable for the implementation of conservation or nature-based resilience projects. The Blue Habitat Cores were delineated by creating a 4-hectare (10-acre) hexagonal grid of all coastal and marine habitats less than 10 meters in depth and then by

[7] Note that Green Infrastructure analysis—as it is referred to in this Assessment—pertains to a specific methodology and is not intended to represent other local planning and management projects.

[8] Note that Blue Infrastructure analysis—as it is referred to in this Assessment—pertains to a specific methodology and is not intended to represent other local planning and management projects.

grouping hexagons according to the American Samoan bathymetric basins and the marine habitats they contain. Unlike the Fish and Wildlife Index, only habitats less than or equal to 10 meters in depth were considered in the Blue Infrastructure analysis since nature-based solutions are more likely to provide coastal protection when implemented in shallow water habitats. For full documentation on how the Blue Habitat Cores were created, please refer to Appendix F and Dobson et al. (2020).

2.6.3 Combining Habitat Cores and Ranking Resilience Hubs

To capture the potential impact the Green and Blue Habitat Cores may have on reducing the effects of coastal flooding on nearby community assets while also benefiting fish and wildlife, the Habitat Cores were scored using the average values of the Community Exposure and Fish and Wildlife Indices to determine the rankings of Resilience Hubs. For details about how Green and Blue Habitat Cores were scored, see Dobson et al. (2020). As noted above, every habitat core feature was converted into a finer-resolution 4-hectare (10-acre) hexagonal grid. As a result, each hexagon also received its own individual ranking, allowing for a finer-scale view of areas within any given Habitat Core. When considered in combination with the Resilience Hubs, the hexagons can help identify areas that may be ideal for resilience-building efforts that achieve dual human community and fish and wildlife benefits. See Appendix A.5 and Appendix F for more details.

RESULTS

The American Samoa Coastal Resilience Assessment reveals abundant opportunities to use nature-based solutions to help build human community resilience while supporting fish and wildlife habitat and species. Nature-based solutions include actions that sustainably manage and utilize natural systems to address societal challenges such as stormwater management, urban flooding, and heat islands while benefiting biodiversity and human well-being. Implementing nature-based solutions, such as wetland or coral reef restoration, can provide tremendous co-benefits to people and wildlife.

The Community Exposure Index shows that areas of high exposure are concentrated around populated areas. Along the coastlines of each island, the Fish and Wildlife Index reveals a concentration of habitat types expected to support wildlife species. As expected, inland and some remote coastal areas outside of urban centers show moderate values that support high concentrations of important habitat for species of concern. Finally, the Resilience Hubs show that there are numerous Hubs across all islands, both along the coastline and inland. For the purposes of this report, the results for all islands are described separately; however, a single model was used for all five islands, which allows results to be directly compared within and among islands.

3.1 Community Exposure Index

The Community Exposure Index for American Samoa shows that exposure to flooding threats is mainly concentrated around the most densely populated areas along the coast. With a total average population density of 106 people per square mile and with the vast majority of residents living along the shoreline, it is unsurprising that low-lying, populated areas are most exposed to flooding threats. On Tutuila, the highest exposure values, indicated by the darkest browns, are associated with the more populous communities of Tafuna, Pago Pago, and Leone (Figures 10). On the Manuʻa Islands, the highest exposure values are found in the villages of Ofu, Olosega, and Luma. When compared to other coastal regions of the United States, American Samoa does not contain vast stretches of highly exposed coastline. In fact, outside of the populated areas, coastal areas around each island exhibit consistently low exposure values. In many of the undeveloped coastal areas this is likely due to the topography of the coastline, which not only prevents high concentrations of community assets from being located directly near the water in many places, but also results in relatively low values for several flood-related threats. The main exception is the Tafuna Plain in southern Tutuila, where medium-high exposure values are more prevalent due to the flat topography and high concentration of assets.

The Threat Index reveals that flood-related threats affect nearly all coastlines throughout American Samoa. However, cumulatively across all inputs, there are relatively few areas that are highly threatened by the coastal flood threats. Those areas with significant development are also areas with flatter topography that are more subject to flooding threats, which is evident in the Community Exposure Index. For instance, the highest Threat values on Tutuila are seen in coastal lagoons and low-lying areas such as the Pala Lagoon and around the Pago Pago International Airport, Fagaʻitua and Masefau Bays, and the exposed eastern shore of the island (Figure 11). This pattern is also evident in Pago Pago Harbor, where high threat values revealed in the Assessment are consistent with regular flooding events observed at the head of the harbor and around Aua. On Aunuʻu, the entire western side of the island shows higher threat values, driven by relatively low elevation and highly erodible soils. In the Manuʻa Islands, a narrow band of high threat values around Ofu and Olosega indicate that most of the coastline is coincident with roadways that occupy low-lying and impermeable surfaces. On the island of Ta’u, the highest values are found on the western side of the island where low-lying assets are at high risk of inundation due to tsunami, sea level rise, and wave-driven flooding.

The topography of the islands strongly influences the presence of flood-related threats and their impacts on the landscape. For example, apart from bays, inlets, and the Tafuna Plain, the islands feature relatively few low-lying areas capable of pooling water. In addition, inputs such as sea level rise, wave-driven flooding, and tsunami inundation are all limited to the immediate coastline. Except for impervious surfaces around densely populated areas, most of the landscape features well- to moderately well-drained soils that help to minimize flooding risks. Relatively high threat values within the interior portions of the islands are largely driven by soil erodibility. It is important to note that the flooding threats included in the Assessment do not explicitly account for the rapid land subsidence observed in American Samoa following a major earthquake 2009 (Han et al. 2019). The associated decrease in elevation across much of the islands means the threats identified in the American Samoa Assessment are conservative and should be interpreted with caution since ongoing post seismic land subsidence is expected to exacerbate sea level rise and coastal flooding in the region (Han et al. 2019). Efforts are currently underway by the University of Hawaiʻi to create improved sea level rise projections that account for recent land subsidence, which will greatly improve the accuracy of currently available data. The Assessment will be updated as new data becomes available.

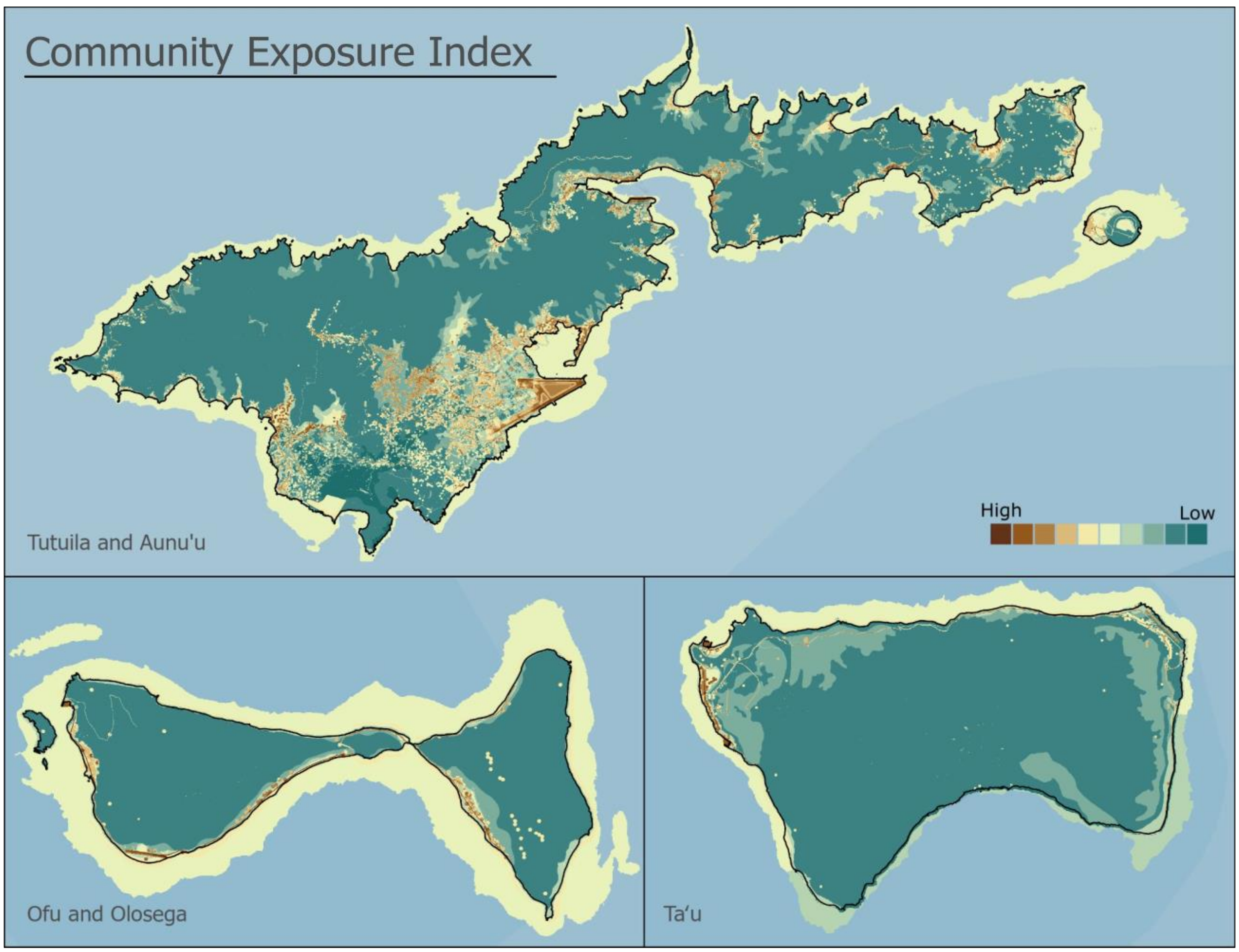

Figure 10. Community Exposure Index for the islands of Tutuila and Aunuʻu (top), Ofu and Olosega (bottom left), and Taʻu (lower right). The Threat and Community Asset Indices are multiplied to produce the Community Exposure Index, which shows areas where assets overlap flood threats. To view results in detail, see [Appendix H] or view results in [CREST].

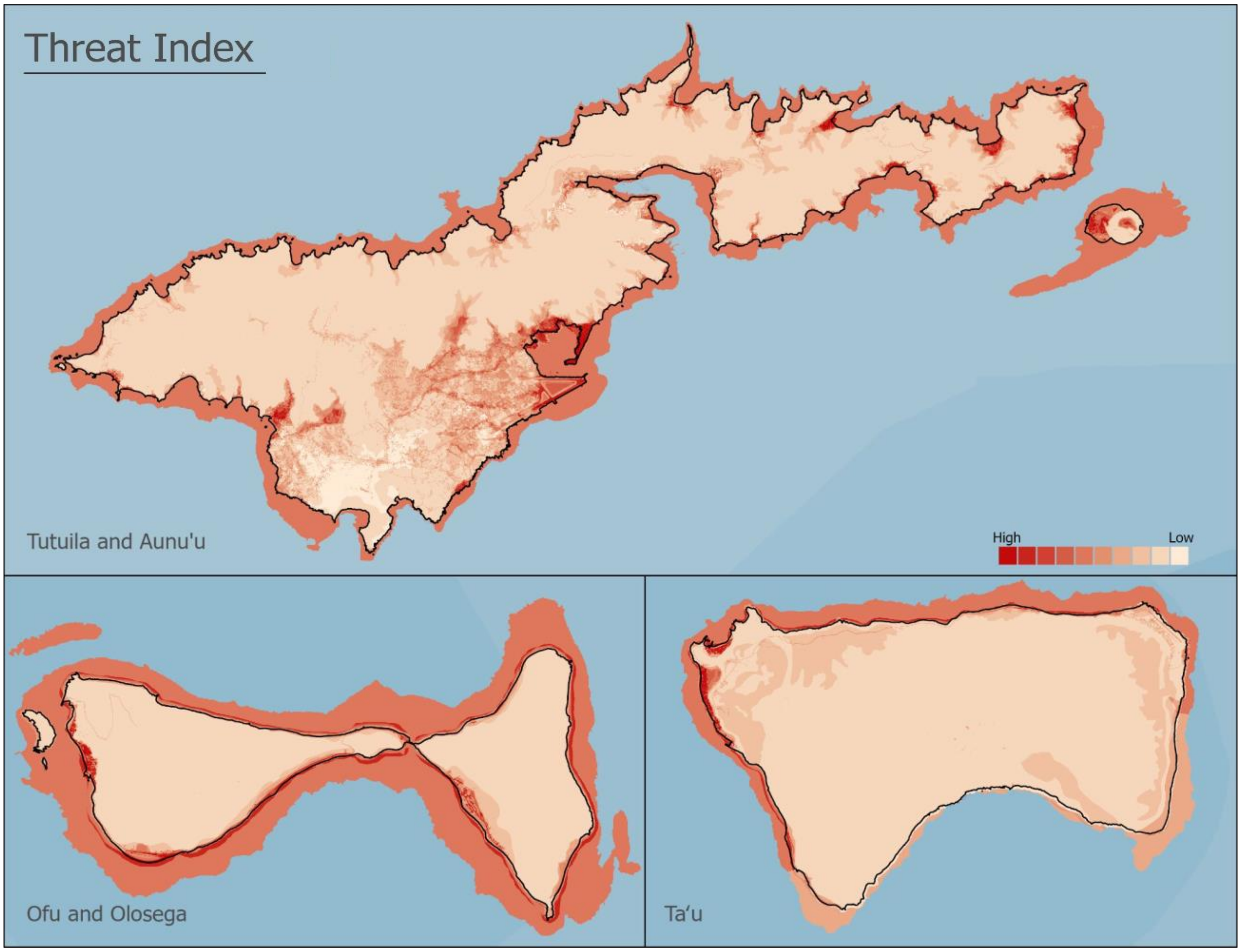

Figure 11. Threat Index for the islands of Tutuila and Aunu'u (top), Ofu and Olosega (bottom left), and Ta'u (lower right). The Threat Index highlights areas where multiple coastal flood threats are present. To view results in detail, see Appendix H or view results in CREST.

While the topography of the region may result in fewer areas subject to numerous flooding threats, portions of American Samoa are densely populated, leaving important community assets exposed to the impacts of flooding. The Community Asset Index identifies concentrations of assets around the developed, populated lowland areas; however, important community assets can be seen throughout the islands, including roads, bridges, communication infrastructure, ports, and airports, all of which are critical for effective emergency response in the event of major flooding. Most community assets are found within the Tafuna Plain and surrounding the Pago Pago Harbor in Tutuila (Figures 12). Major roads, population centers, and socially vulnerable communities are evident in Tutuila. In the islands of Ofu and Olosega, assets are largely restricted to the immediate coastlines where important roads and the Ofu-Olosega Bridge connect the small, isolated villages of Ofu and Olosega. Similarly, the small villages of Ta'u are all connected by two main roads, making the small ports and airport critical lifelines for supplies and emergency response following storm events.

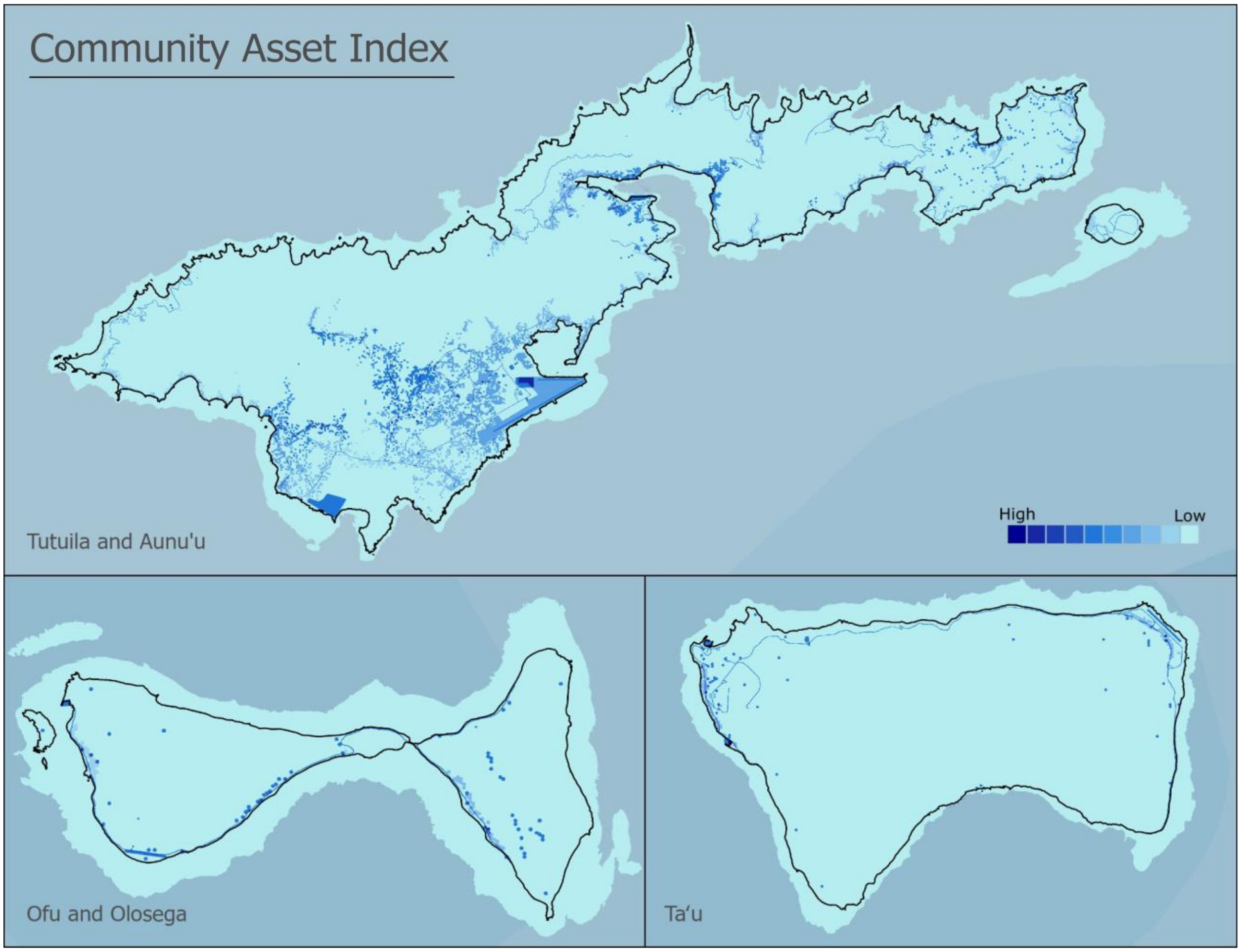

Figure 12. Community Asset Index for the islands of Tutuila and Aunu'u (top), Ofu and Olosega (bottom left), and Ta'u (lower right). The Community Asset Index highlights areas where multiple community assets are present. To view results in detail, see Appendix H or view results in CREST.

At the island-scale, Tutuila clearly features the highest Community Exposure values. By focusing on the village of Tafuna, finer-resolution patterns in exposure become evident (Figure 13). The Threat Index is mostly driven by storm surge, low lying areas, and the prevalence of impervious surfaces. As expected for one of the larger communities on the island, the Community Asset Index is influenced by population density and social vulnerability, with relatively high concentrations of both critical infrastructure and facilities throughout. Together, patterns of high exposure are evident throughout the region. Even within the central portions of the island, such as near Pago Pago (Figure 10), there are areas of very high exposure due to the presence of numerous critical facilities and relatively high population. When combined with low slope, erodible soils, and impermeable surfaces, some of the areas around Pago Pago are highly exposed to flooding threats. To explore the results of the analysis in more detail for any area of interest, visit the Coastal Resilience Evaluation and Siting Tool (CREST) at resilientcoasts.org. For more details about CREST, please refer to Section 3.4 below.

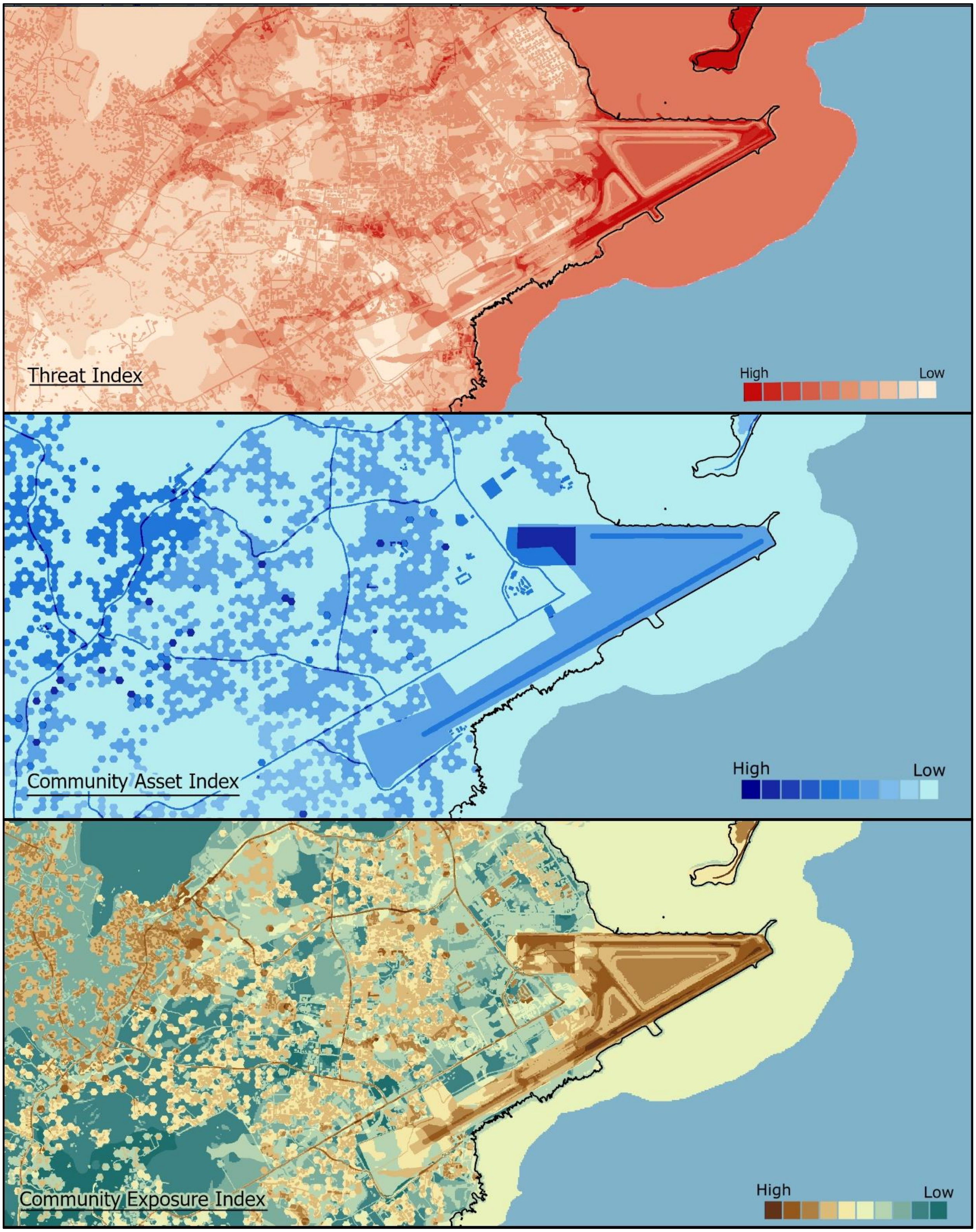

Figure 13. The area around the village of Tafuna, Tutuila, particularly around the Pago Pago International Airport, shows higher values of exposure, resulting from the combination of flood threats and community assets.

3.2 Fish and Wildlife Index

The combined Fish and Wildlife Index shows the highest values within productive nearshore marine waters and biodiverse forests along the islands' mountain ranges (Figures 14). Due to the additive nature of the Fish and Wildlife Index, the highest values are all observed in coastal waters where healthy marine habitats coincide with terrestrial resources such as seabirds and sea turtles. This is evident especially on the islands of Ofu, Olosega, and Taʻu, where there is primary habitat for green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) sea turtles. In other instances, high values are driven by overlapping features, such as areas that are designated for protection or conservation by multiple agencies. This drives high values in both the Marine and Terrestrial Indices. While the impressive fish and wildlife habitats on the islands of Ofu, Olosega, and Taʻu are evident, there are significant fish and wildlife assets throughout all five islands, indicating there are ample opportunities for habitat conservation and restoration projects to sustain American Samoa's biodiversity.

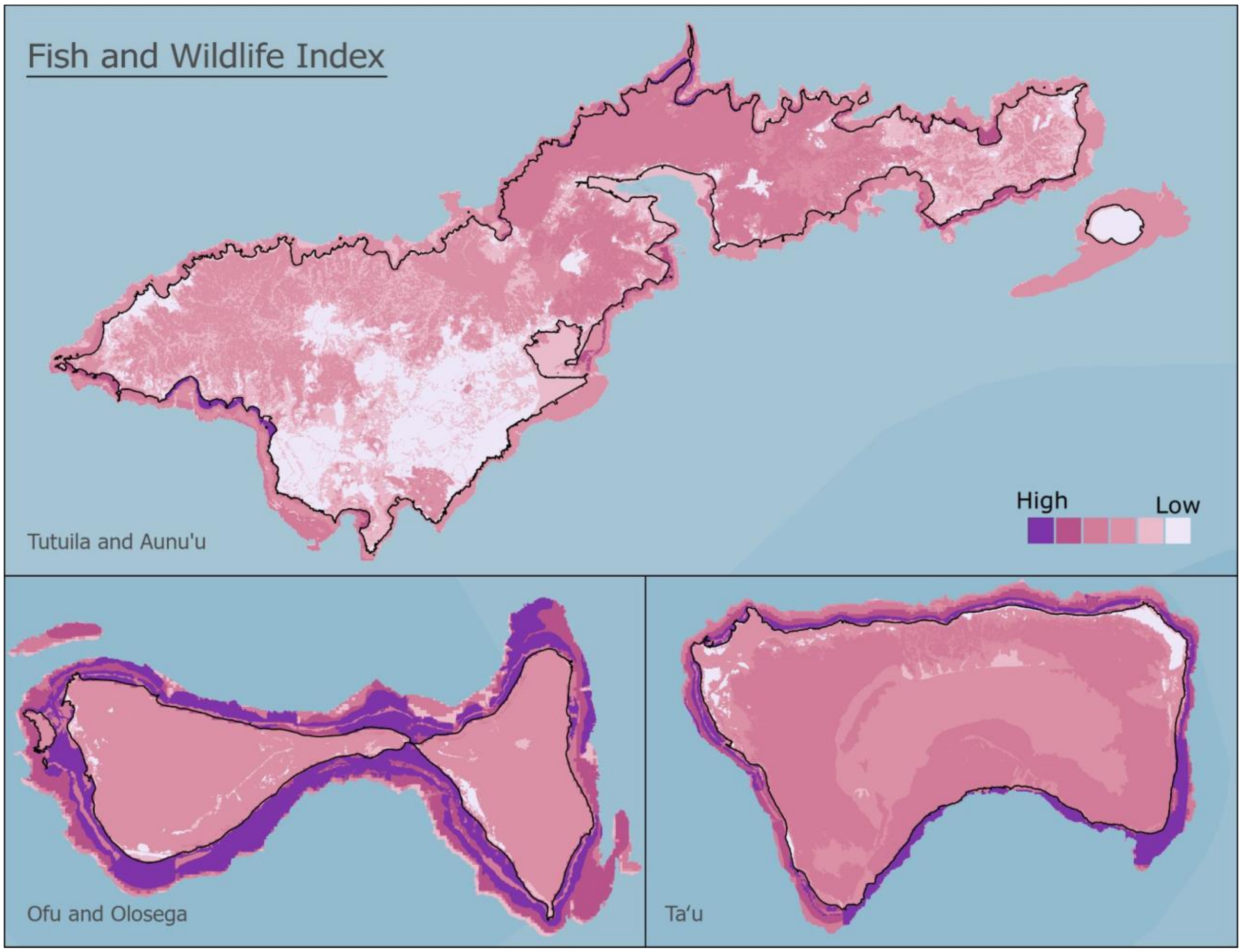

Figure 14. The Fish and Wildlife Index for the islands of Tutuila and Aunuʻu (top), Ofu and Olosega (bottom left), and Taʻu (lower right). Terrestrial and Marine Indices are added to produce the Fish and Wildlife Index, which shows concentrations of fish and wildlife species and their habitats. To view results in detail, see [Appendix H] or view results in [CREST].

As noted in the Methods section, the Terrestrial Index evaluated habitat suitability across four broad species groups. Many of the species included in the American Samoa Comprehensive Wildlife Conservation Strategy (DMWR 2016) rely on high-quality habitat in primary rainforest, which can be found across large parts of Tutuila's interior (Figure 15). Other areas with high concentrations of wildlife assets in the Terrestrial Index reflect the prevalence of protected or managed areas throughout the islands. For instance, some of the highest Terrestrial Index values are seen in portions of the National Park of American Samoa and the Manuʻa Islands Marine Important Bird Area where the presence of high-quality habitat overlaps with lands under protected status. High values in the Terrestrial Index along the coastlines highlight the importance of coastal habitats for migratory birds, sea birds, waterbirds, and sea turtles. For a complete list of species referenced for this analysis, see Appendix E.1.

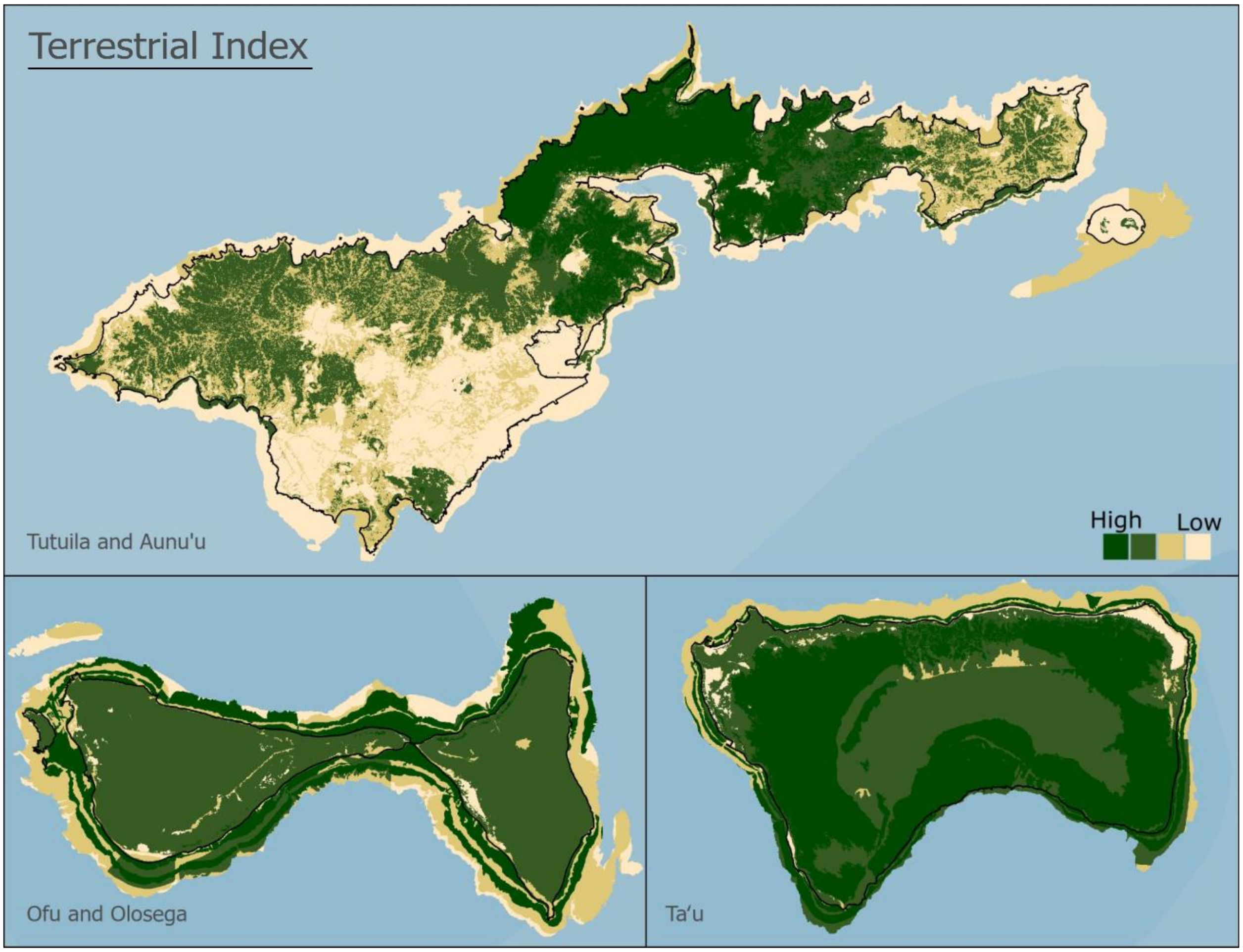

Figure 15. Terrestrial Index for the islands of Tutuila and Aunuʻu (top), Ofu and Olosega (bottom left), and Taʻu (lower right). The terrestrial index highlights concentrations of terrestrial species and their habitat. To view results in detail, see Appendix H or view results in CREST.

The Marine Index reveals many high values around each island, highlighting the importance of marine habitat and species throughout the region (Figure 16). This is largely driven by the prevalence of coral reefs and Essential Fish Habitat (EFH) around the margins of the islands. Despite recent severe bleaching events in 2015 and 2017 (Coward et al. 2020), live coral cover was relatively high along the entire coastline of Taʻu and on the southwestern coast of Tutuila. In addition to the presence of corals, these areas also feature EFH for resource fishes and show high reef fish biomass. The presence of other protected and managed areas, such as the National Marine Sanctuary of American Samoa and the Aua Village Marine Protected Area also contribute to higher scores. Together, these features all indicate these regions harbor significant marine biodiversity.

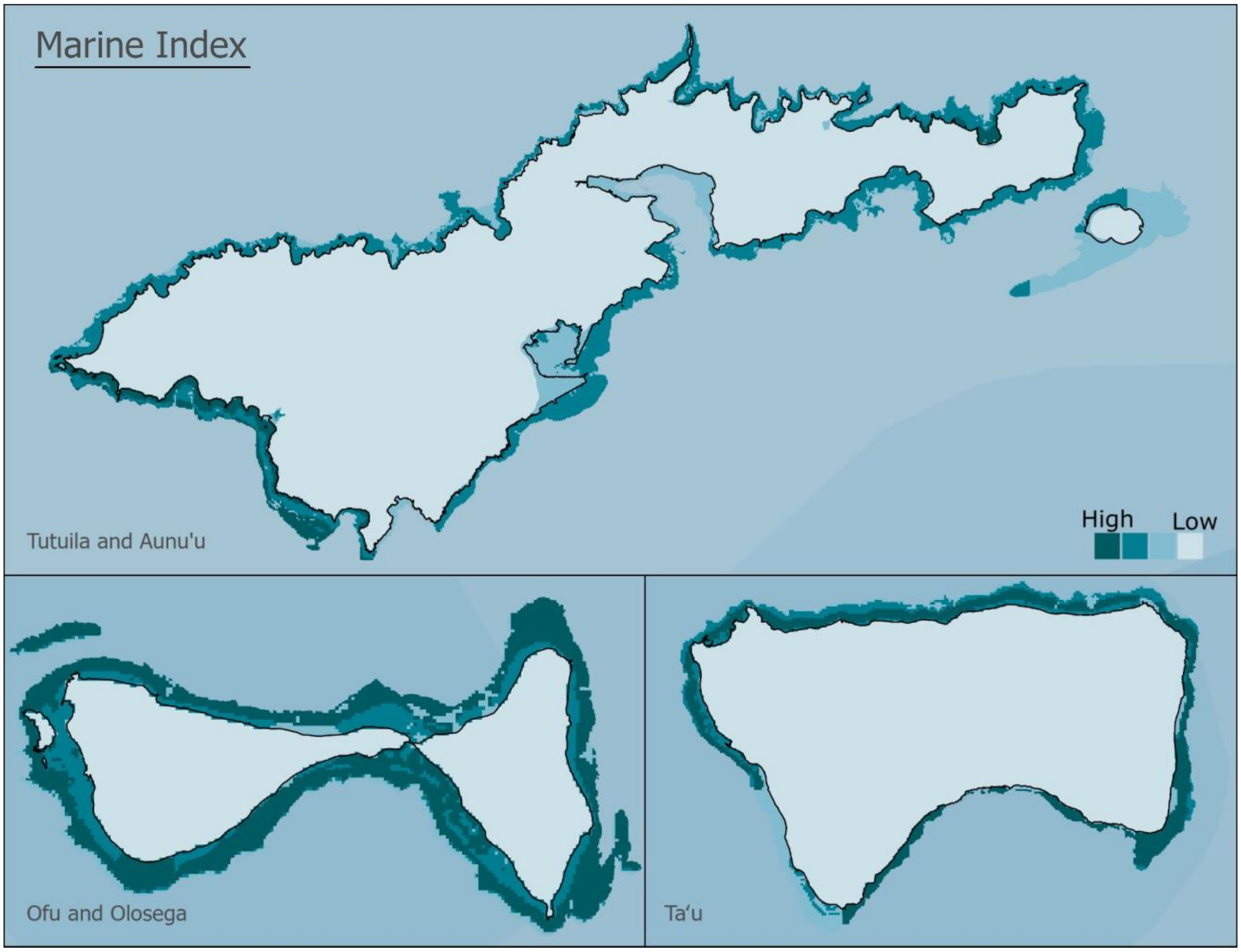

Figure 16. Marine Index for the islands of Tutuila and Aunuʻu (top), Ofu and Olosega (bottom left), and Taʻu (lower right). The marine index highlights concentrations of marine species and their habitat. To view results in detail, see Appendix H or view results in CREST.

Some of the highest Marine, Terrestrial, and combined Fish and Wildlife values identified in the American Samoa Assessment are found along the coast of Ofu and Olosega. Here, high values result from a combination of marine and coastal habitat used by myriad species of conservation concern. The entire coast of Ofu and Olosega is marked by extensive coral reefs and very high reef fish biomass. Marine Index values along the southern shore are also driven by the presence of EFH, the National Park of American Samoa, and the Ofu Vaoto Marine Park (Figure 17). This area features habitat important to sea turtles, sea birds, and land birds, contributing to an increased combined Fish and Wildlife Index score for this region. To explore the results of the analysis in more detail for any area of interest, visit the Coastal Resilience Evaluation and Siting Tool (CREST) at resilientcoasts.org. For more details about CREST, please refer to Section 3.4 below.

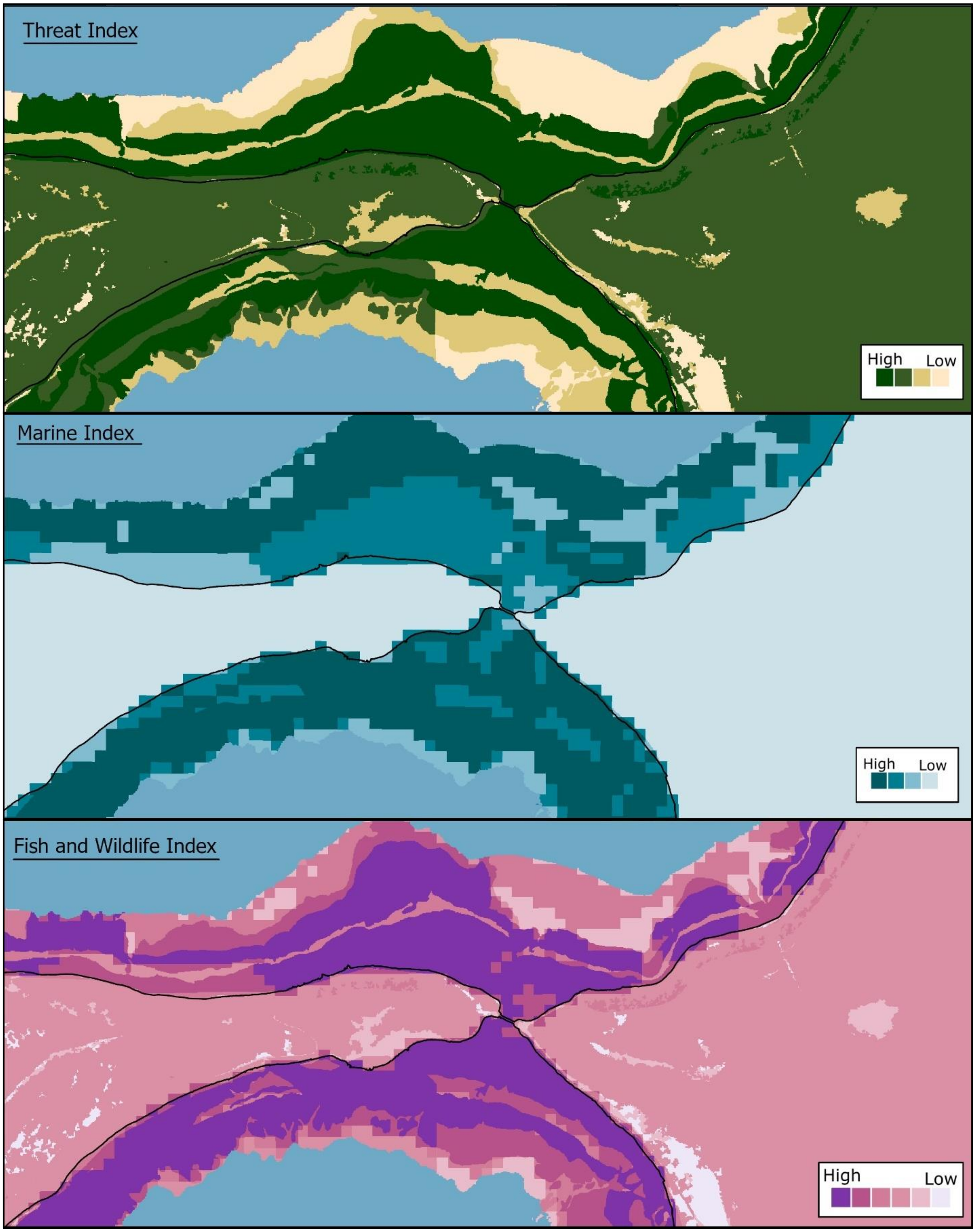

Figure 17. The coasts of Ofu and Olosega shows higher values in both the Terrestrial and Marine indices, resulting in high values in the Fish and Wildlife Index. This is a result of a combination of the presence of several important marine and coastal habitats utilized by marine and terrestrial species.

3.3 Resilience Hub Analysis

The American Samoa Assessment identified many Resilience Hubs throughout the islands. While the eastern portion of Tutuila features many of the highest-ranking Resilience Hubs, the assessment revealed ample opportunities throughout American Samoa to implement nature-based solutions to build human community resilience while benefiting fish and wildlife habitat and the species and ecosystem services they support.

The final Resilience Hub rankings are the product of the Community Exposure and Fish and Wildlife Indices. As described in the Methods section above, the boundaries of the Resilience Hubs are formed through the Green and Blue Infrastructure analysis, which identifies Green and Blue Habitat Cores at least 4 hectares (10 acres) in size. The habitat cores represent areas of contiguous open space that are of a sufficient size to implement a nature-based solution with maximum potential to provide fish and wildlife and flood risk reduction benefits. Once the boundaries of the Blue and Green Habitat Cores are determined, they are ranked based on the product of the Community Exposure and Fish and Wildlife Index values (Figures 18 and 19). Using zonal statistics, a single average rank is then applied to each habitat core to create the combined Resilience Hubs (Figures 20 and 21). To see the variation in ranking within a given Resilience Hub, results are also viewed as a hexagon grid. Each 4-hectare (10-acre) hexagon also receives a rank based on the Community Exposure and Fish and Wildlife Index values (Figures 20 and 21). The hexagons clearly show higher rankings around the coast and adjacent to dense community assets, while more interior and remote locations receive lower ranks.

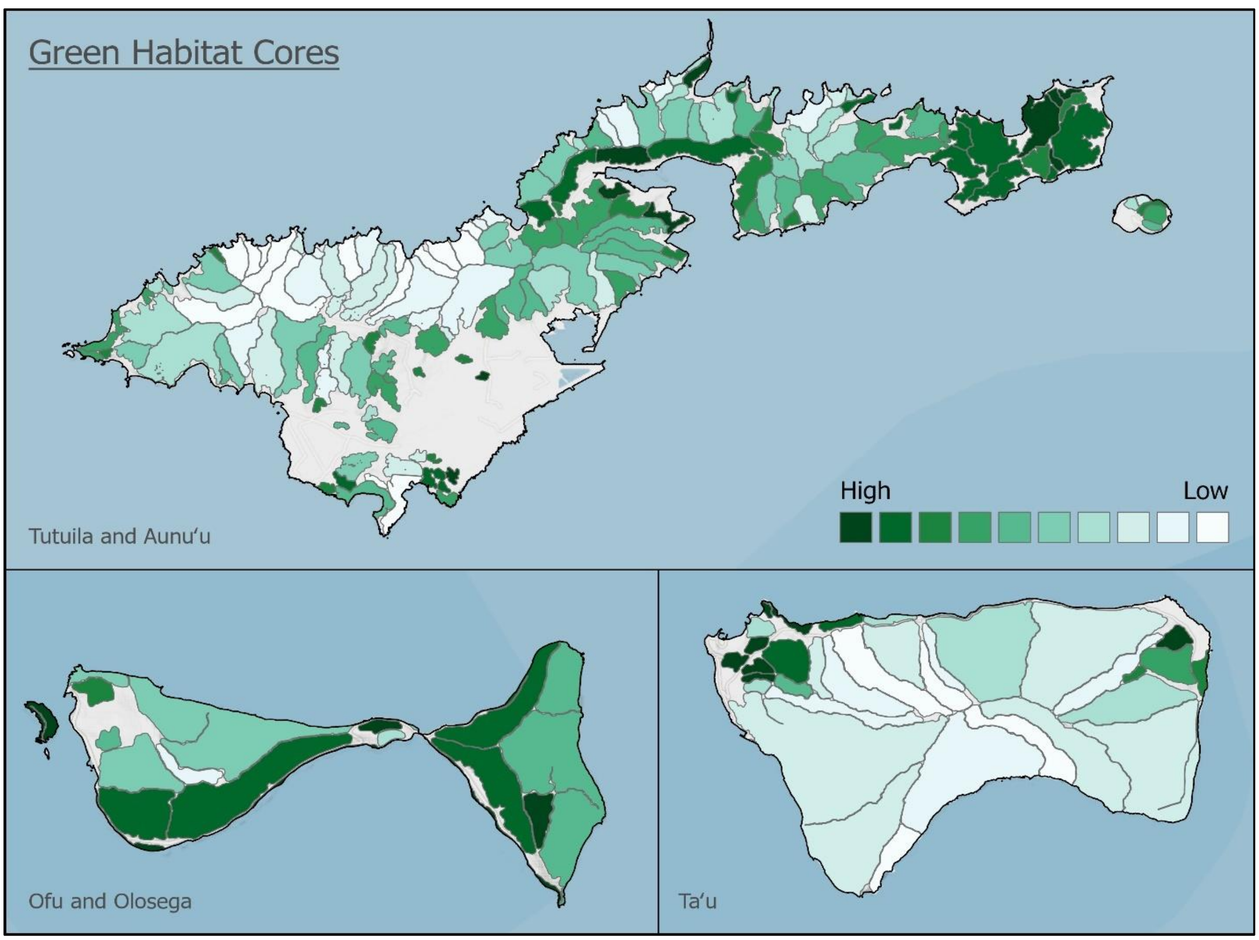

Figure 18. Green Habitat Cores for the islands of Tutuila and Aunu'u (top), Ofu and Olosega (bottom left), and Ta'u (lower right).

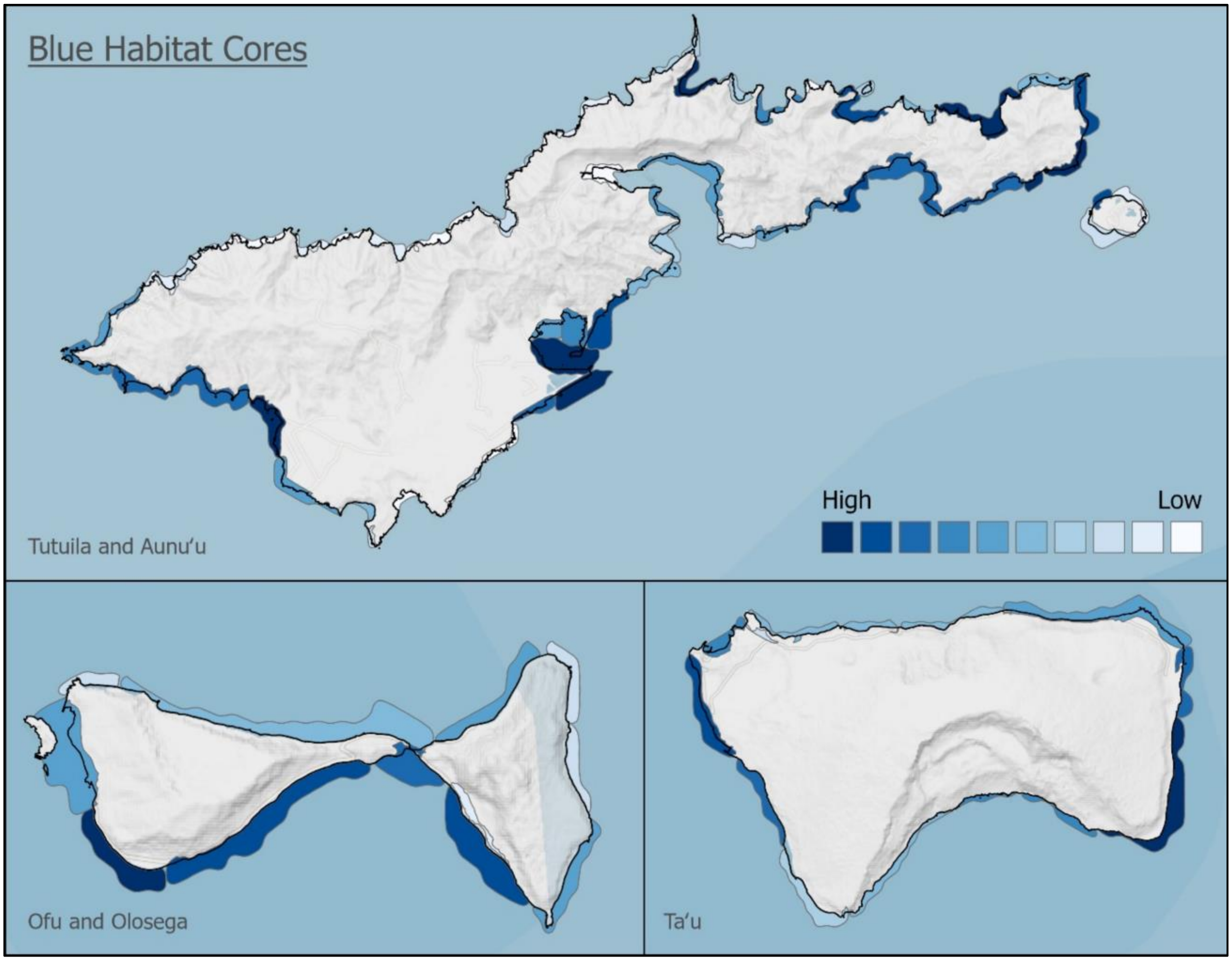

Figure 19. Blue Habitat Cores for the islands of Tutuila and Aunu'u (top), Ofu and Olosega (bottom left), and Ta'u (lower right).

Due to the extensive presence of coral reefs and vast tracts of natural land cover with few fragmenting features, the analysis identified many large Resilience Hubs. High-ranking Hubs represent areas with significant potential for nature-based solutions to achieve benefits for fish and wildlife while also reducing flooding risk to important human community assets. While the less populated islands of Ofu, Olosega, and Ta'u feature high-ranking Hubs, these rankings are largely driven by the presence of fish and wildlife habitat and critical road infrastructure running through most Hubs along the coastlines.

On Tutuila, higher-ranked Resilience Hubs can be found throughout most of the island, particularly in areas surrounding Vatia and along the Tialeogaumu and Maatulua mountain ridges north of Pago Pago Harbor (Figure 20). In Vatia, this is due to the combination of high Community Exposure values, extensive coral reef and wetland habitats in the bay, and the presence of the National Park of American Samoa. Along the relatively undeveloped mountain ranges, there are numerous high-ranking Hubs that are not only home to endangered native forest birds and invertebrates, but also have dense community assets at the base of the mountains along the coast. With numerous villages along the coast and significant cultural and historical resources, this region also has high fish and wildlife values; together, the large tracts of open space highlight potential opportunities for nature-based solutions with dual community and ecosystem benefits.

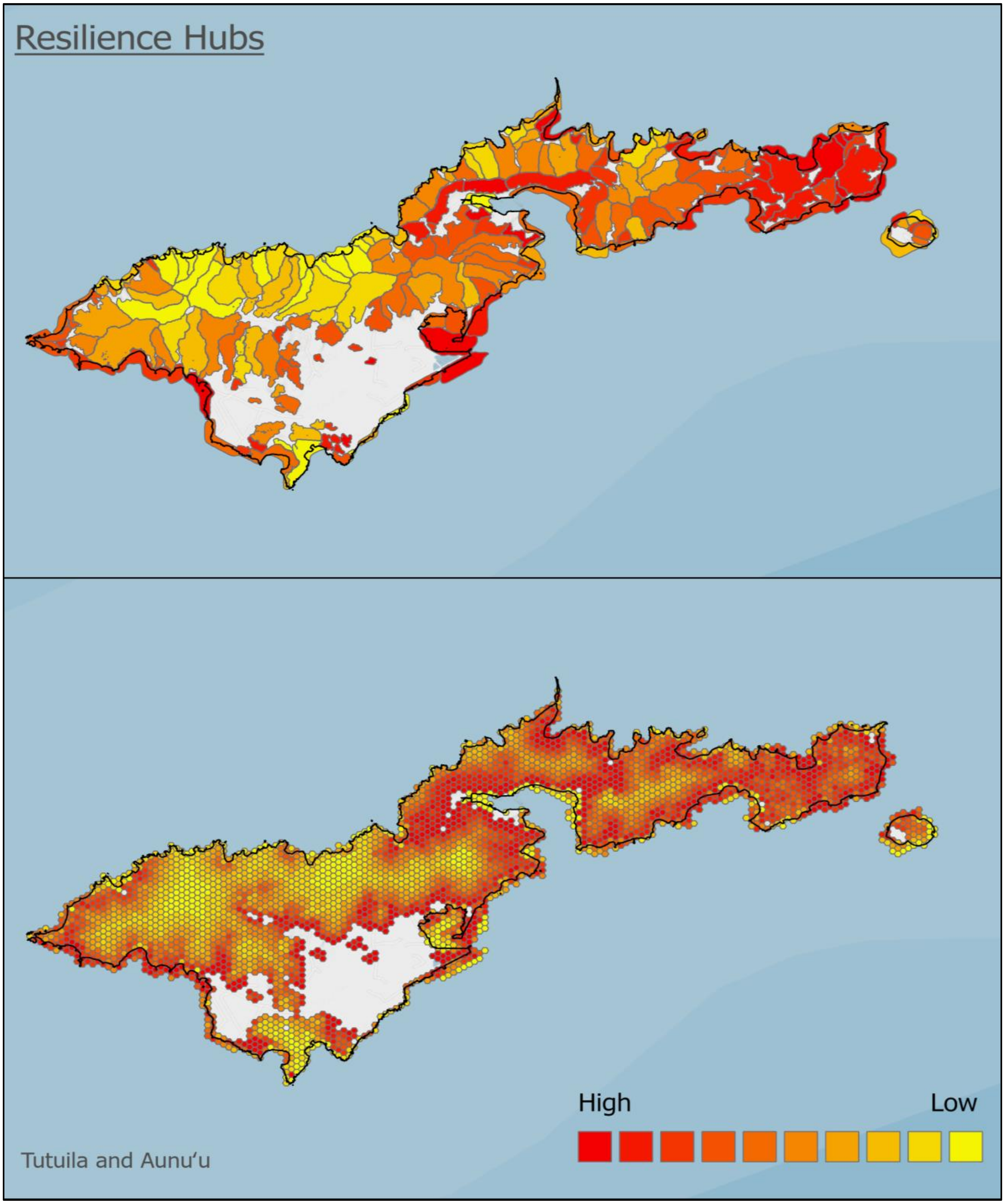

Figure 20. Resilience Hubs and ranked 4-hectare (10-acre) hexagons to view variation in Resilience Hub rankings for the islands of Tutuila and Aunuʻu. Highest ranking areas (darker reds) represent areas well suited for the implementation of nature-based solutions that will benefit both species of conservation concern and human community resilience to flooding threats. To view results in detail, see Appendix H or view results in CREST.

The analysis revealed a large network of Blue Habitat Cores encompassing nearly the entire nearshore marine boundary of all five islands (<10-meter depth) (Figure 19). Blue Habitat Cores found in nearshore areas also received a higher score if multiple habitat types, such as coral reefs, mangroves, or sandy beaches are present in the same areas (within 0.25 kilometers). Areas with multiple habitat types in close proximity may offer opportunities to implement a suite of coordinated nature-based solutions to maximize the potential to protect surrounding coastal communities from storm and flood events.

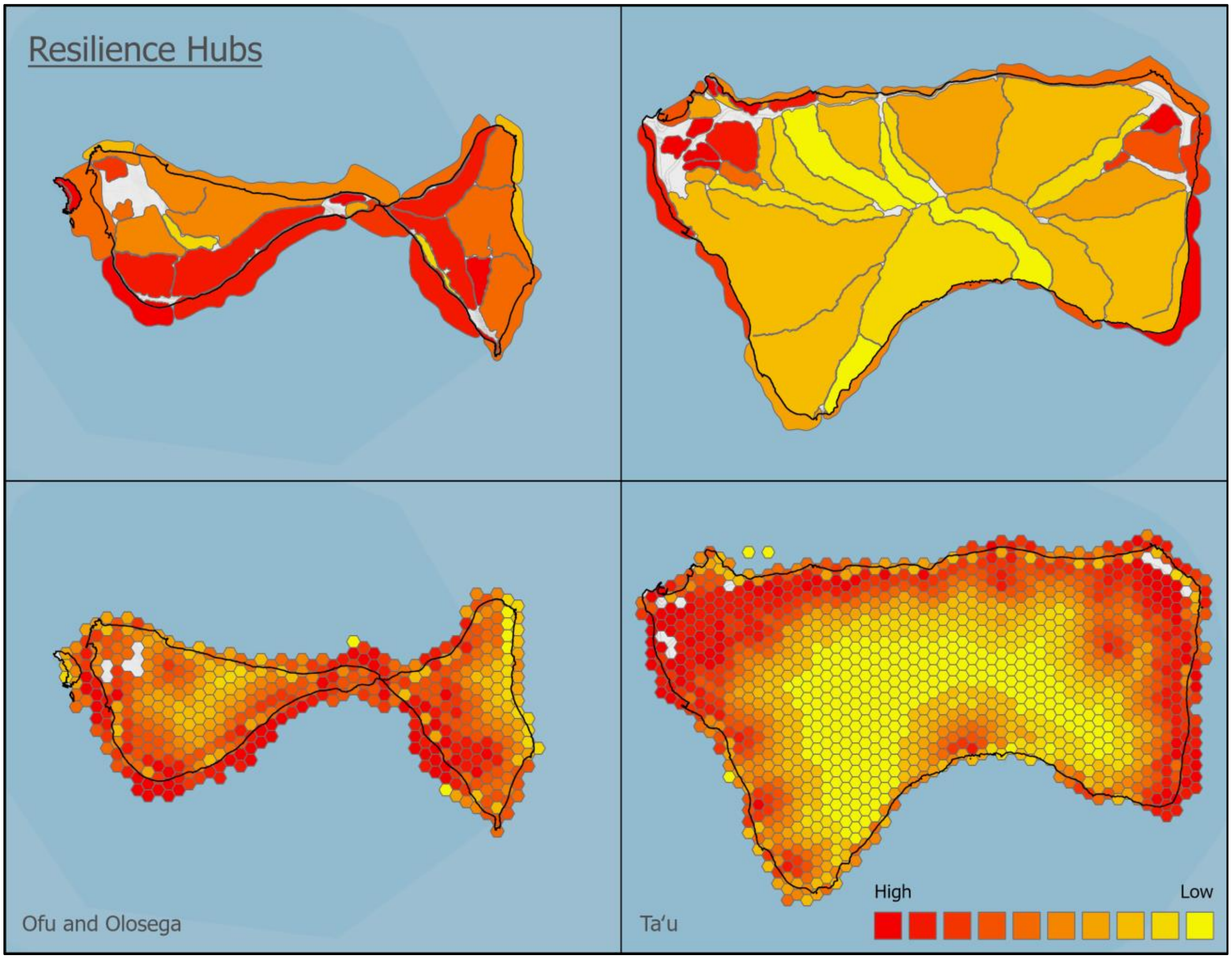

Figure 21. Resilience Hubs and ranked 4-hectare (10-acre) hexagons to view variation in Resilience Hub rankings for the islands of Ofu and Olosega (left) and Ta'u (right). Highest ranking areas (darker reds) represent areas well suited for the implementation of nature-based solutions that will benefit both species of conservation concern and human community resilience to flooding threats. To view results in detail, see Appendix H or view results in CREST.

Resilience Hub size also varied considerably between islands, due in part to the large amount of open and natural land cover found in the interior of most islands. In Tutuila, there are numerous roads, buildings, or other infrastructure that fragment the landscape and produce several relatively small Hubs distributed across much of the island (Figure 20). This is particularly evident in the Tafuna Plain where there are relatively few Green Habitat Cores (Figure 22). This relatively flat area is highly developed and thus features high Community Exposure values; however, there are relatively few patches of contiguous intact habitat that meet the criteria used to identify habitat cores. Therefore, while projects in this area may support important community benefits, there may be limited contiguous terrestrial habitat to support nature-based solutions that can also benefit terrestrial species of conservation concern. Despite limited open space, there are several high-ranking Resilience Hubs including the Naumati Forest. There are also several higher-ranking blue habitat cores in and around the Tafuna Plain and within the Pala Lagoon, suggesting there may be more opportunities to implement nature-based solutions in coastal and nearshore marine habitats, including coral reef conservation and restoration, mangrove restoration, and living shorelines and other techniques that help slow coastal erosion. To explore the results of the analysis in more detail for any area of interest throughout American Samoa, visit the Coastal Resilience Evaluation and Siting Tool (CREST) at resilientcoasts.org. For more details about CREST, please refer to Section 3.4 below.

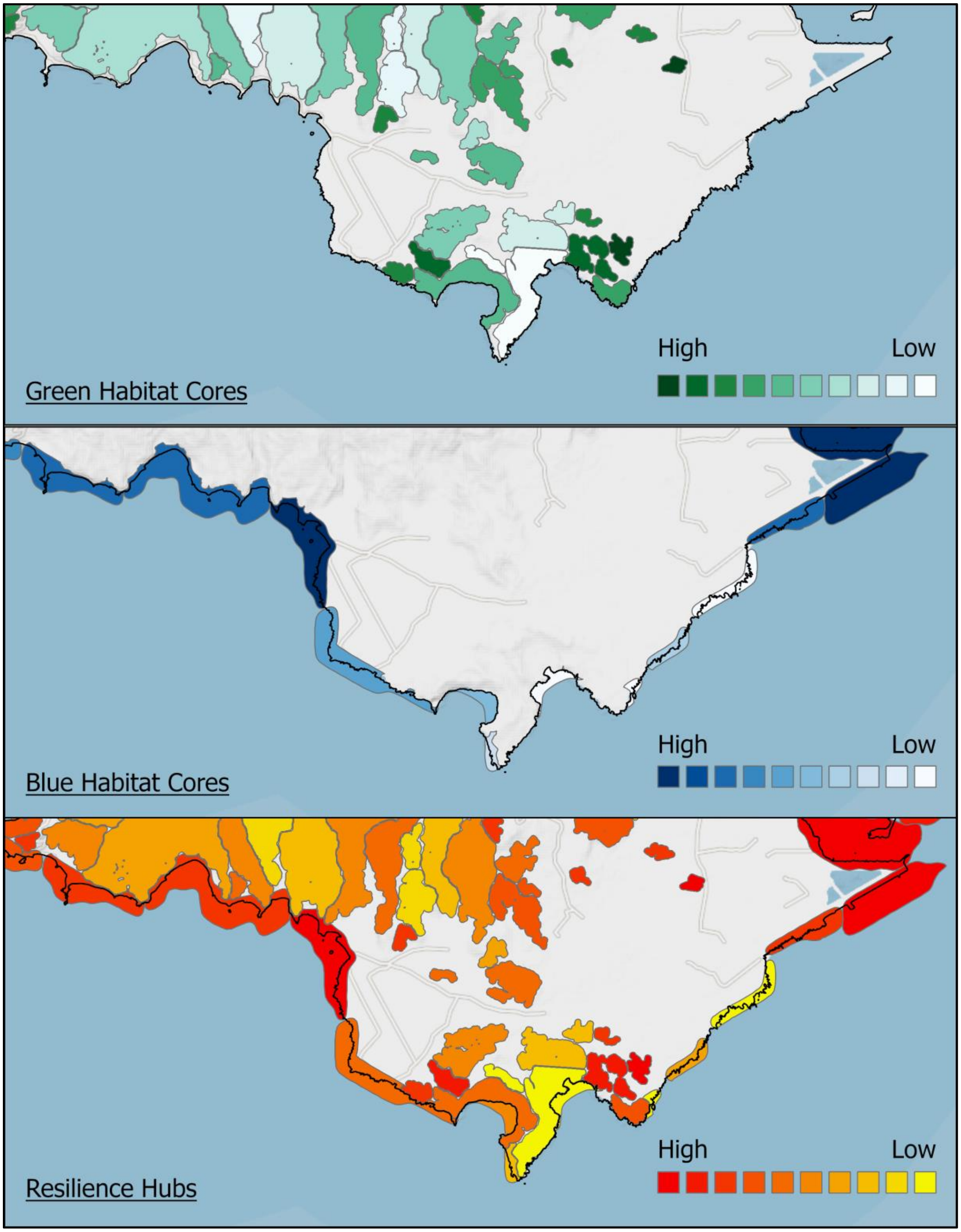

Figure 22. Green Habitat Cores, Blue Habitat Cores, and ranked Resilience Hubs for the southernmost coast of Tutuila.

3.4 Coastal Resilience Evaluation and Siting Tool

To provide an online interface to allow users to interact with key Assessment data, including input data and final models for the Community Exposure Index, Fish and Wildlife Index, and the Resilience Hubs, the Coastal Resilience Evaluation and Siting Tool (CREST) was developed as an accompanying GIS-based web tool (available at resilientcoasts.org). CREST helps users make informed decisions about proposed project sites and address other key questions about how to build resilience within their community. It also allows users full access to the American Samoa Assessment data so they may incorporate them into their own GIS applications or other planning processes. Additionally, CREST provides access to the Assessment results even if the user does not have a GIS background or access to GIS software.

Users can directly access results of the American Samoa Assessment straight from the CREST homepage. In addition to simply exploring the results of the Regional Assessments, CREST allows users to analyze results for specific areas of interest. For instance, if a user has already identified a potential project location, they can draw or upload the project boundary within the tool to view site-specific results for the Resilience Hubs, Community Exposure Index, Fish and Wildlife Index, and the results for each of the model inputs. Alternatively, if a user does not have a specific project location in mind but is interested in evaluating opportunities within a particular region, they can draw a broad area of interest to view results. In both cases, the user can view the results in CREST or download the results in tabular or GIS formats for additional analysis.

CREST is intended to be used as a screening-level tool designed to help identify areas that may be well suited for nature-based solutions. Before planning any resilience projects in American Samoa, it is important to first consult local matai, or chiefs, to explore opportunities in areas governed by traditional land-tenure. As with all GIS analyses, site-level assessments are required to validate results and develop detailed design and engineering plans.

CASE STUDIES

4.1 Demonstrating Local Resilience through Living Shorelines

The high, mountainous islands of American Samoa feature steep terrain interspersed with stream drainages that help to transport sediment to relatively narrow coastal plains underlain by terrigenous and marine sediments that support beaches, wetlands, and mangrove forests (Thornberry-Ehrlich 2008). Due to this rugged topography, coastal development is largely restricted to flat, narrow coastlines that are particularly vulnerable to climate impacts. In particular, sea level rise and more frequent and intense extreme rainfall events result in significant flooding and shoreline erosion (Keener et al. 2021). Coastal erosion is a significant and growing threat that is greatly exacerbated by rapid increases in relative sea level rise. Throughout the islands, seawalls, and other forms of traditional shoreline armoring help to protect coastal infrastructure; however, hardened infrastructure can often accelerate beach loss and worsen erosion (Summer et al. 2018, Keener et al. 2021). With rapid environmental changes expected in the coming years and decades, there is growing interest in innovative solutions that can help coastal villages and habitats adapt.

Nature-based solutions offer one innovative approach to help reduce erosion, protect exposed shorelines from coastal flooding, and provide important habitat for native species. Nature-based solutions include efforts to install living shorelines; plant native vegetation; and restore coral reefs, mangroves, and wetland habitats. Restoring and preserving natural ecosystems can help to attenuate wave energy, store excess water during flooding events, and reduce erosion.

While efforts to improve and conserve coral reef habitats have long provided coastal resilience benefits in American Samoa, other nature-based solutions like living shorelines remain untested, not just in American Samoa but across most tropical volcanic islands in the Pacific. In other locations around the United States, living shorelines have proven an effective alternative to shoreline hardening and seawalls. Living shorelines utilize natural materials to create a robust but gentle transition from uplands to the water. By using natural materials, living shorelines filter upland runoff, provide habitat for fish and wildlife, and prevent erosion. When properly designed and sited, living shorelines are self-sustaining, require less maintenance than seawalls and bulkheads, cost less to install, and provide habitat for fish and wildlife[9]. Living shorelines can even promote the accretion of sand and sediment. However, there are locations where living shorelines are not appropriate. In areas where flooding or wave energy is too severe, a hybrid approach using gray and natural infrastructure may be needed.

Researchers at the University of Hawaiʻi at Mānoa (UHM) are leading an innovative project to implement living shorelines in Lions Park and Coconut Point, Tutuila. With funding from the National Coastal Resilience Fund[10] and other sources, UHM is working with local partners to design and construct a living shoreline that will serve as an important demonstration project for residents and visitors of Tutuila. The project is being implemented through a coordinated effort among the American Samoa Government's Department of Parks and Recreation, Coastal Zone Management Program, Department of Marine and Wildlife Resources, Department of Education, Department of Commerce, and Environmental Protection Agency in addition to the NOAA Coastal Zone Management Program, American Samoa Community College's Marine Science Program and Land Grant Forestry Program, the Coral Reef Advisory Group, and local non-profit organizations Le Tausagi and Finafinau.

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[9] For more information about living shorelines, visit https://www.habitatblueprint.noaa.gov/living-shorelines/.

[10] https://www.nfwf.org/programs/national-coastal-resilience-fund.

The following case study describes ongoing living shoreline activities in and around the Pala Lagoon, using the American Samoa Assessment results to demonstrate the utility of various outputs to evaluate potential locations to site similar types of resilience efforts. Through 2023, the UHM team will work on two distinct living shorelines projects within the lagoon, one along the shore of Lions Park and a second for Nu´uli Uta at Coconut Point (Figure 23).

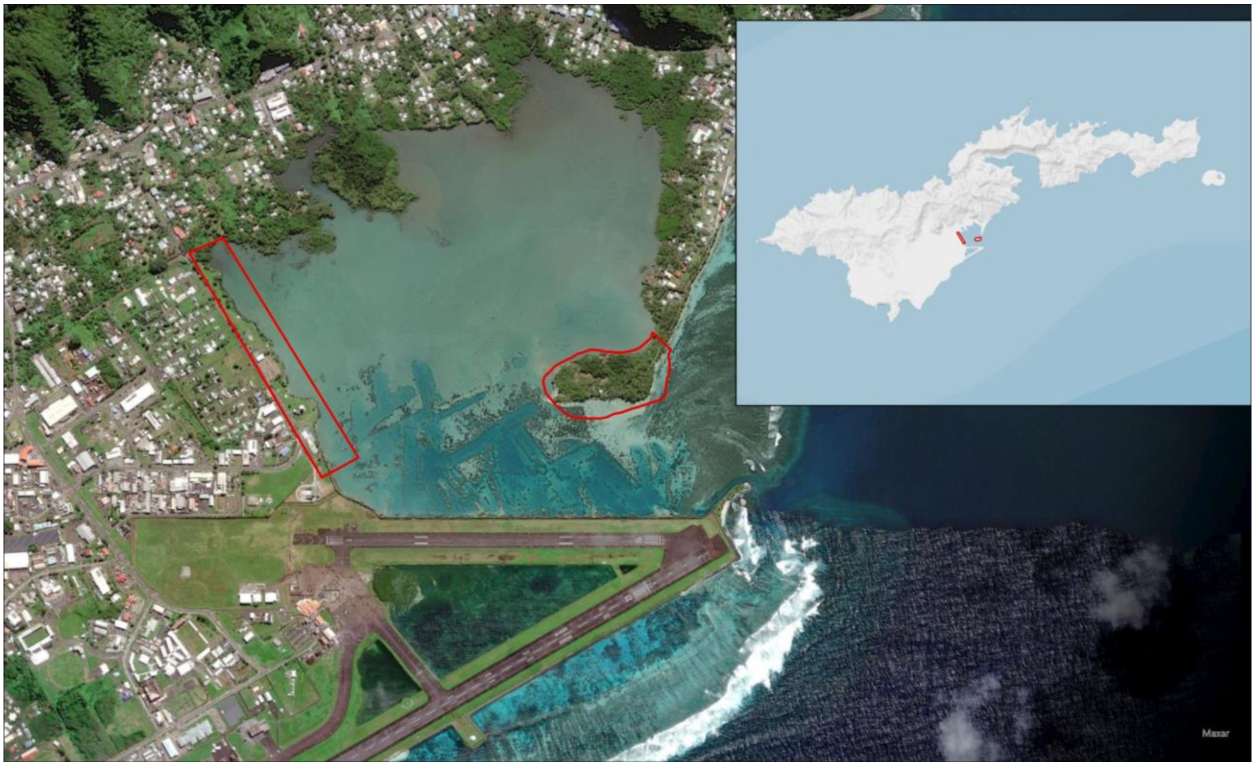

Figure 23. Map showing the location of the Lions Park living shoreline (left) and Nu´uli Uta living shoreline design at Coconut Point (right). Both projects are located in the Pala Lagoon near Tafuna, Tutuila.

As seen in the satellite imagery, the north and east sides of Pala Lagoon are ringed with protective mangroves. However, on the developed western side of the lagoon there are fewer mangroves, leaving Lions Park and surrounding community assets exposed. Owned and managed by the American Samoa Department of Parks and Recreation, the site is ideal for an innovative demonstration project to help promote consideration and adoption of living shorelines in a popular public park visited by many residents (Figure 24). By installing a living shoreline at this site, the project team can demonstrate the utility of nature-based approaches for providing important coastal erosion and flooding protection benefits.

While the American Samoa Assessment reveals that Lions Park is only moderately exposed to flooding threats (Figure 25), this relatively sheltered and low wave energy site within the lagoon is ideal for a natural rock living shoreline that will be planted with native vegetation and seeded with oyster dome reefs to help reduce erosion, create habitat, and grow and adapt to future flooding threats. Even without accounting for ongoing land subsidence, the site is subject to the effects of sea level rise (Figure 26) and is located within a flood-prone area (Figure 27). The Nu´uli Uta site at Coconut Point is a much higher energy site subject to frequent wave energy (Figure 28). Not only is this evident in the Community Exposure Index and sea level rise layer, but it also indicates that this site may require a different living shoreline design better adapted to attenuating wave energy.

Figure 24. Views of the Lions Park living shoreline site. Shoreline erosion is visible along the mid-section of the Lions Park shoreline by the recreational shelter (left). Coastal inundation at high tide on the south end of Lions Park, an area used for recreation and fishing (right). Photo credits: Kelley Anderson Tagarino, University of Hawaiʻi at Mānoa.

Figure 25. The Community Exposure Index results for the Pala Lagoon reveal exposure to flooding threats around the lagoon. The black lines outline the Lions Park (left) and Nuʻuuli Uta (right) living shoreline project locations.

Figure 26. Living shorelines can help to reduce shoreline erosion and flooding associated with sea level rise. Shades represent 1-to-5-foot sea level rise scenarios, with the highest values reprinting a one-foot rise in sea level due to its higher likelihood of occurrence. The black lines outline the Lions Park (left) and Nu'uuli Uta (right) living shoreline project locations.

Figure 27. Living shorelines can help to reduce shoreline erosion and flooding in flood-prone areas. The black lines outline the Lions Park (left) and Nu'uuli Uta (right) living shoreline project locations.

Figure 28. View of the Nu'uuli Uta living shoreline design site. Shoreline erosion is visible along the shore. Prior to the 2009 earthquake and ongoing subsidence, this site featured several feet of dry sand that has since been inundated. Photo credit: Kelley Anderson Tagarino, University of Hawai'i at Mānoa.

The results of the assessment highlight numerous community assets in close proximity to both project sites (Figure 29). The Lions Park site is not only near populated areas, but there are also adjacent critical facilities and infrastructure including Tutuila's only jail, a vocational high school, and the only two roads leading to the airport, bulk fuel storage, and the airport itself. While not identified in the assessment, Lions Park is also an important area for recreation and community use, including a public pool, bathrooms, parking areas, a tennis club, and walking trails. There is also a road leading to the Nu'uuli Uta site at Coconut Point (Figure 29). While living shorelines may not protect all these assets from all coastal flooding threats, the natural shoreline is expected to reduce shoreline erosion.

In addition to the numerous physical benefits of installing the living shoreline and planting vegetation, the project may also provide important habitat for wildlife. The Pala Lagoon is the largest estuary in American Samoa with over 100 acres of estuarine and mangrove habitat important for juvenile fishes, birds, and sea turtles (Figure 30). Oyster reef construction and possibly oyster and clam farming is also being considered to help protect the shoreline, improve water quality, and augment oyster and clam production in the lagoon (Haws et al. 2020).

Figure 29. The Community Asset Index shows concentrations of community assets around the Pala Lagoon. The black lines outline the Lions Park (left) and Nu'uuli Uta (right) living shoreline project locations. Note the numerous critical facilities and assets in proximity to the Lions Park site.

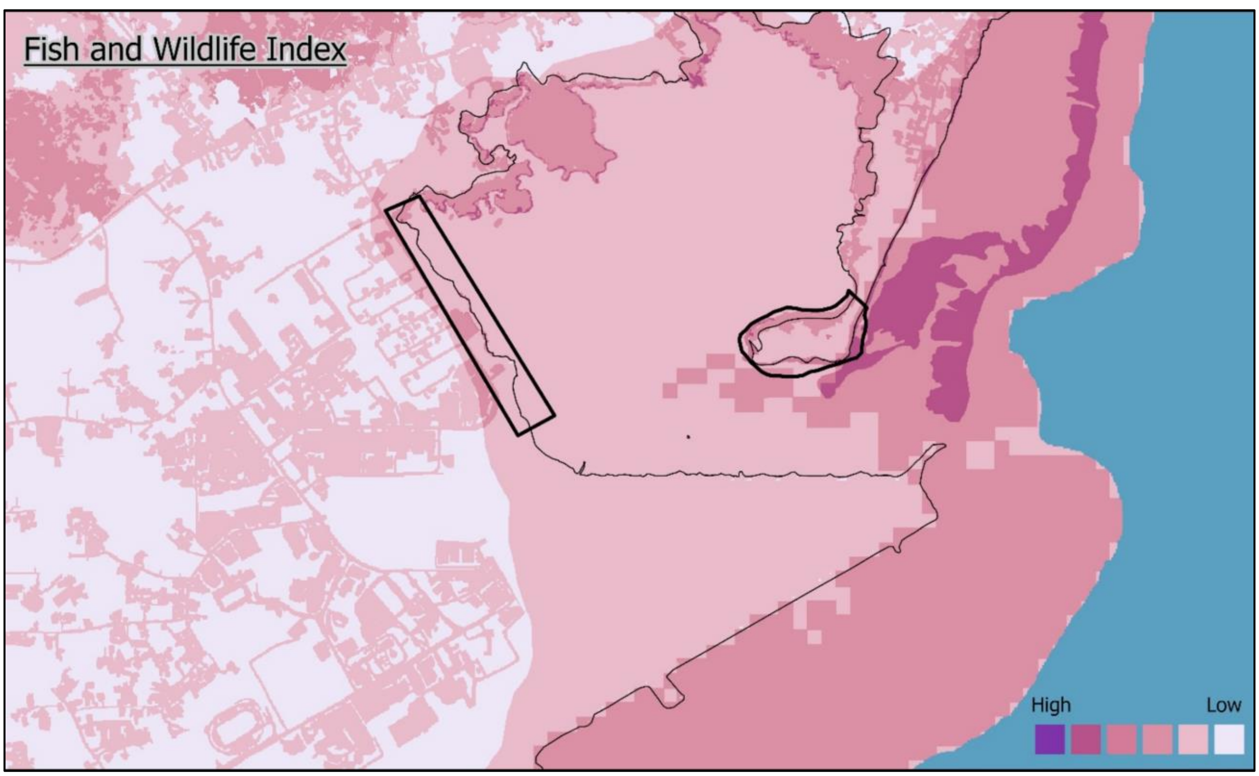

Figure 30. Fish and Wildlife Index results for the Pala Lagoon. The black lines outline the Lions Park (left) and Nu'uuli Uta (right) living shoreline project locations. Note the high fish and wildlife values in the mangrove areas lining the lagoon and nearshore coral reefs west of Coconut Point.

With the presence of considerable flooding threats, concentrations of coastal community assets, and wildlife habitat, living shorelines and other restoration efforts in Pala Lagoon demonstrate the importance of placing resilience projects in areas that can achieve dual benefits for communities and fish and wildlife. The Assessment reveals how Resilience Hubs are a useful tool to identify areas suitable for nature-based, resilience-building interventions. Within and surrounding the lagoon, a range of moderate ranking Hubs are visible (Figure 31). Additionally, by visualizing the 4-hectare (10-acre) hexagonal grid, the user can access finer-resolution information to understand the variation in scores within a Resilience Hub. The Resilience Hubs along the coast, and throughout American Samoa, can help support the prioritization of habitats for other similar types of projects in Tutuila and elsewhere.

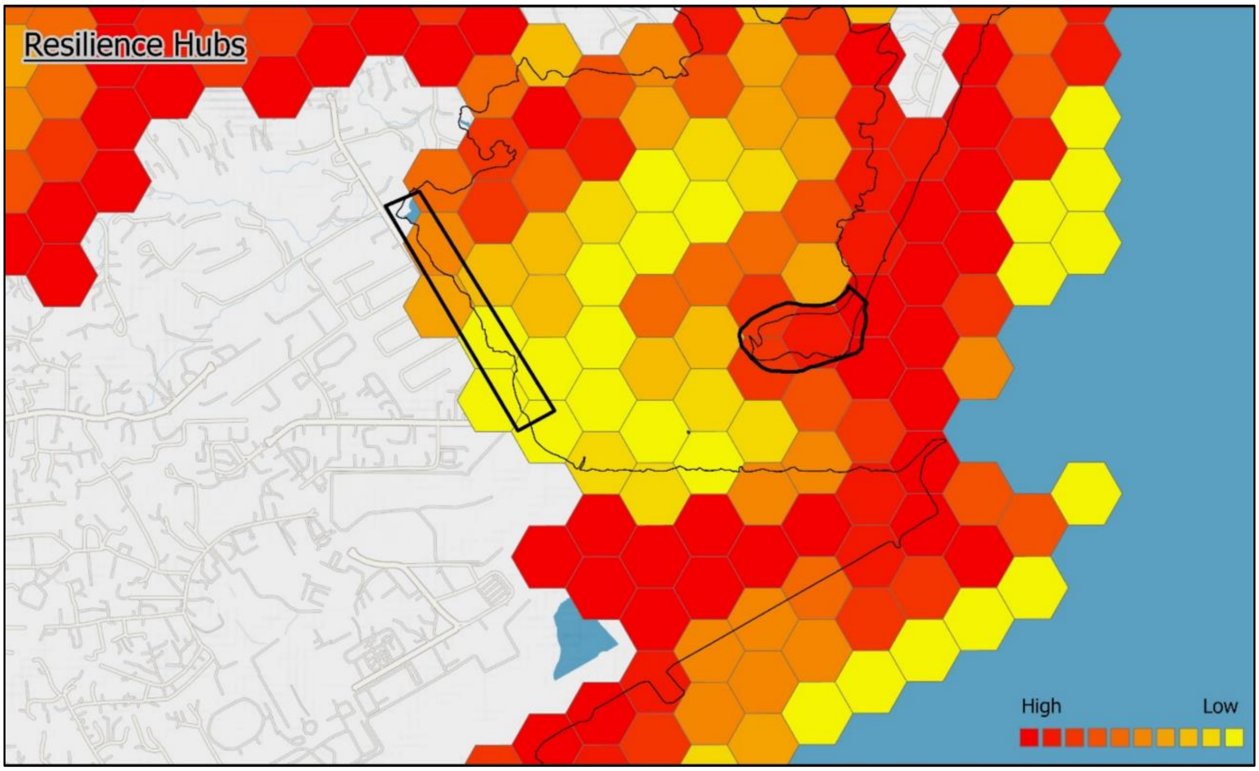

Figure 31. Resilience Hubs indicate that there are multiple areas potentially well suited for restoration projects. The 4-hectare (10-acre) hexagons show variation in scores within Resilience Hubs. The thick black lines outline the Lions Park (left) and Nu'uuli Uta (right) living shoreline project locations.

This collaborative and innovative project will serve as an important proof-of-concept that could be replicated and scaled up at other locations in American Samoa. There is growing interest around using natural and green-gray hybrid approaches to shoreline protection. To harness this momentum and educate residents and decision makers about the benefits of nature-based approaches, the project team will also develop a guide to capture lessons learned and help others replicate living shorelines elsewhere in American Samoa. In addition, the project will engage the local students and community groups in regular volunteer shoreline clean-up events. By engaging community members throughout the process and installing educational signs that will continue to educate visitors, this project is likely to have lasting and transferable benefits for years to come.

CONCLUSION

5.1 Summary and Key Takeaways

As communities in American Samoa face current and future flooding threats from natural events, tools such as this Coastal Resilience Assessment can help decision-makers and other stakeholders use data to make informed decisions about how to identify areas that may be suitable for resilience-focused and nature-based restoration projects. NFWF and NOAA remain committed to supporting programs and projects that improve community resilience by reducing communities' vulnerability to coastal storms, sea-level rise, and other types of coastal flooding by strengthening natural ecosystems and the fish and wildlife habitat they provide.

With over 100 kilometers (60 miles) of coastline combined across all islands, American Samoa remains exposed to a variety of coastal-flood related hazards. The effects of flood-related hazards are compounded in areas with higher populations and assets, such as in areas of southwestern Tutuila. Inland communities are not immune to flood-related threats, especially as they relate to heavy precipitation events and flash flooding. Furthermore, the effects of coastal flooding are exacerbated when combined with heavy precipitation inland, suggesting efforts to build resilience should consider the benefits of a holistic, watershed-wide approach.

American Samoa is ecologically diverse, with an abundance of wildlife assets, both in the terrestrial and marine environments. Combining the information in the Fish and Wildlife Index with the Community Exposure Index, the Assessment identified numerous Resilience Hubs, or areas where resilience-building projects may benefit both human and wildlife communities. As with all GIS analyses, site-level assessments are required to validate results and develop detailed design and engineering plans. The Regional Assessments are intended to be used as a screening-level tool designed to help identify areas that may be well suited for nature-based solutions. The results are also limited by those data available at the time of analysis and by the underlying accuracy and precision of the original data sources; therefore, the assessment may not capture all flood-related threats, community assets, fish and wildlife resources, or areas of open space. Resilience Hubs are not intended to identify all potential opportunities for nature-based solutions, but rather are meant to help assess potential projects based on dual benefits for habitats and human communities.

5.2 Future Work

The Regional Coastal Resilience Assessments were developed through an iterative process supported by substantial guidance from technical and regional experts. The Regional Assessments and the associated Coastal Resilience Evaluation and Siting Tool (CREST) will continue to be updated, refined, and expanded in the future as appropriate. The overarching methodology will continue to be vetted and refined as needed through ongoing Regional Assessments across the United States. The application and continued development of the Assessments will assist NFWF and others in the implementation of nature-based solutions that build community resilience to flooding threats while benefiting fish and wildlife populations nationwide.

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APPENDIX

The following sections describe those data used for the American Samoa Coastal Resilience Assessment in detail, as well as any regional deviations from the methodologies outlined in the Methodology and Data Report (Dobson et al. 2020).

The American Samoa Assessment was completed at a 3-meter resolution, using the projection *NAD 1983 PACP00 UTM Zone 2S* (WKID 102703).

A. Data Summary

A.1 Threat Index

The following is a comprehensive list of datasets used to create the Threat Index for the American Samoa Coastal Resilience Assessment. **Bolded layer names indicate the source data were specific to the American Samoa Assessment.** The flood-related data sets included in the Assessment do not explicitly account for the rapid land subsidence observed in American Samoa following the major 2009 earthquake (Han et al. 2019). The Assessment will be updated as new data becomes available.

Layer Name	Dataset and Source
Flood-prone Areas	FEMA National Flood Hazard Layers (2006), USDA-NRCS SSURGO (2.2 or later)
Sea Level Rise	NOAA Office for Coastal Management Sea Level Rise Inundation Database (2015 or later)
Areas of Low Slope	USGS National Elevation Dataset, 10-meter resolution (most recent available)
Soil Erodibility	USDA-NRCS SSURGO (2.2 or later)
Impervious Surfaces	USDA-NRCS SSURGO (2.2 or later), NOAA Coastal Change Analysis Program Landcover (2010)
Wave Driven Flooding	Floodmasks, USGS (Storlazzi et al. 2019); wave-driven flooding was used because storm surge data were not available for American Samoa
Tsunami Inundation	Modeled maximum inundation extent according to probable future threats, Wood *et al.* 2019

A.2 Community Asset Index

The following is a comprehensive list of datasets used to create the Community Asset Index for the American Samoa Coastal Resilience Assessment. **Bolded layer names indicate the source data was specific to the American Samoa Assessment**.

Layer Name	Dataset and Source
Population Density	U.S. Census Bureau 2010 Decennial Census - place geography (demographic summary profile); 2020 Census data were not available at time of modeling.
Social Vulnerability	Thomas, A.O., Kleiber, D., Hospital, J., Maynard, J., Tracey, D. (2020) Coral Reef Resilience and Social Vulnerability to Climate Change: Affiliated Pacific Islands. Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-20-002a. 6 p. doi:10.25923/5xhp-5k12
Critical Facilities	Schools, Gov't Buildings: USGS National Structures Dataset; Medical Facilities (Hospitals - Tutuila, Public Health Dept. - Tutuila); Law Enforcement and Fire Stations digitized by NEMAC team
Building Footprints	Tutuila, Ta'u: FBNMS; remaining digitized by NEMAC as-needed
Critical Infrastructure *(Various Inputs, see below)*	
Primary roads	*Ofu, Olosega, Ta'u, Aunu'u, Tutuila (east): FBNMS GIS Data Archive; Tutuila (west): TigerLine 2019 Primary and Secondary Roads*
Bridges	*Digitized by NEMAC team*
Airport runways	*HIFLD - Airport Runways*
Ports/Wharfs	*USDOT/Bureau of Transportation Statistics' NTAD (Port Facilities); some digitized using info from Dept. of Port Administration*
Power plants/Substations	*Digitized by NEMAC team*
Wastewater treatment facilities	*EPA FRS Wastewater Treatment Plants*
Communication infrastructure	*FM Transmission Towers (Tutuila); Microwave Service Towers (Tutuila, Ta'u, Ofu, Olosega)*
Petroleum terminals	*Digitized by NEMAC team*
Hazardous sites	*U.S. EPA Facility Registry Service (2016 or later)*
Community Water System	*U.S. EPA Facility Registry Service (2016 or later)*
Cultural & Historic Resources	*American Samoa Historic Preservation Office*

A.3 Terrestrial Index

The following table lists those datasets that were used to create the Terrestrial Index for American Samoa. **Bolded layer names indicate the source data was specific to the American Samoa Assessment**.

Dataset Name	Source and Year
C-CAP Land cover	NOAA Office for Coastal Management (2010)
National Wetlands Inventory	U.S. Fish & Wildlife (most recent available)
National Hydrography Dataset	USGS (most recent available)
Vegetation Maps	USFS (Liu et al. 2011)
Important Bird Areas & Key Biodiversity Areas	BirdLife International (2020)
Environmental Sensitivity Index Species Habitat	NOAA Office of Response and Restoration (2004)
Comprehensive Wildlife Conservation Strategy species list	American Samoa Dept. of Marine and Wildlife Resources, 2016
Habitat Classification Scheme	IUCN Red List of Threatened Species (Version 3.1)
Protected Areas Database of the U.S. (PADUS)	USGS (Version 2.0)
Primary Rainforest and other Important Vegetation Types	Meyer et al. 2017

A.4 Marine Index

The following table lists those datasets used to create the Marine Index for American Samoa.

Dataset Name	Source and Year
Reef Fish Biomass	NOAA National Coral Reef Monitoring Program: Reef Fish Monitoring sector-level data (2018)
Essential Fish Habitat	NOAA Fisheries (2018)
Benthic Habitat Maps	NOAA National Centers for Coastal Ocean Science (2007)
Coral Cover Surveys	NOAA National Coral Reef Monitoring Program, strata-level data (2018)
Mangrove Presence	NOAA C-CAP 2016, Estuarine Wetland classes; mangrove data were not available for all islands included in the Assessment
Marine Protected Areas	USGS Protected Areas Database of the U.S. (PADUS), Version 2.0
Bathymetric Data	Pacific Islands Benthic Habitat Mapping Center

A.5 Resilience Hubs

The following table lists those datasets used to create the Resilience Hubs for American Samoa.

Dataset Name	Source and Year
C-CAP Land Cover Atlas	NOAA Office for Coastal Management; 2010: Tutuila, Manu'a Islands
National Wetlands Inventory	U.S. Fish & Wildlife (most recent data available)
National Hydrography Dataset	U.S. Geological Survey (USGS) 1:24,000
Bathymetric Data	Pacific Islands Benthic Habitat Mapping Center, Coral Reef Ecosystem Division, Pacific Islands Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration (2006)
Coral Cover Surveys	NOAA National Coral Reef Monitoring Program, strata-level data (2019)
Mangrove Presence	NOAA C-CAP 2016, Estuarine Wetland classes
National Elevation Dataset	U.S. Geological Survey (USGS), EROS Data Center
SSURGO Soils Survey	USDA-NRCS SSURGO (2.2 or later)
Roads polyline	OpenStreetMap (latest data available)
Bathymetric Data	Pacific Islands Benthic Habitat Mapping Center
National Wetlands Inventory	U.S. Fish & Wildlife (most recent available)
Benthic Habitat Maps	NOAA National Centers for Coastal Ocean Science (2007)

B. Detailed Methodology: Threat Index

The Threat Index for American Samoa was created by following the methodology outlined in the Methodology and Data Report (Dobson et al. 2020). Any changes to the inputs used in this region, and their sources, are listed in Appendix A.1.

B.1 Wave Driven Flooding

Wave driven flooding was ranked according to probability of occurrence, where a 10-year return period is given a higher rank than a 500-year return period. The following rank value was applied to each return period:

Wave Driven Flooding	Rank Value
0	0
500-year return period	1
100-year return period	2
50-year return period	3
10-year return period	4

A. Import each floodmask vector and add a rank field according to the table above.
    a. Right click layer in Contents > Attribute Table > +Add
        i. Name: Rank; Type: Short Integer
        ii. Save the changes and return to the attribute table
    b. Right click Rank field > Calculate Field > Rank = *see above*
B. Merge floodmasks with regional boundary
C. Rasterize the merged floodmasks and regional boundary
    a. Tool: Polygon to Raster
        i. Input feature: merged floodmasks and boundary
        ii. Value field: Rank
        iii. Cell assignment: Maximum Area
        iv. Priority Field: Rank
        v. Cellsize: 3

B.2 Tsunami Inundation

The data available for tsunami inundation in American Samoa describe maximum extent of inundation only. Therefore, all areas falling inside the maximum inundation extent were assigned a uniform value of 3.

A. Add a rank field to the tsunami inundation vector features.
    a. Right click layer in Contents > Attribute Table > +Add
        i. Name: Rank; Type: Short Integer
        ii. Save the changes and return to the attribute table
    b. Right click Rank field > Calculate Field > Rank = 3
B. Merge inundation extent with regional boundary
C. Rasterize the merged inundation extent and regional boundary
    a. Tool: Polygon to Raster
        i. Input feature: merged inundation extent and boundary
        ii. Value field: Rank
        iii. Cell assignment: Maximum Area
        iv. Priority Field: Rank
        v. Cellsize: 3

B.3 Calculating the Threat Index

The Threat Index was classified into 10 classes in order to multiply them and ultimately create the Community Exposure Index. Below is the classification that was used for the American Samoa Threat Index.

American Samoa Threat Index Distribution

Threat Index Break Value	0 - 1	2	3	4 - 6	7 - 9	10	11 - 12	13	14 - 15	16 - 29
Final Rank Value	1	2	3	4	5	6	7	8	9	10

C. Detailed Methodology: Community Asset Index

The Community Asset Index for American Samoa was created by following the methodology outlined in the Methodology and Data Report (Dobson et al. 2020). Any changes to the inputs used in this region, and their sources, are listed in Appendix A.2.

C.1 Population Density

The methodology for population density is detailed in the Methodology and Data Report (Dobson et al. 2020), the distribution shown in the table below was used to rank population density in American Samoa.

Population Density Distribution for American Samoa	Rank Value
0	0
≤ 74.7	1
≤ 145.4	2
≤ 449.2	3
≤ 997.4	4
≤ 2991.4	5

C.2 Social Vulnerability

To evaluate social vulnerability in American Samoa, data from the U.S. Census, aggregated by the NOAA Coral Reef Conservation Program, were utilized. The metrics include personal disruption, population composition, poverty, labor force structure, and housing characteristics[11]. The methodology for building the input was used as outlined in the Data and Methodology Report (Dobson et al. 2020), with the only exception being the distribution and ranking. The rank values assigned by the original creators were used directly.

C.3 Modifications Made to the Critical Infrastructure and Critical Facilities Inputs

Specific critical infrastructure and facilities were reviewed for each region to identify any data that were non-applicable and/or any additional inputs that should be considered. The table in Section A.2 identifies data sources and data inputs that were included in the American Samoa Assessment.

Infrastructure and facility data inputs were included in the analysis generally following the methodologies found in the Methodology and Data Report (Dobson et al. 2020). An exception to this was that parcel and footprint boundaries of critical infrastructure features were assigned a rank value of three and five, respectively; these rank values match the values that were assigned to parcel and footprint boundaries for features in the critical facilities input.

Cultural and historic sites were included in the Critical Infrastructure component of the Community Asset Index using 2,500 square meter sized hexagons. The spatial arrangement of these hexagons was the same as those that were used to create the Population Density and Social Vulnerability inputs

[11] https://repository.library.noaa.gov/view/noaa/24814

(Dobson et al. 2020). Any hexagon containing >0 historic site locations were assigned a rank value of five, to be included in the Critical Infrastructure input.

C.4 Calculating the Community Asset Index

The Community Asset Index was classified into 10 classes via quantile classification in order to multiply with the threat index to ultimately create the Community Exposure Index. Below is the classification that was used for the American Samoa Community Asset Index.

American Samoa Community Asset Index Distribution

Asset Index Break Value	0	1	2	3	4	5	6	7	8	9 - 17
Final Rank Value	1	2	3	4	5	6	7	8	9	10

D. Detailed Methodology: Community Exposure Index

After classifying both the Threat and Community Asset Indices into 10 classes each, they were multiplied to create the Community Exposure Index. Exposure is the overlap of community assets and flood threats. As this multiplication results in a final index with values from 1-100, the Community Exposure Index was further classified to make it easier to work with and understand the results. The distribution used for the Community Exposure Index in American Samoa is shown below.

American Samoa Community Exposure Index Distribution

Exposure Index Break Value	0 - 1	2	3	4 - 5	6 - 7	8 - 12	13 - 20	21 - 34	35 - 58	59 - 100
Final Rank Value	1	2	3	4	5	6	7	8	9	10

E. Detailed Methodology: Fish and Wildlife Index

E.1 Calculating the Terrestrial Index

The Terrestrial Index for American Samoa is based on the same methodology described in the Methodology and Data Report (Dobson et al. 2020). In addition to the habitat preferences of priority fish and wildlife species described below, areas of native forest were also prioritized. Using the high resolution landcover map for American Samoa developed by Meyer *et al.* (2017), areas of Lowland Rainforest - high canopy ≥ 14 m, Primary Valley Forest, Primary Slope Forest, and Primary Ridge Forest received a rank value of '2'. Lowland Rainforest in the region of the Naumati forest and wetland marshes on the island of Aunu'u were manually increased in value based on the recommendation of local experts.

Because of regional differences, the taxonomic groups between regions may differ. Taxonomic groups are dependent on the species of concern as determined by the American Samoa Comprehensive Wildlife Conservation Strategy (DMWR 2016) and species listed under the U.S. Endangered Species Act. Habitat preferences for those species were then identified in the IUCN Red List of Threatened Species. The following taxonomic groups and associated species were incorporated into the Terrestrial Index for American Samoa.

Sea Birds

Wedge-tailed shearwater (*Puffinus pacificus*)
Christmas shearwater (*Puffinus nativitatus*)
Audubon's shearwater (*Puffinus lherminieri dichrous*)
Collared petrel (*Pterodroma leucoptera brevipes*)
Herald petrel (*Pterodroma arminjoniana heraldica*)
Tahiti petrel (*Pseudobulweria rostrata*)
Blue-grey noddy (*Procelsterna cerulea nebouxi*)
Red-tailed tropicbird (*Phaethon rubricauda*)
White-tailed tropicbird (*Phaethon lepturus*)
White tern (*Gygis a. alba*)
Red-footed booby (*Sula sula rubripes*)
Brown booby (*Sula leucogaster plotus*)
Masked booby (*Sula dactylatra personata*)
Grey-backed tern (*Sterna lunata*)
Sooty tern (*Sterna fuscata oahuensis*)
Bridled tern (*Sterna anaethaetus*)
Great frigatebird (*Fregata minor palmerstoni*)
Lesser frigatebird (*Fregata a. ariel*)
Polynesian storm-petrel (*Nesofregetta fuliginosa*)
Brown noddy (*Anous stolidus pileatus*)
Black noddy (*Anous m. minutus*)

Land Birds

White-rumped swiftlet (*Aerodramus s. spodiopygius*)
Pacific black duck (toloa) (*Anas superciliosa pelewensis*)
Samoan starling (fuia) (*Aplonis atrifusca*)
Polynesian starling (miti vao) (*Aplonis tabuensis manuae/tutuiae*)
Lesser shrikebill (sega o le vau) (*Clytorhynchus vitiensis powelli*)
Pacific imperial-pigeon (lupe) (*Ducula pacifica pacifica*)
Wattled honeyeater (*Foulehaio c. carunculata*)
Shy ground-dove (tuaimeo) (*Alopecoenas stairi*)
Banded rail (*Gallirallus philippensis goodsoni*)
Pacific reef egret (*Egretta s. sacra*)
Purple swamphen (manuali'i) (*Porphyrio porphyrio samoensis*)
Spotless crake (*Porzana t. tabuensis*)
Many-colored fruit-dove (manuma) (*Ptilinopus p. perousii*)
Purple-capped fruit-dove (*Ptilinopus porphyraceus fasciatus*)
Collared kingfisher (*Todiramphus chloris manuae*)
Common barn owl (*Tyto alba delicatula*)
Blue-crowned lory (segaula) (*Vini australis*)
Ma'oma'o (toloa) (*Gymnomyza samoensis*)

Terrestrial Mammals

Sheath-tailed bat (pe'ape'a vai) (*Emballonura semicaudata semicaudata*)	Samoan flying fox (pe'a vao) (*Pteropus samoensis*) Insular/Tongan flying fox (pe'a fanua) (*Pteropus tonganus*)

Reptiles

Lawes skink (pili oua') (*Emoia lawesi*) Green sea turtle (*Chelonia mydas*) Snake-eyed skink (pili) (*Cryptoblepharus poeciloplurus*)	Pacific boa (gata) (*Candoia bibroni*) Hawksbill sea turtle (*Eretmochelys imbricata*)

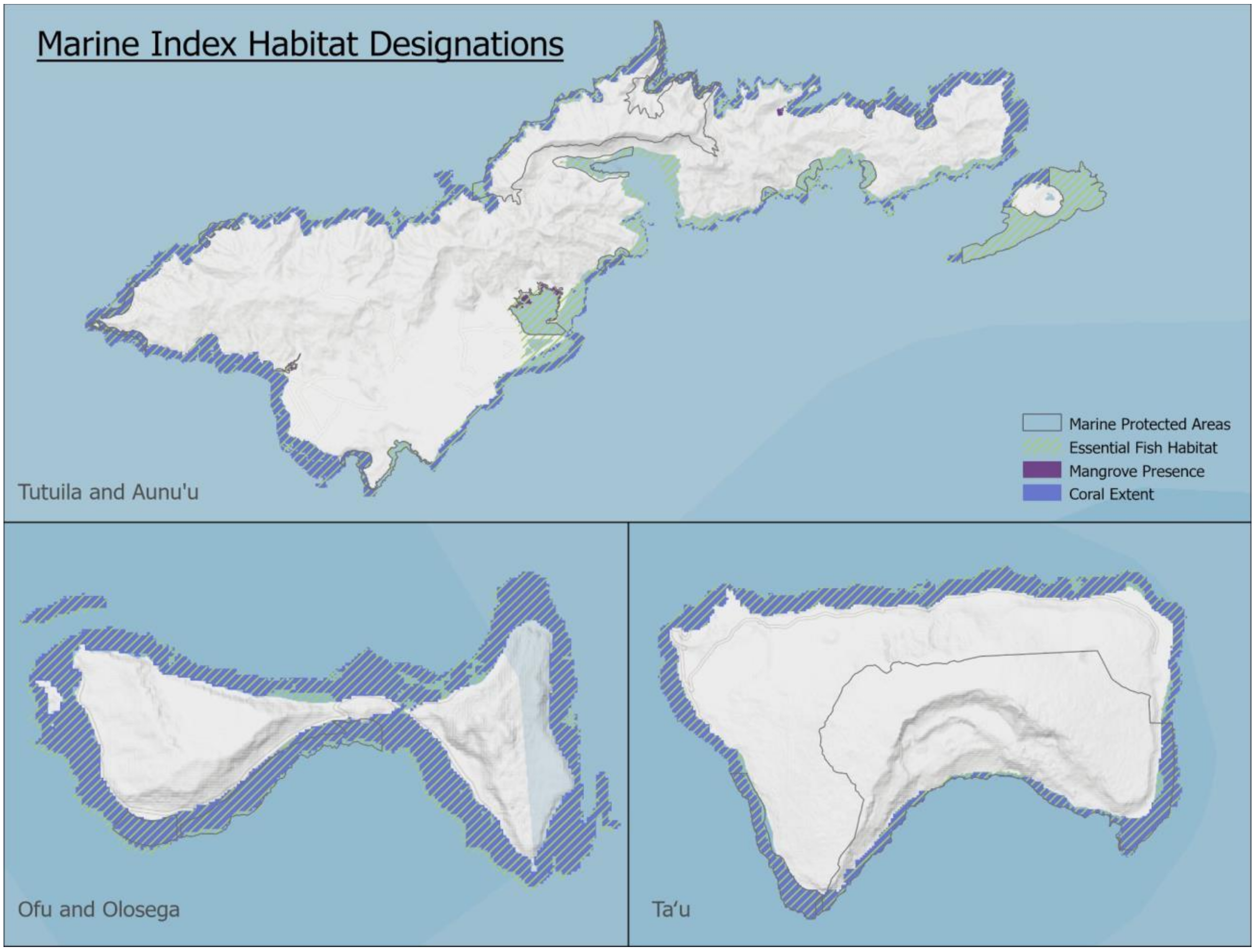
The distribution for the American Samoa Terrestrial Index is displayed below. The final rank value was determined using a quantile distribution and was then combined with the Marine Index to create the Fish and Wildlife Index.

American Samoa Terrestrial Index Distribution

Terrestrial Index Break Values	0 - 3	4	5 - 7	8 - 13
Final Rank Value	1	2	3	4

E.2 Calculating the Marine Index

In general, the same overarching methods were applied in American Samoa as outlined in the Methodology and Data Report (Dobson et al. 2020). However, due to differences in data availability, some modifications to the methods used for American Samoa were necessary. These are discussed in the following sections. See Appendix A.4 for details on datasets used in this analysis. The spatial extent and distribution of mangroves, coral reefs, Essential Fish Habitat, and Marine Protected Areas are shown in the map below.



Coral Cover

The benthic habitat maps available for American Samoa are relatively old and potentially unreliable. Therefore, to incorporate coral cover data from NOAA's National Coral Reef Monitoring Program, each strata-level (depth bin) surveyed was ranked according to the percent coral cover and then rasterized to be included in the Marine Index (Tom Oliver, NOAA, personal communication). The strata-level depth bins were created according to guidance from NOAA using bathymetry as follows:

Strata	Depth
Shallow	0 - 6m
Mid-depth	>6 - 18m
Deep	>18 - 30m

The percent coral cover was ranked across the islands using a quantile distribution and five classes. The following ranking scheme was used to rank coral cover by strata-level in American Samoa. The rank value of ‘0’ shown below is the land area of each island.

Percent Coral Cover in American Samoa	Rank Value
0	0
≤ 19.9	1
≤ 26.7	2
≤ 30.6	3
≤ 39.9	4
≤ 51.5	5

Reef Fish Biomass

Reef fish biomass was used to further identify areas of high biodiversity. Biomass was ranked at the sector level using a quantile distribution of the mean total fish biomass and then ranked and rasterized into five classes to be included in the Index. The ranking scheme for American Samoa is shown below. The rank value of ‘0’ is the land area of the islands.

Reef Fish Biomass in American Samoa	Rank Value
0	0
≤ 40.5	1
≤ 47.1	2
≤ 53.2	3
≤ 70.7	4
≤ 73.3	5

The distribution for the Marine Index is displayed below. The final rank value was determined using a natural breaks distribution for the Index and was then combined with the Terrestrial Index to create the Fish and Wildlife Index.

American Samoa Marine Index Distribution

Marine Index Break Values	0 - 1	2 - 5	6 - 9	10 - 14
Final Rank Value	1	2	3	4

E.3 Calculating the Fish and Wildlife Index

Below is the distribution for the American Samoa Fish and Wildlife Index. As discussed in the Methodology and Data Report (Dobson et al. 2020), the Terrestrial and Marine Indices were classified into four classes before they were added together to create the Fish and Wildlife Index.

American Samoa Fish and Wildlife Index Distribution

Fish & Wildlife Index Break Values	1 - 2	3	4	5	6	7 - 8
Final Rank Value	1	2	3	4	5	6

Using a quantile distribution, the Fish and Wildlife Index was reclassified to remain consistent between Regional Assessment regions and allow readers to distinguish values more easily.

F. Detailed Methodology: Resilience Hubs

The methodology outlined in the Methodology and Data Report (Dobson et al. 2020) for creating the Resilience Hubs was generally followed to model Resilience Hubs in American Samoa; however, regionally specific modifications were applied as follows. Due to the small size of the islands, a smaller area threshold of approximately 4 hectares (10 acres) was used to generate habitat cores in American Samoa. Additionally, a 0.25-kilometer buffer was applied when calculating the average Community Exposure Index values for each Blue and Green Habitat Core as opposed to the 1-kilometer buffer used in other regions.

To rank the Green Habitat Cores, a distance factor was applied to each Green Habitat Core, which prioritized those open, natural landscapes nearest to community assets. To accomplish this, Euclidean distance was calculated to determine the distance between each Green Habitat Core and surrounding community assets. In addition to determining the proximity of Green Habitat Cores to assets, the average density of nearby community assets was also calculated. The average calculated density and distance of nearby community assets to each habitat core was then considered in combination with the average scores from the Fish and Wildlife and Community Exposure Indices to calculate the rank for each Green Habitat Core.

This approach was not taken with the Blue Habitat Cores, which are already scored using presence to valuable marine habitats including live coral cover, reef crest height, beaches, mangroves and other tidally influenced coastal wetlands (seagrass habitat was not included in American Samoa). Blue Habitat Cores received a higher score if more than one habitat type were within 0.25 kilometers of one another.

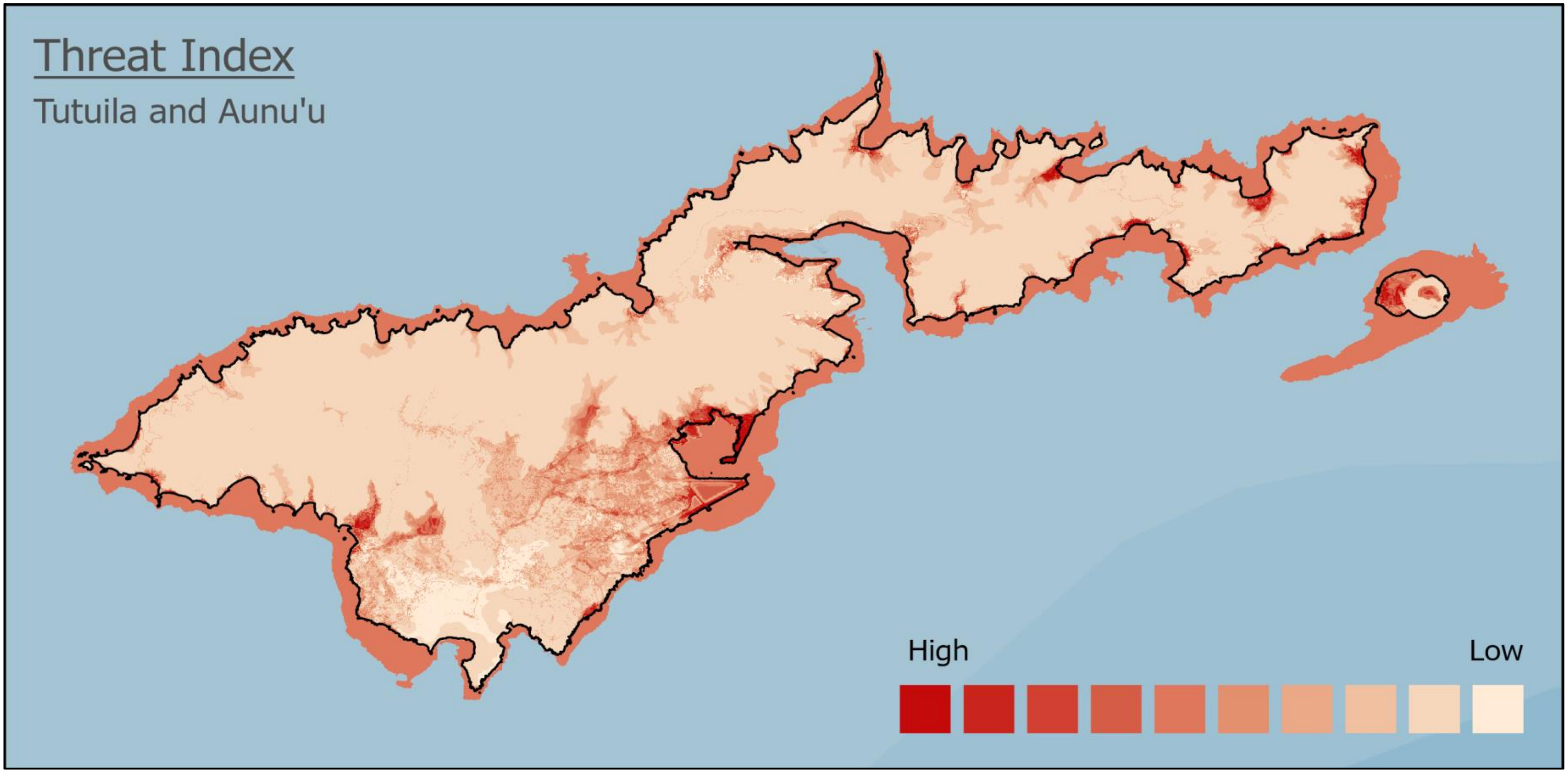
G. Stakeholder Engagement

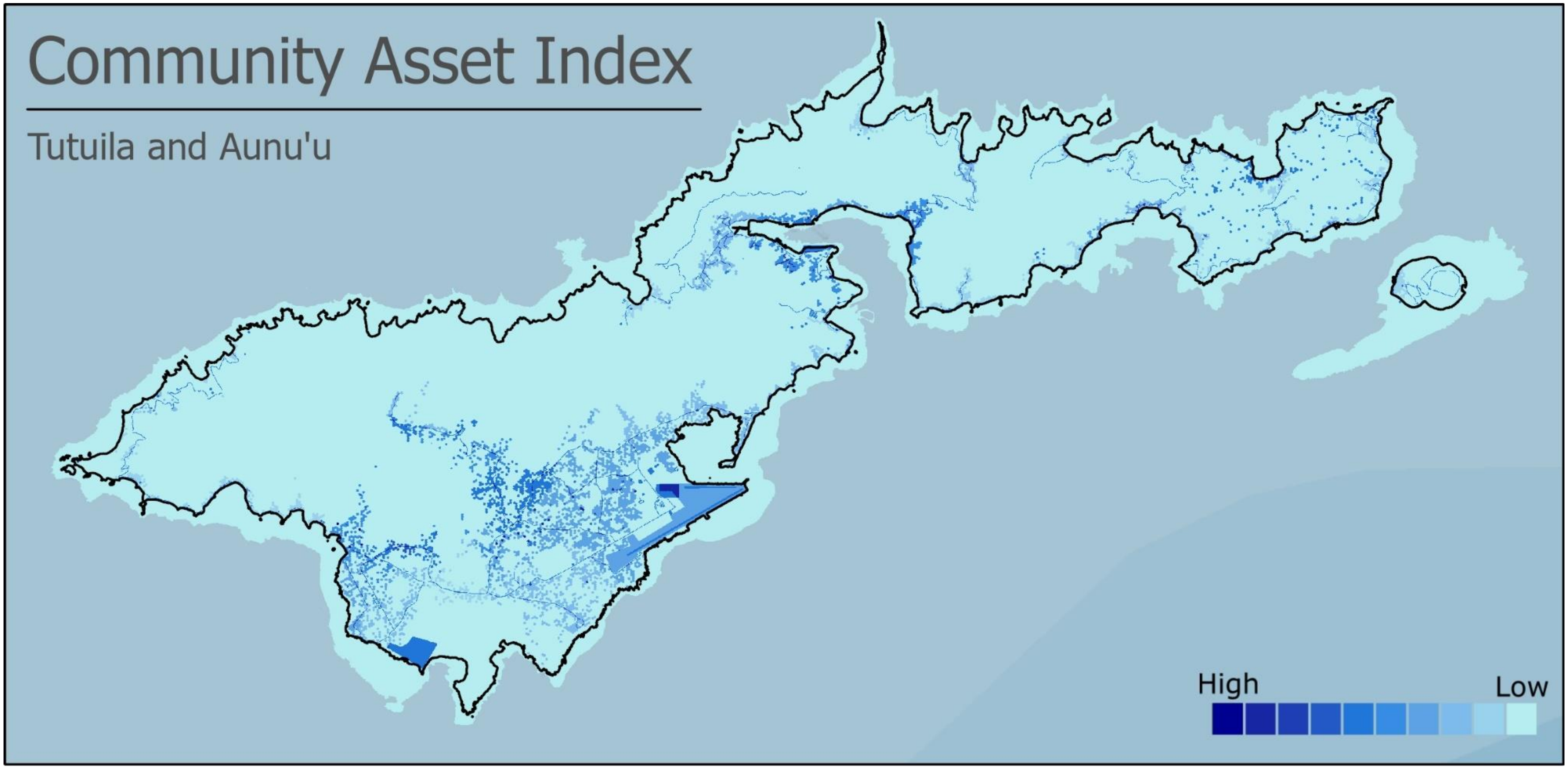
To allow local stakeholders to review and provide input on preliminary Assessment products, the Project Team hosted a virtual stakeholder workshop including a series of three meetings held over the week of March 15, 2021. All invited stakeholders had access to written materials and an online GIS viewer to review draft models and provide comments during and after the workshop. The following list includes all organizations invited to participate in the stakeholder workshop; 30 individuals representing 19 organizations attended the virtual meetings.

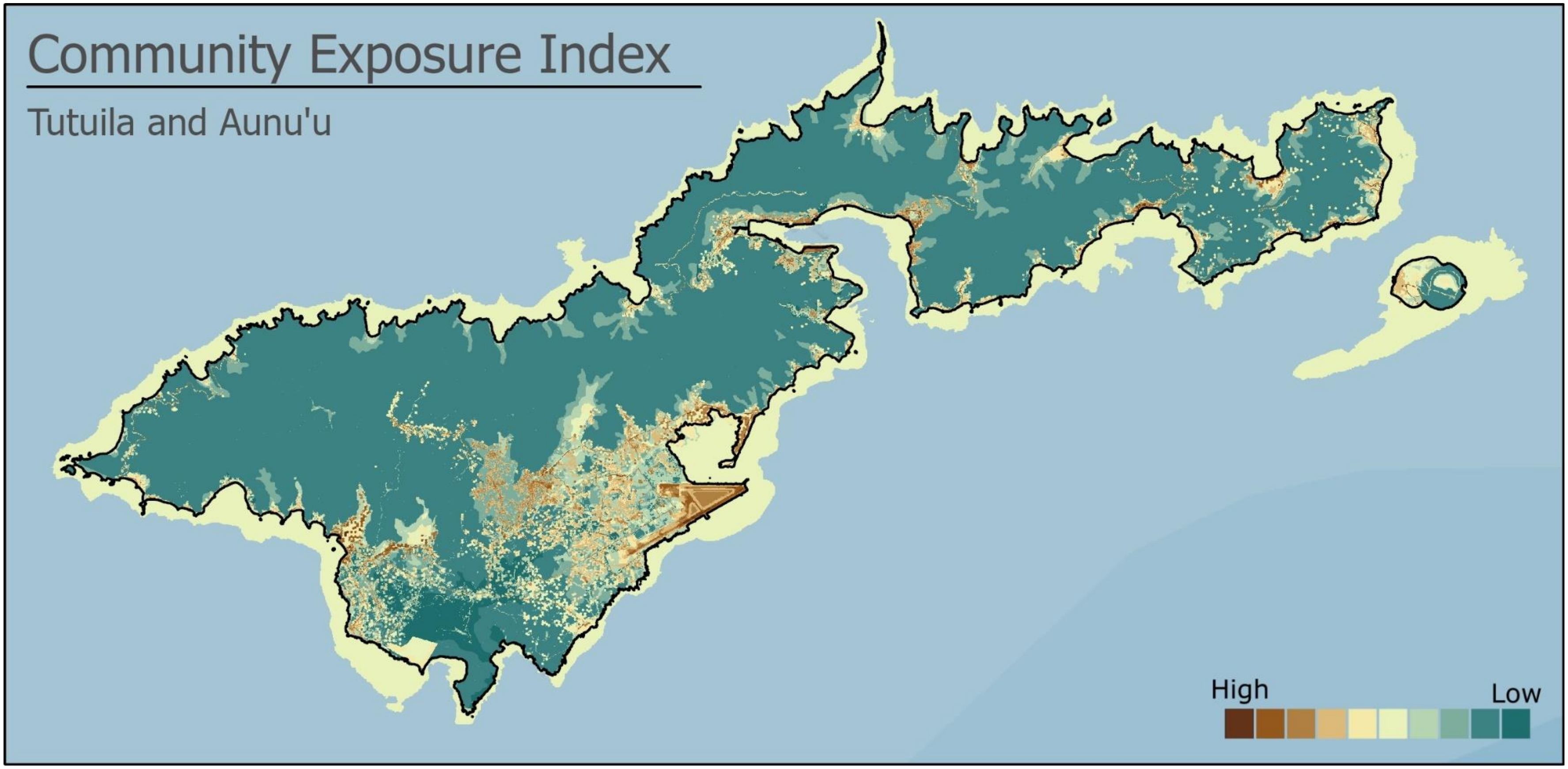
American Samoa Community College
American Samoa Department of Homeland Security
American Samoa Environmental Protection Agency
American Samoa Historic Preservation Office
American Samoa Power Authority
American Samoa's Coral Reef Advisory Group
Department of Commerce, American Samoa Coastal Management Program
Department of Marine and Wildlife Resources
Department of Parks and Recreation
Department of Port Administration
Department of Public Works
East-West Center
Lyndon B. Johnson Tropical Medical Center
Lynker
National Aeronautics and Space Administration
National Oceanic and Atmospheric Administration
National Park Service
Office of Disaster Assistance and Petroleum Management
Pacific Islands Ocean Observing System
U.S. Army Corps of Engineers
U.S. Department of Agriculture
U.S. Environmental Protection Agency
U.S. Federal Emergency Management Agency
U.S. Fish and Wildlife Service
University of Hawaiʻi at Mānoa
University of Newcastle, Australia

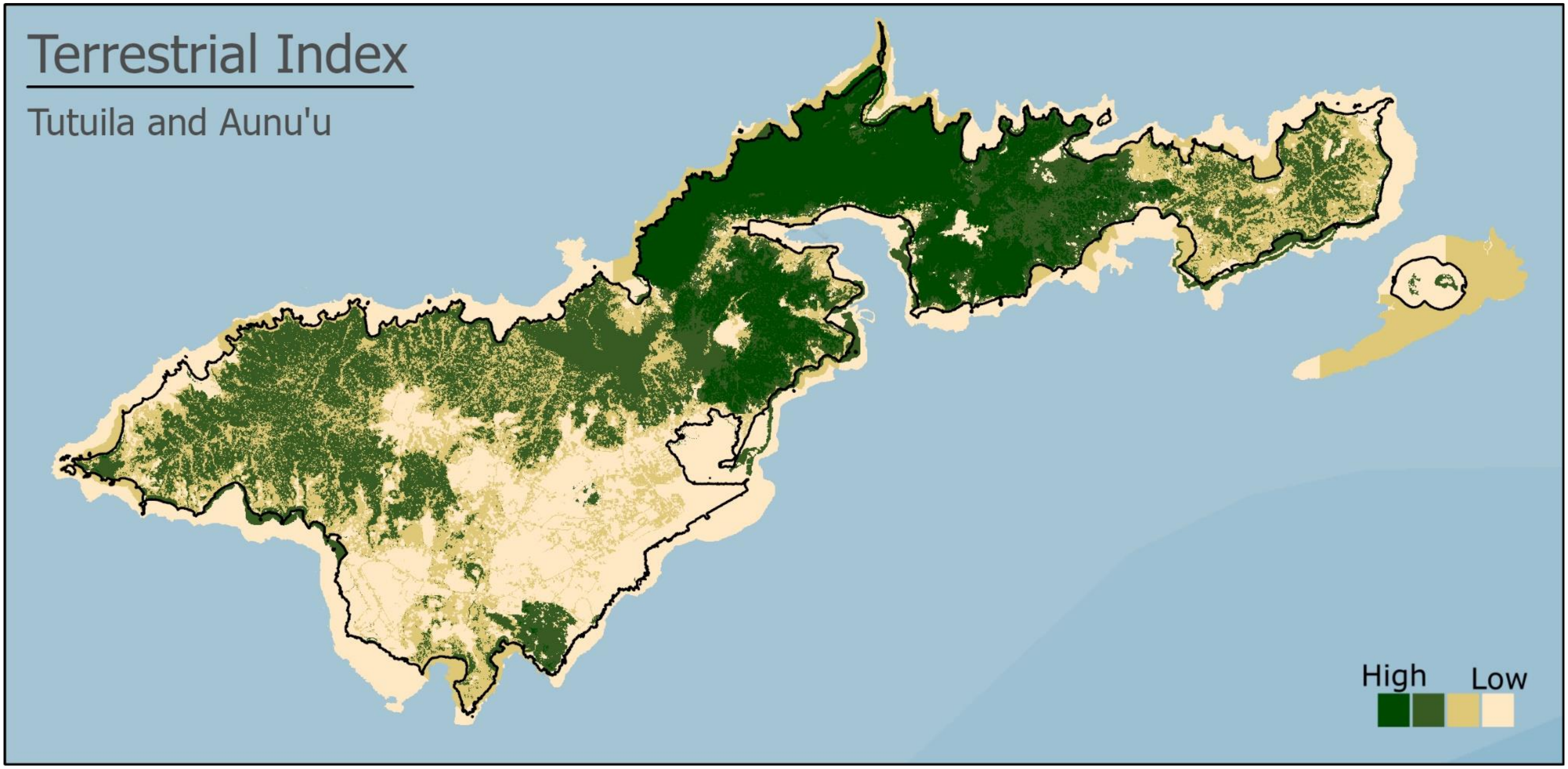
H. Maps

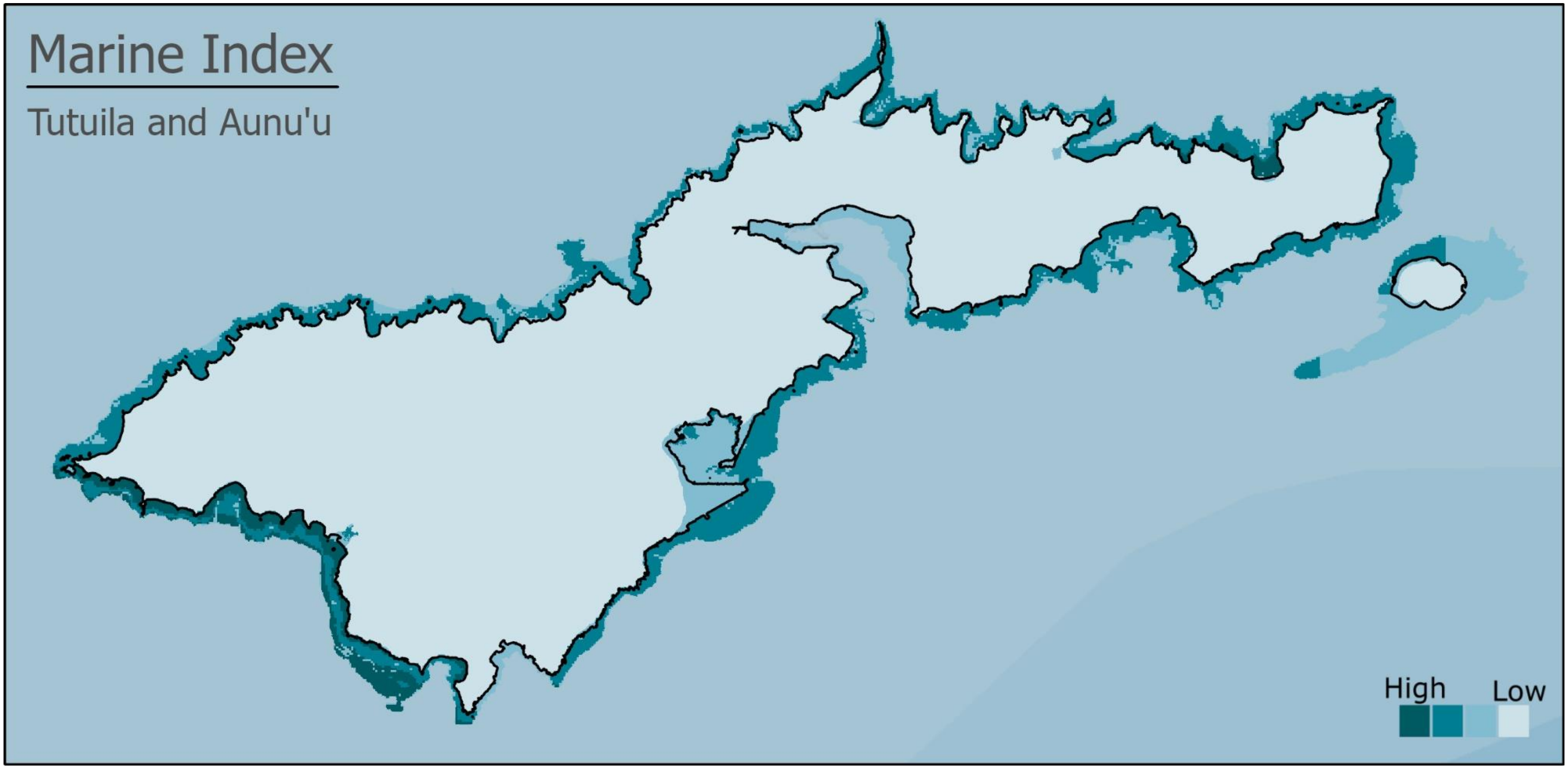
H.1 Maps of Tutuila and Aunu'u

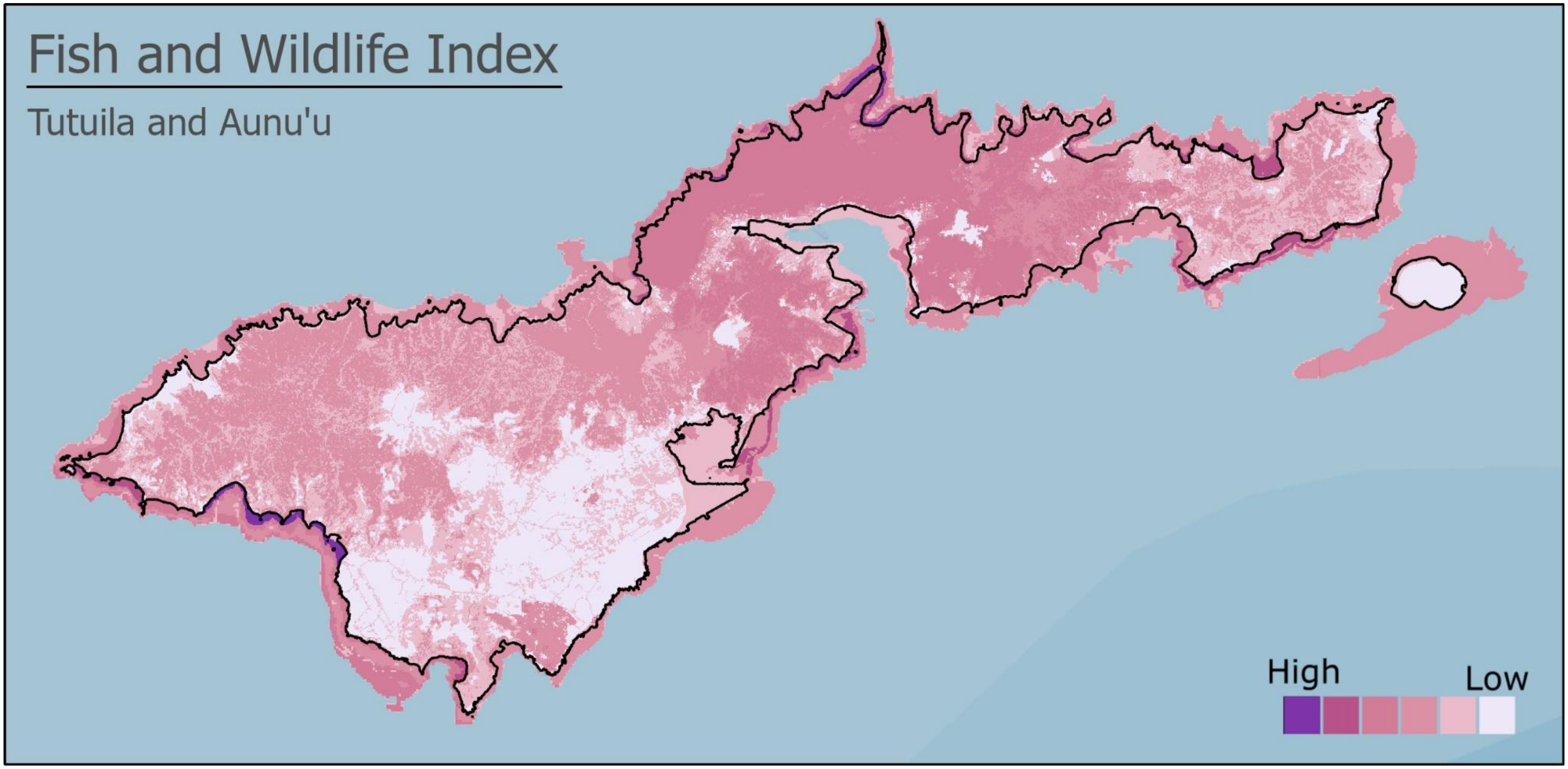


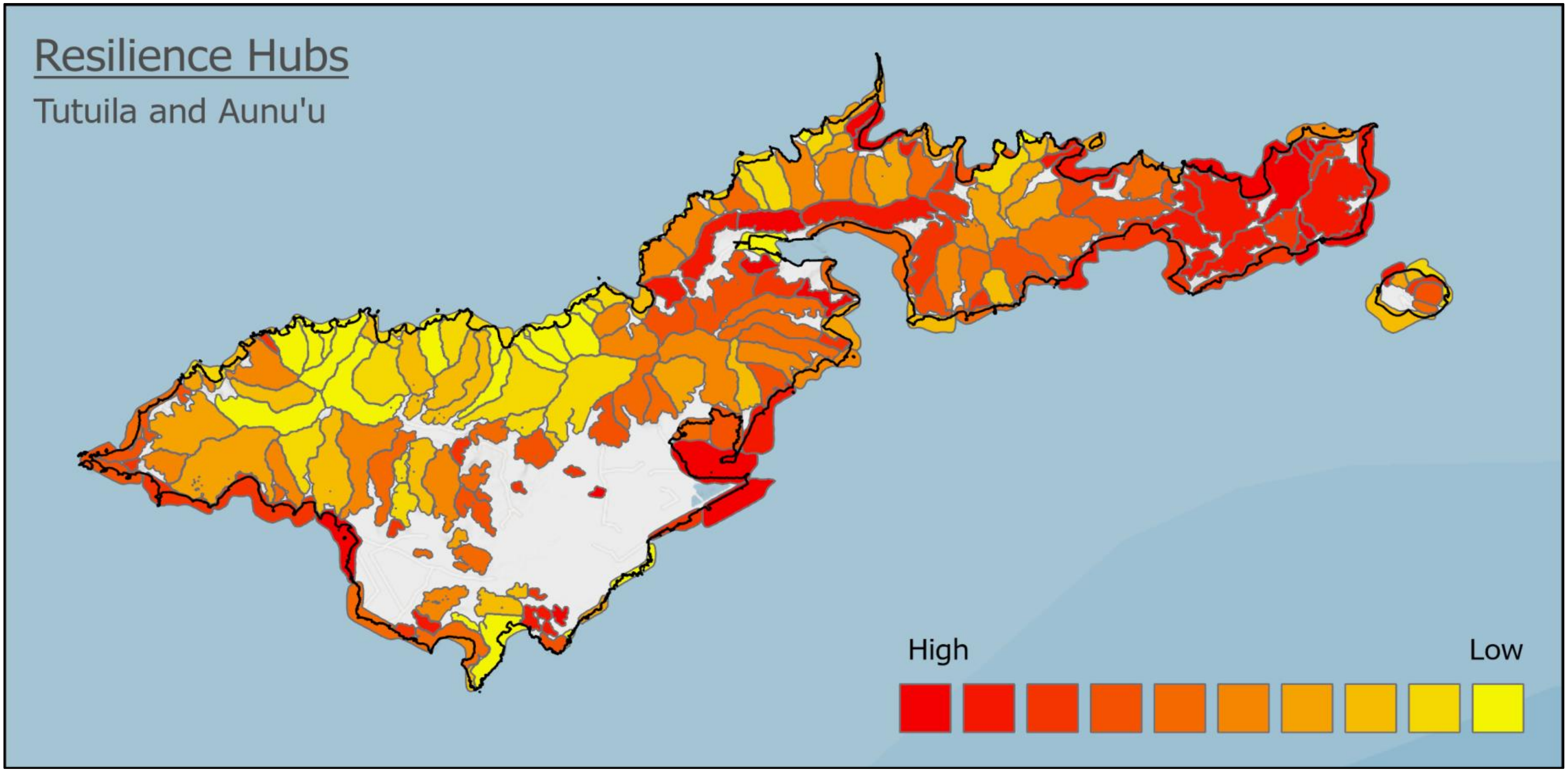

Community Asset Index
Tutuila and Aunu'u
High
Low


Community Exposure Index
Tutuila and Aunu'u
High
Low

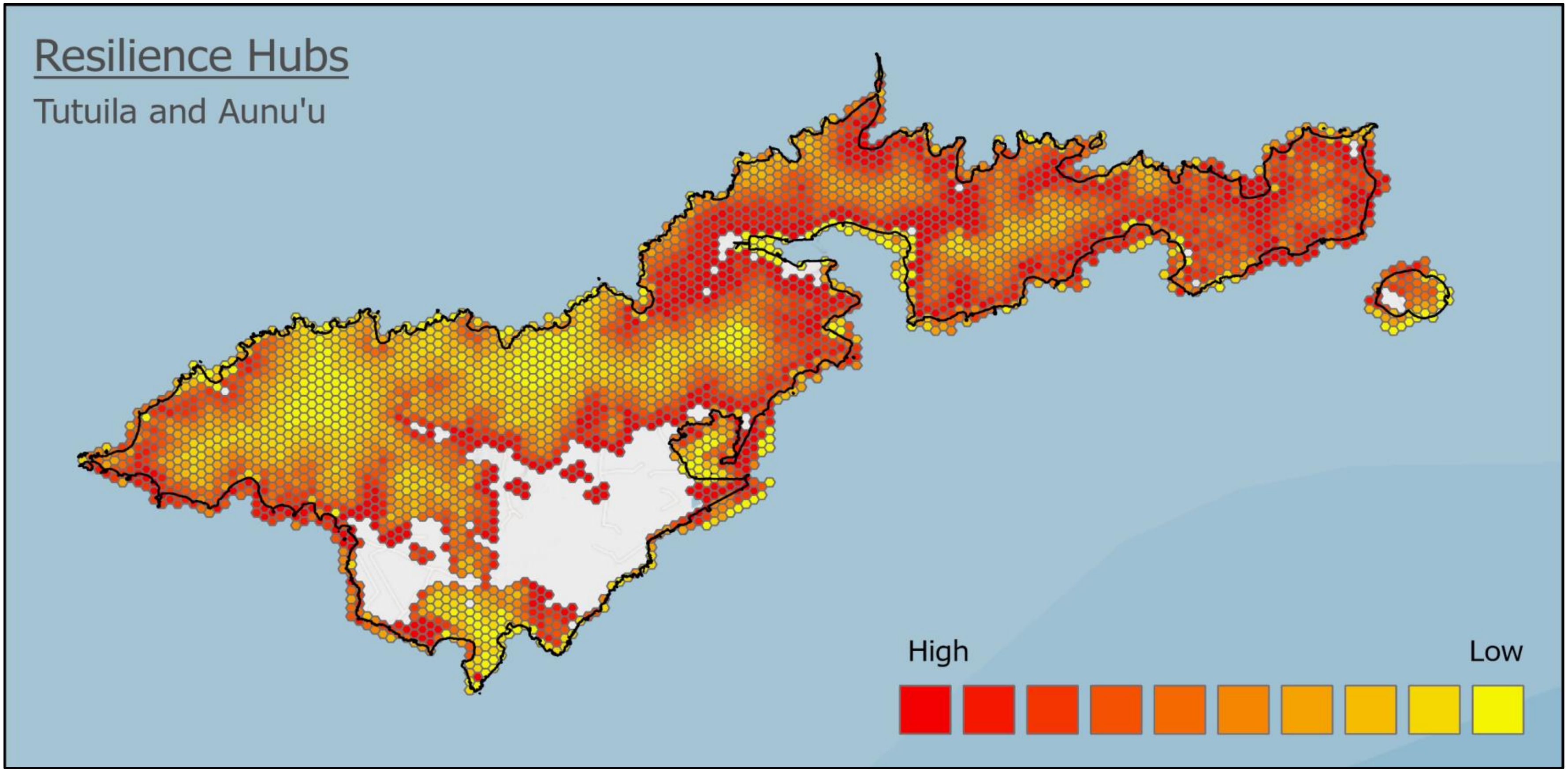

Terrestrial Index
Tutuila and Aunu'u
High
Low


Marine Index
Tutuila and Aunu'u
High
Low

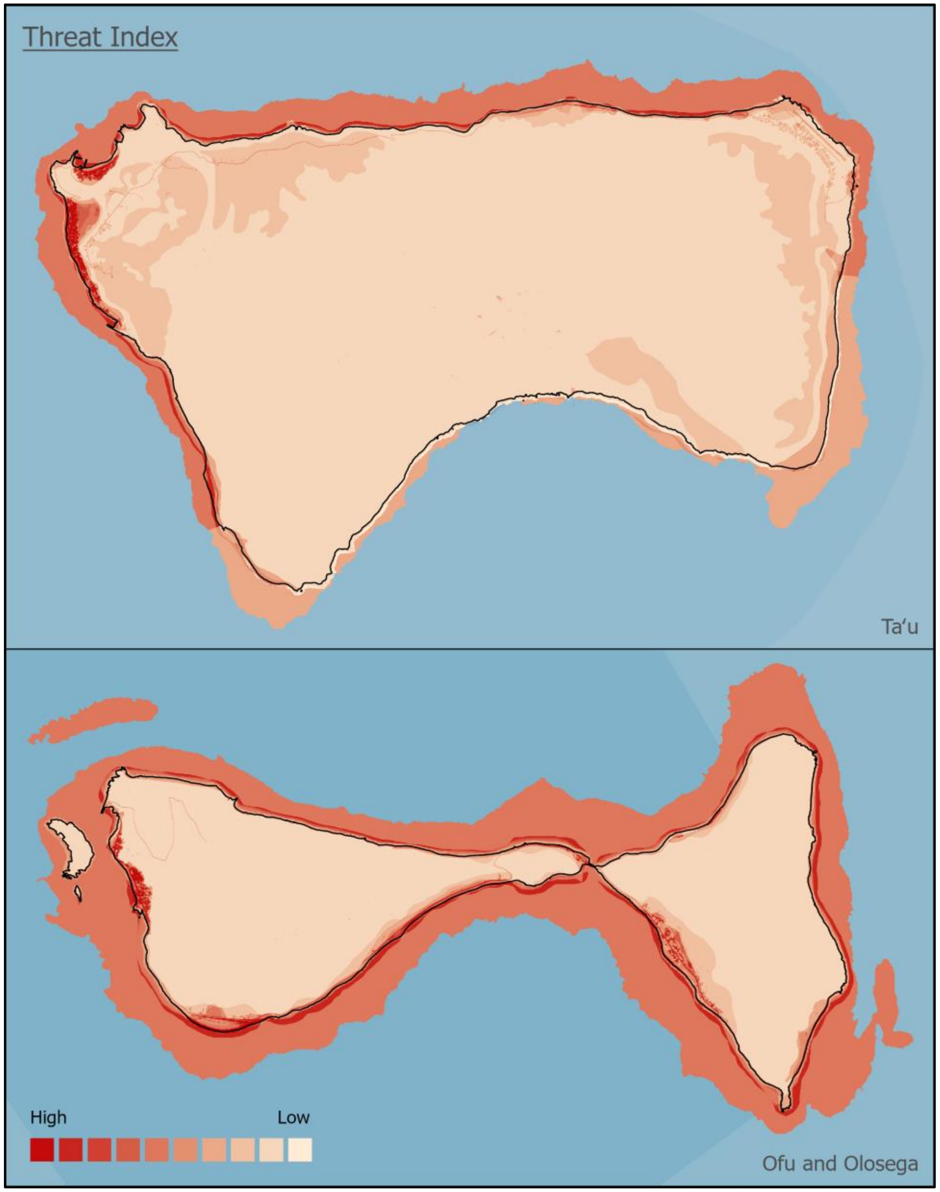

Fish and Wildlife Index
Tutuila and Aunu'u
High
Low

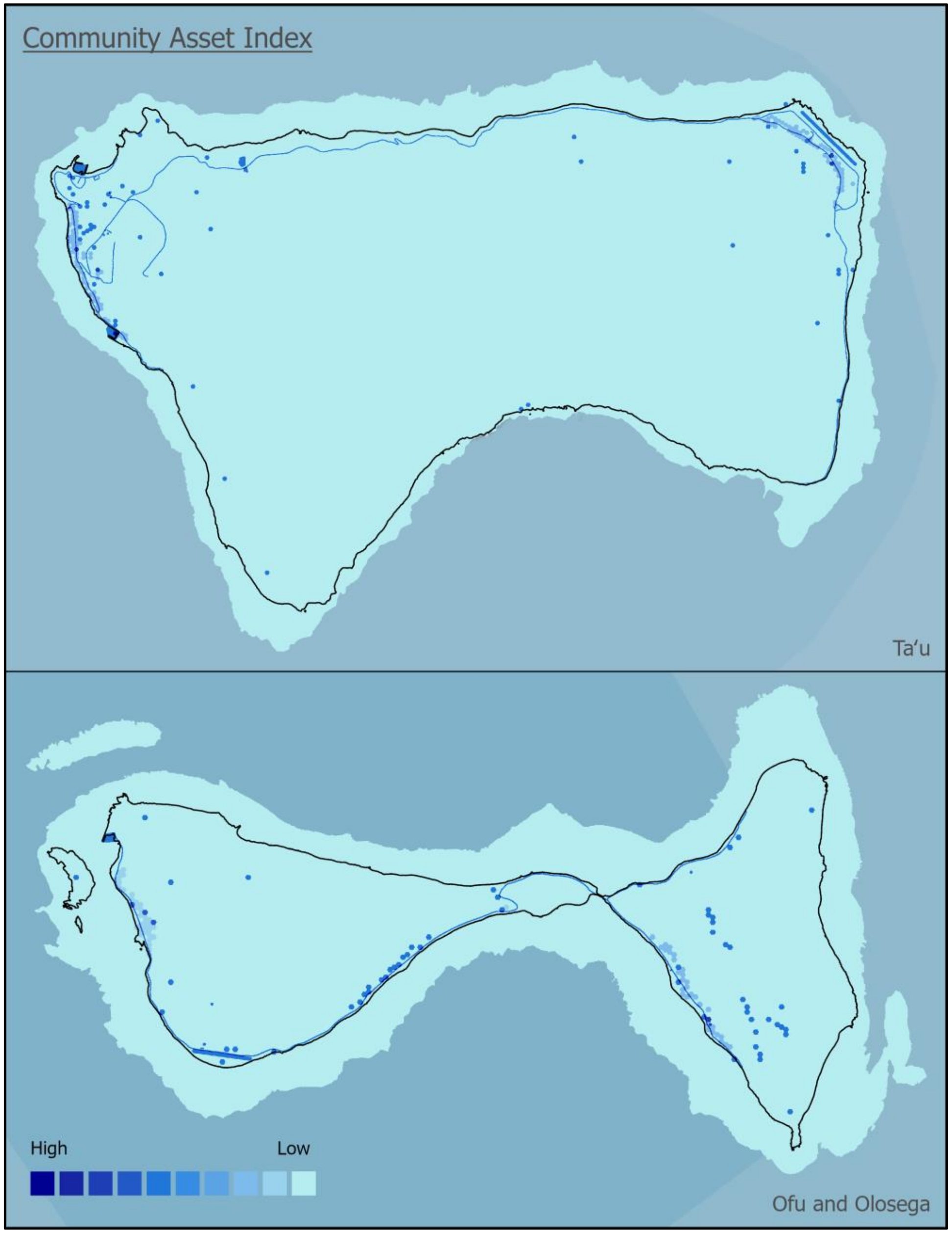


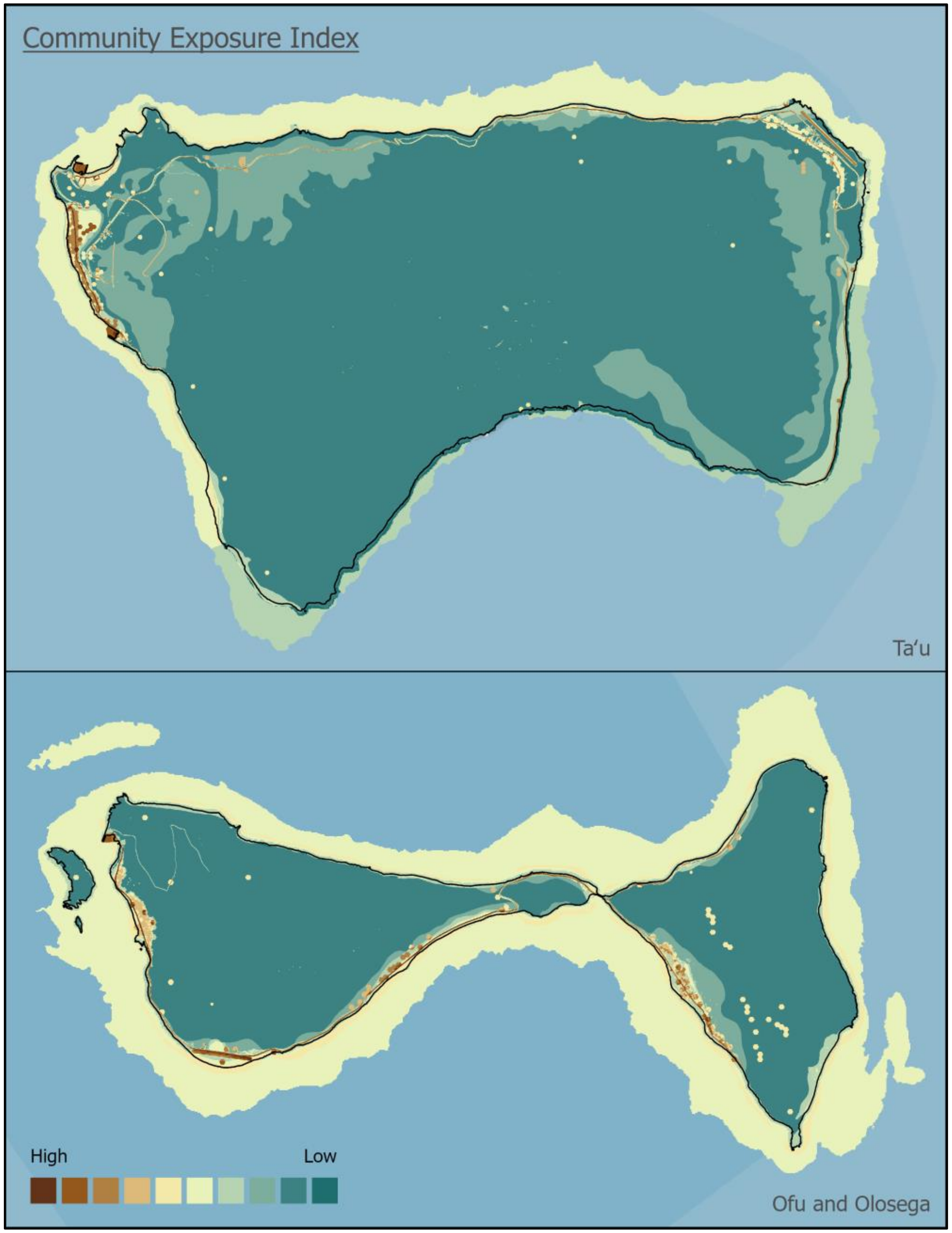
Resilience Hubs
Tutuila and Aunu'u
High
Low

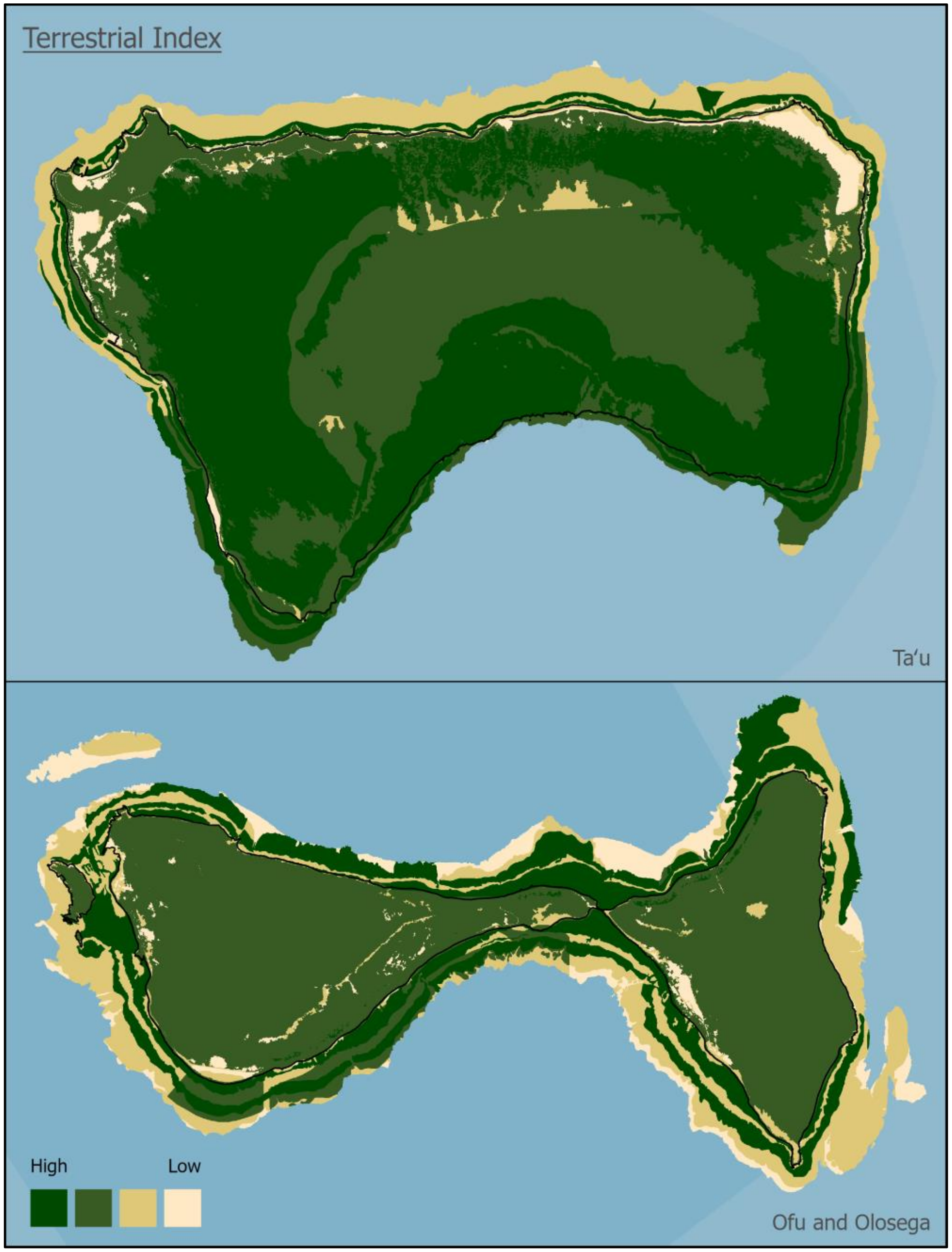

Resilience Hubs
Tutuila and Aunu'u
High
Low

H.2 Maps of the Manu'a Islands

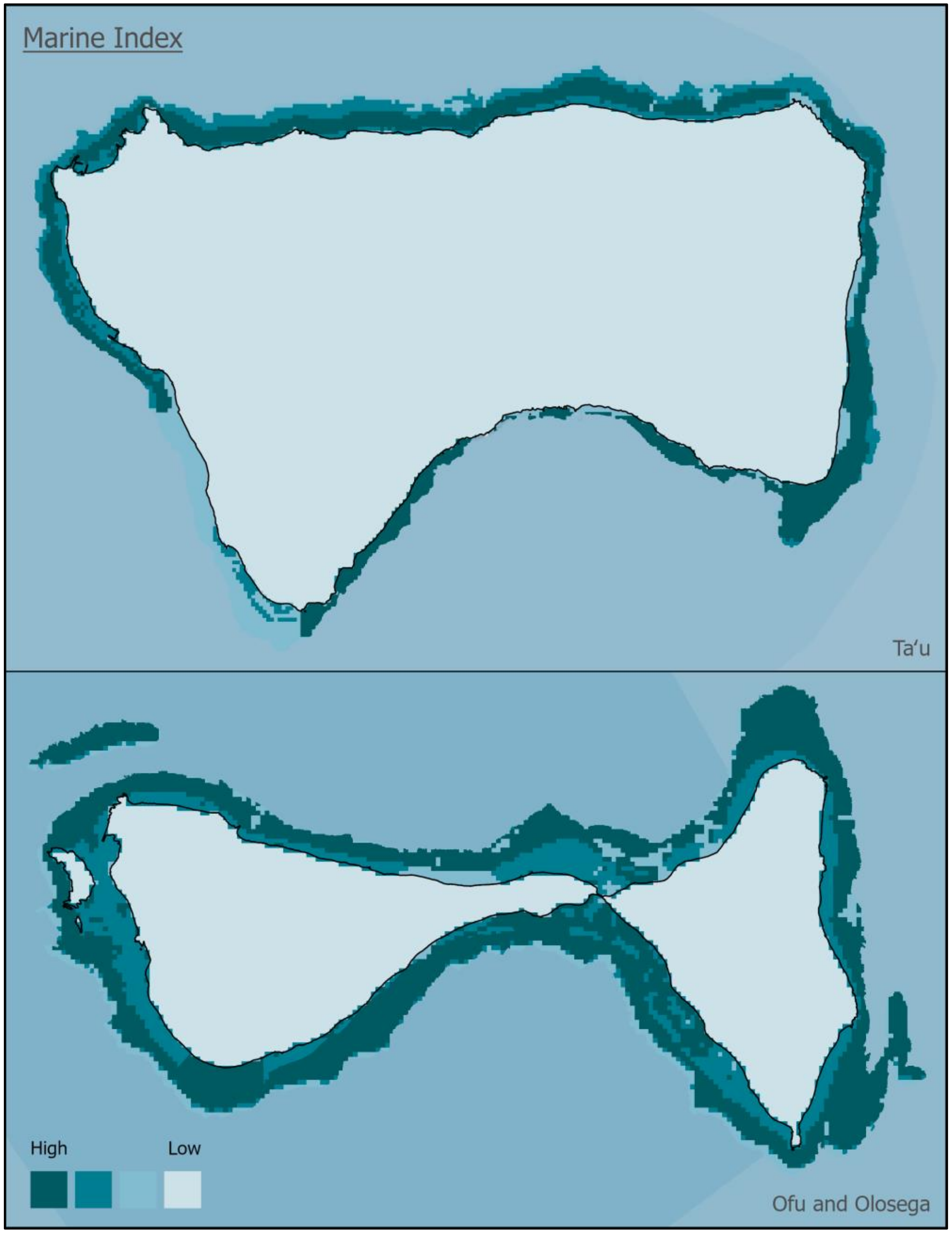



Community Asset Index
Ta'u
High
Low
Ofu and Olosega

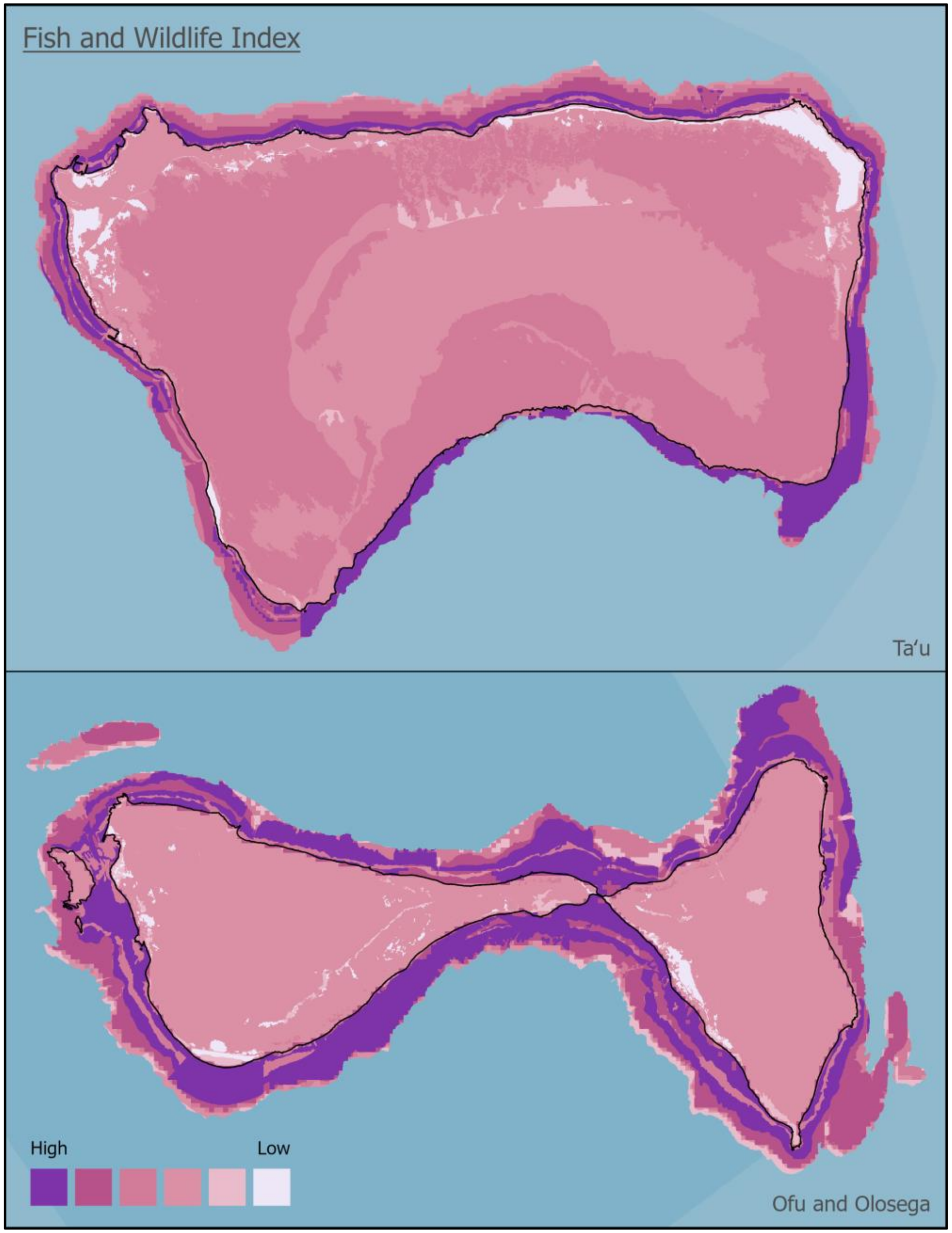

Community Exposure Index
Ta'u
High
Low
Ofu and Olosega

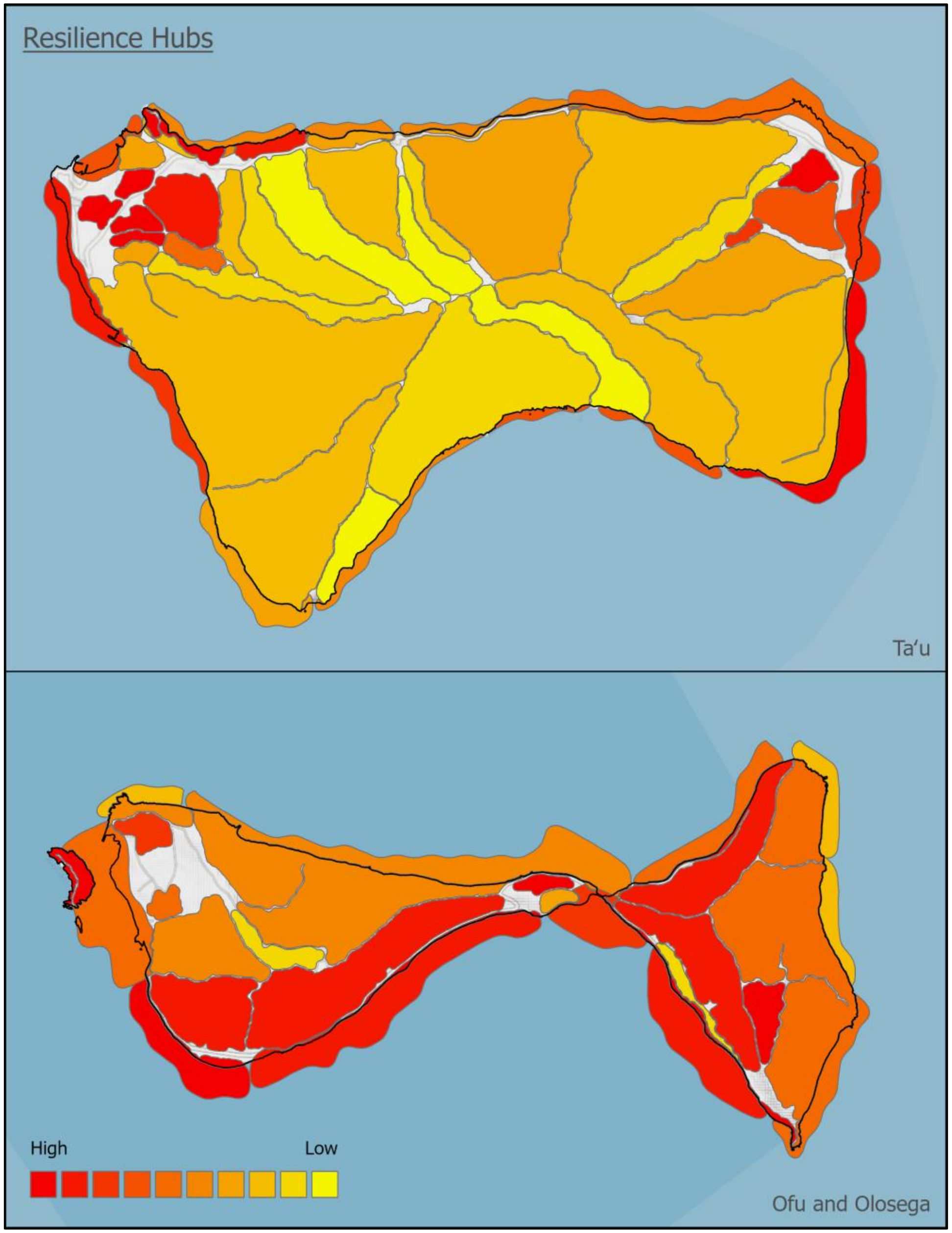


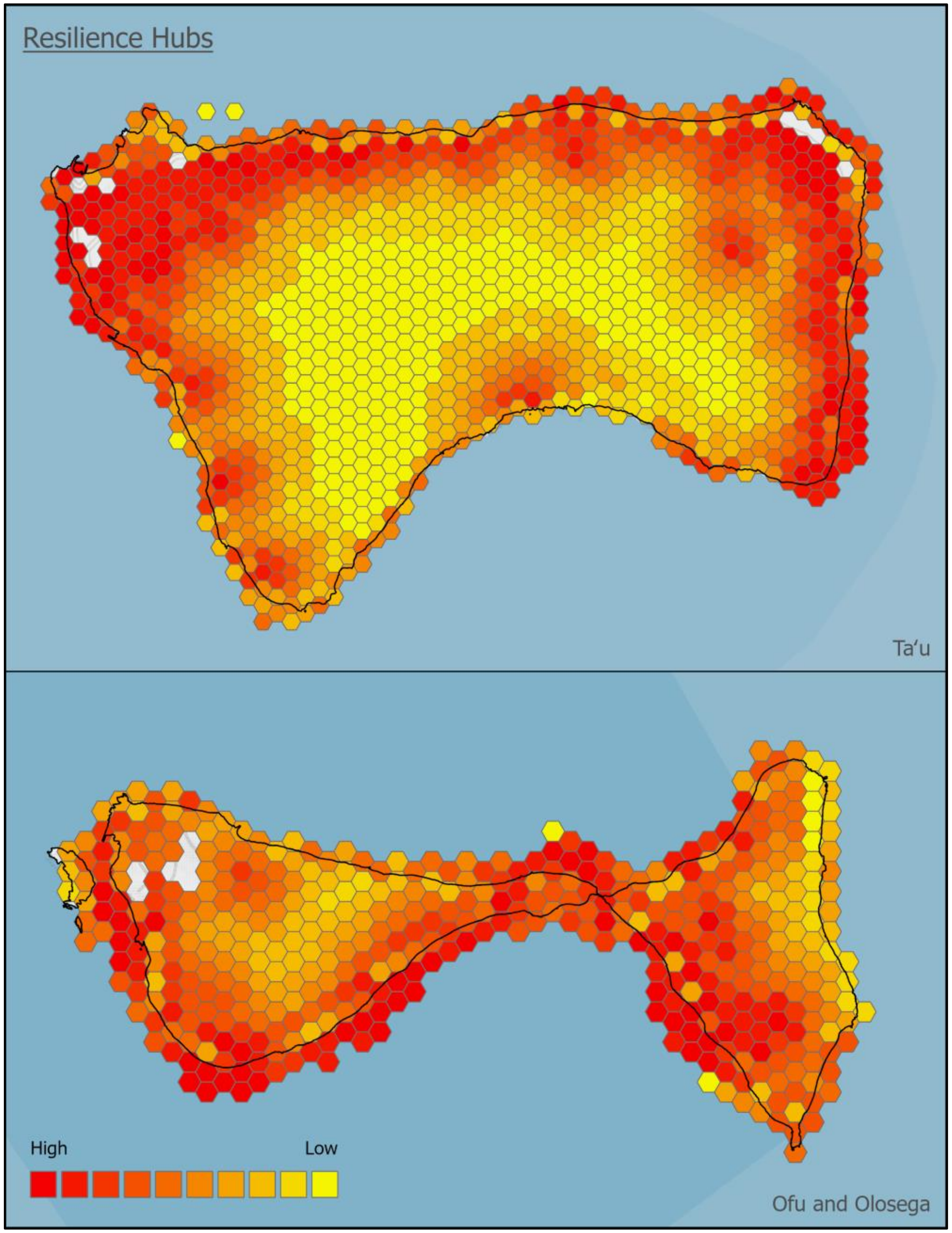
Terrestrial Index
Ta'u
High
Low
Ofu and Olosega



Marine Index
Ta'u
High
Low
Ofu and Olosega


Fish and Wildlife Index
Ta'u
High
Low
Ofu and Olosega


Resilience Hubs
Ta'u
High
Low
Ofu and Olosega


Resilience Hubs
Ta'u
Ofu and Olosega
High
Low