ALASKA COASTAL RESILIENCE ASSESSMENT

2022

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Report cover images: Utqiaġvik, Alaska (top); sockeye salmon (bottom)

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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	Natural, engineered, and hybrid approaches that strategically protect, restore, sustainability manage, or mimic ecosystems to conserve or restore ecosystem functions and natural processes with the goal of reducing community exposure to natural hazards and climate stressors, and enhancing habitat for fish and wildlife.
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 populated areas and locations with high social vulnerability.

EXECUTIVE SUMMARY

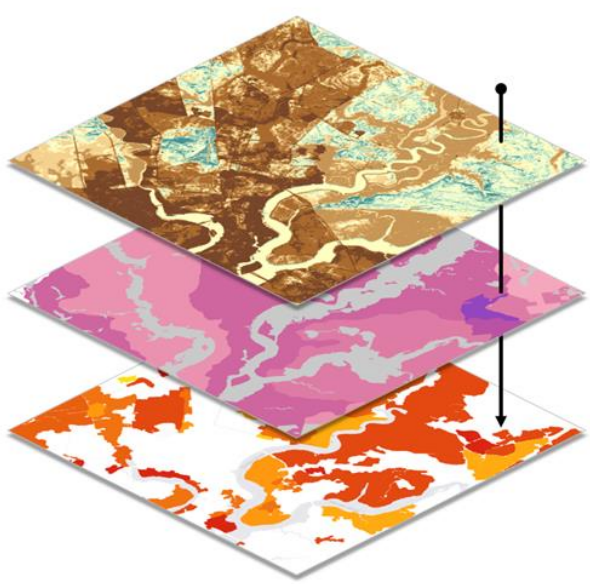
Coastal communities throughout the United States face serious current and future coastal flood-related threats that are predicted to intensify over the short and long term. Dynamic processes such as coastal erosion, storm surge flooding, and river runoff exacerbate the threat from sea level rise. Coastal storms 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 Alaska 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 by 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 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.

OBJECTIVE: REGIONAL COASTAL RESILIENCE ASSESSMENTS

Identify areas on the landscape where nature-based solutions may maximize *fish and wildlife* benefits *and human community resilience* to flooding threats.



Community Exposure Index
Helps identify where the most people and assets are exposed to flooding threats

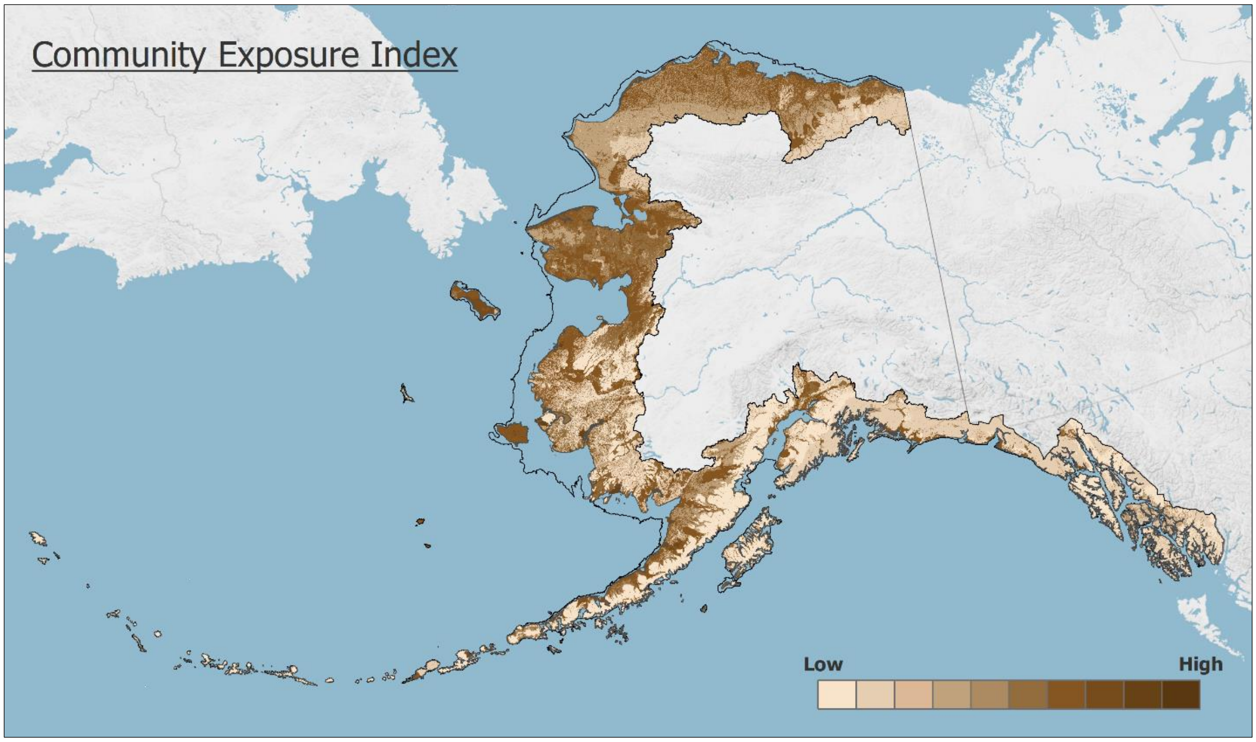
Fish & Wildlife Index
Helps identify where important species and their habitats are located

Resilience Hubs
Areas of natural, open space or habitat where resilience projects may have the greatest potential for dual benefits

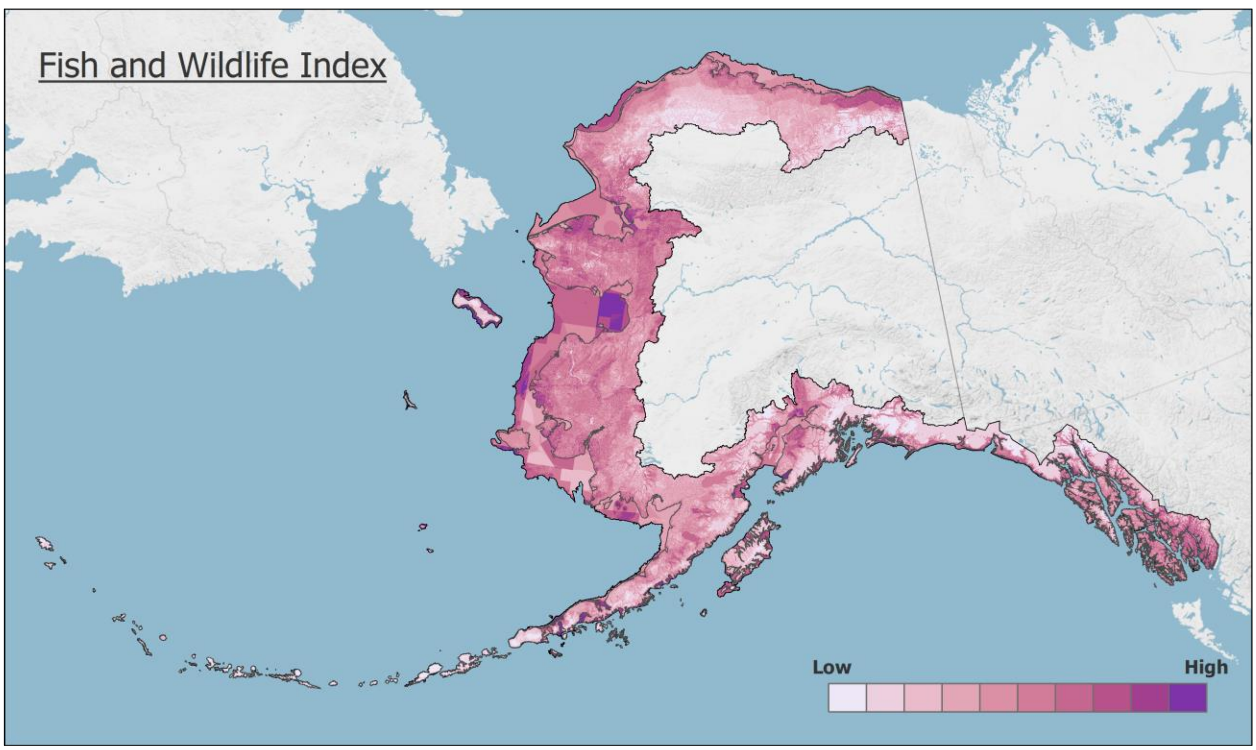
The Assessment identified areas throughout Alaska where human community assets are exposed to a range of coastal-flood related threats. Importantly, the Assessment only considers a community's exposure to flooding threats and not a community's vulnerability or risk. In addition, the analysis identified terrestrial and aquatic areas important for species of conservation concern and subsistence resources. 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 fish and wildlife of Alaska. The primary mapping products from the Alaska Assessment are shown below.

Local community planners, conservation specialists, and others can use the outputs of the Alaska 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 and is not intended to identify all potential opportunities. The Assessment 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 (see Appendix A for a list of important data gaps in Alaska). As with all GIS analyses, site-level assessments are required to validate results and develop detailed design and engineering plans.

This Alaska Coastal Resilience Assessment report provides a detailed discussion of the data and methods used for the three primary analyses (Community Exposure, Fish and Wildlife, and Resilience Hubs), regional results, and case studies. 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 Alaska Assessment (available at resilientcoasts.org).

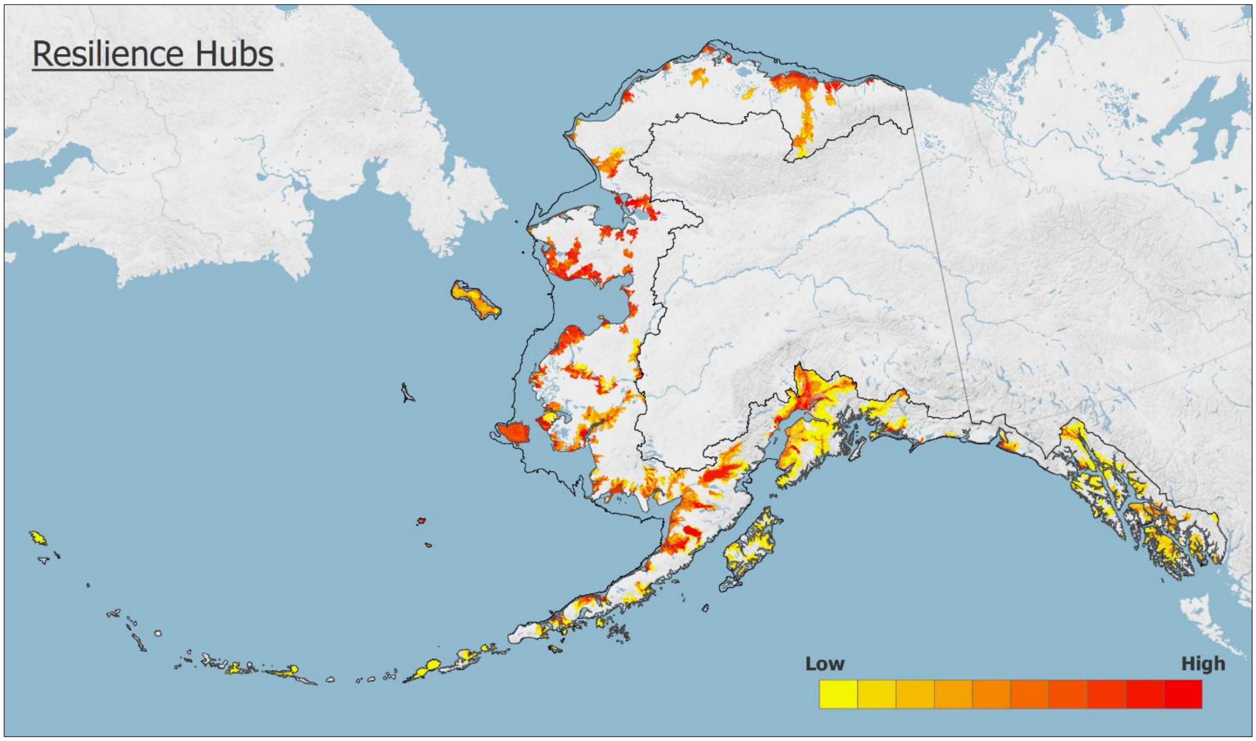


Community Exposure Index for the Alaska Coastal Resilience Assessment. Higher values represent areas where



higher concentrations of community assets are exposed to flooding threats.

Fish and Wildlife Index for the Alaska Coastal Resilience Assessment. Higher values represent areas where numerous species of conservation concern and/or subsistence resources and their habitats are located.



Resilience Hubs for the Alaska 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 Alaska

Alaska is the largest and most northerly state in the United States, featuring large tracts of intact habitat over 570,640 square miles of land. In addition to its large land expanse, Alaska claims a 33,904-mile coastline that represents 38 percent of all U.S. shorelines (ADFG 2015). Polar, temperate continental, and temperate maritime climate zones support 32 ecoregions that vary in geology, topography, habitat, and biota (ADFG 2015). With arctic tundra in the north, maritime tundra along the western deltas and islands, extensive boreal forests that dominate the interior, and far-ranging temperate rainforests along the south central and southeastern coasts, Alaska is home to unique habitats and robust wildlife populations.

The state is sparsely populated with over 733,000 residents, approximately 40 percent of whom live in the largest city, Anchorage[1]. With only 1.3 people per square mile, it is the least densely populated state. Nearly 88 percent of Alaska's large tracts of land are managed by the state or federal government, supporting more than half of all designated wilderness areas in the entire nation. Twelve Alaska Native regional corporations and over 200 local village corporations hold over 44 million acres of land throughout the state (Vynne et al. 2021). Only a small percentage of land is in general private ownership (ADFG 2015).

Supported by relatively undisturbed wilderness, Alaska boasts diverse and healthy habitats that support abundant wildlife populations across the state. The designation of 155 Key Biodiversity Areas[2] demonstrates the number of globally significant sites for species conservation that occur across Alaska. Throughout the state, these areas provide breeding habitat for 7-12 million shorebirds, support over 100 million seabirds (ADFG 2015), and bolster healthy and diverse salmon populations that occupy an estimated 36,000 kilometers of streams (Vynne et al. 2021). While many species remain abundant, Alaska also provides refuge for 30 federally threatened and endangered species, including the wood bison, Northern sea otter, polar bear, 12 whale and pinniped species, three seabird and one shorebird species, four species of marine reptile, one plant, and six fish species (with multiple runs and Distinct Population Segments)[3].

Climate change represents a primary threat to Alaska's diverse wildlife and habitats. Sea ice, tundra, permafrost associated wetlands, and glacially influenced rivers, streams, and fjords all represent priority habitat types vulnerable to climate impacts (ADFG 2015). Alaska is warming twice as fast as the rest of the U.S., leaving habitats, wildlife, and residents vulnerable to current and future climate impacts (Markon et al. 2018). Rising temperatures and changes in precipitation are expected to produce warmer and longer summers; shorter and milder winters; increased precipitation; melting or thawing of glaciers, cryosphere, and permafrost; rising sea levels; and more severe weather events and stronger storm surges (Berman & Schmidt 2019). For instance, since the early 1980s, the extent of arctic sea ice has decreased by an annual average of 3.5-4.1 percent per decade (Markon et al. 2018). As protective

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[1] See 2020 Census for details: https://www.census.gov/library/stories/state-by-state/alaska-population-change-between-census-decade.html.

[2] Birdlife International (2019) World Database of Key Biodiversity Areas. Gland, Switzerland: IUCN.

[3] For a list of threatened and endangered species in Alaska 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/alaska/endangered-species-conservation/endangered-threatened-and-candidate-species-alaska).

landfast sea ice forms later in the season, many coastal communities are left exposed to storm-driven waves, flooding, and severe erosion. In many cases, the sea ice that does form can be thin, exposing coastlines to significant wave action. Reduced sea ice also negatively impacts myriad marine species, including threatened and endangered species and important subsistence resources for Indigenous communities (Markon et al. 2018).

Coastal and riverine flooding represent significant threats among the numerous impacts Alaskan coastal communities face due to the rapidly changing climate. Rising sea levels, thawing permafrost, and more frequent storm surges and wave action due to reduced sea ice extent, all contribute to coastal and riparian erosion that leave coastal communities exposed to flooding (Berman & Schmitt 2019; Lantz et al. 2020). As glaciers melt and precipitation patterns change, communities situated along rivers and within floodplains are also vulnerable to severe flooding and erosion. These compounding effects can cause significant structural damage for communities, in some cases reducing access to critical potable water and sewer services. The Fourth National Climate Assessment estimates that 87 percent of Alaska Native coastal and riverine communities are affected by flooding and erosion (Markon et al. 2018). Since May 2011, there have been 14 flood and storm-related major federally declared disasters in Alaska resulting in public assistance funding from FEMA of over $100 million. Flooding and storm-related damage affected areas throughout the state, including over $24 million in assistance to Southeast Alaska in 2021 alone[4].

Flexible, partnership-driven adaptation planning efforts that integrate traditional knowledge and wisdom are critical to help Alaskans understand the threats, needs, and gaps facing their communities so they may plan, adapt, and help build local resilience to climate threats (Markon et al. 2018). Several recent studies helping communities understand flooding threats include the Statewide Threat Assessment (UAF 2019), Alaska State Hazard Mitigation Plan (ADHSEM 2018), the Alaska Chapter of the National Climate Assessment (Markon et al. 2018), A Toolbox for Resilience and Adaptation in Coastal Arctic Alaska (Pletnikoff et al. 2017), the Coastal Flood Impact Assessment for Alaska Communities (Buzard et al. 2021), and efforts to create high resolution flood exposure maps (Lantz et al. 2020), among many others. The Alaska Coastal Resilience Assessment intends to build on and complement these efforts.

As Alaskan communities take steps to lower their 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 them better plan for future flood and storm events. The Alaska Coastal Resilience Assessment provides a framework that considers both fish and wildlife habitat and resilience for human communities facing growing flooding threats. By focusing on nature-based solutions that utilize natural habitats to reduce flooding threats to communities, this Assessment highlights one of numerous strategies needed to help build resilience on Alaska's rapidly changing landscape.

[4] For a list of federally declared disasters in Alaska, visit FEMA: https://www.fema.gov/disaster/declarations?field_dv2_state_territory_tribal_value=AK&field_year_value=All&field_dv2_declaration_type_value=DR&field_dv2_incident_type_target_id_selective=All.

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[5] 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 where targeted investments can implement resilience-building projects before devastating events occur and impact surrounding communities.

The Alaska 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, American Samoa, and the Commonwealth of the Northern Mariana Islands. The U.S. Great Lakes Assessment is underway (Figure 1).

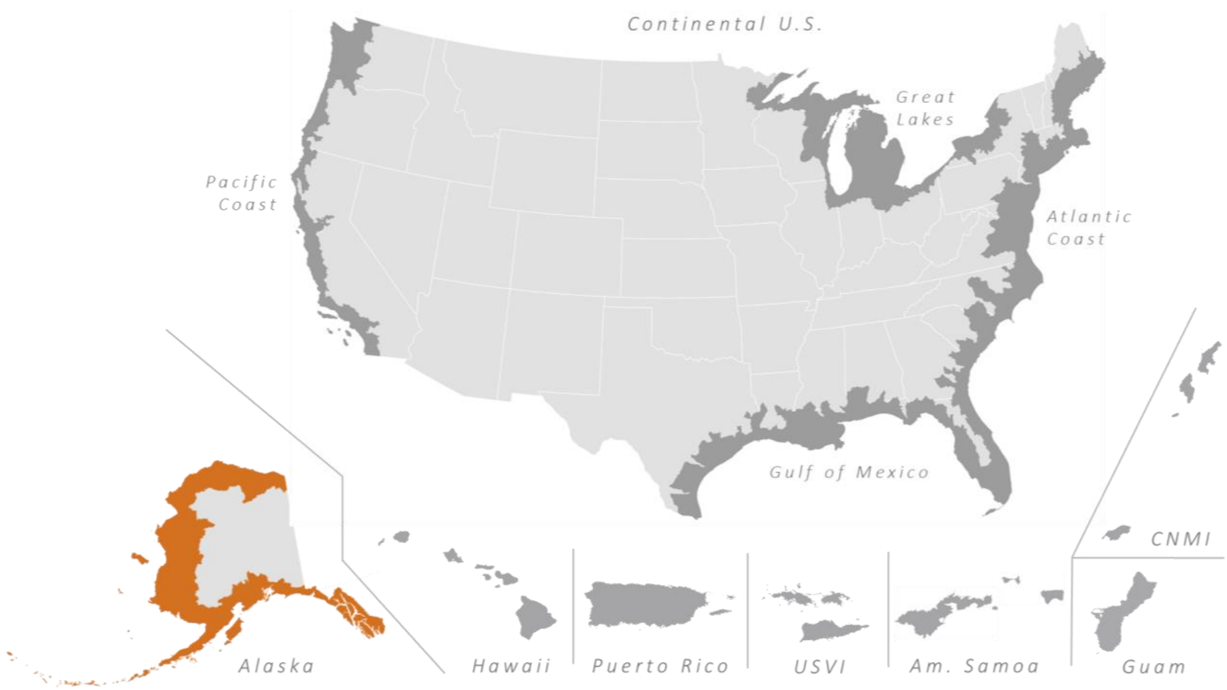

Figure 1. The geographic extent of the Regional Coastal Resilience Assessments in dark gray and the Alaska Assessment in orange. All Regional Assessments will be completed by 2022. Map not shown to scale.

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

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

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 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) 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 possible 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 habitats suitable for the implementation of projects expected to build communities' resilience to flood events while also benefiting fish and wildlife.

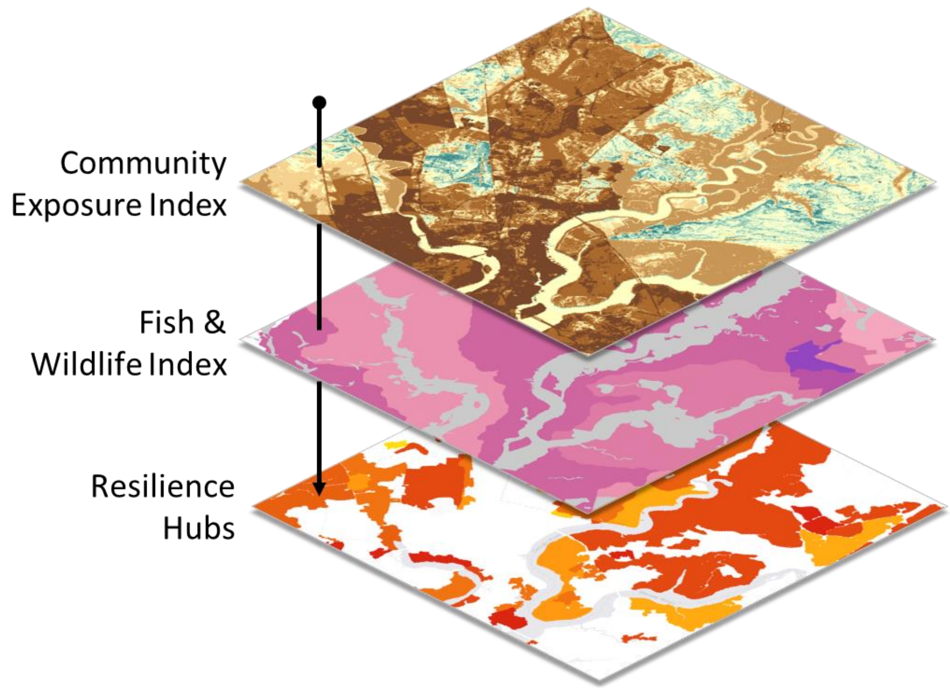

Figure 2. A conceptual model showing the separate, but interrelated components of the Regional Coastal Resilience Assessments.

While 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. 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 Regional Assessments use a Geographic Information System (GIS)-based approach to model landscape characteristics and their potential impacts through three primary analyses: (1) the Community Exposure Index, (2) the Fish and Wildlife Index, and (3) Resilience Hubs.

While both the Gornitz et al. (1994) and the New Jersey research (NJ-DEP 2011) focus on determining the magnitude of flood hazards on the landscape, the Alaska Assessment focuses on the exposure of community assets to flood threats. For example, the Community Exposure Index shows communities as highly exposed if they have critical facilities and/or infrastructure that also overlap with numerous flooding threats.

In addition to mapping human community assets and flooding threats across the landscape to determine exposure, wildlife resources were also identified. Habitat preferences for species of conservation concern, subsistence resources, and other managed species were incorporated into two Indices: the Terrestrial Index and the Aquatic Index. Many species are vulnerable to flood-related stressors such as sea level rise, storm surge, and coastal habitat loss (Powell et al. 2017; Thorne et al. 2018; von Holle et al. 2019). For example, flooding can impact water quality, which can have negative outcomes for sensitive populations of aquatic species (Georgakakos et al. 2014). Flooding can also upset ground-nesting birds and other species vulnerable to coastal inundation. However, neither the Community Exposure Index nor the Resilience Hubs are used to assess the exposure of fish and wildlife or species to flooding threats and should only be used to help identify areas of highly exposed human assets that coincide with areas that feature numerous fish and wildlife assets.

The overarching goal of the Regional Assessments is to identify Resilience Hubs, which help to identify natural, open spaces or habitats suitable for resilience-building conservation or restoration efforts capable of generating dual benefits for human communities and fish and wildlife. These Hubs are determined first by the identification of undeveloped, natural landscapes or habitat cores, and then by the ranked combined averages of the Community Exposure and Fish and Wildlife Indices. The following sections describe the methods used in the Alaska Coastal Resilience Assessment.

2.2 Study Area

The Alaska Assessment focuses on the coastal region of Alaska, including all islands and nearshore marine areas to a 20-meter depth contour. Consistent with other Regional Assessments throughout the U.S., the boundary of the Alaska Assessment follows the coastal watersheds designated by the U.S. Environmental Protection Agency (EPA), which include those watersheds that drain directly to the ocean and are represented at a hydrologic unit code eight scale (HUC-8)[2]. In addition to including the immediate coastline, the study area extends far inland to capture areas that influence or are influenced by coastal flood-related threats. The analysis was completed at a 30-meter resolution.

Figure 3. The Alaska Coastal Resilience Assessment study area. The 20-meter depth contour is shown in black.

2.3 Data Collection and Stakeholder Engagement

The Project Team began data collection efforts by compiling an initial set of publicly available data sets from multiple national and regional sources. In addition, the Alaska 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 eight members representing the Alaska Department of Natural Resources, Alaska Division of Community and Regional Affairs, Alaska Department of Fish and Game, Alaska Ocean Observing System, University of Alaska Anchorage, NOAA Fisheries, 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 tribal governments, universities, non-governmental organizations, and others to provide input into the development of the Alaska Assessment; and
3. Advise on final products and tools, including the effective dissemination of results.

During the initial development of the Assessment, the Project Team established a Technical Working Group consisting of Advisory Committee members and other key stakeholders. In January 2020, the Project Team hosted a one-day Technical Working Group meeting in Anchorage to discuss and gain feedback on the initial design and methods for the Assessment. In addition to the Advisory Committee members, other attendees included representatives from the Denali Commission, Alaska Native Tribal Health Consortium, Alaska Ocean Observing System, Alaska Conservation Foundation, Alaska Sea Grant, U.S. Geological Survey, U.S. Army Corps of Engineers, and the U.S. Fish and Wildlife Service.

Building on initial data collection efforts with input from the Advisory Committee and Technical Working Group, 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 October 4, 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 four weeks following the virtual workshop.

Over 20 people attended the workshop, representing local, tribal, federal, non-government, and academic organizations. For a complete list of all organizations invited to the workshop, see Appendix H. 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, species, and habitats;
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 Alaska.

Participants reviewed draft maps and data sources during and after the workshop, providing important feedback and recommendations to improve the analyses. Not all suggested data sources could be included in the Assessment for various reasons described in Appendix A.

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 Alaska 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 flooding threats (Figure 4). The following equation calculates exposure:

$$\textit{Threat Index} \times \textit{Community Asset Index} = \textit{Community Exposure Index}$$

While the methods used to create the Community Exposure Index are generally consistent among all Regional Coastal Resilience Assessments, the methods were modified for the Alaska Assessment to accommodate differences in data availability, relevant flood-related threats, and human community asset density. The following text describes the specific methods used for the Alaska Assessment; a complete list of datasets included can be found in Appendix B.

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 which 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-related impacts in Alaska were included. Threats are defined as datasets that show coastal flood, erosion, and severe storm hazards on the landscape. Using an ordinal combination method, all inputs were ranked numerically from low to high, representing the risk—not the degree—of impact (MacDonald 2007; Gornitz et al. 1994; NJ-DEP 2011). Each ranked input is used to create the cumulative Threat Index (Ponce Manangan et al. 2014). The Threat Index is then reclassified into 10 classes using a percentile distribution. Additional details on those data used to create the Threat Index for Alaska can be found in Appendix B.1 and Appendix C.

Areas of Low Slope

As a terrain's slope decreases, more land areas become prone to pooling water that can lead to prolonged periods of inundation. This threat input was developed with consideration of the Brunn Rule, which states that every foot rise in water can result in a 100-foot loss of sandy beach (NJ-DEP 2011). In this case, a one percent or less slope is likely to be inundated with a one-foot rise in water, helping to identify low-lying coastal areas that are more susceptible to inundation and changing coastal conditions. For the Alaska Assessment, slope was calculated from the Interferometric Synthetic Aperture Radar (IFSAR) data. More details about the creation of this input can be found in Appendix C.1.

Soil Erodibility

Soil erosion resulting from flooding can drastically alter the landscape and impact human communities. To assess the erodibility of soils throughout coastal watersheds, the USDA-NRCS Gridded National Soil Survey Geographic Database (gNATSGO) K Factor (*kffact)* was used, which measures the susceptibility of soil particles to detachment by water. Soils high in clay have low K values and thus low soil erodibility values in the Assessment because they resist detachment. Conversely, the Assessment assigns high erodibility values to soils with high silt content, which are easily detached and capable of producing high rates of runoff (Renard et al. 2011).

While the gNATSGO dataset is available for most of the state of Alaska, these data are relatively coarse and may not accurately reflect erosion potential at the community scale. Therefore, the Alaska

Assessment utilized results from a recent analysis that assessed the risk of damages from erosion for 187 rural Alaska communities (UAF 2019). The study, known as the Statewide Threat Assessment or STA, placed communities into one of three groups dependent on the immediacy and severity of erosion-related damages to critical infrastructure, where those in Group 1 face severe and immediate threats. The STA data were used in place of the gNATSGO data for each of the 187 rural Alaska communities assessed. For those communities under immediate threat from erosion according to the STA (Group 1), the Project Team assigned the highest erodibility values to each pixel within the community's footprint[6]. Similarly, those communities with long-term vulnerability to erosion (STA Group 2) and those with low vulnerability to erosion (STA Group 3) were assigned moderate and low soil erodibility values in the Alaska Assessment, respectively. More details about the creation of this input can be found in Appendix C.2.

Flood-Prone Areas

Flood-prone areas were identified for the Alaska Assessment through a combination of the FEMA National Risk Index (Coastal and Riverine Flooding Annualized Frequency), USDA-NRCS gNATSGO, and the Statewide Threat Assessment (STA). Similar to the soil erodibility input, the STA results (UAF 2019) for flooding threats were used to generate flood-prone areas values for each of the 187 community footprints assessed. For all other areas within the study area, including those communities not assessed by the STA, FEMA and gNATSGO data were used to assess areas potentially prone to flooding. To prevent flood-prone areas from appearing in locations with high elevation (alpine environments) where flooding is unlikely to occur, the flood-prone input was restricted to elevations less than 20 meters above sea level using the state's high resolution IFSAR data. While areas above 20 meters still receive values for other inputs included in the Threat Index, the elevation threshold applied to the flood-prone area input results in lower overall Threat Index values in higher elevation areas. More details about the creation of this input can be found in Appendix C.3.

Permafrost Thaw

Permafrost can be found in over 80 percent of Alaska and is structurally important to the soils. Thawing of these soils can cause ground subsidence and erosion, both of which can lead to flooding in coastal areas. For the Alaska Assessment, a geohazard risk index due to permafrost thaw was used as a direct indicator of permafrost-related flooding threat (Hjort et al. 2020). Although those data presented in Hjort et al. (2019) cover the entire study area of the Alaska Assessment, where available, the STA results (UAF 2019) were used for the permafrost input in a similar manner to the soil erodibility and flood-prone area inputs. Of the 187 communities assessed by the STA, those with high, moderate, and low risk of damage from permafrost thaw were assigned high, moderate, and low values for the permafrost thaw input in the Alaska Assessment, respectively. More details about the creation of this input can be found in Appendix C.4.

Tsunami Inundation

Coastal areas of Alaska are subject to severe tsunami risks. Historically, tsunamis generated by earthquakes in Alaska have caused damage and loss of life along the West Coast and across the Pacific. Tsunamis generated by nearby earthquakes represent "near-field" hazards. In other words, people have minutes rather than hours to reach safety. The Tsunami Inundation Mapping Program, a collaboration between the Alaska Earthquake Center and the Alaska Division of Homeland Security and Emergency

[6] Community footprints represent boundaries for incorporated cities, Census Designated Places, and Census Blocks according to the Local Boundary Commission. Alaska Department of Commerce, Community and Economic Development, Division of Community and Regional Affairs. Community Transportation Overview. See the State of Alaska Open Data Geoportal: https://gis.data.alaska.gov/datasets/4cbaa40cacfc48ec902ad52095fc370b_0/about.

Management, works to make coastal communities safer by providing state and local officials with the best possible information for addressing the tsunami hazards faced by their communities. Communities are selected with consideration of their tsunami hazard exposure, location, infrastructure, availability of data, and willingness to incorporate the results in a comprehensive mitigation plan. Final maps incorporate the best tsunami science available at the time of publication. More details about the creation of this input can be found in Appendix C.5.

2.4.2 Community Asset Index

The Community Asset Index identifies human community assets that are important to help a community respond to and recover from a flooding event. The Index used datasets that quantify the number of assets present—not their magnitude of vulnerability or susceptibility to flood threats.

In Alaska, the Community Asset Index included social vulnerability, critical infrastructure, critical facilities, and critical transportation infrastructure. All facilities and infrastructure were counted with equal weight in the Assessment, highlighting the importance of all community assets, particularly within remote villages. 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[7]. As with the Threat Index, the Community Asset Index was ultimately reclassified into 10 classes using a percentile distribution. A detailed list of datasets used for all Community Asset Index inputs included in the Alaska Assessment can be found in Appendix B.2. See Appendix D for a description of methods used to create the Community Asset Index.

Social Vulnerability

The social vulnerability input is meant to identify areas in a community where an individual's ability to respond to and cope with the effects of threats might be more or less difficult as compared to other areas in the same area. Disadvantaged households are typically found in areas of higher risk, leaving them vulnerable to flooding, disease, and other chronic stressors (EPA 2021). For the Alaska Assessment, the Denali Commission (2020) annual Distressed Communities report was used to identify socially vulnerable communities, each of which received a single value across their entire community footprint boundary. The Assessment also used the Demographic Index in EJSCREEN to determine social vulnerability, which is the average of the percentage of the population that is low-income and the percentage of the population that is minority in each census block group (EPA 2016). More details about the creation of this input can be found in Appendix D.1.

Critical Infrastructure

The Alaska Assessment included critical infrastructure types that may help communities immediately recover from devastating flood events. The types of critical infrastructure used in the Assessment included wastewater treatment facilities, power plants/substations, major dams, petroleum refineries, hazardous sites, water distribution infrastructure, communication infrastructure, bulk fuel storage, and others. More details about the creation of this input can be found in Appendix D.2.

Critical Facilities

Critical facilities used in the Alaska Assessment included schools, medical facilities, post offices, and fire and police stations identified using the USGS National Structures Dataset. Local data were used in place of the National Structures Dataset whenever possible. It is important to emphasize that these critical facilities provide important services that support the operation of other types of critical infrastructure, such as residential, commercial, industrial, and public properties. These facilities are often prioritized in

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

disaster planning since they may offer refuge to vulnerable populations. More details about the creation of this input can be found in Appendix D.3.

Critical Transportation Infrastructure

In Alaska, transportation infrastructure is quite different than in other regions of the U.S. The road network is relatively small, and many communities, including the state capital, cannot be reached via roads. This means that reliance on air and/or water transportation infrastructure is critical for access to commodities, evacuation, and emergency response. Data for roads, rail, airports and runways, ferry terminals, ports, and harbors were included as a separate input. More details about the creation of this input can be found in Appendix D.4.

2.4.3 Community Exposure Index

To create the Community Exposure Index, the Threat and Community Asset Indices were each given a value of 1 to 10 to indicate a low-to-high presence of threats or assets, respectively. Combination methods traditionally result in the summation of inputs to create a final land suitability index; however, the Alaska Assessment aims to understand exposure—the relationship between potential threats and the presence of community assets. Therefore, a multiplication function was used to understand this relationship. Areas with the highest prevalence of threats and the highest presence of community assets were calculated as having the highest levels of exposure. See Appendix E for a description of the methodology used to calculate the Community Exposure Index.

2.5 Creating the Fish and Wildlife Index

The Fish and Wildlife Index, which consists of terrestrial and aquatic components, allows for a greater understanding of important habitats and fish and wildlife resources to help identify 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 Alaska Assessment, only those species of concern with federal- or state-level protection status, species of greatest conservation concern, important subsistence resources, and/or those species included in resource management plans were considered. A complete list of data can be found in Appendix B and a description of the methods used to create the Fish and Wildlife Index can be found in Appendix F.

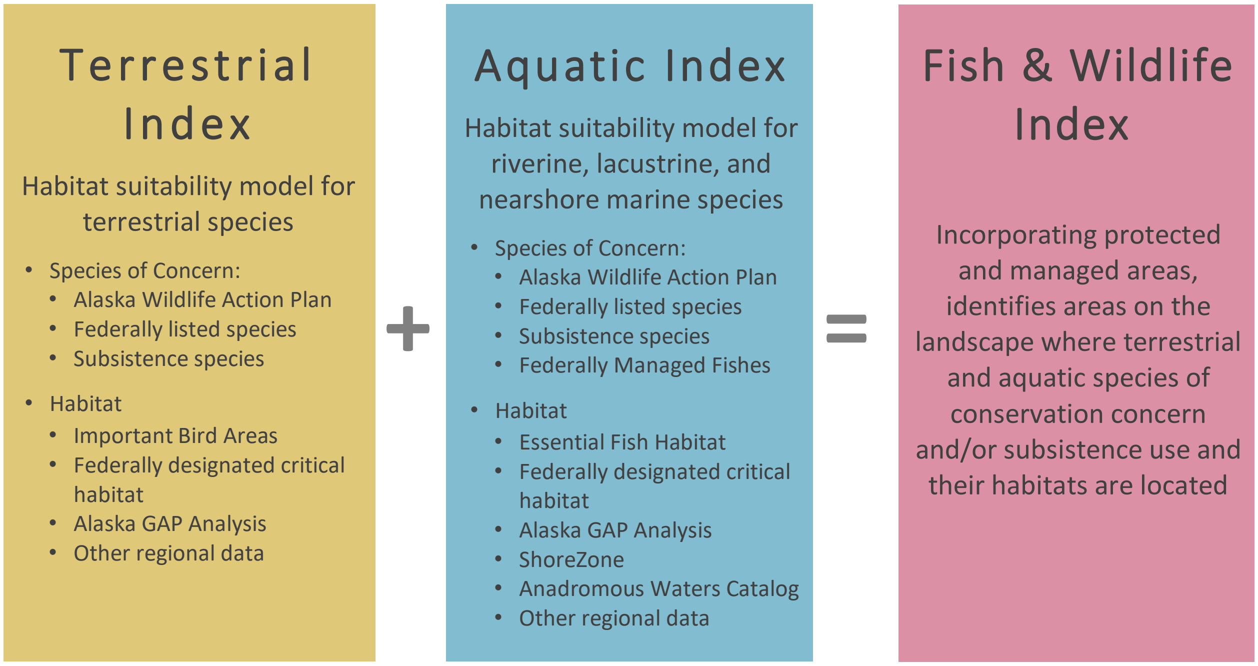

Figure 5. Elements of the Terrestrial and Aquatic Indices used to create the Fish and Wildlife Index.

2.5.1 Terrestrial Index

The Terrestrial Index aims to identify suitable habitats for species of conservation concern and subsistence use. Unlike approaches that rely on uneven species occurrence data, a habitat suitability approach provides the opportunity to model groups of species at a consistent regional scale (Rondini et al. 2011). To develop habitat suitability models, the Assessment first identified the habitat preferences and needs of terrestrial wildlife species of greatest conservation need according to the Alaska State Wildlife Action Plan (ADFG 2015), species listed as threatened or endangered under the U.S. Endangered Species Act, and important subsistence resources as identified by harvest records maintained by the Joint Board of Fisheries and Game[8]. All species included in the Assessment were then grouped into broad taxonomic groupings, including seabirds, land birds, amphibians, and terrestrial mammals. Finally, using the Alaska Gap Analysis Project (Gotthardt et al. 2014), IUCN Habitat Classification Scheme[9], and other habitat-related datasets, habitat preferences were identified for each taxonomic group. Some species were excluded from the analysis if there were insufficient data to determine habitat preferences. Based on those habitat preferences, three levels of habitat suitability were modeled following methods outlined by Rondini et al. (2011).

1. *Primary habitat* represents preferred habitat where the species is known to occur. Using these guidelines, all designated critical habitat for species listed under the Endangered Species Act, as well as habitats identified as important for threatened and endangered species, was considered primary habitat for that species' taxonomic group.
2. *Secondary habitat* represents areas where the species can be found but would be unlikely to persist in the absence of primary habitat. Secondary habitat also coincides with protected areas that are managed for biodiversity, potentially increasing the probability of species utilization.

[8] Alaska Department of Fish and Game. Subsistence Harvests: Non-Fishing Resources. https://gis.data.alaska.gov/datasets/DCCED::subsistence-harvests-non-fishing-resources/about.

[9] IUCN Habitat Classification Scheme, Version 3.1 available at: https://www.iucnredlist.org/resources/habitat-classification-scheme.

3. *Tertiary habitat* includes areas that meet the preferences of the taxonomic group and spatially proximate to either primary or secondary habitat, meaning the species may utilize that habitat patch, but is unlikely to thrive in that habitat alone.

In addition to modeling habitat suitability, the Index also included BirdLife International Important Bird Areas (IBAs), which help to identify areas that support habitat conservation through acquisitions or easements or by encouraging the voluntary adoption of best management practices. The IBAs are combined with habitat suitability to create the Terrestrial Index.

Together, the analysis modeled areas with high species richness for species of conservation concern and subsistence use based on existing distribution data for each species. A complete list of species (organized by taxonomic and species group) included in the Alaska Assessment is available in Appendix F.1.

2.5.2 Aquatic Index

Using similar methods to the Terrestrial Index, the Aquatic Index identifies habitat preferences for species of conservation and subsistence concern that utilize riverine, lacustrine, and nearshore marine habitats. Calling on data from Alaska's Anadromous Water Catalog[10], Alaska Gap Analysis Project (Gotthardt et al. 2014), IUCN Habitat Classification Scheme[9], and NOAA's Essential Fish Habitat (EFH)[11], the Index uses existing species distribution data for species of high conservation or economic importance to identify areas of high species richness. As with the Terrestrial Index, aquatic species included in the Assessment are those listed as species of greatest conservation need according to the Alaska State Wildlife Action Plan (ADFG 2015), species listed as threatened or endangered under the U.S. Endangered Species Act, species with designated EFH under the EFH provisions of the Magnuson-Stevens Act, and important subsistence species identified from Alaska Department of Fish and Game subsistence harvest records[12]. In addition, the Aquatic Index included nearshore marine habitats including surfgrass, eelgrass, rockweed, soft and dark brown kelps, and canopy kelp species[13]. A complete list of species and data sources included in the Aquatic Index is available in Appendix F.3.

2.5.3 Fish and Wildlife Index

To identify areas likely to support a high number of priority species and habitats, the Terrestrial and Aquatic Indices were summed to create one combined Fish and Wildlife Index. In addition, protected and managed areas such as federally managed lands and Alaska Department of Fish and Game Refuges, Sanctuaries, Critical Habitat Areas, and other protected areas were added directly to the Fish and Wildlife Index because they impact more than a single species group and are neither distinctly aquatic nor terrestrial in most cases. By combining the Terrestrial and Aquatic Indices with protected areas, it creates a continuous Fish and Wildlife Index that helps to identify areas where implementing a resilience or restoration project would likely benefit fish and wildlife communities. See Appendix F.5 for more details on the creation of this combined Fish and Wildlife Index.

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[10] Alaska Department of Fish and Game, Anadromous Waters Catalog: https://www.adfg.alaska.gov/sf/SARR/AWC/index.cfm?ADFG=main.home.

[11] NOAA Fisheries Alaska Region Essential Fish Habitat: https://www.fisheries.noaa.gov/alaska/habitat-conservation/essential-fish-habitat-efh-alaska.

[12] Alaska Department of Fish and Game. Subsistence Harvests: Non-Fishing Resources. https://gis.data.alaska.gov/datasets/DCCED::subsistence-harvests-non-fishing-resources/about.

[13] Alaska ShoreZone: https://www.fisheries.noaa.gov/alaska/habitat-conservation/alaska-shorezone.

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 Habitat Cores (Figure 6). These Habitat Cores are then ranked according to the combined average values of the Community Exposure Index and the Fish and Wildlife Index. For a detailed description of data sources and methods, see Appendix B.6 and Appendix G, respectively).

2.6.1 Green Infrastructure

The Green Infrastructure[14] 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 Alaska, NEMAC replicated the analysis to create this important layer for the Alaska 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 community 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 or subsistence 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 Alaska, the Green Infrastructure analysis resulted in the creation of Habitat Cores (Figure 6), which encompass terrestrial, marine, and freshwater aquatic habitats. Due to Alaska's large tracts of undeveloped land with few fragmenting features, many Habitat Cores are divided by HUC-12 watershed boundaries. See Appendix G.1 for details.

Since the Assessment aims to identify areas where nature-based solutions have potential to benefit both fish and wildlife and human communities, the analysis only considered Habitat Cores proximate to human community assets. Therefore, a 5-kilometer (3.1-mile) buffer was applied to all assets identified in the Community Asset Index. Second, those Habitat Cores that did not intersect with the asset buffer were removed from the analysis. This ensures that remaining Habitat Cores are either near human community assets or are within nearby HUC-12 watersheds. See Appendix G.2 for details.

[14] 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.

Figure 6. Unranked Habitat Cores generated from the Green Infrastructure analysis with the addition of riparian corridors in Anchorage.

2.6.2 Addition of Riparian Corridors and Shorelines

When preparing the Habitat Cores, many narrow shorelines and riparian corridors are excluded from the analysis due to the size minimums and other topographical characteristics that are considered in the Green Infrastructure methodology. This is particularly pronounced in urban areas where riparian corridors along small rivers and streams are excluded despite their potential for stream connectivity and urban restoration projects. Similarly, narrow beach and dune systems that represent important opportunities to implement nature-based solutions were excluded through the Green Infrastructure methodology. Therefore, the National Hydrology Dataset (NHD) “flowlines” feature class was used to identify riparian and shoreline Habitat Cores that would have otherwise been excluded from the analysis. The NHD flowlines were used to identify streams and rivers within Alaska’s most populated incorporated places and U.S. Census Designated Places (parts of greater Anchorage area and Juneau, see Figure 6), and to identify all coastlines within a 5-kilometer (3.1-mile) buffer of any community asset. In all cases, coastal and riverine flowlines were buffered by 100 meters and combined with the Habitat Cores generated through methods described in Section 2.6.1. See Appendix G.3 for details.

2.6.3 Creating a Hexagonal Grid

Once the Habitat Cores derived from the Green Infrastructure methodology are combined with the riparian and shoreline Habitat Cores, all features were converted into a finer 4-hectare (10-acre) hexagonal grid (Figure 7). Due to the limited number of fragmenting features, many Habitat Cores can be thousands of acres in size. Therefore, a finer-scale hexagonal grid is important to show variation within a given Habitat Core and can help to facilitate local decision-making commensurate with the size of potential nature-based projects and solutions. See Appendix G.4 for details.

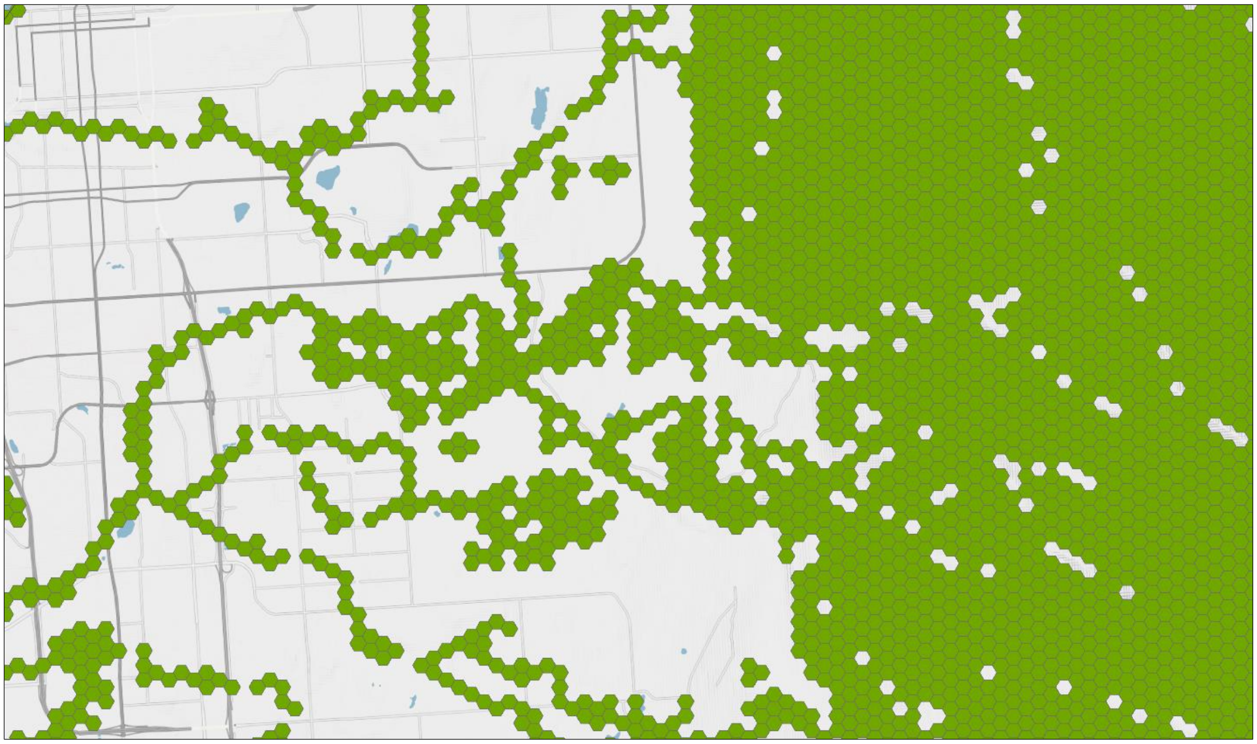

Figure 7. Unranked fine scale 4-hectare (10-acre) hexagonal grid in Anchorage.

2.6.4 Ranking Resilience Hubs

As a final step, both the Habitat Cores and hexagonal grid are scored using the average values of the Community Exposure and Fish and Wildlife Indices to create ranked Resilience Hubs. As the final product of the Assessment, the Resilience Hubs identify areas of open space where implementing a nature-based solution has potential to benefit fish and wildlife while building community resilience to flooding threats. Resilience Hubs are presented in two ways: 1) Resilience Hub Cores provide a coarse-scale view that assigns a single average rank to each Habitat Core, and 2) a Resilience Hub Grid provides a fine-scale view that assigns an average rank to each individual 4-hectare (10-acre) hexagon.

The Resilience Hub Cores and Grid are both scored using the same methods. Using a zonal statistics geoprocessing technique common to many GIS analyses, average values from the Community Exposure Index were calculated for each Habitat Core or hexagon, including the surrounding areas within one kilometer. Incorporating the buffer area was necessary because Habitat Cores and associated hexagons are natural, open landscapes containing few to no exposed community assets. The buffer was determined in consultation with technical experts. Next, the average Fish and Wildlife Index value was calculated for each Core and hexagon without applying a buffer. The average Community Exposure and Fish and Wildlife Index values were then multiplied to produce a score for each Core and hexagon.

Using a geometric interval distribution, the values for the scored Habitat Cores were then classified into a 10-class ranking scale; the scored hexagons were classified into a 10-class ranking scale separately. This 1 to 10 ranking, results in the final Resilience Hubs presented as Resilience Hub Cores and a Resilience Hub Grid. See Appendix G.5 for details.

When considering the Resilience Hubs that result from the Alaska Assessment, the following will generally be true:

(1) Hubs that are not near significant densities of exposed assets will receive lower average Community Exposure Index values, whereas those near more exposed assets will receive higher values;

(2) Hubs containing fewer fish and wildlife assets will receive lower average Fish and Wildlife Index values, whereas those near more fish and wildlife assets will receive higher fish and wildlife values; and

(3) Hubs with the highest Community Exposure Index and Fish and Wildlife Index values will receive a higher ranking.

In summary, the Resilience Hub approach—in determining both 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.

RESULTS

The Alaska Coastal Resilience Assessment reveals abundant opportunities to use nature-based solutions to help build human community resilience while supporting fish and wildlife habitats and species. Nature-based solutions include actions that sustainably manage and utilize natural systems to address societal challenges such as flooding and erosion while benefiting biodiversity and human well-being. Implementing nature-based solutions, such as habitat restoration and conservation, can provide tremendous co-benefits to people and wildlife as described in the case studies outlined below (see Section 4). To explore the findings of the Alaska Assessment, results for the Community Exposure Index, Fish and Wildlife Index, and Resilience Hubs are presented across five different regions of Alaska: Southeast, Southcentral, the Alaska Peninsula and Aleutian Islands, Western Alaska, and Northern Alaska. A single model was used for the entire state, allowing results to be directly compared within and among regions.

3.1 Community Exposure Index

Facing imminent climate threats, Alaska's vast coastal and riverine shorelines are highly exposed to a variety of flood-related threats. Rising temperatures are contributing to widespread permafrost degradation and sea ice loss, leaving communities susceptible to damage from increasingly severe storms, erosion, and flooding. Despite these threats being well known, statewide spatial data describing sea level rise, storm surge, sea ice extent, and other important hazards are limited (Appendix A). By only utilizing those data that are available throughout the study area, the Assessment presents a conservative estimate of the severity and extent of coastal hazards throughout the state.

While limited, those data that are available highlight the severity and extent of coastal hazards throughout the state. This is evident in the results of the Alaska Assessment, where the Community Exposure Index reveals large areas of high exposure as indicated by the darkest shades of brown (Figure 8c). Exposure values are highest in areas where human community assets (Figure 8b) occur in areas facing numerous flooding threats (Figure 8a), which is particularly evident in the vast low-lying wetlands and arctic tundra habitats that dominate Western and Northern Alaska. In the sparsely developed landscapes of Alaska it is unsurprising that only a small proportion (0.01 percent) of the study area received the highest exposure ranking (10); however, the vast majority of communities within the Assessment are highly exposed, with an average value between 6 and 10 in the Community Exposure Index.

The results from the Community Exposure Index reveal regional differences in the density of community assets and prevalence of flood-related threats. For instance, Southeast and Southcentral Alaska include some of the most populated areas in the state, revealing high Community Asset Index values within developed areas that include numerous critical facilities connected by an extensive road network, ports, bridges, and other types of critical infrastructure (Figures 9 and 10). Many of the community assets in these regions occur in low-lying areas that are also subject to numerous flooding threats, leaving areas of high exposure largely restricted to the coast and large lakes. There is frequently a sharp divide between high and low exposure values driven by steep mountainous terrain that serve to eliminate most coastal flooding threats as elevation increases. As expected, some of the highest exposure values occur in and around Anchorage, which is home to almost half of Alaska's residents. Throughout much of Cook Inlet, low-lying and flood-prone areas coincide with community assets (Figure 10). Similarly, populated areas in Southeast Alaska such as Sitka, Ketchikan, Wrangell, and the capital city of Juneau all reveal exposed assets (Figure 9).

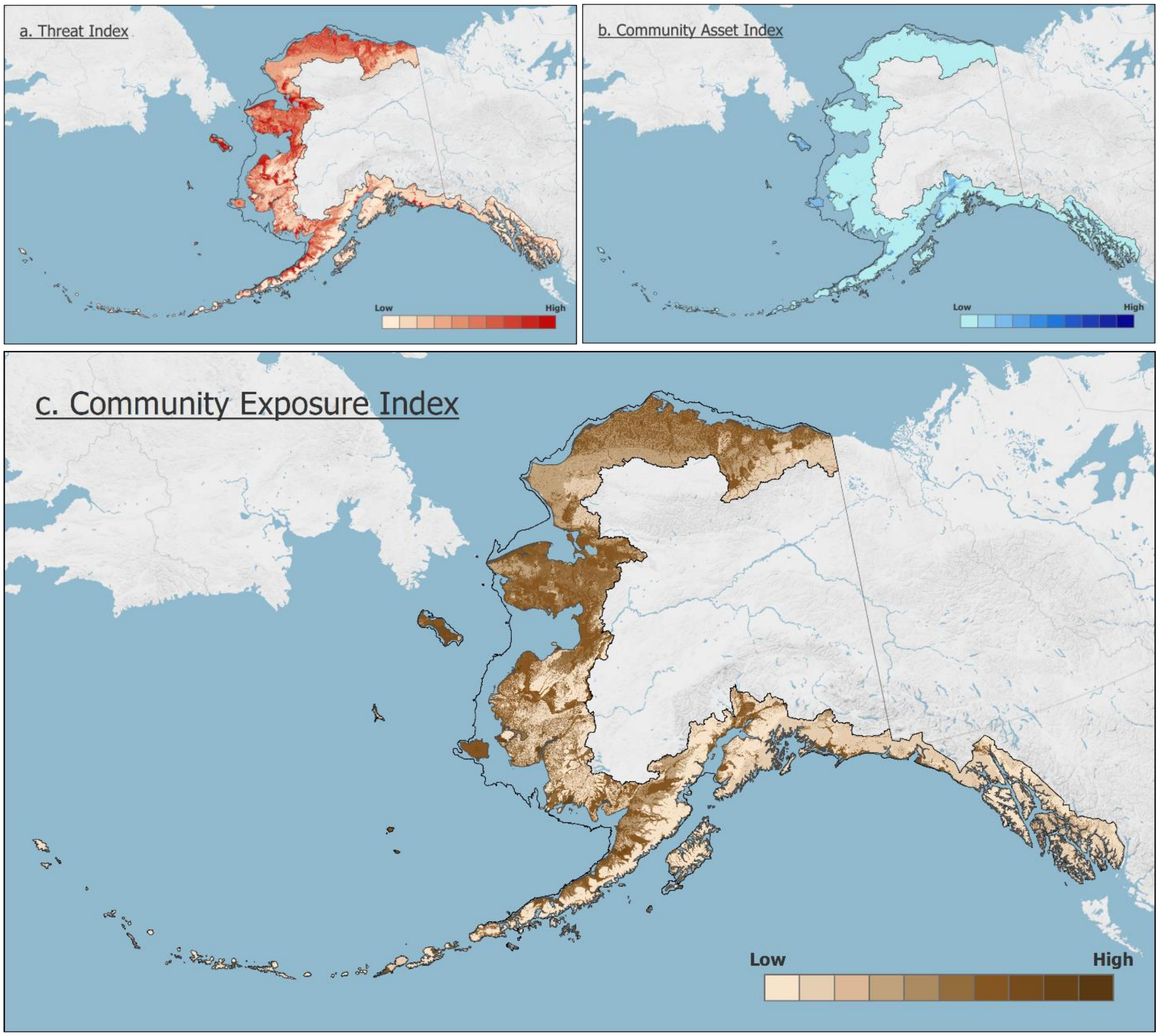

Figure 8. (a) Threat Index, (b) Community Asset Index, and (c) Community Exposure Index values for the Alaska Coastal Resilience Assessment study area. The Threat and Community Asset Indices are multiplied to produce the Community Exposure Index, which shows areas where assets overlap flood threats. To view results in detail, see [CREST](#).

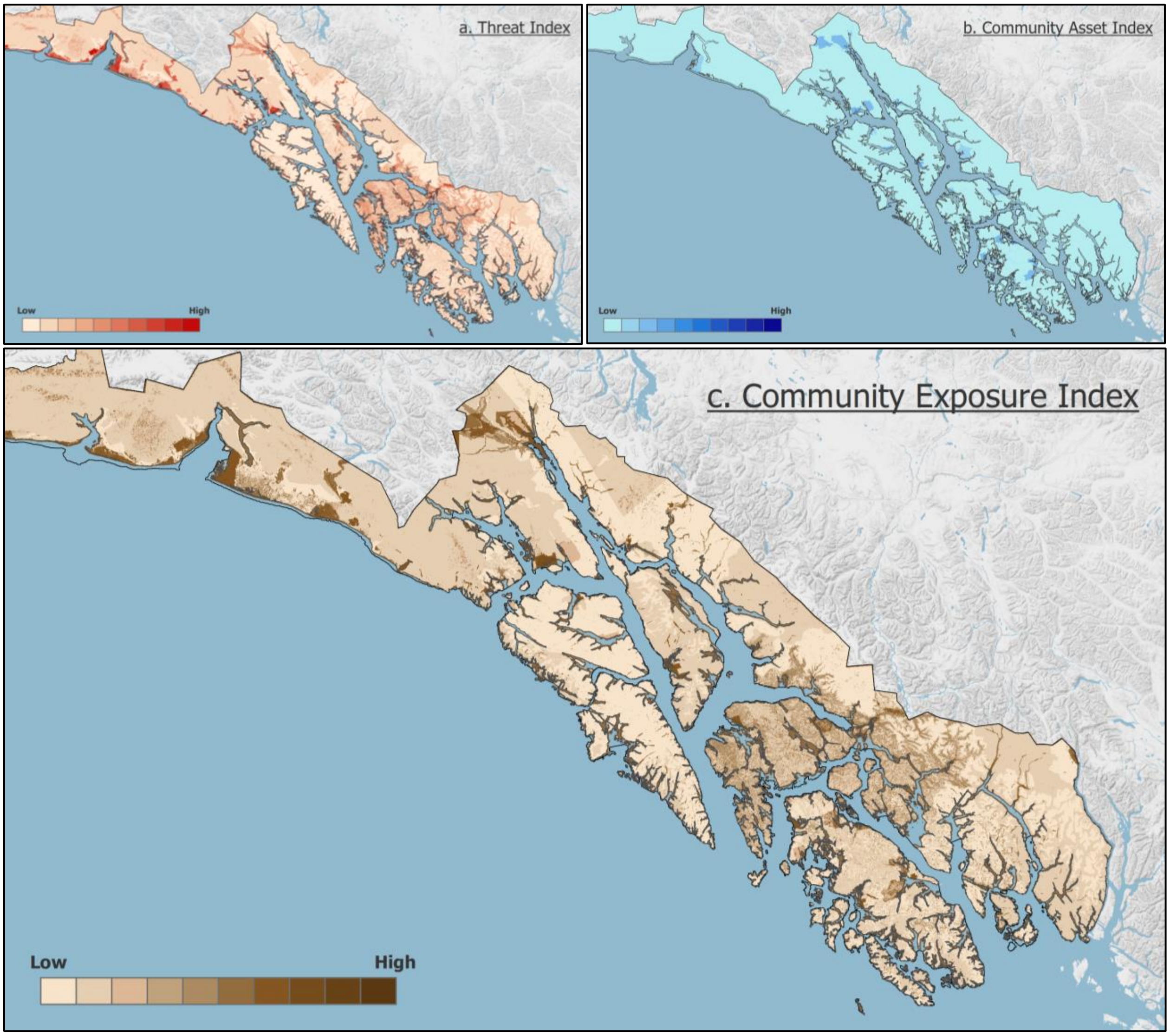

Figure 9. (a) Threat Index, (b) Community Asset Index, and (c) Community Exposure Index values for Southeastern Alaska. To view results in detail, see [CREST](#).

In Southwestern Alaska (Figure 11), exposure values remain low along the high elevation Aleutian Range that is largely dominated by undeveloped public lands. In contrast, the lower elevation areas of the Alaska Peninsula bordering Bristol Bay reveal very high exposure, particularly around the villages of Egegik, Pilot Point, Port Heiden, and Nelson Lagoon, all of which were identified as vulnerable by other studies (UAF 2019). On Kodiak Island and throughout the Aleutian Islands, exposure values are largely restricted to populated areas such as Kodiak, Unalaska, Akutan, and Nikolski. In other cases, such as Umnak Island, the entire island has a high community asset value because the officially designated community footprint[15] covers the entire island.

[15] Community footprints represent boundaries for incorporated cities, Census Designated Places, and Census Blocks according to the Local Boundary Commission. Alaska Department of Commerce, Community and Economic Development, Division of Community and Regional Affairs. Community Transportation Overview. See the State of Alaska Open Data Geoportal: https://gis.data.alaska.gov/datasets/4cbaa40cacfc48ec902ad52095fc370b_0/about.

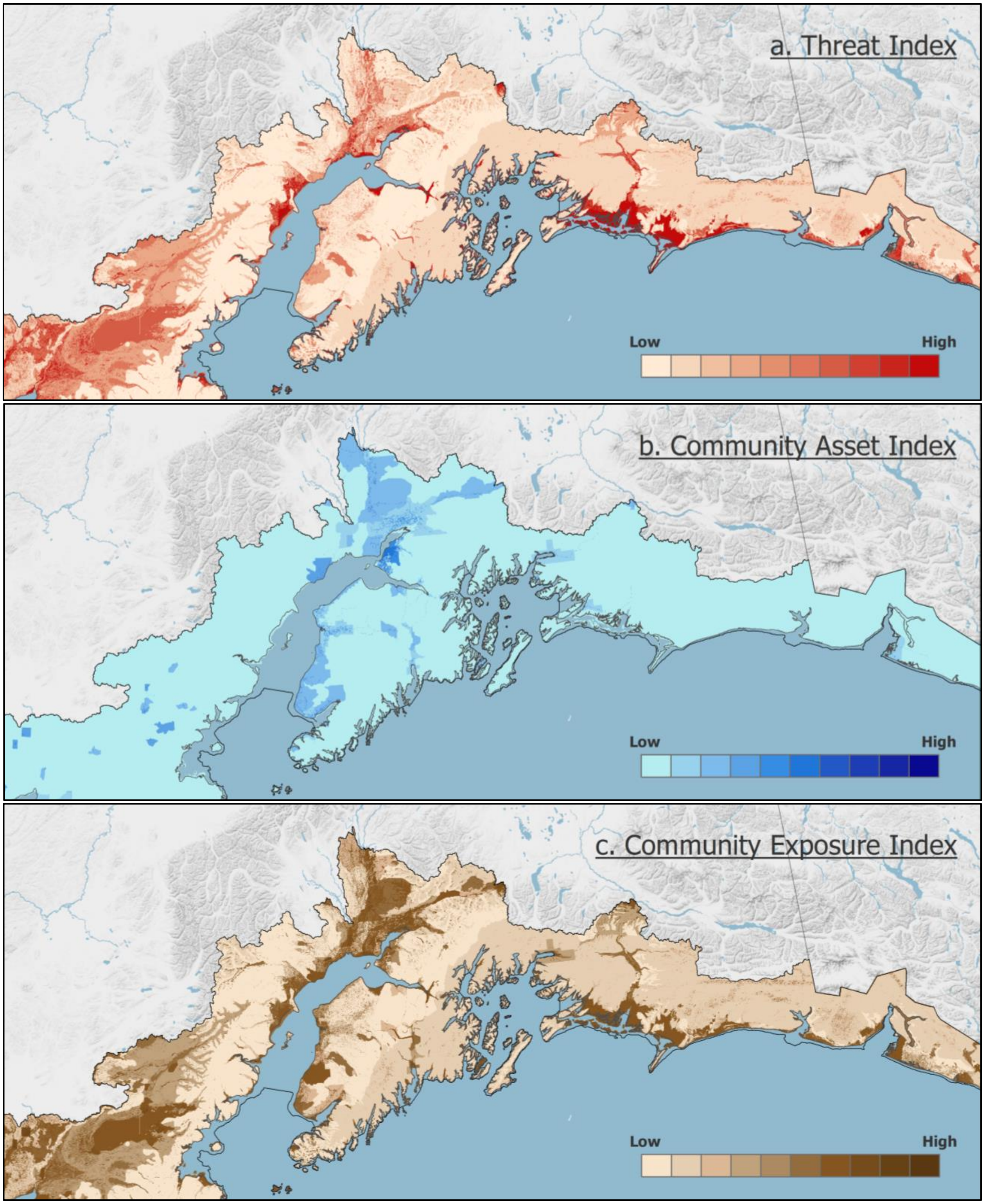

Figure 10. (a) Threat Index, (b) Community Asset Index, and (c) Community Exposure Index values for Southcentral Alaska. To view results in detail, see CREST.

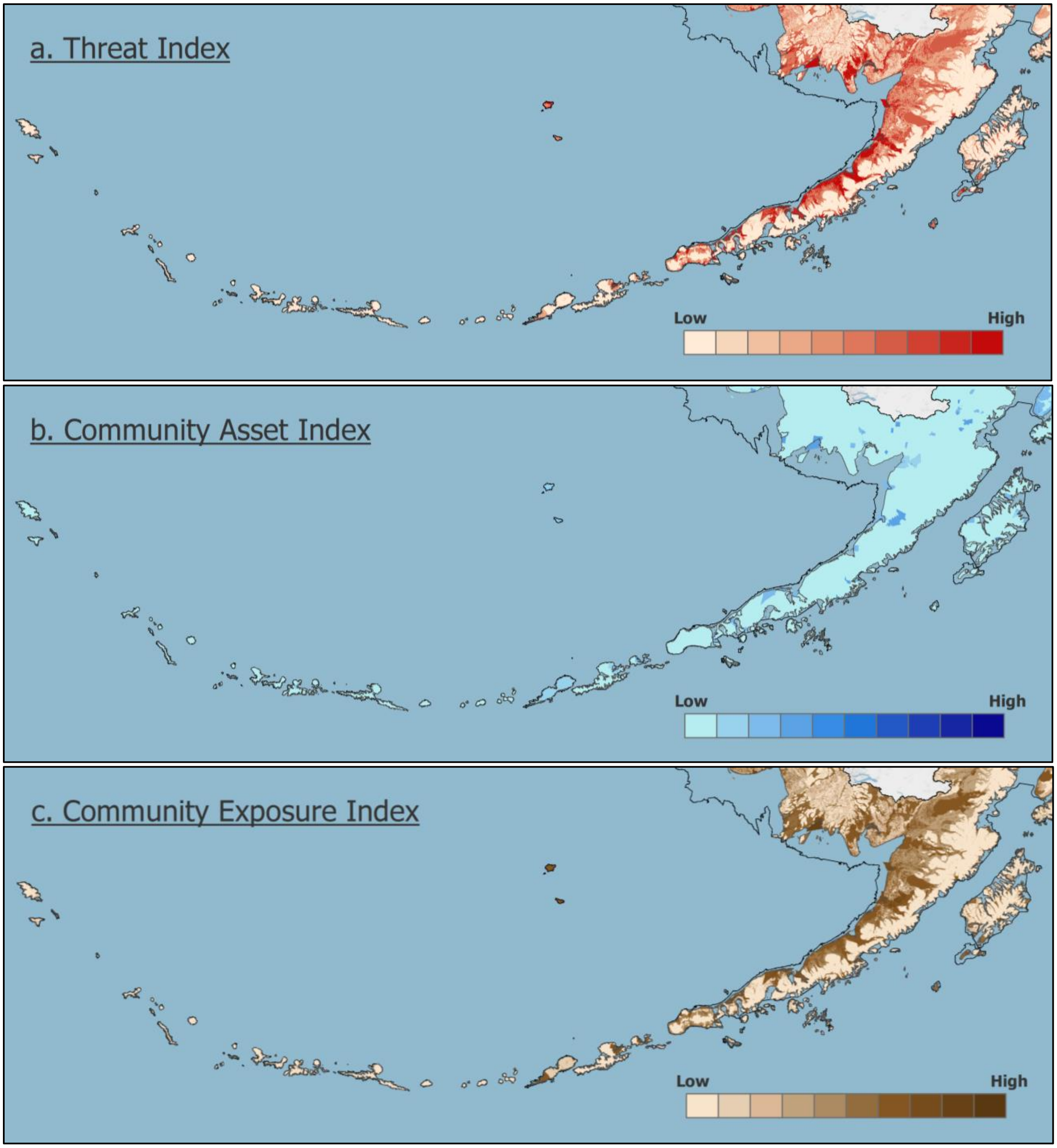

Figure 11. (a) Threat Index, (b) Community Asset Index, and (c) Community Exposure Index values for Southwestern Alaska. To view results in detail, see CREST.

In stark contrast to the other regions, Western and Northern Alaska feature many of the highest Community Exposure Index values (Figures 12 and 13). In fact, 71 percent of the highest-ranking exposure values across the entire study area occur in extensive low-lying wetlands and arctic tundra found in Western and Northern Alaska. The results of the Alaska Assessment relied heavily on estimates of flooding, erosion, and permafrost degradation affecting rural Alaska communities (UAF 2019). The highest Threat Index values identified in this Assessment occur within community footprint boundaries that were classified as highly imperiled across one or a combination of these threats (UAF 2019). The

Community Asset Index further highlights the dozens of remote communities throughout this region, all featuring vitally important community assets including schools, emergency services, airports, wastewater treatment facilities, bulk fuel storage, and other critical resources. Communities such as Shaktoolik, Shishmaref, and Golovin received the highest possible exposure values, highlighting the significant and imminent threats Alaska's rural communities face. Of note, St. Lawrence and Nunivak Islands feature high exposure values over the entire land area, owing to their large community footprints; by zooming into the villages of Savoonga, Gambell, and Mekoryuk, individual community assets become visible (Figure 12). Along the North Slope, the highest exposure values are evident in Wainwright, Utqiaġvik, Nuiqsut, and along the Dalton Highway (Figure 13). In contrast, exposure values decrease in the western section of the Noatak National Preserve and along the northern flank of the Brooks Range east to the Canadian border.

To explore the results of the analysis in more detail for any area of interest throughout the study area, visit the Coastal Resilience Evaluation and Siting Tool (CREST) at resilientcoasts.org. For more details about CREST, please refer to [Section 3.4] below.

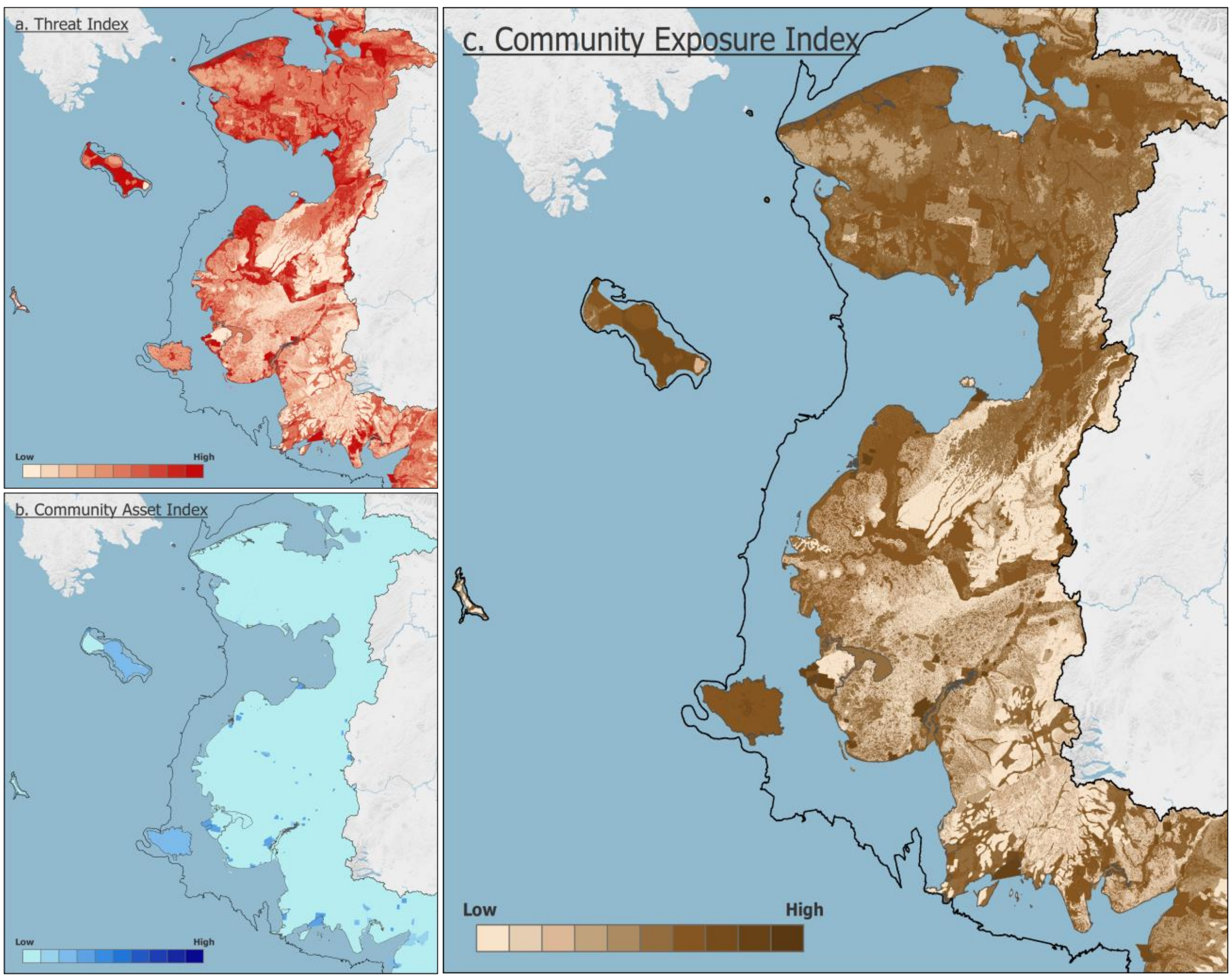

Figure 12. (a) Threat Index, (b) Community Asset Index, and (c) Community Exposure Index values for Western Alaska. To view results in detail, see [CREST].

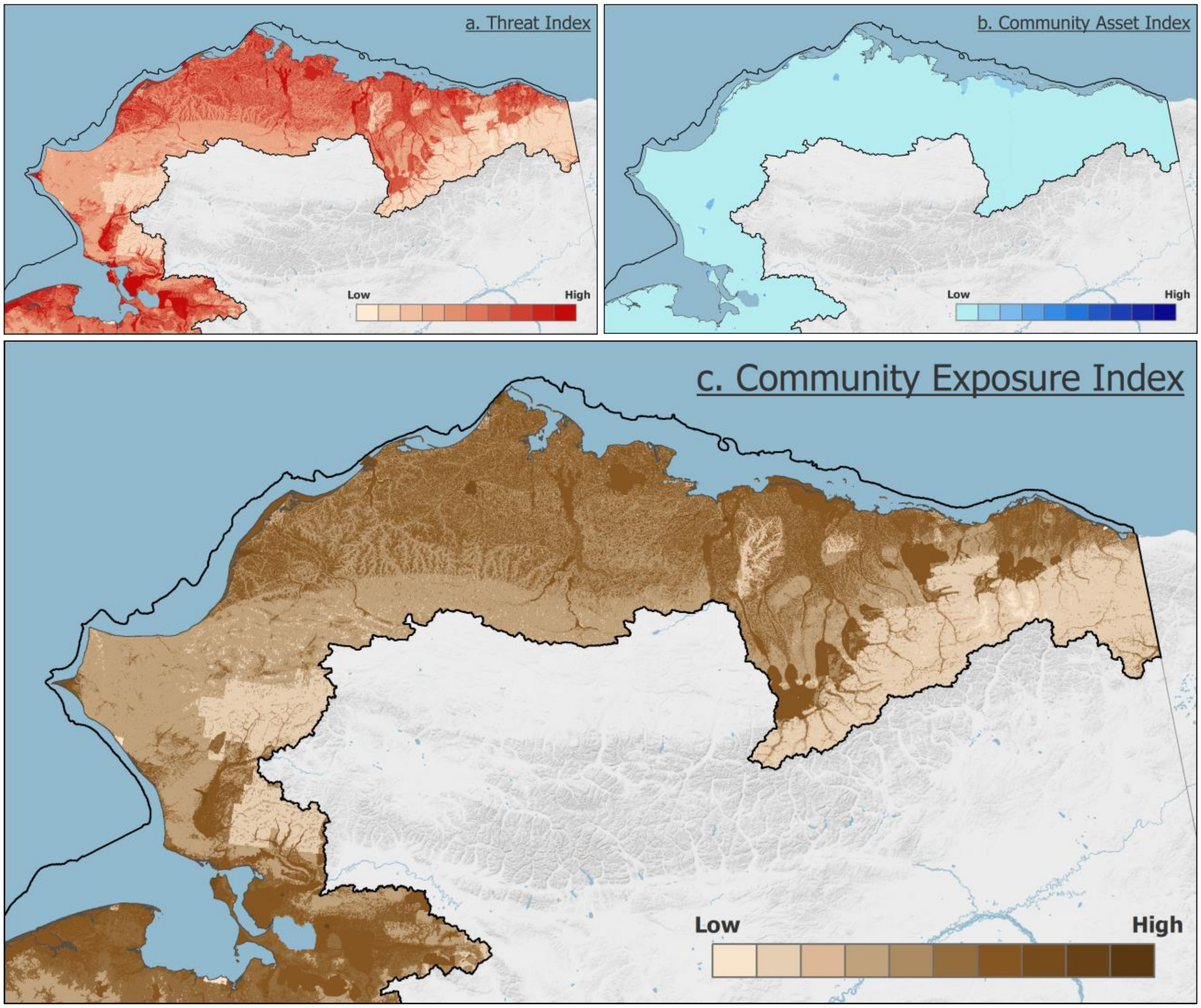

Figure 13. (a) Threat Index, (b) Community Asset Index, and (c) Community Exposure Index values for Northern Alaska. To view results in detail, see CREST.

3.2 Fish and Wildlife Index

Alaska boasts diverse and robust fish and wildlife populations owing to large tracts of intact habitat that spans over 32 distinct ecoregions. Throughout coastal Alaska, habitat types vary considerably, contributing to significant variation in species richness. The Fish and Wildlife Index reveals particularly high values within productive nearshore marine waters, along large river deltas, and within extensive coastal wetland and estuarine systems (Figure 14c). The results from the Fish and Wildlife Index focus on terrestrial, aquatic, and marine species of conservation concern as identified by the Alaska State Wildlife Action Plan (ADFG 2015) and the U.S. Endangered Species Act. Federally managed fish species with designated Essential Fish Habitat and important subsistence resources vital for many residents and Alaska Native communities are also considered. (See Appendix F.1 and Appendix F.3 for a full list of all species included in the Fish and Wildlife Index.) By assessing habitat preferences across various taxonomic groups, the resulting Terrestrial Index (Figure 14a) and Aquatic Index (Figure 14b) each identify areas expected to support numerous species, with the highest values (represented by darker shades) representing the highest relative species richness.

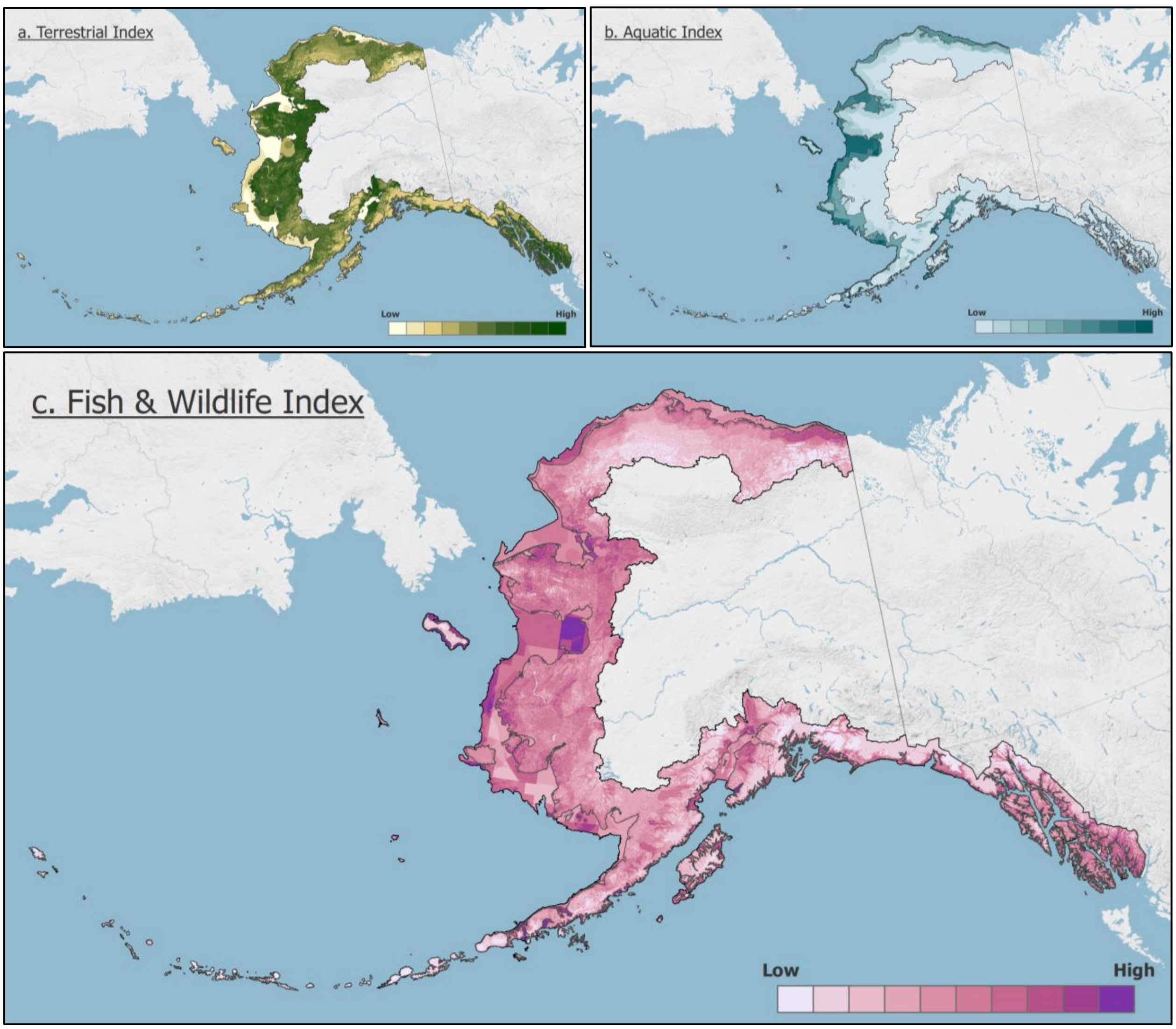

Figure 14. (a) Terrestrial Index, (b) Aquatic Index, and (c) Fish and Wildlife Index values for the Alaska Coastal Resilience Assessment study area. The Terrestrial and Aquatic Indices are summed to create the Fish and Wildlife Index. To view results in detail, see CREST.

Due to the variation in habitats and biodiversity among and within ecoregions (ADFG 2015), there is significant variation in Fish and Wildlife Index values across the study area. In the temperate rainforests and high-altitude mountains of Southeastern Alaska, moderate to high Fish and Wildlife Index values are particularly evident along coastal lowlands, estuaries, and broad river deltas (Figure 15). Terrestrial Index values in this region are bolstered by relatively high richness among terrestrial mammals, such as numerous furbearers and large predators, and several species of amphibians not found in other parts of the state (Figure 15a). In addition, several small Important Bird Areas found throughout Southeast Alaska highlight the global importance of this region for many species of birds, including marbled murrelet (*Brachyramphus marmoratus*). The Aquatic Index identifies the numerous rivers that cut through the region supporting spawning runs of all five species of Pacific salmon (*Oncorhynchus spp.)* and eulachon (*Thaleichthys pacificus)*, all of which provide food for myriad species (Figure 3.8). Nearshore marine habitat also supports marine mammals, including sea otters (*Enhydra lutris kenyoni*) that utilize giant kelp *(Macrocystis pyrifera)* forests and Steller sea lions (*Eumetopias jubatus*) whose rookery on Forrester Island is one of the largest in Alaska.

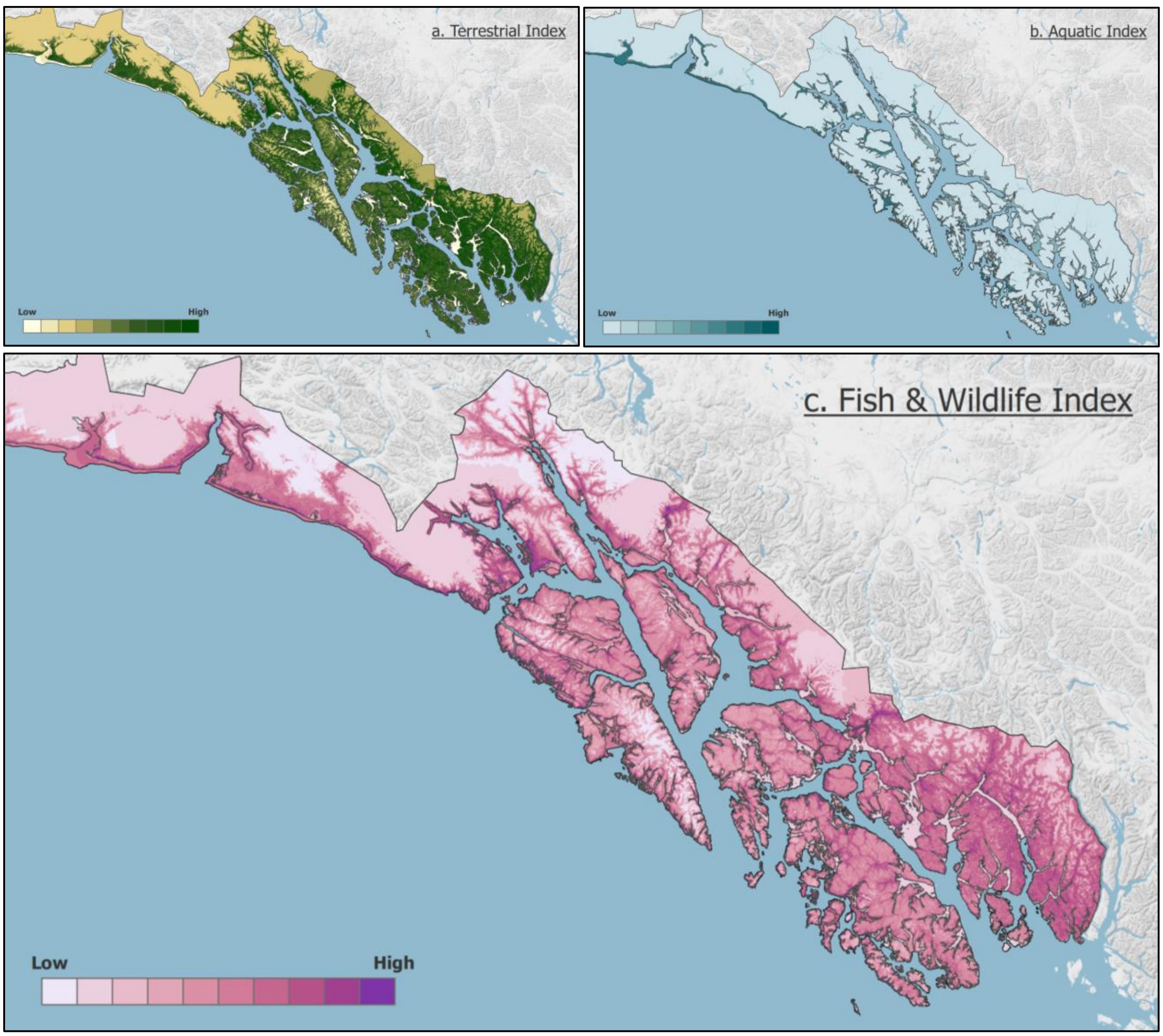

Figure 15. (a) Terrestrial Index, (b) Aquatic Index, and (c) Fish and Wildlife Index values for Southeastern Alaska. To view results in detail, see CREST.

In Southeastern and Southcentral Alaska, the rugged Chugach and St. Elias Mountains feature relatively low diversity and thus very low Fish & Wildlife values (Figures 15 and 16). While relatively few species included in the model occur in this region, mountain goats (*Oreamnos americanus)*, Dall sheep (*Ovis dalli)*, hoary marmots (*Marmota caligata)*, and ptarmigans populate the alpine tundra, and rivers and streams support Dolly Varden (*Salvelinus malma)*, Pacific salmon, and steelhead trout (*Oncorhynchus mykiss)*.

Along the coastal Gulf of Alaska and east of Prince William Sound, the broad coastal plains and large river deltas reveal very high Fish and Wildlife values. For instance, the Copper River Delta serves as important stopover, nesting, and feeding habitat for migratory shorebirds resulting in high values in the Terrestrial Index (Figure 16a). Nearshore marine waters support abundant forage fishes, large steelhead trout runs occur in the Situk and Copper Rivers, and Steller sea lions and Pacific harbor seals (*Phoca vitulina richardii*) use haul out areas along the rocky shorelines, all producing high Aquatic Index scores over much of coastal Gulf of Alaska (Figure 16b).

Relatively high values are also seen along the Cook Inlet Basin (Figure 16). While this area is one of the most developed in the state, the numerous small lakes, swamps, bogs, large rivers, and the productive waters of Cook Inlet, all attract shorebirds and waterfowl, large terrestrial mammals, myriad anadromous and resident fishes, and marine mammals, including the endangered beluga whale (*Delphinapterus leucas*) Cook Inlet Distinct Population Segment.

Kodiak Island and the Gulf coast of the Alaska Peninsula both include high, steep mountain ridges that give way to deeply cut fjords. High valley lakes and glacially fed streams on Kodiak Island support abundant salmon runs that feed robust populations of Kodiak brown bear (*Ursus arctos middendorffi)*. Visible in the Fish and Wildlife Index (Figure 17), the island's coastal cliffs support large seabird colonies of puffins, auklets, and black-legged kittiwake (*Rissa tridactyla*), among others.

Along the Alaska Peninsula, the Terrestrial Index highlights the importance of the coastal wetlands, lagoons, and protected bays for seasonal waterfowl and large shorebird aggregations (Figure 17a). For instance, Izembek and Moffet Lagoons on the Bering Sea side of the Peninsula host more than 500,000 shorebirds each spring including marbled godwit (*Limosa fedoa beringea*) and rock sandpiper (*Calidris ptilocnemis*). Izembek Lagoon also features one of the largest eelgrass beds in the world that together with large intertidal and subtidal kelp forests on the Gulf coast, provide important habitat for myriad marine species (ADFG 2015).

Throughout the Peninsula and Aleutian Islands, the Aquatic Index (Figure 17b) reveals high values within nearshore marine waters, which provide summer feeding grounds for whales, while coastlines offer rookeries and haul out areas for Steller sea lion and Pacific harbor seal. Evident in the Terrestrial Index, the high cliffs and boulder beaches of the Aleutian chain harbor globally significant seabird colonies including red-faced cormorant (*Phalacrocorax urile*) and fork-tailed storm petrel (*Hydrobates furcatus*). The peninsula and islands also provide wintering habitat for threatened Steller's eider (*Polysticta stelleri*) and the endemic Aleutian song sparrow (*Melospiza melodia sanaka*).

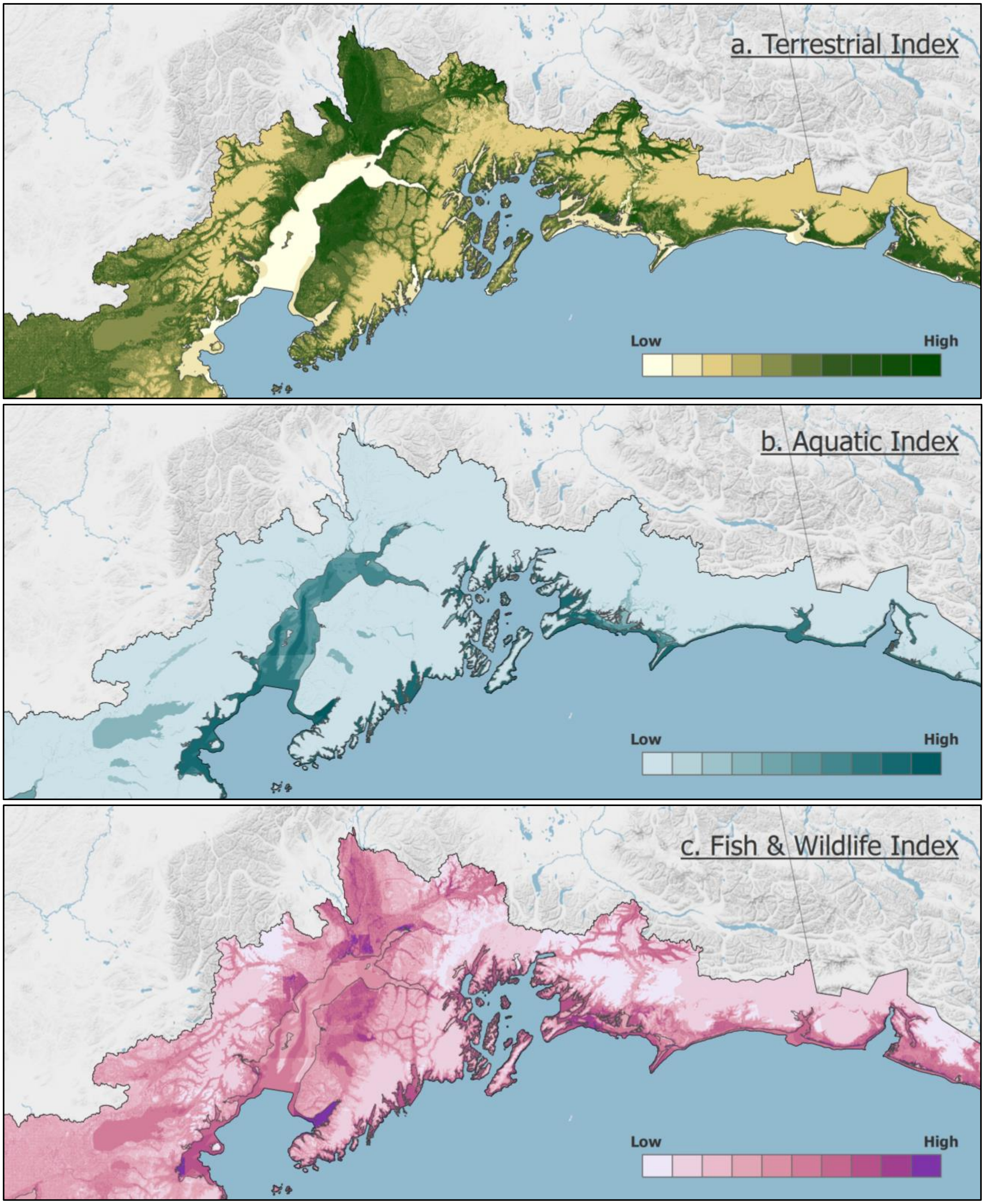

Figure 16. (a) Terrestrial Index, (b) Aquatic Index, and (c) Fish and Wildlife Index values for Southcentral Alaska. To view results in detail, see CREST.

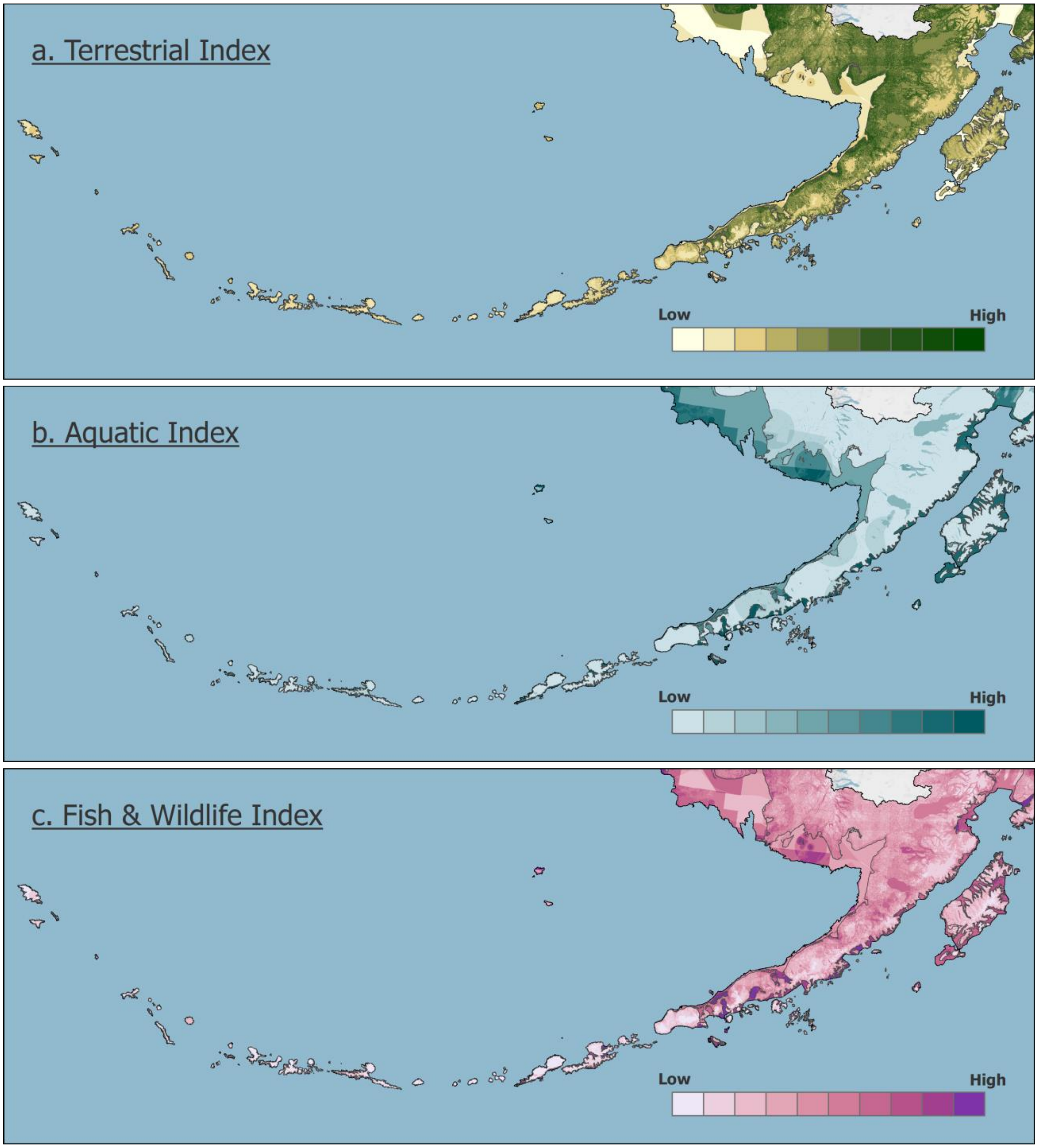

Figure 17. (a) Terrestrial Index, (b) Aquatic Index, and (c) Fish and Wildlife Index values for Southwestern Alaska. To view results in detail, see CREST.

The subarctic tundra dominating Western Alaska features some of the highest Fish and Wildlife Index values across the entire study area (Figure 18). High values are particularly evident in the coastal and nearshore marine areas where important habitat for marine mammals and Essential Fish Habitat for groundfishes, crabs, and Pacific salmon species overlap with large Important Bird Areas and high species richness among seabirds, shorebirds, and waterbirds. Inland, many of the highest Fish and Wildlife values occur over coastal lowland habitat and along river valleys. Moose *(Alces americanus*), caribou (*Rangifer tarandus*), brown bear *(Ursus arctos*), wolverine *(Gulo gulo*), arctic fox (*Vulpes lagopus*), and other land mammals are found throughout much of Western Alaska, contributing to high Terrestrial Index values (Figure 18a). Extensive wetlands, lakes, and ponds also contribute to higher values due to large waterfowl populations, including globally significant populations of black brant (*Branta bernicla nigricans*) along the Yukon-Kuskokwim Delta. Similarly, a wide range of shorebirds utilize coastal littoral and wetland areas during spring and fall migrations. Moderately high Fish and Wildlife values are also present in the Bering Sea islands, including St. Lawrence, St. Matthew, and the Pribilof Islands, all of which contain Important Bird Areas and large seabird breeding colonies.

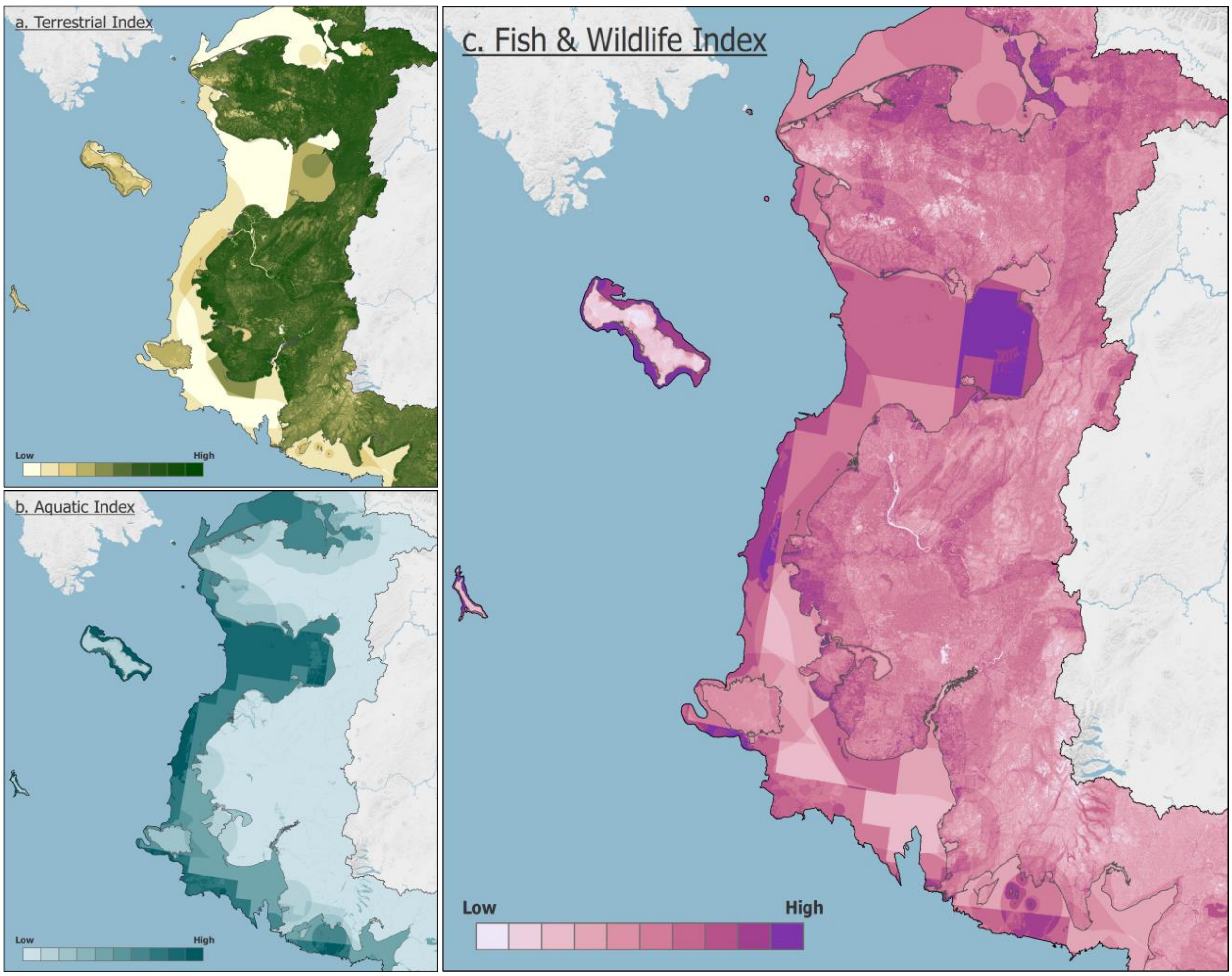

Figure 18. (a) Terrestrial Index, (b) Aquatic Index, and (c) Fish and Wildlife Index values for Western Alaska. To view results in detail, see [*CREST*](CREST)*.*

High Aquatic Index values are also visible throughout much of Western Alaska (Figure 18b). Numerous species of marine mammals utilize nearshore and coastal habitat for feeding and breeding, including beluga, gray, and minke whales that can be found from Bristol Bay to the northern Seward Peninsula. Walruses (*Odobenus rosmarus*), Steller sea lions, polar bears (*Ursus maritimus*), and numerous seal species are found near the coast and along adjacent ice floes. Important pinniped breeding habitat and haul out areas are located throughout the region including the Walrus Islands State Game Sanctuary in northern Bristol Bay and the Pribilof Islands, which provide critical habitat for Steller sea lion and approximately 80 percent of the world's northern fur seal (*Callorhinus ursinus*) population. Anadromous and resident freshwater fishes are also abundant throughout Western Alaska and visible in the Aquatic Index. All five Pacific salmon species are present in the region's many large streams and rivers including significant runs of sockeye (*Oncorhynchus nerka*) in the Kvichak River and chinook (*O. tshawytscha*) in the Nushagak River. Arctic grayling (*Thymallus arcticus*), arctic char (*Salvelinus alpinus*), Dolly Varden, northern pike (*Esox Lusius*), whitefishes, Alaska blackfish (*Dallia pectoralis*), Bering cisco (*Coregonus laurettae*), and other fishes are also prevalent through the region.

Northern Alaska's polar arctic tundra is characterized by a treeless, windswept landscape replete with numerous lakes, wetlands, permafrost-related features, and large rivers winding through the wide coastal plain. The Fish and Wildlife Index (Figure 19) reveals the highest scores along the low-lying coastal plain, which provides nesting habitat for the threatened spectacled eider (*Polysticta stelleri*) and other waterfowl. Over two dozen species of shorebirds utilize breeding habitat including a large proportion of the U.S. breeding populations of long-billed dowitcher (*Limnodromus scolopaceus*), dunlin (*Calidris alpina*), and several sandpiper species. The region is also important for four distinct caribou herds, muskoxen (*Ovibos moschatus*), arctic fox, polar bears, and other land mammals. Moving inland, Fish and Wildlife Index values drop into the Brooks Foothills, but the Aquatic Index still identifies large rivers, streams, and ponds important for arctic char, lake trout (*Salvelinus namaycush*), and Dolly Varden as well as Pacific salmon in the rivers draining into the Chukchi Sea.

To explore the results of the analysis in more detail for any area of interest throughout the study area, visit the Coastal Resilience Evaluation and Siting Tool (CREST) at resilientcoasts.org. For more details about CREST, please refer to Section 3.4 below.

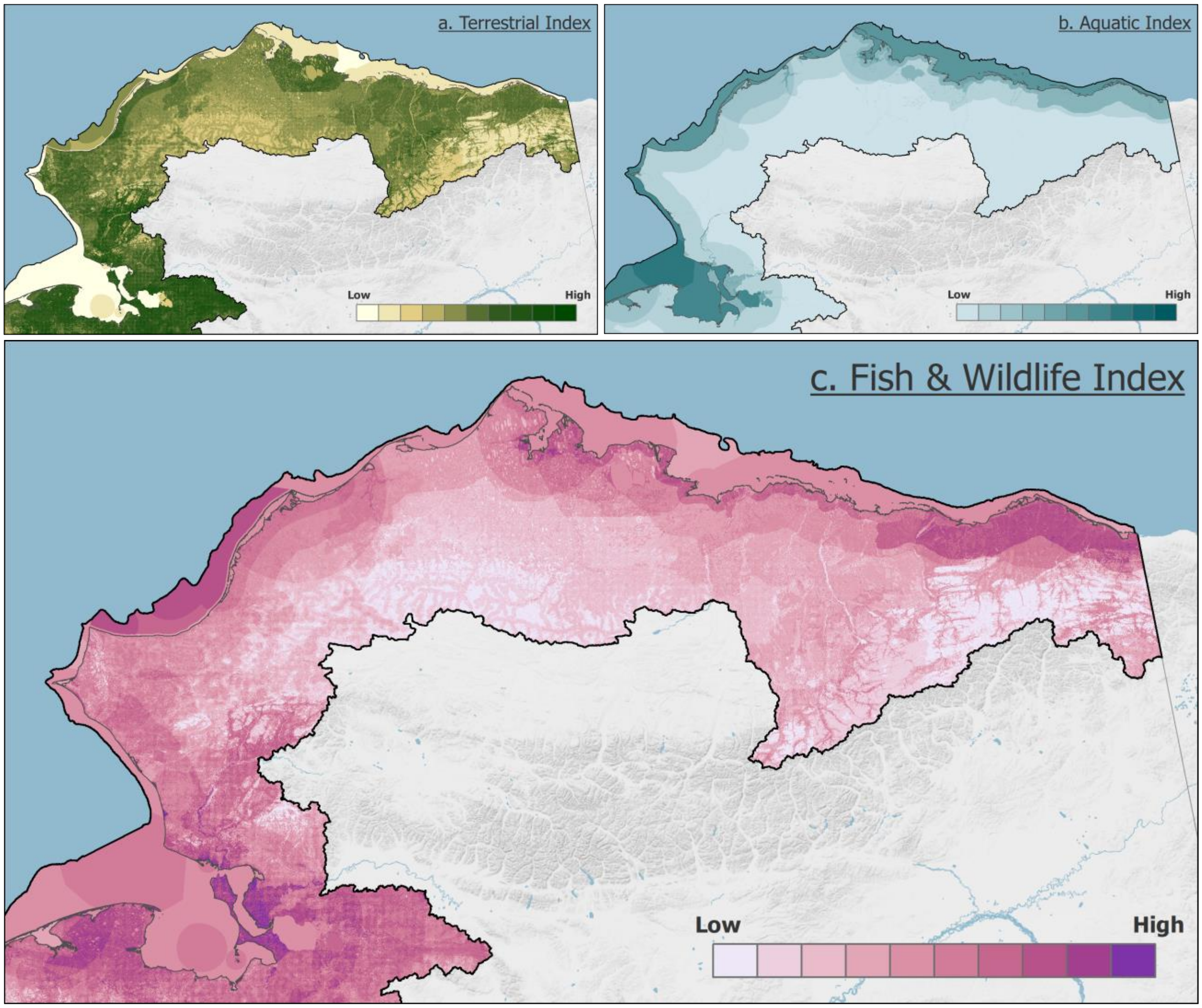

Figure 19. (a) Terrestrial Index, (b) Aquatic Index, and (c) Fish and Wildlife Index values for Northern Alaska. To view results in detail, see CREST.

3.3 Resilience Hubs

The Alaska Assessment identified many Resilience Hubs throughout the state. While Western and Northern Alaska feature many of the highest-ranking Resilience Hubs, the Assessment revealed ample opportunities throughout the study area to implement nature-based solutions that may help build human community resilience while also benefiting fish and wildlife habitat and the species and ecosystem services they support.

The final Resilience Hub rankings identify areas of contiguous open space that are of a sufficient size to provide fish and wildlife and flood risk reduction benefits. As described in the Methods section above, the boundaries of the Resilience Hubs are formed through a Green Infrastructure analysis, which identifies Habitat Cores at least 4 hectares (10 acres) in size. Once the boundaries of the Habitat Cores are determined, a single average rank is applied based on the product of the Community Exposure and Fish and Wildlife Index values. To see additional detail, results are also presented as a Resilience Hub Grid, where Habitat Cores are converted into 4-hectare (10-acre) hexagons. Each hexagon also receives a single average rank based on the Community Exposure and Fish and Wildlife Index values.

Resilience Hub results are presented as both coarse-scale Resilience Hub Cores and a fine-scale Resilience Hub Grid. When viewing the Resilience Hub Cores, large tracts of contiguous open space are helpful to identify connected landscapes, but because each Core receives a single average rank, it can obscure variation within the Core. Therefore, the Resilience Hub Grid is helpful to visualize variation, where the highest-ranking hexagons will occur in those areas in closest proximity to human community assets exposed to flooding threats. In all cases, only the highest-ranking Resilience Hubs represent areas with the greatest potential to implement nature-based solutions capable of achieving dual benefits.

Due to the large scale of the Alaska Assessment, differences between the Resilience Hub Cores and Grid are not easily distinguishable at a state or even regional level. Therefore, readers are encouraged to view the results in more detail for any area of interest by visiting the Coastal Resilience Evaluation and Siting Tool (CREST) at resilientcoasts.org. For more details about CREST, please refer to Section 3.4 below. As an example of the distinction between the Resilience Hub Cores and Grid, Figure 20 zooms into the communities along the Kuskokwim River to provide a side-by-side comparison. The Resilience Hub Cores help to visualize connected watersheds and contiguous habitat; however, the rankings are based on the average values assigning a single score regardless of the size or features within the Core (Figure 20a). By viewing the Resilience Hub Grid, the variation within a given Core becomes visible (Figure 20b). For the purposes of this report, the regional results are shown through the Resilience Hub Grid only (Figure 21).

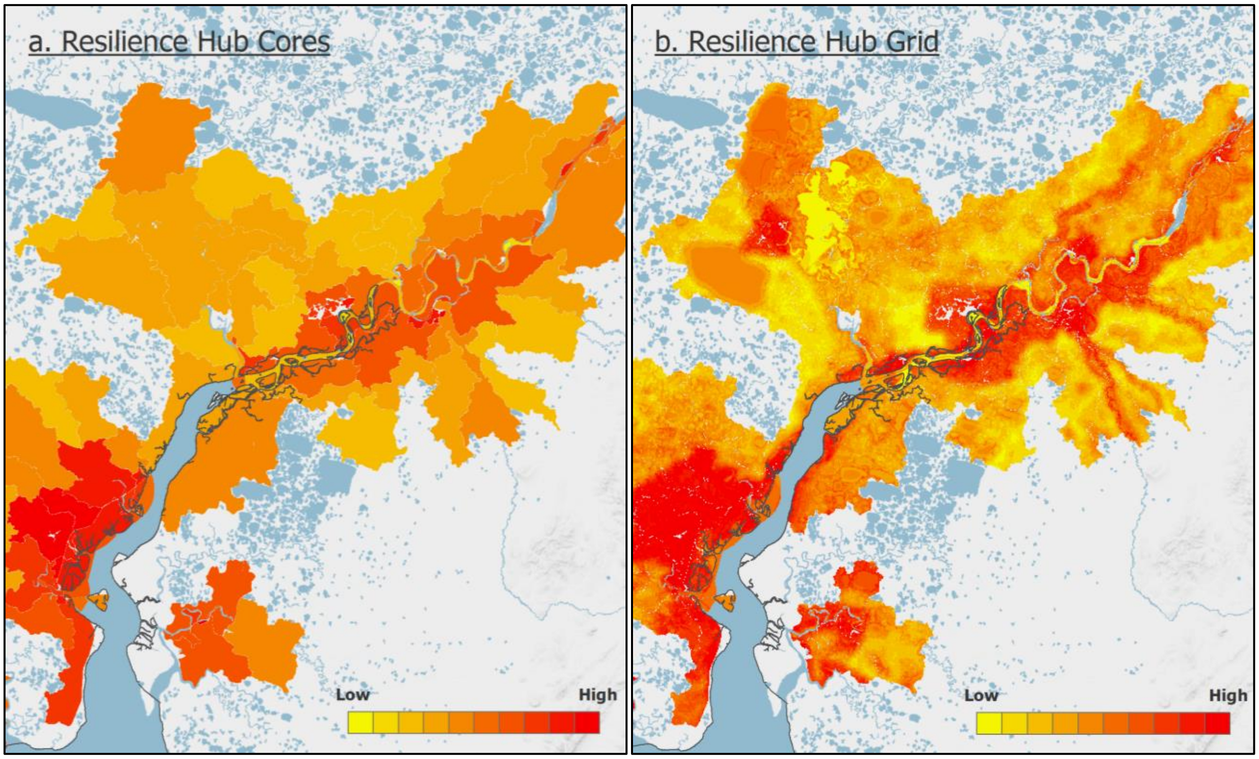

Figure 20. (a) Resilience Hub Cores and (b) Resilience Hub Grid along the Kuskokwim River. When viewed at this scale, the difference between the Cores and Grid become apparent. To view results in detail for other communities, see CREST.

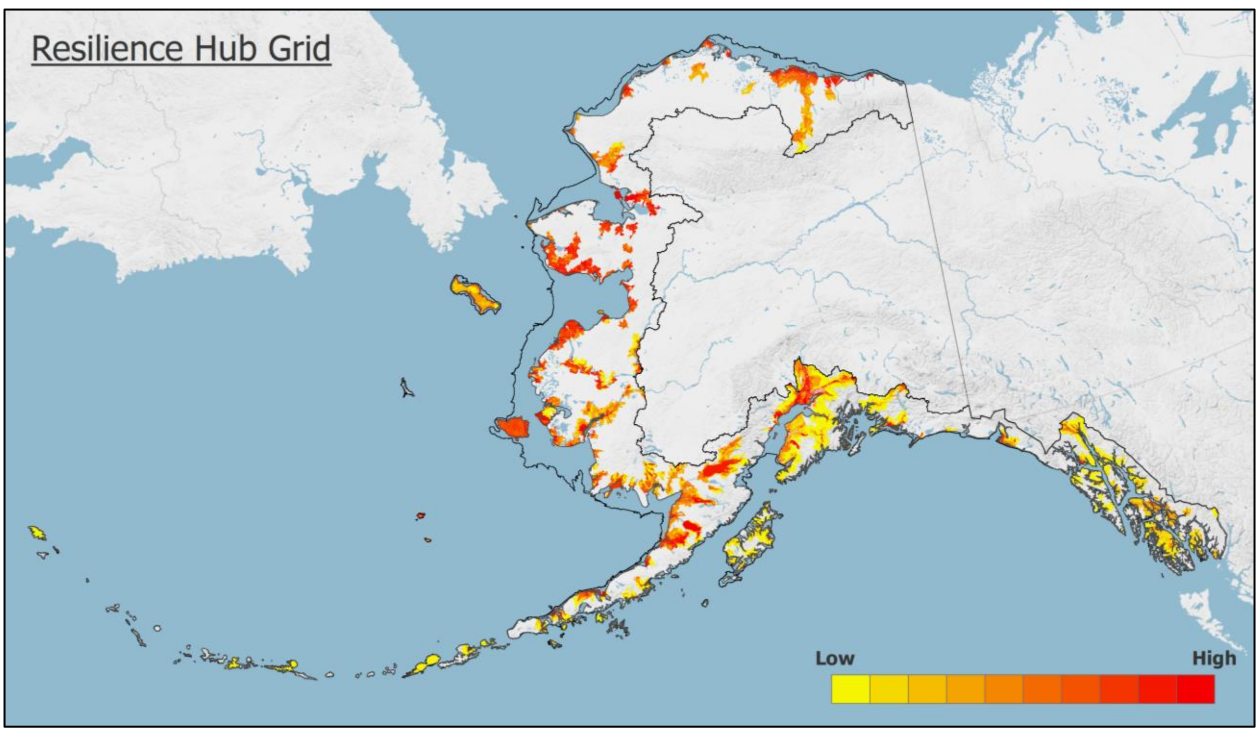

Figure 21. Resilience Hub Grid for the Alaska Coastal Resilience Assessment study area. High ranking Resilience Hubs (darker reds) represent areas well suited for the implementation of nature-based solutions that may benefit both species of conservation concern and human community resilience to flooding threats. To view results in detail, see CREST.

The analysis revealed large differences in the Resilience Hub rankings between regions. For instance, in Southeast and Southcentral Alaska the highest-ranking Resilience Hubs occur within and around the most populated areas in the state such as Anchorage, Wasilla, Homer, Yakutat, Juneau, Wrangell, and Cordova (Figures 22 and 23). This is driven by a combination of moderate Fish and Wildlife values in areas of open space near developed areas. Even within downtown Anchorage where there are relatively few large areas of open space, high ranking Resilience Hubs reveal opportunities for stormwater management, riparian restoration, and other types of projects well suited for urban environments. However, Resilience Hub rankings quickly decrease outside of developed areas, where many very low values are visible. The steep terrain found over much of Southeastern and Southcentral Alaska quickly dampens impact from coastal flooding threats and thus reduces Resilience Hub values, suggesting these alpine environments are poorly suited to nature-based solutions to address flooding threats.

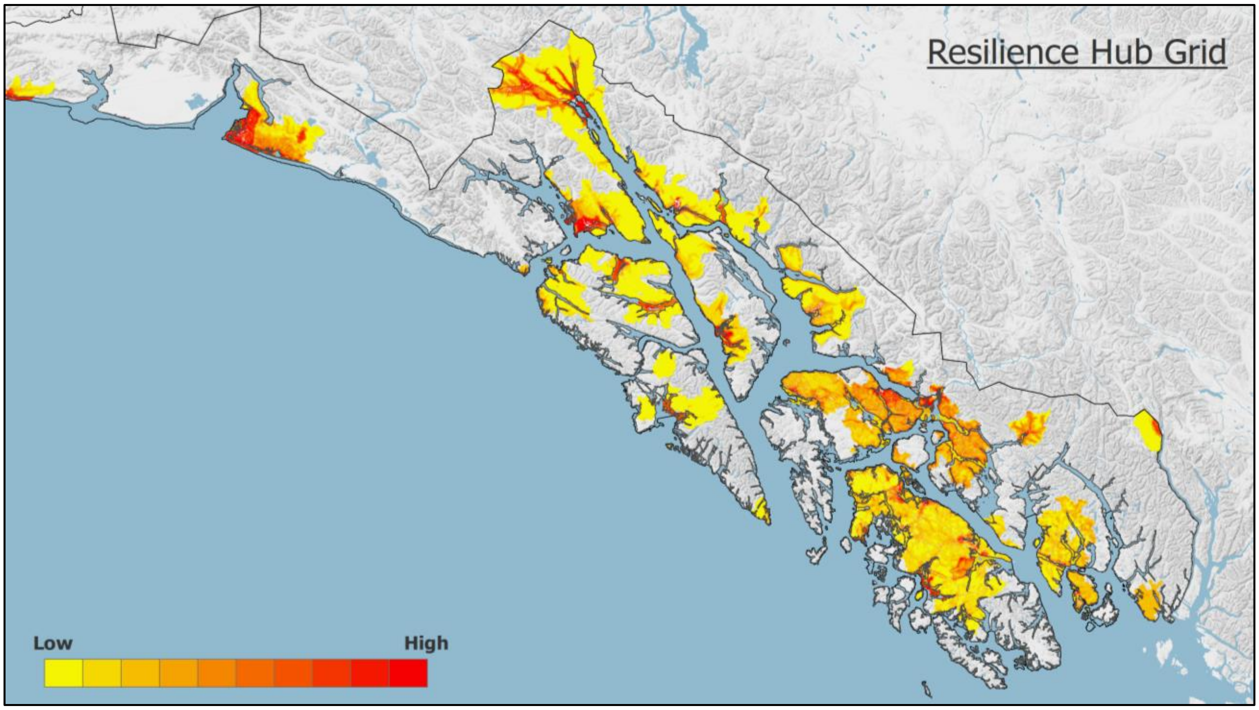

Figure 22. Resilience Hub Grid for Southeastern Alaska. To view results in detail, see CREST.

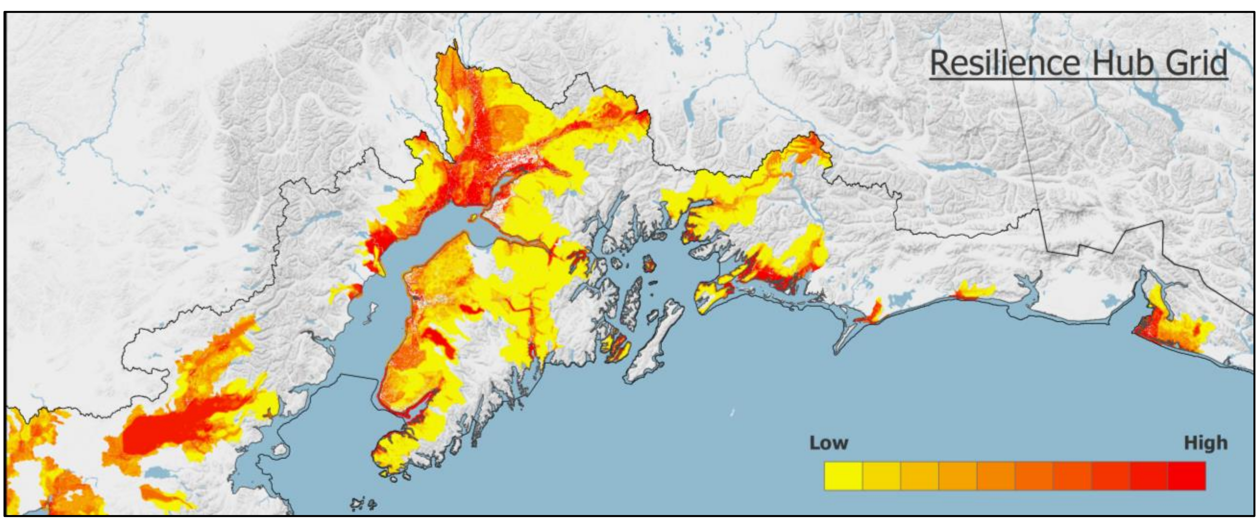

Figure 23. Resilience Hub Grid for Southcentral Alaska. To view results in detail, see CREST.

In Southwestern Alaska, the highest-ranking Resilience Hubs occur along Kodiak Island and the Alaska Peninsula (Figure 24). This is particularly evident along the northern margin of the Peninsula where rural communities along Bristol Bay are highly exposed to flooding threats. The numerous bays and rivers provide excellent fish and wildlife habitat and offer ample conservation opportunities to benefit Ugashik, Egegik, Port Heiden, and other exposed communities. Habitat Cores here are also somewhat smaller, though there are still some large Cores. Community Exposure values are also higher here than in other parts of Southwestern Alaska, though Fish and Wildlife values are primarily the highest directly along the coast. These patterns validate those seen in the Resilience Hubs. On the southern margin of the Alaska Peninsula and throughout the Aleutian Islands, Resilience Hub rankings are relatively low due to a combination of low community asset density and moderate Fish and Wildlife Index values. However, higher-ranked Hubs around Unalaska, Umnak, Shemya, St. George, and St. Paul Islands reveal potential opportunities for nature-based resilience building projects.

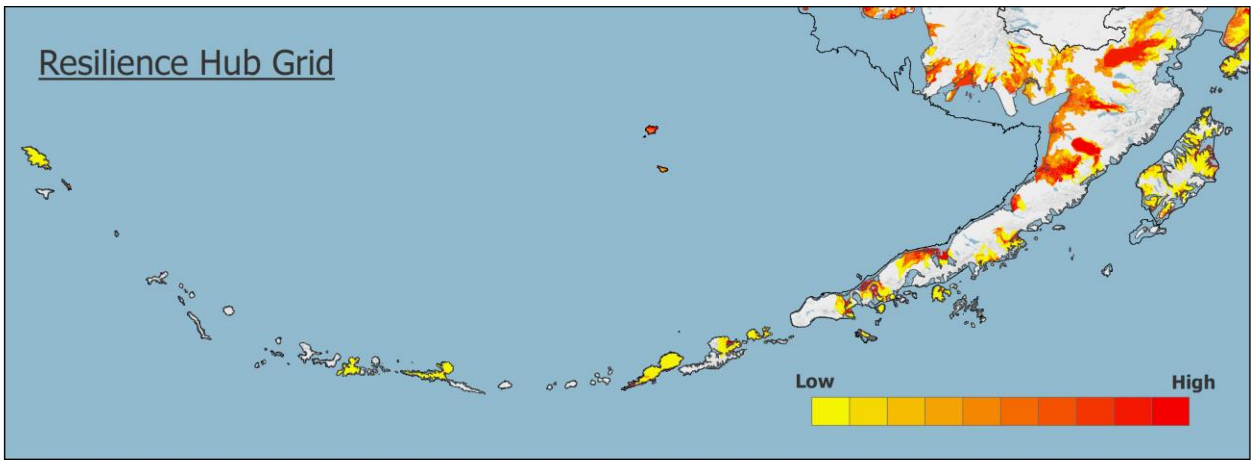

Figure 24. Resilience Hub Grid for Southwestern Alaska. To view results in detail, see CREST.

Across the entire study area, Western and Northern Alaska contain the highest density of highly ranked Resilience Hubs (Figures 25 and 26). Flooding threats extend well inland over extensive low-lying coastal wetland and arctic tundra, leaving many rural Alaska communities exposed to severe and imminent climate-driven flooding hazards (UAF 2019). Rural communities are surrounded by large expanses of undeveloped open space that not only provide important habitat for many species of conservation concern and subsistence use, but also provide opportunities for conservation actions that may help build community resilience. Along the coast, highly exposed communities such as Hooper Bay, Shaktoolik, Nome, Point Hope, Utqiaġvik, and many others are adjacent to, and in some cases surrounded by high-ranked Resilience Hubs. Also, values are typically lower among inland communities, large rivers reveal high Resilience Hub values far inland surrounding communities such as Bethel, Napakiak, and Kwethluk along the Kuskokwim River and Mountain Village and Saint Mary's along the Yukon River. As noted previously, St. Lawrence and Nunivak Islands feature very high Resilience Hub values over nearly the entire land area, owing to their large community footprints[16].

[16] Community footprints represent boundaries for incorporated cities, Census Designated Places, and Census Blocks according to the Local Boundary Commission. Alaska Department of Commerce, Community and Economic Development, Division of Community and Regional Affairs. Community Transportation Overview. See the State of Alaska Open Data Geoportal: https://gis.data.alaska.gov/datasets/4cbaa40cacfc48ec902ad52095fc370b_0/about.

To explore the results of the analysis in more detail for any area of interest throughout the study area, visit the Coastal Resilience Evaluation and Siting Tool (CREST) at resilientcoasts.org. For more details about CREST, please refer to Section 3.4 below.

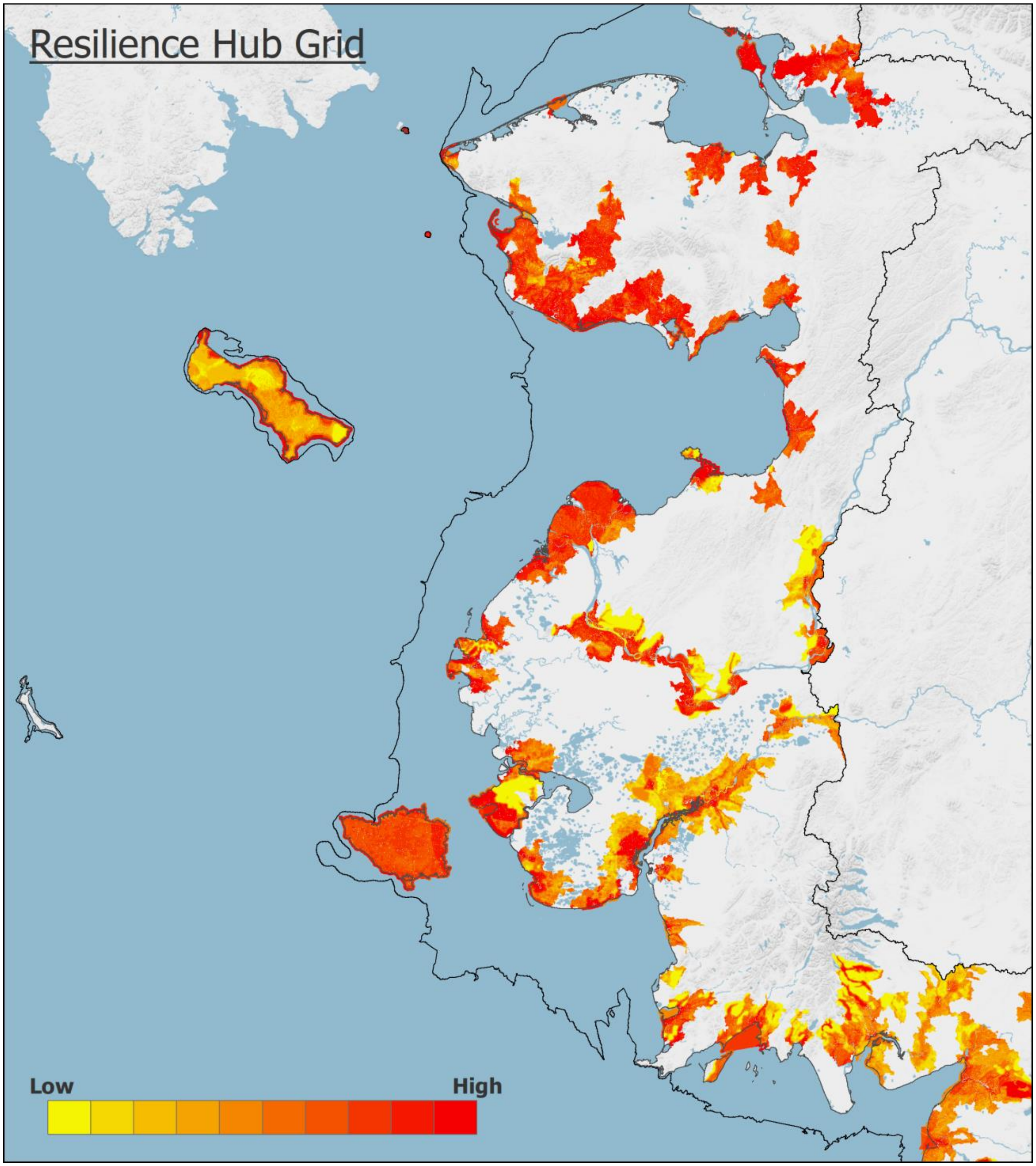

Figure 25. Resilience Hub Grid for Western Alaska. To view results in detail, see CREST.

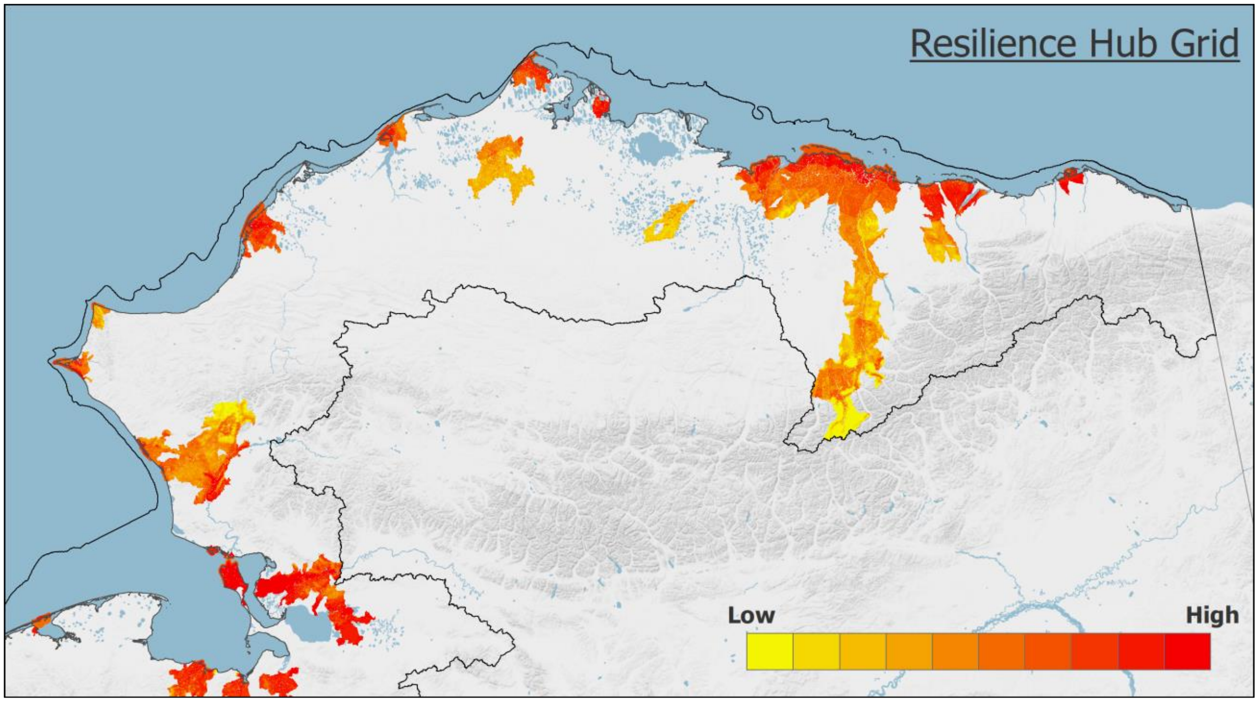

Figure 26. Resilience Hub Grid for Northern Alaska. To view results in detail, see CREST.

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 Alaska 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 Alaska 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. As with all GIS analyses, site-level assessments are required to validate results and develop detailed design and engineering plans.

CASE STUDIES

Communities throughout Alaska face significant and imminent threats due to climate change. Recent studies suggest at least 144 communities throughout Alaska are threatened by erosion, flooding, permafrost degradation, or a combination of all three (UAF 2019). Communities need a wide range of strategies and solutions to protect their residents against more frequent and severe coastal flooding threats. Nature-based solutions offer one such strategy that can help communities utilize Alaska's abundant natural habitat to provide risk reduction benefits. Nature-based solutions are natural, engineered, and hybrid approaches that strategically protect, restore, sustainability manage, or mimic ecosystems to conserve or restore ecosystem functions and natural processes with the goal of reducing community exposure to natural hazards and climate stressors and enhancing habitat for fish and wildlife. For instance, efforts that work to restore coastal marshes, rebuild dunes or natural buffers, or installing living shorelines, among other approaches, all are strategies that reduce climate risks to communities while enhancing habitats. The Alaska Coastal Resilience Assessment aims to identify opportunities to implement nature-based solutions that not only provide habitat and wildlife benefits, but also help build community resilience to flooding threats and other coastal hazards. The following case studies describe several recent and ongoing projects throughout the state[17], using the Alaska Assessment to demonstrate how results can be used to identify potential locations to implement or help advance nature-based solutions.

4.1 Protecting Critical Human Community Assets in Shaktoolik

Shaktoolik is a remote Alaska Native village situated between Norton Sound and over 160,000 acres of low-lying coastal wetlands and arctic tundra. Located on a narrow sand and gravel spit, the village is imminently threatened by severe storm surges and wave-driven flooding, the effects of which are exacerbated by a loss of sea ice throughout Norton Sound. To the east, major precipitation events can cause the Shaktoolik and Tagoomenik Rivers to flood and temporarily disconnect the village from the mainland. The village's exposed coastline and cumulative flooding threats mean Shaktoolik is one of the most imperiled communities in Alaska (UAF 2019).

According to a 2019 survey completed by the Native Village of Shaktoolik, 45 percent of Shaktoolik's 260 residents have reported flooding and/or storm damage in the past five years. Recent community erosion and coastal flooding analyses by the U.S. Army Corps of Engineers revealed that numerous critical community assets are not only vulnerable to erosion (USACE 2009), but the entire community is at risk of flooding during a 100-year storm event (one percent return period) (USACE 2011).

For decades, the Native Village of Shaktoolik, the City of Shaktoolik, and the Shaktoolik Native Corporation have taken steps to help safeguard the community by constructing protective berms. One such berm, situated between the community and Norton Sound is designed to help protect against a 20-year storm event (five percent return period) (Figure 27). However, a lower magnitude winter storm in 2019 produced large waves that topped the berm and caused damage to critical infrastructure. Studies clearly demonstrate the current berm does not provide sufficient protection against large magnitude storms that are expected to increase in frequency under future climate scenarios.

[17] The case studies described in this report are meant to be illustrative and are not meant to highlight the types of projects that may be competitive for National Coastal Resilience Fund or National Fish and Wildlife Foundation funding.

Figure 27. Twenty-year berm adjacent to the Village of Shaktoolik before construction of the new berm. This location shows above-average vegetation cover. Photo Credit: Sophia Katchatag, Native Village of Shaktoolik.

In response, the Native Village of Shaktoolik and partners are increasing the width and height of the existing berm (Figure 28) to withstand maximum storm-surge water levels for a 50-year storm event (two percent return period). With funding from the National Coastal Resilience Fund[18] and other sources, the berm will be constructed using nature-based and locally sourced materials, offering a cost-effective and sustainable solution to enhance protection for the village. The Alaska Assessment reveals very high levels of exposure in Shaktoolik (Figure 29) driven by numerous and severe flooding and erosion-related threats to critical infrastructure assets (Figure 30). The berm will help protect exposed assets, including roads, the village school, and other critical infrastructure. Also at risk are the community’s water treatment plant, power plant, and fuel tank farm, which if flooded threaten public health and the release of contaminants. Traditional gray infrastructure such as a sea wall revetment was not feasible due to cost and long-term maintenance requirements and would not offer any habitat benefit. Working with a regional engineering firm, project-specific models indicate that a vegetated berm will offer sufficient protection during a 50-year storm event potentially saving $10-46 million in infrastructure replacement costs. In addition, and unlike traditional gray infrastructure, the natural berm can be constructed and maintained by Shaktoolik residents, supporting community engagement and local jobs.

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

Figure 28. Map showing the approximate location of the Shaktoolik berm in yellow.

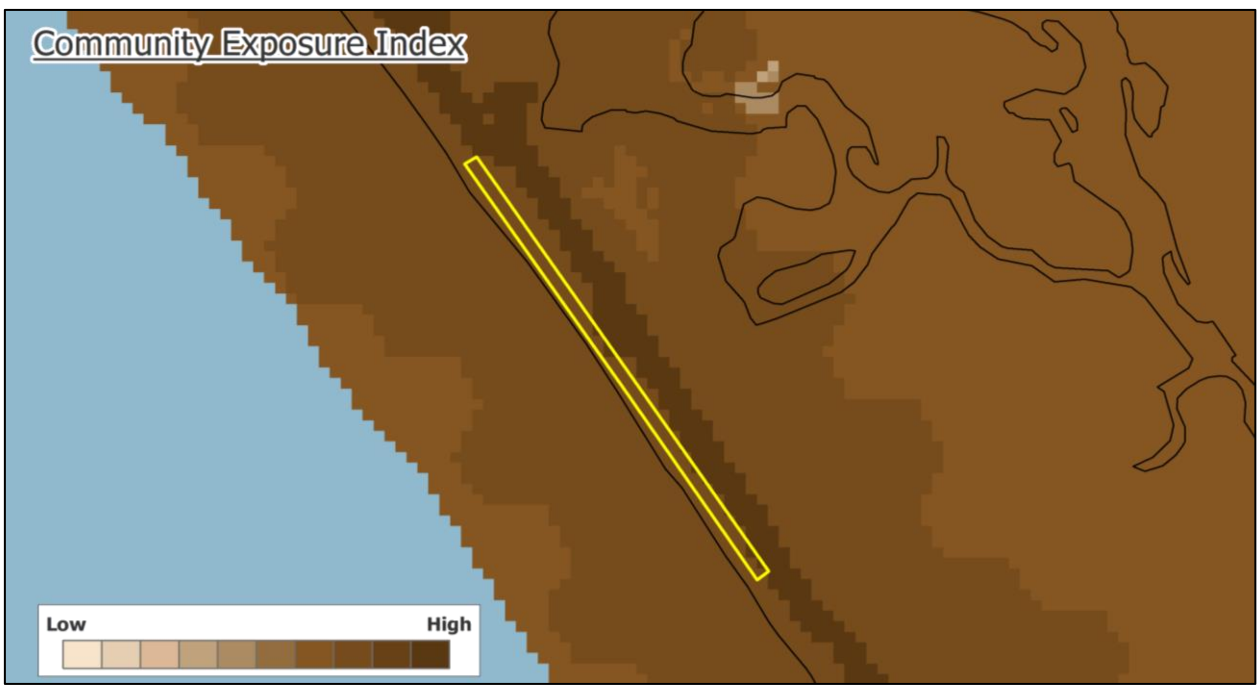

Figure 29. The Community Exposure Index results for the village of Shaktoolik reveal very high exposure to flooding threats within and surrounding the village. The yellow line outlines the approximate location of the nature-based berm.

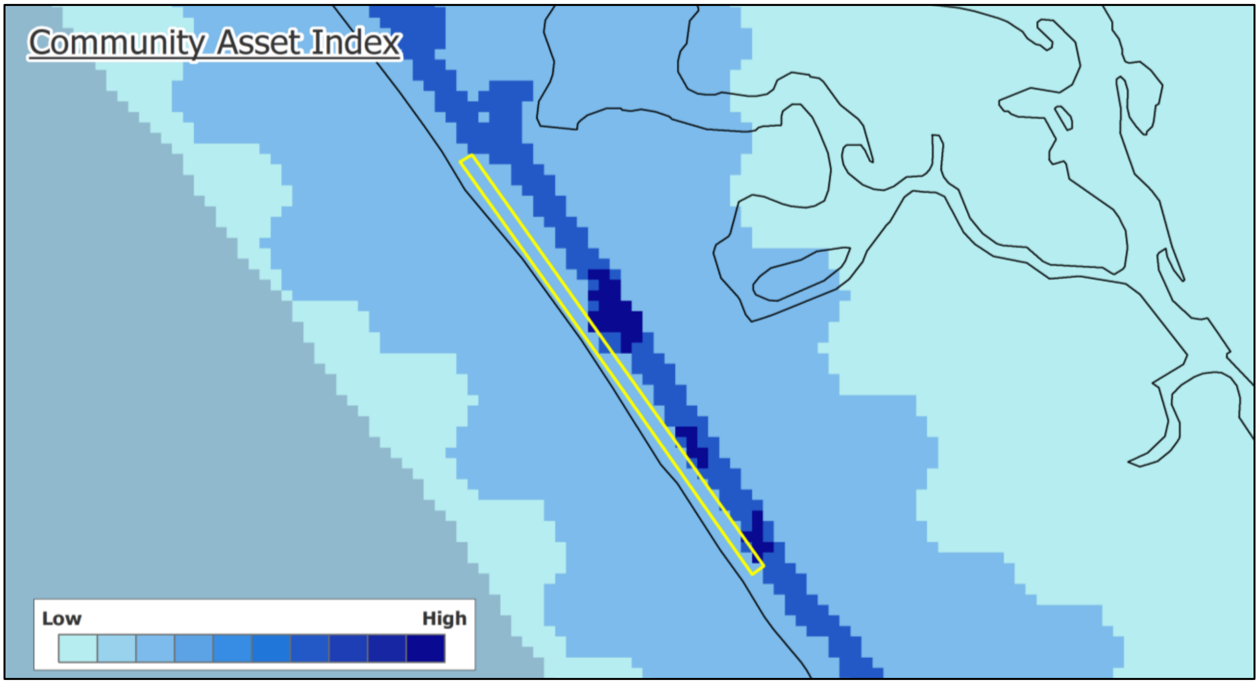

Figure 30. The Community Asset Index shows concentrations of community assets in front of the approximate location of the protective berm (yellow line).

By utilizing natural materials, the berm will also support native vegetation and help restore important coastal dune habitat. The project team will plant native beach wildrye (*Leymus mollis*) on the berm, which will help stabilize soils, reduce erosion, and increase vegetated cover between the community and Norton Sound by 70 percent. In addition to providing direct habitat benefits, the project team estimates that the berm will also help protect community assets and reduce the risk of large-scale contamination of hazardous and biological materials to over 50,000 acres of coastal wetlands. Measures to prevent contamination during storm events are not only critical for human health, but also help protect important habitat for many species including vital subsistence resources.

Restoration activities will create 1.3 acres of dry graminoid herbaceous upland community that supports seabirds and other species. The sprawling wetlands to the east of Shaktoolik provide habitat for migratory birds including critical habitat for the federally threatened spectacled eider (*Somateria fischeri*). The Shaktoolik River supports all five Pacific salmon species, Arctic grayling *(Thymallus arcticus)*, Dolly Varden (*Salvelinus malma*), Arctic char (*Salvelinus alpinus*), and many other freshwater fishes designated as species of greatest conservation concern by the State of Alaska (ADFG 2015). The productive waters of Norton Sound support Essential Fish Habitat for groundfishes, crabs, and Pacific salmon species and are home to numerous protected marine mammals including Pacific walrus *(Odobenus rosmarus)*, ribbon seal *(Histriophoca fasciata)*, and the Eastern Bering Sea stock of beluga whales (*Delphinapterus leucas)*. The results of the Alaska Assessment highlight the importance of this region for both terrestrial and aquatic species (Figure 31).

With concentrations of coastal community assets and wildlife habitat facing significant flooding and erosion threats, the Shaktoolik berm and habitat restoration project demonstrates the potential for multiple resilience-building benefits. The village of Shaktoolik is surrounded by Resilience Hubs with the highest possible ranking, highlighting the suitability and benefits of implementing nature-based, resilience-building interventions (Figure 32). While berms are not always considered nature-based solutions in other parts of the country where they can block tidal connectivity, in Alaska's unique setting with its unique coastal risks, berms constructed from natural materials coupled with habitat restoration provides a viable and cost-effective strategy for building coastal resilience for remote villages.

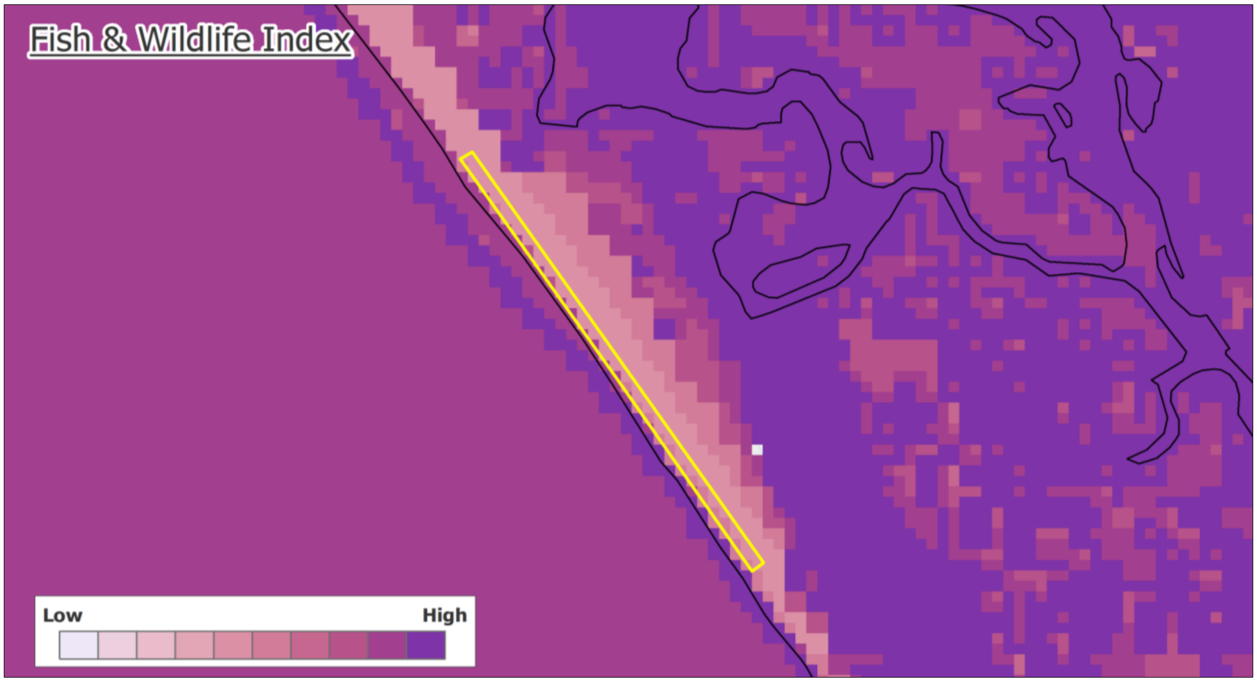

Figure 31. Fish and Wildlife Index results for the village of Shaktoolik revealed very high values within nearshore marine water and the rivers and wetlands to the east of the village. The yellow line outlines the approximate location of the nature-based berm.

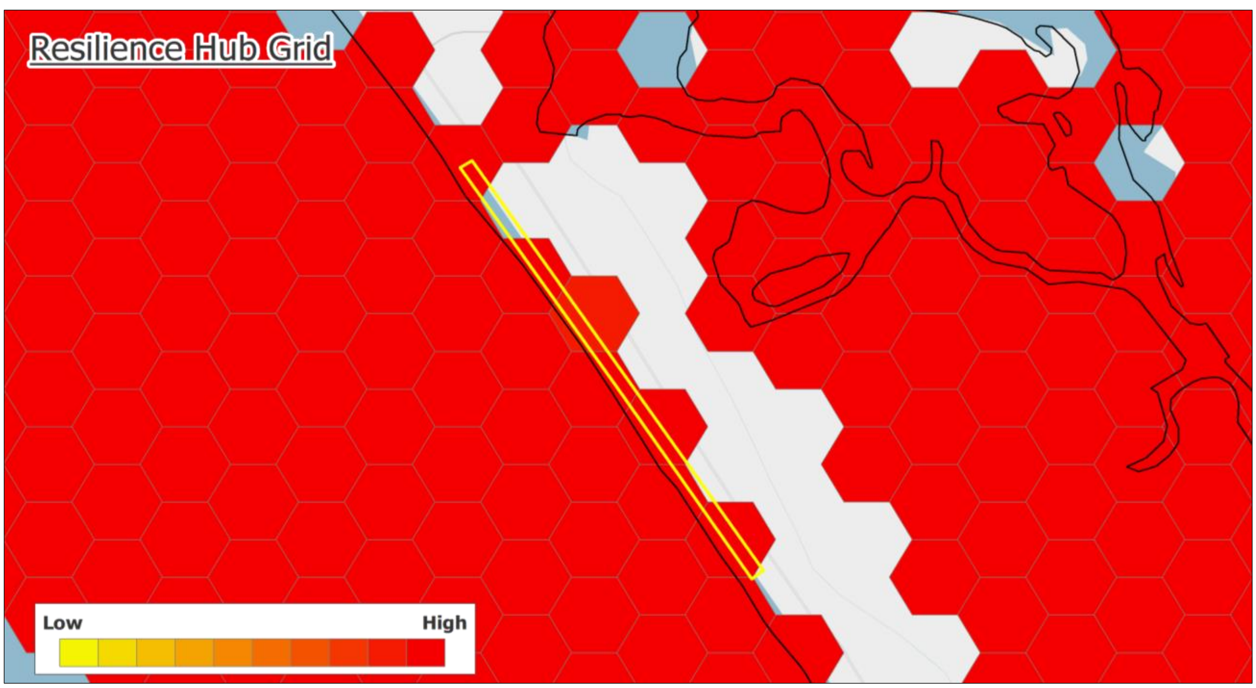

Figure 32. Resilience Hubs reveal nearly all areas of open space surrounding the village of Shaktoolik are suitable for nature-based resilience projects with potential to benefit fish and wildlife and help build community resilience to flooding threats. The Resilience Hub Grid shows 4-hectare (10-acre) hexagons covering areas of open space. The yellow line outlines the approximate location of the nature-based berm.

4.2 Conserving Habitat in the Kenai Peninsula

Nature-based solutions are also a viable strategy in the more developed areas of Southeast and Southcentral Alaska. For instance, fish passage improvement projects can not only open streams and rivers for free passage of important anadromous fishes, but dams and undersized culverts can also contribute to flooding risk for roads and nearby human community assets. Within urbanized areas, stormwater management offers another viable nature-based solution with potential for shared wildlife and flood resilience benefits. While many nature-based solutions rely on engineering and restoration techniques, habitat conservation can also be an important component of building community resilience.

The Kasilof River in the Kenai Peninsula winds through the developed communities of Cohoe and Kasilof, connecting the coast to Tustumena Lake and Harding Icefield in the Kenai Mountains. At its mouth, the Kasilof River Flats Important Bird Area (IBA) supports a biodiverse estuarine delta that provides important stopover feeding areas for migrant waterfowl and shorebirds, including globally significant habitat for the rock sandpiper (*Calidris ptilocnemis*). In addition to providing habitat for 165 observed bird species, the Kasilof River also supports salmon runs that have long supported subsistence fishing for the Dena'ina people, as well as a large personal use fishery for Alaska residents.

Despite the importance of this location for fish and wildlife resources, portions of the lower Kasilof River are under threat of development. In response and with support from ConocoPhillips and the U.S. Fish and Wildlife Service under NFWF's SPIRIT of Conservation grant program[19] and other funding partners, The Conservation Fund partnered with the State of Alaska to acquire 309 acres and 2.25 miles of the Kasilof River under a wildlife-oriented deed restriction (Figure 33).

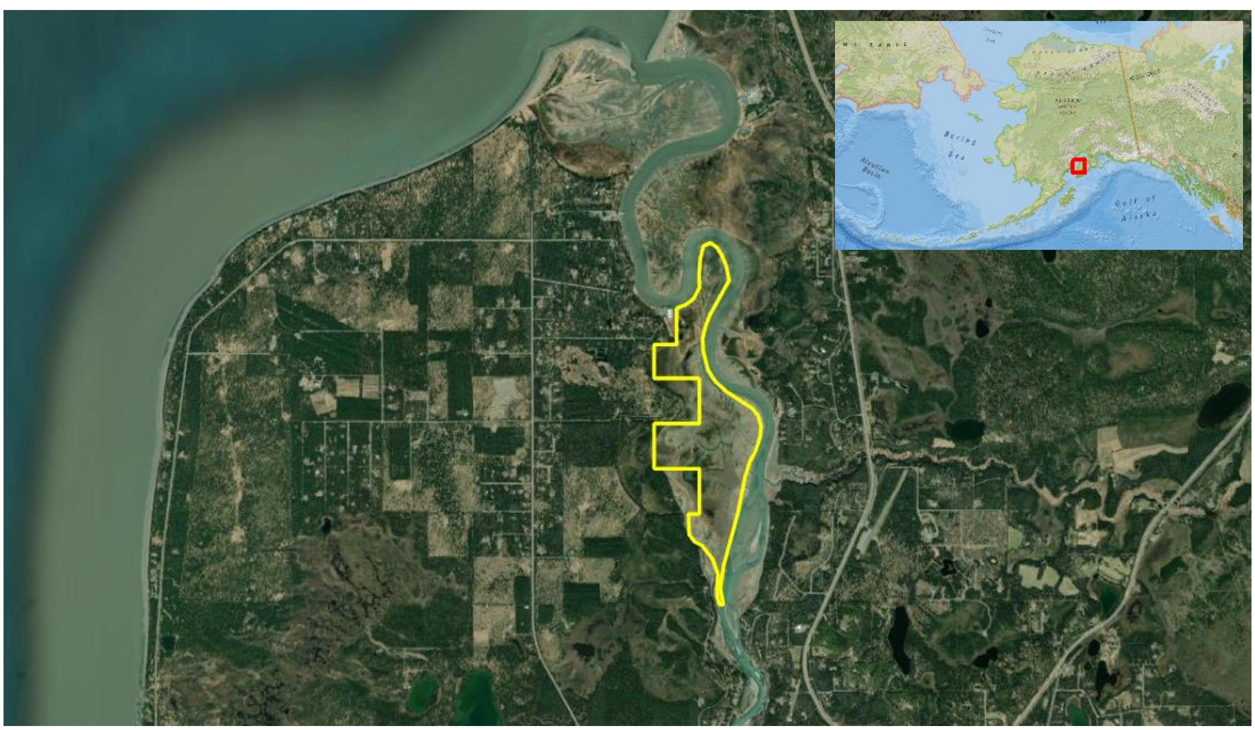

Figure 33. Map showing the boundary of the acquired parcel now under management by the Alaska Division of Parks and Outdoor Recreation in yellow.

[19] https://www.nfwf.org/programs/conocophillips-spirit-conservation-program

The newly acquired land will be associated with the Old Kasilof Landing State Recreational Site and managed by the Alaska Division of Parks and Outdoor Recreation. Together with the adjacent Kasilof Special Use Area, the newly acquired land will bring 51 percent of the Kasilof River Flats IBA under state protection. The Terrestrial, Aquatic, and combined Fish and Wildlife Index results from the Alaska Assessment highlight the importance of this location for many species of conservation and subsistence concern (Figure 34). The expanded park lands will also enhance public use, creating recreational opportunities for bird and wildlife viewing.

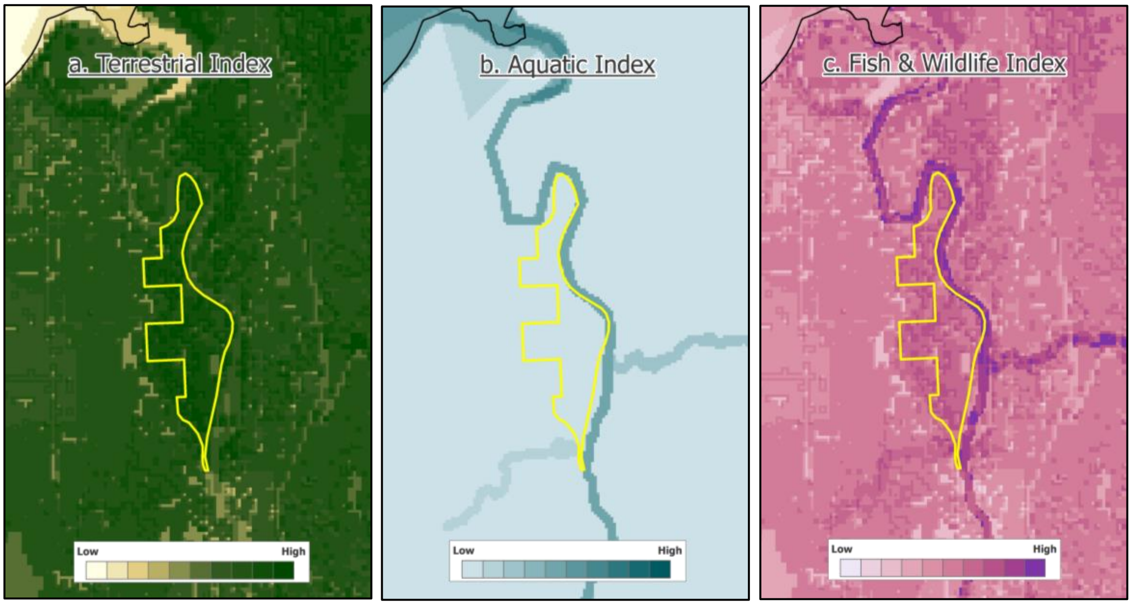

Figure 34. (a) Terrestrial Index, (b) Aquatic Index, and (c) Fish and Wildlife Index results along the Kasilof River and floodplain reveal high values. The yellow line outlines the location of the acquired parcel.

Protecting this land from development is also critical to ensure human community assets are not built within areas exposed to flooding threats (Figure 35). Furthermore, maintaining the presence of undisturbed habitat may continue to buffer nearby residents from flooding impacts. The final Resilience Hubs demonstrate the importance of conserving this high priority area (Figure 36).

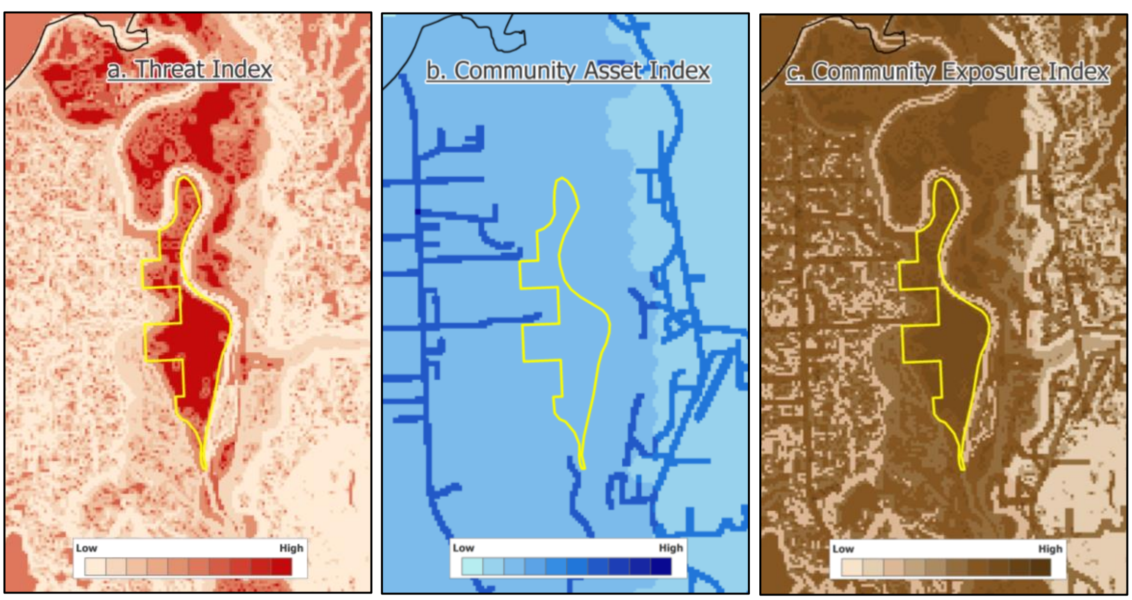

Figure 35. (a) Threat Index, (b) Community Asset Index, and (c) Community Exposure Index results along the Kasilof River show numerous exposed community assets near the acquired parcel outlined in yellow.

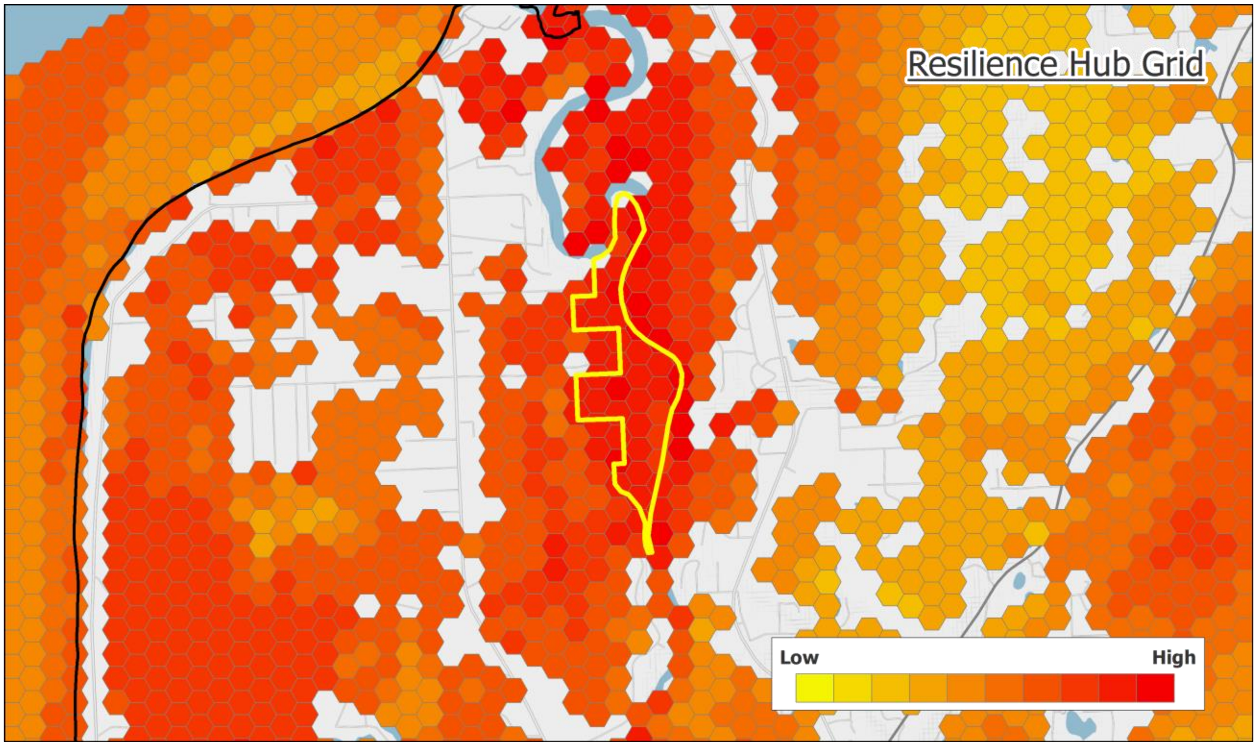

Figure 36. Resilience Hubs along the Kasilof River highlight the suitability of this area for nature-based resilience projects with potential to benefit fish and wildlife and help build community resilience to flooding threats. The Resilience Hub Grid shows 4-hectare (10-acre) hexagons covering areas of open space. The yellow line outlines the location of the acquired parcel.

4.3 Local Adaptation Planning

While some communities have already begun implementing innovative nature-based strategies, other communities require additional data, planning, and capacity to explore and implement projects. While this Alaska Assessment can serve as a starting place for regional and state-wide planning, communities still require more detailed, local analysis to better characterize risk and develop tailored solutions. With funding from the National Coastal Resilience Fund and other sources, the Alaska Native Tribal Health Consortium, State of Alaska Department of Natural Resources, and State of Alaska Division of Community and Regional Affairs are working to gather local data and model flooding and erosion risks for 44 communities (Figure 37), all of which received high exposure values in this Alaska Coastal Resilience Assessment. This important planning effort will provide baseline data to support future studies, help communities better understand the risks they face, and begin to develop a suite of solutions including nature-based approaches. For more information about assessment and planning efforts for communities throughout Alaska, visit the Department of Natural Resources Geological and Geophysical Survey Coastal Hazards webpage[20].

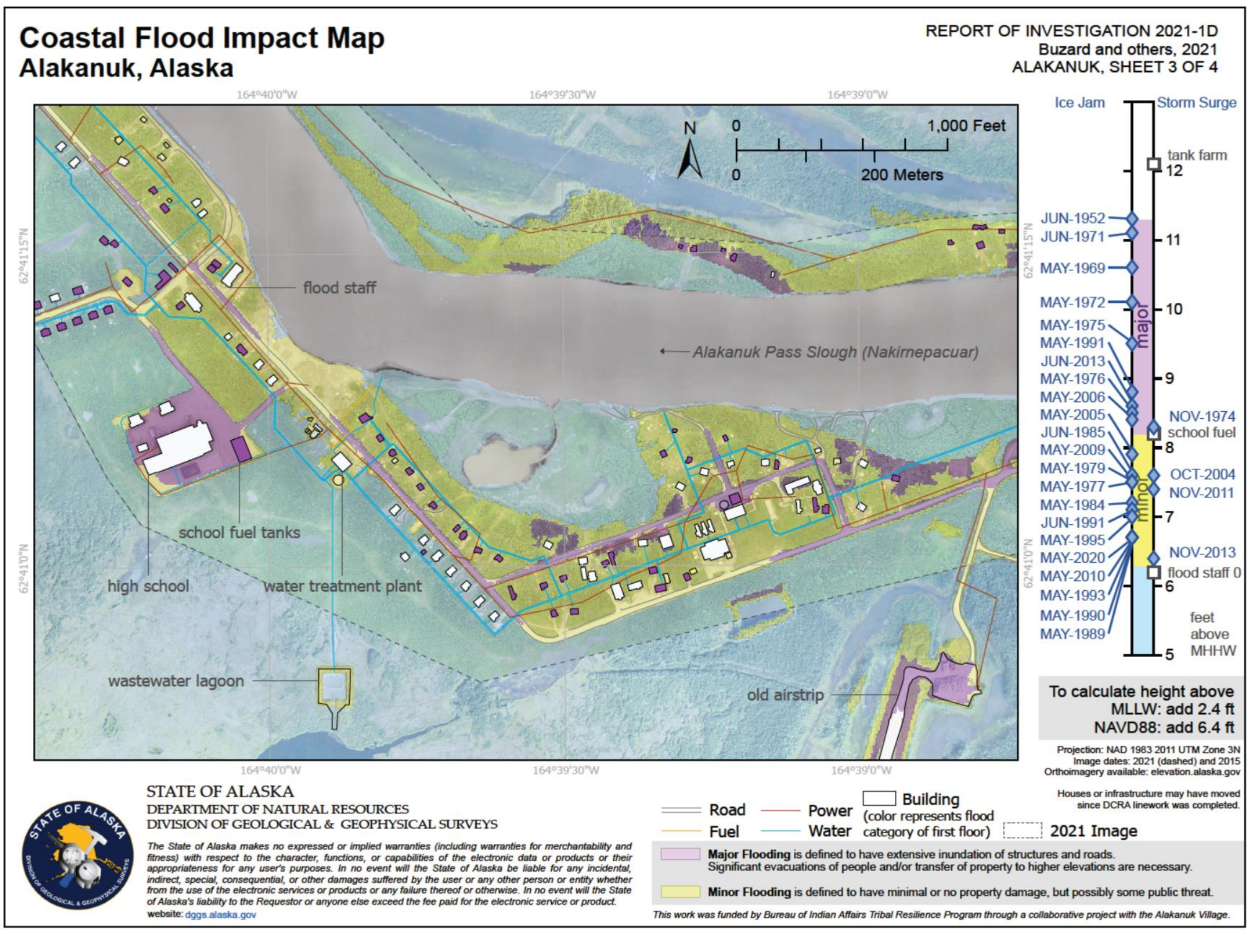

Figure 37. Example products displaying a Coastal Flood Impact Map for Alakanuk, Alaska. The maps show the location of important community assets in relation to major flooding (purple shading) expected to result in extensive inundation of structures and roads and minor flooding (yellow shading) expected to result in minimal to no property damage. Areas subject to major flooding are expected to result in the need for significant evacuation of people and/or transfer of property to higher elevations.

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[20] https://dggs.alaska.gov/hazards/coastal/

CONCLUSION

5.1 Summary and Key Takeaways

As communities in Alaska face current and future flooding threats, 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, nature-based 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.

The Alaska Assessment identified many communities highly exposed to flood related threats, particularly remote communities in Western and Northern Alaska. The Assessment also reveals an ecologically diverse landscape with an abundance of fish and wildlife assets. Combining the information in the Fish and Wildlife Index with the Community Exposure Index, numerous Resilience Hubs are found throughout the study area representing 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 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 by NFWF 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 Alaska Coastal Resilience Assessment was completed at a 30-meter resolution, using the projection NAD 1983 Alaska Albers Equal Area Conic (WKID 3338). The following sections describe data, methods, and other detailed information that were used for the Alaska Assessment.

A. Data Gaps

Several important data gaps and needs were identified in the development of the Alaska Coastal Resilience Assessment. There were several factors that precluded the use of certain data in the Assessment, including those data that were only available for a portion of the study area or lacked supporting metadata or other documentation. The Assessment utilized the best available spatial data at the time of modeling but does not consider all potential flood-related threats, critical community assets, or species information due to data limitations. For instance, important coastal flood-related threats such as sea level rise and storm surge lack statewide geospatial coverage in formats accessible to this Assessment. In other cases, data such as sea ice extent were only available in daily or seasonal formats that did not conform to the types of data required for the Assessment. The Project Team did not gather or generate any new data for this effort and datasets that were not spatially explicit were not included. For a recent review of flood hazard related data and knowledge gaps in Alaska see Williams & Erikson (2021).

A.1 Data Inputs not Included in the Alaska Assessment

Several important datasets were not included in the Alaska Assessment due to significant data gaps and limitations.

Sea level rise – data not available for most of the study area

Sea level rise data are used in all other Regional Coastal Resilience Assessments but were unavailable for Alaska. Sea level rise models estimate potential inundation from future sea level rise projections. They are often available in one-foot increment scenarios ranging from current mean higher high water to six-foot. While estimates of relative sea level rise are available in some areas, these data are not available for most of the state. This is a major data gap that was voiced by participants in the Assessment's development that hinders modeling and adaptation planning efforts.

Storm surge – complete spatial data unavailable, data format incompatible with Assessment

Storm surge data are used in most other Regional Coastal Resilience Assessments but were unavailable for Alaska. Storm surge models estimate inundation associated with specific storm scenarios and are important to understand coastal flood-related hazards. While the Extratropical Storm Surge Water Level Guidance for Alaska provides station-level observations and projections, continuous geospatial data summarized over time for the entire state are unavailable.

Sea ice extent – data format incompatible with Assessment

There are several available data sets that measure observed and model future sea ice extent including winter seasonal maximums and summer seasonal lows (e.g., National Weather Service Alaska Sea Ice Program, NOAA's Pacific Marine Environmental Laboratory downscaled climate forecasts using the Canadian Center for Climate Modeling and Analysis (CCCma) model, Alaska Center for Climate Assessment and Policy). However, these data were incompatible with the Assessment methods, which require a single, continuous input that depicts changes in flood hazard associated with changing sea ice conditions.

Subsistence hunting and fishing areas – complete spatial data unavailable
Subsistence hunting and fishing provide critical food and cultural resources for Alaskan residents. While information is available that describes the location of fish camp allotments and/or hunting grounds for subsistence resources (e.g., Subsistence Resources Used by Kaktovik, Nuiqsut and Utqiaġvik, Community Observer interactive map of subsistence communities where various surveys have occurred), not all data are spatially explicit and data coverage is limited. In some instances, publicly available data are limited or generalized to protect sensitive information. Due to the importance of subsistence resources, the Alaska Assessment used fishing and non-fishing subsistence harvest records from the Alaska Department of Fish and Game to identify species to include in habitat suitability models for the Fish and Wildlife Index.

Benthic habitat – incomplete data
The Aquatic Index methods rely on species distribution and habitat type information. In other regions, spatial data for nearshore marine benthic habitats were available to inform the Aquatic Index. In Alaska, while benthic habitat and/or substrate type data are available for some areas (e.g., the Kachemak Bay NOAA Habitat Focus Area), it was not available statewide and thus could not be included in the Assessment.

A.2 Data Inputs Included in the Alaska Assessment with Limited Coverage
In some cases, data sets that had important gaps or limitations were included in the Alaska Assessment. Updated or more complete datasets would improve the Assessment results.

Flood-prone areas – poor spatial coverage
A common input for all Regional Coastal Resilience Assessments, flood-prone areas combine Federal Emergency Management Agency (FEMA) National Flood Hazard Layer (NFHL) and the U.S. Department of Agriculture -Natural Resources Conservation Service (USDA-NRCS) Gridded National Soil Survey Geographic Database (gNATSGO) to identify areas most exposed to flooding. In Alaska, Communities Participating in the National Flood Program were limited therefore the Assessment used the FEMA National Risk Index Coastal and Riverine flooding hazard types by Census Tract where available. These data were combined with the Statewide Threat Assessment (UAF 2019) and gNATSGO soils data. The limitations of gNATSGO are described under the soil survey data heading below.

Soil survey data – poor spatial coverage
A common input for all Regional Coastal Resilience Assessments, the detailed USDA-NRCS Soil Survey Geographic Database (SSURGO) based on field observations and soil samples is used to describe soil characteristics including flood factors such as erodibility and drainage. In Alaska, these detailed surveys are only available for approximately 15 percent of Alaska. State-wide soil data are available through the Alaska Soil Survey using the State Soil Geographic (STATSGO) dataset, which generalizes more detailed soil survey maps and classifies the remaining area based on geology, topography, vegetation, and climate. The Threat Index for the Alaska Assessment used the USDA-NRCS Gridded National Soil Survey Geographic Database (gNATSGO) as it combines the best available soils data into a single composite dataset with complete coverage More consistent, state-wide soils data based on detailed soil surveys are needed and would improve the Alaska Assessment results.

Tsunami inundation– not available for all communities
Tsunami data typically describe the amount of inundation that could be experienced due to a tsunami and/or where evacuation zones exist (often in the absence of inundation data). The Threat Index for the Alaska Assessment used the Alaska Division of Geological and Geophysical Surveys Tsunami inundation maps, available for many but not all communities. Therefore, areas without tsunami data do not

necessarily indicate those areas are not at risk from inundation due to tsunami. A list of the mapped communities can be found here (https://dggs.alaska.gov/pubs/tsunami).

National Wetland Inventory – poor spatial coverage
The U.S. Fish and Wildlife Service National Wetlands Inventory is a foundational dataset used in all Regional Coastal Resilience Assessments to identify the location, type, and extent of wetland and deep-water habitats. Data were included wherever available, but coverage is limited throughout much of Alaska.

Human community assets – incomplete data (varies by region)
The Community Asset Index for the Alaska Assessment relies on spatial data identifying the location of critical infrastructure. Many datasets were used to identify community assets (see Appendix B for a list of all data included in the Assessment); however, not all forms of infrastructure are well mapped (e.g., transportation infrastructure) and additional mapping of community assets would be beneficial to improve the Assessment.

Social vulnerability – data available at coarse resolution
Data from the Denali Commission were included in the Community Asset Index of the Alaska Assessment. Where those data were unavailable, the U.S. Environmental Protection Agency's Environmental Justice Screening Tool (EJScreen) was used; these data are provided at the Census Block level and do not capture variation among communities within the same block, which are often very large. Other methods to estimate social vulnerability, such as NOAA Alaska Fisheries Science Center Community Profiles for North Pacific Fisheries did not have spatially explicit data available.

Species distribution, range, and habitat use – variable by species group
The Fish and Wildlife Index methods rely on species distribution, range, and habitat use data for species of conservation concern or subsistence use. Data for all species identified in the Alaska Wildlife Action Plan, threatened or endangered species under the U.S. Endangered Species Act, species with Essential Fish Habitat, and subsistence species were included wherever available. However, species distribution and range data were not available for all species. Most notably, small mammals are largely absent from the Alaska Assessment as data were not available.

B. Data Summary

B.1 Threat Index

The following is a comprehensive list of datasets used to create the Threat Index for the Alaska Coastal Resilience Assessment.

Layer Name	Dataset and Source
Flood-prone Areas	FEMA National Risk Index (Coastal and Riverine Flooding Annualized Frequency), USDA-NRCS gNATSGO, UAF et al. 2019
Areas of Low Slope	IFSAR Digital Terrain Model, resampled to 30-meter resolution
Soil Erodibility	USDA-NRCS gNATSGO, UAF et al. 2019
Tsunami Inundation	Alaska Dept. of Natural Resources, Alaska Earthquake Center, and the Alaska Division of Homeland Security and Emergency Management Tsunami Inundation Mapping
Permafrost Thaw	Hjort et al. 2018, UAF et al. 2019
Community Footprints	Alaska Dept. of Commerce, Community, & Economic Development, Division of Community and Regional Affairs "Community Transportation Overview", Places (Cities and Census Designated Places), Census Blocks, city boundaries

B.2 Community Asset Index

The following is a comprehensive list of datasets used to create the Community Asset Index for the Alaska Coastal Resilience Assessment.

Layer Name	Dataset and Source
Social Vulnerability	Denali Commission Distressed Communities Report (2020), U.S. EPA EJSCREEN
Community Footprints	Alaska Dept. of Commerce, Community, & Economic Development, Division of Community and Regional Affairs "Community Transportation Overview", Places (Cities and Census Designated Places), Census Blocks, city boundaries
Critical Facilities	Alaska Dept. of Health and Social Services, Division of Public Health "Healthcare Facilities: Healthcare SafetyNet Directory" Alaska Dept. of Public Safety "Fire Departments" Alaska Dept. of Education & Early Development "Schools: PK-12" Alaska Dept. of Public Safety "Village Public Safety Officers" Alaska Dept. of Commerce, Community, and Economic Development, Division of Community and Regional Affairs "Post Offices"

Layer Name	Dataset and Source
Critical Transportation Infrastructure *(Various Inputs, see below)*	
Primary roads	*Alaska Dept. of Transportation & Public Facilities "Roads"*
Airport runways	*Homeland Infrastructure Foundation-Level Data (HIFLD)*
Railroads	*Alaska Dept. of Commerce, Community, & Economic Development "Alaska Railroad Centerline"*
Bridges	*Alaska Dept. of Transportation & Public Facilities "Bridges"*
Ferry Terminals	*Alaska Dept. of Commerce, Community, & Economic Development "Alaska Marine Highway Ferry Terminals"*
Ports and Harbors	*Alaska Dept. of Commerce, Community, & Economic Development "Ports and Harbors"*
Critical Infrastructure (*Various inputs, see below*)	
Wastewater treatment facilities	*Alaska Dept. of Environmental Conservation Division of Water "Wastewater Treatment"* *Alaska Dept. of Environmental Conservation "Wastewater Collection", AK Certified Water/Wastewater Operator Database*
Power Plants/Substations	*EIA-860, Annual Electric Generator Report; EIA-860M, Monthly Update to the Annual Electric Generator Report; and EIA-923, Power Plant Operations Report (U.S. Energy Information Administration)*
Major dams	*USACE National Inventory of Dams: Dam Lines*
Petroleum terminals	*U.S. Energy Information Administration: EIA-815, Monthly Bulk Terminal and Blender Report*
Petroleum Refineries	*U.S. Energy Information Administration: EIA-820 Refinery Capacity Report*
Hazardous Sites	*Alaska Dept. of Environmental Conservation "Solid Waste Landfills"* *Alaska Dept. of Environmental Conservation "Solid Waste Sites"*
Water Distribution	*Alaska Dept. of Environmental Conservation, Division of Water "Water Distribution"*
Communication Infrastructure	*Homeland Infrastructure Foundation-Level Data (HIFLD) Microwave Service Towers* and *FM Transmission Towers*
Bulk Fuel Storage	*Alaska Energy Authority "Bulk Fuel Inventory Facilities"*
Department of Defense sites	*Homeland Infrastructure Foundation-Level Data (HIFLD) DoD Sites Boundaries (Public)*

B.3 Terrestrial Index

The following table lists those datasets that were used to create the Terrestrial Index for the Alaska Coastal Resilience Assessment.

Layer Name	Dataset and Source
Important Bird Areas	BirdLife International (2020)
Critical Habitat Designations	U.S. FWS
State Wildlife Action Plan Species of Greatest Conservation Concern	Alaska Dept of Fish and Game State Wildlife Action Plan (2015)
Subsistence species	Alaska Department of Fish and Game "Subsistence Harvests: Non-Fishing Resources" (determined by the Joint Board of Fisheries and Game)
Alaska Gap Analysis Project, Distribution Models for Terrestrial Vertebrate species	University of Alaska Anchorage, Alaska Center for Conservation Science (Gotthart et al. 2014)
Species range data	Alaska Natural Heritage Program Wildlife Data Portal (University of Alaska Anchorage, Alaska Center for Conservation Science); range data used for species not included in the Gap Analysis Project
Procellarid range data	IUCN Redlist
Arctic caribou herds range data	University of Alaska Anchorage, Alaska Center for Conservation Science
Elk range data	Alaska Habitat Management Guides (1985)

B.4 Aquatic Index

The following table lists those datasets used to create the Aquatic Index for the Alaska Coastal Resilience Assessment.

Layer Name	Dataset and Source
Habitat Classification Scheme	IUCN Red List of Threatened Species (Version 3.1)
Essential Fish Habitat	NOAA Fisheries Alaska Region Habitat Conservation Division
State Wildlife Action Plan Species of Greatest Conservation Concern	Alaska Dept of Fish and Game State Wildlife Action Plan (2015)
Subsistence species	Alaska Department of Fish and Game "Subsistence Harvests: Fishing Resources" (determined by the Joint Board of Fisheries and Game)
Distribution data for anadromous fish species	Alaska Department of Fish and Game Alaska Anadromous Waters Catalog
Critical Habitat Designations	NOAA and U.S. FWS
Alaska Gap Analysis Project, Distribution Models for Terrestrial Vertebrate species (*marine mammals*)	University of Alaska Anchorage, Alaska Center for Conservation Science (Gotthart et al. 2014)
Distribution data for beluga and bowhead whales	Alaska Department of Fish and Game Alaska Habitat Management Guides (1985)
Distribution data for marine invertebrate subsistence species	Kachemak Bay Ecological Characterization (Marine Invertebrate Distributions); Cook Inlet Environmental Sensitivity Index (Invertebrates) via Alaska Ocean Observing System Ocean Data Explorer
Intertidal and subtidal vegetation	Alaska ShoreZone biological attributes including eelgrass, surfgrass, *Alaria* spp., rockweed, and other soft brown, dark brown, dragon, bull, and giant kelps
Misc. species habitat range, distribution, nesting sites, etc.	Kachemak Bay Ecological Characterization (Finfish Distributions), Audubon Alaska (North Pacific cods, Pacific halibut, capelin, Pacific herring, Atka mackerel, red king crab) via Alaska Ocean Observing System Ocean Data Explorer

B.5 Protected & Managed Areas for Wildlife

Layer Name	Dataset and Source
Protected Areas Managed for Biodiversity	USGS Protected Areas Database of the U.S. (PADUS) (Version 2.0)
State Refuges, Sanctuaries, Critical Habitat Areas, and Wildlife Ranges	Alaska Department of Fish and Game

B.6 Resilience Hubs

Layer Name	Dataset and Source
National Hydrology Dataset	USGS National Hydrology
National Land Cover Dataset, 2016	Multi-Resolution Land Characteristics (MRLC) Consortium - USGS, EPA, NOAA, BLM, NASA, NPS, USDA-NASS, USFWS, US Army COE
National Elevation Dataset, NED 30-meter	U.S. Geological Survey (USGS), EROS Data Center
12-Digit Watershed Boundary Dataset	United States Geological Survey (USGS)
Soils	U.S. Department of Agriculture, National Soil Survey Center, National Coordinated Major Land Resource Area (MLRA) Version 4.2
TIGER Primary and Secondary Roads	U.S. Department of Commerce, U.S. Census Bureau, Geography Division, 2021
TIGER Streets	U.S. Department of Commerce, U.S. Census Bureau, Geography Division, 2021
TIGER Rail Lines	U.S. Department of Commerce, U.S. Census Bureau, Geography Division, 2021
Wetlands	U.S. Fish & Wildlife Service, National Wetlands Inventory
Incorporated places and U.S. Census Designated Places	U.S. Census Bureau, ESRI

C. Detailed Methodology: Threat Index

C.1 Create the Areas of Low Slope Input

A. Use the Raster Clip tool to clip the IFSAR digital terrain model to the regional boundary
    a. Data management tools > Raster > Raster Processing > Clip
B. Create a slope raster from the clipped raster using the Slope Tool
    a. Spatial Analyst Tools > Surface > Slope
        i. Output Measurement: Percent rise
C. Reclassify the Slope raster to a ranked output
    a. Spatial Analyst Tools > Reclass > Reclassify
        i. Choose the Percent Rise raster as the input raster
        ii. Create a distribution with corresponding rank values according to the table below
D. Shift the raster
    a. Data and Management Tools > Projections and Transformations > Raster > Shift
    b. Shift X & Y Coordinates by: 1 (each)
    c. Snap to: *varies by region*

Slope (%)	Rank Type	Rank Value
> 2.00	None	0
1.00 – 2.00	Very low	1
0.75 – 1.00	Low	2
0.50 – 0.75	Moderate	3
0.25 – 0.50	High	4
< 0.25	Very high	5

C.2 Create the Soil Erodibility Input

Create the gNATSGO grid for the attribute "kffact" to evaluate soil erodibility:

A. Add the provided 10-meter grid to the map and resample, if necessary. For Alaska, the raster was resampled to 30-meters.
    d. Data Management Tools > Raster > Raster Processing > Resample:
        i. Input: 10-meter
        ii. output : *30-meter*
        iii. X: 30; Y: 30
        iv. Resampling technique: NEAREST
B. Run the "Create Soil Map" tool from the USDA-NRCS Soil Data Development Toolbox (download data as needed)
    a. To create a soils raster for the "kffact" attribute:
        i. Map Unit Layer = MapunitRaster_30m
            1. SDV Folder = Soil Erosion Factors
            2. SDV Attribute = K Factor, Whole Soil

        3. Aggregation Method = Dominant Condition
    b. Export the temporary layer generated by "Create Soil Map" tool :
        i. Right click layer in the Table of Contents > Data > Export Data
            1. Ensure the correct spatial reference and cell size
            2. Enter the correct folder location
            3. Give the raster output a new name with the ".tif" extension
            4. Click "Save"

Prepare the new Soil Erodibility raster:

C. Reclassify the "kffact" raster according to the table below.
D. Clip the reclassified raster to the regional boundary.
    a. Clip Raster:
        i. Check "Use Input Features for Clipping Geometry"

Soil Erodibility	Rank Type	Rank Value
Null	None	0
< = 0.10 Kffact	Very low	1
0.15 and 0.17 Kffact	Low	2
0.20 – 0.28 Kffact	Moderate	3
0.32 and 0.37 Kffact	High	4
> = 0.43 Kffact	Very high	5

Prepare the Statewide Threat Assessment Community data and calculate the final input:

E. A community footprints layer was created to distribute community-level data for some threat and asset index values compiled by other assessments where a single value was assigned to the entire community
    a. Create community footprints polygon layer
        i. Use the Community Transportation Overview Open Data layer maintained by the Alaska Department of Commerce Community and Economic Development Division of Community and Regional Affairs to identify Alaska communities (point locations)
            1. Filter out Large population centers (2010 Census population >8,000) such as Anchorage along with data scales that are larger than the community-level (e.g., boroughs)
        ii. Identify a polygon boundary to correspond to each community point using Census Designated Place boundaries, city boundaries, and Census Blocks boundaries
            1. As there are sometimes differences in community names between sources, crosswalk the datasets through visual comparison of the point and polygon locations for each community where there are differences. Communities included in the Statewide Threat Assessment (UAF 2019) should also be crosswalked with the data to ensure their threat values can be joined to the community footprints

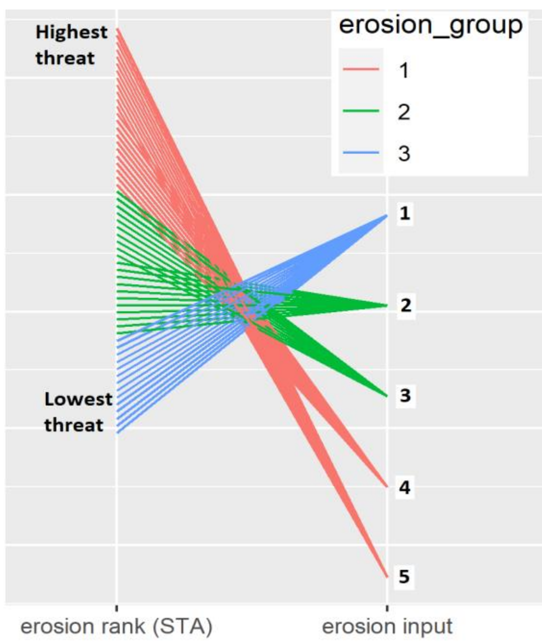
2. As polygon boundaries are identified for each corresponding community point, some community points may need to be removed where multiple points correspond to the same polygon boundary (e.g., Fox River)
3. Merge community boundaries identified for each source into a single community footprints layer
4. Clip community footprints to the regional boundary

b. Join the STA individual threat evaluations for 187 point locations for communities in rural Alaska to the community footprints. This dataset will be used to derive values for erosion, flooding, and permafrost within community footprints

F. Derive values for pixels falling inside the community footprint

a. Assign a rank value, from 1 to 5, to each community footprint where erosion threat risk was assessed by the STA based on the assessment's assigned individual erosion threat risk groupings for each community (1=high, 2=medium, and 3=low)

i. Using the STA individual erosion threat risk rankings, split communities in erosion group 1 into two subsets, and assign the highest-ranking communities in group 1 to rank=5, while the lowest-ranking communities in group 1 are assigned rank=4. Similarly, the highest-ranking communities in erosion group 2 are assigned rank=3 while the lowest-ranking communities in are assigned rank=2. All communities in erosion group 3 are assigned rank=1. (See figure below.)



G. Rasterize the ranked communities and mosaic these communities into the soils raster, ensuring that pixels inside community footprints of communities assessed by the STA take their value from the STA rank, not from the soils raster.

C.3 Create the Flood-Prone Areas Input

Create the gNATSGO grid for the attribute “flodfreqmax” to evaluate flood-prone soils:

A. Run the “Create Soil Map” tool from the USDA-NRCS Soil Data Development Toolbox (download data as needed)
    a. To create a soils raster for the “flodfreqmax” attribute:
        i. Map Unit Layer = MapunitRaster_30m
        ii. SDV Folder = Water Features
        iii. SDV Attribute = Flooding Frequency Class
        iv. Aggregation Method = Max
B. Export the temporary layer generated by “Create Soil Map” tool :
    a. Right click layer in the Table of Contents > Data > Export Data
        i. Ensure the correct spatial reference and cell size
        ii. Enter the correct folder location
        iii. Give the raster output a new name with the “.tif” extension
        iv. Click “Save”

Prepare the new flood-prone soils raster:

C. Reclassify the “flodfreqmax” raster according to the table below
D. Clip the reclassified raster to the regional boundary
    a. Clip Raster:
        i. Check “Use Input Features for Clipping Geometry”

Prepare the FEMA floodplain data:

E. Create a new field in the attribute table to combine the attributes “Coastal Flooding Annualized Frequency” and “Riverine Flooding Annualized Frequency”
    a. Right click layer in Table of Contents > Attribute Table > +Add
        i. Field Name: CombFlood; Type: Double
    b. Calculate field “CombFlood”:
        i. Right click field > Calculate Field:
            1. = CFLD_AFREQ + RFLD_AFEQ
F. Rank the newly combined flood frequency field according to the table below.
    a. In the layer’s attribute table choose “+Add” to add a new field:
        i. Name: Rank; Type: Short
    b. Select by attributes where CombFlood is < 1% and >= 1% and <= 2%, ranking each as they are selected according to the table below

Flood Likelihood	Rank
None (or no data coverage)	0
Combined Flood: less than 1% chance	1
Combined Flood: 1-2% chance (100- or 500- year floodplain)	2
Occasionally-flooded soils (gNATSGO)	3
Frequently-flooded soils (gNATSGO)	4

Restrict flood-prone areas by elevation mask:

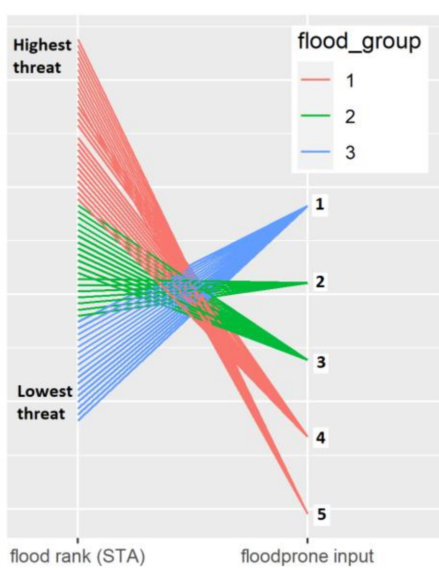
The project team used an elevation mask to restrict flood-prone areas. The elevation mask was used to remove the flood-prone areas input in areas of high elevation, assuming that areas of elevation greater than 20 m are unlikely to flood (personal communication with Advisory Committee). While these areas still receive values in the Threat Index, their values are lower because they do not experience the threat of flooding.

G. Set pixels in the floodfreqmax/soils raster to 0 in areas where elevation is greater than 20 or less than or equal to 0

Prepare the Statewide Threat Assessment Community data and calculate the final input:

H. Derive values for pixels falling inside the community footprint
    a. Assign a rank value, from 1 to 5, to each community footprint where flooding threat risk was assessed by the STA (UAF 2019) based on the assessment's assigned individual flood threat risk groupings for each community (1=high, 2=medium, and 3=low)

Using the STA individual flood threat risk rankings, split communities in flood group 1 into two subsets, and assign the highest-ranking communities in group 1 to rank=5, while the lowest-ranking communities in group 1 are assigned rank=4. Similarly, the highest-ranking communities in flood group 2 are assigned rank=3 while the lowest-ranking communities in are assigned rank=2. All communities in flood group 3 are assigned rank=1. (See figure below.)



I. Rasterize the ranked communities and mosaic these communities into the flodfreqmax/soils raster, ensuring that pixels inside community footprints of communities assessed by the STA take their value from the STA rank, not from the flodfreqmax/soils raster.

C.4 Create the Permafrost Thaw Input

Prepare permafrost data input:

The project team used the "geohazard risk index" due to permafrost thaw published by Hjort *et al*. (2018). As this index is already a direct indicator of threat, the project team simply reclassified the index from a 3-level index to a 5-level index (level 1 was reclassified to 1; level 2 was reclassified 3; level 3 was reclassified to 5).

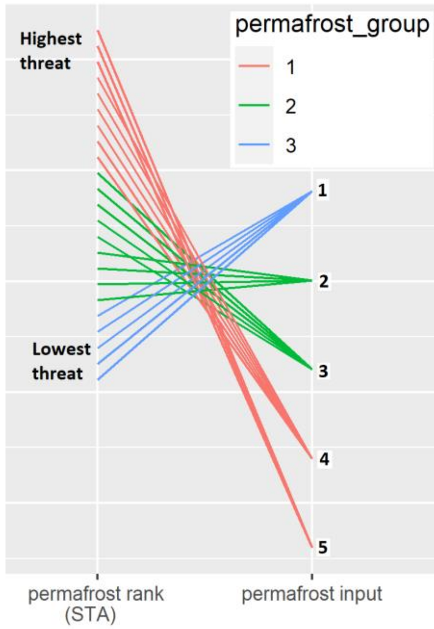
A. Import the geohazard risk index data layer (consensus geohazard risk for RCP2.6 and time period 2041-2060), clip it to the regional boundary, project, and resample to match other threat index inputs.
B. Reclassify the geohazard risk index to a scale of 1-5

Geohazard risk index value	Rank Type	Rank Value
None	None	0
1	Low hazard potential	1
2	Moderate hazard potential	3
3	High hazard potential	5

C. Mosaic ranked risk index with the regional boundary
    a. Tool: Merge
        i. Input features: ranked permafrost risk index and regional boundary

Prepare the Statewide Threat Assessment Community data and calculate the final input:

D. Derive values for pixels falling inside the community footprint
    a. Assign a rank value, from 1 to 5, to each community footprint where permafrost threat risk was assessed by the STA (UAF 2019) based on the assessment's assigned individual permafrost threat risk groupings for each community (1=high, 2=medium, and 3=low)
        i. Using the STA individual permafrost threat risk rankings, split communities in permafrost group 1 into two subsets, and assign the highest-ranking communities in group 1 to rank=5, while the lowest-ranking communities in group 1 are assigned rank=4. Similarly, the highest-ranking communities in group 2 are assigned rank=3, while the lowest-ranking communities in group 2 are assigned rank=2. All communities in permafrost group 3 are assigned rank=1. (See figure below.)



E. Rasterize the ranked communities and mosaic these communities into the permafrost raster, ensuring that pixels inside community footprints of communities assessed by the STA take their value from the STA rank, not from the permafrost raster

C.5 Create the Tsunami Inundation Input

Prepare tsunami modeled depth data (rasters):

A. Import the raster data layer, export with a new name and update the coordinate system
    a. Right click layer in the Table of Contents > Data > Export Raster
B. Reclassify the rasters according to the [Alaska Earthquake Map Viewer]() (see table below)
C. Mosaic the reclassified rasters
    a. Tool: Mosaic
        i. Inputs: All rasters except one
        ii. Target Raster: Make a copy of the raster that was left out of the inputs and name it whatever you want the output to be named. Add the renamed copy as the “target”.
        iii. Since there will be no overlap in rasters, leave them in their default settings
        iv. NoData Value: 255
D. Vectorize the raster mosaic
    a. Tool: Raster to polygon
        i. Input: raster mosaic
        ii. Field: Value
        iii. Uncheck *simplify polygons*
E. Prepare the new vector so it can be used as a raster input:
    a. Remove values of 0 from the new polygon:
        i. Select by Attributes where gridcode = 0; delete selection and save edits
    b. Clip the vector to the regional boundary.
        i. Tool: Clip
            1. Input Features: edited Tsunami mosaic vector
            2. Clip Features: regional boundary

c. Merge the vector with the regional boundary to create values of 0 throughout the entire region where there is no tsunami data
   i. Tool: Merge
      1. Input Datasets: clipped tsunami mosaic, regional boundary

F. Rasterize the merged tsunami and regional boundary vector:
   a. Tool: Polygon to Raster
      i. Input Features: merged tsunami and regional boundary vector
      ii. Value Field: gridcode
      iii. Cell assignment: max area
      iv. Priority field: gridcode
      v. Cell Size: 30

Water Depth	Rank Type	Rank Value
None	None	0
< 1 ft	Moderate	3
1 - 6 ft	High	4
> 6 ft	Very High	5

C.6 Calculating the Threat Index

The Threat Index was clipped to the shoreline boundary created by NEMAC and classified into 10 classes to multiply with the Asset Index and ultimately create the Community Exposure Index. Below is the classification that was used for the Alaska Threat Index.

Alaska Threat Index Distribution

Threat Index Break Value	0	1	2	3	4	5	6	7	8	9 - 20
Final Rank Value	1	2	3	4	5	6	7	8	9	10

D. Detailed Methodology: Community Asset Index

D.1 Create the Social Vulnerability Input

Prepare the data for the analysis:

A. Denali Commission's annual Distressed Communities report:
    a. Use the most recent Distressed Communities Report to give the community footprints a 1 ("distressed") or 0 ("not distressed"); (see *Appendix C.2 Create the Soil Erodibility Input* for detailed methods on the creation of the community footprints layer)
        i. Add a rank field: right click layer in the table of contents > Attribute Table > +Add
            1. Name: Rank; Type: short > Save
        ii. Either use Field Calculator or edit the Attribute Table to give the correct values to the community footprints
B. EPA EJSCREEN data (or other suitable social vulnerability dataset):
    a. Clip the EJSCREEN_StatePct feature class (from the downloaded EJSCREEN_StatePctEJSCREEN_YEAR_StatePctile.gdb) to the region, selecting only the relevant vulnerability index field VULEOPCT (Demographic Index based on 2 factors, % low-income and % minority)
    b. Project the data to match the region

Prepare the analysis area:

C. Using the building footprints for the region, create centroids to represent areas where people live
    a. Data management tools > Features > Feature to Point
        i. Leave "inside" unchecked (uses the representative center of an input feature as its output point location)
D. Create Hexagons for the region
    a. Data Management toolbox > Sampling toolset > Generate Tessellation (Data Management)
        i. Extent: *set to regional boundary*
        ii. Shape type: Hexagon
        iii. Size: 18.5 acres (*Note: this size may differ across regions*)
        iv. Spatial reference: *varies by region*
    b. The output generated will cover the entire regional extent, including areas that are not in the regional boundary. For the next step, there are two options before proceeding:
        i. Select by location where hexagons intersect the regional boundary
            1. Option 1: export the selected features to a new feature class
            2. *Option 2:* with the features selected, run the tool in the next step. The output of that tool will only include the selected features.
E. Select by location where hexagons intersect all community footprints, regardless of distress. Run another Select by Location, **choose "Add to current selection"**, and select hexagons that also intersect building points. Export the selections as one layer.
F. Summarize EJSCREEN in the hexagons throughout the region
    a. Select by location where the community footprints hexagon layer from the step above intersects the building points. Add a search distance of 300m (the approximate width of one of the hexagons).

b. Summarize Within:
    i. Input: Community Footprints Hexagon layer (with selected features)
    ii. Input Summary Features: EJSCREEN
    iii. Check: Keep all input polygons
    iv. Summary Fields: VULEOPCT; Statistic: Mean
    v. <u>Uncheck</u>: Add shape summary attributes

G. Add the Distressed Communities information to the summarized hexagons.
    a. Select by attributes where distressed communities = 1
    b. Select by Location where output hexagons intersect the selected distressed communities layer. Add a search distance of 300m.
        i. Add a field to the hexagon layer and calculate based on this selected attribute
            1. Name: Distressed; Type: Short
            2. Selected Features = 1 ("yes" distressed); reverse selection and make sure any "NULL" values are 0

H. Distribute the averaged social vulnerability in a way that best represents these data, see table below for the distribution used in Alaska
    a. Exclude values and classify data
        i. Right click layer in the Table of Contents > Properties > Symbology > Quantities (Graduated colors) > Classify… > Exclusion…
            1. "Mean Social Vulnerability" = [value]
        ii. Continue to distribute the remainder of the data, checking the map to determine the best breaks

I. Rank the data according to the chosen class distribution
    a. Right click layer in Table of Contents > Attribute Table
        i. Add Field > Name: EJ_Rank; Type: Short Integer
    b. Using Select by Attributes, give each class a rank
        i. Where *mean social vulnerability* <= [lower distribution value] AND *mean social vulnerability* >= [upper distribution value]
        ii. Show selected records
        iii. Right click field Rank > Field Calculator > Rank = 1-2 (reference the table below)
        iv. Repeat for all classes

J. Add a field to calculate the total rank (combine the EJSCREEN rank values and the Distressed Communities presence value)
    a. Add Field > Name: Tot_Rank; Type: Short
    b. Calculate Field: Distressed + EJ_Rank

K. Merge the final vector with the regional boundary to create values of 0 where there is no data

L. Convert new layer from vector to raster:
    a. Conversion Tools > To Raster > Polygon to Raster
        i. Value Field: Tot_Rank
        ii. Cell assignment type: Maximum Area
        iii. Priority field: Tot_Rank
        iv. Cell Size: 30

M. Shift raster
    a. Data Management > Projections and Transformations > Raster > Shift
        i. Input raster: Social Vulnerability raster
        ii. Shift X & Y coordinates by: 1 (each)
        iii. Input snap raster: *varies by region*

N. Clip raster to area of interest for further analysis

Percentile	EJSCREEN Value	Rank Value
<= 50th	≤0.574	1
50th - 90th	≤0.906	2

D.2 Create the Critical Infrastructure Input

A. Prepare data:
    a. Check to make sure points are in line with community maps and/or other sources. Move points in an edit session if necessary.
B. Buffer and Rank the point data after quality control:
    a. Buffer the facilities using the table below. These are the building "footprints".
        i. Geoprocessing > Buffer > Method: Planar
    b. Rank the buffered points
        i. Open attribute table > Add field > "Rank", Type:Short Integer
        ii. Right click new rank field > Calculate Field > Rank = '5'
    c. Merge the buffered feature layers to create a final building "footprints" layer
        i. Geoprocessing > Merge
C. Expand resulting feature to cover entire region to create values of 0 where there are no critical facilities on the landscape
    a. Merge facility feature classes with the regional boundary in the following order: boundary, parcel, footprint
        i. Geoprocessing > Merge
D. Convert merged layer from vector to raster:
    a. Conversion Tools > To Raster > Polygon to Raster
    b. Value Field: Rank
    c. Cell assignment type: Maximum Area
    d. Priority field: Rank
    e. Cell Size: 30
E. Shift raster
    a. Data Management > Projections and Transformations > Raster > Shift
    b. Shift X & Y coordinates by: 1 (each)
    c. Input snap raster: *varies by region*

Input	**Buffer Size** *(meters; method: planar; dissolve type: NONE)*
FM Transmission Towers	10
Water Distribution Points	20
Wastewater Treatment Plants	20
Power Plants	20
Microwave Towers	10
Petroleum Terminals	100
Petroleum Refineries	100
Landfills	20
Bulk Fuel Storage	20
Bridges	100

D.3 Create the Critical Facilities Input

A. Prepare the data:
    d. Check to make sure points are in line with community maps and/or other sources. Move points in an edit session if necessary.
B. Buffer and Rank the point data after quality control:
    a. Buffer the facilities using the table below. These are the building "footprints"
        i. Geoprocessing > Buffer > Method: Planar

Facility Type	**Buffer Amount**
Post Office	20m
Public Safety	30m
Medical, Schools, Fire Departments	50m

    b. Rank the buffered points
        i. Open attribute table > Add field > "Rank", Type:Short Integer
        ii. Right click new rank field > Calculate Field > Rank = '5'
    c. Merge the three layers to create a final building "footprints" layer
        i. Geoprocessing > Merge
C. Expand resulting feature to cover entire regional boundary to create values of 0 where there are no critical facilities on the landscape
    a. Merge facility feature classes with the regional boundary in the following order: boundary, parcel, footprint
        i. Geoprocessing > Merge
D. Convert merged layer from vector to raster:
    a. Conversion Tools > To Raster > Polygon to Raster

b. Value Field: Rank
c. Cell assignment type: Maximum Area
d. Priority field: Rank
e. Cell Size: *varies by region*

E. Shift raster
   a. Data Management > Projections and Transformations > Raster > Shift
   b. Shift X & Y coordinates by: 1 (each)
   c. Input snap raster: *varies by region*

D.4 Create the Critical Transportation Input

A. Download all input data and prepare data:
   a. Clip to region.
   b. Reproject, if necessary.
B. Prepare Roads and Rail datasets:
   a. After the initial data preparation, buffer both Roads and Rail
      i. Geoprocessing > Buffer
         1. Input: **Roads line features**
         2. Output: Roads buffered
         3. Distance: **20 meters**
         4. Side type: full
         5. End type: round
         6. Method: planar
         7. Dissolve type: none
      ii. Geoprocessing > Buffer
         1. Input: **Rail line features**
         2. Output: Rail lines buffered
         3. Distance: **10 meters**
         4. Side type: full
         5. End type: round
         6. Method: planar
         7. Dissolve type: none
   b. Add a rank field to both datasets and rank:
      i. Right click layer in table of contents > Open Attribute Table > Add Field
         1. Name: Rank
         2. Type: Short (or Long)
         3. Save the changes in the ribbon at top and close Fields View
      ii. Right click Rank field > Calculate Field
         1. Rank = 5
         2. Close the attribute table and repeat for the other dataset
C. Prepare Airport Runways dataset:
   a. Buffer airport runways dataset:
      i. Geoprocessing > Buffer
         1. Input: **Runways line features**
         2. Output: Runways buffered
         3. Distance: **30 meters**
         4. Side type: full
         5. End type: round
         6. Method: planar

7. Dissolve type: none

b. Add a rank field and rank:
    i. Right click layer in table of contents > Open Attribute Table > Add Field
        1. Name: Rank
        2. Type: Short (or Long)
        3. Save the changes in the ribbon at top and close Fields View
    ii. Right click Rank field > Calculate Field
        1. Rank = 5

D. Prepare Ferry Terminals, Ports, and Harbors dataset:
    a. Merge ferry terminals, ports, and harbors into a single dataset
    b. Buffer the combined dataset:
        i. Geoprocessing > Buffer
            1. Input: **Ferry terminals, ports, and harbors features**
            2. Output: Ferry terminals, ports, harbors buffered
            3. Distance: **100 meters**
                a. Side type: full
                b. End type: round
                c. Method: planar
                d. Dissolve type: none
    c. Add a rank field and rank:
        i. Right click layer in table of contents > Open Attribute Table > Add Field
            1. Name: Rank
            2. Type: Short (or Long)
            3. Save the changes in the ribbon at top and close Fields View
        ii. Right click Rank field > Calculate Field
            1. Rank = 5

E. Merge resulting features into one Transportation Infrastructure dataset.
    a. Geoprocessing > Merge
        i. Inputs: Rail, Roads, Runways, and Ferry Terminals, Ports, and Harbors.

F. Expand resulting merged features to cover the entire regional boundary to create values of 0 where there is no transportation infrastructure on the landscape
    a. Merge transportation feature class with the regional boundary:
        i. Geoprocessing > Merge
    b. If using a file geodatabase, ensure that any "NULL" values are changed to 0:
        i. In Attribute Table > Select by Attributes > Where Rank IS NULL
        ii. Right click Rank field > Calculate Field
            1. Rank = 0
        iii. Clear selected features

G. Convert merged layers from vector to raster:
    a. Conversion Tools > To Raster > Polygon to Raster
    b. Value Field: Rank
    c. Cell assignment type: Maximum Area
    d. Priority field: Rank
    e. Cell Size: 30

H. Shift raster
    a. Data Management > Projections and Transformations > Raster > Shift
    b. Shift X & Y coordinates by: 1 (each)
    c. Input snap raster: 30

D.5 Combining the Community Asset Input Variables

Similar to the Threat Index, the Community Asset Index is a composite dataset that brings multiple data layers together to identify areas of the landscape that contain densities of assets. The Community Asset Index was clipped to the shoreline boundary and 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 Alaska Community Asset Index.

Alaska Community Asset Index Distribution

Asset Index Break Value	0	1	2	3	4 - 5	6	7	8	9 - 11	12 - 18
Final Rank Value	1	2	3	4	5	6	7	8	9	10

E. 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 Alaska is shown below.

Alaska Community Exposure Index Distribution

Exposure Index Break Value	1	2	3	4	5	6	7 - 21	22 - 35	36 - 59	60 - 100
Final Rank Value	1	2	3	4	5	6	7	8	9	10

F. Detailed Methodology: Fish and Wildlife Index

The Terrestrial Index and the Aquatic Index were calculated as the sum of species distribution inputs for species shown in the species list for each index. Species distribution inputs came from multiple sources, including the Alaska Gap Analysis Project (for terrestrial vertebrates), designated Essential Fish Habitat, and the Anadromous Waters Catalog, among others (see Appendix B.3 and B.4). Species distribution inputs were summed inside species groups, and then the sum of distributions inside each species group was reclassified with a quantile distribution to be in the set {0, 1, 2, 3, 4}. In the reclassified species group raster, areas of primary habitat have the value 4, while all other areas have the value 0 (no species occupy that pixel) or 1, 2, 3, corresponding to low, medium, and high species richness occupying that pixel. See more detailed methods below for the definition of primary habitat in each index. The unclassified Terrestrial Index was then calculated as the sum of classified species groups rasters for terrestrial species groups and Important Bird Areas; the unclassified Aquatic Index was calculated as the sum of classified species groups rasters for aquatic species groups, including marine habitat classes such as kelp. Finally, each sub-index was reclassified using a quantile distribution and 10 classes to calculate the final Terrestrial or Aquatic Index.

F.1 Species Included in the Terrestrial Index

The following table provides a list of species included in the Terrestrial Index organized by taxonomic group. All species included are species of greatest conservation concern in the Alaska Wildlife Action Plan (ADFG 2015), species listed under the U.S. Endangered Species Act (denoted with asterisk), and/or additional subsistence resources with a minimum of 40 harvest records from 1990-2015.

Species of Greatest Conservation Concern

Birds

Raptors

Rough-legged hawk *(Buteo lagopus)*
Bald eagle *(Haliaeetus leucocephalus)*
Golden eagle *(Aquila chrysaetos canadensis)*
Gyrfalcon *(Falco rusticolus)*
Peregrine falcon *(Falco peregrinus)*
Boreal owl *(Aegolius funereus)*
Queen Charlotte goshawk (*Accipiter gentilis laingi*)
American kestrel *(Falco sparverius)*
Northern harrier *(Circus cyaneus)*
Short-eared owl *(Asio flammeus flammeus)*
Great gray owl *(Strix nebulosa)*
Northern hawk owl *(Surnia ulula)*
Western screech-owl *(Megascops kennicottii)*
Snowy owl *(Bubo scandiacus)*

Kingfishers and Woodpeckers

Hairy woodpecker *(Picoides villosus sitkensis)*
Downy woodpecker *(Picoides pubescens glacialis)*
Black-backed woodpecker (*Picoides acticus*)
Northern flicker *(Colaptes auratus luteus)*
Red-breasted sapsucker *(Sphyrapicus ruber)*
American three-toed woodpecker (*Picoides dorsalis*)

Swifts and Hummingbirds

Rufous hummingbird *(Selasphorus rufus)*
Black swift (*Cypseloides niger borealis*)

Larks, Crows, and Jays

Gray jay *(Perisoreus canadensis pacificus)*
Steller's jay *(Cyanocitta stelleri)*
Common raven *(Corvus corax kamtschaticus)*
Horned lark (*Eremophila alpestris arcticola*)

Nuthatches, Chickadees, and Swallows

Bank swallow *(Riparia riparia)*
Barn swallow *(Hirundo rustica)*
Tree swallow *(Tachycineta bicolor)*
Black-capped chickadee *(Poecile atricapillus)*
Chestnut-backed chickadee (*Poecile rufescens*)
Boreal chickadee (*Poecile hudsonicus*)
Gray-headed chickadee (*Poecile cincts lathami*)
Northern shrike (*Lanius excubitor*)

Kinglets, Creepers, Flycatchers, and Wrens

Ruby-crowned kinglet *(Regulus calendula grinnelli)*
Golden-crowned kinglet *(Regulus satrapa)*
Olive-sided flycatcher *(Contopus cooperi)*
Pacific wren *(Troglodytes pacificus)*
Alder flycatcher (*Empidonax alnorum*)
Western wood-pewee *(Contopus sordidulus)*
Brown creeper *(Certhia americana)*
Pacific-slope flycatcher *(Empidonax difficilis)*
Bluethroat *(Luscinia svecica)*
Northern wheatear *(Oenanthe oenanthe oenanthe)*

Thrushes

Swainson's thrush *(Catharus ustulatus)*
Hermit thrush *(Catharus guttatus)*
Varied thrush *(Ixoreus naevius)*

Waxwings, Pipits, and Warblers

Bohemian waxwing *(Bombycilla garrulus)*
Blackpoll warbler *(Setophaga striata)*
American pipit *(Anthus rubescens)*
Arctic warbler *(Phylloscopus borealis)*
Orange-crowned warbler *(Oreothlypis celata)*
MacGillivray's warbler *(Geothlypis tolmiei)*
Common yellowthroat *(Geothlypis trichas)*
Yellow warbler *(Dendroica petechia)*
Townsend's warbler *(Setophaga townsendi)*
American redstart *(Setophaga ruticilla)*
Wilson’s warbler (*Wilsonia pusilla*)

Longspurs, Buntings, and Sparrows

Lapland longspur *(Calcarius lapponicus alascensis)*
Smith's longspur *(Calcarius pictus)*
McKay's bunting *(Plectrophenax hyperboreus)*
Chipping sparrow *(Spizella passerina)*
Savannah sparrow *(Passerculus sandwichensis)*
Golden-crowned sparrow *(Zonotrichia atricapilla)*
White-crowned sparrow (*Zonotrichia leucophrys*)
Snow bunting *(Plectrophenax nivalis)*
American tree sparrow *(Spizella arborea)*
Lincoln's sparrow *(Melospiza lincolnii)*
Dark-eyed junco *(Junco hyemalis oreganus)*
Fox sparrow (*Passerella iliaca*)
Song sparrow (*Melospiza melodia)*
Aleutian song sparrow (*Melospiza melodia sanaka*)

Birds *(continued)*

Blackbirds, Finches, Crossbills, Grosbeaks, and Redpoll

Red-winged blackbird *(Agelaius phoeniceus)*
Rusty blackbird *(Euphagus carolinus carolinus)*
White-winged crossbill *(Loxia leucoptera)*
Pine siskin *(Spinus pinus)*
Common redpoll *(Acanthis flammea)*
Hoary redpoll (*Acanthis hornemanni*)
Pine grosbeak *(Pinicola enucleator flammula)*
Gray-crowned rosy finch (*Leucosticte tephrocotis*)

Ducks, Geese, and Swans

Trumpeter swan *(Cygnus buccinator)*
Emperor goose *(Chen canagica)*
Lesser scaup *(Aythya affinis)*
Common eider (Pacific population) *(Somateria mollissima)*
Steller's eider *(Polysticta stelleri)**
Aleutian cackling goose (*Branta hutchinsii leucopareia*)
Black scoter (*Melanitta americana*)
White-fronted goose (*Anser albifrons elgasi*)
Greater white-fronted goose (*Anser albifrons*)
Spectacled eider *(Somateria fischeri)**
King eider (W. Arctic) *(Somateria spectabilis)*
White-winged scoter *(Melanitta deglandi)*
Pacific black scoter *(Melanitta americana)*
Long-tailed duck *(Clangula hyemalis)*
Black brant (*Branta bernicla nigricans*)
Canada goose (*Branta canadensis occidentalis*)
Taverner's cackling goose (*Branta hutchinsii taverneri*)

Loons and Grebes

Yellow-billed loon *(Gavia adamsii)*
Arctic loon *(Gavia arctica)*
Red-throated loon (*Gavia stellata*)

Procellarids

Laysan albatross *(Phoebastria immutabilis)*
Black-footed albatross *(Phoebastria nigripes)*
Short-tailed albatross *(Phoebastria albatrus)**
Northern fulmar *(Fulmarus glacialis)*
Fork-tailed storm-petrel *(Hydrobates furcatus)*

Cormorants

Red-faced cormorant *(Phalacrocorax urile)*
Pelagic cormorant *(Phalacrocorax pelagicus)*

Oystercatchers and Plovers

Black oystercatcher *(Haematopus bachmani)*
American golden plover *(Pluvialis dominica)*
Pacific golden plover *(Pluvialis fulva)*
Black-bellied plover *(Pluvialis squatarola)*
Killdeer *(Charadrius vociferus)*

Sandpipers

Spotted sandpiper *(Actitis macularius)*
Upland sandpiper *(Bartramia longicauda)*
Whimbrel *(Numenius phaeopus hudsonicus)*
Bristle-thighed curlew *(Numenius tahitiensis)*
Eskimo curlew *(Numenius borealis)**
Bar-tailed godwit *(Limosa lapponica baueri)*
Hudsonian godwit *(Limosa haemastica)*
Marbled godwit *(Limosa fedoa beringea)*
Black turnstone *(Arenaria melanocephala)*
Red knot *(Calidris canutus roselaari)*
Red phalarope *(Phalaropus fulicarius)*
Long-billed dowitcher *(Limnodromus scolopaceus)*
Solitary sandpiper *(Tringa solitaria cinnomomea)*
Dunlin *(Calidris alpina)*
Sanderling *(Calidris alba)*
Rock sandpiper *(Calidris ptilocnemis)*
Wandering tattler *(Tringa incana)*
Pectoral sandpiper *(Calidris melanotos)*
Semipalmated sandpiper *(Calidris pusilla)*
Western sandpiper *(Calidris mauri)*
Short-billed dowitcher *(Limnodromus griseus caurinus)*
Lesser yellowlegs (*Tringa flavipes*)
Surfbird (*Calidris virgata*)
Buff-breasted sandpiper (*Calidris subruficollis*)

Auks

Crested auklet (*Aethia cristatella)*
Least auklet *(Aethia pusilla)*
Whiskered auklet *(Aethia pygmaea)*
Dovekie *(Alle alle)*
Kittlitz's murrelet *(Brachyramphus brevirostris)*
Marbled murrelet *(Brachyramphus marmoratus)*
Ancient murrelet *(Synthliboramphus antiquus antiquus)*
Pigeon guillemot *(Cepphus columba columba)*
Black guillemot *(Cepphus grylle)*
Thick-billed murre *(Uria lomvia arra)*
Common murre *(Uria aalge inornata)*
Tufted puffin *(Fratercula cirrhata)*
Horned puffin *(Fratercula corniculata)*
Parakeet auk (*Aethia psittacula*)
Cassin's auk (*Ptychoramphus aleuticus aleuticus*)

Birds *(continued)*

Gulls, Terns, and Jaegers

Black-legged kittiwake *(Rissa tridactyla)*
Red-legged kittiwake *(Rissa brevirostris)*
Mew gull *(Larus canus brachyrhynchus)*
Herring gull *(Larus smithsonianus)*
Glaucous-winged gull *(Larus glaucescens)*
Sabine's gull *(Xema sabini)*
Pomarine jaeger *(Stercorarius pomarinus)*
Long-tailed jaeger *(Stercorarius longicaudus)*
Aleutian tern *(Onychoprion aleuticus)*
Glaucous gull *(Larus hyperboreus)*

Amphibians

Roughskin newt *(Taricha granulosa)*
Western toad *(Anaxyrus boreas)*
Wood frog (*Lithobates sylvaticus*)
Northwestern salamander (*Ambystoma gracile*)
Long-toed salamander (*Ambystoma macrodactylum*)

Terrestrial Mammals

Hares and Pikas

Snowshoe hare *(Lepus americanus)*
Alaska hare *(Lepus othus)*
Collared pika *(Ochotona collaris)*

Bats

Keen's long-eared bat *(Myotis keenii)*
Little brown bat *(Myotis lucifugus)*
Long-legged myotis *(Myotis volans)*
California myotis *(Myotis californicus)*
Silver-haired bat *(Lasionycteris noctivagans)*

Felids and Canids

Arctic fox *(Vulpes lagopus)*
Alexander Archipelago wolf (*Canis lupus ligoni*)

Subsistence Species *(additional species not included above)*

Felids and Canids

Wolf *(Canis lupus)*
Red fox *(Vulpes vulpes)*
Coyote *(Canis latrans)*
Canadian lynx *(Lynx canadensis)*

Other Furbearers

American beaver *(Castor canadensis)*
Ermine *(Mustela erminea)*
Woodchuck *(Marmota monax)*
American marten *(Martes americana)*
American mink *(Neovison vison)*
Muskrat *(Ondatra zibethicus)*
North American porcupine *(Erethizon dorsatum)*
Least weasel *(Mustela nivalis)*
Wolverine *(Gulo gulo)*

Other Large Land Mammals

Caribou *(Rangifer tarandus)*
Dalls sheep *(Ovis dalli)*
Muskox *(Ovibos moschatus)*
Black bear *(Ursus americanus)*
Elk *(Cervus canadensis)*
Mountain goat *(Oreamnos americanus)*
Moose *(Alces americanus)*
Brown bear *(Ursus arctos)*

Pheasants and Grouse

Rock ptarmigan *(Lagopus muta)*
Ruffed grouse *(Bonasa umbellus)*
Sharp-tailed grouse *(Tympanuchus phasianellus)*
Spruce grouse *(Falcipennis canadensis)*
Willow ptarmigan *(Lagopus lagopus)*

Ducks, Geese, Swans

Canvasback *(Aythya valisineria)*
Common goldeneye *(Bucephala clangula)*
Common merganser *(Mergus merganser)*
Red-Breasted merganser *(Mergus serrator)*
American wigeon *(Anas americana)*
Bufflehead *(Bucephala albeola)*
Green-winged teal *(Anas crecca)*
Blue-winged teal *(Anas discors)*
Long-tailed duck *(Clangula hyemalis)*
Snow goose *(Chen caerulescens)*
Tundra swan *(Cygnus columbianus)*
Gadwall *(Anas strepera)*
Harlequin duck *(Histrionicus histrionicus)*
Mallard *(Anas platyrhynchos)*
Northern pintail *(Anas acuta)*
Northern shoveler *(Anas clypeata)*
Surf scoter *(Melanitta perspicillata)*

Sandpipers

Common snipe *(Gallinago gallinago)*

Terns

Arctic tern *(Sterna paradisaea)*

Cranes

Sandhill crane *(Grus canadensis)*

F.2 Calculating the Terrestrial Index

Process "Primary" habitat data

For Terrestrial Species, federally designated critical habitat is used to define primary habitat in the Assessment. Process as follows:

A. Select by attributes for the species or group of species desired
B. With species selected, clip to the regional boundary
C. Rank the clipped habitat dataset:
    a. Right click layer in Table of Contents > Attribute Table
    b. Add a field:
        i. Name: Rank; Type: short
        ii. Save the changes and close Fields view
    c. Right click Rank field > Calculate Field > Rank = 100
D. Merge the ranked habitat dataset to the regional boundary
E. Rasterize the merged habitat and regional boundary dataset

a. Tool: Polygon to Raster
    i. Input: merged habitat and regional boundary
    ii. Value field: rank
    iii. Cell assignment type: max area
    iv. Priority field: rank
    v. Cell Size: 30

Repeat for each individual species or group of species

Process the GAP distribution rasters

Note: this process will also be used for any marine mammals that have Alaska Gap Analysis Project *data available. Marine mammals will be included in the Aquatic Index (below).*

F. Select only where VALUE = 1 in the raw GAP rasters:
    a. Tool: Extract by Attributes
        i. Value *is equal to* 1
        ii. **Output: GAP_Rasters/Species_Name_GAP_Distribution.tif**
            1. *Note: Remember to add the ".tif" extension manually when the output file name is entered. The tool does not do this automatically as it does for vectors.*
        iii. Important: Be sure to set output coordinates in environments to WKID=3338 for Alaska

G. Change the output raster to vector:
    a. Tools: Raster to Polygon
        i. Field: Value
        ii. Uncheck simplify polygons
        iii. **Output: GAP_Vectors/Species_Name_GAP_Distribution** (shp)

H. Clip the output vector to the region:
    a. Tools: Clip
        i. Input: GAP Distribution vector
        ii. **Output: GAP_Vectors/Species_Name_GAP_Distribution_clip** (shp)

I. Merge the vector with the region:
    a. Tools: Merge
        i. Input: Clipped GAP Distribution Vector, 20-meter depth boundary
        ii. **Output: GAP_Vectors/Final/Species_Name_RegMerge** (shp)

J. Rasterize the newly merged distribution vector
    a. Tools: Polygon to Raster
        i. Input: merged vectors
        ii. Value Field: grid code
        iii. **Output: Raster_Inputs/Species_Name.tif**
            1. *Note: Remember to add the ".tif" extension manually when the output file name is entered. The tool does not do this automatically as it does for vectors.*
        iv. Cell Assignment: max area
        v. Priority field: grid code
        vi. Cell Size: 30

Process other distribution or range data (any other sources)

K. Clip the data to the region
    a. **Output: Species_Name_SOURCE_clip.shp**
    b. Important: Be sure to set the coordinate system in the processing environments to WKID=3338
L. Rank the data with a "1" to be added in:
    a. Add Field: Name: Rank; Type: Short
    b. Calculate Field: Rank = 1
M. Merge with the region
    a. **Output: Species_Name_SOURCE_RegMerge.shp**
N. Rasterize the output:
    a. Value Field: Rank
    b. **Output: Species_Name.tif**
    c. Cell Assignment: max area
    d. Priority field: rank
    e. Cell Size: 30

Combine species group data

At this point, any range, distribution, or primary habitat data identified for each species should be fully processed and ready for use. Use the raster calculator to add together raster data for each species group to create a single raster, excluding any "primary" habitat data. For example, a pixel that appears in the range/distribution maps for 10 individual species within a species group would have a value of 10. This summed raster is then reclassified into 4 classes. In Alaska, species groups for birds are subdivided into two larger groups: land birds and seabirds.

O. Use a quantile distribution and 4 classes, making sure that values of 0 remain 0 (in their own class). Reclassify using this distribution.
P. Use the raster calculator to add any primary habitat for the species group to the reclassified raster.
Q. Reclassify the output so that any values 0-3 retain their value while any values 100+ (i.e., primary habitat plus any overlapping species distribution or range data) become a 4. (If a species group does not have any critical habitat data, or "primary data" in this stage, PADUS and state-level data identifying managed wildlife areas will be used to incorporate secondary and tertiary habitat in the Fish and Wildlife Index calculation later.)

Important Bird Areas

These data are prepared similarly to other datasets:

R. Clip to the region, be sure to set the coordinates in the processing environments to 3338
S. Rank the clipped IBA data:
    a. Open Attribute Table > Add Field:
        i. Name: Rank; Type: short
        ii. Save and close Fields view
    b. Right click Rank field > Calculate Field > Rank = 1
T. Merge ranked IBA data with the regional boundary
U. Rasterize the merged IBA and regional boundary
    a. Tool: Polygon to Raster
        i. Input: merged IBA and regional boundary
        ii. Value field: rank

iii. Cell assignment type: max area
iv. Priority field: rank
v. Cell Size: 30

Species group rasters are added together with Important Bird Areas and then reclassified. The distribution for the Alaska Terrestrial Index is displayed below. The final rank value was determined using a quantile distribution and was then combined with the Aquatic Index to create the Fish and Wildlife Index.

Alaska Terrestrial Index Distribution

Terrestrial Index Break Value	0 - 1	2	3	4	5	6	7	8	9	10 - 13
Final Rank Value	1	2	3	4	5	6	7	8	9	10

F.3 Species Included in the Aquatic Index

The following table provides a list of species included in the Aquatic Index organized by taxonomic group. All species included are species of greatest conservation concern in the Alaska Wildlife Action Plan (ADFG 2015), species with designated Essential Fish Habitat, species also listed under the U.S. Endangered Species Act (denoted with asterisk), and/or additional subsistence resources with a minimum of 40 harvest records from 1990 - 2015.

Essential Fish Habitat

Fishery Management Plan[21] for Salmon Fisheries in the EEZ off Alaska

Pink salmon (*Oncorhynchus gorbuscha*)
Chum salmon (*Oncorhynchus keta*)
Coho salmon (*Oncorhynchus kisutch*)
Sockeye salmon (*Oncorhynchus nerka*)
Chinook salmon (*Oncorhynchus tshawytscha*)

Fishery Management Plan for Bering Sea/Aleutian Islands King & Tanner Crabs

Tanner crab (*Chionoecetes bairdi*)
Snow crab (*Chionoecetes opilio*)
Golden king crab (*Lithodes aequispinus*)
Red king crab (*Paralithodes camtschaticus*)
Blue king crab (*Paralithodes platypus*)

Fishery Management Plan for Fish Resources of the Arctic Management Area

Arctic cod (*Boreogadus saida*)
Saffron cod (*Eleginus gracilis*)
Snow crab (*Chionoecetes opilio*)

Fishery Management Plans for Groundfish (of the Gulf of Alaska and/or Bering Sea and Aleutian Islands Management Area)

Sablefish (*Anoplopoma fimbria*)
Walleye Pollock (*Gadus chalcogrammus*)
Pacific cod (*Gadus macrocephalus*)
Atka mackerel (*Pleurogrammus monopterygius*)
Kamchatka flounder (*Atheresthes evermanni*)
Arrowtooth flounder (*Atheresthes stomias*)
Rex sole (*Glyptocephalus zachirus*)
Flathead sole (*Hippoglossoides elassodon*)
Southern rock sole (*Lepidopsetta bilineata*)
Northern rock sole (*Lepidopsetta polyxystra*)
Yellowfin sole (*Limanda aspera*)
Dover sole (*Solea solea*)
Alaska plaice (*Pleuronectes quadrituberculatus*)
Greenland turbot (*Reinhardtius hippoglossoides*)
Shortspine thornyhead rockfish (*Sebastolobus alascanus*)
Longspine thornyhead rockfish (*Sebastolobus altivelis*)
Rougheye rockfish (*Sebastes aleutianus*)
Pacific Ocean perch (*Sebastes alutus*)
Redbanded rockfish (*Sebastes babcocki*)
Shortraker rockfish (*Sebastes borealis*)
Silvergray rockfish (*Sebastes brevispinis*)
Dark rockfish (*Sebastes ciliatus*)
Greenstriped rockfish (*Sebastes elongatus*)
Rosethorn rockfish (*Sebastes helvomaculatus*)
Quillback rockfish (*Sebastes maliger*)
Black rockfish (*Sebastes melanops*)
Blackspotted rockfish (*Sebastes melanostictus*)
Northern rockfish (*Sebastes polyspinis*)
Redstripe rockfish (*Sebastes proriger*)
Yelloweye rockfish (*Sebastes ruberrimus*)
Dusky rockfish (*Sebastes variabilis*)
Harlequin rockfish (*Sebastes variegatus*)
Pygmy rockfish (*Sebastes wilsoni*)
Sharpchin rockfish (*Sebastes zacentrus*)
Aleutian skate (*Bathyraja aleutica*)
Bering skate (*Bathyraja interrupta*)
Alaska skate (*Bathyraja parmifera*)
Mud skate (*Bathyraja taranetz*i)
Yellow Irish lord (*Hemilepidotus jordani*)
Bigmouth sculpin (*Hemitripterus bolini*)
Great sculpin (*Myoxocephalus polyacanthocephalus*)
Giant octopus (*Enteroctopus dofleini*)

[21] Alaska Management Area Fishery Management Plans: https://www.fisheries.noaa.gov/rules-and-announcements/plans-and-agreements?title=&management_area%5BAlaska%5D=Alaska&sort_by=title

Species of Greatest Conservation Concern

Fishes

Trout and Steelhead

Rainbow/steelhead trout (*Oncorhynchus mykiss*)
Coastal cutthroat trout (*Oncorhynchus clarki clarki*)
Lake trout (*Salvelinus namaycush*)

Pike, Char, and Grayling

Arctic grayling *(Thymallus arcticus)*
Dolly Varden (*Salvelinus malma*)
Arctic char (*Salvelinus alpinus*)
Northern pike (*Esox Lusius*)

Lamprey

Alaskan brook lamprey *(Lethenteron alaskense)*
Western river lamprey *(Lampetra ayresii)*
Arctic lamprey (*Lethenteron camtschatica*)
Pacific lamprey (*Entosphenus tridentate*)

Forage Fish

Pond smelt (*Hypomesus olidus*)
Surf smelt (*Hypomesus pretiosus*)
Rainbow smelt (*Osmerus mordax*)
Longfin smelt (*Spirinchus thaleichthys*)
Trout perch (*Percopsis omiscomaycus*)
Capelin (*Mallotus villosus*)
Eulachon (*Thaleichthys pacificus*)
Pacific herring (*Clupea pallasii*)
Pacific sand lance (*Ammodytes hexapterus*)

Cod and Mackerel

Pacific tomcod (*Microgadus proximus*)
Burbot (*Lota lota*)
Lingcod (*Ophiodon elongates*)

Whitefish, Blackfish, and Inconnu

Humpback whitefish (*Coregonus pidschian)*
Alaska blackfish (*Dallia pectoralis)*
Broad whitefish (*Cregonus nasus*)
Pygmy whitefish (*Prosopium coulterii*)
Round whitefish (*Prosopium cylindraceum*)
Inconnu *(Stenodus leucichthys)*
Least cisco (*Coregonus sardinella)*
Arctic cisco (*Coregonus autumnalis autumnalis*)
Bering cisco (*Coregonus laurettae*)
Least cisco (*Coregonus sardinella*)

Rockfish

Brown rockfish (*Sebastes auriculatus*)
Copper rockfish (*Sebastes caurinus*)
China rockfish (*Sebastes nebulosus*)
Bocaccio (*Sebastes paucispinis*)

Sharks

Salmon shark (*Lamna ditropis*)

Invertebrates

Abalone

Pinto abalone (*Haliotis kamtschatkana*)

Squid

Minimal armhook squid (*Berryteuthis anonychus*)
Giant Pacific octopus (*Enteroctopus dofleini*)

Marine Mammals

Otters

Sea otter (Northern) *(Enhydra lutris kenyoni)**

Walrus and Sea Lions

Pacific walrus *(Odobenus rosmarus)*
Steller sea lion, Western DPS *(Eumetopias jubatus)**
Northern fur seal *(Callorhinus ursinus)*

Seals

Bearded seal, Beringia DPS *(Erignathus barbatus nauticus)**
Ribbon seal *(Histriophoca fasciata)*
Arctic ringed seal *(Pusa hispida hispida)**
Spotted seal *(Phoca largha)*
Pacific harbor seal *(Phoca vitulina richardii)*

Baleen Whales

Gray whale, Eastern North Pacific DPS *(Eschrichtius robustus)**
Bowhead *(Balaena mysticetus)**
North Pacific right whale *(Eubalaena japonica)**
Humpback whale, Western North Pacific and Mexico DPS *(Megaptera novaeangliae)**

Toothed Whales

Killer whale *(Orcinus orca)*
Beluga whale, Cook Inlet DPS *(Delphinapterus leucas)**

Porpoises

Harbor porpoise *(Phocoena phocoena)*

Bears

Polar Bear *(Ursus maritimus)*

Subsistence Species *(additional species not included above)*

Crabs

Dungeness crab (*Metacarcinus magister*)

Cockles, Scallops, Clams, Mussels, and Abalone

Razor clam (*Siliqua patula*)
Cockle (*Clinocardium nuttalii*)
Blue mussel (*Mytilus trossulus*)

F.4 Calculating the Aquatic Index

Process Anadromous Waters Catalog data

A. Export each species from the Anadromous Water Catalog and clip to the Alaska Assessment regional boundary, remembering to change the coordinate system in the geoprocessing environments to 3338.
B. Do not sort the species by any lifestage, rather each species present receives a presence value (e.g., a species attributed as "present" and "spawning" for one stream or lake would only be counted once)
C. Buffer the streams data by 35 meters. This needs to be done so that the data for each species can be merged together
D. If there is data in the "lakes" and "streams" datasets for one species, merge the buffered streams and lakes datasets together to create one dataset for each species

Essential Fish Habitat

Species-specific EFH data serve as "primary" habitat for species of conservation concern within species groups. There are no Habitat Areas of Particular Concern within the 20-m depth boundary.

Process as follows:

A. Select by attributes for the species or group of species desired
B. With species selected, clip to the Alaska Assessment regional boundary
C. Rank the clipped EFH dataset:
    a. Right click layer in Table of Contents > Attribute Table
    b. Add a field:
        i. Name: Rank; Type: short
        ii. Save the changes and close Fields view
    c. Right click Rank field > Calculate Field > Rank = 10
D. Merge the ranked EFH dataset to the regional boundary
E. Rasterize the merged EFH and regional boundary dataset
    a. Tool: Polygon to Raster
        i. Input: merged EFH and regional boundary
        ii. Value field: rank
        iii. Cell assignment type: max area
        iv. Priority field: rank
        v. Cell Size: 30
F. Repeat for each individual species or group of species

Aquatic habitat data from Alaska ShoreZone

Alaska ShoreZone biobands data were used to generate nearshore marine habitat inputs. The "patchy/continuous" codes pertaining to each bioband listed below were used to identify areas of low or high coverage of the habitat class. Because these data are originally in polyline format, buffers were applied before converting to raster for inclusion in the aquatic index.

The habitat types, and their associated bioband codes, that were extracted from Alaska ShoreZone were: Dragon Kelp (ALF), Giant Kelp (MAC), Bull Kelp (NER), Eelgrass (ZOS), Surfgrass (SUR), Alaria (ALA), Soft Brown Kelp (SBR), Dark Brown Kelp (CHB), and Rockweed (FUC).

For each habitat type:

A. Select features with patchy or continuous cover of that habitat type from the Alaska ShoreZone data, using the field matching the bioband code
    a. Select by attributes where <bioband code> includes the values C,P
B. Buffer the selected features and export to a new layer
    a. Tool: Buffer
        i. Distance: 30m
C. Calculate rank value for each buffered line segment
    a. Right click layer in Table of Contents > Attribute Table
    b. Add a field:
        i. Name: Rank; Type: short
        ii. Save the changes and close Fields view
    c. Calculate the Rank field according to cover of the bioband:
        i. Where the bioband code has the value C (continuous), Rank = 2
        ii. Where the bioband code has the value P (patchy), Rank = 1
    d. Clip the ranked, buffered dataset to the Alaska Assessment regional boundary
    e. Merge the ranked, buffered dataset with the Alaska Assessment regional boundary
    f. Rasterize the merged habitat and regional boundary dataset
        i. Tool: Polygon to Raster
            1. Input: merged habitat and regional boundary
            2. Value field: rank
            3. Cell assignment type: max area
            4. Priority field: rank
            5. Cell Size: 30
    g. Repeat for each habitat type

Sum the rasters across habitat types into a single unclassified marine habitat raster. Classify this raster using a quantile distribution into the values {0, 1, 2, 3}, ensuring that pixels with value=0 keep this value. This will be included in the aquatic index as if it were a species group.

Combine Species Group Data

At this point, any range, distribution, or primary habitat data identified for each species should be fully processed and ready for use. Use the raster calculator to *add* together raster data for each species group to create a single raster. This will need to be reclassified.

A. If there is "primary" habitat involved and there are values of 10 or higher, reclass as follows:
    a. Values 0-3 remain the same
    b. Values 10+ should be reclassified to 4
B. If there is no primary habitat involved and there are values >3, reclass as follows:

a. Use a quantile distribution and 4 classes, making sure that values of 0 remain 0 (in their own class). Reclassify using this distribution.

Add the classified species groups rasters together, along with EFH for species not included in the SWAP (described below) to create an unclassed Aquatic Index.

Essential Fish Habitat for species not included in the Alaska Wildlife Action Plan

Calculate an index that represents the number of species with designated Essential Fish Habitat (EFH), for those species not included in the Alaska Wildlife Action Plan (ADFG 2015). This ensures that all designated EFH is reflected in the Aquatic Index.

C. Extract features from the EFH data for species not included in the SWAP, using the species name attribute
D. Generate a raster that gives, for each pixel, the number of species whose designated EFH includes that pixel. This is the EFH index.
E. Reclassify the EFH index into {0, 1, 2, 3} using a quantile distribution and ensuring that pixels with unclassed value of 0 retain that value.

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

Alaska Aquatic Index Distribution

Aquatic Index Break Value	0	1	2	3 - 5	6 - 8	9 - 10	11 - 14	15 - 20	21 - 23	24 - 29
Final Rank Value	1	2	3	4	5	6	7	8	9	10

F.5 Calculating the Fish and Wildlife Index

Protected and Managed Areas

In Alaska, protected and managed areas are not included as inputs to the Terrestrial Index or Aquatic Index, but rather calculated separately to add directly into the Fish and Wildlife Index because they are not distinctly aquatic or terrestrial, but likely serve both groups. They are prepared and added in when the Aquatic and Terrestrial Indices come together to create the Fish and Wildlife Index. The process for preparing both is the same, with the exception of a few selection steps at the beginning.

Protected Areas with a GAP status of 1 or 2 ("Secondary" and "Tertiary" habitat)

A. Using the Protected Areas Database (PADUS), extract areas with a GAP status of 1 or 2. The GAP Status Code is a measure of management intent to conserve biodiversity.
    a. Select by attributes where GAP Status Code = 1 or 2
        i. Status Code 1: an area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events are permitted to proceed without interference or are mimicked through management.
        ii. Status Code 2: an area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.
B. With the records selected, clip the dataset to the regional boundary. This will create a clipped output of only the selected features.
C. Remove State Critical Wildlife Areas from the clipped dataset:
    a. Select by attributes where Local Designation = State Critical Wildlife Area
    b. Delete the selected features and save the changes
D. Rank prepared data
    a. Open Attribute Table and add a Rank field:
        i. Name: Rank; Type: Short
        ii. Save changes and return to attribute table
    b. Right click Rank Field > Calculate Field > Rank = 1
E. Merge ranked data to the regional boundary
F. Rasterize the merged protected areas and regional boundary:
    a. Tool: Polygon to Raster
        i. Input: merged PADUS and regional boundary
        ii. Value field: rank
        iii. Cell assignment type: max area
        iv. Priority field: rank
        v. Cell Size: 30

State Critical Wildlife Areas

G. Clip the dataset to the regional boundary
H. Ranked the clipped data
    a. Open Attribute Table and add a Rank field:
        i. Name: Rank; Type: Short
        ii. Save changes and return to attribute table

b. Right click Rank field > Calculate Field > Rank = 1

I. Merge ranked wildlife areas to the regional boundary

J. Rasterize the merged wildlife areas and regional boundary:
   a. Tool: Polygon to Raster
      i. Input: merged wildlife areas and regional boundary
      ii. Value field: rank
      iii. Cell assignment type: max area
      iv. Priority field: rank
      v. Cell Size: 30

Below is the distribution for the Alaska Fish and Wildlife Index. The Terrestrial and Aquatic Indices were classified into ten classes before they were added together along with the protected and managed areas to create the Fish and Wildlife Index. Using a quantile distribution, the Fish and Wildlife Index was reclassified into ten classes to allow readers to more easily distinguish values.

Alaska Fish and Wildlife Index Distribution

Fish & Wildlife Index Break Values	2 - 4	5	6	7	8	9	10	11	12	13 - 21
Final Rank Value	1	2	3	4	5	6	7	8	9	10

G. Detailed Methodology: Resilience Hubs

G.1 Green Infrastructure

The generation of the Habitat Cores was conducted following the automated processes described in *Evaluating and Conserving Green Infrastructure Across the Landscape: A Practitioner's Guide*, by Karen Firehock (February 2015). For this Assessment, the scripts used to automate the processes were modified from the original toolbox, titled "Green Infrastructure Center Model for ArcGIS Desktop." Due to this automation, detailed steps for the development of Habitat Cores are not provided.

Once Habitat Cores are created, apply the Smooth geoprocessing procedure to the Habitat Cores, with a 100-meter threshold.

G.2 Selection of Habitat Cores nearest to Community Assets

As the Green Infrastructure process will result in many Habitat Cores throughout the entirety of the region, this step filters out those Cores that are too distant from Community Assets, which are expected to provide minimal benefit to resilience-building efforts. The Habitat and Riparian Cores that remain are those that are nearest to Community Assets, therefore providing the most potential benefit for resilience efforts.

A. Select all community assets (vector format) that make up the Community Asset Index
B. Apply a 5-km buffer to the selected assets
C. Select all Cores that spatially intersect with this 5-km buffer
D. Export the selected Cores as a new layer

G.3 Addition of Riparian Corridors and Shorelines

The National Hydrology Dataset (NHD) 'flowlines' feature class was used to identify riparian and shoreline Habitat Cores that would have otherwise been excluded from the analysis due to the size minimums and other topographical characteristics that are considered in the Green Infrastructure methodology. Process as follows:

E. Select coastline and urban NHD flowlines within a 5-kilometer (3.1-mile) buffer of any community asset and merge selections into a single feature class
    a. Clip NHD flowlines to a 5-kilometer (3.1-mile) buffer of any community asset to reduce the number of records in the dataset for the selection
    b. Select By Location NHD flowlines representing Alaska's coastline (FCode = 56600)
    c. Select By Location all streams and rivers within Alaska's most populated places (parts of greater Anchorage area and Juneau)
        i. Select U.S. Census Populated Places (a feature class representing incorporated places and U.S. Census Designated Places attributed with population size) where population class is greater than or equal to 6 (population >=10,000)
    d. Merge selections into a single feature class
F. Buffer merged coastal and urban riverine flowlines by a distance of 100 meters (Side Type = Full)
G. Dissolve buffered flowlines
H. Erase flowlines that already are covered by a Habitat Core and apply an inverse buffer to mimic Habitat Core fragmentation
    a. Use the Erase geoprocessing tool to erase smoothed Habitat Cores from the dissolved flowline buffers

   b. Apply an inverse buffer (-10 m, Side Type = Full) to the resulting features to create separation between Habitat Cores and flowline buffers
   c. Convert the resulting features to singlepart features using the Multipart to Singlepart geoprocessing tool

I. Calculate the area of each of the resulting singlepart features and filter out fragments
   a. Calculate Geometry Attributes for a new field (Area) where the Area Unit = Acres
   b. Select Layer by Attribute where Area is greater than or equal to 10 acres (10 acres was selected to match the minimum area of the Habitat Cores)
   c. Export resulting selection to a new feature class

J. Merge resulting exported selection with smoothed Habitat Cores

G.4 Creating a Hexagonal Grid

With the Habitat Cores merged with the riparian corridors and shorelines, a hexagonal grid is created to cover the regional extent:

K. "Create Grid" tool, and select "Hexagon" as the grid type

L. Set the grid extent to the shapefile that defines the region

M. Determine the parameters of the hexagon geometries
   a. 10-acres in area, or, where applicable, set horizontal and vertical spacing to 216.17-meters

N. Select hexagons that intersect Cores
   a. Select where the hexagonal features have their centroids contained within a Core (note that the hexagonal grid may have to be subdivided so geoprocessing that occurs in memory does not exceed available memory. For Alaska, the hexagonal grid was clipped to a 50-km buffered regional boundary to greatly reduce the number of hexagon features within the feature envelope but over open water and land outside of the regional boundary. The clipped hexagonal grid was then subdivided into individual feature classes with 500,000 features for geoprocessing, then merged back together into a single feature class)

O. Export selected hexagons as an individual "Grid" layer

G.5 Ranking Resilience Hubs

The following steps to score and rank are applicable to both the Habitat Cores and hexagonal grid:

P. Create a field "hub_id" and use the field calculator to generate a unique ID for each Core or "hex_id" for each hexagon.

Q. To calculate Fish & Wildlife Index scores, perform zonal statistics on the Cores and hexagons
   a. Use Cores as the input layer
   b. Select "Mean" as the statistic to calculate
   c. Select the Fish & Wildlife Index as the input raster
   d. Prepare a field "fw_mean" to contain mean scores
   e. Run zonal statistics
   f. "Fw_mean" now contains the Fish and Wildlife score for each Core and hexagon

R. Buffer the Cores or hexagonal grid by 1-km

S. To calculate Community Exposure Index scores, perform zonal statistics on the buffered Cores and hexagons
   a. Use buffered Cores or hexagons as the input layer
   b. Select "Mean" as the statistic to calculate
   c. Select the Community Exposure Index as the input raster

d. Prepare a field “expbuf_mean” to contain mean scores
e. Run zonal statistics
f. “expbuf_mean” now contains the Community Exposure Index score for each buffered Core or hexagon

T. Perform a spatial join to join the “expbuf_mean” scores from the buffered Cores or hexagons to the attribute table of the non-buffered Cores or hexagons
    a. Spatial join or “join attributes by field value,” set join parameter to “one-to-one”
    b. Input layer 1 = non-buffered Cores or hexagons, table field to join by = “hub_id”
    c. Input layer 2 = buffered Cores or hexagons, table field to join by = “hub_id”
    d. If applicable, select only the field “expbuf_mean” field to be joined to the non-buffered cores or hexagons. This will help keep a more manageable attribute table without duplicates.
    e. Save the resulting layer as “hubs_join.shp” (or equivalent “hex_join” feature class for the hexagonal grid. Note that the hexagonal grid will likely need to be stored in a file geodatabase or similar due to the large number of features)
    f. When complete, the non-buffered Cores or hexagons will contain the buffered Community Exposure Index scores in the field “expbuf_mean”

U. Hub Score is the product of the Fish and Wildlife mean and the Community Exposure mean for each Habitat Core or hexagon. Calculate the score of each Habitat Core or hexagon for layer “hubs_join”
    a. Add field “hub_score” (or equivalent “hex_score” for the hexagonal grid) to layer “hubs_join” (float field type) in the attribute table
    b. Using the field calculator, populate the field “hub_score” by multiplying the fields “fw_mean” by “expbuf_mean” (fw_mean * expbuf_mean). The result is the score of each Habitat Core or hexagon
    c. Remove the Habitat Cores or hexagons that have a score of 0 or NULL

V. Determine Hub Rank of layer “hubs_join”
    a. With layer “hubs_join,” add a field in the attribute table called “hub_rank” (integer field type)
    b. Using a quantile distribution, symbolize the values of field “hub_score” into 10 classes
    c. The first classification of score values (lowest values) will be Rank 1 hubs, whereas the last, or tenth classification of score values (highest), will be Rank 10 hubs Use the Field Calculator to apply a formula using the “case” and “when” expressions, or using Select By Attribute:
        i. Select by attribute the hubs that have a “hub_score” of the lowest, class 1 distribution
            1. Using the field calculator, and with class 1 hubs selected, calculate field “hub_rank” to a value of 1
        ii. Select by attribute the hubs that have a “hub_score” of the second-lowest, class 2 distribution
            1. Using the field calculator, and with class 2 hubs selected, calculate field “hub_rank” to a value of 2
        iii. Select by attribute the hubs that have a “hub_score” of the lowest, class 3 distribution
            1. Using the field calculator, and with class 3 hubs selected, calculate field “hub_rank” to a value of 3
        iv. Repeat this procedure until all 10 classes of “hub_score” have defined the values of “hub_rank”

v. The result is final ranked Resilience Hubs Cores

W. Apply Hub Rank distribution to the hexagonal grid to attribute ranking
   a. Remove the hexagonal grid features that have a “hex_score” of 0 or NULL
   b. Add a field “hex_rank” in the attribute table (integer field type)
   c. Use the same 10-class distribution limits that were used to create Hub Ranks to attribute ranks (“hex_rank”) to the hexagonal grid (the upper and lower values will likely need to be extended to the minimum and maximum hexagonal grid values as hexagonal grid zonal statistics were applied at a smaller scale than Habitat Cores)
   d. The result is the final ranked Resilience Hub Grid

Below is the distribution for the Alaska Resilience Hubs: Resilience Hub Cores and the finer-scale Resilience Hub Grid. The Resilience Hubs scores were classified into ten classes using a quantile distribution, and then reclassified into ten rank classes to allow readers to more easily distinguish values.

Alaska Resilience Hubs Distribution

Resilience Hubs Score Break Value	1 - 8.9	9 - 12.9	13 - 17.5	17.6 - 21.9	22 - 26.6	26.7 - 31.0	31.1 - 35.5	35.6 - 40.4	40.5 - 46.9	46.7 - 90.4
Final Rank Value	1	2	3	4	5	6	7	8	9	10

H. 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: one overview on October 5, and one each focused on fish and wildlife and community exposure on October 6, 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 that were invited to participate in the stakeholder review process.

Ahtna Intertribal Resource Commission
Alaska Association of Environmental Professionals
Alaska Beluga Whale Committee
Alaska Conservation Foundation
Alaska Department of Commerce, Community, and Economic Development, Division of Community and Regional Affairs
Alaska Department of Fish and Game, Division of Habitat
Alaska Department of Fish and Game, Division of Wildlife Conservation
Alaska Department of Military and Veterans Affairs, Division of Homeland Security and Emergency Management
Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys
Alaska Department of Natural Resources, Office of History and Archaeology
Alaska Eskimo Whaling Commission
Alaska Federation of Natives
Alaska Geospatial Council
Alaska Native Claims Settlement Act Regional Association
Alaska Native Science Commission
Alaska Native Tribal Health Consortium
Alaska Ocean Observing System
Alaska Sea Grant
Alaska Sea Otter and Steller Sea Lion Commission
Aleut Marine Mammal Commission
Aleutian Pribilof Islands Association
Aleutian Pribilof Islands Community Development Association
Arctic Slope Native Association
Association of Village Council of Presidents
Audubon Alaska
Bering Sea Elders Group
Bristol Bay Borough Planning Department
Bristol Bay Native Association
Central Council of the Tlingit and Haida Indian Tribes of Alaska
Chugachmiut
Cook Inlet Tribal Council
Cook Inletkeeper
Copper River Native Association
Denali Borough Planning Department
Denali Commission
Eskimo Walrus Commission
Eyak Preservation Council
Friends of Alaska National Wildlife Refuges
Haines Borough Planning Department
Indigenous People's Council for Marine Mammals
Inuit Circumpolar Council
Inupiat Community of the Arctic Slope
Juneau Borough Planning Department

Kawerak, Inc.
Kenai Peninsula Borough Planning Department
Kenai Watershed Forum
Ketchikan Gateway Borough Planning Department
Klawock Cooperative Association
Kodiak Area Native Association
Kodiak Island Borough Planning Department
Maniilaq Association
Matanuska-Susitna Borough Planning Department
NOAA National Marine Fisheries Service
NOAA National Weather Service
NOAA Office for Coastal Management
North Slope Borough Department of Wildlife Management
Orutsararmiut Native Council
Southeast Alaska Conservation Council
Tanana Chiefs Conference
The Alaska Center
The Nature Conservancy Alaska
Throwe Environmental
U.S. Arctic Research Commission
U.S. Army Corps of Engineers
U.S. Bureau of Land Management
U.S. Department of Agriculture
U.S. Environmental Protection Agency
U.S. Federal Emergency Management Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey
U.S. National Park Service
University of Alaska Anchorage, Alaska Center for Conservation Science
Yakutat Borough Planning Department