National Park Service

U.S. Department of the Interior

Natural Resource Stewardship and Science

San Juan Island National Historical Park

Natural Resource Condition Assessment

Natural Resource Report NPS/NRSS/WRD/NRR—xxxx

ON THE COVER
Looking east from the park, toward Lopez Island and Strait of Juan de Fuca. Photo by Peter Dunwiddie.

San Juan Island National Historical Park

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Natural Resource Report NPS/NRSS/WRD/NRR—xxx

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This report was prepared under Task Agreement P12AC15016 (Cooperative Agreement H8W07110001) between the National Park Service and Oregon State University

September 2015

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science

Fort Collins, Colorado

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Please cite this publication as:

Adamus, P. R., P. Dunwiddie, and A. Pakenham. 2015. San Juan Island National Historical Park Natural Resource Condition Assessment. Natural Resource Report NPS/NRSS/WRD/NRR—xxx. National Park Service, Fort Collins, Colorado.

NPS xxxx, date xxx

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Executive Summary

We compiled existing data and information to characterize the condition and trends in high priority natural resources in San Juan Island National Historical Park. This report, and the spatial datasets provided with it, is intended to inform and support park managers and scientists in developing recommendations for improving or maintaining natural resource conditions in the park. It also can assist park resource managers in meeting the reporting requirements of the Government Performance Results Act and Office of Management and Budget.

In attempts to describe the current condition and trends of the park's natural resources, we followed generally the U.S. Environmental Protection Agency's "Framework for Assessing and Reporting on Ecological Condition." Specifically, we first noted 10 natural resource themes which this park's managers and scientists, in a prior survey, considered to be most important:

1. Shoreline erosion
2. Hillslope erosion (rill & gullying)
3. Wetlands and riparian areas
4. Invasive species (plant and animal); Areas with evidence of invasive plant or animal species
5. Fire regimes
6. Native plant restoration
7. Areas of pristine or old-growth vegetation
8. Habitat and populations of focal species; Areas of focal species
9. Solitude and silence
10. Urban encroachment/rural development

These are a mix of resources (e.g., #3), processes (#1), stressors (e.g., #10), and conditions (e.g., #9). Consistent with the USEPA's framework for this type of environmental assessment, we sought to keep descriptions of the stressors separate from discussions of the resources, processes, and conditions. We did so by reorganizing the above list within the following framework:

Regional and Local Climate
Shoreline and Marine Resources (1, 8)
Freshwater Resources: Water Quantity, Quality (3, 10)
Terrestrial Vegetation and Land Cover (4, 5, 6, 7, 8)
Wildlife (4, 8)
Air Quality
Natural Quality of the Park Experience (10)

We identified 37 indicators to evaluate the condition and trend of these resources. For each indicator we then attempted to define reference conditions to which we could compare present conditions. When those could be identified and a comparison made, we described the condition of each indicator as "Good," "Somewhat Concerning," "Significant Concern," or "Unknown." We described each indicator's trend as "Improving," "Stable," "Declining," or "Unknown." In each instance where we applied these terms, we also described the certainty associated with our estimate as "High," "Medium," "Low," or as "Not Applicable" (N/A) where condition or trend are Unknown. Where reference conditions that were the basis for our comparisons lacked quantitative standards, we based the assessment on qualitative descriptions of least-altered

resource conditions derived from historical accounts, scientific literature, and professional opinion.

Applying the 37 indicators, we determined that the condition of the following indicators is presently of "Significant Concern" in this park:

- Prairies
- Rare Plant Taxa (*Castilleja levisecta, Ranunculus californicus* var. *californicus, Symphyotrichum hallii*)
- Composition, Age, and Structure of Forests
- Wildlife Associated with Prairie & Oak Woodlands
- Invasive or Harmful Wildlife

We assigned a rating of "Somewhat Concerning" to 16 indicators:

- Eelgrass
- Forage Fish
- Invasive Nearshore Species
- Groundwater Levels and Quality
- Wetland Biological Condition
- Oak Woodlands
- Coastal Strand, Spit, and Dune Communities
- Native Plant Richness and Invasive Plants
- *Crassula connata* (a rare plant)
- Forest Age and Composition
- Sensitive Birds
- Sensitive Mammals
- Habitat Connectivity and Structure
- Nitrogen & Sulfur Deposition
- Visibility & Viewsheds

Information was insufficient to rate the present condition of 16 indicators. With regard to **trends**, we found information was sufficient to rate the recent trends of only 3 of the 37 indicators. Those were Temperature Trends, Precipitation Trends, and Eelgrass.

Acknowledgments

National Park Service staff who helped guide this project or who provided key information included Marsha Davis (NPS Pacific West Regional Office, Seattle), Jerald Weaver (San Juan Island National Historical Park), Mark Huff (North Coast and Cascades Network, Ashford, WA), Regina Rochefort (North Cascades National Park Service Complex, Sedro-Woolley, WA), and Tonnie Cummings (NPS Pacific West Region, Vancouver, WA). We appreciate the earlier efforts made by a University of Washington team to begin preparing this NRCA. Flaxen Conway, director of the Marine Resource Management Program at Oregon State University, administered the project. Chris Chappell was an essential contributor to the vegetation chapter. Greg Jones coached us with the climate data analysis. Michael Ewald analyzed the climate data and conducted the GIS tasks.

1.0 NRCA Background

What is the current condition of natural resources in our nation's national parks? How has that condition changed in recent years? What might be the actual and potential causes of current and future change? This report, prepared under a National Park Service (NPS) agreement with Oregon State University, attempts to address these questions as they pertain to San Juan Island National Historical Park.

Addressing these questions is essential to the mission of the NPS. Thus, the NPS in 2003 initiated overview assessments of each of 270-plus parks which NPS deemed to have significant natural resources and related values. Those assessments, termed "Natural Resource Condition Assessments" (NRCAs), focus on compiling and interpreting existing data, and are intended to complement Inventory and Monitoring (I&M) programs and other efforts that feature the collection of new data. Both programs complement and help support each park's development of a Resource Stewardship Strategy (RSS)[1] and State of the Park Report, which focus instead on management targets and provides guidance on how to respond to and manage threats. NRCAs rely significantly on review and syntheses of existing data and maps, as contrasted with the NPS Vital Signs Program which mainly features the collection of new field data.

NRCAs evaluate current conditions for a subset of natural resources and resource indicators. NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting park resource conditions. They are meant to complement—not replace—traditional issue- and threat-based resource assessments. As distinguishing characteristics, NRCAs:

- are multi-disciplinary in scope;[2]
- employ hierarchic indicator frameworks;[3]

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[1] formerly called a Resource Management Plan (RMP).

[2] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[3] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

- identify or develop reference conditions/values for comparison against current conditions;[4]
- emphasize spatial evaluation of conditions and GIS (map) products;[5]
- summarize key findings by park areas; and[6]
- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as reporting influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day Issues Description that are best interpreted at park, watershed, or landscape scales (though NRCAs are not required to report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of Issues Description, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistic repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work; those data, methods, and reference values are designed to be appropriate for the stated purpose of the project, and are adequately documented. NRCAs can yield new insights about current park resource conditions but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision-making, planning, and partnership activities.

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[4] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management “triggers”).

[5] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[6] In addition to reporting on indicator-level conditions, NRCAs attempt to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks to report on government accountability measures.[8] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts. For more information on the NRCA program, visit http://nature.nps.gov/water/nrca/index.cfm

[7] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[8] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

2.0 Introduction and Resource Setting

Located in northern Washington State, San Juan Island National Historical Park (SAJH) is located on San Juan Island within the San Juan Archipelago, on the boundary between the United States and Canada (Figure 1). The Archipelago is a group of about 800 islands located south of Canada's Gulf Islands and 16 miles across Haro Strait, east of the city of Victoria at the south end of Vancouver Island, British Columbia.

2.1.1 Enabling Legislation

Congress established the park in 1966, authorizing the NPS to acquire property on San Juan Island, "necessary for the purpose of interpreting and preserving the sites of the American and English Camps on the island, and of commemorating the historic events that occurred from 1852-1871 on the island in connection with the final settlement of the Oregon Territory boundary dispute, including the so-called Pig War of 1859" (80 Stat. 737). Thus, management of the park focuses mainly on historic preservation and interpretation.

2.1.2 Geographic Setting

Two spatially discrete units comprise the park: American Camp (1223 acres) on the southeastern end of San Juan Island, and English Camp (923 acres, including Mitchell Hill and Westcott Bay additions). The units are 8.6 miles apart. The park's total of 2384 acres comprises 7% of San Juan Island's land area, and an additional 8% of the island is protected by state and county parks and lands owned by the San Juan County Land Trust, San Juan Preservation Trust, State of Washington Lands Division, and the University of Washington. Together with the park, these protect 24% of the land area within the San Juan Archipelago (Adamus 2011a).

The park encompasses 6.1 miles of marine shoreline (8% of the San Juan Island total) at the junction of the Straits of Georgia and San de Fuca, north of Puget Sound. Like the other islands, San Juan Island is accessible only by boat (including a state-run ferry) or airplane. Its land area is 55 square miles and the population is 6822, yielding a population density of only 124 persons per square mile (2000 census). Two areas of commercial activity and settlement are Friday Harbor (4.3 miles north of American Camp) and Roche Harbor (1 mile north of English Camp). As of 2010, San Juan Island had 110 miles of public roads and 134 miles of private roads, for a total road density of 4.43 road miles per square mile.

Figure 1. Regional context of San Juan Island National Historical Park.

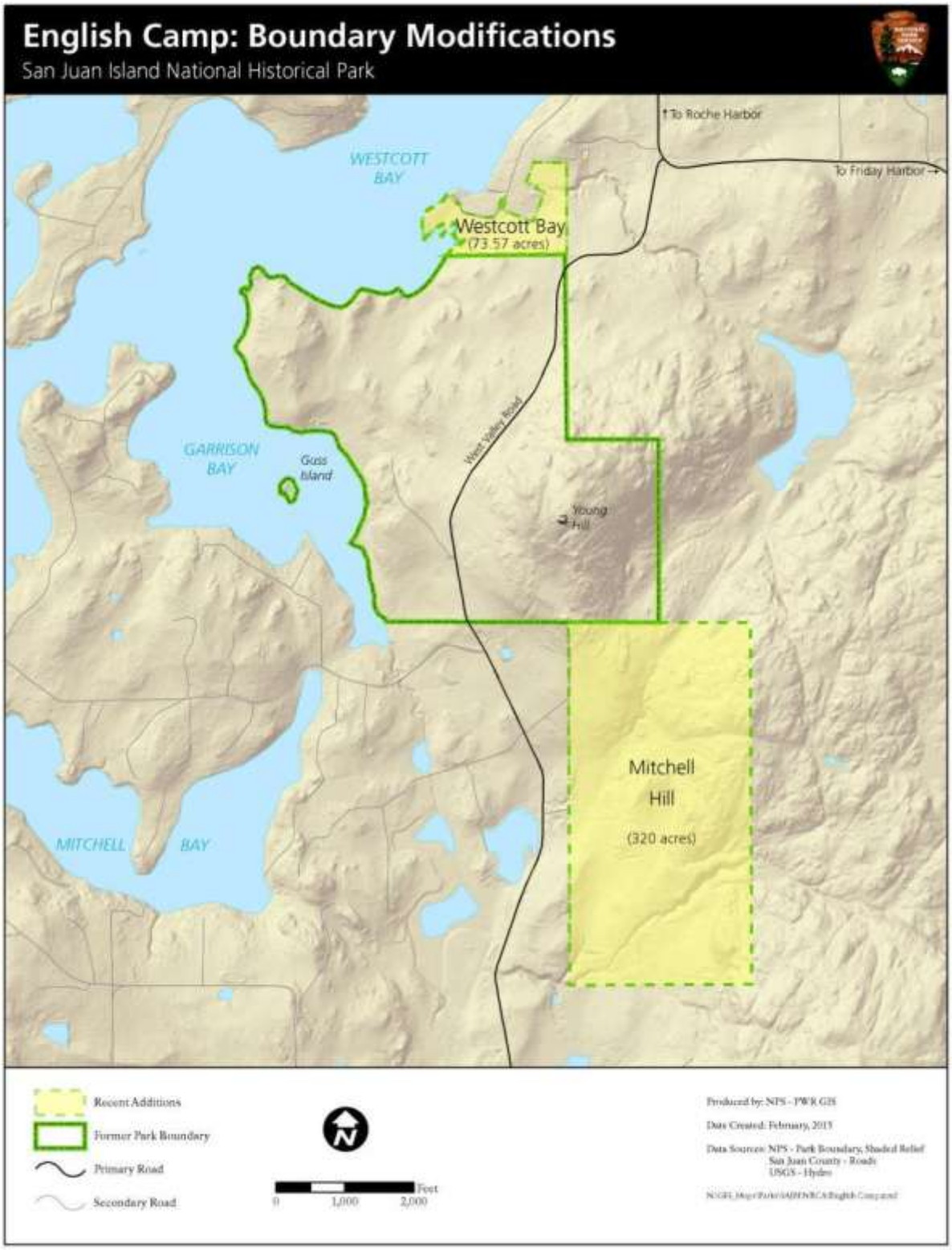

Figure 2. English Camp unit showing recent addition of Mitchell Hill and Westcott Bay.

Archeological excavations of prehistoric sites in the San Juan Islands, including two in American Camp, provide evidence that humans were active in the islands throughout the Holocene (NPS 2008). In the past century, the economic base in the San Juan Islands was built from agriculture, mining, fishing and shellfish aquaculture. Remoteness and limited accessibility kept the numbers of residents and visitors low for several decades. More recently, seasonal tourism, vacation-residency, and retirement residency have become increasingly popular. These and the construction trade that accompanies them account for a major fraction of the local economy. Concomitantly, mining has ceased and farms on the islands have had challenges competing with mainland farms with access to larger markets. Declines in salmon and other fish stocks and changes in fisheries regulations have sharply reduced commercial fishing in the vicinity of the park.

2.1.3 Visitation Statistics

During the past 20 years (1994-2013), an average of 252,189 recreational visitors came to the park annually. Among most of those years the number of visitors has shown no trend (**Figure 3**). In 2013, there were 220,960 recreational visitors, spending a total of 13,863 recreation visitor days.

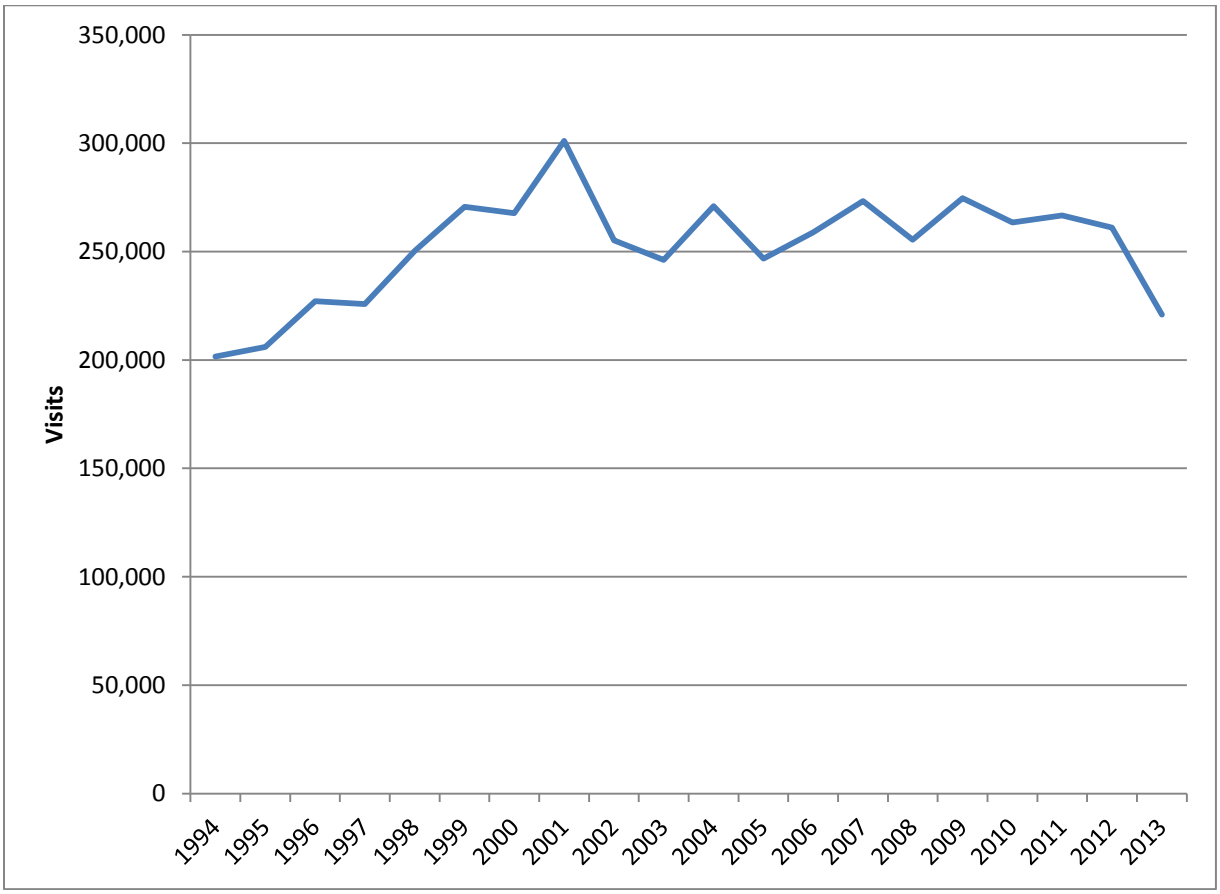

Figure 3. Recreational visits to the park, 1994 to 2013.

From: https://irma.nps.gov/Stats/Reports/National

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

The park is in an ecoregion known as the Puget Lowland (sometimes referred to as Puget Trough). It is also part of a region called the Salish Sea, which includes Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia. Marine scientists also refer to the area within which the park exists as the Georgia Basin, and the park falls within Water Resource Inventory Area (WRIA) 2 as recognized by Washington State natural resource agencies.

Both of the park's units are entirely within the USGS Hydrologic Unit Code (HUC12) subbasin 171100030500. The park's limited water resources comprise the headwaters of very small low-elevation watersheds that drain almost immediately into marine waters. Given their 8-mile spatial separation and nearly equal elevation, no fresh water flows between the American Camp and English Camp units.

2.2.2 Resource Descriptions

The landscapes of the two park units—American Camp and English Camp—differ noticeably. American Camp is mainly a rolling, windswept prairie with spectacular views of vast expanses of marine water in most directions. Located on a peninsula of San Juan Island at the intersection of the Strait of Juan de Fuca and the Strait of Georgia, the south-facing marine waters at American Camp are well flushed by the strong tidal currents and ocean swell of the Haro Strait, while waters on the north side of its peninsula adjoin Griffin Bay, also characterized by strong tidal currents but with less ocean swell. The waters of English Camp are much more sheltered and are within parts of Westcott and Garrison Bays.

The park has three naturally-formed lagoons, coastal ponds that receive tidal water only infrequently. Lagoons are recognized by the Washington Department of Ecology as a particularly important natural feature due to unique geochemistry and relative scarcity in Puget Sound. The park's lagoons are the only ones on San Juan Island. Eelgrass and kelp—critical habitats for salmon and many other species—line the nearshore marine area in much of the park. Chinook and other salmon, as well as the forage fish that support them, regularly use the park's shoreline. Pink salmon and surf smelt use the park's shoreline along Griffin Bay more heavily than most other parts of the San Juan Island shoreline. Shellfishing for clams and crabs occurs in Westcott and Garrison Bays, including on NPS property. Abalone, a shellfish whose populations have declined so much that harvesting in the region is now prohibited, is present in the vicinity of both American Camp and English Camp. In the inside waters of Washington, abalone is currently found only in the San Juan Islands and the Strait of Juan de Fuca (Dethier et al. 2006).

The open landscape at American Camp transitions into forest before extending to the top of Mount Finlayson at 290 feet. In contrast, English Camp, aside from open areas surrounding historic settlements, is mainly forest and oak woodland. Topography is flat or gently sloping near the historical settlements, but rises sharply eastward to the top of Young Hill (elevation 650 feet). The highest elevation on San Juan Island is 1075 feet.

The park is within an area that historically included a mix of lowland conifer forest, extensive dry and wet prairies, coastal bluffs, and beach/strand habitats. Prairies that once covered many

areas of the region, but now are rapidly disappearing, are a key feature of American Camp. Oregon white oak woodland, which also is declining regionally, is a notable feature of the English Camp. Considering the relatively small size of the park, its flora is exceptionally diverse. Rochefort and Bivin (2010) reported a total of 400 species in the park, which represents about 60% of the approximately 684 species recorded for San Juan Island as a whole. Most of the park's plant species are found in similar mainland habitats. Of the many plant species occurring in or near the park, one—the prairie-dwelling *Castilleja levisecta* (golden paintbrush)—has only 12 naturally-occurring populations in the world, and five of these occur within the San Juan and Gulf Islands. The park also supports 25 vegetation associations which the Washington Natural Heritage Program considers to be "Imperiled" or "Critically Imperiled" within Washington or globally.

Only one bird species that is regularly present in the park is currently listed federally as Threatened or Endangered. That is the marbled murrelet, which does not nest in the park (due to lack of old-growth forest which they require), but feeds regularly in marine waters adjoining both units of the park. Larger numbers (up to 100 individuals) occur in Griffin Bay adjoining American Camp than elsewhere in the park. Marine waters of the San Juan Archipelago contain perhaps the highest concentrations of this species in the Pacific Northwest. The San Juan Islands also support the highest nesting densities of bald eagle and peregrine falcon in the Pacific Northwest--(at least 122 bald eagle nesting territories and 20 peregrine falcon territories—and bald eagles nest within the park. In addition, anecdotal evidence suggests that San Juan County (not the park) is believed to support the largest or only populations or densities in the Puget Sound region, the Pacific Northwest, or the entire United States of at least three species: black oystercatcher, vesper sparrow (Oregon subspecies, breeding), and sharp-tailed snake.

Despite the park comprising less than 5% of the land area of San Juan Island, there are only 12 bird species that have been recorded elsewhere on San Juan Island but which have never, to our knowledge, been recorded in the park itself. Of 209 bird species whose records could be traced specifically to either American Camp or English Camp, 199 (95%) have been recorded at American Camp and 114 (55%) from English Camp. The apparently richer avifauna at American Camp is likely due to its greater variety of habitats, longer shoreline, and more visitors (i.e., more people observing and reporting what they see). The amphibian, reptile, and mammal fauna of the park appears to be naturally less species-rich than mainland areas of similar size and land cover. Nonetheless, as development of San Juan Island continues, the park will serve an increasingly important role as a refugium and core source area for maintaining local wildlife diversity. The park also features relatively good air quality, opportunities for quiet and solitude, remarkable vistas, and hiking, whale-watching, and other low-intensity outdoor activities.

2.2.3 Resource Issues Overview

Before the park was established, a significant part had been logged, grazed, and/or farmed. Although those activities severely altered the vegetation, substantial recovery has occurred and continues, aided by modest restoration efforts.

In places, the park's vegetation and soils have been impacted by the introduced European rabbit. The rabbit was first documented on San Juan Island in 1929, and by the late 1920s and early 1930s the rabbit population had increased dramatically on San Juan Island, especially within the American Camp unit of the park. In some years, rabbits have inhabited over 1000 acres of the

prairie at American Camp and adjoining areas. Population size has been monitored since the early 1970s, and has fluctuated since that time. The population is currently at a moderate to low level compared to most of the past years, but still threatens rare vegetation communities of the beach strand and prairie. Several invasive plant species also have reduced the diversity of native prairie, wetland, and woodland plant communities within the park. The unique flora and fauna of the park's prairie and oak woodlands depends on regular fires to set back succession, but decades of fire suppression have allowed other habitat types to become more dominant.

Although relatively little surface water drains into the park and most areas that immediately adjoin the park are managed for conservation, the quality and quality of the park's limited water is vulnerable. Because of the proximity to marine waters, local geology, and the fact that well yields in and near the park are already low, the greatest water resource concern is intrusion of saltwater into groundwater used for drinking. Withdrawal of groundwater by residences directly east of American Camp has the potential to endanger the availability and quality of groundwater and surface water within the park, especially if compounded by longer droughts that might be associated with regional climate change. The rate of groundwater withdrawal by these residences that would be sustainable and not threaten park resources is unknown.

Several factors that are beyond the control of park managers may also threaten park resources. Seabirds, marine mammals, and a host of other marine life along the park's shorelines are facing threats from ocean warming and acidification, as well as persistent contaminants, abandoned fishing nets and plastic microparticles, excessive nutrients, and changing sea levels. Just 12 miles westward across Haro Strait, Victoria is the only major Pacific Coast city north of San Diego without any effective sewage treatment. It currently pumps most of its wastes directly into marine waters. While organic parts of the sewage decompose rapidly in the oxygen-rich waters of Haro Strait which separate Victoria from the park, many substances in household wastewater probably do not. These include pharmaceuticals, heavy metals, hormone-disrupting chemicals, and others that can enter marine food chains and impair reproduction of marine seabirds and marine mammals.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

The park has completed its General Management Plan (NPS 2008) as well as a Fire Management Plan (Rankin 2005). These documents provide park staff with guidance for decisions regarding management of natural and cultural resources, visitation, and development for the next 15 to 20 years. A primary natural resource goal is “restoring the native vegetation without compromising the historic landscape.”

2.3.2 Status of Supporting Science

The park is included in the NPS Inventory and Monitoring (I&M) Vital Signs Program. The foundation document for that program (Weber et al. 2009) lists the following monitoring objectives for this park's prairie and coastal vegetation:

1. Document the location of the forest/prairie interface at ten year intervals.
2. Track changes in the density of trees and shrubs in prairies of American Camp.
3. Determine long-term trends in distribution and abundance of native and exotic plant species.

4. Determine long-term trends in species cover of native and exotic plant species in the native prairie remnants.
5. Determine short-term trends in germination, survival and cover of native species seeded into restored areas.
6. Determine short-term trends in survival and growth of transplanted native grasses in restored areas.
7. Determine long-term trends in plant species cover in restored areas to evaluate how similar restored areas are to native reference communities.

To date, a relatively comprehensive inventory of the park's flora has been completed (Rochefort and Bivin 2005) as well as detailed mapping of vegetation associations (Rocchio et al. 2012). Vegetation response to controlled burns and invasive plant control efforts has been monitored to varying degrees. Landbirds have been monitored along standard transects for over five years as reported by Siegel et al. (2006, 2007, 2008, 2009), Wilkerson et al. (2010), and Holmgren et al. (2011, 2012, 2013). Preliminary surveys have been conducted of intertidal fish (Fradkin 2004, Beamer and Fresh 2012), amphibians, and bats. No systematic surveys have been conducted of intertidal invertebrates, seaweeds, seagrasses, marine birds, marine mammals, terrestrial mammals, reptiles, or butterflies and other terrestrial invertebrates. Monitoring of visibility, air quality, and water quality and quantity has been very limited, and there has been no systematic monitoring of dark night sky or the park's soundscape.

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3.0 Study Scoping, Design, and Implementation

3.1 Project Responsibilities

This is one of two NRCA reports prepared under this contract with the National Park Service. The other report pertains to Ebey's Landing National Historical Reserve. Both projects were led by Dr. Paul Adamus, ecologist, Oregon State University. The vegetation chapters were written by Peter Dunwiddie, the air quality chapters by Tonnie Cummings, and the climate change chapters by Paul Adamus and Anna Pakenham with data analysis support from Michael Ewald. The remainder was written by Paul Adamus with GIS support from Michael Ewald.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

An ecological indicator is any measurable attribute that provides insights into the state of the environment and provides information beyond its own measurement (Noon 2003). Indicators are usually surrogates for properties or system responses that are too difficult or costly to measure directly. Indicators differ from estimators in that functional relationships between the indicator and the various ecological attributes are generally unknown (McKelvey and Pearson 2001). Not all indicators are equally informative—one of the key challenges of an NRCA is to select those attributes whose values (or trends) provide insights into ecological integrity at the scale of the ecosystem.

We reviewed and considered several frameworks for organizing our NRCA effort. We decided to follow generally the Environmental Protection Agency's "Framework for Assessing and Reporting on Ecological Condition" (Young and Sanzone 2002). Specifically, for each priority resource we identified multiple *indicators* of resource condition and defined reference conditions that could be used as a basis for assessing these. In developing the list of indicators and specific measures, we considered the idealized guidance of Harwell et al. (1999): "Useful indicators need to be understandable to multiple audiences, including scientists, policy makers, managers, and the public; they need to show status and/or condition over time; and there should be a clear, transparent scientific basis for the assigned condition."

In 2005, the NPS North Cascades Network's Vital Signs program (Weber et al. 2009) identified the following as important natural resource concerns at this park:

- Effects of European rabbits on vegetation and soil properties
- Restoration of prairies
- Exotic plants
- Visitor use impacts
- Development around Park
- Global climate change
- Oil spills and other catastrophic anthropogenic events

More recently, natural resource issues in the park had been prioritized by the park's staff, using a structured input process. In no particular order, the 10 "focal themes" that were ranked highest (3

on a scale of 0 to 3) from a much longer list of themes considered potentially applicable to parks in this region were:

1. Shoreline erosion
2. Hillslope erosion (rill & gullying)
3. Wetlands & riparian areas
4. Invasive species (plant and animal); Areas with evidence of invasive plant or animal species
5. Fire regimes
6. Native plant restoration
7. Areas of pristine or old-growth vegetation
8. Habitat and populations of focal species; Areas of focal species
9. Solitude and silence
10. Urban encroachment/rural development

These are a mix of resources (e.g., #3), processes (#1), stressors (e.g., #10), and conditions (e.g., #9). Following the advice of Young and Sanzone (2002), we sought to separate these different topics by type, and added other topics considered important by the park's staff. We did so by describing them within the following framework:

Regional and Local Climate
Shoreline and Marine Resources (1, 8)
Freshwater Resources: Water Quantity, Quality (3, 10)
Terrestrial Vegetation and Land Cover (4, 5, 6, 7, 8)
Wildlife (4, 8)
Air Quality
the Natural Quality of the Park Experience (10)

3.2.2 Reporting Areas

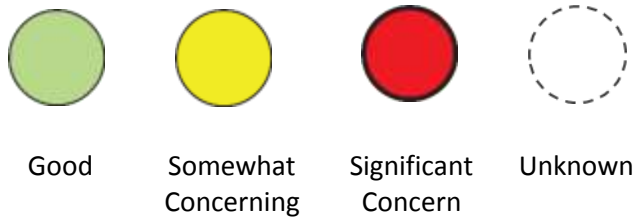
This park does not have large conventional watersheds due to its small size, relatively low topographic relief, and adjacency to marine waters. Therefore, as reporting areas we chose the two park units (American Camp, English Camp) and major habitats (intertidal and nearshore marine waters, prairies, and forest). However, in most cases the information available was sufficient only to attempt a rating for the entire park rather than for these individual units.

3.2.3 General Approach and Methods

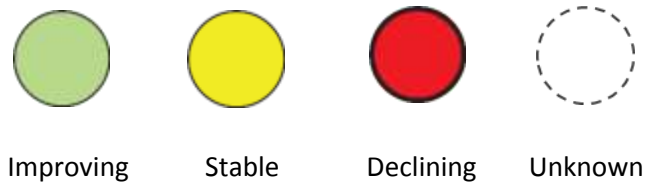
We identified indicators to evaluate the resource concerns listed at the end of section 3.2.1 above. We did so in part by considering indicators identified through the North Coast and Cascades Network's Vital Signs planning process. For each indicator, we attempted to define reference conditions to which we could compare present conditions. A reference condition may be a historical condition (e.g., pre-settlement land cover), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal or objective (e.g., 90% control of an invasive species for at least ten years). In this project, we mostly used pre-settlement historical conditions as best we could determine or hypothesize them.

Making comparisons with those reference conditions, we sought to describe resource condition and trends, along with an estimate of certainty of each, and then attempted to rate these as follows:

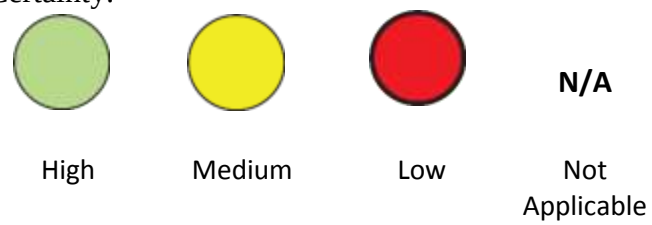
Condition:



Trend:



Certainty:



"Not Applicable" is applied to Certainty where Condition or Trend is Unknown.

We defined these terms in the context of each specific resource or issue we evaluated. Higher priority was assigned to reviewing data (a) for indicators that are anticipated to be most sensitive to the priority resource issues, and/or (b) collected according to a standardized protocol, and/or (c) from multiple years (the farther apart the better), and/or (d) from many locations within the park. We assessed most indicators at the unit or park scale, although connections to regional conditions were noted where supported by previously published or our own analyses. Depending on the indicator being examined, we used either San Juan Island or San Juan County as the frame of reference for these comparisons.

In order to select an appropriate rating, we mainly consulted published reports and analyzed existing data, but we also relied on our own prior experience in these parks studying their natural resources. The assessments began in November 2012 with a scoping workshop that included the Oregon State University study team, members of the NPS Project Oversight Committee[9], and other scientists from the two parks. Held at the Ebey's Landing Historical Reserve on nearby Whidbey Island, Washington, the session included a discussion of NRCA objectives as well as report outlines and potential data sources for this particular document. Then the team traveled to

[9] Mignonne Bivin, John Boetsch, Tonnie Cummings, Marsha Davis, Erv Gasser, Craig Holmquist, Karen Kopper, Robert Kuntz, Mike Larrabee, Allen McCoy, Todd Neel, Ashley Rawhouser, Regina Rochefort, Jon Riedel, Lee Taylor, Catharine Thompson, Jerald Weaver

San Juan Island National Historical Park and discussed issues at both the American Camp and English Camp units.

To identify relevant documents for review, we began with a retrieval from the NPS bibliographic database (IRMA, Integrated Resource Management Applications). We augmented that database using online search engines (Web of Science, Google Scholar) to identify newer publications as well as locating relevant documents pertaining to the region surrounding the park, searching with phrases such as "San Juan County," "Salish Sea," and "Georgia Strait." We obtained complete digital copies (PDFs) of many publications that reported relevant research results from the park and surrounding region. We then indexed all digital documents in an Excel spreadsheet so they could be sorted by topic and year, and prioritized them for review.

When writing this report, we organized it according to the following major sections because they follow closely the key resource concerns faced by San Juan Island National Historical Park. These are:

4.1 Regional and Local Climate
4.2 Nearshore Resources
4.3 Freshwater Resources
4.4 Terrestrial Vegetation and Land Cover
4.5 Wildlife
4.6 Air Quality
4.7 the Natural Quality of the Park Experience

Within each of the above sections, each concern is described using the following structure:

- Background
- Regional Context
- Issue Description
- Data and Methods (including sources of expertise)
- Criteria
- Condition, Trends, and Level of Certainty
- Data Gaps
- Literature Cited

3.3 Literature Cited

Harwell M. A., V. M., T. Young, A. Bartuska , N. Gassman, J. L. Gentile, C. C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini. 1999. A framework for an ecosystem integrity report card. Bioscience 49:543-556.

McKelvey, K. and D. Pearson. 2001. Population estimation with sparse data: The role of estimators versus indices revisited. Canadian Journal of Zoology 79:1754-1765.

Noon, B. 2003. Conceptual issues in monitoring ecological resources. Pages 27-72 *in* D. Busch, and J. Trexler, editor. Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, D. C.

Weber, S., A. Woodward, and J. Freilich. 2009. North Coast and Cascades network vital signs monitoring report (2005). Natural Resource Report NPS/NCCN/NRR—2009/098. National Park Service, Fort Collins, CO.

Young, T. F. and S. Sanzone. 2002. A framework for assessing and reporting on ecological condition. EPA-SAB-EPEC-02-009. U. S. Environmental Protection Agency, Science Advisory Board, Washington, DC. http://www.epa.gov/sab/pdf/epec02009.pdf

Chapter 4. Natural Resource Conditions and Trends

4.1 Regional and Local Climate

Indicator:	Condition	Certainty of Condition	Trend	Certainty of Trend
Temperature	unknown	N/A	significant concern	high
Precipitation	unknown	N/A	significant concern	high

4.1.1 Background

Temperature profoundly influences the metabolism and survival of all species, as well evaporation and the rate and type of geochemical functions in soil and water, fire regimes, and the strength and direction of marine currents. Precipitation is essential for sustaining water table levels, intermittent streams, and wetlands, and thus all vegetation and wildlife. **Figure 4** through **Figure 6** depict monthly conditions of temperature and precipitation in the two units of the park based on data from 1971 to 2000. Little or nothing can be done within the park to measurably affect global, regional, and local climate. However, improved knowledge of past, present, and anticipated future changes can help resource planning efforts.

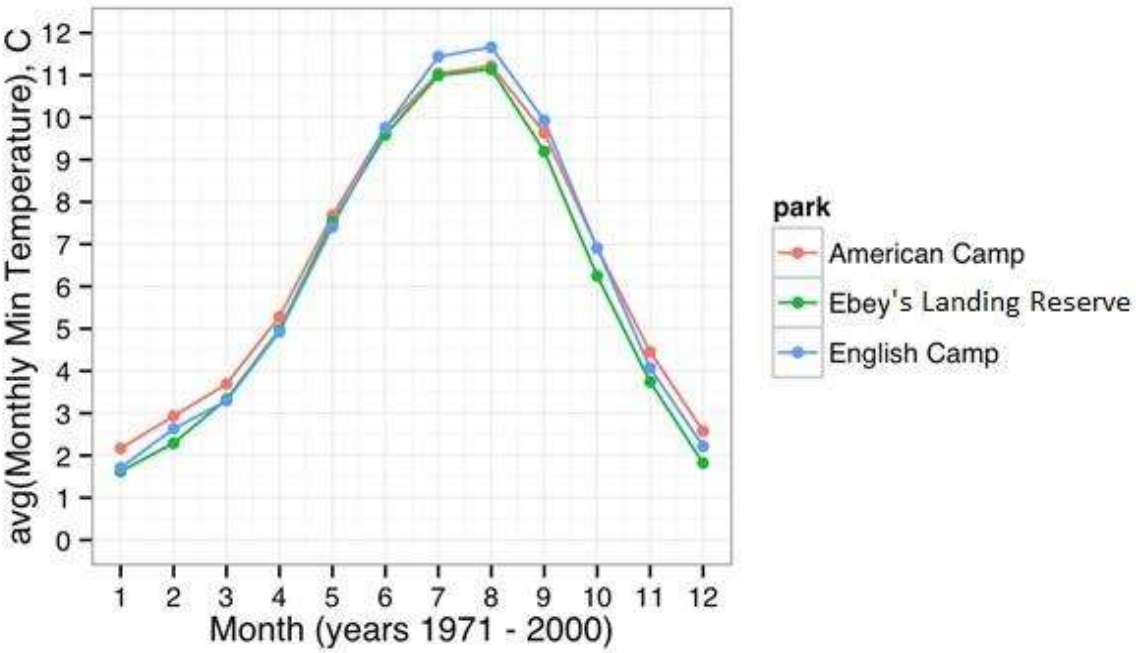


Figure 4. Mean monthly minimum temperature from the modeled PRISM 30-year climate normals by park.

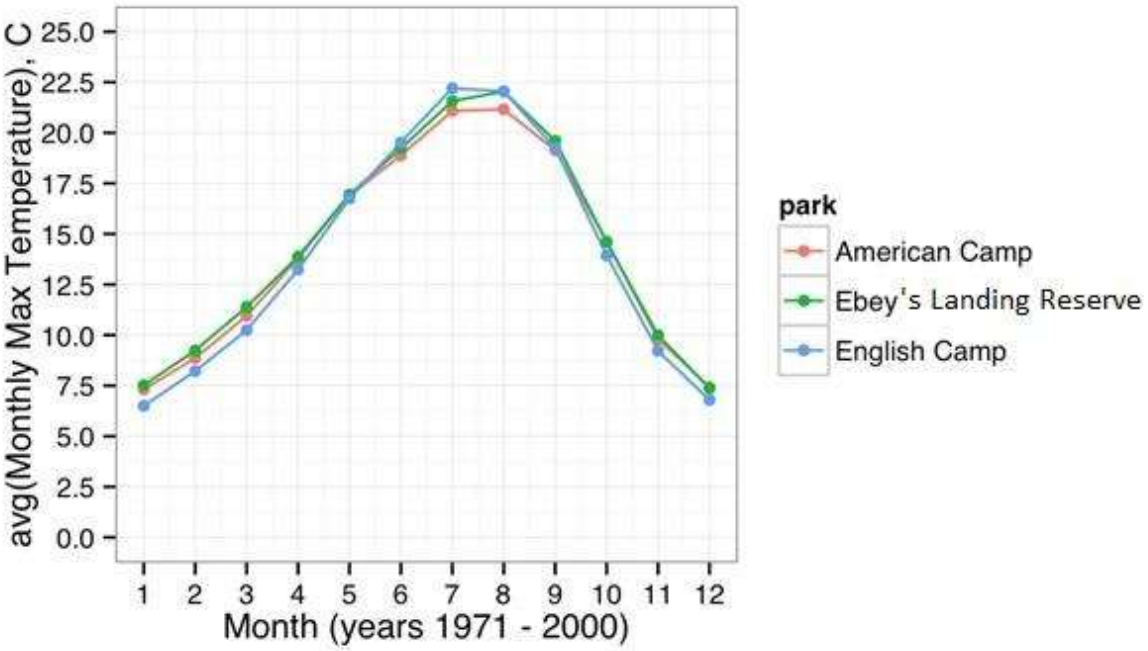


Figure 5. Mean monthly maximum temperature from the modeled PRISM 30-year climate normals by park.

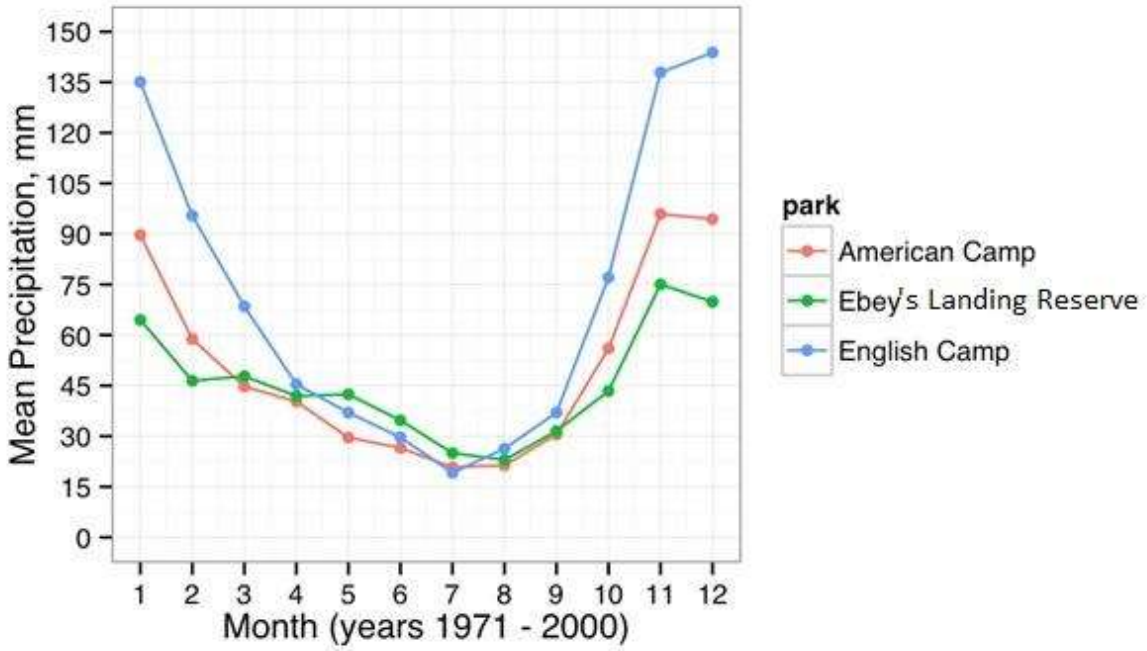


Figure 6. Mean monthly precipitation from the modeled PRISM 30-year climate normals by park.

4.1.2 Regional Context

San Juan Island is dominated by a mild, maritime, modified Mediterranean climate, in part because it is surrounded on all sides by marine waters. It lies on the northern edge of the rain shadow of the Olympic Mountains, and consequently receives much less precipitation than most of western Washington. Prevailing westerly winds shed much of their moisture prior to reaching the island. This relative aridity as compared with surrounding areas contributes to the island's and the park's unique character. The precipitation near American Camp on the southwest end of the island averages 19 inches (48 cm) annually, while at a slightly higher elevation and 8 miles to the north, English Camp's upper slopes average 29 inches (74 cm) of precipitation annually (Cannon 1997). The maritime air surrounding the islands also affects the climate by moderating the temperature. Compared with other northern Puget Sound locations, the summers on San Juan Island are short and cool with very little precipitation, and the winters are mild and moderately dry, although most precipitation falls then. Occasionally in the winter months, freezing temperatures and strong northeasterly winds occur when low-pressure systems off the coast mix with outbreaks of cold air moving down through the Fraser River Valley (Garland 1996). Snowfall occurs occasionally, but most winter precipitation falls as rain (Flora and Sharrow 1992). In general, the prevailing winds are from the south-southeast in winter and west-northwest in summer.

In general, warm years across the Pacific Northwest tend to be warm everywhere in the region, and cool years tend to be cool everywhere in the region. El Niño and the warm phase of the Pacific Decadal Oscillation (PDO, a pattern of inter-decadal climate variability characterized by changes in sea surface temperature, sea level pressure, and wind patterns) also bring warmer and wetter winters to the Pacific Northwest. The three warmest winters on record in the Puget Sound have been during El Niño years (Mote et al. 2005).

Historically, climate became warmer and drier in the Pacific Northwest following the glacial ice retreat, then shifted back to cooler wetter conditions, and now has been warming again. During the twentieth century the winter and spring temperatures increased in western North America generally (Mote et al. 2005). The rate of change varied by location, but generally a warming of 1°C occurred from 1916 to 2003 throughout the western U.S. (Hamlet et al. 2007), with a 1.3°C warming during about the same period specifically in Puget Sound (Mote et al. 2005). The rate of temperature increase from 1947 to 2003 was roughly double that averaged for the entire period from 1916 to 2003. This was largely attributable to the fact that much of the observed warming occurred from 1975 to 2003. Winter months warmed 2.7°F (1.5°C) just since 1950. The climate records also show that rural areas warmed as much as urban stations. Regionwide, the averaged spring and summer temperatures for 1987 to 2003 were 0.87°C higher than those for 1970 to 1986, and spring and summer temperatures for 1987 to 2003 were the warmest since the beginning of the record in 1895 (Westerling et al. 2006). Regionwide, the largest warming trends have occurred in January-March (Hamlet and Lettenmaier 2007).

4.1.3 Issues Description

As a result of greenhouse gases and other emissions, significant changes in the climate of the Pacific Northwest (PNW) are projected for the 21st century and beyond (Snover et al. 2013). Changes prior to mid-century are largely driven by past emissions of greenhouse gases, that are "already in the pipeline," while current decisions about emissions will have a significant effect on warming that occurs after 2050. The exact amount of warming that will occur in this region

after 2050 depends on globally emitted greenhouse gasses in the coming decades (Snover et al. 2013).

For the western U.S., simulations of future climate indicate that average temperatures will likely increase in both winter and summer (Giorgi et al. 2001). The average warming rate in the Pacific Northwest during the next ~50 years is expected to be in the range of 0.1-0.6°C per decade, with a best estimate of 0.3°C per decade. For comparison, warming in the second half of the last century was approximately 0.2°C per decade (Mote et al. 2005, 2008b).

Less certainty is associated with projected changes in regional precipitation than those for temperature. At the University of Washington, computer modeling has predicted increased likelihood of summer droughts despite increased precipitation in the rainy winter season (CIG 2014). Climate models project that future summers will be −6% to −8% drier on average by the 2050s (relative to 1950-1999), with a maximum of 30% drier (Snover et al. 2013, IPCC 2013). During this period, most models project an increase in winter, spring, and fall precipitation ranging from +2 to +7% on average (Snover et al. 2013, Dalton et al. 2013). Heavy rainfall events are projected to become more severe, causing an increase in number of days greater than 1 inch of rain to increase by +13% (±7%) for the 2050s relative to 1971-2000 (Snover et al. 2013, Kunkel et al. 2013).

4.1.4 Data, Methods, and Sources of Expertise

Temperature and precipitation are the two indicators of climate change we focused on, and our trends analysis computed and analyzed specific indices of these. No weather stations have been maintained for a meaningful period within either unit of this park. Thus, to begin, we report the average monthly temperature and precipitation that are projected to have occurred in each of these units during the period 1971-2000. Again, these averages are not based on actual measurements but rather on spatially interpolated estimates generated by the PRISM Climate Group models at Oregon State University (Daly et al. 2008; Daly et al. 2009). We used two spatial climate data sets from PRISM. One is an 800-m resolution gridded monthly time series of mean maximum and minimum temperature and total precipitation for the conterminous United States that covers the period January 1895 through December 2007. The second is the 400-m resolution gridded monthly climate normals from 1971-2000. Monthly grids of mean maximum and minimum temperature and total precipitation are used to assess the spatial characteristics in annual and seasonal (winter, spring, summer, and fall) for the two units of the park. For the 1971-2000 climate normal maps, the data are further summarized by minimum, maximum, median, and quartiles (25%, 75%) for all grids that fall within each park boundary.

Although our analysis describes previous average conditions, the PRISM data cannot be used to calculate meaningful *trends* for the park itself. For that, we calculated trends for the nearest weather station with sufficient long-term data. That was the Olga station on Orcas Island, about 14 miles northeast of American Camp and 14 miles east of English Camp (Davey et al. 2007).

Until recently, there was little standardization of the indices that climatologists calculated to describe specific aspects of temperature and precipitation. A recognition emerged that analysis of average climate conditions, while important, may not be as critical as understanding the change in the frequency or severity of extreme climate events. In response, the CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI) developed a suite of

indices (**Table 1**) for use in understanding the behavior of climate at a given station (Karl et al. 1999; Wang et al. 2003; Peterson 2005). Accurate computation of these indices requires accounting for the many gaps (e.g., measurements missing erratically from various months) that typify most long-term climate records. The ETCCDI has a tool that checks for such gaps as well as addressing outliers (unrealistic values, bad data points, etc.) that could bias an analysis (Peterson et al. 1998). We used that tool in the trends analyses reported here. We calculated the climate indices using the "climdex.pcic" R package (version 1.0-3). We fit the linear regressions using the R "lm" command, and a loess smoother for the smoothed lines in the trend figures.

Table 1. The 27 core climate indices from CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI).

From Karl et al. 1999, Peterson 2005.

Code	Indicator Name	Definitions	Units
		Temperature Indices	
FD0	Frost days	Annual count when TN(daily minimum)<0°C	Days
SU25	Summer days	Annual count when TX(daily maximum)>25°C	Days
SU35	Stress days	Annual count when TX(daily maximum)>35°C	Days
ID0	Ice days	Annual count when TX(daily maximum)<0°C	Days
TR20	Tropical nights	Annual count when TN(daily minimum)>20°C	Days
GSL	Growing season Length	Annual (1st Jan to 31st Dec in NH) count between first span of at least 6 days with TG>5°C and first span after July 1 (NH) of 6 days with TG<5°C	Days
TXx	Max Tmax	Monthly maximum value of daily maximum temperature	°C
TNx	Max Tmin	Monthly maximum value of daily minimum temperature	°C
TXn	Min Tmax	Monthly minimum value of daily maximum temperature	°C
TNn	Min Tmin	Monthly minimum value of daily minimum temperature	°C
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
DTR	Diurnal temperature range	Monthly mean difference between TX and TN	°C
		Precipitation Indices	
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	Mm/ day

R10	Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PRCP>=nn mm, nn is user defined threshold	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when RR>95th percentile	Mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCP TOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm

Criteria

Requirements of the park's resources for specific regimes of temperature and precipitation are unknown. Thus, in the future, historical conditions may be used as the reference. The assumption is that the park's flora and fauna have, over many centuries, selected for a regime similar to that. With regard to trends, a rating of “Good” would consist of all the indices in **Table 1** remaining close to their l00-year historical condition in both units of the park. “Somewhat Concerning” and “Significant Concern” conditions would be defined based on increasing amount of deviation and number of indices that deviate from their l00-year historical condition in both units of the park.

Condition, Trends, and Level of Certainty

Temperature

Our historical temperature compilations for the weather station closest to the park (Olga) with a sufficiently long record are shown in **Figure 4** through **Figure 10**. Trends found to be statistically significant ($p<0.10$) for either the period 1971-2013 or the full time series are listed below. The "full time series" for the Olga station is the period 1891-2013 (with just a few data gaps during the earliest two years). Indices or trends not listed below can be assumed to not be statistically significant.

- Annual mean daily mean temperature is increasing by 0.01°C per year. From 1971 to present, it is increasing at a slightly faster rate of 0.04 °C per year.
- Annual mean daily max temperature is increasing by 0.01°C per for the full time series. From 1971 to present, it is increasing at a slightly faster rate of 0.02 °C per year.
- Monthly minimum value of daily maximum temperature (TXn) increased 0.01 °C per year across the full time series.
- Monthly maximum value of daily maximum temperature (TXx) increased 0.01 °C per year across the full time series.
- The diurnal temperature range (the monthly mean difference between daily max temperature and daily minimum temperature) has increased 0.01 °C per year across the full time series. From 1971 to present it increased 0.02 °C per year.

- The annual count of ice days (days when daily maximum temperature was less than 0 °C) declined 0.017 days per year across the full time series, but not from 1971 to present.
- The annual count of summer-like days (daily maximum>25°C) increased for both the full time series (by 0.03 days per year) and from 1971 to present (0.18 days per year).
- The number of warm days (days when temperature exceeded the 90th percentile), increased 0.06 days per year across the full time series. From 1971 to present, it increased 0.19 days per year.
- Tropical nights (the annual count of when daily minimum temperature is greater than 20 °C) declined 0.001 days per year across the full time series. However, this trend may not be real, as it appears to be driven statistically by just a few years (outliers).
- The annual number of days with a hot spell (at least 6 consecutive days when maximum temperature exceeded the 90th percentile) increased 0.05 days per year across the full time series and 0.31 days per year from 1971 to present.
- The annual number of days with a cold spell (at least 6 consecutive days when minimum temperature was less than the 10th percentile) declined by 0.24 days per year across the full time series.

In summary, 10 of the 17 temperature indices for the Olga weather station data showed a statistically significant warming trend for either the full time series, the most recent period, or both.

In addition, we compared averages during just the past 10 years (2004-2013) with the average for the preceding 10 years (1994-2003). Because of the smaller sample sizes (10 years) the comparisons were not tested for statistical significance. Compared with the prior 10 years, mean annual temperature and mean daily maximum were slightly cooler, growing season was shorter, there were more frost days and ice days, and cold spell duration was longer. However, there were also more summer days (days when the daily maximum exceeded 25°C), longer warm spells (WSDI), and maximum annual temperature was greater.

The combined influence of El Niño and the PDO must be accounted for in order to accurately explain temperature trends in the Puget Sound region over the last century. To do so, Mote et al. (2003) performed a regression analysis using the North Pacific Index (NPI), which reflects the variability of both the PDO and El Niño and their influence on atmospheric circulation in the region. The analysis showed that the NPI accounts for about 40% of the 20th century warming trend in winter months, but has very little influence over the trends observed in other seasons (all of which contribute to the average annual temperature).

Based on the above analysis, we concluded the following:

Condition	Certainty of Condition	Trend	Certainty of Trend
unknown	N/A	significant concern	high

Precipitation

For this park specifically, our historical compilations of precipitation for the Olga station are shown in **Figure 6**. Trends found to be statistically significant ($p<0.10$) for either the period 1971-2012 or the full time series are listed below. The "full time series" for the Olga station is the period 1893-2012, with 7% of the months during the period lacking precipitation data. Indices or trends not listed below can be assumed to not be statistically significant.

- Monthly maximum 1-day precipitation (RX1day) decreased 0.01 mm per year across the full time series.
- Monthly maximum 5-day precipitation (RX5day) decreased 0.03 mm per year across the full time series.
- The number of heavy precipitation days (R10, precip >= 10mm) decreased 0.05 days per year across the full time series.
- The number of heavy precipitation days (R20, precip >= 20mm) decreased 0.01 days per year across the full time series.
- The number of consecutive dry days (CDD) decreased 0.07 days per year across the full time series.
- The number of consecutive wet days (CWD) has decreased 0.09 days per year from 1971 to present.
- The number of very wet days (R95p) decreased 0.31 days per year across the full time series.
- The simple daily intensity index (SDII) declined 0.007 per year across the full time span. From 1971 to present, it increased 0.016 per year. It appears to be showing a long cycle.

With regard to precipitation, we compared averages during just the past 10 years (2004-2013) with the average for the preceding 10 years (1994-2003). We found that during the past 10 years the mean annual precipitation was less, number of days annually with precipitation was fewer, and number of very heavy precipitation days was fewer. However, number of consecutive wet days annually was greater.

In summary, for either the full time series, the most recent period, or both, 6 of the 11 precipitation indices for the Olga weather station data showed progressively drier conditions, one (CDD) showed wetter conditions, and one index (SDII) showed a long cycle.

Condition	Certainty of Condition	Trend	Certainty of Trend
unknown	N/A	significant concern	high

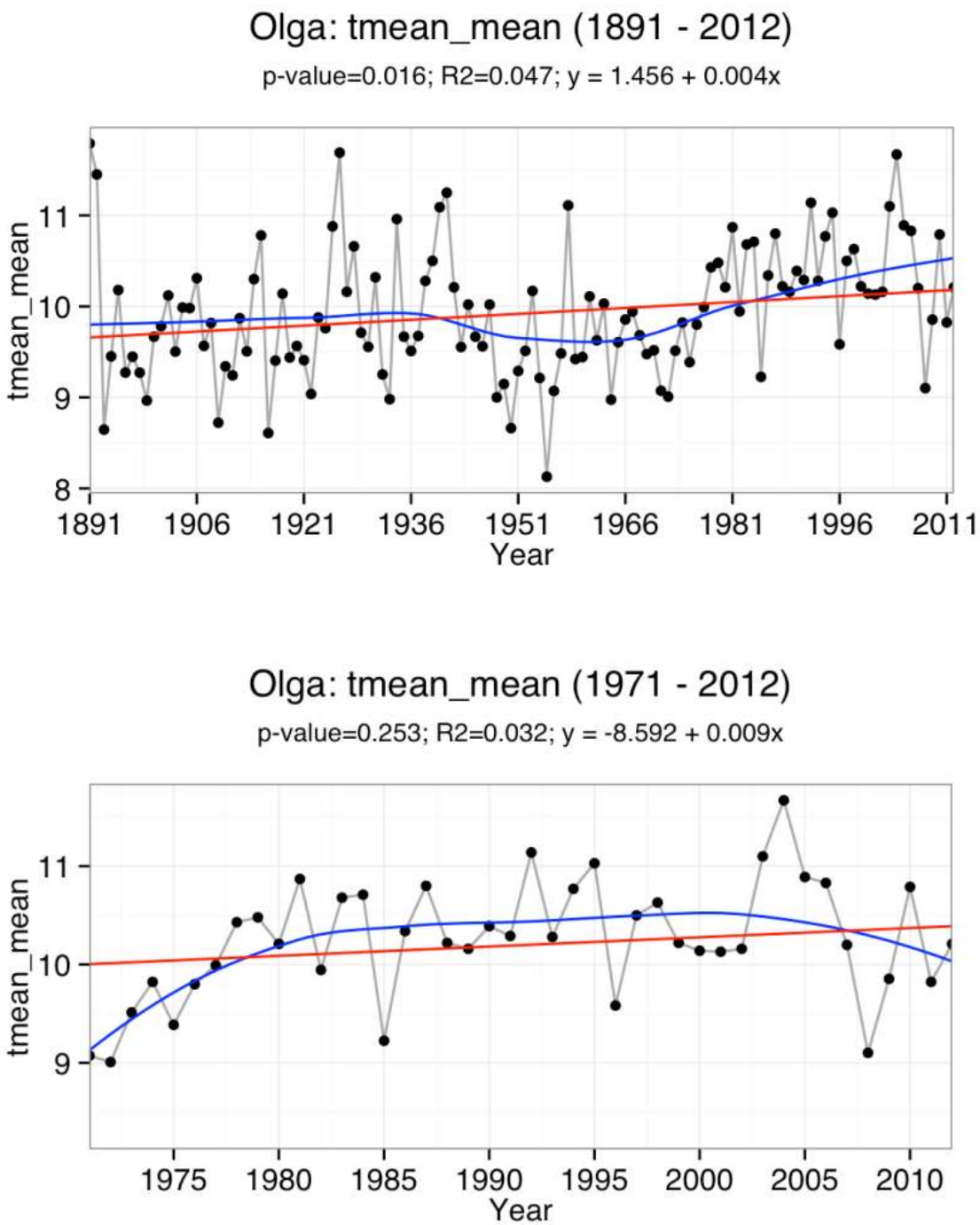


Figure 7. Annual mean daily temperature at Olga for 1891-2012 (upper) and 1971-2012 (lower).

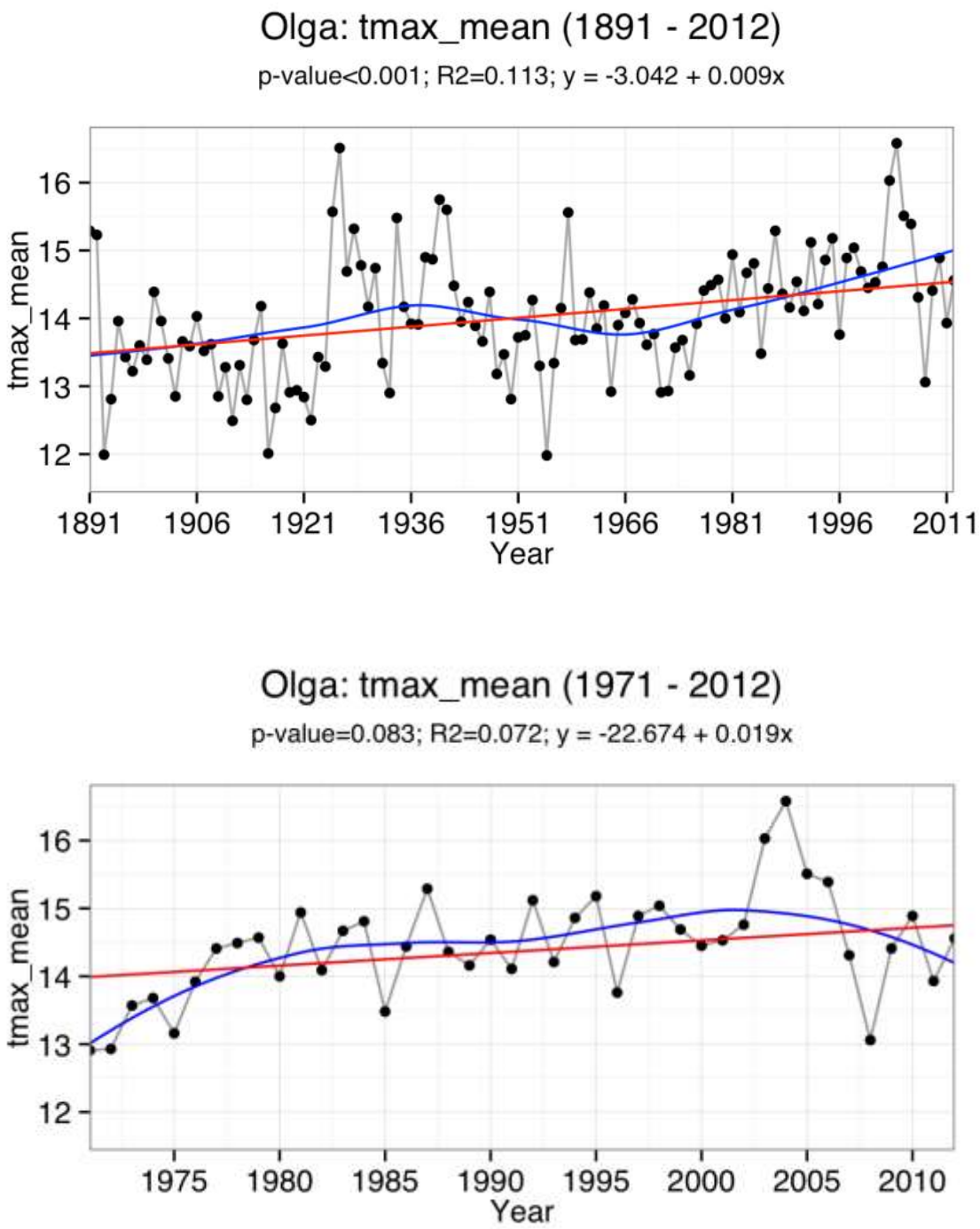


Figure 8. Annual mean daily maximum temperature at Olga for 1891-2012 (upper) and 1971-2012 (lower).

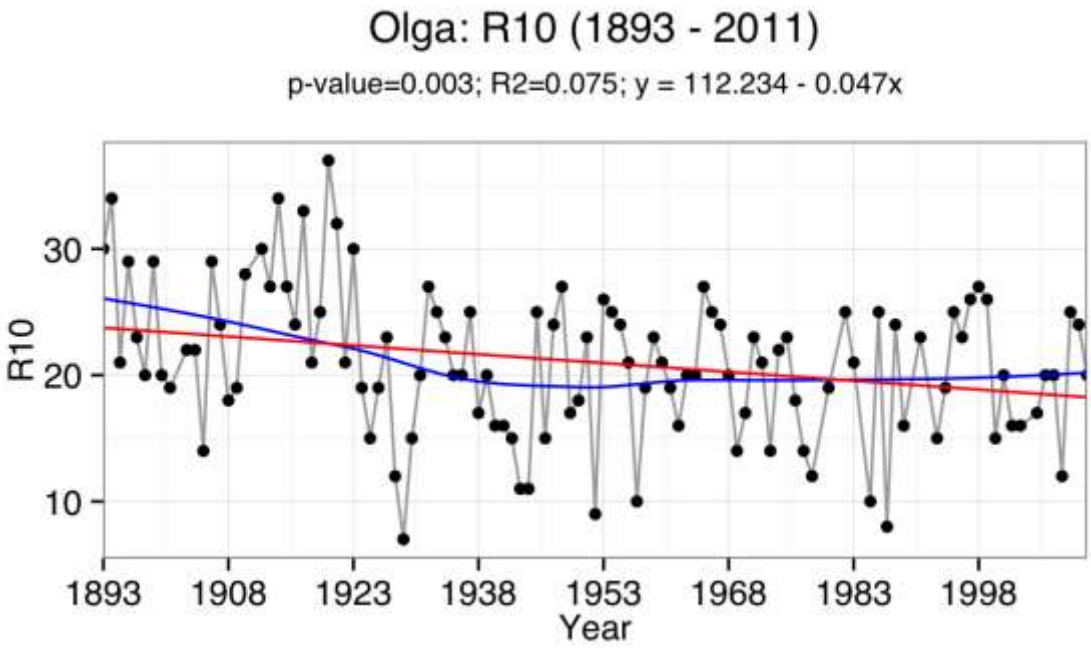


Figure 9. Annual number of days of heavy precipitation (>= 10mm) at Olga for 1891-2012.

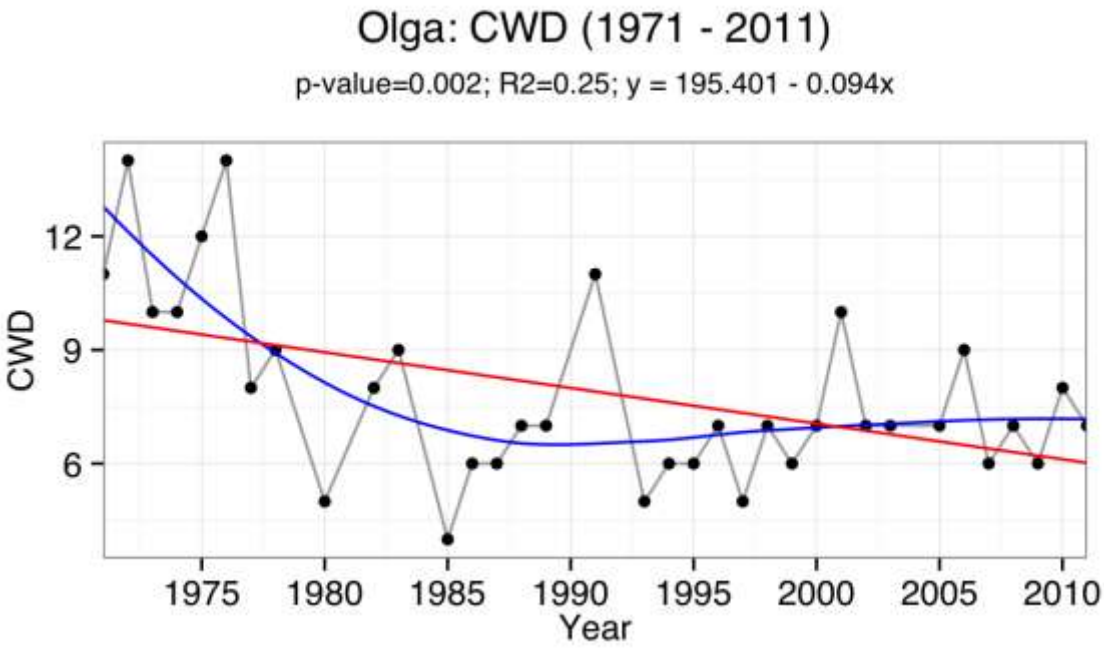


Figure 10. Annual maximum number of consecutive wet days (precip >=1mm) at Olga for 1971-2011.

Data Gaps

- The tolerance, resilience, and adaptability of the park's flora and fauna to long-term changes in temperature and precipitation remain unknown.
- The park lacks a long-term climate monitoring station. The degree to which the Olga weather station located 14 miles away represents accurately the trends in precipitation and temperature in either or both of the park's units remains undetermined.

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4.2 Nearshore Resources

4.2.1 Background

"Nearshore Resources" includes the physical and biological resources of the intertidal, shallow subtidal (seaward to a depth of about 20 m), and marine riparian zones (defined here as landward perpendicular to shoreline about 50 m beyond extreme high tide level). Technically speaking, the park's legal jurisdiction does not include some parts of the intertidal zone nor any of the subtidal (elevations below extreme low tide), but resources in these are discussed because they interact with resources and activities that are within the park's jurisdictional boundaries.

To facilitate management of shoreline resources, the park is working toward defining the exact boundaries of tidal ownership at every point along the 6.67 miles of coast within or along the park's borders. Ownership of most of the park's tidelands is retained by the State of Washington under the jurisdiction of their Department of Natural Resources. However, jurisdiction is patchy at both park units, with tideland ownership by the park sometimes being contiguous with the park-owned adjacent uplands. The park's jurisdiction extends to the extreme low tide line from the cliffs west of Alaska Packer's Rock to east of the restrooms at South Beach. East of that to the eastern boundary, jurisdiction extends only to the mean high tide line. The jurisdictional line meanders from Grandma's Cove to the western boundary of the park and along a short stretch of shoreline north of Jakle's Lagoon. The park's authority extends to the mean high tide line along Fourth of July Beach from the northwestern boundary to west of First Lagoon. At English Camp, the park owns tidelands from the northern edge of the parade ground south to the park boundary, with the remainder being owned by the state.

The sediment composition of the park's intertidal shoreline is described by Fradkin (2004). Intertidal shorelines of both American Camp and English Camp are dominated by unconsolidated sediments (sand or mud). More specifically, because of its sheltered location along Garrison and Westcott Bays, the shoreline at English Camp is characterized by mostly low relief, mud-dominated intertidal areas with scattered salt marsh. In contrast, at American Camp the south shore is much more exposed to the prevailing winds and consists of jutting headlands and gravel pocket beaches on the west that grade into a long sandy beach toward the east and returns to rocky headlands at Cattle Point. Along American Camp's northern shore, along Griffin Bay, intertidal areas are gravel, sand, gravel, and cobble, much of which is covered with drift logs. Rocky areas are interspersed with these unconsolidated areas. At its eastern end, the sandy shore of South Beach is backed by a steep eroding bluff face. Along Griffin Bay, the park's three tidal lagoons are a notable feature.

4.2.2 Regional Context

Located at the intersection of the Strait of Juan de Fuca and the Strait of Georgia, the marine waters at American Camp are well flushed by the strong tidal currents, whereas those in Westcott and Garrison Bay at English Camp are not. At American Camp, the southern and western shores of American Camp are most strongly influenced by oceanographic processes in the eastern Strait of Juan de Fuca and Haro Strait; the eastern shores of American Camp are dominated by processes occurring in the San Juan Channel. The shores of English Camp are influenced by processes occurring in Haro Strait and the southern Strait of Georgia, although these are modified by local processes that occur within the bays.

Partly because of their unique geochemistry and relative scarcity in Puget Sound, lagoons are recognized by the Washington Department of Ecology as a particularly important natural feature. Lagoons are coastal ponds that receive tidal water only infrequently. They are often formed by accretion of beach materials that are deposited via longshore drift. The accreted materials eventually form a beach that separates the lagoons from the open marine environment. The Old Town Lagoon is the smallest and dries in most summers. Jakle's Lagoon is the largest and deepest, and contains water even in very dry summers. Third Lagoon is smaller and shallower than Jakle's, but water persists year-round. These are the only tidal lagoons on San Juan Island (the English Camp unit contains no lagoons). The park's lagoons have been the focus of short-term biological surveys (e.g., Hanson 2001).

The Washington Department of Fish and Wildlife (Wilhere et al. 2013) rated all the shorelines of Puget Sound based on multiple criteria, including the diversity and abundance of marine resources they consider to be of greatest commercial or ecological importance. **Figure 11**shows one series of the ratings assigned to shoreline segments within the two units of the park, as well as those elsewhere on San Juan Island. The American Camp unit's shoreline segments in general received a moderate rating while those along the English Camp shoreline in general received a low rating. However, in describing their methods and criteria, the authors of that study strongly caution against interpreting the ratings at anything finer than a regional or watershed scale. The ratings are related only to other shoreline segments in Puget Sound.

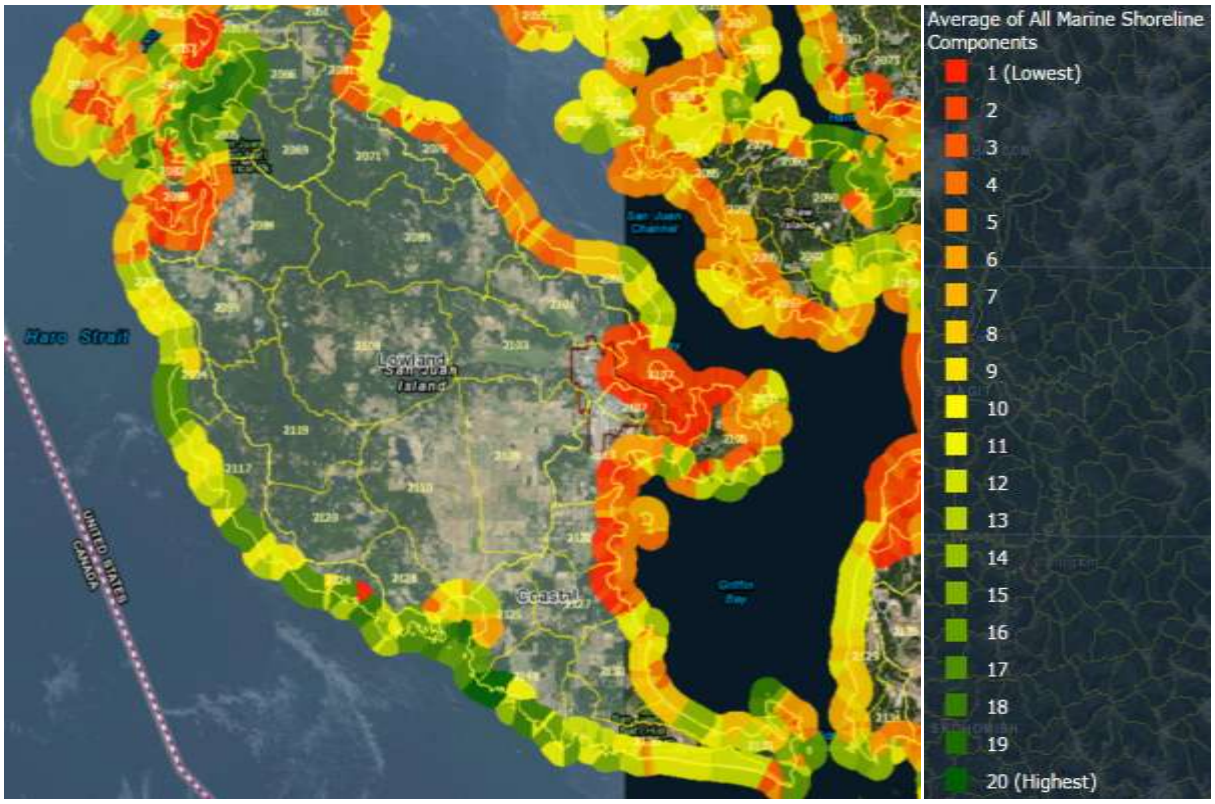

Figure 11. Ratings of San Juan Island marine shoreline segments as assigned by WDFW.

See Wilhere et al. (2013) for rating criteria.

4.2.3 Issues Description

The following are considered to be among the more important factors affecting the park's nearshore resources now or in the future:

- Shoreline Processes and Effects of Artificial Structures
- Storm Flooding and Sea Level Rise
- Pollution and Ocean Acidification
- Marine Debris
- Harvest and Collection of Intertidal Organisms

A short discussion of each follows.

<u>4.2.3.1 Shoreline Processes and Effects of Artificial Structures</u>
Because of the large fetch along the park's southwest shoreline (American Camp), nearshore waters there are dominated by swell. These waves form in the largest storms and fetch is effectively unlimited (fetch is the distance over which the wind blows unobstructed), so the height and the period of these waves are large. They are influenced by seabed topography hundreds of feet offshore, causing them to break far from the shoreline.

San Juan County is unusual in that the source of the waves changes depending on the geographic position and aspect of the shoreline at a given point.

The transport by marine currents of suspended sediment is fundamental to the shaping of shorelines as well as influencing the depth of light penetration in marine waters and the transport of nutrients and toxic substances. Thus, marine currents strongly influence the extent and type of plant and animal habitat that will exist at a given point along a shoreline (Fresh et al. 2004, Thom et al. 2005, Mumford 2007, Sobocinski et al. 2010, Brennan et al. 2009). Segments of shoreline where sediment movement is mostly unidirectional parallel to shore are called *drift cells*. Drift cells may contain (1) a sediment source (usually a feeder bluff); (2) a transport zone where sediments are moved along the shoreline over time; and/or (3) a depositional area. Much of the nearshore sediment originates from the *feeder bluffs*, which are steep, naturally-eroding headlands that intersect tidal waters. Due to the lack of rivers in San Juan County, most beaches depend solely on bluff erosion for sediment. When drift cell currents carrying sediment encounter a feeder bluff, a bedrock formation, or a pier or other sizeable structure perpendicular to the shore, some of the sediment is deposited but much is transported offshore and is permanently "lost" from the nearshore environment.

Along most of San Juan County's shoreline, waves are the dominant mode of sediment transport (Finlayson 2006). Where tidal currents exceed about one knot, tides may play a secondary role in areas that are protected from swell (Curtiss et al. 2009). Along both the south and north shores of American Camp, currents are mostly west to east. At English Camp, currents in Garrison and Westcott Bays are also mostly west to east according to the Washington State Coastal Atlas (2011). Here, waves are mostly generated by local winds. Short-fetch waves have short periods (the time interval between wave heights), are steep, and can generate significant local shear stress (the physical process that strongly influences sediment transport), but they do not penetrate far down into the water column.

The presence of a surf zone defines the overall geomorphology of the shore and the associated ecological communities. For example, surf typically precludes eelgrass and most other vascular plants that live entirely below the water surface. Sediment transport is also intense with the surf zone, creating a highly abrasive environment.

Along the Cattle Point Road that bisects the American Camp unit of the park, natural erosion of a coastal bluff is proceeding at a rate of 1.7 feet per year and is expected to come within 2 feet of the road by approximately 2026, severely threatening its stability (FHWA & NPS 2012). Realignment of 4950 feet of road is planned, permanently altering 3 acres and temporarily disturbing 17 acres. Elsewhere in the park, park staff have partnered with the Washington Conservation Corps to control erosion and stabilize an exposed shell midden, an archaeologically significant feature, on the north coast of the English Camp in Garrison Bay. The project has protected archaeological resources from being washed away or exposed to poachers.

By altering current speeds, bulkheads, docks, and some other types of shoreline infrastructure have the potential to alter the amount, type, and location of sediment that is transported and deposited as well as subsurface light crucial to underwater productivity. A countywide survey of major shoreline modifications in 2007 found that 40 percent of shoreline parcels in San Juan County already have at least one beach structure. Nearly 4,000 modifications were documented,

including over 700 bulkheads, 472 docks, 32 groins, 55 marine railways, 70 boat ramps, 1,914 mooring buoys and floats, 425 pilings (not associated with a dock or marina), 50 marinas/jetties/breakwaters, and 191 "other" intertidal man-made beach structures (Friends of the San Juans 2010). Analysis of shoreline permit activity indicated that a total of 318 shoreline permits for bulkheads were issued between 1972 and 2005. This represents 9 percent of developed shoreline parcels in San Juan County. Between 2000 and 2005, the annual rate of bulkhead development increased to 9 permits per year from 5 per year before 2000. Another study (MacLennan and Johannessen 2008) examined areas representing a range of nearshore characteristics and development patterns and reported that approximately 30 percent of 4.5 miles of feeder bluffs in the study area had been artificially modified. Primary modifications were rock bulkheads or armoring that potentially inhibit sediment supply to the nearshore. The rate of bulkhead related permit activity and projected growth rate of San Juan County has been projected to be 35 percent over the next 20 years (SSPS 2007), so the cumulative local impacts on sediment transport could be measurable.

The park's shoreline contains no artificial structures and none are likely, as they would be incompatible with the park's mission. However, if structures are added to shorelines outside the park but not far away, they could diminish the load of sand and gravel sized sediment that reaches the park's shoreline. This could result in coarsening of the park's nearshore substrates, potentially degrading forage fish spawning habitat and requiring sediment supplements in order to sustain these habitats.

4.2.3.2 Storm Flooding and Sea Level Rise

Flooding is a natural process that in some cases is needed over the long term to sustain nearshore ecosystems. However, flooding can also erode trails, access roads, and historical features, as well as threaten the quality of drinking water from domestic wells, and change natural features that are a focus of protection within the park. Like most of San Juan County, the park is more susceptible to flooding from the ocean rather than from streams and rivers. Coastal flooding usually occurs when large storm systems bring heavy precipitation and high winds, especially when such storms occur during high tide. The entire shoreline of San Juan County is identified as an Area of Special Flood Hazard because tidewaters rise above the ordinary high water mark (OHWM) during storm events of this type. However, San Juan County's Flood Insurance Rate Maps (FIRMs) are not totally accurate; in some areas showing the floodplain at elevations more than 40 feet above the ordinary high water mark. The maps were created in 1977 and are in need of updating.

On a global level, by the year 2100, the IPCC (2007) projected that sea levels will rise 7.1 inches, 13.4 inches, or 23.2 inches (provided as low, intermediate, or high estimates, respectively) (IPCC 2007). A more recent refinement (Cayan et al. 2008) produced low and high estimates of 19.7 inches and 55.1 inches respectively.

In the Puget Sound region, additional local factors influence sea levels: subduction of tectonic plates, isostatic rebound, oceanic winds, coastal winds, and local atmospheric pressure patterns. By considering all of these, experts predict the regional sea level will rise from one to five inches per decade (Baumann et al. 2006), meaning that by the year 2100, under a maximum climate

warming scenario, the rise could be 50 inches (Mote et al. 2008a) to 68.9 inches (Clancy et al. 2009).

Late Glacial sea levels were much higher than today – up to 300 feet or more in some areas (James et al. 2009), and then fell rapidly as isostatically depressed terrain rebounded as the ice melted and the pressure of its weight diminished. While such movement (upward movements of the land mass which could potentially keep up with sea level rise) is a consistent and measurable factor in other parts of the state (e.g., the Olympic Peninsula) it is highly variable in the Puget Sound basin and its net effect on sea level rise is negligible in the north sound, although there is still a small amount of sea level net increase (Verdonck 2006, Canning 2005, and Mote et al. 2008a). This also explains the relatively modest sea level rise observed between 1934 and 2006 at the NOAA Friday Harbor sea level station, a rise that averaged 1.13 mm/year, with a confidence interval of ±0.33 mm (Canning 2005). If this trend continues at the same pace, the local increase over the coming 100 years may be just 4.44 inches (NOAA 2010).

4.2.3.3 Pollution and Ocean Acidification

The park's nearshore plants and animals are potentially harmed by toxic substances in runoff from the land as well as in marine waters that wash over the shore (WDOE & King County 2011). Substances potentially harmful to particular plants and animals or their habitat at concentrations sometimes found in the region's marine waters include heavy metals, flame retardants, detergents, petrochemicals, and nutrients. A constant threat also exists from oil tankers and other commercial vessels that navigate daily through waters close to the park.

San Juan Island currently has no large commercial or industrial developments, dairy farms, or livestock feedlots. Locally degraded water quality on San Juan Island is partly attributable to low summer instream flows, use of the riparian corridor by grazing cattle, residential pesticide use, and untreated runoff from roads (Barsh 2008, 2009, Barsh et al. 2010). Also, just 12 miles across Haro Strait and to the west, Victoria is the only major Pacific Coast city north of San Diego without any sewage treatment, currently pumping its wastes directly into marine waters. While organic parts of the sewage decompose rapidly in the oxygen-rich waters of Haro Strait which separate Victoria from the park, many substances in household wastewater probably do not. These include pharmaceuticals, heavy metals, hormone-disrupting chemicals, and others that can enter marine food chains and disrupt marine mammal reproduction.

One of the largest drivers of declining marine water quality in Puget Sound may be the increasing nitrate concentrations. Puget Sound-wide nitrate increased at a rate of 3 µM per decade while phosphorus has increased only 0.3 µM per decade (Krembs 2013). Excessive algal growth triggered by elevated nitrate levels has caused fall/winter levels of dissolved oxygen to decline to levels harmful to marine life both regionally (Chan et al. 2008) and in Puget Sound (Krembs 2013). This could eventually cause deeper-water populations to shift shoreward where dissolved oxygen levels are greater. Also, nitrate-induced growth of filamentous green algae on shallow hard substrates, when excessive, can limit the diversity of other seaweeds and macroinvertebrates. The effects of nitrate loading are likely to be most noticeable in bays, lagoons, and other areas with restricted circulation.

Evidence is mounting that excessive growth of marine phytoplankton in parts of Puget Sound, triggered mainly by excess nitrate, is due more to human sources than to ocean currents or other

factors (Roberts et al. 2013). This is indicated partly by ratio of silicate to dissolved inorganic nitrogen (Si:DIN), which is considered a sign of human nutrient inputs (Harashima 2007). The ratio in Puget Sound has declined 10 units per decade (Krembs 2013).

In runoff and groundwater on San Juan Island, nitrate is most likely to originate from failing septic systems, vehicles, livestock, and agricultural and residential application of fertilizers (San Juan County HCS 2000, 2004). Nitrate and some toxic substances can also originate from boats, which at times are numerous in the waters next to the park.

Within the coming decades, the park's nearshore marine life also could be altered by increasing ocean temperature and acidity, both associated with global climate change (Okey et al. 2012, Doney et al. 2012). One model predicts a mean decrease in global surface ocean pH ranging from 0.1 to 0.2 units by 2050 (IPCC 2007). Other models suggest that the pH of surface oceans will decrease by 0.3 to 0.4 units by the end of the century (Feely et al. 2008). Because of their dependence on acid-soluble calcium carbonate for shell-building, species most threatened by acidification of their nearshore habitat include crabs, oysters, clams, barnacles, mussels, starfish, zooplankton, and others. Acidification has already been documented in Puget Sound and on the Washington side of the entrance to the Juan de Fuca Strait, with consequent changes in the marine fauna (Wootten et al. 2008, Washington Blue Ribbon Panel on Ocean Acidification 2012).

Marine Water Condition Index Scores for 12 Regions of Puget Sound
1999-2012

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Admiralty Reach	20	13	8	4	0	-5	-3	-5	4	0	-3	-2	14	12
Georgia Basin	-2	14	13	1	-2	10	-2	-7	1	9	-9	7	16	-7
South Hood Canal	16	7	9	3	-4	-9	-1	-11	6	10	-1	-14	-11	1
Central Basin	15	14	12	8	-1	-6	-8	-3	4	1	-7	-10	7	0
Bellingham Bay	10	13	23	-3	1	6	-12	-8	7	2	-12	-14	7	-9
Sinclair Inlet	8	16	13	1	-3	-6	-5	-11	4	1	3	-13	3	-4
Oakland Bay	16	13	14	-4	-7	-9	-5	1	4	-3	1	-6	1	-3
South Sound	19	14	14	-2	2	0	-4	-2	3	0	-8	-12	9	6
Elliot Bay	28	19	5	-3	-9	3	-15	-9	3	4	-8	-5	5	5
Commencement Bay	17	8	13	-3	-5	0	-3	-1	7	-5	-8	-8	2	2
Whidbey Basin	11	8	8	-5	-2	-10	-1	1	9	7	-9	-14	-3	-3
Budd Inlet	8	14	17	1	-13	-9	-7	-1	8	5	3	-8	1	-6

25 to 28
21 to 24
17 to 20
13 to 16
9 to 12
6 to 8
2 to 5
1 to 4
-3 to 0
-7 to -4
-11 to -8
-15 to -12

Figure 3.15. Numbers greater than zero indicate improving water quality and numbers smaller than zero indicate decreasing water quality relative to the baseline (1999-2008). Green shades show improving water quality. Orange to red shades indicate declining conditions. Yellow shows scores between -1 and 1, representing little to no change.
Source: Washington State Department of Ecology, Environmental Assessment Program, Marine Monitoring Unit

Figure 12. Marine water condition index scores for 12 regions of Puget Sound, from Washington State Department of Ecology. This park is in the Georgia Basin.

4.2.3.4 Marine Debris

Plastic and other solid debris enters marine waters from sources both near (e.g., recreational boats, ferries, creosote-covered driftwood) and far (e.g., fishing fleets, aquaculture, ocean dumping) as reviewed by Andrady 2011, Hirai et al. 2011, Hammer et al. 2012, and others. Many studies have documented the harm marine debris (especially microscopic-sized plastic particles) can cause to marine mammals, seabirds, and entire food chains (e.g., Tanaka et al. 2013).

4.2.3.5 Harvest and Collection of Intertidal Invertebrates

Shellfish can be harvested legally in limited parts of the park, and the harvest is regulated by the State of Washington. Intertidal invertebrates, especially those in tidepools, are sometimes collected by curious visitors, although not allowed by park regulations. If harvesting becomes excessive, species richness and food chain structure can be altered. Beach walking is popular in both English and American Camps, and some visitors explore the rocky intertidal areas during low tides. Jenkins et al (2002) conducted an experimental study of the effects of trampling on the rocky shorelines of San Juan County Park. They found that trampling reduced the cover of kelp by 30 percent, and that this reduction persisted through the summer season.

4.2.4 Data and Methods

Indicators that might be used to represent the condition of nearshore resources, and which will be discussed below, include:

- Nearshore water quality
- Eelgrass
- Kelp and other nearshore aquatic plants
- Salmon
- Forage fish
- Nearshore invertebrates
- Invasive nearshore animals and plants

Marine mammals and seabirds are also important indicators of the condition of the park's nearshore environment, but are treated in the Wildlife section of this document.

4.2.4.1 Nearshore Water Quality

For supporting aquatic life, the waters surrounding the San Juan Islands are considered by the Washington State Department of Ecology to be much better than waters in most of Puget Sound and the rest of the region and so have been assigned a “Class AA” rating. However, that rating does not take into account hundreds of chemicals for which no toxicity data or standards exist, such as various pharmaceuticals and hormone disrupters. Moreover, even some of the more conventional pollutants have not been sampled at a spatial scale and frequency sufficient to conclude they are causing no harm to aquatic life in the Salish Sea. Almost no sampling has occurred in marine waters closest to the park’s American Camp unit in Griffin Bay and Haro Strait, and only recently (following the unexplained local disappearance of eelgrass) have marine waters near the park’s English Camp unit been sampled. Samples collected by Wiseman et al. (2000) at the end of the boardwalk at English Camp revealed “distinctive water quality” compared with marine samples from eight other marine sites around the county, being characterized by relatively high dissolved oxygen and low nitrate and soluble phosphate. In

sediments just north of the English Camp unit in Roche Harbor, elevated (but non-lethal) concentrations of lead, copper, and tributyl-tin were found in 2000 (Serdar et al. 2001). The marine circulation in Westcott and Garrison Bays that adjoin the English Camp unit is much less than in the waters adjoining the American Camp unit, which are well flushed by the strong tidal currents flowing in from the Pacific Ocean. Restricted circulation increases the risk of elevated bacterial counts and low-oxygen events harmful to aquatic life.

Criteria

"Good" condition would be no evidence in marine water and sediment samples of any contaminants at levels that could harm people or biological resources (including contaminants such as various detergents, pharmaceuticals, and hormone disrupters which may not currently be regulated by government but which peer-reviewed science shows can cause harm). "Somewhat Concerning" would be occasional and temporary failure to meet state or federal water quality standards, when accompanied by no evidence of harm to humans or biological resources. "Significant Concern" would be chronic failure to meet surface water standards, and/or evidence of harm to humans or biological resources that can be attributed to contaminants in the park's surface water.

Condition, Trends, and Level of Certainty

Although some water quality sampling has occurred in marine waters of the San Juan Islands, the Condition is rated Unknown because there is no reference for comparing and validly evaluating what is normal for waters near the park, and waters within the park have not been adequately sampled.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
unknown	N/A	unknown	N/A

Data Gaps

- There has been no systematic, multi-year monitoring of water quality in the park's nearshore habitats.
- Even when marine waters farther offshore were sampled, the samples have not been analyzed for a full spectrum of chemicals or with sufficient frequency to determine if contaminants are present in concentrations potentially harmful to the species present within the park.
- Ocean acidity has not been measured, but is likely to be an important emerging threat to the park's nearshore resources.

<u>4.2.4.2 Eelgrass</u>

A submerged nearshore plant, the native eelgrass, *Zostera marina*, has been widely recognized as providing exceptional habitat to invertebrates and fish, especially young salmon and the forage fish important to salmon (Murphy et al. 2000, Mumford 2007, Bostrom et al. 2006, Ferraro and

Cole 2007). For example, eelgrass is an important breeding ground for forage fish such as Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypmesus pretiosus*). Eelgrass covers about 9 percent of Puget Sound below the mean lower low water (MLLW) mark (Nelson and Waaland 1997).

Eelgrass beds occur throughout the nearshore zone of San Juan County's shorelines (Washington Coastal Atlas 2011), with a total coverage estimated at 20 percent (SSPS 2007) or 41 percent (Mumford 2007) of the county's shoreline. The beds usually occur as patches or narrow bands near the shore, or as solid meadows in the subtidal zone (Nelson and Waaland 1997). They expand in spring and summer and decrease during fall and winter. The beds commonly form near MLLW and extend to depths from about 6.5 feet (2 meters) above MLLW to 30 feet (9 meters) below MLLW. The depth to which eelgrass grows is determined mainly by water clarity, and the plant's sensitivity to water clarity has been noted as particularly important in the San Juan Straits region, where it has been observed to grow at depths greater than 30 feet (9 meters) (Reeves 2006, PSAT 2007). However, factors such as extremely low or high nutrient levels, substrate composition, presence of other species, and toxic pollutants in the water can affect eelgrass distribution and abundance (Mumford 2007). In Friday Harbor, an eelgrass meadow extends from depths of approximately five feet (1.5 meters) below MLLW to 16 feet (5 meters) below MLLW (Nelson and Waaland 1997). Eelgrass beds can be transplanted and restored if the proper conditions exist (Thom 1990), but determining what is limiting eelgrass at a particular site is a necessary first step.

Competitors of eelgrass in Puget Sound include the non-native brown seaweed, *Sargassum muticum* (Britton-Simmons 2004) and the sand dollar (*Dendraster excentricus*). Where there are excessive nutrients, algae such as sea lettuce (*Ulva* spp.) will overgrow eelgrass. Excessive nutrients also can cause over-growth by algae on eelgrass blades, blocking light, nutrients and gas exchange. Crabs are known to uproot eelgrass (Simenstad et al. 1997), and the sand dollar also disturbs the substrate to a degree that excludes eelgrass. Eelgrass can be buried and killed by sand overwash from storms.

Criteria

After accounting for year-to-year variation, "Good" condition would be represented by eelgrass cover and distribution that is close to the recent historical condition within the park, "Somewhat Concerning" condition would be represented by eelgrass cover and distribution that is slightly more restricted than that, and "Significant Concern" would be loss of eelgrass cover from large portions of their historical range within the park—measured laterally along the shoreline, and/or by change in their vertical distribution (depth).

Condition, Trends, and Level of Certainty

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Somewhat concerning	Medium	Decreasing (Westcott Bay)	High

Within or near the park, significant losses occurred in Westcott-Garrison Bays between 2000 and 2004 (Pentilla 2007, SSPS 2007). Since at least 1995 eelgrass has declined in the San Juan Archipelago generally (Gaeckle et al. 2008). During this time, approximately 82 acres of eelgrass were lost from within 11 small embayments (Dowty et al. 2005, PSAT 2007). Losses in Westcott Bay were first discovered in February 2003 by the Washington Department of Fish and Wildlife (Wyllie-Echeverria et al. 2003). A loss was inferred because Westcott Bay had been surveyed in 2000 and 2001 as part of the Submerged Vegetation Monitoring Project conducted by the Washington Department of Natural Resources. Approximately 35 out of 45 hectares of eelgrass had disappeared from Westcott Bay. Comparison with observations from Dethier and Ferguson (1998) further confirmed the loss. A survey in June 2007 confirmed that the proportion of linear shoreline with eelgrass had decreased from 86% in 1998 to 11% in 2007 (Dethier and Berry 2008). In nearby Garrison Bay, possible changes have not be quantified, but results of the 2003 survey indicated patches south of Bell Point had nearly vanished, based on comparison to aerial photos of the Bay taken in 1992 (Wyllie-Echeverria et al. 2003). The remnant eelgrass in inner Westcott Bay at Bell Point has the lowest genetic diversity of all populations analyzed in the San Juan Archipelago and this could affect population viability (Rearick et al. 2007).

Causes of the loss have not been determined conclusively. A survey in 2007 helped rule out some of the potential causes of eelgrass decline, such as substantial change in sediment type, temperature, or salinity (WDNR 2007). That conclusion was also supported by evidence that associated intertidal invertebrate assemblages in Westcott and Garrison Bay had not changed significantly (Dethier and Berry 2008).

Eelgrass remains abundant in other sheltered subtidal areas within the park, such as along Fourth of July Beach, and it occurs offshore of American Camp in shallow areas of Salmon Banks.

Data Gaps

- Trends in extent and location of eelgrass are not currently being monitored in the park.
- Eelgrass beds can fluctuate is size from year to year naturally, but that natural variation which could be used to define reference condition is not known.
- The adaptability of eelgrass under various scenarios of climate change is unknown.

4.2.4.3 Kelp and Other Nearshore Plants

"Forests" of floating and submerged kelp (a large alga) provide food and refuge for many fish species, including rockfish and young salmon, as well as sea urchins, crabs, mollusks, and a variety of marine mammals including sea otters (Mumford 2007). Most occur in the shallow subtidal zone from MLLW to about 65 feet below MLLW, and prefer high-energy (e.g., rocky) environments where tidal currents renew available nutrients and prevent sediments from covering young plants (Mumford 2007). Kelps do not absorb nutrients from the substrate to which they are attached. They are generally found in water with high salinity, low temperature, high ambient light, hard substrate, and minimal sedimentation (Mumford 2007). Shoreline development that affects water clarity or available light can adversely impact kelp. Floating kelp species occur along approximately 31 percent San Juan County's shoreline, while non- floating kelps, which are much harder to detect, occur along perhaps 63 percent (Mumford 2007). Of the 23 kelp species known to occur in Puget Sound (Mumford 2007), at least 17 have been observed

in the county, based on collections at Cantilever Point, Reed Rock, Friday Harbor, Point George, Shady Cove, McConnell Island, and Burrows Bay (Garbary et al. 1999).

In addition to kelp and other seaweeds, several species of emergent vascular plants occupy the shores of the park and its lagoons. The lagoons or surrounding salt marshes host several species listed by the Washington Natural Heritage Program as "sensitive," such as sharpfruited peppergrass (*Lepidium oxycarpum*), Nuttall's quillwort (*Isoetes nuttallii*), and erect pygmy-weed (*Crassula connata*) as well as a noteworthy vegetation assemblage:

- *Salicornia virginica - Distichlis spicata - Triglochin maritima - (Jaumea carnosa)* Herbaceous Vegetation

Criteria

After accounting for year-to-year variation, "Good" condition would be represented by an extent and distribution of kelp and emergent vascular plants that is close to the recent historical condition within the park, "Somewhat Concerning" condition would be represented by extent and distribution that is slightly more restricted than that, and "Significant Concern" would be loss of kelp cover and emergent vascular plants from large portions of their historical range within the park—measured laterally along the shoreline, and/or in the case of kelp, by a decrease in vertical distribution (maximum depth in the water column).

Condition, Trends, and Level of Certainty

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
unknown	N/A	unknown	N/A

Although kelp beds and a variety of emergent vascular plants are definitely present along the park's shoreline, lack of appropriate reference data makes it impossible to determine if their distribution and extent is within the natural range of variation expected for this environment. Even less is known about the species composition and richness of other macroalgae (seaweeds) within the park.

Data Gaps

- Although the floating kelp canopy area in the Strait of Juan de Fuca in recent years has increased (Berry et al. 2005), the condition and trends of kelp distribution or abundance have not been monitored specifically along the shores of San Juan Island or the park.
- The adaptability of kelp under various scenarios of climate change is unknown.

4.2.4.4 Salmonid Fish

Federal agencies have designated Critical Habitat for "Puget Sound" Chinook and "Hood Canal summer-run" chum salmon, to include all nearshore areas of Puget Sound, including San Juan County. A designation of Critical Habitat is being considered for Puget Sound steelhead and is likely to include nearshore areas. The Puget Sound Salmon recovery plan (SSPS 2007) suggests overall goals and objectives for salmon protection and conservation in San Juan County. Goals

include restoration or protection of 27 tidal marshes including 11 identified as “at-risk” due to development related degradation, conservation of intertidal and subtidal flats that may be at risk due to road construction and residential development, and conservation of eelgrass meadows.

San Juan County shorelines and marine waters are an important habitat to Chinook salmon. This is perhaps owing to presence of many eelgrass beds, forage fish spawning areas, relatively uncontaminated waters, and located at a crossroads for ocean-going salmon movements. In addition, large numbers of chum, pink, sockeye and coho salmon, in various life stages, are found along the county’s nearshore especially from early spring through late summer (Kerwin 2002, SSPS 2007, Barsh and Wyllie-Echeverria 2006, Wyllie-Echeverria and Barsh 2007, Barsh and Murphy 2007, Wyllie-Echeverria 2008, 2008b, Beamer and Fresh 2012). Steelhead and coastal cutthroat trout also occur in the marine waters around the San Juan Islands (Kerwin 2002). Nearshore waters, especially where they consist of pocket estuaries and streams, provide juvenile salmon with refuge from predation, increased food resources, and additional time to make the physiological transformation from freshwater to saltwater. However, juvenile salmon in San Juan County appear to also use coarser, higher energy beaches—more often than is their pattern in most of Puget Sound.

Although salmonids are present seasonally in nearshore waters of both park units, no spawning has been documented for any species within the park. Salmonids are not one of the stronger indicators of local conditions because they move over large areas on a daily basis. Figures 13 through 15 depict the relative degree of use of various shoreline segments in the San Juan Islands by Chinook, pink, and chum salmon. The coloration and numbers represent relative probability of juveniles of each of these species being present in recent shoreline surveys by Beamer and Fresh (2012), whose paper describes the survey procedures and rating methods used. It is apparent that juvenile pink salmon use Westcott Bay near the English Camp unit to a lesser degree than in most of the rest of the San Juan Islands. Use of both park units by juvenile Chinook and chum, and use of the American Camp nearshore by pink salmon, is at or below average compared with the rest of the San Juans.

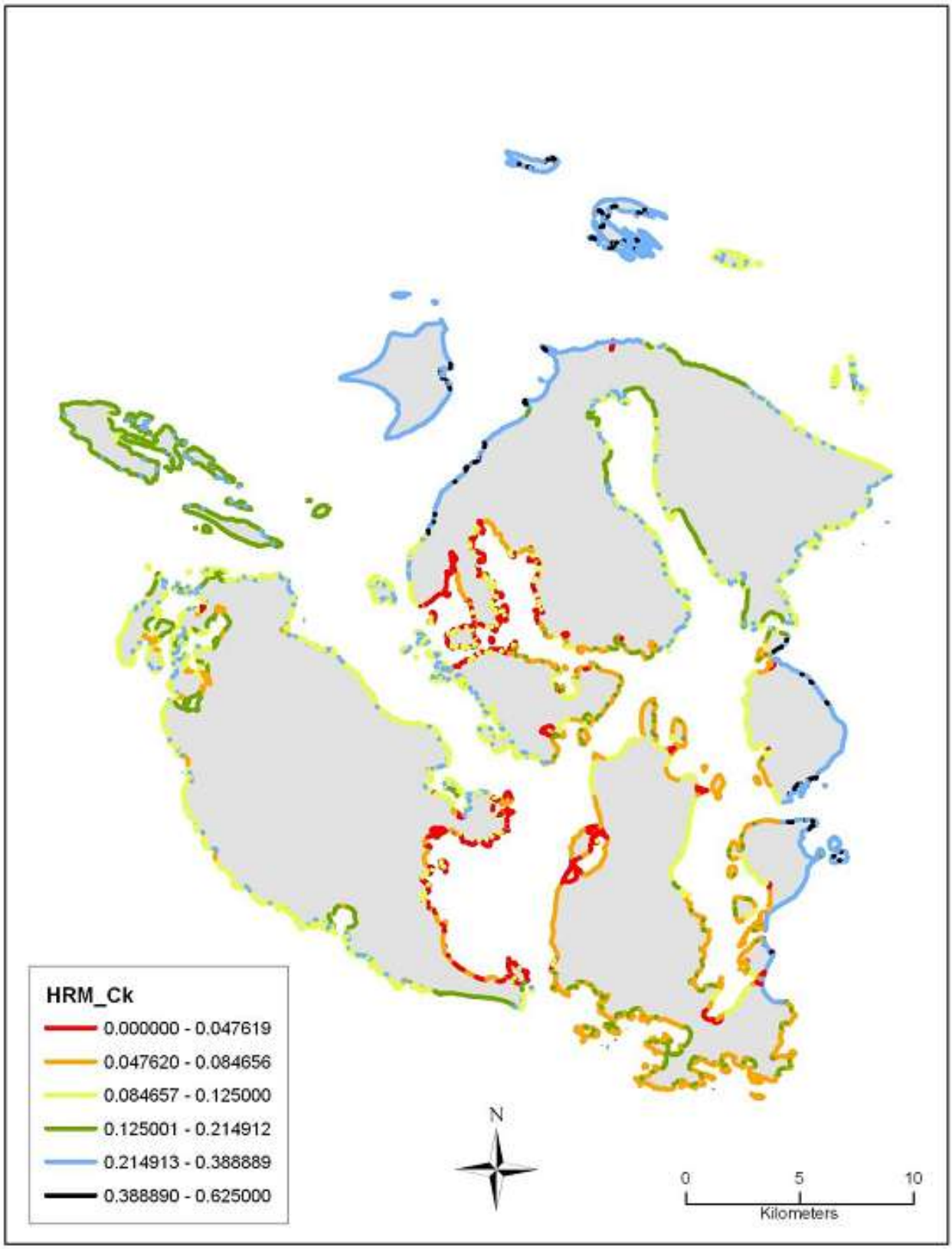

Figure 13. Fish presence probability for wild (unmarked) juvenile Chinook salmon for shoreline habitats in San Juan County.

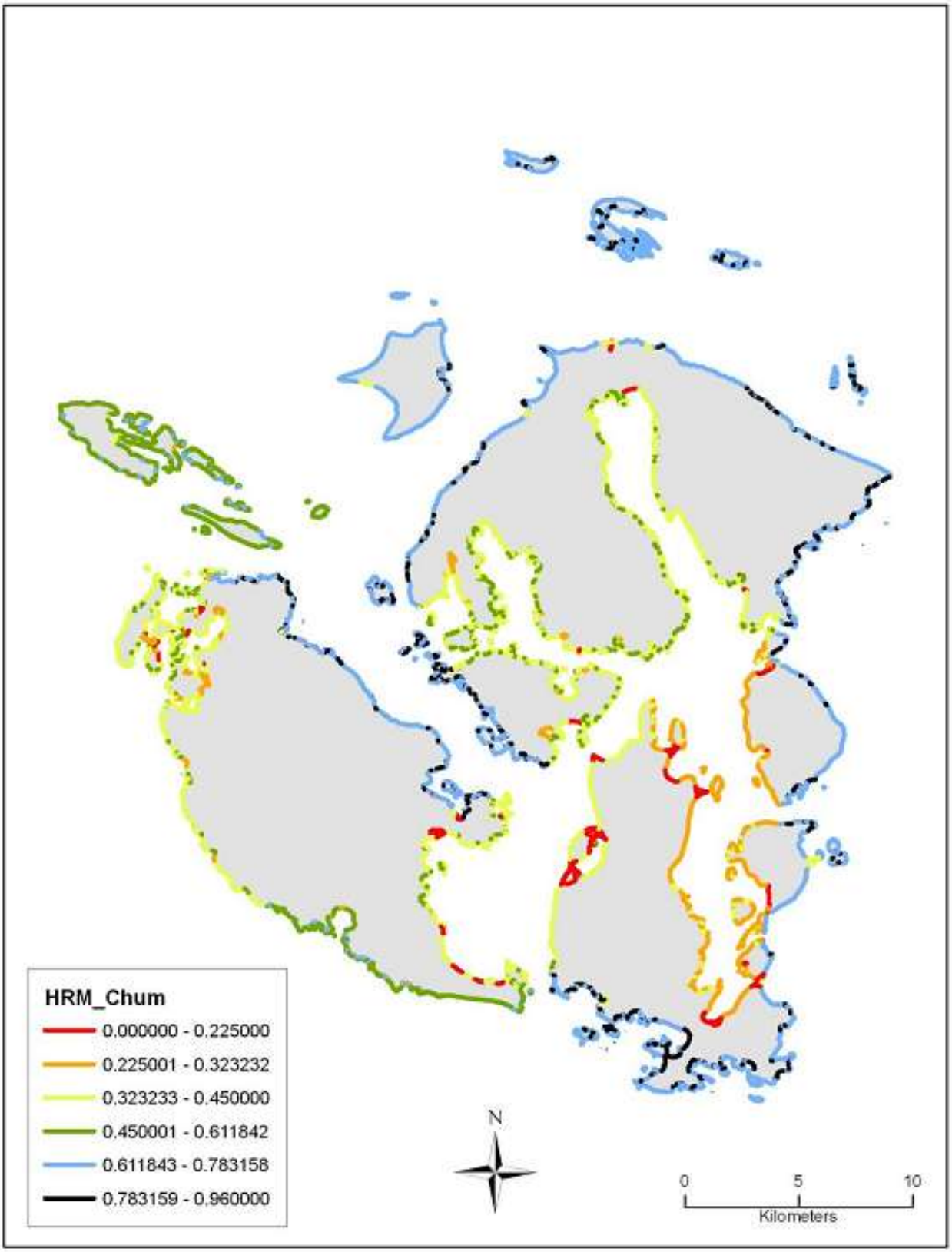

Figure 14. Fish presence probability for juvenile chum salmon in shoreline habitats of San Juan County.

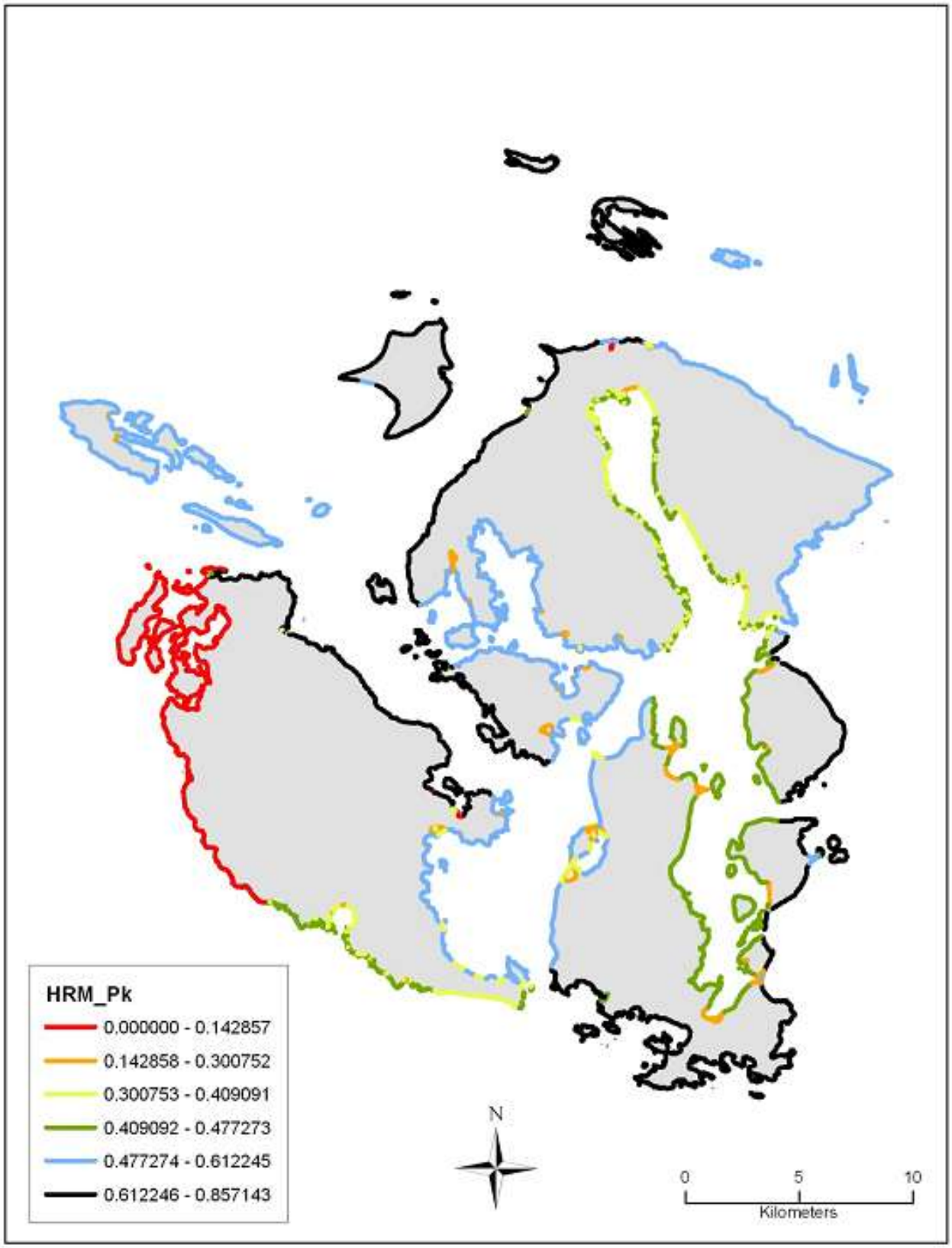

Figure 15. Fish presence probability for juvenile pink salmon in shoreline habitats of San Juan County.

Criteria
After accounting for year-to-year variation, “Good” condition would be represented by duration and frequency of use by juvenile salmonids that is close to the recent historical condition within the park, “Somewhat Concerning” condition would be represented by a measurable reduction in that, and “Significant Concern” would be a major decline. It is important to understand that salmon populations and use of the park’s nearshore areas by salmon is likely to be influenced more strongly by conditions outside of the park.

Condition, Trends, and Level of Certainty

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Unknown	N/A	unknown	N/A

Although some salmon surveys have occurred near the park (e.g., Beamer and Fresh 2012), we rated the Condition as Unknown because there is no reference for comparing and validly evaluating what is normal for waters near the park, and there is no recent baseline for evaluating trends.

Data Gaps
- The year-to-year condition and trends of salmonid fish have not been monitored specifically along the shores of American Camp or English Camp.
- Reasons for the relatively low use (compared to other areas of the San Juans) of the park's shorelines by salmonids, and whether that condition is normal, are unknown.
- The adaptability of salmonid populations under various scenarios of climate change is unknown.

4.2.4.5 Forage Fish
Forage fish are fish species that are consumed during at least part of their life cycle by salmonids, as well as (in many cases) seabirds and marine mammals. In San Juan County, they primarily include surf smelt, Pacific herring, and Pacific sand lance. In this section we also include other nearshore marine fish whose occurrence in the park has been documented: lingcod, greenling, shiner perch, striped surf perch, penpoint gunnel, butter sole, starry flounder, threespine stickleback, and 5 sculpin species (buffalo, Pacific staghorn, tidepool, manacled, silverspotted). In Puget Sound generally, sand lance and threespine stickleback have increased over the past 40 years, and in the Rosario Basin (waters north of Puget Sound that include the park), threespine stickleback has replaced herring as the dominant forage fish species (Greene et al. 2015). In southern and central Puget Sound, large jellyfish have increased dramatically.

A survey of intertidal fish in November 2002 at 11 sites in English Camp and 15 in American Camp yielded 14 species, including surf smelt, sandlance, and herring (Fradkin 2004). In general, forage fish require specific substrate types (Pentilla 2007), clean water with low suspended sediment levels (Levings and Jamieson, 2001; Morgan and Levings, 1989), and suitable spawning and refuge habitat such as eelgrass beds. The county as a whole has about 80

miles of potential forage fish spawning beaches, and approximately 13 miles of documented spawning beaches (Penttila 1999, Wyllie-Echeverria and Barsh 2007, Friends of the San Juans 2004a, 2004b, SSPS 2007), representing roughly 20 percent of the shoreline.

Pacific herring have been federally designated as a Species of Concern. They use the nearshore for all of their life-history stages, and deposit their eggs almost exclusively on eelgrass or other marine vegetation (Penttila 2007) where there is adequate light to support those underwater plants. They may also use middle intertidal boulder/cobble rock surfaces with little or no macroalgae (Penttila 2007).

Like Pacific herring, *surf smelt* and *sand lance* use nearshore habitat for all of their life-history stages. In the county as a whole, surf smelt spawning has been documented at 59 sites and sand lance at 8. Smelt breeding grounds occur in nearshore areas of the English Camp unit, around the perimeter of Bell Point (Friends of the San Juans 2004b).

Criteria

After accounting for year-to-year variation, "Good" condition would be represented by duration and frequency of spawning use by all forage fish species that is close to the recent historical condition within the park, "Somewhat Concerning" condition would be represented by a measurable reduction in spawning distribution or numbers by one or more species, and "Significant Concern" would be a major decline of all species or complete loss of spawning by one.

Condition, Trends, and Level of Certainty

Surveys in 2004 found no herring spawn in the Westcott Bay/ Roche Harbor region (near the English Camp unit of the park) despite its being known until recently as a herring spawning area (Friends of the San Juans 2004b, Stick and Lindquist 2009). This coincided with the loss of eelgrass from that area (Penttila 2007). Juveniles continue to be found in low numbers (Beamer and Fresh 2012).

Figures 16 through 19 depict the relative degree of use of various shoreline segments in the San Juan Islands by major forage fish species. The coloration and numbers represent relative probability of juveniles of each of these species being present in recent shoreline surveys by Beamer and Fresh (2012), whose paper describes the survey procedures and rating methods used. It is apparent that juvenile pink salmon use Westcott Bay near the English Camp unit to a lesser degree than in most of the rest of the San Juan Islands. Use of both park units by juvenile Chinook and chum, and use of the American Camp nearshore by pink salmon, is at or below average compared with the rest of the San Juans. Despite having data from this recent survey, we rated the Condition as Unknown because there is no reference for comparing and validly evaluating what is normal for waters near the park. Trend certainty is rated low because accounts of reduced numbers near the English Camp unit have mainly been anecdotal.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Somewhat concerning	Low	unknown	N/A

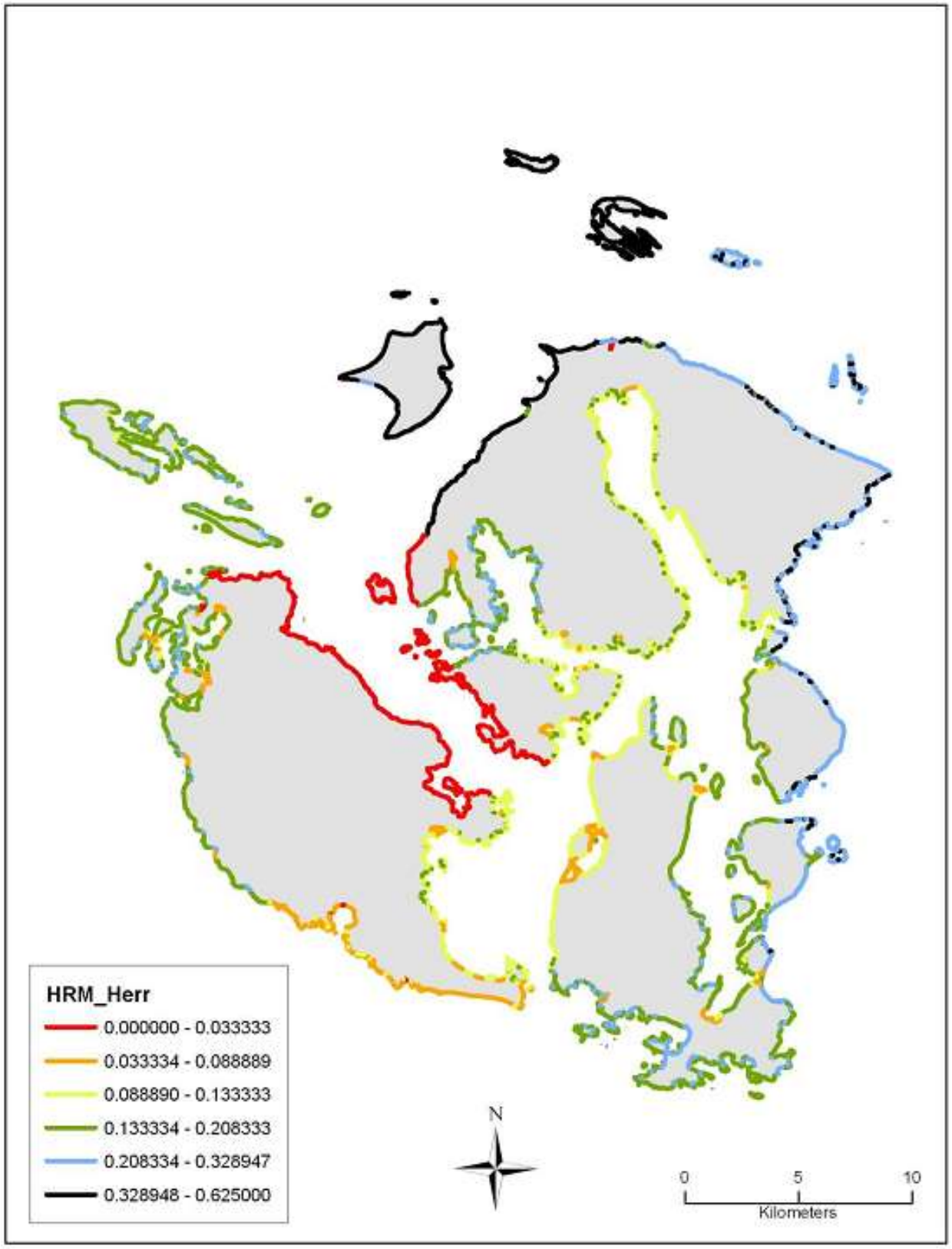

Figure 16. Fish presence probability for juvenile Pacific herring in shoreline habitats of San Juan County.

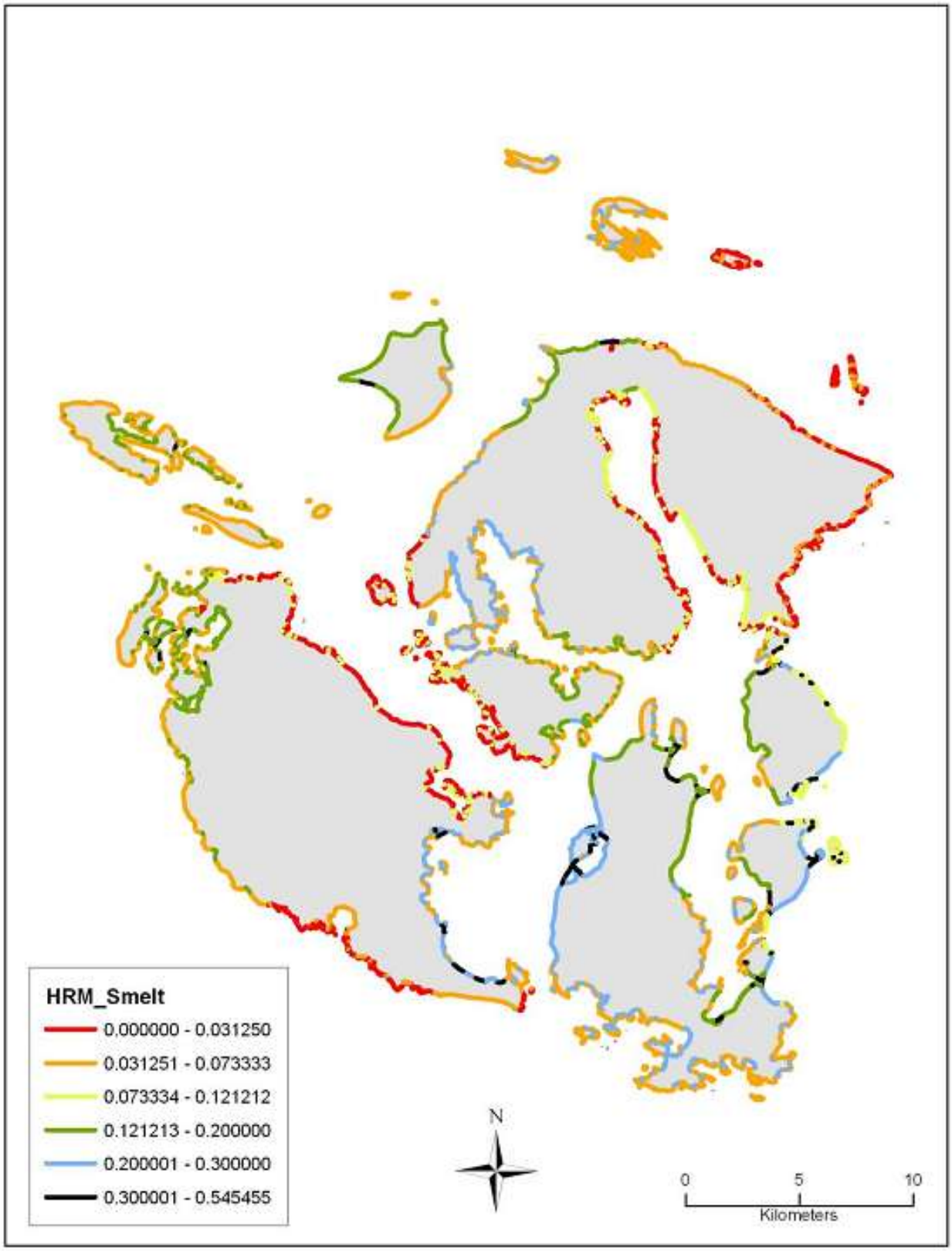

Figure 17. Fish presence probability for juvenile surf smelt in shoreline habitats of San Juan County.

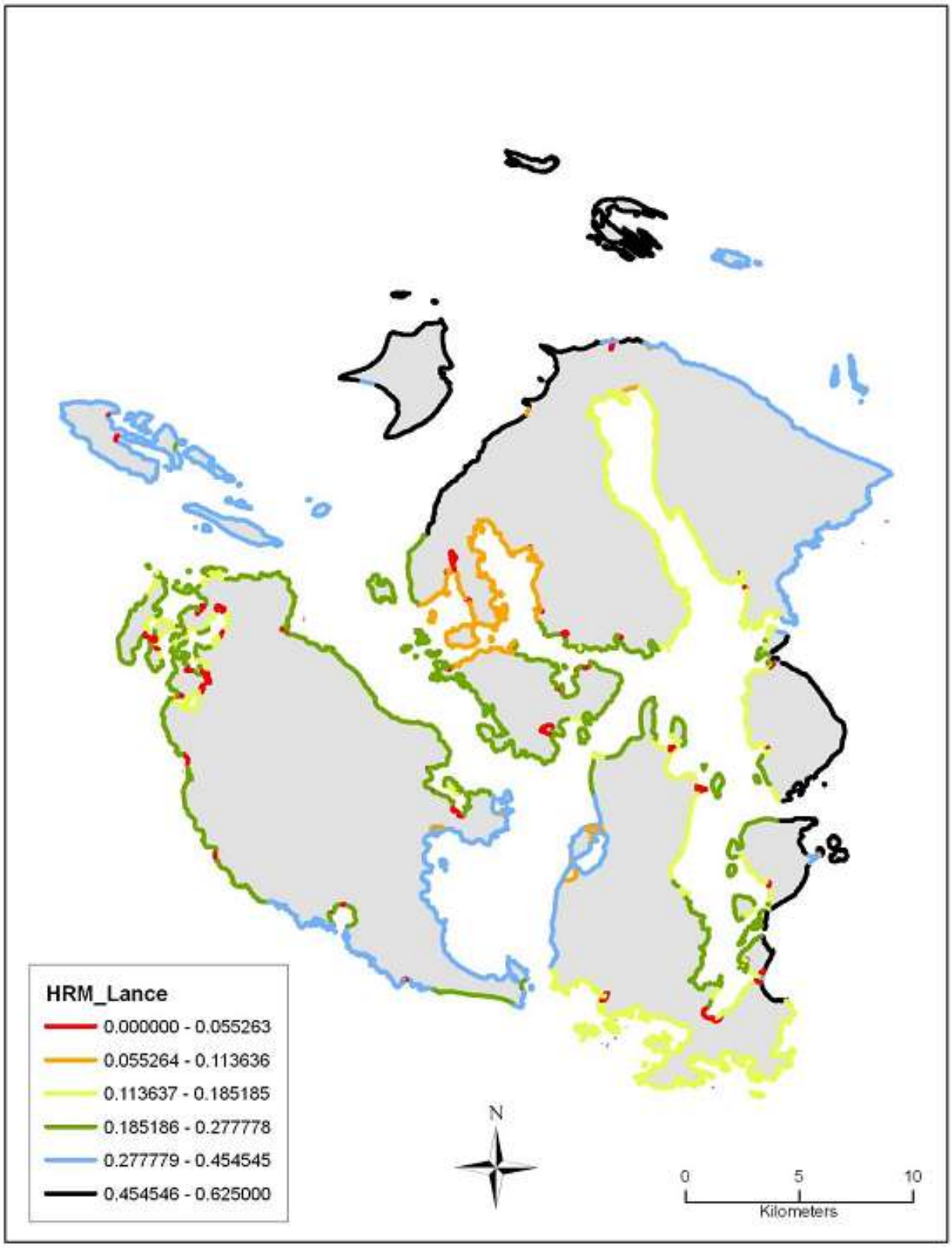

Figure 18. Fish presence probability for juvenile Pacific sand lance in shoreline habitats of San Juan County.

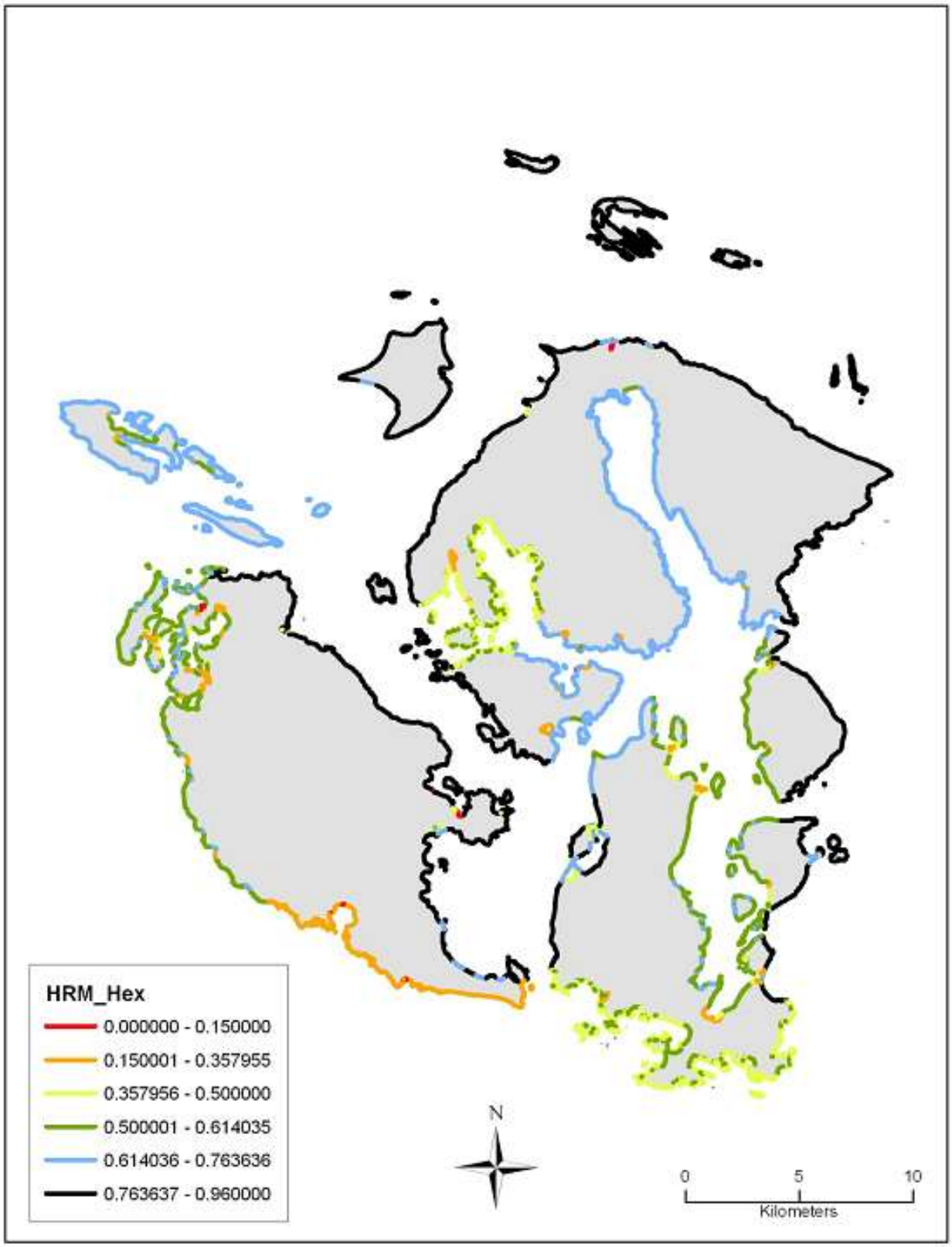

Figure 19. Fish presence probability for juvenile ling cod and greenling in shoreline habitats of San Juan County.

Data Gaps

- The year-to-year condition and trends of forage fish have not been monitored specifically along the shores of American Camp or English Camp.
- The adaptability of forage fish populations under various scenarios of climate change is unknown.

4.2.4.6 Nearshore Invertebrates

Nearshore invertebrates include species that inhabit the intertidal or shallow subtidal zones. They include shellfish as well as many species of unrecognized economic and ecological value. Adults forage amid tidal marsh vegetation, attach to rocks (e.g., barnacles), rest on or burrow in the sediment (e.g., clams), or are highly mobile (e.g., crabs). In general, shellfish depend on specific sediment compositions (such as grain size, amou nt of different grain and gravel sizes, organic content (Dethier 2006).

Sampling of rocky, sand/mud/gravel, eelgrass, and lagoon habitats within the park by Dethier (1993) documented the occurrence of 149 species of macroscopic invertebrates and fishes as well as 58 species of vascular plants, lichens and algae. The author suggested that if more habitat types and sites had been sampled, encompassing greater temporal and tidal variation, the species total might have been 30% higher. She found little overlap between the taxa in rocky versus soft substrates. Permanent plots were established at six sites within American Camp and two within English Camp. Farther out into Griffin Bay which adjoins the park, sediment sampling at one site by Long et al. (2008) found diversity of bottom-dwelling invertebrates (127 taxa) was higher than at nearly all other of the 30 sites sampled throughout a region encompassing the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet.

Within and near the English Camp unit, Dethier and Ferguson (1998) conducted a more intensive survey of Westcott and Garrison Bays for the San Juan County Department of Community Development and Planning. In addition to characterizing the invertebrate faunal diversity there, the study compared intertidal areas open versus closed to clam harvest. Fewer native littleneck clams (*Protothaca staminea*) and fewer bent-nose clams (*Macoma nasuta*) were found in areas open to harvest. Because bent-nose clams are not considered desirable for human consumption, the authors hypothesized that the reduced abundance of bent-nose clams in the area open to shellfish harvest in English Camp likely is due to frequent disruption of its habitat by harvesters targeting native littlenecks. The authors observed that the upper- and mid-intertidal zones of rocky areas within the bays were similar to other rocky shores in the San Juans, but the low zones in most areas were covered with or affected by muddy sediment. Following are highlights for just a few of the hundreds of nearshore invertebrate species present in the park.

San Juan County shorelines provide relatively isolated patches of habitat for numerous **oyster and clam** species. This includes non-native Pacific oyster (*Crassostrea gigas*); various clams including native littleneck clam (*Protothaca staminea*), introduced manila clam (*Venerupis philippinarum*), varnish clam (*Nuttalia obscurata*), butter clam (*Saxidomus gigantea*), and geoduck clams, and mussels.). In the park, clams and oyster beds are present in Westcott Bay (English Camp) as well Griffin Bay (American Camp). Shellfishing for clams and crabs occurs in Westcott and Garrison Bays, including on NPS property. Since 1973, harvesting has been prohibited in the area of the parade ground, but is permitted from the dinghy dock north around

Bell Point up to the property line of the Westcott Bay Sea Farms year-round, in accordance with WDFW regulations. None of the county's shellfish sites are listed as "threatened areas" (due to human health concerns) on the early warning system of the Washington State Department of Health. Although geoduck clams are present in the county, most of the county's intertidal shoreline is unsuitable for this species, and no commercial geoduck clam fisheries have been designated in the county (WDFW 2010).

Pinto abalone (*Haliotis kamtschatkana*) is federally listed as a "Species of Concern." Commercial harvest has never been allowed by Washington, and recreational fisheries have been closed since it was listed in 1994. Populations along the west coast of the United States and Canada have experienced dramatic declines in the last few decades, probably due to multiple causes (NMFS 2007). Current population levels are likely too low to support effective reproduction (Dethier 2006). In the inside waters of Washington, abalone is currently found only in the San Juan Islands and the Strait of Juan de Fuca (Dethier 2006). In the San Juan Archipelago, between 1992 and 2005, abalone declined from 351 animals per site to 103 animals per site at 10 long-term monitoring stations (PSAT 2007). It is strongly associated with kelp (Rogers-Bennett 2007) and is present in the vicinity of both American Camp and English Camp (WDFW PHS data). **Dungeness crab** (*Cancer magister*) is an important fishery resource and listed on WDFW's Priority Habitat and Species list. The species is also a critical component in the food web and is a vital food source for many sensitive or protected species (Fisher and Velasquez 2008). In Puget Sound they are more abundant in waters north of Seattle than south (Bumgarner 1990). Distribution in San Juan County is poorly known but they are known to occur near the English Camp unit. Adults migrate to shallow waters in spring (March through June) to mate (Fisher and Velasquez 2008). After mating occurs, larvae are dispersed by currents. Pandalid **shrimp** (also called humpy shrimp) (*Pandalus goniurus*) are considered by WDFW to be a "Priority Species" due to their recreational, commercial, and tribal importance, and for having vulnerable aggregations that are susceptible to population decline. Concentrations of this shrimp have been documented throughout much of San Juan County's marine waters, including in Griffin Bay (which adjoins the American Camp unit). **Sea urchins** (*Strongylocentrotus* spp.) are critical agents of subtidal community structure in rocky areas due to their intensive grazing of young and adult seaweeds. They are closely associated with kelp, and are consumed by seastars and sea otters (Dethier 2006). A commercial fishery for several sea urchin species exists in the San Juan Islands (Commercial Urchin Harvest Districts 1 and 2). Red sea urchin is present in nearshore waters by American Camp (WDFW PHS data). In general the Puget Sound sea urchin population is considered stable, although population declines in specific geographic areas have been noted (PSAT 2007).

Criteria

After accounting for year-to-year variation, "Good" condition would be represented by (a) levels of native species richness within that are close to those found recently (1990s or later) within the park in the same habitats, and (b) no decline of the abundance of the important species described above. "Somewhat Concerning" condition would be represented by a measurable reduction in (a) or (b), and "Significant Concern" would be a major decline.

Condition, Trends, and Level of Certainty

Most parts of the park's shoreline have not be subject to quantitative or comprehensive surveys of marine invertebrates. Although Dethier (1993) established permanent plots at six sites within American Camp and two within English Camp, apparently these have not been resurveyed or if they have, their data have not been published. Doing so would allow some estimation of trends.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
unknown	N/A	unknown	N/A

Data Gaps

- Although some data are available from the described surveys, no permanent plots have been monitored over time to estimate trends.
- Surveys have not covered all parts of the park's shoreline.
- Surveys seldom have been taxonomically comprehensive.

4.2.4.7 Invasive Nearshore Species

As international and regional shipping traffic expands, Japanese tsunami debris floats westward, and global climate changes, a potential exists for foreign species of marine plants and invertebrates to arrive in the park. Some non-native marine species of commercial value are already present, partly due to intentional introductions decades ago. Many but certainly not all non-native species can reduce populations and diversity of native species.

Criteria

After accounting for year-to-year variation, “Good” condition would be represented by absence of all invasive nearshore animals and plants from the park. “Somewhat Concerning” condition would be represented by presence of one or more such species, with little or no evidence of adverse impacts on native species richness and abundance. “Significant Concern” would be assigned if impacts to native species richness and abundance are demonstrably harmful over large areas of the park’s nearshore.

Condition, Trends, and Level of Certainty

At English Camp, mahogany clams (*Nuttalia obscurata*, also known as the purple varnish clam) have been documented as well as the non-native Pacific oyster (*Crassostrea gigas*) (Dethier and Ferguson (1998). These species are unlikely to spread rapidly into other areas within the English Camp unit or other parts of the park, but could have localized effects on native species. Next to the American Camp unit, the clam is abundant in Griffin Bay (Copello et al. 2004, Klinger et al. 2006). A native of Japan, the solitary tunicate (*Ciona savignyi*) has been recorded from the northern San Juan Islands. The gallo mussel (*Mytilus galloprovincialis*) hybridizes with native mussels and is likely present in or near Westcott Bay. The non-native Atlantic oyster drill (*Urosalpinx cinerea*), Japanese oyster drill (*Ocinebrellus inornatus*), Northern quahog clam (*Mercenaria mercenaria*) and Japanese clam (*Neotrapezium liratum*) have all been found in the Georgia Strait region but not specifically in the park. No obviously negative effects of these occurrences have been documented, and trends are unmeasured. Although currently restricted

mostly to the outer Washington coast, the invasive European green crab (*Carcinus maenas)* could cause major damage to nearshore food webs if it becomes established in the San Juans.

Among nearshore plants, the non-native eelgrass, *Zostera japonica*, is shown in the *Floristic Atlas of the San Juans* as having been found at both English Camp and American Camp: (http://biology.burke.washington.edu/herbarium/resources/sanjuanatlas.php). The invasive seaweed *Sargassum japonica* has been reported from Griffin Bay and Cattle Point in the American Camp unit (Copello et al. 2004); this species also likely occurs in Grandma's Cove. No obviously negative effects of these occurrences have been documented, and trends are unmeasured.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Somewhat concerning	low	Unknown	N/A

Condition is rated Somewhat Concerning because some non-native species are present, but Certainty is rated low because the invasiveness and effects of these and others that may potentially arrive is unknown.

Data Gaps

- Surveys have not covered all parts of the park's shoreline.
- Surveys seldom have been taxonomically comprehensive. For example, invasive tunicates have not been specifically searched for.
- The relative invasiveness of some non-native invertebrates and their actual or potential impacts on native species remain unknown.

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4.3 Freshwater Resources: Water Quantity, Quality

Indicator	Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Groundwater Levels & Quality	Somewhat concerning	Medium	Unknown	N/A
Extent of Surface Water & Wetlands	High	Medium	Unknown	N/A
Surface Water Quality	Unknown	N/A	Unknown	N/A
Wetland Biological Condition	Somewhat concerning	High	Unknown	N/A

4.3.1 Background

Streams, springs, ponds, and wetlands provide essential habitat for many species. Groundwater is a critical source of drinking water as well as helping sustain streamflow and wetlands. The amount, duration, and seasonality of freshwater input to nearshore marine waters profoundly influences the composition and productivity of the species that live there and along the tidal shoreline.

4.3.2 Regional Context

Islands in the Salish Sea are characterized by isolated and limited aquifers. This is particularly true of San Juan Island because it receives less precipitation annually than many other areas in the region. Precipitation recharges groundwater aquifers very slowly, and water from shallow wells is an important source of drinking water for San Juan Island. In the region, fresh groundwater occurs as a lens floating atop denser saltwater in two major aquifer types (Johns 1997). Fractured bedrock aquifers provide little filtration and water yield is typically low. Glacial outwash aquifers can provide better filtration because the water occurs in the spaces between loose sand and gravel, and their yield is typically greater. Both aquifer types occur at American Camp, but only one well is in operation drawing from a fractured bedrock aquifer. Located on the western boundary of the unit, this well supplies the needs of the temporary visitor center. At

English Camp, groundwater occurs in unconsolidated beach deposits, which are highly susceptible to saltwater intrusion, and in fractured bedrock aquifers. Water is drawn from bedrock aquifers by means of two wells with low yields at this unit. This water supplies the maintenance facility, trailer pads, a summer camp site, and a drinking fountain in the parking lot.

The San Juan Islands are a mixture of fractured bedrock aquifers and bedrock overlain with glacial deposits. Glacial deposits yield large quantities of water to wells, but bedrock yields little (perhaps only enough for a single or few households from one well). Recharge, on the other hand, is highly correlated with the amount of land overlain by glacial deposits (Orr et al. 2002). San Juan Island has a mixture of aquifers composed of bedrock and glacial deposits. The northern and southern ends of the island are dominated by glacial deposits. English Camp is a mixture of the two, while American Camp is mostly covered with glacial deposits. Recharge rates in bedrock are usually less than 1.5 inches/year; in glacial deposits they range from 0.5 to 3 inches/year. In sandy soils the rate may be as high as 9 inches/year. With an average precipitation for the Island of 33 inches/year, the average recharge in the English Camp area ranges from 1 to 4 inches/year, with most of the area near 1 inch/year. At American Camp, recharge ranges from 1 to 3.5 inches/year, with most of the area near 1 inch/year. The average recharge across the whole island is 1.99 inches/year.

Park management aims to maintain a balance between the domestic, biological, and physical water supply needs. In order to properly meet each of these requirements, the park must balance three main water rights issues; water rights for administrative purposes, water rights for the protection of park resources, and responding to requests for the exportation of water to adjacent developments from wells within the park (Flora and Sharrow, 1992). Local agreements recognize both park units as separate water utilities, providing the NPS authority to review and accept or reject any action on park boundaries that may affect the water resources within the park.

4.3.3 Issues Description

Three threats that are perhaps the most likely to imperil the park's fresh waters are:

1. Groundwater depletion and degradation
2. Pollutant sources and soil disturbance
3. Climate change

These are described as follows.

4.3.3.1 Groundwater Depletion and Degradation

Groundwater must be recharged by fresh water from precipitation and infiltration at a faster rate than it is withdrawn from aquifers, or water tables will eventually fall, wells will go dry, and ecosystems dependent on that water will be harmed. Well yields in and around the park are already low (e.g., Werrell 1994), so withdrawal of groundwater by residences near the park has the potential to endanger the availability and quality of groundwater within the park, especially if compounded by longer droughts associated with regional climate change. American Camp has been identified as an area of significant recharge (Klinger et.al. 2006). The vulnerability of the park's groundwater is greatest where underlying glacial drift aquifers extend beyond the park boundary, as is the case at American Camp. That is because any polluting land uses that share

that aquifer have enhanced potential for transferring that pollution into the park via lateral groundwater movement.

Three community wells just outside the east boundary of the American Camp unit tap an aquifer beneath the park's Mount Finlayson and are the main source of water for approximately 270 residences located just east of the American Camp unit. In 1998, a Wellhead Protection Plan covering that area was adopted with the intent of reducing aquifer risks from high and medium risk contaminants that might otherwise enter from the land surface.

Unfortunately, the rate of groundwater withdrawal that can occur for decades to come without compromising acceptable-quality drinking water from any of the wells in or near the park is not precisely known. Recharge for San Juan County is estimated at approximately 1.99 inches and is 6 percent of total rainfall (Orr 2002).

Increasing the withdrawals of groundwater, or decreasing recharge by covering the ground with extensive areas of impervious surface (buildings, roads), will eventually cause most groundwater that is withdrawn within about 1000 feet of the marine shore to become unpalatable, as some of it currently is. That is because saltwater intrudes into an aquifer when fresh water is withdrawn faster than it is replenished. The park currently has 30.1 acres of roads, parking lots, buildings, and bare terrestrial areas, as well as 15.4 acres of mowed lawn (Rocchio et al. 2012). When located on a slope, such cover types tend to export runoff more quickly and provide for less recharge of groundwater than does natural vegetation cover. In addition, extensive underground burrow networks created by the large rabbit population at American Camp could be intercepting some infiltrating precipitation and redirecting ("short-circuiting") it closer to marine waters immediately downslope before it can contribute to the aquifer. Finally, conversion of prairie and openlands to forest, in some cases accelerated by intentional plantings, could temporarily reduce surface water available to streams and wetlands, due to greater losses from evapotranspiration.

4.3.3.2 Soil Disturbance and Other Pollutant Sources

Road runoff, animals, soil disturbance (compaction and erosion) by recreationists, and airborne contaminants from distant sources are probably the items most likely to pollute the park's very limited fresh surface waters. The potential for the park's nearshore marine waters becoming contaminated is discussed separately in section 4.2.3.3.

4.3.3.3 Climate Change

If the present century-long trend toward warmer and drier conditions in the park continues, the threat to the park's precarious ground and surface water resources will increase and could cause significant problems.

4.3.4 Data and Methods

4.3.4.1 Groundwater Levels and Quality

Groundwater is the only sizable source of fresh water in most of the park. Because of the island environment, groundwater is extremely vulnerable to depletion and changes in quality.

Criteria

"Good" condition would be average annual groundwater levels that remain stable or increase year-to-year, with conditions of salinity, suspended solids, pathogens, and other contaminants that pose no threat to people or biological resources. "Somewhat Concerning" would be conditions where either groundwater levels show a slight downtrend from year to year (with little or no detected impairment of the availability of drinking water), or where drinking water becomes unpalatable but not dangerous to health. "Significant Concern" would be where groundwater is unavailable for park use due either to lack of quantity (wells go dry, wetlands dry up) or quality (saltwater intrusion, pollution).

Condition, Trends, and Level of Certainty

Shortages of groundwater for park use often occur during summer months when rainfall is minimal and visitation is at a peak. Low yielding wells (less than a few gallons per minute) with water which at times is nearly unpalatable typify the condition at both English Camp and American Camp. Well levels have not been monitored with sufficient regularity to determine over the long term if water tables are falling, or water quality is declining. The well supplying drinking water to American Camp was drawn down to a critical level in the summer of 1994 as the San Juans experienced an extended drought, and it had to be shut down for two months at the height of the visitor s season in order to allow slow recharge to occur.

In accordance with NPS policy, the park has consistently denied requests from adjacent developments to access water from within park boundaries due to the possibilities of exhaustion of park freshwater supplies and detrimental effects on water-dependent resources (NPS 2008). Water rights and supply issues vary between the two units. At American Camp, the well supplying water to the visitor center maintains a certified water right to pump 3.5 gallons per minute or 5,000 gallons per day. This supply is sufficient for current needs, but the water tests high in total suspended solids and chloride rendering it undesirable as drinking water. From 1981 to the present, it has not met the drinking water standards for chloride, which may indicate the influence of saltwater intrusion (in 1970 it was within the acceptable range for chloride). The Washington Department of Ecology cannot issue a new water right if subsequent pumping of wells will cause contamination of fresh groundwater by saltwater unless the effect of seawater intrusion is mitigated.

Well water samples are routinely analyzed to ensure the park is complying with the state of Washington Department of Health drinking water standards for bacteria as well. To date, all bacterial samples have been within allowed limits. The park also analyzes well water for nitrate once annually as required by state regulations, and the results indicate no problems.

At English Camp, two wells supply fresh drinking water. One was drilled in 2000 to supply the needs of the maintenance facility including a low-water washing machine, two sinks, and one toilet. The water is not potable (**Table 2**). This well replaced two low yielding wells that were constructed by the previous landowner on private property just east of the maintenance facility. A second well supplies water to the drinking fountain in the parking lot, two trailer pads, and a group campsite used in summer. It appears that both wells meet the exemption conditions set forth by the Washington Department of Ecology; therefore, obtaining a certified water right is not required.

Table 2. Water quality in two wells at English Camp sampled in 1999 and 2000.

Site	Latitude	Longitude	Date & Time	Parameter	Value	Units
SAJH_L1_ACW	48.4645	-123.0288	5/4/1999 13:00	Depth, bottom	191	ft
			9/28/1999 13:00	Fluoride	0.2	mg/l
				Iron	65	ug/l
				Magnesium	60	mg/l
				Manganese	150	ug/l
				Potassium	25	mg/l
				Silica	19	mg/l
				Sodium	140	mg/l
				Sulfur, sulfate (SO4) as SO4	57	mg/l
				Calcium	61	mg/l
				Chloride	250	mg/l
				Depth, bottom	191	ft
			2/23/2000 10:30	Inorganic nitrogen (nitrate and nitrite) as N	*Non-detect	
				Nitrogen, Ammonia + Organic	0.5	mg/l
				Orthophosphate as P	0.03	mg/l
				Phosphate-phosphorus as P	*Present <QL	
				Ammonia-nitrogen as N	0.13	mg/l
				Depth, bottom	191	ft
SAJH_L1_SBS	48.4570	-122.9985	5/4/1999 11:00	Flow	34.1	gal/min
			9/27/1999 17:00	Inorganic nitrogen (nitrate and nitrite) as N	2.8	mg/l
				Nitrogen, Ammonia + Organic	0.3	mg/l
				Orthophosphate as P	0.12	mg/l
				Phosphate-phosphorus as P	0.12	mg/l
				Ammonia-nitrogen as N	0.02	mg/l
				Flow	9.43	gal/min
			2/23/2000 8:30	Flow	9.43	gal/min

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Somewhat concerning	Medium	Unknown	N/A

Condition of groundwater is rated Somewhat Concerning due to documented instances of high salt content, temporary shortages for visitor use, and the likely sensitivity to climate change and withdrawals from just outside the park.

Data Gaps

- The amount of groundwater recharge needed to sustain the park's wetlands and to avoid degradation of water quality in the park's few wells is unknown.
- A comprehensive set of water quality parameters has not been monitored in the park's wells.

4.3.4.2 Extent of Surface Water and Wetlands

Due to its topography, geology, soils, and climate, the park contains almost no perennial surface water. Nonetheless, its wetland acreage is likely substantial for an area of its size. Note that the *quality* of surface water and wetlands are discussed in other sections of this document.

Criteria

"Good" condition would be represented by (a) streams that flow for a duration and length equal to their historical average in the park, and (b) no loss of wetland acreage due to prolonged drought or other factors, and (c) no loss in excess of their natural turnover rates of wetland vegetation associations recognized as globally imperiled. "Somewhat Concerning" and "Significant Concern" would be represented by progressively smaller duration of flows, wetland extent, and extent of rare wetland vegetation associations.

Condition, Trends, and Level of Certainty

Because the American Camp unit of the park is surrounded on three sides by marine waters, the amount of surface runoff reaching the park from outside is small. East-sloping topography on the unit's east side shields the park from surface runoff originating in the Cattle Point residential developments to its east. The longest potential flow line for incoming runoff is in the American Camp unit's northwest corner, where a line of about 1700 feet connects the park boundary, at elevation 180 ft there, with the top of a 250-ft hill to the northwest (i.e., mean slope = 4 percent). Woodland is the predominant land cover along that flow path, part is conservation land owned by the San Juan County Land Bank, and there are no residences. A channelized stream with a few small excavated ponds parallels the northern border of the American Camp unit but is about 500 ft from its border. It separates the American Camp unit from the Burden Field (Rabbit Run) air strip further north, and it flows into Griffin Bay 500 ft north of the park border. There are no lakes, large ponds, or perennial streams within the American Camp unit, but several wetlands, springs, and short drainageways with seasonal flow are present.

The park's English Camp unit had no streams or other opportunity for input of surface runoff from outside of the park until recently when the Mitchell Hill area was added to it. The Mitchell Hill addition contains three first-order channels and a collective length of about 9000 feet. At least one of them flows year-round during most years. They join together about 0.4 mile downslope from the park's west boundary and then flow through a few ponds and wetlands before reaching Garrison Bay another 0.8 stream-miles from the park. Two of the three channels originate outside the park. The northernmost channel which originates within the park drops about 210 ft over a distance of about 2800 ft for an average percent-slope of 7%. The middle channel originates in a spring and before entering the park from the east, it drops about 115 ft over a distance of about 2050 ft for an average percent-slope of 6%. The southernmost channel probably flows the most consistently and drops about 140 ft over a distance of about 1750 feet for an average percent-slope of 8%. For much of its length within the park it is bounded by steep side slopes, giving it a ravine-like appearance. The two channels that originate outside the park are shaded by forest their entire length beginning at their source, as are all three of the channels as they flow westward through the park's Mitchell Hill addition. About 0.3 mile north of the English Camp park boundary, a mostly-wooded stream feeds into Westcott Bay.

Wetlands were mapped in the park, as in most of the rest of the U.S., at a relatively coarse resolution in the 1980s using aerial imagery available at that time, by the National Wetlands

Inventory (NWI). San Juan County refined the NWI map in 2010 using LiDAR and new aerial imagery but without ground-truthing within the park (Adamus 2011). A wetlands map covering just the park, and featuring higher resolution than the NWI mapping and with some ground-truthing, was prepared for the NPS by Holmes (1998) but did not cover tidal wetlands (except the 3 lagoons at American Camp) or the new Mitchell Hill addition. It was never published, and a copy suitable for review could not be located for this NRCA project. For the park's American Camp unit, the very recent ground-truthed vegetation map indicates wetlands based on field identifications of diagnostic plant communities.

The total wetland acreage in the park, minus the Mitchell Hill and Westcott Bay additions, was reported by Holmes to be 91.9 acres (4% of the park's current area). However, the total may be closer to 410 acres (20% of the park). We arrived at that estimate by referring to data in Rocchio et al. (2012) and summing the areas of vegetation alliances whose defining species have been designated as wetland indicators by federal agencies (i.e., designated as OBL, FACW, or FAC in the Pacific Northwest by the U.S. Army Corps of Engineers (Lichvar 2013). While some of those alliances are likely to also contain upland species, it is also true that some alliances we did not incorporate into the sum include species that are wetland indicators. In any event, soil and hydrologic indicators would also need to be examined on site to ascertain which areas are wetlands subject to regulation under federal and Washington law. In summary, one can probably conclude that this park's wetland area is likely greater than estimated by Holmes (1998) or other existing wetland maps.

Six of the park's associations of wetland vegetation have been designated "imperiled," although none of the individual plant species in these associations are listed as threatened or endangered. "Imperiled" means that the particular combination of species is considered (by the Washington Natural Heritage Program) to be uncommon and/or much less common now than historically at a global or Washington state scale, and is threatened with further losses globally and/or within Washington. These imperiled associations cover 1% of the park's area and comprise 5% of all wetland acreage in the park. Five are only at American Camp, one is only at English Camp, and one is at both.

For the American Camp unit, other NPS documents reported that the Holmes (1998) survey found 26 wetlands comprising 79.2 acres. That tally includes the 3 lagoons that are tidal and therefore are discussed separately in section 4.2. Both wooded and herbaceous wetlands are present and include the following four assemblages ("associations") that are considered imperiled globally or in Washington:

- *Populus tremuloides / Carex obnupta* Forest
- *Salix hookeriana* - (*Salix sitchensis*) Shrubland
- *Cornus sericea* Shrubland
- *Malus fusca - (Salix hookeriana) / Carex obnupta* Shrubland
- *Salicornia virginica - Distichlis spicata - Triglochin maritima - (Jaumea carnosa)* Herbaceous Vegetation

Along the trail between Jakle's Lagoon and Third Lagoon is a wet area that has been variously called a pond or a wetland, as its vegetated area shrinks or expands in response to season and

interannual changes in precipitation. Despite its small (0.3 acre) size, at times it provides the most extensive area of open non-tidal water within the park.

For the English Camp unit, the Holmes (1998) survey found nine wetlands comprising 12.7 acres. Within this unit, the recent vegetation survey by Rocchio et al. (2012) noted the presence of two "imperiled" wetland vegetation associations. One is the *Salicornia* association listed above as also present in the American Camp unit. The other, present only within the Mitchell Hill addition, is:

- *Tsuga heterophylla - (Thuja plicata - Alnus rubra) / Lysichiton americanus - Athyrium filix-femina* Forest

Only a few small patches of this type were located, all at the top of Young Hill, an unusual location for wetlands of any type.

The Mitchell Hill addition, which was not surveyed for wetlands by Holmes (1998), is shown in the coarser-scale NWI and county maps as having no wetlands, but in the center of the Mitchell Hill addition, Rocchio et al. (2012) mapped one forested swamp of western redcedar (dominant) with salmonberry and skunk cabbage, as well as two patches of riparian bigleaf maple-alder swamp along the western edge.

Two "imperiled" vegetation associations identified in the park by Rocchio et al. (2012) contain species which in some situations are wetland indicators:

At English Camp:

- *Camassia quamash - Triteleia hyacinthina* Herbaceous Bald—English Camp

At American Camp:

- *Festuca roemeri - Camassia quamash - Cerastium arvense* Herbaceous Vegetation

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Good	Medium	Unknown	N/A

Condition is rated Good because the extent of surface water and wetlands in the park appears to be limited only by natural factors. Certainty is rated only Medium because wetlands have not be thoroughly delineated.

Data Gaps

- The duration of flow in the park's few ephemeral streams has not been monitored with sufficient regularity to differentiate changes due to local water table drawdown from changes in regional climate.
- Although the park does not appear to have lost any wetlands permanently as a result of management actions, no permanent points have been monitored to determine if the water table that supports the park's wetlands is declining more rapidly than can be attributed to weather changes alone.

- Effects of forest succession on surface water levels are unknown, and could be either positive or negative.
- Trends data are lacking for particular wetland plants and plant associations.

4.3.4.3 Wetland Biological Condition

The biological condition of a wetland can be evaluated, for example, by determining the richness and species composition of its vascular plants, bryophytes, lichens, invertebrates, microbes, algae, birds, amphibians, and mammals. Because of challenges otherwise imposed by species mobility and sample processing costs, vascular plants are used most often. Assessment procedures (e.g., Rocchio and Crawford 2013) are available for distilling exhaustive plant lists into one or more "floristic quality" scores which summarize the wetland's condition, quality, or integrity—as predicted only by vascular plants (different conclusions may be reached by assessing other taxonomic groups or wetland functions).

Non-native plants, especially those that are highly invasive, can rapidly outcompete native species and thus depress overall species richness. They are typically associated with past disturbance of a wetland's soil structure and/or water table, such as by cultivation, grazing, compaction, excavation, or regrading (see also the discussion of invasive terrestrial plants in section 4.4.3.5).

Criteria

For purposes of this assessment, "Good" conditions would be a low level of presence in wetlands of non-native plant species, especially ones considered to be highly invasive. "Somewhat Concerning" and "Significant Concern" would represent increasingly greater proportional cover of invasives. It is not advisable to set specific numeric criteria or thresholds because species vary greatly in their potential for harming native plant richness.

Condition, Trends, and Level of Certainty

Approximately 33% of all vascular plant species in the county (Atkinson & Sharpe 1985) as well as in the park (Rochefort and Bivin 2010) are believed to be exotic, i.e., non-native. A survey in 2010 of 102 San Juan County wetlands found that, in an average quadrat (n= 412), the relative *cover* of vegetation consisted of 32% non-native (exotic) species, and 24% invasive species, which are a subset of non-native species (Adamus 2011). The survey found an average of 18 plant species per wetland (range 3 - 39), averaging 3.23 species per 1 m x 1 m quadrat (range 1-10). The invasive *Phalaris arundinacea* was present in 73% of the wetlands, and the non-native *Holcus lanatus* was in 54%. Although floristic quality index values have not been calculated for any San Juan County wetland, it can be expected that those will correlate with dominance of non-native plants within a wetland. In San Juan County, herbaceous wetlands tend to be more vulnerable to invasion by non-native plants than do densely shaded wetlands. Or perhaps, herbaceous wetlands are more likely to have once been cultivated and thus have suffered greater soil disturbance, including the intentional planting of non-native species as forage for livestock. Much of the western part of the American Camp unit was cropland or pasture before the park was established, having been converted from prairie or wetland. Similarly, part of the English Camp unit was cleared during the military occupation and some of it has been maintained as lawn (non-native grasses) for historical interpretive purposes.

The comprehensive vegetation mapping conducted by Rocchio et al. (2012) shows several of the park's mapped vegetation units classified as "ruderal alliances" (basically, having a high component of non-native species as commonly associated with past disturbances). A large proportion of these are also likely to be wetlands in whole or part, based on their having a significant component of wetland indicator species. In prevalence order, these are:

Ruderal Vegetation Alliance with a Likely Wetland Component	**Acres**
Holcus lanatus - Poa pratensis Provisional Ruderal Alliance	259.1
Agrostis (capillaris, stolonifera) Provisional Ruderal Alliance	148.2
Alnus rubra - Pseudotsuga menziesii Provisional Ruderal Alliance	79.1
Crataegus monogyna / Mixed Forbs & Graminoids Provisional Ruderal Wet Shrubland	16.1
Alnus rubra / Nonnative Grasses Provisional Ruderal Flooded Forest Alliance	13.3
Leymus mollis ssp. *mollis - Holcus lanatus* Provisional Ruderal Alliance	8.4
Equisetum arvense - Mixed Graminoid Provisional Ruderal Wet Meadow Alliance	5.0
Schedonorus pratensis Provisional Ruderal Wet Meadow Alliance	2.4
Juncus gerardii Provisional Ruderal Wet Meadow Alliance	1.3
Alnus rubra / Carex obnupta Provisional Ruderal Flooded Forest Alliance	0.8
Carex leporina Ruderal Wet Meadow Alliance	0.5
Prunus emarginata Provisional Ruderal Flooded Forest Alliance	0.4
TOTAL	534.6

Thus, a very rough estimate of the percentage of the park's wetland area that has significant cover of non-native plants is 23%. However, not all of the ruderal species are highly invasive and thus detrimental to native plant richness. Any efforts to restore native wetland plant communities should focus on ways to remove and avoid re-establishment of non-native species that are most invasive and fare the best in wetlands of the type that occur in the park. These include *Phalaris arundinacea, Holcus lanatus, Vicia sativa*, and *Cirsium arvense*.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Somewhat Concerning	High	Unknown	N/A

Data Gaps

- *Trends* in invasive plant species within the park's wetlands remain unmeasured.
- The effects of invasive species on wetland functions (not just plant richness) have not been measured within the park.

4.3.4.4 Surface Water Quality

Whether ponded or flowing in streams, surface water potentially supports a wide variety of plants and animals, including both aquatic species that live in or along the water and terrestrial species that critically depend on the water for drinking. Fresh surface water is particularly

important for sustaining wildlife on small islands, because marine water is unfit for consumption by most terrestrial vertebrates. The quality of surface water determines its productivity and the species that can live in it or consume it. In particular, dissolved oxygen, temperature, suspended solids, and metals can profoundly affect aquatic and terrestrial life.

Criteria

"Good" condition would be no evidence in surface water samples of any contaminants at levels that could harm people or biological resources (including contaminants such as certain detergents and various hormone disrupters which may not currently be regulated by government but which peer-reviewed science shows can cause harm). "Somewhat Concerning" would be occasional and temporary failure to meet state or federal water quality standards, when accompanied by no evidence of harm to humans or biological resources. "Significant Concern" would be chronic failure to meet surface water standards, and/or evidence of harm to humans or biological resources that can be attributed to contaminants in the park's surface water.

Condition, Trends, and Level of Certainty

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Unknown	N/A	unknown	N/A

The rating of Unknown is given because there has been almost no sampling of water in the park's few short stream segments. Salinity and conductivity were recorded during the 1998 wetland inventory, but no other water quality parameters were measured and those data apparently were not archived. However, the risk to people and biological resources appears small because of the lack of obvious pollutant sources within or uphill from the park, and the lack of well-defined conduits (e.g., streams) for transporting any pollutants into the park from outside.

Data Gaps

- Even when surface waters were sampled, they have not been sampled for a full spectrum of chemicals or with sufficient frequency to determine if contaminants are present in harmful concentrations
- The role of runoff from the park on the quality of local nearshore waters has not been quantified, e.g., in Westcott Bay where it adjoins English Camp.

4.3.5 Literature Cited

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4.4 Terrestrial Vegetation and Land Cover

Indicator	Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend

Prairies	Somewhat Concerning	Medium	Unknown	N/A
Oak Woodlands	Somewhat Concerning	Low	Unknown or Improving	N/A
Coastal Strand, Spit, and Dune Community	Somewhat Concerning	Low	Unknown	N/A
Native Plant Richness & Invasive Plants	Somewhat Concerning	Medium	Unknown	N/A
Castilleja levisecta	Significant Concern	High	Unknown	N/A
Crassula connata	Somewhat Concerning	Low	Unknown	N/A
Ranunculus californicus	Significant Concern	Low	Unknown	N/A
Symphyotrichum hallii	Significant Concern	Low	Unknown	N/A
Forest Age and Composition	Somewhat Concerning	Medium	Unknown	N/A
Forest Structure	Unknown	N/A	Unknown	N/A

4.4.1 Background

Terrestrial vegetation is herein defined to include all plants that occur on uplands, including bryophytes, lichens, and fungi. This report section does not include wetland vegetation, which discussed in section 4.3.4.2. Vegetation is a foundation for terrestrial ecosystem composition, structure, and function. Vegetation *composition* includes an array of ecosystem components such as species, populations, genetic composition, and special habitats. Vegetation *structure* refers to the vertical and horizontal arrangement of components, such as canopy structure and corridors for species movement. Vegetation *function* refers to ecosystem processes such as cycling of nutrients, carbon, and water—which interact with disturbance processes and biological components such as interspecific competition and demographic and reproductive processes. Vegetation dominates biomass and energy pathways and defines the habitat for most other forms of life. Indicators for vegetation composition, structure, and function are therefore essential for defining the ecological integrity of park terrestrial ecosystems. Vegetation structure, function, and composition can be altered by many park activities (e.g., fire management) or from extrinsic factors (e.g., off-site pollution, climate change, invasive species). These affect the structure of the habitat and the natural disturbance regimes, as well as the landscape patterns that create habitat for a wide variety of species.

San Juan Island National Historical Park is within an area that historically included a mix of lowland conifer forest, extensive dry and wet prairies, coastal bluffs, and beach/strand habitats. It is located in some of the driest areas of western Washington, directly in the rain shadow cast by the Olympic Mountains to the southwest. Prairies that once covered many areas of the region, but now are rapidly disappearing, are a key feature of the park. In a region that grows trees so well and is dominated by forest, the occurrence of prairies appears anomalous. These areas historically were largely created and maintained in their treeless state by frequent burns initiated by Native Americans (Boyd 1999, and many others). In this report, we discuss Oregon white oak (*Quercus garryana*) savannas and woodlands along with prairies because they often include many of the same understory species, often occur in proximity to each other, and were historically maintained by similar ecological processes. Archeological excavations of prehistoric sites in the San Juan Islands, including two in American Camp, provide evidence that humans were active in the islands throughout the Holocene (NPS 2008).

4.4.2 Regional Context

Puget Lowland prairies, such as those in the park, are one of the most endangered habitats in Washington (Noss et al. 1995, Chappell et al. 2001, Sheehan 2007, Dunwiddie and Bakker 2011), and are particularly rare in North Puget Sound. These areas historically were largely created and maintained in their treeless state by a combination of soil conditions, relatively dry climate, and frequent burns initiated by Native Americans (Boyd 1999, and many others). In this chapter, we mainly discuss the vegetation of Oregon white oak (*Quercus garryana*) savannas and woodlands along with prairies because they often include many of the same understory species, often occur in proximity to each other, and were historically maintained by similar ecological processes.

Other habitats within the park have important vegetation, too. The rocky bald and oak savanna vegetation on Young Hill, within the English Camp unit of the park, represents plant associations that are rare in Washington (Chappell 2006a&b). Coastal strand and spit vegetation that occurs

adjacent to some of the park's beaches, as well as the dune vegetation that is embedded within the American Camp prairie, is very limited in extent within the Puget Lowland and some of the plant associations are considered imperiled (Rocchio et al. 2012). The dunes are one of fewer than five examples of coastal dunes in the Puget Lowland.

The diversity of habitats represented in the two units of the park host a surprising number of vascular plant species. In a recent inventory of the park flora, 400 species were recorded (Rochefort and Bivin 2010). This represents about 60% of the number (684) they determined were present on San Juan Island based on Atkinson and Sharpe (1985) and other sources. It also represents about half of the total flora (829 – Atkinson and Sharpe 1985) of the San Juan Islands. Close to 67% of the park flora is native, a figure comparable to that observed overall for the San Juans.

Three species listed as threatened by the Washington Natural Heritage Program were recorded as present in the park by Rochefort and Bivin (2010), including *Symphyotrichum hallii, Crassula connata,* and *Ranunculus californicus*. One federally-listed ("Threatened") plant is recorded from San Juan Island: golden paintbrush (*Castilleja levisecta*). Only 12 naturally-occurring populations of this species exist in the world, and five of these occur within the San Juan and nearby Gulf Islands.

4.4.3 Issues Description

As explained in section 3.2, before this NRCA project was initiated, NPS staff identified and ranked a series of themes specific to managing this park's natural resources effectively. These themes are closely related to the "Issues" that are a central organizational element in this NRCA. Therefore, for this section, we closely reviewed this list to identify those that related particularly to Terrestrial Vegetation. We then revised and in some cases redefined specific themes so that they more closely aligned with our perception of what the most important natural resource issues are at the park. **Table 3** lists the most important issues we identified for consideration in this chapter, together with the themes identified by NPS staff that correspond most closely to them. As the table shows, all the issues and indicators we examine in this chapter embrace the themes considered most important (ranked "3") by NPS staff. Furthermore, all of the vegetation-related themes that were assigned a rank of "3" are included here.

Table 3. Vegetation-related issues identified in this report with corresponding themes and theme rankings identified by NPS staff.

Issues	NPS Themes	NPS Rank
Effects of Urban Encroachment/ Rural Development	Urban encroachment/ rural development	3
Intact Native Vegetation	Areas of pristine or old-growth vegetation	3
Prairies and Oak Woodlands & Their Restoration	Native plant restoration	3
Invasive Species & Where They Occur	Invasive species & Areas with evidence of invasive plant or animal species	3/3
Focal Species & Where They Occur	Areas of focal species & Habitat and populations of focal species	3/3
Fire Regimes	Fire regimes	3

We have reorganized these somewhat as "issues" and "indicators." Described immediately below in terms of their potential to affect vegetation, the "issues" are:

- Effects of Altered Fire Regimes
- Effects of Rural Development
- Effects of Grazing and Browsing
- Effects of Recreational Use
- Effects of Invasive Plant Species

4.4.3.1 Effects of Altered Fire Regimes

Fire regimes include the frequency, severity, and area covered by fires over time. Sound management of local ecosystems requires a good understanding of fire regimes.

In this park and region, lightning is not a major source of wildfires. Rather, it is likely that at least some parts of the park were burned by Native Americans prior to settlement of San Juan Island by Euro-Americans, which began in earnest during the late 1800s. In particular, prairies and oak woodlands were maintained largely, if not primarily, by burning (Chappell et al. 2001, Spurbeck and Keenum 2003, Gray and Daniels 2006, Storm and Shebitz 2006, Sprenger and Dunwiddie 2011). Although Native Americans have been present in the Puget Lowlands for over 13,000 years (Kirk and Daugherty 2007), it is unknown how long the practice of burning prairies had been carried on. Some prairies may have remained relatively treeless for millennia even in the absence of regular burning. In other areas, fires may have occurred extensively only for the last several thousand years and almost solely because of intentional fires set by Native Americans (Weiser and Lepofsky 2009). Fires were deliberately set to create conditions that favored the growth of many plants that were important sources of food or medicine to native cultures. For example, fire-associated species such as camas (*Camassia quamash* and *Camassia leichtlinii*), strawberries (*Fragaria* species), bracken (*Pteridium aquilinum*), yampah (*Perideridia gairdneri*) and chocolate lily (*Fritillaria affinis*) thrive in recently burned-over areas and were harvested extensively.

Few clues are available for reconstructing historical fire regimes at either American or English Camp. Very old trees with multiple fire scars are largely lacking, and ponds or bogs containing deposits with preserved charcoal evidence of historic fires are non-existent. However, the rapid establishment of Douglas-fir in recent decades at both sites strongly suggests that historic fires were an important factor in keeping coniferous tree invasion in check (Agee 1984). Native Americans were undoubtedly the major ignition source, but it is uncertain how frequently these areas would have been burned. Based on inferences drawn from reconstructions of fire regimes in similar habitats elsewhere in the region, it seems likely that in the oak savanna/woodlands of Young Hill, fires recurred relatively frequently, perhaps every 7 years or so (Sprenger and Dunwiddie 2011). On the exposed, south-facing slopes of American Camp, grasslands may have persisted historically with fires less frequent than the 3-5 years suggested for many Puget Sound grasslands (Hamman et al. 2011).

The continued lack of fire in the park during the present could drive the drier forest fire regimes even further away from the moderate-severity regime and more into the high-severity regime. After a fire eventually occurs, the post-fire recovery is likely to result in forest structure and composition that differs significantly from historical reference conditions. Moreover, in the long-term, a lack of sufficient oak regeneration and recruitment in woodlands can result as well. On

many sites elsewhere in the region, little or no oak establishment has occurred during the last 100 years (e.g. Dunwiddie et al. 2011). Conversely, many non-native species are well adapted to fire. Because of this, prescribed and wildland fires have the potential to further degrade native composition of prairies, depending on a variety of variable factors associated with fire regimes.

In addition, lack of fire may be negatively impacting the health, and perhaps abundance, of Pacific madrone in western Washington, and, by extension, within the park as well. A fungus that produces cankers (*Fusicoccum arbuti*) is the major pathogen that is contributing to a regional decline in madrone (Elliott et al. 2002, Farr et al. 2005). The fungi's increase since the 1970s is hypothesized to be related to the absence of fire, which was previously the agent probably most responsible for mortality of mature trees (Elliott et al. 2002). Unfortunately for the madrone and wildlife that uses it, especially frugivorous and cavity-nesting birds (Raphael 1987, Gurung et al. 1999), fungal mortality leaves a root burl that is depauperate in resources available for resprouting, in contrast to burn mortality which results in abundant resprouting and renewal of stands (Elliott et al. 2002). If Elliott's hypothesis is correct, mimicking fire mortality of adult trees may be useful through selective cutting.

4.4.3.2 Effects of Rural Development

The impacts of rural development on vegetation and land cover began with EuroAmerican settlement, as San Juan Island's forests and prairies were first converted to agriculture, and then increasingly to roads, buildings, and other infrastructure. By the 1930s, virtually all of the virgin forest remaining in the San Juans had been cut. Within the past 50 years, rural development (i.e., building of homes, roads, conversion of native vegetation to cropland or pasture) has increased significantly near the park and throughout San Juan Island. The relatively small size of this park and its location on an island potentially concentrates the factors associated with nearby development which could impact the park's vegetation. The location of the American Camp unit, on a peninsula surrounded on three sides by extensive marine waters, may somewhat limit the number of airborne propagules reaching the park from adjoining areas, as well as underground runners from plants outside the park's perimeter.

4.4.3.3. Effects of Grazing and Browsing

Although livestock grazing has not been allowed in the park for many decades, populations of deer and European rabbit have been quite high during some years, with very evident effects on native plant density in localized areas (Stevens 1975, Rochefort and Bivin 2010). Areas where rabbits were most abundant and evident during surveys are dominated by non-native species (Rochefort and Bivin 2010). Rabbits not only graze available vegetation, they also dig and churn the soil in ways that leave patchy vegetation and abundant bare ground, which is fertile habitat for establishment of non-native, especially annual, plants. If populations of deer and European rabbit remain high for long periods, tree regeneration may suffer, eventually altering the composition and structure of the maturing forest (Milestone 1986, Agee 1987, Rolph and Agee 1993). Rabbits have apparently already resulted in delays in regeneration of trees on formerly forested agricultural lands. Sustained, elevated deer populations could also impact understory composition of native forests by preferential browsing on deciduous shrubs. This is a common phenomenon in the San Juan Islands (Chappell, pers. obs.)

4.4.3.4 Effects of Recreational Use

While recreational impacts are relatively minor in comparison to the other stressors for the prairies, one state-listed imperiled community type—*Camassia quamash - Triteleia hyacinthina* Herbaceous Bald—has been impacted by trampling by humans on top of Young Hill. This unusual plant association occurs in vernal (seasonally flooded) seeps that occur on rocky balds, making it highly vulnerable to direct trampling or alteration of runoff patterns by visitors (Rocchio et al. 2012).

4.4.3.5 Effects of Invasive Plant Species

The park has 132 non-native species, comprising 33% of the park's total flora. The vast majority of these occur in prairies, other open habitats like dunes/strand, or in ruderal habitats in developed zones (Rochefort and Bivin 2010).

Some non-native plant species seem relatively innocuous in terms of their impacts on native vegetation. However, many are "invasive," meaning they are far more successful than native species in the competition for moisture, light, and other life requirements, and consequently increase rapidly to the detriment of native species whose abundance and distribution is often much more limited locally and regionally. This can result in loss of plant diversity at local and regional scales. Several of these species are known to occur in the park. Others – particularly a number of non-native grasses—are especially problematic in native prairies. Non-native species have become a major component of the flora and of the vegetation composition of the park. An assessment of the abundance and distribution of non-native species, and invasive species in particular, is thus essential for ecological, political, and legal reasons.

Some invasive plant species are classified as "noxious weeds" by government jurisdictions due to their economic and/or biological effects, and control of them is required by law. For example, the Washington State Noxious Weed Board each year identifies weeds and assigns them to one of three groups based on their invasive tendencies, distribution, and abundance around the state (http://www.nwcb.wa.gov/). San Juan County draws upon this state list to designate particular species of importance in the islands, with a subset of these that have been selected for control. Many other noxious weeds are common on the island and are likely to appear (or reappear) in the park, such as Scotch broom (*Cystisus scoparius*) and yellow archangel (*Lamiastrum galeobdolon*). They should be the object of careful, regular searches in likely habitat.

Ruderal forests, such as those that have grown up on former agricultural lands, have much greater abundance and variety of non-native species in their rapidly evolving understories than do native forests. Non-native species are, in general, less prevalent and problematic in forested areas than in the park's non-forested areas. English ivy, English holly, spurge laurel (not reported at the park yet but present nearby) and Herb Robert are the non-native species of most concern in the native, established forests at this time. English ivy is very invasive in forest understories where it can rapidly dominate and outcompete native herbs; it also can overwhelm canopies, occasionally resulting in tree mortality. English holly is very widely dispersed in Puget Lowland forest understories, where it is typically common, but minor in terms of vegetation cover. Gradual increases in the population over time could result in it becoming a prominent component of lower tree canopy layers. Herb Robert is an invasive forb that spreads rapidly via mechanical transport of seeds and is now widespread in forest understories of the region. Spurge laurel is an evergreen shrub that can spread rapidly in dry forest understories once established. Some

additional species of special concern due to their abundance and habits include Himalayan blackberry and evergreen blackberry, which grow around edges and in early-successional forested areas such as the former agricultural lands.

The fungus (*Fusicoccum arbuti*) that causes Pacific madrone decline is probably native in origin, though there is some degree of uncertainty in this regard. It has been present in Washington since at least 1968 (Farr et al. 2005). Even if it is native, in the current environment and disturbance regime its characteristics resemble those of an invasive pathogen.

4.4.3.6 Effects of Hybridization

Genetic issues are important when restoring plant communities as well as individual rare plant species. Whenever possible, using locally and regionally-derived native seed is good practice to ensure that local genotypes are not swamped by genes from other regions, which might not be well-adapted to local conditions. However, there is considerable debate within the restoration community regarding what is an acceptable distance to define appropriate source areas. This debate has intensified as considerations of assisted migration and enhancing resilience to climate change has caused some to argue for considerably larger potential source areas. We have seen no evidence of uniquely-adapted island genotypes, and consider native seed sources within the North Puget Sound region to be acceptable for restoration efforts. In some cases, particularly where sources within this region are unavailable, it may be entirely appropriate to use more distant sources, including from South Sound and even the Willamette Valley. It may be especially important to include genetic material from non-local (e.g., outside the park or San Juan Island) when the local source populations are extremely small, and may have very limited genetic diversity.

Potential hybridization with closely related taxa is another genetic consideration with some species. The very rare *Castilleja levisecta* is known to hybridize with *Castilleja hispida*, and efforts should be made to avoid introducing both taxa in close proximity to one another in restoration plantings. Hybridization is also a concern with the locally rare *Ranunculus californicus*, as it is known to cross with the much more common *Ranunculus occidentalis*. Again, avoiding planting the two species in close proximity is advised to avoid possible genetic contamination and creation of hybrids. To avoid perpetuating or creating hybrids in restoration plantings, care should be taken to collect seed only from known “pure” parental stock, and avoid planting the two species in close proximity.

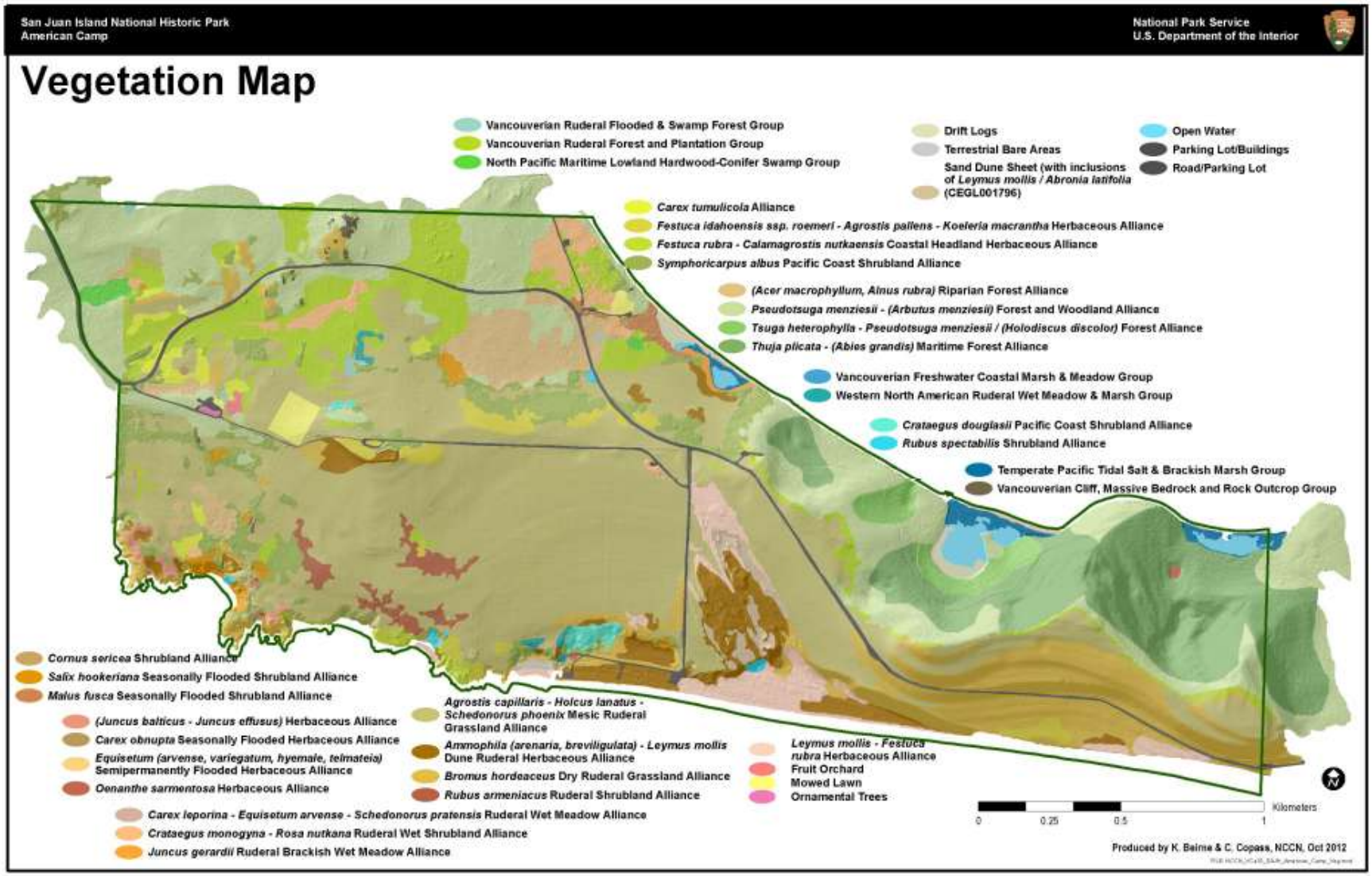

Figure 20. Vegetation map of American Camp.

From Rocchio et al. 2012.

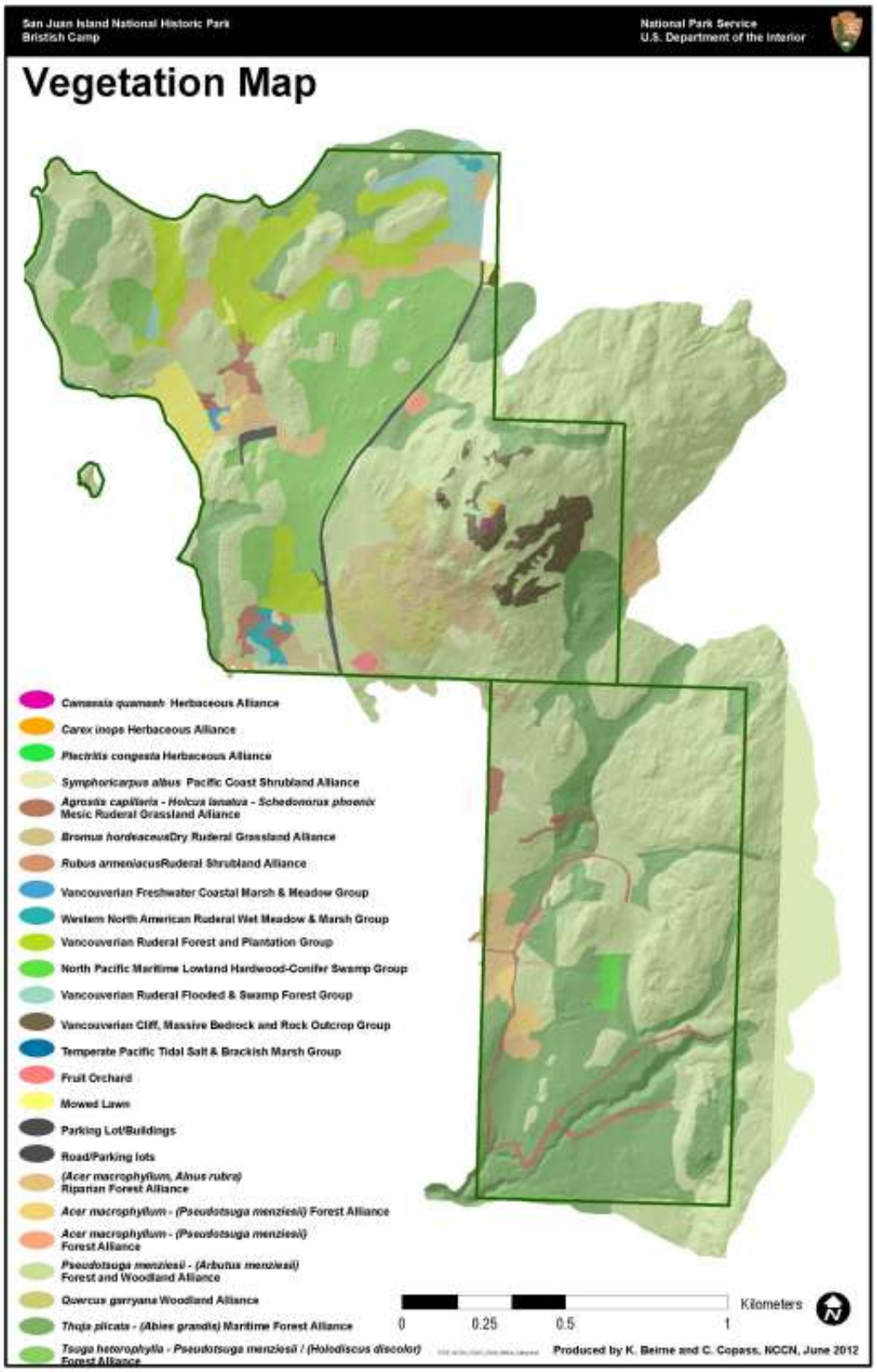

Figure 21. Vegetation map of English Camp and Mitchell Hill

From Rocchio et al. 2012.

4.4.4 Data and Methods

We consider the primary indicator of vegetation condition to be the intactness of native vegetation, which encompasses various aspects of the plant communities.

4.4.4.1 Prairie, Oak Woodland, and Coastal Strand Communities

Prairies ("meadows" in Canada) and oak woodlands can occur on a variety of substrates, including rocky balds, coastal bluffs, and on diverse soil types. All of them share a significant number of grass and forb species, and were maintained by similar ecological processes. We use the term "prairies" to refer to communities with a significant component of native herbaceous species, thereby excluding non-native grasslands and other vegetation types that resemble prairies in structure and physiognomy, but are dominated by exotics. Oak woodlands, when oaks are widely spaced and do not form a contiguous canopy, are often termed savannas. These habitats are of particular importance because a disproportionate number of their herbaceous plant species are regionally rare or uncommon.

Prairies in this region sometimes occur, regardless of local fire history, where substrates have little water-holding capacity, slopes are steep and south- or west-facing, and exposure to wind and salt spray is great. However, a history of frequent burns at a particular location is more likely to support the occurrence and persistence of prairie and oak woodland. In savannas and woodlands, fire plays an important role in maintaining the structure of these systems by killing small trees, limbing up of larger trees, and killing (or top-killing) shrubs.

It is widely recognized today that prescribed fire is required to restore and maintain many of these fire-adapted ecosystems. Fire is particularly important in establishing and maintaining conditions that favor native herbaceous species in prairies and savannas. However, these species are usually extremely seed-limited. Merely restoring fire to a system that is dominated by non-natives will not result in much, if any, increase in the natives (Sinclair et al. 2006, Stanley et al. 2011a). Therefore, in most areas, the use of prescribed fire to restore native prairie species is only recommended when it is accompanied by other methods, such as herbiciding, to help control invasive species, together with extensive seeding of natives (Stanley et al. 2008, 2011b). Mechanical treatments (cutting of trees, mowing of brush and grass) can mimic some of the effects of fire, but the degree to which this mimics the beneficial effects of fire is unknown.

Especially in systems where fire has been excluded for decades, extensive mechanical removal of ladder fuels and jackpots may be necessary before fire can be safely and effectively reintroduced. Without such pre-treatments, many of the larger trees that are to be retained may be killed by fires that burn hotter than intended. This has been recognized by NPS in the oak woodlands at English Camp, where mechanical pretreatment has been used in combination with prescribed burning (Rankin 2005).

Sudden oak death (*Phytophthora ramorum*), a non-native fungal blight, was first recorded in Washington in 2003, and can occur on many of our native species, including Oregon white oak, Douglas-fir, and bigleaf maple. This pathogen can result in significant mortality in some species, such as oaks, presenting a major threat to this vegetation type (http://www.hungrypests.com/the-threat/sudden-oak-death.php). To our knowledge, it has not yet afflicted trees in this park.

Coastal strand and spit habitat that occurs adjacent to some of the park's beaches, as well as the dune vegetation that is embedded within the American Camp prairie, is very limited in extent within the Puget Lowland and some of the plant associations are considered imperiled (Rocchio et al. 2012). The dunes are one of fewer than five examples of coastal dunes in the Puget Lowland. contains three uncommon plant communities. Two are considered globally critically imperiled and one globally imperiled. The dunes are noteworthy for still being somewhat active, that is, sand transport processes are still somewhat intact. This is likely one of very few, and maybe even the only one of, active dune sheets in the Puget Lowland. The relative abundance and in some cases dominance of the native coastal sand verbena (*Abronia latifolia*) in the dunes and strand is indicative of a substantial degree of substrate instability and sand movement, which are critical ecosystem features for these systems which are easily lost via succession in the presence of stable sand. Geomorphic changes related to future sea level rise are a concern for the strand and spit communities.

Criteria

Recognizing the significance of the rare vegetation types within the park, current management goals call for "restoring the native vegetation without compromising the historic landscape" (NPS 2008). We are aware of no studies that have reconstructed the number and composition of species that existed in prairies or oak woodlands during pre-EuroAmerican settlement times in the park or elsewhere in the region. Similarly, it is difficult to determine precise values for the areal extent that prairie remnants must be to ensure a reasonable likelihood of remaining viable over the long term. With no intact reference communities, it is difficult to identify goals for native species diversity, or determine precisely which native species are appropriate to include in restoration plantings. Nonetheless, we suggest the following for prairie and oak woodland communities:

"Good" conditions would be the existence of prairie and oak woodland which:

- Is no less than 25% of its historical extent within the park,
- Retains the historical species composition and/or native species turnover rate.

"Somewhat Concerning*"* would be the existence of prairie and oak woodland which:

- Is at 10-25% of its historical extent within the park,
- Retains a native species component that is somewhat diminished from historical conditions.

"Significant Concern" would be the existence of prairie and oak woodland which:

- is <10% of its historical extent within the park,
- has a native species component that is *much* diminished from historical conditions.

The Prairie Vegetation Monitoring Protocol for the park (Rochefort et al. 2012) identifies 'Ecological Integrity Ratings' that are similar in concept to those described above for prairie vegetation. However, rather than assigning values based on comparisons with the presumed historical extent and composition, as proposed above, the ratings are assigned based on deviations from a recently-measured baseline condition. Because current conditions are dramatically degraded compared with the historical state, this leaves many species and

vegetation associations extremely vulnerable. Thus, condition assessments that utilize comparisons with a historical baseline are likely to provide a more accurate evaluation of long-term system integrity and viability.

Ideally, the above criteria need to be specified more quantitatively, in order to provide useful guidance for managers. There are many obstacles that limit the ability to specify these precisely, which are discussed below. However, we suggest a number of specific criteria here as working hypotheses that should be tested, monitored, and refined as necessary via work in the park, and via research in the surrounding ecoregion.

For *prairies*, more specific criteria would include combinations of three types of measures: (1) areal extent and configuration, (2) native floristic diversity and/or integrity, e.g., FQI - floristic quality index and mean C, the coefficient of conservatism, for each plant species (Swink and Wilhelm 1979, Rocchio and Crawford 2013), and (3) relative cover of native versus non-native species. The Prairie Vegetation Monitoring Protocol for the park (Rochefort et al. 2012) identifies 'Ecological Integrity Ratings' for three types of measures that are similar to those described above. However, they are rated using somewhat different criteria, or have not yet been assigned quantitative values. We propose specific values for these measures based on limited data from the park, other prairies in the ecoregion (Dunwiddie et al. 2013), and our personal experience.

> "Good" conditions would be relatively contiguous patches of native prairie that amount to >200 acres (>25% of historical extent), with >50 native species, a mean C of >3.9, native species clearly dominant, occupying >75% of total relative cover, and very few, if any, aggressive invasive non-native species present.
>
> "Somewhat concerning" would be patches of contiguous prairie amounting to 60-200 acres, 25-50 native species present, a mean C of 3.7-3.9, with non-native species common to predominant (25-75% of total cover is non-native species; >15% relative cover of native species); aggressive invasive non-natives may be common.
>
> "Significant concern" would be patches of contiguous prairie amounting to <60 acres, <25 native species present, mean C of <3.7, non-native species dominant, and relative cover of native species generally <15%.

Areal extent and species richness (# of species) criteria would need to be adjusted downward from these numbers for rocky balds and coastal bluffs because they naturally have fewer species, being small-patch communities associated with geologic substrates of limited distribution.

For *oak woodland*, additional criteria would be the density of conifer and shrub cover, and the occurrence of regeneration sufficient to replace current stands:

> "Good" conditions would be the existence of sparse canopy densities (e.g., savanna) such as when frequent burning was common among native cultures, but oak regeneration that is adequate for replacement.

> "Somewhat Concerning" would be the existence of greater canopy densities with a significant increase in conifer and shrub cover, and somewhat reduced oak regeneration.
>
> "Significant Concern" would be the existence of even denser canopies, with conifers and shrubs becoming dominant in many areas formerly occupied by oaks, and little or no oak regeneration.

Conifers and shrubs are a concern because: (1) conifers in many cases threaten the future existence of oak dominance through profuse establishment, competition, and succession, and (2) shrubs drastically alter the understory composition and suppress or eliminate the cover and diversity of native herbaceous species strongly associated with oak woodland, prairie/savanna, and herbaceous bald ecosystems in this ecoregion. Gedalof et al. (2006) and Dunwiddie et al. (2011) provide some data that might be used to infer reference conditions for oak savannas and woodlands, but their estimates vary widely.

Attempts to quantify criteria and assess the condition of prairie and oak woodland habitats using these criteria are limited by the lack of quantitative, site-specific data on reference condition, e.g., the historical extent, species composition, and/or canopy density at a particular location. Data also are lacking on the frequency and type of fire necessary to maintain these habitats within the park. Some investigators (Dunwiddie 2002, Dunwiddie et al. *in press*) have suggested that the combination of frequent burning and the use of digging sticks (with churning and turning of the soil) by Native Americans on the Puget Lowland prairies would have favored a significantly greater abundance of annual and perennial forbs, and a concomitant lower abundance of perennial graminoids than is seen in present-day good-condition prairies and remnants. Historical and ethnological accounts on Whidbey Island seem to back up this contention, at least on more mesic prairies (White 1980). Currently, most good-condition prairies that are not burned frequently are dominated by perennial grasses, especially Roemer's fescue.

Historical accounts give us more information for oak woodland structure than for prairie composition, suggesting that the Young Hill oak woodland was, from a reference condition perspective, more open than it was in the 1980s, with less woody vegetation in the understory (Agee 1987). Portions, if not all of it, might better be called a savanna than a woodland, though the distinction between the two in this case may be somewhat arbitrary, as we expect that there was natural variation of oak cover that may have incorporated a continuum from savanna to woodland. It is impossible to be more precise with the description of reference conditions in the oak woodland. The oak woodland was apparently also somewhat more extensive than is readily apparent today, as evidenced by large oaks in what is otherwise mostly young Douglas-fir forest (Chappell, pers. obs.). Based on historical descriptions, it has been suggested that the oak woodland arose just after settlement (Thompson 1972, Agee 1987). The southern slope of Young Hill was described as having "…but few trees (oaks) scattered on the southern grassy slope of the mountain." The historical woodland probably had very little shrub cover, probably less than 15% cover. The historical woodland/savanna also probably had few to no conifers in the understory/subcanopy layers (certainly fewer than today), or what were there were transient in establishment and survival, as most that established would have been soon after removed by relatively frequent fires (Gedalof et al. 2006, Sprenger and Dunwiddie 2011). Oak density was likely to have been lower than at present as well, judging by the size and density of existing oaks on site, and research from other sites (e.g., Dunwiddie et al. 2011).

Douglas-fir may have been a significant co-dominant with oak in many pre-settlement woodlands and savannas prior to the selective logging of the large, old Douglas-fir. For example, on nearby Waldron Island, Dunwiddie et al. (2011) document that Douglas-fir was a significant component of the pre-settlement oak woodland/savanna, suggesting that the same may be true at Young Hill, where some large Douglas-fir remain part of the oak woodland system.

Fire return intervals (FRI) are commonly measured as the number of years between fires. Means and variance can be calculated with adequate data over specified time periods. Other aspects of fire regimes that are important to consider but more difficult to assess and track are intensity, severity (degree of mortality to vegetation for example), area burned (areal extent of each fire), seasonality (time of year), and variability in frequency, area, and intensity. FRI is easy to measure, calculate, and track over time, and because it tends to be correlated with severity and intensity.

Historical evidence indicates that reference condition FRI in **prairies** was probably no more than 5 years and perhaps considerably less than that in some areas. Storm and Shebitz (2006) cite ethnographic evidence that burning of prairies in the Puget Sound region occurred annually, although a particular patch of ground on a prairie probably burned somewhat less frequently due to patchy fuels, habitat heterogeneity, and variability in wind, moisture, and other environmental factors. To maintain prairie at American Camp, there may have been less need for such frequent fires due to the generally droughty conditions associated with that site's shallow soils, southern exposure, salt spray, and relatively high winds. Greater confidence in ascertaining the most appropriate FRI for maintaining native prairie on this site could be obtained by careful monitoring after experimental prescribed burns. Such monitoring would be focused on the nature and duration of fire effects on native and non-native species, as well as on fuel quantities and distribution. Available historical information indicates that prairie fires in the ecoregion occurred primarily in late summer and early fall (Storm and Shebitz 2006).

Fire return intervals (FRIs) for stand-replacement fires in the region's lowland **conifer forests** are probably relatively long, at least 200 years and perhaps longer (Agee 1993), and thus occur at frequencies beyond the scope of practical resource management planning. However, less intense fires (low- to moderate-severity), especially in the drier-site forests, have decreased significantly from what we expect reference conditions would have been. Such fires, which historically resulted from the spread of fires that were intentionally lit by Native Americans in nearby prairies, savannas, and oak woodlands, would typically have been patchy and less frequent owing to the greater shade, moisture, and lesser quantities of fine fuel. Although there is nearly ubiquitous evidence of such underburning in old-growth forest fragments in the Puget Lowland, it is difficult to determine what the historical FRI would have been, since many light fires probably left no trace as fire scars. We suspect that the FRI of these fires may have been in the range of 5-30 years.

In the case of oak woodlands, a nearby site on an adjacent island (Waldron) is similar to Young Hill, and has been intensively studied with regards to fire history, providing a local template to establish approximate reference conditions for FRI. Sprenger and Dunwiddie (2011) documented a pre-settlement composite mean fire return interval there of 7.4 years (range 2-31 years), individual-tree FRI of 18.4 years, and a Natural Fire Rotation (interval that it would take for the entire study area to burn) of 32-49 years. Evidence indicated that fires there burned during late

summer and fall only. On nearby Vancouver Island, Gedalof et al. (2006) concluded that pre-settlement fires had been frequent in oak woodland/savanna there, but was unable to construct a precise fire chronology.

For strand and dune communities, criteria for evaluating condition would include size of area characteristic of natural distribution, native plant species diversity/integrity, relative dominance of native versus non-native species, and natural processes (e.g., wind transport of sand, storm surges, beach formation) upon which they depend.

Condition, Trends, and Level of Certainty

Prairies

Although many characteristic prairie species persist, invasive and non-native plants have overtaken the vast majority of the park's prairie. There are many small remnants of native prairie present at American Camp, first identified and classified by community type by Rochefort and Bivin (2010), and subsequently classified according to the National Vegetation Classification as alliances and plant associations and mapped by Rocchio et al. (2012) (**Table 4** and **Table 5**). The majority of the American Camp prairie is classified into ruderal, meaning early successional alliances dominated primarily by non-native grasses. Patches of former prairie, especially near forest margins and on more mesic sites in the northern section of American Camp, are currently dominated by native shrubs, mostly common snowberry (*Symphoricarpos albus*) and Nootka rose (*Rosa nutkana*) that have likely increased in abundance with fire suppression.

Table 4. Frequency and areal extent of mapped upland prairie associations in the park (including oak woodlands, rocky balds, and coastal bluffs, but not dunes or coastal strand) as modified from Rocchio et al. (2012).

USNVC Alliance	# of Polygons	Total Acres
Agrostis (*capillaris, stolonifera*) Provisional Ruderal Alliance	5	148.2
Arrhenatherum elatius Provisional Ruderal Alliance	4	14.3
Bromus (*diandrus, hordeaceus, sterilis*) Provisional Ruderal Alliance	21	105.1
Bromus sitchensis - Elymus glaucus Provisional Ruderal Alliance	9	8.9
Camassia quamash Herbaceous Alliance	2	0.1
Carex inops Herbaceous Alliance	1	0.2
Carex tumulicola Alliance	10	9.3
Festuca roemeri - Agrostis pallens - Koeleria macrantha Herbaceous Alliance	12	16.3
Festuca roemeri Provisional (Restoration) Ruderal Alliance	1	1.3
Festuca rubra - Calamagrostis nutkaensis Coastal Headland Herbaceous Alliance	6	4.6
Holcus lanatus - Poa pratensis Provisional Ruderal Alliance	33	259.1
Plectritis congesta Herbaceous Alliance	1	0
Quercus garryana Woodland Alliance	2	20.5
Racomitrium canescens Nonvascular Alliance	25	17.4
San Juan Islands Ruderal Forbs and Graminoids Alliance	7	34.6
Symphoricarpos albus Pacific Coast Shrubland Alliance	65	68

Non-native plant species now dominate the vast majority of both the American Camp prairie and the Young Hill oak woodland understory. Their dominance is a significant impediment to restoring native species. Some of the most abundant of the non-native herbaceous species in the prairies include common velvetgrass (*Holcus lanatus*), Kentucky bluegrass (*Poa pratensis*), soft brome (*Bromus hordeaceus*), Canada thistle (*Cirsium arvense*), hairy cat's ear (*Hypochaeris radicata*), sheep sorrel (*Rumex acetosella*), common vetch (*Vicia sativa*), colonial bentgrass (*Agrostis capillaris*), yellow hairgrass (*Aira praecox*), poverty brome (*Bromus sterilis*), ripgut brome (*Bromus rigidus*), and quackgrass (*Elymus repens*) (Rochefort and Bivin 2010). Orchardgrass (*Dactylis glomerata*) and tall oatgrass (*Arrhenatherum elatius*) are common in the oak woodland on Young Hill (Rocchio et al. 2012). The latter is of special note due to its well-documented capacity to rapidly overwhelm and dominate the native prairies of the Northwest (Dennehy et al. 2011). Robust, rapidly spreading perennials tend to be more problematic in terms of their capacity to dominate prairies and crowd out the native species, whereas in general, more delicate and annual species appear to co-exist more readily with natives. Velvetgrass, Canada thistle, ripgut brome (an annual), and colonial bentgrass are perhaps the most invasive of the widespread common species in that regard, able to rapidly outcompete natives and difficult to control. Other invasives that are of particular concern include California poppy *(Eschscholzia californica*), which is actively spreading and difficult to control, tansy ragwort (*Senecio jacobaea* - Class B weed), Fuller's teasel (*Dipsacus fullonum*), and spurge laurel (*Daphne laureola*). Of the San Juan County species listed by Washington State as noxious weeds (**Table 5**), several have been reported from the park. The park has 133 non-native species, and while the majority are not listed as noxious weeds, they comprise 33% of the park's total flora (**Table 6**). The vast majority of these occur primarily in prairies, other open habitats like dunes/strand, or in ruderal habitats in developed zones (Rochefort and Bivin 2010).

Table 5. Species designated as Class A, B, or C noxious weeds in Washington, and reported from the park.

Asterisk indicates species selected for control within San Juan County. Sources: NPSpecies, National Park Service 2008, and http://sanjuan.wsu.edu/noxious/documents/2013_SJCweedlistCommon_Nameprintreduced.pdf

Scientific Name	WA Weed Category
*Centaurea stoebe**	B
Cirsium arvense	C
Cirsium vulgare	C
*Daphne laureola**	B
Dipsacus fullonum ssp. *sylvestris**	C
*Geranium robertianum**	B
*Hedera helix**	C
Hypericum perforatum	C
Hypochaeris radicata	C
Leucanthemum vulgare	C
Phalaris arundinacea	C
Rubus armeniacus	C

Rubus laciniatus	C
*Senecio jacobaea**	B

Table 6. Number of vascular plant species recorded in the park, by form and origin, as modified from Rochefort and Bivin (2010).

		Native			Non-native		
Growth Form	**# of Species**	Annual	Biennial	Perennial	Annual	Biennial	Perennial
Forb	257	42	2	128	50	11	24
Graminoid	84	1	0	49	14	0	20
Shrub	28	0	0	24	0	0	4
Tree	31	0	0	22	0	0	9
Total	400	43	2	223	64	11	57

Seed bank surveys demonstrate a great preponderance of non-native species present in the soil on the American Camp prairie, and a dearth of seed from natives (Rochefort and Bivin 2010). This repository of non-native seed presents an enormous challenge in restoring native prairie.

Table 6 clearly illustrates the dominance of non-native vegetation in the prairies, with the three most abundant alliances (by far) being ruderal grasslands dominated by non-natives. Native herbaceous and nonvascular prairie alliances comprise 8.2% of the areal extent of prairie-associated vegetation mapped by Rocchio et al. (2012). An additional 2.9% is oak woodland (with a mostly non-native understory) and 9.6% is native shrubland that occupies mostly what was formerly prairie. The remaining approximately 80% is ruderal, non-native vegetation. While the extent of grass-dominated vegetation that is structurally akin to the original prairie has likely not declined substantially from pre-EuroAmerican settlement times at American Camp, the extent of native prairie clearly has declined dramatically (Young Hill at English Camp has some rocky bald habitat (considered in this treatment as a subset of prairies) in mosaic with oak woodland. A portion of the area is dominated by ruderal, non-native grasses, and another significant portion is dominated by native mosses (Rocchio et al. 2012).

Figure 22. Prairie polygons still dominated by native plants as delineated by field surveys at American Camp.

From Rochefort and Bivin 2010.

Note: the largest of these colored polygons in the central portion of the map is primarily occupied by dunes, which herein are considered separately from prairies as part of 'other less common plant communities' (see section 4.4.4.2).

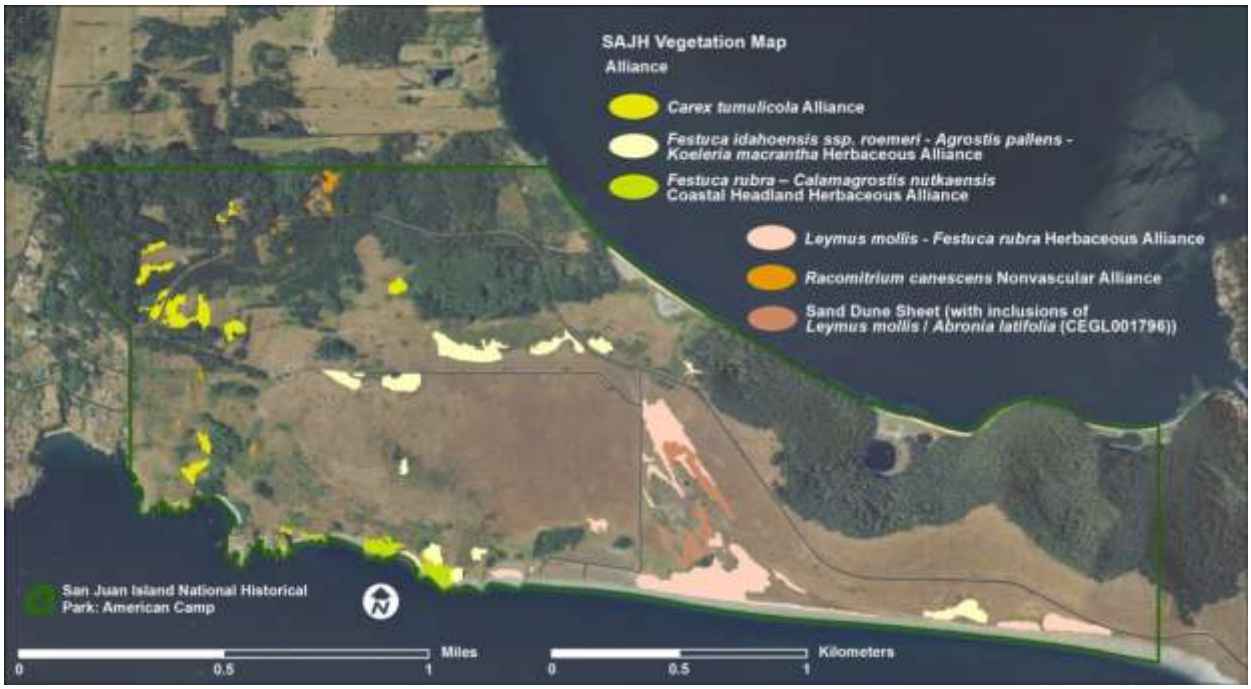

Figure 23. Native upland grassland and nonvascular alliances at American Camp.

From: Rocchio et al. 2012.

Note: *Leymus mollis – Festuca rubra* Alliance and Sand Dune Sheet are dune/strand communities, not prairies, and are addressed in section 4.4.4.2.

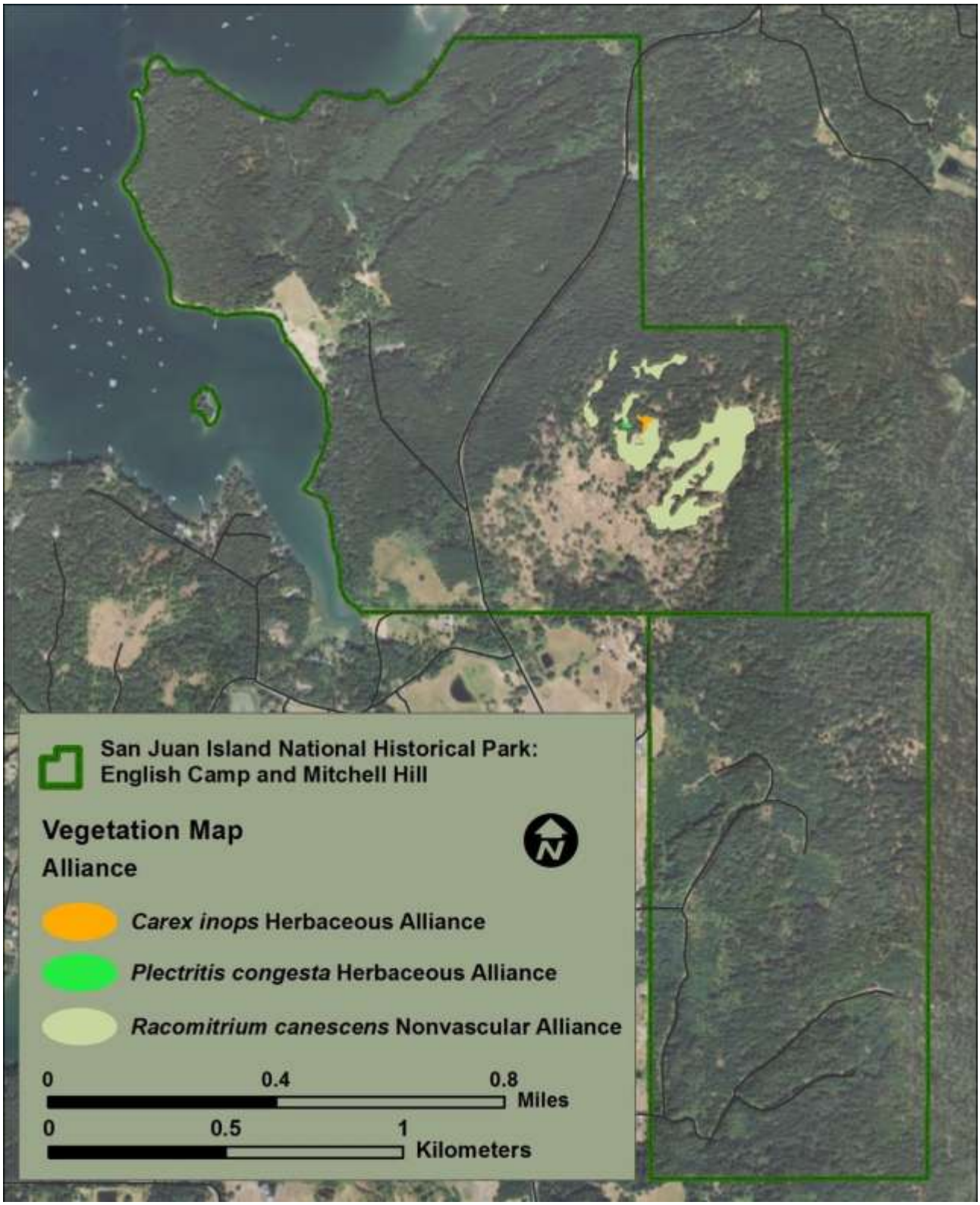

Figure 24. Native upland grassland and nonvascular alliances at English Camp and Mitchell Hill. From Rocchio et al. 2012.

Six plant associations designated as "Imperiled" or "Critically Imperiled" within Washington or globally by the Washington NHP, and reported at the park by Rocchio et al. (2012), are part of the prairie complex (including herbaceous coastal bluffs and rocky balds) that is dealt with in this section. One of these is critically imperiled globally (*Festuca rubra* - (*Camassia leichtlinii, Grindelia stricta var. stricta* Herbaceous Vegetation), primarily occupying coastal bluffs, and another is considered to be globally imperiled (*Festuca rubra* Coastal Headland Herbaceous Vegetation). The remaining four are considered imperiled at least in Washington but have not been ranked globally. The total acreage of all these imperiled associations at the park is currently 30.5 acres, with the majority of this being fragments of the dry prairie community known as *Festuca roemeri* - *Camassia quamash* - *Cerastium arvense* Herbaceous Vegetation. The latter is considered a historical occurrence (functionally extirpated) in Washington because all known occurrences are considered too small to be viable for this once large-patch disturbance-dependent community that may have been a major pre-settlement type in the northern Puget Lowland, thus further emphasizing the need for restoration. The current condition and/or size of all the imperiled prairie associations is significantly compromised to the point of being of "significant concern." *Festuca roemeri* - *Camassia quamash* - *Cerastium arvense* fragments are too small to be viable, and the bald and bluff associations (e.g., (*Camassia quamash* - *Triteleia hyacinthina* Herbaceous Bald) typically are degraded by abundant non-native species and/or trampling impacts.

Loss of San Juan Island's prairie and oak woodland initially was caused by cultivation that accompanied settlement by Euro-Americans. Cultivation focused on the treeless prairies, as their soils were sometimes more productive and they demanded far less effort to farm than was required to clear forested lands. Livestock grazing and the cessation of burning by Native Americans also heavily impacted the landscape at this time. More recently, the loss or degradation of prairie and oak woodland outside of the park has resulted from a surge in rural development on San Juan Island. These early changes in land use set in motion processes that have continued to impact the vegetation up to today. Thus "pristine" native prairies rapidly ceased to exist, either being plowed under, highly altered by the introduction of pasture grasses and extensive livestock grazing, overgrown by forest, shrubs, or other invasive weedy species, or converted by development.

In the general vicinity of the park, Government Land Office (GLO) surveys from the 1800s show large areas that are now forest having once been prairie, as is typical of prairies in the Puget Lowland. However, within the park itself, the American Camp prairie, the largest by far in the park, is still largely an open grassland, albeit largely dominated by non-native species. Historical records indicate that a large ca. 600-acre prairie apparently existed at American Camp at the time of Euro-American settlement (Agee 1984, Rolph and Agee 1993). The prairie was initially expanded by the conversion of forested areas in northwestern American Camp to agriculture (Agee 1987). A substantial portion of those formerly forested areas remained open for many decades after the cessation of agriculture and has been classified in land cover research as "prairie" due to its grassland condition (e.g., McCoy and Dalby 2009). In the last few decades, beginning with a low in the European rabbit population in the 1980s, many of these areas are reforesting with dense very young cohorts of alder and conifers (McCoy and Dalby 2009, Rocchio et al. 2012). During the period 1997-2007, this natural reforestation (or loss of "prairie") totaled about 75 acres (McCoy and Dalby 2009). While this seems on the surface to be of

concern for loss of prairie, since these changes are occurring primarily on historically forested areas with forest soils, concern is probably unwarranted. At American Camp, in the absence of significant, aggressive restoration actions, the current trend in the areal extent of actual native prairie is likely to be a gradual loss, at least according to the definitions we have used here, i.e., vegetation with a significant component of native species, which typically occurred in non-forested areas with characteristic prairie soils. Native prairie species are increasingly being out-competed by invasive grasses and forbs, shrub cover is increasing over time as both native and non-native shrubs encroach into grasslands, and tree invasion (particularly Douglas-fir) continues to accelerate near prairie edges.

At English Camp, trend in areal extent of prairie was relatively stable during the period 1997-2007 (USDA 2005, McCoy and Dalby 2009, Rochefort et al. 2012). The analysis by McCoy and Dalby, however, included open oak woodland as part of prairie, as well as degraded non-native grasslands that were mostly not grassland in the pre-EuroAmerican settlement era. Within the area on Young Hill that includes rocky balds and oak woodland in mosaic, it appears that during the study period, losses of prairie due to tree invasion and growth around the edges of the prairie area were offset by gains in prairie area probably related to thinning and burning restoration activities.

Because of the large uncertainties in undertaking prairie restoration in this region, management actions should be developed and carried out in a well-planned, adaptive management context (Holling 1978; Walters & Holling 1990, Allen and Gunderson 2011). NPS is currently developing a Prairie Stewardship Plan which specifies that. Restoration undertaken with an adaptive management strategy could be most successfully accomplished using a “staged-scale” approach recently developed by prairie restoration practioners in this region (Delvin 2013, Dunwiddie et al., *in prep.*). This approach, which is a modification of traditional adaptive management, allows restoration to proceed at a pace that accelerates over time, while simultaneously gathering essential information using rigorous experimental studies at the restoration site to determine which methods are most successful at accomplishing restoration objectives. This approach to adaptive management requires consistently developing restoration goals, formulating hypotheses on how best to reach these goals, designing studies to test the hypotheses, monitoring to measure the effectiveness of restoration treatments, and revising treatment strategies based on the information gathered from these studies to improve restoration practices moving forward. Where restoration is undertaken in an adaptive management context, *effectiveness monitoring* will be needed as well to assess results so that treatments can be refined accordingly. Consideration should be given to determine whether and how the prairie vegetation monitoring protocol (Rochefort et al. 2012) can be adapted to serve this purpose.

A major obstacle to prairie restoration at the park is a lack of quantities and diversity of locally-sourced native seed that are sufficient to undertake the scale of restoration that is needed. This is being addressed to some extent as various nurseries are beginning to develop supplies. However, for most species, no efforts have yet been made to identify local, wild populations from which seed can be collected to begin the seed-increase process. Or, if such populations are known, many have not yet been collected to provide material to nurseries. For a significant number of species, no local sources exist and restoration will need to rely on sources from elsewhere in Washington. Since it takes considerable time to develop seed in sufficient quantities to restore

prairies at scale, vigorous efforts to generate such seed supplies for the park should be initiated soon.

Oak Woodland

The current extent of oak woodland/savanna has probably declined somewhat from the reference state due to conversion to Douglas-fir forest with succession in the absence of fire. Of more significant concern is the dominance of the present-day oak woodland understory by non-native and invasive species. Infestations of invasive annual grasses have appeared after recent prescribed burning (National Park Service 2008). Another concern is that, after initial prescribed burning, there has not been a decrease in understory shrub cover (K. Kopper, unpubl. data, pers. comm.). Oak woodland stand structure has mostly been improved after recent restoration activities, with lower densities of conifers. Recent combinations of mechanical treatment (thinning of primarily Douglas-fir) and prescribed fires have brought the stand closer to reference conditions. Even prior to the fires, there remained portions of the oak woodland that retained some native herbaceous vegetation, a key attribute of reference condition oak woodland/savanna.

While large areas of former oak woodland and savanna have succeeded to forest in many areas of the region, it does not appear that such large-scale conversion has occurred within the park. At Young Hill, soil surveys and the presence of scattered old oak trees in some forested areas indicate that there has been some loss in areal extent of the oak woodland/savanna in that area, but not a massive decline. As for current trend in areal extent, it appears to be relatively stable based on the work of McCoy and Dalby (2009). Speculation exists that there could have been some areas of oak savanna on more level, mesic portions of the American Camp prairie prior to EuroAmerican settlement and that the oaks were removed entirely by early settlers (Agee 1987). As noted previously, the vast majority of the prairie soils (assumed to be the pre-settlement prairie/oak woodland extent) at American Camp remain in herbaceous dominance and have not converted to conifer forest.

Restoration efforts in the oak woodland/savanna have been substantial and are ongoing. Multiple management treatments have occurred since 1997 and were largely aimed at restoring stand structure and fire regimes. Primarily, this has involved the removal of large numbers of Douglas-fir saplings and young trees, which had extensively invaded the woodland. Mechanical thinning and pile burning of conifers, followed by prescribed fires, have now treated the entire area of the oak woodland at Young Hill. Prescribed fires occurred in 2005, 2006, 2009, and 2010, completed in accordance with a Fire Management Plan (Rankin 2005). The fire management plan's goals for restoration of fire regimes in oak woodlands have been exceeded. We presume that the sum total of these treatments has shifted the trajectory of stand structure in the direction of reference conditions, e.g., less shrub cover and conifer density. Initial monitoring data associated with these management treatments show a large post-treatment decrease in Douglas-fir density (mean 107 trees/acre down to 10.5), with a virtual elimination of pole-size and sapling trees, and no apparent change in shrub cover, with a mean of 30-40% and much variability (K. Kopper, pers. comm.). We assume that there have been changes in understory herbaceous composition as well, but we do not have such information at this time. Given that the understory was thoroughly dominated by non-natives, we would not expect a shift after fire toward more native herbaceous component without active efforts to replant natives. Infestations of cheatgrass

(*Bromus tectorum*) and ripgut brome, both invasive annuals that thrive after fire, were reported and mapped after prescribed burning in the oak woodland (National Park Service 2008).

Coastal Strand, Spit, and Dune Communities

In general, these vegetation types within the park are in fair to good condition. Some areas are noteworthy in being dominated by native species and others are co-dominated, if not locally dominated, by non-natives. The overall ecological integrity of the South Beach strand habitat may be somewhat compromised by recreational impacts in that area. The spits containing the lagoons on the north side of American Camp are undeveloped. One of them, at Third Lagoon, was considered relatively high quality by Natural Heritage Program standards in the 1980's, with native vegetation dominating and insignificant human disturbance or alteration (Kunze 1984).

In summary, we know that the native prairie was much more extensive, and oak woodland was more open than now, but we do not know recent trends, especially with regard to the precise tree density, tree cover (and oak/conifer ratio), or shrub cover and degree of variation that once existed or is appropriate for local conditions. We know even less about the historical extent and current condition of the coastal strand, spit, and dune community within the park. Because prairie, oak woodland, and coastal strand have all been invaded by non-native plants, their condition is rated "Somewhat Concerning." Recent trends in the condition of all three have not been measured and so are rated "Unknown", but restoration efforts in oak woodland are likely improving its condition for many plant species.

	Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Prairies	Somewhat Concerning	Medium	Unknown	N/A
Oak Woodlands	Somewhat Concerning	Low	Unknown or Improving	N/A
Coastal Strand, Spit, and Dune Community	Somewhat Concerning	Low	Unknown	N/A

Data Gaps

- Uncertainty surrounds whether the size of the park's prairie habitats are sufficient, with or without management intervention, to be ecologically sustaining and retentive of all native prairie species. Some clues are offered by species-area curves for native prairies across the region (Dunwiddie et al. 2006) which suggest that even prairies of several hundred

acres are missing significant components of the biota. The degree to which focused management initiatives within these prairies could improve that situation is untested.

- The degree to which mechanical treatments successfully mimic the fires that historically sustained the park's prairies and oak woodlands is unmeasured, due largely to lack of historical reference data on invasive species and stand demographics.
- The degree to which fire and mechanical treatments may benefit or harm other ecosystem components within the parks is unknown. For example, will prescribed fire also enhance habitat elements critical for sustaining less common or sensitive wildlife species such as the endangered island marble butterfly? Key host plants for this butterfly include *Brassica rapa* and *Sisymbrium altissimum*, both of which are non-native weeds that thrive on frequent disturbance. Such types of disturbance may be incompatible with restoration of other assemblages of native prairie species, and may need to be separated from one another, either spatially, or temporally by rotating disturbances across the landscape over time.
- Measurements of sufficient detail and sensitivity to better elucidate the effects of fire, mechanical harvesting, and other activities on forest condition need to be made. Many fire-related parameters besides FRI are important to consider when evaluating the success of fire management in ecological systems. Fuel consumption, scorch on trees, percent kill of seedlings and saplings, topkill of shrubs, removal of moss, lichen, and litter layers, as well as consumption of seed of non-native species, are just a few of the specific effects that may be important to track in some areas of the park where prescribed fire is being used to manage and restore natural resources. Many such parameters quantify aspects of burn intensity and severity that may have ecological effects of particular interest. While the impacts of fires on many of these parameters are directly related to the FRI, the quantity and pattern of effects will often be highly influenced by many other factors besides FRI.
- In oak woodlands, crucial information is lacking regarding the numbers of oaks and conifers in different size classes that are necessary to ensure that canopy trees are replaced as they age, and that the stem densities are maintained at desired densities over the long term. Once collected, data on the number and distribution of trees of various age/size classes can be used in various stand growth models to determine the appropriate abundance distribution of individuals.

4.4.4.2 Less Common Species and Invasive Plants

Criteria

For purposes of this assessment, "Good*"* conditions would be represented by sustained naturally-occurring turnover rates of native plant species and communities currently inhabiting the park. This might include intentionally re-establishing those which were extirpated but have the potential to become re-established. More detailed goals might be to sustain viable populations of each functional group of plants in proportions characteristic of intact but dynamic ecosystems, as well as sustaining metapopulations and gene pool diversity. "Somewhat Concerning" and "Significant Concern" ratings would be assigned depending on the degree to which distributions of native species became fragmented, populations become extirpated or less viable, or communities lost important ecological functions or became dominated by non-native species.

For one of the rarest plants -- golden paintbrush (*Castilleja levisecta)* -- four criteria are proposed to evaluate and track its status within the park. These are based on specific recovery criteria identified in the federal Recovery Plan (USFWS 2000):

- Number of populations: At least two, and preferably three populations would provide sufficient redundancy to make persistence of this species reasonably certain within the Park over at least several decades. The Recovery Plan sets a goal of 20 self-sustaining populations distributed across the extant and historic range of the species. A minimum of four viable populations in the San Juan Islands would be appropriate towards meeting this goal.
- Population size: Criteria within the Recovery Plan specify that the 20 self-sustaining populations must be stable, with stability defined as populations maintaining a 5-year running average size of at least 1,000 individuals. Later elaboration of this criterion by the Technical Advisory Team for *C. levisecta* has further interpreted this to mean 1,000 flowering plants, with clear evidence of successful reproduction occurring within the population. Populations must be separated by at least 1 km to be considered distinct. The Team's experts concluded that a population containing at least 1,000 flowering plants provided sufficient genetic diversity, together with a large enough quantity of seed, to be considered viable.
- Population trend: To remain viable, populations must not only be of sufficient size (see previous criteria), but be stable or growing. Although the number of plants in a population will inevitably fluctuate between years, when assessed over a 5-year period, the size of a viable population should be steady or increasing. A declining trend, and especially if numbers are slipping below 1,000, should be a trigger for closer examination of factors that may be contributing to the decline.
- Population area: Several of the threats to this species, including grazing by wildlife, landslides, and inappropriate burning, may occur within a small area. When this occurs on an extant population of *C. levisecta*, this can result in a dramatic and rapid decline in a population. Therefore, populations are likely to be significantly more resilient and resistant to disturbances if they occupy larger acreages. Ideally, each population should occupy an area of at least several acres.

Criteria to evaluate the other three state-listed rare plant species found at the park would also include number of populations, size of populations, population trend, and population area. However, specific metrics for each of these criteria for each species would need to be developed by expert consultation or research, and then refined over time as more information becomes available.

Condition, Trends, and Certainty

Considering the relatively small size of the park, its flora is exceptionally diverse. Rochefort and Bivin (2010) reported a total of 400 species in the park, which represents about 60% of the approximately 684 species recorded for San Juan Island as a whole. Most of the park's flora is found in similar mainland habitats. That is because, following the retreat of the glaciers 9000 to 10,000 years ago, the channels separating the San Juan and Gulf islands from the adjacent mainland are unlikely to have limited the recolonization of the islands by most plant species (Leopold et al., in prep.). As glaciers retreated, the rate at which species migrated out of their glacier-free refugia and back into northwestern Washington differed among the various taxa,

depending on their mode of dispersal, the distance travelled, and the type of habitats they typically occupied. Humans and other animals also influenced when and which species arrived in the island landscape (Wilson et al. 2009).

As is generally true elsewhere, among the many species occurring in the park, the rarest ones contribute the most to the region's biodiversity. Many are also the most sensitive to environmental change. Moreover, preservation and restoration of rare species is a fundamental legal obligation and a priority of natural resource management. The long-term survival of the park's rare species depends on ensuring that populations are stable or increasing in size, that genetic diversity is maintained, and that there is minimal likelihood that random events will result in their extirpation.

Several plant species considered to be rare in Washington currently occur in San Juan County, or have been recorded there historically (**Table 7**). Several of these could occur in habitats that are present within the park, and three of them have been detected to date: *Crassula connata*, *Ranunculus californicus*, and *Symphyotrichum hallii*. One additional species, the lichen *Niebla cephalota*, is proposed as "sensitive" for inclusion on the proposed rare non-vascular plants list for Washington state. Although none of the other plant species known to occur in the park are considered rare enough to merit legal listing under state or federal regulations, most remain unstudied.

Table 7. Rare vascular plant species recorded from San Juan County, Washington.

LT=Federal Listed Threatened, SC=Federal Species of Concern, E=State Endangered, S=State Sensitive, T=State Threatened, R= review groups of potential concern, X= extant in the park, H= historical occurrence, P= potential habitat present in park but no known occurrences.

Scientific Name	Common Name	State Status	Federal Status	Presence
Arenaria paludicola	marsh sandwort	R		H
Carex pauciflora	few-flowered sedge	S		
Castilleja levisecta	golden paintbrush	E	LT	P
Castilleja victoriae	Victoria's paintbrush	E		
Crassula connata	erect pygmy-weed	T		X
Eurybia merita	Arctic aster	S		
Isoetes nuttallii	Nuttall's quillwort	S		
Lepidium oxycarpum	sharpfruited peppergrass	E		
Liparis loeselii	bog twayblade	E		
Lobelia dortmanna	water lobelia	T		
Meconella oregana	white meconella	T	SC	
Microseris bigelovii	coast microseris	R		H
Ophioglossum pusillum	Adder's-tongue	T		
Orthocarpus bracteosus	rosy owl-clover	E		H
Oxytropis campestris var. *gracilis*	slender crazyweed	S		P
Packera macounii	Siskiyou Mountain ragwort	S		P
Potamogeton obtusifolius	blunt-leaf pondweed	S		
Ranunculus californicus var. *californicus*	California buttercup	T		X

Sanicula arctopoides	footsteps of spring	S		P
Sericocarpus rigidus	white-top aster	S	SC	P
Symphyotrichum boreale	rush aster	T		
Symphyotrichum hallii	Hall's aster	T		X

For an overall snapshot of uncommon plant *communities* in the park, see Rocchio et al. (2012) for details. Only summaries are presented here.

Although the prairies and oak woodlands discussed in section 4.4.4.1 certainly qualify as rare communities in the region, other terrestrial plant communities found at the park that are relatively uncommon or rare and of conservation significance include coastal strand/spit vegetation and dunes and their associated vegetation communities, all of which will be assessed in this section. This section primarily describes three uncommon plant communities that occur within the park's coastal sand dunes and spits. Two are considered globally critically imperiled and one globally imperiled. The dunes are noteworthy for still being somewhat active, that is, sand transport processes are still somewhat intact. This is likely one of very few, and maybe even the only one of, active dune sheets in the Puget Lowland. The relative abundance and in some cases dominance of the native coastal sand verbena (*Abronia latifolia*) in the dunes and strand is indicative of a substantial degree of substrate instability and sand movement, which are critical ecosystem features for these systems which are easily lost via succession in the presence of stable sand. Geomorphic changes related to future sea level rise are a concern for the strand and spit communities.

Table 8. Vascular plant associations designated as "Imperiled" or "Critically Imperiled" within Washington or globally by the Washington NHP, and reported in the park's American Camp (AC), English Camp (EC), and Mitchell Hill (MH) units by Rocchio et al. (2012).

Plant Association	Habitat	AC	EC	MH
Festuca rubra - (*Camassia leichtlinii, Grindelia stricta var. stricta*) Herbaceous	Bald/bluff	X		
Festuca rubra - Ambrosia chamissonis Herbaceous Vegetation	Coastal sand dunes/ spits	X		
Festuca rubra Stabilized Dune Herbaceous Vegetation	Coastal sand dunes/ spits	X		
Pseudotsuga menziesii / Symphoricarpos albus - Holodiscus discolor Forest	Dry forest	X		
Thuja plicata - Abies grandis / Polystichum munitum Forest	Mesic forest	X	X	X
Thuja plicata / Gaultheria shallon Forest	Mesic forest	X	X	X
Quercus garryana / Symphoricarpos albus / Carex inops Woodland	Oak woodland	X		
Populus tremuloides / Carex obnupta Forest	Wetland	X		
Festuca rubra Coastal Headland Herbaceous Vegetation	Bald	X		
Salix hookeriana - (Salix sitchensis) Shrubland	Wetland	X		
Leymus mollis ssp. mollis- Abronia latifolia Herbaceous Vegetation	Coastal sand dunes/ spits	X		
Pseudotsuga menziesii / Gaultheria shallon - Holodiscus discolor Forest	Dry forest	X		X
Pseudotsuga menziesii / Rosa gymnocarpa - Holodiscus discolor / Festuca occidentalis Forest	Dry forest	X		X

Pseudotsuga menziesii - Arbutus menziesii / Holodiscus discolor Forest	Dry forest	X		X
Cornus sericea Pacific Shrubland	Wetland	X		
Malus fusca - (Salix hookeriana) / Carex obnupta Shrubland	Wetland	X		
Salicornia virginica - Distichlis spicata - Triglochin maritima - (Jaumea carnosa) Herbaceous Vegetation	Wetland	X		
Tsuga heterophylla - (Thuja plicata - Alnus rubra) / Lysichiton americanus - Athyrium filix-femina Forest	Wetland		X	
Pseudotsuga menziesii - Abies grandis / Gaultheria shallon - Holodiscus discolor Forest	Dry/ mesic forest	X		
Carex tumulicola Herbaceous Vegetation	Prairie	X		
Plectritis congesta Herbaceous Bald	Bald	X		
Camassia quamash - Triteleia hyacinthina Herbaceous Bald	Bald/ wetland	X		
Carex inops - Eriophyllum lanatum Herbaceous Bald	Bald	X		
Pseudotsuga menziesii - Abies grandis / Holodiscus discolor / Melica subulata Forest	Dry/ mesic forest	X		
Festuca roemeri - Camassia quamash - Cerastium arvense Herbaceous	Prairie	X		

Non-native species that have negative impacts in prairies also have the potential to negatively impact golden paintbrush, Hall's aster, and California buttercup. The most problematic non-natives are tall oatgrass, hairy cat's ear, common St. Johnswort (*Hypericum perforatum*), Canada thistle, common velvetgrass, and colonial. Invasive shrubs like Scotch broom and Himalayan blackberry (*Rubus armeniacus*), while less frequent in the prairies than the herbs, can be extremely deleterious if they become established, by converting the prairie to shrubland. Seed bank surveys demonstrate a great preponderance of non-native species present in the soil on the American Camp prairie, and a dearth of seed from natives (Rochefort and Bivin 2010). This repository of non-native seed presents an enormous challenge in restoring native prairie in particular.

Invasive species also threaten the dune and coastal strand/spit communities. Some of the most abundant non-native species found in these communities are common velvetgrass, Canada thistle, sheep sorrel (*Rumex acetosella*), ripgut brome, poverty brome, and yellow hairgrass (Rochefort and Bivin 2010, Rocchio et al. 2012). One non-native that is unique to the strand and dunes is European searocket (*Cakile maritima*). It is common on South Beach and other strand habitats, where it dominates some rather sparsely vegetated areas. Scotch broom, gorse (*Ulex europaeus*), and Himalayan blackberry can all be very detrimental to strand and spit communities if they become established. European beachgrass (*Ammophila arenaria*) has completed transformed outer coastal dunes where it has been established. The lack of the species at the park, and the concommittant continued instability (natural process still intact in that regard) in the dune field, is noteworthy and very worth being hypervigilant for nascent invasions by this problematic invasive.

Golden Paintbrush *(Castilleja levisecta)*

This species is considered to be rare throughout most of the Pacific Northwest. The State of Washington lists it as Endangered, and the U.S. Fish and Wildlife Service lists it as Threatened. Only 12 naturally-occurring populations exist in the world, and five of these occur within the San Juan and Gulf Islands. There are several reasons this should be considered as one of the pre-

eminent focal species at the park. An historical occurrence of this species was reported from Cattle Point, although the record lacks sufficient detail to know precisely whether it occurred within the boundary of the park (Washington Natural Heritage Program). However, several extant populations continue to exist within 2-3 miles of American Camp, and additional historical populations are known to have occurred in very close proximity to the park. Thus, American Camp is centrally situated within the historical range of this species in the San Juans. Furthermore, considerable habitat exists within the park that is likely to be suitable for sustaining new populations. Since little potential habitat exists in the islands on protected lands that have been dedicated to conservation purposes, the existence of significant potentially suitable acreage within the park positions the park to play a critical role in the recovery and delisting of this rare species. Currently, only a single population in the San Juans exceeds 1000 flowering plants, sufficiently large to meet recovery criteria. Natural succession which causes prairies to become shrublands and forest in the absence of fire threatens *Castilleja levisecta* and Hall's aster (both prairie-dependent species), as well as the park's native plant richness overall.

Attempts to re-establish this species in the park are underway. Re-establishment was initiated at American Camp in 2009 when 400 plugs were installed. One flowering plant was recorded in 2010, but no additional data on this outplanting are available. Additional plugs were outplanted in fall of 2012 at a nearby location. 57 flowering plants were recorded in spring, 2013. Also, attempts have been made to establish new local populations on Waldron, Lopez, and Shaw Islands, and San Juan Island, including at American Camp. These efforts began in 2007, and have included outplanting of nursery-grown plugs of this species, as well as some site management, which has included control of invasive species, cutting of encroaching shrubs and trees, burning, and fencing to reduce access of grazing animals.

Recent studies have suggested that golden paintbrush is likely to be one of the few species that serve as a larval food plant for the Taylor's Checkerspot (*Euphydryas editha taylori*) butterfly (Dunwiddie et al., *in prep.*), a species that was listed as "Endangered" by the U.S. Fish and Wildlife Service in October 2013. Therefore, establishment of robust, viable populations of golden paintbrush may be key in the recovery of this federally-listed butterfly. Great strides have been made in the last several years in establishing *Castilleja levisecta* elsewhere in Washington and Oregon. *C. levisecta* restoration in the park should be closely coordinated with these other recovery efforts to best apply this experience and lessons learned to sites in the park. Such collaboration can be especially helpful in informing and furthering efforts in three areas: selecting the most suitable sites for sustaining *C. levisecta* populations, reliably providing sufficient quantities of material (plugs and/or seed) for establishing *C. levisecta* populations, and managing the sites in ways that are most likely to maintain healthy, viable populations over the long term:

- Site selection: Even within areas identified as generally suitable for supporting a population of *C. levisecta,* experience at other sites has suggested that considerable heterogeneity usually exists, with suitable microsites occurring scattered within a larger matrix that may be less amenable to sustaining individual plants. Careful analysis of vegetation composition on a detailed, fine scale in potential restoration sites can assist managers in identifying these suitable microsites, and avoid expensive losses of plugs outplanted in inappropriate locations. In general, the most suitable habitats tend to retain higher levels of soil moisture, and are dominated by a diversity of perennial native

grasses and forbs. These should be sites where exotic species, especially annual and perennial grasses, are usually scarce and are relatively easily controllable.

- Plant materials and establishment: Production of plugs for outplanting requires considerable coordination with growers to collect sufficient quantities of seed, grow it successfully in containers, and produce the desired quantities of plugs in time for outplanting. By closely coordinating *C. levisecta* recovery efforts at multiple locations, *C. levisecta* recovery efforts in other areas have been able to create redundancies in production, facilitate reallocation of materials to overcome production shortfalls, and ensure the continuity and avoid disruptions in the entire chain of production. It is recommended that park managers explore a similar coordinated effort with others engaged in *C. levisecta* recovery in the San Juans.
- While outplanting of plugs has been helpful in establishing populations of *C. levisecta* in some locales, much greater efficiencies have been created by establishing plants by sowing large quantities of *C. levisecta* seed. This approach also potentially greatly enlarges the genetic diversity that may be represented in the restored population. It is recommended that development of *C. levisecta* seed production beds be prioritized for accelerating recovery of this species at the park. As noted above for plugs, coordinating such seed production with others engaged in similar recovery efforts can provide considerable advantages for all parties.
- Site restoration, management, and maintenance: Once plants are introduced to suitable sites, considerable efforts are necessary to ensure that a viable population is established and flourishes over time. Foremost among these efforts is identifying and abating critical threats. At the park, these are likely to include the following. 1) lack of sufficient host plants, 2) herbivory by mammalian grazers, 3) competition with species that are deleterious to the survival of *C. levisecta*, and 4) maintenance of conditions to ensure successful reproduction of *C. levisecta* by seed. It is recommended that park managers closely evaluate these and any other potential threats, and take proactive measures to ensure that they are adequately addressed. This is necessary to avoid setbacks that can be extremely costly in terms of both time and resources in recovery efforts.

Erect Pygmy-weed (*Crassula connata*)

This was discovered in the park in 2000 by an experienced observer who noted that the population was large (about 750 plants) and occupied an area (about 1 acre) which is relatively large for this species in Washington. It is located at base of the bluffs on South Beach. Given that the species is listed by the State of Washington as Threatened, a preliminary condition of "somewhat concerning" seems warranted. Information to fully assess the condition of this species is insufficient, as is information on its historical abundance here or elsewhere in the state.

California Buttercup (*Ranunculus californicus* var. *californicus*)

Hall's Aster (*Symphyotrichum hallii)*

Hall's aster has been reported at American Camp, but we have insufficient information to assess the condition of this species in the park. California buttercup occurs in several locations at American Camp, with >1800 plants mapped in 33 patches in 2005 (R. Rochefort, personal communication, 2014). However, this is a relatively small number of individuals, and road construction, invasive species, and hybridization with western buttercup all pose significant potential threats. Therefore, both species are rated here as being of "significant concern." Given

what is known about the habitat preferences of these species and their current distribution, we consider it likely that they were, in the pre-settlement era, more widespread and abundant than they are currently on San Juan Island. Both are associated with prairie and related habitats that have declined greatly in area and condition.

	Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Native Plant Richness & Invasive Plants	Somewhat Concerning	Medium	Unknown	N/A
Castilleja levisecta	Significant Concern	High	Unknown	N/A
Crassula connata	Somewhat Concerning	Low	Unknown	N/A
Ranunculus californicus	Significant Concern	Low	Unknown	N/A
Symphyotrichum hallii	Significant Concern	Low	Unknown	N/A

Data Gaps

- Bryophytes and lichens are important contributors to overall biodiversity and ecosystem functions but have not been comprehensively inventoried within the park. Effects of recreation, controlled burns, and other park management activities on these taxa have not been measured, nor are trends known. Frequent burning that facilitates germination of native prairie species is known to generally reduce cover and perhaps diversity of ground-dwelling mosses and lichens.
- For parameters such as species diversity and native/non-native ratios, there is a lack of appropriate target values, i.e., conditions that are both ecologically realistic and practical to achieve with available resources. One tool that can provide a framework for discussing and measuring such biodiversity parameters is the Washington version of the Floristic Quality Assessment (Rocchio and Crawford 2013). Ecologists have only just begun applying this to monitor condition of prairie communities in the park (Rochefort et al. 2012, Dunwiddie et al. 2013) as well as across the region.
- No regular monitoring has occurred of most the park's rarer species of vascular plants such as *Crassula connata, Ranunculus californicus var. californicus,* and *Symphyotrichum hallii*, so trends in size or extent of populations are unknown. Annual forbs and other species that may be especially adapted to regular burning could be

particularly vulnerable to loss (Dunwiddie et al., *in press*). Up-to-date surveys are needed to document population numbers, area occupied, exact locations, and other important data for management. Once relocated, the populations should be monitored periodically so as to assess trends. An effort should be made to assemble known information about each species within the state, through a combination of literature review and expert interviews, in order to better put in context the populations found at the park.

- As related to the ongoing attempts to restore *Castilleja levisecta* to the park, data needs specific to this plant are:
    - Quantifying the associated species in recovery habitat to evaluate the presence and abundance of host species.
    - Evaluating the presence and abundance of species that are likely to be deleterious to *C. levisecta* establishment, such as annuals and non-native perennial grasses.
    - Determining which animals (deer, rabbits, etc.) may be contributing the most to loss of individual plants from grazing, and taking appropriate measures as necessary.
    - Assessing the need for burning or other actions that might create microhabitats more suitable for seed establishment.
    - Detailed information must also be gathered on the demographics and biology of the *C. levisecta* plants that are plugged or seeded on a site. Aspects of particular interest include:
    - Annually monitoring all outplanted individuals to assess survival, flowering, seed production, and loss from grazing, and
    - Annually surveying to detect recruitment of new individuals that may establish from seed.
- Data sufficient to inform management practices are lacking on the condition and areal extent of strand, spit, and dune plant communities in the park. More information on the effects of European rabbits in the dune communities would be useful to better manage this unique ecosystem. As well, information on the specifics of ecosystem processes (e.g., wind transport of sand, berm maintenance, effects of flooding) as they operate on sites in the park would be critical to long-term management of these communities.

4.4.4.3 Forests

This section addresses forests as well as more open woodlands dominated by species *other than oak*. Savannas (scattered trees on grassland) and oak woodlands are discussed in section 4.4.4.1.

Forests dominate at low elevations across western Washington. Their composition and structure is especially influenced by age, substrate, hydrology, history, and local climate. In the region generally, Douglas-fir is the primary dominant species, with western hemlock, grand fir (*Abies grandis*), western red cedar (*Thuja plicata*), bigleaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*) very common and frequent as well. On the drier sites, shore pine (*Pinus contorta* var. *contorta*) and Pacific madrone (*Arbutus menziesii*), are important constituents as well. In an undisturbed state, much of the park would naturally be covered by combinations of these species (Agee 1987). As a result of the region's abundant precipitation and moderate temperatures, many of the conifers can reach ages of 400-800 years, but after over a century of logging, few such trees remain. On shallower soils and where the local climate is relatively dry, such as on San

Juan Island, potential tree height for Douglas-fir on a typical site is only about 120 feet at 100 years (Atterbury 1990).

The San Juan Islands have 70,000 acres of forestland, 60,000 acres of it in private ownership where virtually all of the logging occurs. Past rates of cutting have been many times greater than the rate of local timber growth. Harvest yields have been declining as forest structure has been changed by persistent "high-grading," e.g., yields in the 1990s were only one-third those in the 1950s. Despite relatively low productivity of the islands' forests due to poor soil and climatic conditions, they are being harvested on the average of once every 45 years, resulting in dramatically altered structure. This in turn is likely to cause long-term disappearance of many understory plant species (Halpern and Spies 1995), impoverishing local wildlife habitat.

In the San Juans generally, logging prior to 1925 was probably intensive in certain areas, to generate fuel wood for lime kilns and other early commercial enterprises. Timber harvest records going back to 1925 show a relative lull in logging until the end of World War II, except for a one-year spike in 1934. A post-war boom in logging coincided with the post-war expansion in home construction in the islands. Another upswing in timber harvests occurred in the early 1990s, as timber availability regionwide decreased due partly to federal spotted-owl policy. Limitation of cutting in national forests created sharply rising log prices that peaked around 1995. The limitations increased the demand for timber in private forestland holdings throughout the state, including San Juan County, where essentially all of the forests are privately owned. Windstorms in late 1989 and early 1991 in the county also stimulated high volumes of harvesting. Between 1950 and 2000, an area equivalent to the entire forested landscape of the islands was cut. In 2012, no Washington county had less timber harvested annually than San Juan County (677,000 board feet).

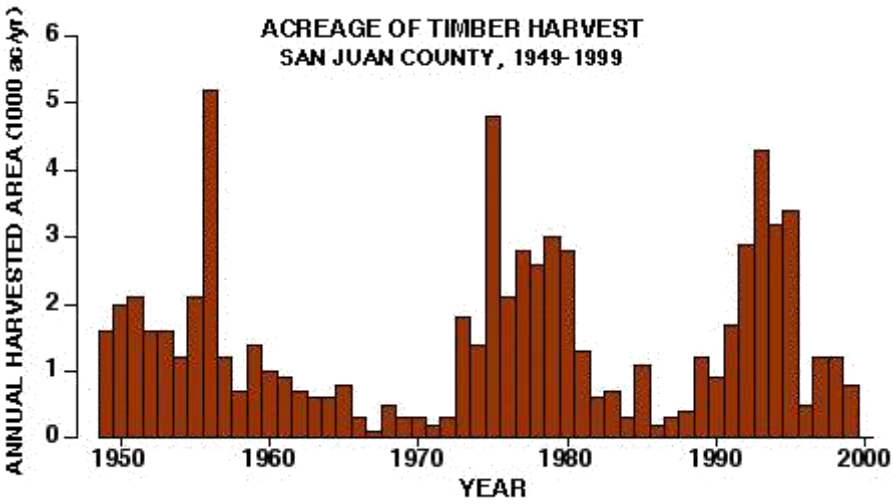

Figure 25. Annual timber harvest in San Juan County, 1949 to 1999.

Compiled at: http://www.rockisland.com/~tom/stats.html .

Criteria
To define reference conditions and thus derive criteria, we reviewed historical records (maps, photos, accounts), considered research and literature pertaining to the region's pre-settlement vegetation, and ultimately used our best professional judgment.

We chose not to set criteria for fire return interval (FRI) in the conifer forest of the park for the following reasons: (1) there is no compelling argument for prescribed fire from a biodiversity conservation perspective (i.e., there are no species totally dependent upon it as there are, for example, with oak woodland/savanna), (2) it would require extensive pre-burn fuel manipulation to re-establish conditions under which such burns could be safely conducted in ways that would mimic their historical behavior and effects, and (3) conducting such understory burns on a regular basis in forested habitats would be difficult and expensive.

Criteria for Forest Age and Composition
This indicator is relatively straightforward. Although we did not measure it directly, it could be derived from aerial imagery (detailed LiDAR images are available for all of the park) combined with field truthing, and can be tracked over time. Stand age classes can be used to some degree as a surrogate for stand structural features. The caveat is that differences in site productivity, as determined by natural factors such as soil type, can strongly impact the rate at which late-successional features are created in a stand. Nonetheless, even on relatively unproductive sites, the older the stand is, the more likely it is to have developed one degree or another of the valued, and now underrepresented, structural features. Criteria for this characteristic are as follows:

> *Good.* Distribution of age class and dominance type is similar (up to 35% different from) the presumed pre-EuroAmerican settlement distribution.
>
> *Somewhat Concerning.* Distribution of age class and dominance type is moderately different from (varying from 35-70%) to the presumed pre-EuroAmerican settlement distribution.
>
> *Significant Concern.* Distribution of age class and dominance type is very different (<20% similarity) than the presumed pre-EuroAmerican settlement distribution.

Table 9 illustrates combinations of stand age and tree dominance types expected to occur frequently in this park. Rocchio et al. (2012) and Agee (1987) provide further detail on stand compositional types. Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, red alder, and Pacific madrone will appear relatively frequently as canopy dominants or co-dominants (defined as the 1-3 most abundant species in the main and upper canopy layers, wherein "dominant" or "co-dominant" species occupy at least 25% of the total canopy cover).

Table 9. Common combinations of vegetation dominance type and stand age expected to occur in the park's forests.

Vegetation	Very Young	Young	Mature	Old-growth
Pseudotsuga menziesii	X	X	X	
Pseudotsuga menziesii – Abies grandis		X	X	
Pseudotsuga menziesii – Arbutus menziesii		X	X	

Pseudotsuga menziesii – Pinus contorta	X	X
Abies grandis		X
Abies grandis – Thuja plicata		X
Alnus rubra	X	X
Alnus rubra – Pseudotsuga menziesii	X	X

Criteria for Forest Structure

Old-growth forest within the Puget Lowland of Washington has been reduced to less than 1 percent of its presumed pre-EuroAmerican settlement distribution. Old-growth forests in the Pacific Northwest have been a major focus of conservation concern for reasons of biodiversity, wildlife, ecosystem function, and decline in extent. Much attention has been paid to developing criteria to evaluate old-growth-associated stand structural features. The USDA Forest Service has developed interim old-growth definitions for all forest series (potential natural vegetation) present on National Forest lands in Washington and Oregon (Fierst et al. 1992, 1993). While the national forests include very little of the Puget Lowland, we believe that a modification of these definitions could be used in this park. Significant areas of the park's forests fall within each of the following forest series: Western hemlock, grand fir, and Douglas-fir. The interim definitions do not include data for westside of the Cascades Grand Fir series, which would likely be intermediate between those for western hemlock and Douglas-fir.

To meet the definition of old-growth, western hemlock stands should have:

- Minimum of 8 standing live trees per acre at least 21-42 inches dbh and >200 years old (varying by site class)
- Decadent trees are present
- Minimum of 2 tree canopy layers
- 4 standing dead trees (snags) per acre, at least 20 inches dbh*
- 29-69 logs at least 8-12 inches diameter (varying by site class)*
  * numbers of snags and logs are typical minimums, but are not required to qualify as old-growth.

For Douglas-fir old-growth:

- Minimum of 8-10 standing live trees per acre at least 24-37 inches dbh and >190-205 years old (varying by site class)
- Decadent trees are present
- Minimum of 2 tree canopy layers
- 1 standing dead tree (snag) per acre, at least 13-17 inches dbh (varying by site class)*
- 4 logs at least 24 inches diameter*
  * numbers of snags and logs are typical minimums, but are not required to qualify as old-growth.

The abundance of logs (downed wood) in Puget Lowland old-growth is less than these interim definitions suggested for the western hemlock series. The prevalence of low- and moderate-severity fires associated with Native American burning likely consumed much of this wood, resulting in lower levels of downed wood than has been suggested in adjacent national forests.

We recommend that NPS contact the USDA Forest Service Region 6 for any updates to these interim definitions, and modify them if necessary to assess old-growth within the park.

Specific criteria for percentage of forests in old-growth conditions are:

Good. > 20% of existing forest landscape meets old-growth definition.
Somewhat Concerning. 5-20% of existing forest landscape meets old-growth definition.
Significant Concern. <5% of existing forest landscape meets old-growth definition.

Reference conditions for forests (both distribution of stand age/type and percentage of old-growth criteria) are based primarily on the work of Agee (1984 & 1987), who reviewed available historical records and photographs to derive as much information as possible regarding pre-settlement conditions and subsequent changes. In addition, he relied upon historical accounts, soil surveys, and ecological research from elsewhere in the ecoregion to construct a broad-brush picture of the landscape cover of major vegetation types. Research regionwide since the 1980s reaffirms Agee's main ideas regarding the role and effects of fire in the pre-settlement landscape. Pre-settlement stand structures and age classes would have been primarily dependent upon the fire regimes. Reference conditions are also informed by extensive field surveys of most existing natural-origin and relatively undisturbed (by Euro-American industry) forest stands throughout the Puget Lowland completed by the Washington Natural Heritage Program (Chappell, pers. obs.).

At English Camp, Agee (1984) described the reference conditions, but provided no information regarding stand age classes. A widespread, stand-replacement fire occurred about 1715-1725 (Agee 1984). If logging had not occurred over virtually the whole of the site, much of the forest would today be old-growth. Another stand-replacement fire may have occurred about 1775 in the northeast portion of English Camp.

At American Camp, Agee (1984) similarly described the reference conditions, but provided no information regarding stand age classes. Early photographs suggest that much of the Douglas-fir on site was larger (some of it evidently >200 years old) than at present. However, the photographic record is very fragmentary in terms of area covered, so there is a great deal of uncertainty, and about all we can conclude is that there was probably more older forest than exists today, especially in the northwestern quarter where all forests are now young.

Chappell's (Washington Natural Heritage Program) surveys of Puget Lowland remnant undisturbed forests, along with J. Henderson's fire history data from the adjacent national forests (Henderson et al. 1989), suggest that percentages of old-growth on the pre-settlement landscape probably fluctuated over time with the occurrence of a few major region-wide fire events. They also suggest that the proportion of the region's landscape with old-growth was probably typically greater than about 1/3 (though with local variation as well), and potentially significantly less than in the adjacent mountains due to higher fire frequencies.

Condition, Trends, and Level of Certainty

<u>Forest Age and Composition</u>

Rocchio et al. (2012) mapped the park's forests using Alliances from the National Vegetation Classification. Natural-origin (as opposed to ruderal) forest alliances that occur on uplands include five types which are mapped in the following figures. It should be noted that the names of the alliances (a coarse-scale vegetation classification unit) do not necessarily imply exactly which species are dominant in the canopy in any location, but are rather names for a broad assemblage of similar community types (associations) that share floristic, compositional, and environmental affinities. **Table 10** summarizes all forest alliances: natural, ruderal, wetland, and upland for the park, **Figure 26** and **Figure 27** illustrate their distribution within the park.

Table 10. Area of mapped forested alliances at the park.

Modified from Rocchio et al. 2012.

USNVC Alliance	Total Acres
(*Acer macrophyllum - Alnus rubra*) Riparian Forest	66.0
(*Alnus - Fraxinus - Populus*) / *Lysichiton americanus* Deciduous Swamp Woodland	3.4
(*Tsuga heterophylla - Picea sitchensis - Thuja plicata - Abies*) / *Lysichiton americanus*	3.0
Acer macrophyllum - (*Pseudotsuga menziesii*) Forest	4.4
Alnus rubra / Nonnative Grasses Provisional Ruderal Flooded Forest	13.3
Alnus rubra - (*Picea sitchensis - Tsuga heterophylla*) Forest and Woodland	1.0
Alnus rubra - Pseudotsuga menziesii Provisional Ruderal	79.1
Alnus rubra / Carex obnupta Provisional Ruderal Flooded Forest	0.8
Prunus emarginata Provisional Ruderal Flooded Forest	0.4
Pseudotsuga menziesii - (*Arbutus menziesii*) Forest and Woodland	784.2
Pseudotsuga menziesii - Pinus contorta Provisional Ruderal	16.7
Pseudotsuga menziesii / Nonnative Grasses Provisional Ruderal	36.2
Thuja plicata - (*Abies grandis*) Maritime Forest	333.6
Tsuga heterophylla - Pseudotsuga menziesii / (*Holodiscus discolor*) Forest	91.3

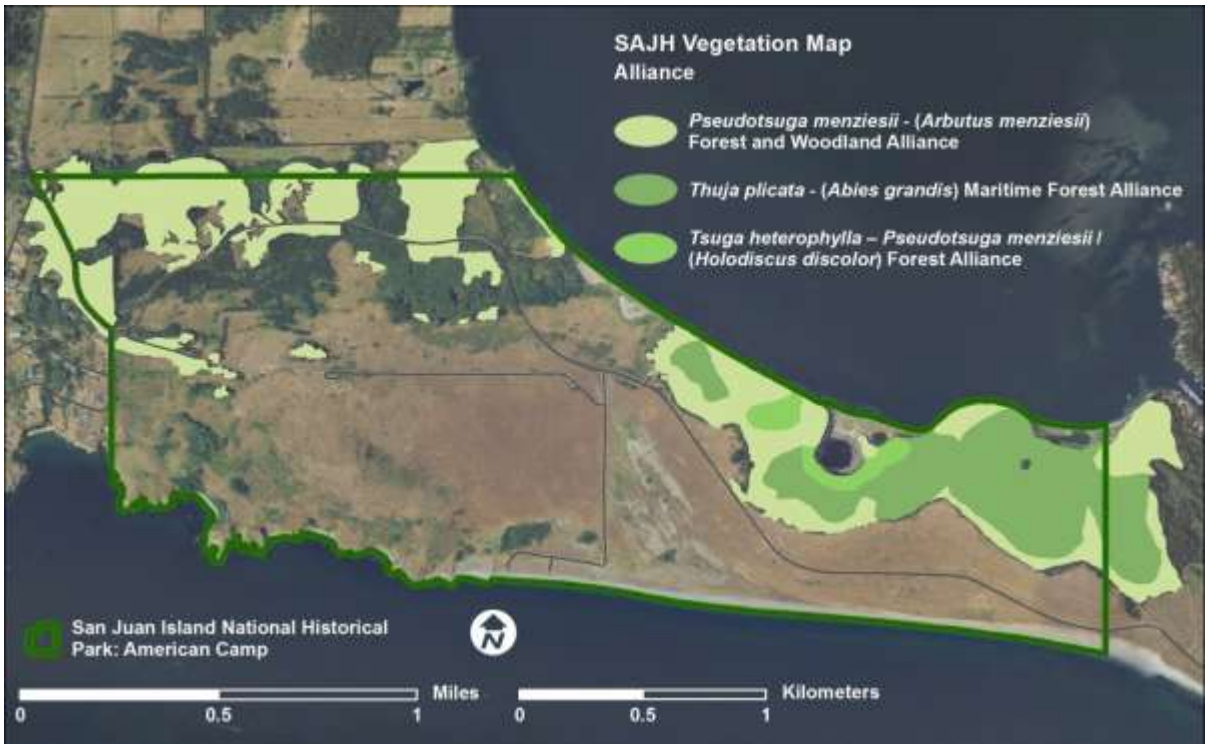

Figure 26. Location of native upland forest alliances at American Camp.

From Rocchio et al. 2012.

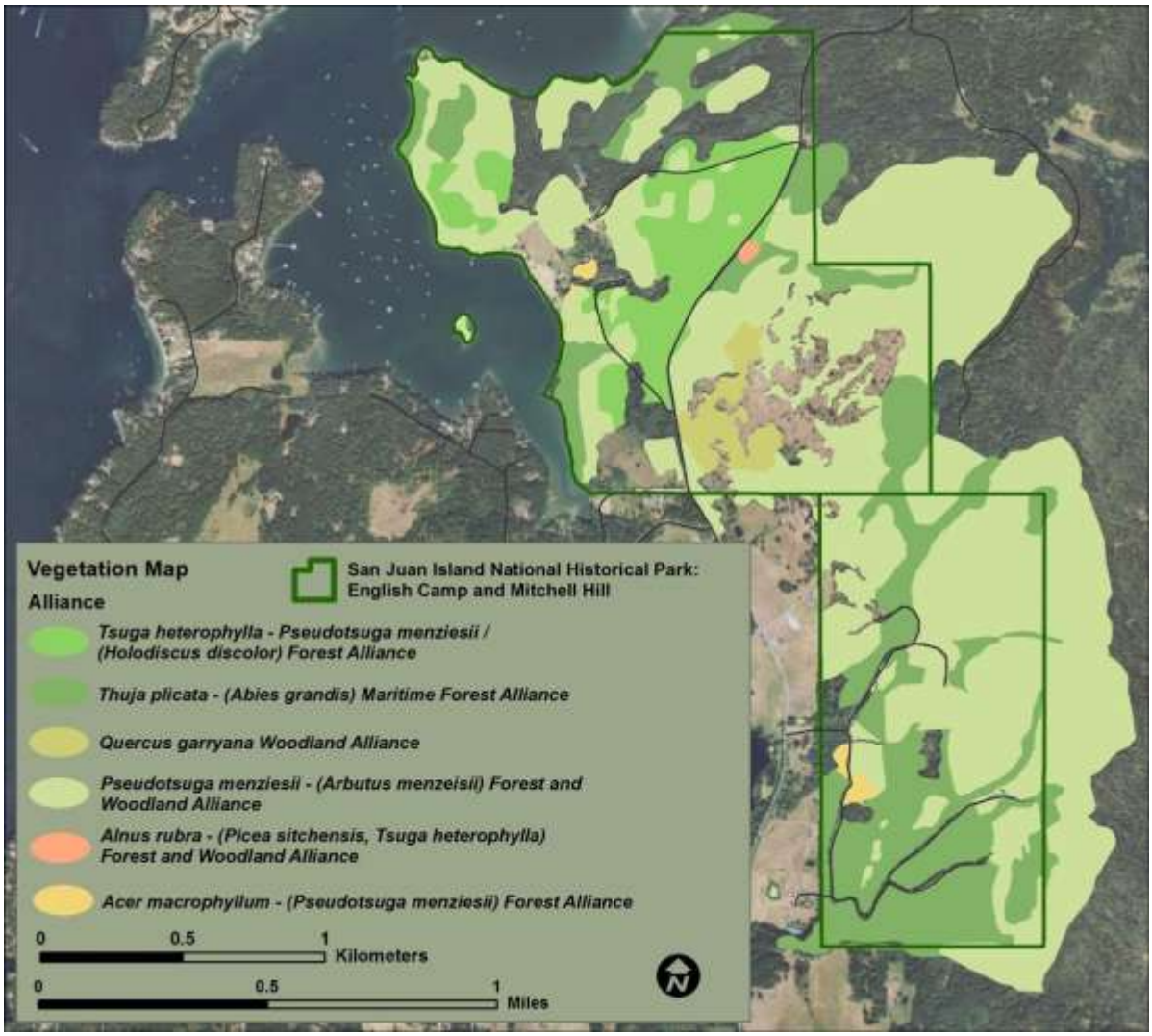

Figure 27. Location of native upland forest alliances at English Camp and Mitchell Hill. From Rocchio et al. 2012.

Forest conditions of note include those at American Camp, on the north slopes of Mount Finlayson, where there is a stand of mature conifer forest approximately 120-130 years old, the result of regeneration following a late 19th-century timber harvest. In the 1950s, portions of the forest in this area were high-graded (largest trees were removed). Small patches there still harbor old trees (Agee 1983), and are likely the site of remnant old-growth structural features. Mature stands such as this are certainly much less common in the Puget Lowland than younger stands, and as such, this forest stands out as slightly unusual in the region. As this stand continues to mature, it will increasingly take on more old-growth characteristics, such as standing dead snags, fallen logs and stumps, windthrow mounds. Silvicultural techniques could be used to accelerate development of late-successional forest structures, especially in young forests or mature forests depauperate in such structures.

A total of 8 forested upland plant associations found in the park are considered either globally or state imperiled (**Table 8**, section 4.4.4.2). All of these are associations endemic to the ecoregion, wherein the vast majority of natural forests have been logged over at least once in the past and where large percentages of forest have also been converted or degraded by development. As noted above, the condition of these communities within the park is for the most part of "significant concern" due to past logging and other activities, though the extent of some of them is substantial.

One such imperiled community of particular note is the *Pseudotsuga menziesii – Arbutus menziesii/ Holodiscus discolor* Forest because of the co-dominance of Pacific madrone. As noted in the Issues Description section, there is some concern about the health and future status of madrone in western Washington due to a fungal pathogen and lack of periodic fires. While it is difficult to imagine the species becoming rare, it seems possible that its abundance could be severely impacted through time by these processes. This would have a profound influence on ecosystem function and wildlife use in this plant association, due to the unique nature of madrone as an evergreen broadleaf tree (just about the only native one), as an abundant source of cavities for wildlife, and as an abundant source of highly nutritious fruit for frugivorous birds.

<u>Forest Structure</u>

Our analysis of LiDAR fine-resolution data for the entire park produced a comprehensive profile of the vegetation canopy heights (

Table 11). A shapefile map of that is available.

Table 11. Distribution of canopy heights (in feet) within the park's American Camp and English Camp units based on LiDAR analysis.

Statistic	American Camp	English Camp
mean	19.34	57.99
median	0.51	64.87
standard deviation	32.56	38.16
minimum	0	0
maximum*	168.2	169.12
1st quartile	0.24	22.08
3rd quartile	26.34	88.74
% at <3 ft	64.04	15.24
% at 3-6 ft	2.27	1.62
% at 6-20 ft	6.34	7
% at 20-50 ft	8.58	15.11
% at 50-100 ft	15.33	47.28
% at > 100 ft	3.23	13.6

* may be overstated due to a few anomalous readings.

The park currently has no old-growth forest. Most of the existing forests are young, although many are verging on mature or have just recently become mature (Agee 1984, 1987). The current distribution of forest age classes in the English Camp unit is strongly weighted toward the ‘young’ (50-100 ft) age class. The LiDAR analysis (

Table **11**) indicates that a tree canopy higher than 100 ft—very little of it mature forest—occupies only 13.6% of English Camp. Locations of the tallest tree stands in the English Camp and American Camp units can be seen in the maps we generated from the LiDAR data (**Figure 28**, **Figure 29**). The abundance of shade-tolerant tree species like western hemlock and western redcedar has likely been locally reduced to some degree with the historical logging of the old-growth. There are significant acreages of very young ruderal forests that have grown up on former agricultural lands and whose composition is likely significantly altered from pre-settlement times.

Despite the apparent absence of old-growth, there is gradual movement in the direction of reference conditions over much of the forested area of the park. Forest management treatments in the form of mechanical thinning and pile burning, and some limited prescribed burning, have been implemented on some forest stand units in northwestern American Camp and at English Camp (the latter thinning only) over the last 15 years. Data are insufficient to indicate whether these treatments are moving the stand structure in the direction of late-successional forest structures. While that is not the stated goal of the treatments, it is one potential benefit of them. Trends in abundance and health of Pacific madrone are unknown at this time.

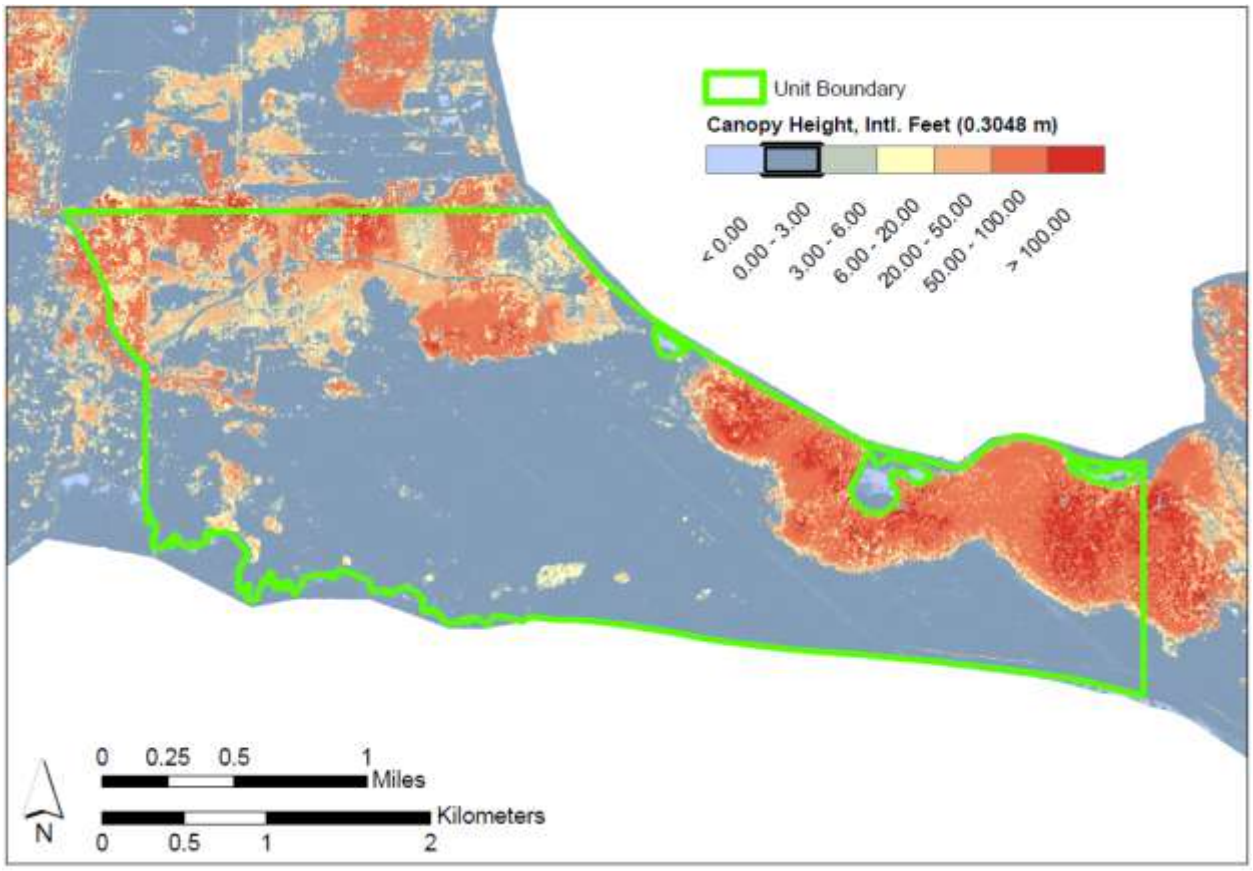

Figure 28. Canopy heights in American Camp from LiDAR image analysis.

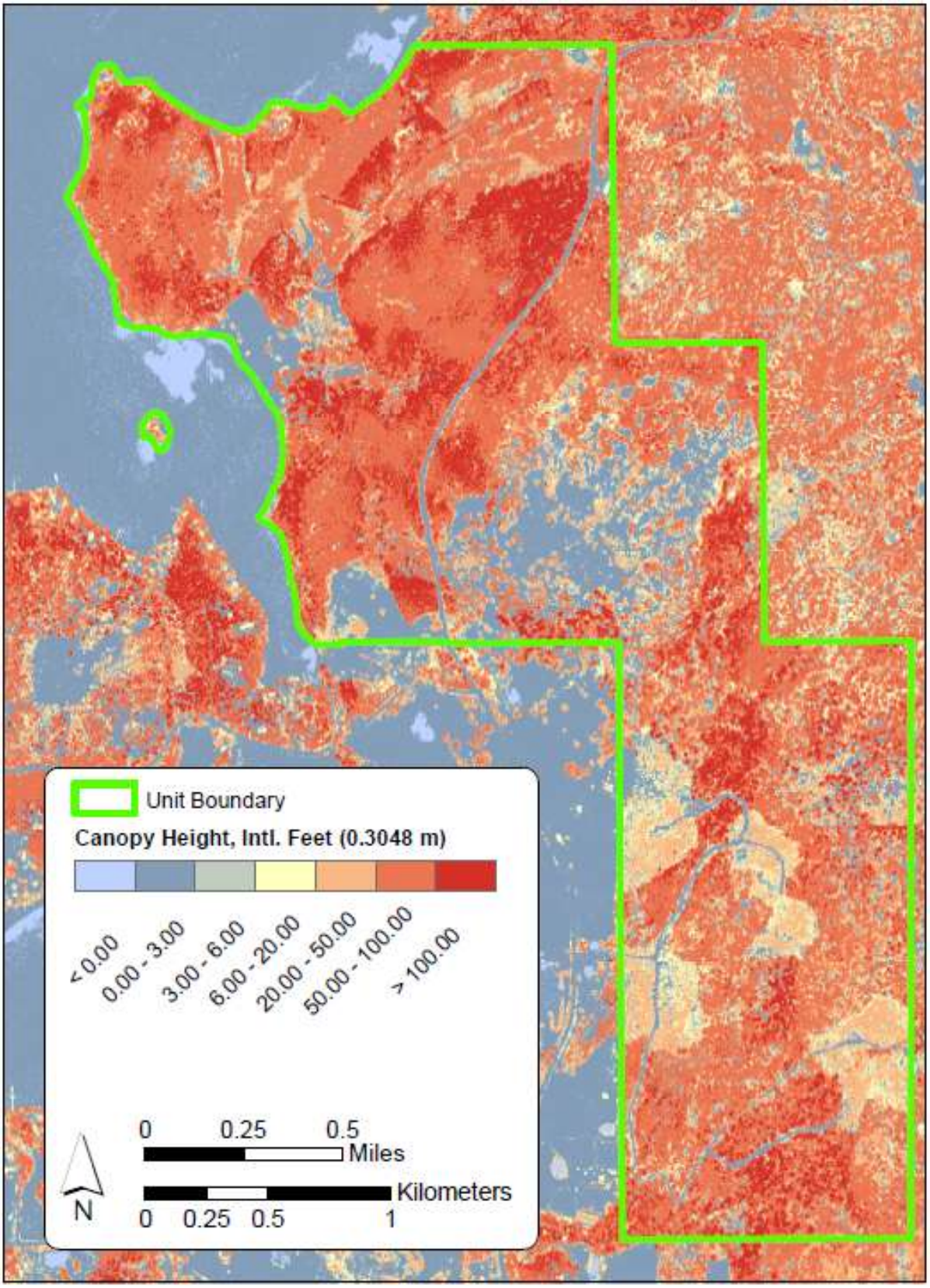

Figure 29. Canopy heights in English Camp and Mitchell Hill from LiDAR image analysis.

Indicator	Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Age and Composition	Somewhat Concerning	Medium	Unknown	N/A
Structure	Unknown	N/A	Unknown	N/A

We rated Age and Composition as "Somewhat Concerning" because condition of the forests has been altered by invasive plants, and distribution of age classes appears to be atypical for lowland environments similar to those in the park, and from what can be inferred from historical accounts. We have low confidence in the exact magnitude of historical changes in forest age, composition, and particularly structure, and have no data by which to evaluate recent trends within the park. That is because, apart from the qualitative descriptions by Agee (1983, 1987), we do not know what structural conditions once existed. Indeed, there are few if any studies that have attempted to reconstruct the composition and density of trees in forests anywhere in this region prior to Euro-American settlement.

Data Gaps

- Data are lacking on stand age/dominance type classes of forests throughout the park, including locations of any remnant stands of mature trees. The LiDAR data and the maps and descriptions in Rocchio et al. (2012) would be logical starting points for attempting to fill these gaps. In the process, consideration might also be given to modifying the Forest Service old-growth definitions so they better fit the environment of the San Juan Islands.
- More refined data and more frequent monitoring are needed to fairly assess the results of reforestation (tree establishment) on formerly forested lands historically converted to agriculture. Such data would help areas that still may require active intervention to encourage tree seedling establishment (Rolph and Agee 1993).
- Data are needed to compare the effects of prescribed burning with those of mechanical harvest and thinning, in terms of multiple forest resources. This assessment could also include information on tree density and vigor that could be used to assess the need for mechanical thinning or other management of these very young stands. Although prescribed burning in conifer forests may have important benefits, including the possibility of bringing the fire regime closer to reference conditions in some regard, from a biodiversity perspective the benefits are arguable. Thinning of the canopy (manual thinning) may be more effective than under-burning for maintaining forest insect and disease populations at local normal levels. Both manual thinning and under-burning can increase species diversity and improve wildlife habitat by encouraging growth of herbs and shrubs, but also increase the risk of enhancing invasive species, ultimately diminishing native plant diversity.

- Pacific madrone stands are maintained by occurrence of frequent fires. The current state of regional decline of madrone could potentially be reversed by carefully planned mechanical treatments aimed at increasing resprouting behavior and preparing appropriate seedbeds. Further research is needed as a basis for such an approach.
- The extent to which forest invasions by non-native plants are altering forest understory composition and structure in the park needs closer examination and monitoring.

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4.5 Wildlife

Resource/ Indicator	Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Sensitive Wildlife:				
Birds	Somewhat Concerning	Medium	Unknown	N/A
Mammals	Somewhat Concerning	Low	Unknown	N/A
Amphibians & Reptiles	Unknown	N/A	Unknown	N/A

Terrestrial Invertebrates	Unknown	N/A	Unknown	N/A
Wildlife Associated with Prairie & Oak Woodlands	Significant Concern	Medium	Unknown	N/A
Invasive or Harmful Wildlife	Significant Concern	High	Unknown	N/A
Habitat Connectivity & Structure	Somewhat Concerning	High	Unknown	N/A

4.5.1 Background

As used herein, "wildlife" refers to terrestrial invertebrates as well as amphibians, birds, and mammals. The opportunity to observe wildlife in natural settings is an important reason many people visit parks. Moreover, wildlife species serve vital ecological roles, such as pollinators, nutrient cyclers, and seed transporters.

Archeological evidence attests to the presence not only of humans in this region as early as 10,000 years ago (Weiser and Lepofsky 2009), but also of a fauna that included many large mammals. Elk, wolves, and bears persisted in the San Juan Archipelago but were extirpated from the San Juan Islands most likely coincident with increased settlement of the islands in the late 1800s.

Based on information compiled from many sources, tables are available which denote (by major island) the presence or absence of all amphibian, bird, and mammal species in the San Juan Archipelago (Adamus 2011a, Appendix 4-A). That document also references those species to major habitat types (Adamus 2011a, Appendix 4-B).

4.5.2 Regional Context

Relative to its size, San Juan County contains a wide variety of habitats. Many areas within the county have by now mostly recovered from disturbances that occurred within the past 150 years, while others continue to be altered, and still others exist in relatively unaltered condition. The effect of this habitat variety and quality on the richness of species in the larger region is unquestionably positive. This is true despite the fact that, in contrast to many mainland parts of western Washington that are of similar size, the county's fauna overall is naturally less diverse. That happens for several reasons. The topography of the county spans less than 3000 feet of elevation, creating less climatic diversity than in many mainland counties, and that in turn constrains the diversity of plants and animals. Perhaps more significantly, the island environment limits the ability of many terrestrial species to colonize or recolonize from adjoining mainland. That same factor makes the decline of any species in the county potentially a greater concern

than a similar decline occurring in mainland counties, because recovery via immigration of new individuals from the mainland is likely to be slower or not occur at all.

Species that primarily inhabit extensive forests also may be absent, or are relatively vulnerable to extirpation, partly because historically forested areas in many parts of the county were fragmented by roads and urban and agricultural development, as well as by natural phenomena. Large mammals such as elk, gray wolf, cougar, and bison were perhaps among the first animals to disappear entirely from the county (probably before the 1900's), if they were present at all, and have never recovered. Species possibly present at one time but now apparently extirpated (absent) from the county include one native game bird (e.g., ruffed grouse), spotted frog, Pacific giant salamander, western pond turtle, and many plant species. A lack of credible and comprehensive faunal surveys, especially during the early years of island occupation by humans, makes it impossible to confirm the disappearance of many plants and animals formerly reported from the county or suspected to have occurred here based on the types of habitats they are known to associate with.

In a region where commercial timber harvest operations are widespread and many natural landscapes have been consumed by agriculture or development, the park preserves a naturally wide range of vegetation associations and successional stages. Anecdotal evidence suggests that San Juan County (not the park) is believed to support the largest or only populations or densities in the Puget Sound region, the Pacific Northwest, or the entire United States of at least the following species: black oystercatcher, vesper sparrow (Oregon subspecies, breeding), marbled murrelet (wintering). island marble butterfly, sharp-tailed snake. We cannot be certain that any of the wildlife species documented within the park are endemic (absent from the surrounding region), although that seems likely the case with the island marble butterfly. It is unknown whether any of the park's native wildlife species are at higher densities within the park than in any other parts of the Pacific Northwest. However, densities of several nesting songbird species appear to be greater than in other national parks in the North Cascades Network.

4.5.3 Issues Description

Among the factors most likely to be impacting the park's wildlife are the following:

- Altered fire regimes
- Contaminants and marine debris
- Infrastructure and human disturbance
- Habitat fragmentation

These are discussed briefly below.

4.5.3.1 Altered Fire Regimes

Although naturally-occurring fires were probably infrequent, decades of wildland fire suppression have affected the types of vegetation and thus the types of habitat available to wildlife (see section 4.4.3.1 for more details). Reduced fire frequency can result in less shrub cover (as trees grow taller and close out light and fewer fire-killed snags, which are necessary for many bats, woodpeckers, and other wildlife (Cahall and Hayes 2009). Fire suppression also facilitates the invasion of naturally-occurring oak woodlands by conifers, with subsequent change toward wildlife species that are more common throughout the Pacific Northwest than those the prefer oak woodlands.

4.5.3.2 Contaminants and Marine Debris

Effects of contaminants on the park's wildlife species have not been monitored. Contaminants such as mercury, flame retardants, and persistent pesticides, potentially transported to the park from mostly distant sources, are a potential concern. Reproductive success of seabirds and marine mammals can be affected by such contaminants, while bats, swallows, and other aerial foragers are likely to be at greatest risk from pesticides in nearby farmlands and gardens. Lost or abandoned fishing gear and other marine debris are a particular threat to seabirds. Since 2002, over 870 unattached gillnets have been removed from the Salish Sea; 505 (58%) of those were removed in the San Juan Islands, and 14% held dead seabirds (Good et al. 2009). This likely represents only a miniscule portion of the numbers of birds that succumb to those nets or by consuming small plastic fragments suspended with other food in marine waters. Common murre and rhinoceros auklet appeared to be particularly vulnerable.

4.5.3.3 Infrastructure and Human Disturbance

Some wildlife species, including many avian nest predators (common raven) are attracted to congregations of people such as at campgrounds, scenic pullouts, and picnic areas, with . resulting increases in nest predation. Also, the unconfined pets that inevitably accompany residential development near a park can dramatically increase predation on songbird and small mammal populations within the park. Some species, such as short-eared owl, appear to avoid areas that are inhabited by people persistently or which are otherwise subject to frequent visits by people, especially people with unleashed pets. The relative sensitivities of all Washington species to human presence and residential development have been categorized in a database by WDFW(2009).

4.5.3.4 Habitat Fragmentation

Habitat fragmentation frequently occurs when the home ranges, especially of forest-dwelling species, are interrupted by roads and other cleared areas. In such situations, individuals are often subjected to greater predation and nest parasitism. Feeding can be interrupted and genetic isolation of local populations may occur, thus lowering reproductive success. Roads and traffic result in more road-killed animals, and in extreme cases, noise associated with roads degrades reproductive success of some species. To some degree, wildlife corridors (usually, unaltered bands of natural vegetation that connect larger patches and so create "connectivity") can lessen fragmentation impacts on wildlife, as can management practices that leave relicts of the original vegetation structure within the cleared areas.

4.5.3.5 Climate Change

Populations of many wildlife species will be unable to adjust to global warming and its effects. The most vulnerable species are those for which the vegetation and physical habitat (e.g., availability of ponds and wetlands) immediately north of their current geographic range are insufficient to support present population levels. Considering the life history and habitat needs of all bird species and geographic distribution of habitat, scientists at the National Audubon Society identified 189 Washington bird species that are most vulnerable to climate change. Of those, the ones that occur regularly within the park number 46, or about 21% of the park's avifauna (**Table 12**).

Table 12. Bird species recorded regularly from the park which may be most vulnerable to climate change. Source: Audubon Washington, http://wa.audubon.org/climate-change .

American Wigeon	Rhinoceros Auklet
Mallard	Ring-billed Gull
Ring-necked Duck	California Gull
Greater Scaup	Western Gull
Lesser Scaup	Glaucous-winged Gull
Bufflehead	Band-tailed Pigeon
Common Goldeneye	Rufous Hummingbird
Hooded Merganser	Hairy Woodpecker
Common Merganser	Willow Flycatcher
Red-breasted Merganser	Pacific-slope Flycatcher
Common Loon	Common Raven
Horned Grebe	Tree Swallow
Red-necked Grebe	Violet-green Swallow
Western Grebe	Red-breasted Nuthatch
Double-crested Cormorant	Brown Creeper
Northern Harrier	Marsh Wren
Bald Eagle	Golden-crowned Kinglet
American Kestrel	Varied Thrush
Peregrine Falcon	Western Tanager
Black Oystercatcher	House Finch
Greater Yellowlegs	Purple Finch
Surfbird	Red Crossbill
Pigeon Guillemot	Pine Siskin

4.5.4 Data and Methods

Four indicators that might be used to monitor this issue (Wildlife) are:

1. Sensitive wildlife
2. Wildlife associated with prairie and oak woodlands
3. Invasive or harmful terrestrial wildlife
4. Habitat connectivity and structure

These are represented by the sections below, which in some instances contain subsections representing different taxonomic groups. For each indicator, we describe criteria we used to rate its condition and trend, and then describe what is known about its condition and trends within the park or nearby areas.

In the following pages the criteria used the evaluate condition and trends are discussed under each of these individually, along with the level of certainty associated with each estimate and a brief discussion of data gaps.

4.5.4.1 Sensitive Wildlife

Resources/Indicators Assessed

Birds
Mammals
Amphibians and Reptiles
Terrestrial Invertebrates

This section discusses animal species that may be sensitive on account of declining numbers within the park or surrounding areas, and/or due to particular aspects of their life history and behavior. The discussion is organized by major groups: birds, mammals, reptiles, amphibians, and terrestrial invertebrates. Background information is presented that characterizes the occurrence of sensitive species within the park as well as contribution of the park to the region's biodiversity, and then summarized in terms of current condition and trends within the park.

Criteria

To be meaningful, criteria for evaluating sensitive or rare species need to account for the natural range of variation in species colonization and extirpation, and for the expected annual fluctuations in population levels. However, data for estimating these are not generally available from the park or from analogous areas nearby. Further, there are no legally-based numeric criteria for evaluating the degree of "intactness" of any of the park's wildlife communities. No agency, institution, or scientific researcher has defined minimum viable population levels, desired productivity or species richness levels, or other biological criteria relevant to any wildlife species in this particular park. Therefore, the reference basis for this indicator is mainly the professional judgment of the author.

For purposes of this assessment, "Good" conditions are represented by sustained naturally-occurring turnover rates of species currently inhabiting a park. This could include intentionally re-establishing those species which were extirpated but have the potential to become re-established. More detailed goals might be to sustain multiple representatives of each functional group in proportions characteristic of intact but dynamic ecosystems and well-functioning complex food webs, as well as sustaining metapopulations and gene pool diversity. "Somewhat Concerning" and "Significant Concern" ratings would be assigned depending on the degree to which species turnover rates and/or terrestrial biodiversity are likely to affect adversely the rates of important ecosystem functions.

On the following pages, these criteria are applied successively to major components of the Reserve's fauna, each with its own section describing condition and trends: Birds, Mammals, Amphibians and Reptiles, and Terrestrial Invertebrates.

***Condition, Trends, and Level of Certainty:* Birds**

The certified park list, published in 2004, includes 172 bird species (114 listed as "Present in Park" and the rest as "Probably Present"). However, the actual number may be 218 if records published since the park list was certified in 2004 are included[10] while excluding 11 species

[10] We obtained the additional records by searching eBird (www.ebird.org, accessed December 15, 2014) for locations within both of the park's units and extracting those data. The data consist of non-systematic observations contributed by dozens of birders, mostly during the current decade. We also added species found by the NPS North

included in the NPS certified list as occurring in the park, but for which we could find no published records[11]. See **Table 17**. Species that have nested in the park number 74, or about one-third of the park's avifauna.

The 228 species in the park's two units combined represent 94% of the 241 bird species occurring on San Juan Island as indicated in the compilation for the Island in Adamus (2011a) plus addition of recent sightings. Despite the park comprising less than 5% of the land area of San Juan Island, there are only 18 species that have been recorded elsewhere on San Juan Island but never, to our knowledge, in the park itself. They are:

> brown pelican, American bittern, green heron, tundra swan, greater white-fronted goose, blue-winged teal, cinnamon teal, Eurasian wigeon, canvasback, Virginia rail, sora, sandhill crane, semipalmated sandpiper, solitary sandpiper, northern goshawk, western screech-owl, northern pygmy-owl, Say's phoebe

Of 218 species whose records could be traced specifically to either American Camp or English Camp, 187 (86%) have been recorded at American Camp and 114 (52%) from English Camp. The apparently richer avifauna at American Camp is likely due to its greater variety of habitats, longer shoreline, and more visitors (i.e., more people observing and reporting what they see). Species which, to our knowledge, have been reported only from English Camp are:

> wood duck, great horned owl, barred owl, common nighthawk, Townsend's solitaire, dusky flycatcher, American redstart

Those reported from American Camp but not English Camp are too numerous to list here.

We retrieved all eBird data from the park and compared maximum number of individuals of various species reported from the park with maxima for those species reported from the rest of San Juan Island. This is an imperfect comparison because effort and season and size of coverage area are not equivalent. However, such a comparison can highlight species for which the park *might* be serving as an important concentration area. Numbers reported for the following appear to be equal or greater at American Camp than reported from anywhere else on San Juan Island (counted only if number of reported individuals was >5):

> red-necked grebe, double-crested cormorant, Brandt's cormorant, surf scoter, red-breasted merganser, black oystercatcher, killdeer, black turnstone, sanderling, dunlin, black-bellied plover, California gull, glaucous-winged gull, Bonaparte's gull, common tern, ancient murrelet, marbled murrelet, pigeon guillemot, rhinoceros auklet, common murre, American kestrel, turkey vulture, cliff swallow, barn swallow, northern rough-winged swallow, violet-green swallow, marsh wren, bushtit, horned lark, Lapland longspur, American pipit, northern shrike, cedar waxwing, American/Northwestern crow, spotted

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Cascades Network systematic surveys (mainly landbirds) from 2006 through 2012, and species from a checklist for Cattle Point.

[11] greater white-fronted goose, cinnamon teal, blue-winged teal, canvasback, Swainson's hawk, Virginia rail, sora, buff-breasted sandpiper, long-tailed jaeger, western screech-owl, and Tennessee warbler.

towhee, Lincoln's sparrow, golden-crowned sparrow, pine siskin, American goldfinch, house finch, red-winged blackbird, brown-headed cowbird.

Numbers reported for the following appear to be equal or greater at English Camp than reported from anywhere else on the Island (counted only if number of reported individuals was >5):

bufflehead, osprey, American robin, house wren, Pacific-slope flycatcher, yellow-rumped warbler, brown creeper, varied thrush, Swainson's thrush, Townsend's warbler, black-throated gray warbler, European starling

Breeding-season surveys (mainly of songbirds) that are of greater methodical rigor have been conducted repeatedly at the same points in both park units in 2005, 2007, 2009, 2011, and 2013. In 2007 (Siegel et al. 2008), the most frequently detected species was American robin (110 detections), followed by American goldfinch (65 detections), savannah sparrow (54 detections), white-crowned sparrow (43 detections), and Pacific-slope flycatcher and Swainson's thrush (each with 42 detections). In 2010 (Holmgren et al. 2011), the most frequently detected species was American robin (61 detections), followed by Canada goose (56 detections), American goldfinch (56 detections), brown-headed cowbird (47 detections), and savannah sparrow (46 detections). In 2011 (Holmgren et al. 2013), the most frequently detected species was American robin (106 detections), followed by American goldfinch (85 detections), white-crowned sparrow (71 detections), savannah sparrow (60 detections), and brown-headed cowbird (59 detections). For each species found, **Table 17** shows the maximum count from the 5 years, the total number of points where detected, and the number of years detected.

Only one bird species that is regularly present in the park is listed federally as Threatened or Endangered. That is the marbled murrelet, which does not nest in the park (due to lack of old-growth forest which they require), but feeds regularly in marine waters adjoining both units of the park. Larger numbers (up to 100 individuals) occur in Griffin Bay adjoining American Camp than elsewhere in the park. Marine waters of the San Juan Archipelago contain perhaps the highest concentrations of this species in the Pacific Northwest. Although another species, the brown pelican, is federally listed as Endangered, it occurs only sporadically in the San Juans and has been observed in marine waters adjoining the park on very few occasions. Horned lark ("streaked" subspecies) is federally designated as a Candidate Species, and bred in the park's prairie habitat until the 1960s or 70s. It still occurs rarely during migration. Peregrine falcon and bald eagle were once federally listed as Threatened. Both occur regularly in the park, but only the eagle is known to nest in the park. The San Juan Islands support the highest nesting densities of these species in the Pacific Northwest (at least 122 bald eagle nesting territories and 20 peregrine falcon territories (see: http://www.frg.org/SJI_project.htm). Continental populations in recent years have recovered to the point where these species are no longer federally listed.

The WDFW maintains a list of "Priority Species and Habitats." That list includes species having no extraordinary legal protection but considered to deserve some level of elevated conservation or management due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance in Washington State. Species in the park that are designated as "Sensitive" on this list are peregrine falcon and bald eagle. Species in the park that WDFW considers to be Candidates for this list, due to preliminary evidence of declining breeding or wintering numbers in Washington, are western grebe, Brandt's cormorant, common murre, tufted puffin, golden eagle, pileated woodpecker, purple martin, Vaux's swift, and vesper sparrow.

Exceptional concentrations of about 1000 Brandt's cormorant and common murre have been reported from American Camp. The WDFW also has priority designations for:

(a) Cavity-nesting waterfowl. In this park those include wood duck, hooded merganser, common goldeneye, and Barrow's goldeneye—although none have been reported nesting in the park.

(b) Concentration areas for alcids (a group of seabirds). In this park, those that have been reported in noteworthy concentrations, with maximum reported numbers, are ancient murrelet (200), marbled murrelet (100), rhinoceros auklet (100), and pigeon guillemot (40)

(c) Concentration areas for loons and grebes. In this park, those that have been reported in noteworthy concentrations, with maximum reported numbers, are Pacific loon (250), horned grebe (80), red-necked grebe (60), and western grebe (15).

(d) Concentration areas for waterfowl. In this park, those that have been reported in noteworthy concentrations are surf scoter (700), bufflehead (353), red-breasted merganser (100), white-winged scoter (60), and harlequin duck (25).

(e) Concentration areas for shorebirds. In this park, those that have been reported in noteworthy concentrations are dunlin (100) and black turnstone (20). Although never present in large numbers, black oystercatcher feeds along the park's shoreline. Maximum count was 28 at American Camp. It is of interest because globally its population is believed to number only about 11,000 individuals, of which perhaps 210 pairs nest along shorelines of the Salish Sea (Golumbia et al. 2009).

(f) Heron rookeries. In this park, a heron rookery was reported in the vicinity of English Camp in 1992 (PHS data from WDFW).

The Audubon Society of Washington has designated two of the park's bird species as being of "Immediate Concern" because of declining statewide populations: olive-sided flycatcher and vesper sparrow.

Cassidy and Grue (2006) analyzed wildlife information statewide for the purpose of recommending additional species in each county that might not meet WDFW criteria for Priority Species status, but which land managers might wish to take additional steps to protect due to their sensitivity to development and important contribution to regional biodiversity. Those known to occur in the park, although not nesting in all cases, are:

Cooper's hawk, golden eagle, barn owl, short-eared owl, northern saw-whet owl, common nighthawk, Vaux's swift, rufous hummingbird, red-breasted sapsucker, hairy woodpecker, olive-sided flycatcher, willow flycatcher, purple martin, tree swallow, brown creeper, Swainson's thrush, varied thrush, yellow warbler, chipping sparrow, vesper sparrow, western meadowlark, red crossbill.

In addition, six *forest-associated* species that breed regularly on adjoining mainlands seldom if ever nest in apparently similar habitat in the park: ruffed grouse, sooty grouse, western screech-owl, red-breasted sapsucker, Hammond's flycatcher, and Vaux's swift.

A large variety of bird species depend on Salish Sea food webs (Gaydos and Pearson 2011). Salmon and other predatory fish that some seabirds feed upon have higher levels in Puget Sound than on the outer coast of Washington (Good et al. 2014). However, populations of some forage fish species that are important foods for seabirds as well as salmon are declining in Puget Sound (Greene et al. 2015). Simultaneous declines have occurred in the Salish Sea's seabird populations and/or those in Puget Sound, from 1975 to the present. Some 14 of 37 species studied showed significant declines during that period, and declines of 11 of those species exceeded 50% (Bower 2009). A somewhat more intensive data analysis was conducted by Vilchis et al. (2014) using annual aerial surveys and Christmas Bird Count data for the period 1994 to 2010. Results of these trend studies of the Salish Sea region are summarized in **Table 13**. Seabird trends data are also available for the Strait of Georgia in nearby parts of British Columbia (Crewe et al. 2012) but are not included here.

Table 13. Trends in regional seabird species as reported by two studies.

Only trends for species that occur within the park or nearby waters are shown (trends were calculated for the entire region). Only trends that were statistically significant are shown. Parentheses as applied to the Vilchis et al. study indicate that the trend differed depending on location within the Salish Sea.

Species	Vilchis et al. 2014	Bower 2009
Brant	increase	
Canada Goose	increase	increase
American Wigeon	increase	
Mallard	increase	
Northern Pintail	increase	
Green-winged Teal	increase	
Scaup (Greater + Lesser)	DECREASE	DECREASE
Black Scoter		DECREASE
SCOTERS (3 spp.)	DECREASE	
Common Goldeneye		DECREASE
Ruddy Duck	DECREASE	DECREASE
MERGANSERS	increase	
Black Oystercatcher	increase	
Dunlin	increase	
Black Turnstone	increase	
Red-throated Loon	DECREASE	DECREASE
Pacific Loon	DECREASE	
Common Loon	DECREASE	increase
LOONS	DECREASE	
Horned Grebe	DECREASE	DECREASE
Red-necked Grebe	(increase)	
Western Grebe	DECREASE	DECREASE
GREBES	(DECREASE)	
Brandt's Cormorant	increase	
Pelagic Cormorant		increase

Double-crested Cormorant	increase	increase
Common Murre	DECREASE	DECREASE
Pigeon Guillemot	increase	increase
Marbled Murrelet	(DECREASE)	DECREASE
Rhinoceros Auklet	DECREASE	
ALCIDS	(DECREASE)	
Bonaparte's Gull	DECREASE	DECREASE
Mew Gull	increase	
Glaucous-winged Gull	increase	DECREASE
GULLS	(increase)	
Bald Eagle	increase	increase

Causes of the regional seabird declines are unknown and cannot be explained solely from interannual climate cycles, e.g., El Niño. Suspected contributors to the declines (or shifts in geographic range) include entrapment in derelict fishing gear, oil spills, contaminants, long-term climate change, commercial fishing techniques, habitat loss both locally and in other parts of these species' ranges (Gaydos and Pearson 2011). For many of the region's wintering alcids and grebes, the more recent and comprehensive analysis of Vilchis et al. (2014) has implicated changes in the availability of low-trophic prey such as forage fish as the major driver of the decline.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Somewhat Concerning (seabirds)	Medium	Unknown	N/A

A better rating is not assigned because several bird species that historically were present have been extirpated, and several of the park's species are experiencing declines regionally and perhaps within the park. Declines are due partly to changing conditions outside of the park. Certainty is rated Medium rather than Low because there are more data available for birds than for other wildlife group.

Data Gaps: Birds

- No systematic data have been collected over the long term from within the park that would allow valid calculation of trends for any of the park's bird species. This is particularly true of marine birds and nocturnal owls.
- For nearly all species, data on reproductive success have not been collected within the park. Such data are required to assess trends and help define minimum viable population levels.

- Relative sensitivities of different bird species to disturbance from traffic and recreationists have not been determined within the park.

Condition, Trends, and Level of Certainty: Mammals

The certified park list, compiled in 2004, includes 20 terrestrial mammal species (12 listed as "Present in Park" and 8 as "Probably Present"). Based on reports compiled by Adamus (2011a), 3 other terrestrial mammals are known from San Juan Island (northern flying squirrel, muskrat, black rat, and perhaps Townsend's chipmunk, house mouse, and Norway rat) but their current status in the park is unknown. Thus, the park supports 71-80% of the terrestrial mammal fauna of San Juan Island. Beaver were once present on San Juan Island but there are no recent records, though they are present on some nearby islands.

Populations of deer and other herbivores have apparently prospered in the park and throughout San Juan Island, largely as a result of the elimination of large predators (other than humans) from the county during early settlement, and the reverting of prairie to intermediate successional stages in the absence of fire (Chamberlain et al. 2007). The increased grazing and browsing has locally reduced the cover of low vegetation and perhaps the diversity of native forbs, with likely consequences for butterflies, other insects, and birds that depend on them (Bassett-Touchell 2008, Martin et al. 2010). Overbrowsing of native shrubs often facilitates invasion by non-native shrubs such as Himalayan blackberry. Damage to native ecosystems from abnormally high deer density has been documented elsewhere in the San Juans (Martin et al. 2010) and on an island in British Columbia (Allombert et al. 2005). Such damage to shrubs and ground cover occurs in places where fragmentation of forests by scattered residential development or agriculture has created deer densities of more than about 1 per 25 acres (Thiemann et al. 2009, Martin et al. 2010).

In the certified mammal list prepared in 2004, 3 species of bats are listed as "Present in the Park" and 6 are listed as "Probably Present." The confirmed species were based on an inventory conducted in 2004, mostly at English Camp (Christophersen 2006). More than 1700 Yuma myotis and big brown bat were counted exiting the Crook House. Roosting concentrations of these species are listed by the WDFW as a Priority Species/Habitat. Because allowing the bats to inhabit the house did not coincide with the preservation and stabilization objectives for this historic building, park staff relocated the colony into artificial bat boxes. A total of approximately 514 Yuma myotis were observed exiting a bat box in 2006, an increase from the 136 bats observed exiting the box in a 2005 inventory. Two bat species whose occurrence in the park has not been confirmed but which are listed as "Probably Present" are considered by the WDFW to be Candidate species for listing as Priority Species. They are Townsend's big-eared bat and Keen's long-eared bat (formerly Keen's myotis).

In addition to terrestrial mammals, at least 7 marine mammals occur regularly in waters near the park: killer whale (resident orca), gray whale, humpback whale, Dall's porpoise, harbor porpoise, Steller's sea lion, and harbor seal. The southern resident **killer whale** is federally listed as Endangered. San Juan County shoreline includes parts of three areas designated as Critical Habitat: the Summer Core Area in Haro Strait and waters around the San Juan Islands; Puget Sound; and the Strait of Juan de Fuca. However, areas with water less than 20 feet deep relative to the extreme high water mark are not included in the Critical Habitat designation. The southern resident killer whale population declined almost 20 percent from 1996 to 2001, but has increased

since then, with 79 whales in the population as of July 2013 (Center for Whale Research: http://www.whaleresearch.com/#!orca-population/cto2). The high frequency of occurrences in San Juan County waters when salmon and other fish species are present suggests that the County is an important habitat and feeding ground for the species (Cullon 2009). **Steller sea lion** was federally listed as Threatened in 1990. Critical Habitat was designated in 1999, but all of it lies outside Washington State. Nonetheless, the WDFW continues to designate it as Threatened. In the fall, winter, and spring months an estimated 800 to 1,000 individuals move through the Strait of Juan de Fuca and Strait of Georgia to feed on Pacific hake and dense stocks of herring that spawn in British Columbia (PSAT 2007). The Eastern North Pacific population of **gray whale** was delisted from federal Endangered status in 1994 but is still considered "Sensitive" by the WDFW. The species is increasingly sighted as individuals pass through San Juan County marine waters during their migration between feeding grounds in Alaska and breeding grounds in Mexico. **Pacific harbor porpoise** is listed by the WDFW as a candidate for state listing, pending acquisition of data clarifying its status and trends. after being extirpated from Washington state, the **sea otter** was re-introduced in 1969 and numbers have increased along the Olympic Peninsula coastline and in the western Strait of Juan de Fuca. Small numbers have been sighted elsewhere in the San Juan Archipelago, and there is at least one credible report from Cattle Point (Lance et al. 2004).

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Unknown	N/A	Unknown	N/A

Although some information is available on mammal species presence in the park, a better rating is not assigned because no recent inventories of mammal species in either unit of the park have been published.

Data Gaps: Mammals

- No inventories of mammal species in either unit of the park have been published.
- With the possible exception of European rabbit, no systematic data have been collected over the long term from within the park that would allow valid calculation of trends for any of the park's mammal species. Monitoring of deer population levels and effects of deer grazing on other resources is particularly needed.
- For nearly all mammal species, data on reproductive success and travel corridors have not been collected within the park. Such data are required to assess trends and help define minimum viable population levels.
- Relative sensitivities of different mammal species to disturbance from traffic and recreationists have not been determined within the park.
- The relative contribution of the park's shoreline, as compared to other nearby shorelines, to populations of marine mammals in the Salish Sea has not been measured.

Condition, Trends, and Level of Certainty: Amphibians and Reptiles

The certified park list, compiled in 2004, contains 3 amphibian species (red-legged frog and Pacific chorus frog which are listed as “Present in Park” and western (boreal) toad listed as “Probably Present”). A survey at American Camp by Nordquist (1975) documented its presence there. The toad is federally listed as a Species of Concern as well as a Candidate for state listing as a Priority Species, due to well-documented declines throughout much of the Pacific Northwest. At least 2 other amphibians have been found on San Juan Island but not, to our knowledge, in the park: American bullfrog and rough-skinned newt. Less certain, long-toed and northwestern salamanders may be present at a few locations on San Juan Island and perhaps the park.

For reptiles, the certified park list contains 3 species: Northwestern garter snake, common garter snake, and northern alligator lizard. The compilation by Adamus (2011a) lists 4 others that have been reported from San Juan Island but not, to our knowledge, in the park: Western fence lizard, western painted turtle, rubber boa, and possibly western terrestrial garter snake. In addition, sharptail snake has been found on nearby Orcas Island (O’Donnell and McCutchen 2008) and is federally listed as a Species of Concern as well as a Candidate for state listing as a Priority Species.

Condition, Trends, and Level of Certainty: Amphibians and Reptiles

Both condition and trends are categorized as Unknown due to lack of systematic surveys in the park, with the exception of a limited and unpublished one conducted in 2002.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Unknown	N/A	Unknown	N/A

Data Gaps: Amphibians and Reptiles

- No recent inventories of amphibian or reptile species in either unit of the park have been published. In particular, data are needed on the current status of sharp-tailed snake (most likely to occur in Mitchell Hill area) and western toad, due to their conservation listings.
- No systematic data have been collected over the long term from within the park that would allow valid calculation of trends for any of the park’s amphibian or reptile species.
- Data on reproductive success and dispersal corridors have not been collected within the park. Such data are required to assess trends and help define minimum viable population levels.
- Effects of prairie and oak woodland habitat restoration (generally, and specific practices such as burning and vegetation thinning) on amphibians and reptiles have not been monitored within the park.
- The relative contribution of the park to populations of various amphibian and reptile species on San Juan Island has not been measured.

Condition, Trends, and Level of Certainty: Terrestrial Invertebrates

No systematic, park-wide inventories of terrestrial invertebrates have been conducted, but the number of species likely numbers in the hundreds. A butterfly inventory conducted in 2003 found 25 butterfly and 4 moth species. Some information on butterflies and moths in the San Juan Archipelago generally is documented in Hinchliff (1996). Federal agencies have designated the Island marble (see section 4.5.4.2 below) and Valley silverspot as Species of Concern. For San Juan County, WDFW has additionally categorized the Taylor's checkerspot as Endangered (see section 4.5.4.2 below), and the valley silverspot, great Arctic, and sand-verbena moth as Candidates for listing. The rare purplish copper (*Lycaena helloides*) and Propertius' duskywing (*Erynnis propertius*) are also tracked by WDFW. The former has been observed in both park units and the latter at English Camp (WDFW Priority Habitats and Species database).

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Unknown	N/A	Unknown	N/A

Data Gaps

- There have been no comprehensive published inventories of butterflies or other terrestrial invertebrates in the park.
- The relative contribution of the park to populations of various pollinating species on San Juan Island has not been measured.

4.5.4.2 Wildlife Associated with Prairie and Oak Woodlands

This section discusses wildlife species that are associated with coastal prairies and/or oak woodlands of San Juan Island. The discussion is organized by major groups: birds, other terrestrial vertebrates (mammals, reptiles, amphibians), and terrestrial invertebrates. Background information that characterizes the status of prairie/oak associated species is presented, and then summarized where possible in terms of current condition and trends within the park. Extensive information characterizing the *vegetation* of prairie and oak woodlands is provided elsewhere in this document (in section 4.4.4.1).

Criteria

To be meaningful, criteria for evaluating these species need to account for the natural range of variation in species colonization and extirpation, and for the expected annual fluctuations in population levels. However, data for estimating these are not generally available from the park or from analogous areas nearby. Further, there are no legally-based numeric criteria for evaluating the degree of "intactness" of any of the park's wildlife communities. No agency, institution, or scientific researcher has defined minimum viable population levels, desired productivity or species richness levels, or other biological criteria relevant to any wildlife species in this particular park. Therefore, the reference basis for this indicator is mainly the professional judgment of the author.

For purposes of this assessment, "Good" conditions are represented by sustained naturally-occurring turnover rates of species currently inhabiting a park. This could include intentionally re-establishing those species which were extirpated but have the potential to become re-

established. More detailed goals might be to sustain multiple representatives of each functional group in proportions characteristic of intact but dynamic ecosystems and well-functioning complex food webs, as well as sustaining metapopulations and gene pool diversity. “Somewhat Concerning” and “Significant Concern” ratings would be assigned depending on the degree to which species turnover rates and/or terrestrial biodiversity are likely to affect adversely the rates of important ecosystem functions.

Condition, Trends, and Level of Certainty

Among 49 bird species that associate highly with prairie-oak habitat in the Pacific Northwest, a significantly large number (21) have experienced extirpations, range contractions, or regional declines (Altman 2011). Of the approximately 112 bird species known to have nested in San Juan County, including those not known to nest in the park, 13 are known to be associated with prairie-oak habitat in an obligate or near-obligate manner for nesting, and at least another 19 nest regularly in such habitat but are not obligates (assignments are based on Altman 2011). However, these totals include 8 species that apparently no longer nest in the county: sandhill crane, northern harrier, burrowing owl, Lewis’ woodpecker, western kingbird, Say’s phoebe, horned lark, western meadowlark, and one species (western bluebird) that was extirpated from the San Juans in 1964 but has recently been re-introduced in the park. For Lewis’s woodpecker, extirpation from the San Juans occurred in the 1950s and 1960s, for horned lark in the 1960s or 1970s, for western meadowlark in the 1980s, and for northern harrier in the early 1990s (Altman 2011). In addition, the *current* nesting status of the following prairie or oak-associated species is uncertain in the park: Cooper’s hawk, common nighthawk, western screech-owl, killdeer, American kestrel, California quail, Anna’s hummingbird, downy woodpecker, western wood-pewee, bushtit, Cassin’s vireo, and Hutton’s vireo.

Many butterflies are strongly associated with prairie habitat. Two that are of particular conservation concern occur, or potentially occur, in the park. They are Taylor’s checkerspot (*Euphydryas editha taylori*) and island marble (*Euchloe ausonides insulanus*). **Taylor’s checkerspot** is a subspecies of Edith's checkerspot, a medium-sized butterfly, and is in imminent danger of going extinct. Since 2001 it has been designated as a Candidate for federal listing under the Endangered Species Act, and the WDFW lists it as a Species of Concern. Only 14 populations are known, all in Washington and Oregon, with almost three-quarters of the known population at only two sites, one of these in San Juan County on private land; its current status there is unknown. The species could potentially occur in grasslands within the park (e.g., American Camp) but has not been reliably documented. Use of specific locations can vary from year to year, a population show large natural fluctuations between years. Preferred habitat is various types of unmowed grasslands and rocky outcrops (even some forested ones), especially those with a dominance of native grasses and located near shorelines. It is a relatively sedentary species which remains year-round and rarely disperses more than 2 miles. Golden paintbrush (*Castilleja levisecta* , a federally-listed Threatened plant species known from only three locations on San Juan Island) is likely to be one of the few plants that serve as a larval food plant for (Dunwiddie et al., *in prep.*), another being harsh paintbrush (*Castilleja hispida*). Some populations in other parts of its range appear to be dependent on the non-native English plantain (*Plantago lanceolata*), a weedy introduced species.

Before its rediscovery on San Juan Island in 1998, the **Island marble** had been believed extinct for 90 years (Jordan et al. 2012), and the San Juan population is the only viable one known. It is

a distinctive subspecies of the Large Marble butterfly which generally occurs east of the Cascade Range in Washington and British Columbia. Coastal shoreline and adjacent prairie on San Juan Island are vital habitat for the species. In 2006, 72 known or potential sites in the county were surveyed, and the island marble was found at 16 sites, most in one of three areas; the southwest coast of San Juan Island (American Camp), the San Juan Valley on San Juan Island, and the central valley of Lopez Island. Host plants include tumble mustard (*Sisymbrium altissimum*), field mustard (*Brassica campestris*), and Puget Sound peppergrass (*Lepidium virginicum menziesii*), all of which occur in the park (Pyle 2004, Lambert 2006). Puget Sound peppergrass grows above mean high tide among driftwood along the American Camp shoreline. Tumble mustard and field mustard are invasive species which utilize a range of habitats, including grasslands. In addition to its larval food plants, the island marble depends on at least 10 different plants for nectar (Pyle 2004).

The gradual shrinkage of the park's prairie and oak woodlands due largely to prolonged fire suppression, the degradation of vegetation cover and structure within prairie as a result of introduced rabbits (see next section), has likely reduced the diversity of native birds and butterflies associated with prairie and oak habitat. However, recent trends of most species are unmonitored.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Significant Concern	Medium	Unknown	N/A

The condition of wildlife associated with prairie and oak woodlands is rated Significant Concern due to disappearance from the park of several characteristic species during the last 50 years. Recent trends within the park are not known for any species associated with these habitats.

Data Gaps

- Trends in butterflies and other insects, especially those which may be crucial to the pollination of prairie and oak woodland plants, are unknown.
- Both immediate and long-term effects of prairie and oak woodland habitat restoration (generally, and specific practices such as burning and vegetation thinning) on butterflies and other terrestrial invertebrates have not been monitored within the park.

4.5.4.3 Invasive or Harmful Wildlife

The wildlife species that has generated the most controversy in this park is the non-native European rabbit (*Oryctolagus cuniculus*). That is discussed below, followed by descriptions of other terrestrial wildlife in the park that are non-native and/or are could be inflicting significant harm to populations of other native wildlife within the park.

Criteria

For purposes of this assessment, "Good" conditions would be a low level of invasion by non-native animal species and no detectable adverse impacts, from any that are present, on the extent, distribution, or functions of native ecosystems within the park. "Somewhat Concerning" and

"Significant Concern" would represent increasingly greater problems with those species based on their extent within the park and their observed effects on extent, distribution, and function of native ecosystems.

Condition, Trends, and Level of Certainty

The European rabbit was first documented on San Juan Island in 1929, and is thought to have been introduced between 1875 and 1895 as a food source for settlers (Couch 1929; Stevens 1975). By the late 1920s and early 1930s, the rabbit population had increased dramatically on the Island, and especially within the American Camp unit of the park. Population expansion has resulted from the species' intrinsically high reproductive potential, combined with favorable climate, relatively few predators within the park, and preferred prairie habitat with succulent vegetation and well-drained soils (Hall 1977, West and Agee 2009). Population size has been monitored since the early 1970s, and has fluctuated over that time (**Figure 30**). A population low occurred in the early 1980's (Taber 1982). The population is currently at a moderate to low level compared to most of the past years. In some years, rabbits have inhabited over 1000 acres of the prairie at American Camp and adjoining areas.

Within its home range, a rabbit will eat almost any available vegetation (Stevens, 1975). In some years, they may consume up to 75% of the available spring production of above-ground biomass (Stevens 1975). Because the native plant species are less adapted to grazing than many of the introduced species, rabbit herbivory tends to favor the non-natives, which gradually changes the composition of the prairie. In addition, over-grazing may result in exposed soil, a likely place for the establishment of invasive plants. As rabbits colonize an area, they create shelter by digging warrens, which are "complex underground burrow systems" (Stevens 1975). Numerous large, well-developed warrens exist at American Camp. The digging and excessive use churns and compacts the soil. This reduces water infiltration of the soil and runoff is increased with soil compaction. It also disrupts the texture of the surface soil by bringing subsurface soil and gravel to the surface. Bare soil is quickly colonized by invasive plants such as Himalayan blackberry, Canada thistle, and bullthistle. The core rabbit colony area at American Camp is virtually devoid of grassland nesting birds and small mammals due to a lack of native vegetation and cover. Prairie restoration is the park's top natural resources goal, but that is thwarted by the activities of rabbits. Rodents are the primary diet for grassland raptors such as northern harrier, short-eared owl, and barn owl—species that seem to occur less frequently now than historically within the American Camp prairie. Thus, population fluctuations of rabbits have cascading effects throughout the American Camp prairie (Lees and Bell 2008).

European rabbits at American Camp are sometimes preyed upon by a small population of red fox (*Vulpes vulpes*), a species not native to the San Juans which was introduced in the late 1940s to help control the rabbits (Schoen 1972). The effect on rabbit populations has been minimal, and additionally the fox has increased predation on native small mammals, grassland birds, and invertebrates—further impacting those communities especially during periods of low rabbit abundance.

Efforts to control rabbits by the park have included construction of a rabbit-proof barrier fence in 2003 along the western boundary of American Camp adjacent to the Eagle Cove subdivision to prevent colonization into the park. In 2004, two north-south barrier fences were erected west of the Grandma's Cove trail to prevent rabbits from colonizing the western portion

of the prairie from the main rabbit colony area. In 2005, the park constructed a north-south barrier fence through the center of the core rabbit colony area, with the eventual goal of dividing that area into smaller management zones. The rabbit-proof fence along the western boundary and the two fence sections west of Grandma's Cove trail appear to be effective at preventing rabbit colonization of the western portion of the prairie.

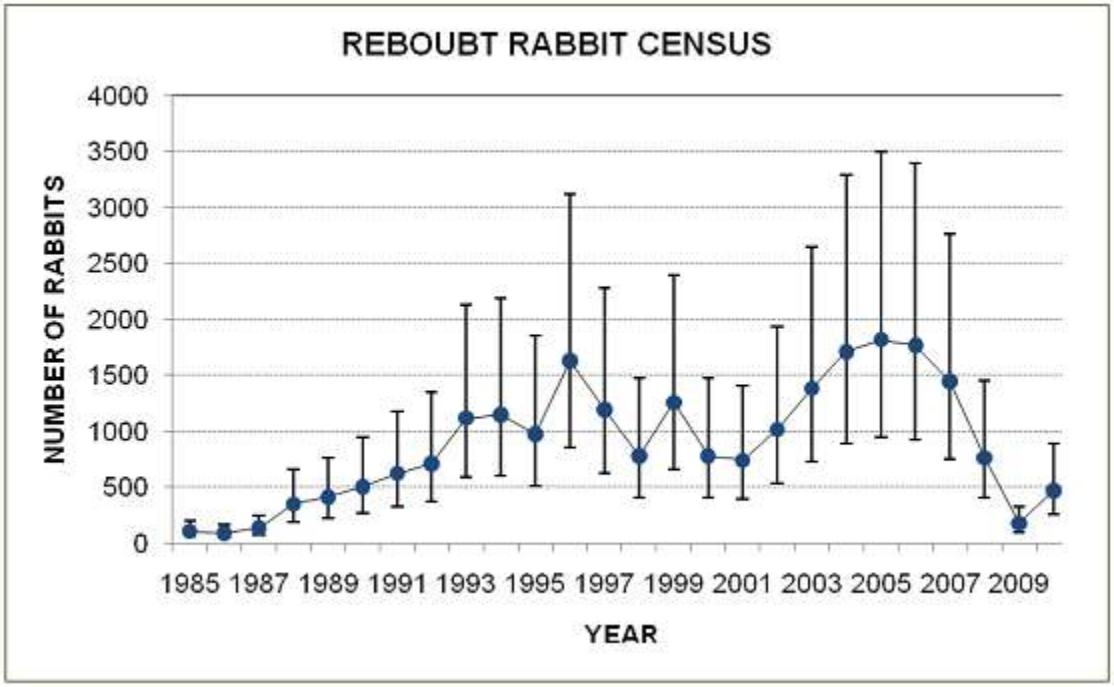

Figure 30. European rabbit population estimate at American Camp from 1985-2010 with 95% confidence intervals.

From West 2010.

Other non-native mammals that are known or likely to be present within the park include black rat and feral house cat. Their population levels and effects on the park's native species are unknown. Impacts to native fauna are most likely to occur where there are dwellings in or just outside of the park boundary. Norway rat and house mouse were documented on San Juan Island in 1928 but a small mammal survey covering a limited area in 1974 found none (Nordquist 1975). An amphibian that is not native to the Pacific Northwest, the American bullfrog, was introduced to San Juan County at some unknown time and has now become established on all the major islands. A countywide wetlands survey in 2010 (which was not focused specifically on amphibians) detected it in 13 of 103 wetlands (Adamus 2011b).

Although native to North America, brown-headed cowbird parasitizes the nests of many other bird species and can have major impacts on their populations. Survey data indicate they are increasing within the park, with causes undetermined (Siegel et al. 2009, Wilkerson et al. 2010, Holmgren et al. 2012). They tend to be more common where forests have been fragmented by small residential developments or agriculture.

A non-native whose North American range is currently expanding faster than that any other bird species is the Eurasian collared dove. It arrived in the Pacific Northwest about a decade ago, spreading from the south and east. Numbers on San Juan Island and in the park have increased noticeably since about 2010. Impacts on the native mourning dove or other species are undetermined. Other birds not native to the Pacific Northwest that occur regularly in parts of the park are European starling, house sparrow, rock pigeon, California quail, wild turkey, and ring-necked pheasant. Eurasian skylark was introduced to Vancouver Island around 1902 and was first seen on San Juan Island in 1960, eventually becoming a "locally common breeding resident" in the prairie at American Camp (Lewis and Sharpe 1987). Because this was the only place in the U.S. where it could be found, for years many birders visited the park just to see it. However, the population declined and the last confirmed sighting may have been in 1999.

Condition, Trends, and Level of Certainty

The severe disruption of native ecosystems caused by at least one park invader—European rabbit—is well documented. Other species that are most likely to be having adverse effects within the park include feral cat (predation on ground-nesting and migrant birds), European starling (displace native cavity-nesting birds from nest sites) and brown-headed cowbird (parasitizes nests of many songbirds). Aside from European rabbit, nearly nothing is known about the trends of non-native wildlife in the park.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Significant Concern	Medium	Unknown	N/A

Data Gaps

- No published data were found that involved comprehensive censuses of the park's rabbit population in recent years.
- No surveys of feral cats have been conducted in the park despite their likely effect on bird and small mammal populations.

4.5.4.4 Habitat Connectivity and Structure

A paradigm of conservation biology is that islands tend to support fewer wildlife species compared to mainland areas. Water—especially wide stretches of water with cold swift marine currents—potentially poses a formidable barrier to animals attempting to colonize islands from nearby larger mainland areas. Even birds (songbirds at least) are reticent to cross, on a daily basis, wide expanses lacking in cover. Owing partly to this effect, San Juan Island, situated more than 20 miles west of mainland Washington and 15 miles east of the much larger Vancouver Island, hosts noticeably fewer mammal species (Schoen 1972, Weisbrod 1979). Several birds and mammals that are common on adjoining mainland and Vancouver Island are absent from San Juan Island despite an abundance of apparently suitable habitat, e.g., black-capped chickadee, Steller's jay, ruffed grouse, sooty grouse, Douglas squirrel, beaver. The slightly depauperate fauna of San Juan Island is likely attributable as well to its small size, which (other factors being equal) would result in less variety of habitats.

Marine waters are not the only feature that can inhibit species dispersal. Even within an island, movements of some individual mammals and birds can be hindered by wide expanses of land that contains little or no vegetative cover, due either to natural factors or artificial removal of forest canopy as associated with residential development and road-building. Good connectivity of habitat patches having complex vegetation structure is important for sustaining populations of many species. At a landscape scale, an important ecological goal is to sustain corridors or stepping-stones of relatively unaltered habitat. One study found that connectivity of natural habitat was a better predictor of bird movements than was proportion of an area comprised of natural habitat (Tremblay & St. Clair 2011). Corridors of perennial vegetation facilitate required movements of many mammals, birds, and especially amphibians (Machtans et al. 1996). In contrast, linear clearings wider than 30 - 45 m will alter food-searching movements of several forest-dwelling bird species (Belisle & Desrochers 2002, Tremblay & St. Clair 2009, 2011). Reconnecting habitat patches with corridors of vegetation amplifies biodiversity conservation both within and beyond areas already set aside as natural preserves (e.g., Damschen et al. 2006). The WDFW (2008) recognizes "Biodiversity Areas and Corridors" as a Priority Habitat and suggests jurisdictions consider using systematic approaches for identifying and protecting them. However, "habitat fragmentation" is species-specific and difficult to recognize. Landscapes that are too fragmented for one species are ideal for another. Habitat patches that are too small or narrow for one species are optimal for others. "Corridors" and "landscape connectivity" that facilitate movements of some species sometimes facilitate movements of their predators or competitors as well (e.g., Rogers et al. 1997, Novotny 2003, Sinclair et al. 2005).

A survey in 2007 of the San Juan County shoreline reported an average 25 percent loss of marine riparian forest cover between 1977 and 2006 (MacLennan and Johannessen 2008). Such loss and resulting fragmentation is likely to have adversely altered the movements of some forest-associated bird and mammal species. However, at least within the American Camp unit, the forest canopy has been increasing as result of fire suppression and natural succession, and in the process, it may be causing prairie habitat to become more isolated from other patches of grassland on San Juan Island. The effects of forest regrowth on connecting or isolating populations of animals are likely to be magnified on account of the American Camp unit comprising most of a peninsula surrounded on three sides by water.

Criteria

Meaningful criteria for evaluating habitat connectivity need to account for the natural range of variation in species colonization and extirpation, and for the expected annual fluctuations in population levels. For purposes of this assessment, "Good" conditions would be represented by unbroken connectivity of natural vegetation (not necessarily forest) on all terrestrial sides of each park unit. "Somewhat Concerning" would represent a measurable loss of corridors that connect habitat suitable for locally rare or sensitive wildlife species. "Significant Concern" conditions would represent widespread and irreversible losses of those corridors as a result of roads, buildings, and other newly unvegetated surfaces. The reference condition is imagined to be the landscape within and around the park as it may have existed in the early 1800s just prior to rapid settlement by Euro-Americans.

Condition, Trends, and Level of Certainty

At American Camp, wooded habitat both within and immediately outside the park is unfragmented by land uses, but the expanding woodlands threaten to separate the park's prairie habitat from grasslands outside the park. A narrow road runs the length of the American Camp unit but traffic is relatively light and speeds are fairly slow. Nearly all land adjoining the unit's east end is managed for conservation by the Washington Department of Natural Resources and the San Juan County Land Bank. Beyond that, in the Cattle Point settlement, subdivisions contain about 150 lots and a few undeveloped lots remain. At the unit's west end, the Eagle Cove settlement contains about 43 lots with an average size of one acre, and about half have been developed. At the park's northwest corner there are narrow wooded corridors, part owned by the San Juan County Land Bank, that connect the park's woodland to a patchwork of other woodlands totaling about 500 acres, until a gap of 1000 m width is reached about 1.7 miles northwest of the park boundary.

At English Camp, the eastern boundary is contiguous to a block of basically unfragmented forest at least 8 square miles in extent. Within the unit, 25-ft wide West Valley Road bisects the unit and creates the only linear opening of significant extent in the forest canopy. An ecologically important feature of the English Camp unit is its oak woodland. The closest large patch of oak woodland outside the park is about 1.3 miles to the southeast. Nearly all the connecting land is forest.

San Juan County is the only county in the state that has passed a real estate excise tax for purchasing and setting aside significant amounts of land for permanent protection from intensive development. County-owned parks and land bank programs and the San Juan Preservation Trust have together protected over 9% of the county's area primarily for conservation, and an additional 10% of the county's area is within San Juan Island National Historical Park or owned by other Federal or State agencies or private conservation groups.

Condition in the Park	Certainty of Condition	Trend in the Park	Certainty of Trend
Somewhat Concerning	Medium	Unknown	N/A

A rating of Somewhat Concerning is assigned because, while connectivity of the park's forests with forests outside the park is generally good, the connectivity of prairie is poor. Recent trends are not being measured.

Data Gaps

- No studies have determined if the matrix of land cover types surrounding the park significantly restricts movements of amphibians or any other wildlife group.
- Locations of the most-used wildlife corridors adjoining the park have not been determined.

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4.6 Air Quality

Indicators	Condition	Confidence in Condition	Trend	Confidence in Trend
Nitrogen & Sulfur Deposition	Somewhat Concerning	Low	Unknown	N/A
Ozone	Good	Low	Unknown	N/A
Persistent Toxics	Unknown	N/A	Unknown	N/A

A fourth indicator—visibility—is used as an indicator of "Natural Quality of the Park Experience" and is discussed in section 4.7.

4.6.1 Background

Air quality is important for aesthetic, ecological, and health reasons. Ozone, particulates, wet and dry deposition of nutrients, acidifying substances, pesticides, and other contaminants are monitored in many areas of North America, mainly due to concerns regarding their potentially harmful effects on biological communities and/or human health. The 1977 Clean Air Act amendments identified 48 national parks as Class I areas, affording them special air quality protection. All other NPS areas, including this park, are designated as Class II air quality areas. The NPS Organic Act, the Wilderness Act and NPS 2006 Management Policies provide the basis for protection of air quality and air quality related values (AQRVs) in Class II areas.

4.6.2 Regional Context

The principal air masses for the region are derived from the atmosphere over the Pacific Ocean where the air is clean and moist. Occurring on a regular basis, wind-driven mixing through the Strait of Juan de Fuca effectively disperses local air contaminants (Puget Sound Clean Air Agency 2003). Thus, air quality in the Pacific Northwest is good compared with many other areas of the United States (Eilers et al. 1994). Nearby particle monitoring stations at Oak Harbor, Anacortes, and Mount Vernon have not exceeded ambient air quality standards (Franzmann 2003). However, the park is located in the Puget Sound/Georgia Basin airshed which is subject to the movement of air pollutants between the large urban/industrial areas of Seattle/Tacoma/Everett and Vancouver/Abbotsford/Bellingham, as well as the busy Interstate 5 corridor. A 2005 emissions inventory (WDOE 2012) noted that within about 62 miles of the park there are several large industrial sources in the adjacent counties including cement plants, petroleum refineries in Bellingham and Anacortes, an aluminum smelter in Bellingham, and a large pulp mill in Port Townsend (**Figure 31**). In addition, marine vessel traffic with associated emissions is likely increasing in the Georgia Basin and Puget Sound airshed. Long-range transport of pollution from Asia is a growing concern as development there intensifies (Jaffe et al. 2003, Brandenberger et al. 2010).

Close to the park, local sources of emissions include vehicles, marine vessels, agricultural operations, outdoor burning, and woodstoves/fireplaces (Garland 1995, WDOE 2012). A public incinerator and a sand and gravel operation near Friday Harbor closed many years ago. We reviewed information from the National Park Service, Washington State's Department of Ecology's Air Quality Program (http://www.ecy.wa.gov/programs/air/airhome.html), Olympic Regional Clean Air Agency (http://www.orcaa.org/), and US Environmental Protection Agency's Air Pollution monitoring and trends program (http://www.epa.gov/airtrends/index.html). These indicate there are no specific sources of air pollution in the areas of San Juan County that would be part of the park's airshed.

4.6.3 Issues Description

The air pollutants of usual concern in NPS parks are sulfur (S) and nitrogen (N) compounds, ground-level ozone and persistent bioaccumulative toxics (PBTs). Fine particles of sulfur, nitrogen compounds, and other substances in the atmosphere absorb or scatter light, causing haze and reducing visibility (Hand et al. 2011). S and N compounds eventually fall out of the atmosphere and are transferred to the Earth's surface by either wet deposition (e.g., rain, snow, clouds , fog) or dry deposition (e.g., dust particles). The main source of S is coal combustion at power plants and industrial facilities. Oxidized N compounds (i.e., nitrogen oxides) result from fuel combustion by vehicles, power plants and industry. Reduced N compounds (e.g., ammonia and ammonium) are the result of agricultural activities, fire and other sources. Ozone is formed when nitrogen oxides and volatile organic compounds emitted from vehicles, solvents, industry and vegetation react in the atmosphere in the presence of sunlight, usually during the warm summer months. Persistent bioaccumulative toxics include heavy metals like mercury (Hg) and hydrocarbons such as pesticides. Mercury is emitted by coal combustion, incinerators, mining processes, and some other industries.

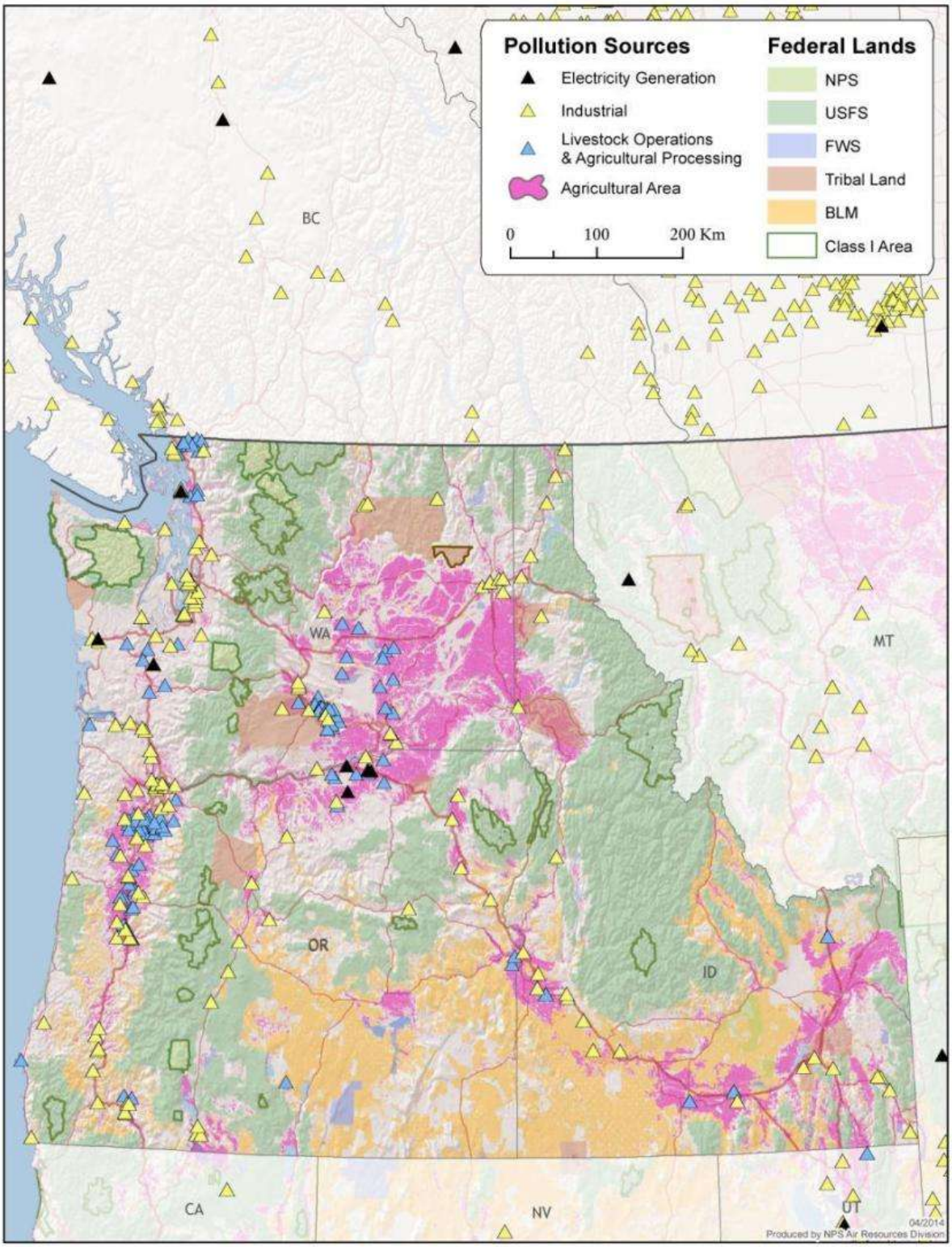

Figure 31. Major air pollution sources and public lands in the Pacific Northwest.

4.6.4 Data and Methods

Except for the passive ozone monitoring in 2004 conducted by the NPS and a visibility camera installed for a short period, in 2001-2003, air quality has apparently not been monitored in the park or San Juan County. Since no monitoring data are available to assess compliance with the NAAQS, San Juan County is "unclassifiable" for all criteria pollutants under the Clean Air Act. In other words, the county cannot be classified as meeting or not meeting the NAAQS for any pollutant.

The NPS Air Resources Division (ARD) evaluated air quality condition and trends in all Inventory and Monitoring (I&M) parks in the contiguous United States by reviewing estimates of deposition and ozone values from closest locations with monitoring data, and interpolated from those data to the parks (NPS 2013a,b).

In the following pages the criteria used the evaluate condition and trends are discussed under each of indicator, along with the level of certainty associated with each estimate and a brief discussion of data gaps.

4.6.4.1 Nitrogen and Sulfur Deposition

N and S compounds change water and soil chemistry, which in turn, affects algae, aquatic invertebrates and soil microorganisms, and can alter ecosystem functions and higher components of the food chain (Sullivan et al. 2011a, Sullivan et al. 2011b, Greaver et al. 2012). Deposition can acidify lakes and streams that have low buffering capacity. Also, because N is an essential plant nutrient, deposited N can change in soil nutrient cycling and plant community structure and composition, with positive or negative results as judged from a human perspective. Some studies from other locations indicate added N can favor exotic species over native prairie vegetation.

Criteria

The EPA has not established air quality standards or thresholds for S and N deposition. In lieu of regulatory standards, the NPS and other federal land managers are increasingly using critical loads to assess the threat of air pollutants to AQRVs. A critical load is the amount of pollution below which significant harmful effects are not expected to occur. At this time, information about acceptable pollution levels and resource sensitivity is limited. As more studies are completed, critical loads will be developed for more pollutants and more ecosystem components.

Because dry deposition data are not available for most parks, conditions and trends of atmospheric deposition are based solely on wet deposition as measured through the National Atmospheric Deposition Program (NADP 2013). The ARD classifies parks with wet deposition less than 1 kg/ha/yr to be in "Good Condition," parks with wet deposition of 1–3 kg/ha/yr are classified as "Warrants Moderate Concern," and parks with wet deposition greater than 3 kg/ha/yr are placed in the "Warrants Significant Concern" category (NPS 2013b). We consider these equivalent to the terms we use in this report: "Good Condition," "Somewhat Concerning," and "Significant Concern." In addition to those criteria, we took into consideration other criteria based on lichen community sensitivity in the Pacific Northwest, as described below.

Condition, Trends, and Level of Certainty

Deposition has not been measured directly in the park. Estimates from interpolated 2005-2009 data suggest that wet N and S deposition in the park may be 0.5 kg/ha/yr for N and 0.6 kg/ha/yr for S. This would put the park in the Good Condition category for N and S deposition according to ARD criteria. However, other data, albeit from only a single plot in the park where lichen community composition was used as an indicator of N deposition, suggest that N deposition may be reducing the proportion of the park's lichens that are sensitive to N (Geiser and Neitlich 2007 and **Figure 32**).

Also, this park's estimated sensitivity to N enrichment was considered "high" by Sullivan (in preparation). The same analysis predicted deposition of N and S in this park may be moderate relative to other I&M parks, while its sensitivity to acidification is probably very low.

Condition	Confidence in Condition	Trend	Confidence in Trend
Somewhat Concerning	Low	Unknown	N/A

Data Gaps

- No data specifically from the park are available from which to calculate condition or trends in N deposition.
- The park's lichens have not been well-inventoried in order to tell how widely they have been impacted by N deposition.

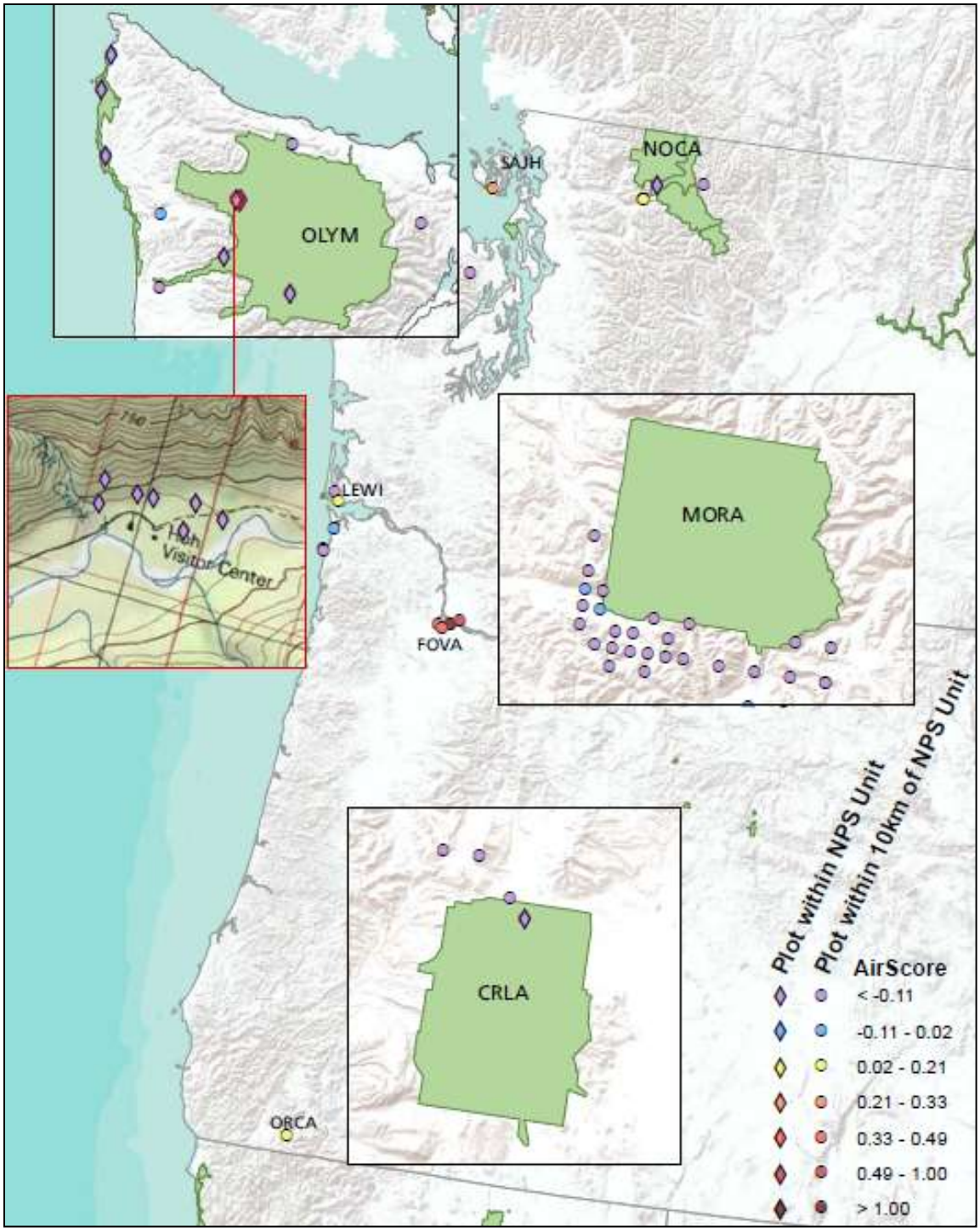

Figure 32. Air quality scores for lichen plots in and near NPS units in western Oregon and Washington.

Scores of 0.21-0.33 or greater exceeded the nitrogen critical load. SAJH is San Juan Island NHP, CRLA is Crater Lake National Park (NP), FOVA is Fort Vancouver National Historic Site, LEWI is Lewis and Clark National Historical Park (NHP), MORA is Mount Rainier NP, NOCA is North Cascades NP, OLYM is Olympic NP (produced by U.S. Forest Service in 2012).

4.6.4.2 Ozone

Ozone is a respiratory irritant and can trigger a variety of health problems including chest pain, coughing, throat irritation and congestion. Ozone also affects vegetation, harming sensitive plant species when concentrations reach critical levels for sufficient duration (USEPA 2013). Ozone causes visible injury (e.g., stipple and chlorosis) and growth effects (e.g., premature leaf loss; reduced photosynthesis; and reduced leaf, root and total size).

Criteria

The EPA's ozone National Ambient Air Quality Standards (NAAQs) were used as a benchmark for rating ozone condition in parks (NPS 2013b). The primary standard, designed to protect human health, and the secondary standard, intended to protect ecosystems, are identical. To attain these standards, the 3-year average annual 4th-highest daily maximum 8-hour ozone concentrations must not exceed 75 parts per billion (ppb). Parks with ozone concentrations less than 61 ppb (concentrations less than 80 percent of the standard) are considered in "Good Condition." Ozone concentrations that ranged from 61-75 ppb (concentrations greater than 80 percent of the standard) places parks in the "Warrants Moderate Concern" category. Concentrations greater than or equal to 76 ppb are assigned to a category called "Warrants Significant Concern." We consider these equivalent to the terms we use in this report: "Good Condition," "Somewhat Concerning," and "Significant Concern."

Recognizing that the current form of the secondary standard does not adequately reflect risk to vegetation, EPA and federal land managers, including the NPS, are considering alternative metrics for a secondary standard. One alternative is the W126, which is a cumulative sum of hourly ozone concentrations over a three month period, with hourly values weighted according to their magnitude. Another alternative is the SUM06, a measure of cumulative three-month ozone exposure that includes only hourly concentrations over 60 ppb. Ozone concentrations below 7 ppm-hours for the W126, and below 8 ppm-hours for the SUM06, are not considered to be a threat to vegetation.

Condition, Trends, and Level of Certainty

The NPS deployed passive ozone samplers at both American Camp and English Camp for one summer in 2004. Because the measurement is an integrated ozone exposure over a one-week period, the results cannot be used to determine nonattainment of the EPA NAAQs for ozone which are based on 8-hour averaged ozone levels. The passive samplers can only provide basic information on the ozone exposures and information about spatial variation in ozone exposure. The 2004 measurements found an average ozone concentration of 20.3 ppb at American Camp (range: 8.8 to 31.3 ppb) and 14.2 at English Camp (range: 4.3 to 21.4).

The 2005-2009 *interpolated* (not measured) ozone data indicated a 3-year average annual 4th-highest daily maximum 8-hour ozone concentration of 52.5 ppb, placing the park in the Good Condition category. The estimated risk of ozone damaging the park's vegetation was considered "low" by Sullivan (in preparation), based on both the W126 value of 1.2 ppm-hours and the SUM06 value of 1.3 ppm-hours. Kohut (2004) assessed the risk of ozone-induced foliar injury at all I&M parks based on species sensitivity, ozone concentrations, and soil moisture (which influences ozone uptake). He concluded there was low risk of ozone injury in this park.

Condition	Confidence in Condition	Trend	Confidence in Trend
Unknown	N/A	Unknown	N/A

Data Gaps

- Ozone measurements within the park have been too infrequent to conclude whether ozone may be harming or limiting growth of some plant species.

4.6.4.3 Persistent Toxins

Deposited mercury is frequently transformed by ecosystem processes into a very toxic form, methylmercury, which biomagnifies in the food chain and can reach harmful levels in fish and wildlife. Biological effects of Hg and other PBTs include impacts on reproductive success, growth, behavior, disease susceptibility and survival (Landers et al. 2008).

Condition, Trends, and Level of Certainty

No data on persistent toxins are available from the park.

Condition	Confidence in Condition	Trend	Confidence in Trend
Unknown	N/A	Unknown	N/A

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4.7 Natural Quality of the Park Experience

Resources/Indicators Assessed

Visibility and Viewsheds

Dark Night Sky

Soundscape

Physical Remoteness and Solitude

4.7.1 Background

Several attributes influence the natural quality of the park experience that is valued by most visitors. Among these attributes are long-distance visibility, a dark starlit night sky, quiet surroundings, and the absence of signs of human alteration (other than those of historic merit). These attributes of the park experience are discussed in this section.

4.7.2 Regional Context

The San Juan Archipelago is considered by many to be among the most scenic, undisturbed, and uncrowded of the relatively-accessible natural areas in the Pacific Northwest. San Juan County is the only county in the state that has passed a real estate excise tax for purchasing and setting aside significant amounts of land for permanent protection from intensive development. County-owned parks and land bank programs and the San Juan Preservation Trust have together protected over 9% of the county's area primarily for conservation, and an additional 10% of the county's area is within San Juan Island National Historical Park or owned by other Federal or State agencies or private conservation groups.

4.7.3 Issues Description

Increasing population growth projected for the region surrounding the park could alter landscape character within the park's viewsheds, reduce long-distance visibility (e.g., from increased vehicle emissions), impinge upon the dark night sky (from more lighting associated with buildings and vehicles), reduce the proportion of sounds that are of natural origin, and degrade the experience of persons for whom finding solitude outdoors is important. At the same time, more people in the region may mean more people likely to visit and enjoy what the park offers.

4.7.4 Data and Methods

Indicators that might be used to monitor this issue (Natural Quality of the Park Experience) include the following:

1. Visibility and Viewsheds
2. Night Sky
3. Soundscape
4. Physical Remoteness and Solitude

4.7.4.1 Visibility and Viewsheds

Visibility is the clarity of the atmosphere, as typically measured by the viewable distance at a particular location and time, and the number of days annually that scenic objects at different distances can be seen. Visibility is restricted by the absorption and scattering of light that is caused by both gases and particles in the atmosphere. Natural factors that decrease visibility include relative humidity above 70 percent, fog, precipitation, blowing dust and snow, and smoke from wildland fires. Human activities reduce visibility when soil is disturbed and creates dust, and when fossil fuels are burned which results in soot and tiny visibility-reducing particles (aerosols). Visibility impairment is reported in deciviews (dv). Lower dv values correspond with better visibility conditions.

"Viewsheds" are the areas that comprise the view into or out of the park that is unobstructed by terrain or human infrastructure. Viewsheds can be assessed in terms of the percentage of 360-degree views, located at various accessible points within a park, that is unobstructed when viewed from eye level. The character of the landscape within each viewshed can also be described.

Criteria

The NPS visibility goal for parks is no human-caused impairment. Condition assessments are based on monitored or interpolated average visibility minus estimated average natural background visibility. There are no widely-accepted criteria for evaluating viewsheds.

Parks with average visibility less that 2 dv above natural conditions are considered by the NPS to be in "Good Condition." Parks with visibility ranging from 2 to 8 dv above natural conditions are considered to be in the "Warrants Moderate Concern" category, and parks with visibility greater than 8 dv above natural conditions are placed in the "Warrants Significant Concern" category. We consider these equivalent to the terms we use in this report: "Good Condition," "Somewhat Concerning," and "Significant Concern." The NPS chose the dv ranges of these categories to reflect the variation in monitored visibility conditions (NPS 2013b). Specifically, these criteria are based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions, where Group 50 is defined as the mean of the visibility observations falling within the range from the 40th through the 60th percentiles. Visibility is estimated from the interpolation of the five-year averages of the Group 50 visibility.

Condition and Trends

Except for a brief period in 2001-2003 (whose data were never analyzed), no visibility monitoring has been conducted in the park. Visibility at the park during the period 2005-2009 was statistically *interpolated* (not measured) to be 5.8 dv on the 20 percent best days and 16.6 dv on the 20 percent worst days (NPS 2013a). The difference between average interpolated visibility and estimated average natural background visibility was 6.2 dv, i.e., current visibility is 62 percent worse than natural conditions. These measurements suggest that visibility at the park

should be classified as in the “Warrants Moderate Concern,” a.k.a., “Somewhat Concerning” category (NPS 2013b).

Condition	Confidence in Condition	Trend	Confidence in Trend
Somewhat Concerning	Low	Unknown	N/A

Data Gaps

- Despite American Camp's reputation for spectacular seascape views, visibility data have not been collected in many years. Data collected earlier were too sparse to be conclusive.

4.7.4.2 Dark Night Sky

Natural lightscapes are critical for viewing a starry sky in its finest detail. They are also critical for maintaining nocturnal habitat of many wildlife species which rely on natural patterns of light and dark for navigation, to cue behaviors, or hide from predators (Gaston et al. 2013). Human-caused light may be obtrusive in the same manner that noise can disrupt a contemplative or peaceful scene. Light that is undesired in a natural or cultural landscape is often called "light pollution." In coastal areas, night-foraging seabirds are often drawn to lights and if disoriented by fog, can be killed when they collide with lights and associated structures (Rich and Longcore 2005).

Criteria

The NPS has developed a system for measuring sky brightness to quantify the source and severity of light pollution. This system, developed with the assistance from professional astronomers and the International Dark-Sky Association, utilizes a research-grade digital camera to capture the entire sky with a series of images. Sky brightness is measured in astronomical magnitudes in the V-band, abbreviated as "mags." The V-band measures mostly green light, omitting purple through ultraviolet and orange through infrared. The magnitude scale is a logarithmic scale: a difference of 5 magnitudes corresponds to a 100x difference in brightness. Lower values (smaller or more negative) are brighter. No consensus has been reached on what the reference values should be.

Condition and Trends

Light pollution from Victoria, British Columbia, is considerable and appears to be increasing. However, no measurements have been taken and trends are unquantified.

Condition	Confidence in Condition	Trend	Confidence in Trend
Unknown	N/A	Unknown	N/A

Data Gaps

- Lack of data collected using NPS protocols is prohibiting any supportable statements about condition or trend of the park's dark night sky.

4.7.4.3 Soundscape

Since 2006, the National Park Service has required parks to identify the levels and types of unnatural sound that constitute acceptable and unacceptable impacts on park natural soundscapes. The natural quiet preserved at the park appeals to many visitors, and it contributes to the purpose of their visit. But this is not only for the benefit of visitors. Preserving the natural quiet of the park is also needed to minimize disturbance to species that require often-subtle auditory cues for reproduction, predator avoidance, navigation, and communication about food locations. The underwater soundscape is particularly important to marine mammals and is easily altered by vessel traffic.

Natural sounds within this park include birdcalls, wildlife rustling in the underbrush, and sounds of wind in the trees and grasses. Louder natural sounds such as the crashing of waves are associated with the bluffs and beaches. Air traffic is a significant source of sound pollution in the park. Other noises include vehicles, boating activities in Garrison Bay, and routine ground maintenance

Criteria

One way of quantifying human-sourced interference with natural sounds is to measure the amount of time that sound pressure levels (SPL's)—measured in decibels (dB) and weighted (dBA) to resemble the response of the human ear—exceed a given value. This can be determined with electronic acoustical monitoring systems. A common reference value range is 35-55 dBA because some studies have noted speech interference and impacts to wildlife above that range, depending also on the soundwave frequency. However, the NPS has not recommended specific criteria for soundscape integrity. "Good" condition might be represented by predictable and widespread occurrence of natural sounds, perhaps allowing for some human-related sounds that travel only short distances for short periods of time. "Somewhat Concerning" and "Significant Concern" might be unnatural sounds that travel greater distances and/or are constant or noticeable for longer periods of time.

Condition and Trends

Trends are expected to correlate with visitor numbers, but sound conditions in the park have not been quantified.

Condition	Confidence in Condition	Trend	Confidence in Trend

Unknown	N/A	Unknown	N/A

Data Gaps

- Lack of data collected using NPS protocols is prohibiting any supportable statements about condition or trend of the park's dark night sky.

4.7.4.4 Physical Remoteness and Solitude

Development in the San Juan archipelago began long ago, and was founded on agriculture, mining (limestone), fishing, and shellfish aquaculture. For a time, the limited ferry service and remoteness of the islands remained a significant barrier. However, with the advent of automobile tourism in the early 20th century, as well as greater discretionary income and more leisure time, tourism increased. Correspondingly, construction of seasonal and year-round homes increased, many occupied by a growing proportion of retirees (Flora and Fradkin 2004). June, July and August are the months of highest visitation at the park (about 40,000 per month). There is substantial visitation in the shoulder seasons as well (March through May, and September through October). During the slower winter months of November through February, the park typically receives about one-quarter the monthly visitation of summer.

Criteria

There are no widely-accepted criteria for the adequacy of remoteness and solitude.

Condition and Trends

Experiencing of solitude within the park is correlated inversely with numbers of park visitors. In 2013, there were 220,960 recreational visitors, spending a total of 13,863 recreation visitor days. Experiencing of solitude also would be expected to correlate inversely with vehicle traffic. For the year 2000, the San Juan County Public Works Department estimated approximately 253,000 cars traveled the Cattle Point Road that leads to American Camp. About 100,000 of those cars went solely to park locations and 153,000 traveled just beyond it to the Cape San Juan residential area. The daily traffic is predicted to increase 7.46 percent per year in this area. A walking trail connecting Friday Harbor to Cattle Point and trails within American Camp may, when completed, increase park visitation somewhat. Ridership on the ferry from Anacortes to Friday Harbor has also increased in recent years. In 2014, the total number of riders was 843,536.

A rating of Unknown is assigned to both Condition and Trend because of lack of accepted criteria.

Condition	Confidence in Condition	Trend	Confidence in Trend
Unknown	N/A	Unknown	N/A

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Chapter 5. Discussion

This assessment serves as a review and summary of available data and literature for focal natural resources in San Juan National Historical Park. The information presented here provides a partial baseline against which changes in condition of components in the future may be compared. However, current condition and trends from recent historical conditions could not be determined for many components due to lack of sufficient well-documented data sets.

The park is noted for its spectacular ocean views and three of the rarest habitat types in Puget Sound: prairies, oak woodlands, and ocean spits. The prolonged absence of fire, combined with locally severe grazing by deer and introduced rabbits, as well as isolation from the mainland and similar habitats elsewhere in Puget Sound, has undoubtedly altered the composition and structure of these habitats as well as the park's forest. Those changes have resulted in the loss or decline of several plant and animal species found in only a few other places within Puget Sound.

The marine waters that adjoin the park support an outstanding array of seabirds, marine mammals, and fish, but those resources are at risk from many factors, most of which are beyond the park's control. At Westcott Bay, the causes of an apparent decline in eelgrass -- an exceptionally productive habitat for marine life -- have never been conclusively determined. In the immediate vicinity of the park, mean annual temperature has increased and precipitation decreased during recent decades. That has increased the risks to the park's groundwater and mostly ephemeral surface waters, which are also highly vulnerable to impacts from residential development in areas adjoining the park.

Fortunately, focused efforts such as those described in section 4.4.4.4 are underway to improve the ecological condition of the park's oak woodland and prairie habitat, using a variety of hands-on management techniques. For the park's forests, animal and plant diversity will benefit the most from management that encourages a diversity of age classes. For the prairies, measures that limit weeds, woody vegetation, and damage from herbivores (primarily deer and exotic rabbits) will speed the recovery of soils and native flora and fauna. By removing invasive plants to establish weed-free connections with native herbaceous cover that exists both within and outside the park, managers will increase the chances of maintaining viable populations of rare species. Continued management of recreational activities with an eye towards protecting sensitive plant communities will help ensure they are not harmed by trampling, erosion, or facilitated spread of invasive plants, and wildlife are not subjected to persistent disturbance.

Table 14 summarizes what this document has reported about the condition and trend of each of the major resource concerns at San Juan Island National Historical Park. What is perhaps most striking is that recent trends in nearly all of the park's most important resources have not been measured. Moreover, for many resources, even their current condition remains virtually unmeasured, e.g., intertidal invertebrates, amphibians, most mammals, mosses and lichens sensitive to air quality, nitrogen deposition, forest structure, toxins in marine waters, dark night sky.

At least two major implications for management derive fom this assessment. First, without expanding the monitoring of the condition of the park's resources -- especially those with greatest potential to be affected by park policies and management -- the risk of damaging the

park's resources will increase, or at least, opportunities will be lost to understand many of the resouces sufficiently to recover them to a more healthy and sustainable state. Second, even without first conducting further research and monitoring, much remains to be done -- and can be done -- to improve the ecological condition of the park's regionally essential prairie and oak woodland habitats and assure their long term survival as a key feature of this park.

Table 14. Summary of condition and trend ratings for indicators and resources used in this assessment.

See individual sections of this document for the reasons behind each rating.

Indicator / Resource	Condition & Trend	Data Gaps
Climate	⇩	
Temperature	⇩	• Temperature needs to be measured daily over the long term within each unit of the park. Correlation with the long-term Olga monitoring station 14 miles away should be determined. • Analyses used in this report should be repeated on data sets that are newer than the 1971-2000 normals as those data become available from the PRISM Climate Group.
Precipitation	⇩	• Precipitation needs to be measured daily over the long term within each unit of the park. Correlation with the long-term Olga monitoring station 14 miles away should be determined. • Analyses used in this report should be repeated on data sets that are newer than the 1971-2000 normals as those data become available from the PRISM Climate Group.
Nearshore Resources		
Nearshore Water Quality	○	• A full spectrum of pollutants potentially harmful to marine life -- such as plastics, pharmaceuticals, endocrine disrupters, pesticides, mercury, and other heavy metals -- should be monitored in sediments and/or nearshore waters of the park. • Ocean acidity should be measured regularly using standard protocols to detect trends in conditions harmful to marine life.
Eelgrass	⇩	• Extent and location of eelgrass needs to be monitored annually in the park. • Westcott Bay should be checked regularly for signs of eelgrass recovery.
Kelp & Other Nearshore Plants	○	• Extent and location of various species of kelp should be monitored annually in the park.
Salmonid Fish	○	• The year-to-year use by salmonids of the shores along the park should be monitored.

Forage Fish		• The extent of current and future use of Westcott Bay by spawning herring should be determined
Nearshore Invertebrates		• A taxonomically comprehensive survey of marine invertebrates inhabitating the park's shoreline and especially its lagoons should be completed and published. • Permanent plots should be established in intertidal habitats and lagoons, and annual changes in marine invertebrates within these should be monitored. • Within the park's marine waters, the current status of the rare pinto abalone should be determined and monitored.
Invasive Nearshore Species		• The park's shorelines should be checked annually for potentially invasive marine invertebrates. • Non-native clams already in the park should be monitored for signs they may be spreading and adversely affecting other sediment fauna.
Freshwater Resources		
Groundwater Levels & Quality		• The amount of groundwater recharge needed to sustain the park's wetlands and to avoid degradation of water quality in the park's few wells should be determined. • Salinity in the park's wells should be regularly monitored for signs of saltwater intrustion into aquifers. • A more comprehensive set of water quality parameters should be measured in the park's wells.
Extent of Surface Water & Wetlands		• The seasonal duration of flow in the park's few ephemeral streams should be determined annually. • Water table levels in representative wetlands should be determined annually.
Wetland Biological Condition		• The extent of invasive plants in the park's wetlands should be monitored annually to determine if control measures are effective. • Floristic quality measures should be calculated for plant communities in the park's wetlands at least once each decade, based on repeated surveys.
Surface Water Quality		• Nitrogen, phosphorus, and other nutrients as well as suspended solids should be measured in the mostly ephemeral streams that enter Westcott Bay, where eelgrass has declined in recent years.
Terrestrial Vegetation and Landcover		
Prairies		• The extent of invasive plants in the park's prairies should be monitored annually to determine if control measures are effective and to measure local impacts from rabbits and

		visitors. • Lichen and moss cover on semi-bare surfaces should be monitored for adverse impacts from foot traffic, airborne pollutants, and fire. • Floristic quality measures should be calculated for plant communities in the park's prairies at least once each decade, based on repeated surveys. • The response of native prairie plant communities to any fires that may occur should be determined.
Oak Woodlands		• Determinations should be made of the numbers of oaks and conifers in different size classes that are necessary to ensure that canopy trees are replaced as they age, and that the stem densities are maintained at desired densities over the long term • Where prescribed fire is being used to manage and restore natural resources, the scorch on trees, percent kill of seedlings and saplings, topkill of shrubs, fuel consumption, removal of moss, lichen, and litter layers, and consumption of seed of non-native species should all be measured.
Coastal Strand, Spit, & Dune Communities		• The extent of invasive plants in these communities should be monitored annually to determine where control measures are most needed.
Native Plant Richness and Invasive Plants		
Less Common Species & Invasive Plants		• A comprehensive inventory of bryophytes and lichens should be conducted throughout the park. • Impacts of fire, herbicides, and air quality on the park's bryophytes, lichens, and uncommon native vascular plants should be monitored.
Golden Paintbrush		• The abundance of species that are likely to be deleterious to *C. levisecta* establishment, such as annuals and non-native perennial grasses, should be regularly measured. • A determination should be made of which animals (deer, rabbits, etc.) may be contributing the most to loss of individual plants from grazing.. • Detailed information on the demographics and biology of plants that are plugged or seeded on a site should be gathered.
Erect Pigmy-weed		• Current population numbers and spatial extent in the park should be determined and monitored regularly in the future.
California Buttercup		• Current population numbers and spatial extent in the park should be determined and monitored regularly in the future. • Rate of hybridization with western buttercup should be measured where both occur.

Hall's Aster		• Current population numbers and spatial extent in the park should be determined and monitored regularly in the future.
Forest Age & Composition		• The extent to which forests are being invaded by non-native plants that alter forest understory composition and structure in the park needs closer examination and monitoring. • Data are needed on stand age/dominance type classes of forests throughout the park, including locations of any remnant stands of mature trees. • More refined data and more frequent monitoring are needed to fairly assess the results of reforestation (tree establishment) on formerly forested lands historically converted to agriculture. Such data would help areas that still may require active intervention to encourage tree seedling establishment • Pacific madrone stands are maintained by occurrence of frequent fires. The current state of regional decline of madrone could potentially be reversed by carefully planned mechanical treatments aimed at increasing resprouting behavior and preparing appropriate seedbeds. Further research is needed as a basis for such an approach.
Forest Structure		• Data are needed to compare the effects of prescribed burning with those of mechanical harvest and thinning, in terms of multiple forest resources. This assessment could also include information on tree density and vigor that could be used to assess the need for mechanical thinning or other management of these very young stands. • Data are needed to assess whether these treatments are moving the stand structure in the direction of late-successional forest structures
Wildlife		
Birds		• No systematic data have been collected over the long term from within the park that would allow valid calculation of trends for any of the park's bird species. This is particularly true of marine birds and nocturnal owls. • For nearly all species, data on reproductive success have not been collected within the park. Such data are required to assess trends and help define minimum viable population levels. • Relative sensitivities of different bird species to disturbance from traffic and recreationists have not been determined within the park.
Mammals		• No inventories of mammal species in either unit of the park have been published. • With the possible exception of European rabbit, no systematic data have been collected over the long term from within the park

		that would allow valid calculation of trends for any of the park's mammal species. Monitoring of deer population levels and effects of deer grazing on other resources is particularly needed. • For nearly all mammal species, data on reproductive success and travel corridors have not been collected within the park. Such data are required to assess trends and help define minimum viable population levels. • Relative sensitivities of different mammal species to disturbance from traffic and recreationists have not been determined within the park.
Amphibian & Reptiles		• No recent inventories of amphibian or reptile species in either unit of the park have been published. In particular, data are needed on the current status of sharp-tailed snake (most likely to occur in Mitchell Hill area) and western toad, due to their conservation listings. • No systematic data have been collected over the long term from within the park that would allow valid calculation of trends for any of the park's amphibian or reptile species. • Data on reproductive success and dispersal corridors have not been collected within the park. Such data are required to assess trends and help define minimum viable population levels. • Effects of prairie and oak woodland habitat restoration (generally, and specific practices such as burning and vegetation thinning) on amphibians and reptiles have not been monitored within the park.
Terrestrial Invertebrates		• Comprehensive published inventories of butterflies or other terrestrial invertebrates are needed for the park.
Wildlife Associated with Prairies & Oak Woodlands		• Trends in butterflies and other insects, especially those which may be crucial to the pollination of the rarest prairie and oak woodland plants, are unknown. • Both immediate and long-term effects of prairie and oak woodland habitat restoration (generally, and specific practices such as burning and vegetation thinning) on butterflies and other terrestrial invertebrates should be monitored.
Invasive or Harmful Wildlife		• Population levels and distribution of feral cats in the park need to be determined due to their likely effect on bird and small mammal populations. • Estimates of numbers and distribution of the park's exotic rabbit population need to be updated and monitoring continued.
Habitat Connectivity & Structure		• The ability of amphibians and other mobile species to disperse through the matrix of land cover types within and surrounding the park needs to be determined. • Locations of the most-used wildlife corridors adjoining the park should be determined.
Air Quality		

Nitrogen & Sulfur Deposition		• N and S deposition specifically in the park should be measured periodically and the data made accessible. • The park's lichen diversity should be inventoried in order to tell how widely they have been impacted by N deposition. • The development of a critical load approach for air quality monitoring in the park would improve the quality and robustness of data collected in the future.
Ozone		• Ozone measurements within the park have been too infrequent to conclude whether ozone may be harming or limiting growth of some plant species. • Updated monitoring is needed to determine condition and trends.
Persistent Toxins		• Mercury and other persistent toxins should be monitored in the park. Effects of management practices on their mobility and bioaccumulation should also be measured.
Natural Quality of the Park Experience		
Visibility & Viewsheds		• Despite American Camp's reputation for spectacular seascape views, visibility data have not been collected in many years, but should be on a regular basis using established protocols.
Dark Night Sky		• No data are available for the park, using NPS measurement protocols. This is needed in order to conclude anything about condition and trends.
Soundscapes		• No data are available for the park, using NPS measurement protocols. This is needed in order to conclude anything about condition and trends.
Physical Remoteness & Solitude		• Criteria need to be developed for evaluating the adequacy of remoteness and solitude in the park.

Appendix 1. Supplemental Biological Data

Table 15. Soils primarily intersected by the American Camp vegetation associations.

Only soils comprising >20% of a mapped vegetation association are listed.

Vegetation Association	% of Veg Map	Associated Soils	Dominant Soils Intersected (%)	% of Soil Map
Cold-deciduous shrubland	1.72	Mitchellbay gravelly sandy loam, 0 to 5 % slopes	39.92	6.58
		Pilepoint loam, 2 to 8 % slopes	52.13	2.04
Douglas-fir-grand fir-western hemlock/salal-ocean spray	4.62	Hoypus sandy loam, 10 to 40 % slopes	23.93	3.26
		Mitchellbay gravelly sandy loam, 0 to 5 % slopes	22.98	6.58
Douglas-fir-grand fir-western hemlock/sword fern	4.34	Everett sandy loam, warm, 3 to 20 % slopes	23.67	5.31
		Sucia loamy sand, 2 to 10 % slopes	20.32	3.28
Douglas-fir-lodgepole pine/ocean spray-snowberry	8.19	Mitchellbay gravelly sandy loam, 0 to 5 % slopes	25.97	6.58
		Sholander-Spieden complex, 0 to 5 % slopes	28.07	7.49
Douglas-fir-Pacific madrone/ocean spray-snowberry	7.87	Everett sandy loam, warm, 3 to 20 % slopes	39.22	5.31
		Hoypus sandy loam, 3 to 25 % slopes	28.22	10.60
Red alder-cottonwood/salmonberry	3.05	Sholander-Spieden complex, 0 to 5 % slopes	82.44	7.49
Red alder-Douglas-fir/snowberry	0.43	Mitchellbay gravelly sandy loam, 0 to 5 % slopes	68.70	6.58
Mesic Grassland	4.27	Beaches-Endoaquents, tidal-Xerorthents association, 0 to 5 % slopes	77.49	5.34
Mesic Grassland w/ shrubs	0.56	Pilepoint loam, 2 to 8 % slopes	60.16	2.04
		Sholander-Spieden complex, 0 to 5 % slopes	33.68	7.49
Mesic Grassland w/ shrubs and tree regeneration	1.02	Sholander-Spieden complex, 0 to 5 % slopes	78.65	7.49
Mesic Grassland w/ tree regeneration	7.98	Mitchellbay gravelly sandy loam, 0 to 5 % slopes	26.96	6.58
		Sucia loamy sand, 2 to 10 % slopes	24.66	3.28
Xeric Grassland with Shrub Islands	31.85	San Juan sandy loam, 2 to 8 % slopes	26.85	19.84
Distichlis spicata - Salicornia virginica intertidal salt marsh	1.19	San Juan sandy loam, 2 to 8 % slopes	33.83	19.84
		San Juan sandy loam, 5 to 20 % slopes	39.06	20.15
Sparsely vegetated sand flats	17.26	San Juan sandy loam, 2 to 8 % slopes	26.05	19.84
		San Juan sandy loam, 5 to 20 % slopes	36.48	20.15

Sparsely vegetated sand dunes	0.89	Beaches-Endoaquents, tidal-Xerorthents association, 0 to 5 % slopes	92.91	5.34
None	3.79	San Juan-Dune land complex, 0 to 20 % slopes	83.93	5.13

Table 16. Soils primarily intersected by the English Camp vegetation associations.

Vegetation Association	% of Veg Map	Associated Soils	Dominant Soils Intersected (%)	% of Soil Map
Douglas-fir/grass	8.38	Haro-Hiddenridge-Rock Outcrop complex, 5 to 30 % slopes	59.30	11.25
Douglas-fir-bigleaf maple/grass	2.58	Doebay-Cady-Rock Outcrop complex, 10 to 30 % slopes	31.46	9.96
		Haro-Hiddenridge-Rock Outcrop complex, 25 to 75 % slopes	25.17	3.63
Douglas-fir-garry oak-Pacific madrone/grass	5.07	Haro-Hiddenridge-Rock Outcrop complex, 5 to 30 % slopes	75.63	11.25
		Haro-Hiddenridge-Rock Outcrop complex, 25 to 75 % slopes	22.98	3.63
Douglas-fir-grand fir-western hemlock/salal-ocean spray	22.68	Cady-Rock Outcrop complex, 5 to 30 % slopes	40.18	15.39
Douglas-fir-grand fir-western hemlock/sword fern	0.63	Coveland-Mitchellbay complex, 2 to 15 % slopes	91.30	7.93
Douglas-fir-lodgepole pine/ocean spray-snowberry	0.00	Cady-Rock Outcrop complex, 5 to 30 % slopes	100.00	15.39
Douglas-fir-Pacific madrone/ocean spray-snowberry	15.28	Doebay-Cady-Rock Outcrop complex, 10 to 30 % slopes	15.91	3.51
Mesic Grassland w/ shrubs and tree regeneration	0.66	Coveland-Mitchellbay complex, 2 to 15 % slopes	42.60	7.93
		Coveland-Mitchellbay complex, 2 to 15 % slopes	36.39	7.93
Mesic Grassland w/ tree regeneration	1.71	Mitchellbay gravelly sandy loam, 5 to 15 % slopes	64.72	2.96
None	1.36	Coveland-Mitchellbay complex, 2 to 15 % slopes	84.47	7.93
Red alder-cottonwood/salmonberry	2.63	Coveland-Mitchellbay complex, 2 to 15 % slopes	28.20	7.93
		Limepoint-Sholander complex, 0 to 8 % slopes	19.55	0.87
Red alder-Douglas-fir/snowberry	2.41	Sholander-Spieden complex, 0 to 5 % slopes	38.86	1.67
		Mitchellbay gravelly sandy loam, 5 to 15 % slopes	25.41	2.96

Table 17. Expanded list of bird species recorded from San Juan Island National Historical Park.

Legend:

Priority Species: C= Candidate, T= Threatened, S= Sensitive, G= suggested by Cassidy and Grue (2007) as being of conservation concern.
Oak/Prairie associate: 1= obligate or near-obligate, 2= associated.
AC= American Camp, EC= English Camp, SJI= San Juan Island, * from nearby Cattle Point checklist but not reported from park
Sources: NPS certified list (NPS).
Other columns from eBird database (www.ebird.org, accessed December 15, 2014) and landbird survey reports by Siegel et al. (2006, 2007, 2008, 2009),Wilkerson et al. (2010) and Holmgren et al. (2011, 2012, 2013).

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
American Avocet	No			1*	0			
American Bittern	No			1*	0			
American Coot	Yes			1	0	Probable	NA	NA
American Crow	Yes			300	30	Present	Common	Breeder
American Dipper	No			1	0			
American Golden-Plover	No			4	0			
American Goldfinch	Yes		2	600	5	Present	Common	Breeder
American Kestrel	Yes		2	5	0	Present	Uncommon	Breeder
American Pipit	No			12	0			
American Redstart	No			0	1			
American Robin	Yes			25	85	Present	Abundant	Breeder
American Wigeon	Yes			40	20	Probable	NA	NA
Ancient Murrelet	No	G		200	0			
Anna's Hummingbird	No		2	1	1			
Baird's Sandpiper	Yes			1	0	Probable	NA	NA
Bald Eagle	Yes	S		10	7	Present	Common	Breeder
Band-tailed Pigeon	Yes			1	1	Present	Uncommon	Resident
Barn Owl	Yes			1	0	Probable	NA	NA
Barn Swallow	Yes			90	6	Present	Common	Breeder
Barred Owl	Yes			0	1	Present	Unknown	Unknown
Barrow's Goldeneye	Yes	G		1	0	Probable	NA	NA
Belted Kingfisher	Yes			2	3	Present	Uncommon	Resident

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Bewick's Wren	Yes		2	7	1	Present	Uncommon	Breeder
Black Oystercatcher	Yes			28	5	Present	Rare	Resident
Black Scoter	Yes			2	0	Present	Rare	Migratory
Black Swift	Yes			1*	0	Probable	NA	NA
Black Turnstone	Yes	G		20	0	Probable	NA	NA
Black-bellied Plover	No			45	0			
Black-billed Magpie	No			1*	0			
Black-capped Chickadee	No			1	0			
Black-headed Grosbeak	Yes			1	1	Present	Rare	Breeder
Black-throated Gray Warbler	Yes		2	1	8	Present	Uncommon	Breeder
Blue-winged Teal	Yes			0	0	Probable	NA	NA
Bobolink	No			1	0			
Bonaparte's Gull	Yes			350	1	Probable	NA	NA
Brandt's Cormorant	Yes	C		1000	1	Probable	NA	NA
Brant	No			2	0			
Brewer's Blackbird	Yes			1	1	Present	Common	Breeder
Brown Creeper	Yes			4	9	Present	Common	Breeder
Brown Pelican	No			0	0			
Brown-headed Cowbird	Yes			25	6	Present	Uncommon	Breeder
Buff-breasted Sandpiper	Yes			0	0	Present	Occasional	Migratory
Bufflehead	Yes	G		60	353	Present	Common	Resident
Burrowing Owl	No			1	0			
Bushtit	Yes		2	12	0	Present	Uncommon	Resident
Cackling Goose	No			0	2			
California Gull	Yes			50	3	Probable	NA	NA
California Quail	Yes		2	31	1	Present	Uncommon	Breeder
Canada Goose	Yes	G		75	50	Present	Common	Resident
Canvasback	Yes			0	0	Probable	NA	NA
Caspian Tern	No			3	0			

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Cassin's Auklet	No			1*	0			
Cassin's Vireo	Yes		2	0	4	Present	Uncommon	Breeder
Cedar Waxwing	Yes			20	5	Present	Uncommon	Resident
Chestnut-backed Chickadee	Yes			28	31	Present	Common	Breeder
Chipping Sparrow	Yes		1	1	2	Present	Common	Breeder
Cinnamon Teal	Yes			0	0	Probable	NA	NA
Clay-colored Sparrow	No			1	0			
Cliff Swallow	Yes			30	2	Present	Uncommon	Migratory
Common Goldeneye	Yes	G		10	1	Present	Common	Resident
Common Loon	Yes			10	2	Present	Common	Resident
Common Merganser	Yes			4	4	Present	Uncommon	Resident
Common Murre	Yes	C		1000	1	Present	Uncommon	Migratory
Common Nighthawk	Yes		2	0	1	Probable	NA	NA
Common Raven	Yes			12	5	Present	Uncommon	Breeder
Common Tern	Yes			8	1	Present	Rare	Migratory
Common Yellowthroat	Yes			4	1	Present	Common	Breeder
Cooper's Hawk	Yes		2	2	0	Probable	NA	NA
Dark-eyed Junco	Yes			20	35	Present	Common	Breeder
Double-crested Cormorant	Yes			150	50	Present	Common	Resident
Downy Woodpecker	Yes		2	4	1	Present	Uncommon	Breeder
Dunlin	No	G		100	0			
Dusky Flycatcher	No			0	1			
Eared Grebe	Yes			1	3	Present	Rare	Resident
Eurasian Collared-Dove	No			12	0			
Eurasian Wigeon	No			1*	0			
European Starling	Yes			180	180	Present	Common	Breeder
Evening Grosbeak	No			1*	1			
Fox Sparrow	Yes			10	1	Present	Common	Resident
Gadwall	Yes			25	0	Present	Rare	Resident

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Glaucous Gull	No			1*	0			
Glaucous-winged Gull	Yes			400	56	Present	Common	Resident
Golden Eagle	Yes	C		1	0	Present	Rare	Resident
Golden-crowned Kinglet	Yes			18	24	Present	Common	Breeder
Golden-crowned Sparrow	Yes			45	1	Present	Common	Resident
Great Blue Heron	Yes			5	4	Present	Common	Resident
Great Horned Owl	Yes			0	1	Probable	NA	NA
Greater Scaup	Yes			10	116	Present	Common	Resident
Greater White-fronted Goose	Yes			0	0	Present	Rare	Migratory
Greater Yellowlegs	Yes			4	0	Present	Uncommon	Migratory
Green Heron	No			0	0			
Green-winged Teal	Yes			5	5	Probable	NA	NA
Gyrfalcon	No			1	0			
Hairy Woodpecker	Yes			1	1	Present	Uncommon	Breeder
Hammond's Flycatcher	Yes			1	1	Present	Rare	Breeder
Harlequin Duck	Yes	G		26	0	Present	Uncommon	Resident
Heermann's Gull	Yes			250	1	Probable	NA	NA
Hermit Thrush	No			4	1			
Herring Gull	No			4	0			
Hooded Merganser	Yes	G		14	2	Present	Uncommon	Resident
Horned Grebe	Yes			80	68	Present	Uncommon	Resident
Horned Lark	Yes		1	12	0	Present	Rare	Migratory
House Finch	Yes			25	0	Present	Common	Breeder
House Sparrow	Yes			30	1	Probable	NA	NA
House Wren	Yes		2	7	9	Present	Uncommon	Breeder
Hutton's Vireo	Yes		2	1	1	Present	Uncommon	Breeder
Killdeer	Yes		2	20	0	Present	Common	Resident
Lapland Longspur	No			20	0			
Least Sandpiper	Yes			12	0	Probable	NA	NA

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Lesser Scaup	Yes			0	6	Probable	NA	NA
Lesser Yellowlegs	Yes			11	0	Probable	NA	NA
Lewis' Woodpecker	No		1	1*	0			
Lincoln's Sparrow	No			25	0			
Long-billed Curlew	No			1*	0			
Long-billed Dowitcher	Yes			1*	0	Probable	NA	NA
Long-eared Owl	No			1	0			
Long-tailed Duck	Yes			10	4	Present	Uncommon	Resident
Long-tailed Jaeger	Yes			0	0	Present	Occasional	Migratory
MacGillivray's Warbler	Yes			1	1	Present	Rare	Breeder
Mallard	Yes			30	15	Present	Common	Breeder
Marbled Godwit	No			1*	0			
Marbled Murrelet	No	T		100	1			
Marsh Wren	Yes			10	0	Present	Uncommon	Breeder
Merlin	No			1	1			
Mew Gull	Yes			500	25	Probable	NA	NA
Mountain Bluebird	No			1	1			
Mourning Dove	Yes		2	6	1	Probable	NA	NA
N. Rough-winged Swallow	Yes			12	2	Present	Uncommon	Breeder
Nashville Warbler	No			1	0			
Northern Flicker	Yes			6	3	Present	Uncommon	Breeder
Northern Fulmar	No			1*	0			
Northern Goshawk	No			0	0			
Northern Harrier	Yes		1	6	0	Present	Uncommon	Resident
Northern Pintail	Yes			250	0	Probable	NA	NA
Northern Pygmy-Owl	No			0	0			
Northern Saw-whet Owl	Yes			1*	0	Probable	NA	NA
Northern Shoveler	Yes			1*	2	Probable	NA	NA
Northern Shrike	Yes			6	0	Probable	NA	NA

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Olive-sided Flycatcher	Yes			4	2	Present	Uncommon	Breeder
Orange-crowned Warbler	Yes			25	15	Present	Common	Breeder
Osprey	Yes			1	8	Present	Rare	Breeder
Ovenbird	No			1	1			
Pacific (Winter) Wren	Yes			5	10	Present	Common	Breeder
Pacific Golden-Plover	No			2	0			
Pacific Loon	Yes	G		250	0	Present	Uncommon	Resident
Pacific-slope Flycatcher	Yes			4	15	Present	Common	Breeder
Palm Warbler	No			1	0			
Parasitic Jaeger	Yes			1	0	Probable	NA	NA
Pectoral Sandpiper	No			4	0			
Pelagic Cormorant	Yes			80	10	Probable	NA	NA
Peregrine Falcon	Yes	S		1	0	Present	Rare	Resident
Pied-billed Grebe	Yes			1	0	Probable	NA	NA
Pigeon Guillemot	Yes	G		40	10	Present	Common	Resident
Pileated Woodpecker	Yes	C		1	2	Present	Uncommon	Breeder
Pine Siskin	Yes			135	25	Present	Common	Breeder
Purple Finch	Yes		2	4	5	Present	Uncommon	Breeder
Purple Martin	Yes	C		4	1	Probable	NA	NA
Red Crossbill	Yes			6	15	Present	Common	Breeder
Red-breasted Merganser	Yes	G		100	30	Present	Uncommon	Resident
Red-breasted Nuthatch	Yes			10	7	Present	Common	Breeder
Red-breasted Sapsucker	Yes			1	0	Present	Rare	Migratory
Redhead	No			0	0			
Red-necked Grebe	Yes			60	3	Probable	NA	NA
Red-necked Phalarope	Yes			8	0	Probable	NA	NA
Red-tailed Hawk	Yes			4	2	Present	Common	Breeder
Red-throated Loon	Yes			1	0	Probable	NA	NA
Red-winged Blackbird	Yes			35	2	Present	Common	Breeder

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Rhinoceros Auklet	Yes	G		100	1	Present	Common	Resident
Ring-billed Gull	Yes			20	3	Probable	NA	NA
Ring-necked Duck	Yes			1	6	Probable	NA	NA
Ring-necked Pheasant	Yes			1	0	Present	Rare	Resident
Rock Pigeon (Feral Pigeon)	Yes			1	1	Probable	NA	NA
Rock Sandpiper	No			3	0			
Rock Wren	No			1	0			
Rough-legged Hawk	No			1	0			
Ruby-crowned Kinglet	No			12	3			
Ruddy Duck	No			1*	0			
Ruddy Turnstone	No			1*	0			
Rufous Hummingbird	Yes			20	5	Present	Common	Breeder
Sanderling	No			20	0			
Sandhill Crane	No		1	0	0			
Savannah Sparrow	Yes		1	30	1	Present	Common	Breeder
Say's Phoebe	No		1	0	0			
Semipalmated Plover	Yes			1	0	Probable	NA	NA
Semipalmated Sandpiper	No			0	0			
Sharp-shinned Hawk	Yes			1	1	Probable	NA	NA
Short-billed Dowitcher	Yes			1*	0	Probable	NA	NA
Short-eared Owl	Yes		1	3	0	Present	Rare	Unknown
Sky Lark	No			14	0			
Snow Goose	No			1	1			
Snowy Owl	Yes			1*	0	Present	Occasional	Migratory
Solitary Sandpiper	No			0	0			
Song Sparrow	Yes			15	8	Present	Common	Breeder
Sooty Shearwater	No			1	0			
Sora	Yes			0	0	Probable	NA	NA
Spotted Sandpiper	Yes			1	0	Probable	NA	NA

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Spotted Towhee	Yes		2	15	10	Present	Common	Breeder
Steller's Jay	No			1	0			
Surf Scoter	Yes	G		700	65	Present	Common	Resident
Surfbird	Yes			15	0	Probable	NA	NA
Swainson's Hawk	Yes			0	0	Present	Occasional	Vagrant
Swainson's Thrush	Yes			2	5	Present	Common	Breeder
Tennessee Warbler	Yes			0	0	Present	Occasional	Migratory
Thayer's Gull	Yes			2	0	Probable	NA	NA
Townsend's Solitaire	Yes			0	1	Present	Uncommon	Migratory
Townsend's Warbler	Yes			1	10	Present	Common	Breeder
Tree Swallow	Yes			2	3	Present	Common	Breeder
Trumpeter Swan	Yes			1*	0	Probable	NA	NA
Tufted Puffin	Yes	C		3	1	Probable	NA	NA
Tundra Swan	No			0	0			
Turkey Vulture	Yes			125	6	Present	Uncommon	Migratory
Varied Thrush	Yes			2	100	Present	Uncommon	Breeder
Vaux's Swift	Yes	C		1	2	Present	Uncommon	Breeder
Vesper Sparrow	Yes	C	1	3	0	Present	Uncommon	Breeder
Violet-green Swallow	Yes			16	10	Present	Common	Breeder
Virginia Rail	Yes			0	0	Probable	NA	NA
Wandering Tattler	No			1	0			
Warbling Vireo	Yes			1	3	Present	Common	Breeder
Western Bluebird	Yes		1	3	0	Probable	NA	NA
Western Grebe	Yes	C		15	9	Probable	NA	NA
Western Gull	Yes			1	4	Probable	NA	NA
Western Kingbird	No		1	1	0			
Western Meadowlark	Yes		1	12	0	Present	Uncommon	Breeder
Western Sandpiper	Yes			50	0	Probable	NA	NA
Western Screech-owl	Yes		2	0	0	Probable	NA	NA

Common Name	NPS certified list	Priority Species	Oak/ Prairie Asso-ciate	AC max count	EC max count	NPS status in SAJH	NPS Abun-dance in SAJH	NPS Resi-dency
Western Tanager	Yes			1	2	Present	Common	Breeder
Western Wood-Pewee	Yes		2	2	1	Probable	NA	NA
Whimbrel	Yes			1	0	Probable	NA	NA
White-crowned Sparrow	Yes			47	5	Present	Common	Breeder
White-throated Sparrow	No			1	0			
White-winged Scoter	Yes	G		60	2	Present	Common	Resident
Wild Turkey	Yes			1	19	Present	Uncommon	Resident
Willow Flycatcher	Yes			1	0	Present	Uncommon	Breeder
Wilson's Snipe	No			1	0			
Wilson's Warbler	Yes			4	3	Present	Uncommon	Breeder
Wood Duck	Yes	G		0	1	Probable	NA	NA
Yellow Warbler	Yes			4	1	Present	Uncommon	Migratory
Yellow-billed Loon	Yes			1*	0	Probable	NA	NA
Yellow-rumped Warbler	Yes			4	5	Present	Common	Breeder

Table 18. Bird species observed during 5 years of systematic breeding-season surveys in San Juan Island National Historical Park's American Camp (AC) and English Camp (EC) units.

Sources: Siegel et al. (2008, 2009),Wilkerson et al. (2010) and Holmgren et al. (2011, 2012, 2013).

	# of Years (of 5)		Max Per Survey Point, Any Year		Sum of Points, All Years	
Common Name	**AC**	**EC**	**AC**	**EC**	**AC**	**EC**
American Crow	5	5	12	5	87	25
American Golden-Plover	1		1		1	
American Goldfinch	5	4	9	2	157	9
American Redstart		1		1		1
American Robin	5	5	9	4	190	74
Bald Eagle	5	4	4	4	35	6
Band-tailed Pigeon	2	3	1	1	4	5
Barn Swallow	5		4		39	
Belted Kingfisher	2	1	1	1	2	1
Bewick’s Wren	5	2	2	1	25	4
Black Oystercatcher		1		4		1
Black-capped Chickadee	1		1		1	
Black-headed Grosbeak	5	3	2	1	20	6
Black-throated Gray Warbler	2	5	1	2	6	39
Brewer’s Blackbird	2		1		2	
Brown Creeper	4	5	2	3	19	29
Brown-headed Cowbird	5	5	5	2	121	31
Bushtit	1		8		2	
California Gull		1		1		1
California Quail	5	2	2	1	30	2
Canada Goose	5	5	31	22	13	28
Caspian Tern	1		2		2	
Cassin's Vireo		4		2		24
Cedar Waxwing	4		8		16	
Chestnut-backed Chickadee	5	5	5	2	63	44
Chipping Sparrow	4	4	1	2	5	11
Clay-colored Sparrow	1		1		1	
Cliff Swallow	1		2		1	
Common Loon	4		1		5	
Common Murre	2		4		2	
Common Raven	5	4	2	4	20	21
Common Yellowthroat	5	1	2	1	29	3
Dark-eyed Junco	5	5	2	4	28	42
Double-crested Cormorant	2		2		2	
Dusky Flycatcher	1		1		1	
Eurasian Collared-dove	2	1	1	1	7	1
European Starling	5	1	11	4	21	1
Evening Grosbeak	2		11		2	
Glaucous-winged Gull	5	1	300	8	28	2

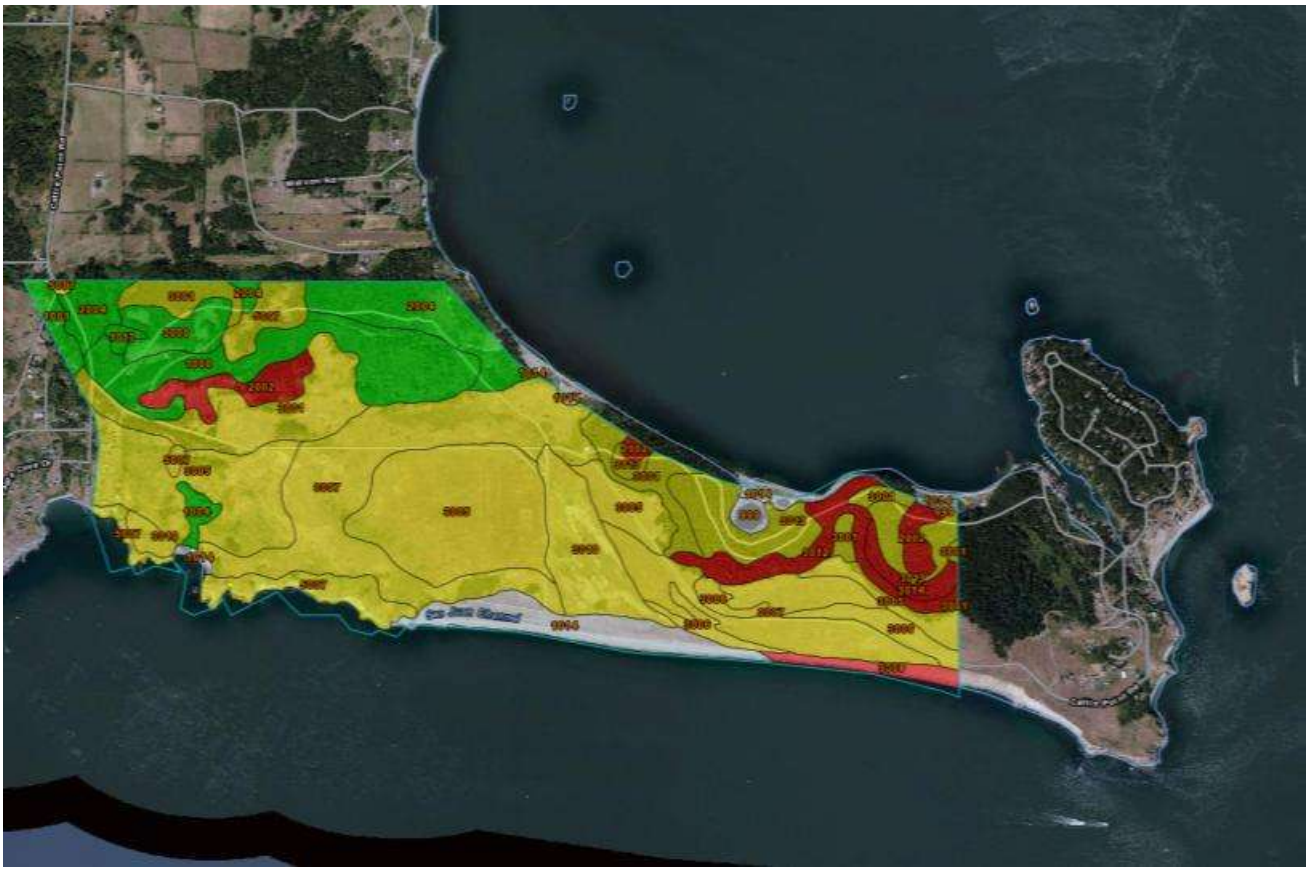
	# of Years (of 5)		Max Per Survey Point, Any Year		Sum of Points, All Years	
Common Name	**AC**	**EC**	**AC**	**EC**	**AC**	**EC**
Golden-crowned Kinglet	5	4	3	1	27	10
Great Blue Heron		1		2		1
Hairy Woodpecker	1	4	1	1	1	9
Hammond's Flycatcher	1	1	1	1	1	1
House Finch	5		4		67	
House Wren	5	5	4	4	75	56
Hutton's Vireo	3	1	2	1	3	1
Killdeer	2		1		3	
MacGillivray's Warbler		1		1		1
Mallard	2		2		2	
Mourning Dove	4	2	2	1	19	2
Nashville Warbler	1		1		1	
Northern Flicker	5	4	1	1	20	8
N. Rough-winged Swallow	5		3		10	
Olive-sided Flycatcher	5	4	1	2	20	17
Orange-crowned Warbler	5	5	3	3	88	74
Osprey		1		1		1
Pacific Loon	1		10		1	
Pacific Wren	5	5	3	2	28	20
Pacific-slope Flycatcher	5	5	3	3	60	89
Pelagic Cormorant	3		3		3	
Pigeon Guillemot	1		35		1	
Pileated Woodpecker	5	4	1	1	10	10
Pine Siskin	5	5	7	3	58	16
Purple Finch	5	4	2	3	47	22
Red Crossbill	4	4	61	5	41	21
Red-breasted Nuthatch	5	5	2	3	52	64
Red-breasted Sapsucker	1		1		1	
Red-tailed Hawk	3		1		4	
Red-winged Blackbird	5		6		56	
Rhinoceros Auklet	3		20		4	
Ring-necked Pheasant	1		1		6	
Rock Wren	1		1		1	
Rufous Hummingbird	5	5	3	2	40	25
Savannah Sparrow	5		7		122	
Song Sparrow	5	5	4	2	68	36
Spotted Towhee	5	5	4	3	107	52
Steller's Jay		1		1		1
Surf Scoter	2		47		3	
Swainson's Thrush	5	5	3	4	87	60
Townsend's Warbler	2	5	2	3	6	48
Tree Swallow	1		1		1	
Turkey Vulture	1		1		1	

	# of Years (of 5)		Max Per Survey Point, Any Year		Sum of Points, All Years	
Common Name	**AC**	**EC**	**AC**	**EC**	**AC**	**EC**
unidentified bird	2		1000		3	
unidentified duck	2		106		2	
unidentified gull	5	3	200	3	85	3
unidentified hummingbird	1	1	1	1	1	1
unidentified sapsucker		1		1		1
unidentified swallow	2		1		3	
unidentified woodpecker	3	2	1	1	5	4
Varied Thrush	2	2	2	2	7	7
Vaux's Swift		2		2		4
Vesper Sparrow	4		2		9	
Violet-green Swallow	2	2	2	2	3	3
Warbling Vireo	5	5	2	2	27	26
Western Tanager	4	5	1	2	20	30
Western Wood-Pewee	1		1		2	
White-crowned Sparrow	5	5	5	3	144	19
Willow Flycatcher	1		1		1	
Wilson's Warbler	5	5	2	2	40	30
Yellow Warbler	4		2		15	
Yellow-rumped Warbler	5	5	1	2	28	12
Total			1000	22	2527	1196

Appendix 2. Soil characteristics of American Camp unit of SAJH.

Site Degradation Susceptibility

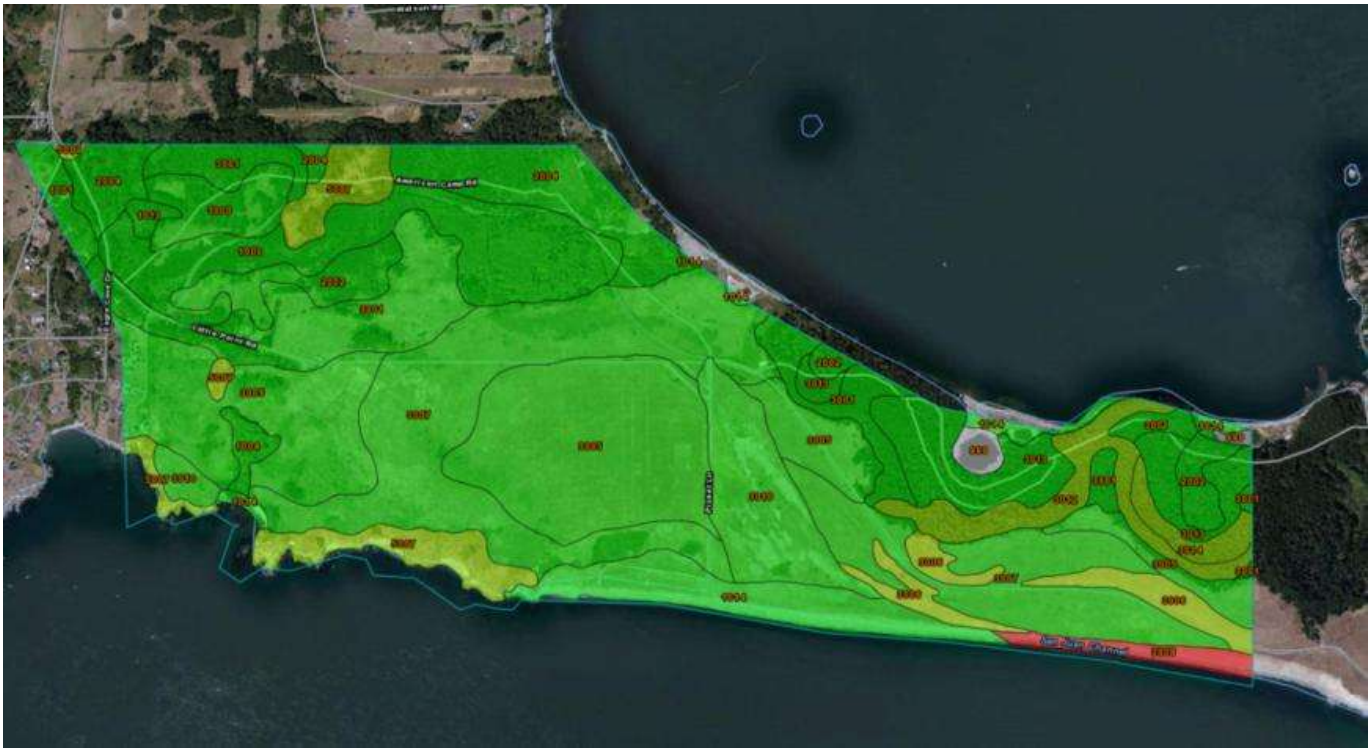
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Moderately susceptible	845.1	66.70%
Slightly susceptible	217.1	17.10%
Highly susceptible	102.8	8.10%
Null or Not Rated	68.9	5.40%

Erosion Hazard (Off-Road, Off-Trail)

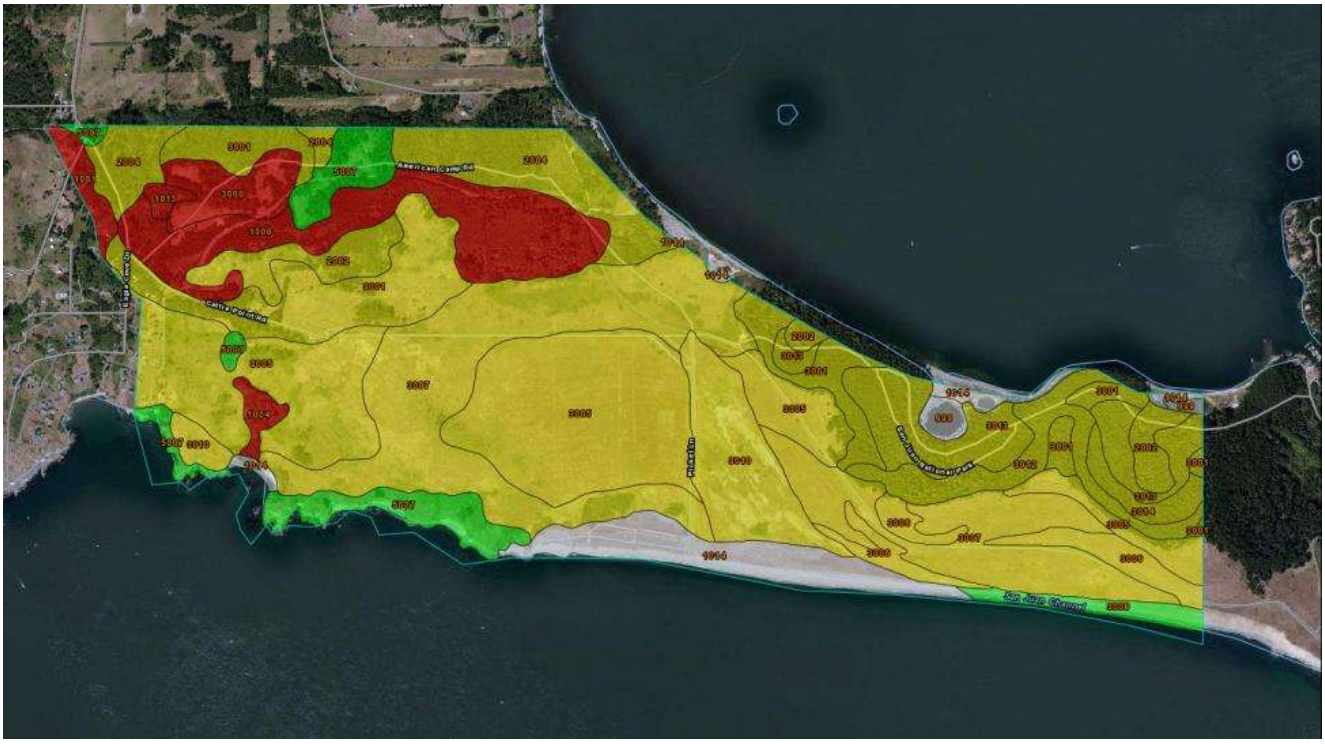
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Slight	1,065.2	84.50%
Moderate	140.1	11.10%
Very severe	13.7	1.10%
Null or Not Rated	7.4	0.60%

Soil Rutting Hazard

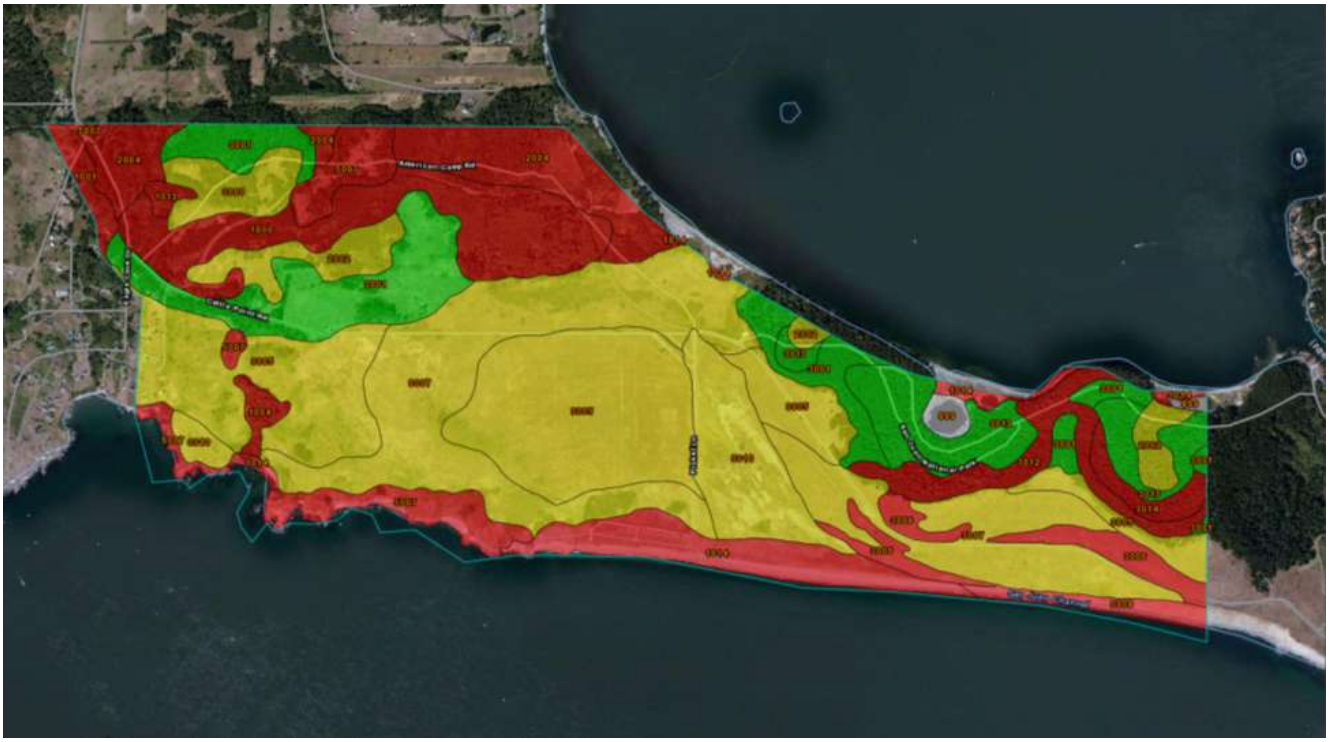
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Moderate	952.6	75.20%
Severe	142.8	11.30%
Slight	72.5	5.70%
Null or Not Rated	69.9	5.50%

Paths and Trails

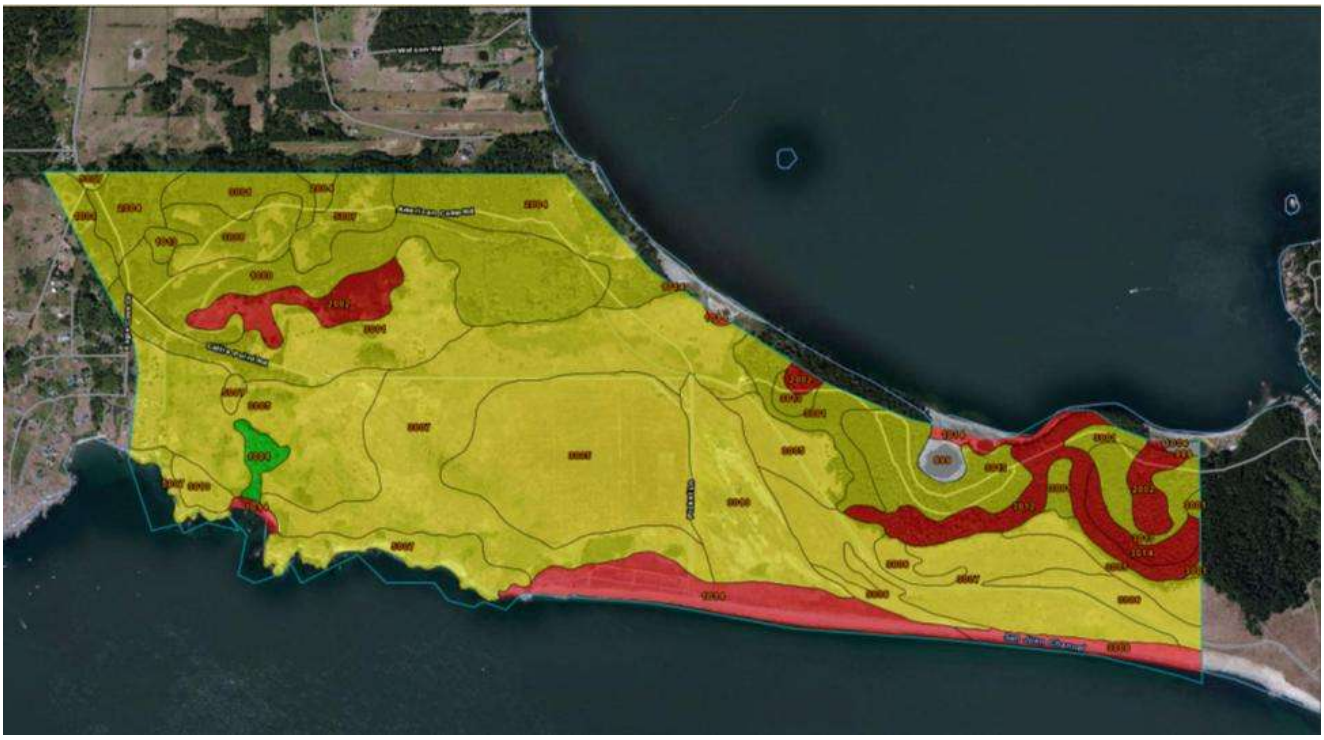
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Somewhat limited	632.4	49.90%
Very limited	412.6	32.60%
Not limited	185.3	14.60%

Fire Damage Susceptibility

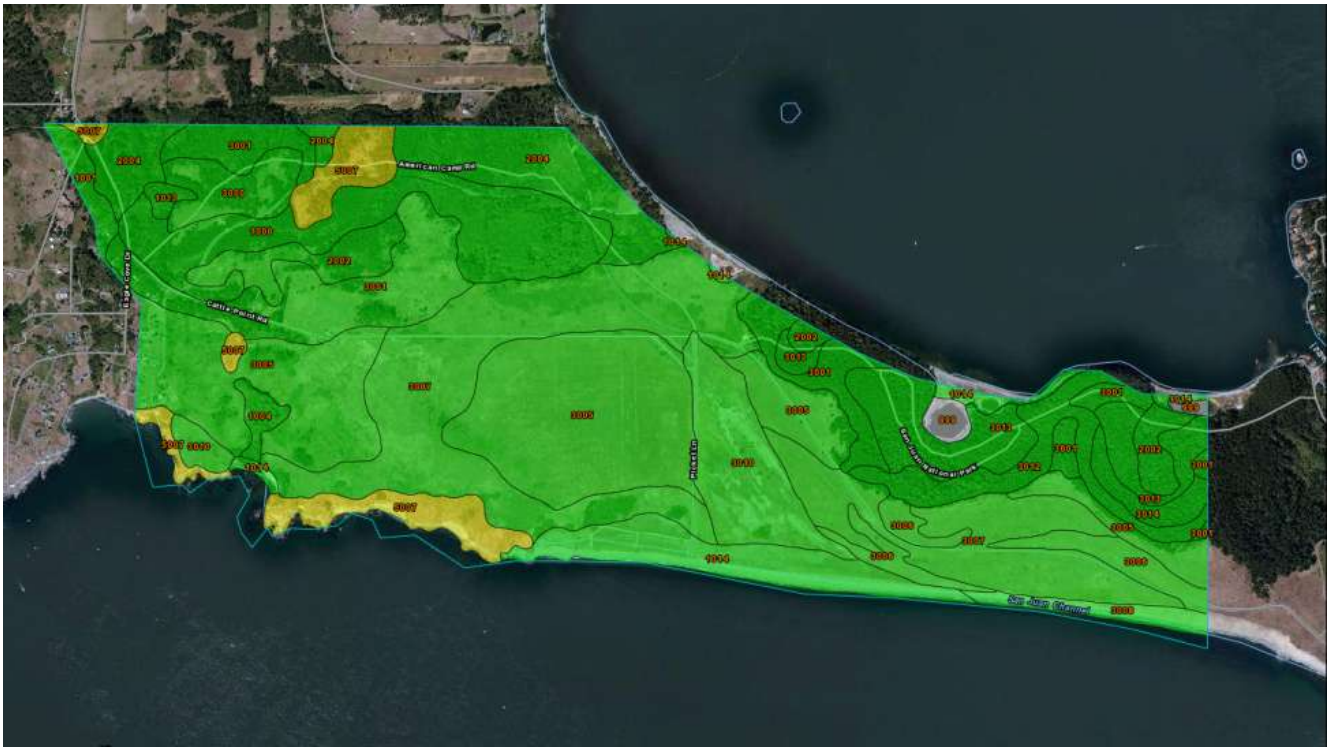
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Moderately susceptible	1,055.3	83.20%
Highly susceptible	164.3	13.00%
Slightly susceptible	6.9	0.50%
Null or Not Rated	7.5	0.60%

Soil Restoration Potential

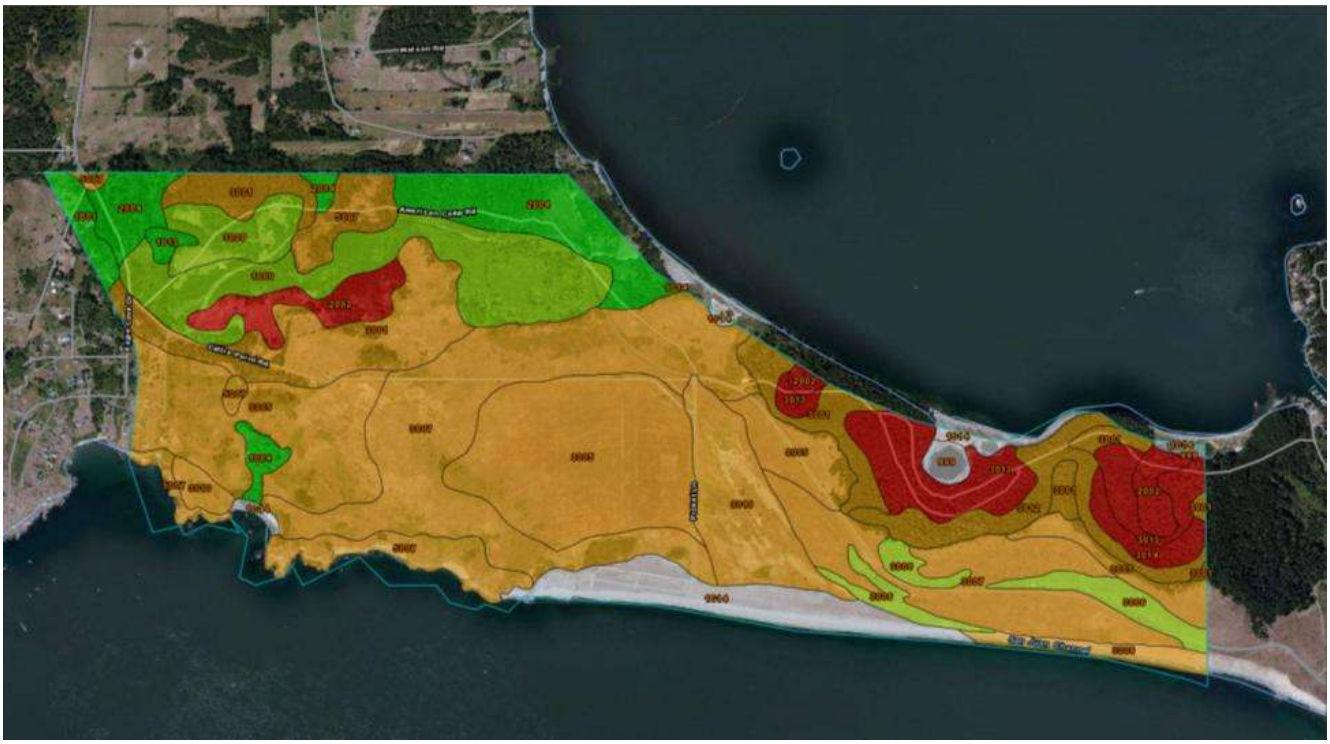
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
High potential	1,171.5	92.40%
Moderate potential	58.7	4.60%
Not Rated	7.5	0.60%
Null or Not Rated	7.5	0.60%

Nitrate Leaching Potential, Nonirrigated

Source: USDA-NRCS Web Soil Survey

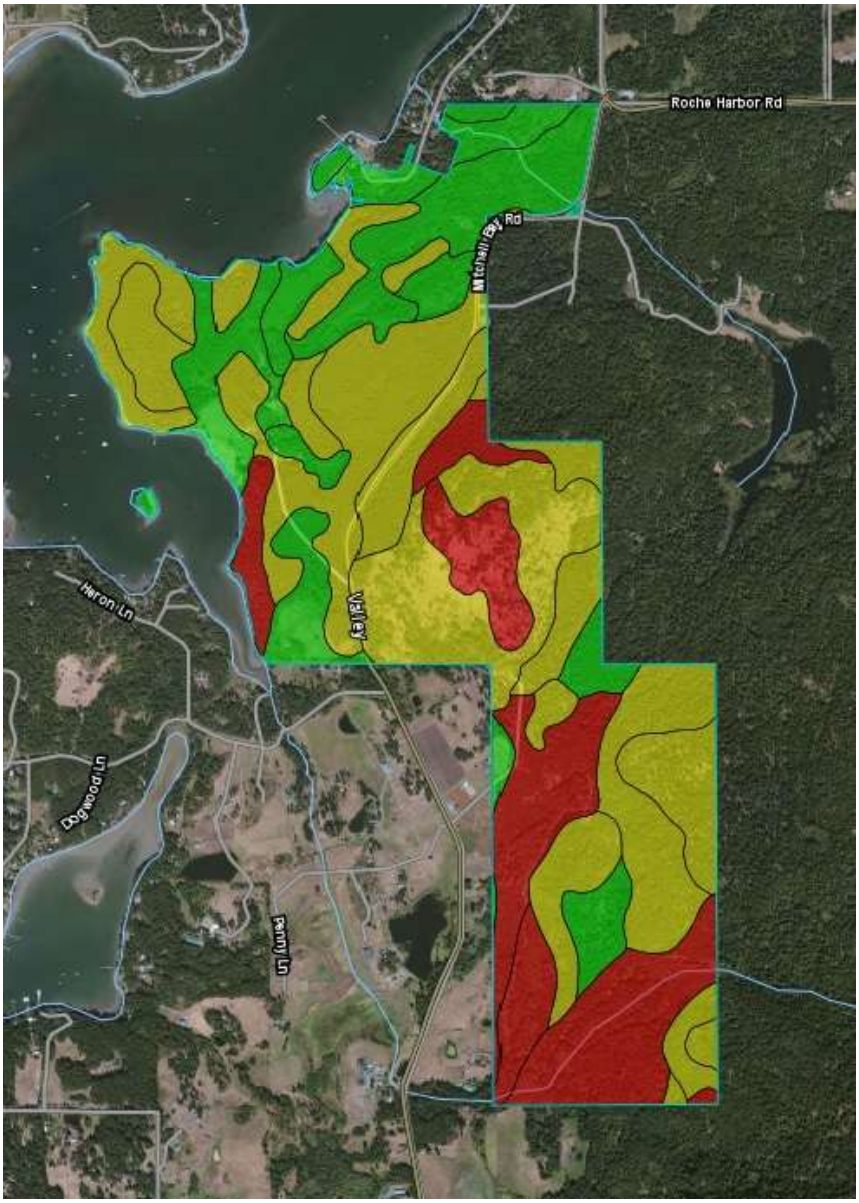


Rating	Acres	%
Moderately high	801.2	63.20%
Moderate	154.9	12.20%
High	113.0	8.90%
Low	95.9	7.60%
Null or Not Rated	68.9	5.40%

Appendix 3. Soil characteristics of the English Camp unit of SAJH.

Site Degradation Susceptibility

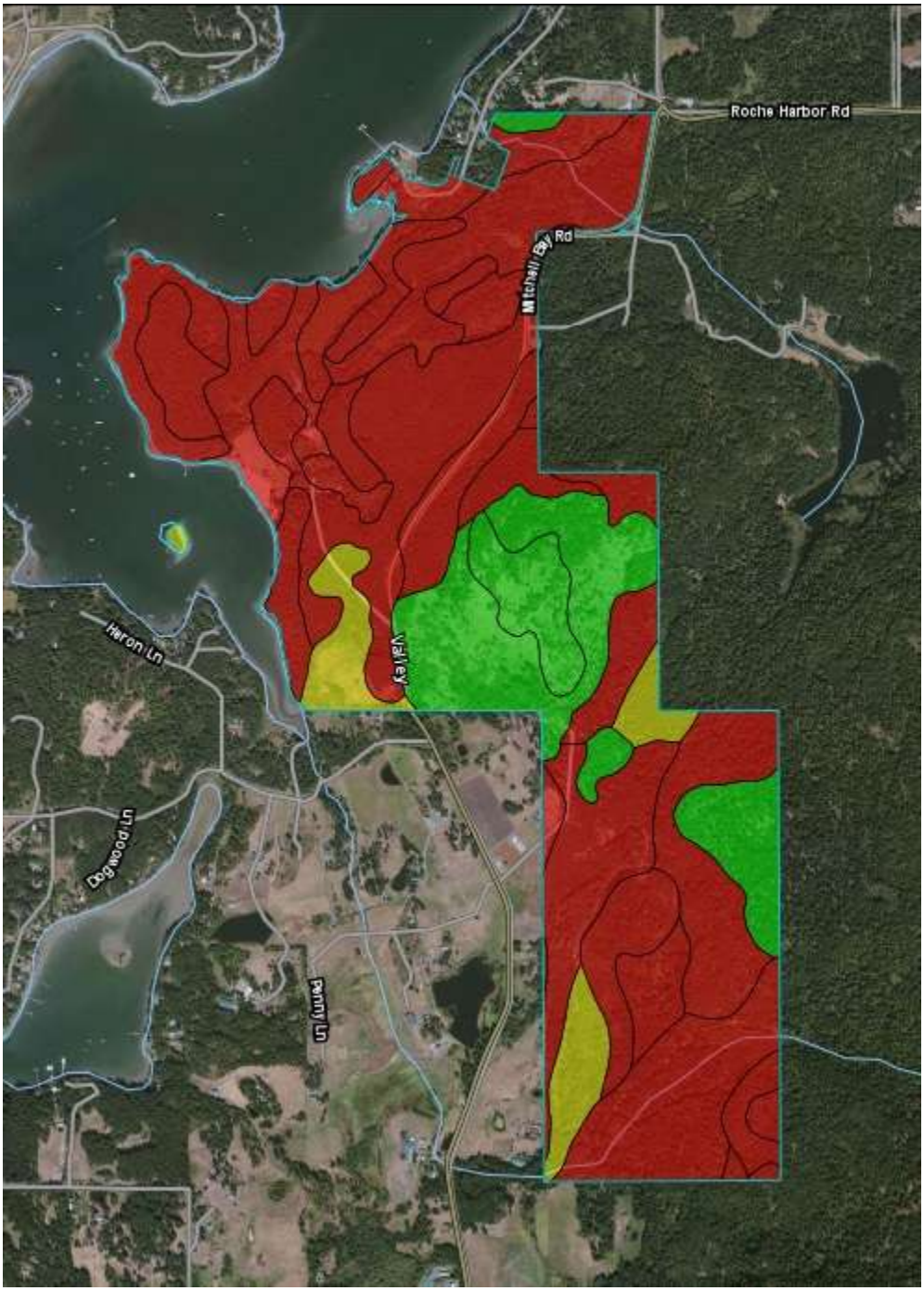
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Moderately susceptible	421.9	51.50%
Highly susceptible	193.4	23.60%
Slightly susceptible	158.2	19.30%
Null or Not Rated	6.2	0.80%

Soil Rutting Hazard

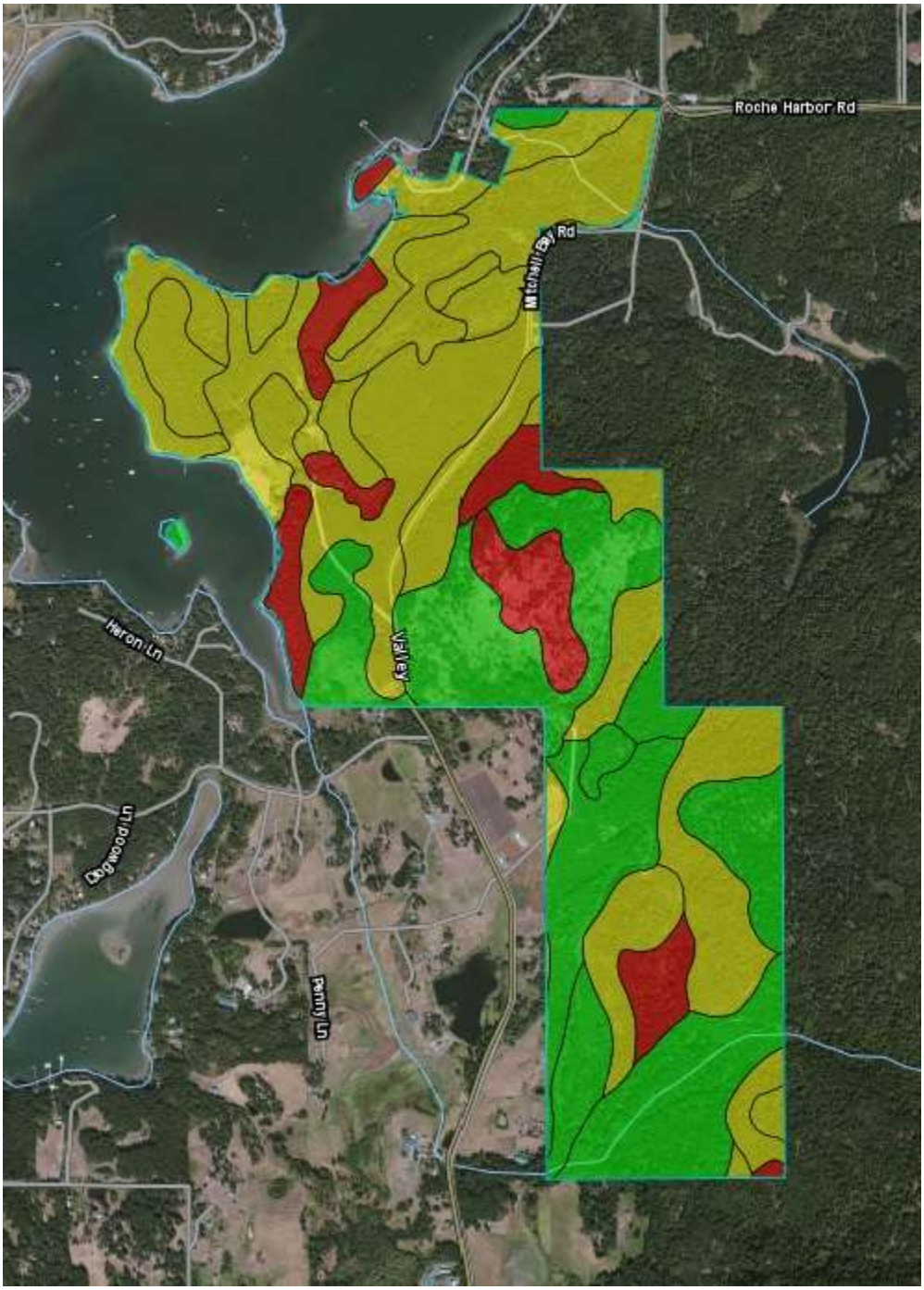
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Severe	567.6	69.30%
Slight	150.9	18.40%
Moderate	55	6.70%
Null or Not Rated	6.2	0.80%

Harvest Equipment Operability

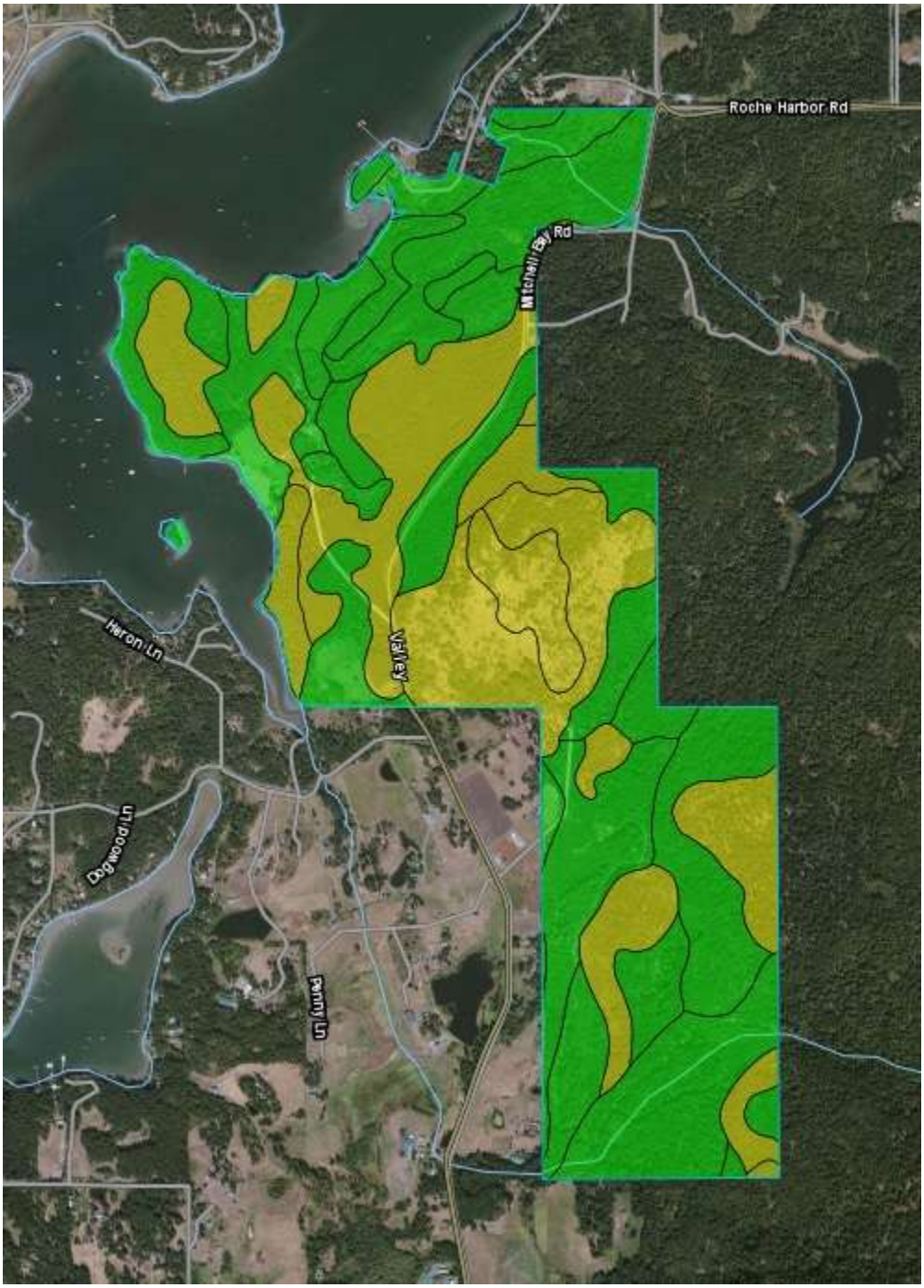
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Moderately suited	387.1	47.30%
Well suited	292.5	35.70%
Poorly suited	93.9	11.50%
Null or Not Rated	6.2	0.80%

Soil Restoration Potential

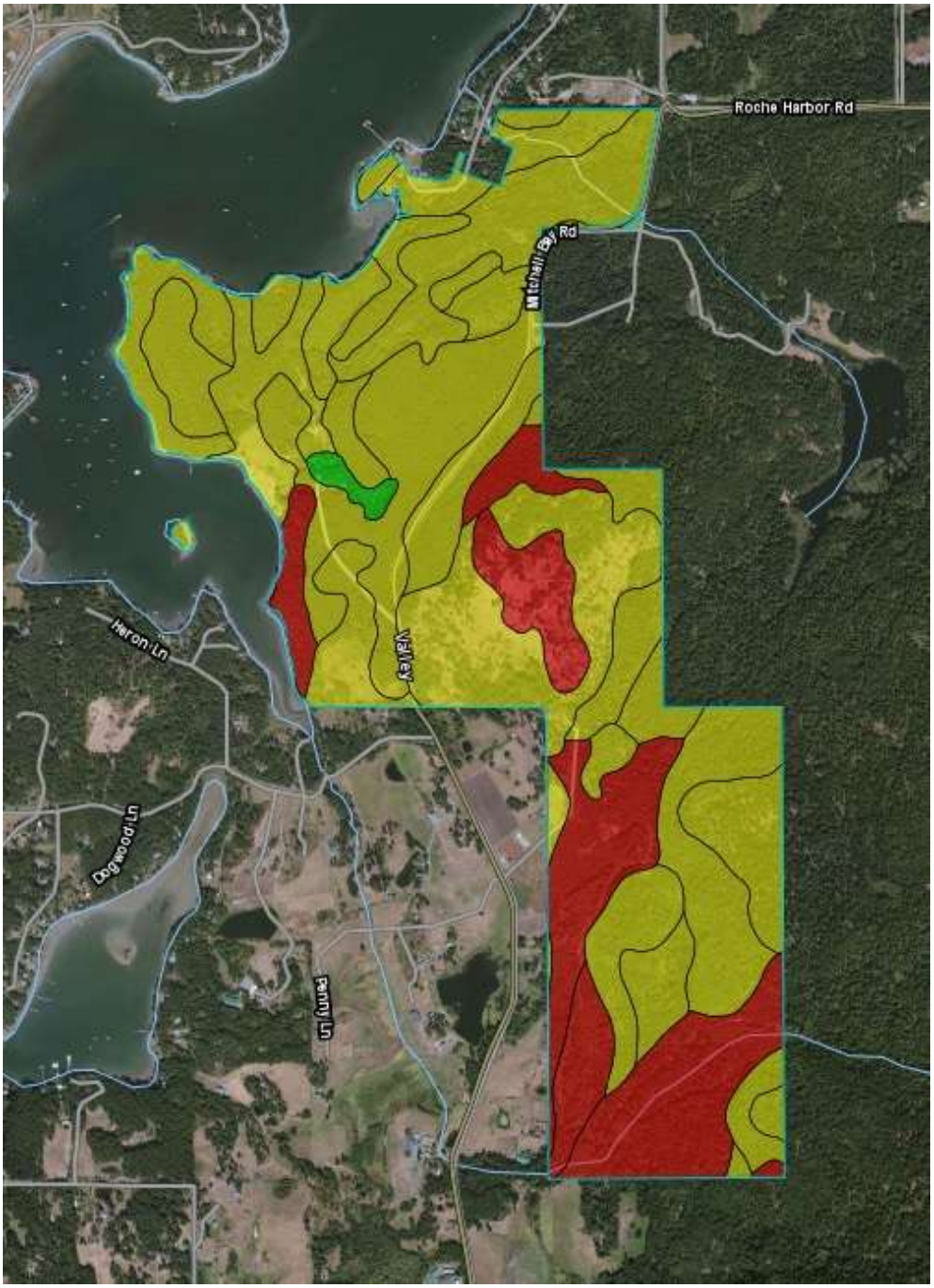
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
High potential	446.2	54.50%
Moderate potential	333.4	40.70%

Fire Damage Susceptibility

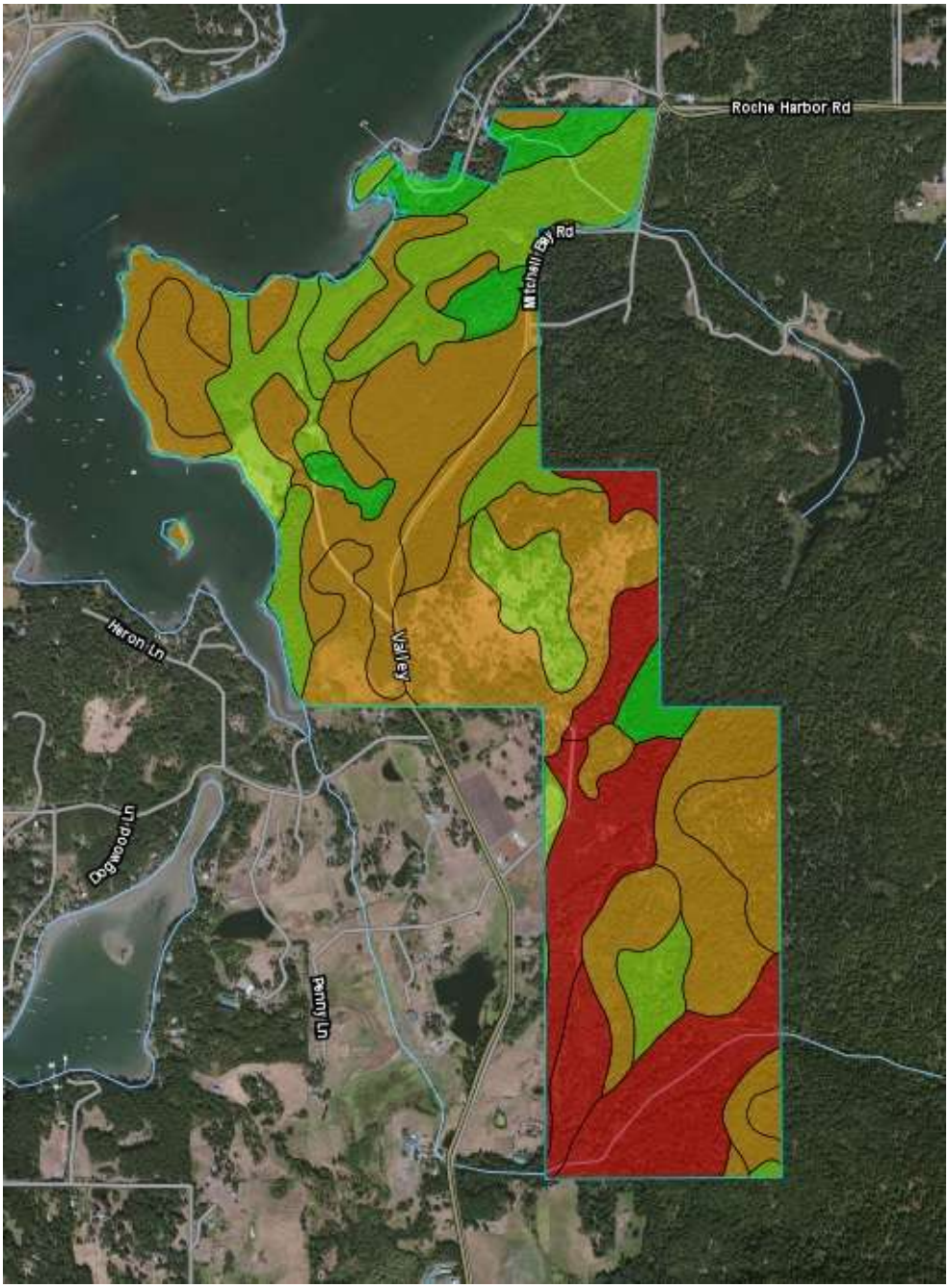
Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Moderately susceptible	572.9	70.00%
Highly susceptible	199.5	24.40%
Slightly susceptible	7.1	0.90%

Nitrate Leaching Potential, Nonirrigated

Source: USDA-NRCS Web Soil Survey



Rating	Acres	%
Moderately high	434	53.00%
Moderate	162.8	19.90%
High	153.6	18.80%
Low	23.1	2.80%
Null or Not Rated	6.2	0.80%

National Park Service

U.S. Department of the Interior

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