



# **Ebey's Landing National Historical Reserve**

## *Natural Resource Condition Assessment*

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

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[photo]

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Natural Resource Report NPS/NRSS/WRD/NRR—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 Ebey's Landing National Historical Reserve (EBLA, or "the Reserve"). This report, and the spatial datasets provided with it, is intended to inform and support Reserve managers and scientists in developing recommendations for improving or maintaining natural resource conditions in the Reserve. It also can assist Reserve resource managers in reporting on their State of the Park and developing their Resource Stewardship Strategy.

In attempts to describe the current condition and trends of the Reserve's natural resources, we followed generally the Environmental Protection Agency's "Framework for Assessing and Reporting on Ecological Condition" (Young and Sanzone 2002). Specifically, we first considered the natural resource themes ranked highest for the Reserve by local NPS staff in a prior survey. In no particular order, they are:

1. Shoreline and soil erosion
2. Groundwater flow and saltwater intrusion
3. Water quality and pesticide runoff
4. Wetlands & riparian areas
5. Habitat conversion of traditional land uses (farming, grazing, etc.)
6. Urban encroachment/rural development
7. Invasive species (plant and animal)

These are a mix of resources (e.g., #4), processes (#1), stressors (e.g., #6), and conditions (e.g., #7). Following the advice of Young and Sanzone (2002), we sought separate these different topics by type, and added other topics considered important by North Coast and Cascades Network natural resource staff. We did so by presenting them within the following framework:

- Changes in Regional and Local Climate
- Changes in Shoreline and Marine Resources (#1)
- Changes in Freshwater Resources: Water Quantity, Quality (#2, 3, 4)
- Changes in Terrestrial Vegetation and Land Cover (#5, 6, 7)
- Changes in Wildlife (#5, 6, 7)
- Changes in Air Quality
- Changes in the Natural Quality of the Reserve Experience (all)

We identified 29 indicators to evaluate these seven resource concerns. For each indicator we then attempted to define reference conditions to which we could compare present conditions. Making that comparison, we described the condition of each indicator as "Good," "Somewhat Concerning," "Significant Concern," or "Indeterminate." We described each indicator's trend as "Improving," "Somewhat Concerning," "Significant Concern," or "Indeterminate." In each instance where we applied these terms, we also described (as high, moderate, or low) the certainty associated with our estimate. 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 29 indicators, we determined that the condition of 3 indicators is Good, 9 are "Somewhat Concerning", and the following 8 are "Significant Concern" for condition and/or trend:

- Temperature
- Groundwater Levels & Quality
- Surface Water Quality
- Prairie Extent, Distribution, & Composition
- Less Common Plant Species & Communities
- Forest Composition, Structure, & Age
- Birds (seabirds, at least)
- Prairie Wildlife
- Soundscape

Information to estimate *trends* was insufficient for all but 7 of the indicators, and none of the trends calculations were considered to have a high degree of certainty.

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We thank Craig Holmquist, formerly the Reserve Manager at Ebey's Landing NHR, for his explanations of resource management concerns and tour of the area. Other National Park Service staff who helped guide this project or who provided key information included Marsha Davis, (all of NPS Pacific West Regional Office, Seattle, WA), 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. Michael Ewald analyzed the climate data and conducted the GIS tasks. Karen DuBose (Island County Environmental Health - Natural Resources) kindly facilitated access to water quality and vegetation data from the County's monitoring program.

# Chapter 1. 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 Ebey's Landing National Historical Reserve.

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)<sup>1</sup> 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;<sup>2</sup>
- employ hierarchic indicator frameworks;<sup>3</sup>
- identify or develop reference conditions/values for comparison against current conditions;<sup>4</sup>

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<sup>1</sup> formerly called a Resource Management Plan (RMP).

<sup>2</sup> The breadth of natural resources and number/type of indicators evaluated will vary by park.

<sup>3</sup> 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

<sup>4</sup> 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,



- emphasize spatial evaluation of conditions and GIS (map) products;<sup>5</sup>
- summarize key findings by park areas; and<sup>6</sup>
- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions of key resources 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 threats and stressors 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 threats and stressors, 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 and peer-reviewed. 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.

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

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alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").

<sup>5</sup> 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.

<sup>6</sup> 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.

management targets. In the near term, NRCA findings assist strategic park resource planning<sup>7</sup> and help parks to report on government accountability measures.<sup>8</sup> 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.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.<sup>9</sup> For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

For more information on the NRCA program, visit <http://nature.nps.gov/water/nrca/index.cfm>

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<sup>7</sup> An NRCA can be useful during the development of a Reserve's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

<sup>8</sup> 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.

<sup>9</sup> The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

## Chapter 2. Introduction and Resource Setting

### 2.1 Introduction

Ebey's Landing National Historical Reserve (the Reserve) is located in the center of Whidbey Island in Puget Sound, Washington (Figure 1). The 35-mile long Whidbey Island comprises 81% of Island County, and the Reserve's 13,617 land acres comprise 12.6% of the land area of Whidbey Island. Another 3955 acres within the Reserve is comprised of the marine waters of Penn Cove. About 25 miles of shoreline border the Reserve, and no place in the Reserve is more than a few miles from the shoreline.



Figure 1. Location of Ebey's Landing National Historical Reserve within the Pacific Northwest.

The Reserve is a unique entity within the National Park system because a majority of the Reserve is not owned by the National Park Service. Most (90%) of the land is in private ownership. Approximately 2,023 acres are protected with NPS-held conservation easements and 684 acres are NPS owned in fee. Coupeville, the county seat, is an incorporated community within the Reserve. The Reserve includes three state parks (Fort Ebey, Fort Casey, and Ebey's Landing), two county or municipal parks (Rhododendron, Oak Harbor Air Park), and lands owned or leased by The Nature Conservancy (Pratt Preserve) and the Whidbey-Camano Land Trust (Libbey Beach Tidelands, Krueger Farm, Ebey's Bluff access points, part of Crockett Lake) (Figure 2). The entire Reserve is a National Register historic district called the Central Whidbey Island Historic District. Unlike other National Parks which employ many resource specialists and a superintendent, the Reserve has no staff aside from a Reserve Manager. The Manager represents the National Park Service on a nine-member policy-setting Trust Board. The nine members include seven local residents (three appointed by the town of Coupeville, four appointed by Island County), and one representative each from Washington State Parks and the National Park Service. Each Trust Board member serves a four year term. The Board shares responsibility with the National Park Service in the functional areas of administration, interpretation, maintenance, land protection, and resource management.

### **2.1.1 Enabling Legislation**

The Reserve was created in 1978 to preserve the land uses and land cover that characterize the area's development from 19<sup>th</sup> century exploration to the present. For almost 150 years, humans have manipulated virtually all of the land within the Reserve, mostly for agricultural purposes. Early during this period logging was also important. The prairies and nearby lands with their rich alluvial soils and treeless character attracted early settlement. The protected harbor of Penn Cove made Coupeville an early port city in the region. A major influx of people came with the development of Fort Casey Military Reservation in the late 1890s ([http://www.nps.gov/the\\_reserve/thepeople.htm](http://www.nps.gov/the_reserve/thepeople.htm)). Ongoing agriculture continues to play a major role in the Reserve's landscape. Commercial logging is no longer practiced within the Reserve, but construction of new homes continues on a managed gradual basis within zoned private lands within and near the Reserve. In addition, a flight training facility (Coupeville Outlying Landing Field (OLF) adjoins the northeast edge of the Reserve, many commercial businesses operate within Coupeville, and commercial aquaculture (for mussels) has been pursued since 1975 in the Reserve's Penn Cove.

### **2.1.2 Geographic Setting**

The central part of Whidbey Island where the Reserve is located is characterized by broad prairies, a deep protected cove, high seaside bluffs, low rolling hills, a few shallow brackish lakes, a narrow rugged beach, and the Island's most productive farmland. The highest elevation within the Reserve is 261 feet above mean sea level, compared with a maximum elevation of 502 feet for all of Whidbey Island.

The larger region is home to more than six million people, concentrated in the major urban centers of Seattle, Washington and Vancouver, British Columbia. Admiralty Inlet, immediately west of the Reserve, is important for shipping and oil transport; the Juan de Fuca corridor is among the most active shipping areas in the world. The history of land

use on Whidbey Island as a whole was documented by White (1980), and Gilbert (1985) described some of the history of the Reserve itself. While agriculture land has diminished somewhat, residential use of the land by commuters, retirees, and vacationers is increasing. Tourism is vital to the economy both locally and statewide. Economic benefits of outdoor recreation in Washington are considerable and have recently been quantified (Briceno and Schundler 2015).



**Figure 2. General features and place names within the Reserve.** The Reserve boundary is shown as a solid green line.

### 2.1.3 Visitation Statistics

No data are available for the Reserve from the National Park Service web site for visitation statistics: <https://irma.nps.gov/Stats/Reports/National> . Visitation has not been measured in this Reserve because of its resident population and the fact that it contains lands jointly administered by different partnerships. For the only period available, Figure 3 depicts visitation statistics for Fort Casey State Park, which occupies a portion of the Reserve.

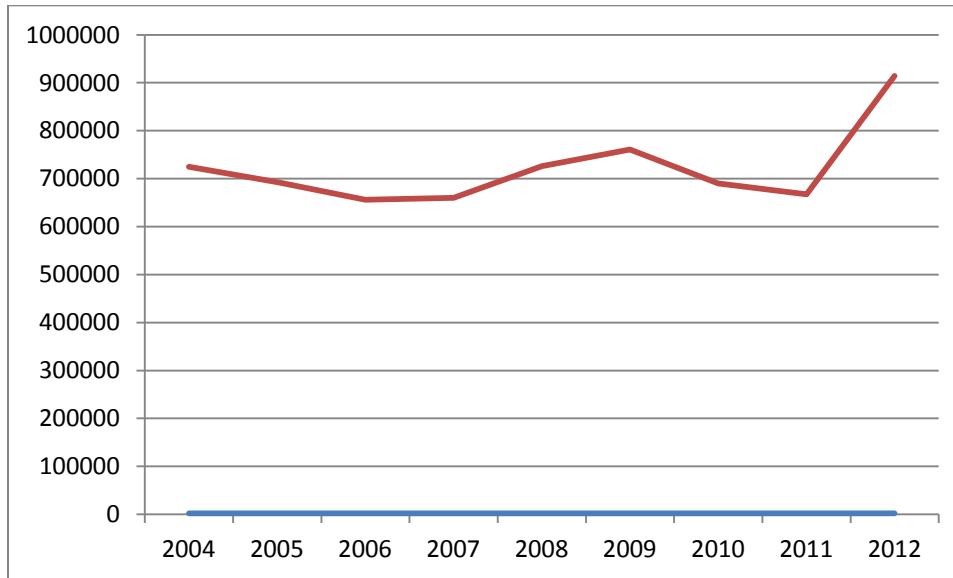


Figure 3. Visits to Fort Casey State Park, 2004 - 2012.

## 2.2 Natural Resources

### 2.2.1 Ecological Units and Watersheds

The Reserve is on Whidbey Island, Island County, Washington, 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 Reserve exists as the Georgia Basin, and the Reserve falls within Water Resource Inventory Area (WRIA) 6 as recognized by Washington State natural resource agencies. The Reserve is entirely within three USGS Hydrologic Unit Code (HUC12) subbasins. The eastern portion is within 1711001910103, most of the western portion is within 1711001911300, and a small portion in the northwest that includes Lake Pondilla is within 1711001910106.

### 2.2.2 Resource Descriptions

The closest large body of land to the west of the Reserve is the Olympic Peninsula, approximately 4 miles across Admiralty Inlet. The closest large body of land to the east is Camano Island, approximately 3 miles across Saratoga Passage. Mainland is roughly 7 miles further east.

Because of its history and unique management status, the Reserve probably includes a greater variety of land uses than do most areas managed by the National Park Service. The Reserve includes substantial areas devoted to agricultural, residential, commercial, recreational, and open space uses.

Hydrologically, a gentle ridge of high land roughly follows the long axis of Whidbey Island in a north-south direction, dividing the Reserve such that roughly half the runoff can be expected to flow westward into Admiralty Inlet and the other half eastward (and northward and southward) into Penn Cove. The Reserve has no perennial streams and only one perennial pond (Lake Pondilla). Many small channels of natural or human origin flow seasonally directly into marine waters, creating no extensive estuaries.

Coastal waters that adjoin the park support extensive beds of kelp and eelgrass that are prime habitat for many marine fish and invertebrates. A major commercial aquaculture operation for mussels exists in Penn Cove, and recreational harvest of shellfish occurs elsewhere in the Reserve. The Penn Cove shoreline contains important spawning areas for two forage fish species: surf smelt and sand lance. Several salmon species, including juvenile Chinook, regularly feed along the Reserve's shoreline. Four natural lagoons are present along the Reserve's shoreline. Lagoons are coastal ponds that receive tidal water only infrequently (Perego's Lagoon) or receive tidal water more regularly, even daily, but are largely enclosed by land (Kennedy's and Grasser's Lagoons). Lagoons are recognized by the Washington Department of Ecology as a particularly important natural feature because of their unique geochemistry and relative scarcity in Puget Sound.

Ecologically, significant portions of the Reserve contain intertidal habitat, coastal strand and bluffs, forest, wetlands, and native prairie. Prairies that once covered many areas of the region, but now are rapidly disappearing, are a key feature of the Reserve. Four of the world's 12 remaining populations of golden paintbrush (*Castilleja levisecta*) occur within the Reserve's remaining prairie. Three other plants considered to be rare in Washington currently occur in the Reserve: *Plectritis brachystemon*, *Sericocarpus rigidus*, and *Silene scouleri* ssp. *scouleri*. In addition, the Reserve supports 3 plant associations considered to be "critically imperiled" in Washington and 9 considered to be "imperiled." Considering the fact that the Reserve occupies only 13% of Whidbey Island, it is noteworthy that it supports at least one-quarter of the Island's known flora.

The Reserve is also faunally diverse. At least 85% of the bird species known to occur on Whidbey Island have been documented from the Reserve. Crockett Lake, a diked coastal lagoon, is of continental importance as a concentration area for migratory shorebirds. Only one of the Reserve's bird species is currently listed federally as Threatened or Endangered. That is the marbled murrelet, which does not nest in the Reserve (due to lack of old-growth forest which they require), but feeds regularly in marine waters adjoining it. The Reserve's shorelines near Keystone and Fort Casey have supported exceptional numbers of several regionally-declining loon, grebe, and alcid species. As well, exceptional concentrations of sea ducks (e.g., scoters), western grebe, and black turnstone have been recorded from Penn Cove. The Reserve's prairies support nesting

northern harrier, a raptor species that appears to be declining in much of western Washington.

### **2.2.3 Resource Issues Overview**

Because of the proximity to marine waters, local geology, and the fact that yields of some wells in and near the Reserve are already low, the greatest water resource concern is intrusion of saltwater into groundwater used for drinking. Water quality is also a significant concern, due to enriched runoff from agricultural and residential areas and proximity to rich and productive shellfish beds. Ebey's Prairie has the highest levels of nitrate runoff of any place in Island County.

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. Agricultural and residential land uses continue within the Reserve as an essential part of its establishment agreement, while occasional conflicts with preservation objectives are sometimes challenging to resolve. Throughout the Reserve, several invasive plant species have likely reduced the diversity of native prairie, wetland, and woodland plant communities. The unique flora and fauna of the park's prairie and oak woodlands depends on regular fires to set back succession, but decades without major fires have allowed other habitat types to become more dominant.

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.

## **2.3 Resource Stewardship**

### **2.3.1 Management Directives and Planning Guidance**

The Reserve has completed its General Management Plan (NPS 2006) which provides guidance for decisions regarding management of natural and cultural resources, visitation, and development for the next 15 to 20 years. Among many goals stated in the Plan, the following are most pertinent to natural resources:

- Natural resource conditions in the Reserve are maintained for natural processes and healthy ecosystems.
- Natural landscapes of bluffs and beaches are maintained in natural conditions with minimal structural intrusions.

In addition, Central Whidbey state parks, including those within the Reserve, were the focus of a more recent plan (Washington State Parks and Recreation Commission 2008).

### **2.3.2 Status of Supporting Science**

Existing information on coastal water resources and watershed conditions in the Reserve was compiled by Klinger et al. (2007). An inventory of the park's flora has been completed (Rocheft 2010) and publication is anticipated soon of maps depicting vegetation associations. Amphibians were inventoried for the NPS by Samora et al.



(2013). No systematic surveys have been conducted of intertidal invertebrates, seaweeds, marine birds, marine mammals, terrestrial mammals, reptiles, or butterflies and other terrestrial invertebrates. Monitoring of visibility and air quality has been very limited, and there has been no systematic monitoring of dark night sky or the park's soundscape.

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## **Chapter 3. Study Scoping, Design, and Implementation**

### **3.1 Preliminary Scoping**

This is one of two NRCA reports prepared under a contract with the National Park Service. The other report pertains to San Juan Island National Historical Park. The assessments began in November 2012 with a scoping workshop at the Ebey's Landing headquarters on Whidbey Island, Washington. The workshop included the Oregon State

University study team and members of the NPS Project Oversight Committee<sup>10</sup>. The investigators then traveled to San Juan Island National Historical Park and discussed issues there.

The technical lead for this project was Dr. Paul Adamus, ecologist, Oregon State University. The vegetation chapter was written by Peter Dunwiddie with contributions from Chris Chappell. The climate change chapter was written by Paul Adamus and Anna Pakenham with data analysis support from Michael Ewald, who also conducted all the GIS tasks. Tonnie Cummings of the National Park Service wrote much of the Air Quality chapter. The remainder of the report was written by Paul Adamus. Flaxen Conway, director of the Marine Resource Management program at Oregon State University, administered the project.

## **3.2 Study Design**

### **3.2.1 Analysis Framework, Focal Resources, and Indicators**

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

- Land-use changes in parts of the Reserve not owned by NPS
- Endangered plants
- Prairie restoration
- Changes in visibility due to airborne particulate matter
- Exotic plants

More recently, natural resource issues in the Reserve were prioritized by the National Park Service staff involved with the Reserve, using a structured input process with stakeholders. In no particular order, the 12 "focal themes" that were ranked highest (3 on a scale of 0 to 3) from a list of 48 themes considered potentially applicable to resource lands in this region were:

- Urban encroachment/rural development
- Habitat conversion (farms, logging, etc.)
- Wetlands & riparian areas
- Traditional land uses (historic, farming, grazing, etc.)
- Invasive species (plant and animal)
- Areas with evidence of invasive plant or animal species
- Shoreline erosion
- Soil erosion
- Water quality

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<sup>10</sup> 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

- Pesticide runoff
- Saltwater intrusion
- Groundwater flow

### **3.2.2 Reporting Areas**

Given the relatively small size of this park, we assessed all indicators at the Reserve scale, although connections to conditions outside the Reserve were noted where supported by previously published analyses. Depending on the indicator being examined, we used either Whidbey Island or Island County as the contextual frame of reference for these comparisons.

### **3.2.3 General Approach and Methods**

At the outset of this project, an attempt was made to identify and obtain all documents relevant to resource concerns at the Reserve. Documents were identified primarily through the NPS's IRMA (Integration of Resource Management Applications) automated literature retrieval system. We augmented that database using online search engines (Web of Science, Google Scholar) to identify newer publications from the Reserve, as well as for locating relevant documents pertaining to the region surrounding the Reserve, searching with phrases such as "Island County", "Whidbey Island", "Penn Cove", "Coupeville". We obtained complete digital copies (PDFs) of several publications that reported relevant research results from the Reserve and surrounding region. We then indexed all digital documents in an Excel spreadsheet so they could be sorted by topic and year.

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. 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.

In developing the list of indicators and specific measures, we considered some basic criteria for useful ecological indicators as provided by 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." Indicators need to be based on probability distributions whenever possible to capture the natural range of variation in conditions, and we have attempted to do that whenever possible. We evaluated the indicators we chose by assigning qualitative descriptors as follows:

**Condition:** Good, Somewhat Concerning, Significant Concern, or Indeterminate.

**Trends:** Improving, Somewhat Concerning, Significant Concern, or Indeterminate.

**Certainty:** High, Medium, or Low.

We defined these terms in the context of each specific resource or issue we evaluated.

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## Chapter 4. Natural Resource Conditions and Trends

This chapter is organized according to the key resource concerns faced by Ebey's Landing National Historical Reserve. This includes all the resource concerns identified previously by NPS scientists as well as additional ones based on our professional judgment.

- Regional and Local Climate
- Nearshore Resources
  - Shoreline erosion
- Freshwater Resources: Water Quantity, Quality
  - Wetlands & riparian areas
  - Water quality
  - Pesticide runoff
  - Saltwater intrusion
  - Groundwater flow

- Vegetation
  - Urban encroachment/rural development
  - Habitat conversion (farms, logging, etc.)
  - Wetlands & riparian areas
  - Invasive species (plant)
- Wildlife
  - Invasive species (animal)
- Air Quality
- Natural Quality of the Reserve Experience
  - Urban encroachment/rural development

Within this chapter, each focal issue or resource is described using the following structure:

- Background
- Regional Context
- Issues Description
- Indicators and Criteria to Evaluate Condition and Trends
  - Criteria
  - Condition and Trends
- Data, Methods, and Sources of Expertise
- Literature Cited

At the beginning of each resource assessment, we provide a brief summary condition statement and color-coded symbol to indicate the current condition and trend. The symbol also indicates the level of our certainty in the reported condition or trend. Narrative descriptions, maps, graphs, and summary tables are used to help support each assessment finding.

## **4.1 Regional and Local Climate**

### ***4.1.1 Background***

Temperature profoundly influences the metabolism and survival of all species, as well as 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 the habitat they ultimately provide to many organisms.

### ***4.1.2 Regional Context***

The Reserve is dominated by a mild and modified Mediterranean climate, in part because it is surrounded on all sides by marine water. It lies within 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 Reserve's unique character. Annual precipitation in the Reserve

during the period 1971-2000 averaged only 21.48 inches (546 mm) per year (Table 1). Compared with other northern Puget Sound locations, the summers on Whidbey Island are short and cool with very little precipitation, and the winters are mild and moderately dry. Most precipitation falls during November through January (Table 1). In Island County generally, the growing season (daily minimum temperature  $>0^{\circ}\text{C}$  most years) is 206 days (NRCS 2008). An average of 255 days per year have cloud cover, while on average, only 43 days have clear skies. Snowfall occurs occasionally, but most winter precipitation falls as rain. In general, the prevailing winds are from the south-southeast in winter and west-northwest in summer.

Table 1. Monthly precipitation and temperature for the Reserve, averaged for years 1971-2000.

Data source: PRISM 30-year climate normals, <http://oldprism.nacse.org/index.phtml>

Indicator	Month	Min	Max	Mean	Median	First Quartile	Third Quartile
Precipitation: Monthly Total (mm)	January	61.9	66.1	64.5	64.5	64.2	64.9
	February	45.0	47.3	46.4	46.5	46.3	46.7
	March	46.4	48.7	47.8	47.8	47.6	48.0
	April	40.8	42.6	41.9	41.9	41.8	42.1
	May	41.5	43.3	42.4	42.4	42.3	42.7
	June	33.8	35.3	34.7	34.7	34.6	34.8
	July	24.7	25.3	25.0	25.0	24.9	25.1
	August	22.5	23.3	23.0	23.0	22.9	23.1
	September	30.2	32.1	31.5	31.6	31.4	31.7
	October	41.5	45.0	43.4	43.4	43.1	43.7
	November	72.2	77.9	75.1	75.0	74.5	75.5
	December	68.6	71.2	69.9	69.8	69.6	70.2
	TOTAL:	529.2	557.8	545.6	545.6	543.0	548.5
Temperature: Monthly Maximum ( $^{\circ}\text{C}$ )	January	7.3	7.7	7.5	7.5	7.4	7.7
	February	9.0	9.5	9.2	9.2	9.1	9.4
	March	11.2	11.5	11.4	11.4	11.3	11.5
	April	13.4	14.2	13.9	13.9	13.8	14.0

Indicator	Month	Min	Max	Mean	Median	First Quartile	Third Quartile
	May	16.5	17.2	16.9	17.0	16.9	17.0
	June	18.6	19.6	19.2	19.3	19.1	19.3
	July	20.7	22.4	21.6	21.6	21.4	21.8
	August	21.1	22.5	22.0	22.1	21.9	22.2
	September	19.0	20.0	19.6	19.6	19.5	19.7
	October	14.1	14.8	14.6	14.6	14.6	14.7
	November	9.8	10.2	10.0	10.0	9.9	10.1
	December	7.1	7.6	7.4	7.4	7.3	7.5
Temperature: Monthly Minimum (°C)	January	1.5	1.7	1.6	1.6	1.6	1.7
	February	2.1	2.5	2.3	2.3	2.2	2.4
	March	3.2	3.4	3.3	3.3	3.3	3.4
	April	4.9	5.1	5.0	5.0	4.9	5.0
	May	7.4	7.7	7.5	7.5	7.5	7.6
	June	9.4	9.8	9.6	9.6	9.5	9.7
	July	10.6	11.4	11.0	11.0	10.8	11.2
	August	10.7	11.6	11.1	11.1	10.9	11.4
	September	8.7	9.7	9.2	9.2	8.9	9.4
	October	5.9	6.6	6.3	6.3	6.1	6.4
	November	3.6	3.8	3.7	3.8	3.7	3.8
	December	1.7	1.9	1.8	1.8	1.8	1.9

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).

During the last 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 have 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 21<sup>st</sup> century and beyond (Snover et al. 2013a, b). 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 approximately 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 (Littell et al. 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, ICDPCD 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. 2013a, b; Kunkel et al. 2013).



Little or nothing can be done within the Reserve to measurably affect global, regional, and local climate. However, improved knowledge of past, present, and anticipated future changes can help resource planning efforts.

#### **4.1.4 Indicators and Criteria to Evaluate Condition and Trends**

Temperature and precipitation are the two indicators of climate change we focused on. We performed a trends analysis of these. Temperature and precipitation data for the National Weather Station in Coupeville, covering only Water Year 2010, were plotted and summarized by Baccus & Huff (2012). We used monthly grids of mean maximum and minimum temperature and total precipitation to assess the spatial variability in annual and seasonal (winter, spring, summer, and fall) conditions for the Reserve during the period 1971-2000. Again, these statistics are not based on actual measurements but rather on spatially interpolated estimates from the 400-m resolution gridded monthly climate normals generated by the PRISM Climate Group models at Oregon State University (Daly et al. 2008; Daly et al. 2009). We also used 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.

From data based on actual measurements, we calculated trends for the Coupeville weather station within the Reserve as well as for two others in the vicinity that have sufficient long-term data. Those were Port Townsend (about 4 miles west of the Reserve), and Anacortes station (about 17 miles north) (Davey et al. 2007). We analyzed those two additional stations due to minor gaps in coverage for the Coupeville station, but it should be understood that their conditions may not represent conditions in the Reserve as accurately as the Coupeville station. The "full time series" for the Coupeville station is the period 1895-2013 (with some data gaps from 1910 to 1924, 88% coverage). The "full time series" for the Port Townsend station is the period 1891-2013 (with only 1896 missing). The "full time series" for the Anacortes station is the period 1905-2013 (no data gaps).

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 CLIVAR<sup>11</sup> Expert Team on Climate Change Detection and Indices developed a suite of indices (Table 2) 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 CLIVAR team 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

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<sup>11</sup> CLIVAR= Climate and Ocean Variability, Predictability, and Change, a project of the World Climate Research Programme (WCRP)

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 2.** The 27 core climate indices from CLIVAR Expert Team on Climate Change Detection and Indices (Karl et al. 1999, Peterson 2005).

Code	Indicator name	Definitions	Units
<b>Temperature Indices</b>			
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 31 Dec) 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
<b>Precipitation Indices</b>			
RX1day	Max 1-day precipitation	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily	Annual total precipitation divided by the	Mm/

Code	Indicator name	Definitions	Units
	intensity index	number of wet days (defined as PRCP $\geq$ 1.0mm) in the year	day
R10	Number of heavy precipitation days	Annual count of days when PRCP $\geq$ 10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PRCP $\geq$ 20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PRCP $\geq$ 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 $\geq$ 1mm	Days
R95p	Very wet days	Annual total PRCP when RR $>$ 95 <sup>th</sup> percentile	mm
R99p	Extremely wet days	Annual total PRCP when RR $>$ 99 <sup>th</sup> percentile	mm
PRCPTOT	Annual total wet-day precip	Annual total PRCP in wet days (RR $\geq$ 1mm)	mm

### ***Criteria***

Temperature and precipitation data are insufficient to quantify reference conditions appropriate for this Reserve, so qualitative statements will define the trends, not the condition. A rating of “Good” would describe a situation where all the indices in Table 2 remain close to their 100-year historical condition. “Somewhat Concerning” and “Significant Concern” situations would be defined based on the amount of deviation and the number of indices that deviate from their 100-year historical condition in the Reserve.

#### **4.1.4.1 Temperature**

### ***Condition and Trends***

Condition: *Indeterminate*

Trend: *Significant Concern - Moderate Certainty.*

Trends found to be statistically significant ( $p < 0.10$ ) are as follows (unmentioned indices from Table 2 can be assumed to not be statistically significant):

- From the late 1800s to present, annual mean daily **mean** temperature is increasing by 0.01°C per year (Anacortes, Port Townsend) for the full time series. From 1971 to present, annual mean daily mean temperature is increasing at a faster rate of 0.04 °C per year.
- From the late 1800s to present, annual mean daily **minimum** temperature is increasing by between 0.01 °C and 0.02 °C per year (at Anacortes, Coupeville, and Port Townsend) for the full time series. From 1971 to present, annual mean daily minimum temperature is increasing at a faster rate, 0.03 °C per year.
- From the late 1800s to present, annual mean daily **maximum** temperature is increasing by 0.01°C per year (Port Townsend) for the full time series. From 1971

to present, annual mean daily maximum temperature is increasing at a faster rate of 0.04 °C per year at the Anacortes station.

- The annual maximum minimum daily temperature (TN<sub>x</sub>) increased at all 3 stations. From the late 1800s to present, TN<sub>x</sub> has been increasing by between 0.005 °C and 0.016 °C per year. From 1971 to present, the rate of increase has increased from between 0.02 °C to 0.08 °C per year. Port Townsend has seen the most dramatic rate increase.
- Both the TX<sub>n</sub> (monthly minimum value of daily maximum temperature) and TX<sub>x</sub> (monthly maximum value of daily maximum temperature) have increased at Port Townsend by 0.01 °C per year across the full time series.
- The monthly minimum value of daily minimum temperature (TN<sub>n</sub>) has increased at Anacortes (0.02 °C per year), Coupeville (0.01 °C per year), and Port Townsend (0.01 °C per year) across the full time series. From 1971 to present, Anacortes and Coupeville have increased by 0.05 °C per year and 0.08 °C per year, respectively.
- The number of cool days (TX < 10<sup>th</sup> percentile) declined at all stations in both the full time series and from 1971 to present.
- The number of cool nights (when TN < 10<sup>th</sup> percentile) declined at Anacortes, Coupeville, and Port Townsend, by (respectively) 0.09 days per year, 0.04 days per year, and 0.07 days per year across the full time series. From 1971 to present, the same stations declined by 0.01 days per year, 0.03 days per year, and 0.07 days per year.
- The annual number of frost days (daily minimum temperature < 0 °C) is decreasing by 0.1 days per year across the full time series. From 1971 to present, FD0 is decreasing between 0.3 and 0.6 days per year. The trends are significant for all 3 stations and for the full time series and from 1971 to present.
- The annual number of ice days (daily maximum < 0 °C) has declined by 0.017 days per year across the full time series.
- Cold spells (>5 consecutive days when TN < 10<sup>th</sup> percentile) became shorter by 0.13 days per year at the Anacortes station across the full time series.
- Warm spells (>5 consecutive days when TX > 90<sup>th</sup> percentile) became longer by between 0.06 days per year at the Port Townsend station across the full time series.
- The annual number of summer-like days (daily maximum > 25° C) increased 0.08 days per year, but only at Port Townsend and only across the full time span. From 1971 to present the Anacortes station shows a stronger positive trend of 0.28 days per year.
- The number of warm days (TX > 90<sup>th</sup> percentile) at Port Townsend increased by 0.05 days per year across the full time series. From 1971 to present, Anacortes and Port Townsend increased by 0.13 days per year and 0.08 days per year, respectively.
- The number of days with warm nights (TN > 90<sup>th</sup> percentile) increased at all stations in both the full time series and from 1971 to present.
- Growing season length increased by 1.008 days per year at Anacortes from 1971 to present.

- The diurnal temperature range (DTR), or the monthly mean difference between daily max temperature and daily minimum temperature, has decreased by 0.01 °C per year for the Anacortes station across the full time series. From 1971 to present, Coupeville and Port Townsend have decreased by 0.03 °C per year.

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 as well as trends within the 1971 to present period that was the other part of our analysis. During that recent period, from 1977 onward the PDO was positive and that could account for some of the warming trends that we found. While the PDO is a natural phenomenon, the degree to which it is influenced by human activities globally and regionally has not been determined precisely. After using the North Pacific Index (NPI) to summarize variability of both the PDO and El Niño, Mote et al. (2003) regressed the NPI with temperature data covering a much larger region and found that NPI accounted for about 40% of the 20th century warming trend in winter months, but had very little influence over the trends observed in other seasons (all of which contribute to the average annual temperature).

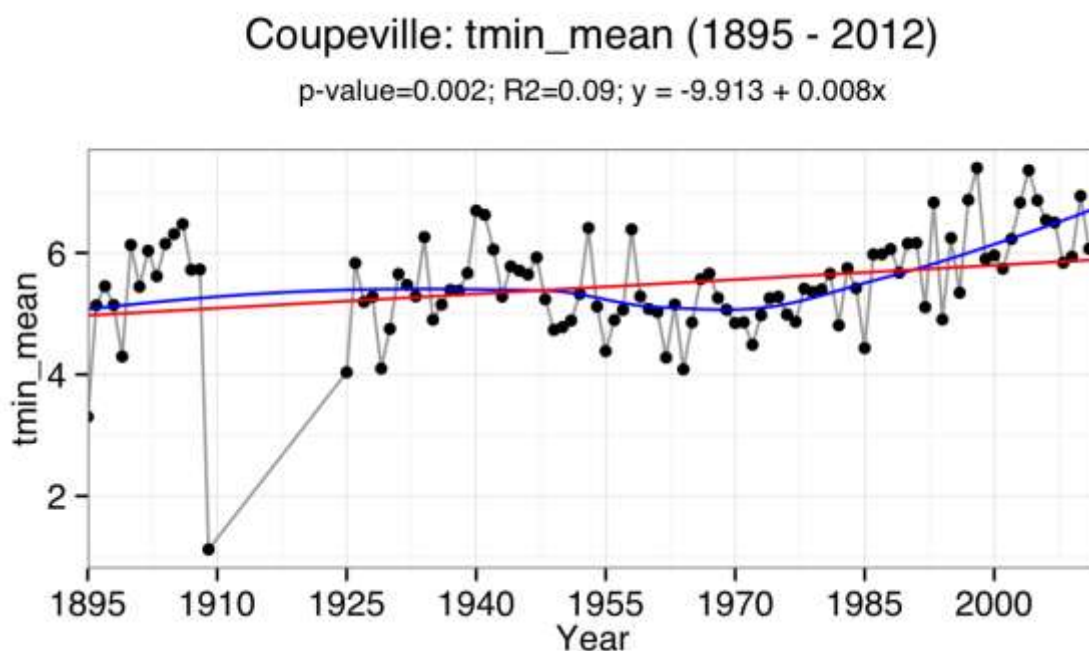


Figure xx. Annual mean daily minimum temperature, 1895-2012

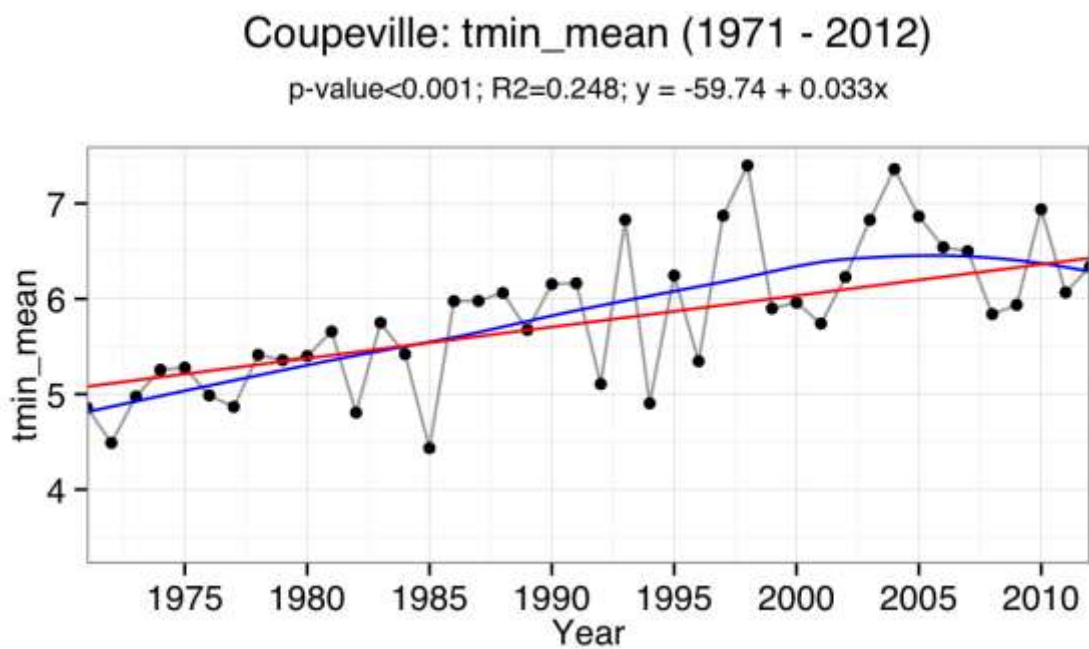


Figure xx. Annual mean daily minimum temperature, 1971-2012

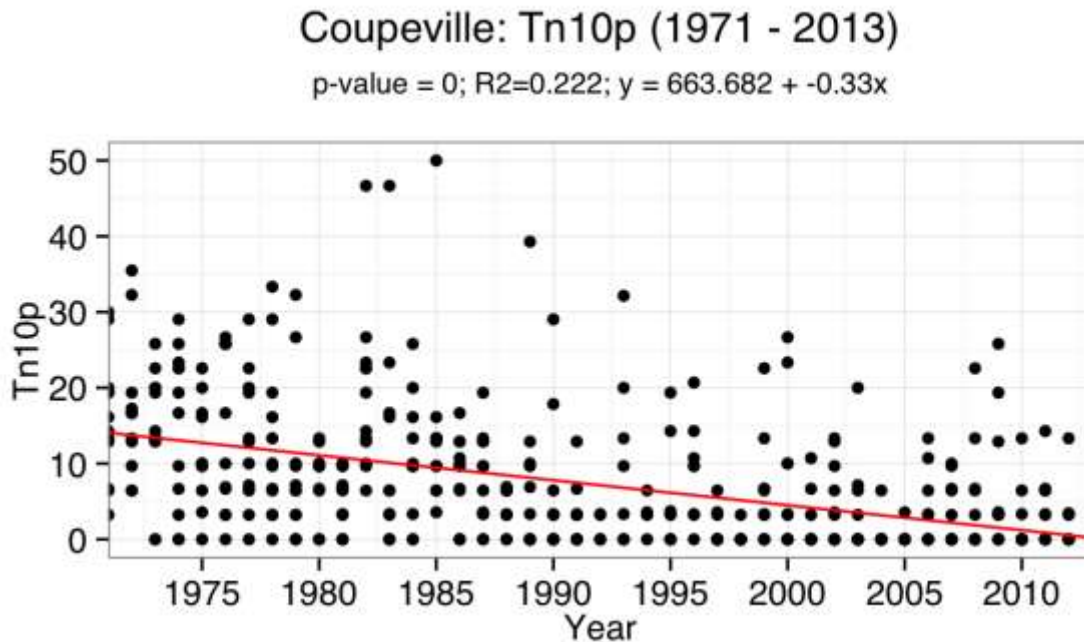


Figure xx. Number of days with cool nights (when temperature < 10<sup>th</sup> percentile), 1971-2013.

#### 4.1.4.2 Precipitation

##### ***Condition and Trends***

Condition: *Indeterminate*

Trends: *Good - Low Certainty*. For the Reserve specifically, our historical compilations of precipitation are summarized in Table 1. The only statistically significant trend we found was an increase in total precipitation of 0.86 mm per year at the Coupeville station, across the full time series. The "full time series" for precipitation at the Coupeville station is the period 1896-2012 (with data gaps scattered across the period, resulting in 68% coverage). The other stations did not have significant trends for any precipitation index. In 2007 a precipitation monitoring station was established in the Reserve's watershed as part of the AgWeatherNet operated by Washington State University. Not enough data have been collected yet to compute meaningful trends from this new station.

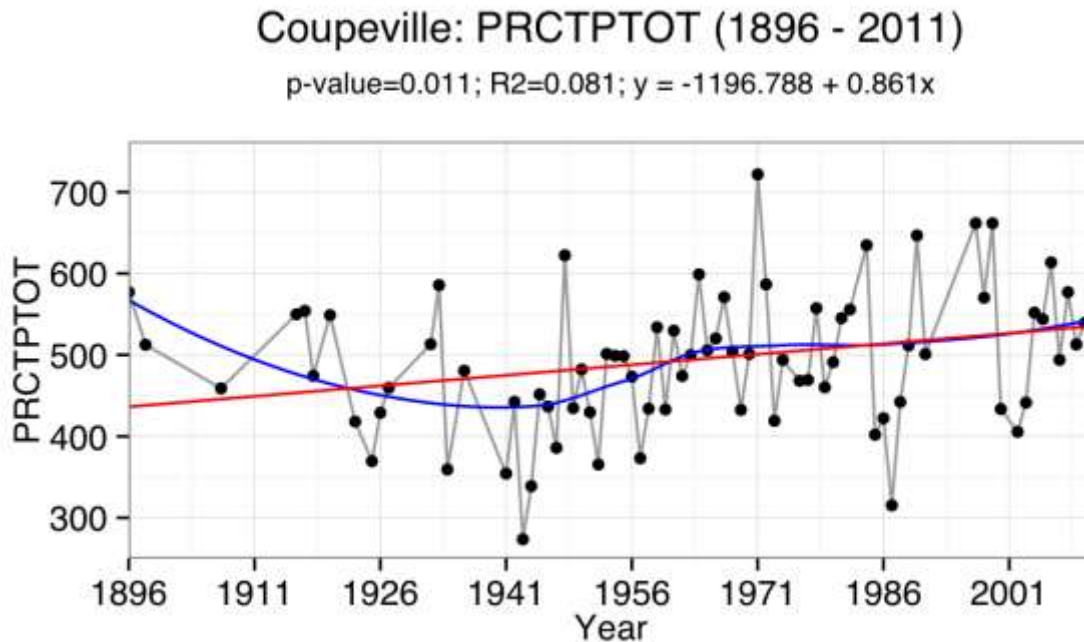


Figure xx., Total annual precipitation at Coupeville, 1896 - 2011.

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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). These resources are discussed even where they do not fall within the Reserve's legal boundary because they interact with resources and activities that are within the boundary. Marine mammals and seabirds, however, are treated in Wildlife section.

Penn Cove is the Reserve's predominant marine water feature. It is part of eastern Puget Sound, and runs in an east-west direction for a length of about 5 miles from the Saratoga Passage. Penn Cove consists of roughly 3,955 acres of water bordered by a 10-mile shoreline that mostly contains high sandy cliffs and muddy tidelands. Penn Cove supports extensive commercial and recreational fisheries. Its waters are used by the commercial aquaculture company, Penn Cove Shellfish, for the production of internationally renowned Penn Cove mussels.

Four natural lagoons are present along the Reserve's shoreline: Kennedy's Lagoon and Grasser's Lagoon on Penn Cove in the northeast, Perego's Lagoon on Admiralty Bay in

the west, and Crockett Lake (lagoon) on Admiralty Bay the southwest. Lagoons are coastal ponds that receive tidal water only infrequently (Perego's Lagoon) or receive tidal water more regularly, even daily, but are largely enclosed by land (Kennedy's and Grasser's Lagoons). Perego's Lagoon (including the associated berm/strand) has been nominated as a coastal wetland sanctuary (Kunze 1984). Historically, large portions of the Crockett Lake lagoon received tidal water daily. However, tide gates constructed over a century ago at its outlet have created a condition wherein only a small portion of the lagoon currently receives tidal water on a daily basis.

Lagoons are recognized by the Washington Department of Ecology as a particularly important natural feature because of their unique geochemistry and relative scarcity in Puget Sound. Most are 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.

#### ***4.2.2 Regional Context***

The Reserve is within a larger intricate network of coastal waterways known as the Salish Sea. The Salish Sea includes the mostly-sheltered marine waters from the southwestern tip of British Columbia to the southernmost part of Puget Sound. Located in the part of the Salish Sea where Puget Sound joins with the Strait of Juan de Fuca, the marine waters of expansive Admiralty Bay on the Reserve's west side are well flushed by strong tidal currents, whereas those of Penn Cove on the east side are much less so.

#### ***4.2.3 Issues Description***

The following are considered to be among the more important factors affecting the Reserve'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.

##### ***4.2.3.1 Shoreline Processes and Effects of Artificial Structures***

The Reserve's shoreline varies from windswept bluffs on the west to the protected shores of Penn Cove on the east. The Reserve's beaches along Admiralty Inlet mostly consist of glacial materials eroded from nearby bluffs. At Ebey's Landing, the beach is gravel-sand and subject to erosion from currents and to accretion from the upland erosion (Gallucci 1980) (Figure 5). The beaches of Whidbey Island, like many of those elsewhere in Puget Sound, are in a naturally constant state of erosion and accretion. Soils on slopes in excess of about 15 percent grade, which includes some of the prairie edges, are subject to severe erosion when the vegetation cover is removed (Figure 4). Approximately half of Island County's shoreline has been classified as unstable, compared with a maximum (for Puget

Sound) of 58% in King County and a minimum of 3% in San Juan County (Shipman 2004).

The transport by marine currents of eroded and 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 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 eroded from bluffs moves in a 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 glacial deposits that intersect tidal waters. Due to the lack of rivers on Whidbey Island, its beaches depend solely on bluff erosion for sediment. When drift cell currents carrying sediment encounter a feeder bluff or 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. In moderation, deposited sediment provides essential spawning and feeding habitat for many forage fish species that support salmon.

Drift currents are generally southward on the Reserve's western shoreline along Admiralty Bay, westward along the north shore of Penn Cove, and both westward and eastward along the rest of Penn Cove. Feeder bluffs comprise 35% of Island County's shoreline, a percentage among Puget Sound counties that is exceeded only by nearby Jefferson County. No other county has a higher percentage of "exceptional" feeder bluffs (based on great height, long open water distance, and the highest volume of sediment per shoreline length in the County) (MacLennan et al. 2013). Nearly the entire western shoreline north of Crockett Lake is comprised of feeder bluff, most of it mapped as "exceptional" (Figure 5). Around Penn Cove, an "exceptional" feeder bluff is present on Penn Cove Road east of Fossil Lane, and feeder bluffs occupy at least one-third of the Penn Cove shoreline within the Reserve.

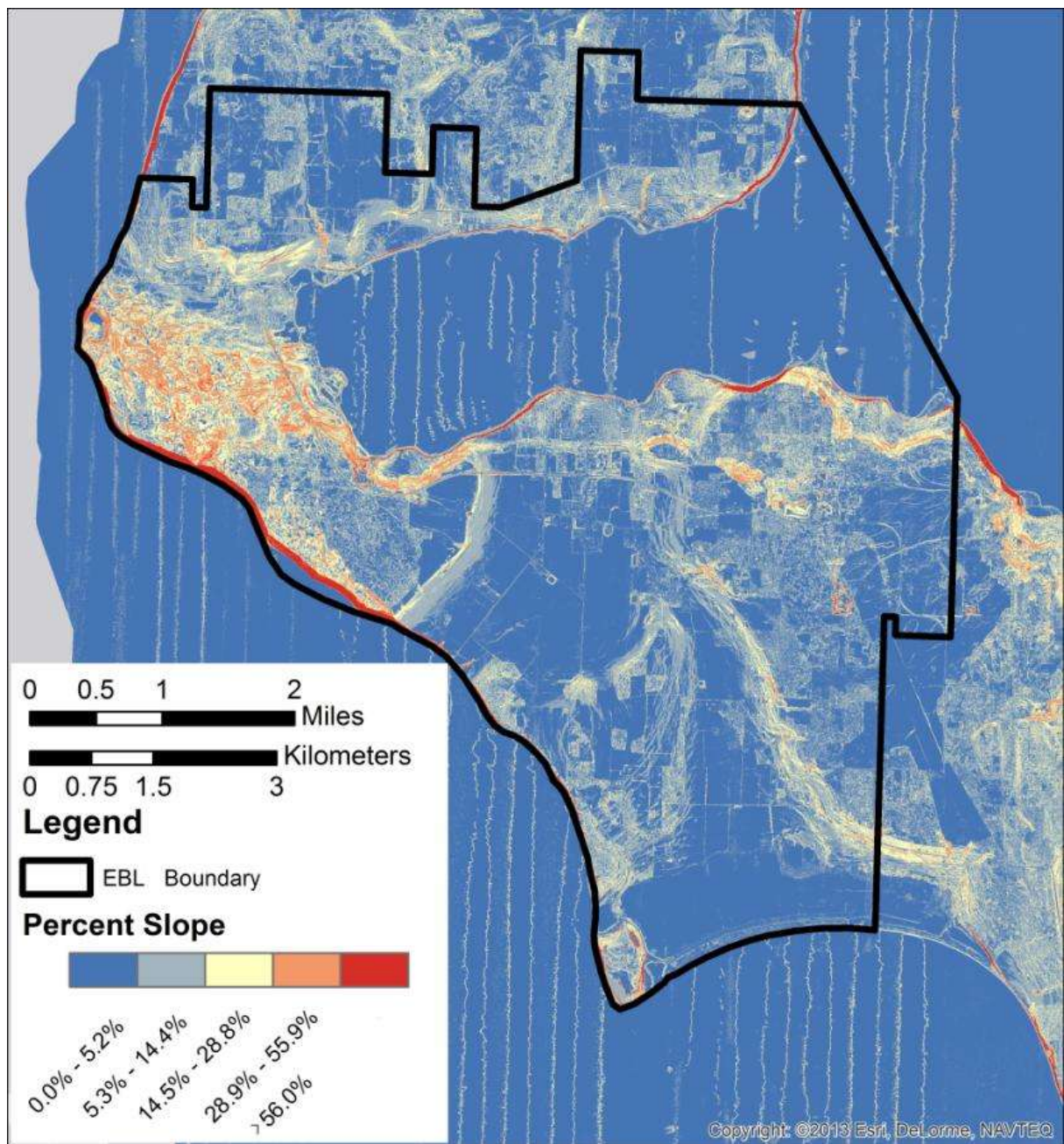


Figure 4. Land slope within the Reserve based on fine-resolution LiDAR imagery.



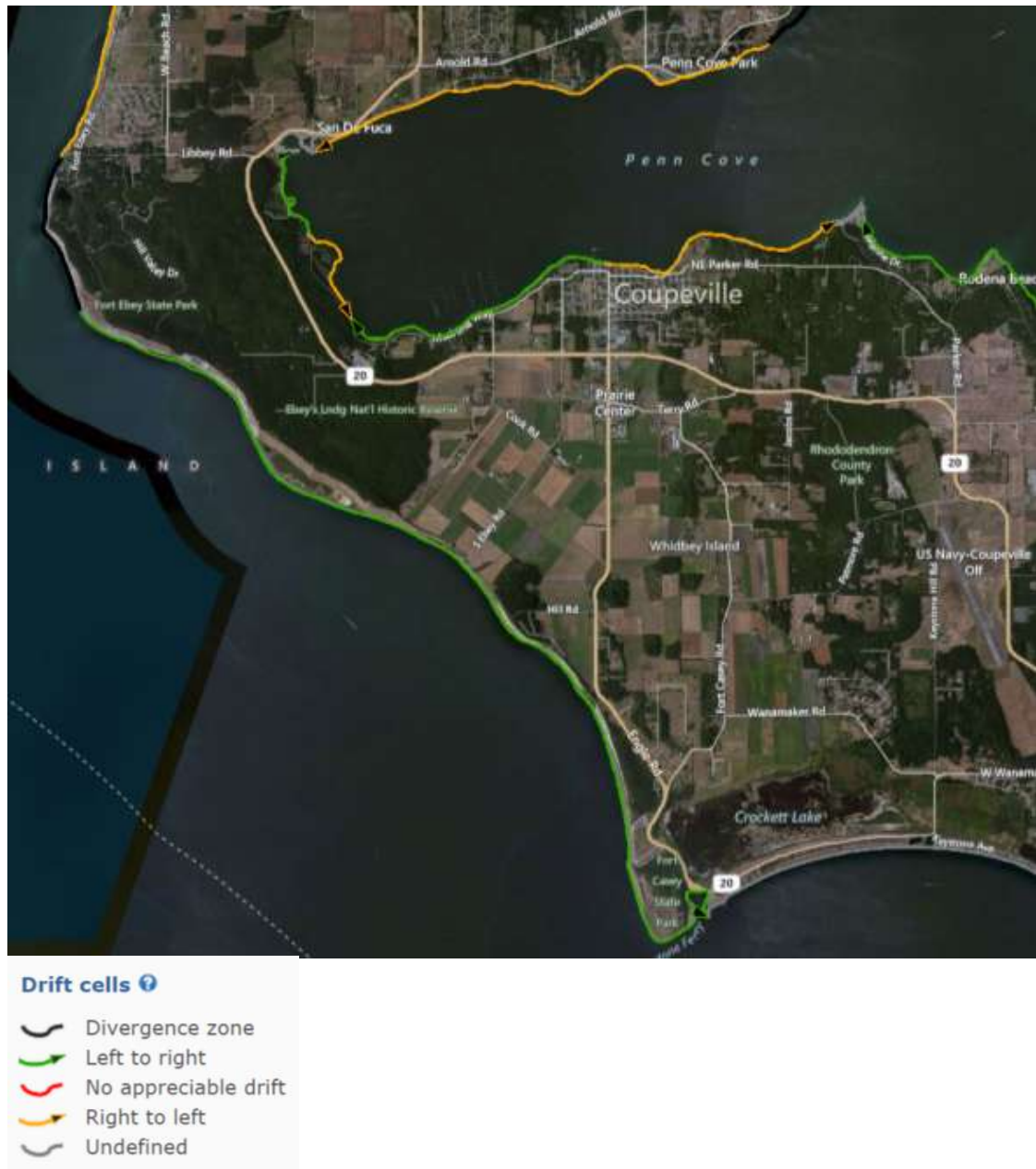
Shoretype & Slopes



**Figure 5. Shoreline types within the Reserve.**

source: <https://fortress.wa.gov/ecy/coastalatlasc/tools/Map.aspx>





**Figure 6. Drift cell flow direction within the Reserve.**

source: Washington Coastal Atlas <https://fortress.wa.gov/ecy/coastalatlas/tools/Map.aspx>

Artificial structures such as bulkheads, docks, and some other types of shoreline infrastructure have the potential to alter drift current direction and speed, and thus the amount, type, and location of sediment that is transported and deposited. This in turn influences the subsurface penetration of light that is crucial to underwater productivity. Shoreline armoring in parts of Penn Cove may be interfering with normal sediment dynamics of these feeder bluffs. Moreover, development at the top of a feeder bluff can accelerate natural erosion by modifying runoff patterns, placing extra weight on the top of a bluff, and removing stabilizing soil and vegetation (Shipman 2004). Also, on-site

septic systems associated with bluff-top residences introduce significantly more water into the bluff soils, promoting accelerated erosion.

Another type of artificial structure -- the tide gates on Crockett Lake -- also affect water circulation and thus salinity, water levels, and habitat conditions within that lagoon. Staff from Fort Casey State Park were originally asked to manage the water levels according to instructions from the Commissioners of Drainage District No. 6. In 1989 or 1990, mosquitoes became a problem and several local citizens began operating the tide gates to lower lake levels, hoping that would alleviate the mosquito problem. They also initiated a program of biological and chemical control for the mosquitoes, with state approval. Many citizens believe the productivity of Crockett Lake has been greatly reduced by manipulation of its levels, and mosquitoes are not as problematic as they once were. Currently, the tide gates are still in place but are not completely effective in excluding marine waters from the lagoon.

#### 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 Reserve. Like nearly all of Whidbey Island, the Reserve is more susceptible to flooding from the ocean than from streams and rivers. Coastal flooding usually occurs when large storm systems bring heavy precipitation and high winds during high tide. Almost the entire shoreline of the Reserve 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. Elevated shoreline areas that are at lower risk of such flooding are along the northern shore of Penn Cove, parts of the Penn Cove waterfront west of Coupeville, and a short segment of shoreline northwest of Crockett Lake.

On a global scale, by the year 2100 sea levels are projected to rise 7.1 inches, 13.4 inches, or 23.2 inches (low, intermediate, and high estimates, respectively) depending on the warming gas emission scenario used (ICDPCD 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 (Mote et al. 2008a), meaning that by the year 2100, under a maximum climate warming scenario, the rise could be 50 inches (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 when the ice melted and the pressure of its weight diminished. In the modern era, upward movements of the land mass which could potentially keep up with sea level rise are the result of tectonic processes and are a consistent and measurable factor in other parts of the state (e.g., the Olympic Peninsula). However, the dominant tectonic process



in the vicinity of Whidbey Island is subsidence rather than uplift (R. Larrabee, personal communication). In northern parts of Puget Sound, there is still a small amount of sea level net increase (Verdonck 2006, Canning 2005, and Mote et al. 2008a). Long-term changes in sea levels have not been measured or modeled in the Reserve specifically, or in any nearby area.

#### 4.2.3.3 Pollution and Ocean Acidification

The Reserve'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, nutrients, and petrochemicals (from creosote-covered driftwood and piers, pesticides, vehicle and boat exhaust). A constant threat also exists from oil tankers and other commercial vessels that navigate daily through waters close to the Reserve. The Port Townsend mill, which at least historically was a significant source of pollutants, is only 4 miles to the west across Admiralty Inlet. Also, just 28 miles to the northwest, Victoria is the only major Pacific Coast city north of San Diego that is mostly without sewage treatment, pumping its wastes directly into marine waters. While organic parts of the sewage decompose rapidly in the oxygen-rich waters which separate Victoria from the Reserve, many substances in household wastewater probably do not. These include pharmaceuticals, heavy metals, endocrine-disrupting chemicals, and others that can enter marine food chains and disrupt marine mammal reproduction.

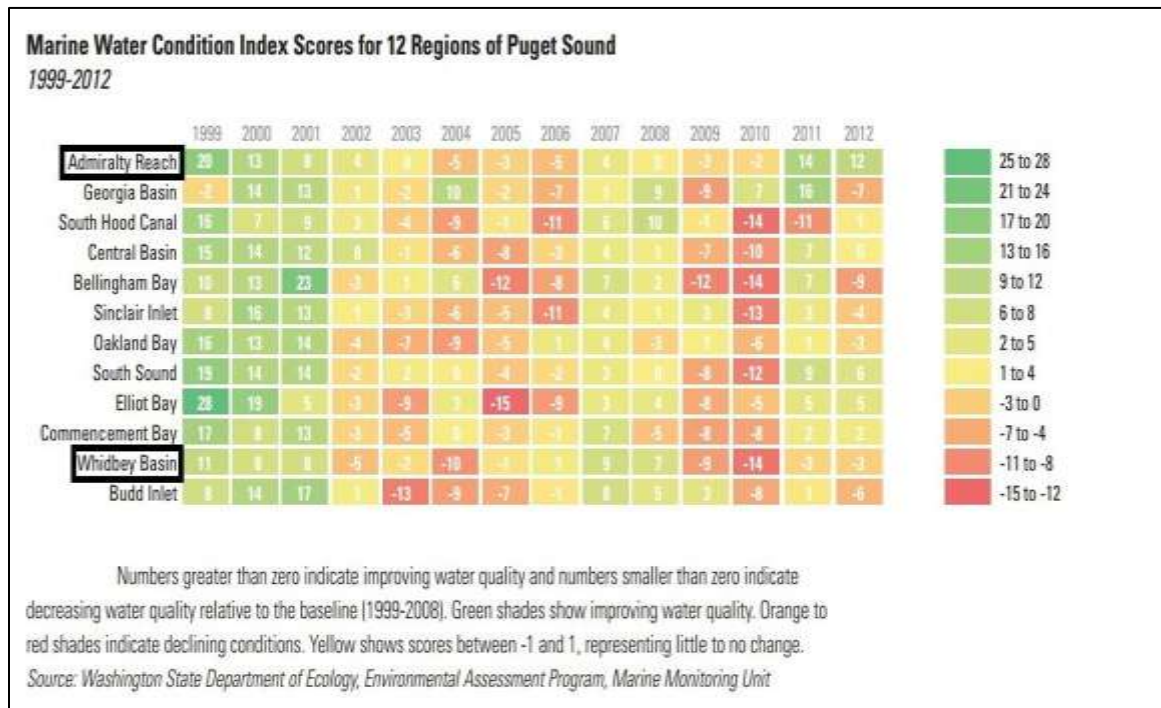
One of the largest drivers of declining marine water quality in Puget Sound may be the increasing nitrate concentrations. Puget Sound-wide nitrate increased at a rate of 3  $\mu\text{M}$  per decade while phosphorus has increased only 0.3  $\mu\text{M}$  per decade (Krembs 2013). Excessive algal growth triggered partly 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 of plants and animals 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 Whidbey Island, nitrate is most likely to originate from failing septic systems, vehicles, and agricultural or residential application of manure and other fertilizers. Nitrate and some toxic substances can also originate from boats, which at times are numerous in the waters next to the Reserve. In addition, the town of

Coupeville discharges sewage effluent into central Penn Cove after treatment by an NPDES-permitted secondary wastewater treatment plant.

Within the coming decades, the Reserve'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 (ICDPCD 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 (Wootton et al. 2008).



**Figure 7. Trends in marine water quality index for areas adjoining the Reserve.**

#### 4.2.3.4 Marine Debris

Plastic and other solid debris enters marine waters from sources both near (e.g., recreational and commercial boats, ferries) 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 plastics) 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

Intertidal invertebrates, especially those in tidepools, are sometimes collected by curious visitors although this is not allowed by Reserve regulations. If harvesting becomes excessive, species richness and food chain structure can be altered. Beach walking is popular in the Reserve, especially at Perego's Lagoon, and some visitors explore the intertidal areas during low tides. In the nearby San Juan Islands, Jenkins et al (2002) found that trampling by tide zone visitors reduced the cover of kelp by 30 percent, and that this reduction persisted through the summer season.

#### **4.2.4 Indicators and Criteria to Evaluate Condition and Trends**

Indicators that might be used to represent the condition of nearshore resources, and which will be discussed in following sections of this chapter, include:

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

To develop meaningful criteria for evaluating these, it is important to understand each indicator's natural range of variation under conditions similar to those present within the Reserve. However, few relevant data are available, either from within the Reserve or from analogous areas, for estimating the expected range of variation of any of these. Therefore, criteria are based on published standards related to ecological harm or on professional judgment of the authors.

##### 4.2.4.1 Quality of Nearshore Water and Sediment

For supporting aquatic life, the waters surrounding Whidbey Island are considered by the Washington State Department of Ecology to be better than waters in much of Puget Sound and the rest of the region and so have been assigned a "Class A" 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 endocrine 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 Penn Cove or Admiralty Inlet. Aside from occasional monitoring in Penn Cove, almost no water quality sampling has occurred in marine waters closest to Whidbey Island.

#### ***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 endocrine 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 Reserve’s surface water.

### ***Condition and Trends***

Condition: *Somewhat Concerning - Low Certainty*. Trend: *Indeterminate*

Certainty is rated low because we found no monitoring data for Penn Cove dissolved oxygen after September 2008 (at which time the dissolved oxygen levels were still potentially harmful) and because there has been very little sampling of the Reserve’s other marine waters.

Marine water sampling prior to that time indicated that Penn Cove regularly experiences hypoxia (severe deficits of dissolved oxygen), to the point that marine species including salmon are likely to avoid such waters or be harmed. It is believed these events have been caused by persistent thermal stratification of the waters within Penn Cove as a result of natural circulation patterns (Keeler and Kearsley 2003, Newton et al. 2002).

Analysis of sediment samples collected from Penn Cove in the mid-1990s indicated no exceedence of Washington's sediment quality standards for metals and some other contaminants. Of 100 Puget Sound sites sampled, the sediments from Penn Cove were "among the least toxic in these tests" (Long et al. 2003). However, Partridge et al. (2013) indicate that in 1997 benthic invertebrates at two Penn Cove sites were "adversely affected" by contaminants.

Results from sampling of fecal coliform bacteria in the marine waters of Penn Cove and Point Partridge in 2002 were found to be variable, with no persisting or widespread problems (Determan 2003). At Partridge Point, none of the three sites sampled in 2002 exceeded the National Shellfish Sanitation Program’s limit of 43 MPN/100 mL fecal coliform.

Marine waters in or near the Reserve have not been analyzed for a full spectrum of potentially harmful chemicals or with sufficient frequency to determine how often or extensively those may be present. In more than half of the Whidbey Basin (an area that includes the area from Penn Cove east to Everett Harbor), benthic invertebrate communities were found to be adversely affected by sediment contaminants in 2007 (Partridge et al. 2013). Between 1997 and 2007, concentrations of lead, biphenyl, and naphthalene increased, suggesting potentially harmful effects, but concentrations of most metals and polycyclic aromatic hydrocarbons, as well as overall sediment toxicity, decreased during that period.

#### 4.2.4.2 Eelgrass

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 pallasii*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*). Eelgrass covers about 9 percent of Puget Sound below the mean lower low water (MLLW) mark (Nelson and Waaland 1997). Eelgrass 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, distribution, and abundance of eelgrass beds can be limited by extremely low or high nutrient levels, unfavorable substrate composition, presence of other species, toxic pollutants, and shading from overwater structures (Mumford 2007). Competitors of eelgrass in Puget Sound include the non-native brown seaweed, *Sargassum muticum* (Britton-Simmons 2004). 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 (*Dendraster excentricus*) also disturbs the substrate to a degree that excludes eelgrass. Eelgrass can be buried and killed by sand overwash from storms. 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.

According to the Washington Marine Vegetation Atlas, eelgrass beds occur along all of the Reserve's shoreline except in a small segment in the innermost (western) part of Penn Cove, along the Crockett Lake barrier beach, and in a small segment just south of Perego's Lagoon. In the Washington Coastal Atlas (NOAA et al. 2014) eelgrass beds are shown as being most dense along the southeast shore of Penn Cove, including Lovejoy Point, Marine Drive/ Parker Road, and Rodena Beach. The volunteer group Island County Beachwatchers, in collaboration with the Island County Marine Resources Committee and Washington State University, has been mapping eelgrass throughout Island County for many years. Their data, which should be considered to be of higher resolution, also shows dense eelgrass beds occurring in the northeast end of Penn Cove along Scenic Highlights Road. See: <http://www.islandcountymrc.org/Projects.aspx>

As part of monitoring of eelgrass throughout Puget Sound, the Washington DNR monitored eelgrass at four locations within the Reserve. At three locations along the southeast shore of Penn Cove, no change in area was detected between the 2006 and the 2011 survey. Likewise no change in area was detected between the 2001 and the 2010 survey near Partridge Point on the west side of the Reserve.

### ***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 Reserve, “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 Reserve -- measured laterally along the shoreline and/or by change in their vertical distribution (depth). The Puget Sound Partnership uses eelgrass as an indicator of the overall health of Puget Sound and has adopted a goal of 20 percent more eelgrass for the Sound as a whole by the year 2020 (PSEMP 2014).

### ***Condition and Trends***

Condition: *Good - High Certainty*. Trends: *Good - Low Certainty*.

Some uncertainty exists regarding whether the eelgrass beds currently present near the Reserve would be slightly more extensive were it not for the presence of some overwater structures.

#### **4.2.4.3 Kelp and Other Seaweeds**

“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, herring, crabs, mollusks, and a variety of marine mammals including sea otters (Mumford 2007). Most kelp forests occur in the shallow subtidal zone from MLLW to about 65 feet below MLLW, especially in mid- or high-energy (e.g., rocky) environments where tidal currents renew available nutrients and prevent sediments from covering young plants (Mumford 2007). Kelp 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.

### ***Criteria***

After accounting for year-to-year variation, “Good” condition would be represented by an extent and distribution of kelp that is close to the recent historical condition within the Reserve, “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 from large portions of their historical range within the Reserve -- measured laterally along the shoreline and/or by a decrease in vertical distribution (maximum depth in the water column).

### ***Condition and Trends***

Condition: *Good - High Certainty*. Trends: *Good - Low Certainty*.

According to the Washington Marine Vegetation Atlas, kelp beds occur along all of the Reserve's shoreline except in Penn Cove. The Washington Coastal Atlas (2014) shows kelp being a bit sparser at Fort Casey and northward to about Hill Road. However, surveys by the volunteer group Island County Beachwatchers, in collaboration with the Island County Marine Resources Committee and Washington State University, show a continuous line of kelp along the entire western shoreline, including Crockett Lake. Much less is known about the species composition and richness of other macroalgae (seaweeds) within the Reserve.

#### 4.2.4.4 Intertidal Vegetation and Invasive Nearshore Plants

In the nearshore environment of Island County, the Washington Natural Heritage Program (NHP) has recognized several vascular plant community types as being of particular conservation concern, i.e., "Imperiled" or "Critically Imperiled" within the state or globally. In the intertidal zone, these include:

- Sandy Moderate-salinity Low Marsh (Critically Imperiled)
- Transition Zone Wetlands (Critically Imperiled)
- Pickleweed (Imperiled)
- Pickleweed - Saltgrass - Seaside Arrowgrass - Fleshy Jaumea (Imperiled)
- Saltgrass - Pickleweed (Imperiled)
- Sandy High-salinity Low Marsh (Imperiled)
- Silty Moderate-salinity Low Marsh (Imperiled)

In the supratidal (coastal spit) zone, they include:

- Bighead Sedge (Critically Imperiled)
- American Dunegrass - Japanese Beachpea (Imperiled)

At least some of these communities occur within the Reserve but their distribution has not been mapped.

#### ***Criteria***

After accounting for year-to-year variation, "Good" condition would be represented by an extent, native species richness, and distribution of these plant communities that is close to the recent historical condition within the Reserve, and unaffected by invasive plants. "Somewhat Concerning" condition would be represented by extent and distribution that is slightly more restricted than that, and "Significant Concern" would be reduction in these native plant communities from large portions of historical range along the Reserve's shoreline.

#### ***Condition and Trends***

Condition: *Somewhat Concerning - Moderate Certainty*. Trend: *Indeterminate*.

A survey of 102 Island County wetlands in 2005 determined that 55% had non-native plant species, representing 1-24% of the cover in any single wetland (Adamus et al.

2006). The most abundant wetland-associated invasive, both countywide and within the Reserve, is reed canarygrass (*Phalaris arundinacea*).

The invasive salt marsh cord grass (*Spartina anglica*) was introduced to nearby Port Susan in the early 1960s and had spread to Penn Cove by the 1980s. The species is considered harmful because it traps sediment so effectively that it converts mudflat into salt marsh. This can crowd out eelgrass beds and thus impact bird, fish, and marine invertebrate populations. This plant has also occurred in Kennedy's Lagoon and a few other locations near Coupeville. At one time Island County had more acres of *Spartina* than in any other county in North Puget Sound. At the height of infestation approximately 250 acres of *Spartina* were present in Island County but due to persistent control efforts, as of 2014 fewer than 50 acres remain in the County. For this invasive species, the downtrend can be categorized as "Good".

In the high marsh of the Reserve's Crockett Lake, the non-native hairy willow-herb (*Epilobium hirsutum*) has become established. Left unchecked, this species has the potential to invade much of the zone now occupied by native Pacific silverweed (*Argentina egedii*, known more commonly as *Potentilla anserina*) (Haubrich 2009). The potentially invasive *Phragmites australis* is also present at Crockett Lake. Poison hemlock (*Conium maculatum*) is common in some parts of Island County but was found in only 2 of 102 wetlands surveyed in 2005, neither of them within the Reserve. However, it has become well-established around the bluffs at Ebey's Landing. The beautiful but highly invasive purple loosestrife (*Lythrum salicaria*) occurs infrequently on Whidbey Island and appears to be currently absent from the Reserve. The invasive creeping buttercup (*Ranunculus repens*) was found in nearly one-quarter of Island County wetlands including some within the Reserve (Adamus et al. 2006).

#### 4.2.4.5 Salmonid Fish

Nearshore waters, especially where they consist of pocket estuaries and streams (Beamer et al. 2006), provide juvenile salmon with refuge from predation, increased food resources, and additional time to make the physiological transformation from freshwater to saltwater. Although salmonids are present seasonally in nearshore waters of both Reserve units, no spawning has been documented for any salmonid species within the Reserve. However, salmonid use of nearshore waters adjacent to the Reserve has been well documented (e.g., Wait et al. 2007). Those waters are considered to be very important for juvenile salmon rearing and migration, particularly pink and chum fry. The local salmon fishery is heavily used, as has been the case for over a century.

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 Island 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 Island County. The western part of



the Reserve is within Geographic Area 3 which the County considers to be of lower priority because it is not adjacent to any of the rivers with natal populations and most habitats are impacted by high wave and current energy (SSPS 2007). However, the geographic priorities in the Salmon Recovery Plan have not been updated to include data from more recent surveys of the nearshore and associated streams. A survey for juvenile Chinook salmon covering 63 small coastal streams draining into the Whidbey Basin (Beamer et al. 2013) found juvenile Chinook salmon present in at least one occasion during 2008–2013 in 32 streams, nearly all of them seasonal streams, many not shown on maps. None within the Reserve were surveyed. In May 2005, NPS staff conducted a 3-day beach seine inventory of intertidal fishes adjacent to the Reserve's shoreline, covering 31 locations. Fish community composition at both Penn Cove and along Admiralty Inlet was dominated by juvenile salmon, particularly chum salmon smolts. Chinook and coho salmon were also found (Fradkin 2011). Within the Reserve, salmon have also been documented from Grasser's Lagoon (Beamer et al. 2006).

### ***Criteria***

After accounting for year-to-year variation in ocean conditions and rearing areas, “Good” condition would be represented by duration and frequency of use by juvenile salmonids that is close to the recent historical condition within the Reserve, “Somewhat Concerning” condition would be represented by a measurable reduction in that, and “Significant Concern” would be a major decline.

### ***Condition and Trends***

*Indeterminate.* Although salmonids occur regularly within the Reserve, the present condition and trends of their populations have not been monitored specifically in the Reserve. Populations and use of the Reserve's nearshore areas are undoubtedly influenced more strongly by conditions outside of the Reserve than conditions within. Within Puget Sound as a whole, the total number of Chinook salmon declined from 2006–2010 (PSEMP 2014).

#### **4.2.4.6 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 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. In Island County, forage fish primarily include surf smelt, Pacific herring, and Pacific sand lance. The occurrence in the Reserve of 25 non-salmonid fish species, many of them forage fish species, was documented by Fradkin (2011).

*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 (Pentilla 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). No spawning or holding areas for herring exist within the Reserve. Herring spawning on Whidbey Island is concentrated at the northwest end of the island and in Holmes Harbor (Penttila 2007).

Like Pacific herring, *surf smelt* and *sand lance* use nearshore habitat for all of their life-history stages. The WDFW has identified Penn Cove as a spawning area for surf smelt and sand lance. For surf smelt, the spawning area exists in the subtidal zone and extends from Snakelum Point around Penn Cove to Monroe's Landing, with the western shore of Penn Cove used only sporadically for spawning. For sand lance, individual spawning areas exist on Snakelum Point, Long Point, Lovejoy Point, Monroe's Landing and just east of San de Fuca.

### ***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 Reserve, "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 and Trends***

*Indeterminate.* Although forage fish spawn within the Reserve, the present condition and trends of their populations have not been monitored specifically along the shores of the Reserve.

#### **4.2.4.7 Shellfish and Other 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, amount of different grain and gravel sizes, organic content (Dethier et al. 2006).

### ***Criteria***

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

### ***Condition and Trends***

*Indeterminate*. Although shellfish and many other nearshore invertebrates are present within the Reserve, the data on populations are mostly qualitative and not of sufficient extent to characterize nearshore invertebrates overall or any key species in a spatially, temporally, or taxonomically comprehensive manner within the Reserve. Marine invertebrates known to exist within the Reserve and which are of commercial or sport interest are described as follows.

**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, NOAA et al. 2010). Current population levels are likely too low to support effective reproduction (Dethier et al. 2006). In the inside waters of Washington, abalone is currently found only along Whidbey Island, the San Juan Islands, and a few areas within the Strait of Juan de Fuca (Dethier et al. 2006). **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 (WDFW 2008). They are documented from Admiralty Head north through Ebey’s Landing to Point Partridge. **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 sea stars (*Pisaster* spp.) and sea otters (*Enhydra lutra*) (Dethier et al. 2006). They are known to be present offshore from Point Partridge. In general the Puget Sound sea urchin population is considered stable, although population declines in specific geographic areas have been noted (PSAT 2007). However, populations of sea stars (starfish) in Puget Sound have plummeted in the last few years as a result of a virus that causes mass wasting (“melting”) of individuals. Die-offs of sea stars showing the characteristic symptoms of this viral syndrome have been documented in the Reserve, and simultaneously, urchin populations appear to be increasing, with the potential to consequently reduce the extent of kelp beds important to many other marine invertebrates and forage fish.

**Clams and mussels** are of particular commercial and sport interest, as well as providing food for some sea ducks whose Puget Sound populations may be declining. Subtidal geoduck is present in three small clusters located offshore at Point Partridge. Hardshell subtidal clam includes a substantial bed documented from Fort Casey State Park to Perego’s Lagoon. The state park is open to clam and oyster harvest year-round. Hardshell subtidal clams are also found in Penn Cove near Kennedy’s Lagoon. Hardshell intertidal clam is documented from Long Point around Penn Cove and beyond Blower’s Bluff. In fact, Penn Cove clam beaches are reputed to be among the most productive in the state. Penn Cove Mussels, Inc., a mussel culture operation, was established in Penn Cove in 1975. In 1996 it became Penn Cove Shellfish. The site is located on the south side of the Cove, sheltered from prevailing winds by a high bluff. The mussels are cultured on floating rafts moored in the cove. Each of the 38 rafts holds approximately 1500-2400 mussel seed collector lines, on which the mussels grow. Between three-quarters to one million pounds of mussels are produced annually.

Three aquaculture districts exist within the waters surrounding the Reserve. District 1E is in Penn Cove on the south shore west of Coupeville and is permitted to Penn Cove Shellfish, LLC. District 2C has no current regulated activities, however geoduck harvesting has been allowed under previously issued shoreline permits. According to the Washington DNR, District 3E, which is located offshore from Fort Ebey State Park, was harvested for geoducks by state and tribal officials several years ago. Although District 3E is a significant bed, the geoducks are too small and not of high commercial value.

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## **4.3 Freshwater Resources: Water Quantity, Quality**

### **4.3.1 Background**

Streams, springs, ponds, and wetlands provide essential habitat for many species, especially on islands that lack large lakes and rivers. 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. Groundwater, too, is critical as a source of drinking water as well as helping sustain

streamflow and wetlands in some cases. The Reserve includes three subbasins as defined by the US Geological Survey: 171100190103 (eastern half of the Reserve, wraps around Penn Cove), 171100190105 (almost the entire western half), and 171100190106 (northwest tip including Lake Pondilla). These subbasins can be further divided into numerous smaller catchments, many of which drain almost immediately into marine waters. For this project, the boundaries of minor catchments where water quality has been sampled were computer-generated using LiDAR imagery and topographic algorithms, and assuming the minimum catchment size to support surface flow in this area is about 2010 square meters. The resulting shapefile was provided to the NPS. Those catchment boundaries have not been field-checked but are believed to be generally accurate, though less so where culverts and storm drains are present in the more developed portions of Coupeville.

#### ***4.3.2 Regional Context***

Islands in the Puget Sound and Strait of Juan de Fuca are characterized by isolated and limited aquifers. The central part of Whidbey Island near where the Reserve is located receives less annual precipitation (23 inches) than any other part of the island, while having the deepest unconsolidated glacial deposits of any part of the island.

#### ***4.3.3 Issues Description***

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

1. Groundwater depletion and degradation
2. Surface water pollutant sources and soil disturbance
3. Climate change

These are briefly described as follows.

##### **4.3.3.1 Groundwater Depletion and Degradation**

Whidbey Island residents depend upon a sole source aquifer with a finite water supply for domestic water and irrigation. Private wells serve as the domestic water supply source for the majority of Island County's residents in the unincorporated portion of the county. The County does not serve as a water purveyor for its residents. The Town of Coupeville operates its own water systems, obtaining the water from a series of city owned wells. The Town currently provides water service to residents within the Coupeville town limits and within a limited service area outside the town. Coupeville obtains its water from a wellfield located adjacent to the abandoned infiltration gallery of the former Fort Casey Military Reservation northeast of Crockett Lake. Two in-town wells provide backup supply during periods of peak demand. The town also maintains a reservoir with a capacity of roughly 500,000 gallons but only 160,000 gallons can be utilized as an effective water supply.

Most wells in the county are less than 200 feet deep and obtain water from the aquifer whose depth ranges from a few feet above sea level to 200 feet below sea level (Figure 11). Deeper wells are mostly for public water supplies (Sumioka and Bauer 2004). Yields

range between 50 to 350 gallons per minute, with most wells yielding less than 100 gallons per minute.

Because the Reserve receives the least precipitation on the island, recharge rates also can be assumed to be less than the average for the island. When located on a slope, roads and other impervious surfaces tend to export runoff more quickly and provide for less recharge of groundwater than does natural vegetation cover. The US Geological Survey is currently refining estimates of recharge to groundwater in various parts of the county, and publication of the data and revised maps is anticipated soon.

Under the State Environmental Policy Act (SEPA) and the Planning Enabling Act (Chapter 36.70 RCW) the County is required to control development to protect groundwater sources. The U.S. Environmental Protection Agency, upon the request of Island County government, designated the county a Sole Source Aquifer in 1982. That provides for an additional review of projects to insure that there will be no degradation to the county's aquifer system. The designation only affects projects that receive federal funding. In 1986, the Washington Department of Ecology designated the entire county a Ground Water Management Area and the County subsequently developed a Ground Water Management Plan.

Water rights are presently over-appropriated in certain areas of the county, particularly northwest and southwest of Penn Cove. If these water rights are fully exercised, water will be removed from the groundwater system at a rate greater than the rate of replenishment (ICDPCD 1998). In the early 1990s the Town issued a moratorium on new water hookups, due to well and distribution system limitations. Since 1993 the Town has issued new water hookups within the town limits and continues to improve its supply and distribution system.

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 which depend on that water will be harmed. Withdrawal of groundwater by residences near the Reserve has the potential to endanger the availability and quality of groundwater within the Reserve, especially if compounded by longer droughts associated with regional climate change. However, neither the wells that have been screened below sea level (as most wells in the county are) nor the near-shore wells that draw from above the sea level, are likely to strongly influence the duration of flow in the island's few streams or the persistence of saturated conditions in the island's wetlands (Doug Kelly, County Hydrogeologist).

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, and the result is unpalatable water. A map portraying seawater intrusion risk ratings shows the area around the Reserve to have very high risk for seawater intrusion (Figure 10).

A groundwater management program has been active since 1992. Under this program, new wells must be metered, water levels must be monitored in April and August of each year in domestic wells in high and medium risk areas, and there is a network of monitoring wells for both water level and water quality. Chloride and conductivity measurements are required in April and August in public water system wells in high and medium risk areas.

#### 4.3.3.2 Pollutant Sources and Soil Disturbance

In areas within or nearest to the Reserve, levels of suspended sediment, nutrients, and other non-point pollutants are excessive and are most likely to originate from fertilized cropland and residential areas, runoff from roads and airstrips, failing septic systems, animals, soil disturbance (compaction and erosion) by recreationists, and airborne contaminants from distant sources.

#### 4.3.3.3 Climate Change

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

#### **4.3.4 Indicators and Criteria to Evaluate Condition and Trends**

The following are addressed as indicators of change in the Reserve's water resources:

- Groundwater Levels and Quality
- Extent of Non-tidal Surface Water and Wetlands
- Surface Water Quality
- Wetland Biological Condition

##### 4.3.4.1 Groundwater Levels and 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 posing no threat to people or biological resources. “Somewhat Concerning” would be conditions where either groundwater levels show a slight downtrend from year to year that is sustained through a wet period (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 use due either to lack of quantity (wells go dry, wetlands dry up) or quality (saltwater intrusion, pollution). The Washington Department of Ecology has used 100 mg/l of chloride as a threshold for describing well water as having high chloride concentration (Culhane 1993). The Island County Code defines risk codes for seawater intrusion as follows:

- Low risk – groundwater level elevation > 8.4 ft; any chloride concentration

- Medium risk – groundwater level elevation  $\leq 8.4$  ft; chloride concentration  $< 100$  mg/l
- High risk – groundwater level elevation  $\leq 8.4$  ft; chloride concentration between 100 and 250 mg/l
- Very high risk – groundwater level elevation  $\leq 8.4$  ft; chloride concentration  $> 250$  mg/l

For nitrate in groundwater, most of the area around the Reserve is rated as having moderate susceptibility to contamination (Figure 8, Figure 9), while Coupeville is considered to have high susceptibility (Island County Water Resources WRAC 2004). Nitrate levels of 1-3 mg/L indicate a developing problem, and a level of 5 mg/L in wells should trigger increased monitoring and remediation.



**Figure 8. Nitrate Leaching Potential, Nonirrigated.**

Rating		Acres in AOI	Percent of AOI
Moderately high	Orange	8,942.2	48.7%
Low	Green	2,900.8	15.8%
Moderate	Yellow-green	653.6	3.6%
High	Red	576.2	3.1%
Null or Not Rated		1,015.4	5.5%

These ratings indicate the potential for nitrate leaching below the root zone, based on inherent soil and climate properties: soil available water capacity, water travel time, precipitation surplus, water table depth and duration, slope gradient.



**Figure 9. Nitrate Leaching Potential, Irrigated.**

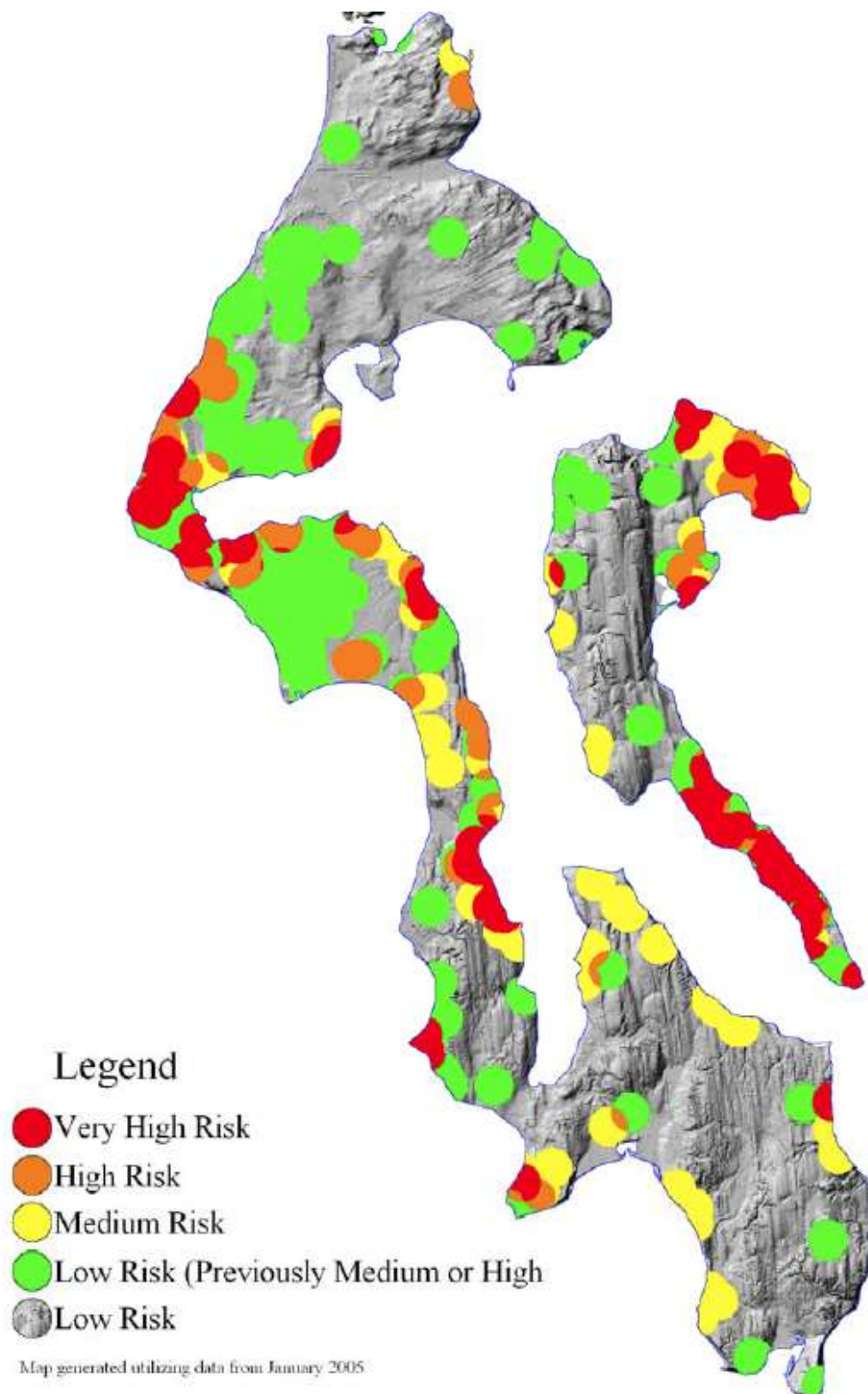
<b>Rating</b>	<b>Acres in AOI</b>	<b>Percent of AOI</b>
High	7,741.9	42.2%
Moderately high	2,501.1	13.6%
Low	2,017.4	11.0%
Moderate	1,256.8	6.8%
Null or Not Rated	570.9	3.1%

### ***Condition and Trends***

Condition: *Significant Concern - High Certainty*. Trends: *Indeterminate*.

Within the Reserve, saltwater intrusion has been documented in wells in the vicinity of West Beach, Coupeville, and Ebey's Prairie. In addition, elevated levels of nitrates in groundwater have been a concern for some wells especially in the unincorporated areas of Central/South Whidbey (Keeler and Kearsley 2003). However, there currently is insufficient information to report on trends. Despite the Reserve containing commercial and residential areas and having areas of high aquifer recharge and susceptibility to pollutants (Figure 12), the presence or absence of some potentially harmful substances (e.g., pharmaceuticals, flame retardants) in those susceptible areas has not been determined.





**Figure 10. Risk of saltwater intrusion on Whidbey and Camano Islands based on groundwater level and groundwater chloride concentration in 2004 (source: Island County Water Resource Management Plan 2004)**

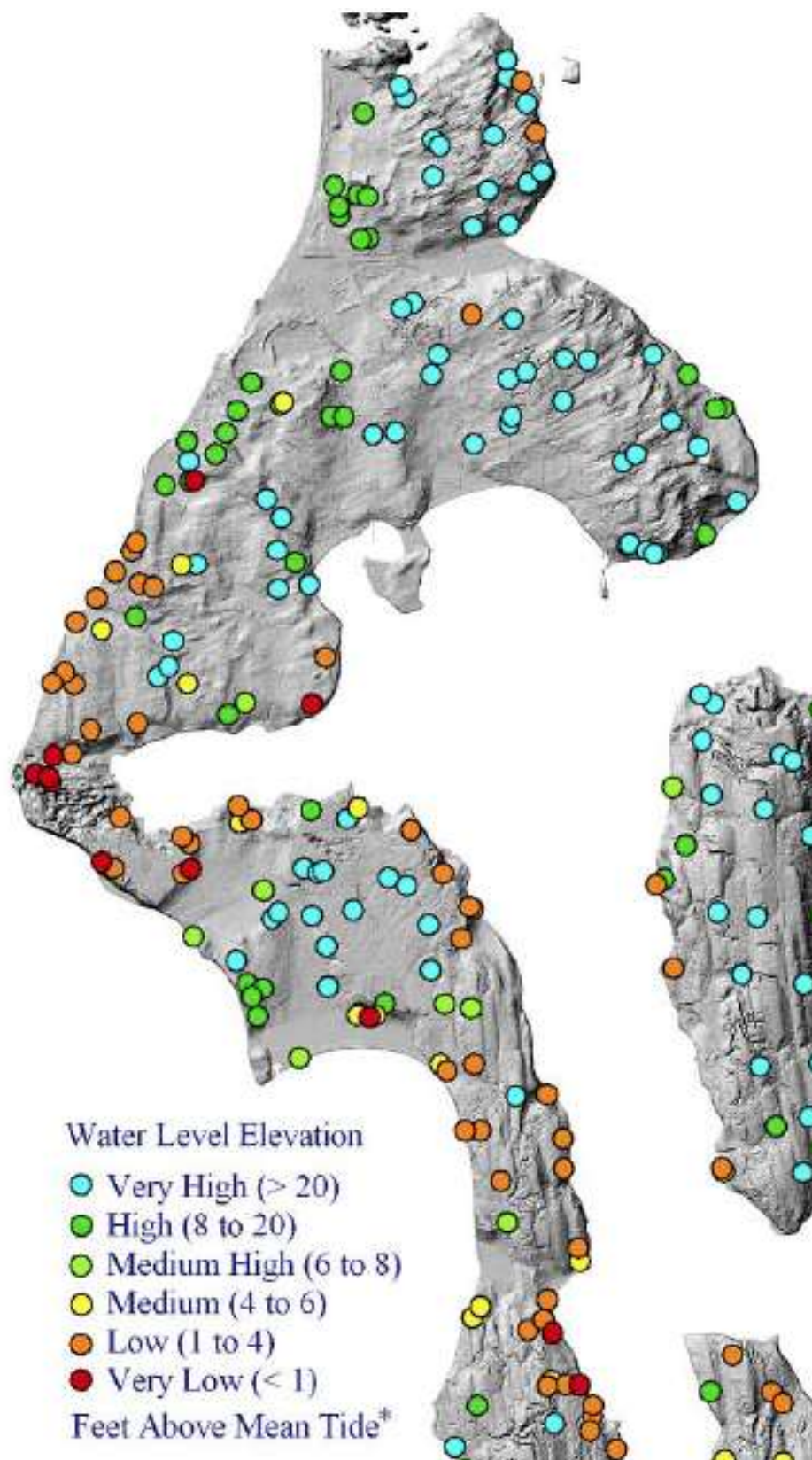


Figure 11. Groundwater level in central Whidbey wells (source: Island County Water Resource Management Plan 2004).

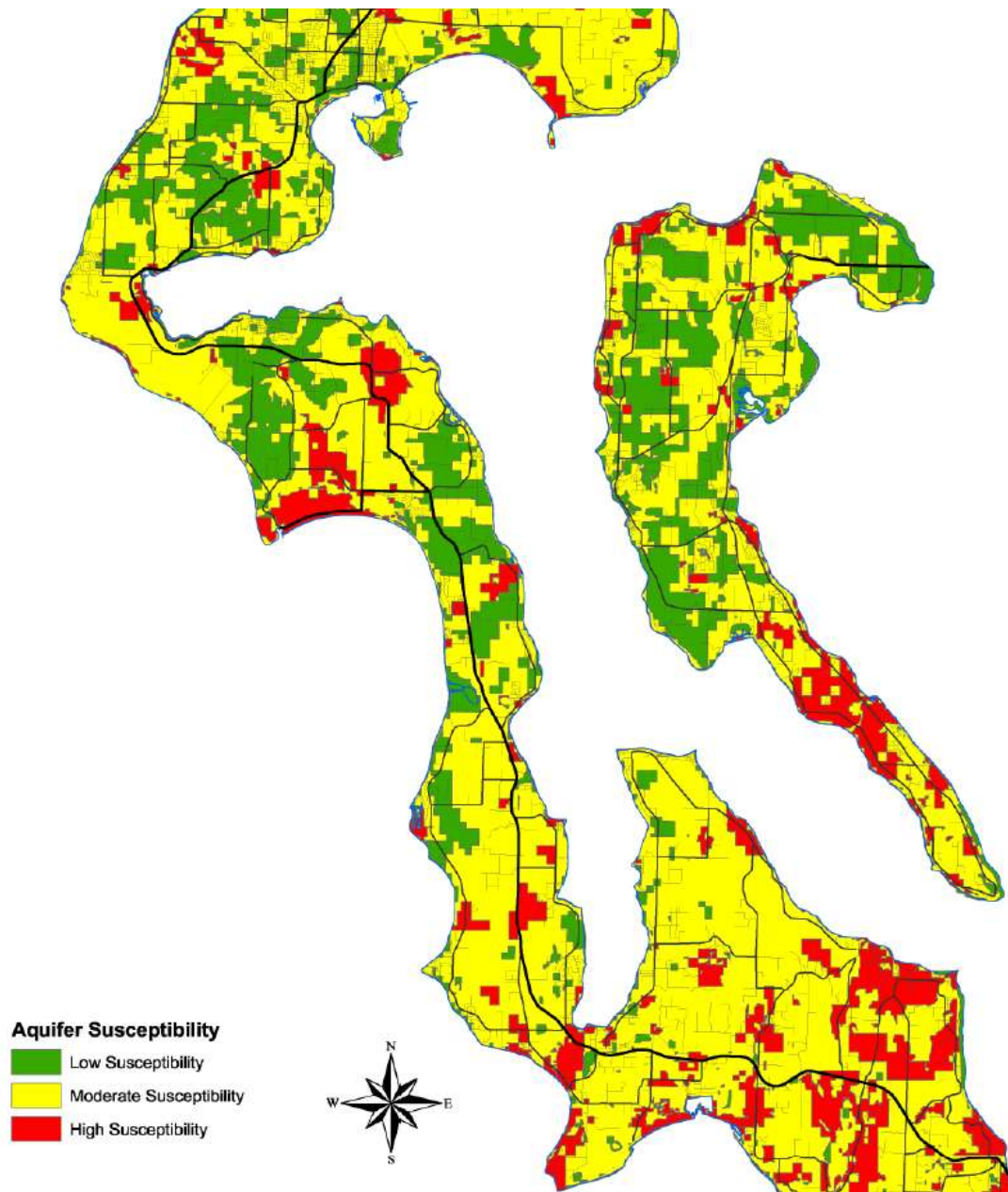


Figure 12. Critical aquifer recharge areas of central Whidbey Island, including the Reserve (source: Island County Water Resource Management Plan 2004).

#### 4.3.4.2 Extent of Non-tidal Surface Water and Wetlands; Wetland Condition

The Reserve contains no streams that flow year-round during normal years. The only lake is Crockett Lake, which was formerly a saltwater lagoon and still has brackish salinity. A small pond called Lake Pondilla is the most significant body of standing fresh water in the Reserve. It formed within a glacial kettle and contains water year-round, making it a rare aquatic type for Whidbey Island and the Puget Sound region. It appears to be highly

dependent on groundwater influx but neither its hydrological nor its biological environment has been fully studied. The amphibian survey of Samora et al. (2013) documented only one amphibian species (Pacific Treefrog) in Lake Pondilla, and also noted the presence of an unidentified turtle.

In the 1980s The National Wetlands Inventory (NWI) mapped wetlands in the Reserve, as in most of the rest of the U.S., at a relatively coarse resolution using aerial imagery available at that time. None of the maps were verified at ground level. Subsequently, as formal wetland delineations have been prepared by consultants for developers as part of their permit applications, many of the formal delineations have been used to revise or augment the NWI maps. Until at least 2009, that revised digital data layer was repositied in the Island County Department of Planning and Community Development (ICDPCD). For freshwater wetlands, the County map indicates there are 3062 acres in 54 wetlands that fall partially or wholly within the Reserve (22% of the Reserve's non-marine area), whereas the NWI map shows only 690 acres (5% of the Reserve's non-marine area).

The biological condition of wetlands and/or streams can be evaluated partly 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).

### ***Criteria***

For wetlands, “Good” condition would be represented by no loss of wetland acreage, no chemical contamination, and no invasive plants within any wetlands. “Somewhat Concerning” and “Significant Concern” would be represented by progressively greater wetland loss, chemical contamination, and/or dominance by invasive plants.

For streams, “Good” condition would be represented by flow that occurs for a duration and length equal to historical average in the Reserve. “Somewhat Concerning” and “Significant Concern” would be represented by progressively smaller duration of flows.

### ***Condition and Trends***

Condition: *Somewhat Concerning* due to invasion of some wetlands by non-native plants that reduce biodiversity, but *Low Certainty* due to lack of data on distribution of many invasive species and contaminants within the Reserve.

Trends: *Indeterminate*, due to lack of monitoring at regular intervals across all wetlands within the Reserve, and lack of long-term surface flow monitoring.

Freshwater (palustrine) wetlands comprise most of the Reserve's wetlands that fall under Clean Water Act jurisdiction. They are mainly associated with Crockett Lake. Before



installation of tidegates there many decades ago, most of these were probably salt marsh (estuarine emergent). The remainder of the Reserve's mapped wetlands are shrub or forested wetland or salt marsh (primarily near the outlet of Crockett Lake and along part of the shoreline within Grasser's, Kennedy's, and Perego's Lagoons). However, the large proportion of soils within the Reserve that are classified as hydric suggests that wetlands -- probably freshwater ones that seldom or never contain surface water -- are actually far more prevalent than indicated by existing maps, or were so historically but have since been drained by ditches and subsurface tile. Descriptions of the Ebey's Prairie area from settlement to the mid-1900s characterized the prairie as "marshy" and "waterlogged" (Kellogg 2001). It likely was once bisected by a broad riparian corridor consisting of waterlogged soils, swampy areas, seasonal ponds, and intermittent flows, which helped recharge the local aquifer (National Park Service 2006). By the mid-1900s, agriculture drainage tiles, drainage ditches, and fill were being installed by local landowners to increase tillable acreage. The extent and location of these drainage tiles or the effects these tiles have had on surface water and subsequently on aquifer recharge in the area remains uncertain.

The Reserve's wetlands may also be classified according to the hydrogeomorphic (HGM) classification of Brinson (1993). By that, the majority would likely be Slope or Depressional. Wetlands with deep peat soils (e.g., bogs and fens) are currently very rare in Island County; none occur within the Reserve. The Reserve's Crockett Lake supports some willow (*Salix* spp.) which despite being widespread in most of Washington, is categorized as "Vulnerable" by the Washington Natural Heritage Program (NHP) in the state generally. None of the plant communities present in the Reserve's wetlands have been designated as "Imperiled" statewide by the NHP. One species that occurs in freshwater wetlands (*Cicuta bulbifera*) and one associated with salt marsh (*Puccinellia nutkaenensis*) are recognized as "Sensitive" by the NHP and have been given "Protected Species" status by the County. They do not appear to be currently present within the Reserve (Rocheft 2010).

A study sponsored by Island County (Adamus et al. 2006) presents a detailed analysis of wetland losses throughout the county during the periods 1985-1998 and 1998-2005. No data are available on loss rates specifically of the Reserve's wetlands, either historically or since its recent establishment. As part of the current NRCA, an Excel database that resulted from the Adamus et al. study is provided to NPS. It describes 132 characteristics of each of the Reserve's 54 mapped freshwater wetlands. The database was mainly derived from available spatial data using GIS. In addition, for the 5 freshwater wetlands within the Reserve that were visited as part of that study, 48 additional characteristics are included. Plants found in these wetlands in 2005 are listed in Appendix 1, Table 18 and additional wetlands whose plants were surveyed by Island County (Water Quality Monitoring Program) during the years 2007-2013 are shown in\*FQA= Floristic Quality Assessment. See Rocchio and Crawford (2013) for definitions of metrics and their interpretation. FQA

Table 19 in the same appendix. Apparently none of the wetlands have been resurveyed to detect changes in plant community composition.

Although at least some of the Reserve's wetlands have been invaded by aggressive non-native plants such as *Phalaris arundinacea*, *Cirsium arvense*, *Epilobium hirsutum*, and *Spartina anglica*, the current extent of the invasion of wetlands is not precisely known and a baseline for the Reserve does not exist, apart from cursory survey of just five wetlands in 2005 and four additional ones in one of the years 2007-2013. There exist no permanent points at which the water table that supports some of the Reserve's wetlands and streams has been monitored.

#### 4.3.4.3 Surface Water Quality

As discussed previously in section 4.3.3.1, residents of Island County are extremely dependent on well water. In many areas with shallow soils, the groundwater that feeds wells is strongly connected with surface waters. Thus, the quality of surface water has a potentially great effect on the water people consume. Moreover, contaminated surface water poses threats to pets, livestock, wildlife, and plants.

Island County is one of only a very few counties in the Pacific Northwest that maintains an extensive surface water monitoring program. Designed in 2005, the program (Adamus 2006) is implemented through an ordinance adopted by the Board of Island County Commissioners in 2006. The program has collected baseline data from 24 locations around the county, and from an additional 43 locations during its first three years. Sample locations are carefully selected and include freshwater wetlands, lakes, and perennial and seasonal streams throughout the county. Several seasonal streams and ditches within the Reserve have been sampled. Where persistent contamination is discovered, the program attempts to trace the source and work with landowners to curtail the problem. A goal is to ensure that public health and valuable resources such as swim beaches, shellfish beds, anadromous fish streams, groundwater, and nearshore habitats are protected from pollutants. The County has published a report summarizing data from the first five years of its program (Island County Environmental Health 2013). In 2007 the National Park Service (Klinger et al. 2007) summarized water resources specifically in the Reserve, but with an almost exclusive emphasis on marine rather than fresh waters.

#### ***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 endocrine 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 County, 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 Reserve's surface water.

Following the laws of Washington State (WAC 173-201A-200 (1)(e)), Island County uses a standard of 14 NTU for turbidity because this is 5 NTU greater than the median for the county (9 NTU) as determined by synthesis of scattered data from the county's relatively undeveloped watersheds prior to 2006. For orthophosphate, the ordinance that established the County's monitoring program set a threshold for lakes of 0.0350 mg/L, but did not set a threshold for streams or wetlands. For nitrate, the County adopted the state drinking water standard of 10 mg/L as its surface water standard. However, from reference data collected from streams in most of the Pacific Northwest, the USEPA (2002) suggested nitrate criteria of 0.12 to 0.31 mg/L, and for the Puget Lowlands specifically, suggested a criterion of 0.26 mg/L. For lakes, the USEPA (2000) suggested a criterion of 0.100 mg/L. A study of farm ponds in the Midwest determined that to maintain species richness of amphibians, the nitrate concentration needed to be less than 2.5 mg/L (Knutson et al. 2004). Nitrate, rather than orthophosphate, tends to be what limits algae in many coastal waters. In some estuaries in other regions, degraded biological communities have been correlated with concentrations of as little as 0.1 mg/L nitrate (USEPA 1989).

### ***Condition and Trends***

Condition: *Significant Concern - High Certainty*. Trends: *Indeterminate*.

The relatively low intensity and dispersed nature of land uses within most of the Reserve, combined with small watersheds due to island location, would seem to support relatively good water quality. However, regular monitoring at one point just above tidewater on the Reserve's west side (58a, see Figure 13) has found concentrations of nitrate (median= 22.1, maximum = 52.8 mg/L), phosphorus (median= 0.41, maximum = 1.69 mg/L), turbidity (maximum = 435 NTU), and fecal coliform bacteria (median= 96, maximum = 73,600) that are higher than anywhere else in Island County, and are often far above thresholds considered to be ecologically safe (Adamus 2006, Island County Environmental Health 2013). Another sample point within the Reserve (SP7) during 2014 had nitrate levels exceeding 100 mg/L on several occasions. At sample point 58a, turbidity was found to exceed the County-specified threshold of 14 NTU during 48% of the visits in 2007 and 16% of the visits during 2010. See data from the Reserve compiled in Appendix 3.

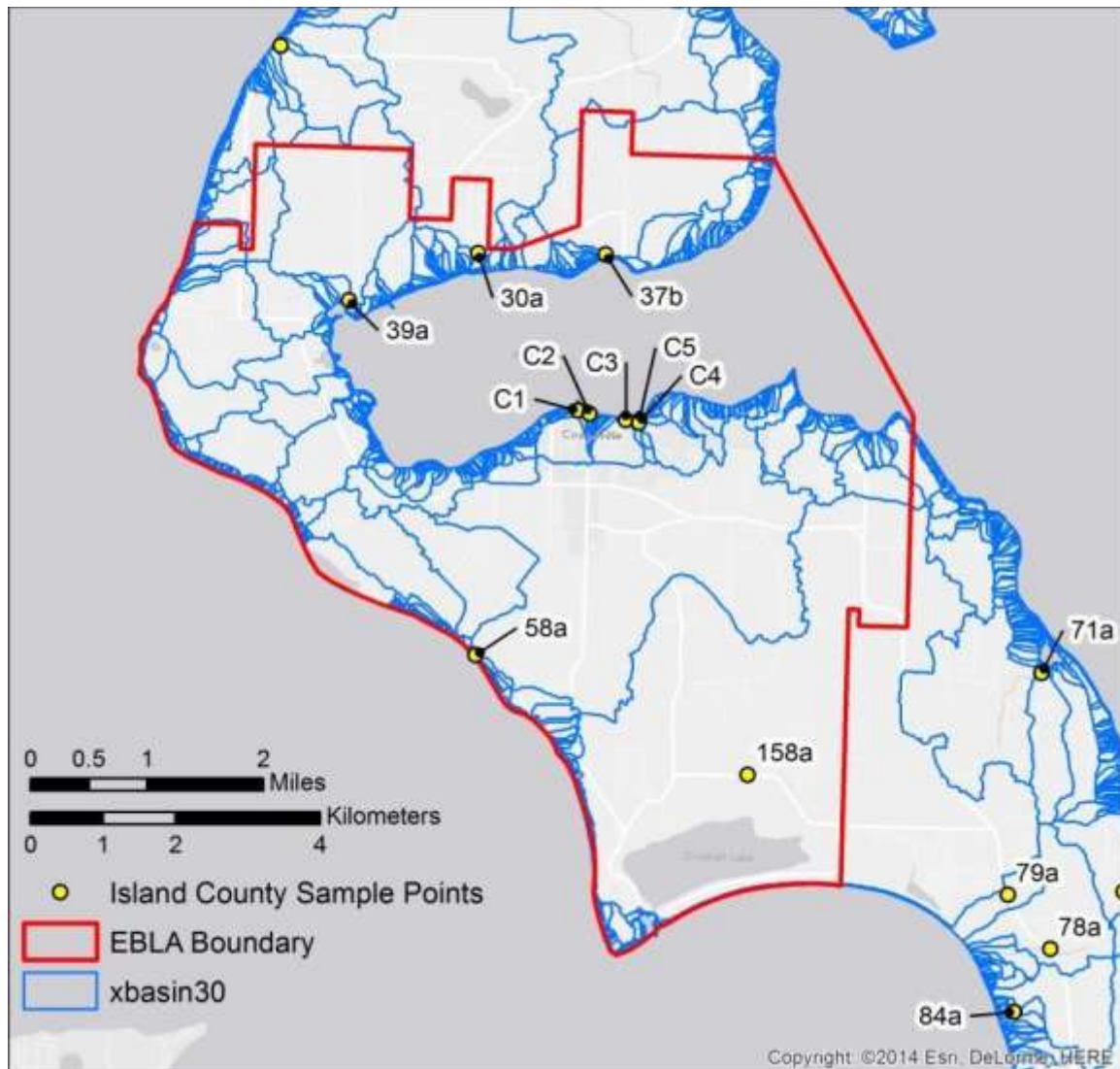
In response to concerns about the water quality conditions within the Reserve, in 2013 the Whidbey Island Conservation District (WICD) initiated an Ebey's Prairie Watershed Stormwater Remediation Project. The purpose was to better understand the hydrology of the area, trace the pollutant sources, and recommend measures to alleviate these water quality problems. Seven sites (Figure 14) were monitored every other week during the rainy seasons from April-June 2013 and November-June 2014, except where water was not present, or present but not flowing. Source identification occurred throughout those months, and storm sampling at source identification locations continued into October 2014. In all, seven discrete storm events were sampled. All baseline sites were sampled during two storms (February 24 and May 23, 2014), all but SP6 and SP7 were sampled February 18, 2014, and source identification work occurred during the remaining four storm events.

The project determined that the high nitrate concentrations at sample points SP7 and 58a are most likely the result of subsurface tile drains that drain agricultural fields underlain by organic soils -- probably a former wetland or prairie. At various times when the fields were cropped over the past century, manure was applied and on other occasions dairy cattle were herded. The nitrate is likely the accumulated legacy of those historical conditions, inasmuch as livestock are no longer present there and use of fertilizer (mainly manure) has been reduced considerably. High levels of fecal coliform in surface waters at a different location (SP4) in the Reserve appeared to be associated with a farm there. The high fecal coliform levels at two locations (SP1a, SP1b) within the Reserve closer to town were tentatively attributed to pets and/or deer.

Despite the outstanding efforts that have been undertaken to monitor surface waters in Island County including in the Reserve, it is yet too early to report on trends, thus the rating above of "Indeterminate" for water quality trends.

Other substances potentially harmful to humans and wildlife include heavy metals, flame retardants, detergents, hormone disrupters, and petrochemicals (mainly pesticides and oil). To date, these apparently have not been measured in surface waters within the Reserve, but should be. Also, as noted in a previous chapter, water quality in Lake Pondilla has not been monitored regularly.



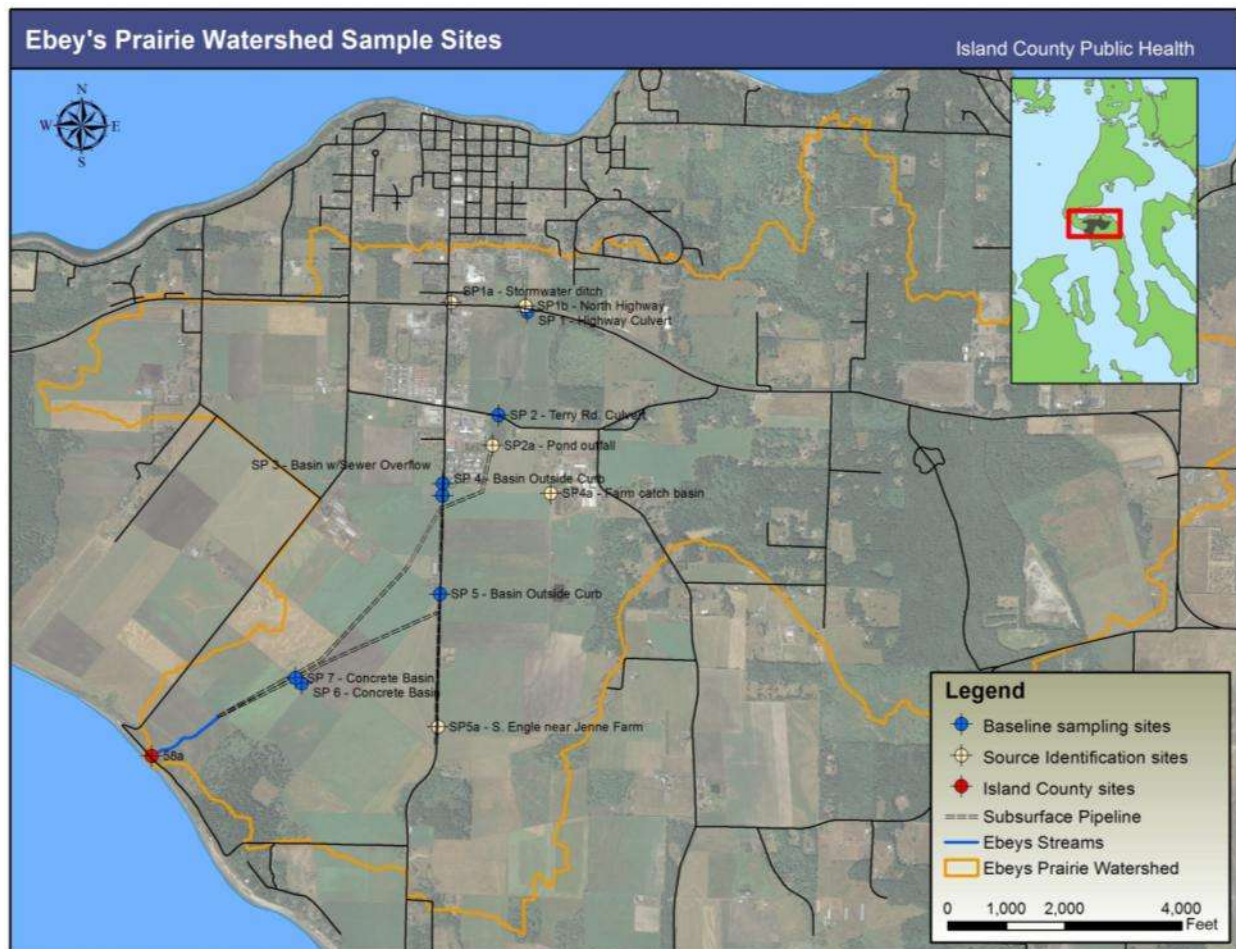


**Figure 13. Points within the Reserve sampled regularly by Island County's Water Quality Monitoring Program.**

Blue lines are the computer-generated contributing watersheds of the sampling points.

Because the Reserve encompasses the small town of Coupeville, urban as well as agricultural sources of pollution are a potential concern. Currently, most of Coupeville's storm water flows directly into Penn Cove without any treatment. Some storm water also enters Admiralty Strait at Ebey's Landing. Tests have found contamination with metals (concentrations of up to 0.005 mg/L total copper and 0.004 mg/L dissolved copper), oil products, excessive nutrients, and fecal coliform bacteria. The National Park Service is a partner in a pilot project to divert storm water runoff into a bioswale on the edge of town. The bioswale percolates this runoff through a mass of roots and soil, which could remove pollutants at least temporarily before the water reaches Puget Sound. Consideration is being given to expanding this experiment to include treated waste water currently being discharged from the town's sewage processing facility into Penn Cove. After being treated again in the bioswale, the water would be used to help irrigate local crops and recharge groundwater. However, caution is advised given the problems currently being

encountered with excessive nutrients discharging from some of the area's drained agricultural lands.



**Figure 14. Locations where surface water was sampled for the Ebey's Prairie Watershed Stormwater Remediation Project in 2014.**

In an effort to map potential relationships between water quality and water flow within Island County, consultants in collaboration with the Washington Department of Ecology recently applied to all of Island County that department's Puget Sound Watershed Characterization methodology -- a GIS-based approach that does not require collection of new data (Stanley et al. 2013). The accuracy of the exercise's predictions was significantly limited by lack of spatial data of appropriate resolution as well as paucity of fundamental hydrologic data on evapotranspiration rates of different vegetation stages, surficial geology, groundwater recharge, and subsurface flow patterns (especially tile drains). Data which the County previously paid to collect and compile in 2005 -- which quantify road density and the intensity of development in the contributing catchments of all wetlands, as well as index the flow paths among wetlands and prioritize particular wetlands based on their potential to store and purify surface water -- were apparently not used in the exercise. Moreover, the effect of wetlands on stream flow and some water quality parameters such as fecal coliform bacteria, temperature, and dissolved oxygen

was assumed to be unidirectional but actually is likely to be heavily dependent on multiple characteristics of an individual wetland.

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#### **4.4 Terrestrial Vegetation and Land Cover**

#### **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 was discussed in section 4.3.4.2.

#### **4.4.2 Regional Context**

The Reserve 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 Reserve. Prairies are one of the most endangered habitats in Washington, and have been reduced to a few percent of historical extent (Noss et al. 1995, Chappell et al. 2001, Sheehan 2007a, Dunwiddie and Bakker 2011). Although several thousand acres still remain in South Puget Sound, in North Puget Sound, prairies have been reduced to just a few acres, most of which are highly degraded. 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 for centuries by frequent burns initiated by Native Americans (Boyd 1999, and many others).

In addition to prairies, coastal strand and spit vegetation that occurs adjacent to some of the Reserve's beaches (e.g., Keystone Spit, Perego's Lagoon) is very limited in extent within the Puget Lowland (Rocchio et al. 2012). The Reserve also contains a few remnant stands of old-growth and mature, natural-origin forests. Those, too, are relatively rare within the Puget Lowland region.

#### **4.4.3 Issues Description**

This chapter addresses all the vegetation-related issues and indicators considered most important (ranked “3”) by NPS staff during the rating exercise described in section 3.0, although 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 Invasive Plant Species
- Effects of Geomorphic and Hydrologic Changes

The “indicators” are:

- Extent, Distribution, and Composition of Prairies and Oak Woodlands
- Extent, Distribution, and Composition of Less Common Plant Species and Communities
- Composition, Structure, and Age of Forests
- Land Cover

Definitions and reasons for selecting these indicators are provided in section 4.4.4.

#### 4.4.3.1 Effects of Altered Fire Regimes

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

In the Reserve and throughout much of the Puget lowlands, lightning is not a major source of wildfires. Rather, it is likely that the prairies and woodlands of central Whidbey were burned regularly by Native Americans prior to settlement by Europeans, 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), little is known about how long the practice of burning prairies had been carried on. In some areas immediately along the coast, prairies may have remained relatively treeless for millennia even in the absence of regular burning due to local edaphic and climatic conditions (Chappell 2006a). In other areas, fires may have occurred extensively during the last several thousand years, and primarily 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 (Turner 1995).

Historical accounts and legacy plant communities of the Puget Lowland and Whidbey Islands indicate that pre-settlement fire regimes, and thus the extent of native prairies (Chappell et al. 2001), have been drastically altered (Spurbeck and Keenum 2003, Gray and Daniels 2006, Sprenger and Dunwiddie 2011). In the absence of active management to maintain native prairie, especially using fire, the areal extent of prairies, as well as their native species composition, is particularly threatened by vegetation succession (Hamman et al., 2011). This includes excessive establishment and growth of Douglas-fir and an increase of shrubs, both of which rapidly exclude many native grasses and forbs. Further, many non-native species are well adapted to fire, so fires have the potential to cause additional degradation of native prairies depending on a variety of factors associated with specific fire regimes. In the absence of fire, natural succession causes prairies to become shrublands and forest, threatening many native prairie species such as golden paintbrush ( *Castilleja levisecta*) and white-topped aster (*Sericocarpus rigidus*).

In addition, lack of fire may be negatively impacting the health, and perhaps abundance of, Pacific madrone (*Arbutus menziesii*) in western Washington, and, by extension, perhaps within the Reserve 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 fruit-eating 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, introducing fire through prescribed burning, or mimicking fire mortality effects on adult trees through selective cutting may be useful.

It is important to recognize that fire is critical to the maintenance of prairies, and fire return intervals (FRI) are commonly used as a measure of 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, since the only information needed is the area burned each year. Furthermore, it tends to be correlated with severity and intensity (Agee 1993). Evidence from grasslands worldwide (Veldman et al. 2015), management of restored prairies using prescribed fire (Hamman et al. 2011), as well as from local historical sources (Boyd 1999), indicates that reference condition FRI in upland dry 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. FRI may be somewhat less frequent for wet prairies, but there is little direct evidence to quantify this more precisely. Available historical information indicates that prairie fires in the ecoregion occurred primarily in late summer and early fall (Storm and Shebitz 2006, Sprenger and Dunwiddie 2011).

The juxtaposition of development and rural landscapes can also alter fire regimes indirectly. Increases in residential development in the forestland-urban interface can increase human-caused fire ignitions. With development also comes significant legal and societal pressures to suppress all fires, which is the predominant mode in the Reserve at this time. Due to resident's concerns about fire damage or smoke impacts, the use of prescribed fire for management becomes more difficult in the societal context of dispersed rural development, as opposed to uninterrupted natural and semi-natural vegetation.

#### 4.4.3.2 Effects of Rural Development and Recreational Use

The impacts of rural development on the Reserve's vegetation and land cover began with Euro-American settlement, as Whidbey Island's forests and prairies were first converted to agriculture, and then increasingly to roads, buildings, and other infrastructure. During the late 1800s and throughout much of the 1900s, virgin or near-virgin forests throughout the region were cut as the demand for timber rapidly grew. Within the past 50 years, rural development (i.e., building of homes, roads, conversion of native vegetation to cropland or pasture) has increased significantly within or near the Reserve and throughout Whidbey Island. The relatively small size of this Reserve, its mixed-use mission, and its

location on an island potentially concentrate the factors associated with development which could impact the Reserve's vegetation.

Development of open agricultural land, prairies, and forested areas for residences and other uses threatens both the areal extent of these habitats as well as the ecological integrity of remaining undeveloped lands via fragmentation and edge effects. Increased human use traffic, whether associated with development or recreation, inevitably increases the incidental or intentional (for landscaping) introduction of invasive plants, as does construction of roads and driveways. The spread of invasive plants can be accelerated by dumping of yard waste and the proliferation of unmarked trails associated with increased use of off-road vehicles and bicycles by recreationists. Timber harvest, especially clearcutting, of young and mature forest stands is also a potential stressor, though large commercial harvests on Whidbey Island ceased over a decade ago. Periodically, trees along the Reserve's roadside powerlines are removed for safety reasons.

Development in and around the Reserve brings about sociological changes as well and those changes can affect the Reserve's natural resources. Constituencies develop that often have a strong interest in how the resources should be managed. Such constituencies can be both an asset and a hindrance to natural resource management. Some may view non-native species as desired entities and oppose their removal; others may object to smoke or other impacts from important vegetation management activities, such as prescribed burning or the use of herbicides. But residents can also be strong advocates to argue on behalf of the Reserve's natural resources.

The Reserve presents unusual management challenges as a result of its unique emphasis on both cultural and natural landscapes. The continued extensive existence of traditional agriculture~~a~~ on the prairie soils of the Reserve (rather than development) leaves open the door for possible future expansion of restored native prairies. However, at times some constituencies have viewed prairie restoration as a threat to agriculture and therefore to traditional land use. It is apparent, though, that urban and rural development is a greater threat because it threatens both native vegetation and agriculture. In this respect, cultural and historical objectives for the Reserve can be in harmony with natural resource objectives.





**Figure 15. Erosion hazard (off-road, off-trail).**

source: <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>

Rating	Acres in AOI	Percent of AOI
Slight	12,226.6	66.6%
Moderate	957.7	5.2%
Very severe	318.0	1.7%
Severe	15.0	0.1%
Null or Not Rated	570.9	3.1%



**Figure 16. Soil rutting hazard.**

Rating		Acres in AOI	Percent of AOI
Moderate		6,738.2	36.7%
Severe		4,873.0	26.5%
Slight		1,461.6	8.0%
Null or Not Rated		1,015.4	5.5%

The ratings indicate the hazard of surface rut formation through the operation of forestland equipment. Soil displacement and puddling (soil deformation and compaction) may occur simultaneously with rutting. Ratings are based on depth to a water table, rock fragments on or below the surface, soil type, depth to a restrictive layer, and slope.



**Figure 17. Suitability for paths and trails.**

<b>Rating</b>	<b>Acres in AOI</b>	<b>Percent of AOI</b>
Very limited	6,764.1	36.8%
Somewhat limited	4,122.3	22.5%
Not limited	2,631.0	14.3%
Null or Not Rated	570.9	3.1%

Paths and trails for hiking and horseback riding should require little or no slope modification through cutting and filling. The ratings are based on the soil properties that affect trafficability and erodibility. These properties are stoniness, depth to a water table, ponding, flooding, slope, and texture of the surface layer.



**Figure 18. Fire damage susceptibility.**

Rating	Acres in AOI	Percent of AOI
Moderately susceptible	11,258.7	61.3%
Highly susceptible	2,157.2	11.8%
Slightly susceptible	101.5	0.6%
Null or Not Rated	570.9	3.1%

These ratings represent the relative risk of creating a water repellant layer, volatilization of essential soil nutrients, destruction of soil biological activity, and vulnerability to water and wind erosion prior to reestablishing adequate watershed cover on the burned site. The ratings are directly related to burn severity (e.g. a low-moderate severity burn will not result in water repellant layer formation). Sandy soils are more susceptible to formation of a water repellant layer. High rock fragment content increases the rate of heat transfer into the soil. Steep slopes increase the vulnerability to water erosion. Susceptibility to formation of hydrophobic or water repellant layers varies by vegetation type. Hot, dry south-facing slopes are more susceptible to fire damage than cooler, north-facing slopes. "Highly susceptible" indicates that the soil has one or more features that are very favorable for soil damage by fire. "Moderately susceptible" indicates that the soil has features that are moderately favorable for damage to occur. "Slightly susceptible" indicates that the soil has features that generally make it unfavorable for damage to occur.



**Figure 19. Potential yields of grass-legume hay.**

These ratings are the estimated average yields (tons per acre) that can be expected for grass-legume hay. In any given year, yields may be higher or lower than those indicated because of variations in rainfall and other climatic factors.

#### 4.4.3.3. Effects of Grazing and Browsing

When deer and other herbivore populations 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). Sustained, elevated deer populations also impact understory composition of native forests by preferential browsing on deciduous shrubs.

Populations of deer on Whidbey Island are exceptionally high due to the relatively mild marine climate, extensive intermixing of open areas and woodland, lack of significant predators, and restrictions on hunting within semi-developed areas of the Reserve (Ruth Milner, WDFW, personal communication). As evidence of high deer populations, Whidbey Island experiences one of the highest rates of deer-vehicle collisions in western Washington. Populations of voles and non-native rabbits also are exceptionally high in some years (Dunwiddie, personal observation). The collective effects of all these grazing herbivores have posed significant problems for prairie restoration. In particular, heavy grazing on endangered golden paintbrush in some areas (Dunwiddie et al. 2013) has forced managers to fence recovery areas to prevent damage to flowering individuals. In areas where managers have been able to install and maintain fencing, flowering of



paintbrush has increased dramatically, and populations have grown rapidly. Although impacts on other prairie species have not been tracked, presumably similar effects are occurring on other species as well due to such grazing. However, fencing is expensive to erect and maintain, cannot reliably exclude all potential grazers, and presents aesthetic issues in some areas and logistical problems related to burning, mowing, and other prairie management activities. Alternative solutions are needed for long-term success of prairie restoration where grazing depredation is high.

#### 4.4.3.5 Effects of Invasive Plant Species

Some non-native plant species seem relatively innocuous in terms of their impacts on native vegetation. However, many are “invasive”, meaning the plant species are far more successful than native species in the competition for moisture, light, and other life requirements, and consequently increase rapidly. Often increases in invasive species come at a cost to the detriment of native species whose abundance and distribution is often much already more limited locally and regionally. ThisThe replacement of native species by invasives can result in loss of plant diversity at local and regional scales. Non-native species have become a major component of the Island's flora and of the vegetation composition of the Reserve (Table 3). 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.

Among the invasive plant species, several are classified as “noxious weeds” by government jurisdictions due to their economic and/or biological effects, and control of them is required by law (Table 3). 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. Island County draws upon this state list to designate particular species of concern in the islands, and a subset of these is selected for control. The National Park Service focuses their weed control efforts on both invasive and noxious weeds, recognizing that some species are ecologically problematic even though they have not been officially designated as “noxious” by the Washington State Noxious Weed Board. The NPS Exotic Plant Management Team has worked closely with State Parks, Island County, and The Nature Conservancy to control several noxious weeds within the Reserve, particularly poison hemlock.

The Washington State Noxious Weed Control Board defines specific classes of noxious weeds: class A, class B designates, class B, and class C:

- Class A Weeds: Non-native species whose distribution in Washington is still limited. Preventing new infestations and eradicating existing infestations are the highest priority. Eradication of all Class A plants is required by law.
- Class B Weeds: Non-native species presently limited to portions of the State. These species are designated for control in regions where they are not yet widespread. Preventing new infestations in these areas is a high priority. In regions where a Class B species is already abundant, control is decided at the local level, with containment as the primary goal.

- Class C Weeds: Noxious weeds which are already widespread in WA or are of special interest to the state's agricultural industry. The Class C status allows counties to enforce control if locally desired.

When controlling an invasion of noxious weeds on a parcel of land there are several different methods of control that can be implemented by the land owner. It is best to use a combination of multiple control methods or integrated pest management (IPM). Methods of control are physical, mechanical, biological, cultural, and chemical. Island County Noxious Weed Control Board (ICNWCB) provides resources to assist land owners with developing and implementing control strategies. When landowners need assistance with identification or developing a control program, the ICNWCB has a program coordinator who can assist with any issues that might arise. The Island County Noxious Weed Control Board Program Coordinator ([thane.tupper@wsu.edu](mailto:thane.tupper@wsu.edu)) also provides useful information.

**Table 3. Species designated as Class A, B, or C weeds in Washington, reported from the Reserve.**  
sources: Rochefort 2010, Dunwiddie et al. 2013 and personal data, Island County;  
<http://www.nwcb.wa.gov/>

Scientific Name	WA Weed Category
<i>Cirsium arvense</i>	C
<i>Cirsium vulgare</i>	C
<i>Conium maculatum</i>	B
<i>Convolvulus arvensis</i>	C
<i>Cytisus scoparius</i>	C
<i>Daphne laureola</i>	B
<i>Daucus carota</i>	C
<i>Foeniculum vulgare</i>	B
<i>Geranium robertianum</i>	B
<i>Hedera helix</i>	C
<i>Hypericum perforatum</i>	C
<i>Hypochaeris radicata</i>	C
<i>Ilex aquifolium</i>	Local concern
<i>Leucanthemum vulgare</i>	C
<i>Lupinus arboreus</i>	Local concern
<i>Phalaris arundinacea</i>	C
<i>Phragmites australis</i>	B
<i>Rubus armeniacus</i>	C
<i>Rubus laciniatus</i>	C
<i>Senecio jacobaea</i>	B
<i>Senecio vulgaris</i>	C
<i>Tanacetum vulgare</i>	C
<i>Ulex europaeus</i>	B

#### 4.4.3.6 Effects of Geomorphic and Hydrologic Changes

Strand and spit communities are unusually vulnerable to changes related to geomorphic landform, hydrology, and hydrologic events. These communities are closely dependent on natural processes of beach formation, storm surge disturbance, sea level fluctuations, sediment erosion/deposition, and wind-mediated sand transport (Gallucci 1980).

Predicted future sea level rise, combined with potentially larger storms, may threaten the stability of strand/spit communities simply through inundation or via higher and more frequent storm surges. Coastal morphology in general could be significantly altered by such events, and thereby alter the distribution and composition of coastal spits and strand. Coastal geomorphic changes are discussed more extensively in Section 4.2.

#### **4.4.4 Indicators to Evaluate Vegetation Condition and Trends**



We consider the primary indicator of vegetation condition to be the intactness of native vegetation, which encompasses various aspects of the plant communities. These aspects include the extent, distribution, composition, age, and structure of the vegetation, all of which vary somewhat in importance in different vegetation types. We address this indicator in relation to important aspects of three major groupings of the Reserve's vegetation:

- Extent, Distribution, and Composition of Prairies and Oak Woodlands
- Extent, Distribution, and Composition of Less Common Plant Species and Communities
- Composition, Structure, and Age of Forests

#### 4.4.4.1 Extent, Distribution, and Composition of Prairies and Oak Woodlands

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. Where oaks are widely spaced and do not form a contiguous canopy, oak woodlands are often termed savannas. However, no oak savannas currently exist in the Reserve, and Douglas-fir savanna/woodland is also almost entirely extirpated. 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 saltspray is great. These more specific and self-limiting environments are often referred to in ecological literature as grassy balds, rocky balds, and/or herbaceous coastal bluffs (Chappell 2006a). Herein, they are treated as a subset of prairies because they share a significant number of grass and forb species. However, a history of frequent burns at a particular location is more likely to support the occurrence and persistence of prairie and oak woodland. These habitats are of particular importance because a disproportionate number of their herbaceous plant species are regionally rare or uncommon.

Loss of Whidbey Island's prairie and oak woodland initially was caused by cultivation that accompanied settlement by Europeans. Cultivation focused on the treeless prairies, as their soils were more productive and they demanded far less effort to farm than was required to clear forested lands (White 1999). Livestock grazing and the cessation of Native American burning also heavily impacted the landscape at this time. More recently, the loss or degradation of prairie likely has resulted from a surge in rural development. 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. Although Island County has the authority to designate prairie as a Habitat of Local Significance under Washington's Growth Management Act, they have not done so.

## Criteria

“Good” conditions would be the existence of prairie:

- no less than 25% of its historical extent within the Reserve,
- retaining their historical species composition and/or native species turnover rate.

“Somewhat Concerning” would be the existence of prairie:

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

“Significant Concern” would be the existence of prairie:

- that is <10% of its historical continuing to decline even from its current extent within the Reserve,
- with a native species component that is *much* diminished from historical conditions.

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

Additional more-specific criteria to help guide prairie restoration and management would include combinations of three types of measures: (1) areal extent and configuration, (2) measures of native floristic diversity and/or integrity, e.g., FQI - floristic quality index, and mean C - 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. We propose specific values for these measures based on limited data from the Reserve, other prairies in the ecoregion (Rochefort et al. 2012, Dunwiddie et al. 2013), and our personal experience. However, considerably more research is needed from prairies of various composition and quality in the region to better understand the range of possible values, and refine these metrics to more accurately track prairie quality and restoration success.

“Good” conditions would be relatively contiguous patches of native prairie that amounted to >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 10-25% of historical extent, >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 <10% of historical extent, <25 native species present, mean C of <3.7, non-native species dominant, and relative cover of native species generally <15%.

## **Condition**

*Significant Concern - Medium Certainty.* Although some characteristic prairie species persist, and a few, small prairie remnants still exist, the vast acreage of native prairie that once comprised Ebey's, Smith, and Crockett Prairies has been reduced to less than 1% of its historical extent. Most has been converted to agriculture or rural residences, fire has been excluded for many decades and has only been reintroduced to a limited extent, and the remaining fragments have been highly degraded by invasive non-native plants. Figure 20 depicts historical vegetation at the Reserve, based on soil surveys that clearly delineate soils formed under grassland or wetland conditions. The map shows that more than 25% of the reserve was grassland/prairie or wetland during the pre-EuroAmerican settlement era. The largest remaining native prairie fragment in the Reserve (other than the coastal bluffs) is the 5 acres at Smith Prairie (Sheehan 2007a, Dunwiddie et al. 2013). Grasser's Hill, another remnant of degraded prairie, is less than 10 acres in extent. The other known prairie sites are mostly less than 1 acre each in current areal extent (Sheehan 2007a). This total of less than 20 acres of existing known prairie, excluding the coastal bluffs, contrasts with the nearly 4000 acres that may have occurred historically within the Reserve. Steve Erickson (personal communication, 2013) conducted a detailed assessment and inventory of prairie remnants within the Reserve about 2001. Floristic data and GIS layers documenting the areal extent of these remnants are in NPS files (Allen McCoy, personal communication 9/12/2013), and provide an excellent baseline for potentially tracking changes in composition and extent of native prairie over time.

Non-native species have the potential to negatively impact rare prairie plants such as golden paintbrush, whitetop aster, Scouler's catchfly, and true babystars. Perennial and annual grasses include some particularly dominant invasives which pose a significant impediment to restoring native species. Some of the most abundant of the non-native grasses and invasive forbs in the prairies are listed in Table 4. In general, robust perennials tend to be more problematic in terms of their capacity to dominate prairies and crowd out the native species. 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. Some invasive plant species can modify prairie soils to facilitate conditions favorable to themselves and other invasives (Jordan et al. 2008). Allelopathy, in which plants produce chemicals that inhibit the growth of competitors, is frequently reported in the literature. However, detailed studies have not been carried out to assess potential allelopathy among the major invasive species in these prairie systems.

**Table 4. Common invasive grasses and forbs in Whidbey Island prairies (Dunwiddie et al. 2013).**

Grasses

<i>Arrhenatherum elatius</i>	tall oatgrass
<i>Agrostis capillaris</i>	colonial bentgrass
<i>Anthoxanthum odoratum</i>	sweet vernalgrass
<i>Bromus hordeaceus</i>	soft brome
<i>Bromus rigidus</i>	ripgut brome
<i>Bromus sterilis</i>	poverty brome
<i>Dactylis glomerata</i>	orchardgrass
<i>Elymus repens</i>	quackgrass
<i>Vulpia bromoides</i>	brome fescue
<i>Holcus lanatus</i>	common velvetgrass
<i>Poa pratensis</i>	Kentucky bluegrass
<i>Schedonorus phoenix</i>	tall fescue

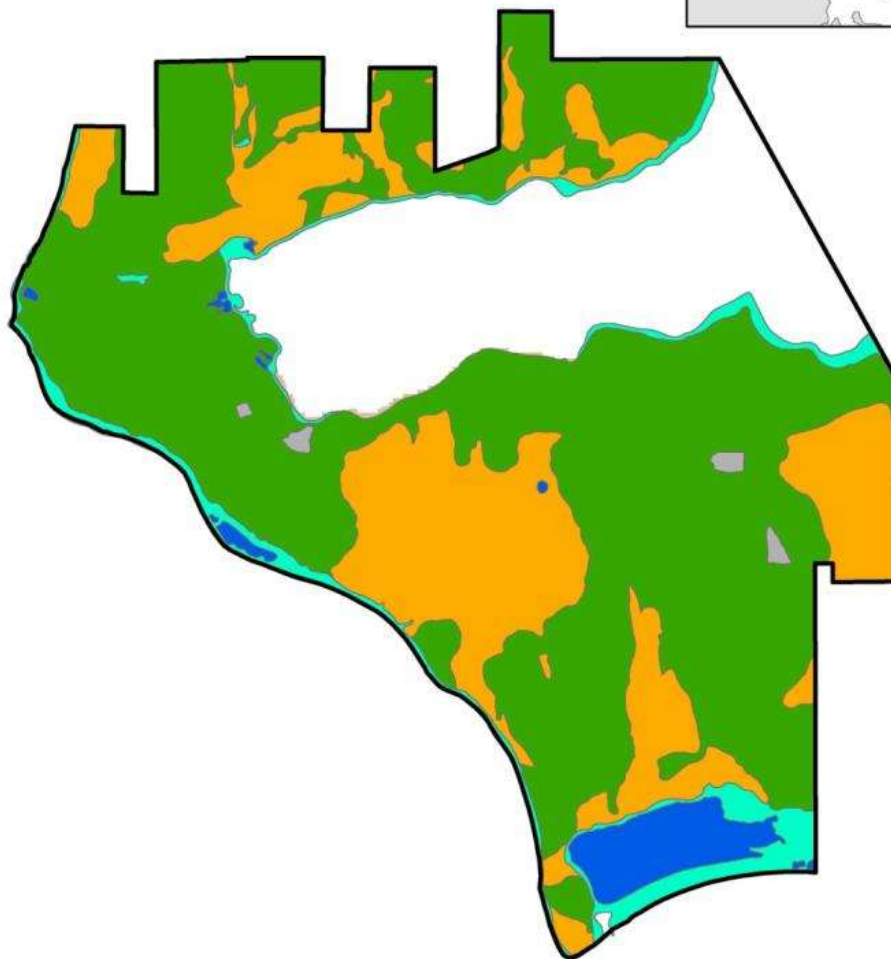
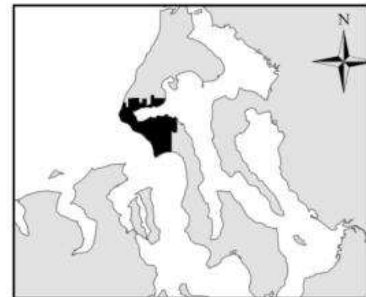
Forbs

<i>Anthriscus caucalis</i>	bur chervil
<i>Cirsium arvense</i>	Canada thistle
<i>Cirsium vulgare</i>	bull thistle
<i>Conium maculatum</i>	poison hemlock
<i>Crepis capillaris</i>	smooth hawksbeard
<i>Hypochaeris radicata</i>	hairy cat's ear
<i>Leucanthemum vulgare</i>	oxeye daisy
<i>Rumex acetosella</i>	sheep sorrel
<i>Vicia sativa</i>	common vetch
<i>Vicia villosa</i>	winter vetch



# Historical Vegetation

	Ha	%
Forest	3636.7	62.5%
Grassland	1546.7	26.6%
Modified	28.2	0.5%
Water	204.3	3.5%
Wetland	399.4	6.9%
Total	5815.3	100.0%



0 1,000 2,000 4,000 Meters  
Produced by UW research team

Source: NPS: Park Boundary, NPS Soil Survey  
Coordinate System: NAD\_1983\_UTM\_Zone\_10N June 2009

Figure 20. Historical vegetation of the Reserve based on analysis of current soil types (from Bakker et al. unpublished).

The herbaceous coastal bluffs are patchily distributed along the western perimeter of the Reserve, confined to the steep slopes immediate above Puget Sound. Thus, they are very limited in extent, but are compositionally similar in many respects to the historically-larger prairies. Their steep topography rendered them unsuitable for agriculture or building upon, so they have probably changed little in extent since EuroAmerican settlement. However, most have been seriously degraded by the invasion and spread of non-native species, which may have been facilitated in some areas by historic livestock grazing (Chappell and Dunwiddie, personal observation). In general, the bluffs include a variable mosaic of areas of herbaceous native/non-native species, extensive areas of dominance by non-native species, and occasional patches of shrubs or small trees. The bluffs are naturally exposed to erosional processes, often creating patches of bare ground that provide abundant opportunities for colonization by non-native plants (del Moral and Hanson 1980). The bluffs at Fort Ebey State Park tend to be in poor condition, with more recreational impacts and greater dominance of non-natives than at Ebey's Landing and Perego's Lagoon (del Moral and Hanson 1980, Chappell, pers. obs.).

The Washington Natural Heritage Program documented an occurrence of the globally critically imperiled plant association *Festuca rubra* - (*Camassia leichtlinii*, *Grindelia stricta* var. *stricta*) Herbaceous Vegetation on the bluff at Ebey's Landing/Perego's Lagoon. This site is one of the largest for its type in the state, with an estimated 45 acres. However, its floristic and vegetative condition is considered fair to poor, due to co-dominance and local dominance by a variety of non-native grasses, and a depauperate native flora (low native richness), likely the result of historical grazing. The abundance of brittle prickly-pear (*Opuntia fragilis*) on this site is noteworthy for this locally unique species.

### ***Trends***

*Significant Concern - Medium Certainty.* Native prairie communities have been on the edge of extirpation for many decades within the Reserve (Sheehan 2007a). However, recent efforts by several organizations have started to restore prairie at a number of sites within the Reserve. Noteworthy among these efforts are the following:

1) The Whidbey-Camano Land Trust has undertaken extremely intensive actions to restore prairie, and particularly habitat for golden paintbrush, at the Naas/Admiralty Head Natural Area Preserve (Sheehan 2007c, Lowe and Sheehan 2010). Their work has focused on aggressive removal of Douglas-fir that have overtaken the prairie remnant over the last several decades. Specific actions to enhance establishment and survival of a diverse suite of native prairie grasses, sedges and forbs include mowing, herbiciding, and burning to reduce cover of shrubs and non-native species, and extensive soil preparation and seeding and planting plugs to enhance establishment and survival of a diverse suite of native prairie grasses, sedges, and forbs, which have been plugged and seeded, and the use of herbicides. This work has significantly enhanced the condition of an existing prairie core of about 1ha, and has expanded it to include approximately 3.3ha.

2) Ecologists with Washington State Parks have worked with State Park staff to enhance about 6 acres of degraded prairie west of the gun batteries at Ft. Casey SP. This has

primarily involved regular mowing to control extensive encroachment of shrubs, as well as planting of golden paintbrush plugs and seed, and fencing to exclude grazers (Sheehan 2007b, Robert Fimbel, personal communication).

3) The National Park Service, in cooperation with the University of Washington, has conducted experimental prairie restoration trials in research plots at the Prairie Overlook. Treatments have included hand-weeding, application of herbicides, and other site-preparation treatments to control non-native grasses, combined with extensive planting of several native species (Mitchell and Bakker 2011).

4) In Smith Prairie, the Pacific Rim Institute has worked to enhance the condition of the existing prairie remnant using burning, mowing, application of herbicides, and seeding of native species. In cooperation with the University of Washington, this core area is being expanded as part of study to develop techniques for restoring native prairie in abandoned agricultural fields (Delvin 2013). Several additional acres are in the process of being restored (Dunwiddie et al. 2013). Delvin's studies also began to restore native prairie in a small area on The Nature Conservancy's Robert Y. Pratt Preserve.

A major challenge for restoration may be the fact that seed banks within the Reserve may have a great preponderance of non-native species present in the soil, and a dearth of seed from most native prairie species. This was the case at American Camp on San Juan Island (Rochefort and Bivin 2010). Another potential challenge to restoring prairies is the fact that individual plants that are being planted in restoration sites might need to first be inoculated with arbuscular mycorrhizal fungi, as those fungi are important for prairie plant growth. However, recent research in the Reserve has suggested that restoration of at least some native prairie plants on abandoned agricultural fields will not require inoculation (Smith 2007).

The current trend in the condition of the coastal bluff communities is unknown. However, their condition and extent have certainly declined since the pre-EuroAmerican settlement era due to increases in non-native species.

### ***Data Gaps***

We are aware of no studies that have reconstructed the number and composition of species that existed in prairies during pre-EuroAmerican settlement times in the Reserve or elsewhere in the region. We are quite confident in our assessments of the direction of change since pre-settlement times, but we have low to medium confidence in the exact magnitude of the change. In terms of the areal extent of prairies within the Reserve, we are relatively confident in the magnitude of change since it has been so extreme and the soil surveys provide a good template for historical conditions. In the case of floristic integrity and vegetation condition, we have much lower confidence in the magnitude of the change because we do not have adequate information on the historical condition for these parameters.

Prairie restoration within the Reserve is still in its infancy, and faces significant hurdles that are distinct from those encountered in other prairies in Washington. In most areas,

prairie restoration has largely involved enhancing existing prairie by controlling invasive species and enhancing the diversity of natives. At the Reserve, virtually all prairie restoration must begin “from scratch”, beginning with abandoned agricultural fields with no extant component of native species whatsoever. Such restoration is largely uncharted territory; only the recent work by Lambert (2006) at American Camp on San Juan Island, and Delvin (2013) at Pacific Rim Institute and the Robert Y. Pratt Preserve begins to provide specific guidance in how prairie restoration might proceed under these conditions. Much more research is needed to develop and refine prairie restoration strategies.

The information gaps outlined in the previous section identify important areas where greater knowledge is needed to restore and manage native vegetation types at the Reserve. We list here a number of critical research questions that are suggested by these information gaps.

1) How can prescribed fire be used most effectively to enhance target native species and communities, and without encouraging the further spread and increase of undesirable non-natives?

It is essential to recognize that fire alone will not restore native species to these systems and, in many cases, can make situations worse by enhancing some invasive plant species. Successful use of fire in the restoration of prairie must approach the process holistically to address diverse restoration issues in a comprehensive manner. It is widely recognized today that prescribed fire is required to restore and maintain many of these fire-adapted ecosystems. While mechanical treatments (cutting of trees, mowing of brush and grass) can mimic some of the effects of fire, many of the ecologically-significant impacts are difficult or impossible to recreate in other ways. Fire is particularly important in establishing and maintaining conditions that favor native herbaceous species in prairies and savannas. It is important to recognize, however, that these species are usually extremely seed-limited, and that 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 the use of herbicides, to help control invasive species, together with extensive seeding of natives (Stanley et al. 2008, 2011b).

2) How can prairies be restored and managed using prescribed fire and other techniques to enhance habitat elements critical for sustaining less common or sensitive wildlife species, such as the endangered Island Marble butterfly, and avoid inadvertent negative impacts?

For example, key host plants for the Island Marble (*Euchloe ausonides insulanus*) 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. As another example, frequent burning generally reduces cover of



ground-dwelling mosses and lichens. This can be an important goal for creating conditions under which the seed of native prairie species will germinate. Yet little is known about the composition and abundance of these non-vascular organisms in island communities, and burning may inadvertently result in negative impacts to such species that have been poorly studied. We particularly recommend careful inventory of these taxonomic groups across the Reserve, particularly in areas where fire will be used as a management tool. In general, prairie management and restoration regimes need to be based on a thorough understanding of habitat requirements and life histories of target species, and carefully balance management practices that account for conflicting or competing resource requirements.

3) What are appropriate target values for species diversity, mean Coefficient of Conservatism (C), and native/non-native ratios?

Work has only just begun applying principles of Floristic Quality Assessment to prairie communities in the Pacific Northwest (Rochefort et al. 2012, Rocchio and Crawford 2013, Dunwiddie et al. 2013). Ecologists have assigned C values (Coefficients of Conservatism) to prairie species across the region, making these values much more generally applicable. However, much remains to be learned about how these parameters can be used to inform and guide prairie restoration practitioners. These parameters need to be carefully evaluated for existing sites throughout the region, and further refined as sites are restored and managed and ecological processes such as fire are re-established.

4) What is the minimum size for restored prairie remnants to ensure that most native species will survive, important ecological processes are intact, and invasion of non-native species is reduced to the greatest degree possible?

To some extent, the answers to this will depend on the restoration goals and the ecological requirements of target taxa. Such data are better known, for example, for various species of grassland-nesting birds. There is little data describing similar requirements for plants, butterflies, or other taxa. Some general guidance for vascular plant diversity can be obtained by examining species-area curves for native prairies across the region (Dunwiddie et al. 2006). These data suggest that even prairies of several hundred acres are missing significant components of the biota. Finally, prairies at the Reserve are physically constrained by the size of the Reserve itself, and more particularly by the land that is potentially available for restoration of native prairie. Therefore, at least initially, it is most prudent to conclude that native remnants should be restored to the maximum size that resources and space allow, and that future restoration efforts should focus on increasing overall area by adding to existing cores and connecting fragments.

5) How can sufficient quantities of native seed from appropriate sources be made available for restoration efforts?

Lack of native seed sources and insufficient quantities of seed and plugs have been a major impediment for prairie restoration in Washington and Oregon. This hurdle is only beginning to be addressed on Whidbey Island as various nurseries are starting to develop supplies, although unless a steady market for this can be guaranteed, nurseries will be

reluctant to invest heavily. For most species, however, 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. Finally, for a significant number of species, no local sources exist, and restoration will need to rely on sources from elsewhere in Washington.

#### 4.4.4.2 Extent, Distribution, and Composition of Less Common Plant Species and Communities

As is true generally, among the many species occurring in the Reserve, the rarest ones contribute the most to the region's biodiversity. Several 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 Reserve'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 localized random events will result in their extirpation.

There is no comprehensive floral inventory, either for Whidbey Island as a whole, or for the Reserve. Rochefort (2010) reported a total of 352 species compiled from various sources which documented collections and records primarily from native-dominated habitats (Table 5). In this report, we incorporated additional records from surveys of the Robert Y. Pratt Preserve (The Nature Conservancy), the Pacific Rim Institute on Smith Prairie (Dunwiddie et al. 2013), and Ft. Casey and Ft. Ebey State Parks (R. Fimbel, WA State Parks), and the Naas Preserve (Dunwiddie, 2011), which increased the total to 445 plant species, 64% of which are native. Compiling data from several sources including Rochefort (2010), we tallied a total of 445 plant species that have been reported from the Reserve. This represents about one-quarter of the entire Island County flora, based on a cursory query of herbarium records (<http://www.pnwherbaria.org/data/search.php>). However, this figure likely underestimates the total flora for the Reserve because most of the land within the boundary has not been surveyed. Furthermore, since much of this land is in cultivation or rural residential use, we suspect that the preponderance of species yet to be documented are non-native, thereby likely raising the proportion of non-natives.

At least 23 plant species classified as noxious have been found within the Reserve, representing 5-7% of the Reserve's known flora (Table 3). All non-native species (not just noxious ones) within the Reserve comprise between 25 (Rochefort 2010) and 33 percent (our estimate) of the Reserve's flora. The vast majority of these occur in open habitats like agricultural fields, dunes/strand, or residential yards in developed zones.

**Table 5. Number of vascular plant species in the Reserve (adapted from Rochefort 2010).**

Growth Form	Total #	# Native Species	# Non-native Species
Forbs	236	150	86
Graminoids	74	43	31
Shrubs and vines	41	34	7
Trees	23	21	2

Growth Form	Total #	# Native Species	# Non-native Species
Total	374	248 (75%)	96 (25%)

Most weed control within the Reserve is done by private landowners. However, one species – poison hemlock (*Conium maculatum*) – has been the focus of a multi-landowner coordinated effort, primarily centered around the bluffs at Ebey’s Landing.

Of the many plant species occurring in the Reserve, only one -- the prairie-dwelling *Castilleja levisecta* (golden paintbrush) -- 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 twelve naturally-occurring populations of this species exist in the world, and four of these occur within the Reserve. In recent years, several new populations have been restored in the Reserve as well. Thus, the Reserve plays a critical role in the successful recovery and delisting of this rare species (Gamon 1993).

In addition to golden paintbrush, several other species considered to be rare in Washington currently occur in Island County, or have been recorded there historically (Table 6Table 6). Three of these, shortspur white plectritis (*Plectritis brachystemon*), white-top aster (*Sericocarpus rigidus*), and Scouler's catchfly (*Silene scouleri* ssp. *scouleri*) are currently known to occur within the Reserve. All of the other species listed in Table 5 potentially could occur in habitats that are present within the Reserve. Few are likely to be rediscovered, but all are potential candidates for restoration.

Although not listed by the Washington NHP, several other species that are known to occur in prairie habitats at the Reserve are of conservation concern due to their scarcity on Whidbey Island (Table 7). These would be important elements to include in restoration of native prairies.

As well, the Reserve's coastal strand/spit habitat is of local conservation concern. Two herbaceous plant associations occurring within this habitat in the Reserve are of particular note according to the Washington NHP:

*Festuca rubra* - *Ambrosia chamissonis* - globally critically imperiled  
*Leymus mollis* ssp. *mollis* – *Abronia latifolia* globally imperiled association

**Table 6. Rare plant species recorded from Island County, Washington.**

\* indicates species with current records in the Reserve. State status abbreviations are as follows: E=Endangered, S=Sensitive, T=Threatened, R1 and R2=Review groups of potential concern, H=Historic, recorded only prior to 1977. Federal Status: LT=Listed Threatened, SC=Species of Concern. From: <http://www1.dnr.wa.gov/nhp/refdesk/lists/plantsxco/island.html>

Scientific Name	Common Name	State Status	Federal Status	County-listed	Historical Only
<i>Agoseris elata</i>	tall agoseris	S		X	H
<i>Balsamorhiza</i>	Puget	R2			H

<i>deltoidea</i>	balsamroot				
<i>Castilleja levisecta</i> *	golden paintbrush	E	LT	X	
<i>Ceratophyllum echinatum</i>	smooth hornwort	R1			H
<i>Cicuta bulbifera</i>	bulb-bearing water-hemlock	S		X	H
<i>Erythronium revolutum</i>	pink fawn-lily	S			H
<i>Fritillaria camschatcensis</i>	black lily	S		X	H
<i>Leptosiphon minimus</i>	true babystars	R1			
<i>Meconella oregana</i>	white meconella	T	SC	X	
<i>Plectritis brachystemon</i> *	shortspur white plectritis	R1			
<i>Ranunculus californicus</i> var. <i>californicus</i>	California buttercup	T			H
<i>Puccinellia nutkaensis</i> *	Alaska alkaligrass			X	
<i>Sericocarpus rigidus</i> *	white-top aster	S	SC	X	H
<i>Silene scouleri</i> ssp. <i>scouleri</i> *	Scouler's catchfly	S			H
<i>Solidago missouriensis</i>	Tolmie's goldenrod	R2			H

Invasive species are potential threats to the coastal strand/spit communities. A variety of non-native grass and forb species are found in these communities, many of them the same as in the areas. Del Moral and Hanson (1980) note orchardgrass, creeping bentgrass (*Agrostis stolonifera*), and velvetgrass as particularly numerous in these habitats. One non-native that is unique to the strand habitat is European searocket (*Cakile maritima*). While it is often common in unstable sand habitats, it does not appear to be a large threat to other native species. Scotch broom (*Cystisus scoparius*), gorse (*Ulex europaeus*), and Himalayan blackberry (*Rubus armeniacus*) can all be very detrimental to strand and spit communities if they become established by stabilizing the sand and by crowding out and out-competing the herbaceous vegetation. The Reserve also features small areas of relatively undisturbed mature and old-growth Puget Lowland forests (covered in detail in section 4.4.4.3).

## 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 Reserve. This might include intentionally re-establishing those that 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, or populations become extirpated or less viable, or communities lost important ecological functions or became dominated by non-native species.

This section focuses initially on the only listed species, *Castilleja levisecta*. Four criteria are proposed to evaluate and track its status within the Reserve:

- The number of populations within the Reserve,
- The number of flowering plants within each population (as a measure of population size),
- Trends in the size of each population over time, and
- Trends in the area occupied by each population.

These criteria are based on specific recovery criteria identified in the federal Recovery Plan (USFWS 2000). For *Castilleja levisecta*, the following apply:

**Number of populations:** Multiple populations of *C. levisecta* within the Reserve provide significant resilience, enabling the species to persist within the Reserve. A disturbance that may significantly impact one population, such as unusually high grazing by deer, is unlikely to uniformly affect all of the populations in an area if they are spatially separated and occur on a variety of sites. At least four, and preferably 5-6 populations probably provide sufficient redundancy within the Reserve to make persistence of this species reasonably certain within the Reserve 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 central Whidbey Island area 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. Consensus among 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 *Plectritis brachystemon*, *Sericocarpus rigidus*, and *Silene scouleri* spp. *scouleri* would also include number of populations, size of populations, population trend, and population area. Because all three currently exist as single occurrences, however, we are confident that their status should be considered to be of “Significant Concern” and in need of urgent management action.

For coastal strand/spit communities, more specific criteria 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., sand transport storm surges, log deposition and disturbance, beach formation) upon which they depend within the natural range of variation.

**Table 7. Vascular plant species associated with prairies and oak woodlands that are considered rare or extirpated on Whidbey Island (from Sheehan 2007a).**

<b>Species Name (NatureServe, 2007)</b>	<b>Common Name</b>	<b>Comments</b>
<i>Agoseris elata</i>	tall agoseris	Possibly extirpated; WNHP listed as sensitive – see narrative
<i>Allium acuminatum</i>	taper-tip onion	locally rare
<i>Balsamorhiza deltoidea</i>	Puget balsamroot	Possibly extirpated; WNHP watch list – see narrative
<i>Camassia quamash</i> var. <i>maxima</i>	common camas	locally uncommon
<i>Carex tumulicola</i>	foothills sedge	See narrative
<i>Castilleja levisecta</i>	golden paintbrush	Federally listed as threatened – see narrative
<i>Castilleja miniata</i> var. <i>dixonii</i>	scarlet paintbrush	locally rare
<i>Chrysopsis villosa</i>	hairy golden-aster	locally rare
<i>Delphinium menziesii</i>	Menzies' larkspur	locally rare
<i>Dichelostemma congestum</i>	Congested snakelily	Possibly extirpated. Syn: <i>Brodiaea congesta</i>
<i>Dodecatheon hendersonii</i>	Henderson's shooting star	locally rare
<i>Erigeron speciosus</i>	showy fleabane	locally rare
<i>Erythronium oregonum</i>	fawn lily or dogtooth violet	locally rare
<i>Festuca roemerii</i>	Roemer's fescue	See narrative. Syn: <i>Festuca idahoensis</i> var. <i>roemerii</i> , <i>F. idahoensis</i>
<i>Geum triflorum</i> var. <i>ciliatum</i>	prairie smoke	One known locality
<i>Fritillaria camschatcensis</i>	black lily	Possibly extirpated; WNHP listed as sensitive – see narrative
<i>Fritillaria lanceolata</i>	chocolate lily	locally uncommon
<i>Iris missouriensis</i>	blue-flag iris	See narrative
<i>Lilium columbianum</i>	orange tiger lily	locally rare
<i>Lomatium nudicaule</i>	barestem desert parsley	locally rare
<i>Lomatium utriculatum</i>	spring gold	locally rare
<i>Lupinus albicaulis</i>	sickle-keeled lupine	locally rare
<i>Microseris laciniatus</i>	cut-leaf microseris	locally rare
<i>Quercus garryana</i>	Oregon white oak Garry oak	Old trees, no recruitment – see narrative
<i>Sericocarpus rigidus</i>	white-top aster	WNHP listed as sensitive – see narrative. Syn: <i>Aster curtus</i>
<i>Solidago spathulata</i>	prairie goldenrod	Two known localities
<i>Sisyrinchium idahoense</i> var. <i>occidentale</i>	Idaho blue-eyed grass	Syn: <i>S. bellum</i> , <i>S. angustifolium</i>
<i>Trifolium triternatum</i>	tomcat clover	locally rare
<i>Triteleia grandiflorum</i>	wild hyacinth	Syn: <i>Brodiaea howellii</i>
<i>Triteleia hyacinthina</i>	fool's onion	Syn: <i>Brodiaea hyacintha</i>
<i>Zygadenus venenosus</i>	death camas	locally rare

Genetic issues are important when restoring plant communities as well as individual rare plant species. The best practice is to whenever possible, use locally and regionally-derived native seed. This ensures 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. The debate on distance 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., off Whidbey Island) when the local source populations are extremely small, and may have very limited genetic diversity.

### ***Condition***

*Somewhat Concerning or Significant Concern - High Certainty.* We organize the discussion around the most sensitive species and communities as follows.

*Castilleja levisecta*. Twelve naturally-occurring populations of golden paintbrush remain in existence. These occur exclusively in southern British Columbia and western Washington, although historically, the species also was found in western Oregon. Four naturally-occurring populations of *C. levisecta* are found within the Reserve boundaries. These include populations at Ft. Casey State Park, Heritage Forest bluff, Naas/Admiralty Inlet NAP, and Ebey's Landing – Hill Road. In addition to these natural populations, efforts have been made to establish new populations at several protected prairie habitats within the Reserve, as well as augment the size and viability of natural populations that had declined to extremely low numbers (Bakker et al. 2012). These efforts began in 2001, and have included outplanting of nursery-grown *C. levisecta* plugs, sowing of seed, as well as extensive site management, including enhancement of native vegetation, control of invasive species, cutting of encroaching shrubs and trees, burning, and fencing to reduce herbivory. Experimental attempts to establish new populations within the Reserve have occurred on Perego's Bluff, Ebey's Landing-Fields, Ebey's Landing – Prairie Overlook, and Smith Prairie. Augmentation of existing populations has occurred at Ft. Casey State Park and Naas/Admiralty Inlet NAP. Two of the efforts to establish new populations are promising – Ebey's Landing-Fields and Smith Prairie – both of which are the focus of continued restoration activities. Restoration efforts at the other two sites have been discontinued. Collectively, these natural, augmented, and newly-established populations amount to a total of six distinct and potentially viable populations.

*Plectritis brachystemon*: This species was first found in the Reserve in 2012, and is known from a single population in Smith Prairie. It appears to be largely confined to an area of several tens of square meters, and may consist of several thousand individuals.  
*Significant Concern.*



*Sericocarpus rigidus*: A single occurrence of this species was first found in an unprotected native prairie remnant on privately-owned property in 1984, and was rediscovered about 2001. It was last observed to occupy about a 100 square meter area in 2002. Population is threatened by shrub invasion (much of remnant already shrub covered) and road work. *Significant Concern*.

*Silene scouleri* spp. *scouleri*. There is only one population and little is known about it. It occurs near the top of the bluff at TNC's Ebey's Landing Reserve. It was last documented in 2004. *Significant Concern*.

Coastal strand and spit communities. *Somewhat Concerning - Medium Certainty*. There are two sites of significant size in the Reserve: Perego's Lagoon and Keystone Spit/Lake Hancock. The former was described in 1984 as in good to excellent condition, dominated by native species, with natural processes intact and operating (Kunze 1984). More recent visits indicate no significant changes (Chappell and Dunwiddie, pers. obs.). Accumulations of large woody debris, which help to armor the berm, appear to remain relatively constant; no beach fires have occurred in the last several decades to impact this. A large-scale cleanup about 2005 removed large quantities of creosoted logs by helicopter, but no follow-up efforts or monitoring have occurred.

The occurrences there of the two imperiled plant associations (*Festuca rubra* - *Ambrosia chamissonis* Herbaceous Vegetation and *Leymus mollis* ssp. *mollis* – *Abronia latifolia* Herbaceous Vegetation) are of significant regional conservation significance due to the combination of their condition and the regional and global rarity of the types. The Keystone Spit is highly modified by the presence of a paved highway on the spit itself, other development, recreation, historic hydrologic alterations in the vicinity, and perhaps other physical alterations. The vegetation there is in poor to fair condition, being a variable mixture of native (most obviously *Leymus mollis* ssp. *mollis* and *Grindelia stricta*) and non-native species, especially grasses (del Moral and Hanson 1980, Chappell, pers. obs.). In some years, the site has supported a very large population of *Plectritis congesta*, a coastal species that is relatively uncommon elsewhere on Whidbey Island.

## ***Trends***

Trends in most of the Reserve's rare plant species diversity are unknown. With the exception of *Castilleja levisecta*, *Plectritis brachystemon*, and *Sericocarpus rigidus* (noted below), trends in other uncommon species remain unmeasured. Given the extensive conversion of native prairie on Whidbey Island, it is known that many species have been locally extirpated, and it is likely that many have been eradicated from the island altogether (see Sheehan 2007a). Since much of this prairie acreage historically occurred within the Reserve boundaries, it is probable that many if not most of these extirpations occurred many years ago from within the Reserve. Changes in species diversity in the Reserve since its establishment are unknown.

*Castilleja levisecta*: The overall trend for this species is *Good*. The number of populations, as well as the changes in size of these populations, are presented in Table 8. In the early 2000s, only three populations were known at the Reserve, and none met the

1000 flowering plant goal for a minimum viable population. In the latter years of that decade, habitat management, population augmentation, and establishment of new sites was underway. By 2010, Ft. Casey and Ebey's Landing-Hill Road had exceeded the goal, and by 2013, three others (Naas/Admiralty Inlet, Smith Prairie, and Ebey's Landing-Fields) had exceeded this goal as well. All four had stable or increasing populations, and if these trends continue, all will have met the 5-year average Federal recovery goal (>1000 plants) by 2016. The area occupied by most populations is also expanding with active management, including restoration of new habitat for augmentation and natural spread of extant populations (Naas, Ft. Casey), as well as creation and enhancement of habitat in newly established populations (Ebey's Landing-Fields, Smith Prairie).

**Table 8. Number of flowering *C. levisecta* plants in populations within the Reserve since 2000.**  
(Source: Joe Arnett, Peter Dunwiddie)

Year	Naas/ Admiralty Inlet	Heritage Forest bluff*	Ft. Casey	Ebey's Landing – Hill Road	Smith Prairie	Ebey's Landing – Fields	Ebey's Landing – Prairie Overlook	Perego's Bluff
<b>2000</b>	97		151	7627				
<b>2001</b>	97		166					
<b>2002</b>	98		185					
<b>2003</b>	122		307					
<b>2004</b>	59		235					
<b>2005</b>	120		260	669				
<b>2006</b>	94		760	214	4	29		15
<b>2007</b>	86		1544	747	16		20	154
<b>2008</b>	148		1713	601	31		16	68
<b>2009</b>	1297		1497	601	143			
<b>2010</b>	1144	80	1538	1487	186	0	19	
<b>2011</b>	1860	71	2471	1984	1355			
<b>2012</b>	3754	67	2534	2656	12071	1375	0	
<b>2013</b>	2609	103	1196	4612	8883	3962		15
<b>2014</b>	2329	109	227	2191	5291	3143		4
<b>5-year avg.</b>	2339	86	1593	2586	5557	x	0	x

\* The Heritage Forest bluff site was not censused prior to 2010.

### ***Data Gaps***

*Castilleja levisecta*: There are no major knowledge or data gaps with this species in the Reserve. The current status and trends in the indicators for this species are well-known. Due to its designated status as a “Threatened” species, considerable attention has been directed at annually documenting these measures, and the threats are generally well-known. At all sites, direct census counts of flowering individuals result in numbers with a

high degree of confidence, although some extrapolations were conducted in the very high density areas within the large Smith Prairie population in 2012.

*Plectritis brachystemon* and *Sericocarpus rigidus*: Due to the limited amount of native prairie habitat on the Reserve, there is little likelihood that other populations of these species will be found. However, very little is known regarding the management of these species, so restoring viable populations of them will require experimental introductions and studies to better understand their biology and ecology.

*Silene scouleri* ssp. *scouleri*: There is no information for this population other than its location. There is a need to assess the population size and area occupied, and to monitor these over time.

Coastal strand and spit communities: There is a need for current, detailed information on species composition that would be adequate to use as a baseline for future monitoring. Detailed mapping of the extent of vegetation and supra-tidal sand at Perego's Lagoon berm would potentially be useful information in the event of future sea level rise.

#### 4.4.4.3 Composition, Structure, and Age of Forests

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 often locally dominant or co-dominant. On the drier sites, Pacific madrone (*Arbutus menziesii*) is an important constituent as well. In an undisturbed state, much of the reserve would naturally be covered by combinations of these species. 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.



**Figure 21. Potential forest productivity.**

These ratings indicate the predicted amount of fiber produced in a fully stocked, even-aged, unmanaged stand of Douglas-fir. It is based on predicted cubic feet per acre per year and calculated at the age of culmination of the mean annual increment (CMAI).

The forests of the Reserve have all been affected to one degree or another by logging and/or associated fires that occurred intensively and extensively during the period 1850 to 1900, and to a lesser degree since then (White 1999). This logging cumulatively removed almost all old (>200 years) trees in most areas, and in many cases resulted in stand replacement and subsequent secondary succession of young stands of trees. Fires associated with the logging era likely burned over many stands before or after they were logged. In some cases, it is likely that significant changes in canopy composition occurred as a result of the logging, for example, regeneration of red alder on moist sites, or increases in relative abundance of shade-tolerant species (western hemlock and grand fir) in response to selective removal of Douglas-fir. Taken together, this history of EuroAmerican disturbance has resulted in forests that are, on average, much younger, with smaller trees, and less down woody debris (see White 1999).

No significant amount of timber harvest has occurred within the Reserve for many years. Similarly, for the county as a whole, the extent of annual timber harvest is among the least among western Washington counties, and occurs entirely on private lands (Table 9).

**Table 9. Timber harvest (volume in thousand board feet) in Island County in 2012, by species.**

source: Washington Department of Natural Resources

Ownership	Species								TOTAL VOLUME
	DOUGLAS FIR	WESTERN HEMLOCK	CEDARS	PONDEROSA PINE	OTHER PINE	OTHER CONIFERS	RED ALDER	OTHER HARDWOODS	
Private - Industrial	0	0	0	0	0	0	0	0	0
Private - Large	0	0	0	0	0	0	0	0	0
Private - Small	325	267	280	0	0	3,388	622	368	5,250
Private - Unknown	85	0	0	0	0	0	0	0	85
<b>Total Private</b>	<b>410</b>	<b>267</b>	<b>280</b>	<b>0</b>	<b>0</b>	<b>3,388</b>	<b>622</b>	<b>368</b>	<b>5,335</b>

### 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 propose two important forest characteristics for which we developed specific criteria:

1. Relative distribution of forest ages and types.
2. Percentage of forest with late-successional stand structures.

Relative distribution and extent of forest ages and types. This characteristic is relatively straightforward. Although we did not measure it directly, it could be derived from a combination of remote sensing or aerial photography and field verification, 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 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 and extent of age class and dominance types are similar (up to 20% different from) to the presumed pre-EuroAmerican settlement distribution.

*Somewhat Concerning.* Distribution of age class and dominance types are moderately different from (varying from 20-70%) to the presumed pre-EuroAmerican settlement distribution.

*Significant Concern.* Distribution of age class and dominance types are very different (<20% similarity) than the presumed pre-EuroAmerican settlement distribution.

Table 10 illustrates combinations of the stand age and tree dominance types that we expect to frequently occur in this Reserve. We expect that Douglas-fir, grand fir, western hemlock, western redcedar, 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 10. Common and known combinations of dominance type and stand age expected to occur in the Reserve.**

Plant Species or Dominance Type	Very Young	Young	Mature	Old-growth
<i>Pseudotsuga menziesii</i>	X	X	X	X
<i>Pseudotsuga menziesii</i> – <i>Abies grandis</i>	X	X	X	
<i>Pseudotsuga menziesii</i> – <i>Arbutus menziesii</i>		X	X	
<i>Pseudotsuga menziesii</i> – <i>Acer macrophyllum</i>	X	X	X	
<i>Pseudotsuga menziesii</i> – <i>Thuja plicata</i> – <i>Tsuga heterophylla</i>		X	X	
<i>Pseudotsuga menziesii</i> – <i>Tsuga heterophylla</i>	X	X	X	X
<i>Abies grandis</i>		X	X	
<i>Acer macrophyllum</i> – <i>Alnus rubra</i>	X	X		
<i>Acer macrophyllum</i>	X	X		
<i>Alnus rubra</i> – <i>Tsuga heterophylla</i>		X		
<i>Alnus rubra</i>	X	X		
<i>Alnus rubra</i> – <i>Pseudotsuga menziesii</i>	X	X		

Percentage of forest with late-successional stand structures. Old-growth forest within the Puget Lowland of Washington has been reduced to less than 1% 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 the reserve. The vast majority of the reserve’s forests fall within the Western Hemlock series, with a small minority in the Grand Fir or Douglas-fir series (drier types than hemlock). 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 series (that is, where hemlock or western redcedar are common or regenerating) 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 series (that is, where there is very little to no hemlock or redcedar regenerating) 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 suggest 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 have 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 Reserve.

Specific criteria related to late successional forest features that we propose are:

*Good.* > 20% of existing forest landscape meets old-growth definitions.

*Somewhat Concerning.* 5-20% of existing forest landscape meets old-growth definitions.

*Significant Concern.* <5% of existing forest landscape meets old-growth definitions.

Our knowledge of reference conditions rely heavily on the historical accounts of White (1980) and our field experience in remnant natural-origin forests at the Reserve and throughout the Puget Lowland (the latter conducted largely as part of a systematic effort by the Washington NHP (Chappell 2006b). White (1999) uses historical accounts to bolster the argument that the vast majority of pre-settlement forests on Whidbey Island were dense old-growth. We presume, based on historical accounts (White 1999, Agee 1993), from inferences based on existing stands of natural-origin (i.e., not originated after logging), and fire history and stand age distribution of adjacent low-montane forests, that the pre-settlement forested landscape of the Puget Lowland was a dynamic mosaic of differing age classes and stand structures, including significant areas of woodland

(<about 60 percent tree canopy cover) associated with more frequent low- to moderate-severity fires (ignited mostly by Native American cultural burning practices in nearby managed habitats, e.g. prairies). Thus, we disagree with White's seemingly blanket statement regarding the ubiquitous presence of old-growth conditions in the pre-settlement forests of Whidbey Island. What we do *not* know, though, is just what was the specific proportional distribution of this mosaic of stand structural types. Nevertheless, it seems relatively clear that there was much more proportional representation, and, based on the historical accounts probably more than half of the total forested area, of old-growth than is present today.

## Condition

*Significant Concern - Medium Certainty.* Our analysis of LiDAR fine-resolution data for the entire Reserve (16,629,312 pixels) produced a comprehensive profile of the vegetation canopy heights (Table 11). A shapefile map of that is available.

**Table 11. Distribution of canopy heights for the Reserve's vegetation.**

Statistic	Vegetation Height (ft)
mean	27.51
median	6.07
standard deviation	30.29
minimum	0.00
maximum*	130.00
1st quartile	0.56
3rd quartile	59.96
%s based on Reserve area of 11,931 acres, of which 4,567 are forested:	
% at <3 ft	44.32
% at 3-6 ft	5.59
% at 6-20 ft	10.02
% at 20-50 ft	10.10
% at 50-100 ft	26.24
% at > 100 ft	3.73

\* artificially truncated at 130 ft due to a few anomalous readings; assumed 130 feet is approximate maximum tree height in this part of Whidbey Island.



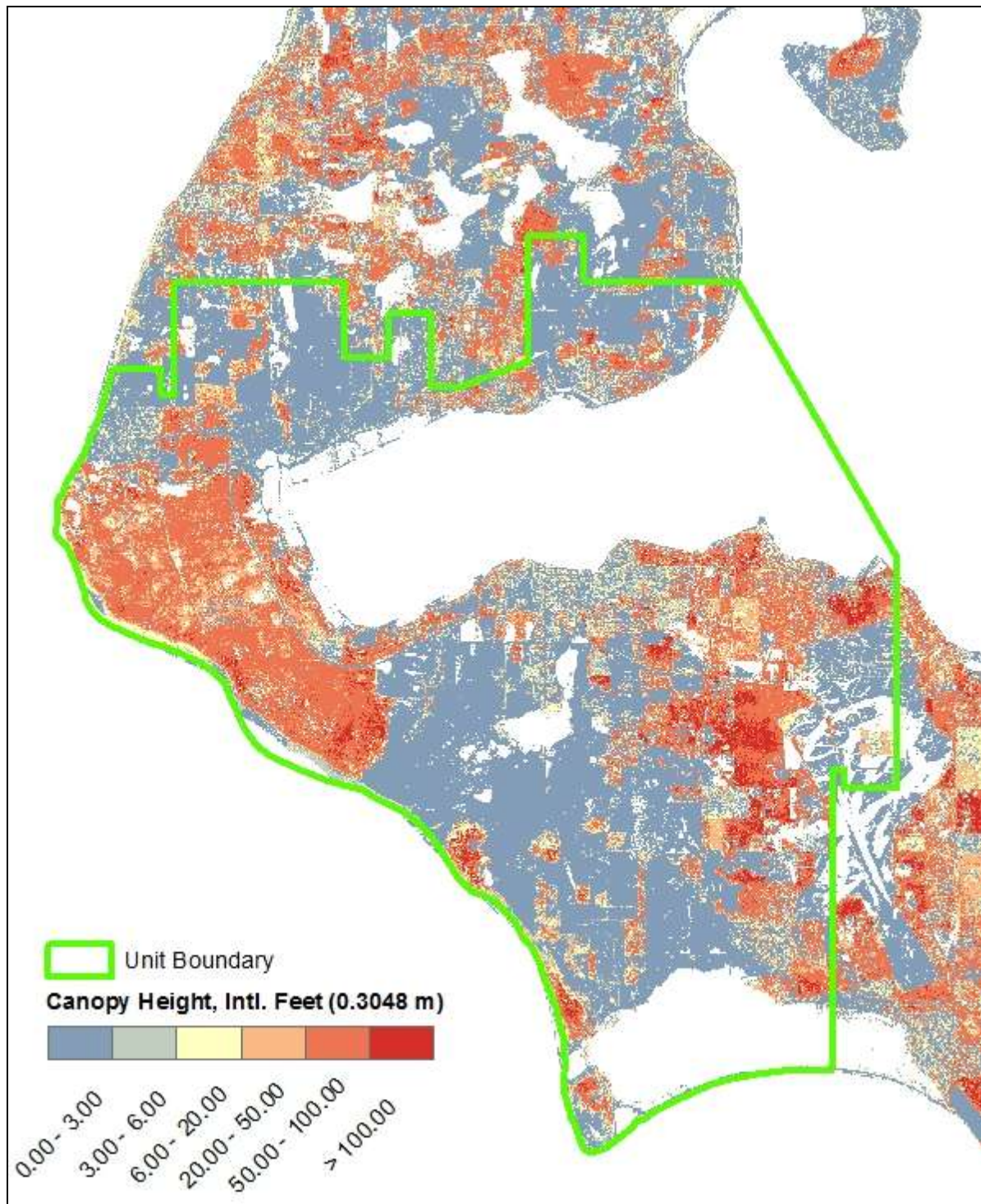


Figure 22. Canopy heights throughout the Reserve.

The total forested area of the Reserve is between 4,567 acres (Bakker et al. 2010) and 4,810 acres (our LiDAR analysis, using a 20-ft tree canopy height to define forest). The current distribution of forest age classes on the Reserve appears to be strongly weighted toward the ‘young’ (50-100 ft) age class, with much less old-growth than would have been present in reference conditions. The LiDAR analysis (Table 11) indicates that a tree canopy higher than 100 ft -- not all of it mature or old growth -- occupies 492 acres. Mature stands (>100 years of age) occupy substantial acreage but have not been thoroughly delineated. Total area of old-growth is probably less than 200 acres (Chappell, pers. obs., 2007 Natural Heritage Program surveys).

Locations of the tallest trees stands throughout the Reserve can be seen in the map we generated from the LiDAR data (Figure 22). An example is the old growth forest by the Camp Casey Conference Center. Fort Ebey State Park has about 30 acres of old-growth within a context of the largest contiguous block of forest, mostly young Douglas-fir and hemlock, extending south out of the Reserve into the Robert Y. Pratt Preserve. Of special note in the state Pratt Preserve is a small area dominated by old Sitka spruce (*Picea sitchensis*) with an understory of salal (*Gaultheria shallon*) and oceanspray (*Holodiscus discolor*). This community is unique in the Puget Lowland, being an upland (as opposed to wetland) site where spruce is likely favored by frequent fog. The Heritage Forest and a nearby stand are mature 140-150 year old stands of Douglas-fir and grand fir that appear to have regenerated naturally after fire, without evidence of logging. Rhododendron County Park has about 80 acres of mostly old-growth Douglas-fir. This is the largest known area of old-growth in the Reserve. Lastly, there is a narrow, probably discontinuous, strip of old-growth, dry-site Douglas-fir extending from Fort Ebey State Park south to Ebey’s Landing and the Robert Y. Pratt Preserve, located at the top of the coastal bluff.

Forest stands of note include occurrences of the following plant associations classified by the Washington NHP as imperiled statewide:

- *Pseudotsuga menziesii* – *Tsuga heterophylla* / *Gaultheria shallon* (Fort Ebey State Park)
- *Pseudotsuga menziesii* – *Tsuga heterophylla* / *Holodiscus discolor* / *Polystichum munitum* (Heritage Forest of Whidbey-Camano Land Trust and one other mature stand)
- *Pseudotsuga menziesii* - *Tsuga heterophylla* / *Rhododendron macrophyllum* - *Vaccinium ovatum* - *Gaultheria shallon* (Rhododendron County Park)

The Reserve's forests appear to be in better condition than the average for the Puget Lowlands. That is, the proportion of stands that are young and very young is lower than average and the proportion of mature and old-growth forest greater than average. There may be proportionately more deciduous forest (mostly alder) than prior to historical timber harvest activities, due to the propensity for alder to proliferate and dominate after logging on moist sites (of which there is an abundance within the Reserve).

The Reserve's forests can be harmed by invasive plant species, although in general the invasives are much less prevalent and problematic than in the non-forest vegetation of the Reserve. English ivy, English holly, spurge laurel (*Daphne laureola*), 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, often killing trees. 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 populations over time could result in it becoming a prominent, if not dominant, component of lower tree/tall shrub 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 forest understories once established. Himalayan blackberry generally does not occur under dense conifer overstories, but can be a pernicious and domineering invader to forest edges and openings, early-successional forests (where it may have significant impacts on successional trajectories), and deciduous forest understories.

Sudden oak death, caused by a non-native fungal blight (*Phytophthora ramorum*), was first recorded in Washington state 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/blue-threat/sudden-oak-death.php>). 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 functions like an invasive pathogen.

### ***Trends***

#### *Somewhat Concerning - Medium Certainty.*

The current trend appears to be a slow development and succession towards greater structural complexity and larger tree size. This trend varies somewhat depending on existing vegetation and site characteristics. For example, alder-dominated stands, if there is inadequate regeneration of conifers, can be slower to succeed toward old-growth characteristics and may even remain for long periods as broadleaf or shrub-dominated communities. There is not great pressure to log the stands within the Reserve, and thus it is unlikely that human activities will set back stand structures to early successional characteristics. However, there is clearly a trend toward gradual loss of forest associated with rural development, which often results in fragmentation and an increase in edge effects within forests in addition to the outright loss of forest acreage (more details in section 4.4.4.4). As previously discussed, White's (1999) historical accounts give us a general idea but not a specific distribution for reference conditions. Thus, for trends we can assign only medium confidence. We do, however, have relatively high confidence in the current limited extent of old-growth.

### ***Data Gaps***

The structural data on forested areas within the Reserve that has been collected has not been as detailed as it should be to assess forest condition, nor has it been analyzed to its

full capacity. Therefore, we do not know precisely the current distribution of stand ages and dominance types.

Data needs include (1) a more accurate and precise accounting of the distribution of stand age classes and dominance types in the forested landscape at the Reserve, (2) a survey to identify areas that qualify as old-growth under the aforementioned criteria, (3) a quantitative assessment of the abundance of late-successional forest structures within significant areas of forest, and (4) a local assessment and potential adjustment of the old-growth criteria using existing old-growth stands on the Reserve and/or elsewhere in the northern Puget Lowland rain shadow area.

The first of these seems both most critical and least costly to accomplish using more sophisticated analysis of the existing LiDAR imagery combined with carefully targeted ground verification. The survey to identify existing stands meeting old-growth criteria could potentially be combined with an assessment of the degree the aforementioned criteria “fit” with actual old (based on age) stands within the Reserve. This would involve collection of field data on stand structures at Rhododendron County Park and Fort Ebey State Park. A quantitative assessment of late-successional stand structures across major forest blocks seems a lower priority than the other data gaps that could be filled - though a comprehensive approach could combine all four projects.

In terms of assessment and monitoring, we recommend the following:

1. Initiate a mapping project focused on stand age/dominance type classes throughout the Reserve.
2. Adapt the Forest Service old-growth definitions to the reserve as a basis for future assessment and monitoring.
3. Assess the current status and health of Pacific madrone on selected lands within the reserve.

#### 4.4.4.4 Land Cover and Land Use

The unique nature of the Reserve-- allowing agricultural and residential use within a National Historical Reserve -- means that the direct and indirect effects of habitat conversion, occurring both inside and outside the Reserve, result in impacts to the natural resources within the Reserve boundary. The construction of roads, houses, and subdivisions, the loss of agricultural land, and logging of forests have directly converted native habitats on the island. The fact that such activities occur within the Reserve increases the likelihood that native vegetation types will be affected. Such effects can take myriad forms, some of which are readily evident, whereas others can be subtle and even go unnoticed for long periods of time. Potential effects on terrestrial vegetation, the subject of this section, arise from diverse sources, including biological, physical, and social.

Historically, within central Whidbey Island, agricultural use of the land has played a large part in the livelihood of the inhabitants. This is still true to some extent but the mainstay of the community economic base has shifted. There is still an active farming community within central Whidbey Island. Typical commercial crops include grass, alfalfa, cabbage, and beet seed for export, lavender, conifer seed, strawberries, barley and

peas. Over 45 percent of the existing Class II lands (productive agricultural) within Island County are found within the Reserve. Within the Reserve, in 2000 there were 3,355 acres in cropland, 1,138 acres in pasture, 1,437 acres in grassland, and 5,290 acres in woodland/forest. The Whidbey Island Conservation District provides conservation plans to landowners at no cost. As of 2000, they were assisting 73 farms within the Reserve, for a total acreage of 7,446 acres. In addition, they are serving 25 woodland owners, with a total acreage of 1,120 acres. Crops grown in the Reserve vary from year to year and in recent years have included grass (for hay), corn, barley, and alfalfa for silage, cabbage, beets, lavender, strawberries, squash, peas, timber, and conifer seed.

### *Criteria*

For all of the Puget Sound region, the Puget Sound Partnership has stated a goal, to be achieved by 2020, of no more than 1000 acres of forest converted per year. However, no criteria have previously been suggested regarding what proportion of land cover types within the Reserve might be desirable for meeting the Reserve's goals. We propose the following, but propose them only as working hypotheses. They attempt to account for landscape-scale ecological thresholds that may be relevant to this particular Reserve.

“Good” conditions would be represented by:

- no less than 60% of the historical extent of natural and semi-natural vegetation (including forests of all conditions and grasslands/shrublands with at least a minimal component of native species) is extant within the Reserve,
- no more than 10% of the reserve’s total area is developed with structures, roads, etc.
- no more than 20% of agricultural lands have been converted to irreversible uses that conflict with conservation of natural and historic values.

“Somewhat Concerning ” would be represented by:

- 30-60% of the historical extent of natural and semi-natural vegetation is extant within the reserve,
- 10-25% of the Reserve’s total area is developed with structures, roads, etc.
- 20-40% of agricultural lands have been converted to irreversible uses that conflict with conservation of natural and historic values.

“Significant Concern” would be represented by:

- less than 30% of the historical extent of natural and semi-natural vegetation (including forests of all conditions and grasslands/shrublands with at least a minimal component of native species) extant within the reserve,
- more than 25% of the Reserve’s total area is developed with structures, roads, etc.
- more than 40% of agricultural lands have been converted to irreversible uses that conflict with natural and historical values.

More research (both at the Reserve and reviews of literature) are needed to better develop, and modify as necessary, these thresholds for the Reserve. Any such thresholds should also take into account a combination of land uses that would maintain adequate

groundwater recharge and surface water quality while supporting a sustainable economy within the county, if not within the Reserve itself.

Measuring the achievement of the above thresholds poses some technical challenges. One is the difficulty of delineating dispersed rural residential development as a land cover type: this tends to underestimate the presence and effects of development on the landscape. Rottle (2003), for example, mapped such dispersed development as structures and roads, but did not modify land cover within which these structures and roads occurred, such that a field with one house per 5 acres would be mapped as a field, not as developed. The second challenge is determining where grasslands have a minimal component of native species. This is impossible from remote sensing but is important to evaluating the landscape-scale contribution of semi-natural vegetation to overall natural resource conservation. We already know where the few grasslands are that have a significant component of natives, but we do not know to what extent, or where, degraded grasslands such as former agricultural lands or pastures might have some native plant presence.

## **Condition**

### *Somewhat Concerning -- Low Certainty.*

The above rating is based on the analysis by Rottle (2003) and Bakker et al. (2010). For purposes of assessing condition with the metrics that we propose, Bakker et al. appears to be a stronger data source because they appear to have done a more thorough job of distinguishing some of the rural development as “developed”, and because their work is more recent. Because we are addressing only upland land cover, we have subtracted wetlands and waters from the total area reported by Bakker for the reserve. That total, minus the waters, is 12,767 acres (Figure 24), and would also set the 100% figure for historical natural vegetation referred to in our criteria. So, a total of 18% of the upland land cover as of 2006 is considered “developed”, and a total of 36% is forest (which we assume is mostly in the ‘natural and semi-natural vegetation’ category, though some rural development could still potentially show up here), and 40% is classified as ‘grass/shrub/prairies’. We are certain that the vast majority of the latter figure for grass/shrub/prairie is *not* natural or semi-natural vegetation as we have defined it. We know the locations of the very few and very small prairie remnants that exist (inconsequential in extent on the overall landscape, totaling less than 20 acres). The coastal bluffs and strand vegetation (the latter of which is also inconsequential) would also qualify as natural or semi-natural vegetation. The remainder of the category ‘grass/shrub/prairies’ are pasturelands, former croplands or former forestry lands that are now in herbaceous or shrub dominance. We think it somewhat likely that relatively few of these areas have a native plant species component sufficient to qualify as natural or semi-natural. So, our overall estimate of the percentage of the landscape remaining in natural and semi-natural vegetation is somewhere between 40% and 60%, with our presumption being that it is likely closer to 40%.

## **Trends**

*Somewhat Concerning -- Moderate Certainty.*

Whidbey Island has seen a significant increase in urban, suburban, and rural development in recent decades, while agricultural uses and large timber harvest projects have declined. The Federal Census of Agriculture shows that the amount of land dedicated to farming in Island County decreased by 19 percent between 1992 and 1997. Since 1978, the total number of farms has increased slightly from 244 to 262. However, the number of full-time farms has decreased by eight percent from 122 farms in 1992 to 112 farms in 1997. Since 1978, the average farm size has also continued to decrease from an average of 89 acres per farm to 61 acres. These changes appear to have come from the sale and redistribution of land that had been large and intermediate sized farms (U.S. Department of Agriculture, 1997). For Puget Sound as a whole during the period 2001 to 2006, forest (excluding federal lands) was converted to non-forest at a rate of 2176 acres per year (PSEMP 2014).



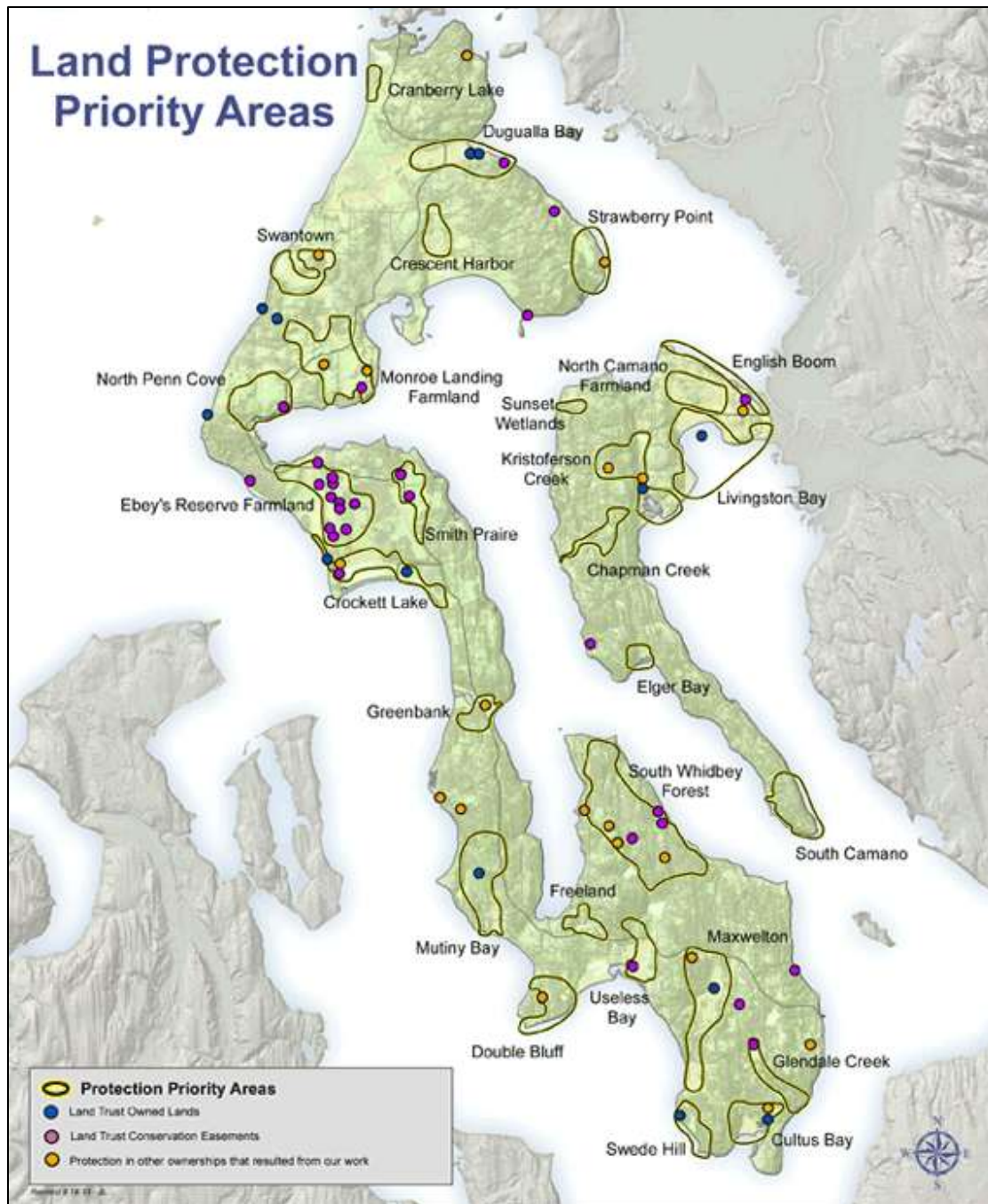


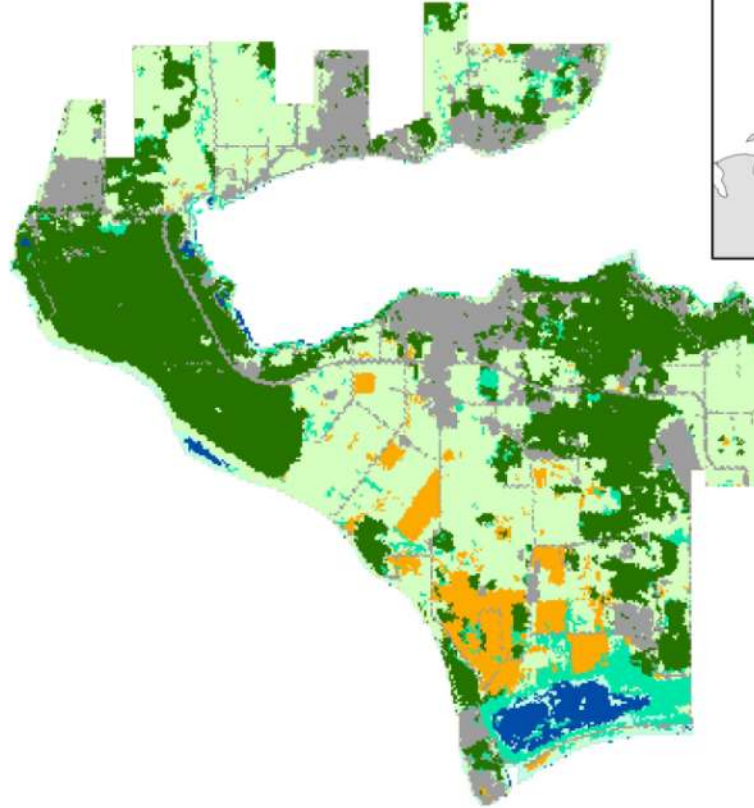
Figure 23. Whidbey-Camano Land Trust land protection priority areas.





# 2006 Land Cover Classes

Land Cover Class	Current Condition		Change from 1996	
	Area (ha)	%	Area (ha)	%
Developed	943	16.5%	4.0	0.4%
Cultivated	322	5.6%	-0.4	-0.1%
Grass/Shrub/Prairies	2056	35.9%	106.1	5.4%
Forest	1848	32.3%	-109.4	-5.6%
Wetland	302	5.3%	3.0	1.0%
Marine and Shoreline	126	2.2%	-46.7	-27.1%
Open Water	130	2.3%	43.4	49.9%
Total Area	5727	100.0%	0.0	N/A



0 1,000 2,000 4,000 6,000 Meters  
Produced by UW research team

Source: NPS: Park Boundary; NOAA: C-CAP landcover layer, 2006  
Coordinate System: NAD\_1983\_UTM\_Zone\_10N  
June 2009

**Figure 24. Land cover classes within the Reserve, representing both current (2006) conditions and change during a 10-year period (1996-2006).**



## Island County Land Use Designations

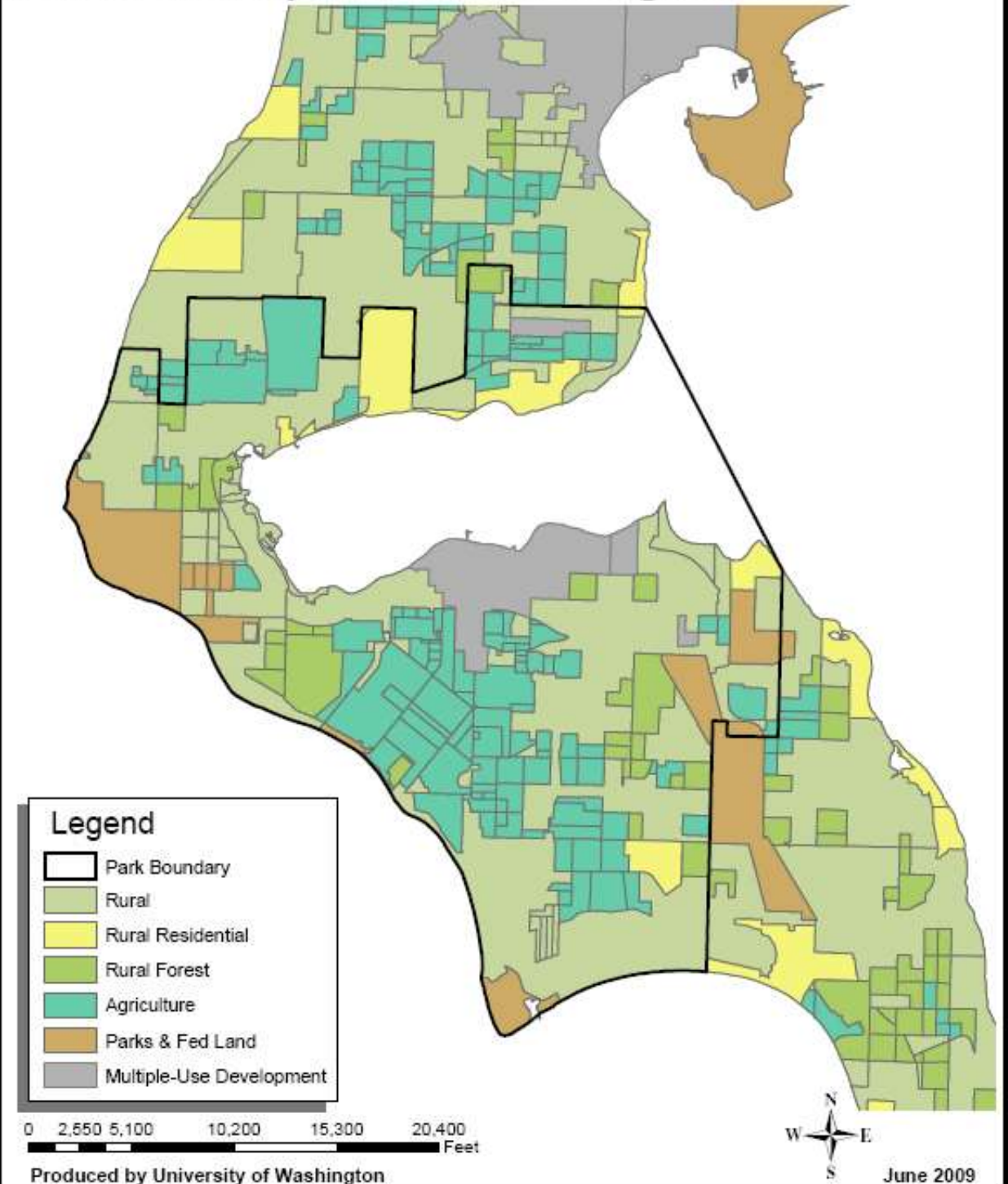


Figure 25. Land use designations within the Reserve and the surrounding area.

Considering trends within the Reserve specifically, we reviewed land cover trend results from two prior studies covering 1983-2000 (Rottle 2003) and 1996-2006 (Bakker et al. 2010). Results of an analysis of more recent land cover changes (2006-2009, and 2009-2011) for all of Island County will be available in early 2015 from WDFW:

[http://wdfw.wa.gov/conservation/research/projects/aerial\\_imagery/index.html](http://wdfw.wa.gov/conservation/research/projects/aerial_imagery/index.html)

In the 1983-2000 comparison, Rottle noted large conversion of agricultural lands, especially pastures (14% decline), to both residential subdivisions (41% increase in urban areas and residential subdivisions) and dispersed rural residential development, and a 44% increase in the number of structures (an indicator of development impact including dispersed rural), a slight decline in forested area (2%), and an increase (11%) in unmanaged grasslands (former pastures and croplands set aside as conservation lands or abandoned) (Figure 25). The conversions to development described by Rottle (2003) support a rating of "Significant Concern" for trends. However, the analysis by Bakker et al. (2010), covering the later period of 1996-2006, estimated an increase of only 0.4% in developed lands during the time period, a loss of 5.6% of forested area, and a gain of 5.4% in grass/shrub/prairies (which apparently includes both pasturelands and unmanaged grassland and shrubland) (Bakker et al. unpublished). They suggest that much of the loss of forest land is attributable to conversion to the grass/shrub category (which might be related to site preparation for development). A rating of "Moderate Certainty" (rather than High Certainty) is assigned to trends because of the differing conclusions of these two studies, even accounting for the fact they covered time periods that partially differed.

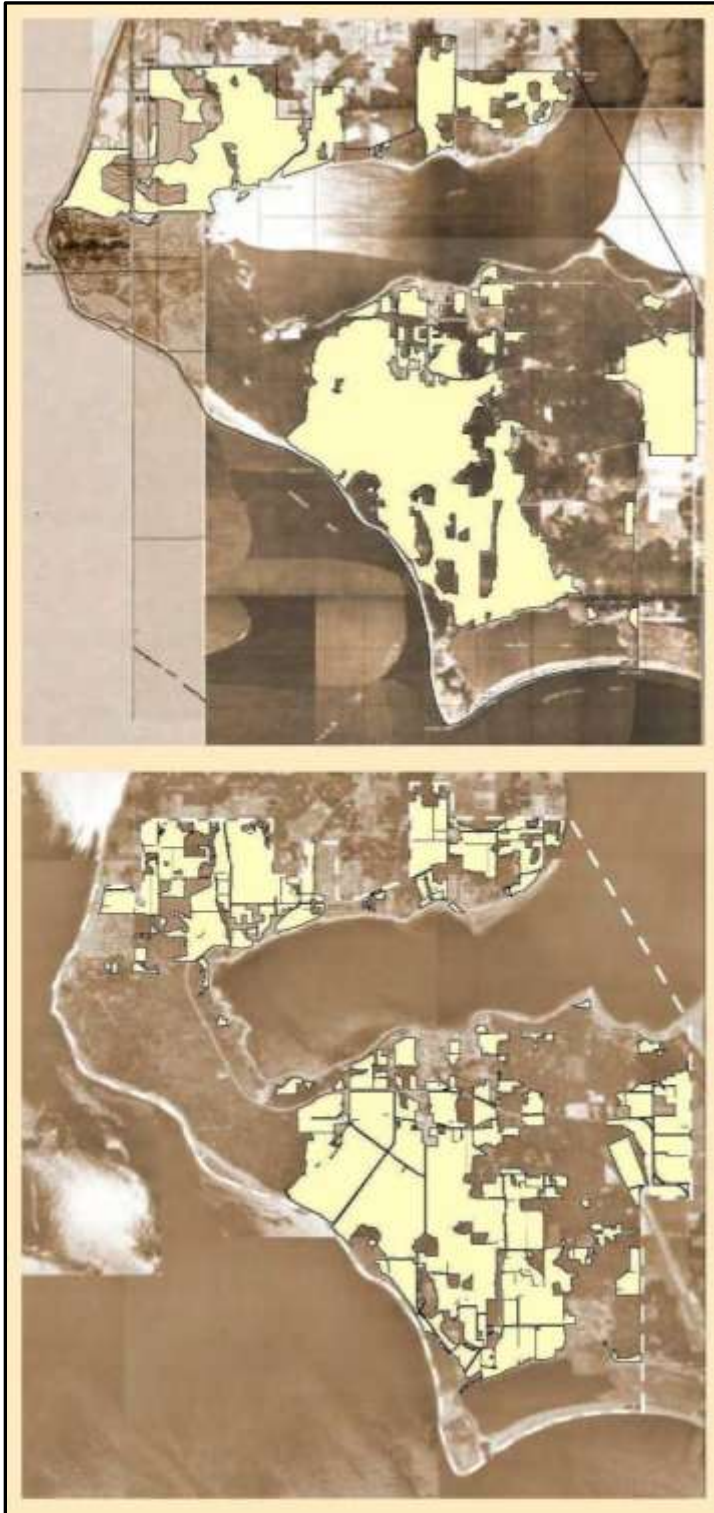
### ***Data Gaps and Recommendations***

As noted earlier, better methods are needed to partition the broad category of non-forested lands that are not cropland. This includes active pastures in varying conditions, abandoned/former croplands or pastures, forests that have been very recently clear-cut, and, of course, a small percentage of actual native or semi-native prairie. Also, more information is needed on the relative frequency of native plant cover within this broad non-forested, non-cropland category.

Potentially competing land and resource management objectives must be reconciled by managers in ways that preserve the best examples, minimize conflicts, and bring about the most successful and long-lasting outcomes. This is most likely to be achieved where synergies and complementary goals can be recognized and implemented. For example, restoration of native prairies will simultaneously recreate elements of the landscape present at the time of Vancouver's visit in 1792 (one of the eras mandated in the Reserve enabling legislation) with preservation of rare vegetation and species. Production of seed of native species to be used in prairie restoration similarly can be carried out as an agricultural enterprise, helping to sustain these characteristic land uses.

Existing areas of natural land cover, especially those already protected in some fashion (e.g., Smith Prairie and Naas Preserve), should be managed as cores or hubs from which to build on for future restoration projects. Existing agricultural lands within the reserve are located almost entirely on prairie or wetland soils. So, with this perspective, the

agricultural lands in proximity to the cores or hubs of natural land, particularly prairie, would be highest priority to maintain as agricultural lands in the near term.



**Figure 26. Land use of ‘agriculture’ as mapped from aerial photography in 2000 and 1941 and in 2000 (adapted from Rottle 2003, figure 8a).**





Figure 27. Change in urban use and residential subdivisions within the Reserve during the period 1983-2000 (Rottle 2003, figure 2a).

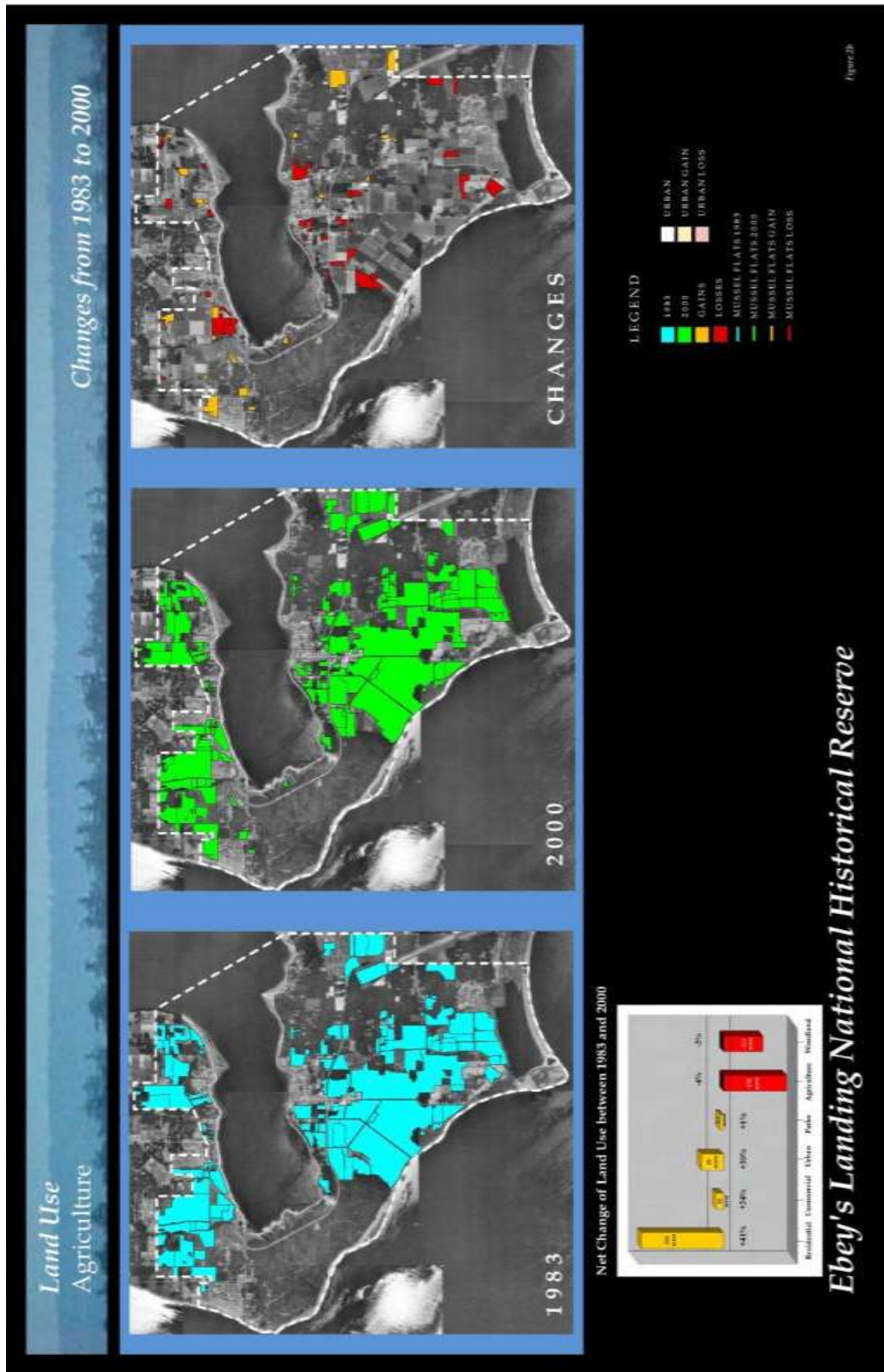


Figure 28. Change in agricultural land use on the Reserve between 1983 and 2000 (Rottle 2003, figure 2b).

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## **4.5 Wildlife**

### **4.5.1 Background**

As used herein, “wildlife” refers to amphibians, birds, mammals, and terrestrial invertebrates. The opportunity to observe wildlife in natural settings is an important

reason many people visit parts of the Reserve. Moreover, wildlife species serve vital ecological roles, such as pollinators, nutrient cyclers, and seed transporters.

In contrast to other areas of Western Washington that are of similar area, Island County's fauna overall is naturally less diverse for several reasons. The county's topography spans only 580 feet of elevation, creating less climatic diversity which in turn constrains the diversity of plants and animals. Perhaps more significantly, the island environment limits the ability of many terrestrial species to colonize from adjoining mainlands, and to persist in otherwise suitable habitats in the county. 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 inhabit only extensive forests also are absent or scarce, and are relatively vulnerable to extirpation because of fragmentation of historically forested areas by roads and urban and agricultural lands in many parts of the county. Large mammals such as elk, gray wolf, and cougar most likely inhabited the county at one time but were among the first animals to disappear entirely (in the mid-1800's) and have never recovered. Also apparently gone are two native gamebirds (e.g., ruffed and sooty grouse), spotted frog, and western pond turtle (R. Milner, WDFW, pers. comm.).

#### **4.5.2 Regional Context**

Relative to its size, the Reserve contains a wide variety of habitats. In a region where commercial timber harvest operations are widespread and where many natural landscapes have been altered heavily by development, the Reserve preserves a wide range of vegetation associations and successional stages. 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 island's fauna overall is naturally less diverse. That happens for several reasons. The topography of the island spans less than about 500 feet of elevation (and less than 270 feet within the Reserve). This creates less climatic diversity than in many mainland areas, 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 on the island or in the Reserve potentially a greater concern than a similar decline occurring in mainland areas, 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 are largely absent from Whidbey Island, or are relatively vulnerable to extirpation. That is partly because historically forested areas in many parts of the island were fragmented by roads and urban and agricultural development, as well as by natural phenomena. Large mammals such as elk, gray wolf, and cougar most likely inhabited Whidbey Island at one time but were among the first animals to disappear entirely (in the mid-1800's) and have never recovered. Other species possibly present at one time but now apparently extirpated (absent) from

the island include two native game birds (e.g., ruffed grouse, sooty grouse), spotted frog, Pacific giant salamander, western pond turtle, and undoubtedly 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 island or suspected to have occurred here based on the types of habitats they are known to associate with.

At the same time, the historical conversion of forest cover to large tracts of open land and prairie created or improved habitat for native open-land species that formerly may have been absent or much less common. Examples are northern harrier and savannah sparrow. It does not appear that any of the wildlife species documented within the Reserve are endemic (absent from the surrounding region) and there is no clear evidence to support any of the Reserve's native wildlife species being at higher densities within the Reserve than in any other parts of the Pacific Northwest.

#### ***4.5.3 Issues Description***

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

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

These are discussed briefly below.

##### 4.5.3.1 Altered Fire Regimes

For centuries, Native Americans burned large areas of the Reserve in order to enhance the land's capacity to support favored native food plants. However, in recent decades, lack of fire within the Reserve has affected the types of vegetation and thus the types of habitat available to wildlife (see section 4.4.3.1). 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 (Hanson and North 2008, Cahall and Hayes 2009). The current absence of fire also facilitates the invasion of prairie and oak woodland by conifers, with subsequent change toward wildlife species that are more common throughout the Pacific Northwest than those the prefer prairie and oak woodland.

##### 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 and marine mammals. Since 2002, over 870 unattached gillnets have been removed from the Salish Sea (Good et al. 2009). Common murre and rhinoceros auklets appeared to be particularly vulnerable. 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.

#### 4.5.3.3 Infrastructure and Human Disturbance

Some wildlife species, including many avian nest predators (crows, ravens) are attracted to congregations of people such as at campgrounds, scenic pullouts, and picnic areas. This has been shown to increase the predation of nests of many other bird species. Crow populations have been shown to increase as a result of urbanization in areas up to at least 0.5 mile from the new urban areas (Oneal & Rotenberry 2009). Also, unconfined pets can dramatically increase predation on songbird and small mammal populations. 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. Noise, night-time outdoor lighting, large picture windows (a collision hazard for birds), trash dumping, and a host of other things associated with humans contribute to avoidance of residential areas by many native wildlife species, and/or to higher mortality rates of animals that attempt to colonize developed areas. Amphibians and reptiles are particularly sensitive. They are especially vulnerable to traffic and to the intentional introduction of non-native predatory fish into ponds and wetlands. The relative sensitivities of all Washington species to human presence and residential development have been categorized 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. Forest gaps caused by placement of roads, driveways, or homes – as well as by natural features such as rockslides and wide tidal channels -- can impact movements of mammals and birds (Trombulak & Frissell 2000, Ortega & Capen 2002). This is especially true when the gaps are wider than about 100 feet (Rich et al. 1994, Rail et al. 1997, St. Clair et al. 1998, Belisle & Desrochers 2002, Laurance et al. 2004, Tremblay & St. Clair 2011), and definitely when wider than 200 ft (Creegan & Osborne 2005, Bosschieter & Goedhart 2005, Awade & Metzger 2008, Lees & Peres 2009). Species that prefer low vegetation may be particularly reluctant to cross forest clearings. 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 hedgerows or other relicts of the original vegetation structure in agricultural fields. See section 4.5.4.3.

Roads and traffic result in more collisions with deer, dispersing amphibians, and other animals (Forman et al. 2002, Clevenger et al. 2003, Massey et al. 2008, Minor & Urban

2010, Tremblay & St. Clair 2009, 2011 and see reviews by Fahrig & Rytwinski 2009, Benitez-Lopez et al. 2010). Chronic noise has been shown to impair reproductive behaviors in songbirds (Wood & Yezerinac 2006, Slabbekoorn & Ripmeester 2008, Barber et al. 2010) and restrict habitat use by bats (Schaub et al. 2008).

#### 4.5.3.5 Pathogens and Parasites

Amphibians in particular are vulnerable to a large number of pathogens and parasites. These include two fungi (*Batrachochytrium dendrobatidis* and *Saprolegnia*). Populations also can be decimated by ranaviruses, and an invertebrate (the trematode *Ribeiroia ondatrae*) is a major cause of amphibian limb malformations. The incidence of these afflictions may be exacerbated by water pollution and increased movements of humans, wildlife, and pets among wetlands.

#### 4.5.3.6 Climate Change

Populations of many wildlife species may be unable to adjust to global climate change and its effects. The most vulnerable species are likely to be 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. Other species not currently present or common in the region may increase. 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 Reserve number 85, or about 38% of the Reserve's avifauna (Table 12).

### **4.5.4 Indicators and Criteria to Evaluate Condition and Trends**

Three indicators that might be used when monitoring wildlife of the Reserve are:

1. Rare or sensitive wildlife species
2. Invasive or harmful terrestrial wildlife
3. 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 Reserve or nearby areas.

**Table 12. Bird species of the Reserve which may be most vulnerable to climate change.**

source: Audubon Washington, <http://wa.audubon.org/climate-change-0>

Greater White-fronted Goose	Ruddy Turnstone
Brant	Surfbird
Trumpeter Swan	Dunlin
Tundra Swan	Rock Sandpiper
Wood Duck	Short-billed Dowitcher
Gadwall	Whimbrel
Eurasian Wigeon	Pigeon Guillemot
American Wigeon	Ancient Murrelet
Mallard	Rhinoceros Auklet
Blue-winged Teal	Ring-billed Gull
Cinnamon Teal	California Gull
Northern Shoveler	Western Gull
Redhead	Glaucous-winged Gull
Ring-necked Duck	Herring Gull
Greater Scaup	Caspian Tern
Lesser Scaup	Common Tern
Bufflehead	Band-tailed Pigeon
Common Goldeneye	Barn Owl
Hooded Merganser	Northern Saw-whet Owl
Common Merganser	Rufous Hummingbird
Red-breasted Merganser	Red-breasted Sapsucker
Red-throated Loon	Hairy Woodpecker
Common Loon	Willow Flycatcher
Horned Grebe	Pacific-slope Flycatcher
Red-necked Grebe	Common Raven
Eared Grebe	Tree Swallow
Western Grebe	Bank Swallow
Double-crested Cormorant	Violet-green Swallow
American Bittern	Red-breasted Nuthatch
Osprey	Brown Creeper
Northern Harrier	Marsh Wren
Bald Eagle	Golden-crowned Kinglet
American Kestrel	Hermit Thrush
Peregrine Falcon	Varied Thrush
Merlin	Western Tanager
Black Oystercatcher	Black-headed Grosbeak
Black-bellied Plover	Yellow-headed Blackbird
Semipalmated Plover	House Finch
American Golden-Plover	Purple Finch
Pacific Golden-Plover	Red Crossbill
Spotted Sandpiper	Pine Siskin
Greater Yellowlegs	Evening Grosbeak
Lesser Yellowlegs	



#### 4.5.4.1 Rare or Sensitive Wildlife Species and Invasive Animals

This section discusses animal species that may be sensitive on account of declining numbers within the Reserve or surrounding areas, and/or due to particular aspects of their life history and behavior. It also discusses non-native species, especially as they may impact rare or sensitive native wildlife. The discussion is organized by major groups: birds, mammals, reptiles, amphibians, and terrestrial invertebrates. Background information is presented that characterizes the occurrence of sensitive or non-native species within the Reserve as well as contribution of the Reserve to the region's biodiversity, and then summarizes what is known of the current condition and trends of these within the Reserve.

#### **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 Reserve or from analogous areas nearby. Further, there are no legally-based numeric criteria for evaluating the degree of "intactness" of any of the Reserve'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 area. 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 the Reserve. 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, and Amphibians and Reptiles.

#### ***Birds***

The certified park list includes 218 bird species (174 listed as "Present in Park" and the rest as "Probably Present"). However, the actual number may be higher if sightings reliably reported since the Reserve list was certified in 2004 are included (bringing the list to 238), and records subtracted for 15 species on the certified list which have not been reported from the Reserve in the past 10 years (reducing the total to 223). See Appendix

2. Bird species abundance and distribution within the Reserve. Appendix 2, Table 20. That table shows maximum counts for species whose records could be traced to specific parts of the Reserve, using eBird data up until November 23, 2014.

The 223 species detected within the Reserve represent 85% of the 261 bird species that have been documented on Whidbey Island as indicated in a compilation for the Island based on all sources: eBird, Breeding Bird Atlas, NPS surveys by Kuntz (2009). Despite the Reserve comprising only 12.6 percent of the land area of Whidbey Island, 85% of the species documented for Whidbey Island have been recorded from the Reserve as well. None of the species absent from the Reserve are known to breed elsewhere on the Island. Focusing just on species that have nested in the Reserve, the certified list contains 70 breeders (about one-third of the Reserve's avifauna). However, as many as 107 species (48% of the Reserve's list) may have bred at some time during the past two decades, based on mostly circumstantial evidence from other sources.

Only one bird species that is regularly present in the Reserve is listed federally as Threatened or Endangered. That is the marbled murrelet, which does not nest in the Reserve (due to lack of sufficient amounts of its required old-growth forest). It feeds regularly in marine waters adjoining the Reserve, with as many as 110 sighted on one date. Three bird species listed federally as "Species of Concern" occur regularly within the Reserve: olive-sided flycatcher, black oystercatcher, and northern harrier. Also, horned lark ("streaked" subspecies) is federally designated as a Candidate Species, and bred in the Reserve's prairie habitat until the 1960s or 70s. It currently is a very rare migrant (only one recent record) and does not breed on Whidbey Island. Peregrine falcon and bald eagle were once federally listed as Threatened and both occur regularly in the Reserve. Although peregrines are an increasingly common nester on the nearby San Juan Islands, they seldom if ever nest on Whidbey Island. At least 9 bald eagle nests are used annually in the Reserve. Continental populations of both species in recent years have recovered to the point where the species are no longer federally listed.

At a state level, Brown Pelican is listed by WDFW as Endangered but has not been recorded from the Reserve, and only one record exists for Whidbey Island (not a nesting record). The WDFW also 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 Reserve that are designated as "Sensitive" on this list are peregrine falcon and bald eagle. Common loon occurs during winter and migration in marine waters of the Reserve and is listed as Sensitive, but only for breeding occurrences. Species in the Reserve 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, and Vaux's swift (only pileated woodpecker is explicitly listed as Sensitive; the others are listed here because they fall under *categories* of birds that WDFW considers to be conservation priorities). The WDFW also has priority designations for:

(a) Cavity-nesting waterfowl. In the Reserve those include wood duck, hooded merganser, common goldeneye, and Barrow's goldeneye. None have been confirmed nesting in the Reserve, although there are recent observations during the breeding season for the first two.

(b) Concentration areas for alcids (a group of seabirds). In the Reserve, those that have been reported in noteworthy concentrations (with maximum counts from eBird) are:

- at Libby Beach: 800 rhinoceros auklet
- at Fort Casey: 200 common murre, 110 marbled murrelet
- at Keystone Ferry Terminal: 200 pigeon guillemot

(c) Concentration areas for loons and grebes. In the Reserve, those that have been reported in noteworthy concentrations (with maximum counts from eBird), are:

- at Penn Cove: 2000 western grebe
- at Fort Casey: 50 red-throated loon, 20 common loon
- at Libbey Beach: 30 horned grebe

(d) Concentration areas for waterfowl. In the Reserve, those that have been reported in noteworthy concentrations (with maximum counts from eBird) are:

- at Crockett Lake: 2000 northern pintail, 1000 american wigeon, 400 gadwall, 255 mallard, 250 green-winged teal, 850 lesser scaup, 215 ruddy duck, 150 bufflehead, 120 hooded merganser
- at Fort Casey: 30 harlequin duck, 20 Barrow's goldeneye
- at Penn Cove: 7000 surf scoter, 3000 white-winged scoter, 250 common goldeneye, 125 bufflehead, 20 Barrow's goldeneye

(e) Concentration areas for shorebirds. In the Reserve, those that have been reported in noteworthy concentrations ) are:

- at Crockett Lake: 20,000 western sandpiper, 11,000 dunlin, 5000 least sandpiper, 444 red-necked phalarope, 380 short-billed dowitcher, 300 black-bellied plover, 200 long-billed dowitcher, 200 sanderling, 180 semipalmated plover, 100 killdeer, 75 greater yellowlegs, 13 lesser yellowlegs, 40 Baird's sandpiper.
- at Penn Cove: 475 black turnstone, 50 surfbird

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 Reserve currently or in the past decade (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, red crossbill.

Although never present in large numbers, black oystercatcher feeds along the Reserve's shoreline and is of interest because globally its population is believed to number only about 11,000 individuals. Perhaps 210 pairs nest along shorelines of the Salish Sea (Golumbia et al. 2009). Maximum counts within the Reserve are 27 at Fort Ebey and 24 along Penn Cove. In addition to being listed federally as a Species of Concern, black oystercatcher is identified as a regional species of high concern by the Northern Pacific Coast Regional Shorebird Management Plan.

Whidbey Island is reputed to have the largest breeding population of northern harriers in western Washington (J. Bettsworth, personal communication with Sarah Schmidt, cited by Watershed Company & Parametrix 2014). Grasslands within the Reserve would seem to provide some of the best habitat in the region.

Pigeon guillemot is the only seabird that nests on Whidbey Island, nesting in about 230 shoreline burrows. There are around 1000 adult birds, about 45% of which attempt to breed in any given year. Out of 24 colonies known to exist on Whidbey Island, from 2 to 5 colonies -- including one in the Reserve at Rolling Hills on Penn Cove -- have been monitored annually since 2007. A pair also has nested on a structure near the Keystone jetty. Data from the 2012 nesting season (Rolling Hills plus another colony) show a 71% fledging success. Based on 373 prey deliveries to chicks, prey choice was 56% gunnel, 30% sculpin and 14% other fish (Rosling 2012).

For supporting large and diverse avian assemblages, the most important areas within the Reserve, if not the entire County, are Crockett Lake, Penn Cove, Fort Casey, Libbey Beach, and Keystone Spit. Crockett Lake and Penn Cove were designated Habitats of Local Importance by Island County's government, and in 2001 were designated Important Bird Areas (IBAs) by Audubon Society of Washington. The Penn Cove IBA includes Grasser's and Kennedy's Lagoons. Grasser's Lagoon supports significant numbers of shorebirds, including high concentrations of turnstones, surfbirds, and rock sandpipers. Those species are normally found in comparable numbers only on jetties and offshore rocks of the open coast. Both Penn Cove and Crockett Lake are listed by WDFW as important winter waterfowl concentration sites. The PSAMP Marine Bird Atlas, comparing Penn Cove with the rest of Puget Sound, places much of Penn Cove in the highest category for densities of wintering scoters. The area from Fort Casey to Libbey Beach is in the next-to-highest category for wintering harlequin duck. Crockett Lake has been an International Shorebird Survey site since 1997 (Drut and Buchanan 2000, Fernandez et al. 2010). It has hosted a colonies of nesting great blue heron and purple martin, as well as serving as a vital pre-migration staging area for large concentrations (1000+ individuals) of aerial-foraging barn and cliff swallows. It also supports large numbers (500+) of red-winged and Brewer's nlackbird.

The impact of non-native birds on populations of the Reserve's native species is unknown. A non-native species 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 southeastern United States and the West Indies. Numbers on Whidbey Island and in the Reserve have increased noticeably since it first arrived in about 2009, and flocks of 20 at Penn Cove in 2013 and 24 at Crockett Lake in 2014 have been reported. 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 Reserve are European starling, house sparrow, rock pigeon, California quail, and ring-necked pheasant. Although native to North America, brown-headed cowbird occurs throughout the Reserve, parasitizing the nests of many other bird species. This can have measurable impacts on their populations. Cowbirds tend to be more common where forests have been fragmented by small residential developments, rights-of-way, or agriculture.

### Condition and Trends

Condition: *Significant Concern – High Certainty*. Trends: *Indeterminate*.

A better rating is not assigned because several bird species that are likely to have been historically present in the Reserve (ruffed grouse, sooty grouse) apparently have been extirpated, and several of the Reserve's species are experiencing declines at least regionally. Declines are perhaps due mostly to changing conditions outside of the Reserve. Certainty is rated High because there are more data available for birds than for other wildlife groups. However, trends are rated "Indeterminate" because no systematic data have been collected over the long term from within the Reserve that would allow calculation of trends for any of the Reserve's bird species.

A large variety of bird species depend on Salish Sea food webs (Gaydos and Pearson 2011). 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. Trends data are also available for coastal birds of 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 Reserve 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.

	Vilchis et al. 2014	Bower 2009
Brant	increase	
Canada Goose	increase	increase
American Wigeon	increase	
Mallard	increase	
Northern Pintail	increase	

	<b>Vilchis et al. 2014</b>	<b>Bower 2009</b>
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, 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.

In addition, seven *forest-associated* species that breed regularly on adjoining mainlands seldom if ever nest in apparently similar habitat on Whidbey Island: Vaux's swift, ruffed grouse, sooty grouse, western screech-owl, red-breasted sapsucker, varied thrush, and hammond's flycatcher.

### ***Mammals***

The certified Reserve list, compiled in 2004, includes 19 terrestrial mammal species (Table 14). However, no systematic, Reserve-wide inventories of mammals have been conducted. The WDFW Priority Habitats & Species database notes the presence of 2 additional mammals: Big brown bat (*Eptesicus fuscus*, in a communal roost) and California myotis (*Myotis californicus*). A few individuals of the former have hibernated in a concrete structure at Fort Casey (Sarah Schmidt, pers. comm.). There are also credible reports of little brown myotis (*Myotis lucifugus*) from Whidbey Island (Sarah Schmidt, pers. comm.).

**Table 14. Certified list of terrestrial mammals documented from the Reserve.**

<b>Common Name</b>	<b>Scientific Name</b>	<b>Present?</b>	<b>Native?</b>
Black-tailed (Mule) Deer	<i>Odocoileus hemionus</i>	yes	yes
Coyote	<i>Canis latrans</i>	Probably	yes
Red Fox	<i>Vulpes vulpes</i>	yes	No
Bobcat*	<i>Lynx rufus</i>	Probably	yes
Northern River Otter	<i>Lontra canadensis</i>	yes	yes
American Mink	<i>Mustela vison</i>	Probably	yes
Northern Raccoon	<i>Procyon lotor</i>	Probably	yes
Keen's Myotis**	<i>Myotis keenii</i>	Probably	yes
Eastern Cottontail	<i>Sylvilagus floridanus</i>	Probably	No
American Beaver	<i>Castor canadensis</i>	Probably	yes
Creeping Vole	<i>Microtus oregoni</i>	Probably	yes
Townsend's Vole	<i>Microtus townsendii</i>	Probably	yes
Muskrat	<i>Ondatra zibethicus</i>	Probably	yes
Deer Mouse	<i>Peromyscus maniculatus</i>	yes	yes
Norway Rat	<i>Rattus norvegicus</i>	Probably	No
Eastern Gray Squirrel	<i>Sciurus carolinensis</i>	yes	No
Townsend's Chipmunk	<i>Tamias townsendii</i>	Probably	yes
Douglas' Squirrel	<i>Tamiasciurus douglasii</i>	Probably	yes
Vagrant Shrew	<i>Sorex vagrans</i>	Probably	yes

\* The certified list reports this as non-native wildcat (*Felis silvestris*) whose range is Asia, Africa, and Europe -- an obvious error.

\*\* Possible error. Long-eared myotis (*Myotis evotis*, not listed here) is believed to be much more common in this region and the two cannot be separated by visual identification.

Populations of deer and other herbivores have prospered in the Reserve and throughout Whidbey Island, largely as a result of the elimination of large predators (other than

humans) from the island during early settlement, and the reverting of prairie to intermediate successional stages in the absence of fire (Chamberlain et al. 2007). As a result, Whidbey Island experiences some of the highest rates of deer-vehicle collisions in western Washington

(<http://www.wsdot.wa.gov/Environment/Biology/FAQwildlifeCollisions.htm>). Damage to native ecosystems from abnormally high deer density has been documented elsewhere (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 addition to terrestrial mammals, at least 7 marine mammals occur in waters in or near the Reserve: killer whale (southern resident orca), gray whale, humpback whale, Dall's porpoise, harbor porpoise, Steller's sea lion, and harbor seal. California sea lion and minke whale also may occur. The southern resident **killer whale (orca)** is federally listed as Endangered. The Whidbey Island shoreline is within the designated Critical Habitat of this species. 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 population declined almost 20 percent from 1996 to 2001, but has increased since then, with 87 of these whales comprising the population in 2007 (NMFS 2008). Individuals or small groups have been occasionally sighted in Penn Cove. **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. 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 often sighted as individuals pass through Island 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.

### **Condition and Trends**

Condition: *Somewhat Concerning – Low Certainty*. Trends: *Indeterminate*.

A higher rating is not assigned because a few large mammals that historically were present have been extirpated, and some of the marine mammals in waters near the Reserve are experiencing declines regionally. Those declines are likely due entirely to changing conditions outside of the Reserve. Certainty is rated Low because apparently there are no published surveys of the Reserve's terrestrial mammals. Likewise, trends are rated "Indeterminate" because no baseline exists and no systematic data have been collected over the long term from within the Reserve.

### ***Amphibians and Reptiles***

The certified Reserve list, compiled in 2004, contains three amphibian species: Pacific chorus frog (treefrog): described as uncommon, long-toed salamander: described as uncommon, and boreal (western) toad: rare. 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. It was not found during the extensive amphibian surveys of Samora et al. (2013) during 2002-2003, but in 2005 was found at multiple locations elsewhere on Whidbey Island (Adamus et al. 2006). Merely protecting an area's wetlands, ponds, and their usual buffers does not ensure the survival of western toad or most other amphibians. During their adult phase, all of western Washington's pond-breeding amphibians require relatively-undeveloped upland habitat extending for thousands of feet from their natal ponds (as summarized by Hruby 2013).

For the first time within the Reserve, the surveys by Samora et al. (2013) documented the presence of four additional amphibian species in the Reserve: northern red-legged frog, rough-skinned newt, northwestern salamander, and Oregon ensatina. Specific locations and habitat characteristics are described by Samora et al.

The same surveys found the non-native American bullfrog just north of but not within the Reserve. An amphibian that is not native to the Pacific Northwest, it was introduced to Whidbey Island at some unknown time and has now become established throughout the island. A countywide wetlands survey in 2005 (which was not focused specifically on amphibians) detected it in several wetlands, none within the Reserve (Adamus et al. 2006).

For reptiles, the certified Reserve list contains 5 species: western terrestrial garter snake, common garter snake, northwestern garter snake, northern alligator lizard, and rubber boa. Only the first is categorized as "Present"; the rest are "Probably Present." The survey of Samora et al. (2013), which did not focus on reptiles, incidentally confirmed the presence of the second species within the Reserve but not any of the others. In addition, the survey detected a turtle in Lake Pondilla but could not determine the species, and thus whether it was native or introduced.

### **Condition and Trends**

Condition: *Somewhat Concerning – Moderate Certainty*. Trends: *Indeterminate*.

A higher rating is not assigned because at least two species -- western toad and spotted frog -- that historically were present were not encountered by the survey of Samora et al. (2013). Also, considering the apparent absence of all but one expected amphibian species from Lake Pondilla, and based on research elsewhere in the Pacific Northwest (Adams et al. 2011), it is likely that non-native predatory bass which were introduced into that pond are degrading its native biodiversity. They should be removed.

"Certainty" is rated Moderate because only the one systematic survey has been conducted, and it did not cover all seasons or areas within the Reserve, nor did it focus on reptiles. Trends are rated "Indeterminate" because no systematic surveys have yet been repeated. Moreover, potential threats to the Reserve's amphibians and reptiles, such as contaminants and pathogens, have not been measured.

#### 4.5.4.2 Wildlife Associated with Prairie Habitat

This section discusses wildlife species that are associated with coastal prairies of Whidbey Island. 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 Reserve. Extensive information characterizing the *vegetation* of prairies is provided elsewhere in this document (section 4.4.4.1). Several factors have together led to the extirpation of several of the Reserve's prairie bird species and will likely doom others if those stresses are continued. These include the gradual shrinkage of the Reserve's prairie due to conversion to farmland and then to prolonged absence of fire, as well as degradation of natural vegetation cover and structure within the prairie, and increased predation by feral house cats. Also, the high densities of deer on Whidbey Island have undoubtedly 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).

#### **Criteria**

For purposes of this assessment, "Good" conditions are represented by sustained naturally-occurring turnover rates of prairie species currently inhabiting an area. 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 prairie species in proportions characteristic of intact but dynamic ecosystems and well-functioning complex food webs, as well as sustaining their 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 prairie wildlife abundance and diversity is anticipated to affect adversely the rates of important ecosystem functions.

#### **Condition and Trends**

Condition: *Significant Concern - High Certainty*. Trend: *Significant Concern - Moderate Certainty*.

Among 49 bird species that associate highly with *prairie-oak habitat* in the Pacific Northwest, a large number (21) have experienced extirpations, range contractions, or regional declines (Altman 2011). Of the many bird species known to have nested in the Reserve, there is no question that 9 of these require prairies or very similar habitat to sustain their populations in this region. These are: northern harrier, short-eared owl, streaked horned lark, western kingbird, western bluebird, vesper sparrow, chipping sparrow, savannah sparrow, and western meadowlark. In October 2013 the US Fish and Wildlife Service designated the streaked horned lark as a Threatened species under the Endangered Species Act. Neither it nor short-eared owl, western kingbird, western bluebird, vesper sparrow, chipping sparrow, nor western meadowlark are believed to currently nest within the Reserve. At least 15 other bird species nest regularly in the Reserve's prairie or oak woodland habitat but are not obligates (Table 15).

**Table 15. Prairie-associated birds known to currently or formerly nest in the Reserve.**

Species	"Breeder" on NPS certified list?	Most certain level of breeding confirmation during 2001-2002 (BBA data)	Year of most recent report from the Reserve during likely breeding season (eBird data)	Prairie/oak Associate? (2= obligate, 1= other)*
California Quail	Yes	Confirmed	2014	1
Northern Harrier	No	Confirmed	2014	2
Cooper's Hawk	No	possible	2014	1
American Kestrel	No	Confirmed	2013	1
Short-eared Owl	No	<none>	2009	2
Anna's Hummingbird	No	<none>	2014	1
Downy Woodpecker	Yes	Confirmed	2011	1
Horned Lark (Streaked)	No	<none>	<unknown>	2
Western Wood-Pewee	No	possible	2014	1
Western Kingbird	No	<none>	2010	2
Cassin's Vireo	No	possible	<unknown>	1
Hutton's Vireo	Yes	Confirmed	2014	1
Black-capped Chickadee	Yes	Confirmed	2014	1
Bushtit	Yes	Confirmed	2014	1
House Wren	Yes	Confirmed	2014	1
Bewick's Wren	Yes	Confirmed	2014	1
Spotted Towhee	Yes	Confirmed	2014	1
Chipping Sparrow	No	possible	<unknown>	2
Savannah Sparrow	Yes	probable	2014	2
Purple Finch	Yes	Confirmed	2012	1
American Goldfinch	Yes	probable	2014	1

\* from Altman (2011)

Also, many butterflies are strongly associated with prairie habitat and its unique assemblage of plant species. One is Taylor's Checkerspot, a subspecies of Edith's checkerspot, a medium-sized butterfly. It is in imminent danger of going extinct. In October 2013 the US Fish and Wildlife Service designated it as Endangered under the Endangered Species Act. 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. Although historically present in prairies of Whidbey Island (Stinson 2005, Sheehan 2007), it is not currently known to be present in Island County. Intensive surveys for the species in the past few years have failed to find it within the Reserve. Golden paintbrush (*Castilleja levisecta*, a federally-listed Threatened plant species whose status in the Reserve is described in section 4.4.4.2) 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. No systematic, Reserve-wide inventories of butterflies or other

terrestrial invertebrates have been conducted, but the number of invertebrate species is likely in the hundreds.

#### 4.5.4.3 Habitat Connectivity

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, Whidbey Island -- situated 3 miles east of the Olympic Peninsula and over a mile west of most of the Washington mainland, and connected to the mainland by only one bridge -- may host fewer animal species than a mainland area of similar size and elevation, but this hypothesis has not been rigorously tested.

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 often simultaneously assist the movements of their predators or competitors as well (e.g., Rogers 1997, Novotny 2003, Hilty & Merenlender 2004, Sinclair et al. 2005). Where natural land form and soils allow it, maintaining wooded corridors just above the high tide line may be particularly important to terrestrial animals that routinely feed along the water line, e.g., mink, bald eagle. Woody cover also provides "landfall" cover to migrant birds as they cross marine waters, and helps shade and maintain temperatures of intertidal habitats of forage fish when those habitats are exposed during summer low tides.

#### *Criteria*

Meaningful criteria for evaluating habitat connectivity need to account for requirements of the target species, natural range of variation in species colonization and extirpation, and 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) throughout the Reserve. “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 Reserve as it may have existed in the early 1800s just prior to rapid settlement by Euro-Americans.

### **Condition and Trends**

Condition: *Somewhat Concerning - High Certainty*. Trends: *Indeterminate*.

Natural habitats -- especially prairie -- have been noticeably fragmented by roads within the Reserve. Nearly all that fragmentation occurred many decades ago, and there appears to have been comparatively little clearing of native vegetation within the Reserve in recent years (Figure 29, and see section 4.3.4.2). On Whidbey Island, wooded corridors probably facilitate the required overland dispersal of amphibians but also facilitate movements of deer which impact amphibian and bird habitat with their grazing of ground cover. Results of a GIS-based analysis of connectivity of natural land cover in Island County are shown in Table 16. The Whidbey-Camano Land Trust has also mapped habitat fragmentation and corridors throughout the county.

Table 16. Fragmentation/connectivity of Island County forests and wetlands as of 1998. (from Adamus et al. 2006).

**Fragmentation of Island County forests, including fragmentation by roads, as indicated by countywide size distribution of contiguously wooded tracts in 1998 satellite imagery**

Wooded Tract Size (acres)	# of tracts	% of total number of tracts	total acres	% of tract acres	# containing known wetlands	% containing known wetlands
<.5	12685	68.56	2549.70	4.82	1265	9.97
.5-.9	2758	14.91	1700.59	3.21	397	14.39
1-4.9	2155	11.65	4341.45	8.21	333	15.45
5-9.9	380	2.05	2624.95	4.96	81	21.32
10-49.9	367	1.98	7971.97	15.07	109	29.70
50-99.9	65	0.35	4437.57	8.39	37	56.92
100-249.9	57	0.31	8698.41	16.44	40	70.18
250-999.9	28	0.15	12983.71	24.54	28	100.00
1000-10,000	6	0.03	7595.92	14.36	6	100.00
>10,000	0	0.00	0.00	0.00	0	0.00

**Number of Island County non-estuarine wetlands that are contiguous with wooded tracts of various sizes, based on 2001 land cover data from the NOAA**

Wooded Tract Size (acres)	# of associated wetlands (ignoring tract fragmentation by roads)	%	# of associated wetlands (counting roads as tract fragmenters)	%
<.5	33	3.69%	38	4.27%
.5-.9	11	1.23%	21	2.36%
1-4.9	45	5.03%	66	7.42%
5-9.9	15	1.68%	26	2.92%
10-49.9	37	4.14%	93	10.45%
50-99.9	20	2.24%	49	5.51%
100-249.9	13	1.45%	143	16.07%
250-999.9	17	1.90%	248	27.87%
1000-10,000	60	6.71%	206	23.15%
>10,000	643	71.92%	0	0.00%

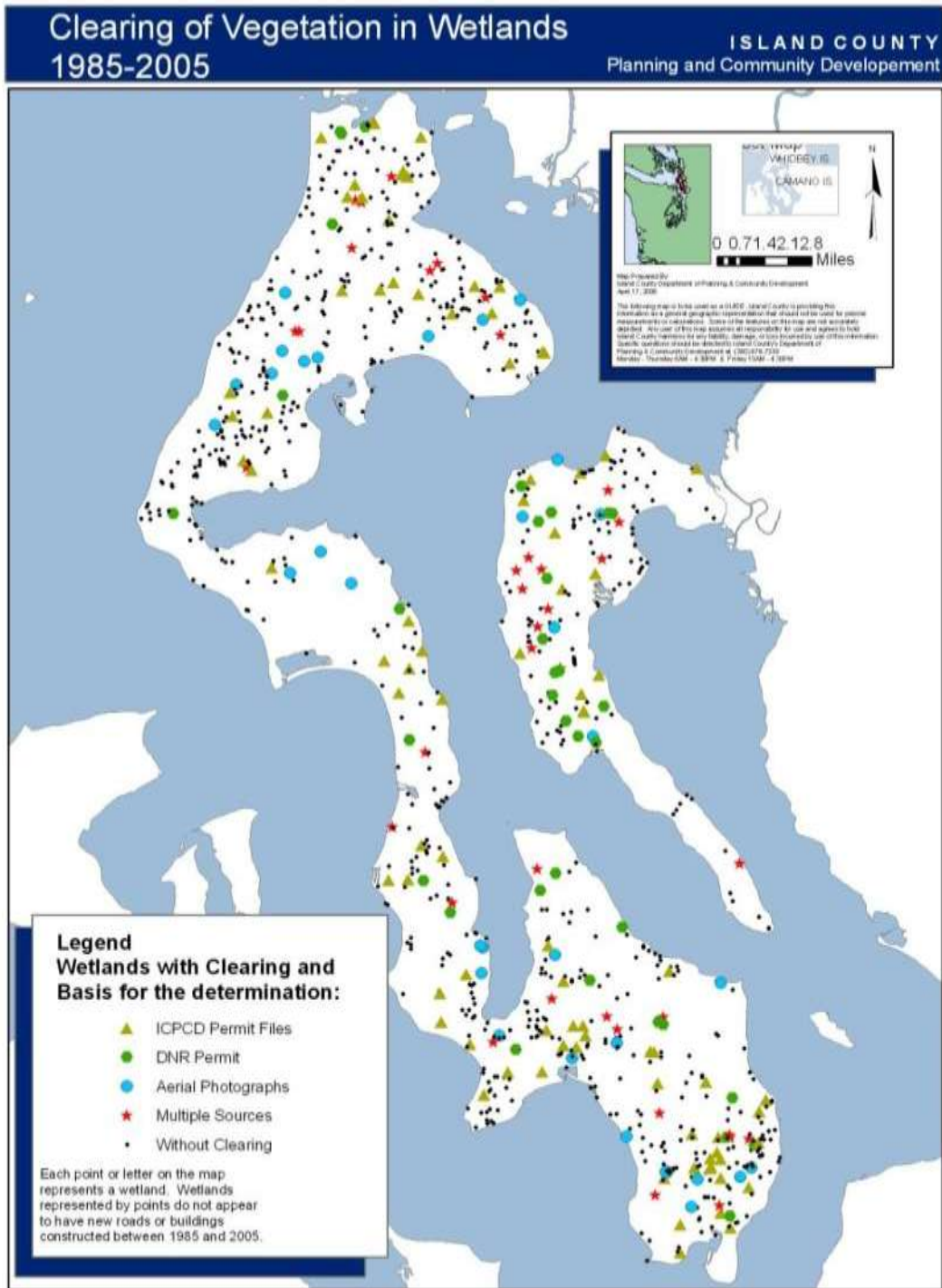


Figure 29. Clearing of vegetation in Island County wetlands, 1985-2005 (from Adamus et al. 2006).

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## **4.6 Air Quality**

### **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 the Reserve, 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), and nearby particle monitoring stations at Oak Harbor, Port Townsend, Anacortes, and Mount Vernon showing no danger of exceeding particulate matter or ozone National Ambient Air Quality Standards (NAAQS) established by the U.S. Environmental Protection Agency (EPA) to protect human health and welfare (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.

Industrial sources in the airshed include oil refineries at Anacortes in Skagit County; Intalco, ARCO, and ConocoPhillips in Whatcom County; and Port Townsend Paper which is approximately five miles west of the Reserve. That source is of particular concern due to its proximity and because the prevailing winds are from the west, especially during summer. In addition, the plume from the mill is often clearly visible from Ebey's Landing and the odor of sulfur compounds can sometimes be detected at the Reserve.

Within the Reserve, vehicle traffic concentrates at the Keystone ferry landing next to Fort Casey, and emissions from the ferry itself as well as from recreational and commercial boats further pollute the air. Recently adopted regulations are anticipated to reduce pollutant emissions from marine vessels by 2020. 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 Reserve, local sources of emissions include aircraft and vehicles at the Whidbey Naval Air Station, road traffic, marine vessels, agricultural operations, outdoor burning, and woodstoves/fireplaces (WDOE 2012). The air pollutants of concern in NPS areas are sulfur (S) and nitrogen (N) compounds, ground-level ozone and persistent bioaccumulative toxins (PBTs).

We reviewed information from 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 EPA's Air Pollution Monitoring and Trends Program (<http://www.epa.gov/airtrends/index.html>). Where information was found, it suggested no major point sources of air pollution near the Reserve.

Air quality has apparently not been monitored in the Reserve or, with the exception of a particulate monitoring station in Oak Harbor (about 4 miles northeast of the Reserve), elsewhere on Whidbey Island. Because data to assess compliance with the NAAQS is non-existent or limited, the county is considered "unclassifiable/attainment" under the Clean Air Act. In other words, the county cannot be classified on the basis of available information as meeting or not meeting the NAAQS for any pollutant.

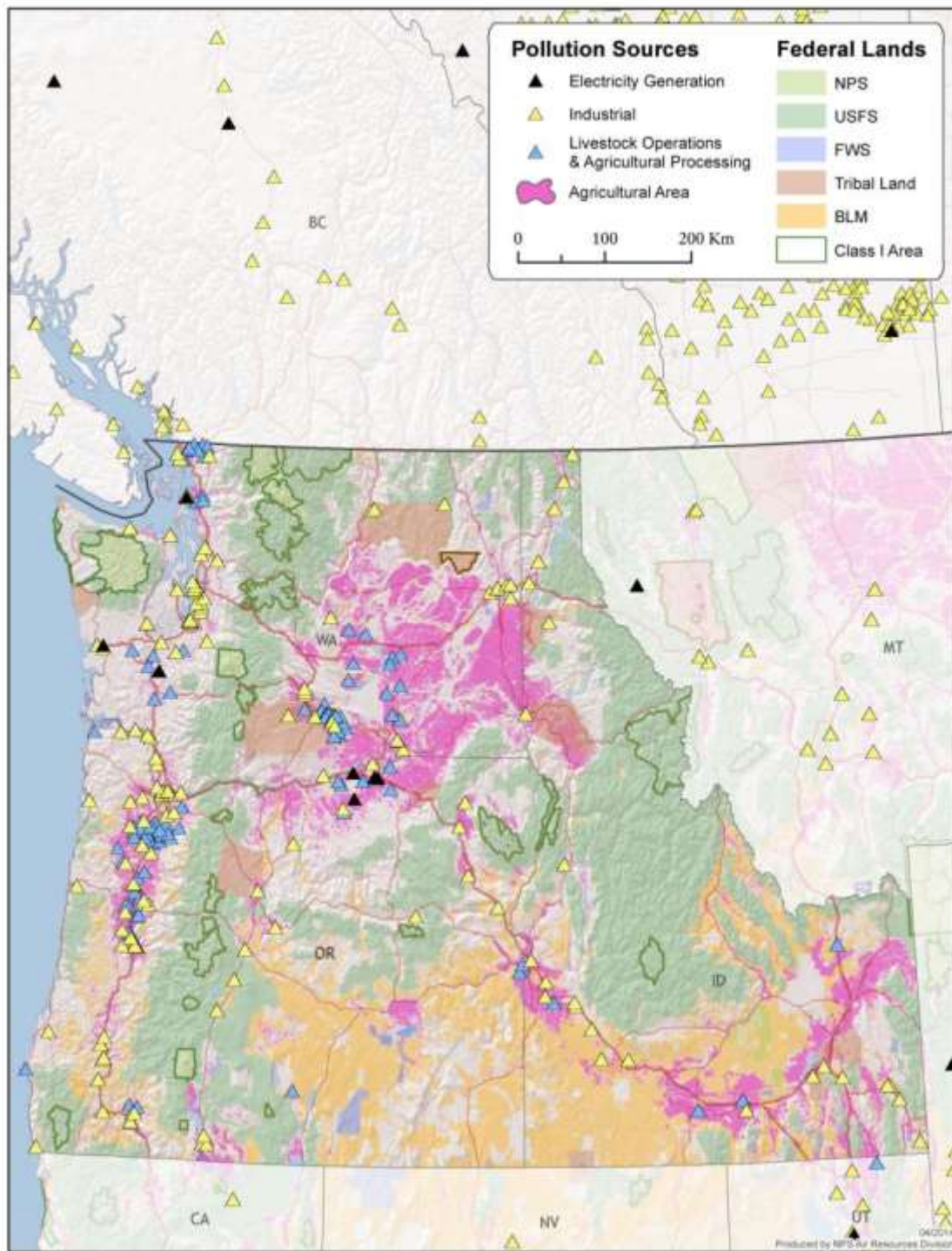


Figure 30. Air pollution sources and public lands in the Pacific Northwest.

#### **4.6.3 Issues Description**

Fine particles of sulfur (S) and nitrogen (N) 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 (rain, snow, clouds or fog) or dry deposition (e.g., via settling, impaction or adsorption). 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 toxins include heavy metals like mercury (Hg) and organic compounds such as pesticides. Mercury is emitted by coal combustion, incinerators, mining processes, and some other industries..

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 soil nutrient cycling and plant community structure and composition, with positive or negative results as judged from a human perspective. 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). 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 mercury and other persistent bioaccumulative toxins include impacts on reproductive success, growth, behavior, disease susceptibility and survival (Landers et al. 2008).

It is not clear how climate change will affect air pollution levels and effects on AQRVs at the Reserve. Changes in precipitation amount and timing could affect deposition of S, N and persistent bioaccumulative toxins. Changes in agricultural practices in response to weather patterns or pests could result in additional pesticide deposition at the Reserve. Increased temperatures and changes in summer precipitation might change the rate of mercury methylation, resulting in increased bioaccumulation in fish and other species. Increased summertime temperatures may also lead to higher ozone levels (USEPA 2009).

#### **4.6.4 Indicators and Criteria to Evaluate Condition and Trends**

We selected the following as indicators of air quality in this park:

- Nitrogen and Sulfur Deposition

- Ozone
- Persistent Bioaccumulative Toxins

A fourth indicator -- visibility -- is used as an indicator of “Natural Quality of the Park Experience” and is discussed in that chapter (4.7).

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 using on-site monitoring data, when available, or interpolated estimates of deposition and ozone values from nearby sites when on-site data were not available (NPS 2013a,b).

## **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 factors related to lichen community sensitivity in the Pacific Northwest (Fenn et al. 2003, Geiser and Neitlich 2007), as described below.

### 4.6.4.1 Nitrogen and Sulfur Deposition

## **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 and Trends**

Condition: *Somewhat Concerning - Low Certainty*. Trends: *Indeterminate*.

Deposition has not been measured directly in the Reserve. Estimates from interpolated 2005-2009 data suggest that wet N and S deposition in the park was about 0.4 kg/ha/yr for both N and S. This would put the Reserve in the Good Condition category for N and S deposition according to ARD criteria.

The relative risk from acidification and nutrient N enrichment was reported for all NPS I&M networks and parks by Sullivan et al. (2011c, d). The analysis predicted deposition of N and S in the Reserve may be moderate relative to other I&M parks, while the Reserve's sensitivity to acidification is probably low. The Reserve's estimated sensitivity to N enrichment was considered “very low” relative to other I&M parks. Some studies from other locations indicate added N can favor exotic over native species in prairie settings. Sullivan (unpublished) compared modeled total N deposition at I&M parks to critical loads values identified by Pardo et al. (2011). Sullivan determined modeled total N deposition of 2.2 kg/ha/yr at the Reserve did not exceed the lowest critical load identified for the region, i.e., 2.7-9.2 kg/ha/yr, which is intended to protect N-sensitive lichen species.

No data are available from which to calculate trends.

#### 4.6.4.2 Ozone

### **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. W126 ozone concentrations below 7 ppm-hours are not considered to be a threat to vegetation.

### **Condition and Trends**

Condition: *Good - Low Certainty*. Trend: *Indeterminate*.

The 2005-2009 interpolated data indicated a 3-year average annual 4th-highest daily maximum 8-hour ozone concentration of 52.5 ppm, which places the Reserve in the Good Condition category. Sullivan (unpublished) analyzed the relative ozone risk to vegetation for all I&M parks. The Reserve was considered at low risk for ozone injury based on a W126 value of 1.2 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). Kohut concluded there was low risk of ozone injury at the Reserve.

No data are available from which to calculate trends.

#### **4.6.4.3 Persistent Bioaccumulative Toxins**

*Indeterminate*. No data were found for the Reserve regarding airborne concentrations of, or impacts from, persistent bioaccumulative toxins.

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## **4.7 Natural Quality of the Park Experience**

### **4.7.1 Background**

Several attributes influence visitor enjoyment of the Reserve. Among the attributes that are associated with the Reserve's natural resources are its long-distance views, a dark starlit night sky, and the relative absence of signs of intensive development. These attributes of the Reserve experience are discussed in this section.

### **4.7.2 Regional Context**

No estimates are available pertaining to annual visitation of the Reserve. However, approximately 500,000 people are estimated to visit the Fort Casey/Crockett Lake area annually (WSCC 2000).

### **4.7.3 Issues Description**

Many changes have occurred since the Reserve was established. The Seattle-Tacoma Metropolitan Area has grown considerably, increasing visitation and residency to central Whidbey Island. Over the years, dairy-based and other types of agriculture have declined within the Reserve while conversion of land to residential use is gradually rising. Washington State Department of Transportation improvements along State Route 20—a State Scenic Highway and the main highway through the Reserve—are incrementally changing the historic road patterns and increasing speeds in favor of the commuter, perhaps at the expense of the park visitor. Increasing population growth projected for the region surrounding the Reserve could alter landscape character within the Reserve'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), further reduce the proportion of sounds that are of natural origin, and degrade the experience of persons for whom finding solitude outdoors is important. As agriculture continues to decline within the Reserve, whether from the declining viability of farming or through increased residential pressures, over time it is fully expected that there will continue to be pressure to fragment land into smaller parcels resulting in loss of open space and the associated rural character of the Reserve. Maintaining the nationally significant rural character of the Reserve is mandated by Congress and is of the utmost importance.

At the same time, more people in the region may mean more people likely to visit and enjoy what the Reserve offers. Nonprofit organizations such as The Nature Conservancy, the Whidbey-Camano Land Trust, and the Au Sable Institute now own and have protected land within the Reserve, preserving agriculture and protecting open space and unique natural resources.

### **4.7.4 Indicators and Criteria to Evaluate Condition and Trends**

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

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. According to the 1995 visitor survey, visitors come to the Reserve predominately because of the beautiful scenery. Scenic resources are among the most important resources within the Reserve that need protection. Part of this protection involves the maintenance of the rural landscape that creates the scenic elements. In terms of scenic resources, the significance of the Reserve is that the historical landscape appears much as it did a century ago. Historic homes, pastoral farmsteads, and commercial buildings are still within their original farm, forest, and marine settings.

#### **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. Parks with average visibility less than 2 dv above natural conditions are considered 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 40<sup>th</sup> through the 60<sup>th</sup> percentiles. Visibility is estimated from the interpolation of the five-year averages of the Group 50 visibility.

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. However, there are no widely-accepted criteria for evaluating viewsheds.

### **Condition and Trends**

Condition: *Somewhat Concerning* – *Medium Certainty*. Trends: *Indeterminate*.

Visibility monitoring has not been conducted at the Reserve. Interpolated 2005-2009 visibility at the Reserve was 6.6 dv on the 20 percent best days and 17.5 dv on the 20 percent worst days (NPS 2013a). The difference between average interpolated visibility and estimated average natural background visibility was 6.8 dv, i.e., current visibility is 68 percent worse than natural conditions. Visibility was in the Warrants Moderate Concern category (NPS 2013b).

#### 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. 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 collide with objects on land and be killed (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. Lower values (smaller or more negative) are brighter. NPS is in the process of determining what the night sky reference values should be.

### **Condition and Trends**

*Indeterminate*. No measurements have been taken and trends are unquantified. In 2003, Island County passed a lighting ordinance to preserve the qualities of the island's night sky resources. All light fixtures must be retrofitted if not in compliance with the regulations.

#### 4.7.4.3 Soundscape

Unwanted sound is called noise. 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. Naturally quiet conditions appeal to many visitors and contribute to the purpose of their visit. But natural quiet is not only for the benefit of visitors. Preserving the natural quiet also minimizes disturbance to species that require often-subtle auditory cues for reproduction, predator avoidance, navigation, and communication about food locations. Natural sounds within the Reserve include birdcalls, crashing of waves, and sounds of wind in the trees and grasses. The underwater soundscape is particularly important to marine mammals and is easily altered by vessel traffic.

## **Criteria**

The NPS has not recommended specific criteria for soundscape integrity. 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. In addition, a metric called the Sound Exposure Level (SEL) is often used to represent all of the sound energy of an event and includes both the intensity of a sound and its duration.

“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**

Condition: *Significant Concern - High Certainty*. Trends: *Indeterminate*.

By far the most apparent noise source is military jets flying at low altitude in and out of the U.S. Navy's Outlying Landing Field (OLF) Coupeville. That facility cuts through Smith Prairie within the Reserve and is used by pilots to practice simulated aircraft carrier landings. When in use, there is an extreme noise impact -- close to 100 dB next to the airfield for several seconds surrounding each takeoff or landing, and up to 125 dB at locations along the flight path 500 feet offshore. Although noise has not been measured specifically in the Reserve, models of sound levels that include the Reserve suggest an average of about 65 decibels at ground level during aircraft practice periods, mainly in the part of the Reserve between Crockett Lake northward to just south of Coupeville. As of 2011 there were 6166 total flight operations per year at that location. Flight schedules vary from several times per week to once a month. The time of day and length of practice sessions also vary erratically. The erratic schedule implies that significant noise impacts can occur on a regular, but inconsistent basis. About 94% of the flights occur during daylight hours (Bremer 2004).



Motorized personal watercraft (e.g., jet skis) are occasionally present in Penn Cove and generate substantial noise for brief periods. Much less noticeable noises emanate from the ferry landing at Fort Casey, farm and maintenance equipment, and vehicle traffic. State Route 20 runs through the Reserve and is used by over 2 million vehicles per year.

#### 4.7.4.4 Physical Remoteness and Solitude

Development of Whidbey Island began long ago, and was founded on agriculture, forestry, and fishing (White 1980). For a time, the limited ferry service and remoteness of the island remained a significant barrier. However, with the advent of automobile tourism in the early 20<sup>th</sup> 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.

June, July and August are the months of highest visitation to parks within the Reserve. Many visitors come in the shoulder seasons as well (March through May, and September through October). During the slower winter months of November through February, the Reserve 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**

*Indeterminate*, because of lack of accepted criteria and limited data on visitor use that is specific to the Reserve. Experiencing of solitude within the Reserve is correlated oppositely with numbers of Reserve visitors, as indirectly reflected by local data on human population and road traffic. In 2003, Ebey's Landing State Park visitation was 84,143; Fort Casey State Park visitation was 727,054; and Fort Ebey State Park visitation was 331,771. Total ridership on the Mukilteo ferry to Whidbey Island was nearly 4 million during 2014, and ridership on the Port Townsend ferry to Whidbey Island then was 723,045.

The population of Island County has grown from <2000 in 1900 to ~ 81,000 in 2008. Projected growth patterns suggest a population of 107,000 by 2030. The annual growth rate was > 3% from 1940-1990, but has been < 2% since then and is projected to stay at about this level through 2030. Population density of Island County is currently about 150 people/km<sup>2</sup> and is projected to reach about 200 people/km<sup>2</sup> by 2030. For comparison, the US Census Bureau estimates that the population density of Washington state was 38 people/km<sup>2</sup> in 2008, and that the density of the United States was 33 people/km<sup>2</sup>.

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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 Ebey's Landing National Historical Reserve. 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 Reserve is noted for its spectacular ocean views, remnant native prairies, and exceptional feeder bluffs and coastal strand. The prolonged absence of fire, combined with locally severe grazing by deer as well as isolation from the mainland and similar habitats elsewhere in Puget Sound, has likely altered the composition and structure of the Reserve's prairies and forest. Also, low-level overflights by military aircraft from airfields close to the Reserve have a major impact during some periods on the Reserve's soundscape.

The marine waters that adjoin the Reserve 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 Reserve's control. In the Reserve, mean annual temperature has

increased during recent decades. That has perhaps increased the risks to the Reserve's groundwater and mostly ephemeral surface waters, which are also vulnerable to impacts from residential development in areas adjoining the Reserve.







Fortunately, focused efforts are underway to improve the ecological condition of the Reserve's prairie habitat using a variety of hands-on management techniques. For the Reserve'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 deer and herbicide drift 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 Reserve, 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, excessive erosion, or facilitated spread of invasive plants, and wildlife are not subjected to persistent disturbance.







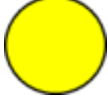
**Error! Reference source not found.** summarizes what this document has reported about the condition and trend of each of the major resource concerns at Ebey's Landing National Historical Reserve. What is perhaps most striking is that recent trends in nearly all of the Reserve's most important resources 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.


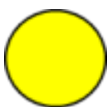
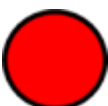



At least two major implications for management derive from this assessment. First, without expanding the monitoring of the condition of the Reserve's resources -- especially those with greatest potential to be affected by Reserve policies and management -- the risk of damaging the Reserve's resources will increase, or at least, opportunities will be lost to understand many of the resources 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 Reserve's regionally essential prairie habitat and assure its long term survival as a key feature of this unique area.






**Table 17. 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
<b>Climate</b>		
Temperature		<ul style="list-style-type: none"> <li>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. Data should be analyzed for long term shifts in the seasonality (monthly means and extremes) of temperature.</li> </ul>
Precipitation		<ul style="list-style-type: none"> <li>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. Data should be analyzed for long term shifts in the seasonality (monthly means and extremes) of precipitation.</li> </ul>
<b>Nearshore Resources</b>		
Nearshore Water Quality		<ul style="list-style-type: none"> <li>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 Reserve.</li> <li>Ocean acidity should be measured regularly using standard protocols to detect trends in conditions harmful to marine life.</li> </ul>
Eelgrass		<ul style="list-style-type: none"> <li>Extent and location of eelgrass needs to be monitored annually in the Reserve.</li> </ul>
Kelp & Seaweeds		<ul style="list-style-type: none"> <li>Extent and location of various species of kelp should be monitored annually in the Reserve.</li> <li>Effects of sea star die-offs on the extent of kelp (via enhanced grazing by urchins) should be monitored.</li> </ul>
Salmonid Fish		<ul style="list-style-type: none"> <li>The year-to-year use by salmonids of the shores along the Reserve should be monitored.</li> </ul>


Forage Fish		<ul style="list-style-type: none"> <li></li> </ul>
Shellfish & Other Nearshore Invertebrates		<ul style="list-style-type: none"> <li>A taxonomically comprehensive survey of marine invertebrates inhabiting the Reserve's shoreline and especially its lagoons should be completed and published.</li> <li>Permanent plots should be established in intertidal habitats and lagoons, and annual changes in marine invertebrates within these should be monitored.</li> <li>The Reserve's shorelines should be checked annually for potentially invasive marine invertebrates.</li> <li>Effects of sea star die-offs on other marine ecosystem components should be monitored.</li> <li>Within the Reserve's marine waters, the current status of the rare pinto abalone should be determined and monitored.</li> </ul>
Intertidal Vegetation and Invasive Plants		<ul style="list-style-type: none"> <li>The extent of invasive plants in the coastal strand should be monitored annually to determine if control measures are effective and to measure local impacts from visitors.</li> </ul>
<b>Freshwater Resources</b>		
Groundwater Levels & Quality		<ul style="list-style-type: none"> <li>The amount of groundwater recharge needed to sustain the Reserve's wetlands and to avoid degradation of water quality in the Reserve's few wells should be determined.</li> <li>Effects of different land cover types and land use practices on groundwater recharge need investigation.</li> <li>Effects on aquifers of wetlands and ponds that may be constructed in the future should be investigated or modeled.</li> </ul>
Extent of Non-tidal Surface Water & Wetlands		<ul style="list-style-type: none"> <li>The seasonal duration of flow in the Reserve's few ephemeral streams should be determined annually.</li> <li>Water table levels in representative wetlands should be determined annually.</li> </ul>
Surface Water Quality		<ul style="list-style-type: none"> <li>Ways should be sought to minimize the export of high loads of nitrate to marine water from farmed Ebey's Prairie soils.</li> </ul>
<b>Terrestrial Vegetation and Landcover</b>		
Prairie Extent, Distribution, & Composition		<ul style="list-style-type: none"> <li>The extent of invasive plants in the Reserve's prairies should be monitored annually to determine if control measures are effective and to measure local impacts from deer and visitors.</li> <li>Floristic quality measures should be calculated for plant communities in the Reserve's prairies at least once each decade, based on repeated surveys.</li> <li>The response of native prairie plant communities to any fires</li> </ul>

		that may occur should be determined.
Coastal Strand, Spit, & Dune Communities		<ul style="list-style-type: none"> <li>The extent of invasive plants in these communities should be monitored annually, especially in areas with significant foot traffic, to determine where control measures are most needed.</li> </ul>
Less Common Species & Invasive Plants		<ul style="list-style-type: none"> <li>A comprehensive inventory of bryophytes and lichens should be conducted throughout the Reserve.</li> <li>Impacts of fire, herbicides, and air quality on the Reserve's bryophytes, lichens, and uncommon native vascular plants should be monitored through use of permanent plots or other methods.</li> </ul>
Golden Paintbrush		<ul style="list-style-type: none"> <li>The abundance of species that are likely to be deleterious to <i>C. levisecta</i> establishment, such as annuals and non-native perennial grasses, should be regularly measured.</li> <li>Detailed information on the demographics and biology of plants that are plugged or seeded on a site should be gathered.</li> <li>HIGH CERTAINTY</li> </ul>
<i>Plectritis brachystemon</i> , <i>Sericocarpus rigidus</i> , and <i>Silene scouleri</i> spp. <i>scouleri</i>		<ul style="list-style-type: none"> <li>Current population numbers and spatial extent in the Reserve should be determined and monitored regularly in the future.</li> </ul>
Forest Composition, Age, & Structure		<ul style="list-style-type: none"> <li>Data are needed on stand age/dominance type classes of forests throughout the Reserve.</li> <li>The extent to which forests are being invaded by non-native plants that alter forest understory composition and structure in the Reserve needs closer examination and monitoring.</li> </ul>
Land Cover & Land Use		<ul style="list-style-type: none"> <li>A spatial database is needed that annually documents the crop type and cultivation practices (e.g., soil treatments, herbicide use, fallow areas) within all of the Reserve's lands.</li> <li>Effects of different land cover types and land use practices on groundwater recharge need investigation.</li> <li>Newer imagery needs to be classified with regard to land cover types and the broad category of non-cropland, non-forested lands needs to be partitioned into finer components (i.e., active pastures vs., abandoned/former croplands or pastures vs. seasonal wetlands vs. actual native or semi-native prairie)</li> <li>Surveys are needed of the relative frequency of native plant cover within this broad non-forested, non-cropland category.</li> </ul>
<b>Wildlife</b>		

Birds		<ul style="list-style-type: none"> <li>No systematic data have been collected over the long term from within the Reserve that would allow valid calculation of trends for any of the Reserve's bird species. This is particularly true of marine birds and nocturnal owls.</li> <li>For nearly all species, data on reproductive success have not been collected within the Reserve. Such data are required to assess trends and help define minimum viable population levels.</li> <li>Relative sensitivities of different bird species to disturbance from traffic and recreationists have not been determined within the Reserve.</li> </ul>
Mammals		<ul style="list-style-type: none"> <li>No systematic data have been collected over the long term from within the Reserve that would allow valid calculation of trends for any of the Reserve's mammal species. Monitoring of deer population levels and effects of deer grazing on other resources is particularly needed.</li> <li>For nearly all mammal species, data on reproductive success and travel corridors have not been collected within the Reserve. Such data are required to assess trends and help define minimum viable population levels.</li> <li>Relative sensitivities of different mammal species to disturbance from traffic and recreationists have not been determined within the Reserve.</li> </ul>
Amphibian & Reptiles		<ul style="list-style-type: none"> <li>The identity of turtles and non-native fish needs to be determined in Lake Pondilla, and the latter removed as a threat to native amphibians and sub-adult turtles.</li> <li>No recent inventories of amphibian or reptile species in either unit of the Reserve have been published. In particular, data are needed on the current status of western toad, due to conservation listings.</li> <li>No systematic data have been collected over the long term from within the Reserve that would allow valid calculation of trends for any of the Reserve's amphibian or reptile species.</li> <li>Data on reproductive success and dispersal corridors have not been collected within the Reserve. Such data are required to assess trends and help define minimum viable population levels.</li> <li>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 Reserve.</li> </ul>
Terrestrial Invertebrates		<ul style="list-style-type: none"> <li>Comprehensive published inventories of butterflies or other terrestrial invertebrates are needed for the Reserve.</li> </ul>
Prairie Wildlife		<ul style="list-style-type: none"> <li>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.</li> <li>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</li> </ul>

		terrestrial invertebrates should be monitored.
Invasive or Harmful Wildlife		<ul style="list-style-type: none"> <li>Population levels and distribution of feral cats in the Reserve need to be determined due to their likely effect on bird and small mammal populations.</li> </ul>
Habitat Connectivity		<ul style="list-style-type: none"> <li>The ability of amphibians and other mobile species to disperse through the matrix of land cover types within and surrounding the Reserve needs to be determined.</li> <li>Locations of the most-used wildlife corridors adjoining the Reserve should be determined.</li> </ul>
<b>Air Quality</b>		
Nitrogen & Sulfur Deposition		<ul style="list-style-type: none"> <li>N and S deposition specifically in the Reserve should be measured periodically and the data made accessible.</li> <li>The Reserve's lichen diversity should be inventoried in order to tell how widely they have been impacted by N deposition.</li> <li>The development of a critical load approach for air quality monitoring in the Reserve would improve the quality and robustness of data collected in the future.</li> </ul>
Ozone		<ul style="list-style-type: none"> <li>Ozone measurements within the Reserve have been too infrequent to conclude whether ozone may be harming or limiting growth of some plant species.</li> <li>Updated monitoring is needed to determine condition and trends.</li> </ul>
Persistent Toxins		<ul style="list-style-type: none"> <li>Mercury and other persistent toxins should be monitored in the Reserve. Effects of management practices on their mobility and bioaccumulation should also be measured.</li> </ul>
<b>Natural Quality of the Park Experience</b>		
Visibility & Viewsheds		<ul style="list-style-type: none"> <li>Despite the Reserve'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.</li> </ul>
Dark Night Sky		<ul style="list-style-type: none"> <li>No data are available for the Reserve, using NPS measurement protocols. This is needed in order to conclude anything about condition and trends.</li> </ul>
Soundscapes		<ul style="list-style-type: none"> <li>Practices that might reduce the periodically severe impacts to the Reserve's soundscape from military aircraft need further investigation and discussion.</li> <li>No data on the natural soundscape of the Reserve, that use NPS measurement protocols, are available.</li> </ul>



Physical Remoteness & Solitude		<ul style="list-style-type: none"> <li>Criteria need to be developed for evaluating the adequacy of remoteness and solitude in parts of the Reserve where this is a desired management objective.</li> </ul>
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## REFORMAT THIS INTO THE PRECEDING TABLE

See section narratives for criteria and justification of each rating.

Priority Issue	Indicators	Condition Rating	Certainty	Trend Rating	Certainty
Climate	Temperature	Indeterminate		Sig. Concern	Moderate
	Precipitation	Indeterminate		Good	Low
Nearshore Resources	Nearshore Water Quality	Some Concern	Low	Indeterminate	
	Eelgrass	Good	High	Good	Low
	Kelp & Other Seaweeds	Good	High	Good	Low
	Intertidal Vegetation & Invasive Plants	Some Concern	Moderate	Indeterminate	
	Salmonid Fish	Indeterminate		Indeterminate	
	Forage Fish	Indeterminate		Indeterminate	
	Shellfish & Other Nearshore Invertebrates	Indeterminate		Indeterminate	
Freshwater Resources	Groundwater Levels & Quality	Sig. Concern	High	Indeterminate	
	Extent of Non-tidal Surface Water & Wetlands	Some Concern	Low	Indeterminate	
	Surface Water Quality	Sig. Concern	High	Indeterminate	
Terrestrial Vegetation	Prairie Extent, Distribution, & Composition	Sig. Concern	Moderate	Sig. Concern	Moderate
	Less Common Plant Species & Communities	Sig. Concern	High	Indeterminate	
	Forest Composition, Structure, & Age	Sig. Concern	Moderate	Some Concern	Moderate
	Land Cover & Land Use	Some Concern	Low	Some Concern	Moderate
Wildlife	Rare or Sensitive Species; Invasive Animals:				
	Birds	Sig. Concern	High	Indeterminate	
	Mammals	Some Concern	Low	Indeterminate	
	Amphibians & Reptiles	Some Concern	Moderate	Indeterminate	
	Prairie Wildlife	Sig. Concern	High	Some Concern	Moderate
	Habitat Connectivity	Some Concern	High	Indeterminate	
Air Quality	Nitrogen & Sulfur Deposition	Some Concern	Low	Indeterminate	
	Ozone	Good	Low	Indeterminate	
	Persistent Toxics	Indeterminate		Indeterminate	
Natural Quality of	Visibility	Some Concern	Moderate	Indeterminate	
	Dark Night Sky	Indeterminate		Indeterminate	

## Appendices

## Appendix 1. Wetland plant survey data from the Reserve.

See shapefiles available from author for locations of these wetlands.

**Table 18. Plants identified by Island County staff in 4 wetlands within Ebey's Landing National Historical Reserve during one-day surveys during one of the years, 2007-2013.**

### Wetland 569

From 15 Transects, 590 points:

Code	Scientific Name	Common Name	No. of occurrences	Percent of Occurrence
JUEF	<i>Juncus effusus</i>	Soft Rush	97	16.44%
ELPA	<i>Eleocharis pachycarpa</i>	Black sand spikerush	82	13.90%
COPA	<i>Conioselinum pacificum</i>	Pacific Hemlock Parsley	72	12.20%
SCTA	<i>Scirpus tabernaemontanii</i>	Softstem bulrush	66	11.19%
SPEU	<i>Sparganium eurycarpum</i>	Giant burreed	56	9.49%
AGST	<i>Agrostis stolonifera (alba)</i>	Creeping bentgrass	46	7.80%
SODU	<i>Solanum dulcamara</i>	Bitter nightshade	46	7.80%
POAR	<i>Potentilla anserina</i>	Silverweed	37	6.27%
RULE	<i>Rubus leucodermis</i>	Blackcap	22	3.73%
SASC	<i>Salix scouleriana</i>	Scouler willow	18	3.05%
COSE	<i>Cornus sericea</i>	Redstem dogwood	15	2.54%
PHAR	<i>Phalaris arundinacea</i>	Reed canary grass	13	2.20%
RUCR	<i>Rumex crispus</i>	Curley dock	5	0.85%
URDI	<i>Urtica dioica</i>	Stinging nettle	4	0.68%
CIAR	<i>Cirsium arvense</i>	Canada thistle	3	0.51%
Bare		Bare ground	3	0.51%
GATRFI	<i>Galium trifidum (cymosum)</i>	Pacific bedstraw	2	0.34%
RUDI	<i>Rubus discolor</i>	Himalayan blackberry	2	0.34%
Moss		Moss	1	0.17%

### Quadrat Data:

Date	7/9/2009		7/9/2009	
Plot tag ID	113		114	
GPS lat	48 11'26 .3"		48 11' 26.4"	
GPS long	122 41.82'		122 41' 79.2"	
Distance from last plot (ft)			100	
Compass from last plot			250	
Nearest recognizable feature	pond		Pond	
Distance to that feature (ft)			30	
Direction to that feature (degrees)			250	
Notes	25ft SW of pond area 20ft NW of willow boundary line.		Pond is 30ft SW of plot	
Species/ Percent Cover	COPA	70	ELPA	20
	JUEF	20	SPEU	40
	DLPA	10	SODU	40

## Wetland 180

Symbol	Scientific Name	Common Name	No. of Occurrences	Percent of Occurrence
PHAR	<i>Phalaris arundinacea</i>	Reed canary grass	96	32.00%
BARE		Bare	65	21.67%
ASTER	<i>Asteraceae Family (sp)</i>	Sunflower family	34	11.33%
SPEU	<i>Sparganium eurycarpum</i>	broadfruit bur-reed	25	8.33%
EPCI	<i>Epilobium ciliatum</i>	Watson willowherb	13	4.33%
ROCU	<i>Rorippa curvisiliqua</i>	curvepod yellowcress	11	3.67%
RUMA	<i>Ruppia maritima</i>	widgeongrass	8	2.67%
CAREX	<i>Carex Family (sp)</i>	Sedge family	8	2.67%
POAM	<i>Polygonum amphibium</i>	water knotweed	7	2.33%
ELAC	<i>Eleocharis acicularis</i>	needle spikerush	6	2.00%
MOSS		Moss	6	2.00%
SAOF	<i>Sanguisorba officinalis</i>	great burnet	4	1.33%
RUCR	<i>Rumex crispus</i>	curly dock	3	1.00%
GATRFI	<i>Galium trifidum</i>	Pacific bedstraw	2	0.67%
HOLA	<i>Holcus lanatus</i>	velvetgrass	2	0.67%
RASC	<i>Ranunculus sceleratus</i>	cursed buttercup	2	0.67%
TRRE	<i>Trifolium repens</i>	white clover	2	0.67%
BRASS	<i>Brassicaceae Family (sp)</i>	Mustard Family	2	0.67%
SODU	<i>Solanum dulcamara</i>	climbing nightshade	1	0.33%
BRCA	<i>Brassica rapa var. rapa</i>	field mustard	1	0.33%
POPAL	<i>Poa palustris</i>	fowl bluegrass	1	0.33%

Quadrat Data: [none]

## Wetland 538

Code	Scientific Name	Common Name	No. of Occurrences	% of Occurrences
BARE		bare ground	37	23.13%
GASH	<i>Gaultheria shallon</i>	salal	32	20.00%
DREX	<i>Dryopteris expansa</i>	spreading woodfern	21	13.13%
POMU	<i>Polystichum munitum</i>	western swordfern	13	8.13%
WATER		water	11	6.88%
ATFI	<i>Athyrium filix-femina</i>	common ladyfern	7	4.38%
MOSS		moss	7	4.38%
TITR	<i>Tiarella trifoliata</i>	threeleaf foamflower	6	3.75%
OESA	<i>Oenanthe sarmentosa</i>	water parsley	6	3.75%
RUUR	<i>Rubus ursinus</i>	California blackberry	6	3.75%
RUSP	<i>Rubus spectabilis</i>	salmonberry	3	1.88%
CAOB	<i>Carex obnupta</i>	slough sedge	3	1.88%
GL	<i>Glyceria (sp)</i>	mannagrass	2	1.25%
WOOD		wood	2	1.25%
RHMA	<i>Rhododendron maximum</i>	great laurel	2	1.25%
SARA	<i>Sambucus racemosa</i>	red elderberry	1	0.63%
VAPA	<i>Vaccinium parvifolium</i>	red huckleberry	1	0.63%

## Quadrat Data:

Date	6/10/2010		6/10/2010	
Plot tag ID	140		141	
GPS lat	48 12.712		48 13.701	
GPS long	122 45.698		122 45.708	
Distance from last plot (ft)	N/A		100	
Compass from last plot	N/A		180	
Nearest recognizable feature	Old Car		Giant Burned Cedar	
Distance to that feature (ft)	100		100	
Direction to that feature (degrees)	292			
Tree species near plot	Red Elderberry, Alder		Hemlock	
Notes				
Species/ Percent Cover	DREX	20	OESA	75
	RUSP	17	WATER	13
	BARE	50	GASH	5
	WATER	2	MOSS	2
	POMU	10	WOOD	5
	TITR	1		

## Wetland 160

Code	Scientific Name	Common Name	No. of Occurrences	% of Occurrences
GASH	<i>Gaultheria shallon</i>	salal	5	12.50%
Wood			7	17.50%
Bareground			1	2.50%
CAOB	<i>Carex obnupta</i>	slough sedge	25	62.50%
Water			2	5.00%

### Quadrat Data:

Date	9/7/2012		9/7/2012	
Plot number	106a		106b	
Plot tag ID	28		29	
GPS lat	48 13.032		48 13.032	
GPS long	122 44.133		122 44.133	
Distance from last plot (ft)				
Compass from last plot				
Nearest recognisable feature	WSDOT property corner		WSDOT property Corner	
Distance to that feature (ft)	31		31	
Direction to that feature (degrees)	120		120	
Notes	There is a fallen tree approximately 31 feet east of the Washington State DOT property corner. Rebar is pounded into this tree (because much of the wetland is under water). The plots were placed back to back off of this fallen tree.			
Species/ Percent Cover	<i>Carex obnupta</i>	100	<i>Carex obnupta</i>	60
			<i>Gaultheria shallon</i>	40

Wetland 160 (continued)

<b>FQA* Calculations</b>	
Mean C (native species)	2.33
Mean C (all species)	2.33
Mean C (native trees)	n/a
Mean C (native shrubs)	4.00
Mean C (native herbaceous)	2.00
FQAI (native species)	12.78
FQAI (all species)	12.78
Adjusted FQAI	23.33
% intolerant (C value $\geq 7$ )	0%
% tolerant (C value $\leq 3$ )	83%
Species Richness (all)	30
Species Richness (native)	30
% Non-native	0%
Wet Indicator (all)	-3.67
Wet Indicator (native)	-3.67
% hydrophyte	83%
% native perennial	100%
% native annual	0%
% annual	0%
% perennial	100%
# species with moderate fidelity to prairies	0
# species with high fidelity to prairies	0
% native forbs	0%
% native graminoids	83%

\*FQA= Floristic Quality Assessment. See Rocchio and Crawford (2013) for definitions of metrics and their interpretation. FQA



Table 19. Plants identified in 5 wetlands within the Reserve in 2005.

These data do not necessarily represent a comprehensive inventory within each wetland. See shapefiles provided with this report for locations of these wetlands.

Wetland ID:	154	206	285	297	303
<i>Agrostis gigantea (alba)</i>	present	0	present	0	0
<i>Alnus rubra</i>	Common	0	present	0	0
<i>Anthoxanthum odoratum</i>	0	0	Common	0	0
<i>Argentina egedii (Potentilla pacifica/anserina)</i>	0	present	present	present	present
<i>Atriplex patula</i>	0	0	0	present	present
<i>Cirsium arvense</i>	present	present	present	0	0
<i>Cirsium vulgare</i>	0	present	present	present	present
<i>Distichlis spicata (stricta)</i>	0	0	0	present	Common
<i>Eleocharis palustris</i>	0	Common	Common	0	0
<i>Cirsium vulgare</i>	0	present	0	present	0
<i>Epilobium ciliatum (watsonii)</i>	present	0	present	0	0
<i>Equisetum arvense</i>	0	present	present	0	0
<i>Festuca rubra</i>	0	present	0	0	present
<i>Galium trifidum (cymosum)</i>	0	0	present	0	0
<i>Geum macrophyllum</i>	present	0	0	0	0
<i>Grindelia integrifolia</i>	0	0	0	present	0
<i>Holcus lanatus</i>	0	present	present	present	present
<i>Ilex aquifolium</i>	present	0	0	0	0
<i>Juncus balticus (arcticus)</i>	0	0	0	present	present
<i>Juncus effusus</i>	present	0	0	0	0
<i>Lonicera involucrata</i>	0	0	0	0	present
<i>Malus (Pyrus) fusca</i>	Common	0	0	0	0
<i>Mentha arvensis (canadensis)</i>	present	0	0	0	0
<i>Nuphar lutea (polysepala)</i>	Common	0	0	0	0
<i>Oenanthe sarmentosa</i>	present	0	0	0	0
<i>Phalaris arundinacea</i>	0	0	0	0	present
<i>Plantago lanceolata</i>	0	0	present	0	present
<i>Plantago maritima</i>	0	0	0	present	0
<i>Ricciocarpus natans</i>	present	0	0	0	0
<i>Rosa nutkana</i>	present	0	0	0	0
<i>Rumex crispus</i>	0	present	present	0	present
<i>Rumex obtusifolius</i>	present	0	0	0	0
<i>Rubus spectabilis</i>	Common	0	0	0	Common
<i>Rubus ursinus</i>	0	0	0	present	present
<i>Sambucus racemosa</i>	present	0	0	present	0

<b>Wetland ID:</b>	<b>154</b>	<b>206</b>	<b>285</b>	<b>297</b>	<b>303</b>
<i>Salix scouleriana</i>	Common	0	0	0	0
<i>Salix sitchensis</i>	0	0	0	0	present
<i>Salicornia depressa (virginica)</i>	0	0	0	Common	Common
<i>Schoenoplectus acutus</i>	0	0	present	0	present
<i>Solanum dulcamara</i>	present	0	0	0	0
<i>Symphoricarpos albus</i>	0	0	0	0	present
<i>Triglochin maritima</i>	0	0	0	0	present
<i>Trifolium repens</i>	0	0	present	0	0
<i>Typha latifolia</i>	present	Common	0	0	present
<i>Urtica dioica</i>	present	0	0	0	0
<i>Veronica americana</i>	present	0	0	0	0

## Appendix 2. Bird species abundance and distribution within the Reserve.

**Table 20. Maximum number (per day & location) reported by bird species, for the Reserve and for Whidbey Island.**

Species in **bold** are ones for which reported numbers within the Reserve were equal or greater than numbers reported for anywhere else on Whidbey Island. Species in **red font** are on NPS certified list but have no reports for the Reserve in eBird or the BBA (Breeding Bird Atlas). *Italicized* species are not on NPS certified list but have been reported to eBird or published in reports as being found within the Reserve. Data in eBird database is mostly credible, but consists of unverified reports from birders, mostly covering the past few decades; coverage by location is uneven.

[illegible]

Species	Whidbey Island	EBLA	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crockett Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododendron Park
Harlequin Duck	30	30	Present	Uncomm.	Resid.	10	24	30	22	12	1		5	
<b>Surf Scoter</b>	7000	7000	Present	Abundant	Resid.	18	200	150	15	19			7000	
<b>White-winged Scoter</b>	3000	3000	Present	Abundant	Resid.	1	4	25	40	18			3000	
Black Scoter	12	8	Present	Uncomm.	Resid.			4		2			2	
Long-tailed Duck	15	15	Present	Uncomm.	Resid.	1	7						6	
Bufflehead	150	150	Present	Abundant	Resid.	10	20	12	32	150			125	
Common Goldeneye	250	250	Present	Common	Resid.	3	4	22	7	16			250	
Barrow's Goldeneye	20	20	Present	Uncomm.	Resid.	1		20	2	4			20	
Ruddy Duck	215	215	Present	Common	Resid.			20	28	215			1	
Hooded Merganser	120	120	Present	Uncomm.	Breeder	2		4	1	120			50	
Common Merganser	16	16	Present	Uncomm.	Resid.			16		4			13	
Red-breasted Merganser	100	25	Present	Common	Resid.	1	15	25	15	20			20	
Ring-necked Pheasant	3	2	Present	Common	Breeder					2	1			
California Quail	50	25	Present	Rare	Resid.	1	25	4		6		1		
Red-throated Loon	50	50	Present	Uncomm.	Resid.	2	12	50		2			1	
Pacific Loon	10	10	Present	Uncomm.	Resid.	1	2	10	3	3			1	
Common Loon	20	20	Present	Common	Resid.	2	4	20	3	4			6	
Yellow-billed Loon	1	1	Probable	NA	NA				1					
Pied-billed Grebe	3	3	Present	Rare	Resid.	1			1	3			1	
Horned Grebe	35	35	Present	Uncomm.	Resid.	6	30	12	10	13			22	
Red-necked Grebe	11	11	Present	Uncomm.	Resid.		4	11	5	8			6	
Eared Grebe	2	2	Present	Rare	Resid.	1				1			2	
<b>Western Grebe</b>	2000	2000	Present	Common	Resid.	3	2	20	2	12			2000	
Clark's Grebe	1	1	Present	Occas.	Vagrant								1	
<i>Northern Fulmar</i>	1	1							1					
<i>Sooty Shearwater</i>	1	1							1					
<i>Leach's Storm-Petrel</i>	1	1												
<i>American White Pelican</i>	3	3								3				
<i>Brown Pelican</i>	1	0												
Brandt's Cormorant	15	15	Present	Uncomm.	Resid.		4	4	15	5				
Double-crested Cormorant	76	76	Present	Common	Resid.	18	10	76	50	30			9	
Pelagic Cormorant	50	50	Present	Common	Resid.	1	10	50	48	15			4	
American Bittern	1	1	Probable	NA	NA					1				

Species	Whidbey Island	EBLA	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crockett Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododendron Park
Great Egret	1	1	Probable	NA	NA					1				
Great Blue Heron	25	25	Present	Uncomm.	Resid.	2	1	22	15	25		1	6	
Little Blue Heron	1	1	Probable	NA	NA					1				
Green Heron	1	1	Probable	NA	NA		1							
Turkey Vulture	5	5	Probable	NA	NA		4	2		5			1	
Osprey	3	2	Probable	NA	NA			1		1		1		
Golden Eagle	1	0	Probable	NA	NA									
Northern Harrier	14	14	Present	Common	Resid.	1	2	5	3	14		1	2	
Sharp-shinned Hawk	2	2	Present	Rare	Resid.		1	1				2	1	
Cooper's Hawk	4	2	Present	Rare	Resid.			2		1		1	1	
Bald Eagle	18	12	Present	Uncomm.	Breeder	2	5	8	4	12		2	4	1
Red-tailed Hawk	10	7	Present	Common	Breeder	1		4	2	7		2	5	3
Rough-legged Hawk	1	1	Probable	NA	NA					1				
<i>Broad-winged Hawk</i>	1	1						1						
American Kestrel	3	2	Present	Uncomm.	Resid.	1		2	1	1		2		
Peregrine Falcon	2	1	Present	Uncomm.	Resid.				1	1			1	
Merlin	1	1	Present	Rare	Resid.	1		1		1				
Virginia Rail	10	6	Present	Uncomm.	Breeder			1		6				
Sora	1	1	Present	Rare	Breeder								1	
American Coot	85	85	Present	Common	Migr.			2		85			1	
Sandhill Crane	0	0	Present	Occas.	Migr.									
Black Oystercatcher	27	27	Present	Rare	Resid.	27	14	4	1	1			24	
Black-bellied Plover	300	300	Present	Uncomm.	Migr.			6	1	300			1	
Semipalmated Plover	180	180	Present	Rare	Migr.			3	8	180				
American Golden-Plover	3	3	Present	Rare	Migr.					3				
Pacific Golden-Plover	1	1	Present	Rare	Migr.					1				
<i>Snowy Plover</i>	1	1								1				
Killdeer	100	100	Present	Common	Breeder	2		12	8	100	1	1	8	
Spotted Sandpiper	6	6	Present	Uncomm.	Resid.			6		1			1	
Ruff	0	0	Probable	NA	NA									
Greater Yellowlegs	75	75	Present	Common	Migr.			4	3	75			14	
Lesser Yellowlegs	50	13	Present	Uncomm.	Migr.			2		13			1	
Willet	1	0	Probable	NA	NA									

Species	Whidbey Island	EBLA	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crockett Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododendron Park
Solitary Sandpiper	1	1	Probable	NA	NA					1				
Ruddy Turnstone	12	12	Present	Uncomm.	Migr.					1			12	
<b>Black Turnstone</b>	475	475	Present	Common	Resid.					2			475	
Surfbird	50	50	Present	Uncomm.	Migr.								50	
Stilt Sandpiper	2	2	Present	Occas.	Migr.					2				
Sanderling	200	200	Present	Uncomm.	Resid.		3	30		200			150	
<b>Dunlin</b>	11000	11000	Present	Common	Resid.			250		11000			120	
Rock Sandpiper	3	3	Probable	NA	NA								3	
Baird's Sandpiper	40	40	Present	Rare	Migr.			4		40				
<b>Least Sandpiper</b>	5000	5000	Present	Common	Migr.			10	32	5000			3	
Pectoral Sandpiper	20	20	Present	Rare	Migr.			6	2	20				
Semipalmated Sandpiper	34	34	Present	Rare	Migr.					34				
<b>Western Sandpiper</b>	20000	20000	Present	Common	Migr.			50	3000	20000			20	
<b>Short-billed Dowitcher</b>	380	380	Present	Uncomm.	Resid.					380				
Long-billed Dowitcher	200	200	Present	Uncomm.	Resid.			1		200			1	
Wilson's Snipe	15	15	Present	Uncomm.	Resid.					15				
American Avocet	3	3	Present	Occas.	Vagrant					3				
Marbled Godwit	2	2	Present	Rare	Migr.			1		2				
Hudsonian Godwit	1	0	Probable	NA	NA									
Bar-tailed Godwit	0	0	Present	Occas.	Vagrant					1				
Long-billed Curlew	1	1	Present	Occas.	Migr.					1				
Whimbrel	4	4	Present	Rare	Migr.					4			4	
Sharp-tailed Sandpiper	2	2	Probable	NA	NA					2				
<i>Curlew Sandpiper</i>	1	1								1				
<i>Red-necked Stint</i>	1	0												
Buff-breasted Sandpiper	6	6	Present	Occas.	Migr.					6				
Red Knot	1	1	Present	Occas.	Migr.				1	1				
<i>Wandering Tattler</i>	1	1						1						
Wilson's Phalarope	9	9	Present	Rare	Migr.					9				
<b>Red-necked Phalarope</b>	444	444	Present	Rare	Migr.					444				
Red Phalarope	32	0	Present	Occas.	Vagrant									
Parasitic Jaeger	1	1	Probable	NA	NA								1	
<i>Pomarine Jaeger</i>	1	0												

Species	Whidbey Island	EBLA	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crocket Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododendron Park
Common Murre	200	200	Present	Uncomm.	Resid.	12	10	200	5	4			1	
Pigeon Guillemot	200	200	Present	Uncomm.	Breeder	24	30	60	200	45			100	
Marbled Murrelet	110	110	Present	Rare	Resid.	2	8	110	6	2			2	
<i>Ancient Murrelet</i>	12	12					4	12		1				
<i>Whiskered Auklet</i>	1	1											1	
<i>Cassin's Auklet</i>	1	1											1	
<b>Rhinoceros Auklet</b>	800	800	Present	Rare	n	85	800	100	33	30			70	
Tufted Puffin	1	1	Probable	NA	NA		1							
<i>Horned Puffin</i>	1	1					1							
<i>Black-legged Kittiwake</i>	1	1												
<i>Sabine's Gull</i>	1	0												
Bonaparte's Gull	150	30	Present	Uncomm.	Migr.	1		7	1	20			1	
Franklin's Gull	1	1	Probable	NA	NA					1				
<i>Black-headed Gull</i>	1	1								1				
Heermann's Gull	200	200	Present	Uncomm.	Migr.	48	40	200	200	95			6	
Mew Gull	170	170	Present	Common	Resid.	5	30	86	8	130			20	
Ring-billed Gull	75	75	Present	Uncomm.	Resid.	20		6	2	75			1	
<b>California Gull</b>	320	320	Present	Uncomm.	Resid.	150	50	250	75	320			50	
Western Gull	10	10	Probable	NA	NA		1	2	3	10			6	
Glaucous-winged Gull	200	200	Present	Common	Resid.	75	200	100	60	100	2		80	
Herring Gull	17	17	Present	Uncomm.	Resid.			8	3	4			1	
Thayer's Gull	6	6	Probable	NA	NA			1	6	4			1	
<i>Glaucous Gull</i>	1	1											1	
<i>Elegant Tern</i>	4	4								4				
Caspian Tern	210	210	Present	Uncomm.	Migr.	1		35	5	210		1	10	
Black Tern	1	0	Probable	NA	NA									
Forster's Tern	1	0	Probable	NA	NA									
Common Tern	2	2	Probable	NA	NA					2			1	
Arctic Tern	1	0	Probable	NA	NA									
Rock Pigeon	70	42	Present	Common	Resid.	1		30	40	22	8	15	34	
Band-tailed Pigeon	8	7	Present	Uncomm.	Resid.	7							2	
<i>Eurasian Collared-Dove</i>	20	20						4		2	2	1	20	
Mourning Dove	11	11	Present	Common	Breeder	11	5	8	2	11	6	2	1	

Species	Whidbey Island	EBLA	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crocket Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododendron Park
Barn Owl	2	1	Probable	NA	NA			1				1		
Great Horned Owl	1	1	Present	Uncomm.	Breeder	1		1		1			1	
<i>Short-eared Owl</i>	2	2								2				
Barred Owl	1	1	Present	Uncomm.	Breeder							1		
<i>Northern Pygmy-Owl</i>	1	1						1						
Northern Saw-whet Owl	1	1	Present	Rare	Breeder	1								
Snowy Owl	1	1	Probable	NA	NA					1				
Vaux's Swift	4	1	Probable	NA	NA			1						
Black Swift	1	0	Probable	NA	NA									
<i>Anna's Hummingbird</i>	2	2				1		1		2			1	
Rufous Hummingbird	15	3	Present	Common	Breeder	2	1	2		2	1		1	
Belted Kingfisher	12	12	Present	Common	Breeder	1		2	3	2			12	
Red-breasted Sapsucker	1	1	Present	Common	Breeder	1		1						
Downy Woodpecker	4	2	Present	Uncomm.	Breeder			2		2	1	1	2	
Hairy Woodpecker	4	4	Present	Common	Breeder	1		4		1		1	1	1
Northern Flicker	9	9	Present	Uncomm.	Breeder	3	2	5		5	1	1	3	1
Pileated Woodpecker	2	2	Present	Rare	Breeder	1		2		1		1	1	
Olive-sided Flycatcher	8	5	Present	Uncomm.	Breeder	5	2	4		1	1	1		
Western Wood-Pewee	2	2	Present	Rare	Resid.			1		2	1			
Willow Flycatcher	5	2	Present	Uncomm.	Breeder					2		1		
Hammond's Flycatcher	1	1	Present	Rare	Migr.			1						
Pacific-slope Flycatcher	10	9	Present	Common	Breeder	9	2	3		2	1			1
Western Kingbird	1	1	Present	Occas.	Migr.							1		
<i>Eastern Kingbird</i>	3	0												
Northern Shrike	2	2	Present	Rare	Migr.				1	1		1		
Cassin's Vireo	1	1	Present	Rare	Migr.									
Hutton's Vireo	5	1	Present	Uncomm.	Breeder	1		1			1			
Warbling Vireo	1	1	Present	Uncomm.	Breeder			1						
Steller's Jay	5	5	Present	Uncomm.	Breeder	1		5		1			1	
<i>Gray Jay</i>	1	1				1								
American/ Northwestern Crow	120	70	Present	Common	Breeder	4	16	70	6	40		6	30	
Common Raven	4	4	Present	Uncomm.	Breeder	2	1	4		2	2	4	2	1



Species	Whidbey Island	EBLA	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crocket Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododendron Park
Northern Rough-winged Swallow	6	6	Present	Uncomm.	Breeder	5	2	6		3		2	1	
<i>Purple Martin</i>	5	5							3	5				
Tree Swallow	50	40	Present	Common	Breeder		4	10	2	40		1	20	
Bank Swallow	7	7	Probable	NA	NA					7				
Violet-green Swallow	50	50	Present	Common	Breeder	6	6	25	1	50		2	10	
<b>Barn Swallow</b>	550	550	Present	Common	Breeder	5	12	30	100	550	8	4	30	
<b>Cliff Swallow</b>	440	440	Present	Common	Breeder	2		30	50	440		1		
Black-capped Chickadee	10	10	Present	Uncomm.	Breeder	7	2	10	5	7		1	4	
Chestnut-backed Chickadee	40	32	Present	Common	Breeder	20	7	20	4	32	5		5	8
Bushtit	30	30	Present	Uncomm.	Breeder	7		10		30	6		1	
Red-breasted Nuthatch	10	4	Present	Common	Breeder	4	2	3		2	1		2	4
Brown Creeper	10	4	Present	Uncomm.	Breeder	2	1	3		2		1		1
<i>Rock Wren</i>	1	0												
House Wren	5	5	Present	Uncomm.	Breeder			2		5		1	1	
Pacific (Winter) Wren	13	13	Present	Common	Breeder	6	1	7		3	1	1	1	3
Marsh Wren	10	10	Present	Uncomm.	Breeder			3		10			1	
Bewick's Wren	5	4	Present	Uncomm.	Breeder	2		4	1	1		1	2	
Golden-crowned Kinglet	53	53	Present	Common	Breeder	15	1	17	6	53			4	12
Ruby-crowned Kinglet	5	5	Present	Uncomm.	Resid.	2	1	5	1	2			1	
<i>Townsend's Solitaire</i>	1	1											1	
Swainson's Thrush	12	3	Present	Uncomm.	Breeder	1		1		3		1		1
Hermit Thrush	5	5	Present	Rare	Migr.	1		1						5
American Robin	250	50	Present	Abundant	Breeder	18	4	40	4	50	4	2	30	8
Varied Thrush	8	8	Present	Uncomm.	Resid.	2		1		8			1	
Mountain Bluebird	0	0	Probable	NA	NA									
<i>Northern Mockingbird</i>	1	1												
European Starling	450	300	Present	Abundant	Breeder	1	5	100	10	300	20	12	30	
<i>Horned Lark</i>	1	1								1				
American Pipit	50	50	Present	Rare	Migr.			1	1	50			3	
<i>White Wagtail</i>	1	1								1				
Snow Bunting	3	3	Probable	NA	NA				3					

Species	Whidbey Island	EBLA	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crockett Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododendron Park
Cedar Waxwing	31	31	Present	Common	Breeder	31	2	14		10	8		2	
Lapland Longspur	27	1	Probable	NA	NA					1				
Bohemian Waxwing	0	0	Probable	NA	NA									
Orange-crowned Warbler	15	3	Present	Uncomm.	Breeder	1	1	3	1	2		2	1	
<i>Nashville Warbler</i>	3	0												
MacGillivray's Warbler	1	2	Present	Rare	Breeder									
Common Yellowthroat	4	4	Present	Common	Breeder		1	2	1	4				
Yellow Warbler	2	2	Present	Uncomm.	Breeder			2		2				
Yellow-rumped Warbler	20	20	Present	Uncomm.	Breeder		1	20		1		1	3	
Townsend's Warbler	1	1	Present	Common	Breeder			1						
Black-throated Gray Warbler	2	2	Present	Uncomm.	Breeder			2			1			
Wilson's Warbler	2	2	Present	Common	Breeder	1	1	2		1				
<i>Green-tailed Towhee</i>	1	0												
Spotted Towhee	25	12	Present	Common	Breeder	5	5	4	1	12	2	1	3	4
Chipping Sparrow	1	1	Present	Occas.	Migr.	1								
<i>Clay-colored Sparrow</i>	1	1												
Savannah Sparrow	75	46	Present	Common	Breeder	2	3	12	2	46	4	25	2	
Fox Sparrow	8	8	Present	Occas.	Vagrant	5	1	8	1	8			1	
Song Sparrow	25	14	Present	Common	Breeder	5	6	8	7	13	4	2	14	3
Lincoln's Sparrow	2	2	Present	Rare	Resid.			1		2			1	
<i>Swamp Sparrow</i>	2	0												
White-throated Sparrow	1	1	Probable	NA	NA			1						
White-crowned Sparrow	50	20	Probable	NA	NA	10	7	20	9	12	8	7	1	1
Golden-crowned Sparrow	39	39	Present	Common	Resid.	1		23	5	39		4	6	
Dark-eyed Junco	46	46	Present	Common	Breeder	13	22	20	3	46	4	25	8	10
Western Tanager	4	1	Present	Uncomm.	Breeder			1			1			
Black-headed Grosbeak	5	2	Present	Uncomm.	Breeder			1		2		1		1
<i>Lazuli Bunting</i>	1	0												
Red-winged Blackbird	275	275	Present	Common	Breeder	1	2	20	1	275			10	
Western Meadowlark	8	8	Present	Rare	Resid.	1		2	1	8				
Yellow-headed Blackbird	1	1	Probable	NA	NA					1				
Brewer's Blackbird	300	300	Present	Common	Breeder	1		36	2	63		10	2	

Species	Whidbey Island	<b>EBLA</b>	NPS Status	NPS Abund.	NPS Habit	Ft. Ebey	Libbey Beach	Ft. Casey	Keystone Landing	Crockett Lake	Pratt TNC	Pacific Rim Inst.	Penn Cove	Rhododen- dron Park
Brown-headed Cowbird	5	5	Present	Common	Breeder	1	1	3	2	5		1		
<i>Bullock's Oriole</i>	3	0												
<i>Gray-crowned Rosy Finch</i>	2	2							3					
House Finch	40	15	Present	Common	Breeder	12	4	10	4	15	6	6	8	
Purple Finch	6	6	Present	Uncomm.	Breeder	6	1	2		3		1	1	
Red Crossbill	60	60	Present	Uncomm.	Resid.	10	1	60		1	2			
Pine Siskin	156	156	Present	Uncomm.	Breeder	8	3	8		156			60	
American Goldfinch	100	100	Present	Common	Breeder	8	15	13	2	100	4	2	4	2
Evening Grosbeak	4	4	Present	Rare				3		4				
House Sparrow	50	40	Present	Uncomm.	Breeder	1	12	20	1	5		1	40	

**Table 21. Highest level of breeding found by the Breeding Bird Atlas project in atlas blocks within the Reserve, 2001-2002.**

CO= Confirmed, PR= Prob., PO= Possible. Areal coverage and level of effort for these 6 unequal-sized blocks was uneven. Some of the BBA reports may be from locations slightly outside of the Reserve boundary.

Source: Opperman, H., K. M. Cassidy, T. Aversa, E. S. Hunn, and B. Senturia. 2006. Sound to Sage: Breeding Bird Atlas of Island, King, Kitsap, and Kittitas Counties, Washington. Published at <http://www.soundtosage.org> by the Seattle Audubon Society. Version 1.1, September 2006.

BLOCK NAME:	Point Partridge	Penn Cove	Ebey's Landing	Long Point	Smith Prairie	Admiralty Head
ATLAS BLOCK #	IS2	IS5	IS6	IS11	IS12	IS13
Township-Range-QuarterSec	T32N R1W SE	T32N R1E SW	T31N R1E NW	T32N R1E SE	T31N R1E NE	T31N R1E SE
Canada Goose			CO	PO	PR	CO
Gadwall		PR			PR	PR
American Wigeon						PO
Mallard	PR	PR			PR	CO
Blue-winged Teal						PR
Cinnamon Teal		CO	PR			PO
Northern Shoveler		CO			PR	PO
Northern Pintail					PR	PO
Green-winged Teal		PR			PR	PO
Lesser Scaup						PO
Ruddy Duck						PO
Ring-necked Pheasant			PO			PO
California Quail	CO	CO	PR	CO	CO	CO
Great Blue Heron	PO		PO	CO	PO	PO
Turkey Vulture			PO		PO	
Osprey			PO			
Bald Eagle	PO	CO	CO	CO	PR	PO
Northern Harrier			PR		CO	CO
Sharp-shinned Hawk			PO			
Cooper's Hawk					PO	
Red-tailed Hawk		PO	PR	PR	PR	PR

BLOCK NAME:	Point Partridge	Penn Cove	Ebey's Landing	Long Point	Smith Prairie	Admiralty Head
American Kestrel				CO	CO	
Peregrine Falcon			PO		PO	PO
Virginia Rail			PO		PR	
Sora		PO				
Killdeer		CO	PR	PO	CO	PO
Black Oystercatcher			PO		PO	
American Avocet					CO	CO
Spotted Sandpiper			PO			
Wilson's Snipe		PO				PO
Glaucous-winged Gull	PO	PO	PO	PO	PO	PO
Pigeon Guillemot	PR	CO	PR		PO	CO
Rock Pigeon		PO	PO			PO
Band-tailed Pigeon	PR	PO	PO	PR	PR	PO
Mourning Dove	PR		PR	PR	PR	PR
Barn Owl			PO		PO	
Great Horned Owl	CO		CO	CO	PO	CO
Barred Owl				PR		
Common Nighthawk			PO		PO	
Rufous Hummingbird	CO	PR	CO	CO	CO	PO
Belted Kingfisher	PO	CO	PO	PO	PO	PO
Downy Woodpecker		PR	PO	CO	PO	PO
Hairy Woodpecker	PR		PR	CO	PO	PO
Northern Flicker	CO		CO	PR	PO	PO
Pileated Woodpecker	PR	PO	PO	PR	PO	
Olive-sided Flycatcher	PR	PO	PR	PR	PR	
Western Wood-Pewee			PO			
Willow Flycatcher			PR		PR	PO
Pacific-slope Flycatcher	CO	PR	PR	PR	PR	PO
Cassin's Vireo			PO	PO		
Hutton's Vireo	PO	PO	PO	CO	PR	PR

BLOCK NAME:	Point Partridge	Penn Cove	Ebey's Landing	Long Point	Smith Prairie	Admiralty Head
Warbling Vireo			PO	PO	PO	PO
Steller's Jay	PR					
American Crow	PR	PR	CO	CO	CO	PR
Common Raven			PO		CO	PR
Tree Swallow			CO		CO	CO
Violet-green Swallow	CO	CO	CO	PR	CO	CO
Northern Rough-winged Swallow	CO	CO	PO		PO	CO
Cliff Swallow			CO		CO	CO
Barn Swallow	PR	PR	CO	PO	CO	CO
Black-capped Chickadee	CO	PO	PO	PO	CO	PO
Chestnut-backed Chickadee	CO	CO	CO	CO	CO	PR
Bushtit	CO	PR	CO		PO	PO
Red-breasted Nuthatch	CO	PO	PO	CO	CO	PR
Brown Creeper	PR		CO	PR	PO	PO
Bewick's Wren	CO	CO	CO	CO	PR	CO
House Wren			CO	PR	PR	CO
Pacific (Winter) Wren	CO	PR	CO	CO	PR	PR
Marsh Wren		PO	PR		PR	
Golden-crowned Kinglet	CO	CO	PO	CO	PO	PO
Swainson's Thrush	PR	PR	PR	PR	PR	PR
American Robin	CO	CO	CO	CO	CO	CO
European Starling	CO	CO	CO	CO	CO	CO
Cedar Waxwing	PR	PR	CO		CO	PR
Orange-crowned Warbler	CO	CO	PR	CO	PR	PO
Yellow Warbler		PR	PO			PO
Yellow-rumped Warbler	PO		CO		PO	PO
Black-throated Gray Warbler			PO			
Townsend's Warbler			PO		PO	
MacGillivray's Warbler					PO	PO
Common Yellowthroat		PR	PO		PO	PO

BLOCK NAME:	Point Partridge	Penn Cove	Ebey's Landing	Long Point	Smith Prairie	Admiralty Head
Wilson's Warbler	PR	PR	PR	PR	PR	PR
Western Tanager	PO		PO	PR	PR	
Spotted Towhee	CO	PR	CO	CO	PR	PR
Chipping Sparrow						PR
Savannah Sparrow		PR	PR	PR	PR	PR
Song Sparrow	CO	CO	CO	CO	CO	CO
White-crowned Sparrow	CO	CO	CO	CO	CO	CO
Dark-eyed Junco	CO	CO	CO	CO	CO	PO
Black-headed Grosbeak		PR	PR	PR	PR	PO
Red-winged Blackbird		CO	CO		PR	CO
Brewer's Blackbird		CO	CO	CO	PR	PO
Brown-headed Cowbird	PR		CO	PR	CO	CO
Purple Finch			CO		PR	PR
House Finch	PR	PR	CO	CO	CO	CO
Red Crossbill	PO			PO	PR	
Pine Siskin	PR	PO	CO		PO	PO
American Goldfinch	PR	PR	PR	PR	PR	PR
Evening Grosbeak						PO
House Sparrow		CO	PR	CO	CO	CO

Table 21. Frequency and maximum count of bird species on the Oak Harbor Christmas Bird Count, 1987-2013.

Species listed in descending order of frequency and maximum annual count. "Party-hr" is a measure of effort (number of birding groups multiplied by hours spent counting during any year's one-day count).

Species	% of Years (of 26)	Maximum Count	Maximum/ party-hr
European Starling	100%	14379	261.44
scoter 3 spp.	100%	6921	98.87
Dunlin	100%	5348	91.60
Surf Scoter	100%	4774	68.20
Glaucous-winged Gull	100%	4054	73.71
American Wigeon	100%	3400	67.33
Brewer's Blackbird	100%	3070	31.25
White-winged Scoter	100%	2446	34.33
American Crow	100%	1888	26.22
Dark-eyed Junco	100%	1725	23.99
Mallard	100%	1614	20.43
American Green-winged Teal	100%	1178	16.83
American Robin	100%	1137	13.13
Red-winged Blackbird	100%	954	9.09
Golden-crowned Kinglet	100%	927	14.15
Northern Pintail	100%	893	16.24
Ruddy Duck	100%	850	12.71
Mew Gull	100%	841	6.35
scaup 2 spp.	100%	819	11.70
Bufflehead	100%	754	8.53
Black Scoter	100%	752	7.79
Chestnut-backed Chickadee	100%	664	6.08
Common Goldeneye	100%	645	9.85
Red-necked Grebe	100%	635	9.07
House Finch	100%	608	5.09



Species	% of Years (of 26)	Maximum Count	Maximum/ party-hr
Barrow's Goldeneye	100%	600	6.67
Black Turnstone	100%	583	8.18
Rock Pigeon	100%	561	5.25
Golden-crowned Sparrow	100%	444	5.50
Song Sparrow	100%	390	3.46
Horned Grebe	100%	365	4.06
cormorant 3 spp.	100%	359	4.45
Greater Scaup	100%	348	4.41
Bushtit	100%	341	6.75
Gadwall	100%	311	6.16
California Quail	100%	257	3.86
House Sparrow	100%	255	2.42
Double-crested Cormorant	100%	254	3.15
Spotted Towhee	100%	235	2.91
Northern Shoveler	100%	229	4.53
Red-throated Loon	100%	208	2.89
Varied Thrush	100%	195	2.02
Black-capped Chickadee	100%	167	1.45
Ruby-crowned Kinglet	100%	159	1.77
Pacific Wren	100%	153	1.49
Ring-billed Gull	100%	153	1.40
Fox Sparrow	100%	148	1.29
Northern Flicker	100%	136	1.61
Hooded Merganser	100%	128	1.77
Red-breasted Merganser	100%	116	1.51
Harlequin Duck	100%	114	1.44
Red-tailed Hawk	100%	101	1.52
Bald Eagle	100%	100	1.20
Common Merganser	100%	98	0.73

Species	% of Years (of 26)	Maximum Count	Maximum/ party-hr
Long-tailed Duck	100%	96	0.98
Common Loon	100%	86	1.27
Great Blue Heron	100%	81	1.16
Pelagic Cormorant	100%	77	1.01
Red-breasted Nuthatch	100%	73	0.59
White-crowned Sparrow	100%	72	1.08
Pigeon Guillemot	100%	66	1.11
Northern Harrier	100%	52	0.54
Bewick's Wren	100%	28	0.31
Belted Kingfisher	100%	21	0.30
Cooper's Hawk	100%	14	0.22
Red-naped Sapsucker	100%	3	0.05
Yellow Warbler	100%	2	0.03
Western Grebe	96%	3220	36.65
Lesser Scaup	96%	413	6.31
Killdeer	96%	205	3.18
Herring Gull	96%	173	2.47
Pacific Loon	96%	46	0.66
Downy Woodpecker	96%	29	0.27
Brown Creeper	96%	27	0.32
Thayer's Gull	96%	26	0.40
Pine Siskin	92%	2893	21.27
Canada Goose	92%	1015	9.81
Common Murre	92%	344	6.25
Sanderling	92%	265	3.72
Mourning Dove	88%	354	3.24
Bonaparte's Gull	88%	134	1.88
Purple Finch	88%	69	0.93
Greater Yellowlegs	88%	49	0.62

Species	% of Years (of 26)	Maximum Count	Maximum/ party-hr
Common Raven	88%	34	0.31
Great Horned Owl	88%	22	0.19
Hairy Woodpecker	88%	21	0.20
Rough-legged Hawk	88%	19	0.21
Pied-billed Grebe	88%	9	0.11
Sharp-shinned Hawk	88%	9	0.13
Eurasian Wigeon	88%	6	0.09
Merlin	88%	5	0.07
Peregrine Falcon	88%	5	0.10
American Coot	85%	584	11.56
Canvasback	85%	176	1.72
Black-bellied Plover	85%	122	1.06
Ring-necked Duck	85%	50	0.48
American Kestrel	85%	6	0.09
Marsh Wren	81%	11	0.15
Black Oystercatcher	77%	74	0.77
Western Meadowlark	77%	66	0.74
Ring-necked Pheasant	77%	24	0.27
Steller's Jay	77%	15	0.15
Glaucous-winged Gull X Western Gull (hybrid)	73%	573	4.21
Western Sandpiper	73%	347	4.82
California Gull	73%	53	0.82
Brandt's Cormorant	73%	22	0.40
Eared Grebe	73%	22	0.34
Marbled Murrelet	69%	36	0.58
Barn Owl	69%	6	0.06
Surfbird	65%	62	0.95
Red Crossbill	62%	58	0.76

Species	% of Years (of 26)	Maximum Count	Maximum/ party-hr
Pileated Woodpecker	58%	8	0.07
American Goldfinch	54%	38	0.69
Savannah Sparrow	54%	20	0.15
Western Gull	54%	19	0.35
Wilson's Snipe	54%	10	0.09
Lincoln's Sparrow	54%	9	0.09
Northern Shrike	54%	4	0.06
Rhinoceros Auklet	50%	24	0.25
Long-billed Dowitcher	50%	13	0.20
Hermit Thrush	50%	7	0.09
Short-eared Owl	50%	4	0.04
Virginia Rail	46%	5	0.10
Hutton's Vireo	46%	4	0.05
Band-tailed Pigeon	42%	106	2.10
Brant	42%	75	1.05
Anna's Hummingbird	42%	35	0.31
Accipiter sp.	42%	5	0.05
Red-breasted Sapsucker	42%	3	0.02
Cedar Waxwing	35%	60	0.66
Trumpeter Swan	31%	109	1.00
Snow Goose	31%	26	0.27
Tundra Swan	31%	16	0.15
Greater White-fronted Goose	31%	2	0.04
Least Sandpiper	27%	68	0.76
merganser sp.	27%	5	0.07
Cinnamon Teal	23%	44	0.62
Evening Grosbeak	23%	22	0.31
Ruddy Turnstone	23%	15	0.21
Ancient Murrelet	23%	11	0.17

Species	% of Years (of 26)	Maximum Count	Maximum/ party-hr
Barred Owl	23%	2	0.01
Brown-headed Cowbird	19%	45	0.70
White-throated Sparrow	19%	2	0.02
Eurasian Collared-Dove	15%	96	0.84
Yellow-rumped Warbler	15%	21	0.30
dowitcher sp.	15%	12	0.09
Redhead	15%	6	0.12
Lesser Yellowlegs	12%	22	0.40
alcid sp.	12%	8	0.09
Northern Goshawk	12%	1	0.01
Blue-winged Teal	8%	104	1.46
Rock Sandpiper	8%	20	0.31
Spotted Sandpiper	8%	10	0.15
American Pipit	8%	5	0.04
Orange-crowned Warbler	8%	2	0.03
Clark's Grebe	8%	1	0.02
Golden Eagle	8%	1	0.01
Heermann's Gull	8%	1	0.01
Wood Duck	8%	1	0.01
Red/Red-necked Phalarope	4%	47	0.47
Western Bluebird	4%	9	0.08
Pine Grosbeak	4%	8	0.05
White-winged Crossbill	4%	6	0.08
Barn Swallow	4%	2	0.01
Chipping Sparrow	4%	2	0.01
House Wren	4%	2	0.04
Whimbrel	4%	2	0.03
Bohemian Waxwing	4%	1	0.01
Brown Pelican	4%	1	0.01

Species	% of Years (of 26)	Maximum Count	Maximum/ party-hr
Cattle Egret	4%	1	0.01
Chukar	4%	1	0.01
Glaucous Gull	4%	1	0.02
Great Egret	4%	1	0.01
Harris's Sparrow	4%	1	0.02
Mountain Chickadee	4%	1	0.01
Prairie Falcon	4%	1	0.01
Rusty Blackbird	4%	1	0.01
Semipalmated Plover	4%	1	0.01
Snow Bunting	4%	1	0.01
Snowy Owl	4%	1	0.01
Townsend's Warbler	4%	1	0.01
Yellow-billed Loon	4%	1	0.01

**Table 22. Statistically significant trends in selected wintering and resident bird species in the Oak Harbor Christmas Bird Count, 1987-2013.**

Species are listed in order from most negative (declining) to most positive (increasing) 26-year trend. Statistical significance:  $p < 0.001$  (\*\*\*),  $< 0.01$  (\*\*),  $< 0.05$  (\*),  $< 0.1$  (+). Ebey's Landing Reserve comprises about xx% of the Count circle, and the portion of each species' data that were from the Reserve in any given year is unknown. With a few exceptions, only species found during at least 22 of the 26 years were analyzed. Trends were calculated using the Mann-Kendall test. For many species, apparent trends are likely to correlate only with trends in observer effort ("party hours"). Separating this from environmental causes of species change would require more sophisticated statistical procedures. Because observer effort had a very strong positive trend ( $p < 0.001$ ) during this period, negative trends reported below are more credible than positive trends.

Species	Statistical Significance	Z-statistic
White-winged Scoter	***	-4.63
Glaucous-winged Gull	***	-4.54
Black Scoter	***	-3.97
Scoter (sum of all 3 species + unknown)	***	-3.97
Scaup (sum of 2 species + unknown)	***	-3.55
American/Northwestern Crow + crow sp.	***	-3.35
European Startling	**	-3.17
Lesser Scaup	**	-3.00
Surf Scoter	**	-2.91
Greater Scaup	*	-2.49
Herring Gull	*	-2.33
Barrow's Goldeneye	*	-2.10
Northern Shoveler	*	-1.98
Ruddy Duck	*	-1.98
American Green-winged Teal	+	-1.90
Red-tailed Hawk	+	1.74
Black-bellied Plover	+	1.75
Golden-crowned Kinglet	+	1.85
Dark-eyed Junco	+	1.94
White-crowned Sparrow	*	2.23
Gadwall	*	2.40
Pelagic Cormorant	*	2.47

<b>Species</b>	<b>Statistical Significance</b>	<b>Z-statistic</b>
Northern Harrier	*	2.54
Black Oystercatcher	**	2.58
Bewick's Wren	**	2.59
Bufflehead	**	2.71
Song Sparrow	**	2.76
Ruby-crowned Kinglet	**	2.84
Northern Flicker	**	2.85
Red-breasted Nuthatch	**	3.18
American Robin	**	3.26
Cooper's Hawk	***	3.31
Black-capped Chickadee	***	3.31
Canada Goose	***	3.33
Brown Creeper	***	3.36
House Sparrow	***	3.37
Chestnut-backed Chickadee	***	3.44
Pacific (Winter) Wren	***	3.49
Red-breasted Merganser	***	3.59
Varied Thrush	***	3.71
Spotted Towhee	***	3.73
Hairy Woodpecker	***	3.77
Fox Sparrow	***	4.15
Downy Woodpecker	***	4.22
Mourning Dove	***	4.24
Anna's Hummingbird	***	4.25
Ring-necked Duck	***	4.38
Common Raven	***	4.71
Bald Eagle	***	4.88
Golden-crowned Sparrow	***	5.58



### Appendix 3. Summary statistics for points within the Reserve sampled by Island County Water Quality Monitoring Program, 2005-2013.

The tables (sample points) are in order from most to fewest samples. Only sites with 3 or more sample dates are summarized. For locations of sample points, see Figure 13 and shapefile provided to NPS with this report.

<b>58a</b>	16-Oct-06	26-Sep-13	% of visits w. no flow=		18%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conductivity (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	144	78	83	148	147	148	146	146	147	136
MIN	0	0.18	0.65	2.66	7.31	42.00	47.90	4.86	1.54	0.01
MAX	73600	1.69	52.80	15.57	8.48	1822.00	144.60	18.35	435.00	1.18
MEAN	1367	0.45	21.05	9.15	7.88	1038.20	99.62	11.53	19.64	0.22
MEDIAN	96	0.41	22.10	9.06	7.93	1113.50	101.15	11.73	8.91	0.16
StDEV	6388	0.24	13.88	2.90	0.26	439.78	13.68	2.01	42.88	0.22

<b>158a</b>	12-Dec-06	26-Sep-13	% of visits w. no flow=		17%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	121	75	65	141	140	141	139	139	139	126
MIN	0	0.10	0.00	2.70	7.01	469.80	13.30	1.46	1.49	0.02
MAX	4800	0.87	6.17	25.10	8.35	1754.00	116.00	14.07	307.00	0.70
MEAN	130	0.26	1.01	10.48	7.60	1092.92	72.63	8.17	16.38	0.28
MEDIAN	10	0.24	0.58	9.93	7.58	1119.00	72.00	8.08	7.00	0.20
StDEV	535	0.13	1.24	4.30	0.22	203.30	15.96	2.04	37.29	0.20

<b>30a</b>	16-Oct-06	19-Jul-12	% of visits w. no flow=		57%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	26	12	9	24	24	24	24	24	24	15
MIN	5	0.09	0.00	1.82	7.59	59.60	84.60	8.39	2.06	0.04
MAX	1110	0.56	1.83	15.70	8.81	767.00	123.20	15.30	101.00	0.42
MEAN	263	0.34	0.34	8.51	7.96	428.48	104.98	12.38	20.98	0.18
MEDIAN	111	0.33	0.04	8.42	7.98	419.00	104.90	12.17	10.65	0.14
StDEV	315	0.13	0.62	3.82	0.29	188.53	8.60	1.83	23.98	0.11

<b>PhytoIn</b>	15-Mar-11	14-Mar-13	% of visits w. no flow=		27%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	17	13	18	19	19	19	19	19	19	6
MIN	0	0.06	0.00	6.02	6.22	102.80	69.00	7.93	7.13	0.01
MAX	600	0.19	0.60	15.20	7.99	522.00	885.00	11.76	268.00	0.10
MEAN	72	0.11	0.24	9.76	7.36	274.36	128.28	9.83	45.65	0.04
MEDIAN	14	0.12	0.17	9.10	7.46	259.10	87.60	9.62	20.40	0.04
StDEV	146	0.04	0.18	2.69	0.42	102.54	183.47	1.08	75.38	0.03

<b>PhytoOut</b>	29-Mar-11	7-Mar-13	% of visits w. no flow=		22%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	10	12	14	18	18	18	17	17	18	5
MIN	0	0.07	0.00	5.05	6.15	131.00	9.70	1.07	0.83	0.02
MAX	90	0.24	0.39	13.40	7.30	417.60	57.10	7.25	43.90	0.03
MEAN	13	0.09	0.14	8.61	6.82	288.57	33.99	3.83	6.09	0.03
MEDIAN	2	0.08	0.09	7.36	6.92	299.30	38.00	4.20	2.03	0.03
StDEV	25	0.05	0.13	2.63	0.32	78.14	16.38	2.17	10.45	0.00

<b>37b</b>	24-Oct-07	7-Oct-08	% of visits w. no flow=		52%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	
n	11	7	3	14	14	14	14	14	13	
MIN	0	0.47	0.00	3.97	6.23	415.00	24.40	2.53	4.66	
MAX	268000	6.32	0.20	14.53	7.44	1943.00	124.20	13.02	256.00	
MEAN	23200	1.73	0.03	9.69	6.99	1237.07	61.63	6.98	53.87	
MEDIAN	22	1.00	0.00	9.10	7.05	1288.00	61.20	7.53	17.00	
StDEV	73717	2.06	0.07	3.63	0.31	509.82	29.13	3.10	74.32	

<b>C1</b>	16-Oct-08	30-Sep-09	% of visits w. no flow=		50%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	8	7	7	8	8	8	8	8	7	8
MIN	120.00	0.00	0.13	4.86	5.16	61.00	99.30	9.77	6.88	0.01
MAX	3100.00	0.14	2.88	16.51	8.52	372.00	123.20	15.04	52.70	0.07
MEAN	797.25	0.06	0.88	9.80	7.51	237.38	115.38	13.21	22.51	0.03
MEDIAN	448.00	0.06	0.47	9.52	7.70	248.00	118.15	13.50	15.10	0.02
StDEV	986.87	0.04	0.99	3.72	1.02	121.15	9.16	1.90	18.11	0.02

<b>C2</b>	16-Oct-08	30-Sep-09	% of visits w. no flow=		80%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	5	5	5	5	5	5	5	5	4	5
MIN	64	0.07	0.14	4.58	6.84	4.70	100.60	9.68	10.10	0.01
MAX	530	0.07	1.14	17.17	7.89	543.00	120.30	14.60	70.40	0.06
MEAN	280	0.07	0.47	9.49	7.47	218.34	110.96	12.87	34.63	0.02
MEDIAN	220	0.07	0.37	7.84	7.55	144.00	113.20	14.27	29.00	0.01
StDEV	190	0.00	0.40	5.03	0.43	217.95	8.86	2.29	29.00	0.02

<b>C3</b>	16-Oct-08	30-Sep-09	% of visits w. no flow=		67%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	5	6	5	6	6	6	6	6	5	6
MIN	600	0.10	0.17	3.59	7.28	138.00	103.70	11.46	6.05	0.01
MAX	15500	0.17	2.08	10.79	7.93	493.00	120.00	15.04	65.40	0.05
MEAN	7642	0.13	0.76	7.84	7.64	385.17	114.45	13.65	21.09	0.02
MEDIAN	9500	0.13	0.53	7.84	7.67	424.50	115.50	13.90	10.90	0.02
StDEV	6373	0.03	0.77	2.56	0.30	129.05	5.79	1.20	24.88	0.01

<b>C4</b>	13-Nov-08	30-Sep-09	% of visits w. no flow=		73%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	3	3	3	3	3	3	3	3	3	3
MIN	263	0.23	0.69	6.81	7.28	392.00	105.10	11.40	6.83	0.01
MAX	1610	0.33	1.88	11.84	8.50	1409.00	118.50	14.46	64.20	0.02
MEAN	984	0.28	1.09	9.19	7.71	771.33	113.93	13.24	31.68	0.02
MEDIAN	1080	0.29	0.69	8.93	7.34	513.00	118.20	13.85	24.00	0.02
StDEV	679	0.05	0.69	2.53	0.69	555.54	7.65	1.62	29.45	0.01

<b>C5</b>	16-Oct-08	30-Sep-09	% of visits w. no flow=		42%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	7	7	6	7	7	7	7	7	6	6
MIN	46	0.12	0.26	5.21	7.40	107.00	107.50	11.35	18.10	0.01
MAX	2300	0.35	0.95	12.88	8.00	1318.00	120.30	14.76	86.70	0.10
MEAN	625	0.21	0.57	8.44	7.66	357.43	114.74	13.49	33.18	0.04
MEDIAN	520	0.21	0.55	7.03	7.69	186.00	115.40	14.38	24.40	0.03
StDEV	762	0.08	0.26	2.75	0.24	430.81	5.30	1.33	26.39	0.04

<b>SP5</b>	4-Apr-13	6-Jun-13	% of visits w. no flow=		0%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	
n	5	6	6	6	6	6	6	6	6	
MIN	0	0.01	24.59	10.08	7.05	1059.00	60.70	6.37	1.00	
MAX	1600	0.30	37.71	14.40	7.26	1403.00	75.90	8.36	8.86	
MEAN	371	0.13	31.13	11.93	7.16	1286.83	68.83	7.40	3.66	
MEDIAN	77	0.12	32.52	11.72	7.16	1309.50	70.35	7.41	2.94	
StDEV	622	0.10	4.91	1.75	0.07	127.40	6.07	0.76	2.93	

<b>SP7</b>	4-Apr-13	6-Jun-13	% of visits w. no flow=		0%				
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)
n	5	6	6	6	6	6	6	6	6
MIN	0	0.12	30.06	8.85	6.82	1702.00	70.90	7.57	1.46
MAX	96	2.26	106.00	12.60	7.23	2916.00	87.10	9.78	30.00
MEAN	24	1.15	74.89	10.25	6.95	2312.00	77.62	8.66	13.06
MEDIAN	11	1.03	75.29	9.63	6.91	2277.00	75.90	8.46	9.05
StDEV	36	0.91	27.30	1.51	0.15	446.25	6.60	0.92	12.58

<b>SP1</b>	4-Apr-13	6-Jun-13	% of visits w. no flow=		17%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	5	5	2	5	5	5	5	5	5	4
MIN	2	0.06	0.00	9.64	6.78	1010.00	81.60	8.77	3.77	0.04
MAX	910	0.17	0.11	13.80	7.21	9116.00	124.10	12.81	29.10	0.16
MEAN	376	0.11	0.03	12.29	7.03	4449.20	104.06	10.65	13.44	0.09
MEDIAN	460	0.07	0.00	12.45	7.16	1916.00	110.80	10.84	11.00	0.07
StDEV	373	0.05	0.05	1.68	0.21	4009.26	17.09	1.53	10.35	0.05

<b>SP2</b>	4-Apr-13	6-Jun-13	% of visits w. no flow=		17%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	Gauge
n	4	5	1	5	5	5	5	5	5	3
MIN	0	0.19	0.00	10.62	6.83	1151.00	16.70	1.74	5.70	0.36
MAX	27	0.53	0.03	13.20	7.60	1862.00	65.40	6.84	35.60	0.46
MEAN	12	0.31	0.01	12.22	7.16	1423.20	50.74	5.44	14.98	0.41
MEDIAN	7	0.27	0.00	12.75	7.09	1351.00	56.60	6.27	8.64	0.40
StDEV	12	0.13	0.01	1.15	0.29	270.42	19.45	2.09	12.21	0.05

<b>SP3</b>	4-Apr-13	6-Jun-13	% of visits w. no flow=		17%					
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)	
n	4	5	4	5	5	5	5	5	5	
MIN	0	0.03	0.00	9.36	7.31	319.00	67.50	7.42	0.96	
MAX	260	0.12	0.98	12.55	8.21	778.00	96.60	94.60	1.88	
MEAN	64	0.06	0.41	10.72	7.83	530.40	82.56	26.17	1.56	
MEDIAN	23	0.05	0.44	10.53	7.99	547.00	82.80	9.11	1.66	
StDEV	110	0.04	0.38	1.18	0.41	181.87	10.51	38.27	0.36	



<b>SP4</b>	4-Apr-13	6-Jun-13	% of visits w. no flow=		17%				
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)
n	4	5	5	5	5	5	5	5	5
MIN	0	0.31	0.92	8.40	6.45	983.00	14.60	1.64	1.86
MAX	6000	0.55	16.49	10.07	7.13	2162.00	77.80	8.73	28.00
MEAN	2166	0.42	9.60	9.21	6.85	1532.80	56.76	6.52	7.47
MEDIAN	30	0.36	10.62	8.81	6.84	1643.00	64.70	7.55	2.28
StDEV	2982	0.11	5.59	0.77	0.26	457.91	25.22	2.90	11.49

<b>SP6</b>	4-Apr-13	6-Jun-13	% of visits w. no flow=		17%				
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)
n	5	5	5	5	5	5	5	5	5
MIN	2	0.09	23.73	9.45	7.01	1536.00	76.00	8.54	1.61
MAX	88	2.78	35.98	11.60	7.82	1771.00	102.40	11.44	25.40
MEAN	28	0.67	29.15	10.17	7.49	1633.80	92.26	10.32	7.29
MEDIAN	19	0.14	28.16	10.02	7.43	1632.00	96.40	10.44	2.76
StDEV	35	1.18	4.43	0.86	0.34	99.33	10.30	1.12	10.17

<b>39a</b>	16-Oct-06	27-Mar-08	% of visits w. no flow=		78%				
	Fecal Coliform	O-Phos (mg/L)	Nitrates (mg/L)	Temperature (C)	pH	Conduc (us/cm)	DO (%)	DO (mg/L)	Turbidity (NTU)
n	6	5	5	8	8	8	8	8	7
MIN	0	0.15	0.14	2.32	7.35	353.00	50.90	5.94	2.78
MAX	24	0.29	1.44	8.77	7.91	470.00	99.10	13.55	22.70
MEAN	9	0.19	0.89	6.26	7.67	410.75	80.40	10.04	10.09
MEDIAN	7	0.17	1.13	6.84	7.73	417.00	84.60	10.37	6.28
StDEV	9	0.06	0.55	2.28	0.20	39.92	16.83	2.49	8.59

<b>58c</b>	3-Mar-09	12-May-09
	Fecal Coliform	Nitrates (mg/L)
n	5	6
MIN	44	0.22
MAX	24600	1.95
MEAN	5813	1.24
MEDIAN	1100	1.18
StDEV	10544	0.62

<b>SP8</b>	9-May-13	23-May-13
	Fecal Coliform	O-Phos (mg/L)
n	3	3
MIN	7	12.40
MAX	27	12.90
MEAN	14	12.59
MEDIAN	9	12.48
StDEV	11	0.27

<b>58b2</b>	19-Mar-09	5-May-09
	Fecal Coliform	Nitrates (mg/L)
n	3	4
MIN	0	4.82
MAX	4500	56.90
MEAN	1242	32.03
MEDIAN	234	33.20
StDEV	2175	22.36

<b>58b1a</b>	25-Mar-09	5-May-09
	Fecal Coliform	Nitrates (mg/L)
n	2	3
MIN	0	101.00
MAX	1770	139.00
MEAN	797	124.00
MEDIAN	620	132.00
StDEV	898	20.22

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