National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Fort Vancouver National Historic Site

Natural Resource Report NPS/FOVA/NRR—2020/2105





ON THIS PAGE
Army Air Corps Pearson Field, State Route 14, and water-front park along the Columbia River (view to east, up-river)
Photo courtesy of the City of Vancouver, WA

ON THE COVER
The Garden at historic Hudson's Bay Company's Fort Vancouver
NPS photo

Natural Resource Condition Assessment

Fort Vancouver National Historic Site

Natural Resource Report NPS/FOVA/NRR—2020/2105

Catherin A. Schwemm, Editor

Institute for Wildlife Studies, Arcata, CA 95518

April 2020

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review, which was provided by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. The level and extent of peer review was based on the importance of report content or its potentially controversial or precedent-setting nature.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Natural Resource Condition Assessment Program website and the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Schwemm, Catherin A. (Editor). 2020. Natural resource condition assessment: Fort Vancouver National Historic Site. Natural Resource Report NPS/FOVA/NRR—2020/2105. National Park Service, Fort Collins, Colorado.

NPS 389/167864, April 2020

Contents

Page

Figures....vii

Tables....ix

Executive Summary....xi

Acknowledgments....xiii

Prologue....xiii

Contributors....xv

Acronyms and Abbreviations....xvii

Chapter 1. NRCA Background Information....1

Chapter 2. Park Resource Setting/Resource Stewardship....5

2.1. Introduction....5

2.1.1. Enabling Legislation/Administrative History....5

2.1.2. Geographic Location and Surrounding Lands....5

2.1.3. Cultural History and Significance....10

2.1.4. Visitation....11

2.2. Physical Resources and Processes....11

2.2.1. Climate....11

2.2.2. Air Quality....12

2.2.3. Geology and Soils....12

2.2.4. Hydrology and Water Quality....12

2.3. Natural Resources....13

2.3.1. Vegetation Communities....13

2.3.2. Plant Species Diversity....17

2.3.3. Animals....17

2.3.4. Threatened/Endangered Species and Communities....18

2.4. Primary Threats to Natural Resources....18

2.5. Resource Stewardship....18

Contents (continued)

Page

2.5.1. Management Directives, Planning Guidance and Research 18

2.5.2. Supporting Science 19

2.6. Literature Cited 19

Chapter 3. Study Approach 23

3.1. Preliminary Scoping 23

3.2. Study Design 23

3.2.1. Focal Study Resources 23

3.2.2. Indicators and Reference Conditions 24

3.2.3. Ecological Framework 24

3.2.4. Data and Methods 25

3.2.5. Condition Assessments 26

3.2.6. Report Format 27

3.3. Project Challenges 28

3.4. Literature Cited 28

Chapter 4. Resource Condition Assessments 29

4.1. Air Quality 29

4.1.1. Background 29

4.1.2. Reference Conditions 31

4.1.3. Data and Methods 33

4.1.4. Resource Condition and Trend 33

4.1.5. Level of Confidence 34

4.1.6. Data Gaps and Research Needs 34

4.1.7. Sources of Expertise 34

4.1.8. Literature Cited 34

4.2. Climate 37

4.2.1. Background 37

Contents (continued)

Page

4.2.2. Reference Conditions 37

4.2.3. Data and Methods 37

4.2.4. Resource Condition and Trend (Climate Change) 38

4.2.5. Level of Confidence 39

4.2.6. Literature Cited 39

4.3. Freshwater Resources (Surface Hydrology, Water Quality, Groundwater Quantity) 41

4.3.1. Background 41

4.3.2. Reference Conditions 42

4.3.3. Data and Methods 42

4.3.4. Resource Condition and Trend 43

4.3.5. Level of Confidence 43

4.3.6. Data Gaps and Research Needs 43

4.3.7. Literature Cited 43

4.4. Native Fauna 46

4.4.1. Background 46

4.4.2. Reference Conditions 48

4.4.3. Data and Methods 48

4.4.4. Resource Condition and Trend 48

4.4.5. Level of Confidence 65

4.4.6. Data Gaps and Research Needs 65

4.4.7. Literature Cited 65

4.5. Sensory Environment: Natural Night Skies and Natural Quiet 69

4.5.1. Background 69

4.5.2. Reference Conditions 70

4.5.3. Data and Methods 71

Contents (continued)

Page

4.5.4. Resource Condition and Trend 72
4.5.5. Level of Confidence 75
4.5.6. Data Gaps and Research Needs 75
4.5.7. Sources of Expertise 75
4.5.8. Literature Cited 75
4.6. Land Cover and Adjacent Land Use 80
4.6.1. Background 80
4.6.2. Reference Conditions 81
4.6.3. Data and Methods 82
4.6.4. Resource Condition and Trend 83
4.6.5. Level of Confidence 85
4.6.6. Literature Cited 85
Chapter 5. Discussion 87
5.1. Assessment Summary 87
5.2. Considerations for Improving Natural Resource Conditions at FOVA 88
Pearson Airfield – Natural Night Sky 88
Human-Wildlife Conflicts 88
Enhancing Values of Urban Open Space 88
5.3. Literature Cited 90

Figures

Page

Figure 2.1. Location of FOVA within the greater Portland-Vancouver region. 6

Figure 2.2. Administration and land ownership of Vancouver National Historic Reserve. 7

Figure 2.3. Fort Vancouver National Historic Site and contiguous properties of the Vancouver National Historic Reserve..... 8

Figure 2.4. Aerial view of the historic Army Air Corps Pearson Field, Hudson's Bay Company's Fort Vancouver, and the south area of the U.S. Army Vancouver Barracks; Columbia River shown in the upper right. 9

Figure 2.5. City of Vancouver Central Park District. 10

Figure 2.6. River height (feet), USGS gage at I-5, Columbia River, 2008–2018. 13

Figure 2.7. Blue camas (*Camassia quamash)* flowers, an important staple food for Chinookan people, grows in wet meadows and prairies. 15

Figure 4.1.1. Public lands and air pollution sources in the Pacific Northwest..... 30

Figure 4.2.1. Trends in average annual temperature at Fort Vancouver from 1977–2006. 38

Figure 4.5.1. All-sky average anthropogenic to natural sky brightness ratio at Fort Vancouver National Historic site and surrounding lands. 73

Figure 4.5.2. Modeled mean existing sound level map for the historic site and the surrounding area..... 74

Figure 4.6.1. Aerial view of Fort Vancouver NHS showing the Pearson Field runway, Fort Vancouver and the pedestrian land bridge over highway 14 to the waterfront park along the Columbia River. 81

Figure 4.6.2. Vegetation map for FOVA. 84

Tables

Page

Table ES.1. Summary of condition assessments for all focal natural resources at Fort Vancouver National Historic Site. xii

Table 2.1. Four major ecosystems found at Fort Vancouver National Historic Site and impacts. 14

Table 2.2. Synthesis of the eight significant periods at Fort Vancouver National Historic Site and associated cultural groups with primary natural resource uses and impacts. 16

Table 3.1. UW draft report (Phase I) focal resources and resulting final report (Phase II) focal resources organized within the NPS Ecological Monitoring Framework. 24

Table 3.2. Focal natural resources, Chapter 4 section, and indicators for FOVA NRCA, presented within the NPS Ecological Framework. 25

Table 3.3a. Symbols used to indicate condition, trend, and confidence of focal resources. 26

Table 3.3b. Example indicator symbols and descriptions. 26

Table 4.1.1. Benchmarks for visibility condition. 31

Table 4.1.2. Benchmarks for human health condition for ozone. 32

Table 4.1.3. Benchmarks for vegetation condition for ozone. 32

Table 4.1.4. Benchmarks for nitrogen and sulfur deposition condition. 33

Table 4.4.1. Species of concern that may be present in or near FOVA. 47

Table 4.4.2. Endangered, Threatened, Sensitive or Candidate Bird Species in Fort Vancouver National Historic Site. 47

Table 4.4.3a. Preliminary insect list for FOVA from Adams 2012: Subphylum Chelicerata, Class Arachnida, Order Aranae. 49

Table 4.4.3b. Preliminary insect list for FOVA from Adams 2012: Subphylum Hexapoda, Class Collembola (Springtails). 49

Table 4.4.3c. Preliminary insect list for FOVA from Adams 2012: Subphylum Hexapoda, Class Insecta. 49

Table 4.4.4. Insect species identified during FOVA Bioblitz May 2016. 52

Table 4.4.5. Bird species known from the Fort Vancouver region; confirmed have been noted from FOVA. 53

Tables (continued)

Page

Table 4.4.6. Mammal species found during the 2016 Fort Vancouver Bioblitz in the FOVA region; most species were not found at FOVA proper. 64

Table 4.5.1. Typical construction noise levels (dBA) that will likely occur during the Pearson Airfield construction project. 74

Table 4.6.1. Consolidation of land cover classes from NLCD data for analysis in this report. 82

Table 4.6.2. Land-cover associations described in Copass and Ramm-Granberg (2016). 83

Table 4.6.3. Land cover comparison of surrounding lands from 1996 to 2006. 83

Table 5.1. Summary of FOVA focal natural resources addressed in this assessment, associated indicators, and a graphic representation of condition, trend, and confidence level. 87

Table 5.2. Summary of generalized vegetation types at FOVA with opportunities for restoration and enhancement, compiled from NPS (2008), Rochefort (2010), and Copass and Ramm-Granberg (2016). 89

Table 5.3. Plant species identified by Rochefort (2010) that are a) native and would be appropriate for restoration efforts, and b) are invasive and should be controlled as part of any restoration projects. 90

Publisher's Note: Natural Resource Condition Assessments provide a snapshot-in-time evaluation of park resource conditions. For this report, most or all of the data discovery and analyses occurred during the period of 2009 to 2018. Thus, park conditions reported in this document pertain to that time period. Due to revised publishing requirements and/or scientific delays, this report was not published until 2020.

Executive Summary

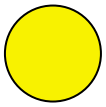
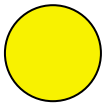
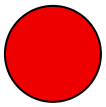
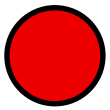
The NRCA study team compiled existing data and information to characterize the condition and trends of focal natural resources at Fort Vancouver National Historic Site. The assessment did not include other areas of Vancouver National Historic Reserve. This report is intended to inform and support park managers in developing recommendations for protecting and improving the condition of natural resources in the park. Focal resource elements selected for assessment were organized into six chapters: 1) Air Quality; 2) Climate; 3) Freshwaters; 4) Native Fauna; 5) Sensory Environment (Natural Night Skies and Natural Quiet); and 6) Habitat Integrity (Land Cover and Use).

Indicators (quantitatively measurable descriptors) were identified to evaluate the condition and trend of each resource. Using these indicators, reference conditions were established for each resource in relation to what is known about the historic values or descriptions of indicators, allowing an assessment of current conditions. If sufficient data were available, the trend in resource condition was determined. However, in most cases sufficient data were not available to provide a quantitative evaluation of condition or trend, so qualitative information and expert opinion were used instead. A confidence level was assigned to each assessment based on the strength of available information.

Conducting a natural resource assessment for a park that was established specifically to preserve cultural and historic resources is problematic, and particularly for this park given the priority of protecting cultural landscapes. That said, the natural resources protected by NPS land management require attention, and many sites set aside to protect cultural values, particularly in urban areas, offer visitors and residents opportunities to experience nature unavailable in otherwise highly populated landscapes. Likewise, these sites often provide habitat for native species that are becoming increasingly rare.

The following table briefly summarizes the condition of assessed resources at FOVA. In no case was a natural resource determined to be in good condition, and in some cases ongoing or proposed human activities portend that conditions may decline in the future. The description of the symbols is provided in Chapter 3, and the assessment process for each resource described in the relevant section (4.x) of Chapter 4.

Table ES.1. Summary of condition assessments for all focal natural resources at Fort Vancouver National Historic Site.

FOVA Resource	Condition and Trend Symbol	Condition and Trend	Assessment
Air Quality (Section 4.1)		Moderate condition, no detectable trends, medium confidence	Air quality at FOVA is of moderate concern. The degree of confidence for all indicators is low because there is no on-site air quality monitoring and only interpolated data were available. No trends are apparent.
Climate (4.2)		Poor condition, downward trend, medium confidence	Given that the climate is changing rapidly from conditions to which organisms and biological systems have adapted, the condition of this resource is poor. The trend is declining, though conditions in the PNW are not changing as rapidly or predictably as in many other parts of the US. Confidence in this assessment is moderate.
Freshwater Resources (4.3)		Moderate condition, no detectable trends, medium confidence	The park has lost most of its historic wetlands and floodplain processes are non-functional. Groundwater quality is of concern but improving. Groundwater quantity is of concern given projections for future use of the aquifer. Confidence in hydrologic changes over time and groundwater conditions is moderate.
Native Fauna (4.4)		Poor condition, no trend, medium confidence	The faunal resource of FOVA bears little resemblance to historic conditions. In particular several mammal species have been extirpated and non-native species are present. Restoration could facilitate the return of some species. Trends are unknown and confidence is high that species have been lost, but low in relation to current conditions given the near-absence of recent surveys.
Natural Night Skies and Natural Quiet (4.5)		Poor condition, downward trend, high confidence	The conditions of natural night skies and natural quiet are poor. The park experiences above average levels of noise for an urban area, and night sky brightness is many times greater than natural conditions. Proposed construction activities and increases in aircraft use at Pearson Airfield will likely increase noise impacts; the trend for natural night skies is unknown. Confidence is high.
Land Cover and Use (4.6)		Poor condition, no detectable trend, high confidence	Land cover in this urban park is primarily non-vegetated or vegetated with non-native species, thus habitat quality for all native species is low. Impacts on natural resources from adjacent lands are of concern. Impervious surface cover in the park is high. Overall, conditions may be improving in response to riparian habitat protection efforts. Confidence is high.

Acknowledgments

We acknowledge the assistance of Dr. Robert Cromwell at Fort Vancouver National Historic Site. We also thank other National Park Service staff for their assistance, including Chris Davis (formerly of San Juan Island National Historic Park), Marsha Davis, Allen McCoy, Tonnie Cummings and Craig Dalby (NPS Pacific West Regional Office, Oakland, CA), Mark Huff (North Coast and Cascades Network, Ashford, WA), Regina Rochefort (North Cascades National Park Service Complex, Sedro-Woolley, WA, Bruce Heise (NPS Geologic Resources Division, Denver, CO), and Emma Brown and Ashley Pipkin (NPS Natural Sounds and Night Skies Division). We also thank Dr. Tim Carruthers (University of Maryland) for conversations about the NRCAs he conducted.

In addition to those students listed as co-authors, the following students contributed to this document: Susan Albrecht, Claire Beyer, Bonnie Eyestone, Jessica Farmer, Whitney Fliss, Lyndsay Gordon, Nicole Hackman, Kelsey Ketcheson, Danielle Pierce, Melinda Sabeti, Robert Schmitt, and Johnny Thepvongsa. Amongst this group, critical leadership was provided by Claire Beyer, Jessica Farmer, Nicole Hackman, and Danielle Pierce.

C. Schwemm greatly thanks Marsha Davis and David Garcelon (IWS).

Prologue

Publisher's Note: Changes in publishing requirements, and in some cases scientific delays, resulted in several NRCA reports not being published in a timely manner. These publications reported on studies initiated in the approximately 2013–2016 timeframe. Since Natural Resource Condition Assessments provide a snapshot-in-time evaluation of park resource conditions, it is important to note that data discovery and analyses for this study was conducted a few years prior to publication. Thus, park conditions reported in this document pertain to that time period. Please see the Publisher's Note at the beginning of the Executive Summary or Chapter 2 for dates specific to this report.

Contributors

Name and affiliation of contributors:

Name	Affiliation
Jonathan D. Bakker	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Tonnie Cummings	Air Resources, National Park Service, Pacific West Region, Vancouver, WA
Kern Ewing	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Thomas M. Hinckley	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Lesley Jantarasami	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Catherine Kilbane	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Joshua J. Lawler	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Megan McCain	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Rachel Mitchel	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Sarah Reichard (Deceased)	School of Forest Resources, College of the Environment, University of Washington, Seattle, WA
Catherin A. Schwemm	Institute for Wildlife Studies. Arcata, CA
Kelly Y. Shea	Program on the Environment, College of the Environment, University of Washington, Seattle, WA
Mu-Ning Wang	Program on the Environment, College of the Environment, University of Washington, Seattle, WA

Acronyms and Abbreviations

ALAN:	Artificial Light at Night
ARD:	Air Resources Division
CPX:	Central Park District (City of Vancouver)
"City":	City of Vancouver, Washington
CO_2:	Carbon dioxide
DOD:	US Department of Defense
EPA:	US Environmental Protection Agency
FOVA:	Fort Vancouver National Historic Site
VNHR:	Vancouver National Historic Reserve
GCM:	General circulation model
GIS:	Geographic information system
HBC:	Hudson's Bay Company
IPCC:	Intergovernmental Panel on Climate Change
I-5:	Interstate Highway 5
LCR:	Lower Columbia River
NLCD:	National Landcover Database
NOAA:	National Oceanic and Atmospheric Administration
NPS:	US National Park Service
NRCA:	Natural Resource Condition Assessment
PNW:	Pacific Northwest region of the US
"Park":	Fort Vancouver National Historic Site
ppm:	Parts per million
"River":	Columbia River
"Site":	Fort Vancouver National Historic Site

“State”:	State of Washington
SR 14:	State Route 14
USFWS:	US Fish and Wildlife Service
USGS:	US Geological Survey
WDOE:	Washington Department of Ecology

Chapter 1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." 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 Strive to Provide…

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

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

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

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

[2] 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

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

[4] 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.

[5] In addition to reporting on indicator-level conditions, investigators are asked 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.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not 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 statistical 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, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

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.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing,

long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] 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.[8] 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.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

---

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

[7] 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.

[8] 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.

Publisher's Note: Natural Resource Condition Assessments provide a snapshot-in-time evaluation of park resource conditions. For this report, most or all of the data discovery and analyses occurred during the period of 2009 to 2018. Thus, park conditions reported in this document pertain to that time period. Due to revised publishing requirements and/or scientific delays, this report was not published until 2020.

Chapter 2. Park Resource Setting/Resource Stewardship

2.1. Introduction

Fort Vancouver National Historic Site encompasses approximately 211 acres (85 ha) of Historic landscapes in the City of Vancouver, Washington. A complex management structure is in place at Fort Vancouver, with the National Park Service (NPS) working in partnership with the State of Washington ("State"), the City of Vancouver ("City"), and several non-governmental entities. In addition, the park is within the Vancouver National Historic Reserve (VNHR) and the Central Park District (CPX) of the City, and a portion of an active airstrip is located on NPS land. The purposes of FOVA are to preserve and interpret: a) the site of the nineteenth century Hudson's Bay Company (HBC); b) the story of settlement of the area that eventually became the Oregon Territory in 1848; and c) the establishment of the U.S. Army's Vancouver Barracks (NPS 2008).

2.1.1. Enabling Legislation/Administrative History

The park was originally established in 1948 as Fort Vancouver National Monument. The purpose of the monument at that time was to preserve and interpret the period of the original Fort Vancouver (1825–1829) and specifically the Hudson's Bay Stockade and the Parade Grounds (NPS 2008). The original fort structures burned in 1866, and reconstruction activities beginning in the 1960s have replicated many of the original buildings. In 1961 the park was expanded and re-designated as Fort Vancouver National Historic Site (FOVA), with the US Department of Defense (DOD) retaining use and ownership of the East and South Barracks, buildings that represent a long period of use by the DOD that began in 1849. The 1961 legislation also stipulated that the Barracks buildings could be transferred to NPS at some future time if DOD did not have further use for them, and this occurred in 2011 (NPS 2012). Detailed descriptions of the management and history of the park are available in sources such as Taylor and Erigero (1992), Merritt (1993), Jones and Jones (2005) and NPS (2008, 2011).

2.1.2. Geographic Location and Surrounding Lands

Fort Vancouver is situated between the Oregon Coast Range to the west and the Cascade Range to the east, an area known as the Willamette Basin – Puget Trough ecoregion (Floberg et al. 2004; Figure 2.1). The site itself is located on a low terrace just to the north of the Columbia River with the City of Vancouver generally to the west and the City of Portland across the river to the southwest (Figure 2.2), and large populations centers to the north and east. Clark County Washington, which includes Vancouver, is the fifth most populated county in the state, with an estimated population in 2017 of approximately 475,000 (755/mi^2; (https://www.census.gov/quickfacts/clarkcountywashington). Estimates are that the population of the

greater Portland-Vancouver area will grow by about 1.5 million (20%) from 2015–2030 (Morzillo et al. 2016).

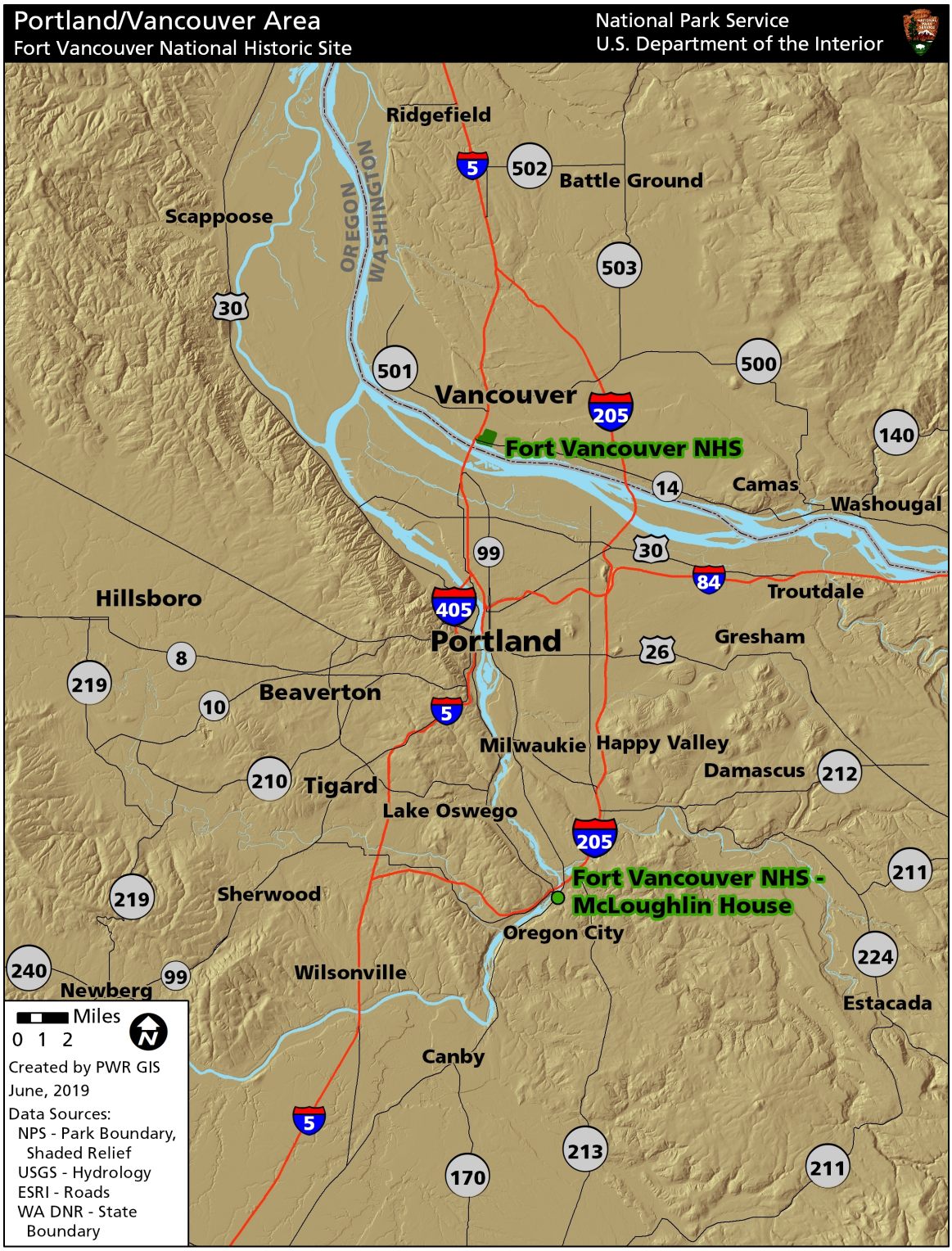


Figure 2.1. Location of FOVA within the greater Portland-Vancouver region.

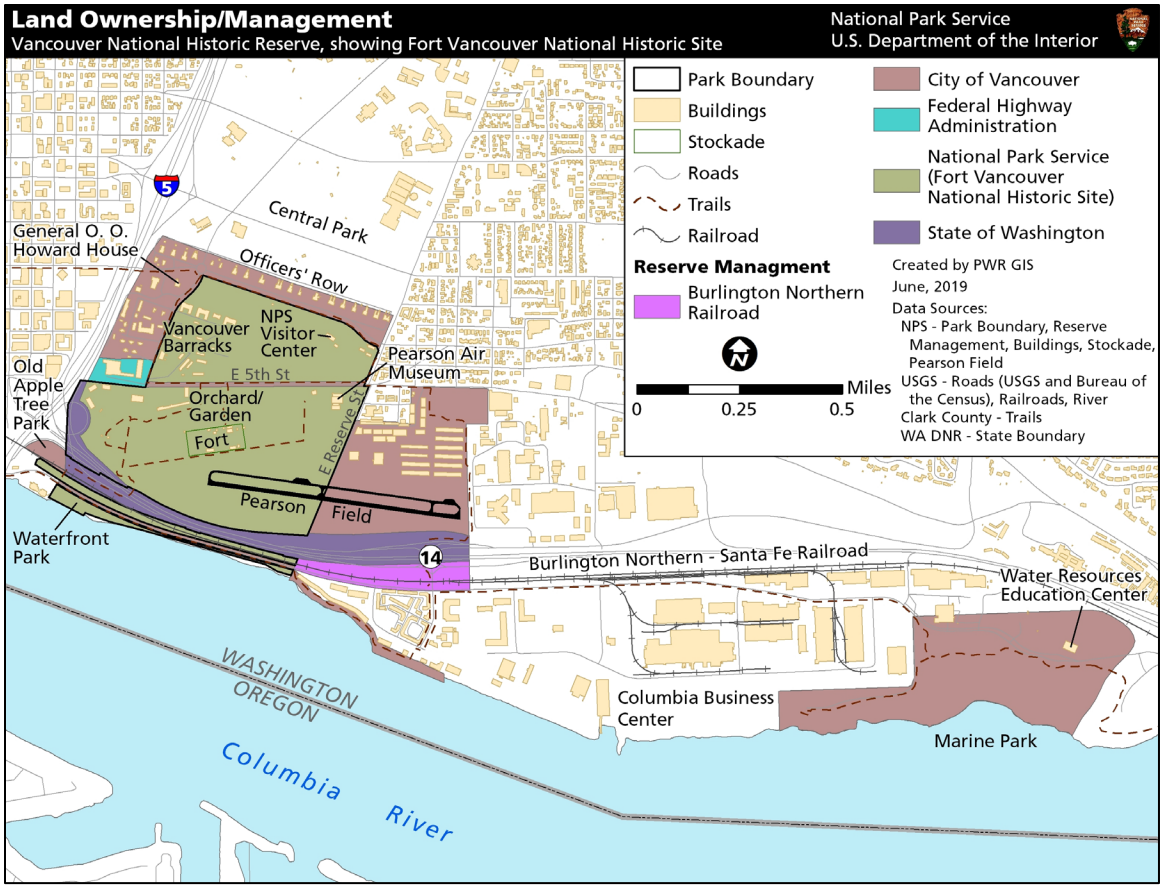


Figure 2.2. Administration and land ownership of Vancouver National Historic Reserve.

Adjacent Land Use

FOVA is also within the Vancouver National Historic Reserve (VNHR) established in 1996 (NPS 2008). The Reserve includes a larger area around FOVA with management shared among several government agencies and partners (Figure 2.2). The Reserve is intended to help preserve, interpret, and encourage public use of lands that have common Historic themes. NPS has been given the authority to act as the lead federal agency for all properties within the VNHR, and the NPS has Memorandums of Agreement with the City to conduct those duties.

In all ways FOVA is ecologically isolated. Other than a detached narrow strip of land along the Columbia River, the park is surrounded on the south by State Route 14 (SR 14), on the west generally by Interstate 5 (I-5), by mixed open space/developed areas to the north, and by high density residential and commercial areas to the east and northeast (Figure 2.3).

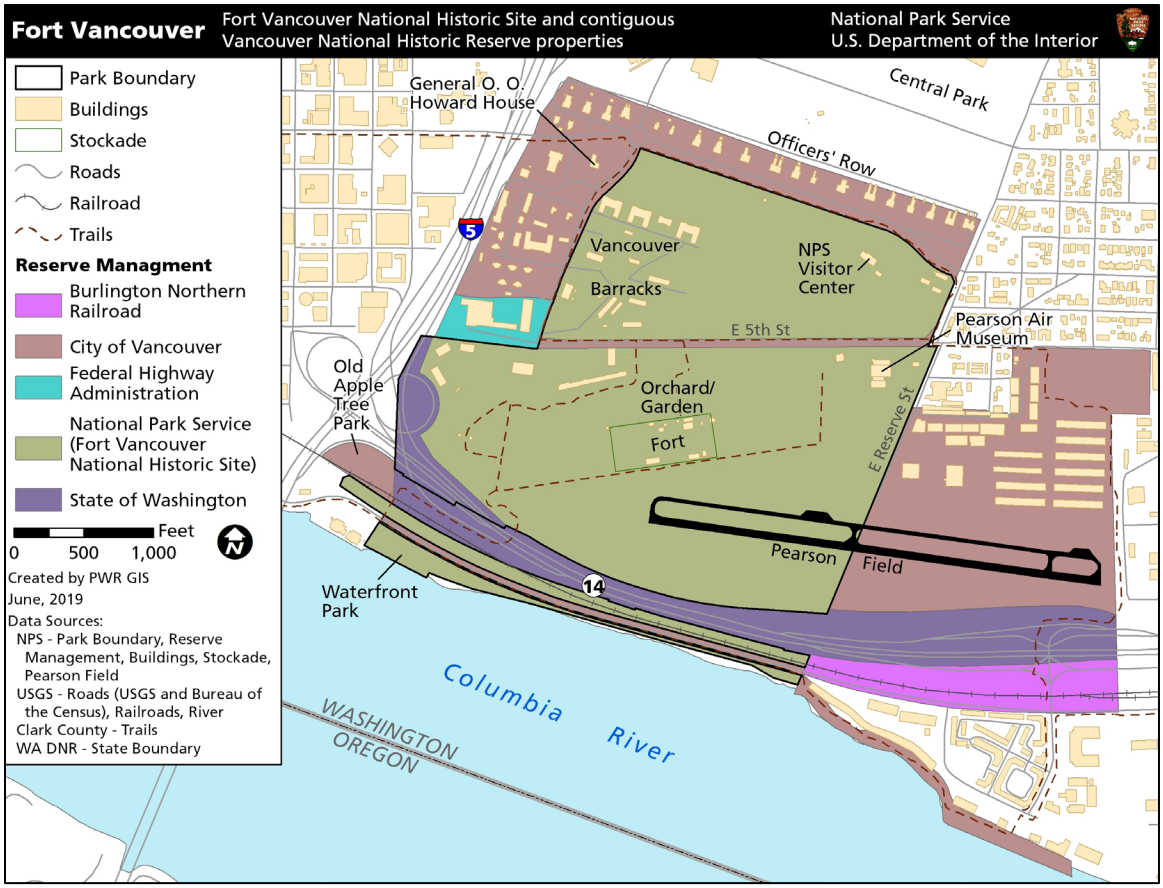


Figure 2.3. Fort Vancouver National Historic Site and contiguous properties of the Vancouver National Historic Reserve.

Pearson Field

Pearson Airfield, named for aviator Alexander Pearson, is located directly east of the main area of FOVA and is included within the VNHR (Figure 2.4). The airfield was constructed in 1923 and has been in use since that time, making it the longest continuously operating airfield in the US. When NPS took over management of FOVA in 1948 the airfield was not included and was instead transferred to the City of Vancouver. In 1972 the City sold the western portion of the airfield back to NPS, resulting in a situation where the eastern portion of the runway is on City-owned land and the western portion on NPS land. The City retains a use and occupancy lease (recently renewed until 2051) for the western portion (NPS 2011). The airfield is used for general aviation purposes only (primarily light fixed-wing and Historic aircraft but no helicopters or jets).



Figure 2.4. Aerial view of the historic Army Air Corps Pearson Field (far ground), Hudson's Bay Company's Fort Vancouver (middle ground on right), and the south area of the U.S. Army Vancouver Barracks (near ground); Columbia River shown in the upper right (City of Vancouver).

Additional Adjacent Land Use

FOVA and VNHR are also within the City of Vancouver Central Park District, which aims to preserve the historic character of the site while integrating uses with adjacent neighborhoods and commercial and academic activities (Figure 2.5; City 2008). The City and NPS have also entered into agreements to work together to maintain the riverfront area of the park as greenspace. The Vancouver Land Bridge was constructed in 2009 as part of an effort to increase pedestrian use of the riverfront while interpreting and communicating Native American art and culture (Daehnke 2012). Adjacent land use is discussed in detail in Section 4.6.



Figure 2.5. City of Vancouver Central Park District. FOVA and VNHR are in the lower half between the Columbia River northward to and inclusive of Officers' Row (City of Vancouver, with permission, https://www.cityofvancouver.us/ced/page/central-park).

2.1.3. Cultural History and Significance

The rich human history of the FOVA site and surrounding regions has been well studied and documented, so only a brief synopsis will be provided here; primary references include Hussey (1991), Taylor and Erigero (1992), Jones and Jones (2005), NPS (2008), Deur (2011) and Wilson (2012).

The region was occupied by native Chinookan people at the time of the HBC arrival (early 1800s). At that time natural resources were plentiful and supported native people and early trappers and settlers with riparian and riverine resources, particularly fish, and abundant deer and elk in addition to beaver (Jetté 2006). Native peoples used fire to burn woody plants and maintain prairies that provided plants used for food and medicine (Copass and Ramm-Granberg 2016).

When the HBC arrived they found a site that would supply both necessary resources and a defendable location. As trading increased more people came from around the world, particularly Hawaii and via the Oregon Trail to benefit from the fur trading economy. To protect these settlers the US Army established the Vancouver Barracks, the first military outpost in the Pacific Northwest. Ultimately the HBC moved its headquarters north to Canada, and as the military post expanded the City of Vancouver began expanding around it.

The army barracks were very important during World War II when much of the defense of the Pacific Coast was centered here. The Vancouver Port allowed ships to bring and take troops from around the world. The war also changed the character of Vancouver from a town that was somewhat overshadowed by cities like Seattle and San Francisco, to a primary industrial and shipping site. Perhaps most importantly Kaiser Shipyards, established in 1942, created an industry around which much of the city grew; over 100 ships were constructed here, most famously the USS George Vancouver.

2.1.4. Visitation

Annual visitation at FOVA over the last decade has ranged from approximately 650,000 to over 1 million. In 2009 the recognition of the Lewis and Clark centennial brought many people to the region with over one million visitors at FOVA that year. On average visitation is highest in July and August with between 90,000 and 150,000 visitors in each of those months (https://irma.nps.gov/Stats). FOVA is a population destination for visitors and residents, with many scheduled events occurring each year (https://www.oregonlive.com/travel/index.ssf/2018/01/how_fort_vancouver_became_one.html).

2.2. Physical Resources and Processes

2.2.1. Climate

The region is characterized by wet winters and mild summers. Summer temperatures of 80–90°F (27–32°C) are common, while winter temperatures can fall below 30°F (1°C). Mean low temperatures in December are 33°F (1°C), and mean high temperatures in September are 73°F (23°C). Average rainfall is approximately 41 in (107 cm) with approximately 7 in (18 cm) of snowfall (Western Regional Climate Center, https://www.wrcc.dri.edu/climate/summaries.php). Most precipitation occurs from October to May. Prevailing winds during the summer are mild and primarily from the northwest, changing to southeasterly in the winter. Occasionally, high windstorms with winds of up to 60–90 mph (97–145 km/hr) can occur. In Portland, a little more than half the days in the year are overcast. Climate is discussed in detail in Section 4.2.

2.2.2. Air Quality

Air quality at FOVA is affected by the surrounding urban area, the I-5 transportation corridor, the adjacent railroad, and Pearson Airfield. Air quality monitoring in Vancouver is the responsibility of the Southwest Clean Air Agency. Air Quality is assessed specifically in Section 4.1.

2.2.3. Geology and Soils

The underlying geology of the Vancouver area is primarily depositional, layered with alluvial sediment deposited by river flows generated by the rising of the Coast range. Subsequent volcanic activity produced lavas that were deposited atop the alluvial sediments in the basin between the Coast and Cascade ranges. Massive floods resulting from glacial melt during the ice age then carried enormous volumes of material, water and ice down the Columbia, much of which was deposited before reaching the ocean (Trimble 1963, Beeson et al 1991, Evarts 2007, Graham 2009, Minor 2011). Eventually the modern Columbia incised through these deposits, and as sea levels rose the ocean covered much of the existing deposits. (Excellent interpretive opportunities of continental geologic processes relating to the Columbia River Basin exist with the Ice Age Floods National Geologic Trail (IAFL) administered by Lake Roosevelt National Recreation Area.)

Geologic processes have resulted in three major soil types at FOVA: modern anthropogenic fill (minimal surface layers), and recent and older alluvium on the terraces. Soils here are highly absorbent and contain high amounts of groundwater (Trimble 1963, McGee 1972, Beeson et al. 1991, Graham 2009, Minor 2011).

2.2.4. Hydrology and Water Quality

High precipitation, local geology, and the hydrologic connection with the Columbia River combine to create a commonly wet ground surface in the vicinity of FOVA. The region was characterized by the presence of several wet meadow sites when the HBC arrived (Taylor and Erigero 1992). Currently a fairly large portion of the Pearson Airfield and the Parade Grounds portion of FOVA are within the 100-year floodplain and a small portion of the riverfront is within the 500-year floodplain (https://gis.clark.wa.gov/mapsonline).

River heights in this section of the Columbia are determined primarily by seasonal flow variation and secondarily by power-peaking regulation at Bonneville dam, with very little tidal input (Jay et al. 2015). An examination of water flow data on the Columbia River at Vancouver (USGS Gaging Station #14144700) shows seasonal variability in river level from between 1–3 ft (< 1 m) in the fall to 10–15 ft (3–5 m) during peak runoff in late spring/early summer (Figure 2.6). Historic records indicate extreme floods in June 1894 and 1948 of 34 and 31 ft (10 and 9 m), respectively, while the most recent maximum height was 27.6 ft (8.4 m) in December 1964.

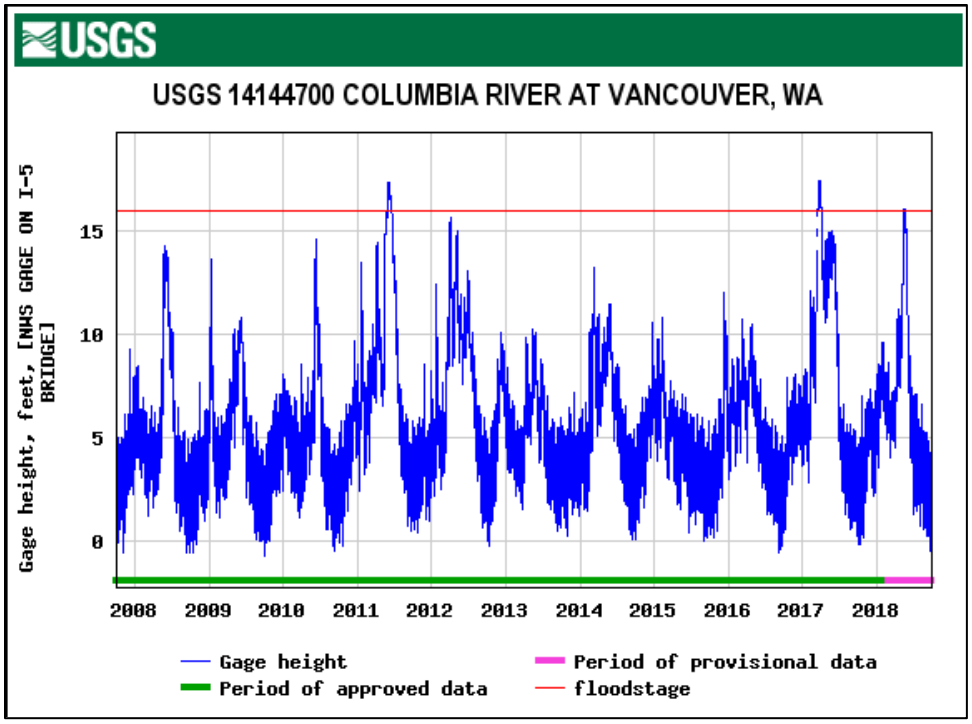


Figure 2.6. River height (feet), USGS gage at I-5, Columbia River, 2008–2018 (USGS, https://waterdata.usgs.gov/nwis/uv/?site_no=14144700&agency_cd=USGS&amp).

Water Quality

All drinking water in the City of Vancouver comes from groundwater. Many of the aquifers in the Vancouver area are contaminated by materials used in past commercial and military operations (Chang et al. 2014). As far as is known, there is no current monitoring of water quality at FOVA by NPS (pers. comm. T. Cummings 2017). Groundwater quality in the aquifer has improved significantly in the past decade, and is generally good with some exceptions. In the Vancouver urban area in 2017, the highest nitrate levels recorded were 4.8 mg/l (10 mg/l is MCL; City 2017). Fertilizer and septic systems are thought to be the source of nitrates. Hydrology and water quality are assessed specifically in Section 4.3.

2.3. Natural Resources

2.3.1. Vegetation Communities

Historic Vegetation

Fort Vancouver National Historic Site occupies an area once rich in natural resources and high in native biodiversity. Historic plant communities that occupied what is now FOVA included riparian (cottonwood [*Populus* sp.] and willow [*Salix* sp.] forests along the Columbia River, freshwater wetlands, floodplain meadows, Garry oak (also called white oak – *Quercus garryana*) upland prairies, and upland coniferous forests (Douglas fir – *Pseudotsuga menziesii*; Taylor and Erigero 1992, Copass and Ramm-Granberg 2016).

Specifically, the Lewis and Clark Expedition described the vegetation at Fort Vancouver as including black cottonwood (*P. trichocarpa*) and Oregon ash (*Fraxinus latifolia*) riparian forests, extensive prairies in the floodplain areas, and coniferous forests on higher sites (Table 2.1). Camas (*Camassia quamash*), a bulb plant in the lily family found in wet meadows and floodplains, was a particularly important food item for the Chinookan people (Stevens et al. 2001; Figure 2.7). Later, during the HBC period, the undeveloped area north of Upper Mill Road was described as consisting of Oregon oaks and Douglas fir trees scattered across a natural prairie (Taylor and Erigero 1992).

Table 2.1. Four major ecosystems found at Fort Vancouver National Historic Site and impacts (compiled from various sources, primarily NPS 1969, Taylor and Erigero 1992, Jones and Jones 2005, Copass and Ramm-Granberg 2016).

Ecosystem	Key Species Supported	Current Description	Major current impacts
Riverine – Riparian	Salmon, birds (including raptors), cottonwoods, willows	Little riparian vegetation remains, varying degrees of bank stabilization with native grass and shrubs	Upstream dams and pollution sources, non-native plants, absence of floodplain processes
Lacustrine	Amphibians, birds	Majority of wetlands filled, small seasonal wetland between Pearson Field and SR 14.	Continued fill and construction, non-native plants,
Oak – prairie savanna	Camas, wapato, Garry oaks	Primarily weedy European grasses; small population of camas in Pearson Field; small population of Garry oaks	Invasive species, mowing and herbicide treatments, irrigation
Upland evergreen forest	Douglas fir	Few native trees remain or are mixed with non-natives, little recruitment of native species	Structural and managerial barriers to recruitment and succession



Figure 2.7. Blue camas (*Camassia quamash)* flowers, an important staple food for Chinookan people, grows in wet meadows and prairies (NPS photo).

Every culture, beginning with the Chinookan people, has modified the landscape and utilized the region's abundant natural resources (Table 2.2). As Fort Vancouver grew, native vegetation was either cleared (e.g., forests to make lumber, meadows and shrublands to create pasture), or replaced by introduced species (for cultivation or formal landscaping). Orchards and gardens were planted soon after the HBC arrived to provide fresh food to people arriving after long ocean journeys and later to feed fort employees and families (Cromwell 2010).

Table 2.2. Synthesis of the eight significant periods at Fort Vancouver National Historic Site and associated cultural groups with primary natural resource uses and impacts (compiled from various sources, primarily NPS 1969, Taylor and Erigero 1992, Jones and Jones 2005, Copass and Ramm-Granberg 2016).

Time Period	Major Cultural Group	Impacts to Natural Resources/Vegetation
Pre-1824	Native American	Fire used to maintain prairies that supported plants for food and medicine; open prairies supported deer and elk; floodplain meadows and forests were dominant landscape features
1824–1826	Hudson's Bay Company	Prairies and wetland ponds were altered to allow cultivation; forests were cut to provide timber for the fort; grazing animals introduced to the land;
1847–1860	Fort Vancouver and Vancouver Barracks	Expansion of the fort resulted in additional forests lost; road-building occurred; agriculture continued and expanded; City of Vancouver began to grow;
1861–1916	U.S. Army	More road and building construction; railroad alters floodplain processes; formal landscapes established; further loss of forests and likely introductions of non-native species;
1917–1918	U.S. Army – WWI	Spruce Mill established and forest clearing accelerates; railroad extended; separation from Columbia River by berms to prevent flooding; more construction for housing
1919–1941	U.S. Army and CCC	Pearson airfield constructed in 1923; further construction of roads and buildings; extensive ornamental tree planting by CCC (Civilian Conservation Corps); loss of riparian vegetation and wetlands
1941–1947	U.S. Army – WWII	Kaiser shipyard constructed; City of Vancouver expands; Columbia River dammed, dredged and channelized
1948–1996	NPS	Reconstruction of historic fort, village, and orchard; construction of NPS facilities; construction of riverfront park and boat launch; tree planting within Parade Grounds; further loss of riparian habitat; removal of additional trees
1997-present	NPS and partners	Further site improvements; relinquishment of Army Barracks to NPS; construction of the Confluence Project Bridge across Highway 14

Existing Vegetation

Because the park's primary mission is to preserve and interpret the cultural condition of the period, vegetation is currently maintained as it might have been after a few decades of European settlement (Copass and Ramm-Granberg 2016). An orchard of approximately 70 fruit trees was planted in 1962, and much of the remaining area of the park is mowed, non-native grass. In addition, much of the site includes non-vegetated areas such as historic structures, replications of buildings of the period, the airfield, roads, and railroads. Maintenance of the airfield for safety likely directs standing water away from the site to remove habitat that may attract birds (Shi et al. 2015, CWE 2018).

The only natural plant association mentioned by Copass and Ramm-Granberg (2016) is a small site of camas wet prairie, though they note that there are many other non-native species present. Adjacent to the river is a riparian forest that contains native cottonwoods, however, invasive Himalayan blackberry (*Rubus armeniacus*) is dominant in the understory (Copass and Ramm-Granberg 2016).

2.3.2. Plant Species Diversity

Approximately 160 plant species are present or probably present in FOVA, over 70% of which are not native (NPSpecies, Rochefort 2010). Taylor and Erigero (1992) provide a list of native plant species present during the HBC period. There are no rare or endangered plant species present in the park.

2.3.3. Animals

Invertebrates

Invertebrates are common throughout the park, but data are extremely limited. Periodic surveys by Adams (2012 and unpublished 2004, 2010, 2011) have produced a limited list of documented insects. Of particular concern is the invasive stinkbug *Halyomorpha halys* which can infest many host species of cultivated plants and trees including fruit trees in orchards (Haye et al. 2015), a threat that may be of future concern to FOVA managers.

Fish, Reptiles and Amphibians

The southern park boundary stretches approximately 3,600 ft (~ 1,100 m) along the Columbia River, and the river supports a diverse fish community. In particular the salmon fishery has been highly impacted as a result of habitat loss, dams, and introduced species. Because so much has been written about the topic (for example see Butler 2004, NPCC 2011, Naiman et al. 2012, NMFS 2013), and the park has little management authority for fish they will not be discussed further.

Within the park there is minimal habitat remaining for amphibians and reptiles. A survey for amphibians was conducted in 2002–2003 (Samora et al. 2013) that included the entire Reserve. Though three species were found in other areas none were found in FOVA, and as far as is known no further surveys have been conducted. Common reptiles and amphibians in the area include western toad (*Anaxyrus boreas*), Pacific tree frog (*Pseudacris regilla*), racer snake (*Coluber constrictor*), and several garter snakes (*Thamnophis* spp.).

Birds

Tall grasses, blackberries, shrubs, and occasional groves of trees characterize the areas of FOVA that are vegetated, and all of these habitats support many species of native birds. Of the 138 bird species found within FOVA, only three are exotic in origin (See Table 4.4.).

Mammals

FOVA is surrounded by commercial, industrial, residential, and aviation development, activities that have removed nearly all native habitat for mammals. Some small and medium-sized species remain, but there have been no recent surveys for mammals in the park since Schaberl et al. (2012). Common native mammal species currently present in the park likely include deer mice (*Peromyscus maniculatus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), coyote (*Canis latrans*), and brush rabbits (*Sylvilagus bachmani)*. Eastern gray squirrels (*Sciurus carolinensis*) and opossums (*Didelphis virginiana*) are present but are not native. Western gray squirrels are State Threatened but have likely been extirpated from the area (Wiles 2016). Beaver (*Castor canadensis*), red fox (*Vulpes vulpes*) and black-tail deer (*Odocoileus hemionus*) were common in the time of the HBC and are found in Clark County but are now absent from the FOVA site. Bats are likely common around

FOVA and species diversity may be high, but almost nothing is known regarding this group. The native faunal resource is addressed in Section 4.4.

2.3.4. Threatened/Endangered Species and Communities

As far as is known there are no endangered or threatened species within FOVA (NPS 2008, Copass and Ramm-Granberg 2016).

2.4. Primary Threats to Natural Resources

Non-native species comprise over 70% of all plant species within the park (NPSpecies, Rochefort 2010). At present, there are two Class A Noxious weeds listed within FOVA: *Silybum marianum* and *Heracleum mantegazziunum.*

Changes in sea level, precipitation, and air temperature due to climate change are likely to have minimal impacts on FOVA. The intensive management of this area will largely mitigate any direct effects. Indirect effects, however, may be more significant.

By far the greatest threat to natural resources is the absence of natural habitats. Even though surrounded by development, the open space of FOVA could support more wildlife than at present and more natural-type vegetation.

2.5. Resource Stewardship

Though the park is primarily intended and designed to preserve historic cultural resources, the abundant natural resources are what attracted both Native Americans and early European visitors to settle here (Butler 2004, Jette 2006, Deur 2011). The early Master Plan (NPS 1969) included very little mention of natural resources, however, the more recent General Management Plan (NPS 2008) discusses natural resources in more detail.

2.5.1. Management Directives, Planning Guidance and Research

General/Resource Plans (listed in reverse chronological order)

The Cultural Landscape Report

The CLR recommends restoration of native riparian, wetland, prairie, oak, and forest habitat on site to allow for interpretation of the historic site condition and resulting development. Furthermore, the Report recommends that "…the Columbia River and its river edge; the site's geomorphology, floodplain terraces, underlying river soils; native riparian and upland vegetation, and any remnant natural systems." are primary natural systems that should be protected or enhanced (Jones and Jones 2005).

General Management Plan

The GMP addresses natural resource protection and management in several areas, including:

- The development of an Integrated Pest Management Program
- Complete baseline surveys of all plants and animals for the entire park
- Maintain important habitat areas (for example by removing asphalt in some areas)
- Increase the use of native vegetation to minimize impacts of the I-5 and SR14 corridors

- Preserve and maintain the native oak trees
- Management of the Riverfront zone to maximize natural resources and environmental integrity, while providing for public enjoyment

2.5.2. Supporting Science

NPS Inventory and Monitoring Program

Several natural resource inventories have been completed for FOVA including amphibians (Samora et al. 2013) and small mammals and bats (Schaberl et al. 2012), and a vegetation classification with map production was completed (Copass and Ramm-Granberg 2016). As far as is known there is no ongoing monitoring for natural resources in FOVA.

2.6. Literature Cited

Adams, M.E. 2012.Taxonomic Survey of Orthoptera at Fort Vancouver National Historic Site: Ecological and Archaeological Implications. National Park Service, Vancouver, WA.

Beeson, M. H., T. L. Tolan, and I. P. Maudin. 1991. Geologic map of the Portland Quadrangle, Multnomah and Washington counties, Oregon and Clark County, Washington. Oregon Department of Geology and Mineral Industries, Portland, OR. Geologic Map Series-75.

Butler, V.L. 2004. Where Have All the Native Fish Gone? The Fate of Fish that Lewis and Clark Encountered on the Lower Columbia River. Oregon Historic Quarterly 105:438–463.

Century West Engineering (CWE). 2018. Pearson Field Airport, Airport Improvements – Draft Environmental Impact Statement. Prepared for City of Vancouver, Washington, by CWE, Portland, OR.

Chang, H., P.R. Thiers, N.R., Netusil, J.A. Yeakley, G. Rollwagen-Bollens, S. Bollens, and S. Singh. 2014. Relationships between Environmental Governance and Water Quality in a Growing Metropolitan Area of the Pacific Northwest, USA. Hydrology and Earth System Sciences 18:1383–1395.

City of Vancouver. (City). 2008. Central Park Plan Update. http://www.cityofvancouver.us/sites/default/files/fileattachments/community_and_economic_development/page/1415/centralplan.pdf

City. 2017. Water Quality Report. https://www.cityofvancouver.us/sites/default/files/fileattachments/public_works/page/1126/fullcityofvancouver-wqreport2017-publishedjune2018.pdf.

Copass, C., and T. Ramm-Granberg. 2016. Vancouver National Historic Reserve vegetation inventory and mapping project. Natural Resource Report NPS/NCCN/NRR—2016/1128. National Park Service, Fort Collins, Colorado.

Cromwell, R.J. 2010. A Short History of the Old Apple Tree, Located in the Old Apple Tree Park. Vancouver National Historic Reserve, Vancouver, WA. National Park Service, Vancouver, WA.

https://www.cityofvancouver.us/sites/default/files/fileattachments/public_works/page/12705/old_apple_tree_history.pdf.

Daehnke, J. 2012. Reflections on the Confluence Project: assimilation, sustainability, and the perils of a shared heritage. American Indian Quarterly 36:503–524.

Deur, D. 2011. An EthnoHistoric Overview of Groups with Ties to Fort Vancouver National Historic Site. Pacific West Region, National Park Service, US Department of the Interior. http://depts.washington.edu/pnwcesu/reports/J9W88050025_Final_Report.pdf.

Evarts, R. C. 2007. Neogene evolution of the Portland Basin. Geological Society of America, Abstracts with Programs 39(4): 28.

Floberg, J., M. Goering, G. Wilhere, C. MacDonald, C. Chappell, C. Rumsey, Z. Ferdana, A. Holt, P. Skidmore, T. Horsman, E. Alverson, C. Tanner, M. Bryer, P. Iachetti, A. Harcombe, B. McDonald, T. Cook, M. Summers, D. Rolph. 2004. Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment, Volume One: Report. Prepared by The Nature Conservancy with support from the Nature Conservancy of Canada, Washington Department of Fish and Wildlife, Washington Department of Natural Resources (Natural Heritage and Nearshore Habitat programs), Oregon State Natural Heritage Information Center and the British Columbia Conservation Data Centre.

Graham, J. 2009. Geologic Resources Inventory Scoping Summary, Fort Vancouver National Historic Site, Washington and Oregon. National Park Service, Geologic Resources Division.

Haye, T., T. Gariepy, K. Hoelmer, J.P. Rossi, J.C. Streito, X. Tassus, and N. Desneux. 2015. Range expansion of the invasive brown marmorated stinkbug, *Halyomorpha halys*: an increasing threat to field, fruit and vegetable crops worldwide. Journal of Pest Science 88:665–673.

Hussey, J.A. 1991. The Women of Fort Vancouver. Oregon Historic Quarterly 92:265–308.

Jay, D.A., K. Leffler, H.L. Diefenderfer, and A.B. Borde. 2015. Tidal-fluvial and estuarine processes in the lower Columbia River: I. Along-channel water level variations, Pacific Ocean to Bonneville Dam. Estuaries and Coasts 38:415–433.

Jetté, M.M., 2006. “Beaver Are Numerous, but the Natives... Will Not Hunt Them”: Native-Fur Trader Relations in the Willamette Valley, 1812–1814. The Pacific Northwest Quarterly 98:3–17.

Jones and Jones. 2005. Vancouver National Historic Reserve Cultural Landscape Report. Seattle, WA.

McGee, D.A. 1972. Soil Survey of Clark County, Washington. Soil Conservation Service, Washington Agricultural Experiment Station, Seattle, WA.

Merritt, J.T. 1993. Administrative History, Fort Vancouver National Historic Site. National Park Service, Seattle, WA. https://www.nps.gov/parkhistory/online_books/fova/adhi/

Minor, R. 2011. Interstate 5 Columbia River Crossing: Archaeology Technical Report for the Final Environmental Impact Statement. Heritage Research Associates, Inc., Eugene, OR.

Morzillo, A.T., Kreakie, B.J., Netusil, N.R., Yeakley, J.A., Ozawa, C.P. and Duncan, S.L., 2016. Resident perceptions of natural resources between cities and across scales in the Pacific Northwest. *Ecology and Society*, *21*(3).

Naiman, R.J., J.R. Alldredge, D.A. Beauchamp, P. A., Bisson, J. Congleton, C. J. Henny, N. Huntly, R. Lamberson, C. Levings, E.N. Merrill, and W.G. Pearcy. 2012. Developing a broader scientific foundation for river restoration: Columbia River food webs. Proceedings of the National Academy of Sciences 109:21201–21207.

National Marine Fisheries Service (NMFS). 2013. ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead. Prepared by the National Marine Fisheries Service, Northwest Region, June 2013.

National Park Service (NPS). 1969. Fort Vancouver National Historic Site, Washington. Master Plan. https://www.nps.gov/parkhistory/online_books/fova/master_plan/index.htm.

NPS. 2008. General Management Plan 2003 and McLoughlin House Unit Management Plan 2007. Fort Vancouver National Historic Site, Vancouver, WA.

NPS. 2011. Fort Vancouver Historic Site, Pearson Field Lease for Runway 08 and Parallel Taxiway, Lease NO. L-FOVA001-11 with City of Vancouver, WA. Covering the period April 1, 2011 through March 31, 2051.

NPS. 2012. Finding of No Significant Impact. East and South Vancouver Barracks Draft Master Plan and Environmental Assessment. National Park Service, U.S. Department of the Interior, Fort Vancouver National Historic Site, Vancouver, WA.

Northwest Power and Conservation Council (NPCC). 2011. Columbia River Basin Fish and Wildlife Program. Northwest Power and Conservation Council, Portland, Oregon, USA. Document 2011-04:47. Available at www.nwcouncil.org/library/2011/2011-04.pdf.

Rochefort, R. M. 2010. Vascular plant inventory of Fort Vancouver National Historic Site. Natural Resource Technical Report NPS/NCCN/NRTR—2010/341. National Park Service, Fort Collins, Colorado.

Samora, B.A., M. Layes, and R. Lofgren. 2013. Vancouver National Historic Reserve amphibian inventory 2002–2003. Natural Resource Technical Report NPS/NCCN/NRTR—2013/732. National Park Service, Fort Collins, Colorado.

Schaberl, J., E. Myers, and M. Reid. 2012. Small mammal inventory and bat reconnaissance at Fort Vancouver National Historic Site/Vancouver National Historic Reserve. Natural Resource Technical Report NPS/NCCN/NRTR—2012/590. National Park Service, Fort Collins, Colorado.

Samora, B.A., M. Layes, and R. Lofgren. 2013. Vancouver National Historic Reserve amphibian inventory 2002–2003. Natural Resource Technical Report NPS/NCCN/NRTR—2013/732. National Park Service, Fort Collins, Colorado.

Shi, X., M. Beutel, T. Long, A. Hellenthal, and C. Bristoll-Groll. 2015. Green stormwater infrastructure strategies for airports: Challenges and opportunities. Environmental Sustainability in Transportation Infrastructure (https://ascelibrary.org/doi/10.1061/9780784479285.001).

Stevens, M., D.C. Darris, and S.M. Lambert. 2001. Ethnobotany, Culture, Management, and Use of Common Camas. Native Plants Journal 2:47–53.

Taylor, T.A. and P.C. Erigero. 1992. Cultural Landscape Report, Vols I and II. National Park Service, Seattle, WA. https://www.nps.gov/parkhistory/online_books/fova/clr/clr.htm

Trimble, D. E. 1963. Geology of Portland, Oregon, and adjacent areas. U.S. Geological Survey, Reston, VA, Reston, VA. Bulletin 1119.

Western Regional Climate Center. https://www.wrcc.dri.edu/climate/summaries.php

Wiles, G. J. 2016. Periodic status review for the western gray squirrel in Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Wilson, D.C. 2012. Hawaiian Presence at Fort Vancouver National Historic Site. Projects in Parks, Archaeology Program, National Park Service. Available at: https://core.ac.uk/download/pdf/.

Chapter 3. Study Approach

3.1. Preliminary Scoping

This project was conducted in two phases. First, the University of Washington (UW) School of Forest Resources was selected by NPS as the collaborative partner. The Principle Investigative team at the UW consisted of Jon Bakker, Kern Ewing, Tom Hinckley, Josh Lawler, and Sarah Reichard. A group of graduate and undergraduate students was also part of the study team and a for-credit class included as part of the student participation. The original intent was to complete a multi-park project for FOVA, Ebey's Landing National Historic Reserve (EBLA), San Juan Island National Historic Park (SAJH) and Lewis and Clark National Historic Park (LEWI). A variety of limitations prevented completion of the NRCAs for EBLA and SAJH, and the team moved ahead with LEWI and FOVA.

After a review of the draft NRCAs for FOVA and LEWI, the NPS determined that a partial reorganization of resource topics and further editing was required. In addition, partly because the project spanned a time period within which the NRCA guidelines were being updated, the UW reports were delivered in a format that was inconsistent with the guidelines. As a result of the UW team winding down, a second phase of the project was later initiated in 2017 to revise and update the phase one reports. This second phase included a review and modification of the resource topics, re-organization of the material into the required NPS NRCA report format, an extended literature search for additional data and information to enhance the condition assessment of some of the parks' resources, and additional writing and editing to update the report. This phase also enabled input from new park staff who brought to light emerging issues and a re-emphasis on resources of current major concern. The second phase was coordinated by Marsha Davis (NPS) and conducted by Cathy Schwemm of the Institute for Wildlife Studies.

3.2. Study Design

3.2.1. Focal Study Resources

In 2005, the NPS North Coast and Cascades Inventory and Monitoring Network's Vital Signs program (Weber et al. 2009) identified the following issues as important natural resource concerns at FOVA:

- Maintenance and restoration of the natural environment
- Preservation of heritage natural resources
- Control of exotic plants
- Challenges of natural resource management within an urban environment

Using the above list as a starting point, the UW and NPS team initially identified 10 focal resources as being of high or moderate priority (Table 3.1). Based on staff input, park documents, review of the draft UW report, and the availability of new information, and to be in compliance with the revised NRCA guidelines, the Phase II team developed the final list of focal resources (Table 3.1). Two of the initial topics—Invasive Species and Native Plant Restoration—are not resources and are not addressed in this report. Though there was fairly significant re-organization of the information

presented in the UW draft report, much of the analyses and data presentations relevant to the focal resources are retained herein.

Table 3.1. UW draft report (Phase I) focal resources and resulting final report (Phase II) focal resources organized within the NPS Ecological Monitoring Framework (Fancy et al. 2009).

Level 1 Category (Fancy et al. 2009)	Phase I Focal Resources	Phase II Focal Resources
Air and Climate	Air Quality	Air Quality
	Climate	Climate
Geology and Soils	–	–
Water	Freshwater Quality	Freshwater Resources
	Hydrology (Flood Potential)	–
	Wetlands and Riparian Areas	–
Biological Integrity	–	Native Fauna
Ecosystem Pattern and Processes	Night Sky	Sensory Environment (Natural Night Skies and Natural Quiet)
	Urban Encroachment	Habitat Integrity (Land Cover and Adjacent Land Use)
	Road and Trail Development	Habitat Integrity (Land Cover and Adjacent Land Use)
–	Invasive Species	–
–	Native Plant Restoration	–

3.2.2. Indicators and Reference Conditions

For each priority resource, the team identified relevant indicators of resource condition. In developing the list of indicators and specific measures, the team considered the idealized guidance of Harwell et al. (1999) and particularly Kershner et al. (2011): "Indicators are quantitative biological, chemical, or physical measurements that reflect the structure, composition, or functioning of an ecological system."

For each indicator the team then attempted to define reference conditions against which present conditions could be compared. A reference condition may be a Historic condition (e.g., pre-settlement land cover), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal or objective (e.g., 90% control of an invasive species for at least ten years). In this project, the team mostly used the period of Lewis and Clark's arrival (i.e., generally pre-settlement, 1805–1806) as best as could be determined or surmised.

3.2.3. Ecological Framework

The team reviewed and considered several frameworks for organizing this NRCA, ultimately deciding to generally follow the NPS Inventory and Monitoring Framework (Fancy et al. 2009; Table 3.2).

Table 3.2. Focal natural resources, Chapter 4 section, and indicators for FOVA NRCA, presented within the NPS Ecological Framework (Fancy et al. 2009).

Level 1 Category	Focal Resources	Indicators
Air and Climate	Air Quality (Section 4.1)	• Visibility • Nitrogen and Sulfur Deposition • Ozone • Persistent toxics
	Climate (4.2)	• Temperature • Precipitation
Geology and Soils	–	–
Water	Freshwater Resources (4.3)	• Surface Water Processes (presence/absence of historic wetlands, floodplain integrity) • Groundwater Quality • Groundwater Quantity
Biological Integrity	Native Fauna (4.4)	• Species Diversity • Presence/Absence of Key Species • Presence/Absence of Non-native Species
Ecosystem Pattern and Processes	Sensory Environment (4.5)	• Nighttime light • Noise levels
	Habitat Integrity (4.6)	• Land Cover • Road Density • Impermeable Surfaces • Adjacent Land Uses

3.2.4. Data and Methods

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

In Phase II additional literature searches were conducted and new information, both published and unpublished, obtained when possible. For example, in the period between Phases I and II, the vegetation mapping effort for the park was completed (Copass and Ramm-Granberg 2016), providing extremely valuable new information on vegetation resources.

3.2.5. Condition Assessments

In order to determine an appropriate condition for each resource, the team consulted published reports and analyzed existing data. However, because in many instances data were generally insufficient to provide measured conditions, the team also relied on their own expertise and the expertise of others with prior experience studying natural resources in FOVA. Each assessment was also described in terms of confidence in the conclusions based on available data and expertise.

The described condition was then represented graphically using the symbols presented in Tables 3.3a and 3.3b and according to NPS NRCA guidelines (https://www.nps.gov/orgs/1439/nrca-guidance.htm). A brief descriptive summary of condition is provided at the beginning of each Section in Chapter 4, and a summary for all resources in presented in Chapter 5.

Table 3.3a. Symbols used to indicate condition, trend, and confidence of focal resources.

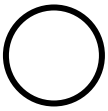
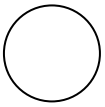
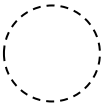
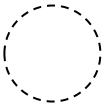
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 3.3b. Example indicator symbols and descriptions.

Symbol Example	Description of Symbol
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

3.2.6. Report Format

Per the NPS NRCA guidelines (https://www.nps.gov/orgs/1439/nrca-guidance.htm), each individual resource assessment in Chapter 4 adheres to the following elements:

Condition Summary

A brief descriptive summary of condition is provided at the beginning of each Section in Chapter 4 using the symbols presented in Tables 3.3a and b and according to NPS NRCA guidelines.

Background

This section describes the resource and why it was selected for inclusion in the project. This section also includes threatened or endangered status if appropriate, biological and ecological descriptions and contexts, and relevance to the NPS mission. If known, threats to the resource or process are included in this section.

Reference Conditions

The measures used to evaluate the condition of the resource are defined here. If no clear science-based measures appear to exist and alternate evaluation methods were utilized, those are also included. The absence of any valid reference is noted here, if necessary.

Data and Methods

This section includes references to both existing data and methodologies as well as specific assessment methods incorporated for the NRCA. NRCAs generally do not include new data collection and are based largely on compilations, syntheses and analyses of pre-existing data for the park's focal resources. These analyses allow the development of a point-in-time profile of a park's resource conditions at the time of the study which can then be used as a baseline for future comparison.

Resource Condition and Trend

This section summarizes what is known about the resource in relation to defined reference conditions.

Level of Confidence

In some cases, very little is known about the status of the resource and/or the conditions that should be used to make the assessment, or both. This section evaluates the level of confidence the team had in making the assessment.

Data Gaps and Research Needs

This section varies in length and scope. In some cases there are clear recommendations for further research or data that would be needed to have a high confidence in making an assessment. For some resources acquiring additional data is either not relevant or far outside the mandate of NPS managers and scientists, and in those situations the section is omitted.

Sources of Expertise

If subject matter experts who are not authors have contributed to the assessment, they will be identified here.

Literature Cited

Each section is followed by a complete cited reference list.

3.3. Project Challenges

This project was intended to result in NRCAs for four regional Historic parks (EBLA, FOVA, LEWI, and SAJH). However, time and resource limitations prevented the completion of the NRCAs concurrently, so each was completed individually. Also, much of the project funding was utilized for graduate students, an approach that NPS has since determined to be largely untenable. The absence of designated natural resource staff at FOVA was also a challenge in regards to obtaining recent data and/or observations on these topics (i.e., cultural resources staff are busy with other projects and/or are unfamiliar with some natural resource subjects).

3.4. Literature Cited

Copass, C., and T. Ramm-Granberg. 2016. Vancouver National Historic Reserve vegetation inventory and mapping project. Natural Resource Report NPS/NCCN/NRR—2016/1128. National Park Service, Fort Collins, Colorado.

Fancy, S.G., Gross, J.E. and Carter, S.L., 2009. Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment*, *151*(1), pp.161–174.

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

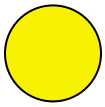
Kershner, J., J.F. Samhouri, C.A. James, and P.S. Levin. 2011. Selecting indicator portfolios for marine species and food webs: a Puget Sound case study. PLoS One, 6(10), p.e25248.

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

Chapter 4. Resource Condition Assessments

4.1. Air Quality

Air quality at FOVA is of moderate concern. The degree of confidence for all indicators is medium because estimates are based on interpolated data from more distant monitors. No trends are apparent.



4.1.1. Background

Visitor enjoyment, the health of park ecosystems and the integrity of cultural resources depend upon clean air. To foster clean air in parks, the NPS monitors air quality, assesses effects on resources, communicates information about air quality issues, advises and consults with regulatory agencies, partners with stakeholders to develop air pollution management strategies, and promotes pollution prevention practices.

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 FOVA, 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 in all areas managed by the NPS. Air quality related values are resources sensitive to air quality, including visibility, lakes, streams, vegetation, soils, and wildlife.

Air Pollution Sources

Most human activities, including manufacturing and industrial processes, agricultural practices, land disturbance and fossil fuel combustion, produce air pollution. FOVA is affected by urban pollution sources in the Portland, Oregon – Vancouver, Washington metropolitan area and by agricultural sources in surrounding rural areas. In addition, air quality in the Pacific Northwest is influenced by pollution generated in Asia that is transported across the Pacific Ocean (National Research Council 2009; Ambrose et al. 2011).

Air Quality Indicators

The air pollutants of primary concern in most NPS areas are sulfur and nitrogen compounds, ground-level ozone, and persistent bioaccumulative toxics.

Sulfur and Nitrogen

The main source of sulfur pollution is coal combustion at power plants and industrial facilities (Figure 4.1.1). Nitrogen compounds, such as nitrogen oxides and ammonia, result primarily from fuel

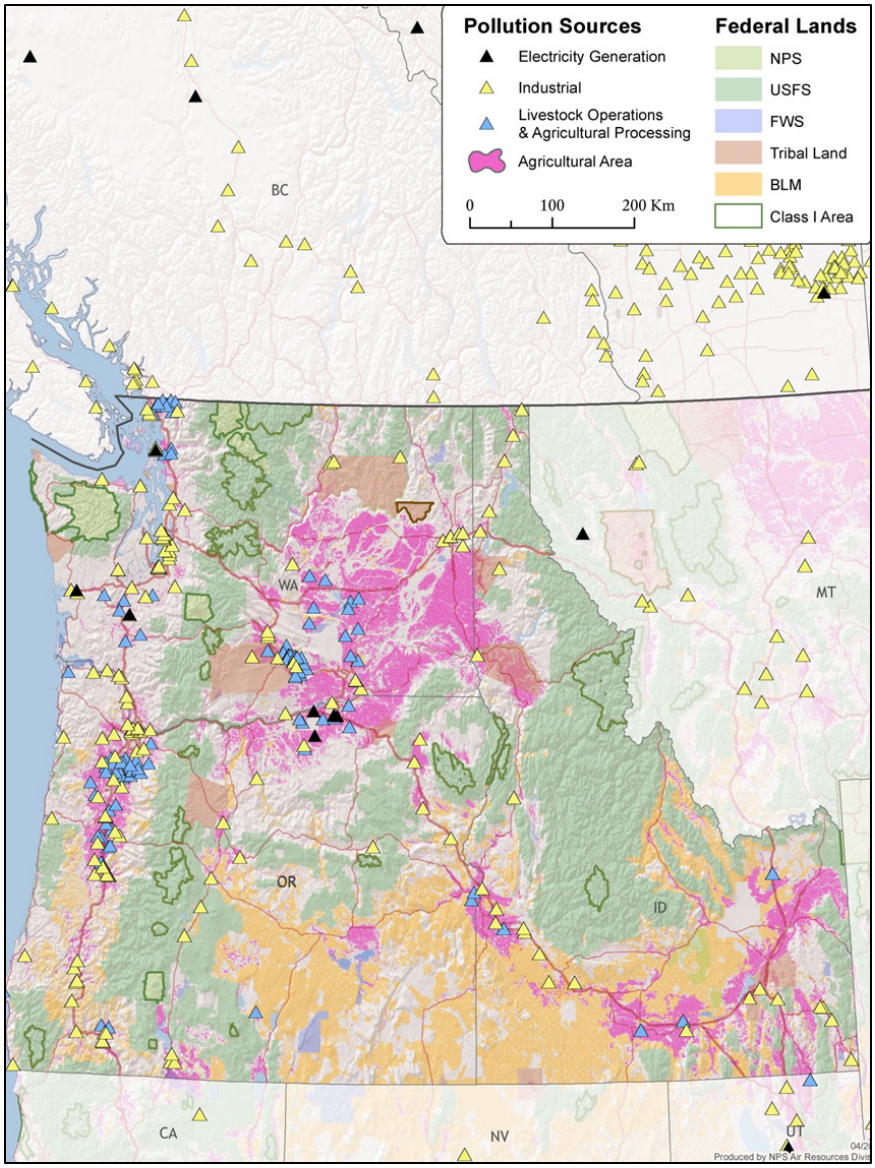


Figure 4.1.1. Public lands and air pollution sources in the Pacific Northwest. Triangles designate point sources that emit greater than 100 tons per year of nitrogen oxides (Cummings et al. 2014).

combustion and agricultural activities. Sulfur and nitrogen pollutants eventually are transferred to the Earth's surface by either wet deposition (e.g., rain, snow, clouds and fog) or dry deposition (e.g., gases and particles). These pollutants change water and soil chemistry, which in turn, affects algae, aquatic invertebrates and soil microorganisms, and can lead to impacts higher in the food chain (Sullivan 2016, Greaver et al. 2012). Deposition can acidify lakes and streams that have low buffering capacity.

Because nitrogen is an essential plant nutrient, nitrogen compounds may cause unwanted fertilization or eutrophication, with subsequent changes in soil nutrient cycling and plant community structure and composition. Fine particles of sulfur and nitrogen compounds, and other pollutants in the atmosphere, absorb or scatter light, causing haze and reducing visibility (Hand et al. 2011).

Ozone

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. 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, causing significant harm to sensitive plant species (EPA 2013). Ozone enters plants through leaf openings called stomata and oxidizes plant tissue, producing visible injury (e.g., stipple and chlorosis) and growth effects (e.g., premature leaf loss; reduced photosynthesis; and reduced leaf, root and total size).

Visibility

Fine particles in the atmosphere absorb or scatter light, causing haze, reducing visibility, and degrading scenic views (Hand et al. 2011). Visibility-impairing particles include anthropogenic pollutants as well as natural compounds like soil and sea salt aerosols. Fine particles are also a significant concern for human health because they lodge deep in the lungs and can cause respiratory problems (Dockery 2009).

Persistent Toxics

Persistent bioaccumulative toxics include heavy metals like mercury (emitted from coal combustion, incinerators and mining processes) and organic compounds such as pesticides and industrial by-products. After mercury is deposited, it can be 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 toxics include impacts on reproductive success, growth, behavior, disease susceptibility and survival (Landers et al. 2008).

4.1.2. Reference Conditions

Visibility

Visibility conditions and trends are expressed in terms of a haze index which correlates incremental changes in haziness to corresponding changes in perceived visibility. The haze index is reported in deciviews (dv). The dv scale is near zero for a pristine atmosphere and increases as visibility degrades.

The NPS Air Resources Division's (ARD) condition assessments are based on estimated average visibility on mid-range days (40th to 60th percentile) minus the estimated natural visibility on mid-range days (NPS 2017). The estimated value is compared to ARD benchmarks (Table 4.1.1). The difference between estimated current conditions and estimated natural visibility represents the human contribution to visibility impairment.

Table 4.1.1. Benchmarks for visibility condition (NPS 2017).

Category	Visibility (dv)
Warrants significant concern	>8
Warrants moderate concern	2–8
Resource is in good condition	<2

Ozone

The ARD's condition assessments for human health risk from ozone are directly related to U.S. EPA's primary National Ambient Air Quality Standard of a 4th-highest daily maximum 8-hour ozone concentration of 70 parts per billion (ppb; NPS 2017). The maximum estimated ozone concentration at a park is compared against ARD benchmarks (Table 4.1.2).

Table 4.1.2. Benchmarks for human health condition for ozone (NPS 2017).

Category	Ozone concentration[1] (ppb)
Warrants significant concern	≥71
Warrants moderate concern	55–70
Resource is in good condition	≤54

[1] Estimated or measured 5-year average of the annual 4th-highest daily maximum 8-hour concentration

Although the primary National Ambient Air Quality Standard is not a good predictor of vegetation response to ozone, EPA has not set a secondary standard that focuses on vegetation. However, in its recent policy assessment of the ozone standards, EPA discussed use of the W126 to assess plant response (EPA 2014). The W126 preferentially weights the higher ozone concentrations most likely to affect plants and sums all of the weighted concentrations during daylight hours. The highest 3-month period that occurs during the growing season is reported in parts per million-hours (ppm-hrs). Based on the information from EPA, research indicates for a W126 value of:

- ≤ 7 ppm-hrs, tree seedling biomass loss is ≤ 2 % per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4–10 % per year in sensitive species.

The ARD compares maximum calculated W126 values at a park to benchmarks tied to the research results to assess vegetation condition related to ozone (NPS 2017, Table 4.1.3).

Table 4.1.3. Benchmarks for vegetation condition for ozone (NPS 2017).

Category	Ozone concentration[1] (ppm-hrs)
Warrants significant concern	>13
Warrants moderate concern	7–13
Resource is in good condition	<7

[1] Estimated or measured 5-year average of the maximum 3-month 12-hour W126 concentration

Nitrogen and sulfur deposition

The ARD's condition assessments for nitrogen and sulfur deposition are based on wet deposition only, rather than total deposition, because the evaluation relies on data collected through the 250-plus National Atmospheric Deposition Program (NADP) monitoring sites. Wet deposition is calculated by multiplying nitrogen or sulfur concentrations in precipitation by normalized precipitation amounts (NPS 2017). A park's maximum calculated deposition is then compared to benchmarks based on the results of studies that related the amount of atmospheric deposition to aquatic ecosystem health (Table 4.1.4). If a park is considered very highly sensitive to acidification or nitrogen nutrient

enrichment relative to other Inventory and Monitoring parks, the condition is adjusted to the next worse condition category.

Table 4.1.4. Benchmarks for nitrogen and sulfur deposition condition (NPS 2017).

Category	Deposition (kilograms hectare^{-1} year^{-1})
Warrants significant concern	>3
Warrants moderate concern	1–3
Resource is in good condition	<1

The ARD bases wet deposition trends on concentrations of nitrogen or sulfur pollutants in precipitation, rather than on deposition amounts of pollutants, so that yearly variations in precipitation amount do not influence trend analyses (NPS 2017). Sulfur wet deposition trends rely on precipitation sulfate concentrations. Nitrogen wet deposition trends use the sum of the molecular weight ratios of nitrate and ammonium concentrations in precipitation.

Persistent Toxics

Risk potential associated with toxics exposure is estimated using literature-based benchmarks for possible effects to fish and wildlife.

4.1.3. Data and Methods

The ARD estimates air quality conditions for visibility, ozone, and nitrogen and sulfur deposition for all parks in the contiguous U.S. using the Inverse Distance Weighting interpolation method and data from national air quality monitoring networks (NPS 2017). If toxics data are available for park biota, they are compared to literature values to assess condition. No toxics data have been reported for FOVA.

4.1.4. Resource Condition and Trend

Sulfur and Nitrogen

Sulfur and nitrogen deposition are not monitored at FOVA. Interpolated 2011–2015 data indicate wet nitrogen and sulfur deposition at the park was 1.3 kilograms hectare^{-1} year^{-1} (kg/ha/yr) and 0.7 kg/ha/yr, respectively (NPS 2019), indicating the park was in the Warrants Moderate Concern category for nitrogen deposition and in the Good Condition category for sulfur deposition. No trend information is available because there are not sufficient on-site or nearby monitoring data. Sullivan (2016) calculated the relative threat from nitrogen and sulfur deposition at all NPS Inventory and Monitoring (I&M) parks. While Sullivan (2016) estimated that ecosystem sensitivity to acidification was very low at FOVA relative to other I&M parks, he estimated sensitivity to nutrient nitrogen enrichment was moderate.

Ozone

Ozone is not monitored at the park. Interpolated 2011–2015 data indicate a 5-year average of the annual 4th-highest daily maximum 8-hour concentration of 56.5 ppb at FOVA (NPS 2019), placing

the park in the Warrants Moderate Concern category. No trend information is available because there are not sufficient on-site or nearby monitoring data.

Interpolated 2011–2015 ozone data indicate the 5-year average of the maximum 3-month 12-hour W126 concentration at FOVA was 2.4 ppm-hrs (NPS 2019), suggesting ozone was not a threat to vegetation at the park. That was consistent with an evaluation by Kohut (2004), who assessed the risk of ozone-induced foliar injury at all I&M parks based on species sensitivity, ozone concentrations, and soil moisture (which influences ozone uptake). He concluded there was low risk of ozone injury at FOVA.

Visibility

Visibility is not monitored at FOVA. Interpolated 2011–2015 data indicate the difference between interpolated average visibility and estimated natural background average visibility was 2.5 dv which Warrants Moderate Concern. No trend information is available because there are not sufficient on-site or nearby monitoring data.

4.1.5. Level of Confidence

Medium because estimates are based on interpolated data from more distant monitors.

4.1.6. Data Gaps and Research Needs

A risk assessment (Sullivan 2016) indicates nitrogen enrichment may be a concern at FOVA. Expanded monitoring could confirm if nitrogen deposition is affecting park air quality related values.

It is not clear how climate change will affect air pollution levels and resources at the park. Changes in precipitation amount and timing could affect deposition of sulfur and nitrogen. Changes in agricultural practices by landowners in southwest Washington and northern Oregon in response to weather patterns or pests could result in additional pesticide deposition at the park. Higher summertime temperatures will also likely lead to higher ozone levels (EPA 2009) in the Pacific Northwest.

4.1.7. Sources of Expertise

For current air quality data and information for this park, please visit the NPS Air Resources Division website at www.nps.gov/subjects/air/index.htm

4.1.8. Literature Cited

Ambrose, J.L., D.R. Reidmiller and D.A. Jaffe. 2011. Causes of high O_3 in the lower free troposphere over the Pacific Northwest as observed at the Mt. Bachelor observatory. Atmospheric Environment 45:5302–5315.

Cummings, T., T. Blett, E. Porter, L. Geiser, R. Graw, J. McMurray, S. Perakis and R. Rochefort. 2014. Thresholds for protecting Pacific Northwest ecosystems from atmospheric deposition of nitrogen: State of knowledge report. Natural Resource Report NPS/PWRO/NRR—2014/823. National Park Service, Fort Collins, Colorado.

Dockery, D.D. 2009. Health effects of particulate air pollution. Annals of Epidemiology 19(4):257–263.

Greaver, T.L., T.J. Sullivan, J.D. Herrick, M.C. Barber, J.S. Baron, B.J. Cosby, M.E. Deerhake, R.L. Dennis, J.B. Dubois, C.L. Goodale, A.T. Herlihy, G.B. Lawrence, L. Liu, J.A. Lynch and K.J. Novak. 2012. Ecological effects of nitrogen and sulfur air pollution in the US: what do we know? Frontiers in Ecology and the Environment 10(7):365–372.

Hand, J.L., S.A. Copeland, D.E. Day, A.M. Dillner, H. Indresand, W.C. Malm, C.E. McDade, C.T. Moore, M.L. Pitchford, B.A. Schichtel and J.G. Watson. 2011. Spatial and seasonal patterns and temporal variability of haze and its constituents in the United States. Report V. ISSN 0737-5352-87. Cooperative Institute for Research in the Environment, Colorado State University. Fort Collins, CO.

Kohut, R. 2004. Assessing the risk of foliar injury from ozone on vegetation in parks in the north coast and cascades network. 32 p. Available at http://www.nature.nps.gov/air/Pubs/pdf/03Risk/nccnO3RiskOct04.pdf.

Landers, D.H., S.L. Simonich, D.A. Jaffe, L.H. Geiser, D.H. Campbell, A.R. Schwindt, C.B. Schreck, M.L. Kent, W.D. Hafner, H.E. Taylor, K.J. Hageman, S. Usenko, L.K. Ackerman, J.E. Schrlau, N.L. Rose, T.F. Blett and M.M. Erway. 2008. The fate, transport, and ecological impacts of airborne contaminants in western national parks (USA). EPA/600/R-07/138. U.S. Environmental Protection Agency, Office of Research and Development, NHEERL, Western Ecology Division, Corvallis, OR.

National Park Service (NPS). 2017. National Park Service Air Quality Analysis Methods. Natural Resource Report NPS/NRSS/ARD/NRR—2017/1490. National Park Service, Fort Collins, Colorado.

NPS. 2019. National Park Service Air Resources Division website. Park Conditions and Trends. https://www.nps.gov/subjects/air/park-conditions-trends.htm

National Research Council. 2009. Global sources of local pollution: an assessment of long-range transport of key air pollutants to and from the United States. The National Academies Press. Washington, DC.

Sullivan, T.J. 2016. Air quality related values (AQRVs) for North Coast and Cascade Network (NCCN) parks: Effects from ozone; visibility reducing particles; and atmospheric deposition of acids, nutrients and toxics. Natural Resource Report NPS/NCCN/NRR-2016/1173. National Park Service, Fort Collins, Colorado.

U.S. Environmental Protection Agency (EPA). 2009. Assessment of the impacts of global change on regional U.S. air quality: a synthesis of climate change impacts on ground-level ozone. An Interim Report of the U.S. EPA Global Change Research Program. EPA/600/R-07/094F. Washington, DC.

EPA. 2013. Integrated Science Assessment of Ozone and Related Photochemical Oxidants (Final Report). EPA/600/R-10/076F. Washington, DC.

EPA. 2014. Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards. EPA-452/R-14-006. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

4.2. Climate

Given that the climate is changing rapidly from conditions to which organisms and biological systems have adapted, the condition of this resource is poor. The trend is declining, though conditions in the PNW are not changing as rapidly or predictably as in many other parts of the US. Confidence in this assessment is medium.



4.2.1. Background

Climate change is affecting natural resources in national parks across the country (Gonzalez 2011, Hansen et al. 2014). Data show that changes in temperature and precipitation are accelerating (Monahan and Fisichelli 2014), and all models predict future increases in the rates of change if CO_2 emissions are not significantly and rapidly reduced (Weaver et al. 2007, Ashfaq et al. 2013, IPCC 2014). Climate change is a strong force that will require species to respond rapidly to environmental conditions to which they are largely unadapted (Burns et al. 2003, Saunders et al. 2007, NPS 2010, Whittington et al. 2013, Corlett and Westcott 2013, Quintero and Wiens 2013).

To protect and preserve resources in this scenario will require immense effort, and the NPS recognizes this challenge (e.g., van Riper et al. 2014). Environmental properties that will be particularly affected by climate change and that have strong influence on natural resources and ecological processes in FOVA are average annual and seasonal temperatures. This report identifies observed and predicted impacts to resource groups from climate change at FOVA in general terms only.

4.2.2. Reference Conditions

Given the realities of climate change it is not possible to determine a reference condition for climate at FOVA. Climate effects are global, and outside of promoting sustainable park operations and educating visitors, NPS resource managers can do little to alter present or future climate effects. An assessment could be made of the extent of change compared to historic climate conditions or to predicted change, but such efforts are beyond the scope of this report. This assessment will present general observations of current and predicted climate conditions as reported by other sources.

4.2.3. Data and Methods

As part of the UW assessment, an analysis was made of changes in daily mean temperatures at FOVA from 1977 to 2006 using the publicly available CRU TS 2.1 monthly climate dataset (Mitchell and Jones 2005; http://www.cru.uea.ac.uk/; Figure 4.2.1). This dataset spans the period from 1901–2002, and covers the global land surface at a 0.5-degree spatial resolution (i.e., grid cells are approximately 50 x 50 km, depending on latitude). Climate data were downscaled to 4-km resolution by the PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Mapping Program (Gibson et al. 2002; http://www.prism.oregonstate.edu/). Data were then downscaled to assess trends in mean annual temperatures and seasonal temperatures (winter: December–February; spring: March–May; summer: June–August; autumn: September–November).

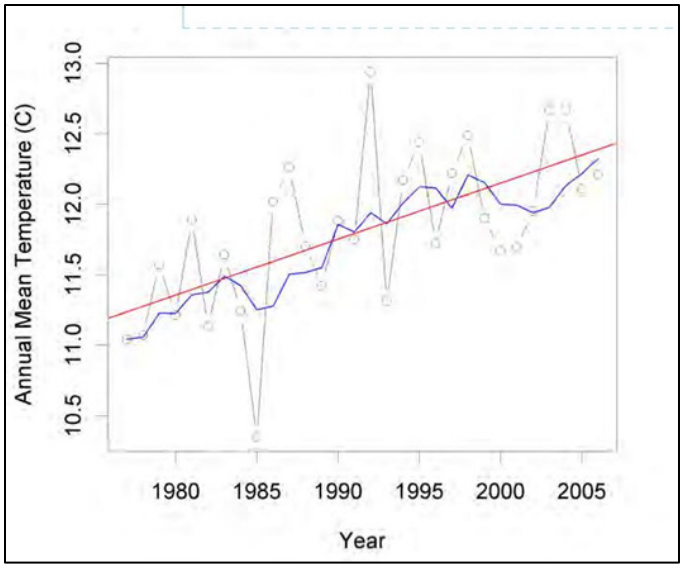


Figure 4.2.1. Trends in average annual temperature at Fort Vancouver from 1977–2006. Circles are average annual temperatures, the blue line is a five-year moving average, and the red line is a trend line fit with restricted maximum likelihood estimation assuming an AR1 time-series pattern in the residuals. Prepared for this report using methods described in Section 4.2.3.

Trends were analyzed using restricted maximum likelihood estimation assuming an AR1 time-series pattern in the residuals. Calculations were done using a generalized least squares method of the nlme (Linear and Nonlinear Mixed Effects Models) contributed package to the R statistical software (Pinheiro et al. 2008, R-project: https://www.r-project.org/). The trend analysis was run for every grid cell that overlapped the park, and the trends were then averaged across all of these grid cells. All analyses were done using ClimateWizard, a tool jointly developed by the UW, University of Southern Mississippi, and The Nature Conservancy (TNC; www.climatewizard.org/; Girvetz et al. 2009).

The potential future threat of climate change was assessed using climate simulations from 16 different general circulation models (GCMs) run for a mid-high (SRES A2) emissions scenario. These climate simulations were downscaled to a 12-km grid (Maurer et al. 2007), and projected changes in average annual temperature, total annual precipitation, and seasonal precipitation were summarized. Climatic conditions averaged over a Historic thirty-year period (1961–1990) were compared to those averaged from 2070–2099. The original climate projections were taken from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset, downscaled by the Lawrence Livermore National Laboratory (LLNL), Reclamation, and Santa Clara University, and are stored and served at the LLNL Green Data Oasis.

The NCCN network does not monitor climate at FOVA.

4.2.4. Resource Condition and Trend (Climate Change)

In 2014, the Intergovernmental Panel on Climate Change (IPCC) released its most recent assessment of the present condition and future of the world's climate. This report concluded that average

temperatures in the PNW will increase by 2.0 °F (1.1 °C) by the 2020s, 3.2 °F (1.8 °C) by the 2040s, and 5.3 °F (2.9 °C) by the 2080s.

Temperature

For the PNW region, temperatures warmed by approximately 0.7 °C (1.3 °F) between 1895–2011, and the frequency of high nighttime minimum temperatures increased (Dalton et al. 2013). From 1977–2006, average annual temperatures increased at FOVA at a rate of 0.04 °C per year (Fig. 4.2.1, $P < 0.01$). Average winter and summer temperatures increased at a rate of 0.05 °C per year ($P < 0.01$). Trends in spring and autumn temperatures were not significant ($P > 0.05$). Temperatures at FOVA are projected to rise by 1.4 °C to 4.0 °C (median of 3.3 °C) between 1961–1990 and 2070–2099.

Precipitation

Precipitation patterns and seasonal averages have generally not changed in the past several decades. Changes in total annual precipitation are projected to range from a decrease of 10.1% to an increase of 23.2% (the median is an increase of 7.2%; Dalton et al. 2013). The general trend towards an increase in total annual precipitation is driven by increases in precipitation in winter (median increase of 12.2%), spring (median increase of 5.1%), and fall (median increase of 3.1%). In contrast, the change in summer precipitation is projected to range from an increase of 3.5% to a decrease of 55.5% (median decrease of 38.1%).

4.2.5. Level of Confidence

Medium to High

4.2.6. Literature Cited

Burns, C. E., K.M. Johnston, and O. J. Schmitz. 2003. Global climate change and mammalian species diversity in US national parks. Proceedings of the National Academy of Sciences 100:11474–11477.

Corlett, R.T. and D.A. Westcott. 2013. Will plant movements keep up with climate change? Trends in Ecology and Evolution 28:482–488.

Dalton, M.M., P.W. Mote, and A.K. Snover [Eds.]. 2013. Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Washington, DC: Island Press.

Gibson, W.P., C. Daly, T. Kittel, D. Nychka, C. Johns, N. Rosenbloom, A. McNab, and G. Taylor. 2002. Development of a 103-year high-resolution climate data set for the conterminous United States. AMS Conf. on Applied Climatology, Portland, OR, May 13–16, 181–183.

Girvetz E.H., C. Zganjar, G.T. Raber, E.P. Maurer, P. Kareiva, and J.J. Lawler. 2009. Applied Climate-Change Analysis: The Climate Wizard Tool. PLoS ONE 4(12):e8320. https://doi.org/10.1371/journal.pone.0008320

Gonzalez, P. 2011. Climate change impacts and carbon in U.S. national parks. 2011. Park Science 28:10–15.

Hansen, A.J., N. Piekielek, C. Davis, J. Haas, D.M. Throbald, J.E. Gross, W.B. Monahan, T. Olliff and S.W. Running. 2014. Exposure of U.S. National Parks to land use and climate change 1900–2100. Ecol. Appl. 24:484–502.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II, Fifth Assessment Report, Cambridge University Press, Cambridge, UK.

Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy. 2007. Fine-resolution climate projections enhance regional climate change impact studies. Eos Trans. AGU 88:504.

Moetasim Ashfaq, S. Ghosh, S.C. Kao, L.C. Bowling, P.Mote, D. Touma, S.A. Rauscher, N.S. Diffenbaugh. Near-term acceleration of hydroclimatic change in the western US. J. Geophys. Res. Atmos., 118(2013), pp. 10676–10693.

Monahan, W.B. and N.A. Fisichelli. 2014. Climate exposure of US national parks in a new era of change. PLoS ONE 9(7): e101302. doi:10.1371/journal.pone.0101302. Available from http://dx.plos.org/10.1371/journal.pone.0101302.

National Park Service (NPS). 2010. National Park Service Climate Change Response Strategy. National Park Service Climate Change Response Program, Fort Collins, Colorado.

Pinheiro, J., D. Bates, S. DebRoy, D. Sarkar, and the R Core team. 2008. nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1–90.

Quintero, I. and J.J. Wiens. 2013. Rates of projected climate change dramatically exceed past rates of climatic niche evolution among vertebrate species. Ecology Letters 16:1095–1103.

Saunders, S., T. Easley, J.A. Logan, T. Spencer, and J.B. Jarvis. 2007. The Challenges of Climate Change. George Wright Forum 24:41–81.

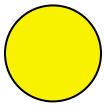
van Riper III, C ., J.R. Hatten, J.T. Giermakowski, D. Mattson, J.A. Holmes, M.J. Johnson, E.M. Nowak, K. Ironside, M. Peters, P. Heinrich, K.L. Coles, C. Truettner and C.R. Schwalbe. 2014. Projecting climate effects on birds and reptiles of the Southwestern United States. U .S. Geological Survey Open-File Report 2014–1050; http://dx.doi.org/1 0.3133/ofr2 0141050.

Weaver, A.J., K. Zickfeld, A. Montenegro and M. Eby. 2007. Long term climate implications of 2050 emission reduction targets. Geophys. Res. Lett. 34:L19703.

Whittington, T., S.T. Olliff and P. Benjamin, eds. 2013. Climate Change Action Plan Report: Intermountain Region. National Park Service, Fort Collins, Colorado.

4.3. Freshwater Resources (Surface Hydrology, Water Quality, Groundwater Quantity)

The site has lost most of its historic wetlands and floodplain processes are non-functional. Groundwater quality is of concern but improving. Groundwater quantity is of concern given projections for future use of the aquifer. Confidence in hydrologic changes over time and groundwater conditions is medium.



4.3.1. Background

Wetlands and Floodplain

At the time of the establishment of the HBC, the site of FOVA was characterized largely by wet meadows and seasonal standing water between the upland forests and the river (Taylor and Erigerio 1992, Jones and Jones 2005). As the outpost developed and more people arrived, most of these sites were filled in to be suitable for cultivation and construction (Taylor and Erigerio 1992).

The site was also situated in an active floodplain; when the Columbia River overtopped its banks water would flow across lands adjacent to the river. (Due to the presence of berms constructed to protect the railroad and SR 14 floods are now a rare occurrence.) Rivers and adjacent lands, when unfragmented from each other, are unique and dynamic lateral ecosystems (Gregory et al. 1991). Periodic flooding delivers important nutrients to riparian ecosystems and is often necessary for germination and survival of flood-adapted riparian plant species. For example, cottonwoods along the Columbia River require frequent conditions of high soil moisture to facilitate reproduction and growth (Braatne et al. 2007, Lytle and Merritt 2004, Williams and Cooper 2005). Past floods have been recorded at over 32 ft above average water levels (Minor 2011).

Surface Water Quality

Surface waters that may impact FOVA resources are limited to the Columbia River and any standing water that may periodically be present. Water quality (WQ) of the sites is generally discussed in terms of human health, but because all drinking water at FOVA is obtained from groundwater and there are minimal extant wetland resources, surface water quality here may be less of a management concern than in many NPS locations. However, many human sources such as wastewater discharge, stormwater runoff, recreation and atmospheric deposition can negatively affect WQ at FOVA (NPS 2000).

Groundwater Quantity

All Vancouver residents obtain their drinking water from groundwater aquifers. The large, unconsolidated Troutdale aquifer is present under much of Vancouver and supplies nearly all municipal supplies (Morgan and McFarland 1996). In the area of FOVA, the aquifer consists of two primary hydrogeologic units; the deeper unit is the Troutdale gravel aquifer, and above that is an unconsolidated sedimentary aquifer of gravel and silt (Mundorff 1964, Orzol and Truni 1999). Primary recharge to the groundwater that feeds Vancouver occurs from precipitation (~87%; Orzol and Truni 1999). Drawdown of the aquifers below Vancouver and Portland is between 13 and 55

mgd (million gallons/day) depending on precipitation (Koreny and Fish. 2007). FOVA obtains irrigation water from a well connected to these aquifers (NPS 2008).

4.3.2. Reference Conditions

Wetlands/Floodplain

Natural hydrological processes should be functioning. For example, if periodic flood events on the Columbia River occurred without restriction such floods would contribute nutrients to floodplain areas that historically included most of FOVA. Historic information shows that there existed several natural wetlands on what is now FOVA, areas that have been largely altered by filling for farmland by early settlers, construction of the airfield and other practices. In an ecologically intact landscape these wetlands would be present and support associated wildlife and vegetation.

Surface Water Quality

The methods and metrics used to assess surface water quality by various agencies are too numerous to discuss here, but are included in the referenced sources as noted. Good summaries of NPS methods are provided in Rawhouser et al. (2012) and Conway-Cranos et al. (2016). Because water quality is not monitored at FOVA and very little is known no reference conditions are presented.

Groundwater Quantity

Determining a reference condition for groundwater quantity as a FOVA resource is problematic given the unconstrained nature of the aquifer and because FOVA uses a relatively minor portion of the water present in the aquifer. Some recent studies have suggested that to maintain ecological integrity groundwater depletion over time should not exceed 10% (de Graaf et al. 2017, Gleeson and Richter 2018).

4.3.3. Data and Methods

Wetlands and Floodplains

An Environmental Assessment was completed for Pearson Field airport improvements (CWE 2018) that includes an investigation of floodplain and water quality impacts. Copass and Ramm-Granberg (2016) classified and mapped all vegetation types at FOVA but found no locations warranting classification as wetlands.

Surface Water Quality

In 2000, NPS conducted a baseline water quality survey for FOVA (NPS 2000). Methods are described therein, however, only two WQ monitoring stations for which they reported data are located on the Washington side of the Columbia River near FOVA and neither are within the park (NPS 2000). Also, because it appears that neither of the sites referred to in that document are currently collecting data and the data are nearly 20 years old, those results will not be included in this assessment.

FOVA is in the Water Resource Inventory Area (WRIA) 28 (“Salmon-Washougal”). The only site on the river upstream from FOVA is the DoE site #28A100 (DoE website). This site appears to have stopped collecting data in 2007 and there do not appear to be any other sites monitored by the State in Clark County.

Groundwater Quantity

As far as is known there is no monitoring by NPS of well levels at the Reserve.

4.3.4. Resource Condition and Trend

Wetlands/Floodplain

Natural floodplain processes have been highly altered, primarily due to significant modifications that have been made to the Columbia River shoreline. As mentioned in Chapter 2, much of the area of FOVA was historically wet much of the year and flooded periodically. Nearly all of the wetland areas have been filled in over time to create acreage usable for building and planting, and most floods are now managed by human alterations to the river shoreline as well as numerous upland diversions.

Surface Water Quality

Very little is known regarding the condition of surface waters within FOVA. Because all stormwater flows directly into the Columbia River without treatment (T. Cumming pers. comm., 2017), any chemicals used on FOVA vegetation such as herbicides, pesticides, or fertilizers will ultimately be introduced to the Columbia system. Natural hydrologic processes, i.e., unaltered flows from uplands to the river, are highly altered but have been so since the times of early settlement.

Groundwater Quantity

Likewise, little is known regarding groundwater processes in the FOVA region as they relate to NPS water uses, though it is likely that the amount of water that NPS uses for irrigation is only a very small portion of the total amount extracted from the aquifer.

4.3.5. Level of Confidence

Medium

4.3.6. Data Gaps and Research Needs

Per capita water demand is expected to increase in coming decades with higher temperatures (Parandvash and Chang 2016). If one is not in place, FOVA managers may wish to develop a water management plan to determine future water needs and assure supplies are adequate in coming years (Section 4.3).

4.3.7. Literature Cited

Braatne, J.H., R. Jamieson, K.M. Gill, and S.B. Rood. 2007. Instream flows and the decline of riparian cottonwoods along the Yakima River, Washington, USA. River Research and Applications 23:247–267.

Century West Engineering (CWE). 2018. Pearson Field Airport, Airport Improvements – Draft Environmental Impact Statement. Prepared for City of Vancouver, Washington, by CWE, Portland, OR.

Conway-Cranos, L. T. Klinter and M. Ramirez. 2016. Draft Report, Synthesis of Water Quality Data for Pacific Northwest National Parks. University of Washington, Seattle, WA.

Copass, C., and T. Ramm-Granberg. 2016. Vancouver National Historic Reserve vegetation inventory and mapping project. Natural Resource Report NPS/NCCN/NRR—2016/1128. National Park Service, Fort Collins, Colorado.

de Graaf, I.E., R.L. van Beek, T. Gleeson, N. Moosdorf, O. Schmitz, E.H. Sutanudjaja, and M.F. Bierkens. 2017. A global-scale two-layer transient groundwater model: Development and application to groundwater depletion. Advances in Water Resources 102:53–67.

Gleeson, T. and B. Richter. 2018. How much groundwater can we pump and protect environmental flows through time? Presumptive standards for conjunctive management of aquifers and rivers. River Research and Applications 34:83–92.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41:540–551.

Jones and Jones. 2005. Vancouver National Historic Reserve Cultural Landscape Report. Seattle, WA.

Koreny, J.S. and T.T. Fish. 2007. Utilizing induced recharge for regional aquifer management. JAWRA Journal of the American Water Resources Association 37:453–466.

Lytle, D.A. and D.M. Merritt. 2004. Hydrologic regimes and riparian forests: a structured population model for cottonwood. Ecology 85:2493–2503.

Minor, R. 2011. Interstate 5 Columbia River Crossing: Archaeology Technical Report for the Final Environmental Impact Statement. Heritage Research Associates, Inc., Eugene, OR.

Morgan, D.S. and W.D. McFarland. 1996. Simulation analysis of the ground-water flow system in the Portland Basin, Oregon and Washington (No. 2470-B). Geological Survey (US).

Mundorff, M.J. 1964. Geology and ground-water conditions of Clark County Washington, with a description of a major alluvial aquifer along the Columbia River (No. 1600). USGPO,

National Park Service (NPS). 2000. Baseline Water Quality Data Inventory and Analysis, Fort Vancouver National Historic Site. Technical Report NPS/NRWRD/NRTR-99/238. National Park Service, Water Resources Division. Fort Collins, Colorado.

NPS. 2008. General Management Plan 2003 and McLoughlin House Unit Management Plan 2007. Fort Vancouver National Historic Site, Vancouver, WA.

Orzol, L.L. and M. Truini. 1999. Evaluation of factors that influence estimated zones of transport for six municipal wells in Clark County, Washington (No. 97-4224). US Geological Survey.

Parandvash, G.H. and H. Chang. 2016. Analysis of long-term climate change on per capita water demand in urban versus suburban areas in the Portland metropolitan area, USA. Journal of Hydrology 538:574–586.

Rawhouser, A. K., L. P. Grace, R. A. Lofgren, R. S. Glesne, J. R Boetsch, C. A. Welch, B. A. Samora, P. Crain, and R. E. Holmes. 2012. North Coast and Cascades Network water quality monitoring protocol. Natural Resource Report NPS/NCCN/NRR—2012/571. National Park Service, Fort Collins, Colorado.

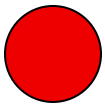
Taylor, T.A. and P.C. Erigero. 1992. Cultural Landscape Report, Vols I and II. National Park Service, Seattle, WA. https://www.nps.gov/parkhistory/online_books/fova/clr/clr.htm

Williams, C.A., and D.J. Cooper. 2005. Mechanisms of riparian cottonwood decline along regulated rivers. Ecosystems 8:382–395.

DoE. 2018. Environmental Information Management System website (https://fortress.wa.gov/ecy/eimreporting/Detail/Detail.aspx?DetailType=Location&SystemStationId=48828213).

4.4. Native Fauna

The faunal resource of FOVA bears little resemblance to historic conditions. In particular, several mammal species have been extirpated and non-native species are present. There appears little likelihood that this resource can be recovered, however, restoration could facilitate the return of some species. Trends are unknown and confidence is high that species have been lost, but low in relation to current conditions given the near-absence of recent surveys.



4.4.1. Background

Surrounding urbanization and a predominance of non-native vegetation result in very little available wildlife habitat at FOVA (NPS 2008, Caywood and Owens 2010, Copass and Ramm-Granberg 2016). Historically the area was rich in wildlife (Taylor and Erigerio 1992), and early naturalists often visited this area specifically for the opportunities to study and document animal species native to the PNW (Hall 1932, Jobanek and Marshall 1992). This assessment reviews the current wildlife resource in relation to historic conditions and the potential for wildlife habitat recovery; Chapter 5 discusses the value of urban open space for wildlife species.

Invertebrates, Amphibians and Reptiles

Invertebrates are important community components that pollinate, transport nutrients, serve as critical food resources particularly for fish and birds, and consume detritus (Cummins and Klug 1979, Hocking and Reimchen 2002). Invertebrates (particularly mollusks and arthropods), were abundant and diverse at the time of settlement (Niwa et al. 2001). Amphibians are relatively abundant in PNW forests and riparian habitats (Olson et al. 2007), but are declining worldwide (Tilghman et al. 2012), and are probably now rare at FOVA. Very little is known about historic reptile diversity but several snake species are currently present.

Landbirds

The natural diversity of vegetation and the presence of multiple habitat types (mountains, uplands, freshwater) facilitate high bird diversity in non-developed areas of the Lower Columbia. FOVA is centered within several Important Bird Areas (IBA; www.birdlife.org) including Vancouver Lake (Clark County), Steigerwald National Wildlife Refuge (NWR), Government Island (Washington State Parks), Smith and Bybee Wetlands (Portland Metro), and Sauvie Island Wildlife Area (Oregon Department of Fish and Wildlife [ODFW]).

Mammals

When Lewis and Clark navigated down the Columbia in the region of FOVA, large mammal species were apparently relatively uncommon (Laliberte and Ripple 2003). Lewis and Clark did not record elk, antelope, bison, bighorn sheep, or wolves in the Columbia Basin though all these species were encountered on the east side of the Cascades. Some authors suggest that the presence of Native Americans as hunters had already reduced at least some of these populations prior to Lewis and Clark's arrival (Laliberte and Ripple 2003).

Bats

Because most North American bat species require foraging areas near freshwater and associated insect resources, bats are a particular group of native animals that may be abundant in and near FOVA (Glendell and Vaughan 2002), particularly given the many bridges across the Columbia and other streams and rivers under which they often roost (Hayes and Wiles 2013). However, bats also require roosting habitat such as trees and caves that may be uncommon in urban areas (Hayes and Wiles 2013), and bats are often unwelcome when they roost in historic buildings or those used by humans (Howard 2009, Fagan et al. 2018; Chapter 5). All bats are protected in Washington State unless they inhabit human structures (Hayes and Wiles 2013).

Animal Species of Concern

Very few animal species of concern, if any, are present in FOVA, though there are several that are present regionally (Table 4.4.1). Fish are not included; birds of concern are identified in Table 4.4.2).

Table 4.4.1. Species of concern that may be present in or near FOVA (OBIC (2016), OCS (2016), and WDFW (2013)).

Common Name	Scientific Name
California floater (mussel)[2]	*Anodonta californiensis*
Columbia pebblesnail[2]	*Fluminicola columbiana*
Western toad[2]	*Bufo boreas*
Townsend's big-eared bat[2]	*Corynorhinus townsendii*
Long-legged myotis[4]	*Myotis volans*

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern;

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.

Table 4.4.2. Endangered, Threatened, Sensitive or Candidate Bird Species in Fort Vancouver National Historic Site (compiled from multiple sources, primarily Kuntz 2005 and CWE 2018).

Common Name	Scientific Name	Federal & State Status
Purple Martin	*Progne subis*	SC
Merlin	*Falco columbarius*	SC
Western Grebe	*Aechmophorus occidentalis*	SC
Vaux's Swift	*Chaetura vauxi*	SC
Common Loon	*Gavia immer*	SS
Bald Eagle	*Haliaeetus leucophalus*	FCo/SS
Peregrine Falcon	*Falco peregrinus*	FCo/SS

FT – Federally Threatened; FCo – Federal Species of Concern; SC – State Species of Concern;

SS – State Sensitive Species; ST – State Threatened Species.

Threats to Native Fauna

Aside from the absence of habitat patches and patch connectivity (Sections 4.5 and 4.6), other impacts of urbanization that reduce native vertebrate abundance and diversity are non-native predators (primarily cats, both feral and outdoor pets, and off-leash dogs (Baker et al. 2005). The urban setting of FOVA also leads to many human-wildlife conflicts. Of particular concern are the efforts made to reduce bird strike risks at Pearson Airfield and any NPS pest control measures that may have negative impacts on native wildlife. This topic is discussed further in Chapter 5.

4.4.2. Reference Conditions

There are no Historic records for invertebrates, amphibians, reptiles, or bats of the Portland-Vancouver region as far as is known. Townsend constructed a bird list of the lower Columbia River and reported that in 1836 (presented in Jobanek and Marshall 2003). Taylor and Erigerio (1992) provide a thorough compilation of vegetation conditions throughout much of the period of interest of FOVA, and some interpretation of wildlife habitat can be made from those descriptions. Early naturalists collected many specimens of mammals during the early period of settlement. For example pocket gophers (*Thomomys dougalsii douglasii*) were collected by Douglas in around 1825 (Hall 1932) and were reported as garden pests, and between 1834–1836 Townsend and Nuttall collected Townsends shrew mole (*Scalops townsendii*) at or near Fort Vancouver and a wolf (*Lupus gigas*) a few miles away. Peale collected a meadow mouse (*Arvicola occidentalis*) likely near the fort sometime prior to 1858 (Hall 1932).

4.4.3. Data and Methods

Very few recent surveys have been conducted for wildlife in FOVA. The only invertebrate survey that is available is by Adams (2012) who conducted a survey specifically of orthopterans (grasshoppers, crickets, katydids and locusts) primarily for their archeological implications. As far as is known there have been no other invertebrate surveys. Amphibian surveys were conducted in August of 2002 and April of 2003, but only at two sites in FOVA (Samora et al. 2013). Hennings and Edge developed a bird list from an urban/riparian study in Portland, OR (Hennings and Edge 2003), and Kuntz II (2005) compiled a bird list for FOVA focused on birds that are assumed residents or breeders. In 2002 a small mammal survey was conducted for four nights in June, and a bat survey on one night in August (Scharbel et al. 2012. Methods are described therein but generally consisted of live-trapping for small mammals and mist-netting for bats. Larger animals were noted when observed.

In May of 2016 a Bioblitz (https://www.nationalgeographic.org/projects/bioblitz/) was conducted in and around FOVA with results available at https://www.inaturalist.org/projects/2016-national-parks-bioblitz-fort-vancouver.

4.4.4. Resource Condition and Trend

Invertebrates, Amphibians and Reptiles

Very little is currently known about the status of invertebrates in FOVA, other than the results of Adams' surveys (Table 4.4.3a–c). Similarly very little is known regarding the diversity or presence of reptiles or amphibians. Amphibian species that were expected but not found by Samora et al. (2013) were Ensatina (*Ensatina eschscholtzii*), western red-backed salamander (*Plethodon*

vehiculum), northern red-legged frog (*Rana aurora*), Oregon spotted frog (*Rana pretiosa*), American bullfrog (*Lithobates catesbeianus*), Pacific treefrog (*Pseudacris regilla*), and western toad (*Anaxyrus boreas*).

Table 4.4.3a. Preliminary insect list for FOVA from Adams 2012: Subphylum Chelicerata, Class Arachnida, Order Aranae.

Family	**Species**
Araneidae (Spiders)	*Araneus diadematus*
Salticidae (Jumping spiders)	*Chalcoscirtus* sp.
	Sitticus sp.
Tetragnathidae (Long-jawed orb-weavers)	*Pachygnatha* sp.
Theridiidae (Cobweb spiders)	*Steatoda grossa* (False Black Widow)
Dysderidae	*Dysdera crocata*
Pholicidae (Cellar spiders)	*Pholcus phalangioides*
Antrodiaetidae (Folding door spiders)	*Antrodiaetus* sp.

Table 4.4.3b. Preliminary insect list for FOVA from Adams 2012: Subphylum Hexapoda, Class Collembola (Springtails).

Order	**Family**	**Species**
Hypogastruridae	Unidentified	Unidentified
Sminthuridae	Unidentified	Unidentified

Table 4.4.3c. Preliminary insect list for FOVA from Adams 2012: Subphylum Hexapoda, Class Insecta.

Order	**Family**	**Species**
Emphemeroptera (Mayflies)	Ameletidae (Comb-mounted minnow mayflies)	*Ameletus* sp.
Odonata (Dragonflies, Damselflies)	Aeshinidae (Darners)	*Rhionaeshna multicolor*
	Coenagrionidae (Narrow-winged damselflies)	*Argia* sp. and *Enallagma* sp.
Dermaptera (Earwigs)	Forficulidae	*Forficula auricularia*
Orthoptera (Grasshoppers, Crickets, Katydids)	Acrididae (Short-horned grasshoppers)	*Chorthuippus curtipennis and Melanoplus femurrubrum*
	Rhaphidophoridae (Camel crickets)	*Ceuthophilus* sp.
	Tettigoniidae (Katydids)	*Tessellana tessellata*
Isoptera (Termites)	Termopsidae (Dampwood termites)	*Zootermopsis nevadensis*

Table 4.4.3c (continued). Preliminary insect list for FOVA from Adams 2012: Subphylum Hexapoda, Class Insecta.

Order	Family	Species
Hemiptera (True bugs)	Cercopidae (Frog hoppers)	Unidentified, old world introduced sp.
	Miridae (Plant bugs)	*Megaloceroea recticornis*
	Miridae (Plant bugs)	*Tropidosteptes* sp.
	Nabidae (Damsel bugs)	*Nabis* sp.
	Reduviidae (Assassin bugs)	*Reduvius personatus*
	Berytidae (Stilt bugs)	*Neoneides muticus*
	Geogoridae (Big-eyed bugs)	*Geocoris bullatus*
	Geogoridae (Big-eyed bugs)	*Geocoris pallens*
	Alydidae (Broad-headed bugs)	*Alydus eurinus*
	Alydidae (Broad-headed bugs)	*Alydus* sp.
	Coreidae (Leaf-footed bugs)	*Ceraleptus pacificus*
	Coreidae (Leaf-footed bugs)	*Leptoglossus occidentalis*
	Pentatomidae (Stink bugs)	*Chinavia hilaris*
	Pentatomidae (Stink bugs)	*Thyanta pallidovirens*
	Scutelleridae (Shield-backed bugs)	cf. *Eurygaster* sp.
	Scutelleridae (Shield-backed bugs)	*Homaemus* sp.
Neuroptera (Lacewings)	Chrysopidae (Green lacewings)	*Chrysopa oculata*
Coleoptera (Beetles)	Carabidae (Ground beetles)	*Amara* sp.
	Carabidae (Ground beetles)	*Broscodera insignis*
	Carabidae (Ground beetles)	*Carabus nemoralis*
	Carabidae (Ground beetles)	*Calathus fuscipes*
	Carabidae (Ground beetles)	*Harpalus affinis*
	Carabidae (Ground beetles)	*Pterostichus* sp.
	Carabidae (Ground beetles)	*Scaphinotus marginatus*
	Dytiscidae (Predaceous diving beetles)	*Rhantus* cf. *gutticollis*
	Anobiidae (Deathwatch beetles)	*Priobium punctatum*
	Dermestidae (Skin beetles, carpet beetles)	*Attagenus unicolor*
	Cerambycidae (Longhorn beetles)	*Judolia instabilis*
	Cerambycidae (Longhorn beetles)	*Rusticoclytus nauticus* (fka *Xylotrechus nauticus*)
	Chrysomelidae (Leaf beetles)	*Chrysolina (Hypericia) hyperici*
	Chrysomelidae (Leaf beetles)	cf. *Stator pruininus* (formerly under BRUCHIDAE, need to verify ID)

Table 4.4.3c (continued). Preliminary insect list for FOVA from Adams 2012: Subphylum Hexapoda, Class Insecta.

Order	Family	Species
Coleoptera (Beetles) (continued)	Coccinelidae (Lady beetles)	*Coccinella septempunctata*
	Coccinelidae (Lady beetles)	*Mulsantina picta*
	Latridiidae (Minute brown scavenger beetles)	*Cartodere nodifer* <Specimen currently missing>
	Latridiidae (Minute brown scavenger beetles)	*Latridius* sp.
	Phalacridae (Shining flower beetles)	*Olibrus* sp.
	Attelabidae (Leaf rolling weevils	*Merhynchites wickhami*
	Curculionidae (Snout beetles, Weevils)	*Nemocestes* sp.
	Curculionidae (Snout beetles, Weevils)	*Otiorhynchus sulcatus*
	Buprestidae (Metallic wood-boring beetles)	*Buprestis aurulenta*
	Cantharidae (Soldier beetles)	*Chauliognathus* sp.
	Hydrophilidae (Water scavenger beetles)	*Hydrophilus triangularis*
	Silphidae (Carrion beetles)	*Nicrophorous marginatus*
	Silphidae (Carrion beetles)	*Thanatophilus lapponicus*
	Staphylinidae (Rove beetles)	*Philonthus* sp.
Hymenoptera (Wasps, bees ants)	Apidae	*Apis mellifera*
	Halictidae (Sweet bees)	*Agapostemon texanus*
	Megachilidae (Mason bees, Leaf-cutter bees)	cf. *Coelioxys* sp.
	Sphecidae (Thread-waisted wasps)	*Chalybion californicum*
	Formicidae (Ants)	*Formica* sp.
	Formicidae (Ants)	*Lasius* sp.
	Formicidae (Ants)	*Leptothorax* sp.
	Formicidae (Ants)	*Pogonomyrmex* sp.
Lepidoptera (Butterflies, Moths)	Noctuidae (Owlet moths)	*Lasionycta perplexa*
Siphonaptera (Fleas)	Ceratophyllidae	*Aetheca wagneri*
Diptera (Flies)	Bibionidae (March flies)	*Bibio* sp.
	Tipulidae (Crane flies)	*Tipula* sp.
	Asilidae (Robber flies)	*Neoitamus brevicornus*
	Bombylliidae (Bee flies)	cf. *Oestranthrax* sp.
	Calliphoridae (Blow flies)	*Calliphora vicina*

Table 4.4.3c (continued). Preliminary insect list for FOVA from Adams 2012: Subphylum Hexapoda, Class Insecta.

Order	Family	Species
Diptera (Flies) (continued)	Dolichopodidae (Long-legged flies)	cf. *Scellus* sp.
	Ephydridae (Shore flies)	*Ochthera* sp.
	Sciomyzidae (Marsh flies)	*Sepedon fuscipennis*
	Syrphidae	*Toxomerus marginatus*
	Syrphidae	*Fazia micrura*

A list of insects identified during a Bioblitz (https://www.nationalgeographic.org/projects/bioblitz/) in May of 2016 is provided in Table 4.4.4.

Table 4.4.4. Insect species identified during FOVA Bioblitz May 2016 (https://www.inaturalist.org/observations/export?projects%5B%5D=2016-national-parks-bioblitz-fort-vancouver).

Order	Species	Common Name
Hemiptera (True bugs)	*Leptopterna dolabrata*	Meadow Plant Bug
Coleoptera (Beetles)	*Chrysolina hyperici*	St. Johnswort Beetle
	Judolia instabilis	Flower longhorn beetle
	Coccinella septempunctata	Seven-spotted Lady Beetle
Hymenoptera (Wasps, bees ants)	*Bombus griseocollis*	Brown-belted Bumble Bee
	B. californicus	California Bumble Bee
	B. mixtus	Fuzzy-Horned Bumble Bee
	B. vosnesenskii	Yellow-faced Bumble Bee
	Apis mellifera	Western Honey Bee
Lepidoptera (Butterflies, Moths)	*Noctua pronuba*	Large Yellow Underwing

Birds

The most recent survey for wildlife in the immediate area appears to be as part of the Environmental Assessment conducted for construction at Pearson Field (CWE 2018). This report found mostly common birds, as well as savannah sparrow, red-tailed hawk, greater Canada goose, Taverner's goose, killdeer, Anna's hummingbird, and American kestrel. All birds documented from FOVA and species that may be here are presented in Table 4.4.5 at the end of this Section.

The closest natural area where birds are frequently recorded is the Steigerwald National Wildlife Refuge and the Sandy River Delta. It is likely that some individuals of rare species found at these locations occasionally transition the area around FOVA but given the absence of habitat few likely remain. There are apparently no streaked horned larks, the only endangered species in the region (CWE 2018). Three exotic bird species have been recorded, house sparrows, European starlings, and pigeons.

Table 4.4.5. Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Acorn Woodpecker	–	–	X	–	–
American Bittern	X	–	–	–	–
American Coot	X	–	–	Probably Present	X
American Crow	X	X	X	Present	X
American Goldfinch	X	–	X	Present	X
American Pipit	X	–	X	–	X
American Robin	X	–	X	Present	X
American White Pelican[2]	–	–	X	–	–
American Wigeon	X	–	–	Probably Present	X
Anna's Hummingbird	X	–	X	–	X
Band-tailed Pigeon	X	–	–	–	–
Barn Swallow	X	X	X	Present	–
Barrow's Goldeneye	–	–	–	–	X
Belted Kingfisher	X	–	–	Probably Present	X
Bewick's Wren	X	–	X	Present	X
Black Phoebe	–	–	–	–	X
Black Scoter	–	–	–	–	X
Black-capped Chickadee	X	X	X	Present	X

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Black-crowned Night Heron	X	–	–	–	–
Black-headed Grosbeak	X	–	X	–	–
Black-throated Gray Warbler	X	–	X	–	–
Blue-winged Teal	X	–	–	–	–
Bonaparte's Gull	X	–	–	–	–
Brewer's Blackbird	X	–	X	Present	X
Brown Creeper	X	–	X	Probably Present	X
Brown-headed Cowbird	X	X	X	Present	–
Bufflehead	–	–	–	Probably Present	X
Bullock's Oriole	–	–	X	–	–
Bushtit	X	–	X	–	X
Cackling Goose	–	–	X	–	X
California Gull	X	–	X	–	X
California Quail	X	–	–	–	–
California Scrub Jay	–	–	X	–	–
Canada Goose	X	–	X	Probably Present	X
Canvasback	X	–	–	–	X
Cassin's Vireo	X	–	–	–	–

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Cedar Waxwing	X	–	X	Probably Present	X
Chestnut-backed Chickadee	X	–	X	Probably Present	X
Chipping Sparrow[4]	X	–	X	Present	–
Cinnamon Teal	X	–	–	–	X
Clark's Grebe	–	–	–	–	X
Cliff Swallow	X	–	X	–	–
Common Goldeneye	–	–	X	–	X
Common Loon[3]	X	–	–	–	X
Common Merganser	X	–	X	Present	X
Common Nighthawk[2]	X	–	–	–	–
Common Raven	X	X	–	Present	X
Common Yellowthroat	X	–	X	–	X
Cooper's Hawk	X	–	–	–	–
Dark-eyed Junco	X	–	X	Probably Present	X
Double-crested Cormorant	X	X	X	Present	X
Downy Woodpecker	X	–	X	–	X
Dunlin	X	–	–	Probably Present	–
Eared Grebe	X	–	–	–	–

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Eurasian Collared Dove	–	–	X	–	X
European Starling	X	–	X	Present	X
Evening Grosbeak	X	–	X	–	–
Fox Sparrow	X	–	–	–	X
Gadwall	X	–	–	–	X
Glaucus Gull	–	–	–	–	X
Glaucus-winged Gull	X	–	X	–	X
Golden-crowned Kinglet	X	–	X	Probably Present	X
Golden-crowned Sparrow	X	–	X	Present	X
Gray Jay	–	–	–	–	X
Great Blue Heron	X	–	X	Probably Present	X
Great Egret	–	–	X	–	X
Greater Scaup	–	–	X	–	X
Greater White-fronted Goose	–	–	–	–	X
Greater Yellowlegs	X	–	–	–	–
Green Heron	–	–	–	–	X
Green-winged Teal	X	–	–	–	X

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Hairy Woodpecker	X	–	X	–	X
Hammond's Flycatcher	X	–	–	–	–
Hermit Thrush	–	–	–	–	X
Herring Gull	X	X	X	Present	X
Hooded Merganser	X	–	–	–	X
Horned Grebe	X	–	–	–	X
House Finch	X	–	X	Present	X
House Sparrow	X	–	X	–	X
House Wren	X	–	X	–	–
Hutton's Vireo	–	–	–	–	X
Killdeer	X	X	X	Present	X
Lazuli Bunting	–	–	X	–	–
Least Sandpiper	X	–	–	–	–
Lesser Goldfinch	–	–	X	–	X
Lesser Scaup	X	–	X	–	X
Lesser Yellowlegs	X	–	–	–	–
Lincoln's Sparrow	X	–	X	–	X
Long-billed Dowitcher	X	–	–	–	–

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
MacGillivray's Warbler	X	–	X	–	–
Mallard	X	–	X	Present	X
Marsh Wren	X	–	–	–	X
Mew Gull	X	–	X	–	X
Mourning Dove	X	X	X	Present	X
Nashville Warbler	–	–	X	–	–
Northern Flicker	X	X	X	Present	X
Northern Harrier	X	–	–	–	X
Northern Pintail	X	–	–	–	X
Northern Rough-winged Swallow	X	X	X	Present	–
Northern Shoveler	X	–	–	–	X
Northern Shrike	X	–	–	–	–
Olive-sided Flycatcher[1,2]	X	–	–	–	–
Orange-crowned Warbler	X	–	X	–	X
Osprey	X	–	X	–	–
Pacific-slope Flycatcher	X	–	X	Probably Present	–
Pacific Loon	–	–	–	–	X
Pacific Wren	–	–	X	–	X

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Pied-billed Grebe	X	–	–	Present	X
Pileated Woodpecker[2]	–	–	X	–	X
Pine Siskin	X	–	X	Probably Present	X
Purple Finch	X	–	X	–	X
Purple Martin[2]	X	–	X	–	–
Red Crossbill	X	–	X	Present	X
Redhead	–	–	–	–	X
Red-breasted Nuthatch	X	–	X	Probably Present	X
Red-breasted Sapsucker	X	–	X	–	X
Red-necked Grebe	–	–	–	–	X
Red-throated Loon	X	–	–	–	X
Red-winged Blackbird	X	–	X	Present	X
Ring-billed Gull	X	X	X	Present	X
Ring-necked Duck	–	–	–	–	X
Ring-necked Pheasant	X	–	–	–	–
Rock Pigeon (Feral Pigeon)	X	X	X	Present	X
Rough-legged Hawk	X	–	–	–	–
Ruby-crowned Kinglet	X	–	X	Probably Present	X

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Ruddy Duck	–	–	–	–	X
Rufous Hummingbird	X	–	–	Probably Present	–
Sandhill Crane	–	–	–	–	X
Savannah Sparrow	X	–	X	–	X
Semi-palmated Plover	X	–	–	Probably Present	–
Snow Goose	–	–	–	–	X
Song Sparrow	X	–	X	Present	X
Spotted Sandpiper	X	–	–	–	X
Spotted Towhee	X	–	X	Present	X
Steller's Jay	X	–	X	Probably Present	X
Swainson's Thrush	X	–	–	–	–
Thayer's Gull	–	–	–	–	X
Townsend's Solitaire	–	–	–	–	X
Townsend's Warbler	X	–	X	–	X
Tree Swallow	X	–	X	–	–
Tundra Swan	–	–	–	–	X
Turkey Vulture	X	–	X	–	–
Varied Thrush	X	–	X	Probably Present	X

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Vaux's Swift[2]	X	–	X	–	–
Violet-green Swallow	X	X	–	Present	–
Virginia Rail	–	–	–	–	X
Virginia's Warbler	–	–	–	–	X
Warbling Vireo	X	–	X	–	–
Western Bluebird[3]	–	–	–	–	X
Western Grebe[2]	X	X	–	Present	X
Western Gull	–	–	–	–	X
Western Kingbird	X	–	–	–	–
Western Meadowlark[2]	X	–	X	–	X
Western Sandpiper	X	–	–	–	–
Western Scrub Jay	X	X	–	Present	X
Western Tanager	X	–	X	–	–
Western Wood-Pewee	X	–	X	–	–
White-breasted Nuthatch	X	–	X	–	X
White-crowned Sparrow	X	–	X	Present	X
White-throated Sparrow	–	–	–	–	X
Willow Flycatcher	X	–	–	–	–

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Wilson's Snipe	X	–	–	–	X
Wilson's Warbler	X	–	X	–	–
Winter Wren	X	–	–	–	–
Wood Duck	X	–	–	–	X
Yellow Warbler	X	–	X	–	–
Yellow-bellied Sapsucker	–	–	–	–	X
Yellow-rumped Warbler	X	–	X	Probably Present	X
Hawks, Falcons and Owls	–	–	–	–	–
American Kestrel	X	X	–	Present	X
Bald Eagle[2]	X	–	X	Probably Present	X
Barn Owl	X	–	–	–	X
Barred Owl	–	–	–	–	X
Burrowing Owl[2]	–	–	–	–	X
Cooper's Hawk	X	–	X	–	X
Great Horned Owl	X	–	X	–	X
Merlin	X	–	–	–	X
Northern Harrier	X	–	–	Probably Present	–
Osprey	X	–	–	–	–

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Table 4.4.5 (continued). Bird species known from the Fort Vancouver region (Kuntz II 2005); confirmed have been noted from FOVA. An "X" indicates that species was observed by that study.

Common Name	NPS 2005 List	NPS 2005 Confirmed	EBird – Fort Vancouver NHS	NPSpecies	Portland Audubon 2017 Christmas Bird Count
Peregrine Falcon[2]	X	–	X	–	X
Red-shouldered Hawk	–	–	–	–	X
Red-tailed Hawk	X	X	X	Present	X
Rough-legged Hawk	X	–	–	–	–
Sharp-shinned Hawk	X	–	X	–	X
Short-eared Owl[4]	X	–	–	–	X
Swainson's Hawk	X	–	X	–	–
Western Screech-owl	X	–	–	–	X

[1] Federal species of Concern

[2] WA or OR state Threatened or Species of Concern

[3] WA or OR state Sensitive or Vulnerable species

[4] Local conservation concern.A subspecies of Canada geese, dusky Canada geese ("duskys"), have been in decline in the PNW as other subspecies have become more abundant (Bromley and Rothe 2003, PFC 2015). Duskys are a common wintering species at many sites throughout the lower Columbia River, particularly at Ridgefield NWR, but if they spend time at FOVA may be considered a hazard to aircraft.

Terrestrial Mammals

At present ungulates have apparently been extirpated from FOVA and have not been seen in the park in several years, though they are common in the greater Vancouver area (Bender et al. 2004). No other large mammals are present. Almost nothing is known about the small mammal community at FOVA. Schaberl et al. (2012) captured five small mammal species, with deer mice (*Peromyscus maniculatus*) being by far the most common. No animals of any species were caught in short or long grass habitats, while the most diversity (three species: deer mice, vagrant shrew, Townsend's vole) was found near the river (Schaberl et al. 2012).

Non-native species found during this survey were house mice (*Mus musculus*) and eastern gray squirrels (*Sciurus carolinensis*). Coyotes (*Canis latrans*) and rabbits (unknown species) are reported from the Pearson Airfield area (https://www.cityofvancouver.us/pearson/page/pearson-aviator-newsletter). The mammal species found during the 2016 bioblitz are listed in Table 4.4.6, though likely most of these species were not found at FOVA specifically.

Table 4.4.6. Mammal species found during the 2016 Fort Vancouver Bioblitz in the FOVA region; most species were not found at FOVA proper (https://www.inaturalist.org/guides/2880).

Native or Non-native Species	Common Name	Scientific Name
Native Species	Coyote	*Canis latrans*
	Red fox	*Vulpes vulpes*
	Mule deer	*Odocoileus hemionus*
	Striped skunk	*Mephitis mephitis*
	Western spotted skunk	*Spilogale gracilis*
	Long-tailed weasel	*Mustela frenata*
	American mink	*Neovison vison*
	Raccoon	*Procyon lotor*
	Eastern cottontail	*Sylvilagus floridanus*
	American beaver	*Castor canadensis*
	Eastern gray squirrel	*Sciurus carolinensis*
	Muskrat	*Ondatra zibethicus*
	Long-tailed vole	*Microtus longicaudus*
	Creeping vole	*Microtus oregoni*
	Townsend's vole	*Microtus townsendii*
	Deer mouse	*Peromyscus maniculatus*
	Pacific jumping mouse	*Zapus trinotatus*
Non-native Species	Vagrant shrew	*Myocastor coypus*
	American shrew mole	*Neurotrichus gibbsii*
	Coast mole	*Scapanus orarius*
	Big brown bat	*Eptesicus fuscus*

Table 4.4.6 (continued). Mammal species found during the 2016 Fort Vancouver Bioblitz in the FOVA region; most species were not found at FOVA proper (https://www.inaturalist.org/guides/2880).

Native or Non-native Species	Common Name	Scientific Name
Non-native Species (continued)	Little brown bat	*Myotis lucifugus*
	Virginia opossum	*Didelphis virginiana*
	House mouse	*Mus musculus*
	Norway rat	*Rattus norvegivus*
	Nutria	*Myocastor coypus*

Bats

Very little is known about bats at FOVA, though they are likely common and species diversity may be relatively high given the presence of the river and artificial habitats such as bridges and old buildings (Erickson and West 2003), as well as the relative diversity of vegetation types that could support insects (Gehrt and Chelsvig 2003). Schaberl et al. (2012) were unsuccessful at mist-netting bats but they only deployed the nets on one night.

4.4.5. Level of Confidence

Medium, overall

4.4.6. Data Gaps and Research Needs

Park managers may wish to investigate whether small improvements in vegetation cover and tree canopies could increase native vertebrate and landbird abundance and density (Foster and Gaines 1991), particularly near riparian areas and where road density is low (Hennings and Edge 2003). Medium and small mammals can often adapt well to urban settings if habitat patch sizes are sufficient (Dickman and Doncaster 1987, Foster and Gaines 1991, Germaine and Wakeling 2001).

The identification of nesting birds during spring and early summer would aid in protecting live nesting sites until young have fledged

Additional suggestions are provided in Chapter 5.

4.4.7. Literature Cited

Adams, M.E. 2012.Taxonomic Survey of Orthoptera at Fort Vancouver National Historic Site: Ecological and Archaeological Implications. National Park Service, Vancouver, WA.

Baker, P.J., A.J. Bentley, R.J. Ansell, and S. Harris. 2005. Impact of predation by domestic cats *Felis catus* in an urban area. Mammal Review 35:302–312.

Bender, L.C., J.C. Lewis, and D.P. Anderson. 2004. Population ecology of columbian black-tailed deer in urban Vancouver, Washington. Northwestern Naturalist 85:53–59.

Bromley, R.G. and T.C. Rothe. 2003. Conservation assessment for the dusky Canada goose (*Branta canadensis occidentalis* Baird). Gen. Tech. Rep. PNW-GTR-591. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 79 p, 591.

Caywood, J and E. Owens. 2010. Vancouver Barracks/Parade Ground: Cultural Landscape Inventory, Fort Vancouver National Historic Site, National Park Service. Cultural Landscape Inventories. 400179. NPS Pacific West Regional Office. Pacific West Regional Office/CLI Database. Published Report-2186802.

Century West Engineering (CWE). 2018. Pearson Field Airport, Airport Improvements – Draft Environmental Impact Statement. Prepared for City of Vancouver, Washington, by CWE, Portland, OR.

Copass, C., and T. Ramm-Granberg. 2016. Vancouver National Historic Reserve vegetation inventory and mapping project. Natural Resource Report NPS/NCCN/NRR—2016/1128. National Park Service, Fort Collins, Colorado.

Cummins, K.W. and M.J. Klug. 1979. Feeding ecology of stream invertebrates. Annual Review of Ecology and Systematics 10:147–172.

Dickman, C.R. and C.P. Doncaster. 1987. The ecology of small mammals in urban habitats. I. Populations in a patchy environment. The Journal of Animal Ecology 56:629–640.

Erickson, J.L. and S.D. West. 2003. Associations of bats with local structure and landscape features of forested stands in western Oregon and Washington. Biological Conservation 109:95–102.

Fagan, K.E., E.V. Willcox, and A.S. Willcox. 2018. Public attitudes toward the presence and management of bats roosting in buildings in Great Smoky Mountains National Park, Southeastern United States. Biological Conservation 220:132–139.

Foster, J. and M.S. Gaines. 1991. The effects of a successional habitat mosaic on a small mammal community. Ecology 72:1358–1373.

Germaine, S.S. and B.F. Wakeling. 2001. Lizard species distributions and habitat occupation along an urban gradient in Tucson, AZ, USA. Biological Conservation 97:229–237.

Gehrt, S.D. and J.E. Chelsvig. 2003. Bat activity in an urban landscape: patterns at the landscape and microhabitat scale. Ecological Applications 13:939–950.

Glendell, M. and N. Vaughan. 2002. Foraging activity of bats in historic landscape parks in relation to habitat composition and park management. Animal Conservation Forum 5:309–316.

Hall, F.S. 1932. A Historic resume of exploration and survey: mammal types and their collectors in the State of Washington. The Murrelet 13:63–91.

Hayes, G. and G.J. Wiles. 2013. Washington bat conservation plan. Washington Department of Fish and Wildlife, Olympia, WA.

Hennings, L.A. and W.D. Edge. 2003. Riparian bird community structure in Portland, Oregon: habitat, urbanization, and spatial scale patterns. Condor 105:288–302.

Hocking, M.D. and T.E. Reimchen. 2002. Salmon-derived nitrogen in terrestrial invertebrates from coniferous forests of the Pacific Northwest. BMC Ecology 2:4. http://www.biomedcentral.com/1472-6785/2/4.

Howard, J. 2009. Bats and historic buildings: the importance of making informed decisions. Journal of Architectural Conservation 15:81–100.

Jobanek, G.A. and D.B. Marshall. 1992. John K. Townsend's 1836 report of the birds of the lower Columbia River region, Oregon and Washington. Northwestern Naturalist, pp.1–14.

Kuntz, R.C. II. 2005. Fort Vancouver National Historic Site: Bird Checklist. Department of the Interior, National Park Service, North Coast and Cascades Network, North Cascades Park Service Complex, Sedro-Woolley, WA.

Laliberte, A.S. and W.J. Ripple. 2003. Wildlife encounters by Lewis and Clark: A spatial analysis of interactions between Native Americans and wildlife. AIBS Bulletin 53:994–1003.

National Park Service (NPS). 2008. General Management Plan 2003 and McLoughlin House Unit Management Plan 2007. Fort Vancouver National Historic Site, Vancouver, WA.

Niwa, C.G., R.E. Sandquist, R. Crawford, [and others]. 2001. Invertebrates of the Columbia River basin assessment area. Gen. Tech. Rep. PNW-GTR-512. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 74 p. (Quigley, T.M., ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).

Olson, D.H., P.D. Anderson, C.A. Frissell, H.H. Welsh, and D.F. Bradford. 2007. Biodiversity management approaches for stream–riparian areas: perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. Forest Ecology and Management 246:81–107.

Oregon Biodiversity Information Center (OBIC). 2016. Rare, Threatened and Endangered Species of Oregon. Institute for Natural Resources, Portland State University, Portland, Oregon. 130 pp.

Oregon Conservation Strategy (OCS). 2016. Oregon Department of Fish and Wildlife, Salem, Oregon.

Pacific Flyway Council (PFC). 2015. Pacific Flyway management plan for the dusky Canada goose. Pacific Flyway Council, care of U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Vancouver, WA.

Schaberl, J., E. Myers, and M. Reid. 2012. Small mammal inventory and bat reconnaissance at Fort Vancouver National Historic Site/Vancouver National Historic Reserve. Natural Resource Technical Report NPS/NCCN/NRTR—2012/590. National Park Service, Fort Collins, CO.

Samora, B.A., M. Layes, and R. Lofgren. 2013. Vancouver National Historic Reserve amphibian inventory 2002–2003. Natural Resource Technical Report NPS/NCCN/NRTR—2013/732. National Park Service, Fort Collins, Colorado.

Taylor, T.A. and P.C. Erigero. 1992. Cultural Landscape Report, Vols I and II. National Park Service, Seattle, WA. https://www.nps.gov/parkhistory/online_books/fova/clr/clr.htm.

Tilghman, J.M., S.W Ramee, and D.M. Marsh. 2012. Meta-analysis of the effects of canopy removal on terrestrial salamander populations in North America. Biological Conservation 152:1–9.

Washington Department of Fish and Wildlife (WDFW). 2013. Threatened and Endangered Wildlife in Washington: 2012 Annual Report. Listing and Recovery Section, Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

4.5. Sensory Environment: Natural Night Skies and Natural Quiet

The conditions of natural night skies and natural quiet are poor. The park experiences above average levels of noise for an urban area, and night sky brightness is many times greater than natural conditions. Proposed construction activities and subsequent increases in aircraft take-offs and landings at Pearson Airfield will increase noise impacts from the airport so a downward trend in natural quiet is anticipated. The trend for natural night skies is unknown. Confidence is high.



4.5.1. Background

The importance of maintaining natural cycles of light and dark at night has become a priority issue in national parks, and increasing attention is being paid by NPS and others toward minimizing the impacts of anthropomorphic sources of light (Henderson et al. 1985, NPS 2006, Duriscoe et al. 2007). Likewise, the increasing impacts on natural quiet in parks from human-generated noise affect humans and natural systems. The level of "sensory pollution" (Swaddle et al. 2015) in FOVA is assessed in terms of impacts to natural quiet and natural night sky conditions.

Natural Night Skies

Artificial Light at Night (ALAN) comes from all sources powered by electricity and batteries as well as indirectly from human-sourced light reflected back from the atmosphere (polarized light; Horvath et al. 2009). "Light pollution" is fundamentally a cultural concept referring to the over-abundance of artificial light in human landscapes (Rogers and Sovick 2001, Sovick 2001, Moore et al. 2013) and is often measured and discussed by NPS as part of the visitor experience (Moore 2001, Longcore and Rich 2004, Smith and Hallo 2013).

Less often addressed are the ecological impacts of artificial light ("ecological light pollution") during diurnal dark periods. Evolutionarily the moon and other celestial objects provided the only source of light at night, and organisms adapted their biology and behaviors to the light patterns of lunar cycles (Duriscoe et al. 2007). Consequently, the dark night sky is considered the natural condition to which biotic components of ecosystems have evolved (Gaston et al. 2013). Thus, ALAN has very different impacts on wildlife and ecological processes than it does on humans (Longcore and Rich 2004, Rich and Longcore 2005, Horvath et al. 2009).

Research has examined the impacts of ALAN on many groups of organisms, including plant populations (Lewanzik and Voight 2014, Somers-Yeates et al. 2016), insects (Meyer and Sullivan 2013, Geffen et al. 2014, Perkin et al. 2014), birds (songbirds, owls, shorebirds, seabirds; Kempenaers et al. 2010, Rodriguez et al. 2012), amphibians (Perry et al. 2008), rodents, bats (Stone et al. 2009), snakes, marine organisms, and primates (Le Tallec et al. 2013; see Gaston et al. 2013 and Davies et al. 2014 for reviews). For example, the presence of ALAN can result in increased predation, reduced productivity, direct mortality, and reduced time for nocturnal foraging (Longcore and Rich 2004, Duriscoe et al. 2007). Cumulatively these impacts can scale up to affect population

dynamics, successional processes and biodiversity (Kyba and Hölker 2013, Gaston and Bennie 2014, Lewanzik and Voigt 2014).

Natural Quiet

Because national parks are often (perhaps wistfully) considered "islands" of quiet (Lynch et al. 2011, Miller 2008), NPS has been working for several decades to establish baseline conditions and develop measuring and monitoring methods for acoustic environments in national parks (Miller 2008). Similar to the topic of light pollution, however, the natural sound environment has primarily been addressed in relation to visitor experiences (Rogers and Sovick 2001, Sovick 2001, Miller 2008, Lynch et al. 2011) with relatively less attention being given to ecological and landscape-scale impacts (Barber et al. 2011) until more recently. Anthropogenic noise has been found to not only interfere with visitor experience, but also disrupts wildlife behavior, fitness, and community composition (Buxton, et al. 2017).

Soundscape ecology is an emerging field that attempts to connect ecological processes with human and natural sounds at landscape scales (Dumyahn and Pijanowski 2011, Pijanowski et al. 2011, Traux and Barrett 2011, Farina 2014). When evaluated ecologically, the impacts of anthropogenic sounds are most commonly considered in terms of effects on wildlife (Francis and Barber 2013, Luther and Gentry 2013). For example, studies have demonstrated the negative impacts of noise on songbirds (Slabbekoorn and Ripmeester 2008, Francis et al. 2009, Francis et al. 2011), bats (Schaub et al. 2008), rodents (Shier et al. 2012), frogs (Barber et al. 2010, Bee and Swanson 2007), and invertebrates (Morley et al. 2014). Prey species are particularly sensitive to human noise because it both mimics predator sounds and masks it (Landon et al. 2003, Chan et al. 2010, Brown et al. 2012). Noise presents diverse threats to species and ecosystems, both terrestrial and aquatic, including altered vocal behavior, reduced abundance in noisy habitats, changes in vigilance and foraging behavior, and impacts on individual fitness and the structure of ecological communities (Shannon, et al. 2016).

Road noise in particular appears to have measurable negative impacts on wildlife, altering animal behavior, movement patterns, ability to find prey (Siemers and Schaub 2011) and breeding processes (Reijnen and Foppen 2006, Bee and Swanson 2007, Barber et al. 2011). Some species are able to adapt to long-term additions of noise in their environment but many are not (Slabbekoorn and Halfwerk 2009, Barber et al. 2010). A growing body of evidence shows that anthropogenic noise also indirectly affects plants by altering ecological services such as enhancing pollination and disrupting seed dispersal (Francis et al. 2012).

4.5.2. Reference Conditions

Natural Night Skies

Increases in ALAN are addressed herein as an impact to natural systems rather than how they may affect the human experience. At FOVA preserving naturally dark skies is related to park priorities of enhancing the visitor experience, conducting interpretive programs regarding astronomy and night skies, and historic and cultural settings within the park as they relate to the nighttime setting and nocturnal wildlife (NPS undated). For natural resources specifically, levels of artificial light should

have no measurable impacts on animal behavior or physiology (i.e., be as close to natural as possible under all conditions; NPS undated).

Natural Quiet

Soundscapes are commonly defined as the total amount of ambient noise in an area measured in terms of frequency and amplitude (decibels [dBA]; Ambrose and Burson 2004). At this point NPS measures noise conditions only in relation to human health and visitor experience (Wood 2015). At FOVA the natural sound environment is related to park priorities of enhancing the visitor experience, conducting interpretive programs, and historic and cultural settings within the park (NPS 2013). For example, 35 decibels (dBA) or less is recommended for sleeping, while 60 dBA would interrupt normal conversation (described in NPS 2013). Wildlife detects sounds differently than humans in most cases; a recent literature survey found that terrestrial wildlife species were commonly impacted by sound at less than 50 dBA (Shannon et al. 2016).

4.5.3. Data and Methods

Night Skies

NPS directives have recommended a ratio of average anthropogenic sky luminance to natural conditions (ALR) be the primary measure for evaluating night sky conditions, though they stress that other metrics such as vertical and horizontal illuminance and impacts to species of concern should be considered for specific purposes (Moore et al. 2013, Wood 2015). The ALR value for FOVA calculated from modelling is 18.6, which means that on average the night sky is many times (1,860%) brighter than natural conditions. At these light levels impacts likely range from individual hormonal and behavioral changes (Gaston et al. 2013, Ouyang et al. 2018) to community disruption (Sanders and Gaston 2018). This metric (ALR) can be directly measured at any particular location but it is more often estimated by modeling.

Measuring the condition of the night sky is challenging because there are both numerous natural phenomena that affect the brightness of the night sky and numerous ways of measuring night-sky brightness. The all-sky light pollution ratio (ALR) is estimated from upward radiant-light observed by satellite, to facilitate comparisons among parks. The ALR is the average anthropogenic sky luminance presented as a ratio over natural conditions.

For this assessment, anthropogenic light was extracted from calibrated VIIRS (Visible Infrared Imaging Radiometer Suite) data. Natural light is determined by simulation model (Duriscoe 2013). One limitation of this method is that it generally does not capture horizontal light trespass from adjacent sources of light pollution. Horizontal trespass is light that falls upon a horizontal surface, such as level ground, in areas where light is not wanted. Horizontal trespass is accounted for in this assessment qualitatively by noting the upward radiance (upward traveling light) of nearby potential light sources under the assumptions that 1) upward radiance at the source correlates to the maximum potential brightness of horizontal trespass, and 2) the brightness of horizontal trespass from a single source diminishes with distance approximately proportionally to the change in upward radiance with distance from that source.

An Environmental Assessment was completed for Pearson Field airport improvements (CWE 2018) which included an investigation of light emission impacts.

Natural Quiet

For most national parks local sound data are unavailable, and similar to methods utilized for assessing night sky brightness, investigators often apply modeling techniques to describe natural sound conditions. Models provide estimates of the difference between natural, ambient quiet and existing noise conditions, though the accuracy of the results depends on spatial resolution (Barber et al. 2011, NPS 2013). Variables incorporated in these models include location, climate, landcover, hydrology, and wind speed (Mennitt et al. 2014, NPS 2013).

An Environmental Assessment was completed for Pearson Field airport improvements (CWE 2018) which included an investigation of noise impacts.

4.5.4. Resource Condition and Trend

Night Skies

The ALR value for FOVA calculated from modelling is 18.6, which means that on average the night sky is many times (1,860%) brighter than natural conditions. At these light levels impacts likely range from individual hormonal and behavioral changes (Gaston et al. 2013, Ouyang et al. 2018) to community disruption (Sanders and Gaston 2018). Figure 4.5.1 shows a general image of night-time lights of the greater Portland-Vancouver area as interpreted from satellite data. Methods used to create the image are at https://www.lightpollutionmap.info/help.html, and the data are from NOAA (https://ngdc.noaa.gov/eog/index.html).

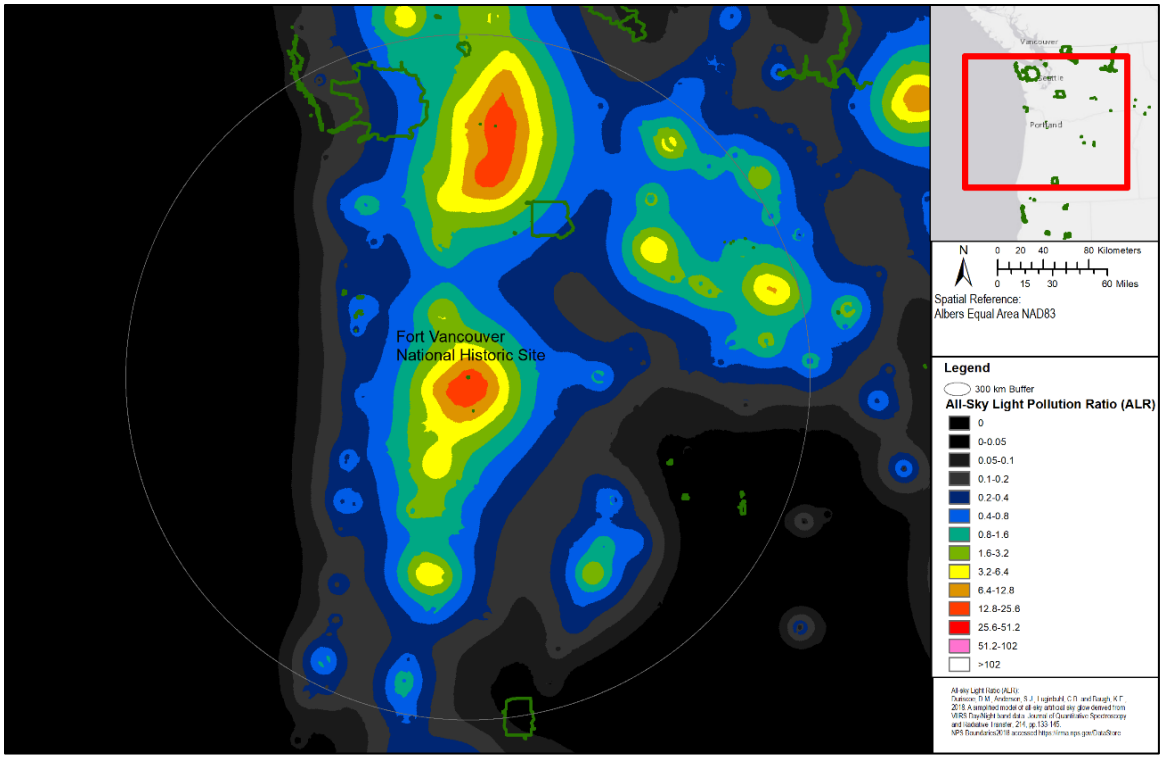
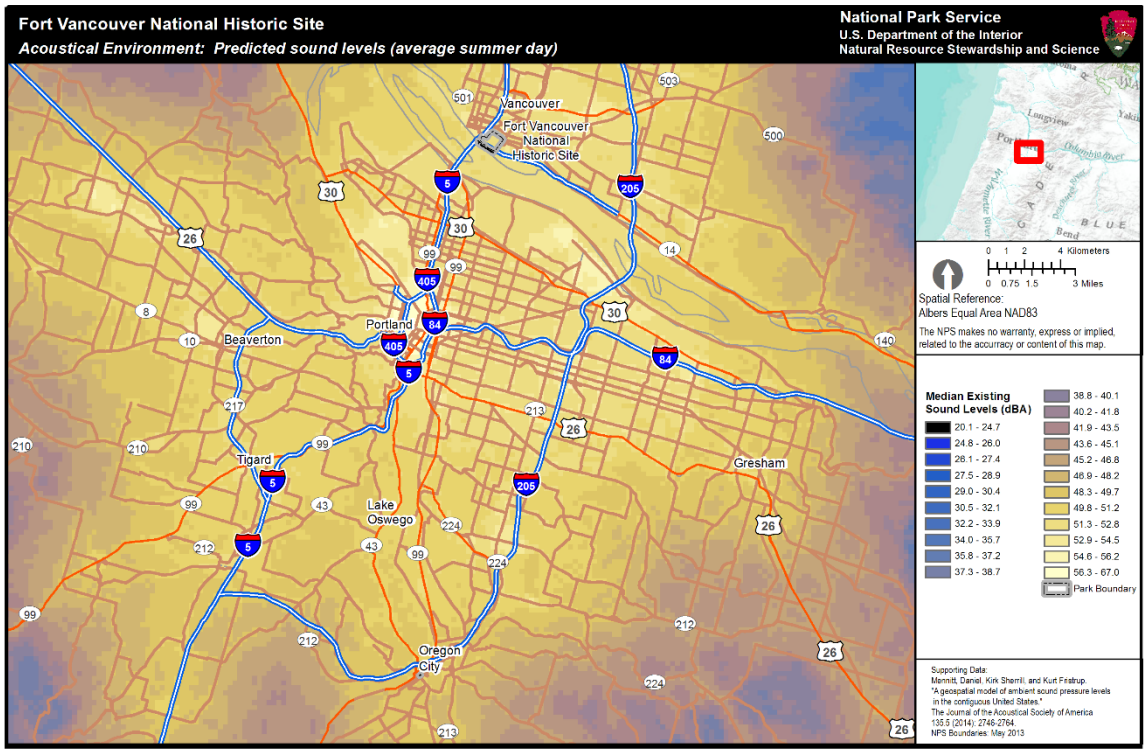


Figure 4.5.1. All-sky average anthropogenic to natural sky brightness ratio at Fort Vancouver National Historic site and surrounding lands. As indicated by the color scale in the legend, blue and black represent areas of lesser impact from artificial light while orange and red represent areas of greater impact. An ALR of 0 indicates pristine conditions while an ALR of 1.0 suggests that anthropogenic light in the night sky is 100% brighter than natural conditions. The modeled ALR value at Fort Vancouver National Historic Site is 18.6, which is 1,860% brighter than natural conditions. A 300 km buffer around the park indicates the distance at which light from distant cities could affect night sky conditions at the National Historic Site (NPS, Natural Sounds and Night Skies Program).

Natural Quiet

The mean LA_{50} existing sound level at FOVA was predicted (via modelling) to be 52.3 dB during the day in midsummer (NPS 2013) (Figure 4.5.2). Mean modeled impact (or the difference between existing and natural sound levels) is predicted to be 18.2 dB. This level of predicted sound does not include additional local impacts such as aircraft activity (NPS 2013). This level of sound reduces the listening area for humans and wildlife by nearly 99% (NPS 2013).

Of concern are activities proposed by the Pearson Airfield construction project. Table 4.5.1 is adapted from CWE (2018) and provides examples of noise levels that would incur from various construction activities. The draft environmental impact report for the project (CWE 2018) says, "Construction noise has the potential to be bothersome to residents near the construction site." Though construction noise is temporary, once the project is completed there will be additional noise impacts from increased take-offs and landings (projected to average 160 propeller operations/day by 2025; CWE 2018). The EIS determined that no noise mitigation measures would be needed as part of the project (preferred alternative), and that further noise analysis was not necessary.



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20150715

Figure 4.5.2. Modeled mean existing sound level map for the historic site and the surrounding area. The modeled mean daytime summer LA_{50} was 52.3 dB, but ranged from 51.7 dB in the least impacted areas to 52.8 dB in the most impacted areas. The map depicts the areas most influenced by human-caused sounds as lighter areas. Each pixel represents 270 m 9 (NPS, Natural Sounds and Night Skies Program).

Table 4.5.1. Typical construction noise levels (dBA) that will likely occur during the Pearson Airfield construction project (CWE 2018).

Equipment	Typical noise level 50 ft from source
Paver	89
Roller	74
Truck	88
Water Truck	88
Dozer	85
Scraper	89
Grader	85
Loader	85
Back Hoe	80
Concrete Mixer	85

4.5.5. Level of Confidence

High

4.5.6. Data Gaps and Research Needs

Park managers may want to work with the Natural Sounds and Night Skies Division to increase monitoring of baseline light and noise levels over time (NPS undated and 2013). Specifically, NPS units are encouraged to adjust management practices when practical to reduce noise levels associated with park operations (NAE 2010, NAE 2013), and to develop lighting plans that include least-obtrusive night lighting practices (NPS undated, Dick 2016).

4.5.7. Sources of Expertise

Emma Brown, Acoustical Resource Specialist, NPS Natural Sounds and Night Skies Division

Ashley Pipkin, Biologist, NPS Natural Sounds and Night Skies Division, Pacific West Region

4.5.8. Literature Cited

Ambrose, S. and S. Burson. 2004. Soundscape studies in national parks. George Wright Forum 21:29–38.

Barber, J.R., K.M. Fristrup, C.L. Brown, A.R. Hardy, L.M. Angeloni and K.R. Crooks. 2010. Conserving the wild life therein: protecting park fauna from anthropogenic noise. Park Science 26:26–31.

Barber, J.R., C.L. Burdett, S.E. Reed, K.A. Warner, C. Formichella, K.R. Crooks, D.M. Theobald and K.M. Fristrup. 2011. Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. Landscape Ecology 26:1281–1295.

Bee, M. A., and E. M. Swanson. 2007. Auditory masking of anuran advertisement calls by road traffic noise. Animal Behav. 74:1765–1776.

Brown, C.L., A.R. Hardy, J.R. Barber, K.M. Fristrup, K.R. Crooks and L.M. Angeloni. 2012. The effect of human activities and their associated noise on ungulate behavior. PlosOne 7: e40505.

Buxton, R. T., McKenna, M. F., Mennitt, D., Fristrup, K., Crooks, K., Angeloni, L., & Wittemyer, G. (2017). Noise pollution is pervasive in US protected areas. *Science*, *356*(6337), 531–533.

Century West Engineering (CWE). 2018. Pearson Field Airport, Airport Improvements – Draft Environmental Impact Statement. Prepared for City of Vancouver, Washington, by CWE, Portland, OR.

Chan, A. A.Y., P. Giraldo-Perez, S. Smith, and D.T. Blumstein. 2010. Anthropogenic noise affects risk assessment and attention: the distracted prey hypothesis. Biology Letters 6: 458–461.

Davies, T.W., J.P. Duffy, J. Bennie, and K.J. Gaston. 2014. The nature, extent, and ecological implications of marine light pollution. Frontiers in Ecology and the Environment 12:347–355.

Dick, R. 2016. Guidelines for Outdoor Lighting for Low-Impact Lighting. International Dark-Sky Association, http://darksky.org/.

Dumyahn, S.L. and B.C Pijanowski. 2011. Beyond noise mitigation: managing soundscapes as common-pool resources. Landscape Ecol. 26:1311–1326.

Duriscoe, D. M. 2013. Measuring anthropogenic sky glow using a natural sky brightness model. *Publications of the Astronomical Society of the Pacific*, *125*(933), 1370.

Duriscoe, D.M., C.B. Luginbuhl and C. Moore. 2007. Measuring night-sky brightness with a wide-field CCD camera. PASP, 119:192–213

Farina, A. 2014. Soundscape ecology. Netherlands: Springer.

Francis, C.D., C.P. Ortega and A. Cruz. 2009. Noise pollution changes avian communities and species interactions. Current biology 19:1415–1419.

Francis, C.D., J. Paritsis, C.P. Ortega and A. Cruz. 2011. Landscape patterns of avian habitat use and nest success are affected by chronic gas well compressor noise. Landscape Ecol. 26:1269–1280.

Francis, C.D. and N.J. Kleist, C.P. Ortega and A. Cruz. 2012. Noise pollution alters ecological services: enhanced pollination and disrupted seed dispersal. Proceedings of the Royal Society, 279, 2727–2735.

Francis, C.D. and J.R. Barber. 2013. A framework for understanding noise impacts on wildlife: an urgent conservation priority. Frontiers in Ecology and the Environment 11:305–313.

Gaston, K.J. and J. Bennie. 2014. Demographic effects of artificial nighttime lighting on animal populations. Environ. Rev. 22:323–330 (2014). dx.doi.org/10.1139/er-2014-0005. Published at www. Nrcresearchpress.com/er

Gaston, K.J., J. Bennie, T. W. Davies, and J. Hopkins. 2013. The ecological impacts of nighttime light pollution: a mechanistic appraisal. Biological Reviews 88:912–927.

Geffen, K.G., R.H.A. Grunsven, J. Ruijven, F. Berendse, and E. M. Veenendaal. 2014. Artificial light at night causes diapause inhibition and sex-specific life history changes in a moth. Ecology and Evolution 4:2082–2089.

Henderson, D., M.A. Yocke and H. Hogo. 1985. Night sky – a valuable resource in the nation's National Parks.

Horvath, G., G. Kriska, P. Malik and B. Robertson. 2009. Polarized light pollution: a new kind of ecological photopollution. Front. Ecol. Environ. 7:317–325.

Kempenaers, B., P. Borgström, P. Loës, E. Schlicht, and M. Valcu. 2010. Artificial night lighting affects dawn song, extra-pair siring success, and lay date in songbirds. Current Biology 20:1735–1739.

Kyba, C.C.M. and F.Hölker. 2013. Do artificially illuminated skies affect biodiversity in nocturnal landscapes? Landsc. Ecol 10 (2013).

Landon, D. M., P. R. Krausman, K. K. G. Koenen, and L. K. Harris. 2003. Pronghorn use of areas with varying sound pressure levels. Southwestern Naturalist 48:725–728.

Le Tallec, T., M. Perret, and M. Théry. 2013. Light pollution modifies the expression of daily rhythms and behavior patterns in a nocturnal primate. PloS one 8:e79250.

Lewanzik, D. and C.C. Voigt. 2014. Artificial light puts ecosystem services of frugivorous bats at risk. Journal of Applied Ecology 51:388–394.

Longcore, T. and C. Rich. 2004. Ecological light pollution. Front. Ecol. Environ. 2:191–198.

Luther, D. and K. Gentry. 2013. Sources of background noise and their influence on vertebrate acoustic communication. Behaviour 150:1045–1068.

Lynch, E., D. Joyce and K. Fristrup. 2011. An assessment of noise audibility and sound levels in U.S. National Parks. Landscape Ecol. 26:1297–1309.

Mennitt, D., K. Sherrill, and K. Fristrup. 2014. A geospatial model of ambient sound pressure levels in the contiguous United States. The Journal of the Acoustical Society of America 135:2746–2764.

Meyer, L.A. and S.M.P. Sullivan. 2013. Bright lights, big city: influences of ecological light pollution on reciprocal stream–riparian invertebrate fluxes. Ecological Applications 23:1322–1330.

Miller, N.P. 2008. U.S. National Parks and management of park soundscapes: A review. Applied Acoustics 69:77–92.

Moore, C.A. 2001. Visual estimation of night sky brightness. The George Wright Forum 18: 46–55.

Moore, C.A., F. Turina and J. White. 2013. Recommended Indicators and Thresholds of Night Sky Quality for NPS State of the Park Reports Interim Guidance; May 7, 2013. Natural Sounds and Night Skies Division WASO, Natural Resource Stewardship and Science, Ft. Collins, CO.

Morley, E.L., G. Jones, and A.N. Radford. 2014. The importance of invertebrates when considering the impacts of anthropogenic noise. Proceedings of the Royal Society of London B: Biological Sciences 281:20132683.

National Academy of Engineering (NAE). 2010. Technology for a Quieter America. The National Academies Press. https://doi.org/10.17226/12928.

NAE. 2013. Protecting National Park Soundscapes. The National Academies Press. https://www.nap.edu/catalog/18336/protecting-national-park-soundscapes

National Park Service (NPS). 2006. Management Policies.

NPS. Undated. Night Skies and Photic Environment Resource Summary, Fort Vancouver NHS. NPS Natural Sounds and Night Skies Division, Ft. Collins, CO.

NPS. 2013. Acoustic Environment and Soundscape Resource Summary, Fort Vancouver NHS. NPS Natural Sounds and Night Skies Division, Ft. Collins, CO.

Ouyang, J.Q., S. Davies, and D. Dominoni. 2018. Hormonally mediated effects of artificial light at night on behavior and fitness: linking endocrine mechanisms with function. Journal of Experimental Biology 221:p.jeb156893.

Perkin, E.K., F. Hölker and K. Tockner. 2014. The effects of artificial lighting on adult aquatic and terrestrial insects. Freshwater Biology 59:368–377.

Perry, G. B.W. Buchanan, R.N. Fisher, M. Salmon, and S.E. Wise. 2008. Effects of artificial night lighting on amphibians and reptiles in urban environments. Urban Herpetology:239–256.

Pijanowski, B.C., L.J. Vllanueva-Rivera, S.L. Dumyahn, A. Farina, B.L. Krause, B.M. Napoletano, S.H. Gage and N. Pieretti. 2011. Soundscape ecology: the science of sound in the landscape. Bioscience 61:203–216.

Reijnen, R. and R. Foppen. 2006. Impact of road traffic on breeding bird populations. Chapter 12 in: Davenport, J. and J.L. Davenport, eds. The ecology of transportation: managing mobility for the environment. Springer Netherlands.

Rich, C. and T. Longcore, eds. 2005 Ecological Consequences of Artificial Night Lighting. Island Press, Washington, DC. 480 pp.

Rodríguez, A. B. Rodríguez, Á. J. Curbelo, A. Pérez, S. Marrero, and J.J. Negro. 2012. Factors affecting mortality of shearwaters stranded by light pollution. Animal Conservation 15:519–526.

Rogers, J. and J. Sovick. 2001. Let There Be Dark: The National Park Service and the New Mexico Night Sky Protection Act. George Wright Forum 18:37–45.

Sanders, D. and K.J. Gaston. 2018. How ecological communities respond to artificial light at night. Journal of Experimental Zoology Part A: Ecological and Integrative Physiology. DOI: 10.1002/jez.2157.

Schaub, A., J. Ostwald, and B. M. Siemers. 2008. Foraging bats avoid noise. Journal of Experimental Biology 211:3174–3180.

Shannon, G., M.F. McKenna, L.M. Angeloni, K.R. Crooks, K.M. Fristrup, E. Brown, K.A. Warner, M.D. Nelson, C. White, J. Briggs, and S. McFarland. 2016. A synthesis of two decades of research documenting the effects of noise on wildlife. Biological Reviews 91:982–1005.

Shier, D.M., A.J. Lea, and M.A. Owen. 2012. Beyond masking: endangered Stephen's kangaroo rats respond to traffic noise with footdrumming. Biological Conservation 150:53–58.

Siemers, B.M. and A. Schaub. 2011. Hunting at the highway: traffic noise reduces foraging efficiency in acoustic predators. Proceedings of the Royal Society B: Biological Sciences 278:1646–1652.

Slabbekoorn, H. and W. Halfwerk. 2009. Behavioural ecology: noise annoys at community level. Current Biology 19:R693–R695.

Slabbekoorn, H. and E.A. Ripmeester. 2008. Birdsong and anthropogenic noise: implications and applications for conservation. Molecular Ecology 17:72–83.

Smith, B. L. and J.C. Hallo. 2013. A system-wide assessment of night resources and night recreation in the U.S. national parks: A case for expanded definitions. Park Science 29:54–59.

Somers-Yeates, R., J. Bennie, T. Economou, D. Hodgson, A. Spalding, and P.K. McGregor. 2016. Light pollution is associated with earlier tree budburst across the United Kingdom. In Proc. R. Soc. B 283, No. 1833, p. 20160813.

Sovick, J. 2001. Toward an appreciation of the dark night sky. George Wright Forum 18:15–19.

Stone, E.L., G. Jones and S. Harris. 2009. Street lighting disturbs commuting bats. Current Biology 19:1123–1127.

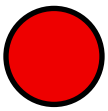
Swaddle, J.P., C.D. Francis, J.R. Barber, C.B. Cooper, C.C. Kyba, D.M. Dominoni, G. Shannon, E. Aschehoug, S.E. Goodwin, A.Y. Kawahara, and D. Luther. 2015. A framework to assess evolutionary responses to anthropogenic light and sound. Trends in Ecology and Evolution 20:1–11.

Traux, B. and G.W. Barrett. 2011. Soundscape in a context of acoustic and landscape ecology. Landscape Ecology 26:1201–1207.

Wood, L. 2015. Acoustic Environment and Soundscape Resource Summary, Fort Vancouver National Historic Site. Natural Sounds & Night Skies Division.

4.6. Land Cover and Adjacent Land Use

Land use in this urban park is primarily non-vegetated or vegetated with non-native species, thus habitat quality for native species is low. Impacts on natural resources from adjacent lands are of concern. Impervious surface cover in the park is high. Overall conditions may be improving with habitat protection along the river. Confidence is high.



4.6.1. Background

Land Cover

Though many places in urban areas are considered "open space", few of them support plant communities dominated by native species (Wilde et al. 2015). Where vegetation is altered from natural conditions or absent, natural ecosystems are impaired (Chong et al. 2014). Impervious surfaces—places where vegetation generally is absent and there is no direct path for rainfall to return to the ground– are present in many areas of FOVA. Impervious surfaces reduce the ability of natural ground cover and soil to filter toxic and dangerous materials from stormwater runoff (Arnold and Gibbons 1996, Brabec et al. 2002, Frazer 2005). Impervious surfaces also degrade water quality, often at distances from detection, particularly during the wet season in the Pacific Northwest (Pratt and Chang 2012).

Adjacent Land Use

FOVA is a very urban park, surrounded on three sides by human development. There is an active public airstrip inside the park boundaries, and park lands themselves are largely developed or maintained in a way that preserves open spaces as they were during the period of Historic interest rather than in a natural state. FOVA is also the anchor point of the City of Vancouver's Central Park Zone ("CPX"; City 2008). In addition to FOVA, the CPX includes the entire Vancouver National Historic Reserve (VNHR), Pearson Airfield and adjacent facilities, and residential, academic, and commercial developments to the north and east (Figure 2.5). The CPX is abutted by Industrial land use designated areas to the east, and Commercial designations to the west of I-5 (City 2011). Open Space and Public Facility land use in Vancouver is approximately 10% (City 2011).

Pearson Field opened in 1905 and has operated continually since that time, making it the oldest operating airfield in the United States. Pearson Field is owned mostly by the City of Vancouver, but a portion of the field—the west end of the single runway—is owned by NPS and leased back to the City. The lease arrangement was renewed by NPS in 2011 for 40 more years (expires in 2050; NPS 2011a). Significant improvements to the runway, taxiways, and associated buildings that would facilitate increased air traffic and address safety concerns have been proposed (CWE 2018).

The City is part of the greater Portland-Vancouver metropolitan area, and many people commute daily across the Columbia River (City 2011). The primary transportation link across the river between the two cities is Interstate 5 (I-5), which crosses directly to the west of FOVA. Immediately

south of FOVA and adjacent to the river is the four-lane State Route 14 (SR 14; “Lewis and Clark Highway”). SR 14 joins I-5 just north of the river, essentially at the southwest corner of FOVA.

Due to traffic congestion, limited capacity and age of the bridge, the I-5 bridge is often a bottleneck which impedes traffic on the freeway and on the river. A joint study between the Oregon and Washington State departments of transportation initiated in the 1990s was meant to investigate approaches to replacing the bridge. In the early 2000s controversy ensnarled the project and ultimately legislative support from Oregon ended in 2013. However, in recent years interest in the project, particularly from Washington, has increased and the project is again being debated.

A significant addition to FOVA and CPX was the Vancouver Land Bridge which was completed in 2008. The bridge begins at the southern portion of FOVA and crosses over SR 14 to Old Apple Tree Park where there is a walkway that goes under the railroad tracks, allowing pedestrians to eventually access the river shoreline (Figure 4.6.1). The bridge itself is planted with native plant species historically utilized by the Native Americans of the region, however, as far as is known the structure is not used by any wildlife species (i.e., it is not considered a wildlife corridor or part of an ecological network; Ignatieva et al. 2011).



Figure 4.6.1. Aerial view of Fort Vancouver NHS showing the Pearson Field runway, Fort Vancouver and the pedestrian land bridge (on left) over highway 14 to the waterfront park along the Columbia River (City of Vancouver).

4.6.2. Reference Conditions

From a natural resource perspective, reference conditions for both land cover and adjacent land use should be related to conditions as they existed at the time of the establishment of the HBC: vegetated

areas of park lands should be comprised of native species in plant communities closely resembling those of the early 1800s, there should be no impervious surfaces or paved roads, and no adjacent land uses should impact ecological functions or limit animal dispersal and migration.

4.6.3. Data and Methods

Land Cover

Current land cover and changes in land use from 1996–2006 both within FOVA and for surrounding areas were analyzed. Data from the Coastal Change Analysis Program (C-CAP) were used. C-CAP is part of the National Landcover Database (NLCD), a nationally standardized database of land cover and land change information developed from Landsat data (NOAA 2009). C-CAP data are normally mapped within 25 standard classes, but for this assessment were consolidated to seven classes (Table 4.6.1). The 1996 land cover data were obtained from the NOAA website, and the 2006 land cover data from Nate Herold (NOAA Coastal Services Center, Charleson, SC). Data from within FOVA and from a defined buffer zone excluding FOVA were analyzed.

Table 4.6.1. Consolidation of land cover classes from NLCD data for analysis in this report.

NLCD Land Cover Classes	Derived Land Cover Type – FOVA
High, Medium, and Low Intensity Open Space	Developed
Cultivated crops	Cultivated
Pasture/Hay, Grassland/Herbaceous, Scrub/Shrub	Grass/Shrub/Prairies
Deciduous, Evergreen, Mixed	Forest
Palustrine (Forested, Scrub/Shrub, Emergent), Estuarine (Forested, Scrub/Shrub, Emergent)	Wetland
Unconsolidated Shore, Barren Land, Palustrine Aquatic Bed, Estuarine Aquatic Bed	Marine and Shoreline
Open Water	Open Water

The vegetation mapping effort described in Copass and Ramm-Granberg (2016) derived twelve land-cover association types (Table 4.6.2).

Impervious surfaces within FOVA were quantified as a continuous variable from remote sensing datasets. Data are from 2006, and are based on 30 x 30 m pixels. The percent impervious surface within each pixel was calculated and mapped using the techniques suggested by Yang et al. (2003). Pixels were classified into 11 bins based on their percent impervious surface (0%, and then in bins of width 10%), and analyzed using both the total amount of impervious area (summing the percent impervious surface of each pixel) and the proportion of each pixel that was impervious. Finally, the impervious surface layer and the 2006 land cover type layer were overlaid and the total impervious surface by cover type calculated.

Table 4.6.2. Land-cover associations described in Copass and Ramm-Granberg (2016).

Class/ Macrogroup/ Alliance	Associations
Non-vegetated	• Road/parking lots • Parking lot/buildings • Terrestrial bare areas • High density housing
Cultural	• Arboretum • Orchard • Mowed lawn • Lawn with trees • Shrub garden • Vegetable garden
Herbaceous	• *Bromus* provisional ruderal • *Camassia quamash* wet prairie
Forest/Woodland	• Populus balsamifera ssp. trichocarpa/ Rubus ameniacus ruderal

Adjacent Land Use

Land use types adjacent to FOVA were subjectively examined using imagery and maps available from many sources.

4.6.4. Resource Condition and Trend

Land Cover

From 1996–2006, 28% (166 acres) of surrounding forest lands and 30% (17 acres) of surrounding river shorelines were lost (Table 4.6.3). Although most of the forest conversion was to developed land, development does not seem to be increasing very rapidly in the surrounding area (1% or 143 ha increase during the 10-year period).

Table 4.6.3. Land cover comparison of surrounding lands from 1996 to 2006. Changes calculated as occurring within FOVA are too small to be reported.

	Current Condition		Change (1996–2006)	
Cover Type	**Ha**	**%**	**Ha**	**%**
Developed	11,408	78.3%	142.7	1.3%
Cultivated	165	1.1%	−8.6	−5.0%
Grass/Shrub/Prairie	797	5.5%	21.9	2.8%
Forest	423	2.9%	−166.0	−28.2%
Wetland	782	5.4%	4.9	0.6%
Shoreline	41	0.3%	−17.4	−29.7%
Total	**13,616**	**–**	**–**	**–**

Copass and Ramm-Granberg (2016) found that only 9% of the VNHR was natural vegetation (Figure 4.6.2**)** Only 5% of FOVA is classified as having zero percent impervious surface, over 20% of the park has more than 50% impervious surface. Most of FOVA's impervious surface area results from roads, buildings and the Pearson Air Field (Figure 4.6.2, gray areas), and the City is allowed to "…remove trees and vegetation and deter wildlife (birds) as necessary in the interest of safety." (NPS 2011).

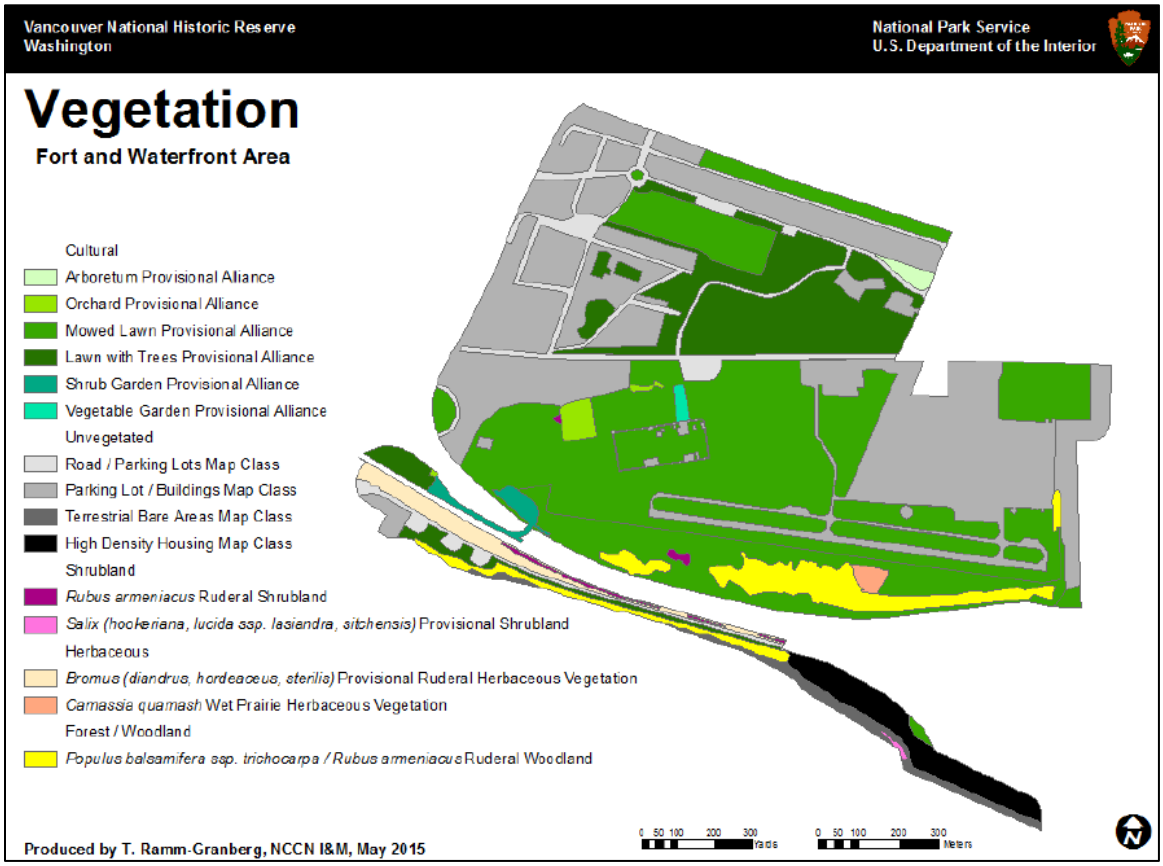


Figure 4.6.2. Vegetation map for FOVA (Copass and Ramm-Granberg 2016).

Adjacent Land Use

As mentioned, FOVA is surrounded in two directions (generally east and west) by high-density and industrial land use, on the north by the Central Park District which is a mix of open space and multi-use areas, and on the south by the Columbia River. In no direction has the amount of open space that could be considered good quality wildlife habitat (e.g., dominated by native plant species) increased. There are also no existing or planned open space corridors that connect with FOVA (City 2011).

The river shoreline has been designated "Natural" by the City (City 2008) with an associated definition of areas that are "…relatively free of human influence or that include intact or minimally degraded shoreline ecological functions intolerant of human use. These systems require that only very low intensity uses be allowed in order to maintain the ecological functions and ecosystem-wide

processes. Consistent with the policies of the designation, restoration of degraded shorelines within this environment is appropriate." (City 2012).

Future

Natural resource protection does not appear to be a priority goal for the City regarding the Central Park District, and instead it seems that this space is intended to be primarily a gathering place for residents and visitors. Several policies in the Central Park Update (City 2008) indicate that facility use and even growth in use are goals, for example: "Ensure that Central Park continues to support and enhance public use and gathering places in a vibrant, and compactly-clustered developed environment." (CP-3); "…encourage signature public projects that maximize the gateway location to Central Park and the Historic Reserve." (CP-4); "The institutions and services that are currently located in the Central Park area are significant community resources that should continue to grow as needed to meet future requirements, be centrally located, and easily accessible to all." (CP-5).

At the same time there are provisions for sustainable use practices and some consideration of natural resources, including: "Manage and enhance wildlife habitat: keep disturbance to a minimum and retain prime vegetation features to the extent possible…" and "Restore the health of degraded sites where appropriate by improving habitat for indigenous species through native plants and closed-loop water system." (CP-24). However, it does seem like following practices that encourage natural resource protection while pressure for development increases and the local land-use planning environment "leans" toward less zoning regulation (Kline et al. 2014) will be challenging.

4.6.5. Level of Confidence

High

4.6.6. Literature Cited

Arnold Jr., C. A., and C. J. Gibbons. 1996. Impervious surface coverage: the emergence of a key urban environmental indicator. J. Amer. Planning Assoc. 62:243–258.

Brabec E., S. Schulte, P. L. Richards. 2002. Impervious surfaces and water quality: A review of current literature and its implications for watershed planning. Journal of Planning Literature 16:499–514.

Century West Engineering (CWE). 2018. Pearson Field Airport, Airport Improvements – Draft Environmental Impact Statement. Prepared for City of Vancouver, Washington, by CWE, Portland, OR.

Chong, K.Y., S. Teo, B. Kurukulasuriya, Y.F. Chung, S. Rajathurai, and H.T.W. Tan. 2014. Not all green is as good: Different effects of the natural and cultivated components of urban vegetation on bird and butterfly diversity. Biological Conservation 171:299–309.

City of Vancouver (City). 2008. Central Park Plan Update. http://www.cityofvancouver.us/sites/default/files/fileattachments/community_and_economic_development/page/1415/centralplan.pdf

City of Vancouver (City). 2011. Vancouver Comprehensive Plan, 2011–2030. City of Vancouver Long Range Planning, Vancouver, WA.

City of Vancouver (City). 2012. Shoreline Master Program, Ord. M-4021. City of Vancouver, Vancouver WA.

Copass, C., and T. Ramm-Granberg. 2016. Vancouver National Historic Reserve vegetation inventory and mapping project. Natural Resource Report NPS/NCCN/NRR—2016/1128. National Park Service, Fort Collins, Colorado.

Frazer, L. 2005. Paving paradise: the peril of impervious surfaces. Environmental Health Perspectives 113:456–462.

Ignatieva, M., G.H. Stewart, and C. Meurk. 2011. Planning and design of ecological networks in urban areas. Landscape and Ecological Engineering 7:17–25.

Kline, J.D., P. Thiers, C.P. Ozawa, J.A. Yeakley, and S.N. Gordon. 2014. How well has land-use planning worked under different governance regimes? A case study in the Portland, OR-Vancouver, WA metropolitan area, USA. Landscape and Urban Planning 131:51–63.

National Park Service (NPS). 2011. Fort Vancouver Historic Site, Pearson Field Lease for Runway 08 and Parallel Taxiway, Lease NO. L-FOVA001-11 with City of Vancouver, WA. Covering the period April 1, 2011 through March 31, 2051.

Pratt, B. and H. Chang. 2012. Effects of land cover, topography, and built structure on seasonal water quality at multiple spatial scales. Journal of Hazardous Materials 209:48–58.

Wilde, H.D., K.J. Gandhi, and G. Colson. 2015. State of the science and challenges of breeding landscape plants with ecological function. Horticulture Research 2:14069.

Yang, L., C. Huang, C.G. Homer, B.K. Wylie, and M.J. Coan. 2003. An approach for mapping large-area impervious surfaces: synergistic use of Landsat-7 ETM+ and high spatial resolution imagery. Canadian Journal of Remote Sensing 29:230–240.

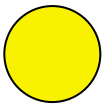
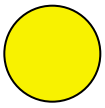
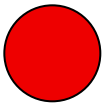
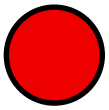
Chapter 5. Discussion

5.1. Assessment Summary

This assessment serves as a review and summary of available data and literature for focal natural resources in Fort Vancouver National Historic Site. Table 5.1 summarizes the condition and trend of each of the resources addressed in this assessment. None of the focal resources are considered to be in good condition, and several downward trends are suspected. A synthesis of the information provided herein leads to a few areas of concern that park managers may want to give particular attention to: impacts of Pearson Airfield on natural resources, human-wildlife conflicts, and the values of urban open space and associated opportunities for improving biodiversity while maintaining cultural integrity. This discussion also references the natural resource areas of concern identified in Weber et al. (2009) for FOVA:

- Maintenance and restoration of the natural environment
- Preservation of heritage natural resources
- Control of exotic plants
- Challenges of natural resource management within an urban environment

Table 5.1. Summary of FOVA focal natural resources addressed in this assessment, associated indicators, and a graphic representation of condition, trend, and confidence level. Focal resources are organized within the NPS Ecological Monitoring Framework (Fancy et al. 2009).

Level 1 Category	FOVA Resource	Indicators	Condition and Trend
Air and Climate	Air Quality	• Visibility • Nitrogen and Sulfur Deposition • Ozone	
	Climate	• Temperature • Precipitation	
Water	Freshwater Resources	• Presence/Absence of Wetlands • Functional Floodplain Processes • Groundwater Quality	
Biological Integrity	Native Fauna	• Species Diversity • Presence/Absence of Key Species • Presence/Absence of Non-native Species	
Ecosystem Pattern and Processes	Sensory Environment	• Natural Night Skies • Natural Quiet	
	Habitat Integrity	• Land Cover • Adjacent Land Use	

5.2. Considerations for Improving Natural Resource Conditions at FOVA

Pearson Airfield – Natural Night Sky

Pearson is an active airfield located directly adjacent to and partly within FOVA, with important cultural and Historic ties to the site. Many local residents and visitors utilize the facilities of the airfield, but most managers recognize that the presence of the facility and associated aircraft operations have generally negative impacts on natural resources. In particular, new (additional) lighting is proposed for the Pearson Airfield construction (CWE 2018), and as discussed in Section 4.5, artificial light at night has overwhelmingly negative consequences for wildlife. Lighting programs that minimize light at night while maintaining safety should be investigated by FOVA managers and discussed with airfield designers, both for the benefit of animals at night as well as human health (Gaston et al. 2017, Davies and Smyth 2018).

Human-Wildlife Conflicts

Pearson Airfield

In most cases activities associated with airports are not compatible with wildlife and natural ecosystems (DeVault et al. 2011). For example, standing water (wetlands) that could support native plants and provide small vertebrate and bird habitat are often removed to reduce the risk of bird strikes (Dolbeer 2006, NPS 2011, CWE 2018). Bird-hazing is also common at airports (Belant 2011), though it is unknown whether this occurs at Pearson. As far as is known, there have only been four confirmed bird strikes with geese (or any other bird species) since 1992 at Pearson (http://www.city-data.com/airports/Pearson-Field-Airport-Vancouver-Washington.html). Viable measures that both address aircraft safety and protect wildlife and wildlife habitat should be considered by NPS managers and encouraged for use at the airfield (Blackwell et al. 2013, DeVault et al. 2013, Swaddle et al. 2016).

NPS Management

No information is available to determine whether mammals, in particular rodents and bats, are considered pest species and managed as such by NPS at FOVA. Given that rodents can do significant damage to historic structures and artifacts and that native deer mice (*Peromyscus maniculatus*) and non-native rats are present and often abundant, some level of rodent control is likely occurring (pers. comm. T. Cummings 2017). If management entails only physical exclusion methods there are likely few impacts to wildlife. If, however, managing for rodents includes methods that introduce rodenticides into the environment those efforts should be seriously re-evaluated. The negative effects of rodenticides on non-target wildlife, particularly urban carnivores and raptors, has been well-documented (Badzik et al. 2014, Elliott et al. 2014), and it is important that rodents be managed in accordance with NPS and general IPM policies (Blackwell et al. 2016). Likewise, bats should be excluded from human-occupied buildings, if necessary, and not treated as pests, given that all bats in the park are native species (Voigt et al. 2016, Fagan et al. 2018).

Enhancing Values of Urban Open Space

Though the historic natural vegetation at FOVA has been almost completely replaced with cultural plants and gardens, the value of the site as a biodiversity reservoir in an urban setting is something that could be enhanced (Nooten et al. 2018). The abundance of natural resources was one of the

primary reasons the HBC selected this location for its headquarters (Taylor and Erigero 1992), and when asked, people often respond that they prefer natural rather than mowed and highly managed vegetation in urban settings (Unterweger et al. 2017). For example urban forests that include understory shrubs and native herbaceous species, even when dominated by non-native trees, can support diverse invertebrate, bird, and bat communities (McIntyre 2000, Chace and Walsh 2006, Chen and Jim 2008, Smith and Gehrt 2010, Seamans 2013, Threlfall et al. 2017). Small forests in urban landscapes can also provide needed ecosystem services such as shade and carbon sequestration (Dimoudi and Nikolopoulou 2003, Roy et al. 2012), and increased plant diversity often results in higher pollinator abundance (Bates et al. 2011, Hennig and Ghazoul 2012).

The river shoreline provides perhaps the greatest opportunities for recovering rare native habitats. Within the City the river shorelines have been designated as being of statewide significance, which means that among other things they could be managed for uses that are of statewide over local benefits, including maintaining the natural character, managing for long-term (over short-term) benefits, protecting the natural resources and ecological functions, and increasing recreational opportunities (City 2011, Clark County Code undated).

Restoration and stewardship of natural resources as they existed in the early 1800s offers the opportunity to better document and interpret the integrated history of natural and cultural development (Table 5.2). Specifically, previous studies and reports have suggested that a vegetation management plan for FOVA would be extremely useful (Rochefort 2010, Copass and Ramm-Granberg 2016). Taylor and Erigero (1992) and Rochefort (2010) suggest that restoration of native riparian, wetland, prairie, oak, and forest habitat on-site would not only improve wildlife habitat but also allow for interpretation of the historic site condition and resulting development (Table 5.3). It is hoped that this assessment will aid in such endeavors.

Table 5.2. Summary of generalized vegetation types at FOVA with opportunities for restoration and enhancement, compiled from NPS (2008), Rochefort (2010), and Copass and Ramm-Granberg (2016).

Ecosystem	Current Description	Management Opportunities
Riverine – Riparian	Little riparian vegetation remains, varying degrees of bank stabilization with native grass and shrubs	Restore riparian vegetation, though very little opportunity to restore historic river functions
Lacustrine	Majority of wetlands filled, small seasonal wetland between Pearson Field and SR 14, relatively large wetland near WREC	Restoration and enhancement of historic wetland sites
Oak – prairie savanna	Primarily weedy European grasses; small population of camas in Pearson Field; small population of Garry oaks	Restore and protect native vegetation where possible including oak grove, minimize lawn area
Upland forest	Few native trees remain or are mixed with non-natives, little recruitment of native species	Additional tree planting in areas north of Officer's Row when possible

Table 5.3. Plant species identified by Rochefort (2010) that are a) native and would be appropriate for restoration efforts, and b) are invasive and should be controlled as part of any restoration projects.

Native vs. Invasive Plant Species	Common Name	Scientific Name	Growth Form
Native plant species appropriate for restoration efforts	Oregon ash	*Fraxinus latifolia*	Tree
	Garry oak	*Quercus garryana,*	Tree
	Black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	Tree
	Snowberry	*Symphoricarpos albus*	Shrub
	Cluster rose	*Rosa pisocarpa,*	Shrub
	Pearly everlasting	*Anaphalis margaritacea*	Herbaceous perennial
	Common sneezeweed	*Helenium autumnale*	Herbaceous perennial
	White-panicled aster	*Symphyotrichum lanceolatum* var. *hesperium*	Herbaceous perennial
	Common camas	*Camassia quamash*	Herbaceous perennial
	Cotton batting plant	*Pseudognaphalium stramineum*	Herbaceous annual or perennial
Invasive plant species that should be removed or controlled	Reed canary grass	*Phalaris arundinacea*	Perennial bunchgrass
	Tall fescue	*Schedonurus arundinaceum*	Perennial bunchgrass
	Colonial bentgrass	*Agrostis capillaris*	Perennial grass

5.3. Literature Cited

Badzik, B., C. L. J. DiSalvo, D. E. Buttke, and M.F. Chase. 2014. Rodent Exclusion Manual, Mechanical Rodent Proofing Techniques: a training manual for National Park Service Employees. Natural Resource Report, National Park Service, Fort Collins, CO.

Bates, A.J., J.P. Sadler, A.J. Fairbrass, S.J. Falk, J.D. Hale, and T.J. Matthews. 2011. Changing bee and hoverfly pollinator assemblages along an urban-rural gradient. PloS one, 6(8), p.e23459.

Belant, J.L. 2011. Bird harassment, repellent, and deterrent techniques for use on and near airports. Vol. 23, Transportation Research Board. Washington, DC.

Blackwell, B.F., T.W. Seamans, P.M. Schmidt, T.L. De Vault, J.L. Belant, M.J. Whittingham, J.A. Martin, and E. Fernández-Juricic. 2013. A framework for managing airport grasslands and birds amidst conflicting priorities. Ibis 155:199–203.

Blackwell, B.F., T.L. DeVault, E. Fernández-Juricic, E.M. Gese, L. Gilbert-Norton, and S.W. Breck. 2016. No single solution: Application of behavioural principles in mitigating human–wildlife conflict. Animal Behaviour 120:245–254.

Century West Engineering (CWE). 2018. Pearson Field Airport, Airport Improvements – Draft Environmental Impact Statement. Prepared for City of Vancouver, Washington, by CWE, Portland, OR.

Chace, J.F. and J.J. Walsh. 2006. Urban effects on native avifauna: a review. Landscape and Urban Planning 74:46–69.

Chen, W.Y. and C.Y. Jim. 2008. Assessment and valuation of the ecosystem services provided by urban forests. In Ecology, Planning, and Management of Urban Forests (pp. 53–83). Springer, New York, NY.

City of Vancouver (City). 2011. Vancouver Comprehensive Plan, 2011–2030. City of Vancouver Long Range Planning, Vancouver, WA.

Clark County. Undated. Clark County Code: 40.460 Shoreline Master Program. https://ecology.wa.gov/DOE/files/44/4416b003-a512-481a-ac56-4b801af864e3.pdf.

Copass, C., and T. Ramm-Granberg. 2016. Vancouver National Historic Reserve vegetation inventory and mapping project. Natural Resource Report NPS/NCCN/NRR—2016/1128. National Park Service, Fort Collins, Colorado.

Davies, T.W. and T. Smyth. 2018. Why artificial light at night should be a focus for global change research in the 21st century. Global Change Biology 24:872–882.

DeVault, T.L., J.L. Belant, B.F. Blackwell, and T.W. Seamans. 2011. Interspecific variation in wildlife hazards to aircraft: implications for airport wildlife management. Wildlife Society Bulletin 35:394–402.

DeVault, T.L., Blackwell, B.F. and Belant, J.L. eds., 2013. Wildlife in Airport Environments: Preventing Animal–Aircraft Collisions Through Science-Based Management. Johns Hopkins University Press, Baltimore, MD.

Dimoudi, A. and M. Nikolopoulou. 2003. Vegetation in the urban environment: microclimatic analysis and benefits. Energy and Buildings 35:69–76.

Dolbeer, R.A. 2006. Height distribution of birds recorded by collisions with civil aircraft. The Journal of Wildlife Management 70:1345–1350.

Elliott, J.E., S. Hindmarch, C.A. Albert, J. Emery, P. Mineau, and F. Maisonneuve. 2014. Exposure pathways of anticoagulant rodenticides to nontarget wildlife. Environmental Monitoring and Assessment 186:895–906.

Fancy, S.G., J.E. Gross, and S.L. Carter. 2009. Monitoring the condition of natural resources in US national parks. Environmental Monitoring and Assessment 151:161–174.

Fagan, K.E., E.V. Willcox, and A.S. Willcox. 2018. Public attitudes toward the presence and management of bats roosting in buildings in Great Smoky Mountains National Park, Southeastern United States. Biological Conservation 220:132–139.

Gaston, K.J., T.W. Davies, S.L. Nedelec, and L.A. Holt. 2017. Impacts of artificial light at night on biological timings. Annual Review of Ecology, Evolution, and Systematics 48:49–68.

Hennig, E.I. and J. Ghazoul. 2012. Pollinating animals in the urban environment. Urban Ecosystems 15:149–166.

McIntyre, N.E. 2000. Ecology of urban arthropods: a review and a call to action. Annals of the Entomological Society of America 93:825–835.

National Park Service (NPS). 2008. General Management Plan 2003 and McLoughlin House Unit Management Plan 2007. Fort Vancouver National Historic Site, Vancouver, WA.

NPS. 2011. Fort Vancouver Historic Site, Pearson Field Lease for Runway 08 and Parallel Taxiway, Lease NO. L-FOVA001-11 with City of Vancouver, WA. Covering the period April 1, 2011 through March 31, 2051.

Nooten, S.S., P. Schultheiss, J. Wright, C. Macdonald, B.K. Singh, J.M. Cook, and S.A. Power. 2018. What shapes plant and animal diversity on urban golf courses? Urban Ecosystems 21:565–576.

Rochefort, R. M. 2010. Vascular plant inventory of Fort Vancouver National Historic Site. Natural Resource Technical Report NPS/NCCN/NRTR—2010/341. National Park Service, Fort Collins, Colorado.

Roy, S., J. Byrne, and C. Pickering. 2012. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban Forestry & Urban Greening 11:351–363.

Seamans, G.S. 2013. Mainstreaming the environmental benefits of street trees. Urban Forestry & Urban Greening, 12:2–11.

Swaddle, J.P., D.L. Moseley, M.K. Hinders, and E.P. Smith. 2016. A sonic net excludes birds from an airfield: implications for reducing bird strike and crop losses. Ecological Applications 26:339–345.

Smith, D.A. and S.D. Gehrt. 2010. Bat response to woodland restoration within urban forest fragments. Restoration Ecology 18:914–923.

Taylor, T.A. and P.C. Erigero. 1992. Cultural Landscape Report, Vols I and II. National Park Service, Seattle, WA. https://www.nps.gov/parkhistory/online_books/fova/clr/clr.htm

Threlfall, C.G., L. Mata, J.A. Mackie, A.K. Hahs, N.E. Stork, N.S. Williams, and S.J. Livesley. 2017. Increasing biodiversity in urban green spaces through simple vegetation interventions. Journal of Applied Ecology 54:1874–1883.

Unterweger, P.A., N. Schrode, and O. Betz. 2017. Urban Nature: Perception and Acceptance of Alternative Green Space Management and the Change of Awareness after Provision of Environmental Information. A Chance for Biodiversity Protection. Urban Science 1:24. DOI: doi:10.3390/urbansci1030024.

Voigt, C.C., K.L. Phelps, L.F. Aguirre, M.C. Schoeman, J. Vanitharani, and A. Zubaid. 2016. Bats and buildings: the conservation of synanthropic bats. In Bats in the Anthropocene: Conservation of Bats in a Changing World (pp. 427–462). Springer, DOI 10.1007/978-3-319-25220-9_14.

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

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 389/167864, April 2020



Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525