National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Lewis and Clark National Historical Park

Natural Resource Report NPS/LEWI/NRR—2020/2108

ON THIS PAGE
View from Fort Columbia State Park across the mudflats to Cape Disappointment State Park, a unit of Lewis and Clark National Historical Park. Photo by T. Hinckley.

ON THE COVER
Looking south across the mouth of the Columbia River from Cape Disappointment. Photo by C. Schwemm.

Natural Resource Condition Assessment

Lewis and Clark National Historical Park

Natural Resource Report NPS/LEWI/NRR—2020/2108

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

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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.

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Executive Summary

The NRCA study team compiled existing data and information to characterize the condition and trends of high priority natural resources in Lewis and Clark National Historical Park. This report and the spatial datasets provided with it are intended to inform and support park managers and scientists in developing recommendations for protecting and improving the condition of natural resources in the park. The NRCA can also assist park resource managers in meeting the reporting requirements of the Government Performance Results Act and Office of Management and Budget.

Resource elements selected for assessment were organized into eleven chapters: 1) Air Quality; 2) Climate; 3) Freshwaters (includes Surface Hydrology/Quality and Groundwater Hydrology/Quality); 4) Estuaries (includes Physical Elements, Biological Components, and specifically Juvenile Salmon), 5) Forest Health and Disturbance; 6) Non-salmonid Fish; 7) Amphibians; 8) Mammals; 9) Natural Night Skies and Natural Quiet; 10) Nearshore Physical Environment; and 11) Landuse and Connectivity.

Indicators (quantitatively measurable descriptors) were identified to evaluate the condition and trend of these resources. Reference conditions were established for each indicator, though in some cases sufficient data were not available to provide a quantitative evaluation for an indicator. The selection and identification of indicators even when data are not available for analysis is an important exercise, however, because it establishes a need for new data and provides the foundation for future assessments that may be able to incorporate data that currently do not exist.

For each resource, measures for each indicator selected for that resource were compared with reference conditions. In many cases the absence of data for reference conditions and/or the current state of indicators allowed only qualitative comparisons, and for those resources confidence in the assessment was generally low. Evaluation of all indicators for a resource was made subjectively to come to a conclusion regarding the current condition of a resource. With this information the authors then provided their best judgement on each resource condition in terms of management response using the terms "Good", "Of Moderate Concern", "Of Significant Concern", or "Unknown." Trends in condition were described as "Improving", "Stable", "Declining", or "Unknown." Finally, as mentioned, the confidence in each resource assessment was provided as "High", "Medium", or "Low".

The following table (Table ES.1) briefly summarizes the condition of assessed resources. The assessment process for each resource is provided in Chapter 4. Chapter 5 provides a summary (synthesis) of resource conditions for the park.

Table ES.1. Summary of condition assessments for all focal resources.

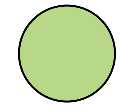
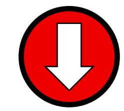
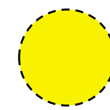
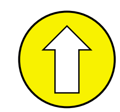
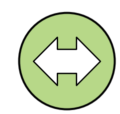
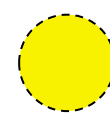
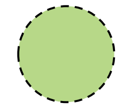
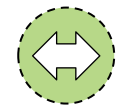
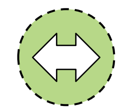
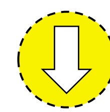
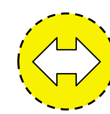
LEWI Resource	Condition and Trend	Assessment	Condition and Trend
Air Quality (Section 4.1)	Good condition, no detectable trends, medium confidence	Air quality is not monitored on-site; there are impacts from river traffic and urban areas but there are no identified threats from nearby land sites. Confidence is medium.	
Climate (Section 4.2)	Poor condition, downward trend, high 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, and confidence in this assessment is high.	
Freshwater Resources (Surface Hydrology and Groundwater) (Section 4.3)	Good condition, no detectable trends, low confidence	Freshwater resources in LEWI appear to be in moderate condition but there are very few current data available. Streamflow conditions are generally unknown and may be of concern in relation to possible changes in precipitation patterns related to climate change and potential withdrawals from the Lewis and Clark River. Groundwater quantity appears good but groundwater quality is of concern. There are no detectable trends and confidence is low.	
Estuaries and Juvenile Salmon (Section 4.4)	Moderate condition, upward trend, medium confidence	The condition of several estuaries in LEWI has greatly improved as a result of comprehensive restoration efforts. Biological conditions are of moderate concern given an apparent absence of data regarding fish presence and presence/absence of invasive species. The trend is improving and confidence is medium.	
Forest Health and Disturbance (Section 4.5)	Good condition, no detectable trend, medium confidence.	Forests appear to be in relatively good condition though disease and impacts from climate change are concerns. Disturbance processes will continue to structure forests, and severe storms may increase in frequency with changing climate conditions. There no detectable trends and confidence is medium.	
Non-salmonid Fish (Section 4.6)	Moderate condition, no detectable trend, low confidence.	Non-salmonid fish appear to be in moderate condition and there are few appearent direct threats to fish in LEWI. But external impacts are significant and confidence is low given the absence of data.	

Table ES.1 (continued). Summary of condition assessments for all focal resources.

LEWI Resource	Condition and Trend	Assessment	Condition and Trend
Amphibians (Section 4.7)	Good condition, no detectable trends, low confidence	LEWI provides important habitat resources for amphibians and this group appears to be in good condition. Climate change impacts to forests and hydrological regimes is a concern. There are no detectable trends but confidence is low given the absence of information.	
Mammals (Section 4.8)	Good condition, no detectable trends, low confidence	Mammals appear to be in good condition though very little is known about any species other than elk. Habitat in LEWI is generally good and there are few known direct threats. The potential introduction of white-nose syndrome to the Pacific Northwest is a concern for bats. Other than for elk there is no information on trends and confidence is low.	
Natural Night Skies & Natural Quiet (Section 4.9)	Good condition, no detectable trends, medium confidence	LEWI is fortunate to have relatively few impacts to natural night skies and quiet. There are no detectable trends though there are few empirical data to support observational assessments.	
Nearshore Marine Conditions (Section 4.10)	Moderate condition, downward trend, low to medium confidence	Multiple impacts of climate change on oceanic processes are occurring and are predicted affect LEWI coastal resources even more strongly in the future. The trend is downward given ongoing climate change and confidence in future conditions is low to medium.	
Landuse & Habitat Connectivity (Section 4.11)	Moderate condition, no detectable trends or stable, high confidence in current landuse but low confidence in habitat integrity in relation to landuse.	Some adjacent landuses almost certainly impair migration and dispersal of some species, however, data to identify such impacts are scarce. Impervious surface cover in park sites is low and road density in Washington sites is moderate. Recent land additions provide important protections to existing resources but many upstream areas are still utilized for timber extraction. The trend is generally stable with some loss of open space to development in adjacent lands but with additions of functional habitat like restored estuaries and recently protected sites. Confidence in the assessment for current landuse is high but low for impacts of landuses on resources, particularly wildlife.	

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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.

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Acronyms and Abbreviations

ARD: Air Resources Division

CCAP: Coastal Change Analysis Program

CO_2: carbon dioxide

DDT: dichlorodiphenyltrichloroethane

EPA: Environmental Protection Agency

FIPS: Federal Information Processing Standard

GCM: general circulation model

GIS: Geographic information system

HUC: hydrologic unit code

IPCC: Intergovernmental Panel on Climate Change

LEWI: Lewis and Clark National Historical Park

MYa: millions of years ago

NLCD: National Landcover Database

NOAA: National Oceanic and Atmospheric Administration

NOCA: North Cascades National Park Complex

NPS: National Park Service

NRCA: Natural Resource Condition Assessment

NWI: National Wetlands Inventory

ORDEQ: Oregon Department of Environmental Quality

PBDE: polybrominated diphenyl ether

PCB: polychlorinated biphenyl

ppm: parts per million

RSI: Request for Statement of Interest

SLR: sea level rise

TIA: total impervious area

TNC: The Nature Conservancy

USFWS: US Fish and Wildlife Service

USGS: US Geological Survey

UW: University of Washington

WADOE: Washington Department of Ecology

WRIA: Water Resource Inventory Area

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 Geographic Information System (GIS) products;[4]
- Summarize key findings by park areas;[5] and
- 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.

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Chapter 2. Park Setting and Resource Stewardship Context

2.1. Introduction

Lewis and Clark National Historical Park (LEWI) preserves, restores, and interprets key historic, cultural, scenic, and natural resources throughout the lower Columbia River. These sites are primarily associated with the Lewis and Clark Expedition's arrival at and exploration of the Pacific coast, and commemorates the 1805–1806 winter encampment at Fort Clatsop. (NPS 2015). Though originally comprised of only the Fort Clatsop site, the 2005 LEWI legislative boundary expanzion now includes seven sites in both Oregon (Clatsop County; 738 ha/1,824 ac) and Washington (Pacific County; 575 ha/1,421 ac), near the mouth of the Columbia River (Table 2.1a and 2.1b, Figure 2.1-1).

Table 2.1a. LEWI units within the national park legislative boundary in Washington and Oregon (NPS).

State	Unit	Owner or Manager	Area ha (acres)
Washington	Cape Disappointment State Park (within LEWI legislative boundary)	Washington State Parks and Recreation Commission, NPS, US Army Corps of Engineers[1]	564 (1,394)
	Clark's Dismal Nitch	NPS, State of Washington, Pacific County[2]	78 (192)
	Middle Village – Station Camp	NPS, private landowner, State of Washington[3]	190 (469)
	Total Authorized Boundary	–	832 (2,055)
Oregon	Fort Clatsop Unit	NPS, private landowners[4]	525 (1,297)
	Salt Works[5]	NPS	0.25
	Sunset Beach State Recreation Area	Oregon Parks and Recreation Department	90 (222)
	Yeon Property	NPS	44 (107)[6]
	Total Authorized Boundary	–	658 (1,626)
Total Authorized Boundary			**1,490 (3,680)**

[1] Of the 1,725 acres of Cape Disappointment, 1,394 are within the park's legislative boundary. NPS conducts natural resource inventories and monitoring on these lands as well as collaborates with Washington State Parks on natural resource projects. Projects falling on NPS owned land are subject to NEPA, NHPA, and other federal laws.

[2] NPS owns and manages 154 acres. Washington Department of Transportation owns and operates the safety rest area, Pacific County owns 5 acres. The State of Washington owns the tidelands.

[3] NPS owns and manages 8 acres. As of publication, discussions are still on-going for the possible acquisition or easement of 347 privately owned acres. The State of Washington owns the tidelands.

[4] Private landowners own approximately 37 acres within the Fort Clatsop Unit.

[5] Because of its small size, Salt Works is not evaluated in this document.

[6] This acreage is subject to a final cadastral survey.

Table 2.1b. Nearby state parks in Washington and Oregon that are not within the LEWI legislatative boundary (NPS).

State	Unit	Owner or Manager	Area ha (acres)
Washington	Cape Disappointment State Park (outside LEWI legislative boundary)	Washington State Parks and Recreation Commission	134 (331)*
	Fort Columbia State Park	Washington State Parks and Recreation Commission	240 (593)
Oregon	Ecola State Park	Oregon Parks and Recreation Department	528 (1,304)
	Fort Stevens State Park	Oregon Parks and Recreation Department	1,619 (4,000)

* These 331 acres are outside of the LEWI legislative boundary.

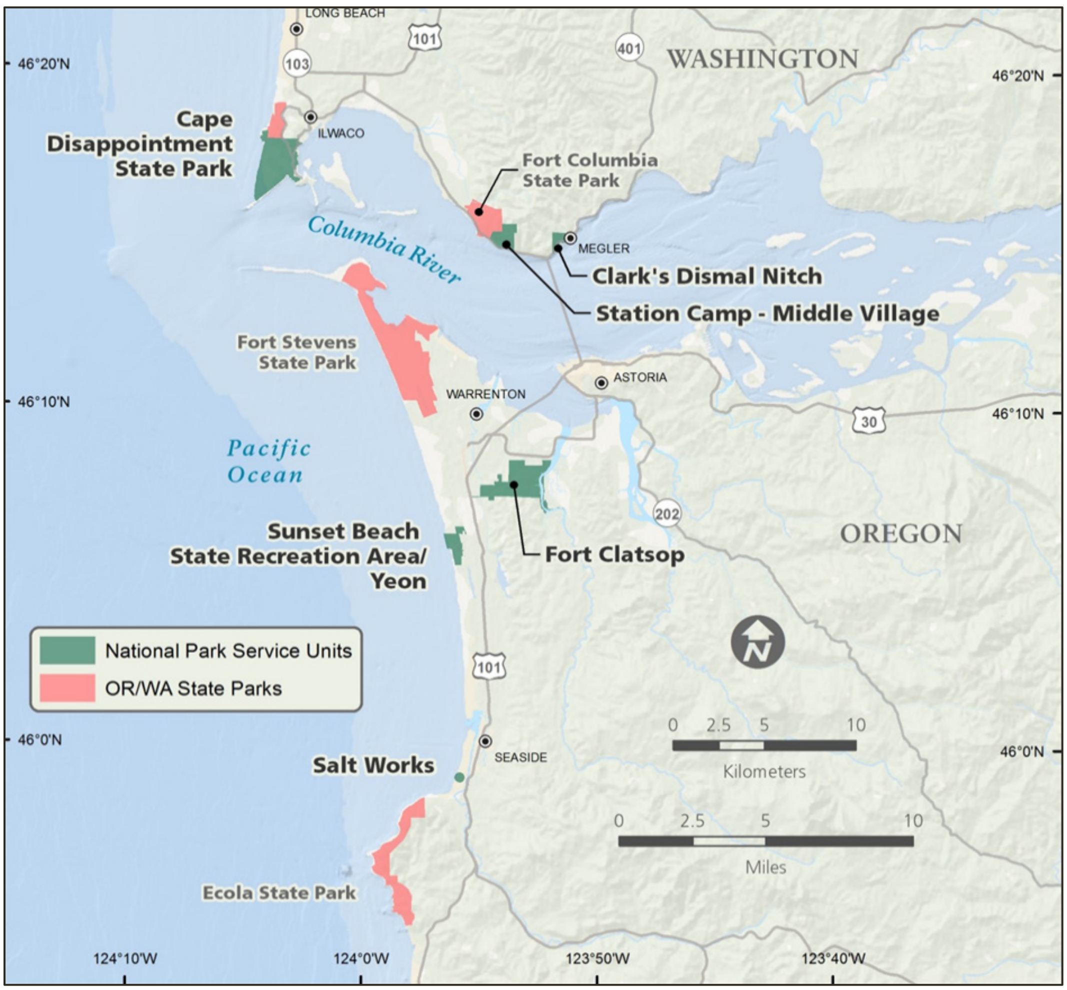

Figure 2.1-1. Map of Lewis and Clark National Historical Park legislative boundary and nearby state parks (University of Washington, School of Forest Resources, GIS).

Some of these sites include contiguous non-NPS lands owned by other jurisdictions within the LEWI boundary (Table 2.1a). The National Park Service, Army Corps of Engineers, and Washington State have entered into an agreement in which the visitor services, law enforcement, and maintenance functions of Cape Disappointment State Park lands within the LEWI jurisdiction operate under the Washington State Parks and Recreation Commission. The NPS conducts natural resource inventories and monitoring on these lands as well as collaborates with Washington State Parks on natural resource projects. Projects falling on NPS owned land are subject to NEPA, NHPA, and other federal laws. In addition to the seven LEWI units there are several nearby state parks (shown in orange in Figure 2.1-1) whose managers often work collaboratively with NPS to protect shared natural resources. Some assessments within this report include data from these state parks outside of the LEWI boundary.

2.1.1. Enabling Legislation/Administrative History

In the early 1900s the Oregon Historical Society began purchasing land where the original Fort Clatsop was believed to have been located. Congress was first petitioned to officially recognize the site in 1906, and though no action was taken at that time, by the late 1930s NPS had determined the site should instead be a state park. Not until the mid-1950s when a collaboration of local groups built a replica of the fort to commemorate the 150th anniversary of the Lewis and Clark winter encampment did Congress revisit the question of national significance. Fort Clatsop National Memorial, comprised of approximately 125 ac (51 ha) surrounding the assumed site of the fort, was authorized in May 1958 and officially designated in October 1962. In 1966 the Memorial was included in the National Register of Historic Places, with the 0.2 ac Salt Works parcel added in 1979.

With the passage of the Fort Clatsop Boundary Expansion Act in 2002, the size of Fort Clatsop increased to approximately 1,500 acres (607 ha). The Memorial was subsequently re-designated as a National Historical Park in October 2004 with the passage of the Lewis and Clark National Historical Park Designation Act. This legislation also added an additional 2,055 acres (832 ha), including Dismal Nitch Station Camp Middle Village, Fort Canby (now Cape Disappointment). In 2004 the Fort to Sea trail was established, and in 2006 approximately 1,200 acres (486 ha) were purchased from Weyerhaeuser. Most recently the 107 acre (44 ha) Yeon Property was purchased and added to the park. A detailed history of the park is provided in Cannon (1995) and in the park's Foundation Document (NPS 2015).

2.1.2. Geographic Location and Physical Setting

Lewis and Clark National Historical Park is unusual within the National Park system in that two sites included within the park are not specifically managed by NPS. Though not all sites will be addressed in this report, all sites within LEWI are briefly described below.

<u>National Park and State Park sites in Oregon</u>

The *Fort Clatsop* unit includes the site believed to have been where Lewis and Clark constructed their winter encampment. The site is adjacent to the Netul River (now known as the Lewis and Clark River), and provided the expedition with fresh water and forest resources to sustain them through the winter. About a mile from the fort site on the river is Netul Landing, a former commercial log dump site that is now a day use area with picnic shelters.

The *Fort to Sea Trail,* commemorating the approximate route used by the expedition, begins at Fort Clatsop and continues to the ocean terminating at *Sunset Beach State Recreation Area*. Just to the south is the recently acquired Yeon Property.

Ecola State Park is located north of Cannon Beach, OR, and includes the most intact forest stand in any of the units. The site is significant as the location where expedition members trekked in 1806 to scientifically describe a beached whale and trade for its oil and blubber. *Fort Stevens State Park*, located on the most northwestern tip of Oregon and constructed during the Civil War, is the largest state park in the area and is characterized by extensive salt marsh habitat.

<u>National Park and State Park sites in Washington</u>
Clark's Dismal Nitch is located adjacent to the Columbia River just east of the Astoria Bridge. The site is named after a passage in Clark's journals: "canoes loaded in great haste and Set Out, from this dismal nitich where we have been confined for 6 days passed, without the possibility of proceeding on, returning to a better Situation, or get out to hunt, Scerce of Provisions, and torents of rain poreing on us all the time" (Clark in Moulton 1990). Middle Village – Station Camp is the former site of an important Chinook tribal trading center and is now an interpretive day use site. Fort Columbia State Park is located on the Columbia River adjacent to the Middle Village – Station Camp unit in Washington. Fort Columbia and Cape Disappointment (previously Fort Canby) were former military sites placed to defend the mouth of the Columbia River from 1896 to 1947. Cape Disappointment State Park is located on the peninsula at the extreme southwestern tip of Washington and includes twenty-seven miles of coastline, much of which has been accreted since the construction of the northern jetty. The name refers to Captain John Meares failure in 1788 to locate the previously charted Columbia River.

<u>Surrounding Landuse</u>
LEWI sites are surrounded by multiple types of landuse and water resources. The lands around the park are a mix of open space (primarily forests and coastal habitats), agricultural lands, and developments and housing. The Columbia River adjoins LEWI sites in both Washington and Oregon, as does the Pacific Coast (Figure 2.1-2). An assessment of landuse and habitat connectivity is provided in Section 4.11.

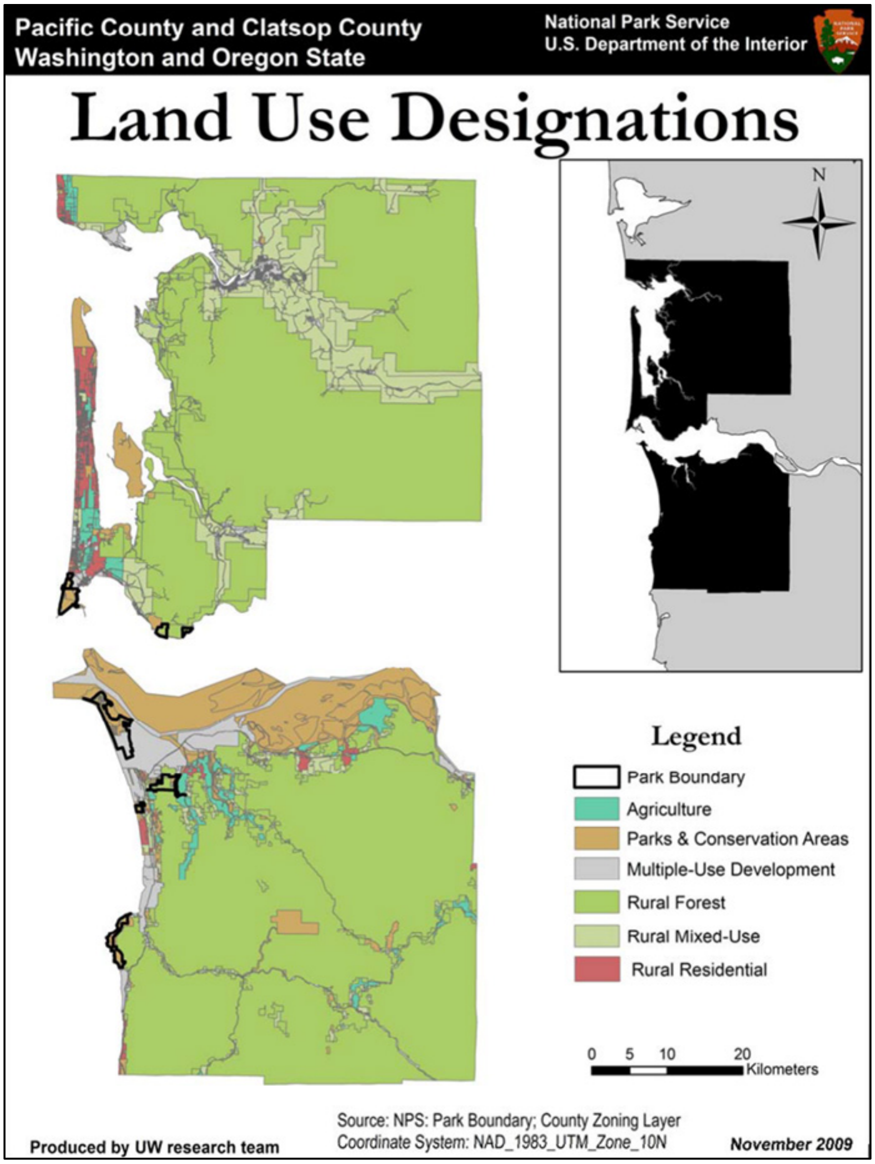

Figure 2.1-2. Landuse designations within Pacific and Clatsop counties, including LEWI units and nearby state parks. Data summarized in Section 4.11. (University of Washington, School of Forest Resources).

2.1.3. Cultural History and Significance

From the time of early Native Americans to the arrival of Lewis and Clark and then permanent Euro-American settlements, the region surrounding the mouth of the Columbia River has provided humans with substantial natural resources. The protection and interpretation of the cultural history that resulted is one of the missions of the NPS at LEWI (NPS 2015). Many excellent resources exist that document the cultural history of LEWI, so only a brief summary of the cultural resources of the park will be presented here. Readers are directed to sources such as Cannon (1995), Bergman (2008), and Deur (2016) for greater treatment of the rich history of humans in northwestern Oregon and southwestern Washington.

The depiction of the Chinookan speaking people as recorded in the Lewis and Clark journals is considered to be among the best-documented post-contact views of daily life and culture among these tribes (Cannon 1995). Abundant marine and coastal resources supported one of the largest and densest indigenous populations north of Mexico (Deur 2016). The first European-Chinookan contact is reported from 1792, but between that period and the arrival of Lewis and Clark in 1805, disease had devastated the Native American populations (Boyd and Boyd 1999, Ronda 2002).

Following the establishment of Fort Clatsop, other people utilized the site. European settlement of Washington and Oregon increased following the signing of a boundary treaty with Great Britain in 1846. Carlos Shane received a land claim for Fort Clatsop in 1850 and over time all of the remaining old-growth forests were cleared as timber mills were built and logging production boomed. The extensive land clearing of the time also facilitated the establishment of orchards, small gardens, and land for animal grazing. Many estuaries and wetlands were also lost when they were diked and filled with soil to increase available farmland.

Around the beginning of the 20th century transportation expanded to include railroads, allowing even greater trade to occur. For example, clay of suitable quality for pottery was available at the Fort Clatsop site and extraction occurred between 1887 until about 1920 (Cannon 1995). Commercial fishing, particularly for salmon, increased in ports such as Ilwaco, WA, and Astoria, OR, and dams were built on the Columbia River, initiating the decline of most of the region's salmon species (Chapman 1986).

2.1.4. Visitation

From 2007–2016, annual visitation to Fort Clatsop and Salt Works ranged from ~192,000 to ~282,000 with an average of ~232,000 for the period. The park's visitor counting methodology has not been updated since the addition of other units to the park. Visitation in 2016 was approximately 4 percent greater than in 2015 (http://irma.nps.gov/stats). Visitation surveys were conducted for the Memorial in 1986 (Fort Clatsop National Memorial 1995), and repeated in 1987 and 1988. Results showed that 60 percent of the visitors visited the park because of their interest in Lewis and Clark Expedition history, 12 percent had heard about the park's programs, and another 11 percent expressed a passing interest. Approximately 70 percent were first time visitors and more than half lived outside of Oregon; 75 percent were family groups. A considerable portion of visitation is associated with commercial tours provided by chartered buses and tour ships (21,300 visits in 2003–04).

2.2. Physical Resources and Processes

2.2.1. Climate

The climate of LEWI is relatively mild and largely moderated by marine influences. Annual precipitation averages 70–90 in (180–230 cm), and is most abundant in autumn and winter. The mean annual temperature between 1971–2000 was 51°F (11°C), with mean January temperatures of 37°F (3°C) and July temperatures of 68°F (20°C; WRCC 2009). There are frequent periods of summer fog and snow is rare. Intense Pacific storms can include extreme winds, for example in December of 2007 a storm brought winds of over 100 mph (160 kmh). Climate is discussed in detail in Section 4.2.

2.2.2. Geology

Much of the area underlying LEWI sites is ~60 MYa basalt (late Paleocene to early Eocene) including the Crescent Formation which appears in rock found at Cape Disappointment, Fort Columbia, and Middle Village – Station Camp (Babcock and Carson 2000). During the Eocene, sedimentary material (sand and mudstones) was deposited on this basal sea floor material. Repeated basalt flows from eastern Washington and Oregon during the Miocene reached the coast. Subsequent uplift resulted in exposure and erosion of these deposits; an example can be seen at Haystack Rocks near Ecola State Park.

During the Pleistocene, glacial dams formed in what is now the northern Rocky Mountains. When those dams periodically broke, enormous volumes of trapped ice, water, and debris washed down through the Columbia Gorge, depositing material and forming new canyons. Beginning about 8,500 years BP, the development of extensive sand and alluvial deposits occurred as seas began rising (Cooper 1958, Meyers 1996, Rankin 1983, Reckendorf et al. 1985 and 2001, Woxell 1998).

Several prominent landforms that reflect geologic history are visible including the sedimentary hills that make up the Fort Clatsop unit, the basalt remnants at Cape Disappointment, McKenzie and Tillamook Heads, the summits of Bald and Clark's Mountains and Scarborough Hill, and the sand and alluvial depositional lowlands which include the sand dune plains of NW Clatsop County (Fort Stevens, Sunset Beach and the Yeon Property).

Geologically, the entire Pacific Northwest (PNW) is affected by the interactions of several large tectonic plates located in the north Pacific (Dziak 2006). Seismic activity generated by plate movements (and other factors more complex than can be discussed here), has resulted in a series of historical, major subduction earthquakes off the coast, often with associated tsunamis (Geist 2005, Meyers et al. 1996). The most recent event was the Cascadia earthquake of January 26, 1700 (Benson et al. 2001, Jacoby et al. 1997). There is some evidence of an approximate 300-year periodicity to these events (Benson et al. 2001, Meyers et al. 1996), and regional public safety authorities generally take the threat of a tsunami quite seriously (Wood et al. 2010, Komar et al. 2013, Sleeter et al. 2017).

<u>Clatsop Plains</u>

A geologic feature that has particular relevance to ecological processes is the Clatsop Plains. (Reckendorf et al. 2001; Figure 2.2-1). The vertical change in elevation of the dunes ranges from 30–70 ft (9–21 m) and the distance between the dunes ranges from less than 100 ft to over 300 ft (30–90 m). The dune system is relatively young, with the oldest dune dated to approximately 5,000 years ago. Between the dunes are seasonal ponds, lakes and associated welands where visible water indicates that groundwater levels are very close to the surface.

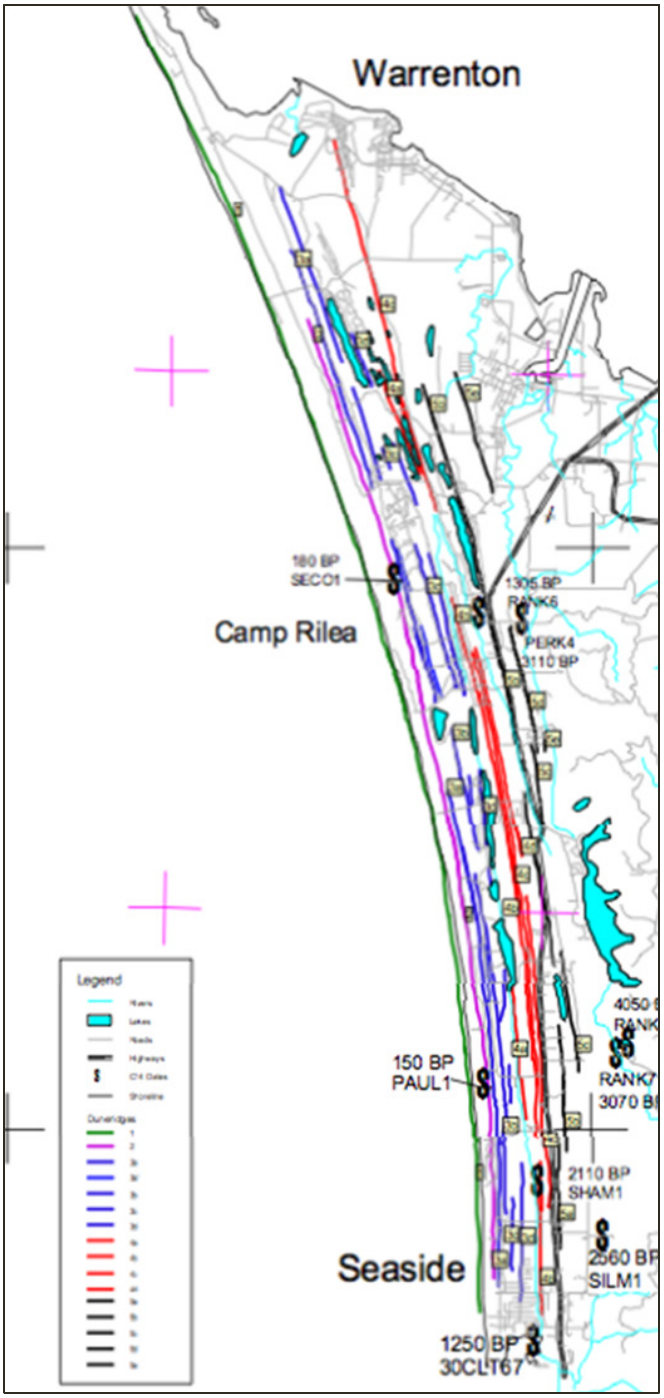

Figure 2.2-1. Diagram of the series of dune ridges associated with the Clatsop Sand Dune Plains (Reckendorf et al. 2001). The basemap is from the Oregon State GIS Center, Universal Transverse Mercator Projection, Zone 10, 1983 North American Datum, Portland State University GeoData Clearinghouse.

2.2.3. Soils

In Clatsop County, geological history and surface processes have resulted in five different soil categories (Smith and Shipman 1988): flood plains, terraces, and dunes (13% of Clatsop County);

soils on sedimentary and basalt mountains (43%); warm soils on flood plains and terraces (3%); warm soils on mountains (29%); and cold soils on mountains (12%). Warm and cold are related to distance from the ocean and elevation, respectively. These five categories are composed of 9 map units and 23 sub-units. Soils range from well-drained sands to clay and organic mucks.

The first two categories of soil dominate the Oregon units of LEWI. Many of these soils, particularly those derived from mudstone, are prone to movement and large slides occasionally occur at the interface between basalt and sedimentary rock types (Schlicker et al. 1961). In addition, poorly drained soils are often associated with shallow rooted trees that are then prone to windthrow (Agee 2000). For Pacific County (north of the Columbia River in Washington), a similar distribution of soil types is found.

2.2.4. Hydrology and Water Quality

The aquatic resources of LEWI are well described and evaluated by Klinger et al. (2007). A variety of water resources are present including upland rivers and streams, tidally-influenced (brackish) estuaries and wetlands, small springs and surface lakes, coastal (marine) waters, and groundwater (fresh and brackish; Figure 2.2-2).

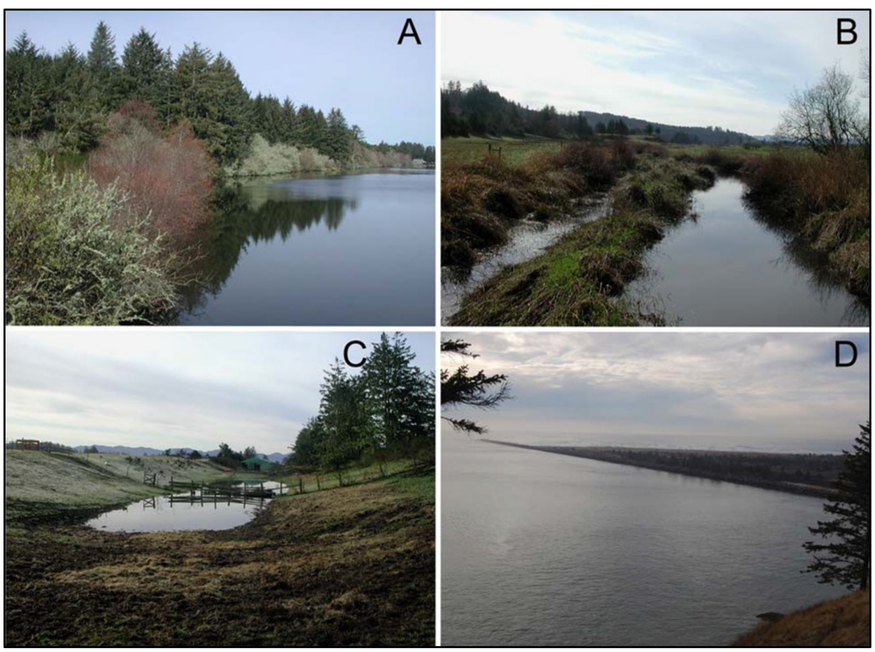

Figure 2.2-2. Photographs illustrating some of the water resource features at LEWI: A. Sunset Lake (lacustrine wetland with willow, red osier dogwood, and Sitka Spruce); B. Skipanon River – Transition between sedimentary hills to east (left side of the picture) and coastal dune prairie system to west; C. A palustrine wetland next to a cattle pasture in the Clatsop Plains (dune prairie system); D. North jetty and the Pacific Ocean from Cape Disappointment. Photographs by T. Hinkley.

There are a total of 13 mi (21 km) of shoreline and 152 acres (62 ha) of water included in LEWI and nearby state parks. Freshwater resources are assessed in Section 4.3 and estuaries in Section 4.4. Youngs Bay and Baker Bay are prominent features of the lower Columbia River Estuary (CRE).

Youngs Bay is located on the south side of the Columbia River (Oregon) between Astoria and Warrenton, OR. The bay is fed by four rivers: the Lewis and Clark, Youngs, Klaskanine, and Wallooskee (Walluski). Baker Bay, on the north side of the river (WA) is fed by the Chinook River.

Coastal and Tidal Processes

The natural resources as well as the cultural history of LEWI are strongly tied to the presence of the Columbia River and the Pacific Ocean. Specifically, tidal processes are a primary input to functioning healthy estuaries. The tides at the mouth of the Columbia River range from approximately 5 ft to over 8 ft (2–3 m; Table 2.2-1). Dikes were constructed in Youngs Bay and the Lewis and Clark River between 1917 and 1939, and jetty construction in the region began as early as 1885 near the mouth of the Columbia River. These activities have reduced wave action and currents throughout the CRE (Jay et al. 2016). Recent restoration efforts have restored important tidal inputs at many sites; and estuaries are assessed in Section 4.4.

Table 2.2-1. Tidal data (NOAA 2009).

Location	Mean Range (ft/m)	Spring Range	Mean Tide Level
Columbia River entrance (N. Jetty, WA)	5.6/1.7	7.5/2.3	4.0/1.2
Fort Canby, Jetty "A", WA.	6.2/1.9	8.3/2.5	4.5/1.4
Chinook, Baker Bay, WA	6.1/1.9	8.1/2.5	4.3/1.3
Seaside, 12th Ave. Bridge, OR	4.7/1.4	5.8/1.8	2.8/0.9
Warrenton, Skipanon River, OR	6.5/2.0	8.3/2.5	4.4/1.3
Astoria (Youngs Bay), OR	6.7/2.0	8.6/2.6	4.5/1.4

Of primary importance to nearshore resources are oceanic upwelling processes that bring colder water and nutrients from lower depths to the ocean surface. Coastal upwelling in the eastern Pacific is a powerful dynamic that affects ocean chemistry, climate, coastal geomorphology, and marine and nearshore ecosystems (Hickey and Banas 2003).

2.2.5. Water Quality

The Columbia River is a major source of toxics and other pollutants to estuaries and coastal resources in LEWI, while upstream and urban uses affect streams and other freshwater sites (Klinger et al. 2007, Hand et al. 2018). Groundwater is sensitive to contamination, and with rising sea levels associated with climate change salt water intrusion may become a problem. Surface and groundwater quality are addressed in Section 4.3.

2.2.6. Fire

Natural (non-human ignited) fires are rare in the moist conditions of Pacific Northwest forests (Agee 1993). There is evidence that Native peoples utilized fire to clear areas for the improvement of deer and elk habitat and specific plant species, but those practices do not appear to have been practiced on a landscape scale (Deur 2016). Fire processes in relation to forest condition are discussed in Section 4.5.

2.3. Biological Resources

LEWI units contain a variety of ecosystems including marine intertidal, sandy shorelines and dunes, brackish estuaries, rocky headlands, temperate rainforests and riparian corridors. Ecoregionally, LEWI lies within the Coastal Sitka Spruce ecosystem at the convergence of the Coast Range habitat and the wetlands of the Columbia River estuary. Because all LEWI sites lie within about 10 miles (16 km) of the Pacific Ocean, park natural resources are highly affected by oceanic processes and conditions.

2.3.1. Vegetation Communities

The historical vegetation for the LEWI units and nearby state parks in Oregon is shown in Figure 2.3-1. Significant portions of Fort Stevens and Sunset Beach show no data as they are derived from sand and alluvial depositions that were not present historically. The historical vegetation was dominated by forests, especially at Fort Clatsop; Agee (2000) estimated that approximately 40% of the forest was old-growth. Wetlands were particularly evident at Fort Stevens, while grasslands and sand dunes were present at Fort Stevens and Sunset Beach. Ecola State Park was mostly forested.

The current vegetation of LEWI and surrounding regions is described in detail in Kagan et al. 2012 and summarized from that report and other sources below.

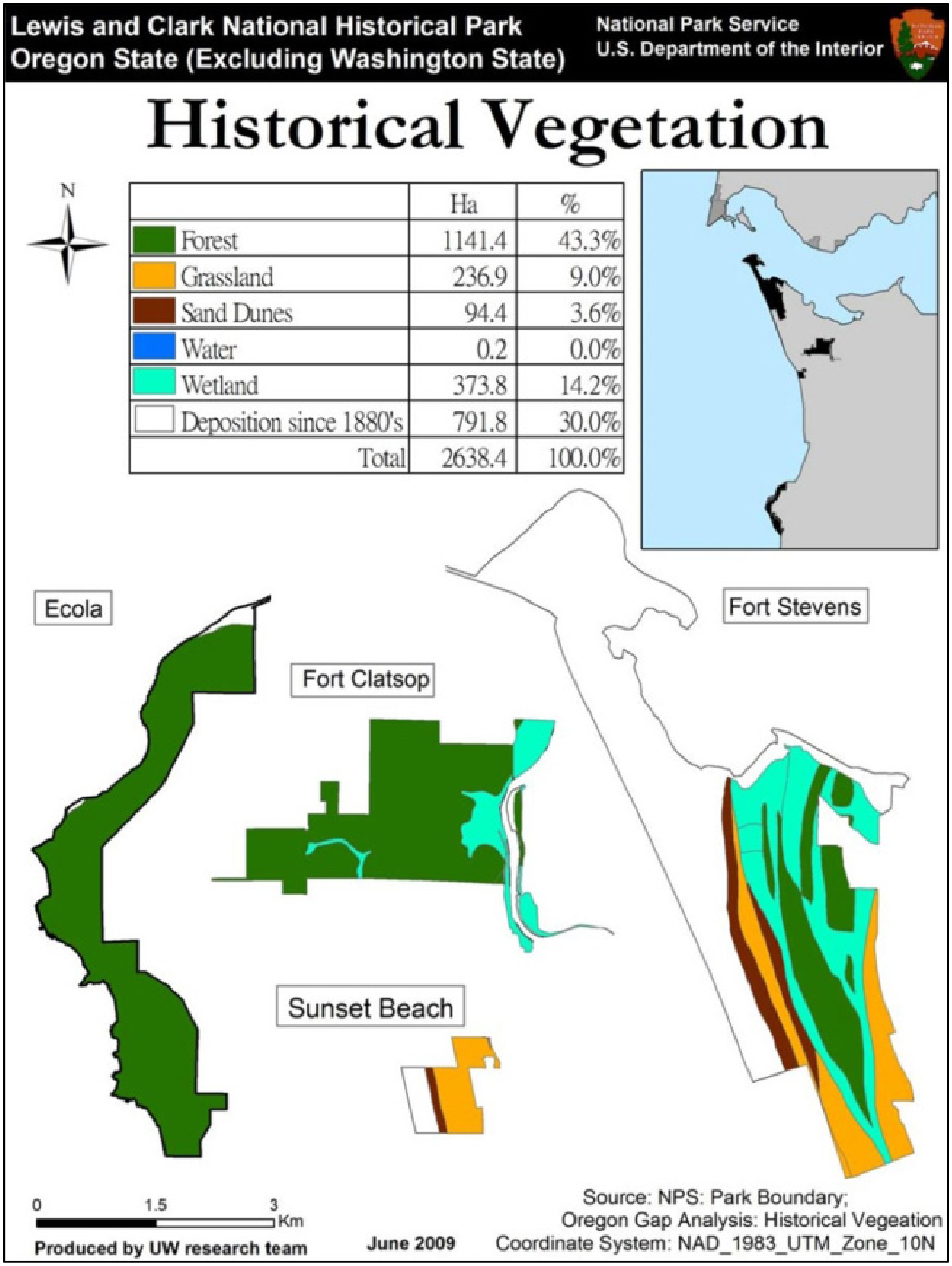

Figure 2.3-1. Historical vegetation of the Ecola, Fort Clatsop, Fort Stevens, and Sunset Beach units. Comparable data have not been compiled for units in Washington (University of Washington, School of Forest Resources).

Forests

Historically, large Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) trees dominated the forests of LEWI (Figure 2.3-2). Prior to European settlement at least 40% of the coastal hills were old-growth Sitka spruce/western hemlock forests (Agee 2000). Today, less than 5% of the original old-growth forest remains; in the study area, the largest stand is currently found in Ecola State Park and Cape Disappointment has a few remnant stands. Other sites have forests on their second, third, and even fourth rotation (NPS 2011b). At the Fort Clatsop unit, forests are being actively restored to accelerate their trajectory to a forest more natural in structure, function, and appearance. (NPS. 2011b). Kagan et al. (2012) calculated approximately 4,443 acres (1,798 ha) of all forest types (including disturbed) in the study area, with the large majority being alder upland and Sitka spruce forests.

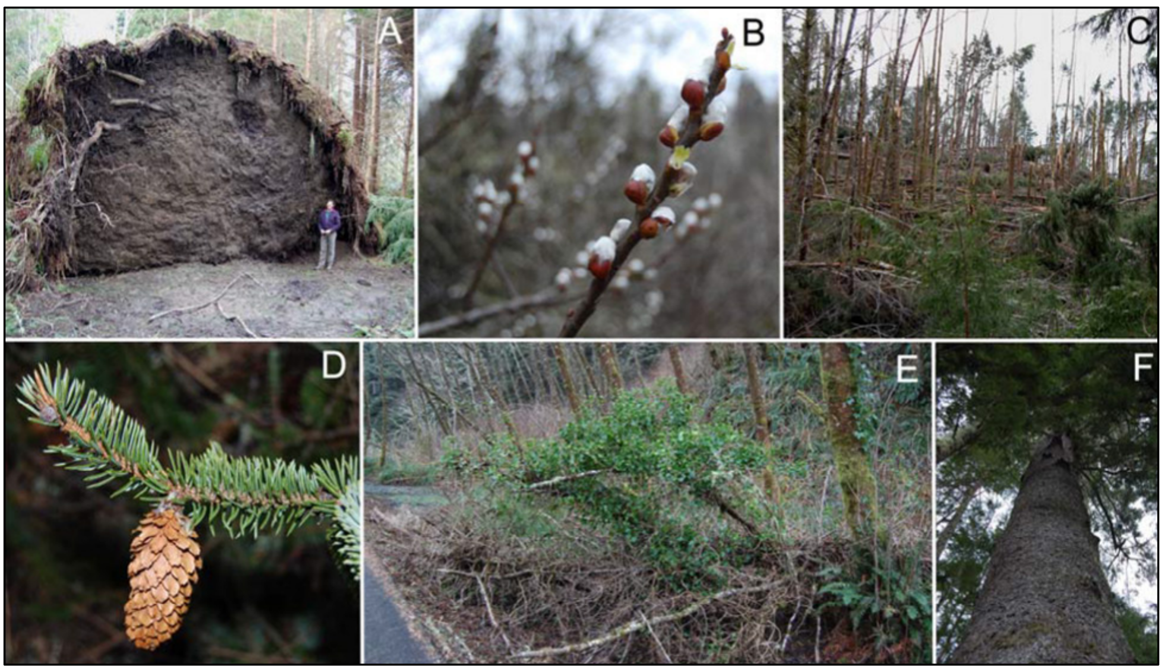

Figure 2.3-2. Photographs illustrating some of the upland resources: A. Root wad of a large, 80-year-old Sitka spruce uprooted as a result of the December 2007 windstorm. B. Late March 2009 willow buds. C. Forest damage as a result of the December 2007 windstorm. D. Sitka spruce branch and cone. E. Invasive English ivy on red alder at Beard's Hollow, Cape Disappointment. F. Stem and crown of an old-growth Sitka spruce in Ecola State Park. All photographs by T. Hinckley.

Nearshore/Dunes

Coastal and dune plant communities have changed dramatically since European settlement. Extensive grazing in the late 19th and early 20th centuries damaged the soil layers and exposed dune sand to wind erosion leading to severe dust storms that could at times close US Highway 101. In order to stabilize the dunes European beach grass (*Ammophila arenaria*) and shore pine (*Pinus contorta* var. *contorta*) were planted in the 1930s. Ecologically important native dune plants include the early blue violet (*Viola adunca*), a host for the threatened Oregon Silverspot butterfly (*Speyeria* *zerene hippolyta*). Kagan et al. (2012) calculated 2,011 acres (814 ha) of all dune types (includes herbaceous headland).

Wetlands/Estuaries

LEWI and nearby state parks contain 14 types of wetlands within five wetland systems (Marine, Estuarine, Palustrine, Lacustrine, and Riverine), as identified by the National Wetland Inventory (NWI; NPS 1994). Estuarine and marine wetlands are common in the study area, and compose 45% of the current aquatic ecosystems. Because estuaries have been lost and degraded all along the Pacific Coast and particularly along the Columbia, these sites are significant for the estuarine resources they protect. Kagan et al. (2012) calculated approximately 344 acres (139 ha) of tidal fresh-brackish marsh and salt marsh.

LEWI does not have large areas of freshwater ponds, lakes, or riverine ecosystems. A spring near Fort Clatsop, believed to be the source of drinking water for the expedition, flows for approximately nine months of the year and is the source of a small stream that flows to the Lewis and Clark River. Freshwater Resources are assessed in Section 4.3, and Estuaries in Section 4.4.

Plant Diversity

In total, 382 vascular plant taxa have been recorded within the study area, approximately 30% of the 1,287 species present in the regional species pool (Appendix 1). The proportional distribution of plant species among taxonomic groups is very similar with the regional species pool: dicots account for ~ 70% of the species richness, monocots for 25%, and the other taxonomic groups for small amounts. A total of 73 bryophyte taxa have been documented with about two-thirds being true mosses (Appendix 2). Ninety-nine species of fungi have been recorded, half of which are gilled fungi. Sixty-one lichen taxa have been recorded, most of which have a foliose growth form (Appendix 2).

2.3.2. Species and Communities of Concern

Rare Plant Communities

Several plant communities (associations) found in LEWI and nearby state parks are regionally or globally rare and/or of concern (Table 2.3-1). Big-headed sedge communities were once common along the coast but have now become rare due mostly to the conversion of dunes to developed sites and the presence of non-native grasses (Wise and Kagan 2012). Local occurrences of big-headed sedge occur at Fort Stevens and Cape Disappointment. Pacific Reedgrass –Blue Wildrye perennial grasslands occur at the North Head headland in Cape Disappointment, the only known location in southwest Washington and one of three occurrences for the entire state (Washington State Parks and Recreation Commission 2004). These grasslands are more common in Oregon with a stand in Ecola State Park.

Table 2.3-1. Rare plant associations present at Lewis and Clark National Historical Park. Compiled from Kagan et al. 2012 and Nature Serve (https://www.natureserve.org/).

Scientific Names	Common Names	Growth Form	Rank*
Carex macrocephala	big-headed sedge	herbaceous dune association	G1G2S1
Picea sitchensis/Carex obnupta – Lysichiton americanus	Sitka spruce / slough sedge – skunk cabbage	forested swamp	G2G3S1
Festuca rubra	red fescue	coastal grassland	G2S2
Calamagrostis nutkaensis – Elymus glaucus	Pacific reedgrass – blue wildrye	perennial grassland	G2S1
Carex lyngbyei – Argentina egedii	Lyngby sedge – Pacific Silverweed	herbaceous salt marsh	G4S2

*. Global Ranks as reported by NatureServe. State rank for Oregon as determined by Oregon Biodiversity Information Center. Rank Definitions: G=Global, S=State, T=Taxon (variety, subspecies). 1=Critically imperiled; 2=Imperiled; 3=Rare, uncommon, or threatened; 4=Not rare and apparently secure; 5=Demonstrably widespread, abundant, and secure.

Rare Plant Species

Ocean-bluff bluegrass (*Poa unilateralis*) is identified as Threatened in Washington and in LEWI is found only at Cape Disappointment on cliffs and ledges near the coast (Sayce and Roche 2015); the species is more common in Oregon. Coyote brush (*Baccharis pilularis*) is also identified as Threatened in Washington and found at Cape Disappointment, where it exists at the northern extent of its range (Morrison et al. 2005).

Animals

Thirty-one animal species found in LEWI are listed as Endangered, Threatened, Candidate, or Sensitive (Table 2.3-2). Many listed species in LEWI have ranges that extend far outside park sites, such as fish and birds, so may spend only short periods of their life cycle in the park.

Table 2.3-2. Endangered, Threatened, Sensitive, and Candidate animal species in LEWI (compiled from multiple sources). Status codes: E = Endangered; T = Threatened; C = Candidate; Co = Species of Concern (only reported at the Federal level for species that are also identified at the State level); and S = Sensitive.

Group	Scientific Name	Common Name	Federal	Oregon	Washington
Amphibians	*Dicamptodon copei*	Cope's giant salamander	–	S	–
	Rhyacotriton kezeri	Columbia torrent salamander	–	S	–
	Plethodon dunni	Dunn's salamander	–	–	C
	Rana aurora aurora	Northern red-legged frog	Co	S	–
Birds	*Aechmophorus occidentalis*	Western grebe	Co	–	C
	Brachyramphus marmoratus	Marbled murrelet	T	T	T
	Cerorhinca monocerata	Rhinoceros auklet	–	S	–
	Charadrius alexandrinus nivosus	Western snowy plover	T	T	E
	Dryocopus pileatus	Pileated woodpecker	Co	S	C
	Falco columbarius	Merlin	Co	–	C
	Falco peregrinus	Peregrine falcon	Co	–	S
	Gavia immer	Common loon	Co	–	S
	Haematopus bachmani	Black oystercatcher	–	S	–
	*Haliaeetus leucocephalus**	Bald eagle	*	T	S
	*Pelecanus occidentalis californicus**	Brown pelican	*	E	E
	Phalacrocorax penicillatus	Brandt's cormorant	–	–	C
	Podiceps grisegena	Red-necked grebe	–	S	–
	Progne subis	Purple martin	Co	S	C
	Uria aalge	Common murre	–	–	C
Invertebrates	*Speyeria zerene hippolyta*	Oregon silver-spot butterfly	T	–	E
Fish	*Acipenser medirostris*	Green sturgeon	T	–	–
	Lampetra richardsoni	Western brook lamprey	–	S	–

* Delisted due to recovery

Table 2.3-2 (continued). Endangered, Threatened, Sensitive, and Candidate animal species in LEWI (compiled from multiple sources). Status codes: E = Endangered; T = Threatened; C = Candidate; Co = Species of Concern (only reported at the Federal level for species that are also identified at the State level); and S = Sensitive.

Group	Scientific Name	Common Name	Federal	Oregon	Washington
Fish (continued)	*Oncorhynchus keta*	Chum salmon (Columbia River [ESU)	T	S	C
	Oncorhynchus kisutch	Coho salmon (Lower CR ESU)	T	E	C
	Oncorhynchus kisutch	*Coho salmon (Oregon Coast ESU)*	T	–	–
	Oncorhynchus mykiss	Steelhead salmon (LCR ESUs)	T	S	C
	Oncorhynchus mykiss	Steelhead salmon (Middle Columbia River ESU)	T	–	C
	Oncorhynchus mykiss	Steelhead salmon (Snake River ESU)	T	–	C
	Oncorhynchus mykiss	Steelhead salmon (Upper Columbia River ESU)	T	–	C
	Oncorhynchus mykiss	Steelhead salmon (Oregon Coast ESU)	Co	–	–
	Oncorhynchus tshawytscha	Chinook salmon (LCR ESU)	T	S	C
	Oncorhynchus tshawytscha	Chinook salmon (Upper Columbia River ESU, spring run)	E	–	C
	Oncorhynchus tshawytscha	Chinook salmon (Upper Willamette River ESU spring run)	T	–	C
	Oncorhynchus tshawytscha	Chinook Salmon (Snake River ESU, fall run)	T	T	C
	Oncorhynchus tshawytscha	Chinook Salmon (Snake River ESU, spring/summer run)	T	T	C
	Thaleichthys pacificus	Eulachon	T	_	C
Mammals	*Lasiurus cinereus*	Hoary bat	–	S	–
	Myotis californicus	California myotis	Co	S	–

* Delisted due to recovery

Table 2.3-2 (continued). Endangered, Threatened, Sensitive, and Candidate animal species in LEWI (compiled from multiple sources). Status codes: E = Endangered; T = Threatened; C = Candidate; Co = Species of Concern (only reported at the Federal level for species that are also identified at the State level); and S = Sensitive.

Group	Scientific Name	Common Name	Federal	Oregon	Washington
Mammals (continued)	*Myotis thysanodes*	Fringed myotis	Co	S	–
	Myotis volans	Long-legged myotis	Co	S	–

* Delisted due to recovery

Invertebrates

The Oregon silverspot butterfly (*Speyeria zerene hippolyta*) has been extirpated from several historical sites, and there are currently no self-sustaining populations in the area. A successful captive breeding and recovery program is working to re-establish populations and this species was recently reintroduced to Saddle Mountain State Natural Area. LEWI partners with the North Coast Land Conservancy, the Institute for Applied Ecology, and the USFWS to test the effectiveness of different site preparation treatments to recover the wildflower community to support a possible reintroduction on the Clatsop Plains.

Birds

Marbled Murrelet

Marbled murrelets ("murrelets") are small seabirds that forage at sea but nest in mature coniferous forests from northern California to British Columbia. Murrelets travel a maximum of 20–40 mi (30–60 km) inland (Hamer and Nelson 1995, NPS 2010a, 2011b) to nest, most often in western hemlock and Sitka spruce stands with moderate canopy cover. The older forests of Cape Disappointment provide suitable nesting habitat and WDFW biologists spotted murrelets in flight while surveying near Middle Village-Station Camp (C. Cole pers. comm. 2016).

Northern Spotted Owl

Northern spotted owls are present in Clatsop County but are not known to nest in or near LEWI sites (NPS 2010a, NPS 2011b), and there is no critical habitat nearby (https://www.fws.gov/pacific/ecoservices/nso/northern%20oregon%20coast%20ranges.pdf).

Fish

Numerous alterations to hydrologic processes and habitats throughout the CRE have impacted many fish species. The condition of most if not all salmon species in the CRE has declined, a situation well-studied by many agencies, tribes, and stakeholders. Adult salmon are rare in LEWI estuaries or rivers, but juvenile salmon require the kinds of habitat LEWI estuaries provide. Juvenile salmon are discussed in Section 4.4 in relation to estuary condition, and non-salmonid fish are addressed in Section 4.6.

Mammals

Fishers

Fishers (*Pekania pennant*), are small mustelids that were extirpated from western Oregon. The species has been proposed for reintroduction, and some small portions of LEWI might provide appropriate habitat (Halsey et al. 2015, Hiller 2015).

Elk

Roosevelt elk (*Cervus canadensis roosevelti*) have a strong connection to the history of the Lewis and Clark Expedition. Their abundance along the Netul River was a key factor in the selection of Fort Clatsop for the winter encampment. During their four months, the expedition shot 131 elk. Elk not only provided a food source, but also provided tallow for candles, and hides for clothing and over 350 pairs of moccasins (Griffin et al. 2011). While Roosevelt elk were extirpated from other parts of

Western Oregon, the herds around Fort Clatsop survived and were used to repopulate other areas of the state. Elk are discussed further in Section 4.8

2.4. Relevant Regional and Landscape-scale Information

2.4.1. Disturbance

Wind storms are a major disturbance factor within LEWI. Other types of natural disturbances (tsunamis, fires) are much less common but could have significant effects on resources depending on where and when they occur. The increasing likelihood of severe storms in relation to climate change is discussed in Section 4.2, and impacts of wind on forests in Section 4.5.

2.4.2. Shoreline erosion

The southwest coasts of Washington are structured by erosion and accretion. Beaches are fed by sediments from the Columbia River basin and distributed by the river plume generally in a north-northwestward direction in response to nearshore winds and currents (Hickey et al. 1998). In recent decades the rate of accretion has slowed largely due to impoundment of those Columbia Basin sediments behind dams throughout the basin.

An example of an area that is now experiencing substantial erosion is Cape Disappointment State Park to the extent where beachside areas once targeted for campground construction have been removed from the planning process due to erosion. Park managers have also decommissioned sewer ponds because of fears that the ocean might erode into them. Researchers at Oregon State University predict that by 2020, the shore areas for about six miles north of North Head may retreat between 100 and 300 meters (http://www.beachapedia.org/State_of_the_Beach/State_Reports/WA/Beach_Erosion).

2.4.3. Adjacent landuse

The areas surrounding and adjacent to LEWI properties are a mix of protected open space, private managed forests, and urban development. Landuse and habitat integrity are addressed in Section 4.11.

2.5. Primary Threats to Natural Resources

2.5.1. Invasive Plants

LEWI contains proportionally more noxious weeds and non-native vascular plant species (41%) than expected based on the regional species pool. This calculation may be higher than expected due to significant efforts by LEWI staff to locate and treat (and thus document) the presence and locations of noxious weeds. In order to stabilize dunes, European beach grass (*Ammophila arenaria*), American beach grass (*A. breviligulata*), Scotch broom (*Cytisus scoparius*) shore pine (*Pinus contorta* var. *contorta*) and other non-native species were planted in the 1930s. While the planting of these species helped stabilize the dunes, these and other non-native species now dominate in many areas.

2.5.2. Invasive Animals

Approximately ten invasive animal species are known from LEWI (Table 2.3-3) Perhaps of most concern is the New Zealand mud snail (NZM; *Potamopyrugus antipodarum*), a highly invasive aquatic invertebrate. NZM were first discovered in the Snake River, Idaho in the 1980s (Hall et al. 2006). Highly prolific in the absence of natural predators, NZM can reproduce rapidly and infestations can permanently disrupt aquatic ecosystems (Levri et al. 2007, Bennett et al. 2015). NZM are rapidly spreading throughout the western United States, have become established in rivers in 10 western states and three national parks, and were first observed in the lower reaches of the Columbia River in 1996 (Bersine et al. 2008).

Table 2.3-3. Key non-native animals found in or near LEWI (compiled from multiple sources).

Group	Scientific Name	Common Name
Invertebrates	*Potamopyrugus antipodarum*	New Zealand mud snail
	Arion spp.	European slug
	Cipangopaludina chinensis	Chinese mystery snail
	Corbicula fluminea	Asian clam
	Cornu aspersum	garden snail
Birds	*Passer domesticus*	house sparrow
	Sturnus vulgaris	European starling
	Molothrus ater	brown-headed cowbird
	Strix varia	barred owl
Amphibians	*Lithobates catesbeianus*	bullfrog
Fish	*Lepomis gibbosus*	pumpkinseed
	Micropterus salmoides	largemouth bass
	Perca flavescens	yellow perch
	Cyprinus sp.	*Asian carp*
Mammals	*Didelphis virginiana*	virginia opossum
	Myocastor coypus	nutria
	Rattus rattus	black rat

2.6. Resource Stewardship

2.6.1. Management Directives, Planning Guidance and Research

General/Resource Plans

Resource Management Plan

Resource management plans have been produced since 1973, most recently in 1995. The primary objectives for management include 1) re-creation of native plant communities where ecologically feasible; 2) re-creation of traditional animal populations where ecologically feasible; 3) measuring the impact of humans on the environment; and 4) monitoring the impact of humans on the environment. The major resource management emphasis before the park's expansion has been on reforestation of the site to regain the forest canopy that Lewis and Clark described in their journals.

General Management Plan

The park's General Management Plan dates back to 1995, when the park was still only 125 acres. Its preferred alternative included the expansion of the park to include the current boundaries of the Fort Clatsop and Sunset Beach unit. It also called for forest management to return the "forest landscape representative of that experienced by the Corps of Discovery" as well as wetland restoration including the modification of dikes (NPS 1995). This general framework has been adopted in specific restoration efforts.

Fire Management Plan

Published in 2011 (NPS 2011a), the primary objective of the fire program at LEWI in relation to natural resources is to apply prescribed fire to better understand regional ecosystems and their relationship to historic fire, and investigate how fire can be used now to promote management goals.

Specific Resource/Restoration Efforts

- Otter Point Restoration Plan (NPS 2010b): see Section 4.4.
- Colewort Creek Wetland Restoration Plan (NPS 2012): see Section 4.4.
- Forest Restoration Plan (NPS 2011b): see Section 4.5.

2.6.2. Supporting Science

NPS Inventory and Monitoring Program

Climate, intertidal commnities, landbirds, landscape dynamics, elk, and forest vegetation are currently monitored at LEWI (Weber et al. 2009).

2.6.3. Regional Partnerships

One of the management challenges for LEWI's natural resources is the somewhat complicated administrative and management structure. Management involves a complex of federal, state, and local agencies, with park units spread along the Pacific Coast and on both sides of the mouth of the Columbia River. It is thus important that NPS work with partners to achieve management goals and protect resources.

In restoring former industrial timberlands, the NPS has learned from the experiences of The Nature Conservancy at the Ellsworth Creek Preserve. The Northern Oregon Restoration Partnership is a source of native trees and plants for park projects including forest restoration.

When working on estuarine restoration, the park has collaborated with a suite of partners including the Columbia River Estuary Study Taskforce (CREST), Lower Columbia River Estuary Partnership (LCREP), North Coast Watershed Association, the US Fish and Wildlife Service, the Oregon Watershed Enhancement Board, Washington DOT, the Bonneville Power Administration, US Army Corps of Engineers, and the Washington State Governor's Salmon Recovery. Working with these partners not only allows the park to tap into other funding sources, but it also expands the expertise than can be brought to bear on these complicated projects from road engineers to fish biologists.

The park works on invasive species control with many landowners in the North Coast Cooperative Weed Management Area including the North Coast Land Conservancy, Oregon State Parks, and

Washington State Parks to share crews and expertise. And, as detailed above, these same agencies along with the USFWS and the Institute for Applied Ecology (IAE) are working on silverspot butterfly recovery.

Websites for these organizations are included following Section 2.7.

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CREST: www.columbiaestuary.org

Lower Columbia River Estuary Partnership: www.estuarypartnership.org

The Nature Conservancy: https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/ellsworth-creek/

North Coast Watershed Council: http://www.clatsopwatersheds.org/

North Coast Cooperative Weed Management Area: https://lowercolumbiacwmas.wordpress.com/north-coast-cwma/

North Coast Land Conservancy: https://nclctrust.org/

Oregon State Parks: https://oregonstateparks.org/

Oregon Watershed Enhancement Board: https://www.oregon.gov/oweb/Pages/index.aspx

US Fish and Wildlife: https://www.fws.gov/oregonfwo/ and https://www.fws.gov/wafwo/

Washington State Governor's Salmon Recovery: www.rco.wa.gov/salmon_recovery/gsro.shtml

Washington State Parks and Recreation Commission: https://parks.state.wa.us/

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 Lewis and Clark National Historic Park (LEWI), Fort Vancouver National Historic Site (FOVA), San Juan Island National Historic Park (SAJH) and Ebey's Landing National Historic Reserve (EBLA). A variety of limitations prevented completion of the NRCAs for SAJH and EBLA, and the team moved ahead with LEWI and FOVA.

After a review of the draft NRCAs for LEWI and FOVA, 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

As mentioned in Chapter 2, this NRCA focused on units of LEWI with significant natural resources: Clark's Dismal Nitch, Middle Village – Station Camp, and Cape Disappointment State Park in Washington, and Fort Clatsop, Sunset Beach State Recreation Area in Oregon. For some resources, the nearby state parks of Fort Columbia State Park, Ecola State Park, and Fort Stevens State Park were included. In addition, several coastal and riverine sites were included in the assessments for Hydrology and Groundwater (Section 4.3), Estuaries (Section 4.4), Non-salmonid Fish (Section 4.6), and Coastal Resources (Section 4.10).

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

- Inventory of newly acquired lands;
- Restoration of natural resources and processes;
- Impacts of land-use practices outside of park boundaries and in Columbia River Estuary;
- Elk population status and future trends; and

- Spread of terrestrial and aquatic non-native species.

During early conversations with the University of Washington team and NPS, and using the above list as a starting point, the team identified 19 NPS focal resources as being of high or moderate priority (Table 3.2-1).

Table 3.2-1. Initial identified LEWI focal resources place within the NPS Ecological Framework.

Level 1 Category	LEWI Resource
Air and Climate	Air Quality (Section 4.1)
	Climate (4.2)
Geology and Soils	–
Water	Freshwater (4.3)
Biological Integrity	Estuaries (4.4)
	Forest Health and Disturbance (4.5)
	Non-salmonid Fish (4.6)
	Amphibians (4.7)
	Mammals (4.8)
Ecosystem Pattern and Processes	Extent of Ecological System/Habitat Types
	Landscape Composition
	Landscape Pattern and Structure

Based on staff input, park documents, review of the Phase I report, and to be in compliance with the revised NPS NRCA guidelines, the Phase II team developed the following list of resources for assessment and assigned them the following sections in Chapter 4:

4.1. Air Quality

4.2. Climate

4.3. Freshwaters (Surface Hydrology, Groundwater Quantity, Surface and Groundwater Quality)

4.4. Estuaries and Juvenile Salmon

4.5. Forest Health and Disturbance

4.6. Non-salmonid Fish

4.7. Amphibians

4.8. Mammals

4.9. Natural Night Skies and Natural Quiet

4.10. Nearshore Physical Environments

4.11. Landuse and Habitat Connectivity

Though there was fairly significant re-organization of the information presented in the Phase I report, much of the analyses and data presentations were retained in the Phase II document.

3.2.2. Indicators and Reference Conditions

For each priority resource the team identified multiple 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 historical condition (e.g., pre-settlement land cover), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal or objective (e.g., 90% control of an invasive species for at least ten years). In this project, 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 National Park Service Inventory and Monitoring Framework (Fancy et al. 2009; Table 3.2-2).

Table 3.2-2. Focal natural resources of LEWI selected for assessment, presented within the NPS Ecological Framework (Fancy et al. 2009).

Level 1 Category	LEWI Resource	Indicators
Air and Climate	Air Quality (Section 4.1)	• Visibility • Nitrogen and Sulfur Deposition • Ozone
	Climate (4.2)	• Temperature • Precipitation
Geology and Soils	–	–
Water	Freshwater (4.3)	• Surface Water Quality • Surface Water Quantity (streamflow) • Groundwater Quality • Groundwater Quantity (levels)
Biological Integrity	Estuaries (4.4)	• Physical Elements (sea level, tidal processes) • Biological Elements (absence of non-native plants, absence of non-native invertebrates) • Juvenile Salmon (presence/absence, diversity)
	Forest Health and Disturbance (4.5)	• Demography and Structure • Species Diversity • Presence of Downed Wood

Table 3.2-2 (continued). Focal natural resources of LEWI selected for assessment, presented within the NPS Ecological Framework (Fancy et al. 2009).

Level 1 Category	LEWI Resource	Indicators
Biological Integrity (continued)	Non-salmonid Fish (4.6)	• Total abundance • Presence of key/rare species • Absence of non-natives
	Amphibians (4.7)	• Diversity • Presence/absence of Key Species
	Mammals (4.8)	• Species diversity • Presence of carnivores • Absence of non-native species
Ecosystem Pattern and Processes	Natural Night Skies and Natural Quiet (4.9)	• Nighttime light • Noise levels
	Nearshore Marine (4.10)	• Ocean acidification • Sea-level rise • Sea surface temperatures • Large wave and storm frequency
	Landuse and Habitat Connectivity (4.11)	• Land Cover • Road Density • Impermeable Surfaces

3.2.4. Data and Methods

To identify relevant documents for review, the Phase I 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, searching with phrases such as "Clatsop/Pacific County," "Columbia River Estuary," and "Northwestern Oregon." 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 Phase I and II, the vegetation mapping effort for the park was completed (Kagan et al. 2012), providing extremely valuable new information on vegetation resources. In addition a great deal of new information beca.me available regarding climate change impacts and predicted future conditions.

3.2.5. Reporting Areas

Because there are many disparate sites in LEWI that each have a unique suite of resources, it was determined that assessments for most focal resources would be reported park-wide rather than by watershed or management designation.

3.2.6. Condition Assessments

Per the NPS NRCA guidelines, each individual resource assessment includes the following elements:

3.2.6.1. Elements

Background

This section describes the resource and generally 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. Though NRCAs generally do not include data collection and are based largely on compilations, syntheses, and new analyses of pre-existing data, this report includes the development of two horizontal profiles, one using the Fort to Sea Trail and the other traversing a major part of Cape Disappointment State Park, which are included in the appendix.

Resource Condition and Trend

This section summarizes what is known about the resource in relation to described 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

Subject matter experts not identified elsewhere are listed here.

Literature Cited

Each section is followed by a complete cited reference list. In addition, as part of the final product a database of all references included in the full document will be delivered to NPS.

3.2.6.2. Condition Summaries

The described condition was then represented graphically using the symbols presented in Tables 3.2-3 and 3.2-4 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 discussed and presented graphically in Chapter 5 and Figure 5.1-1.

Table 3.2-3. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

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 3.2-4. Example indicator symbols and descriptions of how to interpret them.

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.

3.3. Project Challenges

This project was intended to result in NRCAs for four regional historical parks (EBLA, FOVA, LEWI, and SAJH). However, time and resource limitations prevented the completion of the NRCAs coincidentally, 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 unworkable.

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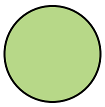
Chapter 4. Natural Resource Conditions

4.1. Air Quality and Air Quality Related Values

Air quality at LEWI is generally good to excellent, though visibility, nitrogen deposition and sulfur deposition warrant 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

Air quality is a fundamental resource of all units of the National Park System. It affects human health and visitor enjoyment, and good air quality helps ensure the integrity of park resources and values. To foster clean air in parks, the National Park Service (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 Lewis and Clark National Historical Park (LEWI), 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 Class II areas. Air quality related values are resources sensitive to air pollution and include visibility, lakes, streams, vegetation, soils, and wildlife.

<u>Air Pollutants and Sources</u>

There are many sources of air pollution; some are natural and some are anthropogenic, i.e., human-caused. Air pollutants of concern include sulfur and nitrogen compounds, fine particulates, ground-level ozone, and persistent bioaccumulative toxics, such as mercury. Potential effects include visibility impairment; ozone-induced human health problems and damage to vegetation; aquatic and terrestrial acidification and eutrophication; and neurological, respiratory, and other health issues associated with exposure to toxins.

The NPS focuses on reducing the impact of anthropogenic pollution on park resources. Most human activities, including manufacturing and industrial processes, agricultural practices, land disturbance, and fossil fuel combustion, produce air pollution. Lewis and Clark National Historical Park is not close to the region’s large cities and agricultural regions; however, ship traffic at the mouth of the Columbia River is likely a major source of emissions for the area (Figure 4.1-1). Trans-Pacific transport is also a significant source of air pollution to the west coast of North America (Yu et al. 2012).

The main source of sulfur pollution is coal combustion at power plants and industrial facilities. Oxidized nitrogen compounds (i.e., nitrogen oxides) result from fuel combustion by vehicles, power plants, and industry. Reduced nitrogen compounds (e.g., ammonia and ammonium) are the result of agricultural activities, fire, and other sources. Ozone is formed when nitrogen oxides and volatile

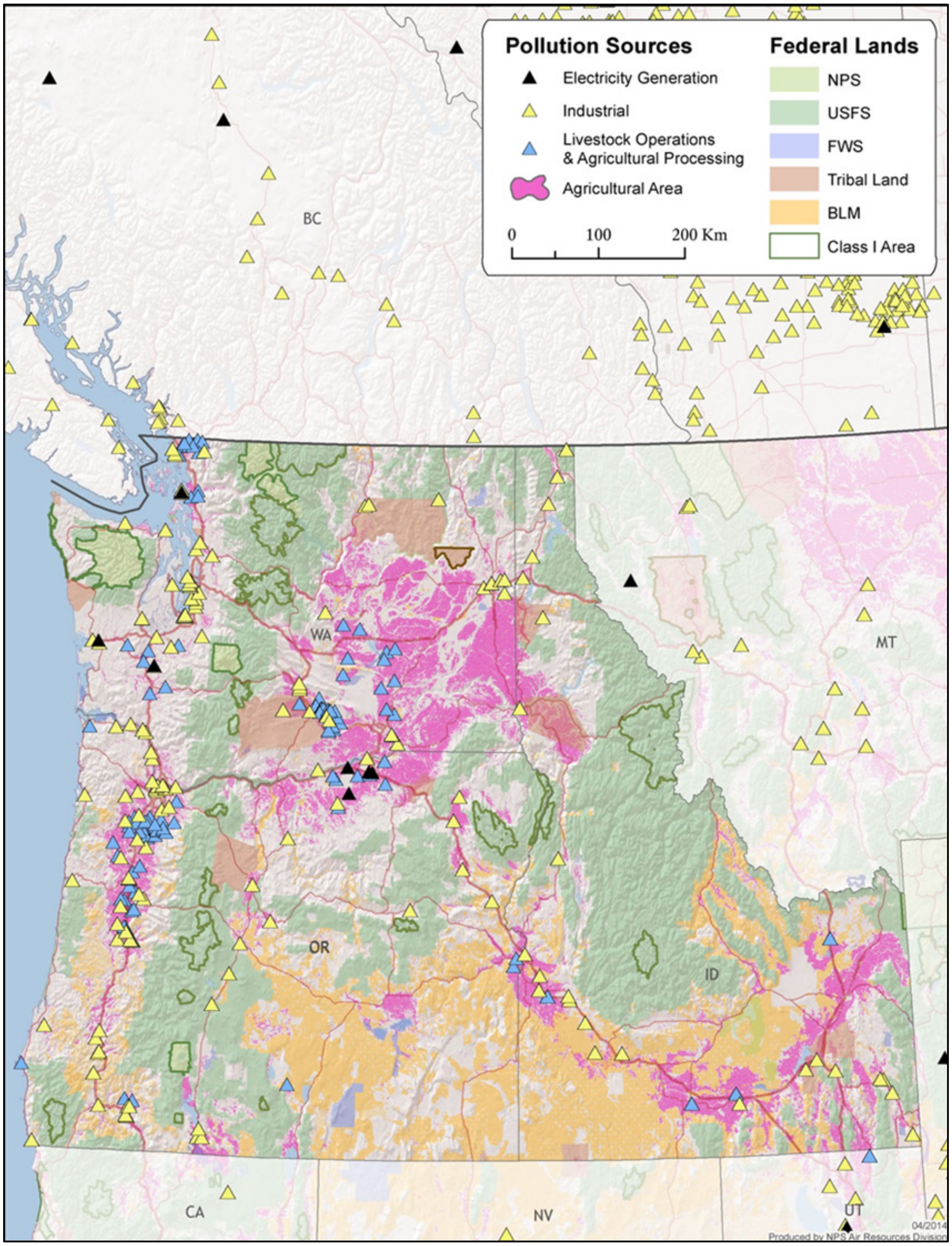


Figure 4.1-1. Public lands and air pollution sources in the Pacific Northwest. Triangles designate point sources that emit greater than 100 tons per year of nitrogen oxides (Cummings et al. 2014).

organic compounds emitted from vehicles, solvents, industry, and vegetation react in the atmosphere in the presence of sunlight, usually during the warm summer months. Persistent bioaccumulative toxics include heavy metals like mercury and organic compounds such as pesticides. Coal combustion, incinerators, mining processes, and other industries emit mercury.

Visibility

Among the experiences that visitors to national parks treasure is enjoying the breathtaking scenery – majestic mountains contrasted against a pure blue sky or a spectacular array of stars at night. 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).

Ozone

Ozone is a respiratory irritant that can trigger a variety of human health problems including chest pain, coughing, throat irritation, and congestion. Ozone also affects vegetation, causing significant harm to sensitive plant species (EPA 2014). Ozone enters plants through leaf openings called stomata and oxidizes plant tissue, causing visible injury (e.g., stipple and chlorosis) and growth effects (e.g., premature leaf loss; reduced photosynthesis; and reduced leaf, root, and total size).

Nitrogen and Sulfur Deposition

Airborne pollutants are eventually deposited through either wet deposition (i.e., rain, snow, clouds, and fog) or dry deposition (i.e., particles and gases) onto vegetation, soils, streams, and lakes. Sulfur and nitrogen deposition can have a significant effect on natural systems, and nitrogen is of particular concern in the western U.S. where many ecosystems are nitrogen-limited. Over time, excess nitrogen deposition alters biodiversity and plant and soil chemistry, with cascading effects through ecosystems (Cummings et al. 2014). Excess nitrogen deposition also leads to increased nitrate leaching to water bodies, where it can cause eutrophication, acidification, or dead zones.

The NPS, other land managers, and the U.S. Environmental Protection Agency ("EPA") use critical loads to determine the threshold for ecosystem sensitivity to nitrogen deposition. A critical load is technically defined as "…the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment are not expected to occur according to present knowledge." (Nilsson and Grennfelt 1988). Critical loads are typically expressed in terms of kilograms per hectare per year (kg ha^{-1} yr^{-1}) of wet or total (wet plus dry) deposition. Critical loads can be developed for a variety of ecosystem responses, including shifts in aquatic plankton or terrestrial lichen and plant species, changes in soil chemistry, and lake and stream acidification. In general, as nitrogen deposition increases, additional resources are affected and ecological effects become more pronounced (Cummings et al. 2014; Figure 4.1-2). The goal of the NPS is to limit nitrogen deposition to levels that do not exceed the minimum critical load for a park's most sensitive resources.

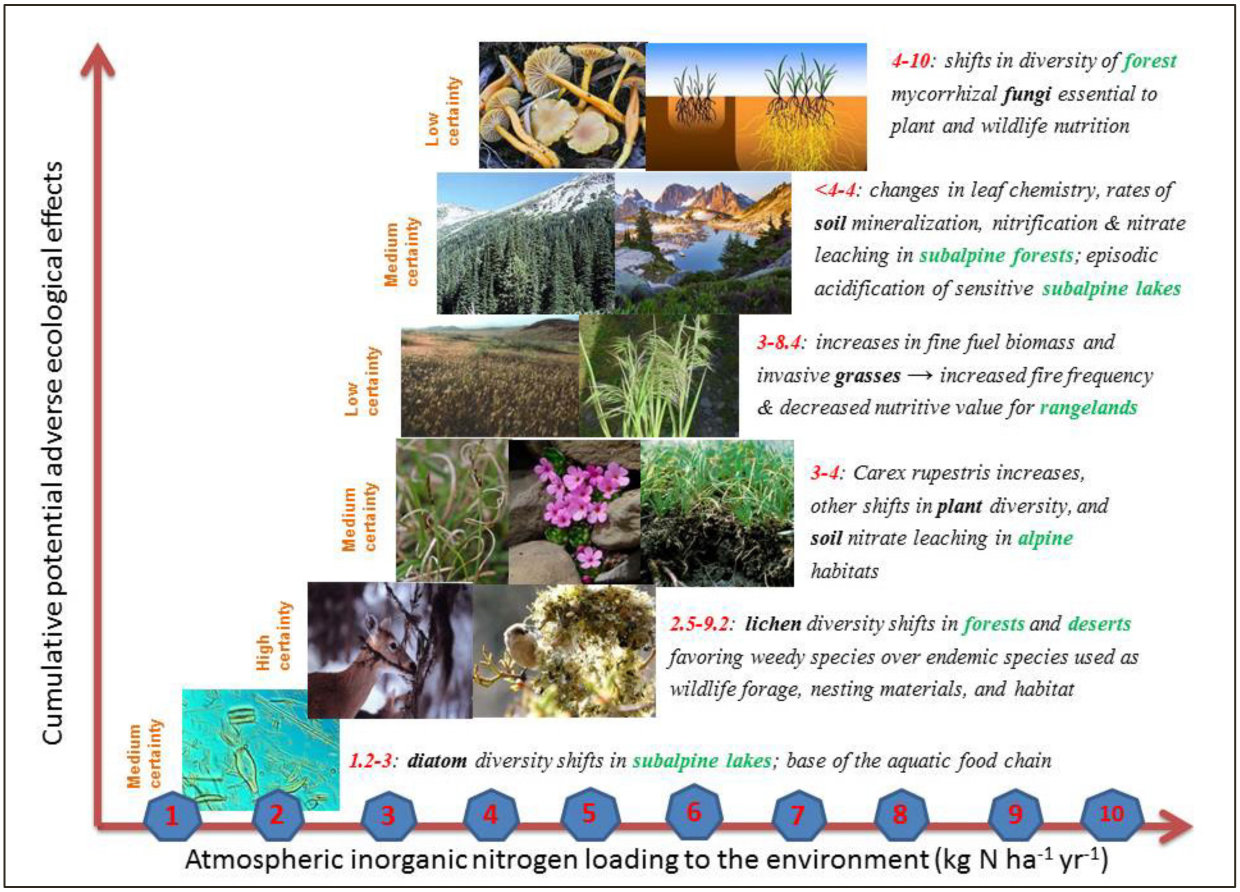


Figure 4.1-2. Cumulative potential adverse ecological effects associated with atmospheric nitrogen deposition in the Pacific Northwest. The reliability assessments are as follows: High Certainty when a number of published papers of various studies show comparable results, Medium Certainty when the results of some studies are comparable, and Low Certainty when very few or no data are available in the Pacific Northwest so the applicability is based on expert judgment (Cummings et al. 2014).

Persistent Bioaccumulative Toxins

Persistent bioaccumulative toxins consist of heavy metals such as mercury, current and historic use pesticides, industrial chemicals, and by-products of fuel combustion. Concerns mainly pertain to impacts on humans and wildlife. Effects vary with the type of pollutant, but include declines in reproductive success, growth, and neurological function, and increased disease susceptibility (Landers et al. 2008).

4.1.2. Reference Conditions

Benchmarks were established based on regulatory standards, natural visibility goals, and ecological thresholds. Values estimated for each park were compared to ARD benchmarks for specific measures of ozone, visibility, and atmospheric deposition (Table 4.1-1).

Table 4.1-1. Indicators and specific measures for air quality condition assessments (NPS 2017).

Indicator	Specific Measure
Visibility	Visibility on mid-range days minus natural visibility condition on mid-range days
Ozone	Human health: 4th-highest daily maximum 8-hour concentration
	Vegetation health: 3-month maximum 12-hour W126*
Deposition	Sulfur wet deposition
	Nitrogen wet deposition

* The W126 is based on a cumulative sum of hourly ozone concentrations during a rolling 3-month period, where the hourly values are weighted according to their magnitude.

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 ARD's 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 4.1-2). The difference between estimated current conditions and estimated natural visibility represents the human contribution to visibility impairment.

Table 4.1-2. Benchmarks for visibility condition (NPS 2015).

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 EPA's primary National Ambient Air Quality Standard of a 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb; NPS 2015). Note that EPA lowered the primary standard to 70 ppb in late 2015, but ARD had not yet revised its condition assessment to reflect the lower number. The maximum estimated ozone concentration at a park is compared against ARD benchmarks (Table 4.1-3).

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.

Table 4.1-3. Benchmarks for human health condition for ozone (NPS 2015).

Category	Ozone concentration* (ppb)
Warrants significant concern	≥76
Warrants moderate concern	61–75
Resource is in good condition	≤60

* Estimated or measured 5-year average of annual 4th-highest daily maximum 8-hour concentration

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 4.1-4).

Table 4.1-4. Benchmarks for vegetation condition for ozone (NPS 2017).

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

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

<u>Nitrogen and Sulfur Deposition</u>

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-National Trends Network (NADP-NTN) monitoring sites in the United States. 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 4.1-5). 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 4.1-5. 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

Persistent Bioaccumulative Toxins

Benchmarks for persistent bioaccumulative toxins vary depending on the type of pollutant. At LEWI, mercury has been monitored through the Dragonfly Mercury Project in 2015 to 2018 (https://www.nps.gov/articles/dragonfly-mercury-project.htm). Benchmarks for this data are still being developed, but early analysis indicates less than 315 ppb (dry weight) are likely to be in the lowest risk category for fish that prey on dragonflies (Eagles-Smith et al. 2018).

4.1.3. Data and Methods

This air quality assessment used the methods developed by the NPS Air Resources Division (ARD) for a consistent Service-wide approach to evaluating conditions and trends in visibility, ozone, and deposition at NPS units throughout the continental U.S. (Taylor 2017). In brief, data collected by federal, state, and local monitoring networks were evaluated with an Inverse Distance Weighted interpolation method to estimate air quality conditions for parks. Even though the data were derived from all available monitors, data from the closest stations to a park "outweighed" the rest. The estimates were based on the most recent 5-year averages, and the values in each park were compared to ARD benchmarks for specific measures of ozone, visibility, and atmospheric deposition (referenced above). Benchmarks were established based on regulatory standards, natural visibility goals, and ecological thresholds.

The ARD calculates short-term trends from data collected over a 10-year period at on-site or nearby representative monitors, where available. Because these data are not available for LEWI, visibility, ozone, and deposition trends were not calculated for the park.

The evaluation of nitrogen critical loads for LEWI used the results from ARD's Critical Loads and Estimated Exceedances website (NPS 2016a). The methods followed the approach described in Pardo et al. (2011), which recommended a range of critical load values for each of the Level 1 ecoregions identified in the ecosystem classification system developed through the Commission for Environmental Cooperation for North America (Commission for Environmental Cooperation 1997). Lewis and Clark National Historical Park is located in the Marine West Coast Forests ecoregion, and critical loads have been identified for three out of five terrestrial ecosystem components in that ecoregion: forests (i.e., trees and soils), lichen and bryophytes, and mycorrhizal fungi. Critical loads were compared to estimated total nitrogen deposition to identify possible exceedances. An exceedance suggests increased potential of ecological harm.

This report also uses data collected by students and park staff as part of the Dragonfly Mercury Project, a partnership between the National Park Service, the United States Geological Survey (USGS), the University of Maine, and other entities. More than 90 parks participated in 2017.

4.1.4. Resource Condition and Trend

The ARD's Air Quality Condition and Trends website (NPS 2016b) provides information on visibility, ozone, and deposition for LEWI based on 2009–2013 data.

Visibility
Estimated average visibility on mid-range days at LEWI was 9.1 dv. Subtracting the park's estimated natural visibility of 5.0 dv on mid-range days, the assumed contribution from human-caused haze was 4.1 dv. Compared to ARD's benchmarks, visibility at LEWI warranted moderate concern.

Ozone
The 4th-highest daily maximum 8-hour ozone concentration for LEWI was 56.5 ppb, which is well below both the former primary National Ambient Air Quality Standard of 75 ppb as well as the new 70 ppb value. The maximum 3-month 12-hour W126 was 1.9 ppm-hrs, which is much lower than levels known to harm vegetation, i.e., 7–13 ppm-hrs. Compared to ARD benchmarks for ozone, human health and vegetation were in good condition. Kohut (2004) assessed the risk of ozone-induced foliar injury at all Inventory and Monitoring parks based on species sensitivity, ozone concentrations, and soil moisture (which influences ozone uptake). He concluded there was low risk of ozone injury at LEWI.

Deposition
Estimated wet nitrogen deposition at LEWI was 1.9 kg ha^{-1} yr^{-1}. Compared to ARD deposition benchmarks, this level indicates nitrogen deposition was of moderate concern. Estimated sensitivity to nitrogen nutrient enrichment ranked moderate at LEWI relative to all Inventory and Monitoring parks (Sullivan 2016). Estimated wet sulfur deposition at the park was 1.4 kg ha^{-1} yr^{-1}, a level that indicated moderate concern compared to ARD deposition benchmarks. Lewis and Clark National Historical Park was ranked as having low sensitivity to acidification relative to other Inventory and Monitoring parks (Sullivan 2016). Based on the estimated 2010–2012 total average nitrogen deposition at LEWI of 3.7 kg ha^{-1} yr^{-1}, the minimum nitrogen critical load for lichens and bryophytes may be exceeded at the park (Table 4.1-6). However, the presence of *Usnea longissimi* in the Visitor Center parking lot, a lichen that is known to be susceptible to airborne pollutants, suggests air quality at that location is in good condition.

Table 4.1-6. Estimated 2010–2012 three-year average total (i.e., NADP-NTN monitored wet plus modeled dry) nitrogen deposition and minimum critical loads for five terrestrial ecosystem components in the Marine West Coast Forests ecoregion at Lewis and Clark National Historical Park (NPS 2016a).

Ecosystem Component	Kg/ha/yr
Total Nitrogen Deposition	3.7
Forests*	5.0
Herbaceous Plants and Shrubs	NA
Lichens and Bryophytes	2.7
Mycorrhizal Fungi	5.0
Nitrate Leaching	NA

* Trees and soils

Persistent Bioaccumulative Toxins

The Dragonfly Mercury Project has published two years of data from Lewis and Clark NHP (Eagles-Smith et al. 2018; Table 4.1-7).

Table 4.1-7. Mean concentration of total mercury in dragonfly larvae, ppw dry weight (Eagles-Smith et al. 2018).

Location	2015	2016
Kwis Kwis Pond*	82	108
Sunset Beach	50	104
Yeon	17	37

* Located in the Fort Clatsop Unit.

4.1.5. Level of Confidence

Medium

4.1.6. Data Gaps and Research Needs

Lichen community studies would corroborate if nitrogen critical loads have been exceeded at LEWI. In addition, fertilization studies could be conducted in nitrogen-sensitive ecosystems, such as wetlands, to assess plant species' response to increased deposition.

It is not clear how climate change will affect air pollution levels and effects on air quality related values at LEWI. Changes in precipitation amount and timing could affect deposition of sulfur, nitrogen, and persistent bioaccumulative toxics. Increased temperature and changes in precipitation patterns could enhance nitrogen deposition-associated effects on plant biodiversity and nutrient cycling in ecosystems (Cummings et al. 2014). Changes in agricultural practices in response to weather patterns or pests could result in additional pesticide deposition at LEWI. Increased summertime temperatures may lead to higher ozone levels (EPA 2009).

Data indicate that Tran-Pacific air pollution is increasing (Lin et al. 2014). While there are encouraging reports recently that China is taking steps to reduce emissions, it is unclear the degree to which these changes will resolve concerns across all air pollutants, and whether other nations upwind of LEWI will also strengthen emission controls.

Potential coal, gas, and oil terminals along the Columbia River could lead to increases in vessel traffic with high particulate matter and gaseous emissions (Mueller et al. 2011). Environmental Impact Studies for these projects should address potential air quality impacts to park resources from vessels in transit.

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

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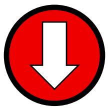
4.2. Climate

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, and confidence in this assessment is high.



4.2.1. Background

Climate change is affecting natural resources and processes in national parks across the country at an increasing rate. Data show that changes in temperature and precipitation are accelerating, 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). At present there is no credible scientific disagreement that climate warming is driven primarily by human activities (Abatzoglou et al. 2014, Wuebbles et al. 2017).

Climate change is a strong force that will require species, populations, and physical processes to respond rapidly to environmental conditions to which they are largely unadapted (Corlett and Westcott 2013). To protect and preserve resources in this scenario will require immense effort (e.g. van Riper et al. 2014). The National Park Service (NPS) recognizes that climate change presents an enormous challenge for natural resource managers (Saunders et al. 2007, NPS 2010, Whittington et al. 2013).

Regional Climate

Temperatures at the mouth of the Columbia River are moderated by the effects of the ocean (OCCIR 2012). Low temperatures occasionally reach freezing and below, for example in 2011 there were several periods where temperatures were in the low 20s°F (−7°C) and snowfall occurred (Lofgren and Huff 2013). High temperatures are generally less than 70°F (21°C) but can reach into the 80s (27°C; Lofgren and Huff 2013). The mean maximum August temperature at Astoria airport (AST, approx. 2 mi/3 km from Fort Clatsop from 1953–2015 was 69°F (21°C) and the mean minimum temperature 37°F (13°C; https://www.ncdc.noaa.gov/).

Most precipitation in the region arrives as rainfall brought by Pacific storms between October and April (OCCRI 2012). At AST average annual rainfall was 69 in (175 cm) from 1953–2014 (Western Regional Climate Center [WRCC]). Snowfall is rare; during the same period there was an average of 4.2 in (10.7 cm) of snow per year. Summers are mostly dry, though fog is common (Oregon Climate Service, http://ocs.oregonstate.edu/. Precipitation amounts vary between watersheds, for example the Colewort Creek watershed receives approximately 80 in (202 cm)/year, while the Megler Creek watershed receives approximately 100 in (256 cm)/year.

Pacific Decadal Oscillation

The Pacific Decadal Oscillation (PDO) is a pattern of inter-decadal climate variability characterized by large-scale changes in sea surface temperatures, sea level pressure and wind patterns in the Pacific Ocean (Newman et al. 2016). It is a dynamic ocean-atmosphere coupled climate phenomenon. The

PDO has warm (positive) and cool (negative) phases, each of which are currently thought to last for up to a few decades before transitioning from one to the other.

The El Nino Southern Oscillation (ENSO) describes the part of the coupled system's interaction between the ocean and atmosphere in the tropical latitudes in the Pacific Ocean, especially the eastern and central part, which consequently influence climate variations at higher latitudes in the Americas. ENSO transitions in a shorter, quasi-periodic variation between three phases: warm (positive; El Nino), cold (negative; La Nina) and neutral. In recent decades ENSO has been identified as one of the primary drivers of climate in the PNW (Abatzoglou et al. 2014). Though very relevant to an assessment of climate in the PNW, ENSO is a complex process that will not be described further in this assessment; for more information the reader is referred to Mantua and Hare (2002) and Newman et al. (2016).

4.2.2. Reference Conditions

Given the realities of climate change it is not possible to determine a reference condition for climate at LEWI. 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 predicted and current climate conditions as reported by other sources.

4.2.3. Data and Methods

The North Coast and Cascades Network (NCCN) reports climate data (primarily precipitation and temperature) collected at LEWI from four partner stations—three in Oregon and one in Washington (Lofgren and Huff 2013). The National Climate Data Center (NCDC) maintains temperature and precipitation records for these stations that are available online for Fort Clatsop (beginning in 1998 and ending in 2017), Astoria airport (1953), Seaside (1930), and Long Beach, WA experimental station (1967; (www.ncdc.noaa.gov). Long-term climate analyses using multiple temperature and precipitation variables for many national park units were compiled by Monahan and Fisichelli (2014) with methods described therein.

Changes in daily mean temperature at LEWI from 1977 to 2006 were analyzed using the publicly available CRU TS 2.1 monthly climate dataset (Mitchell and Jones 2005; http://www.cru.uea.ac.uk/). 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).

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 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 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 historical 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.

4.2.4. Resource Condition and Trend

Temperature

Average temperatures in the region have increased minimally (approx. 1.3°F/0.7°C) in the last century (OCCRI 2012, Abatzoglou et al. 2014, Mote et al. 2014, NCA 2014)(Figure 4.2-1). Nearly all models predict continued increasing regional temperatures over coming decades, though changes will not be nearly as great as they will be in places such as the southwestern US (England et al. 2015). Models used by the IPCC (2014) suggest temperature increases over averages from 1970–1999 of 2.0°F/1.1°C to as high as 9.7°F/5.4°C, depending on models applied, by the end of the century (Mote and Salathe Jr. 2010, Mote et al. 2014).

Regionally, temperatures will increase most in the summer, resulting in longer growing periods (Abatzoglou et al. 2014, Mote et al. 2014). For this assessment no significant trend was found for average annual temperatures at LEWI from 1977–2006 or in average seasonal temperatures (Table 4.2-1). Depending on the GCM model applied, temperatures at LEWI are projected to rise from between 2.2°F (1.2 °C) to 6.7°F (3.7°C) by the end of this century, with summer temperatures increases being relatively greater than other seasons. Global climate models project increases in average annual temperature in the Pacific Northwest of 1.1°C (2.0°F) by the 2020s, 1.8°C (3.2°F) by the 2040s, and 5.3°F (2.9°C) by the 2080s (CIG 2009).

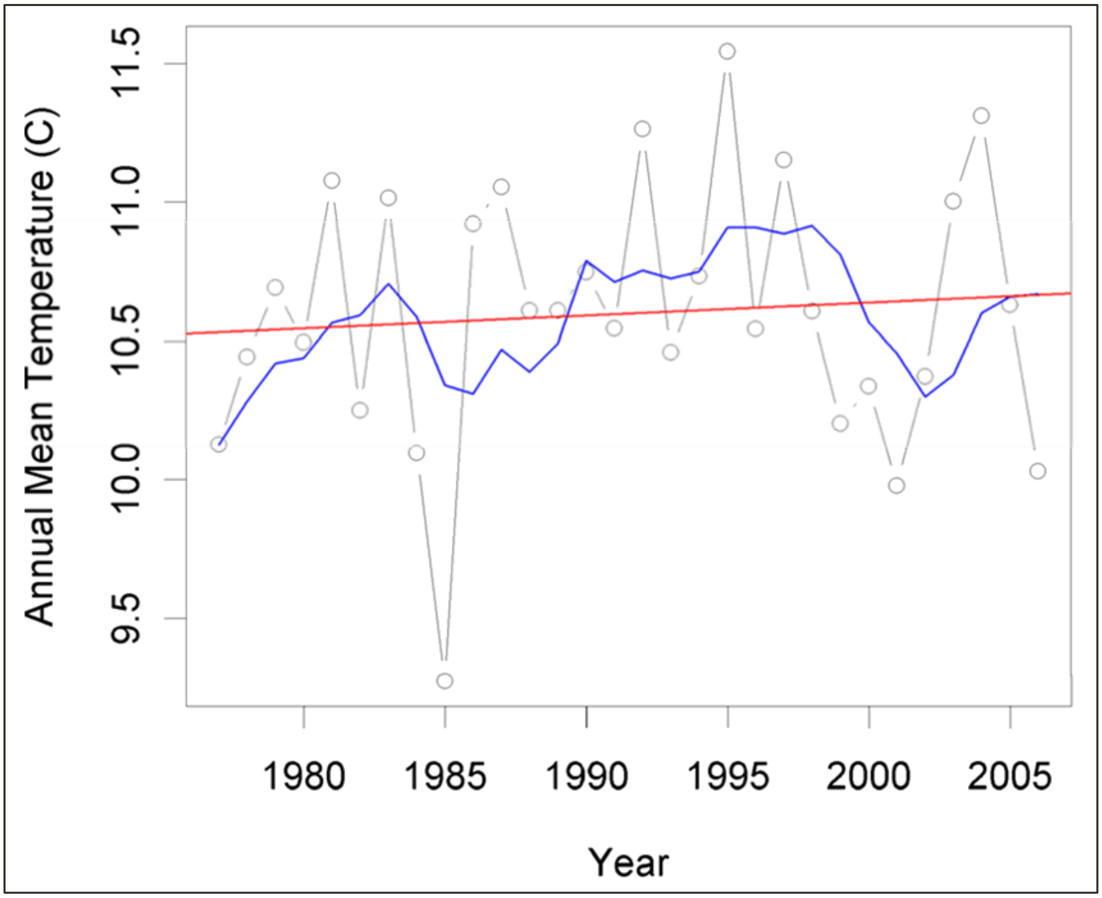


Figure 4.2-1. Trends in average annual temperature at LEWI from 1977–2006. Circles are average annual temperatures, the blue line is a five-year moving average, and the red line is a trend line fit with restricted maximum likelihood estimation assuming an AR1 time-series pattern in the residuals. Note that this trend line is not statistically significant ($P > 0.05$)(this study).

Table 4.2-1. Historical (1961–1990), recent (1977–2006), and projected future (2070–2099) temperature and precipitation at LEWI. Historical and recent data are from the Astoria Airport weather station. W = Winter (Dec–Feb); Sp = Spring (Mar–May); Su = Summer (June–Aug); F = Fall (Sept-Nov). Future temperature and precipitation were calculated by applying the median projected changes (see text for details) to the historical data; they therefore are not directly comparable to the historical and recent data but are provided for comparison.

Temperature or Precipitation	Time Period	Annual	W	Sp	Su	F
Mean Temperature (ºF/ºC)	Historic (1961–1990)	50.9/10.5	42.8/6.0	48.6/9.2	59.4/15.2	52.7/ 1.5
	Recent (1977–2006)	5.4/10.8	43.7/6.5	49.6/9.8	59.5/15.3	52.7/11.5
	Projected future (2070–2099)	56.3/13.5	47.7/8.7	52.5/11.4	66.2/19.0	56.7/13.7
Total Precipitation (in/cm)	Historic	66.4/168.7	28.1/71.5	14.7/37.3	4.9/12.4	18.7/47.5
	Recent	66.5/169.0	27.1/68.8	15.7/39.9	4.7/12.0	19.0/48.4
	Projected future	72.0/183.0	31.3/79.6	15.7/39.9	3.0/7.7	19.8/50.4

Precipitation

Long-term changes in average precipitation have not yet been detected in the PNW (Oregon Climate Change Research Institute [OCCRI] 2012, Mote et al. 2014, NCA 2014). Change predictions for the northwestern portion of Oregon indicate a possible decline of up to 20% under some emission scenarios, though estimates range from an increase of 23% to this minimum (Mote et al. 2014, Retallack et al. 2016). Though there is uncertainty regarding changes in annual precipitation, nearly all models predict that the seasonal distribution of precipitation will change, with greater relative change occurring in winter and less in summer (Mote et al. 2014, Retallack et al. 2016). An important result of changes in seasonal patterns with significant ecological implications is much earlier spring snowmelt (Vano et al. 2015). Storm intensity (water volume/time) is predicted to increase in the PNW, particularly in the summer, and in fact increases in intensity have been detected for the greater Portland, OR region during the period 1999–2015 (Cooley and Chang 2017).

Gonzales et al. (2018) found a 17% per century decline in precipitation at the park from 1950–2010, but this trend was not statistically significant ($p>.05$). They forecast an increase in precipitation ranging from 3% to 5% by 2100.

4.2.5. Level of Confidence

For past and current conditions – high. For future trends – moderate to high.

4.2.6. Data Gaps and Research Needs

NPS faces many social challenges in responding to climate change, including budget constraints, uncertainty regarding agency priorities, and the vagaries of public perception and awareness (Archie et al. 2012, NPS 2015).

There is also an acknowledged need by climate scientists for downscaled ecologic information regarding short and long-term responses to climate change for most if not all species and systems of interest (Parmesan 2006, van Riper et al. 2014). In response, managers need specific direction to mitigate for climate change, and funding resources to implement resource protections (Cross et al. 2013).

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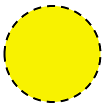
4.3. Freshwater Resources

Freshwater resources in LEWI appear to be in moderate condition but there are very few current data available. Streamflow conditions are generally unknown and may be of concern in relation to possible changes in precipitation patterns related to climate change and potential withdrawals from the Lewis and Clark River. Groundwater quantity appears good, but groundwater quality is of concern. There are no detectable trends and overall confidence is low.



4.3.1. Background

Water and hydrologic processes are fundamental to all natural resources at LEWI. Abundant rainfall, the influences of the Columbia River, and marine inputs are all drivers of and impact LEWI ecosystems. Nearly all LEWI sites are located at or very near the terminus of their respective watersheds, a situation which puts park resources at risk from upstream inputs (NPS 1994, NPS 2000, Pringle 2001, EPA 2009, LCEP 2012). LEWI sites are further impacted by natural and human activities that occur in the massive Columbia Basin (~260,000 mi^2/673,400 km^2) as the river carries thousands of tons of material to the Columbia River Estuary (CRE) each year (Wise et al. 2007, Alvarez et al. 2014).

Lewis and Clark intuitively understood the connection between rivers and upland resources (Moody et al. 2003), and science has since shown that hydrologic connectivity is a critical component of functioning ecosystems (Kondolf et al. 2006, Olson and Burnett 2009, Heino 2013). Unimpeded connections between upland rivers, tributaries, and the ocean are essential for the survival of anadromous fish populations (Gaydos et al. 2008, Roegner et al. 2008, Fullerton et al. 2010) and facilitates the transportation of nutrients and propagules of many organisms (seeds, eggs; Moggridge et al. 2009, Acreman et al. 2014). In addition to linear connections, floodplain processes—where flood waters periodically travel laterally to inundate lands above and outside regular water courses—are often necessary for maintaining riparian communities (Thomas 2003).

The integrity of streams and rivers has been highly altered by human activities around the world (Friberg 2014). Along the Pacific Northwest coast logging, specifically, but also other upstream impacts have increased erosion and altered hydrologic processes and riparian habitat integrity (Moore and Wondzell 2005, Kaufmann and Hughes 2006, Alberti et al. 2007). Impeding natural river flow through dams and diversions has had numerous and devastating impacts on salmon populations throughout the region (Lackey 2003, Sheer and Steel 2006).

The Hydrologic resources at LEWI of primary concern are surface water hydrology (streamflow), surface water quality, groundwater quantity, and groundwater quality. Estuaries are addressed separately in Section 4.4.

<u>Streamflow and Connectivity</u>

The minimum amount of water needed in a moving body of water to support native ecosystems, processes, and species and recently been termed "environmental flow" (Poff and Matthews 2013).

The practice of diverting water from a stream or river for human use has likely had a greater negative impact on riparian ecosystems than any other factor (Bunn and Arthington 2002, Arthington 2012). For example, withdrawals of water primarily for irrigation throughout the Columbia River Basin are estimated to have reduced tributary flow to the main river by approximately 7% since the beginning of the 20th century (Jay et al. 2016).

The primary rivers that flow through LEWI sites in Oregon before entering the Columbia are the Lewis and Clark river (21 mi/34 km long) and the Skipanon River (7 mi/11 km long). For the Fort Clatsop unit, surface water consists of the tidally-influenced Lewis and Clark River, low-gradient brackish sloughs, freshwater ponds, and small fresh water streams (e.g., Alder and Perkins Creeks) and springs. The Megler Creek watershed feeds Dismal Nitch in Washington

Groundwater Quantity

Significant freshwater resources also exist in bedrock aquifers beneath LEWI lands (Sytsma 2005). In Oregon, groundwater is recharged primarily by precipitation rather than upland surface runoff and quantities thus vary according to season (NPS 1994, Cole and ODEQ 2004). In many areas beneath LEWI sites the groundwater resource is very near the surface (<100 ft/ 30 m), resulting in springs and lakes that are directly connected to subsurface waters (McFarland 1983, NPS 1994, Nielsen 2004, Sytsma 2005, ESA 2014). In particular, the Clatsop Plains is characterized by connectivity between groundwater and surface water dynamics and quality (http://or.water.usgs.gov/pubs/Online/Html/WSP2425/), and these connections have implications for surface resources (Winter et al. 1998). In general, the subsurface waters of the northern Coast Range are considered one continuous aquifer

The upper part of the aquifer beneath the Long Beach Peninsula is comprised of dune sand and marine sand, and reaches a depth of approximately 200 ft (60 m; McFarland 1983). Beneath the sand is a clay zone of reduced permeability, and below that is a deep aquifer that extends to bedrock at about 700 ft (210 m). Mean annual precipitation is about 70 in (170 cm) in Astoria, and potential recharge varies from 50–70 in (127–178 cm) per year. Recharge in beach sands is high compared to the rest of the county, even though rainfall may be lower; the terrain is flat and the soil is highly permeable until saturated (McFarland 1983).

Surface Water Quality

Upstream factors that are known to impact water quality at LEWI sites include upstream water discharges, herbicide, pesticide and stormwater runoff, timber harvesting, mining, and road construction (Klinger et al. 2007, NPS 2000, NMFS 2011, LCEP 2012, Welch and Rawhouser 2017). While timber activities were historically a primary stressor on water quality in LEWI sites (NPS 1994), these impacts have been greatly reduced in the past several decades. Aerial application of herbicides containing glyphosates such as Roundup®, a practice less regulated in Oregon than in other west coast states, can have multiple and cumulative effects on water quality and aquatic organisms (Vera et al. 2010, Battaglin et al. 2014). Emerging contaminants are pharmaceuticals that include hormones and chemicals that can be harmful to humans and wildlife. These materials are introduced into the watershed via septic systems and improper disposal and can accumulate in organic tissues, particularly in estuaries where compounds can precipitate in to sediments (Nilsen et al. 2014, Granek et al. 2016).

Toxic materials in surface waters affect both humans and wildlife, for example, fish in the lower portion of the Columbia River tend to have higher toxic concentrations than those in higher reaches (LCEP 2012, Nilsen and Morace 2014). Klinger et al. (2007) presented a thorough summarization of water quality data and conditions through (approximately) 2006 and included a description of the NPS 2000 report. This assessment provides information available after the period covered in Klinger et al. (2007).

Groundwater Quality

Groundwater quality can be degraded by almost any material that enters the surface layer of the earth. One common source of pollution to groundwater is leachate (material that percolates through soil) from landfills and poorly managed waste systems. Septic systems, particularly those that are overloaded, sited on porous soils and/or placed too close to wells can leak into groundwater reserves. Underground storage tanks may also leak material in to the groundwater system. Agricultural practices, particularly the use of herbicides and pesticides and feedlot runoff are primary sources of groundwater pollution in many areas (Spalding and Exner 1993, Mahar and Datta 2000, Randall et al. 2008, Domagalski et al. 2008).

4.3.2. Reference Conditions

Streamflow and Connectivity

Watershed connectivity and hydrologic processes from upstream to downstream park sites should not be impeded, and there should be no barriers to fish movements. Floodplain processes should be in place and functioning.

Groundwater Quantity

Groundwater should continue to supply springs and ephemeral surface lakes. Well levels should show no decreasing trends. One historic study estimated wells in the Coast Range of Oregon generally yielded less than 10 gallons/minute (McFarland 1983).

Surface and Groundwater 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), Klinger et al. (2007), and Conway-Cranos et al. (2016).

Historic studies that examined Coast Range aquifers for potential injection sites found the waters to be suitable for domestic use, with low concentrations of dissolved solids (<1,000 mg/L) though some closest to the coast had greater concentrations due to salines (McFarland 1983). The groundwater parameters tested by the Oregon Department of Environmental Quality (ODEQ) are listed below with the minimum acceptable levels determined by the EPA (EPA 2017)(Table 4.3-1). Only those parameters for which some wells exceeded maximum amounts allowed are included.

Table 4.3-1. Maximum acceptable limits for a subset of groundwater quality parameters (ODEQ 2018a).

Parameter	Max. acceptable level
Nitrate	3 mg/L
Arsenic	10 µg/L (µg/L = ppm)
Bacteria / *E. coli*	–
Manganese	50 µg/L
Uranium	30 µg/L
Various pesticides	–

4.3.3. Data and Methods

Streamflow and Connectivity

Though stream geomorphology and surface water dynamics were identified as high priority vital signs for monitoring at LEWI by NCCN (Weber et al. 2009), the programs are not funded at this time. As far as is known there are no sampling protocols for floodplain processes, nor are there any USGS gaging stations either within LEWI watersheds or within a reasonable upstream distance. The only streamflow information that appears to be available are average stream flow, peak flow, and fish passage flows that were estimated for Dismal Nitch/Megler Creek, though mostly using modeling techniques rather than direct measurements (ESA 2014).

Groundwater Quantity

As far as is known there are no public data available for ground water quality in or near LEWI sites (Klinger et al. 2007). A search of the USGS Water Information System for Oregon (https://nwis.waterdata.usgs.gov/or/nwis) and Washington (https://nwis.waterdata.usgs.gov/wa/nwis/) revealed either no data (Clatsop) or no current data (Pacific). Remote sensing techniques such as ground penetrating radar (GPR) have been used by individual investigators (Peterson et al. 2007) but these data are not publically available as far as is known.

Surface Water Quality

Available information suggests that a fair amount of water quality sampling was conducted when new park lands were acquired and as the NCCN Inventory and Monitoring program was beginning, but that few if any data are available for the last decade or more (Bischoff et al. 2000, Klinger et al. 2007, ODEQ 2015, Conway-Cranos et al. 2016). A very thorough watershed assessment for the Necanicum River Watershed was conducted by Snyder et al. (2002) around the same time (early 2000s). Though the NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012) includes LEWI in the sampling schedule, no data from that program are currently publicly available.

The State of Oregon maintains 2–4 sites near or upstream of LEWI properties (https://orwater.deq.state.or.us/Login.aspx). As far as is known there are no water quality monitoring sites maintained by the State of Washington near LEWI sites (https://fortress.wa.gov/ecy/eap/riverwq/regions/state.asp).

Groundwater Quality

Groundwaters are sampled and reported on by the Oregon Department of Environmental Quality with methods provided in various publications (https://www.oregon.gov/deq/wq/Pages/WQ-Assessment.aspx).

4.3.4. Resource Condition and Trend

Streamflow and Connectivity

Very few data exist to determine whether streamflows in LEWI are environmental flows. At present there are no indications that flows are at risk, though there are ongoing and proposed withdrawals from the Lewis and Clark River for non-agricultural human uses that may affect flow amounts (Klinger et al. 2007; Bischoff et al. 2000; C. Clatterbuck pers. comm. 2016). The only stream that seems to have been measured in a relatively recent timeframe is Megler Creek (ESA 2014), which was estimated to have a base flow of approximately 5 ft^3/second (cfs) or less.

During the low-flow period of late summer and early fall some smaller streams in LEWI do stop flowing, but it is not clear if those are natural conditions or result from diversions or other impacts upstream (NPS 1994). Climate change impacts are predicted to reduce flows where precipitation declines and/or temperatures increase (TNC and CIG 2016). At present it does not appear that LEWI streams are at risk from significantly lower rainfall in coming decades, but seasonal patterns are almost certainly going to change (Section 4.2).

Groundwater Quantity

Groundwater appears to be plentiful in LEWI, as evidenced by the presence of surface water and springs around the Clatsop Plains, though withdrawals from large distances away can potentially affect aquifer depths (Ferguson and Gleeson 2012). No other data are apparently available to determine significant changes in groundwater levels.

Surface Water Quality

The State of Oregon reported index scores for all river monitoring sites from 2008–2017 (ODEQ 2018b) with methods included therein. During that period one site near LEWI, #10812—Skipanon Road at Hwy 101—was rated as being in Very Poor condition due primarily to the high level of total dissolved solids, though conditions at the time were improving. The other sites upstream from LEWI—#10817 on the Lewis and Clark River—was rated as Good with no trend.

The EPA currently lists the Lewis and Clark River as impaired due to low dissolved oxygen and elevated fecal coliform, and the Skipanon River as impaired due to low dissolved oxygen, *E. coli* and elevated fecal coliform, but most of those data are from 2004 (https://watersgeo.epa.gov/mywaterway/; https://www.deq.state.or.us/wq/assessment/rpt2012/results.asp).

A report on surface water quality testing by the NCCN Inventory and Monitoring team is in draft format. The preliminary findings (Welch and Rawhouser 2018) and for the three sampled streams are:

- Skipanon River (LEWI)

    - Exceeded CWA standards for water temperature and has not met the minimum threshold for dissolved oxygen concentration since monitoring was initiated;
    - Supports a depauperate benthic invertebrate assemblage consisting primarily of mollusks and amphipods.
- Colewort Creek (LEWI)
    - Has met all officially established CWA standards since monitoring was imitated;
    - Had a three-day exceedance in water temperatures that might influence salmon and trout spawning and incubation;
    - Supported a moderately diverse array of benthic invertebrates typically dominated by non-insect, midge, and stonefly taxa.
- Megler Creek (LEWI)
    - Has met all CWA standards since monitoring was initated;
    - Supports a diverse "healthy" array of taxa dominated by mayflies, stoneflies, and dipteran taxa.

Groundwater Quality
Groundwater beneath the Clatsop Plains is known to be impacted by factors that degrade water quality. In 2018 the State of Oregon reported on the status of groundwater quality for the North Coast Basin (ODEQ 2018a) which includes the Clatsop Plains, from 2015–2016 and found excessive levels for arsenic and manganese (Table 4.3-2).

Table 4.3-2. Parameters tested from Clatsop Plains wells by the State of Oregon (ODEQ 2018a).

Parameter	Well sample from Clatsop Plains	Max. acceptable level
Nitrate	not detected	3 mg/L
Arsenic	≥ 10.0 µg/L	10 µg/L (µg/L = ppm)
Bacteria / *E. coli*	not detected	0
Manganese	≥ 300 µg/L	50 µg/L
Uranium	not detected	30 µg/L
Various pesticides	1 parent pesticide detected	–

One active well in the Fort Clatsop unit was tested by DEQ in 2015. Total coliform was measured at 2 MPN/100 mL, making it unsafe for drinking but safe for its current use as irrigation for a native plant nursery.

4.3.5. Level of Confidence
Moderate to High for overall connectivity, though probably Low to Moderate for knowledge of floodplain processes. Moderate for surface water quality. Low for groundwater quantity or quality in areas relevant to LEWI resources. Overall level of confidence is low.

4.3.6. Data Gaps and Research Needs

Very few data exist describing flow conditions on any LEWI streams. The last time flow of the Lewis and Clark River was directly measured was 1966; streamflow was therefore identified as a high priority data need in the park's Foundation Document. Climate change impacts and potentially additional diversions could affect these flows and have impacts on both freshwater and estuarine resources (NPS 2015). For example, the nearby town of Warrenton owns withdrawal rights that exceed summertime flows (Bischoff et al. 2000). Sampling streamflow in relation to salmon life cycles and migration periods would be consistent with most present-day studies of streamflow in the PNW (Dittmer 2013).

The water quality monitoring program for the park should continue to be conducted as directed in the NCCN Water Quality Monitoring Protocol (Rawhauser et al. 2012), which calls for sampling of three sites (Colewort Creek, Megler Creek, and Skipanon River) at a minimum schedule of once per year during the low water period (late July – early October), and more often during heavy runoff and flood events if staff are available (Conway-Cranos et al. 2016).

4.3.7. Sources of Expertise

Chris Clatterbuck, Lewis and Clark National Historical Park

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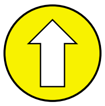
4.4. Estuaries and Juvenile Salmon

The condition of several estuaries in LEWI is greatly improved as a result of comprehensive restoration efforts. Biological conditions are of moderate concern given an apparent absence of data regarding fish presence and presence/absence of invasive species. The trend is improving condition, but confidence is medium.



4.4.1. Background

Estuaries

Powerful tidal influences at the mouth of the Columbia River in concert with upstream inputs have created extremely productive wetland ecosystems in the Columbia River Estuary (CRE). Estuaries are coastal wetland sites where freshwater mixes with marine waters and tidal processes dominate. These sites are among some of the most productive ecosystems on earth, supporting highly diverse and unique communities (Barbier et al. 2011), including fish, birds, shellfish, and vegetation (Sherwood et al. 1990, Bottom et al. 2005, Jay et al. 2016). Coastal wetlands also function to moderate damaging effects to human life and property from erosion and storms (Gedan et al. 2011).

Estimates are that perhaps up to 90% of the estuarine wetlands that once existed along the Pacific Coast of the US have been lost (Callaway et al. 2012), and that up to 70% of all estuaries in the PNW have been lost or functionally degraded due to human activities since the beginning of the 20th century (Borde et al. 2003, Fresh et al. 2005, Bottom et al. 2008, Lev et al. 2008, Marcoe and Pilson 2017). Locally, over 90% of the historic estuarine wetlands along the Lewis and Clark River were lost to diking. By 2000, only approximately 13 acres remained in the watershed (Bischoff et al. 2000). Since then, the park has restored 78 acres and partners have restored another 25 acres (NPS 2010).

Salmon

Juvenile salmon are included in this section as a resource because of the strong coupling of estuary condition with juvenile salmon survival and growth (Bottom et al. 2008). Coastal wetlands in the CRE provide some of the most productive habitat for juvenile and spawning anadromous fish in North America (Bottom et al. 2005, Fresh et al. 2005, LCEP 2012a, Diefenderfer et al. 2013). For example variability in the performance of juvenile Chinook salmon is explained primarily by when and where they resided in estuarine habitats (Chittaro et al. 2018), and a primary contributor to population declines of salmon has been the alteration and destruction of estuarine habitats (Bottom et al. 2005, Weitkamp et al. 2013). The restoration of these sites has been identified as a necessary step in the effort to recover many populations of fish in the Columbia Basin (NMFS 2013).

In general, species in the Salmonidae family spawn (lay eggs) in fresh water but spend some portion of their life at sea. After hatching and early development, juvenile salmonids (smolts) mature for a period of time (less than one to several years) in tidal estuaries or other freshwater sites before migrating to the ocean, though use patterns and behavior in estuaries is extremely species specific

(Weitkamp et al. 2014). Some species mature before migrating while others migrate as very young fish, and some species do both. Some species are further identified by the season in which they migrate, and these differences can be included in legal definitions for protection (Evolutionarily Significant Units – ESUs). Salmon species and ESUs known to inhabit estuaries in the Lower Columbia region are listed in Table 4.4-1.

Because so much research has been conducted on salmon in the PNW, this report will provide only a brief overview of the species and population units occurring within estuaries in LEWI; a thorough summary is provided in NMFS 2013.

Table 4.4-1. Anadromous Fish species and ESUs native to the Lower Columbia Estuary. Status: E = Endangered; T = Threatened; S = ; C = Species of Concern (compiled from multiple sources).

Scientific Name	Common Name	ESUs	Status Federal; OR; WA	Locations in LEWI
Oncorhynchus tshawytscha	Chinook salmon	a. Snake River, fall run b. Snake River, spring/summer run c. Mid-Columbia River, summer run d. Lower Columbia River, fall run e. Upper Willamette River, spring run (Lower Columbia River ESUs)	T;S;C	South Clatsop Slough: juvenile out-migration March–June; adult upstream migration August–November.
O. kisutch	Coho salmon	a. Lower Columbia River ESU b. Oregon Coast ESU	T; E; C	South Clatsop Slough; Otter Point (LCR); Middle Village – Station Camp
O. mykiss	Steelhead	a. Lower Columbia River ESUs: b. Lower Columbia, summer run c. Lower Columbia, winter run d. Oregon Coast, winter run (SOC) e. Southwest Washington, winter run f. Middle Columbia, winter run g. Upper Willamette winter run	T; E/S;C	South Clatsop Slough; Middle Village – Station Camp
O. keta	Chum salmon	a. Lower Columbia River ESU	T; E/S;C	South Clatsop Slough: juvenile out-migration March–May; adult upstream migration October–November; Middle Village – Station Camp
O. clarkia	Coastal cutthroat trout	a. SW Washington/Columbia River ESU	none; S; none (but species of C)	Several park streams

Impacts to CRE

Physical Changes

With the arrival of settlers, many of the wetlands of the CRE were converted to farmlands and other uses by filling them with soil and other materials (Ruggiero et al. 2016). Levees and dikes were constructed to keep water from flooding farmlands and more recently to facilitate ship traffic and increase boating safety (Bischoff et al. 2000, Moritz et al. 2003). The conversion of wetlands not only directly degraded habitat, but also limited or prevented tidal flow to resources further upstream (NPS 2011). Tidal processes are fundamental to estuarine productivity, and in the CRE can be extreme; the mean tide range in Astoria, Oregon is more than 6 ft (2 m), and saline waters are detectable six miles (10 km) up the Columbia River (NPS1994).

Biological Changes

For reasons that have been extensively discussed, the enormous salmon populations that were once were present in the CRE and provided a critical resource for native Chinookan people have declined dramatically. Conversely, the introduction of novel and often invasive species has further altered ecological function in estuaries (Ricciardi 2015). Surveys in the early 2000s found that over 80 species of plants, invertebrates and vertebrates have been introduced to the Lower Columbia since the mid-1800s (Sytsma et al. 2004). In particular New Zealand mud snails (*Potamopyrgus antipodarum*; NZMS) first discovered in the Columbia River estuary system in 1996 (Bersine et al. 2008), have rapidly expanded in distribution with population densities as high as 200,000/m2 in Youngs Bay (Litton 2000). American shad (*Alosa sapidissima*) were introduced to the Columbia River from the Atlantic and are now extremely common in the CRE (Weitkamp et al. 2012). Several invasive plant species have successfully established in estuaries as well, most notably reed canarygrass (*Phalaris arundinacea*), a plant that outcompetes many native species greatly reducing plant community diversity wherever it establishes (Diefenderfer et al. 2016).

Climate Change

Multiple effects of climate change have already and will continue to affect estuaries (Weitkamp et al. 2016). The potential impacts of sea level rise, ocean acidification, and increasing storm and high wave events on LEWI coastal resources are discussed in Section 4.10.

4.4.2. Reference Conditions

Numerous efforts have been conducted and are ongoing to assess changing conditions of wetland resources within the CRE, often in concert with efforts to restore salmon populations (Simenstad and Cordell 2000, Bottom et al. 2005, Hayslip et al. 2006, Diefenderfer et al. 2013). Associated with these projects are various methods of measuring component and system condition (Hayslip et al. 2006, Johnson et al. 2008, Roegner et al. 2009). Rather than attempt to duplicate those efforts here, this assessment will utilize a few common metrics to assess overall estuary conditions in LEWI (Hallet et al. 2016), but not necessarily in relation to the conditions that existed in 1805–1806 given that such information is unavailable (Sherwood et al. 1990).

Water heights should vary within ranges to which native plants have become adapted (Jarell et al. 2016) and tidal processes should function naturally (Wolanski and Elliott 2015, Munsch et al. 2017). Because changes in these measures are presently most strongly tied to climate change, they will be discussed separately in Secion 4.10. The total area of functional estuaries should be maintained and optimally increase. Kagan et al. (2012), using imagery and data collected in 2009–2010, calculated approximately 344 acres (139 ha) of tidal fresh-brackish marsh and salt marsh in LEWI and nearby state parks.

Specifically, the area occupied by reed canarygrass should not negatively affect natural plant communities (Sayce 2003; Kagan et al. 2012; Diefenderfer et al. 2016). Post-restoration research in other areas has shown that the persistence of non-native wetland plants, even after removal efforts, limited recovery of native species (Clifton et al. 2018). NZM and other invasive invertebrates should be absent (Systma et al. 2004; Bersine et al. 2008; Davidson et al. 2008). Juvenile salmon of all species and ESUs should be present according to historical records. Finally, as much as possible, juvenile salmon should be present in numbers that reflect increasing populations.

4.4.3. Data and Methods
Kagan et al. (2012) mapped the extant area of wetlands in 2009–2010. Several methods are available to determine changes in extent at any point in the future using similar methods.

Monitoring of vegetation in estuaries has been conducted for several years by NPS as well as CREST and LCEP, and is summarized most recently by Fermin and Cole (2018). Mean cover (proportion of ground surface cover by species) is used as a metric to compare changes over time. For this assessment only mean cover of reed canarygrass will be assessed.

As far as is known, there have been no recent efforts to sample non-native invertebrates or fish. Sampling for native fish including juvenile salmon occurs periodically. From 2010–2013 Roegner et al. (2015) sampled fish at Pt. Adams Beach, adjacent to Fort Stevens State Park, with methods described therein. Schwartz et al. (2013) reported on fish sampling at South Clatsop Slough and Alder Creek from 2007–2011.

4.4.4. Resource Condition and Trend
The physical characteristics, geography, geology, and ecologic history of the CRE systems have been well-studied and reported elsewhere; summaries can be found in Roegner et al. (2008), LCEP (2012a), and others.

The total extent of functioning estuary habitat in LEWI has increased in the last ten years as a result of restoration but overall is still much reduced from historic conditions. The cover of reed canarygrass has declined in several locations following restoration and directed efforts to remove it (e.g. Alder Creek), though it is persistent at other sites (e.g. Otter Creek). Overall non-native species have declined relative to native species at South Clatsop Slough and Alder Creek, but have increased at Otter Point and Colewort Creek (LCEP 2012b, Fermin and Cole 2018). The presence and persistence of invasive plant species in some wetlands even following restoration in some cases is problematic (Adams and Galatowitsch 2005. New Zealand mud snails are present in all LEWI sites (C. Cole pers. comm. December 2018).

Juvenile Salmon presence/absence and abundance
For Columbia River salmon in general, NOAA (2016) found: a) fall-run Chinook may be slightly increasing (positive trend), but spring-run Chinook are still at high risk; b) Chum salmon remain at very high risk with low abundances; c) Coho salmon may be experiencing some improvement, or the data may reflect more intensive monitoring; d) both winter and summer-run steelhead remain at high risk with low abundance.

In a multi-year study of Trestle Bay, Weitkamp et al. (2012) found enormous temporal variability in fish assemblages and particularly salmon diversity. Juvenile Chinook and Coho were the most common salmon species detected, and were found in in 63 and 45 percent of the seine samples from 2007–2010, respectively. However, salmon were detected much less often than non-salmonids (Weitkamp et al. 2012). A study in the Grays River estuary (a Columbia tributary approximately 15 mi [24 km] northwest of Fort Clatsop on the Washington side) found relatively high use of restored estuary sites by juvenile Coho (Craig et al. 2014).

Very little is known regarding current conditions of juvenile salmon use of the restored estuaries in LEWI. From 2007–2011 in South Clatsop Slough and Alder Creek, Schwartz et al. (2013) reported apparent increase at both sites in the total number of individual salmon caught. At South Clatsop Slough only five individuals were caught in 2007, but 736 were caught in 2011. (Differences in sampling methods, which may have been partially responsible for the differences, are discussed in that report.) Likewise, the number of individuals caught at Alder Creek was two in 2007 but 134 in 2011. In some years only one species was caught at Alder Creek (Coho), but in 2008 five species were caught at South Clatsop Slough (Coho, chum, Chinook, cutthroat, and steelhead).

4.4.5. Level of Confidence
Medium

4.4.6. Data Gaps and Research Needs
Additional biological and physical data in estuaries at local spatial scales (acres to mi^2) would aid managers, restoration ecologists, salmon ecologists and conservationists (e.g. Table 6.7 in Johnson et al. 2008), and analysts (Diefenderfer et al. 2013, Cheng et al. 2015, NPS 2015, Conway-Cranos et al. 2016). In particular, the park's Foundation Document identified the need to sample restoration sites for salmonids as a high priority data need (NPS 2015).

Additional system elements should be monitored, for example sediment, phytoplankton, impacts of mud snails, amphibians and birds (Roegner et al. 2008, Schwartz et al. 2015, Conway-Cranos 2016).

Standardization of data collection and management methods across the CRE would be helpful (Borde et al. 2012, Fermin and Cole 2018). While the park's wetland monitoring data have been entered into a multi-agency database, other projects have not inputted data, limited the potential for comparisons.

Overall ecological processes in estuaries, particularly those that have been the recipients of intense restoration work, should be studied (Diefenderfer et al. 2016). For example, birds are often unmonitored in restoration assessments (e.g. Roegner et al. 2008), and many rare bird species often rely on estuary and marsh habitats for at least some portion of their life cycle (Correll et al. 2017).

The insectivorous and planktonic resources in estuaries are also critical habitat elements for many fish and bird species and are often undersampled (Koehn et al. 2016).

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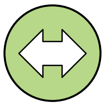
4.5. Forest Health and Disturbance Processes

Forests appear to be in relatively good condition, though this varies depending on the park unit and disease and impacts from climate change are concerns. Disturbance processes will continue to structure forests, and severe storms may in fact increase in frequency. There are no detectable trends, and confidence is medium.



4.5.1. Background

When Lewis and Clark arrived at the Oregon Coast at the beginning of the 19th century the forests they encountered were mostly old-growth stands of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) with a dense understory that made the forest "almost impenetrable" (Lewis in Moulton 1990, UNP 2005). As settlement increased the area was logged and rapidly converted to residential, agricultural, and industrial uses, and by 1920 the old growth forests had disappeared from around Fort Clatsop (Deur 2016). There are now few stands of old-growth trees remaining in northwestern Oregon and southwestern Washington. Cover of large and very large conifers in coastal ranges has declined by approximately 60% over the last half-century while younger conifer stands dominated by Douglas ("Doug") fir and hemlock have increased by nearly 200% (Kennedy and Spies 2004). Shrub and hardwood cover have also declined (Kennedy and Spies 2004). Historic forest conditions are discussed in detail in NPS (2011a), so only a brief discussion is provided herein.

<u>Coastal Forests and Disturbance</u>

Wind

Forests in the Pacific Northwest (PNW) are structured by interactive effects of climate, disturbance, topography, and distance from the coast (Wimberly and Spies 2001, Franklin et al. 2017). Research has determined that prior to settlement and land conversion, relatively frequent but strong disturbances resulted in landscapes that included a mix of open sites, areas of standing deadwood and fallen trees, early successional herbaceous associations, and old stands (Agee 2000, Nonaka and Spies 2005, NPS 2011a).

Wind, mainly from the southwest (Ruth and Yoder 1953), is the primary natural disturbance factor affecting LEWI forests. (Logging has been by far the most dominant disturbance in PNW forests over the last two centuries [Wimberly et al. 2000], but does not currently occur on LEWI lands.) Data indicate that winds strong enough to topple mature trees (70–90 mph/110–145 kmh) at landscape scales occur approximately every 20 years, while more frequent but less powerful storms can damage stands of smaller trees, particularly those adjacent to previously-downed stands where open canopies provide little wind resistance (Greene et al. 1992, Beese 2001, Wimberly and Spies 2001, Long and Whitlock 2002, Harcombe et al. 2004, NPS 2011b).

Native and late-successional tree species (e.g. Sitka spruce) have acquired morphologic and mechanical traits that allow them to resist and survive strong winds much more often than do individuals of non-native (planted) or early-successional species (ex: hemlock and Doug fir; Ruth and Yoder 1953, Brüchert and Gardiner 2006). Following large blowdowns open canopies and areas of treefall allow germination and growth of herbaceous species and small trees, conditions that further facilitate increased diversity of birds and small vertebrates (Lindenmayer et al. 2006, Swanson et al. 2011, Swanson et al. 2014, Thorn et al. 2014, Waldron et al. 2014).

Fire

Large-scale fires along the Oregon coast prior to settlement were relatively rare. Estimates are that fire-return intervals ranged from several hundred to over a thousand years (Long and Whitlock 2002, Whitlock et al. 2003). When fires did occur, likely during conditions of easterly dry winds coinciding with drought (Franklin et al. 2017), they were intense enough to destroy large areas of mature spruce while leaving smaller areas of partially or un-burned trees among the old-growth stands (Agee 2000, Wimberly and Spies 2001, Long and Whitlock 2002, Wimberly 2002, NPS 2011b). A particular period of large fires occurred between the mid-19th and early 20th centuries, concurrent with European settlement, though it is not known whether specific fires were intentionally started by humans, accidentally started, or were lightning-caused (Wimberly and Spies 2001).

Disease

Swiss Needle Cast (SNC) is a disease caused by the ascomycete fungus *Phaeocryptopus gaeumannii.* The fungus defoliates Doug fir trees and negatively impacts the photosynthetic ability of the tree (Hansen et al. 2000, Manter et al. 2003). Though the fungus is native to Pacific Coast forests, until the past few decades the disease was not considered a serious threat to regional forest stands (Hansen et al. 2000). Recently, however, SNC has become a primary threat to Doug fir stands in Washington and Oregon (Shaw et al. 2011, Lee et al. 2017). Symptoms of the disease include chlorosis, decreased needle retention, loss of height and diameter growth, and ultimately the death of the tree. It is unclear whether mortality is directly from defoliation or indirectly from reduced tree vigor and other disease/insect effects (Kelsey and Manter 2004). A combination of relatively mild, humid conditions and extensive replanting of Doug fir on coastal sites previously occupied by a mixture of western hemlock, red alder, and Sitka spruce may have led to the current epidemic conditions (Hansen et al. 2000).

4.5.2. Reference Conditions

Demography and Structure

Forests should include multiple age stands stages (“seres”) including mature, intermediate, and open sites that are created post-disturbance (Nonaka and Spies 2005, NPS 2011a, Franklin et al. 2017). There should be an absence of human inputs that interrupt successional trajectories leading to forest maturity and complexity (e.g. invasive species, pollutants, roads). In particular early successional forests should include downed wood, relatively extensive cover of herbaceous species, and tree species recruitment (NPS 2011b, Kosugi et al. 2016).

While Wimberly (2002) recommends that naturally caused, long-interval fire should be utilized to direct forests toward conditions listed above, the presence of commercial timberland adjacent to relatively small park units closes this management option (NPS 2011b). Although tree diseases are a natural disturbance at some scales, climate change and specifically warmer conditions appear to be increasing the frequency and impacts of diseases such as SNC. Consequently, it may be that resilient forests in coming decades will be those that are relatively free from serious disease outbreaks (Sturrock et al. 2011, Millar and Stephenson 2015).

Species Diversity

The Lewis and Clark Expedition described the vegetation at the Fort Clatsop Memorial site as a mixture of large, dense conifer forests and extensive fresh and brackish water wetlands. Forest vegetation was a mixture of large Sitka spruce and western hemlock and, on the wetter sites, a combination of western redcedar, Sitka spruce and red alder (Agee 2000). Optimally conditions would be similar, including the absence of non-native species.

Presence of Downed Wood

Natural debris should be present on the forest floor to provide habitat, particularly for amphibians and small mammals (Martin and McComb 2002, NPS 2011b, Swanson et al. 2011). Dead tree snags should be left standing after disturbance (Pollock et al. 2012, Franklin et al. 2017). Non-native tree species should be absent.

4.5.3. Data and Methods

Most of the information used to assess the forest resources comes from Kagan et al. (2012), NCCN Forest Monitoring Reports (Acker et al. 2014), and recent data (Waldrop et al. 2018).

4.5.4. Resource Condition and Trend

Demography and Structure

Current forests in LEWI are characterized by Sitka spruce-dominated stands older than 30 years, young Doug Fir – hemlock stands (20–30 years) that are largely recovering from timber harvesting, and open stands created by modern-era windstorms (Kagan et al. 2012; Table 4.5-1)). A few remnant old-growth stands can be found in both Ecola State Park and Cape Disappointment. Most of the second growth forest was logged in the early 1900s, but some LEWI sites have healthy, robust stands of second growth forests that are beginning to demonstrate structural properties of mature forests (Kagan et al. 2012). Forests at Cape Disappointment are in good condition.

Variable density thinning, snag creation, and underplanting of diverse species has occurred on 520 acres between 2012 and 2019 (C. Clatterbuck pers. comm. 2016). Preliminary data from forest sampling in a historically single-aged stand forest where thinning treatments are being applied, showed an increase in smaller trees in the thinned plots, suggesting recruitment is occurring where the canopy has been opened (Waldrop et al. 2018). The 2007 windstorm created approximately 185 acres of blowdown; these stands have been modeled to produce the desired multiple-age diverse stands (NPS 2011a; C Clatterbuck pers comm.)

Overall there are very few forest stands left in all of the PNW that have not been significantly altered by human activity (NPS 2011a, Acker et al. 2015). Old growth forests can only be restored over centuries of time and in the absence of significant disturbance, so given historic impacts, landscape-scale anthropogenic activities, and climate change, even determined and directed efforts will not result in the re-establishment of old-growth stands resembling those present in 1805 (Nonaka and Spies 2005). Instead the goal is healthy forests with multiple-aged stands (NPS 2011b).

Table 4.5-1. Current structure of forests and general locations in LEWI (summarized from Kagan et al. 2012).

Forest Type	Dominant Species	Locations
Alder Upland	Red alder, Sitka spruce, western hemlock.	• Dismal Nitch • Middle Village/Station Camp, Ft. Clatsop • Cape Disappointment,
Big-leaf Maple Upland	Big-leaf maple, Doug fir	• Ft. Clatsop
Mesic Hemlock Upland	Western hemlock, Doug fir	• Dismal Nitch • Middle Village/Station Camp, Cape Disappointment
Wet Hemlock Upland	Western hemlock, Doug fir	• Dismal Nitch • Ft. Clatsop
Sitka Spruce Upland	Sitka spruce, grand fir, western hemlock, western red-cedar	• Dismal Nitch • Middle Village/Station Camp, Ft. Clatsop • Cape Disappointment
Sitka Spruce Upland Young	Same as Sitka spruce upland but disturbed within past ~40 years	• Ft. Clatsop
Disturbed*	–	• Dismal Nitch • Ft. Clatsop, Sunset Beach/Yeon

* Disturbed forests refer to forests with substantial blowdown areas

Plant Species Diversity

Recent monitoring recorded six native tree species on the permanent plots at Cape Disappointment and one non-native species (Acker et al. 2014; Table 4.5-2). The average number of species on each plot (species richness) was 3.7, with hemlock and spruce being the most common. At Fort Clatsop, planting strategies for commercial forests have resulted in an over-representation of Doug fir; Forest restoration thinning is preferentially falling Doug fir and underplanting with Sitka spruce, western redcedar, and big leaf maple (NPS 2011a). Preliminary data comparing thinned and unthinned treatments show greater cover of herbaceous plants and shrubs in treated plots (Waldrop et al. 2018). The 2007 Great Coastal Gale created patches of open canopies, particularly at the Fort Clatsop unit, and have seen growth of understory herbaceous plants and shrubs in response (C. Clatterbuck pers. comm. 2016). At Yeon, the older shore pines that were not blown down in the storm of 2007 are reaching the end of their life, and the park is considering management that would facilitate a transition into to a Sitka spruce-western hemlock forest (C. Clatterbuck pers. comm. 2016).

Table 4.5-2. Tree species included in permanent forest plots at Lewis and Clark National Historical Park (Acker et al. 2014).

Scientific Name	Common Name
Alnus rubra	red alder
Malus fusca	western crabapple
Picea sitchensis	Sitka spruce
Rhamnus purshiana	cascara
Tsuga heterophylla	western hemlock
Alnus rubra	red alder
Ilex aquifolium (exotic)	English holly

Presence of Downed Wood

There are approximately 110 acres/272 ha of forest identified as disturbed in the park, mostly in Sitka spruce, that have relatively open canopies and greater amounts of downed wood than in undisturbed areas (Kagan et al. 2012). Overall the number of dead standing trees in the park is relatively high (Acker et al. 2014). Thousands of trees were blown down during the 2007 Great Coastal Gale event which created large areas with open canopies but also left beneficial woody debris on the ground. Because NPS did not conduct timber salvage operations after the December 2007 storm, the woody debris left in place provided "safe sites" for seedlings and young plants and habitat for insects, small vertebrates and landbirds (Lindenmayer et al. 2006, Thorn et al. 2014, Waldron et al. 2014, Cole pers. comm. 2016) Preliminary data show increasing amounts of woody debris over 5 years in most but not all plots (Waldrop et al. 2018).

Disease

Currently SNC is causing an epidemic west of the Oregon coast range from Coos Bay to Astoria and northward into Washington. Though less of a driver than wind (Reilly and Spies 2016), disease is affecting some LEWI forests, particularly along the Fort-to-Sea Trail and the former Weyerhaeuser property of Fort Clatsop (T. Hinckley, personal observation). Stands of Doug fir not on LEWI lands but along the coast near the dunes have significant infestations of SNC. Recently several alder species in western Oregon have been infected by *Phytophthora siskiyouensis*, (a new species of water mold in the genus that causes sudden oak death), the first time the disease has been found in alder (Sims et al. 2015). Predictions are that increasing temperatures associated with climate change will facilitate even greater incidences of SNC as well as other tree diseases within the Oregon and Washington coastal ranges (Lee et al. 2017, Agne et al. 2017).

Fire

Fires in LEWI are currently rare. Fire frequency in the PNW west of the Cascades is predicted to decline by nearly 50% under most climate change scenarios (Sheehan et al. 2015).

Disturbance

Temperatures will likely increase in the PNW with climate change (Section 4.2) but strong coastal influences at LEWI will likely maintain moist conditions that moderate fire severity (Long and

Whitlock 2002). Altered disturbance processes may affect forest ecosystem resilience (Seidl et al. 2017). Large wind storms will likely not abate and in fact may become more frequent and/or intense with climate change (Hopkinson et al. 2008). Spruce and hemlock trees are naturally recruiting into the area of the 2007 blowdown (C. Clatterbuck pers. comm. 2016).

4.5.5. Level of Confidence

Medium

4.5.6. Data Gaps and Research Needs

Protected forests such as those found in LEWI provide critical habitat, ecosystem services, and opportunities for research (Kennedy and Spies 2004). Management practices that protect forests in a resilient state, for example that facilitate native species recruitment after disturbance and limit the potential for invasive species to establish, will help lead to long-term persistence of forest ecosystems (Everham and Brokaw 1996, Acker et al. 2015).

Long-term monitoring will glean important data regarding forest recovery following logging, forest responses to disturbance, results of post-disturbance management approaches, and likely successional trajectories under variable climate change conditions (Knapp et al. 2012, Waldrop et al. 2018). For example, many vertebrate species are more common in young seral forests after disturbance (Swanson et al. 2014) and vertebrate surveys following blow-downs would provide important information on overall wildlife diversity in the region. However, even though such practices will protect forests as much as is possible and allow natural processes to occur, it is almost certain that no management strategy will lead to the restoration of the old growth forests that existed in 1805 (Nonaka and Spies 2005).

While timber cruises (estimates of standing timber) have been conducted for the forests at Fort Clastsop and Dismal Nitch forest, detailed forest inventories have not been done for the Yeon unit or the forests at Middle Village – Station Camp, sites that are in negotiation for purchase. In particular, the shore pines at Yeon that were planted for dune stabilization are nearing climax stage and are vulnerable to future windstorms that could kill trees and thus increase fuel loads. Younger Sitka spruce and Western hemlock are recruiting into the site but often experience competition from the younger pines. Given these conditions and threats, a plan to transition the forest into a Sitka spruce – Western hemlock composition is needed.

4.5.7. Sources of Expertise

Chris Clatterbuck and Carla Cole, Lewis and Clark National Historical Park

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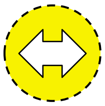
4.6. Animal Species of Concern – Non-salmonid Fish

Non-salmonid fish in LEWI are of moderate concern. Many species are abundant, but several rare species continue to decline. Numerous impacts including migration barriers, habitat loss, and predation and harvest are cause for concern. Insufficient information on current fish diversity and the status of species of concern preclude any determination of trend. Confidence is low.



4.6.1. Background

Many species of fish other than salmon inhabit the freshwater streams and tidal estuaries of LEWI (Brenkman et al. 2008: Table 4.6-1). Due primarily to habitat loss and degradation, migration barriers and climate change, several fish species are of conservation concern. If not otherwise referenced, all of the general species information provided below was obtained from agency websites, in particular NOAA (www.westcoast.fisheries.noaa.gov), and USFWS (https://www.fws.gov/oregonfwo/articles.cfm?id=149489457).

Species of Concern

Eulachon (Columbia River Smelt, Thaleichthys pacificus, Southern DPS)

Eulachon, also called smelt, are small (max. 10 in/25 cm), anadromous fish found from Alaska to Northern California. Lewis proclaimed them "superior to any fish I have ever tasted" and sketched one in his journal (Lewis in Moulton 1992). Eulachon migrate to the ocean from freshwater sites as juveniles then spend 3–5 years in saltwater before returning upstream to spawn. Eulachon declined to very low numbers beginning in the late 1980s, so much so that the southern Distinct Population Segment (DPS) of Columbia River Smelt was listed as threatened in 2010 (NMFS 2017). Populations have fluctuated since then, seeing some significant increases during the 2000s but mostly declining in recent years (Gustafson et al. 2016).

[Eulachon (*Thaleichthys pacificus*) from Wikipedia: "This work has been released into the **public domain** by its author, **James Crippen**. This applies worldwide." https://en.wikipedia.org/wiki/File:Eulachon.jpg]

Table 4.6-1. Non-salmonid fish documented or potentially present in LEWI with protected status (if any). List source is NPSpecies.

Common Name[1]	Scientific Name	Fed/WA/OR	Known or (Potential) Locations [2]	Open Water (Columbia River)[3, 4]
American shad (N)	*Alosa sapidissima*	–	Colewort, (Skipanon), South Clatsop Slough	X
Banded Killifish	*Fundulus diaphanus*	–	Colewort, Alder, (Skipanon), South Clatsop Slough, Alder	X
Bay (northern) anchovy	*Engraulis mordax*	–	–	X
Black crappie (N)	*Pomoxis nigromaculatus*	–	Colewort	–
Chislemouth	*Acrocheilus alutaceus*	–	Skipanon, Colewort	–
English sole	*Parophrys vetulus*	–	–	X
Eulachon (smelt)	*Thaleichthys pacificus*	none/ none/ C	Skipanon, Colewort	–
European carp (N)	*Cyprinus carpio*	–	–	–
Lamprey (western brook)	*Lampetra richardsoni*	C/ S/ OCS	Skipanon, Trail, (Colewort)	–
Lamprey (river)	*L. ayresii*	–	–	X
Lamprey (Pacific)	*L. tridentate*	C/ none/ none	–	X
Lamprey spp.	–	–	Hansen, South Clatsop Slough	–
Largemouth bass (N)	*Micropterus salmoides*	–	Colewort, South Clatsop Slough	–
Largescale sucker	*Catostomus maacrocheilus*	–	Alder	–
Longfin smelt	*Spirinchus thaleichthys*	–	Colewort, (Skipanon)	X
Northern squawfish	*Ptychocheilus ooregonensis*	–	–	–
Pacific herring	*Clupea pallasii*	–	–	X
Pacific tomcod	*Microgadus proximus*	–	–	X
Peamouth	*Mylocheilus caurinus*	–	Colewort, Junction of Alder and Lewis and Clark River, (Skipanon), South Clatsop Slough	–

[1] Where “(N)” = not native.

[2] Sources: Brenkman et al. 2008; Schwartz et al. 2013; and Welch and Rawhouser 2017.

[3] Sources: Weitkamp et al. 2012; and Roegner et al. 2015.

[4] Where “X” = species was observed in open water.

Table 4.6-1 (continued). Non-salmonid fish documented or potentially present in LEWI with protected status (if any). List source is NPSpecies.

Common Name[1]	Scientific Name	Fed/WA/OR	Known or (Potential) Locations [2]	Open Water (Columbia River)[3, 4]
Pumpkin seed sunfish (N)	*Lepomis gibbosus*	–	Colewort	–
Sculpin (coastrange)	*C. aleuticus*	–	Colewort, West Fork Ness	–
Sculpin (Pacific staghorn)	*Leptocottus armatus*	–	Colewort, Ness, Alder, (Skipanon)	X
Sculpin (prickly)	*C. asper*	–	Skipanon, Colewort, Alder, Hansen	–
Sculpin (reticulate)	*C. perplexus*	–	Colewort, Ness, Alder, (Skipanon)	–
Sculpin (riffle)	*Cottus gulosus*	–	Colewort, Ness, Trail, (Skipanon)	–
Sculpin (torrent)	*C. rhotheus*	–	–	–
Shiner surfperch	*Cymatogaster aggregata*	–	Colewort, South Clatsop Slough, Alder	X
Smelt	*Thaleichthys pacificus*	–	South Clatsop Slough, Alder	–
Starry flounder	*Platichthys stellatus*	–	–	X
Sturgeon (white)	*Acipenser transmontanus*	–	(Skipanon)	–
Sturgeon (green)	*A. medirostris*	T/ none/ none	–	–
Surf smelt	*Hypomesus pretiosus*	–	–	X
Threespine stickleback	*Gasterosteus aculeatus*	–	Skipanon, Colewort, Ness, Trail, West Fork Ness, Alder, Hansen, South Clatsop Slough	X
Yellow perch	*Perca flavescens*	–	–	–

[1] Where "(N)" = not native.

[2] Sources: Brenkman et al. 2008; Schwartz et al. 2013; and Welch and Rawhouser 2017.

[3] Sources: Weitkamp et al. 2012; and Roegner et al. 2015.

[4] Where "X" = species was observed in open water.

The greatest threats to eulachon in the CRE are climate change impacts on both marine and freshwater habitats, and by-catch in shrimp fisheries (NMFS 2016). The Lower Columbia River (LCR) supports the largest known spawning population of eulachon, and critical habitat includes the LCR up to the Bonneville Dam (CFR 2011). Eulachon in the LEWI area spawn in the mainstem of the Columbia and some tributaries.

Lampreys (Lampreta spp.)

Lampreys are a very ancient group of anadromous fish that have several prehistoric characteristics. Lampreys look much like eels because they lack paired fins, have a sucker-mouth ("oral disk") and no jaws. They also have breathing holes instead of gills. Lampreys spawn in spring and early summer in clear streams with gravel substrates where the larvae spend several buried in the streambottom. After migrating they spend 1–3 years at sea before returning to spawn. Lampreys were and are a valued resource for Native Americans of the region (Close et al. 2002).

Estimates are that a quarter to one-half of the approximately 44 species of lamprey in the world are of conservation concern (Maitland et al. 2015). Two species of lamprey found in the PNW—Pacific and western brook—look nearly identical and often require genetic examination to determine species (Docker et al. 2016), but are both of conservation concern. Threats to both species are similar, and include migration obstacles (dams and diversions), reduced stream flows, impaired water quality, habitat degradation, harvest, and predation. In LEWI brook lamprey were found in Perkins Creek in 2005 (Bottom et al. 1984). Alder Creek and South Clatsop Slough as well as other portions of the Lewis and Clark River have been identified as potential habitat.

[Pacific Lamprey (*Entosphenus tridentatus*); USFWS Photo / Dave Herasimtschuk]

[Western brook lamprey (Lampetra richardsonii) inventoried at Perkins Creek in LEWI; NPS photo]

Sculpins (coastrange, prickly, riffle, reticulate and torrent)

Several species of both freshwater and saltwater sculpins are present in the Columbia Basin. Sculpins have strong pectoral fins that allow them to hold to stream substrates while feeding. Sculpin were historically largely sympatric with many salmon species (Swain and Reynolds 2015) but have declined due to similar factors, particularly barriers to migration (LeMoine and Bodensteiner 2014, Tabor et al. 2017) and introduction of non-native predator fish (White and Harvey 2001).

[Pacific staghorn sculpin (*Leptocottus armatus*) inventoried at Colewort Creek in LEWI; NPS photo

4.6.2. Reference Conditions

The Columbia River subpopulation of eulachon is estimated to have been many millions of individuals prior to the beginning of the 20th century (NMFS 2017), so at this point the reference condition should be increasing populations.

Species composition of lampreys varies seasonally; Pacific lamprey are present in the CRE in the winter and spring, while western river lamprey are present from spring through early fall (Weitkamp et al. 2015). Lampreys have been detected in the Skipanon River and Perkins Creek. Colewort Creek likely includes appropriate habitat.

Several species of sculpin are common to Coast Range streams and can be highly sympatric (Finger 1982, Brown et al. 1995). In general sculpins should be fairly common with relatively high diversity.

Overall non-salmonid fish communities should be stable and species of conservation concern stable or increasing.

4.6.3. Data and Methods

Though fish in wadeable streams and lakes were identified as high priority vital signs for monitoring at LEWI by NCCN (Weber et al. 2009), the programs are not funded at this time. Brenkman et al. (2008) conducted fish surveys in Ness Creek, Trail Creek, and the Skipanon River in 2005, and Schwartz et al. (2013) conducted non-salmonid fish surveys at South Clatsop Slough and Alder Creek between 2007–2011. Weitcamp et al. (2012) conducted a very thorough study of fish communities at two sites in the CRE, one being at Trestle Bay adjacent to Fort Stevens State Park where they sampled the outward migration period from mid-April to early July. Roegner et al. (2015) sampled fish at Pt. Adams Beach, adjacent to Fort Stevens State Park from 2010–2013. Survey methods are described in each report.

4.6.4. Resource Condition and Trend

<u>Eulachon</u>
Eulachon continue to experience population declines in the eastern Pacific (Gustafson et al. 2016, NMFS 2017). Climate change driven ocean conditions are identified as the primary cause of the declines, with bycatch mortality as an additional primary cause. Predictions are that conditions will not improve sufficiently in coming years to lead to increased populations (Sharma et al. 2016, NMFS 2017), though predicted increases in fall stream flows may be of some benefit (Sharma et al. 2016).

<u>Pacific Lamprey</u>
Populations of Pacific lamprey have declined in most if not all locations from the time of an Oregon Fish and Wildlife report in 2005 (OFW 2005) to current conditions (Sharma et al. 2016, Clemens et al. 2017). As with all anadromous species in the Columbia basin the primary causes of decline are barriers to fish passage and loss of habitat (OFW 2005, Clemens et al. 2017). Predicted higher stream flows in the fall will likely have a negative effect on productivity (Sharma et al. 2016). Climate change effects will increase limitations on Pacific lamprey populations (Sharma et al. 2016).

<u>Western Brook Lamprey</u>
Brook lamprey are also declining, though less is known about their status (OFW 2005). Barriers to passage, particularly road culverts, remain a primary threat to population persistence. Brenkman et al. (2008) noted spawning behavior by brook lamprey in Trail Creek.

<u>Sculpins</u>
Very little is known regarding sculpins in LEWI waters, though they were fairly common in past surveys (Table 4.6.1).

4.6.5. Level of Confidence

Low

4.6.6. Data Gaps and Research Needs

Because of population declines in eulochon, Pacific lamprey, and Brook Lamprey, additional surveys in the waters of Lewis and Clark would provide managers with critical information on the abundance and trend of these culturally important and vulnerable species. Such surveys should vary temporally and seasonally throughout all park streams and water bodies to identify abundance and trend of the entire fish assemblage (Brenkman et al 2008).

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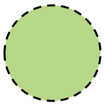
4.7. Animal Species of Concern – Amphibians

LEWI provides important habitat resources for amphibians and they appear to be in good condition. Climate change impacts to forests and hydrological regimes is a concern. There are no detectable trends but confidence is low given the absence of information.



4.7.1. Background

Amphibians are common in the Pacific Northwest, where abundant rainfall and temperate forests create habitats supportive of species like salamanders that generally require perennially moist conditions (Welsh and Droege 2001). Salamanders are a particularly large and diverse group of tailed amphibians that fill important ecological roles as insect consumers and prey for larger vertebrates in many systems (Davic and Welsh 2004). Several characteristics of amphibians, including the presence of gills, permeable skin, and the need to lay eggs in water ("anamniotic"), require that they live near seasonal if not permanent sources of freshwater. This assessment will address amphibian diversity in general and species of concern that occur in LEWI. Approximately 17 species of salamanders, newts (unique salamanders), toads, and frogs are known from LEWI (Table 4.7-1).

Table 4.7-1. Amphibian Species found in LEWI primarily from NPS (2011) and Samora et al. (2015).

Conservation Category	Scientific Name	Common Name	Status[1]	2002–2005 Surveys[2, 3]	Samora et al. 2015 [3]
Rare/Of Concern	*Dicamptodon copei*	Cope's giant salamander	SV-OR; M-WA;	X	X
	D. tenebrosus	Coastal/ Pacific giant salamander	–	X	X
	Plethodon dunni	Dunn's salamander	CO-F;	X	X
	Rhyacotriton kezeri	Columbia torrent salamander	CO-F; SV-OR;	X	X
	Rana aurora	Northern red-legged frog	CO-F;	X	X
Other Native Species	*Plethodon vehiculum*	Western red-backed salamander	–	X	X
	P. vandykei	Van Dyke's salamander	–	?	?
	Aneides ferreus	Clouded salamander	–	?	?
	Ambystoma gracile	Northwestern salamander	–	X	X
	A. macrodactylum	Long-toed salamander	–	?	?
	Ensatina eschscholtzii	Ensatina	–	X	X
	Taricha granulosa	Rough-skinned newt	–	X	X
	R. catesbeiana	Oregon spotted frog	–	?	?
	Pseudacris regilla	Northern Pacific treefrog	–	–	X
	P. regilla	Pacific chorus frog	–	X	–
	Anaxyrus boreas	Western toad	–	?	?
Not Native	*Rana pretiosa*	American bullfrog	–	X	X

[1] Where: CO-F = Federal species of concern; SV-OR: = Oregon sensitive/vulnerable; M-WA = Washington monitor species;

[2] Reported in NPS 2011.

[3] Where "X" means that species was observed during that effort.

Communities (Diversity)
In northwestern temperate rainforests the abundance and diversity of amphibians are strongly correlated with forest successional stage (Ashton et al. 2006, Welsh and Hodgson 2013). In particular the presence of leaf litter, downed wood, and moist conditions protected by tree canopies support higher numbers of amphibians (Olson et al. 2007, Kluber et al. 2009, Tilghman et al. 2012). Where trees are harvested, studies have demonstrated that retaining woody debris results in greater abundance of amphibians (Tilghman et al. 2012, Otto et al. 2013). Consequently, the condition of salamander communities is commonly used as a proxy for overall forest health in PNW coniferous forests (Welsh and Hodgson 2008, Welsh and Hodgson 2013).

Threats to Amphibians
The decline of amphibians across the globe and in the PNW have been well-studied; summaries include Blaustein et al. (1995), Olson et al. (2007), Semlitsch et al. (2009), and Lanoo (2014). Amphibians have been negatively impacted by a myriad of mostly anthropogenic factors, including logging, road building, stream sedimentation, increased water temperatures, degraded water quality (the presence of toxics), reductions in stream habitat complexity, and climate change (Blaustein et al. 1995, Kaufman and Hughes 2006, Olson et al. 2014). In particular, the massive loss of old-growth forests in the PNW and resulting forest fragmentation has led directly to amphibian declines (Blaustein et al. 1995, Cushman 2006). In some places invasive species such as bullfrogs (*Rana pretiosa*) and non-native fish that prey on and compete with native amphibians are threats (Bucciarelli et al. 2014). Higher stream temperatures have been shown to reduce abundance of some amphibian species (Welsh and Hodgson 2008, Pollett et al. 2010).

LEWI Species of Concern

Cope's Giant Salamander (Dicamptodon copei)

Cope's giant salamanders (CGS) are moderately sized, reaching total lengths at maturity of nearly 8 in (200 mm). Because of their size they are often the dominant amphibious predator in riparian systems (Foster et al. 2015). Many individuals never reach full maturity (transform) and live their entire life in a larval stage, only growing to about half the size of a fully transformed adult even though they can attain sexual maturity (Foster and Olson 2014).

[Cope's giant salamander (*Dicamptodon copei*); USGS photo https://armi.usgs.gov/gallery/detail.php?id=776]

Cope's giant salamanders range along the PNW coast from the Olympic peninsula in Washington to NW Oregon, primarily west of the Cascades though they were recently found east of the Cascades in Oregon (Bury et al. 2014). The primary habitats for CGS in coniferous forests are small to medium sized cold-water streams and occasionally small lakes connected to flowing water (Foster and Olson 2014). Available habitat within their range has been reduced by many of the factors discussed above, with increased stream temperatures resulting from loss of tree (shade) cover and flow restrictions (Semlitsch et al. 2009, Foster and Olson 2014). This species is listed as Sensitive in Oregon and as Monitored in Washington; it has no Federal status.

Pacific (Coastal) Giant Salamander (Dicamptodon tenebrosus)

Pacific Giant Salamanders (PGS) are the largest salamanders in Oregon, reaching almost 13 in (330 mm) in length. They are often sympatric with CGS but range further south into northern California. Threats to PGS are also similar to those for CGS (Jones and Welsh 2005). Buffer strips along stream courses are important habitat components (Curtis and Taylor 2004).

[Coastal giant salamander (*Dicamptodon tenebrosus*) inventoried in the Fort Clatsop unit of LEWI; NPS photo]

Columbia Torrent Salamander (Rhyacotriton kezeri)

The Columbia Torrent Salamander has a relatively restricted range from southwest Washington to northwestern Oregon (Russell et al. 2004). This species is much smaller than giant salamanders and is highly aquatic (O'Donnell and Richart 2012). Torrent salamanders require shaded, cold streams with gravel substrates (Russell et al. 2005), and are most common in streams with higher flows (Wilkins and Peterson 2000). Because they prefer old growth conditions, torrent salamanders are at greater risk where logging activities remove larger, coniferous trees (Wilkins and Peterson 2000, Grialou et al. 2000, Russell et al. 2005). Columbia torrent salamanders are currently being evaluated for listing under the US Endangered Species Act due to restricted range, habitat threats, and introduced species (FWS 2015); they are listed as Sensitive in Oregon and as a Monitored species in Washington.

[Columbia torrent salamander (*Rhyacotriton kezeri*) inventoried in the Cape Disappointment unit of LEWI; NPS photo]

Dunn's salamander (Plethodon dunni)

Plethodon salamanders like Dunn's salamander do not have lungs and so spend much of their time below ground or under surface litter where conditions are continually moist (Olson and Kluber 2014). Dunn's prefer mature, unfragmented forests (Martin and McComb 2003) and are often associated with springs and seeps. This is a Species of Concern in Washington.

[Dunn's salamander (*Plethodon dunni*) inventoried at the Fort Clatsop unit of LEWI; NPS photo]

Northern red-legged frog (Rana aurora)

Northern red-legged frogs are found in freshwater ponds and slow-water streams where standing water persists for at least half the year. Breeding sites are located in forested areas with some clearing and sunny locations (OCS 2016). Habitat loss and degradation as well as predation by non-native species have been identified as the primary threats to red-legged frogs. This is a Sensitive species in Oregon and a Federal Species of Concern.

[Red legged frog (*Rana aurora*) inventoried at LEWI; NPS photo]

4.7.2. Reference Conditions

Historically (and likely still by 1805), most if not all streams in the PNW would have supported high amphibian diversity and abundance (Wilkins and Peterson 2000, Adams and Bury 2002, Russell et al. 2005). It is not known how many species were potentially present prior to settlement by Europeans, but at a minimum all of the species listed in Table 4.7-1 should be present. Rare species should not show declining trends.

4.7.3. Data and Methods

Though amphibians in lakes and wadeable streams were identified as high priority vital signs at LEWI by NCCN (Weber et al. 2009), amphibian monitoring is not currently funded. Patterson (2012) conducted a cursory survey for amphibians during a larger bird and mammal survey at the Yeon Property and noted amphibians when he found them. Non-random surveys were conducted at Fort Clatsop, Sunset Beach, and Cape Disappointment in 2002 and 2005, and these are the most thorough surveys for amphibians from LEWI that are known with methods described in Samora et al. (2015). As far as is known there is no information on abundance or distribution of any species noted above in LEWI.

4.7.4. Resource Condition and Trend

<u>Communities</u>
Amphibian diversity on park sites appears to be relatively high. Samora et al. (2015) found 11 species in surveys that lasted only a few days in two separate years, though these surveys were over 15 years ago. Patterson (2012) found four species and an egg mass of another even though looking for amphibians was not the primary goal of his surveys.

<u>Species</u>
All of the species of concern except coastal giant salamanders were found by Samora et al. (2015) but only at Cape Disappointment. Foster et al. (2015) found Cope's salamanders in Washington and Oregon, but only at Cape Disappointment within LEWI. Columbia torrent salamanders, Dunn's salamanders and northern red-legged frogs were found at Fort Clatsop. Red-legged frogs are fairly common (Samora et al. 2015).

4.7.5. Level of Confidence

Low

4.7.6. Data Gaps and Research Needs

There is a serious need for update amphibian surveys in LEWI. Samora et al. (2015) were successful in finding most species in two separate years, but those efforts were now over ten years ago, and as far as is known no additional surveys have been conducted. The monitoring program for amphibians should also be implemented, as this was identified as a high priority for LEWI during vital signs development (Weber et al. 2009).

Amphibians are somewhat difficult to detect, so locating and correctly documenting individual species requires some level of expertise. In many cases the probability of finding animals will depend on season and location (Sagar et al. 2007), so while all species may in fact be present, confirming that will be problematic.

Habitat management to protect amphibians should be ongoing. For example, maintaining free-flowing conditions with stream buffers are one of the most important actions for conserving amphibian populations in the PNW (Vesely and McComb 2002). Poor water quality is a primary threat to amphibians, so any water quality issues within the park near likely amphibian habitat should be addressed.

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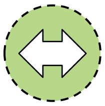
4.8. Animal Communities of Concern – Mammals

Mammals appear to be in good condition, though very little is known about any species other than elk. Habitat in LEWI is generally good and there are few known direct threats. White-nose syndrome is somewhat of a concern for bats. Other than for elk there is no information on trends, and confidence is low.



4.8.1. Background

A discussion of all mammal species in LEWI is beyond the scope of this report, so mammals will be addressed as five general groups: small mammals, medium-sized mammals, large carnivores, deer and elk, and bats.

Small Mammals

The term “small mammals” generally refers to insectivores (non-bat species that require some meat in their diets, usually in the form of insects), and small rodents (species that do not require meat though many are omnivores). Small mammals are key prey species as well as consumers in nearly all terrestrial systems (Prevedello et al. 2013). For example, the diversity and abundance of small mammals are community attributes often included in assessments of forest condition, particularly in relation to post-logging processes (Carey and Harrington 2001, Zwolak 2009). Effects of forest management practices vary largely in relation to the characteristics of forest floor debris; greater complexity of surface materials in general favors diversity of habitat specialists (Butts and McComb 2000, Sullivan et al. 2012).

Small mammal diversity in LEWI is characterized by the relatively high number of species associated with riparian and forest habitats such as shrews compared to taxa more associated with grass and shrublands, like *Peromyscus* species other than the ubiquitous *P. maniculatus* (Table 4.8-1). Red tree voles (*Arborimus longicaudus*) are the only small mammal found in the region that is of conservation concern. Red tree voles primarily utilize old growth forests on wet sites (Corn and Bury 1986), so the near-absence of old-growth stands in LEWI sites probably means that red tree voles have been extirpated from park lands (NPS 2011, Price et al. 2015). Because many sites in LEWI were acquired with a history of logging, assessing the condition of small mammal communities in the park will aid in measuring the success of forest recovery efforts (Carey and Johnson 1995).

Table 4.8-1. Mammal species (non-bats) confirmed from LEWI (compiled from multiple sources).

Group	Species Name	Common Name	Notes/Special Status	Sources
Small Mammals	*Sorex bairdii**	Baird's shrew	Limited distribution	–
	S. bendirii	Pacific water shrew	Largest N.A. shrew	WA Monitored;
	*S. monticolus**	Dusky/montane shrew	–	–
	*S. trowbridgii**	Trowbridge's shrew	–	Petterson 2009
	*S. vagrans**	Vagrant shrew	Common; documented on Yeon property	Petterson 2009, Patterson 2012
	*Neurotrichus gibbsii**	American shrew-mole	Smallest species of mole	Petterson 2009
	Scapanus orarius	Coast mole	–	–
	S. townsendii	Townsend's mole	Largest species of mole; Endangered in Canada due to very restricted range but common in U.S. coastal regions from WA to northern CA.	–
	*Peromyscus maniculatus**	Deer mouse	Most common small mammal trapped by Petterson (2009); documented on Yeon property	Petterson 2009, Patterson 2012
	*Microtus oregoni**	Oregon (creeping) vole	documented on Yeon property	Petterson 2009, Patterson 2012
	M. townsendii	Townsend's vole	–	Petterson 2009
	*Arborimus albipes**	White-footed vole	US Species of Concern; restricted to western OR and northwest CA; OR Sensitive Species	–
	Clethrionomys californicus	California red-backed vole	–	–
	Mustela erminea	Short-tailed weasel	–	Petterson 2009
	Spermophilus beecheyi	Beechey ground squirrel	–	–
	*Glaucomys sabrinus sabrinus**	Northern flying squirrel	–	–
	*Tamiasciurus douglasii**	Douglas' squirrel	–	–
	*Zapus trinotatus**	Pacific jumping mouse	–	Petterson 2009
	*Tamias townsendii**	Townsend's chipmunk	–	NPS 2011 (unidentified)

* indicates association with non-coniferous vegetation per Hagar 2007

Table 4.8-1 (continued). Mammal species (non-bats) confirmed from LEWI (compiled from multiple sources).

Group	Species Name	Common Name	Notes/Special Status	Sources
Small Mammals (continued)	*Microtus longicaudus*	Long-tailed vole	Never documented from LEWI but may be present in appropriate habitats	Manning and Edge 2004
Medium and Large-sized Species	*Lepus americanus**	Snowshoe hare	–	–
	Sylvilagus bachmani	Brush rabbit	–	–
	Spilogale gracilis	Western spotted skunk	–	NPS 2011
	*Aplodontia rufa**	Mountain beaver	–	–
	Castor canadensis	Beaver	Documented by camera trap at Yeon property	NPS 2011, Patterson 2012
	Lontra canadensis	River otter	–	NPS 2011
	Mustela erminea	Short-tailed weasel	–	NPS 2011
	M. frenata	Long-tailed weasel	–	–
	M. vison	Mink	–	NPS 2011
	Ondatra zibethicus	Muskrat	–	NPS 2011
	Procyon lotor	Raccoon	–	–
	*Odocoileus hemionus columbianus**	Black-tail deer	Documented by camera trap at Yeon property	Patterson 2012
	*Cervus elaphus roosevelti**	Roosevelt Elk	Documented by camera trap at Yeon property	Patterson 2012
	Vulpes	Red fox	–	–
	Canis latrans	Coyote	Documented by camera trap at Yeon property	NPS 2011, Patterson 2012
	Lynx rufus	Bobcat	–	NPS 2011
	Puma concolor	Cougar	Scat and possible claw sharpening scratches from a cougar were found a Yeon property	Patterson 2012
	*Ursus americanus**	Black bear	–	–
Non-native Mammals	*Rattus norvegicus*	Norwegian Rat	Not in NPSpecies	NPS 2011
	R. rattus	Black Rat	–	NPS 2011

* Indicates association with non-coniferous vegetation per Hagar 2007.

Table 4.8-1 (continued). Mammal species (non-bats) confirmed from LEWI (compiled from multiple sources).

Group	Species Name	Common Name	Notes/Special Status	Sources
Non-native Mammals (continued)	*Didelphis virginiana*	Virginia opossum	–	NPS 2011
	Myocastor coypus	Nutria	–	NPS 2011

* indicates association with non-coniferous vegetation per Hagar 2007.

Medium-sized Mammals

This group includes lagomorphs—rabbits and hares—and other medium-sized species such as raccoons and beavers. Carnivores in this group are often termed “meso-predators”, animals that often have strong impacts on prey species where large predators such as wolves and mountain lions are absent (Elmhagen and Rushton 2007). Many species of medium-sized mammalian carnivores likely utilize LEWI sites.

Large Carnivores

The large carnivore group includes species that live wholly on live prey but can also include omnivores such as black bears (*Ursus americanus*). These species usually have very large home ranges and strong limiting impacts on prey species (Carbone and Gittleman 2002, Korpimäki and Krebs 1996). Black bears are common on the Long Beach peninsula and have been photographed at Cape Disappointment. At the Fort Clatsop unit, bears have been photographed by visitors and staff and documented on camera traps; one bear den site was found by staff in 2011. Mountain lions (*Felis concolor*) have been seen on one camera trap at Fort Clatsop and may be present around other LEWI sites though they are probably not resident in any of them. No gray wolves (*Canis lupus*) are known to be present in northwest Oregon or southwest Washington.

Deer and Elk

Roosevelt elk (*Cervus canadensis roosevelti*; “elk”) are the largest of the four subspecies of elk found in North America and currently range from the coastal regions of Northern California to British Columbia and Alaska. Elk are an important herbivore in northwest ecosystems, though in cases where natural limiting factors have been removed (wolves) elk populations at high levels can have unsustainable impacts on vegetation (Starns et al. 2015). When Lewis and Clark arrived at the Pacific coast elk were common in the region and were a staple of the expedition for both meat and fur (Griffen et al. 2014). Over the next century, however, many herds were lost or depleted as a result of hunting pressures and loss of habitat as forests were converted to farms and managed for timber production. Conservation efforts have restored herds in the area surrounding Fort Clatsop (NPS 2011).

Columbian black-tailed deer (*Odocoileus hemionus columbianus*’; “black-tails”) are the most common deer found west of the Cascades. Black-tails prefer early seral-stage vegetation, and though good estimates are difficult to obtain, it appears that numbers of black-tail have declined as forests have matured and clear-cutting has declined (ODFW 2008). Numbers of black-tail appear to be regulated mostly by survival of fawns and available forage (Forrester and Wittmer 2013).

Ungulate populations in national parks are often a management challenge; these species are iconic in park settings and visitors and employees alike enjoy their presence, however, at high population levels deer and elk can have negative impacts on native vegetation, in some cases promoting non-native species (Vavra et al. 2007, Didion et al. 2009). Elk in particular are very common in post-disturbance forests in response to young trees as preferred browse (Toweill et al. 2002, Swanson et al. 2014). Elk in LEWI also represent a landscape element present at the time of the Lewis and Clark encampment that park managers would like to protect (Cole et al. 2012).

Bats

Bats are a diverse group of mammals found throughout the world outside of the high arctic and Antarctica. There are approximately 47 bat species in North America comprising four families. Common to all bat species is a nocturnal life history that includes the physiological adaptations of echolocation and flight, but other aspects of bat ecology vary across species. In particular taxa differ greatly in their habitat requirements and social behaviors, for example in whether they are colonial or solitary, hibernate or migrate, or require the establishment of maternity colonies for reproduction (Adams 2003). Bats are extremely important insect predators and pollinators, and the economic and ecologic value of maintaining healthy bat communities is substantial (Boyles et al. 2011, Kunz et al. 2011).

The majority of bat species in the PNW utilize upland and riparian tree canopies for foraging and roosting (Wunder and Carey 1996, Ober and Hayes 2008). Several species of bats known to occupy LEWI sites are of concern at state and national levels; species with special status designations are noted in Table 4.8-2.

Table 4.8-2. Bats reported from LEWI (compiled from multiple sources).

Species	Common Name	NPSpecies[5]	Hayes and Wiles 2013/ Rodhouse et al. 2015/ Faford 2008	Habits (avg. mass/wingspan)	Status in OR and WA and conservation priority (Hayes and Wiles 2013)
Corynorhinus townsendii[1]	Townsends' big-eared	X	Yes/ Not modeled/ No	In Washington found in multiple forest types, shrub-steppe, riparian, and open fields; forages widely; roosts and establishes hibernacula in caves, mines and buildings; easily disturbed; (11g/28cm);	Insufficient data to determine trends but this species is considered at-risk throughout its range; Fed. Species of Concern; OR Sensitive; WA Candidate.
Eptesicus fuscus[2] #[4]	Big brown	–	Yes/ High/ Yes	Wide-ranging in multiple habitats, common in forests; hibernates in mines and caves; (17g/36cm)	Very common, no detectable overall trends; low to medium concern other than WNS though protection of known hibernacula and maternity roosts is important.
Lasionycteris noctivagans M[3]	Silver-haired	–	Yes/ High/ Yes	Forages near woodland ponds and streams; roosts in trees and snags; thought to be migratory with unknown winter range; (12g/29cm);	Insufficient data to determine trends; usually at low densities; protection of snags is important; OR Sensitive;
Lasiurus cinereus[1] M[3]	Hoary	X	Yes/ High/ Yes	Largest bat in WA, forages in many habitats including forests and riparian; roosts mostly in trees but also buildings and caves; (28g/36cm)	Insufficient data to determine trends; at risk during migration from wind turbines; OR Sensitive;
Myotis californicus	California	X	Yes/ High/ Yes	Forages in arid habitats, edges of mixed-conifer woodlands, desert scrub; roosts in multiple sites; (4g/24cm)	Former C2 species, insufficient data to determine trends; low to medium; common in Washington and western Oregon; elevs 2,600–9,000 ft. OR Sensitive; Fed. Species of Concern;
M. evotis	Western long-eared	X	Yes/ Medium-High/ Yes but only once	Foraging behavior in the PNW not well documented but likely in conifer canopies; roosting sites include structures, caves and mines; (7g/28cm)	Insufficient data to determine trends; loss of snags as roost sites may be a threat; low to medium; uncommon in western Washington; WNS may be a threat; WA Monitored;

[1]Iindicates association with non-coniferous vegetation per Hagar 2007.

[2]Iindicates species that have been affected by WNS outside PNW

[3] An "M" at the end of a species name indicates a migratory species (Adams 2003).

[4] A "#" at the end of a species name indicates that species was diagnostic symptoms of WNS (https://www.whitenosesyndrome.org/static-page/bats-affected-by-wns; 7/12/18)

[5] An "X" Indicates that species was listed in NPSpecies.

Table 4.8-2 (continued). Bats reported from LEWI (compiled from multiple sources).

Species	Common Name	NPSpecies[5]	Hayes and Wiles 2013/ Rodhouse et al. 2015/ Faford 2008	Habits (avg. mass/wingspan)	Status in OR and WA and conservation priority (Hayes and Wiles 2013)
M. lucifugus[2] #[4]	Little brown	–	Yes/ High/ Yes	Roosts in tree cavities and bark crevices; often occupies human structures; (12g/25cm)	Common and widespread; medium;
M. thysanodes	Fringed	X	/Low to Medium/ No	–	OR Sensitive; WA Monitored;
M. volans #[4]	Long-legged	X	Yes, but may not be near coast/ Low to Medium/ No	Dependent on snags in coniferous forests during summer for roosting and rearing young (Lacki et al. 2010); (8g/28cm)	Fed. Species of Concern; OR Sensitive; WA Monitored;
M. yumanensis #[4]	Yuma	X	Yes/ High/ Yes	Strongly associated with water sources and lower elevations; establish large maternity colonies; (5g/24cm)	Widespread and generally common; disturbance at maternity colonies is a threat; Fed species of concern

[1]Iindicates association with non-coniferous vegetation per Hagar 2007.

[2]Iindicates species that have been affected by WNS outside PNW

[3] An "M" at the end of a species name indicates a migratory species (Adams 2003).

[4] A "#" at the end of a species name indicates that species was diagnostic symptoms of WNS (https://www.whitenosesyndrome.org/static-page/bats-affected-by-wns; 7/12/18)

[5] An "X" Indicates that species was listed in NPSpecies.

Threats to Mammals

Numerous ecological and physical changes in ecosystems affect diversity and population viability of mammal species. Most importantly, habitat fragmentation (Section 4.11) limits the resources available to medium and larger species that require connectivity between portions of their range that provide diverse resources (Fahrig and Merriam 1994), thus mammals with large home ranges are more impacted than smaller species by habitat fragmentation and loss of migration and dispersal routes (Saunders et al. 1991, Krauss et al. 2010, Webb et al. 2011).

The presence of free-ranging domestic dogs and cats from homes near the park is a possible threat to native small carnivore populations such as foxes and raccoons as well as native prey populations (Vanak and Gempper 2010, Doherty et al. 2015). Threats to elk in LEWI include loss and degradation of habitat and possibly elk hoof disease (Griffin et al. 2014, Han and Mansfield 2014, Clegg et al. 2015). White-nose syndrome (WNS) is a serious and largely fatal disease of bat colonies that was discovered in Washington in 2016 (WDFW, USGS) but has not yet been documented from Oregon. Timber and land management practices have impacts on bat populations via habitat destruction and loss of roosting sites such as large snags (Law et al. 2016).

The effects of changing climate will affect all species differently (Moritz et al. 2008). Recent research suggests that medium-sized vertebrate species and those that are resource generalists will experience fewer negative impacts and be at lower risk of extinction than small or very large species (Morelli et al. 2012, Rowe et al. 2011, Schloss et al. 2012, Kelt et al. 2013, Elmhagen et al. 2015). The degree to which climate change will alter a particular species distribution or abundance depends on that organisms' ability to adapt to changing resource and environmental conditions (Inouye et al. 2000, Rowe et al. 2015). The ability to disperse will also affect the likelihood that a species will survive climate change effects that threaten habitats (Schloss et al. 2012).

4.8.2. Reference Conditions

In general, a decline in small and medium-sized mammal abundance or fundamental changes in mammal diversity would suggest disruptions to existing food webs and trophic interactions (Leibold 1996). Changing mammal communities could also indicate alterations to the system from human impacts, for example the absence of native predators (Rowe et al. 2011). Increasing abundance of non-native rats and feral carnivores would be cause for concern.

Small Mammals

Measureable reductions in diversity over time would be cause for concern. Because small mammal species differ greatly in population dynamics and response to changing resource conditions, without regular monitoring many years would likely pass before trends were noted (Moritz et al. 2008). Petterson (2009) conducted one of the few small mammal surveys in the area, results of which could be considered the minimum species list for sites similar in vegetation to the Fort Clatsop area (Table 4.8-3). The presence and population stability of small mammal species with old- or second-growth habitat affinities would suggest healthy and recovering forest communities (Lomolino and Perault 2001)

Table 4.8-3. Small mammal habitat associations for LEWI from Petterson (2009).

Scientific Name	Common Name	Habitat associations
Microtus oregoni	Creeping vole	• Disturbed oldfield • Mixed conifer • Mixed conifer/hardwood • Mixed dune and pine
M. townsendii	Townsends vole	• Saltwater wetland
Neurotrichus gibbsii	American shrew-mole [mole]	• Disturbed oldfield
Peromyscus maniculatus	Deer mouse	• Freshwater wetland • Saltwater wetland • Disturbed oldfield • Mixed conifer • Mixed conifer and hardwood • Mixed dune and pine
Sorex trowbridgii	Trowbridge's shrew	• Disturbed oldfield • Mixed conifer • Mixed conifer/hardwood
S. vagrans	Vagrant shrew	• Freshwater wetland • Saltwater wetland • Disturbed oldfield • Mixed dune and pine
Tamiasciurus douglasii	Douglas' squirrel	• Mixed conifer
Zapus trinotatus	Pacific jumping mouse	• Freshwater wetland • Disturbed oldfield

Medium-sized Mammals and Large Carnivores

Very little is known regarding the medium and large-size mammal groups and species of LEWI. Minimally the entire complement of species previously documented from the park (Table 4.8-1) should continue to be present.

Deer and Elk

As far as is known there do not exist established numbers for desired densities of elk (or elk sign) on LEWI lands. Ideally elk populations would be sufficient to be self-sustaining, but not so large as to have impacts on vegetation.

Bats

As with medium and large mammals very little is known regarding bat species diversity in LEWI or any information regarding any individual populations. The species previously noted from park sites should continue to be present. WNS should be absent.

4.8.3. Data and Methods

Data on population status or distribution for mammals in LEWI is sparse. Petterson (2009) conducted small mammal surveys but only at Fort Clatsop and that was over 15 years ago (2001). A survey was conducted on the Yeon property in 2011–2012 by Celata Research Associates (Patterson 2012) with methods described therein. As far as is known there are no studies or surveys of mammals on LEWI sites in Washington. The only other known comparable study was by Martin and McComb (2002) who surveyed small mammal diversity at sites within the central Oregon Coast range (Salmonberry and Little Lobster Creek Watersheds), at sites similar to Big-Leaf Maple Upland mapped by Kagan et al. (2012). Their study found 14 species, some of which were more strongly associated with patch size (the presence of a patch and hence edge habitat), while others were not.

Deer and Elk

Two index measures are utilized to estimate abundance and detect population trends for elk. Fecal pellet group surveys are used to determine relative use of areas within the Fort Clatsop Unit. The proportion of area occupied (PAO) is described by comparing the number and patterns of detected sign by observers. (Methods are described in detail in Griffin et al. 2014). Surveys are conducted in the winter season. Standardized road surveys are also employed.

Bats

Species list from three very different studies are provided in Table 4.8-2 as the potential bat list for LEWI environs. Hayes and Wiles (2013) provided range maps for all species found in North America, and any species whose range includes LEWI on this map was included in Table 4.8-2. Rodhouse et al. (2016) conducted a macroecological study, and species included in their models as being likely at the Columbia River mouth are so indicated in Table 4.8-2. LEWI staff are currently (2018) conducting acoustic surveys for bats. So far, they have been able to detect all species in Table 4.8.2 except Myotis volans, a species which had previously been mist netted. Finally, a study was conducted for the City of Portland, and though occurring some distance from LEWI may further suggest species likely to be found along the Columbia River, and particularly in association with more urban sites (Faford 2008). All species noted in that study with high or moderate confidence are also identified in Table 4.8-2.

4.8.4. Resource Condition and Trend

Approximately 43 species of mammals (non-bats) have been documented from LEWI sites, four of which are not native (Table 4.8-1). Given the near-absence of information on mammal communities in LEWI, habitat conditions may serve as a proxy measure (Bunnell et al. 1999). For example the decisions by park management to leave downed wood after windstorms almost certainly provides important habitat for small mammals (Manning and Edge 2004). Red alder stands have also been shown to provide important mammal habitat in the coast ranges (McComb et al. 1993).

There are at present no indications that any native mammal species is experiencing population declines or is at risk of local extinction, but confidence in very low given the absence of data. In particular, the park has no confirmed sightings of porcupines, occurring in the forests of the Fort Clatsop, Yeon, or Sunset Beach unit (C. Cole pers comm. 2016). Predicting which species will be most affected by impacts of climate change is beyond the scope of this assessment. Medium-sized mammals may be more protected from extinction risks that larger or smaller species (Ripple et al. 2017).

Spatial distribution and habitat use patterns of elk in LEWI were apparently fairly consistent during the four years of monitoring (2008–2012; Griffin et al. 2014; Figure 4-8.1). Though pellet counts declined over the period, this decline was not statistically significant, and no attempt was made in that report to estimate elk densities. During approximately the same period ODFW estimated that elk numbers in Clatsop County were stable (NPS 2011). For the Saddle Mountain Unit that surrounds the Oregon park units, ODFW has since reduced the number of tags for antlerless elk, eliminated antlerless elk from the disabled hunter program, and also eliminated a bowhunting season for antlerless elk in response to declining populations (ODFW 2016). Park staff have noticed that development northwest of Fort Clatsop in 2009 has altered future elk habitat use patterns in the area (C. Clatterbuck pers. comm. 2016).

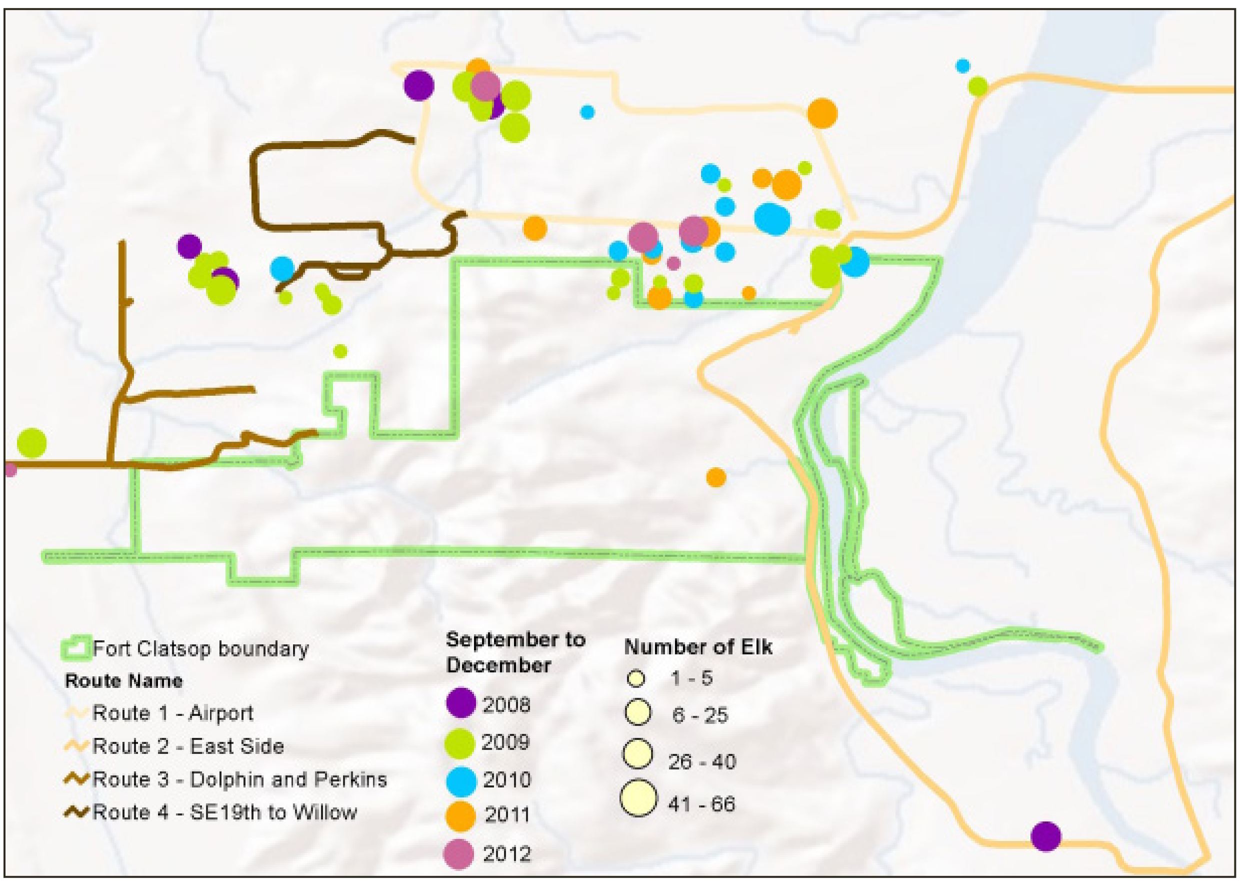


Figure 4.8-1. Fall elk sightings during driving surveys (Griffin et al. 2014).

Approximately ten species of bats have been documented from LEWI sites (Table 4.8-2), though abundance of any particular species does not appear high (Petterson 2009). White-nose syndrome has not been detected regionally, and LEWI staff will be testing for WNS on park lands in 2018.

4.8.5. Level of Confidence
Low

4.8.6. Data Gaps and Research Needs
Much more work is needed to provide information on mammal populations. Seasonal bat surveys are needed on a regular basis to document current bat diversity as well as monitor for WNS and future declines in species numbers (Petterson 2009, Patterson 2012). Bats are often missing from traditional forest studies (Christy and West 1993), and overall much more work needs to be done to survey and monitor bats in National Parks (Rodhouse et al. 2016). In the absence of surveys, bat habitat can almost certainly be improved by leaving dead trees and snags in place whenever possible (Kroll et al. 2012, Lacki et al. 2013).

Additional small mammal surveys, with specific methods for rodents versus insectivores, are also needed (Petterson 2009). For example shrews are especially difficult to trap in standard small mammal traps and when they are caught often die before release, so this group is often underrepresented in standard mammal surveys (Innes and Bendell 1988, Haymond et al. 2003). Likewise the season within which small mammals are trapped should be consistent across sampling periods.

Elk monitoring should continue and perhaps be expanded to include areas outside park boundaries if possible (Griffin et al. 2014, NPS 2015).

Remote sensing techniques such as camera traps could be used to obtain information on use of park lands by larger species such as carnivores.

4.8.7. Sources of Expertise
Chris Clatterbuck and Carla Cole, Lewis and Clark National Historical Park

4.8.8. Literature Cited

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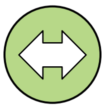
4.9. Ecosystem Integrity: Natural Night Skies and Natural Quiet

The resources of natural night skies and natural quiet are in moderate to good condition. While the park is relatively quiet except near roads, nighttime lights from nearby cities are noticeable. There are no observed trends, and confidence is medium.



4.9.1. Background

Natural Night Skies

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 to minimizing the impacts of anthropomorphic sources of light (Henderson et al. 1985, Duriscoe et al. 2007). Anthropogenically-derived light comes from all sources powered by electricity and batteries as well as indirectly from human-sourced light which is 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 within the 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 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, artificial light at night 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 artificial night light 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, McLaren et al. 2018), 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 artificial light at night 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 affect population dynamics, successional processes and biodiversity (Kyba and Hölker 2013, Gaston and Bennie 2014, Lewanzik and Voigt 2014).

Natural Quiet

Soundscapes are commonly defined as the total amount of ambient noise in an area measured in terms of frequency and amplitude (decibels; Ambrose and Burson 2004). 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 soundscapes in national parks (Miller et al. 2008). Similar to the topic of light pollution soundscapes have primarily been addressed as a cultural resource in relation to visitor experiences (Rogers and Sovick 2001, Sovick 2001, Miller 2008, Lynch et al. 2011), however, increasing attention is being given to ecological and landscape-scale impacts, both terrestrial and aquatic (Barber et al. 2011, 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, Shannon et al 2016). 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). A growing body of evidence shows that noise also affects plants by enhancing pollination and disrupting seed dispersal (Francis et al. 2012).

Road noise appears to have measurable negative impacts on wildlife, altering animal and bird behavior (McClure et al. 2013), 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 others are not (Barber et al. 2010), and impacts at individual and population scales can further translate up to ecosystem and process levels (Slabbekoorn and Halfwerk 2009).

4.9.2. Reference Conditions

Natural Night Skies

Increases in light levels at night from natural conditions are addressed herein as an impact to natural systems rather than how they may affect the human experience. Levels of artificial light should have no measurable impacts on animal behavior or physiology. However, given that the impacts of artificial light at night, both direct and ambient, to wildlife are unmeasured, as a natural resource nighttime light should be as close to natural as possible under all conditions.

Natural Quiet

Similarly, anthropogenic noise is addressed herein as an impact to wildlife populations and not as it may degrade the visitor experience. That said, at this point NPS measures noise conditions only in relation to human health (NPS 2015), for example 35 decibels (dB, $L_{Aeq,\,1s}$) or less is recommended for sleeping, while 60 dB $L_{Aeq,\,1s}$ would interrupt normal conversation (described in NPS 2013). Clearly these values may or may not have relevance to wildlife behavior and biology (Barber et al. 2011), but wildlife responses to noise in terrestrial environments has been shown to occur at noise levels as low as 40dB (Shannon et al. 2016).

4.9.3. Data and Methods

Natural 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 (NPS 2015, Moore et al. 2013). An ALR value of 0.0 indicates no effect of anthropogenic light and a value of 1.0 indicates the existing environment is 100% more bright than natural conditions. This metric can be directly measured at any particular location but it is more often estimated by modeling.

Natural Quiet

For most national parks local sound level data are unavailable, so investigators likewise apply modeling techniques to describe the condition of the acoustic environment on an average summer day at 270 meter resolution. 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, Mennitt et al. 2014). Increases in sound level reduce the distance that animals can hear, for example how well predators can detect active prey. The results of a modeling exercise conducted for LEWI are presented in NPS 2015. In addition, an Environmental Assessment was done for Station Camp that included measuring noise from the roads in the area, particularly Highway 101 (NPS 2010).

4.9.4. Resource Condition and Trend

Natural Night Skies

The average ALR value for LEWI determined from modelling (NPS undated) was 0.63, meaning artificial light cause the night sky to be 63% brighter than it would be under natural conditions. Figure 4.9-1 shows a general image of night-time lights of the greater Astoria, Oregon 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).

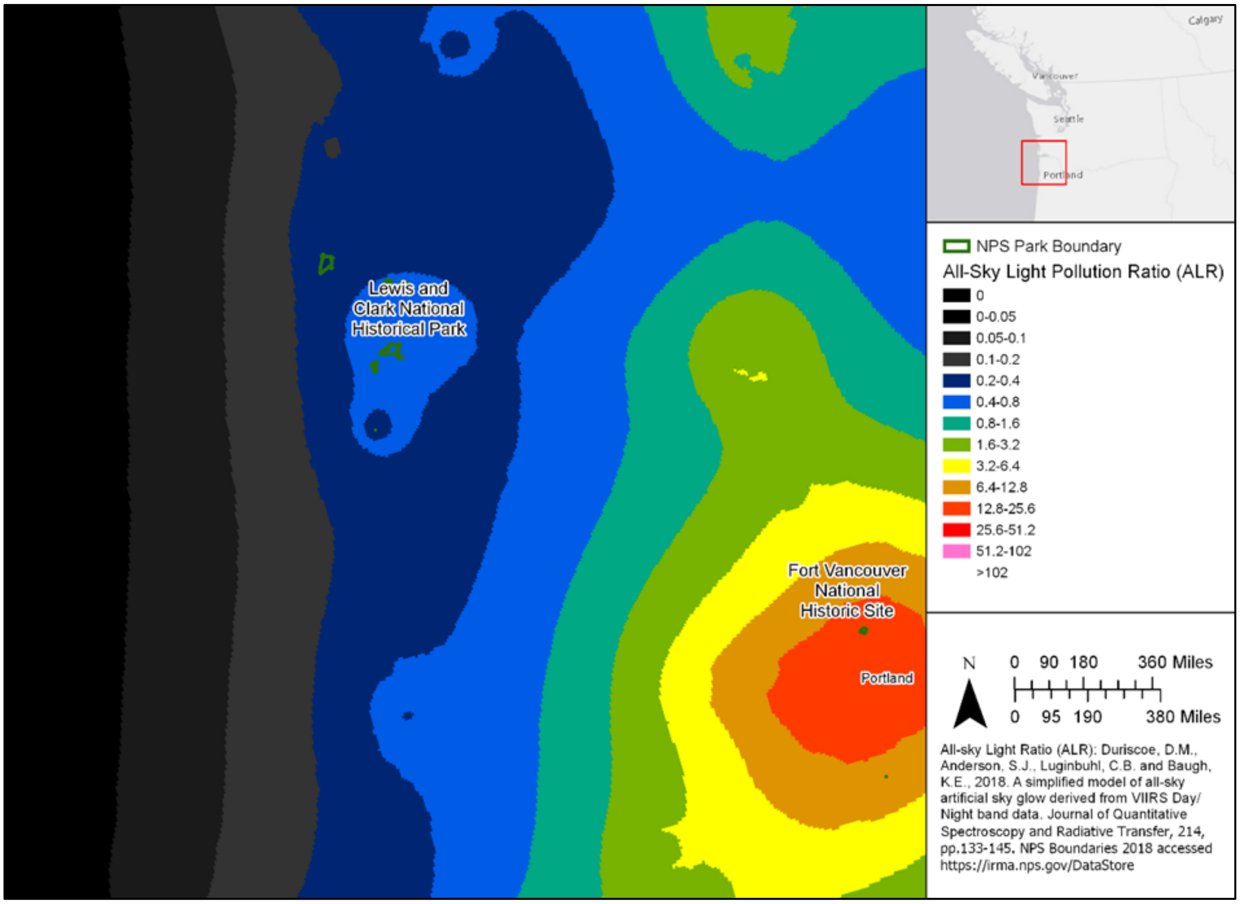


Figure 4.9-1. All-sky average anthropogenic to natural sky brightness ratio at Lewis and Clark National Historical Park and surrounding lands. As indicated by the color scale in the legend, blue and black represent areas of lesser impact from artificial light while orange and red represent areas of greater 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. Mean ALR in the park is about 0.63, meaning existing conditions are about 63 % brighter than natural levels (NPS, Natural Sounds and Night Skies Program).

<u>Natural Quiet</u>

The average sound level impact determined from modelling for LEWI was 6.5 dB (L_{A50}) (above natural conditions), and ranged from 0.8–15.9 dB (Figure 4.9-2). This increase is not insubstantial; as mentioned in NPS 2015 if an animal can naturally hear a sound within 100 ft^2, an increase of 6.5 dB reduces that area to 2 ft^2. Near roads and areas of human activity (including the Columbia River) noise levels are obviously higher than they are in more remote areas, and LEWI provides many places where human noise is minimal. Studies conducted as part of the Station Camp – Middle Village environmental assessment (NPS 2010) found that noise levels predictably increased with road proximity, particularly US Hwy 101. Particular impacts noted by park staff are highway noise, Coast Guard helicopters, small airplanes from the local airport, trucks on roads that transit park lands and noise from training at the nearby National Guard base (C. Clatterbuck pers. comm. 2017).

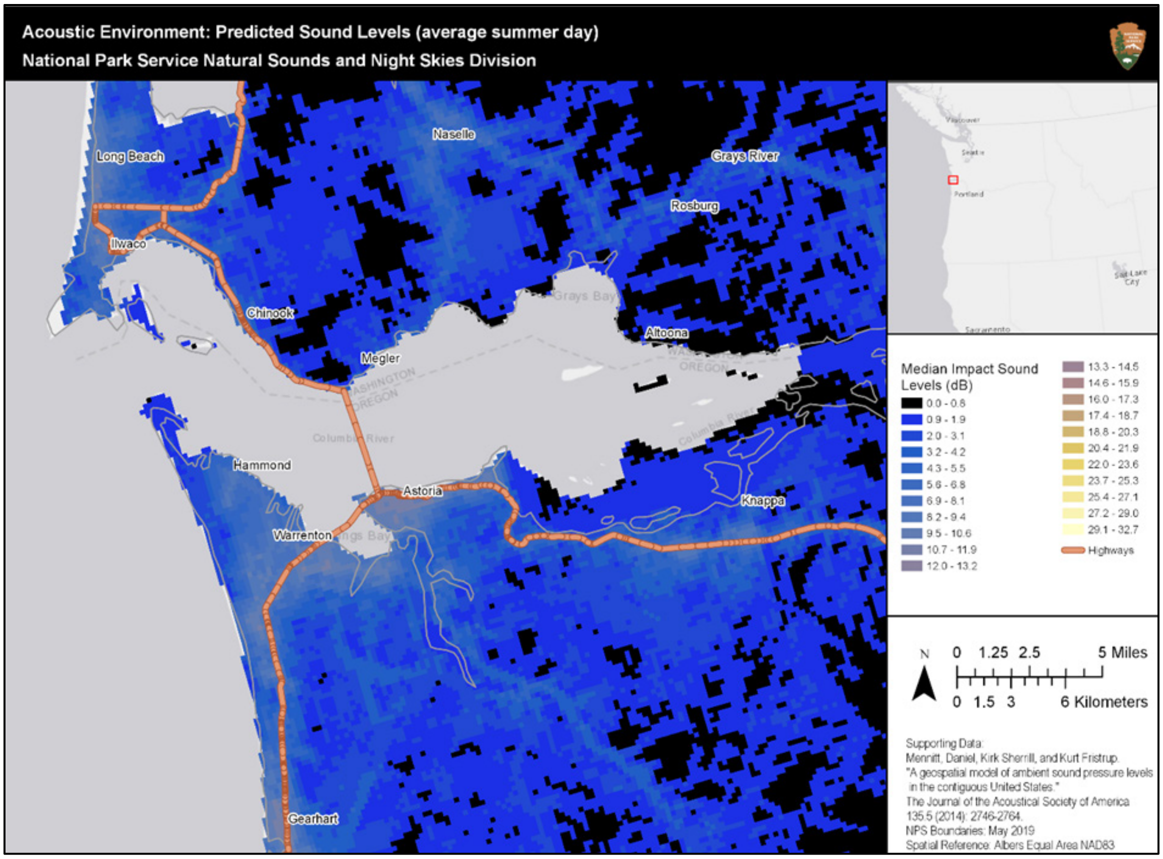


Figure 4.9-2. Modeled mean LA_{50} impact map for Lewis and Clark National Historical Park and the surrounding area. The modeled mean daytime summer LA_{50} impact was 6.5 dB, but ranged from 0.8 dB in the least impacted areas to 15.9 dB in the most impacted areas. The map depicts the areas most influenced by human-caused sounds as lighter areas. Each pixel represents 270 m (NPS, Natural Sounds and Night Skies Program).

4.9.5. Level of Confidence

Medium

4.9.6. Data Gaps and Research Needs

In 2017 and 2018, LEWI established two long-term acoustic monitoring sites to provide park resource staff with information on the status and trends of birdsong phenology by quantifying levels of bioacoustic activity. This research project is the result of a technical assistance request from the park to the NPS Natural Sounds and Night Skies Division. It involves deployment of Wildlife Acoustics SM4 digital audio recorders that record before, during, and after sunrise from March – August, to capture peak songbird activity. To assess whether any change in songbird activity occurs, additional yearly (or biennial) datapoints will be needed.

Model outputs for existing acoustic and night sky conditions provide useful information about the quality of these resources. Direct measurements of anthropogenic sky luminance and average sound level would provide a baseline for the park. If additional information is needed contact the Natural Sounds and Night Skies Division for assistance.

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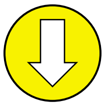
4.10. Nearshore Marine Conditions

Multiple impacts of climate change on oceanic processes and LEWI coastal resources are occurring and are predicted to intensify. The trend is downward given ongoing climate change and confidence in future conditions is medium.



4.10.1. Background

General

Changes in the chemical and physical conditions of the eastern Pacific Ocean are affecting the coastal resources of LEWI in Oregon and Washington (Reeder et al. 2013). All of the LEWI sites are at very low elevations, making them extremely vulnerable to oceanic and climate processes that alter historic interactions between coastal ecosystems and marine dynamics (Hoegh-Guldberg and Bruno 2010, Peterson 2013, Mote et al. 2014, NCA 2014). Physical changes occurring in the world's oceans as a result of climate change most affecting PNW coastal resources include ocean acidification (OA), sea level rise (SLR), increasing sea surface temperatures (SST), and the frequency and impacts of disturbance events, particularly storm-driven waves (Halpern et al. 2009, Feely et al. 2012, Komar et al. 2013, Cheng et al. 2015).

Ocean Acidification

Scientists estimate that approximately one-quarter to one-third of all CO_2 that is added to the atmosphere by the burning of fossil fuels is absorbed by the ocean (Caldeira and Wickett 2003, Berman et al. 2011, Doney et al. 2009). The addition of carbon dioxide causes the pH levels of ocean waters to decline making them more acidic (Byrne 2014). Under these conditions fewer carbonate minerals are available to organisms for skeletal and shell development, directly affecting numerous zooplankton, shellfish, and fish populations (Gruber et al. 2012, Hofmann et al. 2014, Chan et al. 2016).

Anthropogenic ocean acidification also has indirect effects, for example increased CO2 has been shown to impair sensory abilities of both predator and prey marine fish species (Cripps et al. 2011, Leduc et al. 2013, Waldbusser and Salisbury 2014). Upwelling events driven by the California Current naturally bring more CO2 to coastal areas (LCEP 2012, Lachkar 2014). However, studies strongly indicate that human-caused increases in atmospheric CO_2 have had a large role in increasing pH above historic levels (Doney et al. 2012, Gruber et al. 2012).

Sea Level Rise

Climate-driven sea-level rise is threatening shoreline resources worldwide and along the eastern Pacific coast (Vermeer and Rahmstorf 2009, Dalrymple et al. 2012, IPCC 2014). Sea levels change continually, but increasing average heights of oceans and the frequency with which higher sea levels exacerbate impacts from high tides and storms are of concern (Carson et al. 2016). Sea level rise (SLR) is somewhat mediated in the PNW as this region continues to experience uplift following the release of glacial pressure during the ice age (Mote et al. 2008, Mote et al. 2014, Sweet and Park

2014). However, predictions are strong that rising sea levels will be greater than increases in land elevation for the PNW over the next century (Dalrymple et al. 2012, Komar et al. 2013, Griggs et al. 2017).

Of particular relevance to LEWI resources are the effects that rising sea levels will have on estuaries, where ecosystems have adapted to historic tidal processes and water levels (Cheng et al. 2015). Estuaries will be particularly affected if higher sea levels result in the loss of tidal influences, i.e. if these areas are permanently inundated (Craft et al. 2009, Peterson 2013). Greater mean high tide levels will alter the extent and perimeters of estuaries, impacting critical habitat for juvenile salmon (Flitcroft et al. 2013; Section 4.4). Increasing sea levels will further impact beaches through sand erosion, sea cliff retreat, increased flooding and salinity intrusion (Vermeer and Rahmstorf 2009, Peterson 2013, Helaire et al. 2016).

Sea Surface Temperatures

Though the processes are complex, in general average SST around the globe are rising coincident with atmosphere warming (Doney et al. 2012). Estimates are that from 1995–2008 the temperature of the upper 2,300 ft (700 m) of water in global oceans increased by approximately 0.2°C (Howard et al. 2013). The effects of rising SST on marine resources are complex and often indirect (Doney et al. 2012); increasing temperatures, often associated with global oceanic processes such as PDO, are likely affecting survival, population persistence and even behavior of many seabird and salmon species (Peck et al. 2008, Kilduff et al. 2015, Mantua 2015, Crozier 2015), and in particular juvenile salmon in the Columbia River Estuary (CRE; Daly and Brodeur 2015). Increasing ocean temperatures are also facilitating greater occurrences of harmful algal blooms (HABs; Anderson et al. 2012, Gobler et al. 2017). Further increases in SST could exacerbate global climate change by adding more CO2 to the atmosphere through evaporation from warmer waters (Howard et al. 2013).

Disturbance Events – Wave and Storm Impacts

Ocean waves and tidal surges are continuous processes that over time have substantial influence on shoreline geomorphology and nearshore ecology. Periodic storms, especially when combined with high tides, can result in wave energy that can relocate large volumes of sand and damage vegetation as well as human structures (Allan and Komar 2002, Allan and Komar 2006, Tebaldi et al. 2012, Komar et al. 2013). Though storms, waves, and tides are ongoing and natural processes, what is of concern are changes in storm frequency and wave intensity resulting from climate change. Over the last 30 years increased wave heights have had a greater impact on shoreline erosion than has the rise in sea level (Ruggiero 2012, Tebaldi et al. 2014). Combined with increasing sea levels, the potential for storms and waves to further damage shorelines is predicted (Barnard et al. 2015).

Disturbance Events – Earthquakes and Tsunamis

The region is vulnerable to tsunamis generated by earthquakes on both the Cascadia Subduction Zone, located about 70 mi (113 km) off of the Pacific coast, and from more distant locations (Witter et al. 2003, Klinger et al. 2007, Peters et al. 2007). Undersea earthquakes and resulting tsunamis are natural events that, as far as we know, are not human-driven and are not manageable. However, the impacts of tsunami waves on coastal regions could be exacerbated by higher average sea levels (Yeh et al. 2012). Past tsunamis along the Washington and Oregon coasts are estimated to have been up to

26 ft (8 m) high relative to mean low water levels (Atwater et al. 1995, Peterson et al. 2008). Sediments carried upriver by wave surges have been found as far as 0.5–1 mi (1–2 km) inland (Peterson et al. 2008). Estimates are that tsunami waves generated by a future large earthquake (magnitude 8 or larger) could cause water and debris to travel up to ten miles (16 km) up the Columbia River (Yeh et al. 2012) with an associated sea level rise of 3–6 ft (1–2 m; Dalrymple et al. 2012). While future events are likely and predicted to occur within the next century (Peters et al. 2007, Komar et al. 2013, Mote et al. 2014), reference and current conditions for earthquakes and tsunamis will not be discussed further.

4.10.2. Reference Conditions

Acidification, Sea Level Rise, Sea Surface Temperatures

Many authors suggest that any trending decreases in pH, even in small increments, should be of concern (Byrne 2014, Chan et al. 2016). Any continuing trend in increasing sea level is also cause for concern (Section 4.4). Given that data are lacking that quantify the level of SST change that would affect ecological processes, populations, and/or organisms in LEWI, at this point any increasing trend is of concern.

Disturbance Events – Wave and Storm Impacts

Wave heights off the Oregon coast in the summer average 5 ft (1.5 m) and are double that height in the winter (Baron et al. 2015). Wave heights during average-size but large storms can reach 32 ft with some of the strongest El Nino-generated storms generating waves as high as 45 ft (14 m; Komar et al. 2013, Baron et al. 2015).

4.10.3. Data and Methods

Research and monitoring of large-scale processes such as SST increases, acidification, sea level rise and storm and wave impacts are conducted by numerous institutions and agencies. Descriptions of specific methods and analyses are far beyond the scope of this assessment; below are provided very brief and simplified summaries of representative efforts being conducted either at local sites or for which global data sets and models have been downscaled to provide regional (generally Northern California, Oregon, and Washington coasts) assessments and predictions. Of particular interest to investigators analyzing CRE conditions are several NOAA buoys that collect data on sea temperatures and wave heights, specifically Station 46050 located west of Newport OR (https://www.ndbc.noaa.gov/station_page.php?station=46050). Additional descriptions of techniques and often historical climate data are available in referenced sources.

Ocean Acidification

All current information about OA is provided at much larger spatial scales than the coastal region of LEWI. Several agencies and research groups are monitoring pelagic and nearshore water chemistry in the PNW, often in relation to the impacts that OA is having on commercial shellfish operations (http://www.pacshell.org/ocean-acidification-monitoring.asp; Barton et al. 2015).

Sea Level Rise

Baron et al. (2015) describe their methodology for predicting SLR along the coast of Tillamook County, OR. Very briefly, they corrected global SLR predictions for local conditions. They also calculated the relationship of estimated SLR to predicted global temperature increase as provided within IPCC scenarios.

The University of Hawaii Sea Level Center maintains tide gauges around the world, including one at Tongue Point in Astoria, OR (JASL #572), that collected data from 1925–2016 (https://uhslc.soest.hawaii.edu/rqds/pacific/doc/qa572a.dmt). The gauge has been used by several papers in order to make SLR predictions close to LEWI (Tebaldi et al. 2012, Caffrey et al. 2018).

Sea Surface Temperature Rise

Real-time sea surface temperature monitoring is done primarily by NOAA (https://www.nodc.noaa.gov/dsdt/cwtg/npac.html) for the Northern Pacific. NASA-JPL produces a global, daily, high-resolution analysis of SST. Numerous investigators utilize these data for modeling and comparisons (e.g. Brown et al. 2016).

Disturbance Events – Wave and Storm Impacts

Offshore buoys and tide gauges managed by NOAA and other agencies collect wave data at local scales. Baron et al. (2015) developed coastal change hazard assessments using climate change scenarios including predicted storm events to predict future water levels and resulting hazard zones. Hazard zones were then applied to local conditions.

4.10.4. Resource Condition and Trend

Ocean Acidification

Ocean acidification is happening at rates that preclude the ability of ocean systems and biological organisms to compensate apace. Estimates are that by the end of the century the average acidity of the ocean will increase by 100–150% above pre-industrial levels (Feely et al. 2012, Chan et al. 2016). Regionally, winds that favor local upwelling processes, (upwelling also affects water chemistry), have apparently intensified over the last several decades (Lachkar 2014). The strengthening of upwelling processes is likely tied to climate change and some authors believe upwelling will continue to increase, particularly within the California Current System, while others have reached different conclusions (Lachkar 2014, Sydeman et al. 2014, Chan et al. 2016, Turi et al. 2016, Wang et al. 2015). Ocean acidification was implicated in a 2009 HAB, which was the longest and most harmful bloom on record in the PNW. The bloom was caused by the dinoflagellate *Akashiwo sanguinea*, which produced a toxic foam on PNW beaches and killed some 10,000 marine and shore birds died as a result, including white-winged and surf scoters, loons, grebes, and murres (Phillips et al. 2011).

Sea Level Rise

Estimates of future sea-level rise for the south-central Washington coast vary considerably among scenarios (Mote et al. 2014, Sweet and Park 2014). Predictions of sea level increase by 2050 range from 1–18 in (3–45 cm) with a median estimate of 5 in (12.5 cm; Mote and Salathe Jr. 2010, Tebaldi et al. 2012, Miller et al. 2018). Similar changes are expected along the Oregon coast (Pfeffer et al., 2008; Vermeer and Rahmstorf, 2009).

Predictions for the lower Columbia River Estuary by 2050 have average increases of 7.5 in (19 cm) at Tongue Point (Tebaldi et al. 2012, Caffery et al. 2018) and 3.6 inches (9cm) at a point west of the Astoria – Megler Bridge (Miller et al 2018, data available at: http://www.wacoastalnetwork.com/files/theme/wcrp/mapdata/RSLProjections_Lat46.2N_Long123.9W.xlsx). The difference in estimates may be explained by differences in tectonic uplift that occur over short distances in the Astoria-Warrenton area (Talke et al. 2018).

At some point sites that are now exposed during low tides will likely be permanently inundated, a situation that will have enormous ecological implications (Sweet and Park 2014, Fitzgerald et al. 2008, Delgado et al. 2018). Most LEWI sites are within a region the USGS Coastal Change Hazards has determined have a 10–33% chance of high shoreline retreat (https://marine.usgs.gov/coastalchangehazardsportal). However, analysis of tide guage data from Astoria showed no change in daily or monthly means in the period 1925–2016 (https://uhslc.soest.hawaii.edu/rqds/pacific/doc/qa572a.dmt).

Sea Surface Temperatures

Average ocean temperatures have increased globally (Mote and Salathe Jr. 2010), and local anomalies are becoming more extreme (Crozier 2015). Regionally, a recent and significant marine warming event occurred in the northeastern Pacific in the winter of 2013–2014. A large mass of warm water, eventually referred to as “the Blob”, began forming in the fall of 2013. During the spring and summer of 2014 this warm water spread across a large area, resulting in many areas where temperatures increased relative to historic averages by more than 4°C (Peterson et al. 2016). In the fall of 2014 a decrease in upwelling strength along the coast allowed the Blob to move very close to shore across the PNW. This led to sea surface temperatures off the coast of Oregon have continued to be above normal, (through the spring of 2016), consistent with a positive PDO pattern (Peterson et al. 2016).

Disturbance Events – Wave and Storm Impacts

Over the last several decades there has been an increase in the occurrence of major storm events in the eastern North Pacific, likely related to higher sea surface temperatures and strong El Ninos (Brominski et al. 2013, Komar et al. 2013). The average height of waves during 100-years storm events was approximately 32 ft (10 m) up until 1996 (Allan and Komar 2002). Between 1997 and 2000 there were six major storms that generated wave heights greater than that, in particular in March 1999 when a storm produced 46 ft (14 m) waves (Allan and Komar 2002). The March 1999 storm also generated a peak storm surge (water reaching above mean high tide) of 5.2 ft (1.6 m) along the Washington coast and 2.0 ft (0.6 m) along the Oregon coast (Allan and Komar 2002). National Park sites in the PNW are predicted to be particularly at risk from wave and storm surge in comparison to other regions (Caffey et al. 2018).

Average wave heights on the PNW coast, both storm-driven and otherwise, have also been increasing, though since about 2000 there has been a decline apparently related to the cooler phase of the PDO (Allan and Komar 2006, Brominski et al. 2013). For example, the El Ninos of 1982–1983 and 1997–1998 increased wave heights by an average of ~10–20 in (25–50 cm.; Komar et al. 2013. Flood risk in many watersheds of the PNW is anticipated to increase along with anticipated warming temperatures that will cause a greater proportion of precipitation to fall as rain rather than snow (Salathe et al. 2014).

4.10.5. Level of Confidence

Confidence in current conditions is relatively high for the greater CRE, but medium to low at scales relevant to management and restoration of individual estuaries and wetland ecosystems in LEWI. Confidence in future conditions is medium.

4.10.6. Data Gaps and Research Needs

Acquiring additional data on water chemistry and temperature at scales relevant to individual estuaries would aid managers and restoration ecologists. Additional data would also greatly assist with predictive efforts, for example a very thorough and advanced study on predicted water level increases and impacts to wetland vegetation found that the data available for the lowest section of the Columbia River (mouth to river kilometer [rkm] 5) did not allow for the level of analysis as did the remainder of the river to Bonneville Dam (Jay et al. 2016). Finally, research indicates that vegetation compositional considerations may help counter increasing ocean acidification (Chan et al. 2016).

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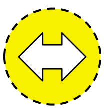
4.11. Ecosystem Integrity: Landuse and Habitat Connectivity

Some adjacent landuses almost certainly impair migration and dispersal of some species, however, data to identify such impacts are scarce. Impervious surface cover in park sites is low, and road density in Washington sites is moderate. Recent land additions provide important protections to existing resources; however, upstream lands are still harvested for timber.

The trend is generally stable with some loss of open space to development in adjacent lands but with additions of functional habitat like restored estuaries and recently protected sites. Confidence in the assessment for current landuse is high but is low for impacts of landuses on resources, particularly wildlife.



4.11.1. Background

The ways in which lands surrounding national parks are utilized can often have substantial impacts on natural resources and ecological processes within parks (Fahrig and Merriam 1994, Hansen and DeFries 2007, Wade and Theobald 2010, Rudnick et al. 2012, Hansen et al. 2014), and require consideration during restoration and management planning efforts (Rudnick et al. 2012). Many aspects of human presence – noise, light, roads, air and water pollution – individually and collectively degrade the ability of ecosystems to function naturally, and human development occurs very near or often adjacent to park lands at all sites.

Though NPS generally has relatively little direct control over landuse activities outside park boundaries, identifying potential impacts can assist with resource management goals and support NPS positions and interactions with adjacent communities and partners (Rudnick et al. 2012). The impacts to natural quiet and natural night skies are addressed in Section 4.9 and hydrologic/watershed connectivity in Section 4.3. This section assesses the condition of park ecosystems with respect to land-cover within the park and land-uses adjacent to and upstream of park lands.

Land Cover

Habitat fragmentation is generally described as an alteration of large areas of continuous wild space into smaller patches by the presence of human activities and development (Fahrig and Merriam 1994, Hansen and DeFries 2007). A reduction in available habitat eliminates resources necessary for survival of individuals while the loss (actual or virtual) of connectivity between habitats has additional and often greater long-term negative effects on population sustainability (Fahrig and Merriam 1994, Berger 2004, Benitez-Lopez et al. 2010). Because there are no specific data available that describe habitat use by animal species that utilize LEWI sites and adjacent lands, land cover type will be considered here as a proxy indicator for general habitat quality, though it is likely only partially valid to do so (Fischer and Lindenmayer 2007, Mortelliti 2013).

Roads

The presence of roads in and near natural areas is a primary contributor to habitat fragmentation and loss of overall ecosystem integrity (Trombulak and Frissell 2000, Strittholt and Dellasala 2001, Rudnick et al. 2012, Dietz et al. 2013, Riley et al. 2014). Roads and associated vehicle traffic affect ecological interactions through direct impacts (animal mortality), and indirectly via increased noise, the introduction of toxic materials and non-native species, reductions in genetic diversity (Delaney et al. 2010), and multiple impacts from human disturbance on animal behavior (Mader 1984, Tyser and Worley 1992, Benitez-Lopez et al. 2010, Dietz et al. 2013, Kitzes and Merenlender 2014). Road influence can extend tens to hundreds of meters from the road surface (Riiters and Wickham 2003). At larger scales these impacts accumulate, changing and redefining habitat landscapes (Hawbaker et al. 2006).

Impervious Surfaces

Impervious surfaces—places where water is prevented from re-saturating the soil—reduce groundwater recharge, degrade water quality in streams, and alter natural flow processes (Shuster et al. 2005). Typical anthropogenic impervious surfaces (IS) include roads, roofs, parking lots, driveways, and sidewalks. In addition, bare rock and compacted soils are mostly impervious. For example, impervious surfaces (IS) increase runoff, decrease infiltration, collect pollutants, and accelerate the connectivity between a rainfall event and nearby wetlands. In residential and commercial areas, flood waters can cause sewers to overflow, which flushes raw sewage into riparian areas (Forman et al. 2003). Impervious surfaces do not support vegetation so these sites have higher thermal conductivities than vegetated surfaces and collect solar heat, thus producing urban "heat islands" (Melaas et al. 2016**).**

Areas with IS may also be considered as proxies for sites that partially or completely impede animal movement (Van Dyck and Baguette 2005, Evans et al. 2017). Thus the relative extent of IS within parks and watersheds has become an indicator of ecosystem health (Arnold and Gibbons 1996; Brabec et al. 2002).

4.11.2. Reference Conditions

Land Cover

Because measures of ecosystem and habitat integrity are species and process specific, there are no common reference conditions for land cover for LEWI natural resources (Piekielek and Hansen 2012, Rudnick et al. 2012). Ideally there would be no negative impacts (direct or indirect) on resources from outside landuses. Population dynamics of species that move in and out of the park would be maintained, indicating the absence of barriers to travel and genetic exchange. Thus lands adjacent to (and of course within) LEWI sites should not prevent animal movement nor facilitate the introduction of novel species.

Roads

Research (cited above) has mostly converged on the conclusion that roads of all types alter animal movements, thus road density can be used as an indicator of general habitat condition (i.e. not species-specific) particularly in forests (Heilman et al. 2002, AGBRS 2009). Ideally the condition would be no roads in LEWI that limited migration or dispersal, but since this is unrealistic in a modern context the reference condition will be no increase in roads, while understanding that a reduction in road presence would be the best condition.

Impervious Surfaces

There should be no increase in impervious surfaces, and as with roads, a reduction in the extent of surfaces within and adjacent to LEWI that limit or prevent water return to the soil layer would be the best condition.

4.11.3. Data and Methods

Land Cover

Two efforts are drawn upon to assess current land cover and recent land cover changes. First, data from the Coastal Change Analysis Program (C-CAP) were used to assess current and recent changes in land cover. C-CAP is part of the National Landcover Database (NLCD), a nationally standardized database of land cover and land change information (NOAA 2009). Data are developed from Landsat Thematic Mapper (TM) digital satellite imagery and mapped at a 1:100,000 scale into standard classes constituting major landscape components. Pixels are 30 m x 30 m. Land cover data have an overall target accuracy of 85% (Homer et al. 2004). The C-CAP data contain 25 land cover classes that for this analysis were consolidated into seven derived land cover types (Table 4.11-1).

Table 4.11-1. Land cover types in LEWI, nearby state parks, and surrounding area (Pacific County, WA, and Clatsop County, OR)(compiled from multiple sources).

Derived Land Cover Type	NLCD Land Cover Classes
Developed	2) Developed, High Intensity 3) Developed, Medium Intensity 4) Developed, Low Intensity 5) Developed, Open Space
Cultivated	6) Cultivated Crops
Grass/Shrub/Prairies	7) Pasture/Hay 8) Grassland/Herbaceous 12) Scrub/Shrub
Forest	9) Deciduous Forest 10) Evergreen Forest 11) Mixed Forest
Wetlands	13) Palustrine Forested Wetland 14) Palustrine Scrub/Shrub Wetland 15) Palustrine Emergent Wetland 16) Estuarine Forested Wetland 17) Estuarine Scrub/Shrub Wetland 18) Estuarine Emergent Wetland

Table 4.11-1 (continued). Land cover types in LEWI, nearby state parks, and surrounding area (Pacific County, WA, and Clatsop County, OR)(compiled from multiple sources).

Derived Land Cover Type	NLCD Land Cover Classes
Marine and Shoreline	19) Unconsolidated Shore 20) Barren Land 22) Palustrine Aquatic Bed 23) Estuarine Aquatic Bed
Open Water	21) Open Water

Data for 1996 were obtained from the NOAA website, and for 2006 from Nate Herold (NOAA Coastal Services Center, Charleson, SC). The 2006 data were used to assess current condition with respect to land cover. Short-term changes in land cover were assessed by examining the change from 1996 to 2006. Analyses were conducted at various scales (within individual units of LEWI and nearby state parks, within LEWI as a whole, and within Pacific and Clatsop Counties) to determine whether trends within LEWI were comparable to those in the larger landscape.

Secondly, the North Coast and Cascades Network (NCCN) of the NPS developed a Landscape Dynamics Monitoring Protocol (Antonova et al. 2012) which was utilized to assess landscape changes from 1985–2011 for LEWI (Copass and Antonova. 2018). Methods are described therein, but like the above analysis utilized LANDSAT data (Copass and Antonova 2018). Somewhat differently, this effort measured specific types of changes on the land (Table 4.11-2).

Table 4.11-2. Summarization of landscape change types used in Copass and Antonova 2018.

Landscape Change Type	Definition
Agricultural Clearing	First time removal of vegetation for agricultural purposes.
Clearing	A range of forest management practices
Coastal	Partial to complete vegetation removal at coastal sites due to all inputs
Development	Complete removal of vegetation for construction
Mass Movement	Processes that remove vegetation such as landslides and erosion
Progressive Defoliation	Vegetation remains but data indicate loss of greenness such as in relation to disease
Tree Toppling	Trees have fallen without direct human input, usually due to wind but could be tree mortality due to other causes
Wetland Restoration	Actively restored wetland sites
Windthrow Salvage	Specific sites where trees felled by the 2007 storm were subsequently removed

Impervious Surfaces

Impervious surfaces within the LEWI units and nearby state parks were quantified as a continuous variable from multi-sensor and multi-source 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%). The total amount of impervious area (summing the percent impervious surface of each pixel) and the proportion of each pixel that was impervious were each considered. Finally, the impervious surface layer and the 2006 land cover type layer were compared and the total impervious surface calculated for each cover type. Kagan et al. (2012) also mapped impervious surfaces within LEWI and nearby state parks; methods for their assessment are included therein.

Roads

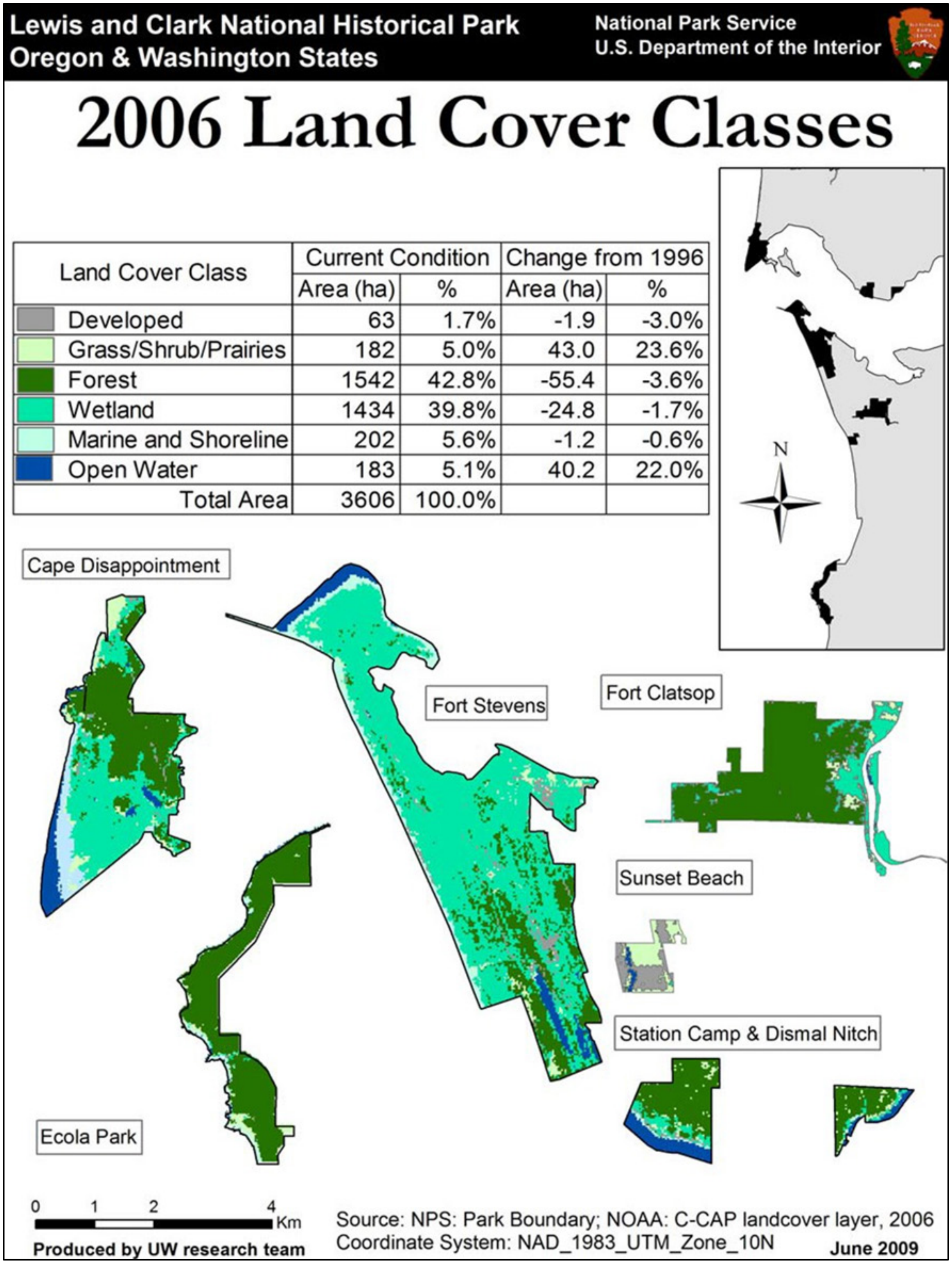
There is scientific precedent for using the concentration of roads in a given geographic area (road density) as an indicator (USFS 2006; Watts et al. 2007; Lin 2006; Hawbaker et al. 2006). Road density is usually reported as length of road per area unit of land (e.g. km of road per square km). However, little research exists on specific thresholds of acceptable road densities, though Lin (2006) proposes a "derived road density" that could be used in future research. For this report an analysis was prepared that uses road density as an indicator of landuse and ecosystem health. Road locations were obtained from WDNR (2009); only roads classified by DNR as "transportation roads" were included in the analysis. Road data were only available for Washington, so the analysis was restricted to the three LEWI units in that state. Road density data within each unit were compared to the density in the rest of Pacific county. Historical road density data were not available.

4.11.4. Resource Condition and Trend

Land Cover

For the most part lands adjacent to LEWI are either developed or have been utilized for logging and agriculture. For example, over 70% of the lands within Clatsop County are managed by the Oregon Department of Forestry or private entities for timber production, activities that generally have negative impacts on downstream natural systems (NPS 2011). At the scale used here, between 1996 and 2006 LEWI sites lost a relatively small amount of forest cover (3.6%; Figure 4.11-1). Approximately 25 ha (62 ac) of wetlands were apparently converted to open water in that period, though this result could have been due to analysis error or other factors (Table 4.11-3).

Copass and Antonova (2018) found that the greatest land cover changes resulted from clearing (usually in association with timber activities) on private lands within their larger study area (approx. 70,000 ha/174,000 ac). Agricultural clearing and development were the greatest sources of change in areas adjacent to LEWI sites.



Land Cover Class	Current Condition		Change from 1996	
	Area (ha)	%	Area (ha)	%
Developed	63	1.7%	-1.9	-3.0%
Grass/Shrub/Prairies	182	5.0%	43.0	23.6%
Forest	1542	42.8%	-55.4	-3.6%
Wetland	1434	39.8%	-24.8	-1.7%
Marine and Shoreline	202	5.6%	-1.2	-0.6%
Open Water	183	5.1%	40.2	22.0%
Total Area	3606	100.0%		

Figure 4.11-1. Land cover types within LEWI units and nearby state parks in 2006. The inset table summarizes the land cover in 2006 and changes in land cover since 1996. (University of Washington, School of Forest Resources).

Table 4.11-3. Comparison of land cover within LEWI and nearby state parks to that of the rest of Pacific and Clatsop counties. Current condition data are from 2006, and change data are from 1996–2006 (this study).

Cover Type	Excluding LEWI and state parks		LEWI and state parks	
	Current ha (%)	Change 1996–2006	Current	Change
Developed	8,724 (2%)	766 (9%)	63 (2%)	−1.9 (−3%)
Cultivated	243 (<1%)	−3.9 (−2%)	0	0
Grass/Shrub/ Prairie	113,003 (25%)	61,935 (55%)	182 (5%)	43.0 (24%)
Forest	288,167 (65%)	−63,378 (−22%)	1,542 (43%)	−55.4 (−4%)
Wetland	27,001 (6%)	8.6 (0%)	1,434 (40%)	−24.8 (−2%)
Marine and Shoreline	9,013 (2%)	714.1 (8%)	202 (6%)	−1.2 (−1%)
Open Water	628 (<1)	−42.1 (7)	183 (5)	40.2 (22)

Land acquisitions in the past several decades have improved the potential for habitat connectivity. (The "potential" qualifier is used here because although additional open space lands almost certainly increase the opportunities for animal movement, as far as is known no studies have investigated this hypothesis.) Sunset Beach and the Yeon unit are two examples of lands that might have been developed or altered from open space. However, development to the northwest of Fort Clatsop has occurred on a scale too small by 2011 to be detectable at larger analysis scale (C. Clatterbuck pers. comm. 2016).

Overall, landscape change within LEWI, (LEWI sites with 2 km buffer), between 1985–2011 occurred on 15% of the total area. Average annual change was approximately 30 ha (74 ac). Most of the observed change was attributable to trees that fell during and then salvaged after the December 2007 storm (Copass and Antonova 2018).

Impervious Surfaces

Overall LEWI is highly vegetated and less than 2% of the park is classified as developed, meaning that IS occupies a very small amount of LEWI. Specifically, Kagan et al. (2012) found 0% IS cover at Fort Clatsop, 1% at Ecola, 2% at Station Camp/ Ft. Columbia and Sunset Beach/Yeon, 3% at Ft. Stevens and Cape Disappointment, and 9% at Dismal Nitch, for a total of 2.2% cover. The additional analysis conducted for this report showed that most of the park surface (98.6%) does not have IS, and that the total IS cover within LEWI is only about 8 ha (20 ac; Figure 4.11-2). The IS that is present in LEWI sites is not equally distributed among land cover types; the developed land cover class accounts for 42% of the IS, forests 28%, and wetlands 23%. Nearly all of the IS in the park is created by roads.

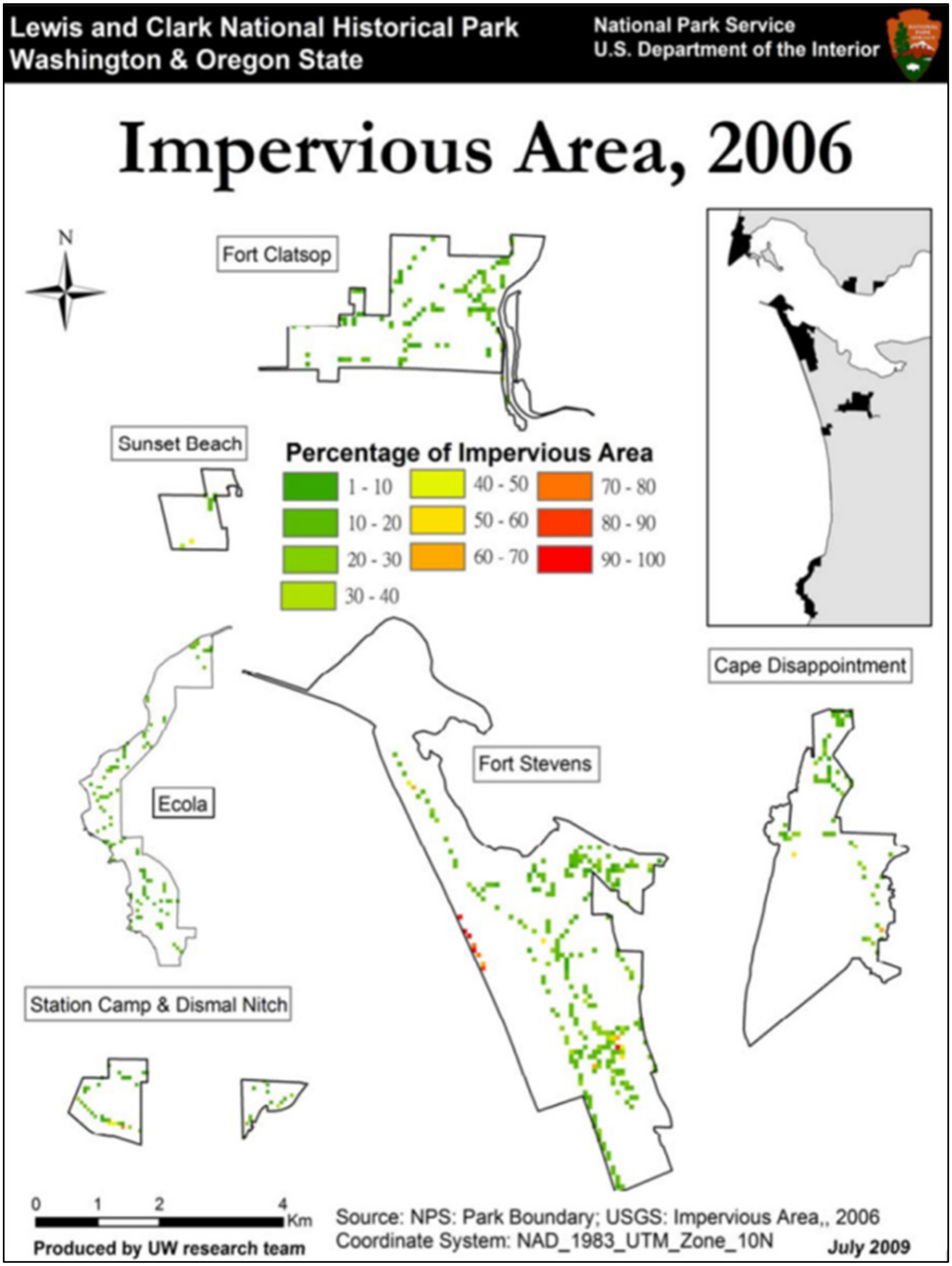


Figure 4.11-2. Impervious surfaces within LEWI. The proportion of impervious surfaces within a given 30 x 30 m pixel ranges from zero (white) to 100% (red). (University of Washington, School of Forest Resources).

Roads

Road density in Washington LEWI sites ranged from 1.7 km/km^2 at Station Camp and Dismal Nitch to 2.8 km/km^2 at Cape Disappointment (Figure 4.11-3; no road density data were available for Oregon.) In comparison, the road density for all of Pacific County, WA is 2.4 km/km^2, and all of these values are greater than the mean density of public roads in the U.S. as a whole (1.2 km/km^2; Forman 2000).

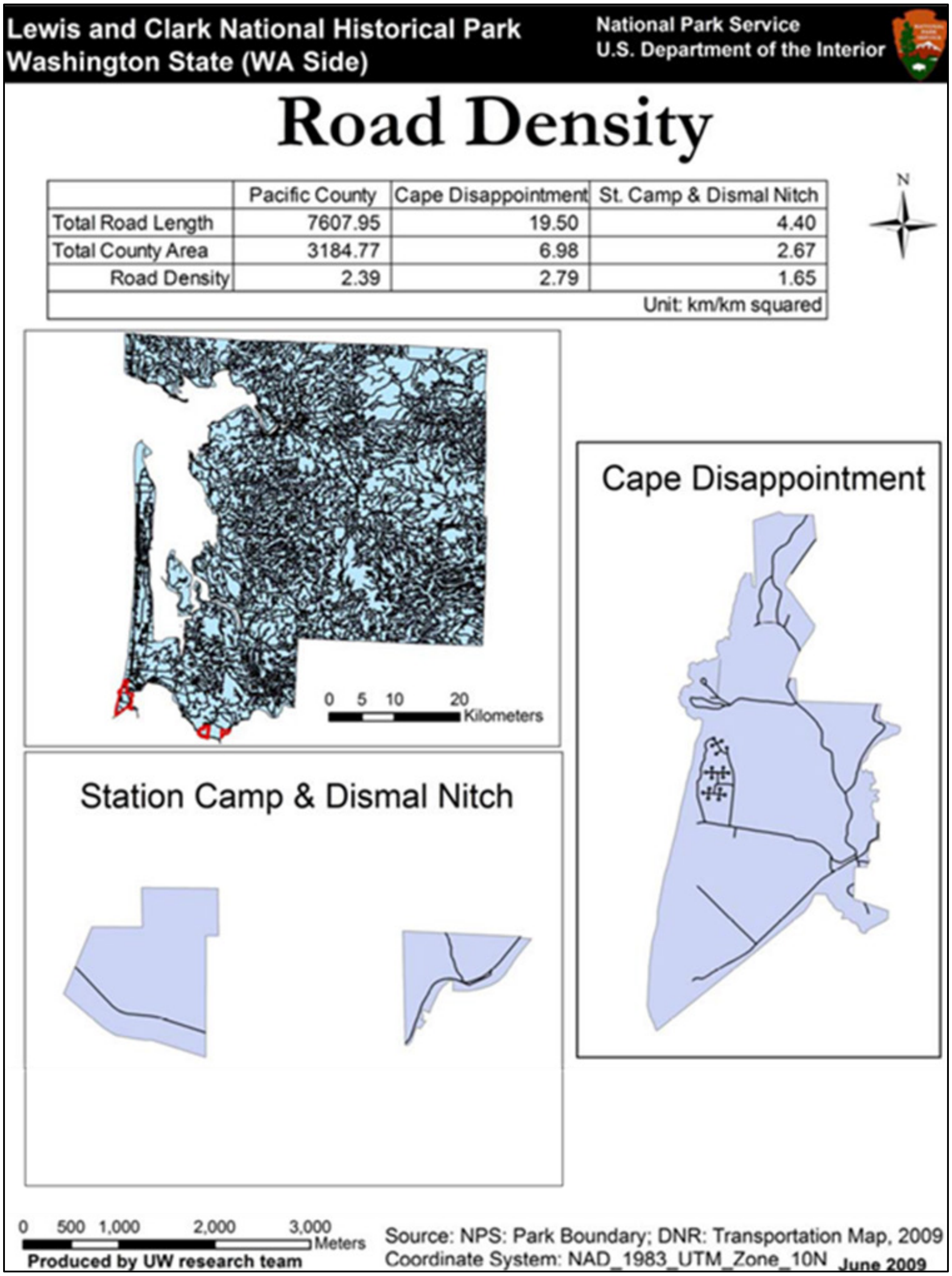


Figure 4.11-3. Roads within Pacific County, Washington, including the Cape Disappointment, Station Camp, and Dismal Nitch units of LEWI. The inset table contains the calculation of road density for these areas. (University of Washington, School of Forest Resources).

4.11.5. Level of Confidence

The level of confidence in current land cover conditions is high given the available data. However, confidence in how surface conditions translate to habitat connectivity or quality is extremely low.

4.11.6. Data Gaps and Research Needs

Data Needs

As mentioned above, land cover may or may not be a valid proxy for habitat connectivity, particularly since habitat requirements are unique for all species for which conservation efforts may be desired (Umetsu et al. 2008, Rayfield et al. 2011, Kool et al. 2013). The importance of protected lands for wildlife conservation reflects the need to maintain open space connectivity, particularly for wildlife (Hansen and DeFries 2007).

A focused area of research that is needed is to determine the habitat needs, particularly related to connectivity, that would be required for successful reintroduction of the federally threatened Oregon silverspot butterfly on the Clatsop Plains. As discussed in Section 2.6.3, the park and several partners are evaluating potential methods for restoring native plant communities necessary for butterfly recovery in the region. Past studies have concluded that the Yeon unit alone is not sufficient in size to support butterflies but that it could provide important resources within a larger landscape of connected habitat. Thus, research is needed to determine which elements of required butterfly habitat are currently or could potentially be provided on the Yeon property.

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Chapter 5. Discussion

5.1. Assessment Summary

This assessment serves as a review and summary of the available information for a selected set of focal natural resources in Lewis and Clark National Historical Park. The assessments are valid for the period of review (approximately 2016–2018), and are intended to provide managers with information useful for prioritizing short-term natural resource management projects, determining funding needs, and as comparisons with future large-scale or focused natural resource assessment efforts. A summary of natural resource conditions for focal resources assessed in this report is provided in Table 5.1-1.

Specific areas of concern identified during the project and discussed briefly below include: 1) the need to manage forest, coastal and riparian habitats for climate change resilience, 2) the importance of protecting upland habitat connectivity, and 3) areas where additional research and/or monitoring is particularly needed (presented in Table 5.2-1).

5.2. Ecosystem Resilience to Climate Change

5.2.1. Forest Resiliency

Impacts of climate change on forests of the Pacific Northwest are predicted to include more frequent disturbances and extreme environmental events (DellaSalla et al. 2015, Halofsky et al. 2018). In addition, fragmented and smaller forest stands, as are found in LEWI, are at relatively greater risk from climate change impacts (DellaSalla et al. 2015). However, recent efforts have identified risk factors and potential mitigation responses for northwest forests, and incorporating such information into future management planning has the potential to greatly improve forest resiliency (Johnstone et al. 2016). The park's Forest Restoration Plan incorporated resiliency by including actions—such as variable density thinning and planting more diverse species—that would transition the forest away from a dense monotypic stand into a more diverse forest community that would be resilient to changing conditions (NPS 2011). Future active forest management should continue to utilize information gleaned from forest monitoring and research to manage forest resources (Section 4.5).

5.2.2. Estuaries and Coastal Habitats

Global processes related to climate change will continue to affect coastal habitats. In particular increases in sea surface temperatures and sea levels are affecting coastal resources in largely negative ways; higher temperatures result in more frequent occurrences of harmful algal blooms and numerous impacts to key ecosystem components such as marine mammals and salmon (Section 4.10).

As with forests, resource managers can best protect resources by increasing resiliency to impacts at local scales. Estuary restoration should continue to focus on creating and enhancing sites that can adapt to greater periods of inundation. For example, variable elevations within an estuary as well as high plant species diversity have been shown to increase resiliency to sea level rise (Belleveau et al. 2015, Parker and Boyer 2017). Efforts that reduce sediment and nutrient loads at local scales also

Table 5.1-1. Summary of natural resource conditions for focal resources assessed in this report, organized within the Ecological Monitoring Framework (Fancy et al. 2009).

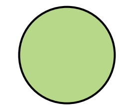
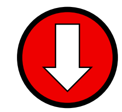
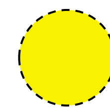
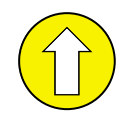
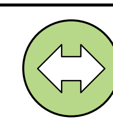
Level 1 Category	LEWI Resource(s)	Indicators	Condition and Trend
Air and Climate	Air Quality (Section 4.1)	• Visibility • Nitrogen and Sulfur Deposition • Ozone	
	Climate (4.2)	• Temperature • Precipitation	
Geology and Soils	–	–	–
Water	Hydrology and Groundwater (4.3)	• Surface Water Quality • Surface Water Quantity (Flow) • Groundwater Quality • Groundwater Quantity (Levels)	
	Estuaries and Juvenile Salmon (4.4)	• Physical: ○ Sea Level ○ Tidal Processes ○ Extent • Biological: ○ Relative Cover of Invasive Plants ○ Presence/absence of Invasive Invertebrates ○ Juvenile Salmon: ■ Presence/Absence ■ Abundance	
Biological Integrity	Forest Health and Disturbance (4.5)	• Demography and Structure • Species Diversity • Presence of Downed Wood	

Table 5.1-1 (continued). Summary of natural resource conditions for focal resources assessed in this report, organized within the Ecological Monitoring Framework (Fancy et al. 2009).

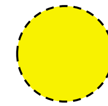
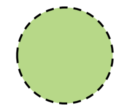
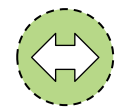
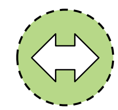
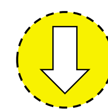
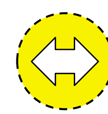
Level 1 Category	LEWI Resource(s)	Indicators	Condition and Trend
Biological Integrity (continued)	Non-salmonid Fish (4.6)	• Total Abundance • Presence of Key/Rare species • Absence of Non-natives	
	Amphibians (4.7)	• Diversity • Presence/Absence of Key Species	
	Mammals (4.8)	• Species Diversity • Presence of Carnivores • Absence of Non-native Species	
Ecosystem Pattern and Processes	Natural Night Skies & Natural Quiet (4.9)	• Nighttime Light • Noise Levels	
	Nearshore Marine (4.10)	• Ocean Acidification • Sea-level Rise • Sea Surface Temperatures • Large Wave and Storm Frequency	
	Landuse & Habitat Connectivity (4.11)	• Land Cover • Road Density • Impermeable Surfaces	

Table 5.2-1. Areas identified within the scope of this assessment where additional research and/or monitoring is particularly needed for LEWI resources.

LEWI Resource	Monitoring/Survey Needs	Research/Management Needs
Air Quality	Implement air quality monitoring within the park	Investigate levels of nitrogen and impacts of nitrogen on ecological systems, e.g. lichen communities and wetland systems (Cummings et al. 2014);
Climate	–	Acquire downscaled ecologic information regarding short and long-term responses to climate change (Parmesan 2006, van Riper et al. 2014)
Hydrology and Groundwater	Monitor streamflow conditions as they relate to diversions by adjacent landowners, (such as the City of Warrenton, Bischoff et al. 2000, NPS 2015), and salmon lifecycles (Dittmer 2013). Continue water quality monitoring as directed in the NCCN Water Quality Monitoring Protocol (Rawhauser et al. 2012)	–
Estuaries and Juvenile Salmon	Acquire additional biological and physical data in estuaries at local spatial scales (acres to mi2) (Diefenderfer et al. 2013, Cheng et al. 2015, NPS 2015, Conway-Cranos et al. 2016). Monitor restoration effects on more estuary components including sediment, phytoplankton, impacts of mud snails, amphibians and birds (Roegner et al. 2008, Schwartz et al. 2015, Conway-Cranos 2016). Continue working towards increased standardization of data collection and management methods across the Columbia River Estuary (Borde et al. 2012, Fermin and Cole 2018).	Investigate changing ecological processes in estuaries (e.g. bird communities and planktonic resources), particularly at those sites that have received intense management (Roegner et al. 2008, Diefenderfer et al. 2016, Koehn et al. 2016, Correll et al. 2017).
Forest Health and Disturbance	Monitor forest faunal community responses to management, particularly birds, amphibians and small mammals (Swanson et al. 2014)	–

Table 5.2-1 (continued). Areas identified within the scope of this assessment where additional research and/or monitoring is particularly needed for LEWI resources.

LEWI Resource	Monitoring/Survey Needs	Research/Management Needs
Non-salmonid Fish	Implement surveys that vary temporally and seasonally throughout all park streams and water bodies, to capture the entire fish assemblage (Brenkman et al 2008)	–
Amphibians	Conduct thorough amphibian surveys in appropriate seasons (Sagar et al. 2007, Samora et al. 2015) Implement the NCCN monitoring program (Weber et al. 2009, Samora et al. (2015)	Consider impacts to amphibians from habitat alterations, specifically streamflow and water quality impacts (Vesely and McComb 2002).
Mammals	Conduct regular/seasonal bat surveys parkwide (Petterson 2009, Patterson 2012, Rodhouse et al. 2016) Implement small mammal monitoring for rodents and insectivores, particularly in forest and riparian areas (Innes and Bendell 1988, Haymond et al. 2003, Petterson 2009) Elk monitoring should continue and perhaps be expanded to include areas outside park boundaries if possible (Griffin et al. 2014, NPS 2015) Consider the use of remote sensing techniques such as camera traps to obtain information on use of park lands by larger species such as carnivores.	Consider bat habitat within forest management and restoration, for example by leaving dead trees and snags in place whenever possible (Kroll et al. 2012, Lacki et al. 2013).
Natural Night Skies and Natural Quiet	Conduct annual to biennial acoustic monitoring of songbird activity Make direct measurements of anthropogenic sky luminance and average sound level to create a baseline for the park.	Consider modeling outputs for existing acoustic and night sky conditions
Nearshore Marine	Acquire additional data on water chemistry and temperature at scales relevant to individual estuaries (Chan et al. 2016, Jay et al. 2016).	–

Table 5.2-1 (continued). Areas identified within the scope of this assessment where additional research and/or monitoring is particularly needed for LEWI resources.

LEWI Resource	Monitoring/Survey Needs	Research/Management Needs
Landuse and Habitat Connectivity	–	Investigate primary habitat needs for medium to large mammal species in relation to habitat connectivity (Umetsu et al. 2008, Rayfield et al. 2011, Kool et al. 2013)

increase the potential for better ecosystem function in estuaries (Strain et al. 2015). Any constructed features that alter natural tidal processes and/or streamflow should be removed.

5.2.3. Upland Riparian Habitat Quality and Connectivity

Protection and enhancement of estuary habitats should progress coincidentally with protection of upstream resources. Many groups of species, but particularly fish, amphibians, and birds are dependent on healthy riparian systems. In addition, stream courses have been identified as "climate corridors", ecosystem features that may facilitate species movement in response to climate change (Keeley et al. 2018, Krosby et al. 2018).

Water quality in streams should be monitored, and sources of toxic and sediment input eliminated from park streams. Headwaters of major rivers and streams are most protected when the land surrounding them is not utilized in ways that harm riparian function, so incorporating as much upstream land as is necessary to protect watershed integrity should be a management priority. Watershed protection efforts will almost certainly require enhanced partnerships with adjacent landowners and stakeholders, for example in efforts to remove non-native aquatic species (Buktenica et al. 2018).

5.3. Habitat Quality and Connectivity for Terrestrial Species

Terrestrial species, particularly medium and large-size mammals, are nearly always negatively affected by habitat fragmentation (Section 4.11). Preventing further fragmentation within LEWI and surrounding lands should be a priority for NPS and its partners. Many studies have demonstrated the impacts of edge effects and human presence resulting from roads and trails on vertebrate populations (Section 4.11, Gutzwiller et al. 2017, Bötsch et al. 2018), so any addition fragmentation in LEWI should be prevented and extant barriers to dispersal and migration removed when possible.

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Appendix 1. List of vascular plant species recorded within LEWI

Park-specific data were obtained from the NPS Certified Species List for LEWI and from technical lists provided by NPS staff (Table A1-1). Taxonomy, classification into taxonomic groups, and nativity are from the USDA Plants database (USDA 2010). The “Regional Pool?” column refers to whether each taxa is recorded in the Plants database within Pacific County, WA, and/or Clatsop County, OR. Data are sorted alphabetically by taxonomic group (dicot, fern, gymnosperm, horsetail, lycopod, monocot) and then by scientific name.

Table A1-1. List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots	*Abronia latifolia*	Coastal sand verbena	–	–
	Acer circinatum	Vine maple	–	–
	A. macrophyllum	Bigleaf maple	–	–
	A. platanoides	Norway maple	X	–
	Achillea millefolium	Common yarrow	–	–
	Alnus rubra	Red alder	–	–
	Anaphalis margaritacea	Western pearlyeverlasting	–	–
	Angelica genuflexa	Kneeling angelica	–	–
	A. lucida	Seacoast angelica	–	–
	Anthemis cotula	Chamomile	X	–
	Arctostaphylos uva-ursi	Kinnikinnick	–	–
	Argentina egedii ssp. *egedii*	Pacific silverweed	–	–
	Aruncus dioicus	Goatsbeard	–	–
	Atriplex prostrata	Triangle orache	–	–
	Baccharis pilularis	Coyote bush	–	–
	Barbarea orthoceras	Wintercress	–	–
	Bellis perennis	English daisy	X	–
	Bidens cernua	Nodding beggartick	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*B. frondosa*	Devil's beggartick	–	–
	Boykinia occidentalis	Coastal brookfoam	–	–
	Brassica rapa	Field mustard	X	–
	Buxus sp	Ornamental box	X	X
	Cabomba caroliniana	Carolina fanwort	–	–
	Cakile edentula	American searocket	–	–
	Callitriche hermaphroditica	Northern water star-wort	–	–
	C. stagnalis	Pond water-starwort	X	–
	Calystegia sepium ssp. *sepium*	Hedge false bindweed	X	X
	Cardamine angulata	Seaside bittercress	–	–
	C. breweri var. *orbicularis*	Sierra bittercress	–	–
	C. hirsuta	Hairy bittercress	X	–
	C. oligosperma	Hairy bittercress	–	–
	Cardionema ramosissimum	Sandmat	–	–
	Centaurea cyanus	Cornflower	X	–
	Cerastium arvense	Field chickweed	–	–
	C. fontanum ssp. *vulgare*	Mousear chickweed	X	–
	C. glomeratum	Sticky chickweed	X	–
	Ceratophyllum demersum	Rigid hornwort	–	–
	Chamaesyce maculata	Spotted sandmat	–	X
	Chamerion angustifolium	Fireweed	–	–
	Chenopodium album	Lamb's quarters	–	–
	Chrysosplenium glechomifolium	Pacific golden saxifrage	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*Cicuta douglasii*	Western water hemlock	–	–
	Cirsium arvense	Canadian thistle	X	–
	C. brevistylum	Short-styled thistle	–	–
	C. edule	Edible thistle	–	–
	C. vulgare	Bull thistle	X	–
	Claytonia perfoliata	Miner's lettuce	–	–
	C. sibirica var. *sibirica*	Siberian springbeauty	–	–
	Conioselinum gmelinii	Pacific hemlock-parsley	–	–
	Conyza canadensis	Canadian horseweed	–	–
	Cornus sericea	Redosier dogwood	–	–
	Corydalis scouleri	Scouler's corydalis	–	–
	Cotoneaster franchetii	Franchet's cotoneaster	X	–
	C. horizontalis	Rockspray cotoneaster	X	X
	Cotula coronopifolia	Common brassbuttons	X	–
	Crataegus monogyna	Singleseed hawthorn	X	–
	Crepis capillaris	Smooth hawksbeard	X	–
	Cymbalaria muralis	Kenilworth ivy	X	–
	Cytisus scoparius	Scotch broom	X	–
	Daucus carota	Queen Anne's lace	X	–
	Deutzia sp	Deutzia	X	X
	Dicentra formosa	Pacific bleeding heart	–	–
	Digitalis purpurea	Purple foxglove	X	–
	Dipsacus fullonum	Fuller's teasel	X	–
	Epilobium ciliatum ssp. *glandulosum*	Fringed willowherb	–	–

* An "X" indicates that the column condition ("non-native" or "absent from the regional species pool") applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*E. minutum*	Minute willowherb	–	–
	Erechtites glomerata	Cutleaf burnweed	X	X
	E. minima	Coastal burnweed	X	–
	Escallonia rubra	Redclaws	X	X
	Eschscholzia californica	California poppy	X	X
	Fragaria chiloensis	Beach strawberry	–	–
	Frangula purshiana	Cascara buckthorn	–	–
	Fuchsia magellanica	Hardy fuchsia	X	X
	Galium aparine	Cleavers	–	–
	G. trifidum	Small bedstraw	–	–
	G. triflorum	Fragrant bedstraw	–	–
	Gaultheria shallon	Salal	–	–
	Geranium molle	Dovefoot geranium	X	–
	Geum macrophyllum	Large-leaf avens	–	–
	Glechoma hederacea	Groundivy	X	–
	Gnaphalium palustre	Western marsh cudweed	–	–
	G. uliginosum	Marsh cudweed	X	–
	Hedera helix	English ivy	X	–
	Heracleum maximum	Common cowparsnip	–	–
	Heuchera micrantha	Small-flowered alumroot	–	–
	Hieracium albiflorum	White hawkweed	–	–
	Hippuris vulgaris	Common mare's tail	–	–
	Hydrocotyle ranunculoides	Floating marsh-pennywort	–	–
	Hydrophyllum tenuipes	Pacific waterleaf	–	–

* An "X" indicates that the column condition ("non-native" or "absent from the regional species pool") applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*Hypericum anagalloides*	Creeping St Johnswort	–	–
	H. perforatum	Common St Johnswort	X	–
	H. scouleri ssp scouleri	Scouler St Johnswort	–	X
	Hypochaeris radicata	Hairy cat's ear	X	–
	Ilex aquifolium	English holly	X	–
	Impatiens capensis	Spotted touch-me-not	–	–
	Lamium purpureum	Purple deadnettle	–	–
	Lapsana communis	Nipplewort	–	–
	Lathyrus japonicus	Purple beach pea	–	–
	L. latifolius	Perennial sweetpea	–	–
	L. littoralis	Silky beach pea	–	–
	L. palustris	Marsh pea	–	–
	Leucanthemum vulgare	Oxeye daisy	–	–
	Lilaeopsis occidentalis	Western grasswort	–	–
	Lonicera involucrata	Twinberry honeysuckle	–	–
	L. periclymenum	European honeysuckle	–	–
	Lotus corniculatus	Birdsfoot trefoil	–	–
	L. pedunculatus	Greater birdsfoot trefoil	–	–
	L. unifoliolatus	Spanish clover	–	–
	Ludwigia palustris	Marsh seedbox	–	–
	Lupinus latifolius	Broadleaf lupine	–	–
	L. littoralis	Seashore lupine	–	–
	L. rivularis	Streambank lupine	–	–
	Lycopus americanus	American bugleweed	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*Lonicera involucrata*	Twinberry honeysuckle	–	–
	L. periclymenum	European honeysuckle	–	–
	Lysimachia terrestris	Earth loosestrife	–	–
	Lythrum portula	Water purslane	–	–
	L. salicaria	Purple loosestrife	–	–
	Mahonia aquifolium	Tall Oregon grape	–	–
	Malus fusca	Oregon crabapple	–	–
	M. pumila	Paradise apple	–	–
	Marah oreganus	Western wildcucumber	–	–
	Matricaria discoidea	Pineapple weed	–	–
	Medicago lupulina	Black medic	–	–
	Melilotus officinalis	Yellow sweetclover	–	–
	Mentha aquatica	Water mint	–	–
	M. arvensis	Field mint	–	–
	M. pulegium	Pennyroyal	–	–
	M. x *piperita*	Peppermint	–	–
	Menziesia ferruginea	Rusty menziesia	–	–
	Mimulus dentatus	Tooth-leaved monkeyflower	–	–
	Moneses uniflora	Single delight	–	–
	Montia parvifolia ssp. *flagellaris*	Littleleaf minerslettuce	–	–
	Morella californica	California wax myrtle	–	–
	Mycelis muralis	Wall lettuce	–	–
	Myosotis discolor	Changing forget-me-not	–	–
	Myosotis laxa	Bay forget-me-not	–	–

* An "X" indicates that the column condition ("non-native" or "absent from the regional species pool") applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*Myriophyllum aquaticum*	Braziliam watermilfoil	–	–
	Myriophyllum hippuroides	Western water milfoil	–	–
	Myriophyllum sp	Milfoil	–	–
	Navarretia squarrosa	Skunkbush	–	–
	Nuphar lutea ssp. *polysepala*	Yellow pond-lily	–	–
	Nymphaea odorata	American white waterlily	–	–
	Oemleria cerasiformis	Indian plum	–	–
	Oenanthe sarmentosa	Water parsley	–	–
	O. glazioviana	Evening primrose	–	–
	Osmorhiza purpurea	Purple sweet cicely	–	–
	Oxalis oregana	Redwood sorrel	–	–
	O. trilliifolia	Threeleaf woodsorrel	–	–
	Pachysandra terminalis	Japanese pachysandra	–	–
	Parentucellia viscosa	Yellow glandweed	–	–
	Petasites frigidus var. *palmatus*	Arctic sweet coltsfoot	–	–
	Physocarpus capitatus	Pacific ninebark	–	–
	Plantago coronopus	Buckhorn plantain	–	–
	P. lanceolata	Narrowleaf plantain	–	–
	P. major	Broadleaf plantain	–	–
	P. subnuda	Coastal plantain	–	–
	Polygonum amphibium var. *emersum*	Longroot smartweed	–	–
	P. aviculare	Prostrate knotweed	–	–
	P. hydropiper	Marshpepper	–	–

* An "X" indicates that the column condition ("non-native" or "absent from the regional species pool") applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*P. hydropiperoides*	Swamp smartweed	–	–
	P. paronychia	Beach knotweed	–	–
	P. persicaria	Lady's-thumb	–	–
	Populus balsamifera	Balsam poplar	–	–
	Prunella vulgaris ssp. *lanceolata*	Lance selfheal	–	–
	P. vulgaris ssp. *vulgaris*	Common selfheal	–	–
	Prunus avium	Sweet cherry	–	–
	P. cerasus	Sour cherry	–	–
	P. domestica	European plum	–	–
	P. laurocerasus	Cherry laurel	–	–
	Ranunculus acris	Tall buttercup	–	–
	R. ficaria	Lesser celandine	–	–
	R. flammula	Lesser spearwort	–	–
	R. repens	Creeping buttercup	–	–
	R. sceleratus	Celeryleaf buttercup	–	–
	R. uncinatus	Woodland buttercup	–	–
	Rhododendron macrophyllum	Pacific rhododendron	–	–
	R. occidentale	Western azalea	–	–
	Ribes bracteosum	Stink currant	–	–
	R. divaricatum	Spreading gooseberry	–	–
	R. lacustre	Prickly currant	–	–
	R. laxiflorum	Trailing black currant	–	–
	R. sanguineum	Flowering currant	–	–
	Rorippa curvisiliqua	Curvepod yellowcress	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*R. islandica*	Northern marsh yellowcress	–	–
	Rosa nutkana	Nootka rose	–	–
	Rubus armeniacus	Himalayan blackberry	–	–
	R. laciniatus	Cutleaf blackberry	–	–
	R. parviflorus	Thimbleberry	–	–
	R. spectabilis	Salmonberry	–	–
	R. ursinus	Pacific blackberry	–	–
	Rumex acetosella	Common sheep sorrel	–	–
	R. conglomeratus	Clustered dock	–	–
	R. crispus	Curly dock	–	–
	R. obtusifolius	Bluntleaf dock	–	–
	Sagina apetala	Annual pearlwort	–	–
	S. maxima	Stickystem pearl-wort	–	–
	S. procumbens	Birdeye pearlwort	–	–
	Salicornia depressa	American glasswort	–	–
	Salix alba	Golden willow	–	–
	S. hookeriana	Dune willow	–	–
	S. lucida ssp. *lasiandra*	Pacific willow	–	–
	S. sitchensis	Sitka willow	–	–
	Sambucus racemosa	Red elderberry	–	–
	Samolus valerandi ssp. *parviflorus*	Smallflower water pimpernel	–	–
	Scrophularia californica	California figwort	–	–
	Sedum oreganum	Oregon stonecrop	–	–
	Senecio jacobaea	Tansy ragwort	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*S. sylvaticus*	Woodland ragwort	–	–
	S. triangularis	Arrowleaf groundsel	–	–
	S. vulgaris	Common groundsel	–	–
	Sidalcea hendersonii	Henderson's checkerbloom	–	–
	Sium suave	Common waterparsnip	–	–
	Solanum dulcamara	Bittersweet nightshade	–	–
	Solidago canadensis	Canada goldenrod	–	–
	S. simplex	Rand's goldenrod	–	–
	Sonchus asper	Spiny sowthistle	–	–
	S. oleraceus	Common sowthistle	–	–
	Sorbaria kirilowii	Giant false spiraea	–	–
	Sorbus aucuparia	European mountain ash	–	–
	Spergula arvensis	Corn spurry	–	–
	Spergularia rubra	Red sandspurry	–	–
	Spiraea douglasii	Rose spirea	–	–
	Stachys mexicana	Mexican hedgenettle	–	–
	Stellaria crispa	Crisp starwort	–	–
	S. humifusa	Salt marsh starwort	–	–
	S. longipes	Longstalk starwort	–	–
	S. media	Common chickweed	–	–
	Symphoricarpos albus	Ccommon snowberry	–	–
	Symphyotrichum subspicatum	Douglas aster	–	–
	Tanacetum camphoratum	Camphor tansy	–	–
	Taraxacum officinale	Common dandelion	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*Teesdalia nudicaulis*	Barestem teesdalia	–	–
	Tellima grandiflora	Bigflower tellima	–	–
	Tiarella trifoliata	Threeleaf foamflower	–	–
	Tolmiea menziesii	Youth on age	–	–
	Trifolium dubium	Hop clover	–	–
	T. hybridum	Alsike clover	–	–
	T. pratense	Red clover	–	–
	T. repens	White clover	–	–
	T. subterraneum	Subterranian clover	–	–
	T. wormskioldii	Springbank clover	–	–
	Triphysaria pusilla	Dwarf owl's-clover	–	–
	Urtica dioica ssp. *gracilis*	Stinging nettle	–	–
	Vaccinium ovalifolium	Alaskan huckleberry	–	–
	V. ovatum	Evergreen huckleberry	–	–
	V. parvifolium	Red huckleberry	–	–
	Veronica americana	American speedwell	–	–
	V. arvensis	Corn speedwell	–	–
	V. scutellata	Skullcap speedwell	–	–
	V. serpyllifolia	Thymeleaf speedwell	–	–
	Vicia nigricans ssp. *gigantea*	Giant vetch	–	–
	V. sativa ssp. *nigra*	Common vetch	–	–
	V. tetrasperma	Lentil vetch	–	–
	Vinca minor	Common periwinkle	–	–
	Viola glabella	Pioneer violet	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Dicots (continued)	*V. sempervirens*	Evergreen violet	–	–
	Weigela sp	Weigela	–	–
Ferns	*Adiantum aleuticum*	Aleutian maidenhair	–	–
	Athyrium filix-femina	Lady fern	–	–
	Blechnum spicant	Deer fern	–	–
	Botrychium multifidum	Leathery grapefern	–	–
	Dryopteris expansa	Spreading woodfern	–	–
FERNS (continued)	*Polypodium glycyrrhiza*	Licorice fern	–	–
	P. scouleri	Leathery polypody	–	–
	Polystichum munitum	Western swordfern	–	–
	Pteridium aquilinum	Western brackenfern	–	–
Gymnosperms	*Abies grandis*	Grand fir	–	–
	A. procera	Noble fir	–	–
	Araucaria araucana	Monkeypuzzle tree	X	X
	Cedrus libani	Cedar of Lebanon	X	X
	Chamaecyparis lawsoniana	Port Orford cedar	–	–
	Picea sitchensis	Sitka spruce	–	–
	Pinus contorta var. *contorta*	Shore pine	–	–
	P. nigra	Austrian pine	X	X
	P. pinaster	Maritime pine	X	X
	P. sylvestris	Scots pine	X	X
	Pseudotsuga menziesii	Douglas-fir	–	–
	Thuja plicata	Western redcedar	–	–
	Tsuga heterophylla	Western hemlock	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Monocots	*Agrostis capillaris*	Colonial bentgrass	X	–
	A. exarata	Spike bentgrass	–	–
	A. scabra	Rough bentgrass	–	–
	Agrostis stolonifera	Creeping bentgrass	X	–
	Aira praecox	Yellow hairgrass	X	–
	Alisma plantago-aquatica	European water plantain	X	X
	A. triviale	Northern water plantain	–	–
	Alopecurus geniculatus	Water foxtail	X	–
	A. pratensis	Meadow foxtail	X	–
	Ammophila arenaria	European beachgrass	X	–
	A. breviligulata	American beachgrass	–	–
	Anthoxanthum odoratum	Sweet vernalgrass	X	–
	Bromus carinatus	California brome	–	–
	B. hordeaceus	Soft brome	X	–
	B. sitchensis	Alaska brome	–	–
	Calamagrostis nutkaensis	Pacific reed grass	–	–
	Carex aquatilis var. *dives*	Sitka sedge	–	–
	C. deweyana	Dewey's sedge	–	–
	C. kobomugi	Japanese sedge	X	X
	C. leptopoda	Taperfruit shortscale sedge	–	–
	C. lyngbyei	Lyngbye's sedge	–	–
	C. macrocephala	Largehead sedge	–	–
	C. obnupta	Slough sedge	–	–
	C. pansa	Sanddune sedge	–	–

* An "X" indicates that the column condition ("non-native" or "absent from the regional species pool") applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Monocots (continued)	*C. stipata*	Owlfruit sedge	–	–
	Crocosmia x *crocosmiiflora*	Crocosmia; montbretia	X	X
	Cynosurus echinatus	Bristly dogtail grass	X	–
	Dactylis glomerata	Orchardgrass	X	–
	Danthonia californica	California oatgrass	–	–
	Digitaria sanguinalis	Hairy crabgrass	–	–
	Echinochloa crus-galli	Barnyardgrass	X	–
	Eleocharis ovata	Ovate spikerush	–	–
	E. palustris	Common spikerush	–	–
	E. parvula	Dwarf spikerush	–	X
	Elodea canadensis	Canadian waterweed	–	–
	Elymus repens	Quackgrass	X	–
	Festuca rubra	Red fescue	–	–
	Glyceria grandis	American mannagrass	–	X
	G. leptostachya	Slender-spike mannagrass	–	–
	Goodyera oblongifolia	Western rattlesnake plantain	–	–
	Holcus lanatus	Common velvetgrass	X	–
	Hyacinthoides non-scripta	English bluebell	X	–
	Iris pseudacorus	Yellow flag iris	X	–
	Isolepis cernua	Low bulrush	–	–
	Juncus acuminatus	Tapertip rush	–	–
	J. arcticus	Baltic rush; mountain rush	–	–
	J. articulatus	Jointed rush	–	–
	J. bufonius var. *occidentalis*	Toad rush	–	X

* An "X" indicates that the column condition ("non-native" or "absent from the regional species pool") applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Monocots (continued)	*J. effusus* var. *effusus*	common rush	–	X
	J. effusus var. *pacificus*	Pacific rush	–	X
	J. ensifolius	Swordleaf rush	–	–
	J. hesperius	Slender-stemmed rush	–	X
	J. oxymeris	Pointed rush	–	X
	J. supiniformis	Spreading rush	–	–
	J. tenuis	Path rush	–	–
	Lemna minor	Water lentil	–	–
	Leymus mollis	American dune grass	–	–
	Lilaea scilloides	Flowering quillwort	–	–
	Lolium perenne ssp. *perenne*	perennial ryegrass	X	X
	L. perenne ssp. *multiflorum*	Italian ryegrass	X	–
	Luzula congesta	Heath woodrush	X	X
	L. parviflora	Smallflowered woodrush	–	–
	Lysichiton americanus	American skunk cabbage	–	–
	Maianthemum dilatatum	False lily of the valley	–	–
	Najas flexilis	Nodding waternymph	–	X
	Narcissus sp	Daffodil	X	X
	Phalaris arundinacea	Reed canarygrass	–	–
	Poa annua	Annual bluegrass	X	–
	P. howellii	Howell's bluegrass	–	X
	P. pratensis	Kentucky bluegrass	–	–
	P. trivialis	Rough bluegrass	X	–
	P. unilateralis	Ocean bluff bluegrass	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Monocots (continued)	*Polypogon monspeliensis*	Annual rabbitsfoot grass	X	–
	Potamogeton crispus	Curly pondweed	X	–
	P. foliosus	Leafy pondweed	–	–
	P. gramineus	Grassy pondweed	–	–
	P. zosteriformus	Flatstem pondweed	–	X
	Prosartes smithii	Largeflower fairybells	–	–
	Sagittaria latifolia	Wapato	–	–
	Schedonorus phoenix	Tall fescue	X	–
	Schoenoplectus acutus	Hardstem bulrush	–	–
	S. tabernaemontani	Softstem bulrush	–	–
	Scirpus microcarpus	Smallfruit bulrush	–	–
	Sisyrinchium californicum	Golden blue-eyed grass	–	–
	S. idahoense	Blue-eyed grass	–	–
	Sparganium eurycarpum	Broadfruit bur-reed	–	X
	Spirodela polyrrhiza	Giant duckweed	–	–
	Streptopus amplexifolius	Claspleaf twistedstalk	–	–
	Torreyochloa pallida	Pale false mannagrass	–	–
	Triglochin maritima	Seaside arrow-grass	–	–
	Trillium ovatum	Pacific trillium	–	–
	Trisetum canescens	Tall trisetum	–	–
	Triticum aestivum	Common wheat	X	–
	Typha angustifolia	Narrowleaf cattail	–	–
	T. latifolia	Common cattail	–	–
	Vallisneria Americana	American eelgrass	–	–

* An “X” indicates that the column condition (“non-native” or “absent from the regional species pool”) applies to this species.

Table A1-1 (continued). List of vascular plant species recorded within LEWI.

Taxonomic Group	Scientific Name	Common Name	Non-native	Absent from regional species pool
Horsetails	*Equisetum arvense*	Field horsetail	–	–
	E. hyemale	Scouringrush horsetail	–	–
	E. telmateia	Giant horsetail	–	–
	Lycopodium clavatum	Running clubmoss (Lycopod)	–	–

* An "X" indicates that the column condition ("non-native" or "absent from the regional species pool") applies to this species.

Literature Cited

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Appendix 2. List of fungi and lichen species recorded within LEWI

Park-specific data were obtained from the NPS Certified Species List for LEWI and from technical lists provided by NPS staff (Table A2-1). Taxonomy, classification into morphological groups, and nativity are from Vitt et al. (1988), Pojar and MacKinnon (1994), Hutten et al. (2001), McCune and Geiser (2009), and Trudell and Ammirati (2009). Data are sorted alphabetically by taxon (fungi or lichen) followed by morphological group (fungi: bird's nest, boletes, club / coral / fan, crust, cup, gilled, jelly, morel and false morel, parasitic, puffball, secotioid, slime mold, and spine; lichen: crustose, foliose, and fruticose) and scientific name.

Table A2-1. List of fungi and lichen species recorded within LEWI.

Morphological Group	Scientific Name	Common Name
Birds Nest Fungi	*Nidula candida*	Common gel bird's nest
	N. niveotomentosa	Jellied bird's nest
Boletes Fungi	*Boletus calopus*	Bitter bolete
	B. coniferarum	Bitter bolete
	B. edulis	King bolete
	B. mirabilis	Admirable bolete
	B. piperatus	Peppery bolete
	B. smithii	Smith's bolete
	B. truncatus	Boletus truncatus
	B. zelleri	Zeller's bolete
	Leccinum clavatum	Birch bolete
	Suillus brevipes	Short-stemmed slippery jack
	S. caerulescens	Douglas-fir suillus
	S. luteus	Slippery jack
	S. tomentosus	Blue-staining slipper jack
	S. umbonatus	Umbonate slippery jack
	Tylopilus pseudoscaber	Dark bolete
Club/Coral/Fan Fungi	*Calocera viscosa*	Yellow tuning fork
	Clavaria purpurea	Purple club coral
	Clavulina cristata	Crested coral
	Cordyceps militaris	Caterpillar fungus
	Lentaria byssiseda	Cotton-base coral
	Ramaria araidspora	Red coral mushroom
	Xylaria hypoxylon	Carbon antlers
Crust Fungi	*Fomitopsis pinicola*	Red belled polypore

Table A2-1 (continued). List of fungi and lichen species recorded within LEWI.

Morphological Group	Scientific Name	Common Name
Crust Fingi (continued)	*Ganoderma tsugae*	Hemlock varnish shelf
	Laetiporus sulphureus	Sulfur shelf, chicken of the woods
	Laxitextum bicolor	Two-toned parchment
	Merulius tremellosus	Wild dry rot
	Steccherinum ochraceum	Ochre spreading tooth
	Trametes versicolor	Turkey tail
Cup Fungi	*Aleuria aurantia*	Orange peel
	Bisporella citrina	Yellow fairy cups
	Chlorociboria aeruginascens	Green stain
	Otidea leporina	Yellow rabbit ears
	Pseudoplectania nigrella	Hairy black cap
	Sarcosoma mexicana	Starving man's licorice
	Scutellinia scutellata	Eyelash pixie cup
Gilled Fungi	*Agaricus praeciaresquamosus*	Flat-top agaricus
	A. subrutilescens	Wine-colored agaric
	Amanita aspera	Yellow-veiled amanita
	A. constricta	Constricted grisette
	A. fulva	Tawny grisette
	A. gemmata	Jonquil amanita
	A. muscaria	Fly agaric
	Armillariella mellea	Honey mushroom
	Cantharellus cibarius	Chantrelle
	C. infundibuliformis	Winter chanterelle
	Catathelasma ventricosa	Imperial cat
	Chroogomphus tomentosus	Wooly pine spike
	C. vinicolor	Pine spike
	Coprinus atramentarius	Inky cap, tippler's bane
	Cortinarius collinitus	Slimy-banded cort
	Cortinarius violaceus	Violet cort
	Entoloma conferendum var. *conferendum*	Star-spored entoloma
	Gymnopilus spectabilis	Big laughing mushroom
	Hygrocybe flavescens	Yellow waxycap
	Hygrophoropsis aurantiaca	False chantrelle
	Laccaria laccata	Lackluster laccaria
	Lactarius deliciosus	Delicious milk cap

Table A2-1 (continued). List of fungi and lichen species recorded within LEWI.

Morphological Group	Scientific Name	Common Name
Gilled Fungi (continued)	*L. rufus*	Red-hot milk cap
	L. scrobiculatus	Scrobiculate milk cap
	L. substriatus	Slimy red milk cap
	Lepiota rubrotincta	Red-eyed parasol
	L. sp (Cristata Group)	Brown-eyed parasol
	Marasmiellus candidus	Pinwheel marasmius
	Mycena acicula	Candycorn mushroom
	M. capillaripes	Petite parasol
	M. epipterygia	Yellow-stalked mycena
	Naematoloma fasciculare	Sulphur tuft
	Panellus serotinus	Late fall oyster
	Paxillus atrotomentosus	Velvet pax
	Phaeocollybia spadicea	Kit's phaeocollybia
	Pholiota aurivella	Golden pholiota
	P. malicola	Forgettable pholiota
	P. terrestris	Terrestrial pholiota
	Pleurocybella porrigen	Angel's wings
	Pleurotus ostreatus	Oyster mushroom
	Pluteus cervinus	Deer mushroom
	Psilocybe pelliculosa	Conifer psilocybe
	P.be semilanceata	Liberty cap
	Russula brevipes	Short stemmed russula
	R. rosacea	Rosy russula
	R. xerampelina	Shrimp russula
	Strobilurus occidentalis	Spruce cone mushroom
	Stropharia ambigua	Questionable stropharia
	Tricholoma magnivalare	Matsutake
	T. vaccinum	Russet-scaly trich
Other Fungi	*Dacrymyces palmatus*	Orange jelly (Jelly)
	Pseudohydnum gelatinosum	Jelly tooth (Jelly)
	Tremella mesenterica	Witch's butter (Jelly)
	Helvella lacunosa	Fluted black elfin saddle (Morel)
	Hypomyces lactifluorum	Lobster mushroom (Parasitic)
	Lycoperdon perlatum	Common puffball (Puffball)
	Gastroboletus turbinatus	Bogus boletus (Secotioid)
	Lycogala epidendrum	Wolf'smilk slime (Slime mold)

Table A2-1 (continued). List of fungi and lichen species recorded within LEWI.

Morphological Group	Scientific Name	Common Name
Other Fungi (continued)	*Hydnellum peckii*	Red-juice tooth (Spine)
	H. suaveolens	Fragrant hydnellum (Spine)
	Hydnum repandum	Spreading hedgehog (Spine)
Crustose Lichen	*Ichmadophila ericitorum*	Peppermint drop lichen
Foliose Lichen	*Cavernularia hultenii*	Hulten's pitted lichen
	C. lophyrea	Pitted lichen
	Cetrelia cetruroides	Cetrelia cetruroides
	Collema nigrescens	Blistered jelly lichen
	Evernia prunastrii	Oakmoss
	Heterodermia leucomelos	Ciliate strap-lichen
	Hypogymnia apinnata	Beaded tube lichen
	H. enteromorpha	Bone lichen
	H. heterophylla	Seaside tube lichen
	H. inactiva	Inactive tube lichen
	H. occidentalis	Western tube lichen
	H. physodes	Monk's hood
	H. tubulosa	Tube lichen
	Hypotrachyna sinuosa	Riparian loop lichen
	Leptogium palmatum	Antlered jellyskin
	Lobaria pulmonaria	Tree lungwort
	L. scrobiculata	Textured lungwort
	Melanelixia fuliginosa	Melanelixia lichen
	Menegazzia terebrata	Honeycombed lichen
	Nephroma helveticum	Fringed kidney lichen
	N. resupinatum	Naked kidney lichen, cat's paw lichen
	Parmelia hygrophila	Shield lichen
	P. squarrosa	Salted shield
	P. sulcata	Powdered shield
	P. arnoldii	Arnold's parmotrema lichen
	P. chinense	Chinese parmotrema lichen
	P. crinitum	Parmotrema lichen
	Peltigera collina	Dog lichen
	P. membrenacea	Membraneous felt lichen
	P. neopolydactyla	Many-fruited pelt
	Physcia adscendens	Hooded rosette lichen
	P. aipolia	Hoary rosette lichen

Table A2-1 (continued). List of fungi and lichen species recorded within LEWI.

Morphological Group	Scientific Name	Common Name
Foliose Lichen (continued)	*Platismatia glauca*	Crinkled rag lichen
	P. herrei	Tattered rag lichen
	Pseudocyphellaria anomola	Netted specklebelly lichen
	P. anthrapsis	Pseudocyphellaria anthrapsis
	Sticta limbata	Spotted felt lichen
	T. orbata	Variable wrinkle-lichen
	Xanthoria parietina	Yellow scale
	X. polycarpa	Cushion xanthoria
Fruticose Lichen	*Sphaerophorus globosus*	Globe ball lichen
	Alectoria sarmentosa	Witch's hair
	A. vancouverensis	Vancouver witch's hair
	Bryoria glabra	Horsehair lichen
	Cladonia fimbriata	Slender pixie cup
	C. furcata	Many forked cladonia
	C. squamosa var. *subsquamosa*	Dragon cladonia
	C. sulphurina	Greater sulphur cup
	C. transcendens	Variable pebblehorn
	Pilophorus acicularis	Nail lichen
	Ramalina dilacerata	Cartilage lichen
	R. farinacea	Dotted ramalina
	R. menzeisii	Lace lichen
	R. roesleri	Roesler's cartilage lichen
	Usnea cornuta	Beard lichen
	U. filipendula	Fishbone beard lichen
	U. glabrata	Lustrous beard lichen
	U. longissima	Usnea longissima
	U. scabrata	Usnea scabrata

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