National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Natural Resource Condition Assessment for Lewis and Clark National Historical Park

Natural Resource Report NPS/XXXX/NRR—20XX/XXX

ON THE COVER

View from Fort Columbia State Park across the mudflats to Cape Disappointment State Park, a unit of Lewis and Clark National Historical Park (T. Hinckley image)

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Natural Resource Report NPS/XXXX/NRR—20XX/XXX

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National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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Acronyms and Abbreviations

ARD –Air Resources Division

C-CAP – Coastal Change Analysis Program

CO_2 – carbon dioxide

DDT – dichlorodiphenyltrichloroethane

EBLA – Ebey's Landing National Historical Reserve

EPA – Environmental Protection Agency

FIPS – Federal Information Processing Standard

FOVA – Fort Vancouver National Historic Site

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

MORA – Mount Rainier National 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

OLYM – Olympic National Park

ORDEQ – Oregon Department of Environmental Quality

PBDE – polybrominated diphenyl ether

PCB – polychlorinated biphenyl

ppm – parts per million

RSI – Request for Statement of Interest

SAJH – San Juan Island National Historical Park

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

Executive Summary

This report is a Natural Resource Condition Assessment (NRCA) for Lewis and Clark National Historical Park (LEWI). The NRCA is intended to assist Park managers and external researchers by (i) providing a synthesis of information about natural resources at LEWI, (ii) describing the threats known or thought to be affecting these resources, (iii) analyzing information from a series of metrics and other descriptors of resource condition, and (iv) evaluating information richness and identifying key information gaps.

This report is structured into five primary sections: (1) **NRCA Background Information**; (2) **Context and Methods** (a description of the context surrounding the preparation of this NRCA, indicator selection, and methods used to quantify indicators); (3) **Park Description** (a description of the park and synthesis of information describing the current condition of its natural resources); (4) **Threats and Stressors** (an in-depth review of a suite of environmental threats and stressors with respect to LEWI's natural resources); and (5) **Conclusions and Information Needs** (a summary of the conclusions from these reviews, and identification of key information / data gaps).

Context and Methods

At LEWI, we concentrated on 7 units of the park with significant natural resources. We simultaneously evaluated the natural resources at LEWI and at Ebey's Landing National Historical Reserve (EBLA), Fort Vancouver National Historic Site (FOVA), and San Juan Island National Historical Park (SAJH). To the extent possible, we applied the same methods to all parks to enable inter-park comparisons, although a variety of limitations prevented completion of the NRCAs for EBLA and SAJH. Since the intention to make comparisons among the four parks was an integral part of our analytical process, it continues to be reflected in this report.

The NPS provided us with a prioritized list of 48 issues and resources for LEWI and the other parks. Nineteen of these issues were rated as 'high' or 'moderate' priority at LEWI; most of these related to the biotic condition of its natural resources. We identified indicators that would provide quantitative information relevant to these issues.

This NRCA is based largely on compilations, syntheses, and new analyses of pre-existing data, and an in-depth review of the scientific literature associated with LEWI. New field data consisted of 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.

A major component of this project was the development of materials through a sequence of courses for advanced undergraduate and graduate students, and through research assistantships to a number of graduate students.

We evaluated five categories of threats and stressors: climate change, biodiversity, land use, air and water, and other stressors. We identified several indicators for each category, and evaluated each indicator with respect to its current condition (good, moderate concern, significant concern) and trend (improving, stable, declining, no data).

Park Description

LEWI protects and commemorates an ecological and cultural landscape representative of the very early 19th century when Lewis and Clark arrived at the month of the Columbia River and spent the next several months exploring the area. It is comprised of thirteen units located on both sides of the Columbia River in Washington and Oregon. The currently authorized boundary of LEWI encompasses 1359 ha (3358 acres).

One of the management challenges for LEWI's natural resources is its complicated administrative / management structure. Management involves a complex of federal, state, and local agencies. Park units are spread in a narrow band along the Pacific Coast on either side of the mouth of the Columbia River. Landscape-level planning is complicated by the small size of the park and their distribution within a matrix of non-park lands.

The vegetation has been dominated by forests and wetlands both historically and at present. However, the structural complexity of the forests has changed significantly as there is little old-growth forest left and large areas dominated by second- and third-growth Douglas-fir stands. A considerable amount of beach accretion has occurred since the Lewis and Clark expedition.

Considering all units together, LEWI contains 382 vascular plant taxa (about 30% of the regional species pool) along with 233 taxa of non-vascular plants (bryophytes, fungi, lichens) and 284 animals. In terms of species listed under the Endangered Species Act, there are two listed plants and 31 listed animal taxa in or associated with LEWI.

Threats and Stressors

Table ES.1 provides a visual summary of our assessment within each category.

Climate Change: Although we see relatively little evidence of directional trends in climatic parameters over short timeframes, our assessment is that the trend for these indicators is declining. Temperatures at LEWI are projected to rise, and precipitation to shift seasonally such that summers are drier than at present. Sea level is projected to rise, and ocean acidification to continue.

Biodiversity: Non-native species are one of the greatest threats to biodiversity within the United States. LEWI contains proportionally more noxious weeds and non-native vascular plant species (41%) than expected based on the regional species pool. We suspect that this difference reflects more comprehensive floristic assessments within LEWI and aggressive management actions by NPS staff to locate and treat noxious weeds as they colonize areas within LEWI. The proportion of non-native animals is low (< 1%), though many of the faunal records are incomplete. We lack adequate data to examine trends in biodiversity such as colonization by new non-native species or the eradication of species due to management activities.

Land Use: Habitat destruction, one aspect of land use, is one of the greatest threats to biodiversity within the United States. However, our land use indicators suggest that land use is currently a relatively low threat within LEWI. Impervious surfaces are present on a small proportion of the land base. Road density is in the same range as in the region. Human population pressure is low and forecast to remain relatively low. County zoning designations reflect existing land uses for each park unit. With the exception of population density, we do not have adequate data to examine changes in land use over time.

Air and Water: Air quality at LEWI is currently thought to be excellent, though it is not being monitored by the NPS. Surface water quality is a moderate concern as the Columbia River is a major source of such toxics as mercury, DDT and its derivatives, PCBs, and PBDEs. Groundwater is plentiful but a moderate concern as it is sensitive to contamination. With rising sea levels, salt water intrusion may become a problem. We lack adequate data to examine trends in air and water quality.

Other Stressors: Diseases are a significant concern within particular habitats. For example, Swiss needle cast is a concern within second- and third-growth Douglas-fir stands. 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 depending on where and when they occurred. Tidal activity has been significantly altered by humans through the establishment of dikes, jetties, culverts, and other structures. In the last few years, estuarine restoration activities in the last few years have begun to restore this process by breaching dikes.

Table ES.1. Summary evaluation of indicators within each of five categories (columns) of threats and stressors facing the natural resources of LEWI. Symbol shape and color reflect current condition (green: circle good; yellow diamond: moderate concern; red stop sign: significant concern). The arrow or question mark within each symbol reflects trend data (improving, stable, declining, no data). For example, our overall assessment of climate change at LEWI is that current conditions are good but the trend is declining.

Climate Change	**Biodiversity**	**Land Use**	**Air and Water**	**Other Stressors**
Air Temperature	Noxious Weeds	Impervious Surfaces	Air Quality	Diseases
Precipitation	Non-native Plants	Road Density	Surface Water Quality	Natural Disturbances
Sea Level Rise	Non-native Animals	Population Density	Groundwater	Altered Hydrology
Ocean acidification		Zoned Land Use		

Information Needs

Natural resource management at LEWI is hindered by a lack of site-specific information about key taxa and processes. For example, species diversity information is incomplete for some groups (e.g., insects) and missing for others (e.g., benthic invertebrates). In addition, these data should be tracked for each unit so that analyses can be conducted at the unit-scale and at the park-scale.

While it is difficult assessing the current condition of LEWI's natural resources, it is even more challenging assessing their temporal trends. For example, the species richness data that we possess are static and do not permit assessments colonization by new species, local extirpations of native species, or the control of individual non-native species through management activities. We lack comparable trend data about many other indicators.

LEWI would benefit from a GIS repository in which spatially explicit management activities are tracked. For example, we know that substantial estuarine restoration activities have occurred in recent years, but do not have documentation of when and where they occurred.

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

Chapter 1 - NRCA Background Information

Note: this chapter was provided by the NPS.

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The indicators targeted for evaluation depend on a park's resource setting, status of park-level resource stewardship planning and science in identifying priority indicators for that park, and availability of useful data and qualified expertise to assess current conditions for each indicator included on a list of potential study indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, but 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 logical reference conditions/values to compare current condition data against[3,4]
- Emphasize spatial evaluation of conditions and GIS (map) products[5]
- Summarize key findings by park areas[6]
- Follow national NRCA guidelines and standards for study design and reporting products

[1] However, 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 reporting 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 reference conditions

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")

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

[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall conditions, existing/emerging resource issues, and suggest future scientific studies and management activities that could help protect or restore park resources

Although current condition reporting relative to logical reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe 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: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for the park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change impacts on park natural resources is not a priority objective for NRCAs. However, the existing condition analyses and data sets developed in an NRCA should provide useful information for subsequent climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures[8].

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy(RSS) but study scope can be tailored to also work well as a post-RSS project

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

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of existing data from multiple and diverse sources, at a level of rigor and sophistication that reflects our present data and knowledge base for each resource or indicator that is evaluated. Statistically repeatable analyses should be conducted where the underlying data and methods support it. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

Chapter 2 – Context and Methods

2.1 Preliminary Scoping

The U.S. Congress, in its FY 2003 Appropriations Act, instructed and funded the National Park Service (NPS) to assess environmental conditions in watersheds where National Park units are located. The goal of these assessments is "to provide an ecological assessment of resource conditions (Health) that will assist managers in developing actions to reduce and prevent impairment of park resources" (NPS 2008). Pilot Natural Resource Condition Assessments (NRCAs) began to be conducted a few years later; results of a few of these have been released to date (e.g., Vaux et al. 2008; Carruthers et al. 2009).

In March 2008, the NPS released a 'Request for Statement of Interest' (RSI) for NRCAs at four parks in the North Coast and Cascades Vital Signs Monitoring Network. The four designated parks were:

- Ebey's Landing National Historical Reserve (EBLA)
- Fort Vancouver National Historic Site (FOVA)
- Lewis and Clark National Historical Park (LEWI)
- San Juan Island National Historical Park (SAJH)

The objectives of the assessments were to:

- Interpret key park resources in a regional context (significance, issues)
- Provide an interdisciplinary (holistic) snapshot of current resource conditions, by park areas
- Document high-priority data gaps and resource condition threats and stressors
- Describe at-risk park areas and resources

The NRCAs were intended as general level assessments to provide broad ecological information at a park-wide level.

Background information about each park was provided in Attachment 2 of the RSI. Attachment 3 of the RSI provided a list of 48 issues and resources, with each item prioritized for importance within each park unit by NPS staff (Table 2.1).

Table 2.1. Issues and resources identified and ranked by the NPS for each park. Ranking: 3 = highest priority, 2 = moderate priority, 1 = low priority, 0 = lowest priority and/or does not exist at park, 'unk' = unknown at park. This list is organized into groups of issues that are ranked as being common to most parks, important regionally, important for a single park, or of low importance (see Section 2.4.1 for details). Issues identified as being of high or moderate priority at LEWI are in bold italics.

Scale of Ranking	NPS Issue	EBLA	FOVA	LEWI	SAJH
Common	***Urban encroachment/rural development***	3	3	3	3
	Recreation	1	3	2	2
	Wetlands & Riparian Areas	3	3	3	3
	Invasive species	3	3	3	3
	Areas with evidence of invasive species	3	3	2	3
	Native plant restoration	2	3	2	3
	Areas of focal species	unk	2	2	3
	Habitat for focal species	unk	2	2	3
	Global warming	2	2	2	1
	Clean water	3	2	2	2
	Shoreline erosion	3	1	2	3
Regional	***Logging or habitat conversion***	2	0	3	3
	Road and trail development	1	2	1	2
	Areas of pristine or old-growth vegetation	2	1	1	3
	Species inventories	unk	2	3	unk
	Point sources of pollution	1	3	1	2
	Pesticides / contaminants in groundwater	2	1	unk	2
	Hazardous waste	unk	2	3	1
	Groundwater flow	3	0	unk	2
	Saltwater intrusion	3	0	0	2
	Soil erosion	3	1	1	2
	Night sky	1	2	1	2
Park-specific	Social trails	2	1	0	1
	Lakes and streams	2	0	1	1
	Estuarine restoration	unk	0	3	unk
	Past logging and restoration of those lands	1	0	3	1
	Phenological cycles	0	2	1	1
	Pesticide runoff	3	1	unk	1
	Water diversion	0	0	2	0
	Stream bank erosion	0	0	2	1
	Hillslope erosion (rill & gullying)	1	0	1	3
	Floatable debris	1	0	0	2
	Fire regimes	1	1	1	3
	Fire suppression and fuels management	1	1	1	2
	Flood control	0	1	2	0
	Flooding regimes	0	2	1	1
	Moisture and climatic cycles	2	1	unk	1
	Solitude and silence	1	1	1	3
	Soil compaction	2	1	1	1
Low Importance	Roadless areas	0	1	1	1
	Cave or karst features	0	0	0	1
	Abandoned mine lands	0	0	0	0
	Grazing	0	1	0	1
	Airborne dust	1	0	1	1
	Carbon sequestration	unk	1	unk	1
	Karst processes	0	0	0	0

Earthworks stabilization	0	0	0	1
Water rights	1	0	1	0

2.2 Approach

For this project, a Cooperative Agreement was established between the Department of the Interior and the Pacific Northwest Cooperative Ecosystem Studies Unit to conduct NRCAs as a collaborative effort between the NPS and the University of Washington (UW). The PI team at the UW consisted of Jon Bakker, Kern Ewing, Tom Hinckley, Josh Lawler, and Sarah Reichard. All PIs are from the School of Forest Resources, and each brought unique expertise and experience in NPS units to the project. Joel Siderius was also a member of the PI team, but transferred out-of-state relatively soon after the project began.

We developed a common approach that was applied to all four parks. Key elements of this approach were (1) a consistent faculty team of the five co-PIs, (2) specific and consistent responsibilities for each faculty member (Bakker - EBLA and Condition/Stressor Indicators, Ewing – wetlands and groundwater, Hinckley – FOVA and LEWI, Lawler – GIS, Reichard – SAJH and invasives), (3) development of material using a mixed graduate – undergraduate student course framework, (4) multiple visits to park units, (5) a thorough review of a number of different approaches to developing assessment protocols, (6) indication of common elements of assessment, classification, and reporting, and (7) extensive review of materials associated with each park or with the area in which each park is situated.

The project began in August 2008. A three-quarter sequence of 5-credit courses, the centerpiece of the project, was offered through the College of Forest Resources (since renamed the School of Forest Resources) and the Program on the Environment during the 2008-2009 academic year (Table 2.2).

During Autumn quarter, the course met twice per week for two hours. Initial meetings focused on gaining familiarity with each park internet and literature searches, park visits, and guest lectures by Chris Davis, Marsha Davis, and Mark Huff. Park visits served to introduce students to park history and administrative units, and included a walking or a walking / driving tour. Often Park personnel made available both published and unpublished reports as well as GIS files.

During Winter quarter, half of the students were new to the project. Therefore, several exercises including new field trips to the Parks were designed to familiarize all students with progress made during the Autumn quarter as well as the specific goals for Winter quarter. The principal goal during this quarter was to develop the condition and stressor indicators.

During Spring quarter, we retained the most productive students from the Winter quarter and recruited one new student. Due to the resulting familiarity with the project, considerable progress was made; rough drafts of the reports for each of the four parks were prepared and a detailed and thorough presentation of the work since September was presented to NPS staff from the regional office and parks in the North Coast and Cascades Network.

Three graduate students continued to work on the project following this three-quarter course sequence. Two of these students (Rachel Mitchell and Mu-Ning Wang) had been involved since

Autumn 2008, and the other (Catherine Kilbane Gockel) since March 2009. They focused on specific condition and stressor indicators for each Park.

Funds were received in October 2008. More than 95% of the funds were used to support graduate student participation in the project. Additional graduate student support was provided by the School of Forest Resources.

Table 2.2. Summary of student enrollment in the three courses offered during the 2008 – 2009 academic year. Student numbers are summarized by major; if a student was doing a minor, that degree is also listed. G – graduate student; UG – undergraduate.

Major	Autumn Quarter		Winter Quarter		Spring Quarter	
	Major	Minor	Major	Minor	Major	Minor
Dance	1 UG					
Education			1 UG			
Environmental Studies	4 UG	1 UG	4 UG		2 UG	
Forest Resources	3 G	2 UG	3 G; 1 UG	3 UG	2 G	1 UG
Forest Resources/ Public Affairs	2 G		1 G		2 G	
International Studies	1 UG					
Landscape Architecture	1 G		1 G			
Total	12		11		6	

2.3 Reporting Areas

2.3.1 Multiple Park Focus

Our task was to provide Natural Resource Condition Assessments for four regional historical parks (Figure 2.1):

- Ebey's Landing National Historical Reserve (EBLA)
- Fort Vancouver National Historic Site (FOVA)
- Lewis and Clark National Historical Park (LEWI)
- San Juan Island National Historical Park (SAJH).

Unfortunately, a variety of limitations prevented completion of the NRCAs for EBLA and SAJH. However, this intention to make comparisons among the four parks was an integral part of our analytical process, and thus is reflected in this report.

These parks have several common features: they are relatively small, emphasize cultural and historical resources, and involve more than one owner or partner. They also share a mild, maritime, Mediterranean climate, though they differ greatly in the amount of precipitation they receive (Table 2.3).

Figure 2.1. Geographic region of the four regional historical parks (Ebey's Landing, Fort Vancouver, Lewis and Clark, and San Juan Island).

Table 2.3. Historical (1971-2000) climate data for the four parks. Data are from WRCC (2009).

Park	Reference Weather Station	Mean Total Annual Precipitation (mm)	Mean Annual Temperature (°C)	Mean Minimum January Temperature (°C)	Mean Maximum July Temperature (°C)
EBLA	Coupeville	543	10.1	1.5	22.3
FOVA	Vancouver 4 NNE	1065	11.0	0.2	25.6
LEWI	Astoria WSO Airport	1705	10.6	2.6	20.2
SAJH	Olga 2 SE	715	9.7	0.9	21.2

There are some important differences among the parks. For example:

- The boundary of EBLA encompasses the most area, yet the NPS owns fee-title to only a small proportion of this land.
- FOVA is the smallest and most urban of the parks.
- LEWI has the greatest number of partner units.
- SAJH can only be reached by boat or plane.

All four parks are influenced by tides (Table 2.4). The mean range varies from 1.3 feet (0.4 meters) at Vancouver, Washington to 7.8 feet (2.4 meters) at Coupeville. Tides and the movement of saline water have an important influence on tidal wetlands and estuaries. In all likelihood, the tidal influences at FOVA do not currently include an influx of saline water, though future rises in sea level may alter this – especially during storm surges.

Table 2.4. Tidal data at locations in and around the four parks. Tidal influence occurs all the way up the Columbia River to FOVA (NOAA 2009b).

Park	Location	Mean Range (ft)	Spring Range (ft)	Mean Tide Level (ft)
EBLA	Bush Point, Whidbey Island, WA	5.9	9.4	5.6
	Sunset Beach, Whidbey Island, WA	4.3	7.4	4.7
	Coupeville, Penn Cove, Whidbey Island, WA	7.8	11.5	6.7
FOVA	Vancouver, WA	1.3	1.8	-.-
LEWI	Seaside, 12th Avenue bridge, Necanicum River	4.7	5.8	2.8
	Columbia River entrance (N. Jetty)	5.6	7.5	4.0
	Fort Canby, Jetty "A", WA.	6.2	8.3	4.5
	Chinook, Baker Bay, WA	6.1	8.1	4.3
	Warrenton, Skipanon River, OR	6.5	8.3	4.4
	Astoria (Youngs Bay), OR	6.7	8.6	4.5
SAJH	Friday Harbor, San Juan Island, WA	4.8	7.8	4.7

2.3.2 Ecological Reporting Units - Common

All four parks represent interesting biogeographic and administrative units. EBLA and SAJH are located on islands, but within a matrix of non-NPS lands. All parks have marine and freshwater wetlands, although the only marine influence at FOVA is on Columbia River heights resulting from tidal influences. Some parks have estuary, spring, lacustrine, and small riverine wetlands, and some are bordered by large riverine systems (the Columbia River Watershed).

Jurisdictional boundaries are complex and include two States (Washington and Oregon), multiple counties (Clark, Clatsop, Pacific, Island, and San Juan), and two municipalities (Coupeville and Vancouver). Agencies responsible for management include the USDI National Park Service, USDI Bureau of Land Management, US Army Corps of Engineers, US Army, Washington State Parks, Oregon Parks and Recreation Department, the Washington State Historical Society, and the City of Vancouver.

2.3.3 Ecological Reporting Units – LEWI

Although the legislative boundary of LEWI currently encompasses 12 units with another slated for future purchase (Figure 3.1; Table 3.1), this NRCA focused on 7 units with significant natural resources:

- Clark's Dismal Nitch
- Fort Clatsop Unit
- Station Camp
- Cape Disappointment State Park
- Sunset Beach State Recreation Area
- Ecola State Park
- Fort Stevens State Park

As discussed below (Section 3.2.1), the complex ownership patterns associated with LEWI complicate its analysis and management. In addition, the units differ in size, history, and quantity of research history. Finally, the thoroughness of coverage depends on the resources being analyzed in a particular area.

Where possible, we assessed indicators spatially by comparing data from within LEWI with data from the surrounding area. We used the counties (Pacific County, WA, and Clatsop County, OR) as the standard frame of reference for these comparisons.

2.4 Indicator Selection Process

2.4.1 Assessment Framework

NPS staff and the RSI indicated that assessments should be developed within the structure of an assessment framework produced by the EPA (Young and Sanzone 2002). The EPA framework consists of three process- and three pattern-based categories. Each category is divided into a number of subcategories (Table 2.5).

We began by categorizing each NPS issue within the most appropriate category and subcategory from the EPA framework (Appendix 1). NPS issues spanned all categories (Table 2.6), though there was only one issue relating to ecological processes and it was not ranked highly by any park.

NPS staff had characterized each issue in terms of importance within each park. We further characterized each issue as being common to all parks (high or moderate priority in ≥ 3 parks), important regionally (high or moderate priority in 2 parks), or important for a single park (high or moderate priority in one park). While identifying indicators, we focused on those issues identified as being of moderate or high priority in at least one park, with an emphasis on those that were common to all parks or important regionally. We attempted to identify indicators that would provide insight into these issues.

In total, 19 NPS issues were rated as being of high or moderate priority at LEWI (Table 2.6). Almost half of these related to the EPA category of ‘Biotic Condition’.

Table 2.5. Categories and subcategories within the EPA assessment framework. Adapted from Table ES-1 in Young and Sanzone (2002).

Category	Subcategory	Examples
Landscape Condition	Extent of Ecological System/Habitat Types	
	Landscape Composition	
	Landscape Pattern and Structure	
Biotic Condition	Ecosystems and Communities	-Community Extent -Community Composition -Trophic Structure -Community Dynamics -Physical Structure
	Species and Populations	-Population Size -Genetic Diversity -Population Structure -Population Dynamics -Habitat Suitability
	Organism Condition	-Physiological Status
Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)	Nutrient Concentrations	-Nitrogen -Phosphorus -Other Nutrients
	Trace Inorganic and Organic Chemicals	-Metals -Other Trace Elements -Organic Compounds
	Other Chemical Parameters	-pH -Dissolved Oxygen -Salinity -Organic Matter
	Physical Parameters	
Ecological Processes	Energy Flow	-Primary Production -Net Ecosystem Production -Growth Efficiency
	Material Flow	-Organic Carbon Cycling -Nitrogen and Phosphorus Cycling
Hydrology and Geomorphology	Surface and Groundwater Flows	-Pattern of Surface Flows -Hydrodynamics -Pattern of Groundwater Flows -Salinity Patterns -Water Storage
	Dynamic Structural Characteristics	-Channel/Shoreline Morphology, Complexity -Extent/Distribution of Connected Floodplain -Aquatic Physical Habitat Complexity
	Sediment and Material Transport	-Sediment Supply/Movement -Particle Size Distribution Patterns -Other Material Flux
Natural Disturbance Regimes	Frequency	
	Intensity	
	Extent	
	Durations	

Table 2.6. Distribution of issues and resources identified by NPS staff within the categories of the EPA assessment framework (Young and Sanzone 2002). All issues and resources considered by the NPS (Table 2.1) are summarized under 'All Parks', and only those ranked as high or moderate priority at LEWI are summarized under 'LEWI'. A detailed description of the correspondence between the EPA assessment framework and the NPS issues is provided in Appendix 1.

	All Parks		LEWI	
Category	**Number**	**Percentage**	**Number**	**Percentage**
Landscape condition	7	15	3	16
Biotic condition	14	29	9	47
Chemical / physical characteristics	7	15	2	11
Hydrology / geomorphology	11	23	4	21
Ecological processes	1	2	0	0
Natural disturbance	5	10	1	5
Other	3	6	0	0
Total	48	100	19	100

2.4.2 Candidate Resources and Indicators

Criteria that we considered when choosing indicators included:

- Importance – we focused primarily on indicators that would provide insight into issues ranked as moderate or high priority by at least one park, with an emphasis on those that were common to all parks or important regionally

- Quantitative – appropriate quantitative data were available

- Scientifically defensible

- Feasible to calculate from extant data

- Precedence – had been used in previous studies

In terms of precedence, we reviewed the variables being monitored through the NPS Vital Signs program for parks in the North Coast and Cascades Network (NPS NCCN 2009). Relatively few of these applied to our four focal parks (Table 2.7). We also reviewed the variables used in other studies (TGBPSEIWG 2002; Klinger et al. 2006, 2007a, 2007b; Nagorski et al. 2008; Vaux et al. 2008; Carruthers et al. 2009).

We focused primarily on the terrestrial resources of the parks. Aquatic resources have been dealt with recently for LEWI, EBLA, and SAJH by Klinger et al. (2006, 2007a, 2007b); the reader is referred to these reports for more detailed considerations of aquatic resources.

In total, we selected 30 indicator variables for analysis in LEWI (Table 2.8). Most of these indicators were also used in the NRCAs for the other parks included in our scope. Identified variables were categorized with respect to the NPS issues that they addressed, the category within the EPA assessment framework that they fit into, and the habitat(s) to which they provide insight. Finally, we also identified whether each indicator provided information about the current condition of the park's natural resources or of a stressor on those resources. The results for condition indicators are considered in Section 3.3, while stressors are considered in Chapter 4.

Table 2.7. Vital Signs being examined within each park of the NPS North Coast and Cascades Network (NPS NCCN 2009).

Vital Sign	EBLA	FOVA	LEWI	MORA	NOCA	OLYM	SAJH
Climate	X	X	X				X
Fish assemblages				X	X	X	
Glaciers				X	X	X	
Intertidal			X			X	X
Landbirds			X	X	X	X	X
Landscape dynamics	X	X	X	X	X	X	X
Mountain lakes				X	X	X	
Subalpine vegetation				X	X	X	

2.5 Forms of Reference Conditions/Reference Values

For each indicator, we attempted to identify a quantitative benchmark against which to compare the data from the park. Benchmarks were obtained from the published literature and/or expert opinion. We gave more weight to benchmarks that were also used by other studies.

Most indicators provided a snapshot of **condition** at a single point in time. Indicators that had data of sufficient temporal resolution were also able to provide information about **trends** over time. We categorized indicators with respect to these two elements. We developed a series of symbols (Figure 2.2) whose color and shape indicated condition. Symbols were modeled after traffic signs for ease of interpretation. Inlaid within each symbol was either an arrow indicating trend (improving, stable, declining) or a question mark indicating that we did not have sufficient data to assess trends.

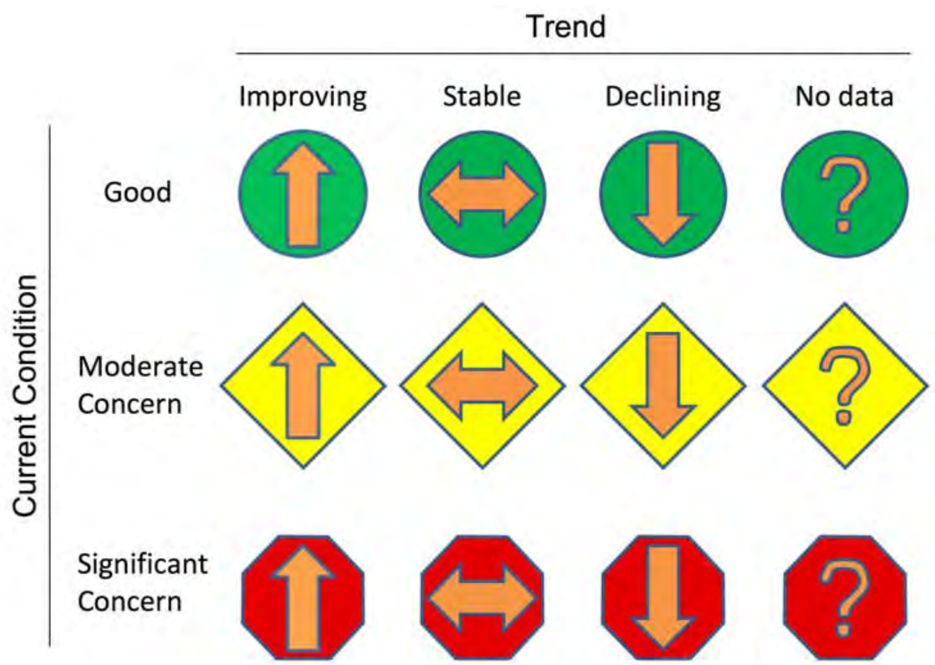


Figure 2.2. Symbols used to characterize indicators with respect to current condition (green, yellow, and red circles) and trends (arrows). The question mark is used for indicators that lacked trend data. These symbols are adapted from those used by NPS ARD (2009).

Table 2.8. Indicators selected for use at LEWI. Included for each indicator are a verbal description, its units and benchmark (where applicable), its indicator type (C = Condition, S = Stressor), the NPS priorities that it addresses, the category within the EPA assessment framework (Young and Sanzone 2002) to which it belongs, and the sections in this report where the methods and results are described. This list is sorted by the order in which indicator methods are presented.

Indicator	Units	Benchmark	C/S	NPS Priorities	EPA Category	Methods	Results
Endangered plant species	Proportion of native species in park	Proportion in regional species pool	C	Species inventories	Biotic Condition	2.6.1	3.3.1
Endangered species, by taxonomic group	Number of species	-	C	Species inventories	Biotic Condition	2.6.1	3.3.1
Non-native species	Ratio of native to non-native species in park	Ratio in regional species pool	S	Invasive species; Species inventories	Biotic Condition	2.6.1	4.2.3, 4.2.4
Noxious weeds	Number of species	Number of listed noxious weeds in regional species pool	S	Invasive species	Biotic Condition	2.6.1	4.2.2
Species richness, by taxonomic group	Number of species	Number in regional species pool	C	Species inventories	Biotic Condition	2.6.1	3.3.1
Vascular plants - distribution among taxonomic groups	% in each group	Distribution in regional species pool	C	Species inventories	Biotic Condition	2.6.1	3.3.1
Current extent of each land cover type	% of total terrestrial area, 2006	Distribution in region	C	Logging or habitat conversion; Areas of pristine or old-growth vegetation; Past logging and restoration of those lands	Landscape Condition	2.6.2	3.3.2
Historical extent of each vegetation type	% of total terrestrial area	-	C	Areas of pristine or old-growth vegetation	Landscape Condition	2.6.2	3.2.8
Recent change in land cover types	% change, 1996-2006	Change in region	C	Logging or habitat conversion; Areas of pristine or old-growth vegetation; Past logging and restoration of those lands	Landscape Condition	2.6.2	3.3.2
Future annual and seasonal air temperatures	Change in temperature; degrees C (2070-2099)	1961-1990 temperature	S	Global warming	Chemical/Physical Characteristics	2.6.3	4.1.2
Future annual and seasonal precipitation	Change in precipitation (%); (2070-2099)	1961-1990 temperature	S	Global warming	Chemical/Physical Characteristics	2.6.3	4.1.3
Future sea-level rise	cm; 2050 and 2100	-	S	Global warming	Chemical/Physical Characteristics	2.6.3	4.1.4
Historical sea-level rise	mm/year	-	S	Global warming	Chemical/Physical Characteristics	2.6.3	4.1.4

Indicator	Units	Benchmark	C/S	NPS Priorities	EPA Category	Methods	Results
Mean annual and seasonal air temperatures	Degrees C; trend over time (1977-2006)	-	S	Global warming	Chemical/Physical Characteristics	2.6.3	4.1.2
Mean annual and seasonal precipitation	mm; trend over time (1977-2006)	-	S	Global warming	Chemical/Physical Characteristics	2.6.3	4.1.3
Ocean acidification	change in pH	-	S	Global warming	Chemical/Physical Characteristics	2.6.3	4.1.5
Amount of impervious surfaces	% of area	10% of Total Impervious Area (TIA)	S	Urban encroachment/rural development; Road and trail development; Recreation	Landscape Condition	2.6.4	4.3.2
Location of impervious surfaces	% of area, by land cover type	10% TIA	S	Urban encroachment/rural development; Road and trail development; Recreation	Landscape Condition	2.6.4	4.3.2
Population	# in region, 1900-2030; trend over time		S	Urban encroachment/rural development; Road and trail development; Recreation; Solitude and silence	Landscape Condition	2.6.4	4.3.4
Population density	# per ha in region, 1900-2030; trend over time		S	Urban encroachment/rural development; Road and trail development; Recreation; Solitude and silence	Landscape Condition	2.6.4	4.3.4
Population growth rate	Annual growth rate in region, 1900-2030		S	Urban encroachment/rural development; Road and trail development; Recreation; Solitude and silence	Landscape Condition	2.6.4	4.3.4
Road density	km per km2	Regional mean	S	Road and trail development; Roadless areas	Landscape Condition	2.6.4	4.3.3
Zoning	% of area, by land use designation	Distribution in region	S	Urban encroachment/rural development	Landscape Condition	2.6.4	4.3.5
Air quality		-	S	Airborne dust	Chemical/Physical Characteristics	2.6.5	4.4.2
Current extent of wetlands	% of wetland area, by wetland type	-	C	Wetlands and riparian areas; Lakes and streams	Landscape Condition	2.6.5	3.3.4
Groundwater		-	S	Clean water; Pesticides/contaminants	Hydrology/ Geomorphology	2.6.5	4.4.4

Indicator	Units	Benchmark	C/S	NPS Priorities	EPA Category	Methods	Results
				in groundwater; Water diversion; Groundwater flow; Saltwater intrusion			
Surface water quality		-	S	Clean water; Water diversion; Soil erosion; Pesticide runoff; Stream bank erosion; Floatable debris; Flood control; Flooding regimes	Chemical/Physical Characteristics	2.6.5	4.4.3
Disease		-	S		Biotic Condition	2.6.6	4.5.1
Disturbances		-	S		Natural Disturbance Regimes	2.6.6	4.5.2
Elevational profiles		-	C/S		Landscape Condition	2.7	3.2.8, 3.3.5, 4.6

2.6 Common Definitions and Methods

We sought to use methods that enabled comparisons among parks. Where possible, therefore, we relied on state or national datasets. Although finer scale local datasets were available for some of the variables assessed with national datasets, these finer scale datasets did not share classification schemes or spatial scales. Indicators are presented in this section in the order that they are considered later in the report.

Indicators that provide insight into the current condition of LEWI's natural resources are presented in two main categories: biodiversity and land cover. Indicators associated with threats and stressors are presented in five broad categories: climate change, biodiversity, land use, air and water, and other stressors. In the following sections, we present a scientific rationale for our choice of indicators. The results for indicators of current condition are presented in Section 3.3, and the results for indicators of threats and stressors are presented in Chapter 4.

2.6.1 Biodiversity

Plant and animal diversity data provide insight into the condition of the biota and threats facing the biota. To characterize the biota of LEWI, we focused on general measures of biodiversity for a wide range of taxonomic groups. We also summarized the number of endangered species within LEWI relative to the regional species pool. Non-native species have been identified as the second greatest threat to biodiversity (Wilcove et al. 1998). We quantified the number of non-native species within LEWI relative to those in the regional species pool. We also summarized the number of noxious weeds (plant species that are economically or ecologically problematic).

2.6.1.1 Species Richness

General measures of biodiversity can act as proxies for disturbance levels, as biodiversity has been shown to decline in response to increasing disturbance (Lawton et al. 1998). Certified Species Lists were obtained from the NPSpecies database (NPS 2009). Park service employees compiled the information in these lists from historical records, museum specimens and historical species distribution. More recent information was also provided by NPS staff (e.g., Brenkman et al. 2007). The Certified Species Lists may not be exhaustive. For example, Sayce's (2004) species list for Cape Disappointment State Park includes some plant species (e.g., *Scirpus americanus*, *S. maritimus*) that are not in the Certified Species List. However, we could not assess the accuracy of identifications in other sources and therefore elected to use only the Certified Species Lists in this analysis.

Species were organized by broad taxonomic groups: vascular plants, bryophytes, fungi, lichens, and animals. Species within each broad taxonomic group were further classified by taxon or growth form. Complete species lists for each taxon and growth form are provided as appendices to this report:

- Vascular plants (dicots, ferns, gymnosperms, horsetails, lycopods, and monocots) – Appendix 2

- Bryophytes (liverworts, peat mosses, and true mosses) – Appendix 3

- Fungi (bird’s nest fungi, boletes, club / coral / fan fungi, crust fungi, cup fungi, gilled fungi, jelly fungi, morel and false morel, parasitic fungi, puffball, secotioid fungi, slime mold, and spine fungi) – Appendix 4

- Lichens (crustose, foliose, and fruticose growth forms) – Appendix 4

- Animals (vertebrates: amphibians, birds, fish, mammals, reptiles; invertebrates: crustaceans, insects, mollusks) – Appendix 5

Data about total species numbers in each taxonomic group were used to assess the current condition of biodiversity (section 3.3.1).

For vascular plants, we compared the number of taxa present in LEWI against the regional species pool. We defined the species pool as all vascular plant species recorded in Pacific County, WA, and Clatsop County, OR. Data were obtained from the USDA Plants database (USDA 2010). Pacific County has 871 taxa, and Clatsop County has 974 taxa; together, these two counties have 1232 taxa in the database. However, an additional 55 taxa have been recorded at LEWI but are not present in the county-level data from the USDA Plants Database. Including these taxa brings the total for the regional species pool to 1287 taxa.

2.6.1.2 Endangered Species

Endangered species are an indicator of the health and extent of ecosystems. We cross-referenced each species against WA state (WDNR 2010), OR state (OBIC 2010), and federal (USFWS 2010) lists of endangered species statuses (see Table 2.9 for definitions). We focused only on species that were formally listed (Endangered, Threatened, Sensitive, Candidate) in at least one jurisdiction. The number of species in each status was quantified and used to assess the current condition of biodiversity (section 3.3.1). Plants and animals were considered separately.

For vascular plants, we compared the proportion of endangered species within LEWI to the proportion of endangered species within the regional species pool.

Table 2.9. Definitions of Endangered Species Act terms and abbreviations used in this document. Federal definitions are from USFWS (2005). Washington state definitions are from WDFW (2010). Oregon state definitions are from LCS (2004) and ODFW (2009).

Jurisdiction	Abbreviation	Definition
Federal	Endangered (E)	An animal or plant species in danger of extinction throughout all or a significant portion of its range.
Federal	Threatened (T)	An animal or plant species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
Federal	Candidate (C)	A plant or animal species for which FWS or NOAA Fisheries has on file sufficient information on biological vulnerability and threats to support a proposal to list as endangered or threatened.
Federal	Species of Concern (Co)	An informal term referring to a species that might be in need of conservation action.
WA	Endangered (E)	Any wildlife species native to the state of Washington that is seriously threatened with extinction throughout all of a significant portion of its range within the state. WAC 232-12-297, Section 2.4
WA	Threatened (T)	Any wildlife species native to the state of Washington that is likely to become an endangered species within the foreseeable future throughout a significant portion of its range within the state without cooperative management or removal of threats. WAC 232-12-297, Section 2.5
WA	Sensitive (S)	Any wildlife species native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats. WAC 232-12-297, section 2.6
WA	Candidate (C)	Fish and wildlife species that the Department will review for possible listing as State Endangered, Threatened or Sensitive. A species will be considered for designation as a state Candidate if sufficient evidence suggests that its status may meet the listing criteria defined for State Endangered, Threatened or Sensitive. WDFW Policy M-6001
OR	Endangered (E)	The identified species is in danger of extinction throughout all or a significant portion of its range.
OR	Threatened (T)	The species is likely to become endangered in the foreseeable future.
OR	Sensitive (S)	Naturally-reproducing fish and wildlife species, subspecies, or populations which are facing one or more threats to their populations and/or habitats.
OR	Candidate (C)	Either the species does not face imminent extinction or additional information is necessary to determine whether it may qualify as threatened or endangered.

2.6.1.3 Noxious Weeds

It is important to recognize that not all non-native species are equally problematic, and that some native species can also be problematic. For vascular plants, one way this is recognized is through the designation of noxious weeds (Table 2.10). Noxious weeds are typically highly competitive; difficult to control, and have large impacts on the habitats they invade. In Washington State, noxious weeds are designated at the state or county level. In Oregon, they are designated at the state level. There are three designations for noxious weeds in each state.

We cross-referenced the regional species pool against the 2010 noxious weed lists for Washington (WSNWCB 2010) and Oregon (ODA 2010). A total of 44 noxious weed species are present in the pool; 35 of these are non-native species. We then quantified the number of noxious weeds present in LEWI, and calculated the proportion of vascular plants designated as such in LEWI. We compared these data against the number and proportion of noxious weeds in the regional species pool.

Table 2.10. Oregon (ODA 2010) and Washington (WSNWCB 2010) definitions of noxious weed designations used in this document.

State	Designation	Definition
OR	A	A weed of known economic importance which occurs in the state in small enough infestations to make eradication or containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent. Recommended action: Infestations are subject to eradication or intensive control when and where found.
OR	B	A weed of economic importance which is regionally abundant, but which may have limited distribution in some counties. Recommended action: Limited to intensive control at the state, county or regional.
OR	T	A priority noxious weed designated by the Oregon State Weed Board as a target for which the ODA will develop and implement a statewide management plan. "T" designated noxious weeds are species selected from either the "A" or "B" list.
WA	A	Non-native species whose distribution is still limited. Preventing new infestations and eradicating existing infestations are the highest priority. Eradication of all Class A plants is required by law.
WA	B	Non-native species presently limited to portions of the State. Species are designated for control in regions where they are not yet widespread. Preventing new infestations in these areas is a high priority. In regions where a Class B species is already abundant, control is decided at the local level, with containment as the primary goal.
WA	C	Noxious weeds which are already widespread in the State or are of special interest to the state's agricultural industry. Class C status allows counties to enforce control if locally desired.

2.6.1.4 Non-native Species

Non-native plant species are estimated to be the second largest threat to native plant species after habitat conversion (Wilcove et al. 1998). Invasion by non-native plant species can fundamentally alter the structure and function of native ecosystems, which can have a cascading effect on other species reliant on those ecosystems.

We identified the nativity of each species recorded within LEWI based on information from the USDA Plants database (USDA 2010), NPS staff, and expert knowledge. The number of non-native species in each taxonomic group was quantified and used to assess the threat that non-native species pose to LEWI (Section 4.2). Flora and fauna were considered separately.

For vascular plants, we obtained the nativity of each species in the regional species pool from USDA (2010). We then compared the proportion of non-native species within LEWI to the proportion of non-native species within the regional species pool.

Results of this analysis are presented in Sections 4.2.3 and 4.2.4.

2.6.2 Land Cover and Recent Changes in Land Cover

2.6.2.1 Current and Recent Changes in Land Cover

To assess current land cover and recent changes in land cover, we used data from the Coastal Change Analysis Program (C-CAP). C-CAP is part of the National Landcover Database (NLCD), a nationally standardized database of land cover and land change information (NOAA

2009a). Data are developed from Landsat Thematic Mapper (TM) digital satellite imagery and are 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. We consolidated these classes into 7 derived land cover types (Table 2.11).

We obtained 1996 land cover data from the NOAA website, and 2006 land cover data from Nate Herold (NOAA Coastal Services Center, Charleson, SC). We used 2006 data to assess current condition with respect to land cover. We assessed short-term changes in land cover by examining the change from 1996 to 2006. Analyses were conducted at various scales (within individual units of LEWI, 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. Results of this analysis are presented in Section 3.3.2.

Table 2.11. Land cover types in LEWI and surrounding area (Pacific County, WA, and Clatsop County, OR).

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)
Wetland	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)
Marine and Shoreline	19 (Unconsolidated Shore), 20 (Barren Land), 22 (Palustrine Aquatic Bed), 23 (Estuarine Aquatic Bed)
Open Water	21 (Open Water)

2.6.2.2 Historical Land Cover

The historical vegetation on LEWI units within Oregon was assessed using data from the Oregon Natural Heritage Program (Kagan et al. 1999, Kiilsgaard 1999, Tobalske 1999). There was no equivalent analysis for units in Washington. We used data from two watersheds (Young's Bay system and the Skipanon). Five habitat types were defined: (1) forest (includes Sitka spruce-western hemlock, western hemlock, and Douglas-fir), (2) grassland (includes sand dune prairies, shrub swamp, and coastal headlands), (3) sand dunes (relatively new deposits), (4) wetlands (includes estuarine, riverine, palustrine and lacustrine wetlands), and (5) open water. Results of this analysis are presented in Section 3.2.8.

2.6.3 Climate Change

In March 2007, the Intergovernmental Panel on Climate Change (IPCC) released its most recent assessment of the present condition and future of the world's climate. This was followed by "The Washington Climate Change Impacts Assessment" (CIG 2009), the most reliable and up-to-date assessment of projected changes for the Pacific Northwest. Critical summary aspects of this report are detailed below, with particulars for LEWI.

We assessed four aspects of climate and climate change: temperature, precipitation, sea-level rise, and changes in marine pH (i.e., ocean acidification). For temperature and precipitation, we distinguished between analyses of short-term recent trend (1977-2006) and projected changes between historical (1961-1990) and future (2070-2099) periods. The results of these analyses are presented in Section 4.1.

2.6.3.1 Present Trends in Temperature and Precipitation

Temperature and precipitation are important indicators and directly affect habitat suitability and ecological processes. Using the period of 1970-1990 as a baseline, global climate models project increases in average annual temperature in the Pacific Northwest of 1.1 ºC (2.0 ºF) by the 2020s, 1.8 ºC (3.2 ºF) by the 2040s, and 2.9 ºC (5.3 ºF) by the 2080s (CIG 2009).

We analyzed changes in temperature at LEWI from 1977 to 2006 using the publicly available CRU TS 2.1 monthly climate dataset (Mitchell and Jones 2005; http://www.cru.uea.ac.uk/). 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). We focused on daily mean temperature; other variables available in this dataset are daily minimum and maximum temperatures, diurnal temperature range, precipitation, wet day frequency, frost day frequency, vapour pressure and cloud cover.

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/). We used these downscaled data 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 2008). 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).

2.6.3.2 Projected Changes in Temperature and Precipitation

We assessed the potential future threat of climate change 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). We summarized projected changes in average annual temperature, total annual precipitation, and seasonal precipitation. We compared climatic conditions averaged over a historical thirty-year period (1961-1990) 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.

2.6.3.3 Sea-Level Rise

According to the IPCC (2007), predicted sea level rises by 2090-2099 will range from 18 to 59 cm (7-23”) depending upon the emission scenario used. This estimate is likely relatively conservative because it does not include contributions from the melting of polar ice sheets. Changes in apparent sea level are a product of multiple processes. Along the Washington and Oregon coasts, the two most important processes are sea-level rise (predominantly driven by thermal expansion and snow and ice melt) and changes in the relative height of the land (subsidence and uplift).

We obtained data about historical sea-level rise along the Washington coast (Canning 1991). We also found data for estimated future sea-level rise for the southern and central Washington coast in 2050 and 2100 (Mote et al. 2008). We considered three scenarios: “low”, “medium”, and “very high” sea-level rise. These estimates are based on global sea-level rise projections, potential subsidence and uplift, and (for the “very high” estimate) contributions from melting ice masses. They are not predictions, but instead are meant to serve in an advisory capacity (Mote et al. 2008).

2.6.3.4 Ocean Acidification

Ocean acidification is a result of CO_2 being absorbed from the atmosphere. Since the Industrial Revolution, atmospheric CO_2 levels have increased from 280 to 385 ppm and ocean pH levels of have dropped from 8.21 to 8.10 (a decrease of 0.11 pH units). The Intergovernmental Panel on Climate Change (IPCC 2007) projects that atmospheric CO_2 levels in 2100 will be between 540 and 800 ppm – such changes may reduce ocean pH by an additional 0.3 units. Ocean acidification was implicated in significant marine bird kills during late summer/autumn 2009 along the Oregon and Washington Coasts and in increasing frequencies of red tides along Pacific Beaches and within Puget Sound (Welch 2009). In addition, recent upwellings along the western North America continental shelf have led to enhanced and prolonged periods of aragonite undersaturation (Feely et al. 2008). Such waters are corrosive (i.e., “acidified”) to any aragonitic calcifying organisms – many of which are critical in the food chain and are important directly in the culture and economy of shellfish.

All current information about ocean acidification is provided at much larger spatial scales than LEWI and its surroundings; however, the coastal units of LEWI are located near the critical zone of upwelling that occurs off of the west coast of North America. As consequence, changes in ocean currents, timing, location and duration of upwelling, and acidification will impact marine life and associated freshwater and terrestrial species. We reviewed the published literature for information that was relevant to LEWI.

2.6.4 Land Use

Land use is one way that humans directly affect the natural resources of an area. Habitat destruction has been identified as the greatest threat to biodiversity (Wilcove et al. 1998). We focused on four measures of land use: impervious surfaces, road density, human population, and zoned land use.

2.6.4.1 Impervious Surfaces

The percentage of a watershed covered in impervious surfaces is a key indicator of watershed condition and, when compared to other watersheds or over time, is an indicator of stressors to that watershed. Typical anthropogenic impervious surfaces include roads, roofs, parking lots, driveways, and sidewalks. In addition, bare rock and compacted soils are mostly impervious. The amount of impervious surface has been recognized as a key indicator in assessing the degree and extent of development, especially urbanization, and is commonly used in urban land use classification (Lu and Weng 2006). With the increase in urban sprawl, the amount of impervious surfaces has become a key issue in habitat health (Arnold and Gibbons 1996; Brabec et al. 2002).

An increase in impervious surfaces initiates a chain of events that cause hydrologic changes including changes in flow regime, aquatic habitat structure, water quality, water temperature, biotic interactions, and food sources (Karr 1991). For example, impervious surfaces increase runoff, decrease infiltration, collect pollutants, and accelerate the connectivity between a rainfall event and nearby wetlands. According to Lombard (2006), the majority of water pollution problems in the Puget Sound are related to non-point source stormwater runoff from human-altered landscapes. Streams in impervious watersheds tend to be flashier (i.e., have higher high water flows and lower low water flows). During low flow periods, stream water temperatures tend to be higher, which reduces dissolved oxygen concentrations. 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 or robust vegetation growth, reduce shading and evaporative cooling, have higher thermal conductivities than vegetated surfaces, and collect solar heat, thus producing urban “heat islands.”

Total impervious area (TIA) is the "intuitive" definition of imperviousness: that fraction of the watershed covered by constructed, non-infiltrating surfaces such as concrete, asphalt, roads, paths and buildings. Konrad and Burges (2001) suggest a critical value of 20% total impervious area. For comparison, Dinicola (1989) assumed that low density residential land uses (1 unit per 2-5 acres) had a TIA of 10%, suburban areas had a TIA of 35%, and commercial areas had a TIA of 90%.

We quantified impervious surfaces within the LEWI units 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%). We considered the total amount of impervious area (summing the percent impervious surface of each pixel) and the proportion of each pixel that was impervious. Finally, we overlaid the impervious surface layer and the 2006 land cover type layer (Section 2.6.2.1) and calculated the total impervious surface by cover type. Results of this analysis are presented in Section 4.3.2.

2.6.4.2 Road Density

Roads are prominent and intrinsic components of development, but have complex ecological, economic, and social impacts on ecosystems and watersheds (Forman and Alexander 1998). The most significant effect of roads is fragmentation of landscapes and habitats, but they also introduce chemical contaminants and invasive species to the ecosystem (Trombulak and Frissell 2000; Forman and Deblinger 2000; Forman et al. 2003; Havlick 2002). Associated noise pollution and edge effects can negatively impact the density of bird populations and small animals, as does mortality due to traffic (Lin 2006). Roads also alter the hydrologic network and increase human use of nearby areas. At larger scales, these impacts accumulate, thus changing and redefining landscape patterns (Hawbaker et al. 2006). Road influence zones extend tens to hundreds of meters from the road surface (Riiters and Wickham 2003).

Road density is an indicator of the threats facing an ecological community, as well as fragmentation of wildlife habitats and natural landscapes. Riiters and Wickham (2003) found that roads are precursors to future impacts because they make possible land development and the further expansion of the road network itself. Road density can be used as a surrogate measure for human activity and is generally indicative of habitat condition (e.g., AGBRS 2009). There is scientific precedent for using the concentration of roads in a given geographic area (road density) as an indicator (US Forest Service 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).

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. Here, we used road density as an indicator of land use and ecosystem health. We obtained road locations from WDNR (2009). We only included roads classified by DNR as “transportation roads” in our analysis. Road data were only available for Washington, so this analysis was restricted to the three LEWI units in that state. We compared road density data within each unit to the density in the rest of Pacific county. Historical road density data were not available. Results of this analysis are presented in Section 4.3.3.

2.6.4.3 Human Population

Human population data provide insight into several priority NPS issues: urban encroachment/ rural development, road and trail development, and recreation. Population data are most consistently obtained and reported on a county basis, so we based our analyses on Pacific and Clatsop Counties. Population data were compared for the period from 1900-2030. We obtained historic population data (1900-2008) from US censuses (www.census.gov/population). Population projections (2010-2030) for Pacific County were obtained from the Office of Financial Management, State of Washington. Population projections for Clatsop County were obtained from the Department of Administrative Services, State of Oregon.

Population data were compared in terms of total population, population growth rate, and population density. Population growth rate was calculated as the annual rate of change between one census and the next; 2008 data were not included in these calculations. Population density was calculated as total population divided by land area. Results of this analysis are presented in Section 4.3.4.

2.6.4.4 Zoned Land Use

Land use can adversely affect ecosystems and biodiversity by degrading air, soil, and water, and destroying, modifying, and fragmenting habitats (DeFries et al. 2004, Foley et al. 2005). Urbanization is one of the leading causes of species endangerment and extinction both in the US and globally (Czech et al. 2000, McKinney 2006, McDonald et al. 2008). Urbanization has been shown to reduce local species diversity, particularly in bird populations (Marzluff 2001, Chace and Walsh 2006, McKinney 2006). Habitat alteration from urbanization can be drastic and largely irreversible, often far outweighing any negative ecological consequences associated with forestry, traditional farming, and other less intensive land uses (Marzluff and Ewing 2001).

Zoned land use data were collected from the Planning Departments of Clatsop County, OR, and Pacific County, WA. Each county has their own zoning classification system. The Clatsop County system includes 42 zones (Clatsop County 2007). The Pacific County system includes 18 zones (Pacific County 2004). We reclassified each zoned land use into one of six broad categories:

- Agriculture – includes animal husbandry, cranberry growing areas, aquaculture and shellfish areas, and livestock grazing areas.
- Park and Conservation Areas – state and federal parks, wildlife refuges, freshwater lakes, and natural areas.
- Rural Forest
- Rural Mixed-Use – rural lands and low-density rural residential areas, along with some agricultural and forestry practices.
- Multiple-Use Development – cities and incorporated areas, areas zoned for commercial or industrial use, and mixed-use.
- Rural Residential – low and high-density residential neighborhoods along with areas for recreation and tourism uses.

A crosswalk between the detailed classification systems of each county and our classification system is provided in Appendix 8.

We examined the proportional distribution of zoning categories within LEWI units and within the counties themselves. Results of this analysis are presented in Section 4.3.5.

2.6.5 Air and Water

An extensive report on coastal water resources and watershed condition within LEWI was prepared by Klinger et al. (2007a). We therefore devoted less attention to these resources compared with LEWI's terrestrial resources. However, we did summarize data about LEWI's air quality, extent and type of wetlands, regional surface water quality, and groundwater.

2.6.5.1 Air Quality

We reviewed information from the National Park Service, Oregon State Department of Air Quality (http://www.oregon.gov/DEQ/AQ/), Washington State's Department of Ecology's Air Quality Program (http://www.ecy.wa.gov/programs/air/airhome.html), Olympic Regional Clean Air Agency (http://www.orcaa.org/), and US Environmental Protection Agency's Air Pollution monitoring and trends program (http://www.epa.gov/airtrends/index.html). These sources suggest that there are no specific measures or sources of air pollution in the areas of Clatsop or Pacific Counties that would be part of LEWI's airshed. Local problems might arise with specific chemicals (from spills) or particulates (from fires or wood burning stoves), but reports did not list any specific incidents. Results of this analysis are presented in Section 4.4.2.

2.6.5.2 Wetland Classification

The National Wetlands Inventory (NWI; http://www.fws.gov/wetlands/) is a US Fish and Wildlife Service program that inventories and maps aquatic systems. It uses the Cowardin Classification System (Cowardin et al. 1979) to classify polygons into five main ecological systems (marine, estuarine, riverine, lacustrine, and palustrine) and subcategories within each ecological system. The NWI provides a nationally consistent definition of wetlands and deepwater habitats for mapping and monitoring. Data and maps derived from NWI are used to track gains and losses of wetlands. A visual representation of the Cowardin Classification System is provided in Appendix 6. We used the NWI system to describe wetlands and other aquatic ecosystems within each park. Results from this analysis are presented in Section 3.3.4; a detailed summary is available in Appendix 7.

2.6.5.3 Surface Water Quality

Surface water quality reflects stressors within the aquatic environment and throughout watersheds. We reviewed several recent reports about water quality in and around LEWI (e.g., Herger and Hayslip 2000; Hayslip et al. 2006; Klinger et al. 2007a; EPA 2009). Results of this analysis are presented in Section 4.4.3.

2.6.5.4 Groundwater

Groundwater, as an important natural resource, may be depleted or contaminated. Wells provide access to groundwater; if the rate of recharge is inadequate to replace the amount removed, the water table may drop. Wells also create a pathway from the ground surface to the water table if the well is improperly sealed. Contaminants from the surface may reach the ground water. Injection wells specifically introduce fluids into the ground; the fluid may be clean water for groundwater recharge, or it may be potentially harmful, when injection is used for the disposal of hazardous waste (WDOE 1997).

In the recharge zones of aquifers, solid and liquid wastes can degrade groundwater; two common sources of pollution are leachate from municipal or private landfills and poorly treated effluent from waste systems. Septic systems can effectively treat home wastewater, but may fail to do so if they are overloaded, sited on porous soils such as sands or gravels, or placed too close to one another or too close to water wells.

Underground storage tanks that leak may be a source of groundwater pollution. Examples of solutions commonly leaked into ground water include gasoline from service stations, cleaning fluids, heating oil, and any number of liquids that have been used to wash machinery, equipment, vehicles, etc.

Agricultural practices can result in groundwater pollution. Runoff from feedlots or dairies is common. Pesticides and fertilizers may be directly applied to the land or these substances and fuels may leak and pollute runoff. Raw materials storage (ensilage, wood waste, manure) may result in infiltration of pollutants into the ground water. Application of too much fertilizer, application at the wrong time, poorly graded fields, or absence of tailwater ponds may result in contaminants such as nitrates entering the groundwater.

Pollutants commonly measured because of their presence in contaminated water systems include nitrate, bacteria, pesticides, volatile organic compounds (VOC's), and metals (Cole 2004). Nitrate levels above 2 mg/l indicate anthropogenic activities. Nitrate sources include dispersed non-point sources such as agricultural activities or septic systems, and point sources that generate nutrient-rich waste products. Detection of bacteria in groundwater may indicate contamination from non-point sources like septic systems or from point sources that handle manure or store waste or sludge. Poor well construction may also result in bacterial contamination. Pesticides, VOC's and metals are generally found in isolated samples of groundwater, and their presence may be linked to point sources such as landfills, or to transitory events (they are measured but do not reappear) (Cole 1997).

Results of this analysis are presented in Section 4.4.4.

2.6.6 Other Stressors

2.6.6.1 Diseases

The presence of specific pests or diseases, other than Swiss needle cast on young Douglas-fir, were not specifically mentioned in literature or visits. However, trees will become susceptible to root and stem rots as they age. For old-growth Douglas-fir, Sitka spruce, and western hemlock, the concern is not the disease *per se*, but the fact that there are relatively few individuals within the park. Climate change may impact the prevalence of diseases in ways that we are not yet able to predict. Results of this analysis are presented in Section 4.5.1.

2.6.6.2 Disturbances

Forests of this region have been historically subjected to fire and wind as disturbance agents (Agee 2000) and, if disease and insect problems involve whole stands, then these factors go from being factors responsible for individual and small group mortality to a disturbance. We reviewed the importance of these and other disturbances (natural and anthropogenic) for the natural resources of LEWI. Results of this analysis are presented in Section 4.5.2.

2.7 Methods Unique to LEWI

Two transects were developed to illustrate spatially the interactions among geology, soils, aquatic systems, terrestrial vegetation, and stressors. Specific points were selected along each transect (most represented a point of significant change in some landscape feature). At each point, elevation, position, landform, and general overstory and understory species were described. Disturbances, whether natural or anthropogenic, were also noted at each point.

Transect A is a profile of the Fort to Sea Trail and stretches from the Lewis and Clark River Trail to the Pacific Ocean. It was completed in March 2009 by Hinckley and Wang. Transect A is used in Section 3.2.8.1 to describe in greater detail the distribution of historical vegetation and wetland types, in Section 3.3.5.1 to describe interactions between resource types, and in Section 4.7 to provide a landscape perspective on the present condition and trend of the vegetation and of stressors.

Transect B went from the Pacific Ocean along the south side trail at Beard's Hollow and then over North Head to the North Head Light House at Cape Disappointment State Park. It was completed in May 2009 by Hinckley, Ellison, and others. It is used in Section 3.3.5.2 to describe interactions between resource types, and in Section 4.7 to provide a landscape perspective on the present condition and trend of the vegetation and of stressors.

Chapter 3 - Park Description

Lewis and Clark National Historical Park (LEWI) is located in the Pacific Northwest, in the states of Oregon and Washington. The Pacific Ocean forms the western boundary of LEWI and the Columbia River divides the northern and southern units of LEWI. The Park commemorates and features the 1805 – 1806 exploration and over-wintering of the Lewis and Clark Expedition.

Critical cultural, historical and ecological features are spread over two counties in two states. LEWI is a major component of a regional effort to preserve and enhance ecological features in the Lower Columbia River; partners in this effort include the Columbia River Estuary Study Taskforce (CREST: http://www.columbiaestuary.org/), Lower Columbia River Estuary Partnership (http://www.lcrep.org/), Lower Columbia River Watershed Council (http://www.lcrwc.com/), the Washington State Governor's Salmon Recovery (http://www.governor.wa.gov/gsro/regions/lower.asp), and the Oregon Sand Dunes (e.g., The Nature Conservancy (http://www.nature.org/wherewework/northamerica/states/oregon/). An element of Maya Lin's Confluence Project (http://www.confluenceproject.org/) is present at Cape Disappointment State Park. It is situated at the mouth of the Columbia River and was dedicated on November 18, 2006 (http://journeybook.confluenceproject.org/#/site/cape-disappointment/art-installations/site/).

3.1 Size and Location of Park

Lewis and Clark National Historical Park is made up of 13 park units located on a 40-mile stretch of the Pacific coast from Long Beach, WA to Cannon Beach, OR (Figure 3.1, Table 3.1). The units extend from Ecola State Park in the south to Cape Disappointment State Park in the north. All sites are within 15 km of the Pacific Ocean. This report focuses on the seven units that contain significant natural resources: Cape Disappointment State Park, Clark's Dismal Nitch, Ecola State Park, the Fort Clatsop unit, Fort Stevens State Park, Station Camp, and Sunset Beach State Recreation Area.

Figure 3.1. Map of Lewis and Clark National Historical Park and its various units.

Table 3.1. Statistics about the various units of LEWI. Acreages were provided by NPS staff. Units that are a focus of this report are indicated in bold italics.

Unit	State	Owner or Manager	Area (ha)	Area (acres)
1. Cape Disappointment State Park (formerly Fort Canby State Park)	*WA*	*Washington State Parks[1] and other land owners including USDI Bureau of Land Management, National Park Service and US Army Corps of Engineers.*	*504.2*	*1246*
2. Clark's Dismal Nitch	*WA*	*National Park Service[2]*	*76.1*	*187.94*
3. Ecola State Park	*OR*	*Oregon Parks and Recreation Department[3]*	*527.7*	*1304*
4. Fort Clatsop Unit[4]	*OR*	*National Park Service*	*513.5*	*1269*
5. Fort Columbia State Park	WA	Washington State Parks	240.0	593
6. Fort-to-Sea Trail Corridor	OR	National Park Service, Oregon Parks and Recreation Department & others	2.2	5.50
7. Fort Stevens State Park	OR	Oregon Parks and Recreation Department	1618.7	4000
8. Memorial to Thomas Jefferson	WA	National Park Service (on US Army Corps of Engineer Land) (proposed)	8.1	20
9. Netul Landing	OR	National Park Service	23.4	57.91
10. Saltworks	OR	National Park Service	0.1	<0.25
11. Station Camp	*WA*	*National Park Service (including possible conservation easement)*	*157.9*	*390.12*
12. Sunset Beach State Recreation Area	*OR*	*Oregon Parks and Recreation Department*	*64.7*	*160*
13. Yeon Property	OR	National Park Service (recently purchased)	42.3	104.5
Total Authorized Boundary		WA: Cape Disappointment, Station Camp, Dismal Nitch OR: Fort Clatsop Unit, Sunset Beach, Yeon Property, Salt Works	1358.9	3358
Total Area Encompassed by all units			3745.4	9255

[1] Washington State Parks (http://www.parks.wa.gov/)

[2] National Park Service (Lewis and Clark National Historical Park: http://www.nps.gov/lewi/index.htm)

[3] Oregon Parks and Recreation Department (http://www.oregon.gov/OPRD/PARKS/index.shtml)

[4] Total area of this unit includes the following: original Memorial (125.5 acres), Weyerhauser acquisition (922.70 acres), Falleur (36.06 acres), LCNPA - Otter Pt. (33 acres), LCNPA - Netul (57.91 acres), Ness (81.50 acres), Tagg Farm easement (0.95 acres), Ft to Sea Trail corridor (5.50 acres), O'Casey/Angus (7.94 acres).

3.2 Physical Setting and Management Framework

The physical, biological, and cultural attributes of Lewis and Clark National Historical Park (LEWI) are described by Wetherbee and Hall (2006), and the aquatic resources of LEWI are described and evaluated by Klinger et al. (2007a). This section provides an overview of the location of LEWI and its individual units, describes its general features, provides a brief overview of the history of the site, and covers human uses of the area over time.

3.2.1 Setting and Management

Fort Clatsop National Memorial was established in 1958 "for the purpose of commemorating the culmination, and the winter encampment, of the Lewis and Clark Expedition following its successful crossing of the North American Continent" (PL 85-435, 72 Stat. 153). Fort Clatsop was the first U.S. military post west of the Rocky Mountains, although the expeditionary party only occupied it for a little over three months. The work done by the party in collecting and reporting flora and fauna contributed to an early understanding of the natural resources of the United States. The depiction of the Chinook peoples as recorded in the expedition's reports is considered to be among the best-documented post-contact views of daily life and culture among these tribes (Cannon 1995). In addition to the obvious historic importance of LEWI, the various units contain a variety of ecosystems ranging from soft sediment intertidal areas in the estuary, extensive sandy shorelines and dunes, rocky headlands, temperate rainforests, riparian zones, and swamps, as well as rural land used for farming, dairying, and grazing (NPS 2006a).

Since the National Memorial designation was made in 1958, the Park has continued to expand. In 1979 the 0.2 acre Salt Works parcel was purchased in Seaside. The Fort Clatsop unit's authorized boundary expanded to about 1,200 acres in 2002 under the Fort Clatsop Boundary Expansion Act. A major expansion came in 2004 with the passage of the Lewis and Clark National Historical Park Designation Act, which added units in Washington (Cape Disappointment State Park, Station Camp, and Dismal Nitch) and additional sites in Oregon. In 2006, the Memorial Site was greatly expanded with the addition of 1200 acres purchased from Weyerhaeuser and formerly held by Willamette Industries. The Yeon Property was recently purchased. Currently, the authorized boundary for LEWI encompasses 1359 ha (3358 acres) in 7 units.

There are three units in Washington state. The largest is Cape Disappointment State Park, located on the peninsula at the extreme south-western tip of Washington and including twenty-seven miles of beachline. While this unit continues to be managed by Washington State Parks, it is within the legislative boundaries of LEWI as defined in the 2004 LEWI designation act. The other two Washington units are located upstream along the Columbia River. They are Middle Village/Station Camp, a site of both pre- and post-contact international significance located west of the Astoria bridge, and Clark's Dismal Nitch, a smaller unit located just east of the Astoria Bridge.

All of the other existing units of LEWI are located in Oregon. The Fort Clatsop unit is located in a forested area on the Lewis and Clark River southeast of Astoria. The Fort to Sea trail connects the Fort Clatsop unit to the ocean. It terminates at Sunset Beach State Recreation Area, which is owned by Oregon State Parks but is within the legislative boundaries of LEWI and is cooperatively managed by the two agencies. Directly south of Sunset Beach is the recently acquired Yeon property. Collectively, these two properties comprise the Sunset Beach/Yeon unit.

Three state parks have special cooperative relationships with LEWI. Ecola State Park is located north of Cannon Beach, Oregon, and includes nine miles of coastline and the most pristine forests of any of the units. Fort Stevens State Park is located on the peninsula at the extreme north-western tip of Oregon. It is the largest unit (4,000 acres) and includes the largest amount of salt marsh present in the units. Fort Columbia State Park is located on the Columbia River adjacent to the Station Camp unit in Washington. It is not included in this study, though Ecola and Fort Stevens State Parks are.

3.2.2 Climate

The climate of LEWI is mild, maritime, and Mediterranean (Table 2.3). Precipitation is between 180 and 230 cm (70 – 90"), with heavier quantities falling on the higher hills, and is most abundant in autumn and winter; growing season rainfall is typically less than 10% of the annual total. There are frequent periods of summer fog; winter snow is infrequent, but does increase with elevation and distance inland. During storms, winds can exceed 160 km/h (100 mph) (e.g., December 1-2 storm of 2007).

3.2.3 Air Quality

LEWI is designated a Class II Airshed. This designation was established by Congress to facilitate the implementation of air quality provisions of the Clean Air Act. It allows a moderate increase in certain air pollutants. The Clean Air Act (Section 118) requires that the National Park Service comply with all federal, state, and local air pollution control laws. In Oregon, air quality related concerns are managed by the Oregon Department of Environmental Quality (ORDEQ). Clatsop County, Oregon, does not have county level ordinances regarding air pollution: they defer these concerns to ORDEQ. In Washington, air quality related concerns are managed by the Washington State Department of Ecology (WADOE). Pacific County, Washington, defers concerns to WADOE and the Olympic Regional Clean Air Agency.

Air quality monitoring is not conducted at LEWI by either ORDEQ or WADOE because coastal winds generally maintain clean air conditions in the area. Under certain conditions, air quality can be occasionally impacted by nearby forest slash burning and from living history fires conducted in association with re-enactments conducted at Fort Clatsop. Odors from pulp mills in western Washington can infrequently be detected, but such impacts are generally of short duration. Increasing industrial and urban development in the surrounding area may cause air quality problems in the future.

The National Park Service Air Resources Division (ARD) administers an extensive Air Monitoring Program that measures air pollution levels in national parks. The purpose of the Program is to establish current air quality conditions and to assess long-term trends of air pollutants that affect park resources. It has three primary components: visibility, gaseous pollutants (mainly ozone), and atmospheric deposition (wet and dry) (http://www.nature.nps.gov/air/monitoring/index.cfm). However, it is not implemented in LEWI since it is a 'Class II' air quality area.

3.2.4 Geology

LEWI is within the Columbia embayment of the Coast Range Province. This area is characterized by Cenozoic era sedimentary strata capped by Eocene and Oligocene basaltic lavas that are exceptionally thick (McKee 1972). The surface geology that is currently visible consists of Tertiary marine and non-marine sediments and basalts from extensive basalt flows associated with the Miocene (NPS 2006a).

The geology of this region is shaped by five major historical events that can be seen in the present landscape and landforms (Alt and Hyndman 1978, 1984; Lund 1972; Mueller and

Mueller 1997; Schlicker et al. 1972; Schuster 2005; Walsh 1987). Much of the area is underlain by ~60 MYa basalt (late Paleocene to early Eocene) including basalt from the Crescent Formation, which appears in rock found at Cape Disappointment (Babcock and Carson 2000), Fort Columbia, and Station Camp. During the Eocene, sedimentary material (sand- to mudstones) were deposited on this basal or sea floor material. During the Miocene, there were repeated basalt flows from eastern Washington and Oregon that reached the coast in either narrow or broad flows. Most prominent of these is the basalt intrusion from the Grande Ronde Flow that is prominently displayed in Ecola State Park. Uplifting during these periods resulted in exposure and erosion of these deposits. Beginning about 8500 years BP, there was the development of extensive sand and alluvial deposits as sea level began to acquire its present elevation (Cooper 1958; Meyers 1994; Rankin 1983; Reckendorf et al. 1985, 2001; Woxell 1998). Following the initial construction of the jetties at the mouth of the Columbia in 1868, there were greatly accelerated deposits of sand both north and south of the jetties (Allan and Hart 2005).

Because of the interaction between the Juan de Fuca Plate and the North American Plate, there have been a series of historical, major subduction earthquakes off the Coast that have produced significant tsunamis (Geist 2005, Meyers et al. 1996). The most recent was the Cascadia earthquake in 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). Whether the interaction of these plates will continue to produce large earthquakes or not is under question (Dziak 2006).

From this geological history, today one witnesses a number of prominent landforms within LEWI. These landforms are (1) the sedimentary hills that make up the Fort Clatsop unit, (2) the basalt remnants at Cape Disappointment, McKenzie and Tillamook Heads, the summits of Bald and Clark's Mountains in Ecola State Park, and Scarboro Hill of Fort Columbia State Park, and (3) the sand and alluvial depositional lowlands which include the sand dune plains of NW Clatsop County (Fort Stevens, Sunset Beach and the Yeon Property), sand deposits and dunes of Cape Disappointment and the Lewis and Clark River flood plain and tidal flats alluvium.

3.2.5 Soils

In Clatsop County, the associated geological history and landforms have led through physical and chemical weathering to five different soil categories (Smith and Shipman 1988). These are soils found in (A) flood plains, terraces, and dunes (13% of Clatsop County), (B) soils on sedimentary and basalt mountains (43%), (C) warm soils on flood plains and terraces (3%), (D) warm soils on mountains (29%), and (E) 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.

For Pacific County (north of the Columbia River in Washington), a similar distribution of soil types is found. A much more comprehensive perspective on the interaction between geology, soils, and vegetation is presented in Section 3.3.5.

3.2.6 Interaction of Geology and Soils
Soils, particularly those derived from mudstone, are prone to movement and occasionally large slides 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 wind throw (Agee 2000).

3.2.7 Aquatic and Terrestrial Systems
The location of the various units of LEWI next to the Columbia River and the Pacific Ocean, the strong Mediterranean, maritime climate, the four principle geological features and associated soils (sedimentary and basalt formations and the sand and alluvial deposits) result in a rich and diverse system of marine and freshwater and terrestrial habitats. Elevation ranges are small, but slopes and aspects as well as proximity to summer on-shore wind and associated humidity result in a rich flora and fauna. European-American settlement has resulted in land use changes, dramatic alterations in riverine and estuary systems as a result of channelization and diking, extensive logging and subsequent replanting often with Douglas-fir, changes in beach deposition and erosion due to the construction of the north and south side jetties on the Columbia River, cessation of Native burning and initiation of heavy grazing on the Clatsop plains, road construction and the introduction of non-native species.

Watersheds are delineated by the US Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 sub-regions, 352 accounting units, and 2262 cataloging units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6 digit accounting units and the 8-digit cataloging units are generally referred to as basins and sub-basins, respectively. HUC is defined as the Federal Information Processing Standard (FIPS) and generally serves as the backbone for the country’s hydrologic delineation. The various units of LEWI are within the Lower Columbia/Young’s Bay Subbasin (HUC 17080006, in the Lower Columbia Basin) and the Necanicum Subbasin (HUC 17100201, in the Northern Oregon Coastal Basin).

The HUC system is rarely used in Washington State because the system is at variance with the State’s Water Resource Inventory Area (WRIA) system, which pre-dates the HUC system and is mandated by statute. Washington’s WRIA system, developed in the 1960s, specifies 25 WRIAs in Washington’s coastal zone, whereas the HUC system identifies 28 HUC-8 watersheds in the same region. The units of LEWI within Washington State are located in WRIA 24 (Willapa).

3.2.8 Historical Vegetation
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). The area was logged in the 1850s and converted to residential, agricultural, and industrial uses. By 1900, the old

growth forests had disappeared from Fort Clatsop. A few remnant old-growth stands can be found in both Ecola State Park and Cape Disappointment (see Section 3.3.3). The second growth forest was logged in the early 1900s. The forest is considered an important part of the cultural landscape and the NPS is attempting to use it to help visitors better understand the historic significance and visual condition of the site at the time of Lewis and Clark's visit.

The historical vegetation for the LEWI units in Oregon is shown in Figure 3.2. 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. Grasslands and sand dunes were present at Fort Stevens and Sunset Beach. Ecola State Park was mostly forested.

Wind, mainly from the southwest, is the major disturbance factor affecting vegetation at LEWI. It is thought that the historic vegetative pattern is mainly a result of infrequent wind disturbances which opened small openings suitable for the establishment of Sitka spruce. Fire also plays a role but intervals between major fires are thought to be very long. Although infrequent, wildland fires can be severe and serve as a stand replacement event. Fire was likely used by Native Americans on the Clatsop dune prairies and on the coastal headlands.

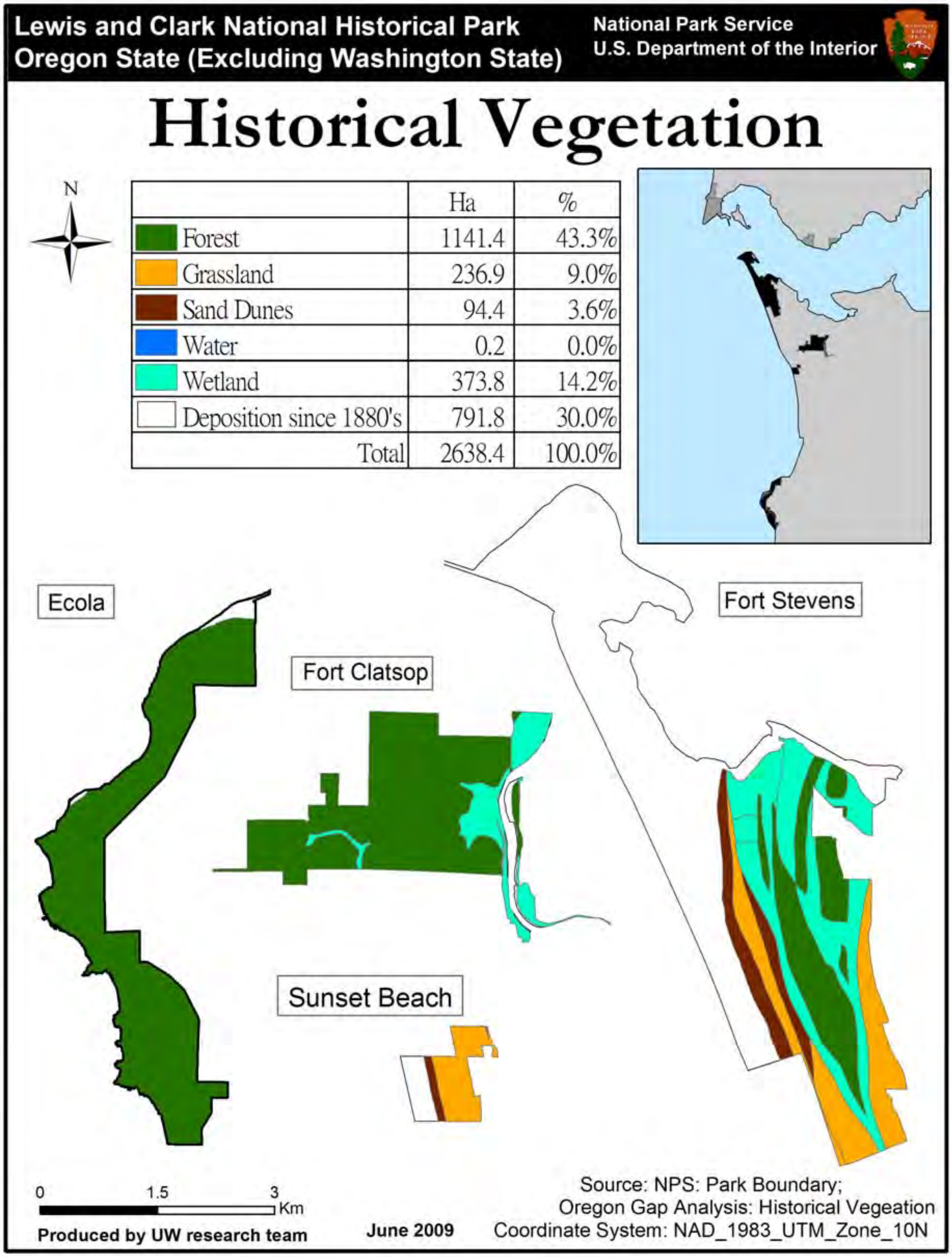


Figure 3.2. Historical vegetation of the Ecola, Fort Clatsop, Fort Stevens, and Sunset Beach units. Comparable data have not been compiled for units in Washington.

3.2.8.1 Transect A: Fort to Sea Trail

Transect A follows the Fort to Sea Trail from the Lewis and Clark River to the Pacific Ocean (Figure 3.3). It begins at the canoe landing near the confluence of Alder Creek and the Lewis and Clark River. Although it doesn't follow a straight line, it comes close to representing a true cross-section. And, although information in Figure 3.3 appears complex, it tells a very simple story. Beginning near sea level at the Lewis and Clark River, the trail skirts a recovering estuary and ascends to a bench that has the most structurally diverse and oldest forest of the Fort Clatsop Unit. It then enters second- and third-growth forests containing an increased presence of western hemlock and Douglas-fir. As a result of the December 2007 windstorm, there is extensive blow down of trees – in some cases all trees in areas of several acres. Upon reaching the overlook at the summit (~100 m (325') elevation), the trail descends steeply in a series of switch-backs through a young, planted Douglas-fir forest to a branch of Perkins Creek. This forest has been damaged by Swiss needle cast. For the next distance, the trail is either next to Perkins Creek, crossing an incoming branch, or upslope in plantation Douglas-fir stands. Perkins Creek illustrates a relatively rapid return to a healthy riverine – palustrine system with extensive red alder and Sitka spruce trees, beaver dams, and associated wetland plants. After crossing the western fork of Perkins Creek, the trail leaves the sedimentary hills, crosses the alluvial plain associated with the Skipanon River, and then ascends and descends a series of 10 relatively parallel dunes to the beach at the Pacific Ocean.

Geologically, there are only three important features – sedimentary rocks (mostly sandstones), alluvial deposits, and sand deposits. There are 14 different soil classifications (depending upon slope, parent material, and time), though these can be easily grouped. For example, the soils become increasingly younger, and are all derived from sand deposits, as one goes west from the Skipanon River. The soil series names change as the age of deposit change (and associated weathering and profile formation). East of the Skipanon River, the soils are similarly simple although there are many different series shown. Basically there are three soil types – those derived from sedimentary sandstone rock and occurring on slopes of different steepness, those derived from sand deposits between the Skipanon and the Pacific Ocean, and those derived from alluvial deposits in association with the Skipanon or Lewis and Clark Rivers.

The associated original/historical ecosystems are also portrayed and likely fell into (from the Lewis and Clark River to the Pacific Ocean) estuarine, forest (old-growth Sitka spruce/western hemlock), palustrine, riverine, lacustrine, prairie and marine systems.

3.2.8.2 Transect B: Cape Disappointment State Park

Transect B (Figure 3.11) starts at the Pacific Ocean and runs east along the Discovery Trail to the parking lot. In then joins the Westwind Trail to the North Head Lighthouse parking lot, and follows the North Head Trail to the lighthouse. Historical vegetation in the first section (Pacific Ocean to Discovery Trail parking lot) was likely a beach-dune or a beach dune with saltwater marsh. Between the parking lots, the vegetation was likely old-growth Sitka spruce forest. The area around the North Head Lighthouse would have been dominated by herbaceous and shrubby headland vegetation.

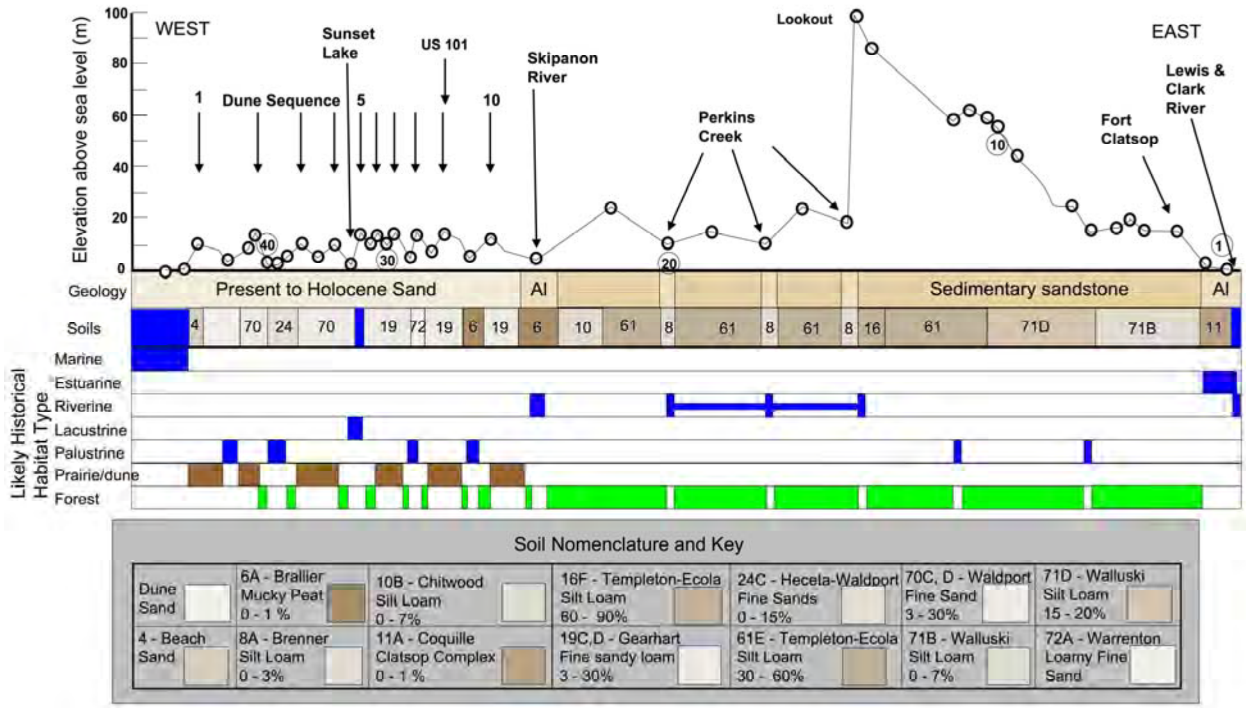


Figure 3.3. Transect A, following the Fort to Sea Trail from the Lewis and Clark River in the east (right side) to the Pacific Ocean in the west (left side). Trail was walked and recorded from right to left, hence the sample point numbering scheme. At each of 47 measurement points, elevation was measured and general habitat condition and over- and understory species composition were described. Habitats shown above represent those thought to have existed at the time of Lewis and Clark's occupation at Fort Clatsop. Soil series and bedrock/parent material geology are also provided. The Coquille-Clatsop and Walluski classifications include silt loams, muck, and silty clay loams. The Coquille-Clatsop soils have wetness and flood hazard limitations. The Walluski soils are limited by slow permeability and susceptibility to compaction. This profile is repeated in Figure 4.7, where it is drawn to emphasize the condition and trend of the habitats.

3.2.9 Cultural History

Native Americans made both sides of the Columbia River their homes and their presence was noted by Lewis and Clark during their visit in 1805 and 1806. A very detailed cultural history, particularly of the Fort Clatsop Memorial Site, is provided in chapter 2 of Cannon (1995).

The 120 acre parcel originally designated for the Memorial is listed on the National Register of Historic Places. This listing is for both natural processes and cultural values and includes the Fort replica, wetlands, sloughs, estuary and the spruce/hemlock forests. The 120 acres is zoned "historical" which defines the landscape as a cultural landscape within NPS management policies (Fort Clatsop National Memorial 1995).

The Oregon Historical Society began acquiring land for the Memorial in 1901 (approximately 3 acres) and added another two acres in 1928; a bronze marker was then placed at the site. A replica of the Fort was constructed in 1955 by local organizations. This effort helped establish the National Memorial. The Fort replica is the focal point for a variety of interpretative and living history programs which are designed to help visitors understand the significance of the Lewis and Clark Expedition and to help them appreciate the role of local Indians in the success the journey.

Additional historical features include:

- A spring located about 50 yards north of the Fort replica; it is believed to have been used by the Expedition members.

- A canoe landing and storage area located about 250 yards south and east of the Fort replica.

- An approximately two and one-half mile trail to the coast used by the Lewis and Clark party for hunting purposes and to access the Salt Works site. There were 31 documented trips from the Fort to the coast by party members. The exact location of the trail has not been determined.

- The Salt Works site used by the Expedition for salt making; approximately three and one-half bushels were made. While the Salt Works site is unattended, it has an interpretive plaque explaining the relationship of the site to the Fort.

- Museum collections of rare books, natural and cultural specimens, and historical photos and prints.

Historically, the Fort Clatsop unit involves more than just the Lewis and Clark occupation. Previous and subsequent use of the site includes Indian occupation, farming, an orchard, home-sites, clay mining and brick firing, a sawmill, mid-19th century post office, dike construction, boat repair, ship landing and wharf, and a stage line. Some of these activities and cultures are included in existing interpretive programs, especially as they relate to describing the landscape changes that have occurred since the Expedition.

3.2.10 Management History

A very detailed administrative and management history, particularly of the Fort Clatsop Memorial Site, can be found in Chapters 3 (Legislative History), 4 (Managing Fort Clatsop National Memorial), and 5 (Development of Fort Clatsop National Memorial) of Cannon (1995).

3.2.11 Visitor Use

Annual visitation between 1985 and 1998 ranged from ~160,000 to ~280,000 and averaged ~209,400. Peak months for visits were July and August. The fewest visits occurred in December – February. Obviously other areas of the Park complex were used, but their numbers are less certain. This number of people concentrated in such a small area can have a dramatic impact on the resources of the park. A very detailed visitor use record, particularly of the Fort Clatsop Memorial Site, can be found in Chapter 6 of Cannon (1995).

A pulse survey was conducted for the Memorial in 1986 (Fort Clatsop National Memorial 1995). The survey was repeated in 1987 and 1988 to identify trends and add to the information database. The survey provided park management a comprehensive look at who park visitors are, where they come from and why, and an evaluation of park services. 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). An informal survey in 1992 indicated that most visitors to the Salt Works had not visited the fort replica site.

3.3 Detailed Description of Natural Resources

This section provides a detailed description of indicators that provide insight into the current condition of the LEWI's natural resources. Each indicator is assessed on the basis of its condition and trend over time. Symbols (Figure 2.2) were modeled after traffic signs for ease of interpretation. Condition is indicated by symbol shape and color: green circles indicate good condition, yellow diamonds indicate moderate concern about the condition, and red octagons indicate significant concern about the condition. Inlaid within each symbol is an arrow indicating trend (improving, stable, declining) or a question mark indicating that we did not have sufficient data to assess trends.

3.3.1 Biodiversity

3.3.1.1 Key Findings

The key findings from this section are as follows:

- LEWI contains 30% of the regional species pool of vascular plants (382 taxa), in addition to 233 non-vascular species.
- 284 vertebrate and invertebrate species recorded within LEWI.
- LEWI has a total of 33 Endangered, Threatened, Sensitive, or Candidate species. These are primarily birds and fish.
- Data for individual units are not available, so we are unable to examine the biodiversity of individual units.
- Data that would permit analyses of trends (extirpations, colonizations, etc) are not available, so we are unable to determine how biodiversity has changed over time.
- Data are missing or incomplete for some taxonomic groups (insects, benthic invertebrates, etc.), so we are unable to determine the condition of these resources.

3.3.1.2 Plant Richness

In total, 382 vascular plant taxa have been recorded within LEWI (Table 3.2; Appendix 2). Fifty-five species from LEWI were not included in the regional species pool (defined as the species lists for Pacific County, WA, and Clatsop County, OR contained in the USDA Plants database). LEWI, therefore, contains about 30% of the 1287 species present in the regional species pool.

The proportional distribution of plant species among taxonomic groups is very similar between LEWI and 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 within LEWI. About two-thirds of these are true mosses (Appendix 3).

Ninety-nine species of fungi have been recorded within LEWI, half of which are gilled fungi. Sixty-one lichen taxa have been recorded, most of which have a foliose growth form (Appendix 4).

With a few exceptions (Sayce and Eid 2003, Sayce 2004), the current species lists are compiled for the entire park rather than on a per-unit basis. As a result, we are unable to examine the biodiversity of individual units. The species lists also do not include information about extirpations, colonizations. We therefore are unable to assess changes such as the loss of native species, invasion by new exotic species, or successful control and extirpation of exotic species from within LEWI.

Table 3.2. Vascular plant, bryophyte, fungi, and lichen taxa recorded in LEWI, and vascular plant taxa in the regional species pool (Pacific County, WA, and Clatsop County, OR; such data are not available for bryophytes, fungi, and lichens). Each taxonomic group is subdivided into broad taxonomic groups and reported numerically and as a percent of the total.

Taxonomic Group	**LEWI**		**Regional Species Pool**	
	Number	Percent	Number	Percent
Vascular Plants	382	100	1287	100
Dicots	*259*	*68*	*903*	*70*
Monocots	*97*	*25*	*327*	*25*
Gymnosperms	*13*	*3*	*18*	*1*
Ferns	*9*	*2*	*28*	*2*
Horsetails	*3*	*1*	*7*	*1*
Lycopods	*1*	*<1*	*4*	*<1*
Bryophytes	73	100	-	-
Liverworts	*21*	*29*		
Peat mosses	*3*	*4*		
True mosses	*49*	*67*		
Fungi	99	100	-	-
Boletes	*15*	*15*		
Club / coral / fan	*7*	*7*		
Crust	*7*	*7*		
Cup	*7*	*7*		
Gilled	*50*	*51*		
Other (see Appendix 4)	*13*	*13*		
Lichens	61		-	-
Crustose	*1*	*2*		
Foliose	*41*	*67*		
Fruticose	*19*	*31*		
Total	615		-	-

3.3.1.3 Animal Richness

A total of 250 vertebrate species have been recorded in LEWI. Birds comprise the largest proportion of these species, and reptiles the smallest (Table 3.3).

A total of 34 invertebrate species have been recorded in LEWI. Most of these are insects, though these numbers likely reflect incomplete assessments rather than the true state of the biodiversity of these taxonomic groups. There is also little information about benthic invertebrates and other taxonomic groups.

Table 3.3. Animal species found within LEWI, by taxonomic group.

Taxonomic Group	Number of Species	Percent
Vertebrates	250	100
Amphibians	*11*	*4*
Birds	*166*	*66*
Fish	*24*	*10*
Mammals	*46*	*18*
Reptiles	*3*	*1*
Invertebrates	34	100
Crustaceans	*1*	*3*
Insects	*28*	*82*
Molluscs	*5*	*15*
Total	284	

3.3.1.4 Endangered Species

LEWI has no federally listed endangered plants, but two species, ocean-bluff bluegrass (*Poa unilateralis*) and coyote brush (*Baccharis pilularis*), are listed as threatened by Washington state. Both of these species occur at Cape Disappointment State Park.

Thirty-one animals are listed as Endangered, Threatened, Candidate, or Sensitive species (Table 3.4). Most of these are birds or fish with wide ranges and that therefore spend only a portion of their life cycles at LEWI. Eight species are listed as threatened at the federal level, 12 are classified as 'Species of Concern' (not a legal listing designation), and two have been delisted due to recovery. In Oregon, two species are listed as endangered, three are listed as threatened, and 16 are listed as sensitive. In Washington, three species are listed as endangered, one as threatened, 12 as candidates, and three as sensitive.

Table 3.4. Endangered, Threatened, Sensitive, and Candidate species in LEWI. Data are sorted alphabetically by taxon and then by scientific name. Status codes are defined in Table 2.9. E – endangered; T – threatened; C – candidate; Co – species of concern (only reported at federal level for those species that are listed in either OR or WA); S – sensitive.

Scientific Name	Common Name	Taxon	Federal	OR	WA
Baccharis pilularis	Coyote bush	Plant	-	-	T
Poa unilateralis	Ocean bluff bluegrass	Plant	-	-	T
Dicamptodon copei	Cope's giant salamander	Amphibian	-	S	-
Rhyacotriton kezeri	Columbia torrent salamander	Amphibian	Co	S	-
Plethodon dunni	Dunn's salamander	Amphibian	Co	-	C
Rana aurora aurora	Northern red-legged frog	Amphibian	Co	S	-
Aechmophorus occidentalis	Western grebe	Bird	Co		C
Brachyramphus marmoratus	Marbled murrelet	Bird	T	T	T
Cerorhinca monocerata	Rhinoceros auklet	Bird	-	S	-
Charadrius alexandrinus nivosus	Western snowy plover	Bird	T	T	E
Dryocopus pileatus	Pileated woodpecker	Bird	Co	S	C
Falco columbarius	Merlin	Bird	Co	-	C
Falco peregrinus	Peregrine falcon	Bird	Co	-	S
Gavia immer	Common loon	Bird	Co	-	S
Haematopus bachmani	Black oystercatcher	Bird	-	S	-
Haliaeetus leucocephalus	Bald eagle	Bird	*	T	S
Pelecanus occidentalis californicus	Brown pelican	Bird	*	E	E
Phalacrocorax penicillatus	Brandt's cormorant	Bird	-	-	C
Podiceps grisegena	Red-necked grebe	Bird	-	S	-
Progne subis	Purple martin	Bird	Co	S	C
Uria aalge	Common murre	Bird	-	-	C
Speyeria zerene hippolyta	Oregon silver-spot butterfly	Insect	T		E
Acipenser medirostris	Green sturgeon	Fish	T	-	-
Lampetra richardsoni	Western brook lamprey	Fish	-	S	-
Oncorhynchus keta	Chum salmon (Columbia River ESU)	Fish	T	S	C
Oncorhynchus kisutch	Coho salmon (Lower Columbia River ESU)	Fish	T	E	C
Oncorhynchus mykiss	Steelhead salmon (Lower Columbia River ESUs)	Fish	T	S	C
Oncorhynchus tshawytscha	Chinook salmon (Lower Columbia River ESUs)	Fish	T	S	C
Thaleichthys pacificus	Eulachon	Fish	-	-	C
Lasiurus cinereus	Hoary bat	Mammal	-	S	-
Myotis californicus	California myotis	Mammal	Co	S	-
Myotis thysanodes	Fringed myotis	Mammal	Co	S	-
Myotis volans	Long-legged myotis	Mammal	Co	S	-

* Delisted due to recovery

3.3.2 Land Cover

Land cover analysis methods are presented in Section 2.6.2. We analyzed current land cover and change over a ten-year period (1996-2006) within LEWI (Figure 3.4) and within the rest of Pacific and Clatsop counties.

3.3.2.1 Inside LEWI

LEWI is dominated by forests and wetlands (43% and 40% of the area, respectively; Table 3.5). There is relatively little land in grass/shrub/prairie land cover (5%). Less than 2% of the park is classified as developed, and no lands are classified as cultivated.

Between 1996 and 2006, LEWI lost a relatively small amount of forestland (3.6%), probably to natural disturbances. The grass/shrub/prairie and the open water land cover types increased during this period, while development declined slightly. About 25 ha within LEWI that were classified as wetland in 1996 were classified as open water in 2006. This could reflect vegetation changes but it could also be associated with measurement error or changes due to tidal influence (personal communication, McCombs, NOAA, 2009a). Likewise, we attribute the perceived increase in marine and shoreline in the counties to a combination of vegetation change (transition from forest), measurement error, and tidal influence.

Forests are dominant in Ecola State Park, the Fort Clatsop unit, Cape Disappointment, Station Camp, and Dismal Nitch. Wetlands are dominant in Fort Stevens State Park and Cape Disappointment. Development is dominant at Sunset Beach. Individual park units experienced relatively small changes in land cover between 1996 and 2006 (Table 3.6). The largest changes relate to forest loss at Dismal Nitch and Sunset Beach, although these units are small so the actual magnitude of the changes is exaggerated when considering percent changes.

Table 3.5 Comparison of land cover within LEWI to that of the rest of Pacific and Clatsop counties. Current condition data are from 2006, and change data are from 1996-2006.

	Land Excluding LEWI				**LEWI**			
	Current Condition		**Change (1996-2006)**		**Current Condition**		**Change (1996-2006)**	
Land Cover Type	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Developed	8,724	2.0%	766.2	8.8%	63	1.7%	-1.9	-3.0%
Cultivated	243	0.1%	-3.9	-1.6%	0	0.0%	0	0.0%
Grass/Shrub/Prairies	113,003	25.3%	61,934.8	54.8%	182	5.0%	43.0	23.8%
Forest	288,167	64.5%	-63,377.6	-22.0%	1,542	42.8%	-55.4	-3.6%
Wetland	27,001	6.0%	8.6	0.0%	1,434	39.8%	-24.8	-1.7%
Marine and Shoreline	9,013	2.0%	714.1	7.9%	202	5.6%	-1.2	-0.6%
Open Water	628	0.1%	-42.1	-6.7%	183	5.1%	40.2	22.0%
Total	446,778	100.0%			3,606	100.0%		

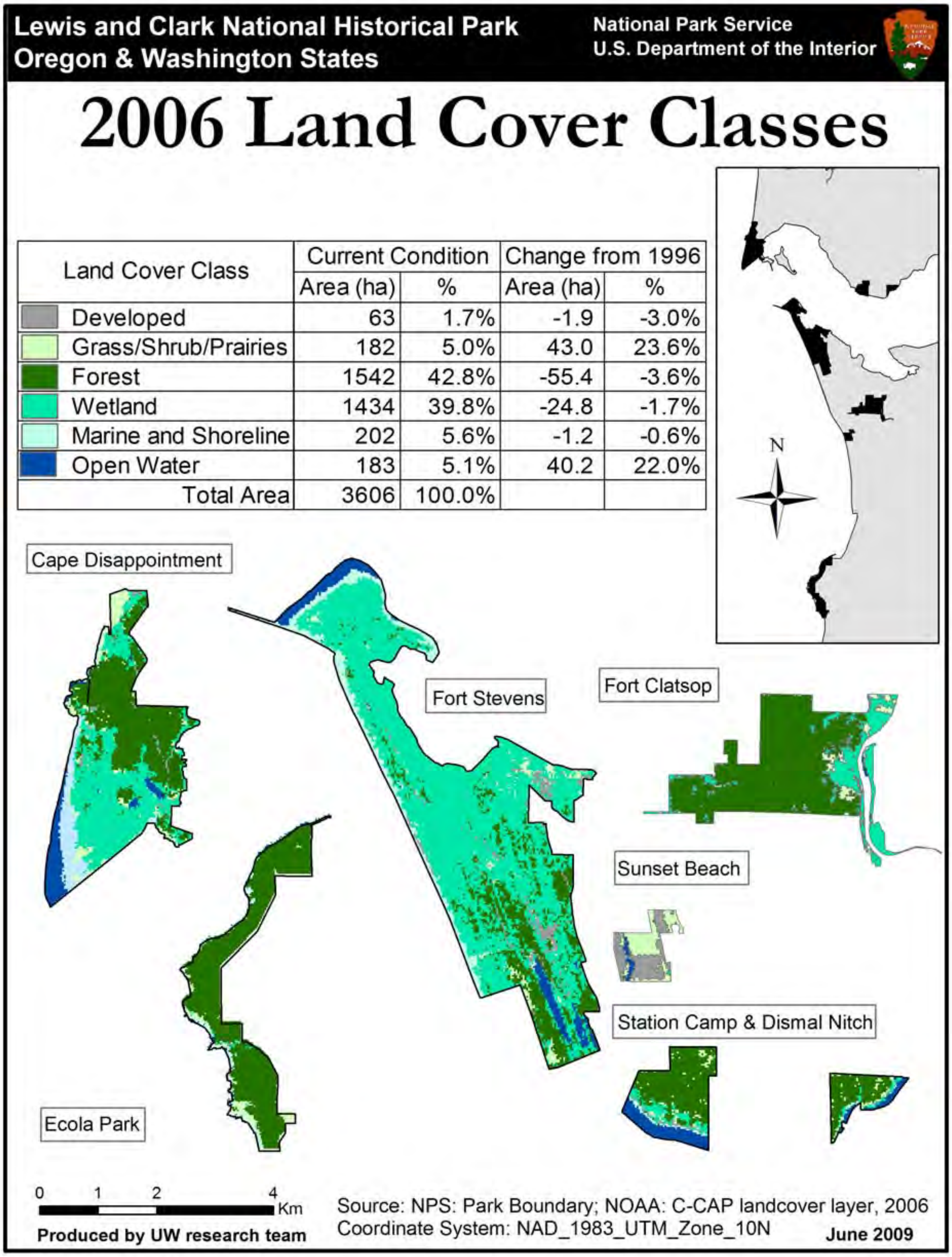
Table 3.6. Changes in land cover type between 1996 and 2006 for each unit of LEWI.

Land Cover Type	Cape Disappointment	Dismal Nitch	Station Camp	Fort Stevens	Ecola	Fort Clatsop	Sunset Beach
Developed	-0.1%	-0.1%	0.2%	-0.1%	0.0%	0.0%	0.4%
Cultivated	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Grass/Shrub/Prairies	2.6%	7.3%	4.0%	0.2%	0.5%	0.0%	6.2%
Forest	-2.5%	-9.2%	-4.4%	-0.8%	-0.6%	0.1%	-8.9%
Wetland	0.5%	0.0%	-0.5%	-1.8%	0.1%	-0.2%	-0.3%
Marine and Shoreline	-0.1%	0.1%	0.0%	-0.1%	-0.2%	0.0%	2.2%
Open Water	-0.5%	1.9%	0.7%	2.7%	0.1%	0.0%	0.7%

3.3.2.2 Outside LEWI

Compared to LEWI, the rest of Pacific and Clatsop counties contain a much higher proportion of the forest and grass/shrub/prairie land cover types, and a much smaller proportion of wetlands (Table 3.5; Figure 3.5). Development accounts for about the same proportion of the land area for the counties as a whole as for LEWI. As in LEWI, there is little cultivated land in the counties.

Between 1996 and 2006, Pacific and Clatsop counties lost 22% (63,377.6 ha) of their forestlands, mostly due to clearcutting; many of these areas were classified as grass/shrub/prairie in 2006. Development increased by 8.8% in the counties but declined slightly in LEWI.



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 3.4. Land cover types within LEWI units in 2006. The inset table summarizes the land cover in 2006 and changes in land cover since 1996.

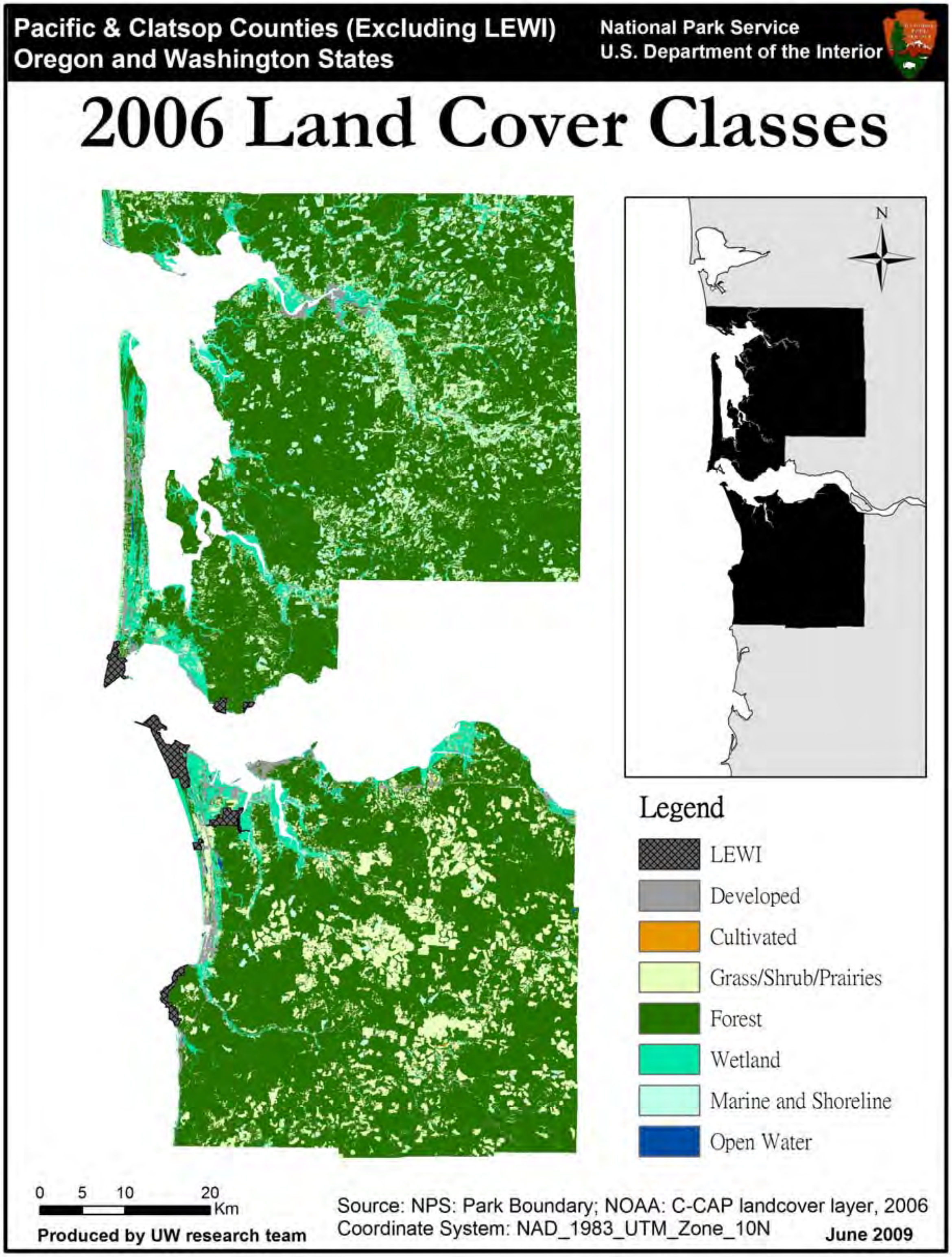


Figure 3.5. Land cover classes within Pacific and Clatsop counties (excluding LEWI) in 2006. Land cover types in 2006 and changes since 1996 are summarized in Table 3.5.

3.3.3 Terrestrial Resources

LEWI lies within the Coastal Sitka Spruce ecosystem at the convergence of the Coast Range habitat and the extensive and fertile wetlands of the Columbia River estuary. The dominant terrestrial ecosystems are forests and sand dune prairies.

3.3.3.1 Forests

Historically, large Sitka spruce and western hemlock trees dominated the forests of LEWI. Prior to European settlement, at least 40% of the coastal hills were old-growth Sitka spruce/western hemlock forest (Agee 2000). Today, less than 5% of the original old-growth forest remains – the largest components are found in Ecola State Park while Cape Disappointment has a few remnant trees (Figures 3.6).

As noted earlier, much of the original old-growth forest (as much as 40% of the original forested landscape) has been logged and is either in second or third growth naturally regenerated or plantation forests or converted to other land uses. Scattered in Cape Disappointment and Ecola State Parks are remnant patches of old-growth Sitka spruce; other sites have healthy, robust stands of second growth forests that are beginning to demonstrate structural properties of mature forests. In spite of the extensive blowdown, a result of the December 2007 windstorm, there are still many young, plantation forests. Some of these stands, particularly those dominated by off-site Douglas-fir, have significant infestations of Swiss needle cast disease.

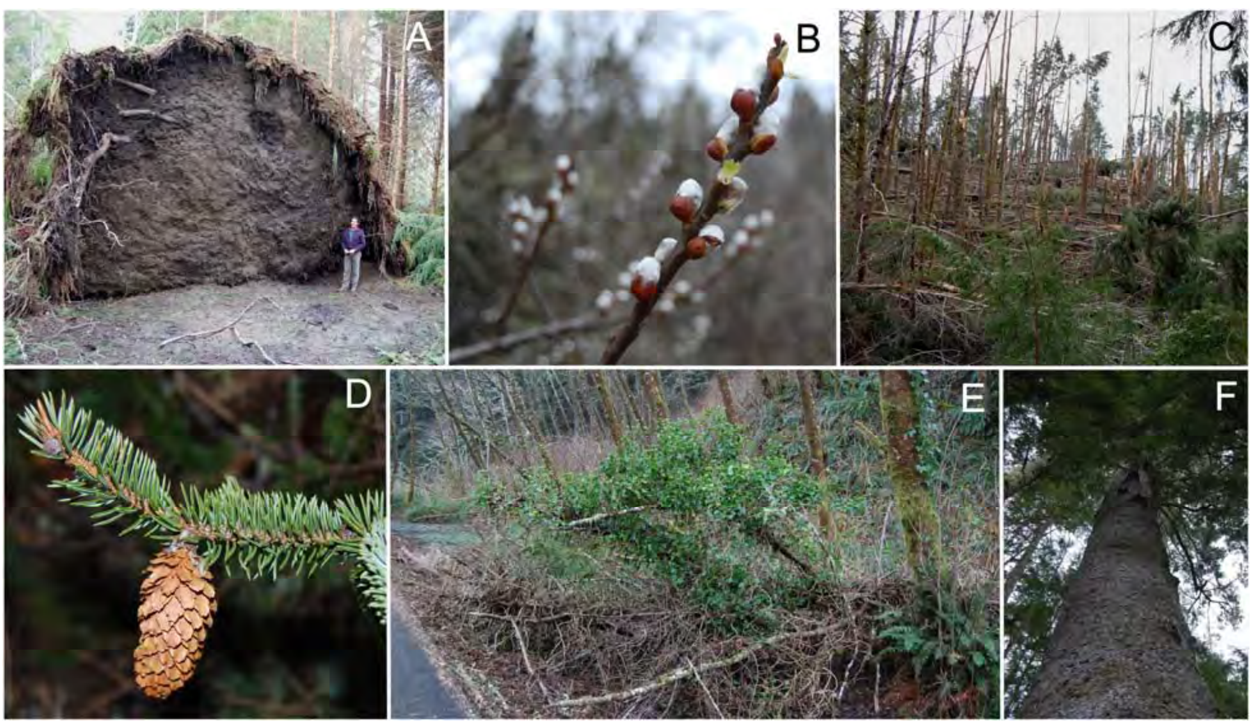


Figure 3.6. Photographs illustrating some of the upland resources at LEWI: A. Root wad of a large, 80-year-old Sitka spruce uprooted as a result of the December 2007 windstorm. B. Late March 2009 willow buds. C. Forest damage as a result of the December 2007 windstorm. D. Sitka spruce branch and cone. 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.

3.3.3.2. Sand Dune Prairies

The Clatsop Plains Sand Dunes are a unique young dune system on the southern edge of the Columbia River delta, adjacent to forested hills (Figures 3.7 and 3.8). In general, the dunes are characterized by at least five dune series, each partitioned into smaller categories of a – d, separated by shallow valleys (Reckendorf et al. 2001). The vertical change in elevation of the dunes ranges from 30 to 70 feet and the distance between the dunes ranges from less than 100 feet to over 300 feet. The third series of dunes have a distinct flat top, most likely due to human filling of the dune area, while the best-known series is the oldest (dune series 5) occupied by sections of highway 101. This dune system is relatively young; the oldest dune has been dated approximately 5000 years old. In the early 1900s two jetties were built to the north and south of the Columbia River delta, dramatically increasing beach accretion rates, gaining up to 1 km of new beach in places. Even with sea-level rises due to climate change (unless severe), LEWI will continue to gain beaches, and the dune complex will continue to grow – the two jetties will continue to have a strong influence. This phenomenon has various pros and cons for park management associated with it, including new substrate for invasive species and problems with drifting or blowing sand.

Within the dune slack areas, there are many seasonal ponds, lakes and associated wetlands where lake levels reflect groundwater levels. For example, Neacoxie Creek, the outlet to Sunset Lake, drains into the Necanicum River, which is the only river that flows across the length of the 15 mile dune plain. These lakes and wetlands are further discussed below.

Plant communities in dune systems are typically heterogeneous. Plants typical to coastal dune prairies in Clatsop County Oregon have been documented and identified by D. Hayes. This list identifies key species as indicators of plant diversity along with the early blue violet (*Viola adunca*), a host for the endangered Oregon Silverspot butterfly (*Speyeria zerene hippolyta*). Plant communities and habitat have changed dramatically since European settlement. Extensive grazing in the late 19th and early 20th centuries led to extensive damage of the surface layers and the resulting exposure of dune sand to wind erosion. Winds then created dust storms that would close US Highway 101, the Coast Highway. In order to stabilize the dunes, the use of European beach grass (*Ammophila arenaria*) and shore pine (*Pinus contorta* var. *contorta*), along with a double dune fence in dune series 2, were implemented in the 1930s. While the planting of European beach grass and shore pine may have helped to stabilize the dunes, they and other non-native species such as Scotch broom (*Cytisus scoparius)* have dominated many areas.

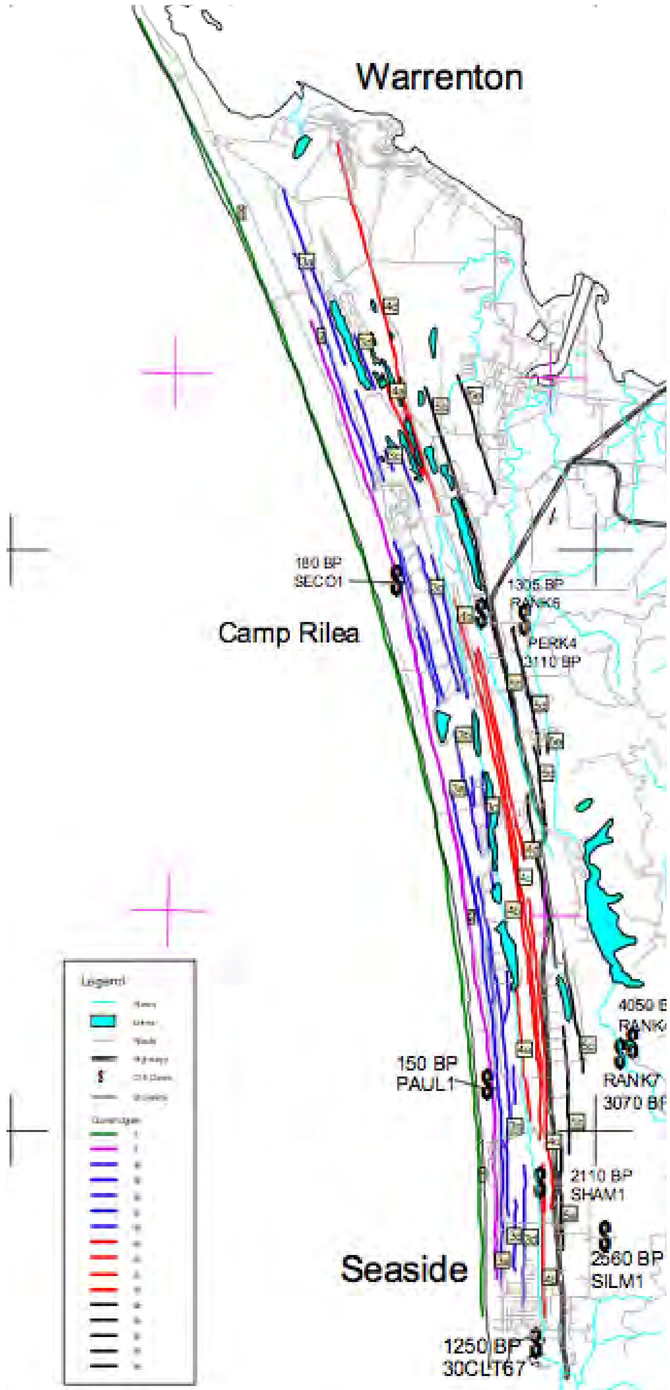


Figure 3.7. Diagram of the series of dune ridges associated with the Clatsop Sand Dune Plains (Reckendorf et al. 2001). The basemap is from the Oregon State GIS Center, Universal Transverse Mercator Projection, Zone 10, 1983 North American Datum, Portland State University GeoData Clearinghouse. See Figure 3.8 for greater detail.

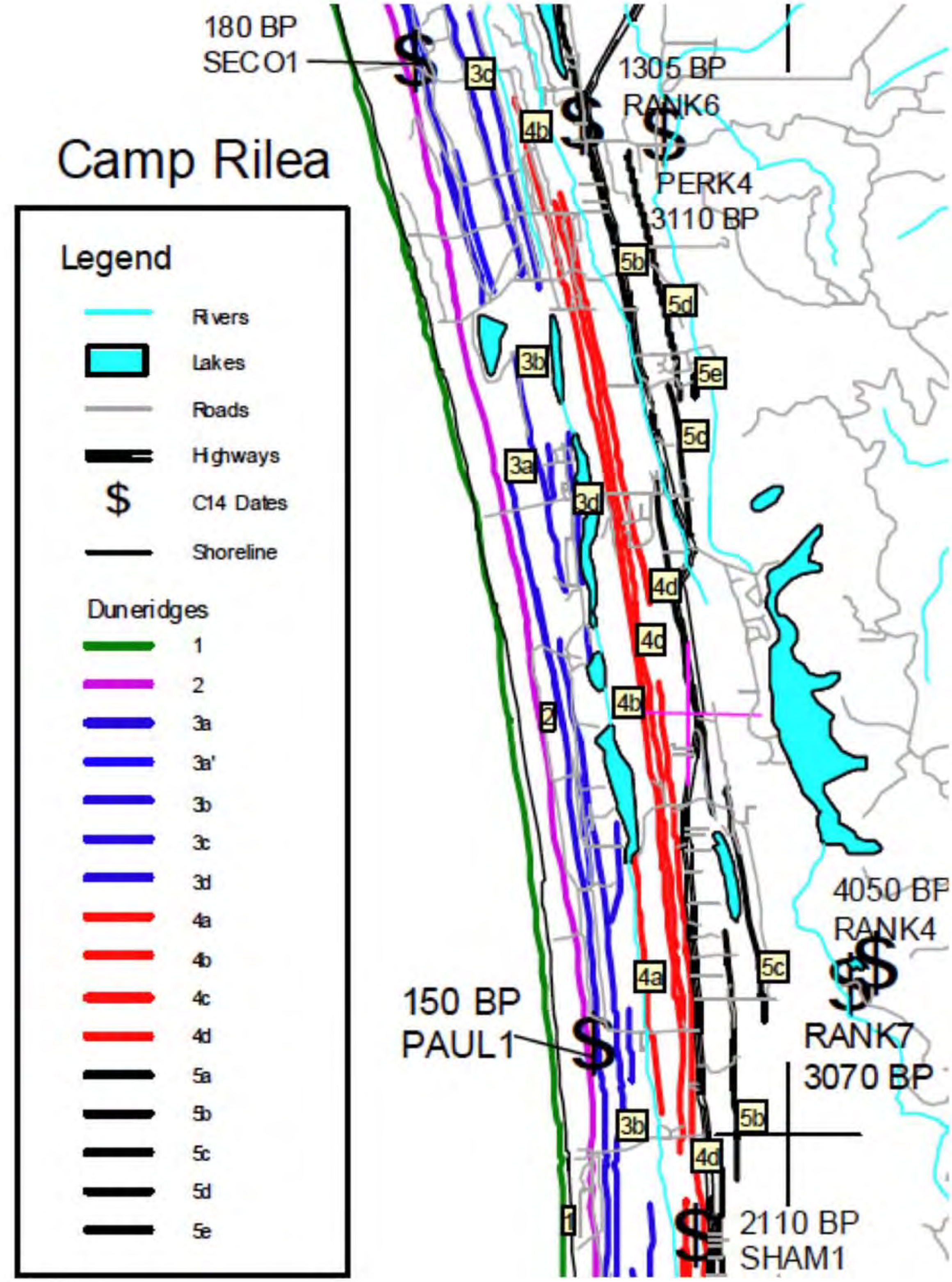


Figure 3.8. Detail of Figure 3.7 showing the series of dunes extending inland from the Pacific Ocean. The green line is dune 1, and the furthest inland black line is dune 10.

3.3.4 Aquatic Resources

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. A significant previous tidal estuary associated with the Lewis and Clark River was recently restored in 2007 the removal of two tide gates and the replacement of a culvert with a bridge. As a result of these actions, it has regained its connection to the tides and saline water. The Fort-to-Sea trail (Section 3.3.5.1) intersects several of these elements as well as the Skipanon River.

LEWI contains 14 types of wetlands within five wetland systems (Marine, Estuarine, Palustrine, Lacustrine, and Riverine), as identified by the National Wetland Inventory (NWI) (Fort Clatsop National Memorial 1994a). Almost one third (31%) of LEWI is categorized as aquatic ecosystems by the NWI (Figure 3.9). Both tidal and non-tidal wetlands are present. Estuarine and marine wetlands are common in LEWI, and compose 45% of the park's current aquatic ecosystems. Half (51%) of the park's estuarine and marine wetlands are intertidal unconsolidated shore or intertidal emergent. LEWI is one of the few remaining areas along the Pacific Coast containing significant estuarine resources.

Freshwater forested/shrub wetlands make up 30% of LEWI's aquatic ecosystems. Almost half (48%) of the freshwater forested/shrub wetlands are palustrine scrub-shrub, while 36% are palustrine forested. Most (84%) of LEWI's freshwater forested/shrub wetlands are seasonally flooded. A fifth of the park's current aquatic ecosystems are freshwater emergent wetlands. Notably, 40% of LEWI's freshwater emergent wetlands are partly drained or ditched. LEWI does not have large areas of freshwater pond, lake, or riverine ecosystems. A historic spring in the Fort Clatsop unit flows for approximately nine months of the year and is the source for a small stream that flows to the Lewis and Clark River. It is believed to be the water source for the Lewis and Clark party while they wintered at the Fort.

We also analyzed LEWI's current aquatic ecosystems within individual park sites (Figure 3.9; see detailed data in Appendix 7):

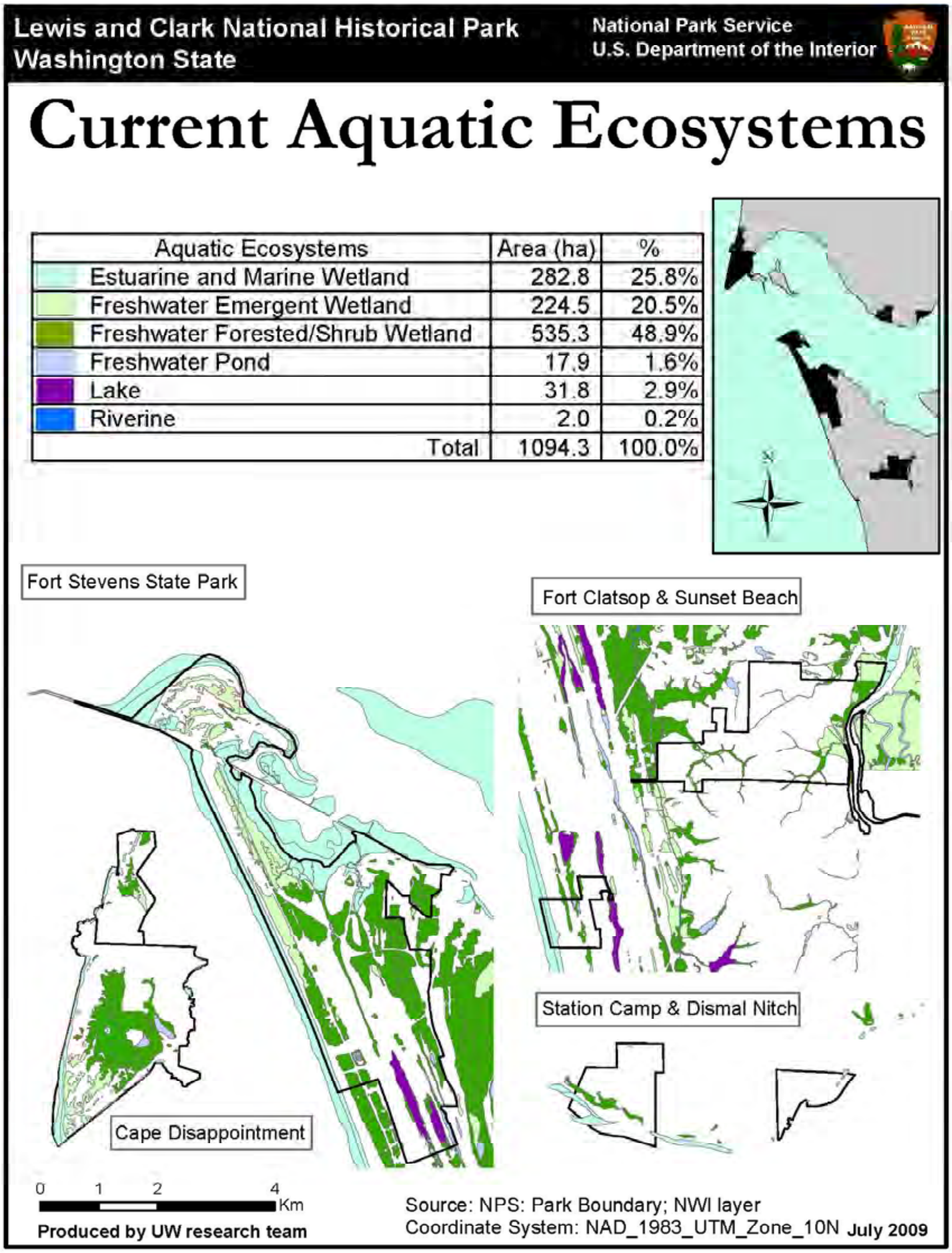
- At Fort Clatsop, almost all (94%) of the aquatic ecosystems are either freshwater emergent wetlands or freshwater forested/shrub wetlands.

- Sunset Beach's aquatic ecosystems are mostly estuarine and marine wetlands (55%), with a major portion in freshwater forested/shrub wetlands (36%).

- Forty-four percent of Fort Stevens' aquatic ecosystems are freshwater forested/shrub wetlands, while 31% are estuarine and marine wetlands.

- The majority (64%) of Cape Disappointment's aquatic ecosystems are freshwater forested/shrub wetlands.

- Station Camp's aquatic ecosystems are mainly estuarine and marine wetlands (54%) and freshwater forested/shrub wetlands (45%).



Aquatic Ecosystems	Area (ha)	%
Estuarine and Marine Wetland	282.8	25.8%
Freshwater Emergent Wetland	224.5	20.5%
Freshwater Forested/Shrub Wetland	535.3	48.9%
Freshwater Pond	17.9	1.6%
Lake	31.8	2.9%
Riverine	2.0	0.2%
Total	1094.3	100.0%

Figure 3.9. Aquatic and wetland ecosystems within LEWI. Data are from NWI; note that most of these data for LEWI and the surrounding area (Pacific and Clatsop Counties) were collected and digitized in 1980-1981. Some NWI data for the Oregon coast were collected and digitalized in 2000. Detailed data about each unit are found in Appendix 7.

- Clark's Dismal Nitch has almost no aquatic ecosystems; it has only 0.72 ha of aquatic ecosystems, and its largest single type (palustrine forested) makes up only 0.6 ha.

Aquatic systems within and surrounding the park have been greatly altered (Figure 3.10). These impacts are most strongly documented for the Oregon units. The Lewis and Clark River has been extensively diked, reducing or eliminating highly productive estuarine habitat. These diked tidelands were used for agriculture. Around the park, these areas continue to be used for agriculture, dairy and rural and industrial development. Estuary restoration has been a recent focus at LEWI that can reverse alterations to its aquatic systems. However, quantitative data about these efforts are not available.

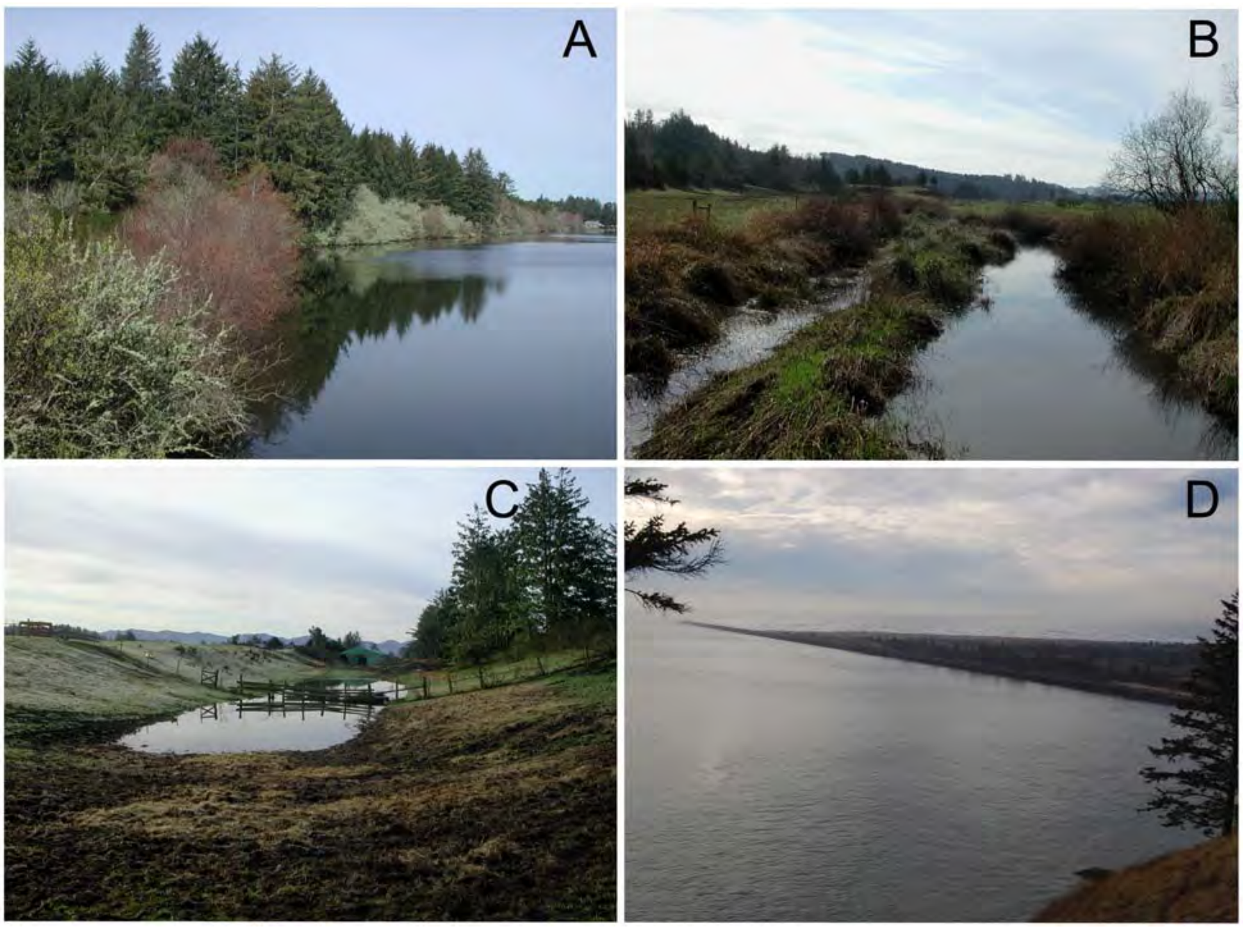


Figure 3.10. Photographs illustrating some of the water resource features at LEWI: A. Sunset Lake (lacustrine wetland with willow, red osier dogwood, and Sitka spruce), B. Skipanon River - Transition between sedimentary hills to east and coastal dune prairie system to west. C. A palustrine wetland next to a cattle pasture in the Clatsop Plains (dune prairie system). D. North jetty and the Pacific Ocean from Cape Disappointment. Photographs by T. Hinckley.

3.3.5 Interactions between Resource Types

3.3.5.1 Transect A: Fort to Sea Trail

The first transect follows the Fort to Sea Trail from the Lewis and Clark River to the Pacific Ocean (Figure 3.3). It begins at the canoe landing near the confluence of Alder Creek and the Lewis and Clark River. A description of the different vegetation types was provided in Section 3.2.8.1. Except for roads, soils and geology are largely unaltered along this transect. It is important to note several features about the conditions of the vegetation and wetlands (see also Figure 3.10).

Beginning near sea level at the Lewis and Clark River, the trail skirts an estuary that was diked and farmed until the dike was breached. Near the Fort is an area of older Sitka spruce and western hemlock which is becoming structurally (and therefore, historically) interesting and visually appropriate to the time of the Lewis and Clark period. However, soon after this relatively small stand, the trail enters second and third growth forests containing an increased presence of western hemlock and Douglas-fir. As a result of the December 2007 windstorm, there is extensive blow down of trees – in some cases all trees in areas of several acres. In addition, much of the trail is on former logging roads. Upon reaching the look-out at the summit (~100 m [325'] elevation), it descends steeply in a series of switch-backs through a young, dense, planted Douglas-fir forest to a branch of Perkins Creek. This forest, and several stands on the other side of Perkins Creek, show defoliation symptomatic of Swiss needle cast. For the next segment, the trail is either next to Perkins Creek, crossing an incoming branch, or upslope in plantation Douglas-fir stands. Perkins Creek illustrates a relatively rapid return to a healthy riverine – palustrine system with extensive red alder and Sitka spruce trees, beaver dams, and associated wetland plants. After crossing the western fork of Perkins Creek, the trail leaves the sedimentary hills, crosses the alluvial plain associated with the Skipanon River, and ascends and descends a series of 10 relatively parallel dunes to the beach at the Pacific Ocean. Throughout this section of the trail, one observes elements of healthy wetland and terrestrial systems, but most significantly impacted. Construction of roads and buildings including very recent housing developments, pastures with segments of either manure accumulation or heavy hoof damage, sand dunes with planted lodgepole pine and European beach grass. However, the December 2007 windstorm blew many - and in some sections all - of the 50 – 60 year old trees down.

3.3.5.2 Transect B: North Head Light House, Cape Disappointment

The second transect goes from the Pacific Ocean along the south side trail at Beard's Hollow and then over North Head to the North Head Light House at Cape Disappointment (Figure 3.11). It was anticipated that the Sitka spruce forests in this area would demonstrate increasing structural diversity and in some cases, old-growth characteristics. Twenty points were established along this transect. At ten points, overstory and understory species were identified; for the overstory, the basal area per acre was measured and the diameter of the largest tree of each species was measured.

This transect is physically simpler than the first (Figure 3.3) as the geology and soils are not as diverse. Geological parent material range from young beach sand to sedimentary sandstone and Crescent Formation basalt. Soils reflect those derived from such parent material and the slope angles they were found on. Much of the geology and soils are similar to those found in the Fort to Sea Trail transect – new is the basalt and the Washington names for soils derived from these various parent materials.

The first point of this transect is the wave front (Time: 11:05 am [PDT] on May 9, 2009) at the Pacific Ocean. Point 2 is on the gentle side of a dune with European (*Ammophila arenaria*) and American beach grass (*A. breviligulata*). Between points 2 and 3, there are a few young red alders and 3 to 5-year-old Sitka spruce. At point 3, there are dense and intermixed stands of Pacific wax myrtle (Myrica californica) and 12- to 15-year-old Sitka spruce. Points 4 and 5 are the western and eastern end of a 50 m high basalt headland – mixed with native species were Himalayan blackberry and English holly. Sitka spruce trees near point 4 were approximately 20-years-old. Point 5 begins the current freshwater wetland that contains overstory Sitka spruce, willow, and red alder and understory sword (*Polystichum munitum*) and lady fern (*Athyrium filix-femina*), salmonberry (*Rubus spectabilis*), skunk cabbage (*Lysichiton americanus*), red elderberry (*Sambucus racemosa*) and cow parsnip (*Heracleum maximum*). This wetland in Beards Hollow continues to point 8 (a bridge) – along the trail between points 5 and 8 are stands of red alder with basal areas (measured with a keyhole prism) near 115 ft^2/acre and maximum diameters (at breast height) of 32 to 38 cm (12.5-15”). English ivy (*Hedera helix*) is particularly prevalent on the south side of the trail. Sitka spruce trees near point 8 were about 80-years-old. When Lewis and Clark observed Beards Hollow, the shoreline was inland from point 5 and the area between points 6 and 8 was part of a saltwater marsh. These changes in the position of the shoreline were accelerated due to the presence of the north jetty on the Columbia River.

At point 9 and continuing to point 18 is a second growth stand of mostly Sitka spruce and western hemlock with an occasional red alder. The understory varies from thick, deep salal (*Gaultheria shallon*) to sword fern with occasional bracken fern (*Pteridium aquilinum*), two species of *Vaccinium* (*V. parvifolium* and *V. ovatum*), fool’s huckleberry (*Menziesia ferruginea*), and salmonberry. Along this section of the transect, basal area indices varies from 300 to 480 ft^2/acre (for comparison, dense, highly productive stands of Douglas-fir and coastal redwood may have basal area indices of 500 and 550 ft^2/acre, respectively), maximum diameters of second growth trees are 149 cm (59”), 139 cm (55”), and 66 cm (26”) for Sitka spruce, western hemlock and red alder respectively. There are several large old-growth trees near point 16, with a maximum diameter of 250 cm (98.6”). A list of native, non-native and noxious plant species found in Cape Disappointment State Park is provided by Sayce (2004).

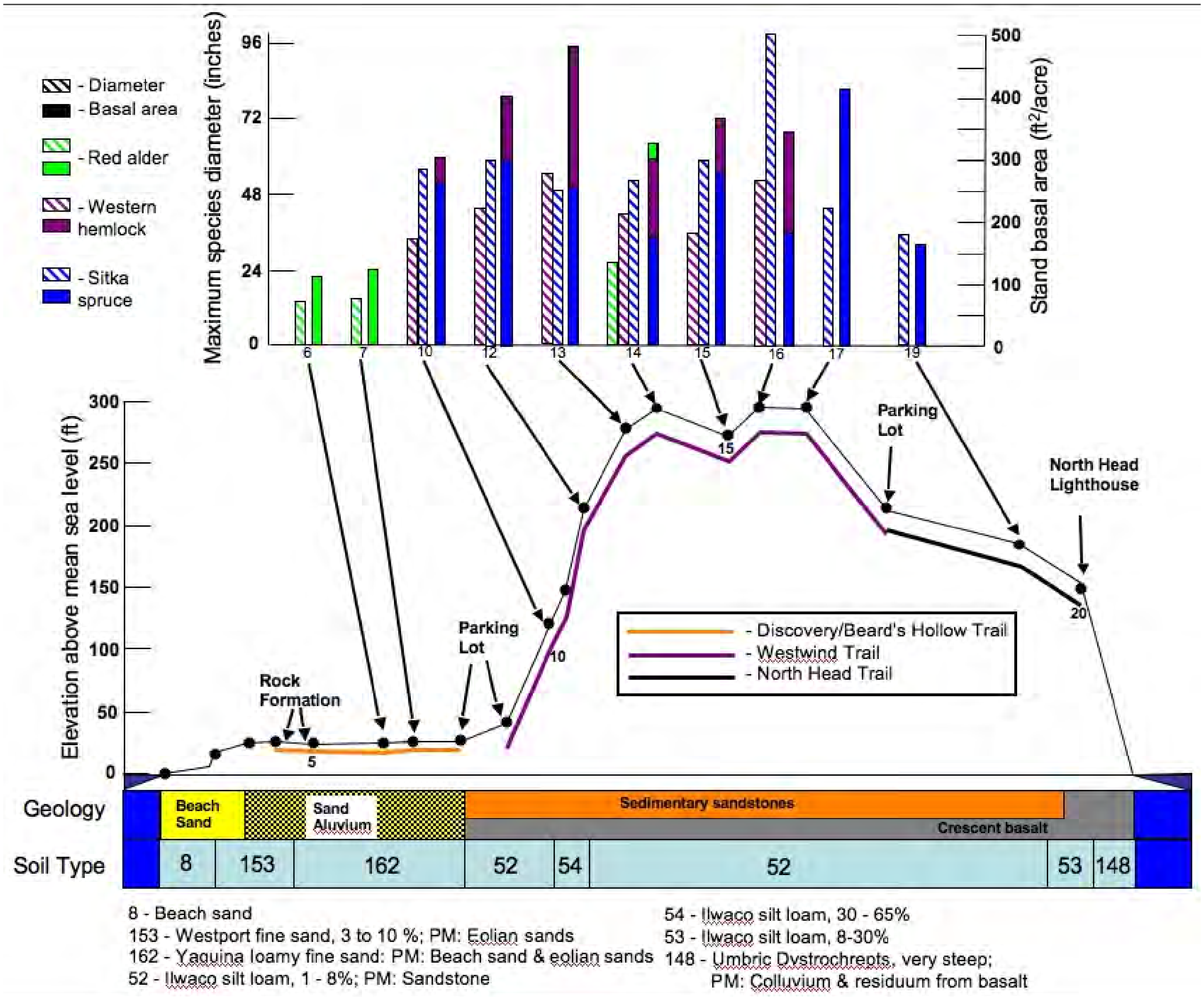


Figure 3.11. Transect B, from the Pacific Ocean to the North Head Lighthouse (Cape Disappointment State Park) via the Discovery Trail, Westwind, and North Head Trails. This transect is shaped like a half circle, as it starts and ends at the Pacific Ocean. The eastern-most extent is between positions 14 and 16.

Chapter 4 - Threats and Stressors

This chapter describes five broad categories of threats and stressors to the natural resources in LEWI: climate change, biodiversity, land use, air and water, and other stressors. Several indicators were identified within each category (Table 4.1; detailed methods in Section 2.6). Each indicator was assessed on the basis of its condition and trend over time. Symbols (Figure 2.2) were modeled after traffic signs for ease of interpretation. Current condition is indicated by symbol shape and color: green circles indicate good condition, yellow diamonds indicate moderate concern about the condition, and red octagons indicate significant concern about the condition. Inlaid within each symbol is an arrow indicating trend (improving, stable, declining) or a question mark indicating that we did not have sufficient data to assess trends.

Table 4.1. Categories and indicators of stressors at LEWI.

Climate Change	Biodiversity	Land Use	Air and Water	Other Stressors
Air temperature	Noxious weeds	Impervious surface	Air quality	Diseases
Precipitation	Non-native plants	Road density	Surface water quality	Natural disturbances
Sea level rise	Non-native animals	Population density	Groundwater	Altered hydrology
Ocean acidification		Zoned land use		

4.1 Climate Change

4.1.1 Key Findings

The key findings from this section are as follows:

- Although the recent trend for temperature is relatively minimal, future projections are for a warmer climate
- Precipitation is more difficult to model than temperature, but projections are generally for wetter conditions, but with a seasonal change to drier summers
- Sea level will increase
- Ocean pH has declined and will continue to do so

These changes may significantly affect the terrestrial and marine resources within LEWI.

4.1.2 Air Temperature

There was no significant trend in average annual temperatures at LEWI from 1977-2006 (Figure 4.1; $P > 0.05$). Similarly, there were no significant trends in average seasonal temperatures ($P > 0.05$).

Depending on the general circulation model (GCM) used, temperatures at LEWI are projected to rise by between 1.2 ºC and 3.7 ºC (median 3.0 ºC) between 1961-1990 and 2070-2099. Summer temperature is projected to increase more than that of other seasons: median projected temperature increases are 2.2 ºC for spring, 3.8 ºC for summer, 2.2 ºC for autumn, and 2.7 ºC for winter (Table 4.2).

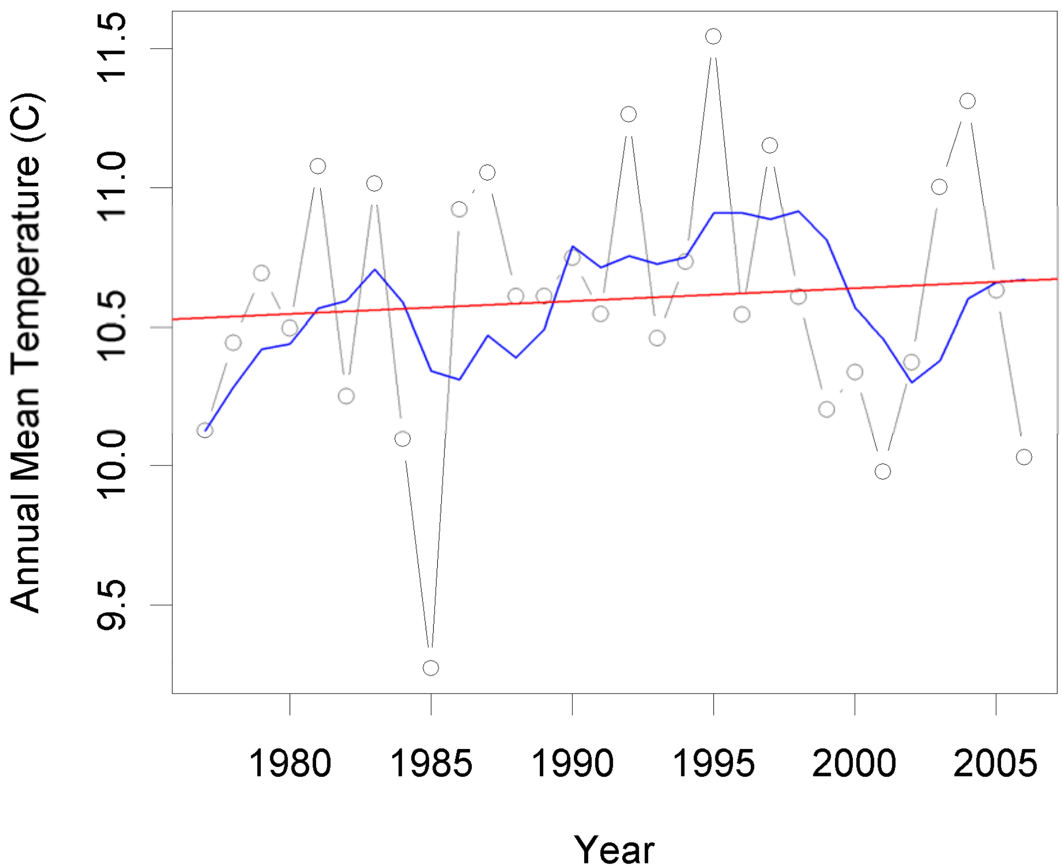


Figure 4.1. Trends in average annual temperature at LEWI from 1977-2006. Circles are average annual temperatures, the blue line is a five-year moving average, and the red line is a trend line fit with restricted maximum likelihood estimation assuming an AR1 time-series pattern in the residuals. Note that this trend line is not statistically significant (*P* > 0.05).

Table 4.2. Historical (1961-1990), recent (1977-2006), and projected future (2070-2099) temperature and precipitation at LEWI. Historical and recent data are from the Astoria WSO Airport weather station. W – winter (December-February); Sp – spring (March-May); Su – summer (June-August); A – autumn (September-November). Future temperature and precipitation are 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.

	Mean Temperature (ºC)					**Total Precipitation (mm)**				
Period	**Annual**	**W**	**Sp**	**Su**	**A**	**Annual**	**W**	**Sp**	**Su**	**A**
1961-1990	10.5	6.0	9.2	15.2	11.5	1687	715	373	124	475
1977-2006	10.8	6.5	9.8	15.3	11.5	1690	688	399	120	484
2070-2099	13.5	8.7	11.4	19.0	13.7	1830	796	399	77	504

4.1.3 Precipitation

Depending on the GCM model used, projected changes in total annual precipitation at LEWI range from a decrease of 8.9% to an increase of 23.3%. The median projection is an increase of 8.5%. The seasonal distribution of precipitation is projected to change, with more precipitation in winter (median increase of 11.3%), spring (median increase of 7.0%), and fall (median increase of 6.0%), and less precipitation in summer projected to decrease from 1.0% to 51.3% (median decrease of 38.1%; projected decreases range from 1.0% to 51.3%).

4.1.4 Sea Level Rise

Global average sea-level rise was 1.8 ± 0.5 mm/year from 1961-2003 and 3.1 ± 0.7 mm/year from 1993-2003 (IPCC 2007). Sea-level rise in Washington has generally tracked global sea level rise at a rate of 1 to 2.5 mm/year (Canning 1991), although local uplift and subsidence of the coastal land mass have resulted in different degrees of apparent sea-level rise along different parts of the Washington coast.

Estimates of sea-level rise for the south central Washington coast (Mote et al. 2008) vary considerably among scenarios. In 2050, estimates range from 3 cm (1”) [low scenario] to 45 cm (18”) [very high scenario], with the "medium” scenario at 12.5 cm (5”). In 2100, estimates range from 6 cm (2”) [low scenario] to 108 cm (43”) [very high scenario], with the medium estimate at 29 cm (11”). Thieler and Hammar-Klose (2000) provide an older assessment of sea-level rise for the entire U.S. Pacific coast.

4.1.5 Ocean Acidification

Since the Industrial Revolution, atmospheric CO_2 levels have increased from 280 to 385 ppm and ocean pH levels of have dropped from 8.21 to 8.10 (a decrease of 0.11 pH units). The IPCC (2007) projects that atmospheric CO_2 levels in 2100 will be between 540 and 800 ppm – such changes may reduce ocean pH by an additional 0.3 units.

Ocean acidification was implicated in an Autumn 2009 algal bloom, which was the longest and most harmful bloom on record in the Pacific Northwest. The bloom was caused by *Akashiwo sanguinea*, which produced a toxic foam on Pacific Northwest beaches. Some 10,000 marine and shore birds died as a result, including white-winged and surf scoters, loons, grebes, and murres (Welch 2009). This was the second such event in the last three years, highlighting our lack of understanding of the causal mechanisms that underlie these events and our inability to predict them. There is also some evidence that diatoms, another red-tide organism (http://www.whoi.edu/page.do?pid=11913&tid=282&cid=12506), have also increased in recent years although records are very poor (http://www.nwfsc.noaa.gov/hab/index.html). In addition, the direct effects of ocean acidification on calcium shells and exoskeletons will have huge effects on food chains and directly impact juvenile salmon and other fauna.

4.2 Biodiversity

4.2.1 Key Findings

The key findings from this section are as follows

- 23 species of noxious weeds have been recorded in LEWI. This is a higher proportion than in the regional species pool, but may reflect more aggressive monitoring and control efforts within LEWI.

- 41% of plant species within the park are non-native. Proportionally more non-native species in LEWI than in the regional species pool; this likely reflects more comprehensive monitoring within LEWI.

- 3.5% of animal species within the park are non-native

- Data for individual park units are not available, so we are unable to assess the occurrence of noxious weeds and non-native species at that scale.

- Data about colonization by new non-native species or successful control efforts that result in the extirpation of a noxious weed are not available, so we are unable to assess trends in the occurrence of these types of species.

4.2.2 Noxious Weeds

Twenty-three species designated as noxious weeds are known to occur within LEWI (Table 4.3). Most of these species are designated as Class B (see definition in Table 2.10) in OR and/or WA, indicating that they are regionally abundant.

The proportion of noxious weeds is higher within the park than in the regional species pool (Table 4.4). However, this may reflect the careful monitoring and proactive weed control efforts within LEWI. In addition, we do not have trend data about these noxious weeds. For example, it is plausible given the management efforts at LEWI that some of these species have been eradicated from the park and no longer occur there.

4.2.3 Non-native Plants

Of the 382 vascular plant species documented in LEWI, 155 (40.6%) are non-native in origin. The proportion of non-native species in LEWI is twice that in the regional species pool (Table 4.4). There are at least two reasons for this difference. First, 55 species documented in LEWI have not been officially recorded within the regional species pool (Pacific County, WA, and Clatsop County, OR) according to the USDA Plants Database. Of these 55 taxa, 31 are non-native. Second, and more importantly, more comprehensive vascular plant floristic surveys appear to have been conducted in LEWI than in the rest of the county land base.

There are no non-native non-vascular plant species recorded at LEWI.

Table 4.3. Noxious weeds found within LEWI. Noxious weed designations for OR and WA are defined in Section 2.6.1.3.

Species	Common Name	OR	WA
Cabomba caroliniana	Carolina fanwort		B
Cirsium arvense	Canadian thistle	B	C
Cirsium vulgare	bull thistle	B	C
Cytisus scoparius	Scotch broom	B	B
Daucus carota	Queen Anne's lace		B
Elymus repens	quackgrass	B	
Equisetum telmateia	giant horsetail	B	
Hedera helix	English ivy	B	C
Hypericum perforatum	common St. Johnswort	B	C
Hypochaeris radicata	hairy cat's ear		B
Iris pseudacorus	yellow flag iris	B	C
Lathyrus latifolius	perennial sweetpea	B	
Leucanthemum vulgare (Chrysanthemum leucanthemum)	oxeye daisy		B
Lythrum salicaria	purple loosestrife	B	B
Myriophyllum aquaticum (Myriophyllum brasiliense)	Brazilian watermilfoil	B	B
Nymphaea odorata	American white waterlily		C
Phalaris arundinacea	reed canarygrass		C
Potamogeton crispus	curly pondweed		C
Ranunculus ficaria	lesser celandine	B	
Rubus armeniacus (Rubus discolor)	Himalayan blackberry	B	C
Rubus laciniatus	cutleaf blackberry		C
Senecio jacobaea	tansy ragwort	B,T	B
Senecio vulgaris	common groundsel		C

Table 4.4. Summary statistics regarding noxious weeds and non-native plants within LEWI and in the regional species pool. Note that the regional species pool contains 55 taxa recorded in LEWI but not in the USDA plants database; these taxa are not included in the tallies for either county.

	LEWI	Regional Species Pool	Clatsop County	Pacific County
Total Vascular Plant Species	382	1287	974	871
Noxious Species	23	44	29	36
% Noxious	6.0%	3.4%	3.0%	4.1%
Non-native Species	155	281	185	191
% Non-native	40.9%	21.8%	19.0%	21.9%

4.2.4 Non-native Animals

Nine of the 250 vertebrate species recorded within LEWI are non-native (Table 4.5). A surprisingly small proportion of the bird species (2 of 165) are non-native. Although it is likely that these species compete with native species for habitat, food and territory, there are no reliable data for these interactions within LEWI. None of these species have been identified as 'deleterious exotic wildlife' by the Washington State Department of Fish and Wildlife (WSDFW 2010).

One of the 34 invertebrate species recorded within LEWI is non-native. The New Zealand mud snail (*Potamopyrugus antipodarum*) is a highly invasive, high-impact species and is of great concern. It was first discovered in the Snake River, Idaho in the 1980s (Hall et al. 2006). It is now rapidly spreading throughout the western United States and has become established in rivers in 10 western states and three national parks. It is a parthenogenic livebearer with high reproductive potential. The greatest densities range from 100,000 to 750,000 per square meter. It has been observed on in the lower reaches on both sides of the Columbia River (http://www.esg.montana.edu/aim/mollusca/nzms/status.html). It has no natural predators or parasites in the United States and its main impact is on the food chain as it is not a preferred prey and outcompetes native snails and aquatic insects for food.

Exotic species are widespread throughout coastal estuaries and the Columbia River (Hayslip et al. 2006). Data from 1999-2000 demonstrated that 75-80% of the area was invaded to some extent and that 12-25% was highly invaded. These areas contain more exotic species than the Puget Sound area. However, these exotic species are not present in the current species lists for LEWI.

Table 4.5. Non-native animals found within LEWI. Species are sorted alphabetically by taxon and then by scientific name.

Scientific Name	Common Name	Taxon
Vertebrates		
Rana catasbeiana	bullfrog	Amphibian
Passer domesticus	house sparrow	Bird
Sturnus vulgaris	European starling	Bird
Lepomis gibbosus	pumpkinseed	Fish
Micropterus salmoides	largemouth bass	Fish
Perca flavescens	yellow perch	Fish
Didelphis virginiana	virginia opossum	Mammal
Myocastor coypus	nutria	Mammal
Rattus rattus	black rat	Mammal
Invertebrates		
Potamopyrugus antipodarum	New Zealand mud snail	Mollusc

4.3 Land Use

Land use and changes in land use were evaluated for both the Oregon and Washington sides when data were available. Four metrics were used: percentage impervious surface, human population density, road density (data for only Washington State available) and zoned land use planning.

4.3.1 Key Findings

The key findings from this section are as follows:

- Impervious surfaces occupy a very small amount of LEWI.
- Road density in the LEWI units within Washington is in the same range as the rest of the county. No road density data were available for Oregon.
- Human population pressure is low and expected to remain relatively low.

- County zoning designations appear appropriate within most LEWI units.

- Development or conversion due to land use designations does not appear to be a significant threat to LEWI in the near future, although there is some potential for future development immediately around the units, particularly in the immediate vicinity of Warrenton on the north side of the Oregon units and Seaside and Gearhart on the south sides. The units that appear most vulnerable to changes in land use designation are Fort Clatsop, Fort Stevens, and Sunset Beach.

4.3.2 Impervious Surfaces

Methods for analyzing impervious surfaces are presented in Section 2.6.4.

The Total Impervious Surface (TIA) of LEWI is 8.2 ha. Most of the park surface (98.6%) does not have impervious surfaces (Figure 4.2). Most of the impervious surfaces were roads, and three-quarters of individual pixels had < 20% impervious surfaces (Figure 4.3).

Impervious surfaces are not equally distributed among land cover types. The developed land cover class accounts for 41.5% (3.4 ha) of the TIA. Much of the rest of the TIA is found in forests (28%; 2.3 ha) and wetlands (23%; 1.9 ha), largely due to roads.

4.3.3 Road Density

Methods for analyzing road density are presented in Section 2.6.4.

Road density ranged from 1.65 km/km^2 at Station Camp and Dismal Nitch to 2.80 km/km^2 at Cape Disappointment (Figure 4.4). In comparison, the road density for all of Pacific County is 2.39 km/km^2. 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).

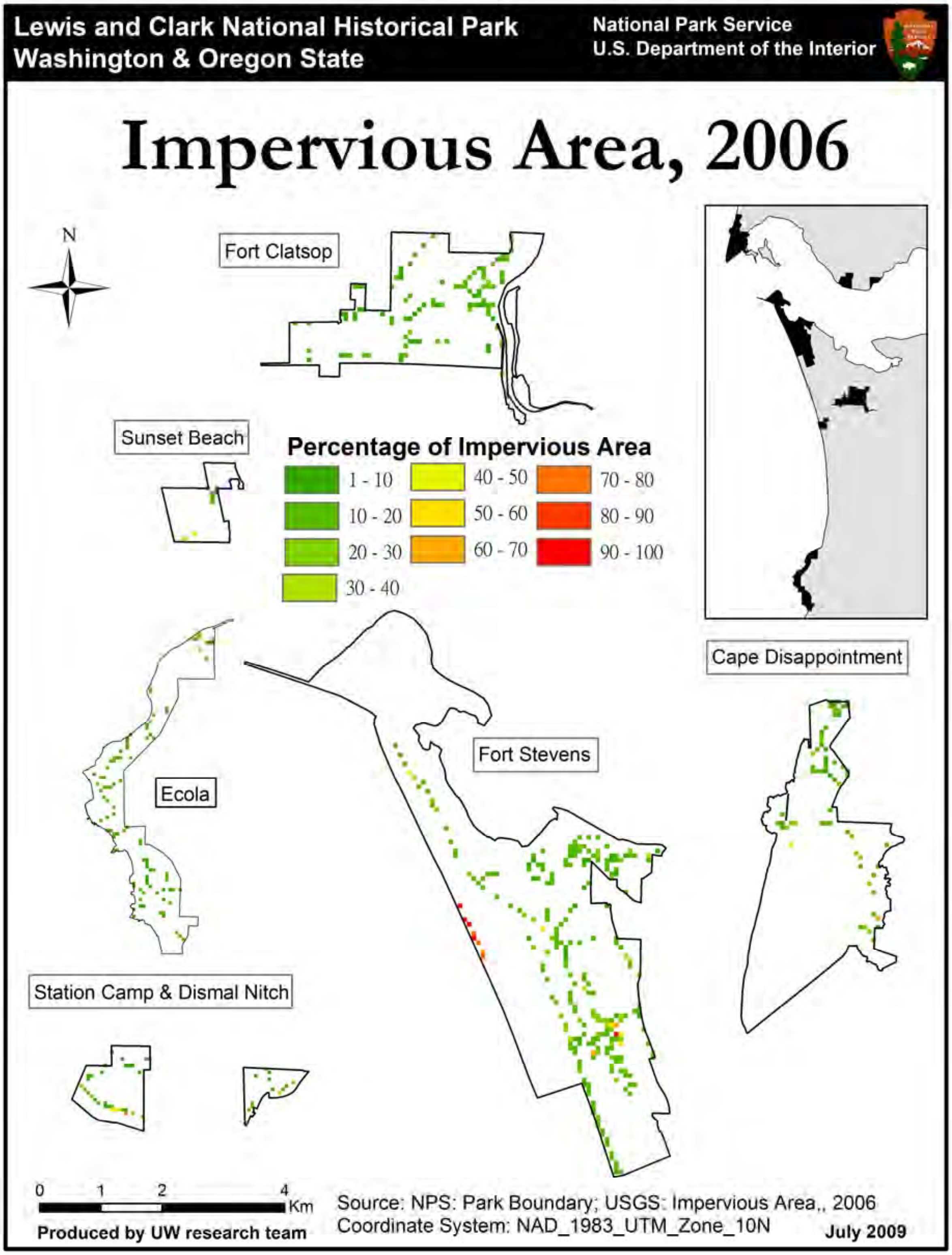


Figure 4.2. Impervious surfaces within LEWI. The proportion of impervious surfaces within a given 30 x 30 m pixel ranges from zero (white) to 100% (red).

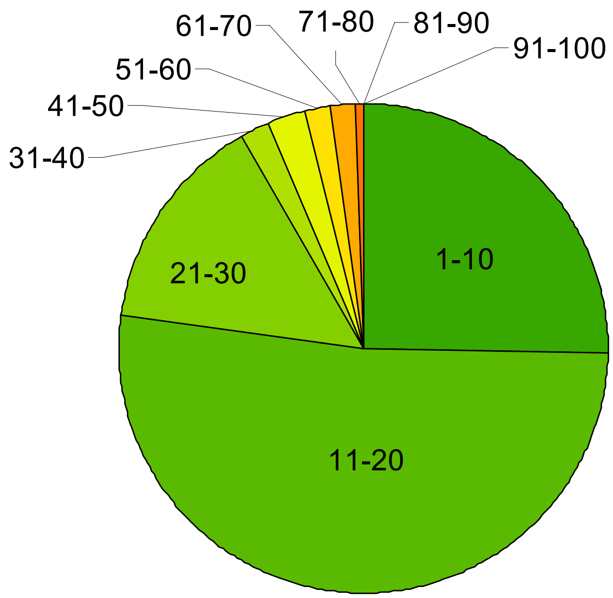
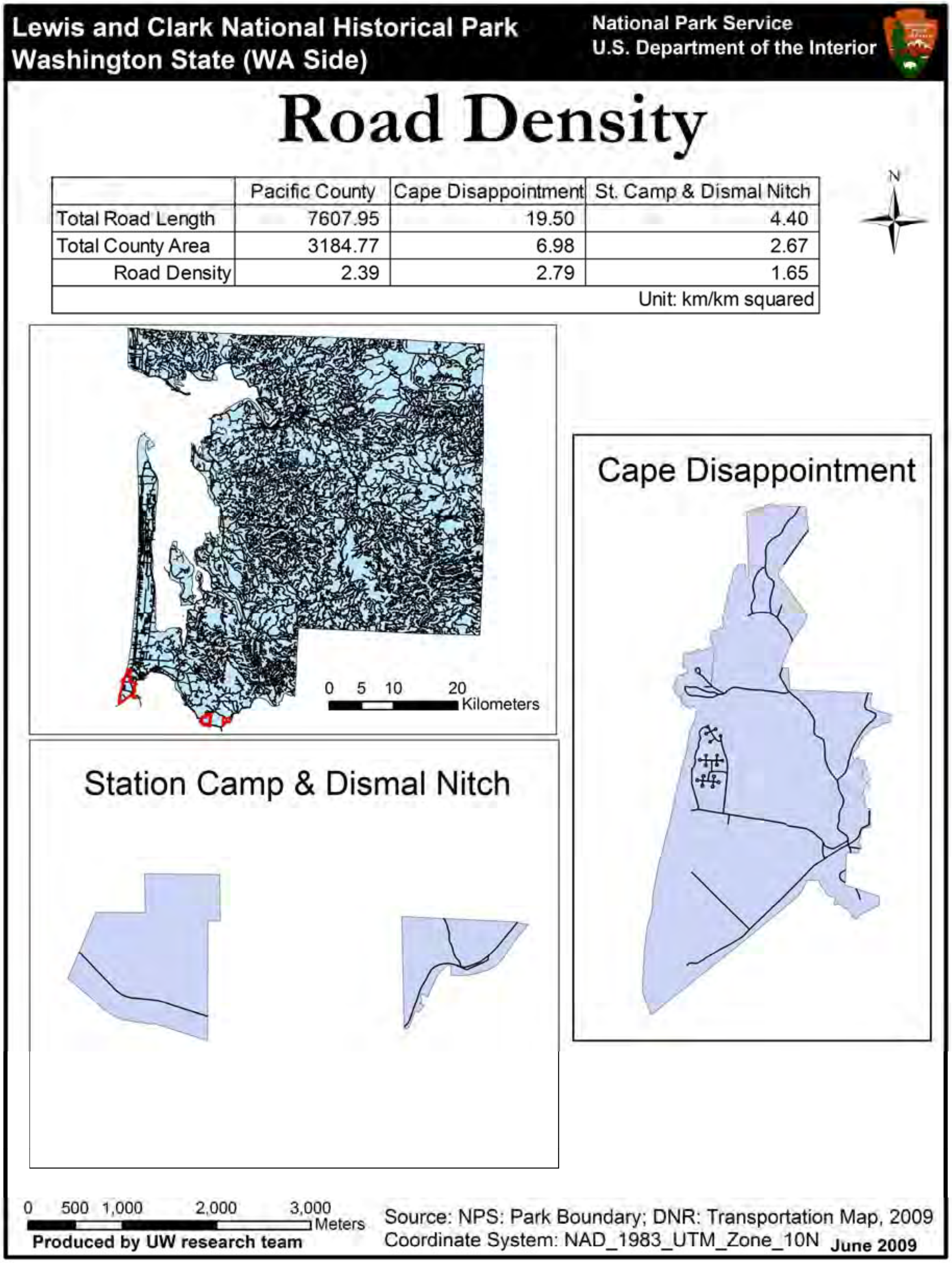


Figure 4.3. Proportion of impervious surfaces within pixels of LEWI. Note that this figure summarizes only the 1.4% of pixels that contained impervious surfaces; 98.6% of LEWI did not contain impervious surfaces.



	Pacific County	Cape Disappointment	St. Camp & Dismal Nitch
Total Road Length	7607.95	19.50	4.40
Total County Area	3184.77	6.98	2.67
Road Density	2.39	2.79	1.65
			Unit: km/km squared

Figure 4.4. Roads within Pacific County, Washington, including the Cape Disappointment, Station Camp, and Dismal Nitch units of LEWI. The table contains the calculation of road density for these areas.

4.3.4 Human Population

Methods for analyzing the human population are presented in Section 2.6.4.

The joint population of Pacific and Clatsop counties grew from < 18,700 in 1900 to ~ 58,700 in 2008 (Table 4.6). Projected growth patterns suggest a population of ~61,600 by 2030. The annual growth rate was > 2% from 1900-1920, but has been < 2% since then and < 1% since 1980. It is projected to stay well below 1% through 2030.

Population density is currently about 12 people per square km, and is projected to reach about 14 people per square km by 2030. For comparison, the US Census Bureau estimates that the population density of Washington state was 38 people per square km in 2008, and that the density of the United States was 33 people per square km. Although neither county is densely populated, the development of the coastal area and Warrenton in northwestern Clatsop County are having considerable impact on certain parts of LEWI – notably at Fort Stevens State Park, Fort Clatsop, and Sunset Beach.

Table 4.6. Joint population of Pacific County, WA, and Clatsop County, OR, from 1900 through 2030. 1900-2008 population data are from the US census (www.census.gov/population), and 2010-2030 data are projected by state offices. The annual growth rate is the annualized rate of change between that year and the next census (2008 data were not included in the growth rate calculations). Population density is the number of people per square km (There are 2.6 km^2 per square mile).

Year	Population	Annual Growth Rate	Population Density	Note
1900	18,748	4.33	4	
1910	28,638	2.85	6	
1920	37,921	-0.49	8	
1930	36,094	1.19	8	
1940	40,625	1.54	9	
1950	47,334	-1.18	10	
1960	42,054	0.51	9	
1970	44,269	1.17	10	
1980	49,726	0.48	11	
1990	52,183	0.82	11	
2000	56,614	0.32	12	
2008	58,675		13	Not included in growth rate calculations
2010	58,433	0.31	13	Projection
2015	59,357	0.26	13	Projection
2020	60,146	0.26	13	Projection
2025	60,947	0.22	13	Projection
2030	61,628		14	Projection

4.3.5 Zoned Land Use

Methods for analyzing zoned land use are presented in Section 2.6.4. We analyzed current land use zoning within LEWI and within Pacific County, WA, and Clatsop County, OR.

4.3.5.1 Inside LEWI

Almost two-thirds of LEWI is zoned as Park and Conservation Areas, followed by about equal amounts of Rural Forest and Multiple-Use Development (Table 4.7). Land use designations vary considerably among LEWI units. Fort Stevens is zoned as Park and Conservation Areas, and as Multiple-Use Development. Ecola State Park is zoned almost entirely as Park and Conservation Areas. Fort Clatsop is zoned primarily as Rural Forest, followed by Park and Conservation Areas and Agriculture. Sunset Beach is zoned as Park and Conservation Areas and as Rural Mixed-Use. Dismal Nitch and Station Camp are zoned entirely as Rural Forest. Cape Disappointment is zoned almost entirely as Park and Conservation Areas.

Table 4.7. Land use designations within LEWI units. Land use designations are defined in Section 2.6.4. A detailed crosswalk showing all zoning districts within Pacific County, WA, and Clatsop County, OR is provided in Appendix 8.

Land Use Designation	**LEWI**		**Fort Stevens**	**Ecola**	**Fort Clatsop**	**Sunset Beach**	**Dismal Nitch**	**Station Camp**	**Cape Disappt.**
	Area (ha)	%	%	%	%	%	%	%	%
Agriculture	40	1.2	0.0	0.0	7.6	0.0	0.0	0.0	0.0
Multiple-Use Development	577	16.7	36.6	0.3	0.3	0.0	0.0	0.0	3.4
Rural Mixed-Use	38	1.1	0.0	0.0	0.4	37.7	0.0	0.0	0.0
Rural Forest	619	18.0	0.0	1.7	78.1	0.0	100.0	100.0	0.0
Rural Residential	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Park & Conservation Areas	2,171	63.0	63.4	98.0	13.6	62.3	0.0	0.0	96.6

4.3.5.2 Outside LEWI

Pacific and Clatsop Counties are primarily rural, and their land use designations appear designed to keep them as such (Table 4.8; Figure 4.5). Three quarters of the combined land area is designated as Rural Forest. The next most abundant zoning designations are Rural Mixed-Use and Parks and Conservation Lands, each of which accounts for about 9% of the area.

Most of Pacific County's lands are designated Rural Forest. Lands designated for Agriculture or as Rural Residential are concentrated on the coast of the Pacific Ocean. Rural Mixed-Use is concentrated in the valley near Willapa. Other than LEWI units, Pacific County's designated Park and Conservation Areas are found primarily in Leadbetter State Park and Long Island.

Clatsop County's land use designations are largely similar to those of Pacific County. With the exception of its Northwest corner, where the LEWI units are situated, most of the county is designated as Rural Forest. Agriculture, Multiple-Use Development, and Rural Mixed-Use designations are all concentrated around Astoria. An important way in which Clatsop County differs from Pacific County is that its entire Northern section (along the Columbia River) is designated Park and Conservation Areas. In contrast, Pacific County maintains its Rural Forest designation to the Columbia River's edge.

Table 4.8. Land use designations within Pacific and Clatsop counties. Land use designations are defined in Section 2.6.4. A detailed crosswalk showing all zoning districts within Pacific County, WA, and Clatsop County, OR is provided in Appendix 8.

Land Use Designation	**Pacific & Clatsop Counties Combined**		**Clatsop County**		**Pacific County**	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	9,255	1.9	5,907	2.4	3,348	1.4
Multiple-Use Development	18,227	3.8	14,223	5.8	4,004	1.7
Rural Mixed-Use	42,991	8.9	5,634	2.3	37,357	15.7
Rural Forest	362,905	75.1	181,192	74.1	181,713	76.2
Rural Residential	7,857	1.6	1,579	0.6	6,278	2.6
Parks & Conservation Lands	41,906	8.7	36,068	14.7	5,838	2.4
Total	483,141	100.0	244,603	100.0	238,538	100.0

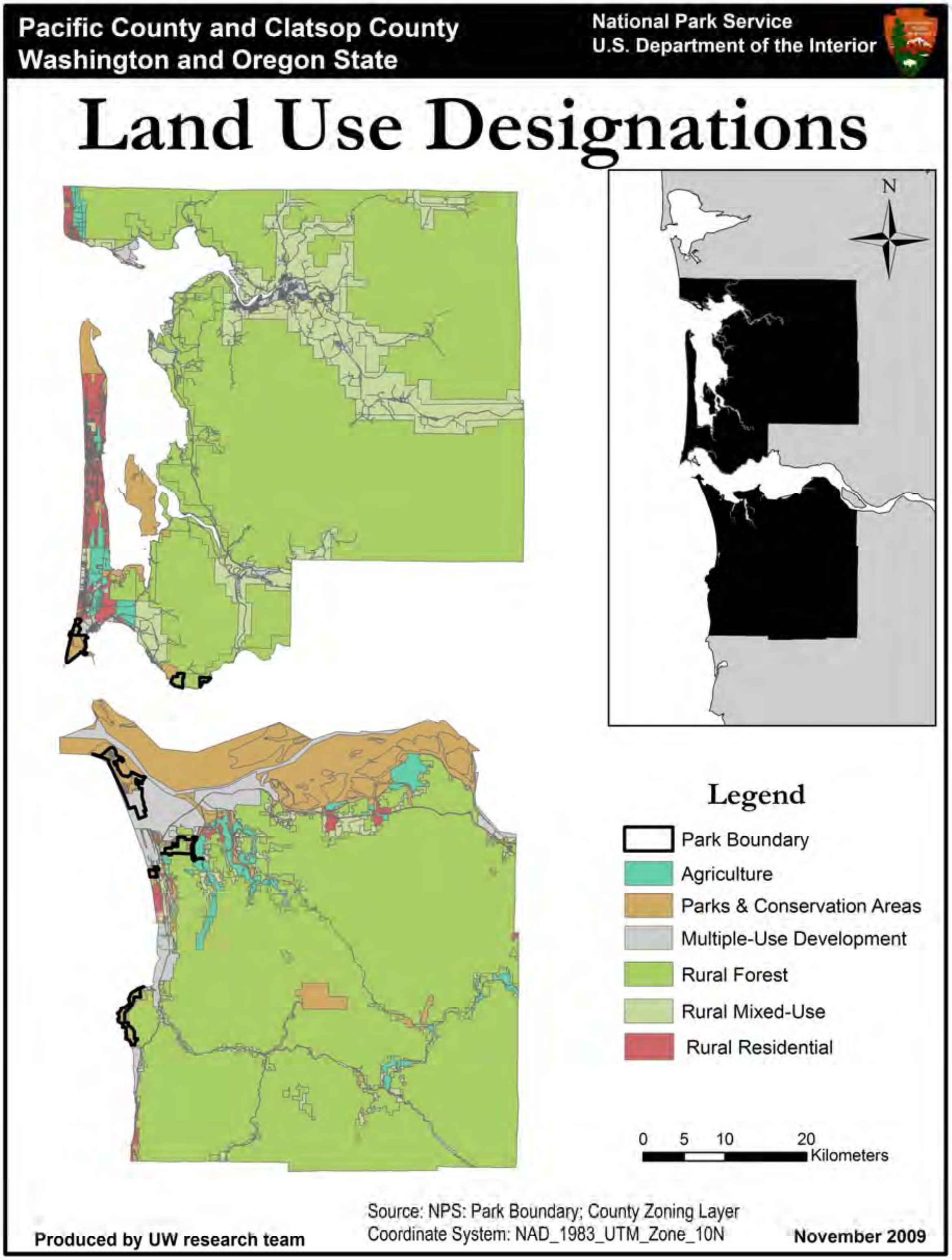


Figure 4.5. Land use designations within Pacific and Clatsop counties, including LEWI units. Data are summarized in Table 4.8.

4.4 Air and Water

4.4.1 Key Findings

The key findings of this section are as follows:

- Air Quality – No significant episodes or sources of local air pollution have been noted or cited. However, long-distant transport (e.g., Asia and western fires) provides input of carbon monoxide, heavy metals (e.g., mercury), ozone and particulates (PM2.5). Mercury appears to be the only significant input.

- The Columbia River contains high levels of mercury, DDT, PCBs and PBDEs. We lack specific data about these contaminants within LEWI, and about trends in contaminant levels.

- Limited data suggest intermittent elevated nitrate, phosphorus and coliform bacteria levels that are often attributable to direct human and indirect human sources (e.g., agriculture and livestock).

- Agriculture and roads may increase sediment loading and turbidity.

- Groundwater is plentiful in LEWI, but the coastal sand aquifers are sensitive to contamination. A number of potential contamination sources have been identified.

4.4.2 Air Quality

Regional- and long-distant transport of air pollutants particularly PM2.5, ozone and Hg are likely the largest threats to air quality at LEWI (Anenberg et al. 2009; Finley et al. 2009; Jaffe et al. 2005, 2008; Weiss-Penzias et al. 2006, 2007). These authors have noted long-distance transport of a suite of pollutants from Asia as a result of fires in Siberia, industrial activity in eastern China or the burning of coal in much of China. Finley et al. (2009) estimated that wildfires (e.g., southern California to southern Oregon) are a significant source of PHg (particulate bound mercury), approximately equal to anthropogenic sources. Implications for these transport quantities and pathways for Hg means that fish in the Columbia River Watershed or indigenous fish and amphians in LEWI may have elevated Hg levels such as noted in OLYM (EPA 2009, Landers et al. 2008). In addition to the high Hg levels in fish from two OLYM lakes, mammals (mink and otter) and birds (kingfisher) that ate fish were also high in Hg. In lakes in MORA, fish had elevated levels of both Hg and polybrominated diphenyl ethers (PBDE or flame retardants) (Landers et al. 2008).

As National Ambient Air Quality Standards are reduced, global economic development and associated pollution rises, wildfires (as a result of historical fire suppression, present-day fuel accumulation, and climate change) increase, and weather and climate changes, remote locations such as LEWI may find air pollution a future threat. However, predicted atmospheric nitrogen deposition is much lower in the Pacific Northwest than in many other terrestrial regions of the world (Bobbink et al. 2010).

As noted earlier (Section 3.2.3), the NPS does not monitor air quality within LEWI. Nonetheless, data from other parks in the region (NPS ARD 2009) indicate the following:

- Visibility – moderate concern and stable at MORA, NOCA, and OLYM
- Nitrogen deposition – significant concern and degrading at MORA and OLYM; significant concern and stable at NOCA
- Sulfur deposition – significant concern and improving at MORA and NOCA; significant concern and stable at OLYM
- Ozone – moderate concern and stable at MORA; good condition and degrading at NOCA; good condition and stable at FOVA; no data for OLYM

4.4.3 Surface Waters

The EPA assessed streams within the Coast Range ecoregion in 1994 and 1995 (Herger and Hayslip 2000). They used probability-based selection of sample sites and obtained data from 104 sites. However, only one of their sites (WA001S; Map # 95) was near a LEWI unit; it is just north of Dismal Nitch. They focused on water chemistry, physical habitat, vertebrate (fish and amphibians) community, and benthic macroinvertebrate community data. Inferences were intended for the entire sample area, so analyses were made using cumulative distribution functions rather than analyzing individual sites. They found that most streams contained fish and other vertebrates and that about a third had low levels of aquatic benthic macroinvertebrate richness. The percent of fine sediment in streams was correlated with agriculture and road type disturbances.

The EPA assessed the condition of estuaries throughout Oregon and Washington in 1999-2000 (Hayslip et al. 2006). They used probability-based selection of sample sites and obtained data from 251 sites, including a large number from the lower Columbia River. Estuaries were generally rated to be in good condition with respect to sediment contamination and total organic carbon levels, dissolved oxygen levels in the water, and nutrient levels (as measured by nitrogen and chlorophyll a concentrations). However, fish sampled in the lower Columbia River were identified as having high tissue concentrations of mercury, zinc, and DDT.

More recently, the EPA analyzed toxin levels throughout the Columbia River basin (EPA 2009). Given the proximity of the Columbia River to the various LEWI units, these concerns are likely also a factor in the estuaries and nearshore waters around LEWI. Four main contaminants were analyzed: mercury (including methylmercury), dichlorodiphenyltrichloroethane (DDT) and its breakdown products, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ether (PBDE) flame retardants. Mercury continues to be a cause of fish consumption advisories throughout the basin. Although DDT and PCBs have been banned in the US since the 1970s, they continue to persist in the environment. PDBEs are present in many consumer goods and persist in the environment, but have not been regulated by the EPA. The report noted large gaps in current information about these contaminants, and about their trends over time. In addition, we lack adequate information about ‘emerging contaminants’ such as pharmaceuticals.

In an evaluation of potential source water contamination that would impact drinking water quality for the town of Seaside, OR (Harvey 2000), the following potential sources of water pollution were identified: managed forest lands, managed agricultural, grazing or nursery lands, livestock areas/boarding stables, several quarries, residential areas with septic systems and wells, parking areas, roads, trails and pipeline or transmission line corridors. Because the water supply for Seaside comes from the upstream portions of the Necanicum River, small to medium sized streams in LEWI could share one or more of these potential sources of pollution.

Bischoff et al. (2000) conducted a comprehensive assessment of the Skipanon River. They evaluated riparian structure and stature, stream channel alterations and barriers to fish movement and passage, upland risks to stream water, and stream water quality and temperature with regard to salmon spawning and rearing. Their key findings include:

- Water temperatures often exceeded ideal temperatures for rearing
- 95% of the phosphorus values collected were greater than the 0.05 mg/L standard suggesting excess anthropogenic inputs
- Only 23% of the nitrate values exceeded the standard (0.30 mg/L)
- Fecal coliform bacteria levels were high: 89% and 72% of the samples exceeded 14 and 43 fecal coniform bacteria per 100 mL.
- Generally, turbidity values were well below standards; however, during periods of intense rainfall and runoff, turbidity increases dramatically.
- Forestry per se has low impacts whereas forest and rural roads have moderate impacts on peak flows.

The Drinking Water Program at the Oregon Department of Human Services provides data about water quality in the Lewis and Clark River near Warrenton (http://170.104.63.9/inventory.php?pwsno=00932). For example, concentrations of trihalomethane and haloacetic acids, by-products from chlorination and other disinfectants, were elevated above maximum contaminant levels (MCLs) between June 2004 and September 2005 but below the MCL at all other sample dates. Only two samples exceeded standards for coliform between January 2002 and April 30, 2010. Other critical organic and inorganic components including arsenic were all below detection limits.

Previous reports (Fort Clatsop National Memorial 1994a, Klinger et al. 2007a) identified other potential impacts on aquatic ecosystems, including pesticide and fertilizer use, illegal dumping of household and industrial rubbish and toxic waste, and soil erosion from forest management activities.

Infrequent sampling by the Oregon DEQ indicates that the Lewis and Clark River and Youngs Bay have aluminum, dissolved oxygen and fecal coliform levels that do not meet state water quality level standards (Fort Clatsop National Memorial 1994b). The park began monitoring water quality in 1994, and has been following a consistent monitoring schedule since 1998. LEWI is currently working with the Water Resources Division and the network I&M program to expand the monitoring program to include newly acquired lands.

4.4.4 Groundwater

In general, groundwater is plentiful in LEWI (Frank 1970). The population of the area depends largely upon shallow coastal sand aquifers underneath the Long Beach Peninsula and Clatsop Plain (Figure 4.6). The upper part of the aquifer beneath the Long Beach Peninsula is comprised of dune sand and marine sand, and reaches a depth of 60 m (200’). Beneath the sand is a clay zone of reduced permeability, and below that is a deep aquifer that extends to bedrock at about 210 m (700’). Mean annual precipitation is about 1700 mm in Astoria, but variability is high. Estimated potential evapotranspiration is about 635 mm (25”) per year, and potential recharge varies from 1270-1780 mm (50-70”) 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 (Cline 1969).

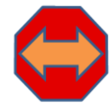
Both domestic and agricultural uses make demands on this water resource. At present, however, water quality is a greater concern than water use. The coastal sand aquifers are very sensitive to contamination because the water table sits only 10-15 feet below the surface and is overlain by highly permeable sands. In addition, development is occurring on top of these permeable sands. Septic systems are common, and urban runoff may contain metals, lawn fertilizers and other pollutants. Agriculturally managed cranberry bogs along the center of the peninsula are treated with pesticides and fertilizers and may be contiguous with the water table (Davis et al. 1997). Although flushing times for the aquifer are short, septic systems and solid waste disposal sites are still leaking into the aquifer. Population growth in the region would be detrimental to the aquifer system (Blakemore 1995).

Highly industrialized sites, such as those around Astoria, have a legacy of inadequately controlled disposal of industrial, marine and logging wastes that have found their way into water supplies. These sites are likely having a negative impact on benthic life, but the flushing is substantial and groundwater is not at risk other than locally.

Carey and Yale (1990) found that some well sites along the Long Beach Peninsula had high levels of pollutants. High chloride levels, found in a few wells, could indicate that there is contamination from sea spray, septic systems or seawater intrusion (background levels should be 7-8 mg/L). Likewise, some wells showed higher levels of nitrates. One sample from Ocean Park contained 14 mg/L; the drinking water standard is 10 mg/L. At this same site, chloride concentration was 25 mg/L. Nitrates could come from septic systems; another potential source is agricultural runoff from cranberry bogs which are fertilized in the summer (when these water samples were taken). Excessive amounts of iron occur in some peninsula groundwater samples (Cline 1969). Sampling done in 2008 found nitrate levels that varied from “not detectable” to 9.7 mg/L. Chloride levels varied from 6.1 to 51.7 mg/L (USGS 2008).

Another potential source of groundwater pollution is insecticides from cranberry cultivation. A 1996 study found elevated levels of three organophosphate insecticides in drainage ditch water near Grayland (near the boundary between Pacific and Grays Harbor County but in coastal dune bogs similar to the ones to the south). Guthion, Lorsban and Diazinon exceeded water quality criteria for the protection of aquatic life (Davis et al. 1997). The report on the incident stated that little information existed to determine the environmental pathways followed by this contamination. No high levels of any insecticides were found in crabs, oysters, or sticklebacks, but moderate levels were found in sticklebacks, which are consumed regularly by wildlife. In subsequent sampling, on the Long Beach Peninsula, selected pesticides were not found above the analytical detection limits.

4.5 Other Stressors



4.5.1 Diseases

Swiss Needle Cast is a foliage disease of Douglas-fir (*Pseudotsuga menziesii*) caused by the ascomycete fungus *Phaeocryptopus gaeumannii*, resulting in defoliation and reduction of growth. Currently it is causing an epidemic west of the Oregon coast range from Coos Bay to Astoria and northward into Washington. It was first discovered on Douglas-fir that was imported to Europe in the early 20th Century, hence the name "Swiss" needle cast. The pathogen itself is native to the Pacific Northwest and specific to Douglas-fir. Under most conditions it is a benign component of the tree canopy; however, a combination of relatively mild, humid conditions and extensive replanting of Douglas-fir on coastal sites previously occupied by a mixture of western hemlock, red alder, and Sitka spruce has likely led to the epidemic conditions. Symptoms generally include chlorosis, decreased needle retention, loss of height and diameter growth and in situations where conditions persist, tree mortality may occur (Hansen et al. 2000, Maguire et al. 2002, Manter et al. 2003). It is unclear whether the mortality is directly from the defoliation or indirectly from reduced tree vigor and other disease/insect problems (Kelsey and Manter 2004). Much of the recently acquired parcel from Weyerhaeuser contains young, dense second and third growth stands of Douglas-fir. Such stands and the presence of Swiss needle cast can be easily seen along the Fort-to-Sea Trail, especially as one descends from the overlook towards the south fork of Perkins Creek (T. Hinckley, personal observation).

4.5.2 Disturbances

4.5.2.1 Wind

Wind disturbances have been and will continue to be a major disturbance for all of the forested units of LEWI. The early December wind storm of 2007 broke and uprooted significant numbers and area of forest in both the Sand Dune Plains (largely the planted shore pine) and the second and third growth forests in the Fort Clatsop unit. Many of these stands were prioritized for a restoration thinning (see Chi 2008); however, the wind storm greatly accelerated the creation of gaps – monitoring of recovery and identifying areas still needing thinning should be high priorities.

Pacific storms also generate large storm surges which can significantly affect dune erosion and formation (Allan and Komar 2002). These surges may increase in significance in the light of anticipated climate change (Craft et al. 2009).

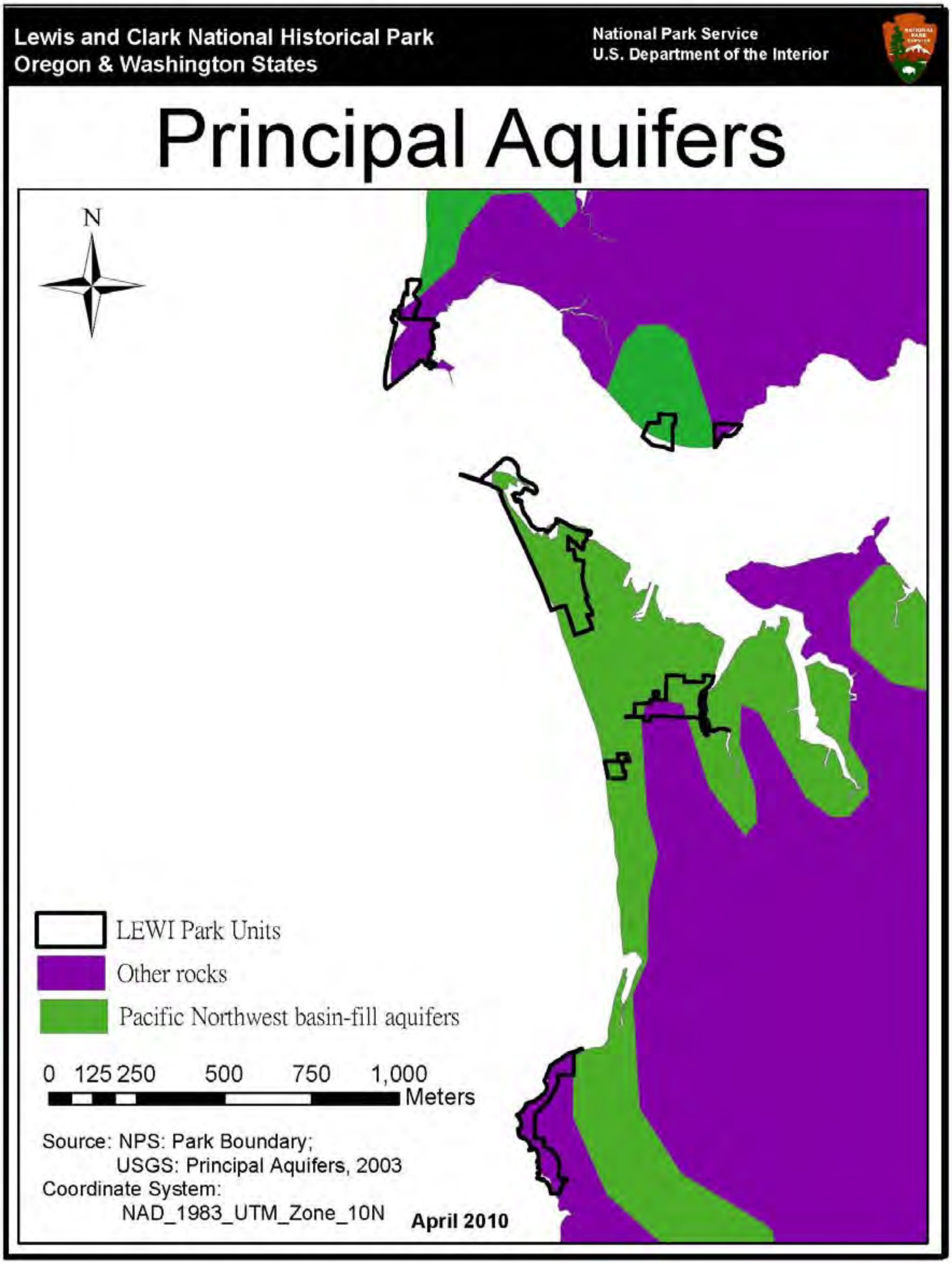


Figure 4.6. Groundwater map of LEWI units and surrounding areas.

4.5.2.2. Tsunami

The region is vulnerable to tsunamis generated by earthquakes on the Cascadia Subduction Zone, located about 70 miles off of the Pacific coast, and from distant sources (Klinger et al. 2007a). The damage caused by a large local earthquake event would be extensive and extreme. A very recent modeling effort (Righi and Arcas 2010) using Alaska-Cascadia and Kuril-Kamchatka sources resulted in waves as high as 7 m for Newport, OR. Data from the Oregon Department of Geology and Mineral Industries indicate that the towns of Hammond and Warrenton would be in great danger with tsunami-generated waves of 10-30 m (33-100’). Based on the topography of the region, a 10 m tall wave would come up the Skipanon River and go two hundred yards up Perkins Creek. Most critical is having a system that warns, instructs, and identifies safe places for Park personnel and visitors.

The likelihood of such an event over any given decade is very small, but an historical perspective is important. At Seaside, OR, five tsunamis in the past 2000 years can be detected as far inland as 2 km along the 5-km stretch of coast at Seaside (Gonzalez et al. 2006). Soil deposits from these tsunamis reached heights of 10 m. Major tsunamis occurred in 1700 and 770. The 1964 Alaskan tsunami reached the G Street Bridge in Gearhart and as far south as Avenue Q along the Necanicum River.

4.5.2.3 Fire

Fires are relatively infrequent, but when they occur, they are of high intensity (Agee 2000). Agee (2000) suggests that there were likely large stand replacing fires, perhaps associated with the 1700 earthquake. Climate change, presence of fuels from thinning or wind throw trees, and the presence of people may increase the likelihood of fire.

4.5.2.4 Altered Hydrology

Jetties, dikes, channelization, culverts, ditching and other factors have likely resulted in multiple impacts to marine shoreline, lakes, stream, estuary and other wetland habitats. These impacts are being offset by estuary restoration activities in recent years. Emerging in the future will be the significant prospect of continued and, perhaps, accelerated rise in sea level resulting in increased beach erosion and loss of existing and restored estuaries.

4.6 A Landscape Perspective on Stressors

One way to understand how these various stressors come together over major segments of the landscape is to once again return to Transects A and B.

Transect A provides a profile of the Fort (actually Lewis and Clark River) to Sea Trail. The condition of each habitat or ecosystem type along this profile is shown in Figure 4.7 and was assessed by comparing it to what was believed to have occurred at the time of Lewis and Clark (actual evaluation was a combination of the Oregon Gap Study and Agee 2000). In most cases, current conditions ranged from ok to poor with most types showing positive changes. Of the forested stands, only the plantation Douglas-fir was judged to be in a declining state due to high levels of infection with Swiss needle cast. These stands also contained few other tree species.

The western-most section of Perkins Creek is close to a road; this likely is why ATV tracks were present in the creekbed and surrounding wetlands. The dune-prairie system was judged to be in a declining state due to current livestock grazing and trampling, erosion, manure, and the presence of non-native species (Scotch broom and Himalayan blackberry) in the shore pine zone and youngest dune complexes. The shore pine zone sustained considerable damage as a result of the December 2007 windstorm. It also represents a non-historical vegetation community as shore pine was planted added in the early twentieth century to stabilize the dunes. Finally, the youngest dune complexes contain non-native beachgrass and a few other invasives.

Transect B (Figure 3.11) runs through Cape Disappointment State Park and spans four habitat types: dune beach, emergent freshwater wetland, second-growth Sitka spruce / western hemlock forest, and headlands. The dune beach was most susceptible to human impacts and contained evidence of considerable human activity. The emergent freshwater wetland contained some invasives; the largest issue was English ivy, which is being actively managed. The second-growth Sitka spruce / western hemlock forest was young but included compositional and structural elements of an older stand. Its rapid growth will clearly result in old-growth structures in a relatively short time and without the need for active management. The headlands contained a few invasives but were in relatively good shape. Human traffic was restricted to the trail itself.

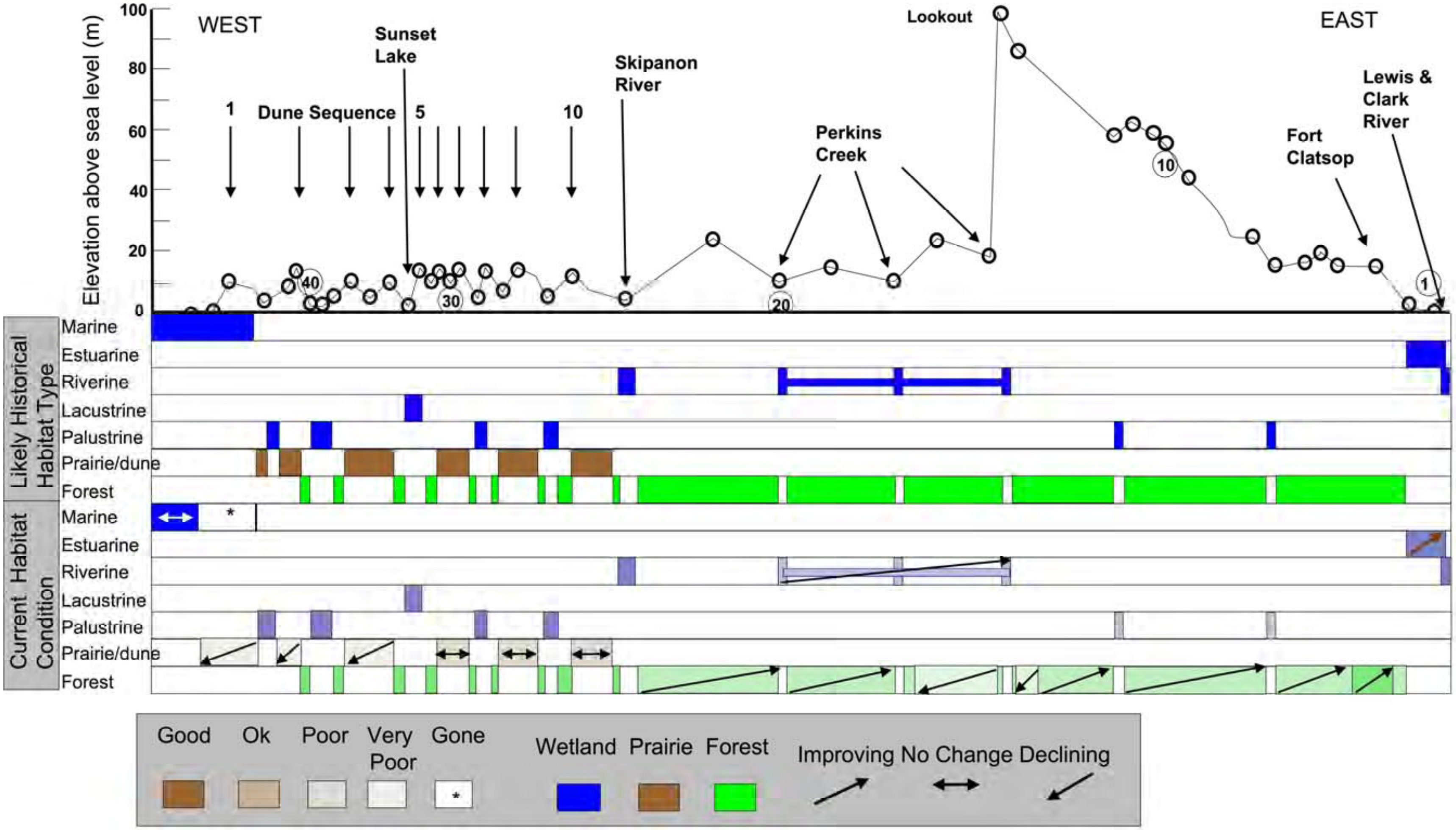


Figure 4.7. Transect A, showing a profile of historical and current habitats, including the current condition and trend of each habitat, along the Fort-to-Sea trail. The Pacific Ocean is to the left and the Lewis and Clark River to the right. This is the same profile as in Figure 3.3, but is drawn to emphasize the condition and trend of the habitats.

Chapter 5 - Conclusions and Information Needs

5.1 Current Condition

Lewis and Clark National Historical Park (LEWI) is located in a cultural, ecological and geographical setting that is noteworthy. It contains a rich diversity of plant and animal species, both relatively rare and iconic ecosystems, structurally diverse plant communities and rich ecotones, and a visually, educationally, and historically a rich cultural history of one of the major periods of the Lewis and Clark Expedition.

LEWI's 13 constituent units are spread in a narrow band along the Pacific Coast on either side of the mouth of the Columbia River. One of the challenges for management of LEWI's natural resources is its complicated administrative / management structure. Management involves a complex of federal, state, and local agencies. In addition, landscape-level planning is complicated by the small size of the park and their distribution within a matrix of non-park lands.

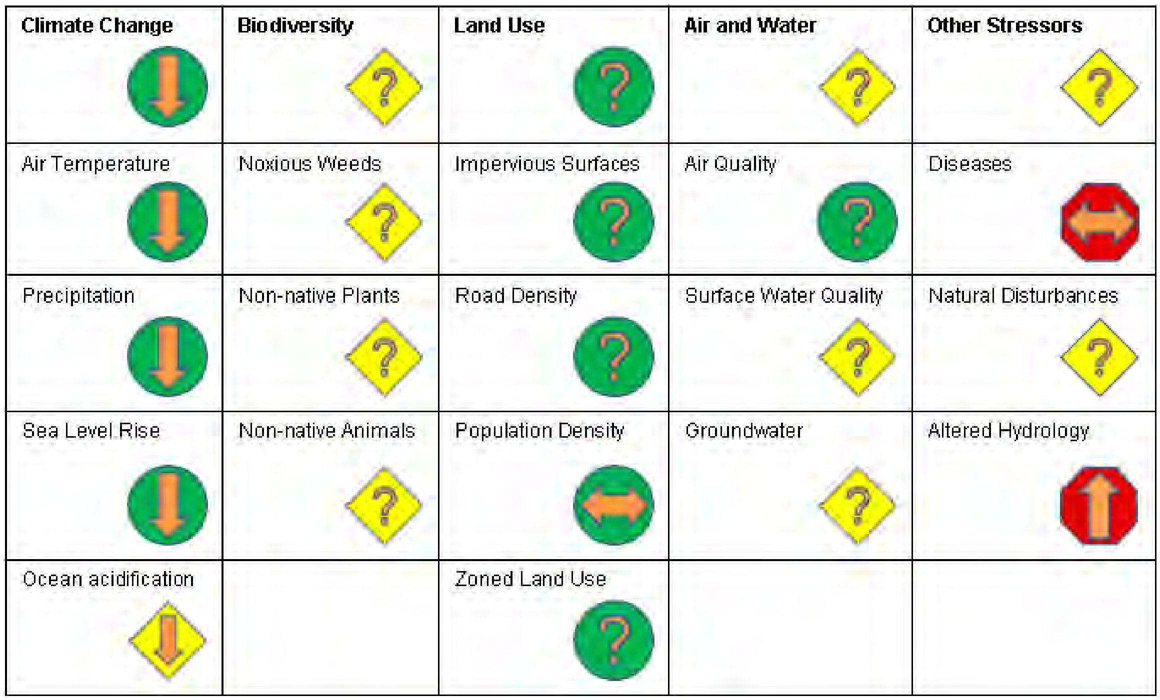
The vegetation has been dominated by forests and wetlands both historically and at present. However, the structural complexity of the forests has changed significantly as there if little old-growth forest left and large areas dominated by second- and third-growth Douglas-fir stands. A considerable amount of beach accretion has occurred since the Lewis and Clark expedition.

Considering all units together, LEWI contains about 30% of the regional species pool of vascular plants along with 233 taxa of non-vascular plants (bryophytes, fungi, lichens) and 284 animals. In terms of species listed under the Endangered Species Act, there are two listed plants and 31 listed animals in or associated with LEWI.

5.2 Threats and Stressors

Here we summarize our evaluation of threats and stressors on the natural resources of LEWI (Table 5.1). This is followed by a summary of our conclusions within each category.

Table 5.1. Summary evaluation of indicators within each of five categories (columns) of threats and stressors facing the natural resources of LEWI. Symbol shape and color reflect current condition (green: circle good; yellow diamond: moderate concern; red stop sign: significant concern). The arrow or question mark within each symbol reflects trend data (improving, stable, declining, no data).



Climate Change	Biodiversity	Land Use	Air and Water	Other Stressors
Air Temperature	Noxious Weeds	Impervious Surfaces	Air Quality	Diseases
Precipitation	Non-native Plants	Road Density	Surface Water Quality	Natural Disturbances
Sea Level Rise	Non-native Animals	Population Density	Groundwater	Altered Hydrology
Ocean acidification		Zoned Land Use		

5.2.1 Climate Change

Although we see relatively little evidence of directional trends in climatic parameters over short timeframes, our assessment is that the trend for these indicators is declining. Temperatures at LEWI are projected to rise by 1.2 to 3.7 ºC between 1961-1990 and 2070-2099. Precipitation is projected to increase somewhat, and to shift seasonally such that summers are drier than at present. Sea level is projected to increase, although the range of estimates for the magnitude of this increase is considerable. Ocean acidification has occurred and is projected to continue to occur as atmospheric CO_2 levels increase.

Sea-level rise may be the most significant impact of climate change on the units associated with LEWI. Climate change will likely alter the distribution patterns of aquatic (both freshwater and marine) and terrestrial organisms. Ocean acidification, oxygen depletion zones, and harmful algal blooms will greatly affect marine bird and animal composition and diversity. Climate change potentially represents the single greatest threat to the Park Service's Mission of Preservation of both cultural and natural resources.

5.2.2 Biodiversity

LEWI contains proportionally more noxious weeds and non-native vascular plant species (41%) than expected based on the regional species pool. We suspect that this difference reflects more comprehensive floristic assessments within LEWI and aggressive management actions by NPS staff to locate and treat noxious weeds as they colonize areas within LEWI.

The proportion of non-native animals is low (< 1%), though many of the faunal records are incomplete. The magnitude of the effects caused by non-native animals may be disproportionate to their abundance since they can compete with and feed on native species, and can also alter vegetation structure and composition.

Non-native species are one of the greatest threats to biodiversity within the United States. Continued monitoring and management are required to minimize their effects on the native biota that LEWI is mandated to preserve.

5.2.3 Land use
Habitat destruction, one aspect of land use, is one of the greatest threats to biodiversity within the United States. However, our land use indicators suggest that land use is currently a relatively low threat within LEWI. Impervious surfaces are present on a small proportion of the land base. Road density is in the same range as in the region. Human population pressure is low and forecast to remain relatively low. County zoning designations appear appropriate for the units.

However, these analyses are conducted at a regional (county) level; at smaller spatial scales there are areas near the park units that may experience more intensive land use. Examples include the areas around Warrenton, Seaside, Gearhart, and Astoria. In addition, the fragmentation of the units is a concern as it complicates landscape-scale planning and management.

With the exception of human population pressure, we do not have data to assess the trends in these indicators.

5.2.4 Air and Water
Air quality at LEWI is currently thought to be excellent, though it is not being monitored by the NPS. Surface water quality is a moderate concern as the Columbia River is a major source of such toxics as mercury, DDT and its derivatives, PCBs and PBDEs. Groundwater is plentiful but a moderate concern as it is sensitive to contamination from a variety of sources. With rising sea levels, salt water intrusion may become a problem.

Although there are repeated measurements of water quality data regionally that could be used to assess trends, few such data points occur within the LEWI units.

5.2.5 Other Stressors
Diseases are a significant concern within particular habitats. For example, Swiss needle cast is a concern within second- and third-growth Douglas-fir stands.

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 depending on where and when they occurred. Because of their stochastic nature, it is difficult to assess trends associated with these disturbances.

Tidal activity is an important disturbance process along the coast that has been significantly altered by humans through the establishment of dikes, jetties, culverts, and other structures. Estuarine restoration activities in the last few years have begun to restore this process by breaching dikes, etc. Rising sea levels may increase beach erosion and alter the location and size of estuaries.

5.3 Cross-park Comparisons

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 for EBLA and SAJH so we were unable to make cross-park comparisons as we had originally intended.

FOVA and LEWI are linked by the Columbia River and historically were important Native American sites. They differ strongly in size, degree of urbanization, matrix composition, and fragmentation. In addition, FOVA seeks to display a more complex cultural history than LEWI yet contains few remnants of its historical vegetation and is least likely to be able to recover these.

There is much more information about the natural resources of LEWI (though this picture is still incomplete). Climate change is an important stressor at both parks, though sea-level rise and ocean acidification will more strongly affect LEWI. Non-native species and plant communities are a larger issue at FOVA, as is land use (road density, population density, and other urban pressures). Air quality issues at LEWI relate to regional and global air transport patterns, whereas those at FOVA relate more strongly to local patterns. Water quality is a greater concern at FOVA given the high degree of urbanization and historical industrial activity around it.

5.4 Information Needs

Natural resource management at LEWI is hindered by a lack of park-specific information. For example, species diversity information is relatively complete for taxa such as vascular plants, fungi, lichens, and birds, but is incomplete for some groups (e.g., insects) and missing for others (e.g., benthic invertebrates). In addition, these data would be most useful if recorded for each unit rather than for LEWI as a whole. The current data are relatively complete for some units and known to be incomplete for others.

While it is difficult assessing the current condition of LEWI’s natural resources, it is even more challenging assessing their temporal trends. For example, the species richness data that we possess are static and do not permit assessments colonization by new species, local extirpations of native species, or the control of individual non-native species through management activities. We lack comparable trend data about many other indicators.

Finally, LEWI would benefit from a GIS repository in which spatially explicit management activities are tracked. For example, substantial estuarine restoration activities have occurred in recent years, but we do not have documentation of when and where they occurred. This is also the case for several other NPS issues that are spatially explicity and were rated of high importance at LEWI – for example, ‘Areas with evidence of invasive species’, ‘Native plant restoration’, and ‘Areas of focal species’.

Chapter 6 - References

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Appendices

Appendix 1. Correspondence between the EPA assessment framework (Young and Sanzone 2002) and the issues and resources identified and ranked by the NPS. Within each park, each issue is ranked on an ordinal scale from 0 (lowest priority) to 3 (highest priority); 'unk' means that the importance of that issue for that park unit is unknown. Issues are color-coded according to the spatial scale of concern (park-specific (orange), regional (yellow), common (green)). Each issue is also categorized as a condition indicator (C) or a stressor indicator (S). This table is a supporting document for Table 2.8.

EPA Assessment Framework Category/ Subcategory/ Theme	**NPS Issue**	**NPS Score**					**C / S**
		EBLA	**FOVA**	**LEWI**	**SAJH**	**Mean**	
Landscape Condition							
Extent of Ecological System / Habitat Types							
Historical Extent of Each Vegetation Type							
Current Extent of Each Land Use Type							
	Urban encroachment/rural development	**3**	**3**	**3**	**3**	**3.00**	S
	Logging or habitat conversion	**2**	**0**	**3**	**3**	**2.00**	S
	Road and trail development	**1**	**2**	**1**	**2**	**1.50**	S
	Social trails	**2**	**1**	**0**	**1**	**1.00**	S
	Recreation	**1**	**3**	**2**	**2**	**2.00**	S
	Roadless areas	**0**	**1**	**1**	**1**	**0.75**	C
	Cave or karst features	**0**	**0**	**0**	**1**	**0.25**	C
Landscape Composition							
Landscape Pattern/Structure							
Biotic Condition							
Ecosystems and Communities							
Community Extent							
	Wetlands & Riparian Areas	**3**	**3**	**3**	**3**	**3.00**	C
	Lakes and streams	**2**	**0**	**1**	**1**	**1.00**	C
	Areas of pristine or old-growth vegetation	**2**	**1**	**1**	**3**	**1.75**	C
	Estuarine restoration	**unk**	**0**	**3**	**unk**	**1.50**	C
	Past logging and restoration of those lands	**1**	**0**	**3**	**1**	**1.25**	C
	Abandoned mine lands	**0**	**0**	**0**	**0**	**0.00**	C
Community Composition							
	Invasive species	**3**	**3**	**3**	**3**	**3.00**	S
	Areas with evidence of invasive species	**3**	**3**	**2**	**3**	**2.75**	S
	Species inventories	**unk**	**2**	**3**	**unk**	**2.50**	C
	Native plant restoration	**2**	**3**	**2**	**3**	**2.50**	C
Trophic Structure							
Community Dynamics							
	Grazing	**0**	**1**	**0**	**1**	**0.50**	S
Physical Structure							
Species or Population Measures							

EPA Assessment Framework **Category**/ Subcategory/ Theme	NPS Issue	NPS Score EBLA	FOVA	LEWI	SAJH	Mean	C / S
Population Size							
Genetic Diversity							
Population Structure							
Population Dynamics							
Habitat Quality							
	Areas of focal species	unk	2	2	3	2.33	C
	Habitat for focal species	unk	2	2	3	2.33	C
Organism Condition							
Physiological Status							
	Phenological cycles	0	2	1	1	1.00	C
Symptoms of Disease or Trauma							
Signs of Disease							
Chemical/Physical Characteristics							
Nutrient Concentrations							
Nitrogen							
Phosphorus							
Other nutrients							
Trace Inorganic and Organic Chemicals							
-	Point sources of pollution	1	3	1	2	1.75	S
-	Pesticides / contaminants in groundwater	2	1	unk	2	1.67	S
-	Pesticide runoff	3	1	unk	1	1.67	S
Metals							
Other trace elements							
Organic compounds							
	Hazardous waste	unk	2	3	1	2.00	S
Other Chemical Parameters							
pH							
Dissolved oxygen/redox potential							
Salinity							
Organic matter							
Other							
Physical Parameters							
Soil/sediment							
Air/water							
	Global warming	2	2	2	1	1.75	S
	Airborne dust	1	0	1	1	0.75	S
Hydrology/Geomorphology							
	Clean water	3	2	2	2	2.25	C

EPA Assessment Framework **Category**/ Subcategory/ Theme	NPS Issue	NPS Score EBLA	FOVA	LEWI	SAJH	Mean	C / S
Surface and Groundwater Flows							
Pattern of surface flows (rivers, lakes, wetlands, and estuaries)							
	Water diversion	**0**	**0**	**2**	**0**	**0.50**	S
Hydrodynamics							
Pattern of groundwater flows							
	Groundwater flow	**3**	**0**	**unk**	**2**	**1.67**	C
	Karst processes	**0**	**0**	**0**	**0**	**0.00**	C
Spatial and temporal salinity patterns (estuaries and wetlands)							
Water storage							
	Saltwater intrusion	**3**	**0**	**0**	**2**	**1.25**	C
Dynamic Structural Characteristics							
Channel morphology; Shoreline characteristics; Channel complexity							
Distribution and extent of connected floodplain (rivers)							
Aquatic physical habitat complexity							
Sediment and Material Transport							
Sediment supply and movement							
	Stream bank erosion	**0**	**0**	**2**	**1**	**0.75**	C
	Shoreline erosion	**3**	**1**	**2**	**3**	**2.25**	C
	Hillslope erosion (rill & gullying)	**1**	**0**	**1**	**3**	**1.25**	C
	Soil erosion	**3**	**1**	**1**	**2**	**1.75**	C
	Earthworks stabilization	**0**	**0**	**0**	**1**	**0.25**	C
Particle size distribution patterns							
Other material flux							
	Floatable debris	**1**	**0**	**0**	**2**	**0.75**	S
Ecological Processes							
Energy Flow							
Primary production							
Net ecosystem production							
	Carbon sequestration	**unk**	**1**	**unk**	**1**	**1.00**	C
Growth efficiency							
Material Flow							
Organic carbon cycling							
N and P cycling							
Other nutrient cycling (e.g., K, S, Si, Fe)							

EPA Assessment Framework Category/ Subcategory/ Theme	NPS Issue	NPS Score EBLA	FOVA	LEWI	SAJH	Mean	C / S
Biological Processes							
Community dynamics							
Population dynamics							
Natural Disturbance Regimes							
Wind							
Fire							
-	Fire regimes	**1**	**1**	**1**	**3**	**1.50**	S
-	Fire suppression and fuels management	**1**	**1**	**1**	**2**	**1.25**	S
Flood Regime							
-	Flood control	**0**	**1**	**2**	**0**	**0.75**	S
-	Flooding regimes	**0**	**2**	**1**	**1**	**1.00**	S
Climate Change							
-	Moisture and climatic cycles	**2**	**1**	**unk**	**1**	**1.33**	S
Other							
-	Solitude and silence	1	1	1	3	1.50	C
-	Night sky	1	2	1	2	1.50	C
-	Soil compaction	2	1	1	1	1.25	C
	Water rights	1	0	1	0	0.50	C

Appendix 2. 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. 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.

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Abronia latifolia	coastal sand verbena	Dicot	Yes	Yes
Acer circinatum	vine maple	Dicot	Yes	Yes
Acer macrophyllum	bigleaf maple	Dicot	Yes	Yes
Acer platanoides	Norway maple	Dicot	No	Yes
Achillea millefolium	common yarrow	Dicot	Yes	Yes
Alnus rubra	red alder	Dicot	Yes	Yes
Anaphalis margaritacea	western pearlyeverlasting	Dicot	Yes	Yes
Angelica genuflexa	kneeling angelica	Dicot	Yes	Yes
Angelica lucida	seacoast angelica	Dicot	Yes	Yes
Anthemis cotula	chamomile	Dicot	No	Yes
Arctostaphylos uva-ursi	kinnikinnick	Dicot	Yes	Yes
Argentina egedii ssp. egedii	Pacific silverweed	Dicot	Yes	Yes
Aruncus dioicus	goatsbeard	Dicot	Yes	Yes
Atriplex prostrata	triangle orache	Dicot	Yes	Yes
Baccharis pilularis	coyote bush	Dicot	Yes	Yes
Barbarea orthoceras	wintercress	Dicot	Yes	Yes
Bellis perennis	English daisy	Dicot	No	Yes
Bidens cernua	nodding beggartick	Dicot	Yes	Yes
Bidens frondosa	devil's beggartick	Dicot	Yes	Yes
Boykinia occidentalis	coastal brookfoam	Dicot	Yes	Yes
Brassica rapa	field mustard	Dicot	No	Yes
Buxus sp	ornamental box	Dicot	No	No
Cabomba caroliniana	Carolina fanwort	Dicot	Yes	Yes
Cakile edentula	American searocket	Dicot	Yes	Yes
Callitriche hermaphroditica	norther water star-wort	Dicot	Yes	Yes
Callitriche stagnalis	pond water-starwort	Dicot	No	Yes
Calystegia sepium ssp. sepium	hedge false bindweed	Dicot	No	No
Cardamine angulata	seaside bittercress	Dicot	Yes	Yes
Cardamine breweri var. orbicularis	sierra bittercress	Dicot	Yes	Yes
Cardamine hirsuta	hairy bittercress	Dicot	No	Yes
Cardamine oligosperma	hairy bittercress	Dicot	Yes	Yes
Cardionema ramosissimum	sandmat	Dicot	Yes	Yes
Centaurea cyanus	cornflower	Dicot	No	Yes
Cerastium arvense	field chickweed	Dicot	Yes	Yes
Cerastium fontanum ssp. vulgare	mousear chickweed	Dicot	No	Yes
Cerastium glomeratum	sticky chickweed	Dicot	No	Yes
Ceratophyllum demersum	rigid hornwort	Dicot	Yes	Yes
Chamaesyce maculata	spotted sandmat	Dicot	Yes	No
Chamerion angustifolium	fireweed	Dicot	Yes	Yes
Chenopodium album	lamb's quarters	Dicot	Yes	Yes
Chrysosplenium glechomifolium	Pacific golden saxifrage	Dicot	Yes	Yes
Cicuta douglasii	western water hemlock	Dicot	Yes	Yes

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Cirsium arvense	Canadian thistle	Dicot	No	Yes
Cirsium brevistylum	short-styled thistle	Dicot	Yes	Yes
Cirsium edule	edible thistle	Dicot	Yes	Yes
Cirsium vulgare	bull thistle	Dicot	No	Yes
Claytonia perfoliata	miner's lettuce	Dicot	Yes	Yes
Claytonia sibirica var. sibirica	Siberian springbeauty	Dicot	Yes	Yes
Conioselinum gmelinii	Pacific hemlock-parsley	Dicot	Yes	Yes
Conyza canadensis	Canadian horseweed	Dicot	Yes	Yes
Cornus sericea	redosier dogwood	Dicot	Yes	Yes
Corydalis scouleri	Scouler's corydalis	Dicot	Yes	Yes
Cotoneaster franchetii	Franchet's cotoneaster	Dicot	No	Yes
Cotoneaster horizontalis	rockspray cotoneaster	Dicot	No	No
Cotula coronopifolia	common brassbuttons	Dicot	No	Yes
Crataegus monogyna	singleseed hawthorn	Dicot	No	Yes
Crepis capillaris	smooth hawksbeard	Dicot	No	Yes
Cymbalaria muralis	Kenilworth ivy	Dicot	No	Yes
Cytisus scoparius	Scotch broom	Dicot	No	Yes
Daucus carota	Queen Anne's lace	Dicot	No	Yes
Deutzia sp	deutzia	Dicot	No	No
Dicentra formosa	Pacific bleeding heart	Dicot	Yes	Yes
Digitalis purpurea	purple foxglove	Dicot	No	Yes
Dipsacus fullonum	Fuller's teasel	Dicot	No	Yes
Epilobium ciliatum ssp. glandulosum	fringed willowherb	Dicot	Yes	Yes
Epilobium minutum	minute willowherb	Dicot	Yes	Yes
Epilobium sp	willoweed	Dicot	Yes	No
Erechtites glomerata	cutleaf burnweed	Dicot	No	No
Erechtites minima	coastal burnweed	Dicot	No	Yes
Escallonia rubra	redclaws	Dicot	No	No
Eschscholzia californica	California poppy	Dicot	No	No
Fragaria chiloensis	beach strawberry	Dicot	Yes	Yes
Frangula purshiana	cascara buckthorn	Dicot	Yes	Yes
Fuchsia magellanica	hardy fuchsia	Dicot	No	No
Galium aparine	cleavers	Dicot	Yes	Yes
Galium trifidum	small bedstraw	Dicot	Yes	Yes
Galium triflorum	fragrant bedstraw	Dicot	Yes	Yes
Gaultheria shallon	salal	Dicot	Yes	Yes
Geranium molle	dovefoot geranium	Dicot	No	Yes
Geum macrophyllum	large-leaf avens	Dicot	Yes	Yes
Glechoma hederacea	groundivy	Dicot	No	Yes
Gnaphalium palustre	western marsh cudweed	Dicot	Yes	Yes
Gnaphalium uliginosum	marsh cudweed	Dicot	No	Yes
Hedera helix	English ivy	Dicot	No	Yes
Heracleum maximum	common cowparsnip	Dicot	Yes	Yes
Heuchera micrantha	small-flowered alumroot	Dicot	Yes	Yes
Hieracium albiflorum	white hawkweed	Dicot	Yes	Yes
Hippuris vulgaris	common mare's tail	Dicot	Yes	Yes
Hydrocotyle ranunculoides	floating marsh-pennywort	Dicot	Yes	Yes
Hydrophyllum tenuipes	Pacific waterleaf	Dicot	Yes	Yes

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Hypericum anagalloides	creeping St Johnswort	Dicot	Yes	Yes
Hypericum perforatum	common St Johnswort	Dicot	No	Yes
Hypericum scouleri ssp scouleri	Scouler St Johnswort	Dicot	Yes	No
Hypochaeris radicata	hairy cat's ear	Dicot	No	Yes
Ilex aquifolium	English holly	Dicot	No	Yes
Impatiens capensis	spotted touch-me-not	Dicot	Yes	Yes
Impatiens ecalcarata	spurless touch-me-not	Dicot	Yes	Yes
Impatiens x pacific	I capensis/I ecalcarata hybrid	Dicot	Yes	No
Lamium purpureum	purple deadnettle	Dicot	No	Yes
Lapsana communis	nipplewort	Dicot	No	Yes
Lathyrus japonicus	purple beach pea	Dicot	Yes	Yes
Lathyrus latifolius	perennial sweetpea	Dicot	No	Yes
Lathyrus littoralis	silky beach pea	Dicot	Yes	Yes
Lathyrus palustris	marsh pea	Dicot	Yes	Yes
Leucanthemum vulgare	oxeye daisy	Dicot	No	Yes
Lilaeopsis occidentalis	western grasswort	Dicot	Yes	Yes
Lonicera involucrata	twinberry honeysuckle	Dicot	Yes	Yes
Lonicera periclymenum	European honeysuckle	Dicot	No	No
Lotus corniculatus	birdsfoot trefoil	Dicot	No	Yes
Lotus pedunculatus	greater birdsfoot trefoil	Dicot	No	Yes
Lotus unifoliolatus	Spanish clover	Dicot	Yes	Yes
Ludwigia palustris	marsh seedbox	Dicot	Yes	Yes
Lupinus latifolius	broadleaf lupine	Dicot	Yes	Yes
Lupinus littoralis	seashore lupine	Dicot	Yes	Yes
Lupinus rivularis	streambank lupine	Dicot	Yes	No
Lycopus americanus	American bugleweed	Dicot	Yes	Yes
Lysimachia terrestris	earth loosestrife	Dicot	Yes	Yes
Lythrum portula	water purslane	Dicot	No	Yes
Lythrum salicaria	purple loosestrife	Dicot	No	Yes
Mahonia aquifolium	tall Oregon grape	Dicot	Yes	Yes
Malus fusca	Oregon crabapple	Dicot	Yes	Yes
Malus pumila	paradise apple	Dicot	No	No
Marah oreganus	western wildcucumber	Dicot	Yes	Yes
Matricaria discoidea	pineapple weed	Dicot	No	Yes
Medicago lupulina	black medic	Dicot	No	Yes
Melilotus officinalis	yellow sweetclover	Dicot	No	Yes
Mentha aquatica	water mint	Dicot	No	Yes
Mentha arvensis	field mint	Dicot	Yes	Yes
Mentha pulegium	pennyroyal	Dicot	No	No
Mentha x piperita	peppermint	Dicot	Yes	No
Menziesia ferruginea	rusty menziesia	Dicot	Yes	Yes
Mimulus dentatus	tooth-leaved monkeyflower	Dicot	Yes	Yes
Moneses uniflora	single delight	Dicot	Yes	Yes
Montia parvifolia ssp. flagellaris	littleleaf minerslettuce	Dicot	Yes	Yes
Morella californica	California wax myrtle	Dicot	Yes	Yes
Mycelis muralis	wall lettuce	Dicot	No	Yes
Myosotis discolor	changing forget-me-not	Dicot	No	Yes
Myosotis laxa	bay forget-me-not	Dicot	Yes	Yes

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Myriophyllum aquaticum	braziliam watermilfoil	Dicot	No	Yes
Myriophyllum hippuroides	western water milfoil	Dicot	Yes	No
Myriophyllum sp	milfoil	Dicot	Yes	No
Navarretia squarrosa	skunkbush	Dicot	Yes	Yes
Nuphar lutea ssp. polysepala	yellow pond-lily	Dicot	Yes	Yes
Nymphaea odorata	American white waterlily	Dicot	Yes	Yes
Oemleria cerasiformis	Indian plum	Dicot	Yes	Yes
Oenanthe sarmentosa	water parsley	Dicot	Yes	Yes
Oenothera glazioviana	evening primrose	Dicot	No	No
Osmorhiza purpurea	purple sweet cicely	Dicot	Yes	Yes
Oxalis oregana	redwood sorrel	Dicot	Yes	Yes
Oxalis trilliifolia	threeleaf woodsorrel	Dicot	Yes	Yes
Pachysandra terminalis	Japanese pachysandra	Dicot	No	No
Parentucellia viscosa	yellow glandweed	Dicot	No	Yes
Petasites frigidus var. palmatus	arctic sweet coltsfoot	Dicot	Yes	Yes
Physocarpus capitatus	Pacific ninebark	Dicot	Yes	Yes
Plantago coronopus	buckhorn plantain	Dicot	No	Yes
Plantago lanceolata	narrowleaf plantain	Dicot	No	Yes
Plantago major	broadleaf plantain	Dicot	No	Yes
Plantago subnuda	coastal plantain	Dicot	Yes	No
Polygonum amphibium var. emersum	longroot smartweed	Dicot	Yes	Yes
Polygonum aviculare	prostrate knotweed	Dicot	No	Yes
Polygonum hydropiper	marshpepper	Dicot	No	Yes
Polygonum hydropiperoides	swamp smartweed	Dicot	Yes	Yes
Polygonum paronychia	beach knotweed	Dicot	Yes	Yes
Polygonum persicaria	lady's-thumb	Dicot	No	Yes
Populus balsamifera	balsam poplar	Dicot	Yes	Yes
Prunella vulgaris ssp. lanceolata	lance selfheal	Dicot	Yes	Yes
Prunella vulgaris ssp. vulgaris	common selfheal	Dicot	Yes	Yes
Prunus avium	sweet cherry	Dicot	No	No
Prunus cerasus	sour cherry	Dicot	No	No
Prunus domestica	European plum	Dicot	No	No
Prunus laurocerasus	cherry laurel	Dicot	No	Yes
Ranunculus acris	tall buttercup	Dicot	Yes	Yes
Ranunculus ficaria	lesser celandine	Dicot	No	No
Ranunculus flammula	lesser spearwort	Dicot	Yes	Yes
Ranunculus repens	creeping buttercup	Dicot	No	Yes
Ranunculus sceleratus	celeryleaf buttercup	Dicot	Yes	Yes
Ranunculus uncinatus	woodland buttercup	Dicot	Yes	Yes
Rhododendron macrophyllum	Pacific rhododendron	Dicot	Yes	No
Rhododendron occidentale	western azalea	Dicot	Yes	No
Ribes bracteosum	stink currant	Dicot	Yes	Yes
Ribes divaricatum	spreading gooseberry	Dicot	Yes	Yes
Ribes lacustre	prickly currant	Dicot	Yes	Yes
Ribes laxiflorum	trailing black currant	Dicot	Yes	Yes
Ribes sanguineum	flowering currant	Dicot	Yes	Yes
Rorippa curvisiliqua	curvepod yellowcress	Dicot	Yes	Yes
Rorippa islandica	northern marsh yellowcress	Dicot	Yes	No

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Rosa nutkana	Nootka rose	Dicot	Yes	Yes
Rubus armeniacus	Himalayan blackberry	Dicot	No	Yes
Rubus laciniatus	cutleaf blackberry	Dicot	No	Yes
Rubus parviflorus	thimbleberry	Dicot	Yes	Yes
Rubus spectabilis	salmonberry	Dicot	Yes	Yes
Rubus ursinus	Pacific blackberry	Dicot	Yes	Yes
Rumex acetosella	common sheep sorrel	Dicot	No	Yes
Rumex conglomeratus	clustered dock	Dicot	No	Yes
Rumex crispus	curly dock	Dicot	No	Yes
Rumex obtusifolius	bluntleaf dock	Dicot	No	Yes
Sagina apetala	annual pearlwort	Dicot	No	Yes
Sagina maxima	stickystem pearl-wort	Dicot	Yes	Yes
Sagina procumbens	birdeye pearlwort	Dicot	No	Yes
Salicornia depressa	American glasswort	Dicot	Yes	Yes
Salix alba	golden willow	Dicot	No	No
Salix hookeriana	dune willow	Dicot	Yes	Yes
Salix lucida ssp. lasiandra	Pacific willow	Dicot	Yes	Yes
Salix sitchensis	Sitka willow	Dicot	Yes	Yes
Sambucus racemosa	red elderberry	Dicot	Yes	Yes
Samolus valerandi ssp. parviflorus	smallflower water pimpernel	Dicot	Yes	Yes
Scrophularia californica	California figwort	Dicot	Yes	No
Sedum oreganum	Oregon stonecrop	Dicot	Yes	Yes
Senecio jacobaea	tansy ragwort	Dicot	No	Yes
Senecio sylvaticus	woodland ragwort	Dicot	No	Yes
Senecio triangularis	arrowleaf groundsel	Dicot	Yes	Yes
Senecio vulgaris	common groundsel	Dicot	No	Yes
Sidalcea hendersonii	Henderson's checkerbloom	Dicot	Yes	Yes
Sium suave	common waterparsnip	Dicot	Yes	Yes
Solanum dulcamara	bittersweet nightshade	Dicot	No	Yes
Solidago canadensis	Canada goldenrod	Dicot	Yes	Yes
Solidago simplex	Rand's goldenrod	Dicot	Yes	Yes
Sonchus asper	spiny sowthistle	Dicot	No	Yes
Sonchus oleraceus	common sowthistle	Dicot	No	Yes
Sorbaria kirilowii	giant false spiraea	Dicot	No	No
Sorbus aucuparia	European mountain ash	Dicot	No	Yes
Spergula arvensis	corn spurry	Dicot	No	Yes
Spergularia rubra	red sandspurry	Dicot	No	Yes
Spiraea douglasii	rose spirea	Dicot	Yes	Yes
Stachys mexicana	Mexican hedgenettle	Dicot	Yes	Yes
Stellaria crispa	crisp starwort	Dicot	Yes	Yes
Stellaria humifusa	salt marsh starwort	Dicot	Yes	Yes
Stellaria longipes	longstalk starwort	Dicot	Yes	Yes
Stellaria media	common chickweed	Dicot	No	Yes
Symphoricarpos albus	common snowberry	Dicot	Yes	Yes
Symphyotrichum subspicatum	Douglas aster	Dicot	Yes	Yes
Tanacetum camphoratum	camphor tansy	Dicot	Yes	Yes
Taraxacum officinale	common dandelion	Dicot	Yes	Yes
Teesdalia nudicaulis	barestem teesdalia	Dicot	No	Yes

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Tellima grandiflora	bigflower tellima	Dicot	Yes	Yes
Tiarella trifoliata	threeleaf foamflower	Dicot	Yes	Yes
Tolmiea menziesii	youth on age	Dicot	Yes	Yes
Trifolium dubium	hop clover	Dicot	No	Yes
Trifolium hybridum	alsike clover	Dicot	No	Yes
Trifolium pratense	red clover	Dicot	No	Yes
Trifolium repens	white clover	Dicot	No	Yes
Trifolium subterraneum	subterranian clover	Dicot	No	Yes
Trifolium wormskioldii	springbank clover	Dicot	Yes	Yes
Triphysaria pusilla	dwarf owl's-clover	Dicot	Yes	Yes
Urtica dioica ssp. gracilis	stinging nettle	Dicot	Yes	Yes
Vaccinium ovalifolium	Alaskan huckleberry	Dicot	Yes	Yes
Vaccinium ovatum	evergreen huckleberry	Dicot	Yes	Yes
Vaccinium parvifolium	red huckleberry	Dicot	Yes	Yes
Veronica americana	American speedwell	Dicot	Yes	Yes
Veronica arvensis	corn speedwell	Dicot	No	Yes
Veronica scutellata	skullcap speedwell	Dicot	Yes	Yes
Veronica serpyllifolia	thymeleaf speedwell	Dicot	Yes	Yes
Vicia nigricans ssp. gigantea	giant vetch	Dicot	Yes	Yes
Vicia sativa ssp. nigra	common vetch	Dicot	No	Yes
Vicia tetrasperma	lentil vetch	Dicot	No	Yes
Vinca minor	common periwinkle	Dicot	No	Yes
Viola glabella	pioneer violet	Dicot	Yes	Yes
Viola sempervirens	evergreen violet	Dicot	Yes	Yes
Weigela sp	weigela	Dicot	No	No
Adiantum aleuticum	Aleutian maidenhair	Fern	Yes	Yes
Athyrium filix-femina	lady fern	Fern	Yes	Yes
Blechnum spicant	deer fern	Fern	Yes	Yes
Botrychium multifidum	leathery grapefern	Fern	Yes	Yes
Dryopteris expansa	spreading woodfern	Fern	Yes	Yes
Polypodium glycyrrhiza	licorice fern	Fern	Yes	Yes
Polypodium scouleri	leathery polypody	Fern	Yes	Yes
Polystichum munitum	western swordfern	Fern	Yes	Yes
Pteridium aquilinum	western brackenfern	Fern	Yes	Yes
Abies grandis	grand fir	Gymnosperm	Yes	Yes
Abies procera	noble fir	Gymnosperm	Yes	Yes
Araucaria araucana	monkeypuzzle tree	Gymnosperm	No	No
Cedrus libani	cedar of Lebanon	Gymnosperm	No	No
Chamaecyparis lawsoniana	Port Orford cedar	Gymnosperm	Yes	Yes
Picea sitchensis	Sitka spruce	Gymnosperm	Yes	Yes
Pinus contorta var. contorta	shore pine	Gymnosperm	Yes	Yes
Pinus nigra	Austrian pine	Gymnosperm	No	No
Pinus pinaster	maritime pine	Gymnosperm	No	No
Pinus sylvestris	Scots pine	Gymnosperm	No	No
Pseudotsuga menziesii	Douglas-fir	Gymnosperm	Yes	Yes
Thuja plicata	western redcedar	Gymnosperm	Yes	Yes
Tsuga heterophylla	western hemlock	Gymnosperm	Yes	Yes
Equisetum arvense	field horsetail	Horsetail	Yes	Yes

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Equisetum hyemale	scouringrush horsetail	Horsetail	Yes	Yes
Equisetum telmateia	giant horsetail	Horsetail	Yes	Yes
Lycopodium clavatum	running clubmoss	Lycopod	Yes	Yes
Agrostis capillaris	colonial bentgrass	Monocot	No	Yes
Agrostis exarata	spike bentgrass	Monocot	Yes	Yes
Agrostis scabra	rough bentgrass	Monocot	Yes	Yes
Agrostis stolonifera	creeping bentgrass	Monocot	No	Yes
Aira praecox	yellow hairgrass	Monocot	No	Yes
Alisma plantago-aquatica	European waterplantain	Monocot	No	No
Alisma triviale	northern water plantain	Monocot	Yes	Yes
Alopecurus geniculatus	water foxtail	Monocot	No	Yes
Alopecurus pratensis	meadow foxtail	Monocot	No	Yes
Ammophila arenaria	European beachgrass	Monocot	No	Yes
Ammophila breviligulata	American beachgrass	Monocot	Yes	Yes
Anthoxanthum odoratum	sweet vernalgrass	Monocot	No	Yes
Bromus carinatus	California brome	Monocot	Yes	Yes
Bromus hordeaceus	soft brome	Monocot	No	Yes
Bromus sitchensis	Alaska brome	Monocot	Yes	Yes
Calamagrostis nutkaensis	Pacific reed grass	Monocot	Yes	Yes
Carex aquatilis var. dives	Sitka sedge	Monocot	Yes	Yes
Carex deweyana	Dewey's sedge	Monocot	Yes	Yes
Carex kobomugi	Japanese sedge	Monocot	No	No
Carex leptopoda	taperfruit shortscale sedge	Monocot	Yes	Yes
Carex lyngbyei	Lyngbye's sedge	Monocot	Yes	Yes
Carex macrocephala	largehead sedge	Monocot	Yes	Yes
Carex obnupta	slough sedge	Monocot	Yes	Yes
Carex pansa	sanddune sedge	Monocot	Yes	Yes
Carex stipata	owlfruit sedge	Monocot	Yes	Yes
Crocosmia x crocosmiiflora	crocosmia; montbretia	Monocot	No	No
Cynosurus echinatus	bristly dogtail grass	Monocot	No	Yes
Dactylis glomerata	orchardgrass	Monocot	No	Yes
Danthonia californica	California oatgrass	Monocot	Yes	Yes
Deschampsia cespitosa	tufted hairgrass	Monocot	Yes	Yes
Digitaria sanguinalis	hairy crabgrass	Monocot	Yes	Yes
Echinochloa crus-galli	barnyardgrass	Monocot	No	Yes
Eleocharis ovata	ovate spikerush	Monocot	Yes	Yes
Eleocharis palustris	common spikerush	Monocot	Yes	Yes
Eleocharis parvula	dwarf spikerush	Monocot	Yes	No
Elodea canadensis	Canadian waterweed	Monocot	Yes	Yes
Elymus repens	quackgrass	Monocot	No	Yes
Festuca rubra	red fescue	Monocot	Yes	Yes
Glyceria grandis	American mannagrass	Monocot	Yes	No
Glyceria leptostachya	slender-spike mannagrass	Monocot	Yes	Yes
Goodyera oblongifolia	western rattlesnake plantain	Monocot	Yes	Yes
Holcus lanatus	common velvetgrass	Monocot	No	Yes
Hyacinthoides non-scripta	English bluebell	Monocot	No	Yes
Iris pseudacorus	yellow flag iris	Monocot	No	Yes
Isolepis cernua	low bulrush	Monocot	Yes	Yes

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Juncus acuminatus	tapertip rush	Monocot	Yes	Yes
Juncus arcticus	Baltic rush; mountain rush	Monocot	Yes	Yes
Juncus articulatus	jointed rush	Monocot	Yes	Yes
Juncus bufonius var. occidentalis	toad rush	Monocot	Yes	No
Juncus effusus var. effusus	common rush	Monocot	Yes	No
Juncus effusus var. pacificus	Pacific rush	Monocot	Yes	No
Juncus ensifolius	swordleaf rush	Monocot	Yes	Yes
Juncus hesperius	slender-stemmed rush	Monocot	Yes	No
Juncus oxymeris	pointed rush	Monocot	Yes	No
Juncus supiniformis	spreading rush	Monocot	Yes	Yes
Juncus tenuis	path rush	Monocot	Yes	Yes
Lemna minor	water lentil	Monocot	Yes	Yes
Leymus mollis	American dune grass	Monocot	Yes	Yes
Lilaea scilloides	flowering quillwort	Monocot	Yes	Yes
Lolium perenne ssp. perenne	perennial ryegrass	Monocot	No	No
Lolium perenne ssp. multiflorum	Italian ryegrass	Monocot	No	Yes
Luzula congesta	heath woodrush	Monocot	No	No
Luzula parviflora	smallflowered woodrush	Monocot	Yes	Yes
Lysichiton americanus	American skunk cabbage	Monocot	Yes	Yes
Maianthemum dilatatum	false lily of the valley	Monocot	Yes	Yes
Najas flexilis	nodding waternymph	Monocot	Yes	No
Narcissus sp	daffodil	Monocot	No	No
Phalaris arundinacea	reed canarygrass	Monocot	Yes	Yes
Poa annua	annual bluegrass	Monocot	No	Yes
Poa howellii	Howell's bluegrass	Monocot	Yes	No
Poa pratensis	Kentucky bluegrass	Monocot	Yes	Yes
Poa trivialis	rough bluegrass	Monocot	No	Yes
Poa unilateralis	ocean bluff bluegrass	Monocot	Yes	Yes
Polypogon monspeliensis	annual rabbitsfoot grass	Monocot	No	Yes
Potamogeton crispus	curly pondweed	Monocot	No	Yes
Potamogeton foliosus	leafy pondweed	Monocot	Yes	Yes
Potamogeton gramineus	grassy pondweed	Monocot	Yes	Yes
Potamogeton zosteriformus	flatstem pondweed	Monocot	Yes	No
Prosartes smithii	largeflower fairybells	Monocot	Yes	Yes
Sagittaria latifolia	wapato	Monocot	Yes	Yes
Schedonorus phoenix	tall fescue	Monocot	No	Yes
Schoenoplectus acutus	hardstem bulrush	Monocot	Yes	Yes
Schoenoplectus tabernaemontani	softstem bulrush	Monocot	Yes	Yes
Scirpus microcarpus	smallfruit bulrush	Monocot	Yes	Yes
Sisyrinchium californicum	golden blue-eyed grass	Monocot	Yes	Yes
Sisyrinchium idahoense	blue-eyed grass	Monocot	Yes	Yes
Sparganium eurycarpum	broadfruit bur-reed	Monocot	Yes	No
Spirodela polyrrhiza	giant duckweed	Monocot	Yes	Yes
Streptopus amplexifolius	claspleaf twistedstalk	Monocot	Yes	Yes
Torreyochloa pallida	pale false mannagrass	Monocot	Yes	Yes
Triglochin maritima	seaside arrow-grass	Monocot	Yes	Yes
Trillium ovatum	Pacific trillium	Monocot	Yes	Yes
Trisetum canescens	tall trisetum	Monocot	Yes	Yes

Scientific Name	Common Name	Taxon	Native?	Regional Pool?
Triticum aestivum	common wheat	Monocot	No	Yes
Typha angustifolia	narrowleaf cattail	Monocot	No	Yes
Typha latifolia	common cattail	Monocot	Yes	Yes
Vallisneria americana	American eelgrass	Monocot	Yes	Yes

Appendix 3. List of bryophyte 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. Taxonomy, classification into taxonomic groups, and nativity are from Harthill and O'Connor (1975), Vitt et al. (1988), Pojar and MacKinnon (1994), and Hutten et al (2001). Data are sorted alphabetically by taxonomic group (liverwort, peat moss, true moss) and then by scientific name.

Scientific Name	Common Name	Taxon	Native?
Bazzania denudata	bazzania denudata	Liverwort	Yes
Calypogeia azurea	blue pouchwort	Liverwort	Yes
Calypogeia fissa	pouchwort	Liverwort	Yes
Cephalozia lunulifolia	threadwort	Liverwort	Yes
Cephaloziella turneri	Turner's threadwort	Liverwort	Yes
Chiloscyphus pallescens	chiloscyphus pallescens	Liverwort	Yes
Conocephalum conicum	scented liverwort	Liverwort	Yes
Frullania nisquallensis	hanging millepede liverwort	Liverwort	Yes
Lepidozia reptans	little-hands liverwort	Liverwort	Yes
Pellia neesiana	ring pellia	Liverwort	Yes
Porella navicularis	tree-ruffle navicularis	Liverwort	Yes
Riccardia latifrons	germanderwort	Liverwort	Yes
Riccardia multifida	germanderwort	Liverwort	Yes
Riccia fluitans	crystalwort	Liverwort	Yes
Scapania bolanderi	yellow-ladle liverwort	Liverwort	Yes
Scapania undulata var. *undulata*	water earwort	Liverwort	Yes
Cephalozia bicuspidata bicuspidata	two-toothed threadwort	Liverwort	Yes
Diplophyllum albicans	striped foldedleaf	Liverwort	Yes
Gyrothyra underwoodiana	Underwood's gyrothyra	Liverwort	Yes
Porella cordaeana	cliff scalewort	Liverwort	Yes
Radula bolanderi	leafy liverwort	Liverwort	Yes
Sphagnum girgensohnii	Girgensohn's peat moss	Peat moss	Yes
Sphagnum pacificum	Pacific sphagnum moss	Peat moss	Yes
Sphagnum palustre	prairie sphagnum	Peat moss	Yes
Antitrichia curtipendula	hanging moss	True moss	Yes
Atrichum selwynii	Selwyn's atrichum moss	True moss	Yes
Aulacomnium androgynum	lover's moss	True moss	Yes
Brachythecium albicans	lawn moss	True moss	Yes
Bryum capillare	bryum moss	True moss	Yes
Calliergonella cuspidata	calliergonella moss	True moss	Yes
Ceratodon purpureus	purple horntooth	True moss	Yes
Claopodium crispifolium	rough moss	True moss	Yes
Dicranum fuscescens	curly heron's-bill moss	True moss	Yes
Dicranum scoparium	broom moss	True moss	Yes
Didymodon vinealis var. *vinealis*	didymodon moss	True moss	Yes
Ditrichum pusillum	ditrichum moss	True moss	Yes
Epipterygium tozeri	Tozer's epipterygium moss	True moss	Yes
Eurhynchium oreganum	Oregon beaked moss	True moss	Yes
Eurhynchium praelongum	slender beaked moss	True moss	Yes
Fontinalis antipyretica	willow moss	True moss	Yes
Fontinalis howellii	Howell's fontinalis moss	True moss	Yes
Heterocladium macounii	Macoun's heterocladium moss	True moss	Yes

Scientific Name	Common Name	Taxon	Native?
Hookeria lucens	hookeria moss	True moss	Yes
Hygrohypnum ochraceum	hygrohypnum moss	True moss	Yes
Hylocomium splendens	splendid feather moss	True moss	Yes
Hypnum circinale	coiled-leaf moss	True moss	Yes
Isothecium myosuroides	tree moss, isothecium moss	True moss	Yes
Leucolepis acanthoneuron	leucolepsis umbrella moss	True moss	Yes
Neckera douglasii	Douglas' neckera	True moss	Yes
Oligotrichum aligerum	oligotrichum moss	True moss	Yes
Orthotrichum consimile	orthotrichum moss	True moss	Yes
Orthotrichum lyellii	Lyell's orthotrichum moss	True moss	Yes
Plagiomnium insigne	coastal leafy moss	True moss	Yes
Plagiothecium undulatum	undulate plagiothecium moss	True moss	Yes
Pogonatum contortum	contorted pogonatum moss	True moss	Yes
Pohlia cruda	pholia moss	True moss	Yes
Pohlia proligera	pholia moss	True moss	Yes
Polytrichastrum alpinum	alphine hair-cap moss	True moss	Yes
Polytrichum commune	common hair-cap moss	True moss	Yes
Polytrichum formosum	hair-cap moss	True moss	Yes
Polytrichum juniperinum	juniper hair-cap moss	True moss	Yes
Porotrichum bigelovii	Bigelo's porotrichum moss	True moss	Yes
Pseudotaxiphyllum elegans	elegant pseudotaxiphyllum moss	True moss	Yes
Rhizomnium glabrescens	fan moss	True moss	Yes
Rhytidiadelphus loreus	lanky moss, goose-neck moss	True moss	Yes
Rhytidiadelphus squarrosus	bent-leaf moss, square goose-neck moss	True moss	Yes
Rhytidiadelphus triquetrus	rough goose-neck moss	True moss	Yes
Sanionia uncinata var. *symmetrica*	symmetric sanionia moss	True moss	Yes
Tetraphis pellucida	four-tooth moss	True moss	Yes
Tortula muralis	tortula moss	True moss	Yes
Ulota obtusiuscula	obtuse ulota	True moss	Yes
Ulota phyllantha	ocean ulota	True moss	Yes
Zygodon viridissimus var. *rupestris*	zygodon moss	True moss	Yes

Appendix 4. 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. 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.

Scientific Name	Common Name	Taxon	Morphological Group	Native?
Nidula candida	common gel bird's nest	Fungi	Bird's nest	N/A
Nidula niveotomentosa	jellied bird's nest	Fungi	Bird's nest	N/A
Boletus calopus	bitter bolete	Fungi	Boletes	N/A
Boletus coniferarum	bitter bolete	Fungi	Boletes	N/A
Boletus edulis	king bolete	Fungi	Boletes	N/A
Boletus mirabilis	admirable bolete	Fungi	Boletes	N/A
Boletus piperatus	peppery bolete	Fungi	Boletes	N/A
Boletus smithii	Smith's bolete	Fungi	Boletes	N/A
Boletus truncatus	boletus truncatus	Fungi	Boletes	N/A
Boletus zelleri	Zeller's bolete	Fungi	Boletes	N/A
Leccinum clavatum	birch bolete	Fungi	Boletes	N/A
Suillus brevipes	short-stemmed slippery jack	Fungi	Boletes	N/A
Suillus caerulescens	douglas-fir suillus	Fungi	Boletes	N/A
Suillus luteus	slippery jack	Fungi	Boletes	N/A
Suillus tomentosus	blue-staining slipper jack	Fungi	Boletes	N/A
Suillus umbonatus	umbonate slippery jack	Fungi	Boletes	N/A
Tylopilus pseudoscaber	dark bolete	Fungi	Boletes	N/A
Calocera viscosa	yellow tuning fork	Fungi	Club / coral / fan	N/A
Clavaria purpurea	purple club coral	Fungi	Club / coral / fan	N/A
Clavulina cristata	crested coral	Fungi	Club / coral / fan	N/A
Cordyceps militaris	caterpillar fungus	Fungi	Club / coral / fan	N/A
Lentaria byssiseda	cotton-base coral	Fungi	Club / coral / fan	N/A
Ramaria araidspora	red coral mushroom	Fungi	Club / coral / fan	N/A
Xylaria hypoxylon	carbon antlers	Fungi	Club / coral / fan	N/A
Fomitopsis pinicola	red belled polypore	Fungi	Crust	N/A
Ganoderma tsugae	hemlock varnish shelf	Fungi	Crust	N/A
Laetiporus sulphureus	sulfur shelf, chicken of the woods	Fungi	Crust	N/A
Laxitextum bicolor	two-toned parchment	Fungi	Crust	N/A
Merulius tremellosus	wild dry rot	Fungi	Crust	N/A
Steccherinum ochraceum	ochre spreading tooth	Fungi	Crust	N/A
Trametes versicolor	turkey tail	Fungi	Crust	N/A
Aleuria aurantia	orange peel	Fungi	Cup	N/A
Bisporella citrina	yellow fairy cups	Fungi	Cup	N/A
Chlorociboria aeruginascens	green stain	Fungi	Cup	N/A
Otidea leporina	yellow rabbit ears	Fungi	Cup	N/A
Pseudoplectania nigrella	hairy black cap	Fungi	Cup	N/A
Sarcosoma mexicana	starving man's licorice	Fungi	Cup	N/A
Scutellinia scutellata	eyelash pixie cup	Fungi	Cup	N/A
Agaricus praeciaresquamosus	flat-top agaricus	Fungi	Gilled	N/A
Agaricus subrutilescens	wine-colored agaric	Fungi	Gilled	N/A

Scientific Name	Common Name	Taxon	Morphological Group	Native?
Amanita aspera	yellow-veiled amanita	Fungi	Gilled	N/A
Amanita constricta	constricted grisette	Fungi	Gilled	N/A
Amanita fulva	tawny grisette	Fungi	Gilled	N/A
Amanita gemmata	Jonquil amanita	Fungi	Gilled	N/A
Amanita muscaria	fly agaric	Fungi	Gilled	N/A
Armillariella mellea	honey mushroom	Fungi	Gilled	N/A
Cantharellus cibarius	chantrelle	Fungi	Gilled	N/A
Cantharellus infundibuliformis	winter chanterelle	Fungi	Gilled	N/A
Catathelasma ventricosa	imperial cat	Fungi	Gilled	N/A
Chroogomphus tomentosus	wooly pine spike	Fungi	Gilled	N/A
Chroogomphus vinicolor	pine spike	Fungi	Gilled	N/A
Coprinus atramentarius	inky cap, tippler's bane	Fungi	Gilled	N/A
Cortinarius collinitus	slimy-banded cort	Fungi	Gilled	N/A
Cortinarius violaceus	violet cort	Fungi	Gilled	N/A
Entoloma conferendum var. *conferendum*	star-spored entoloma	Fungi	Gilled	N/A
Gymnopilus spectabilis	big laughing mushroom	Fungi	Gilled	N/A
Hygrocybe flavescens	yellow waxycap	Fungi	Gilled	N/A
Hygrophoropsis aurantiaca	false chantrelle	Fungi	Gilled	N/A
Laccaria laccata	lackluster laccaria	Fungi	Gilled	N/A
Lactarius deliciosus	delicious milk cap	Fungi	Gilled	N/A
Lactarius rufus	red-hot milk cap	Fungi	Gilled	N/A
Lactarius scrobiculatus	scrobiculate milk cap	Fungi	Gilled	N/A
Lactarius substriatus	slimy red milk cap	Fungi	Gilled	N/A
Lepiota rubrotincta	red-eyed parasol	Fungi	Gilled	N/A
Lepiota sp (Cristata Group)	brown-eyed parasol	Fungi	Gilled	N/A
Marasmiellus candidus	pinwheel marasmius	Fungi	Gilled	N/A
Mycena acicula	candycorn mushroom	Fungi	Gilled	N/A
Mycena capillaripes	petite parasol	Fungi	Gilled	N/A
Mycena epipterygia	yellow-stalked mycena	Fungi	Gilled	N/A
Naematoloma fasciculare	sulphur tuft	Fungi	Gilled	N/A
Panellus serotinus	late fall oyster	Fungi	Gilled	N/A
Paxillus atrotomentosus	velvet pax	Fungi	Gilled	N/A
Phaeocollybia spadicea	Kit's phaeocollybia	Fungi	Gilled	N/A
Pholiota aurivella	golden pholiota	Fungi	Gilled	N/A
Pholiota malicola	forgettable pholiota	Fungi	Gilled	N/A
Pholiota terrestris	terrestrial pholiota	Fungi	Gilled	N/A
Pleurocybella porrigen	angel's wings	Fungi	Gilled	N/A
Pleurotus ostreatus	oyster mushroom	Fungi	Gilled	N/A
Pluteus cervinus	deer mushroom	Fungi	Gilled	N/A
Psilocybe pelliculosa	conifer psilocybe	Fungi	Gilled	N/A
Psilocybe semilanceata	liberty cap	Fungi	Gilled	N/A
Russula brevipes	short stemmed russula	Fungi	Gilled	N/A
Russula rosacea	rosy russula	Fungi	Gilled	N/A
Russula xerampelina	shrimp russula	Fungi	Gilled	N/A
Strobilurus occidentalis	spruce cone mushroom	Fungi	Gilled	N/A

Scientific Name	Common Name	Taxon	Morphological Group	Native?
Stropharia ambigua	questionable stropharia	Fungi	Gilled	N/A
Tricholoma magnivalare	matsutake	Fungi	Gilled	N/A
Tricholoma vaccinum	russet-scaly trich	Fungi	Gilled	N/A
Dacrymyces palmatus	orange jelly	Fungi	Jelly	N/A
Pseudohydnum gelatinosum	jelly tooth	Fungi	Jelly	N/A
Tremella mesenterica	witch's butter	Fungi	Jelly	N/A
Helvella lacunosa	fluted black elfin saddle	Fungi	Morels and false morels	N/A
Hypomyces lactifluorum	lobster mushroom	Fungi	Parasitic fungi	N/A
Lycoperdon perlatum	common puffball	Fungi	Puffball	N/A
Gastroboletus turbinatus	bogus boletus	Fungi	Secotioid	N/A
Lycogala epidendrum	wolf'smilk slime	Fungi	Slime mold	N/A
Hydnellum peckii	red-juice tooth	Fungi	Spine	N/A
Hydnellum suaveolens	fragrant hydnellum	Fungi	Spine	N/A
Hydnum repandum	spreading hedgehog	Fungi	Spine	N/A
Ichmadophila ericitorum	peppermint drop lichen	Lichen	Crustose	Yes
Cavernularia hultenii	Hulten's pitted lichen	Lichen	Foliose	Yes
Cavernularia lophyrea	pitted lichen	Lichen	Foliose	Yes
Cetrelia cetruroides	cetrelia cetruroides	Lichen	Foliose	Yes
Collema nigrescens	blistered jelly lichen	Lichen	Foliose	Yes
Evernia prunastrii	oakmoss	Lichen	Foliose	Yes
Heterodermia leucomelos	ciliate strap-lichen	Lichen	Foliose	Yes
Hypogymnia apinnata	beaded tube lichen	Lichen	Foliose	Yes
Hypogymnia enteromorpha	bone lichen	Lichen	Foliose	Yes
Hypogymnia heterophylla	seaside tube lichen	Lichen	Foliose	Yes
Hypogymnia inactiva	inactive tube lichen	Lichen	Foliose	Yes
Hypogymnia occidentalis	western tube lichen	Lichen	Foliose	Yes
Hypogymnia physodes	monk's hood	Lichen	Foliose	Yes
Hypogymnia tubulosa	tube lichen	Lichen	Foliose	Yes
Hypotrachyna sinuosa	riparian loop lichen	Lichen	Foliose	Yes
Leptogium palmatum	antlered jellyskin	Lichen	Foliose	Yes
Lobaria pulmonaria	tree lungwort	Lichen	Foliose	Yes
Lobaria scrobiculata	textured lungwort	Lichen	Foliose	Yes
Melanelixia fuliginosa	melanelixia lichen	Lichen	Foliose	Yes
Menegazzia terebrata	honeycombed lichen	Lichen	Foliose	Yes
Nephroma helveticum	fringed kidney lichen	Lichen	Foliose	Yes
Nephroma resupinatum	naked kidney lichen, cat's paw lichen	Lichen	Foliose	Yes
Parmelia hygrophila	shield lichen	Lichen	Foliose	Yes
Parmelia squarrosa	salted shield	Lichen	Foliose	Yes
Parmelia sulcata	powdered shield	Lichen	Foliose	Yes
Parmotrema arnoldii	Arnold's parmotrema lichen	Lichen	Foliose	Yes
Parmotrema chinense	Chinese parmotrema lichen	Lichen	Foliose	Yes
Parmotrema crinitum	parmotrema lichen	Lichen	Foliose	Yes
Peltigera collina	dog lichen	Lichen	Foliose	Yes
Peltigera membrenacea	membraneous felt lichen	Lichen	Foliose	Yes
Peltigera neopolydactyla	many-fruited pelt	Lichen	Foliose	Yes

Scientific Name	Common Name	Taxon	Morphological Group	Native?
Physcia adscendens	hooded rosette lichen	Lichen	Foliose	Yes
Physcia aipolia	hoary rosette lichen	Lichen	Foliose	Yes
Platismatia glauca	crinkled rag lichen	Lichen	Foliose	Yes
Platismatia herrei	tattered rag lichen	Lichen	Foliose	Yes
Pseudocyphellaria anomola	netted specklebelly lichen	Lichen	Foliose	Yes
Pseudocyphellaria anthrapsis	pseudocyphellaria anthrapsis	Lichen	Foliose	Yes
Sticta limbata	spotted felt lichen	Lichen	Foliose	Yes
Tuckermanopsis chlorophylla	powdered wrinkle-lichen	Lichen	Foliose	Yes
Tuckermanopsis orbata	variable wrinkle-lichen	Lichen	Foliose	Yes
Xanthoria parietina	yellow scale	Lichen	Foliose	Yes
Xanthoria polycarpa	cushion xanthoria	Lichen	Foliose	Yes
Sphaerophorus globosus	globe ball lichen	Lichen	Fruticose	Yes
Alectoria sarmentosa	witch's hair	Lichen	Fruticose	Yes
Alectoria vancouverensis	Vancouver witch's hair	Lichen	Fruticose	Yes
Bryoria glabra	horsehair lichen	Lichen	Fruticose	Yes
Cladonia fimbriata	slender pixie cup	Lichen	Fruticose	Yes
Cladonia furcata	many forked cladonia	Lichen	Fruticose	Yes
Cladonia squamosa var. *subsquamosa*	dragon cladonia	Lichen	Fruticose	Yes
Cladonia sulphurina	greater sulphur cup	Lichen	Fruticose	Yes
Cladonia transcendens	variable pebblehorn	Lichen	Fruticose	Yes
Pilophorus acicularis	nail lichen	Lichen	Fruticose	Yes
Ramalina dilacerata	cartilage lichen	Lichen	Fruticose	Yes
Ramalina farinacea	dotted ramalina	Lichen	Fruticose	Yes
Ramalina menzeisii	lace lichen	Lichen	Fruticose	Yes
Ramalina roesleri	Roesler's cartilage lichen	Lichen	Fruticose	Yes
Usnea cornuta	beard lichen	Lichen	Fruticose	Yes
Usnea filipendula	fishbone beard lichen	Lichen	Fruticose	Yes
Usnea glabrata	lustrous beard lichen	Lichen	Fruticose	Yes
Usnea longissima	usnea longissima	Lichen	Fruticose	Yes
Usnea scabrata	usnea scabrata	Lichen	Fruticose	Yes

Appendix 5. List of animal 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. Data are sorted alphabetically by taxonomic group (amphibian, bird, crustacean, fish, insect, mammal, mollusc, reptile) and then by scientific name

Scientific Name	Common Name	Taxon	Native?
Ambystoma gracile	northwestern salamander	Amphibian	Yes
Dicamptodon copei	Cope’s giant salamander	Amphibian	Yes
Dicamptodon tenebrosus	Pacific giant salamander	Amphibian	Yes
Ensatina eschscholtzii	ensatina	Amphibian	Yes
Plethodon dunni	Dunn’s salamander	Amphibian	Yes
Plethodon vehiculum	western red-backed salamander	Amphibian	Yes
Pseudacris regilla	Pacific chorus frog	Amphibian	Yes
Rana aurora aurora	northern red-legged frog	Amphibian	Yes
Rana catesbeiana	bullfrog	Amphibian	No
Rhyacotriton kezeri	Columbia torrent salamander	Amphibian	Yes
Taricha granulosa	rough-skinned newt	Amphibian	Yes
Accipeter cooperii	Cooper's hawk	Bird	Yes
Accipiter striatus	sharp-shinned hawk	Bird	Yes
Actitis macularius	spotted sandpiler	Bird	Yes
Aechmophorus occidentalis	western grebe	Bird	Yes
Aegolius acadicus	northern saw-whet owl	Bird	Yes
Agelaius phoeniceus	red-winged blackbird	Bird	Yes
Aix sponsa	wood duck	Bird	Yes
Anas acuta	northern pintail	Bird	Yes
Anas americana	American widgeon	Bird	Yes
Anas clypeata	northern shoveler	Bird	Yes
Anas crecca	green-winged teal	Bird	Yes
Anas platyrhynchos	mallard	Bird	Yes
Anthus rubescens	American pipet	Bird	Yes
Aphriza virgata	surfbird	Bird	Yes
Ardea alba	great egret	Bird	Yes
Ardea herodias	great blue heron	Bird	Yes
Arenaria melanocephala	black turnstone	Bird	Yes
Aythya affinis	lesser scaup	Bird	Yes
Aythya collaris	ring-necked duck	Bird	Yes
Aythya marila	greater scaup	Bird	Yes
Bombycilla cedrorum	cedar waxwing	Bird	Yes
Bonasa umbellus	ruffed grouse	Bird	Yes
Brachyramphus marmoratus	marbled murrelet	Bird	Yes
Branta canadensis	Canada goose	Bird	Yes
Branta hutchinsii	cackling goose	Bird	Yes
Bubo virginianus	great horned owl	Bird	Yes
Bucephala albeola	bufflehead	Bird	Yes
Bucephala clangula	common goldeneye	Bird	Yes
Buteo jamaicensis	red-tailed hawk	Bird	Yes
Buteo lineatus	red-shouldered hawk	Bird	Yes
Butorides virescens	green heron	Bird	Yes
Calidris alba	sanderling	Bird	Yes
Calidris alpina	dunlin	Bird	Yes
Calidris bairdii	Baird's sandpiler	Bird	Yes

Scientific Name	Common Name	Taxon	Native?
Calidris canutus	red knot	Bird	Yes
Calidris mauri	western sandpiper	Bird	Yes
Calidris melanotos	pectoral sandpiper	Bird	Yes
Calidris minutilla	least sandpiler	Bird	Yes
Calypte anna	Anna's hummingbird	Bird	Yes
Carduelis pinus	pine siskin	Bird	Yes
Carduelis tristis	American goldfinch	Bird	Yes
Carpodacus mexicanus	house finch	Bird	Yes
Carpodacus purpureus	purple finch	Bird	Yes
Cathartes aura	turkey vulture	Bird	Yes
Catharus guttatus	hermit thrush	Bird	Yes
Catharus ustulatus	Swainson's thrush	Bird	Yes
Cepphus columba	pigeon guillemot	Bird	Yes
Cerorhinca monocerata	rhinoceros auklet	Bird	Yes
Certhia americana	brown creeper	Bird	Yes
Ceryle alcyon	belted kingfisher	Bird	Yes
Chamaea fasciata	wrentit	Bird	Yes
Charadrius alexandrinus nivosus	western snowy plover	Bird	Yes
Charadrius vociferus	killdeer	Bird	Yes
Chroicocephalus philadelphia	Bonaparte's gull	Bird	Yes
Circus cyaneus	northern harrier	Bird	Yes
Cistothorus palustris	marsh wren	Bird	Yes
Colaptes auratus	northern flicker	Bird	Yes
Contopus borealis	olive-sided flycatcher	Bird	Yes
Contopus sordidulus	western wood-peewee	Bird	Yes
Corvus brachyrhynchos	American crow	Bird	Yes
Corvus caurinus	nortwestern crow	Bird	Yes
Corvus corax	common raven	Bird	Yes
Cyanocitta stelleri	Steller's jay	Bird	Yes
Dendroica coronata	yellow-rumped warbler	Bird	Yes
Dendroica nigrescens	black-throated gray warbler	Bird	Yes
Dendroica occidentalis	hermit warbler	Bird	Yes
Dendroica petechia	yellow warbler	Bird	Yes
Dendroica striata	blackpoll warbler	Bird	Yes
Dendroica townsendi	Townsend's warbler	Bird	Yes
Dryocopus pileatus	pileated woodpecker	Bird	Yes
Elanus leucurus	white-tailed kite	Bird	Yes
Empidonax difficilis	Pacific slope flycatcher	Bird	Yes
Empidonax traillii	willow flycatcher	Bird	Yes
Euphagus cyanocephalus	Brewer's blackbird	Bird	Yes
Falco columbarius	merlin	Bird	Yes
Falco mexicanus	prairie falcon	Bird	Yes
Falco peregrinus	peregrine falcon	Bird	Yes
Falco sparverius	American kestrel	Bird	Yes
Fulica americana	American coot	Bird	Yes
Gallinago delicata	Wilson's snipe	Bird	Yes
Gavia immer	common loon	Bird	Yes
Gavia pacifica	Pacific loon	Bird	Yes
Gavia stellata	red-throated loon	Bird	Yes

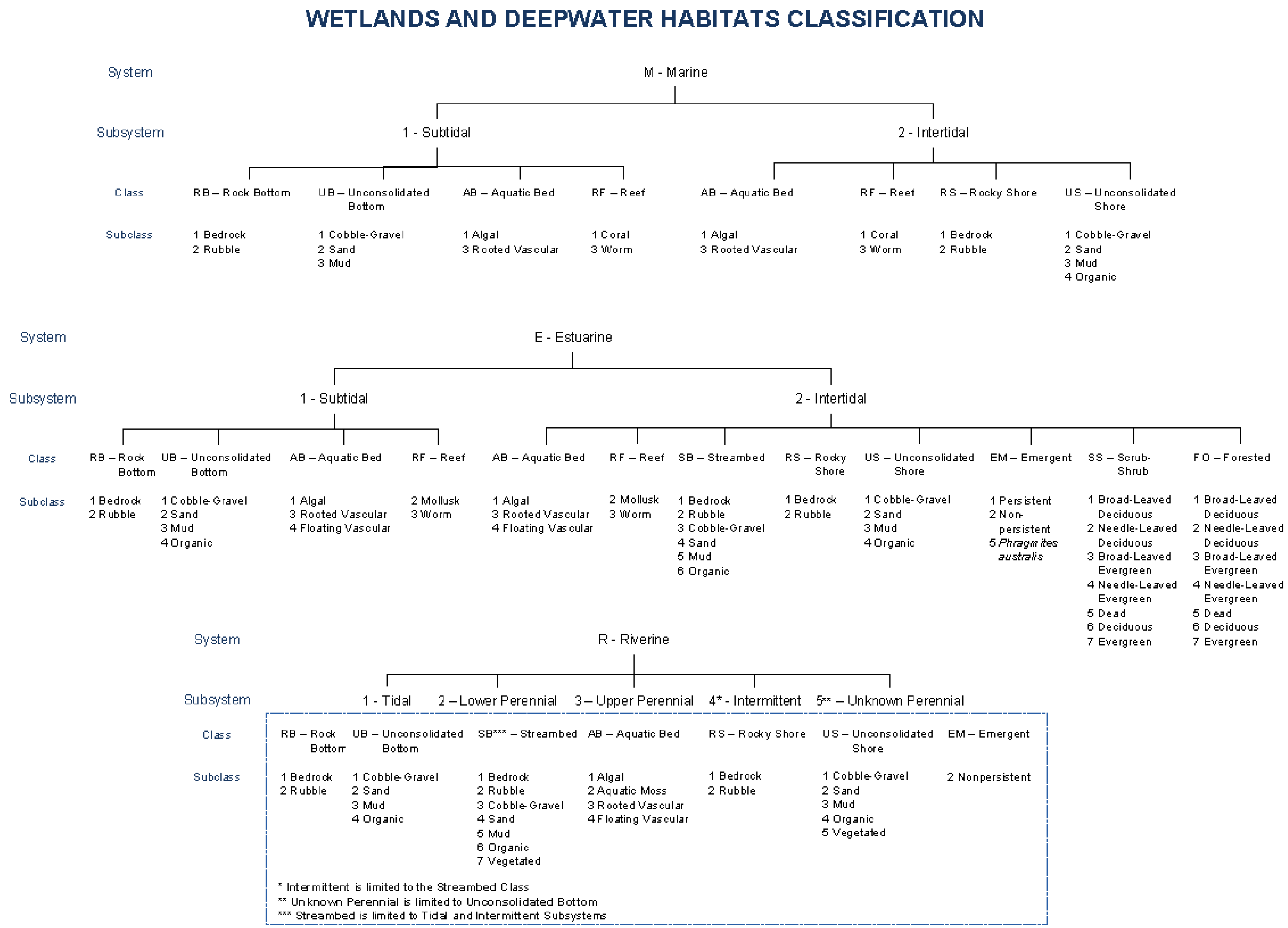
Scientific Name	Common Name	Taxon	Native?
Geothlypis trichas	common yellowthroat	Bird	Yes
Glaucidium gnoma	northern pygmy owl	Bird	Yes
Haematopus bachmani	black oystercatcher	Bird	Yes
Haliaeetus leucocephalus	bald eagle	Bird	Yes
Hirundo rustica	barn swallow	Bird	Yes
Histrionicus histrionicus	harlequin duck	Bird	Yes
Ixoreus naevius	varied thrusy	Bird	Yes
Junco hyemalis	dark-eyed junco	Bird	Yes
Larus argentatus	herring gull	Bird	Yes
Larus californicus	California gull	Bird	Yes
Larus canus	mew gull	Bird	Yes
Larus delawarensis	ring-billed gull	Bird	Yes
Larus glaucescens	glaucous winged gull	Bird	Yes
Larus herrmanni	Heermann's gull	Bird	Yes
Larus hyperboreus	Glaucous gull	Bird	Yes
Larus occidentalis	western gull	Bird	Yes
Limnidromus griseus	short-billed dowitcher	Bird	Yes
Limnodromus scolopaceus	long-billed dowitcher	Bird	Yes
Limosa fedoa	marbled goodwit	Bird	Yes
Lophodytes cucullatus	hooded merganser	Bird	Yes
Loxia curvirostra	red crossbill	Bird	Yes
Melanitta perspicillata	surf scooter	Bird	Yes
Melospiza georgiana	swamp sparrow	Bird	Yes
Melospiza lincolnii	Lincoln's sparrow	Bird	Yes
Melospiza melodia	song sparrow	Bird	Yes
Mergus Merganser	common merganser	Bird	Yes
Mergus serrator	red-breasted merganser	Bird	Yes
Molothrus ater	brown-headed cowbird	Bird	Yes
Numenius phaeopus	whimbrel	Bird	Yes
Oporornis tolmiei	MacGillivray’s warbler	Bird	Yes
Otus kennicottii	western screech-owl	Bird	Yes
Pandion haliaetus	osprey	Bird	Yes
Passer domesticus	house sparrow	Bird	No
Passerculus sandwichensis	savannah sparrow	Bird	Yes
Passerella iliaca	fox sparrow	Bird	Yes
Patagioenas fasciata	band-tailed pigeon	Bird	Yes
Pelecanus occidentalis	brown pelican	Bird	Yes
Petrochelidon pyrrhonota	cliff swallow	Bird	Yes
Phalacrocorax pelagicus	pelagic cormorant	Bird	Yes
Phalacrocorax penicillatus	Brandt's cormorant	Bird	Yes
Phalacrocorx auritus	Double-crested Cormorant	Bird	Yes
Phaloropus lobatus	ring-necked phalarope	Bird	Yes
Phasianus colchicus	ring-necked pheasant	Bird	Yes
Pheucticus melanocephalus	black-headed grosbeak	Bird	Yes
Picoides pubescens	downy woodpecker	Bird	Yes
Picoides villosus	hairy woodpecker	Bird	Yes
Pipilo maculatus	spotted towhee	Bird	Yes
Piranga ludoviciana	western tanager	Bird	Yes
Podiceps auritus	horned grebe	Bird	Yes

Scientific Name	Common Name	Taxon	Native?
Podiceps grisegena	red-necked grebe	Bird	Yes
Podilymbus podiceps	pied-billed grebe	Bird	Yes
Poecile atricapillus	black-capped chickadee	Bird	Yes
Poecile rufescens	chestnut-backed chickadee	Bird	Yes
Progne subis	purple martin	Bird	Yes
Psaltriparus minimus	bushtit	Bird	Yes
Puffinus griseus	sooty shearwater	Bird	Yes
Rallus limicola	Virginia rail	Bird	Yes
Regulus calendula	ruby-crowned kinglet	Bird	Yes
Regulus satrapa	gold-crowned kinglet	Bird	Yes
Rissa tridactyla	black-legged kittiwake	Bird	Yes
Sayornis nigricans	black phoebe	Bird	Yes
Selasphorus rufus	rufous hummingbird	Bird	Yes
Sitta canadensis	red-breasted nuthatch	Bird	Yes
Sphyrapicus ruber	red-breasted sapsucker	Bird	Yes
Sterna caspia	Caspian tern	Bird	Yes
Strix varia	barred owl	Bird	Yes
Sturnus vulgaris	European starling	Bird	No
Tachycineta bicolor	tree swallow	Bird	Yes
Tachycineta thalassina	violet-green swallow	Bird	Yes
Thryomanes bewickii	Bewick's wren	Bird	Yes
Tringa incana	wandering tattler	Bird	Yes
Tringa melanoleuca	greater yellowlegs	Bird	Yes
Troglodytes troglodytes	winter wren	Bird	Yes
Turdus migratorius	American robin	Bird	Yes
Tyto alba	barn owl	Bird	Yes
Uria aalge	common murre	Bird	Yes
Vermivora celata	orange-crowned Warbler	Bird	Yes
Vireo gilvus	warbling vireo	Bird	Yes
Vireo huttoni	Hutton's vireo	Bird	Yes
Wilsonia pusilla	Wilson's warbler	Bird	Yes
Zenaida macroura	mourning eove	Bird	Yes
Zonotrichia atricapilla	golden-crowned sparrow	Bird	Yes
Zonotrichia leucophrys	white-crowned sparrow	Bird	Yes
Neomysis mercedis	opussum shrimp	Crustacean	Yes
Acipenser medirostris	green sturgeon	Fish	Yes
Catostomus macrocheilus	largescale sucker	Fish	Yes
Cottus aleuticus	coastrange sculpin	Fish	Yes
Cottus asper	prickly sculpin	Fish	Yes
Cottus gulosus	riffle sculpin	Fish	Yes
Cottus perplexus	reticulate sculpin	Fish	Yes
Cottus rhotheus	freshwater sculpin	Fish	Yes
Cymatogaster aggregate	shinner surf perch	Fish	Yes
Fundulus diaphanous	banded killifish	Fish	No
Gasterosteus aculeatus	threespine stickleback	Fish	Yes
Lampetra richardsoni	western brook lamprey	Fish	Yes
Lampetra sp	lamprey	Fish	Yes
Lepomis gibbosus	pumpkinseed	Fish	No
Leptocottus armatus	Pacific staghorn sculpin	Fish	Yes

Scientific Name	Common Name	Taxon	Native?
Micropterus salmoides	largemouth bass	Fish	No
Mylocheilus caurinus	peamouth	Fish	Yes
Oncorhynchus clarki	cutthroat trout	Fish	Yes
Oncorhynchus keta	chum salmon	Fish	Yes
Oncorhynchus kisutch	coho salmon	Fish	Yes
Oncorhynchus mykiss	steelhead	Fish	Yes
Oncorhynchus tshawytscha	Chinook salmon	Fish	Yes
Perca flavescens	yellow perch	Fish	No
Spirinchus thaleichthys	longfin smelt	Fish	Yes
Thaleichthys pacificus	eulachon	Fish	Yes
Anthrenus verbasci	varied carpet beetle	Insect	Yes
Camponotus pennsylvanicus	carpenter ant	Insect	Yes
Ceuthophilus maculatus	camel cricket	Insect	Yes
Colias eurytheme	orange sulphur butterfly	Insect	Yes
Cteneucha rubroscapus	black-shouldered ctenucid moth	Insect	Yes
Gnorimosphaeroma insulare		Insect	Yes
Hyles lineate	white-lined sphynx moth	Insect	Yes
Inocellia inflata	square-headed snakefly	Insect	Yes
Lepisma saccharina	silverfish	Insect	Yes
Leptocoris rubrolineatus	box elder beetle	Insect	Yes
Limenitis lorquini	Lorquin’s admiral butterfly	Insect	Yes
Liposcelis sp.	booklice	Insect	Yes
Myrmecocystus spp.	honey ant	Insect	Yes
Nymphalis antiopa	mourning cloak butterfly	Insect	Yes
Oniscus asellus	sowbug	Insect	Yes
Papilio rutulus	western tiger swallowtail butterfly	Insect	Yes
Papilio zelicaon	anise swallowtail butterfly	Insect	Yes
Plodia interpunctella	Indian meal moth	Insect	Yes
Pyrrharctia isabella	wooly bear caterpillar, Isabella moth	Insect	Yes
Speyeria zerene hippolyta	Oregon silver-spot butterfuly	Insect	Yes
Sympetrum vicinum	yellow-legged meadowhawk	Insect	Yes
Tinea pellionella	casemaking clothes moth	Insect	Yes
Tineola bisselliella	webbing clothes moth	Insect	Yes
Trypodendron lineatum	striped ambrosia beetle	Insect	Yes
Vanessa atalanta	red admirable (red admiral) butterfly	Insect	Yes
Vanessa cardui	painted lady butterfly	Insect	Yes
Vespula sp.	yellowjacket	Insect	Yes
Zootermopsis angusticollis	Pacific coast termite	Insect	Yes
Aplodontia rufa	mountain beaver	Mammal	Yes
Arborimus albipes	white-footed vole	Mammal	Yes
Canis latrans	coyote	Mammal	Yes
Castor canadensis	beaver	Mammal	Yes
Cervus elaphus roosevelti	Roosevelt elk	Mammal	Yes
Clethrionomys californicus	western red-backed vole	Mammal	Yes
Didelphis virginiana	Virginia opossum	Mammal	No
Glaucomys sabrinus sabrinus	northern flying squirrel	Mammal	Yes
Lasiurus cinereus	hoary bat	Mammal	Yes
Lepus americanus	snowshoe hair	Mammal	Yes
Lontra canadensis	river otter	Mammal	Yes

Scientific Name	Common Name	Taxon	Native?
Lynx rufus	bobcat	Mammal	Yes
Microtus oregoni	creeping vole	Mammal	Yes
Microtus townsendii	Townsend’s vole	Mammal	Yes
Mustela erminea	short-tailed weasel	Mammal	Yes
Mustela frenata	long-tailed weasel	Mammal	Yes
Mustela vison	mink	Mammal	Yes
Myocastor coypus	nutria	Mammal	No
Myotis californicus	California myotis	Mammal	Yes
Myotis evotis	long-eared myotis	Mammal	Yes
Myotis thysanodes	fringed myotis	Mammal	Yes
Myotis volans	long-legged myotis	Mammal	Yes
Myotis yumanensis	yuma myotis	Mammal	Yes
Neurotrichus gibbsii	American shrew-mole	Mammal	Yes
Odocoileus hemionus columbianus	Columbian black-tailed deer	Mammal	Yes
Ondatra zibethicus	common muskrat	Mammal	Yes
Peromyscus maniculatus	deer mouse	Mammal	Yes
Phoca vitulina	harbor seal	Mammal	Yes
Plecotus townsendii townsendii	Townsend’s big-eared bat	Mammal	Yes
Procyon lotor	raccoon	Mammal	Yes
Puma Concolor	cougar	Mammal	Yes
Rattus rattus	black rat	Mammal	No
Scapanus orarius	coast mole	Mammal	Yes
Scapanus townsendii	Townsend’s mole	Mammal	Yes
Sorex bairdii	Baird's shrew	Mammal	Yes
Sorex bendirii	Pacific marsh shrew	Mammal	Yes
Sorex monticolus	montane shrew	Mammal	Yes
Sorex trowbridgii	Trowbridge’s shrew	Mammal	Yes
Sorex vagrans	vagrant shrew	Mammal	Yes
Spermophilus beecheyi	California ground squirrel	Mammal	Yes
Spilogale gracilis	western spotted skunk	Mammal	Yes
Sylvilagus bachmani	brush rabbit	Mammal	Yes
Tamias townsendii	Townsend’s chipmunk	Mammal	Yes
Tamiasciurus douglasii	Douglas’ squirrel	Mammal	Yes
Ursus americanus	black bear	Mammal	Yes
Zapus trinotatus	Pacific jumping mouse	Mammal	Yes
Ariolimax columbianus	banana slug	Mollusc	Yes
Arion ater	European black slug	Mollusc	Yes
Clinocardium nuttalli	cockle	Mollusc	Yes
Littorina sp.	periwinkle snail	Mollusc	Yes
Potamopyrgus antipodarum	New Zealand Mud Snail	Mollusc	No
Elgaria coerulea	northern alligator lizard	Reptile	Yes
Thamnophis ordinoides	northwestern garter snake	Reptile	Yes
Thamnophis sirtalis	common garter snake	Reptile	Yes

Appendix 6. Details of the Cowardin classification system (Cowardin et al. 1979) as used in the National Wetlands Inventory (NWI).



WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

System: L - Lacustrine

- **Subsystem:** 1 - Limnetic
  - **Class:** RB – Rock Bottom
    - **Subclass:** 1 Bedrock; 2 Rubble
  - **Class:** UB – Unconsolidated Bottom
    - **Subclass:** 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
  - **Class:** AB – Aquatic Bed
    - **Subclass:** 1 Algal; 2 Aquatic Moss; 3 Rooted Vascular; 4 Floating Vascular
- **Subsystem:** 2 - Littoral
  - **Class:** RB – Rock Bottom
    - **Subclass:** 1 Bedrock; 2 Rubble
  - **Class:** UB – Unconsolidated Bottom
    - **Subclass:** 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
  - **Class:** AB – Aquatic Bed
    - **Subclass:** 1 Algal; 2 Aquatic Moss; 3 Rooted Vascular; 4 Floating Vascular
  - **Class:** RS – Rocky Shore
    - **Subclass:** 1 Bedrock; 2 Rubble
  - **Class:** US – Unconsolidated Shore
    - **Subclass:** 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
  - **Class:** EM – Emergent
    - **Subclass:** 2 Nonpersistent

System: P - Palustrine

- **Class:** RB – Rock Bottom
  - **Subclass:** 1 Bedrock; 2 Rubble
- **Class:** UB – Unconsolidated Bottom
  - **Subclass:** 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
- **Class:** AB – Aquatic Bed
  - **Subclass:** 1 Algal; 2 Aquatic Moss; 3 Rooted Vascular; 4 Floating Vascular
- **Class:** US – Unconsolidated Shore
  - **Subclass:** 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
- **Class:** ML – Moss-Lichen
  - **Subclass:** 1 Moss; 2 Lichen
- **Class:** EM – Emergent
  - **Subclass:** 1 Persistent; 2 Nonpersistent; 5 *Phragmites australis*
- **Class:** SS – Scrub-Shrub
  - **Subclass:** 1 Broad-Leaved Deciduous; 2 Needle-Leaved Deciduous; 3 Broad-Leaved Evergreen; 4 Needle-Leaved Evergreen; 5 Dead; 6 Deciduous; 7 Evergreen
- **Class:** FO – Forested
  - **Subclass:** 1 Broad-Leaved Deciduous; 2 Needle-Leaved Deciduous; 3 Broad-Leaved Evergreen; 4 Needle-Leaved Evergreen; 5 Dead; 6 Deciduous; 7 Evergreen

MODIFIERS

In order to more adequately describe the wetland and deepwater habitats, one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

Water Regime			Special Modifiers	Water Chemistry			Soil
Nontidal	Saltwater Tidal	Freshwater Tidal		Coastal Halinity	Inland Salinity	pH Modifiers for all Fresh Water	
A Temporarily Flooded	L Subtidal	S Temporarily Flooded-Tidal	b Beaver	1 Hyperhaline	7 Hypersaline	a Acid	g Organic
B Saturated	M Irregularly Exposed	R Seasonally Flooded-Tidal	d Partly Drained/Ditched	2 Euhaline	8 Eusaline	t Circumneutral	n Mineral
C Seasonally Flooded	N Regularly Flooded	T Semipermanently Flooded-Tidal	f Farmed	3 Mixohaline (Brackish)	9 Mixosaline	l Alkaline	
E Seasonally Flooded/ Saturated	P Irregularly Flooded	V Permanently Flooded-Tidal	h Diked/Impounded	4 Polyhaline	0 Fresh		
F Semipermanently Flooded			r Artificial	5 Mesohaline			
G Intermittently Exposed			s Spoil	6 Oligohaline			
H Permanently Flooded			x Excavated	0 Fresh			
J Intermittently Flooded							
K Artificially Flooded							

Appendix 7. Area (ha) of each category of wetland within each of the four parks.

Code	Description	EBLA	FOVA	LEWI	SAJH
Estuarine and Marine Wetland					
E2AB/USN	Estuarine Intertidal Aquatic Bed/Unconsolidated Shore	148.0	0.0	0.0	0.0
E2AB	Estuarine Intertidal Aquatic Bed	0.0	0.0	0.0	0.0
E2EM/USN	Estuarine Intertidal Emergent/Unconsolidated Shore	0.0	0.0	0.0	0.8
E2EM	Estuarine Intertidal Emergent	1.4	0.0	137.0	2.5
E2RS	Estuarine Intertidal Rocky Shore	1.9	0.0	1.8	0.0
E2US	Estuarine Intertidal Unconsolidated Shore	33.1	0.0	49.7	64.5
M2AB/USN	Marine Intertidal Aquatic Bed/Unconsolidated Shore	61.2	0.0	0.0	0.0
M2RS	Marine Intertidal Rocky Shore	0.0	0.0	2.6	0.0
M2US	Marine Intertidal Unconsolidated Shore	0.0	0.0	91.7	0.5
	Total Estuarine and Marine Wetland	**245.5**	**0.0**	**282.8**	**68.3**
Freshwater Emergent Wetland					
PEM/SS	Palustrine Emergent/Scrub-Shrub	13.2	0.0	43.2	0.0
PEM	Palustrine Emergent	49.3	0.0	181.3	0.0
PEM1A	Palustrine Emergent Persistent	0.0	0.0	0.0	0.5
	Total Freshwater Emergent Wetland	**62.5**	**0.0**	**224.5**	**0.5**
Freshwater Forested/Shrub Wetland					
PFO/SS	Palustrine Forested/Scrub-Shrub	0.0	0.0	2.4	0.0
PFO	Palustrine Forested	9.2	0.0	252.8	0.0
PSS/EM	Palustrine Scrub-Shrub/Emergent	4.5	0.0	13.9	0.0
PSS/FO	Palustrine Scrub-Shrub/Forested	0.0	0.0	14.2	0.0
PSS1C	Palustrine Scrub-Shrub Broad-Leaved Deciduous	0.0	0.0	0.0	0.2
PSS	Palustrine Scrub-Shrub	5.3	0.0	252.0	0.2
	Total Freshwater Forested/Shrub Wetland	**19.6**	**0.0**	**535.3**	**0.4**
Freshwater Pond					
PAB	Palustrine Aquatic Bed	1.5	0.0	8.8	0.0
PUB	Palustrine Unconsolidated Bottom	7.3	0.0	9.1	2.4
PUS	Palustrine Unconsolidated Shore	0.4	0.0	0.0	0.0
	Total Freshwater Pond	**9.2**	**0.0**	**17.9**	**2.4**
Lake					
L1UB	Lacustrine Limnetic Unconsolidated Botton	9.5	0.0	21.5	0.0
L2AB	Lacustrine Littoral Aquatic Bed	0.0	0.0	10.3	0.0
L2UB	Lacustrine Littoral Unconsolidated Bottom	194.6	0.0	0.0	0.0
	Total Lake	**204.1**	**0.0**	**31.8**	**0.0**
Riverine					
R1UB	Riverine Tidal Unconsolidated Bottom	0.0	0.0	0.3	0.0
R2UB	Riverine Lower Perennial Unconsolidated Bottom	0.0	0.0	0.1	0.0
R3UB	Riverine Upper Perennial Unconsolidated Bottom	0.0	0.0	1.1	0.0
R4US	Riverine Intermittent Unconsolidated Shore	0.0	0.0	0.6	0.0
	Total Riverine	**0.0**	**0.0**	**2.0**	**0.0**
	Total area of all aquatic ecosystems	**540.9**	**0.0**	**1094.3**	**71.6**

Appendix 8. Detailed list of land use zoning codes from Pacific and Clatsop counties. Data in the 'Symbol', 'Detailed Name', and 'Category' columns are from Clatsop County (2007) and Pacific County (2004).

County	Symbol	Detailed Name	Category	This Designation
Clatsop	EFU	Exclusive Farm Use	Rural Agricultural Lands	Agriculture
Clatsop	AD	Aquatic Development	Development	Multiple-Use Development
Clatsop		City		Multiple-Use Development
Clatsop	HI	Heavy Industrial	Development	Multiple-Use Development
Clatsop	HWY	Highways		Multiple-Use Development
Clatsop	MI	Marine Industrial	Development	Multiple-Use Development
Clatsop	QM	Quarry and Mining	Conservation Other Resources	Multiple-Use Development
Clatsop	RC-MFR	Rural Community-Multi Family Residential	Development	Rural Residential
Clatsop	RSA-MFR	Rural Service Area-Multi Family Residential	Development	Rural Residential
Clatsop	RSA-SFR	Rural Service Area-Single Family Residential	Development	Rural Residential
Clatsop	UGB	Urban Growth Boundary	Development	Multiple-Use Development
Clatsop	AC1	Aquatic Conservation One	Conservation Other Resources	Park and Conservation Areas
Clatsop	AC2	Aquatic Conservation Two	Conservation Other Resources	Park and Conservation Areas
Clatsop	AN	Aquatic Natural	Natural	Park and Conservation Areas
Clatsop	CS	Coastal Shorelands	Conservation Other Resources	Park and Conservation Areas
Clatsop	EAC	Ecola Aquatic Conservation	Conservation Other Resources	Park and Conservation Areas
Clatsop	LW	Lake and Wetland	Conservation Other Resources	Park and Conservation Areas
Clatsop	NS	Natural Shorelands	Natural	Park and Conservation Areas
Clatsop	NU	Natural Uplands	Natural	Park and Conservation Areas
Clatsop	NAC2	Nepanicum Estuary Aquatic Conservation	Conservation Other Resources	Park and Conservation Areas
Clatsop	OPR	Open Space, Parks and Recreation	Conservation Other Resources	Park and Conservation Areas
Clatsop	RM	Recreation Management	Conservation Other Resources	Park and Conservation Areas
Clatsop	AF	Agriculture Forest	Conservation Forest Lands	Rural Forest
Clatsop	F80	Forest 80	Conservation Forest Lands	Rural Forest
Clatsop	AC-RCR	Arch Cape Rural Community Residential	Rural Lands	Rural Residential
Clatsop	CBR	Coastal Beach Residential	Rural Lands	Rural Residential
Clatsop	CR	Coastal Residential	Rural Lands	Rural Residential
Clatsop	GC	General Commercial	Rural Lands	Multiple-Use Development
Clatsop	KS-RCR	Knappa-Svensen Rural Community Residential	Rural Lands	Rural Residential

County	Symbol	Detailed Name	Category	This Designation
Clatsop	LI	Light Industrial	Rural Lands	Multiple-Use Development
Clatsop	MR	Military Reserve	Rural Lands	Multiple-Use Development
Clatsop	NC	Neighborhood Commercial	Rural Lands	Multiple-Use Development
Clatsop	RA1	Residential Agriculture 1	Rural Lands	Rural Mixed-Use
Clatsop	RA2	Residential Agriculture 2	Rural Lands	Rural Mixed-Use
Clatsop	RA5	Residential Agriculture 5	Rural Lands	Rural Mixed-Use
Clatsop	RCC	Rural Community Commercial	Rural Lands	Rural Mixed-Use
Clatsop	RCC-LI	Rural Community Commercial and Light Industrial	Rural Lands	Rural Mixed-Use
Clatsop	RCI	Rural Community Industrial	Rural Lands	Rural Mixed-Use
Clatsop	RCR	Rural Community Residential	Rural Lands	Rural Residential
Clatsop	SFR1	Single Family Residential 1	Rural Lands	Rural Residential
Clatsop	TC	Tourist Commercial	Rural Lands	Multiple-Use Development
Clatsop	W-RCR	Westport Rural Community Residential	Rural Lands	Rural Residential
Pacific	AG	Agricultural	Natural Resource	Agriculture
Pacific	AQ	Aquaculture	Natural Resource	Agriculture
Pacific	CC	Community Commercial	Commercial	Multiple-Use Development
Pacific	I	Industrial	Industrial	Multiple-Use Development
Pacific	MU	Mixed Use	Mixed Use	Multiple-Use Development
Pacific	MU-T	Mixed Use (Tokeland)	Mixed Use	Multiple-Use Development
Pacific		Incorporated		Multiple-Use Development
Pacific		Shoalwater Tribe		Rural Mixed-Use
Pacific		TMIX		Multiple-Use Development
Pacific	CD	Conservation	Natural Resource	Park and Conservation Areas
Pacific	FC	Commercial Forestry	Natural Resource	Rural Forest
Pacific	FT	Transitional Forestry Land	Natural Resource	Rural Forest
Pacific	RR-1	Remote Rural	Residential	Rural Mixed-Use
Pacific	RL	Rural Lands	Residential	Rural Mixed-Use
Pacific	R-2	General Residential	Residential	Rural Residential
Pacific	R-3	Resort	Mixed Use	Rural Residential
Pacific	R-1	Restricted Residential	Residential	Rural Residential
Pacific	RR	Rural Residential	Residential	Rural Residential

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