Inventory of the Mosses, Liverworts, Hornworts, and Lichens of Olympic National Park, Washington: Species List

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Units of Measure for Conversions

1 meter = 39.37 inches
1 kilometer = 0.62 miles
1 square centimeter (cm\(^2\)) = 0.15 square inches (in\(^2\))
1 square kilometer (km\(^2\)) = 0.39 square miles (mi\(^2\))
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Inventory of the Mosses, Liverworts, Hornworts, and Lichens of Olympic National Park, Washington: Species List

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Abstract

The identification of non-vascular cryptogam species (lichens, mosses, liverworts, and hornworts) is especially challenging because of their small size, their often microscopic or chemical distinguishing features, and their enormous diversity. Consequently, they are a poorly known component of Olympic National Park, despite their ecological and aesthetic importance. This project is the first attempt at a systematic, comprehensive survey of non-vascular cryptogams in the Park and presents the current species list with descriptions of the substrate and vascular vegetation type where they were observed. The authors strove to collect from as many park environments as feasible, and distributed collections along important environmental gradients in different regions of the park using vascular vegetation as an environmental indicator. They also collected opportunistically when interesting habitats or microhabitats were encountered. Finally, the authors updated the nomenclature in the Park’s previous collection of non-vascular plants. This study identified approximately 13,200 bryophyte and lichen species, adding approximately 425 new species to the Olympic National Park Herbarium. These data, combined with select literature reports and personal data from Martin and Karen Hutten, added more than 350 species to the previously documented Olympic Peninsula lichen and bryophyte list. The authors discuss the list in a local, regional, and global context of rarity, as well as address some general topics regarding cryptogam conservation and further work needed in Olympic National Park.

Introduction

The identification of cryptogam species (lichens, mosses, liverworts, and hornworts) is especially challenging because of their small size, their often microscopic or chemical distinguishing features, and their enormous diversity. Consequently, they are a poorly known component of Olympic National Park (ONP), despite their ecological and aesthetic importance. Although experts have created partial species lists for ONP (Sharpe, 1956; Harthill, 1964; Thomson, 1969; Kunze, 1980; Hong and others, 1989) based on surveys of limited areas, a systematic, comprehensive survey has not been conducted. The improved inventory of ONP cryptogams represented by this project enables ONP to protect populations of rare and sensitive species, assess the damage caused by illegal harvest, and contribute information to the Bureau of Land Management (BLM) and U.S. Forest Service (USFS) Sensitive Species Programs.

This document presents the current species list of mosses, liverworts, hornworts, and lichens of ONP, along with descriptions of substrate and vascular vegetation type where they were observed. The authors discuss the list in a local, regional, and global context of rarity, as well as address some general topics regarding cryptogam conservation and further work needed in ONP. The authors do not believe it to be a complete list, nor do they analyze or summarize species distribution or community structure.

Although ONP comprises slightly less than 10 percent of the Olympic Peninsula (OP), it protects the bulk of the unmanaged ecosystems and thereby represents the flora that may once have been present on the entire OP. Because some collections and some of the records in the Park’s herbarium come from outside of the Park, conclusions and generalizations are sometimes applied only to ONP and sometimes to the entire OP.
Geographic and Biologic Context for the Inventory

ONP is the centerpiece of the OP, which is a 13,800-km² landmass in the extreme northwest corner of the conterminous United States (fig. 1). The Peninsula resembles an island because it is surrounded on three sides by water and on the fourth by a deep river valley: the Pacific Ocean to the west, the Strait of Juan de Fuca to the north, Hood Canal to the east, and the Chehalis River Valley to the south. The Olympic Mountains (Olympics) rise from sea level to culminate at Mount Olympus near the center of the Peninsula at 2,430 m. Geologic uplift, heavy precipitation, and a dynamic glacial history have created a radial pattern of 11 major river valleys centered on the mountains. ONP covers 3,700 km² in two units: 3,530 km² in the central mountainous core and a narrow 170-km² strip extending 84 km along the coast (Olympic National Park, 1999).

Mountainous areas in general are characterized by steep moisture and temperature gradients, resulting in substantially different environments over short distances. The moisture gradient is especially steep in the Olympic Mountains, reflecting the wet maritime climate, and results in exceptionally high levels of precipitation along the western slope. The substantial climatic and elevation gradients of the Peninsula create a diversity of habitats within the park. Environmental regimes range from mild, maritime conditions on the coast to harsh, alpine areas at high elevations to dry, near-continental climate in the northeast. Consequently, cold-stressed alpine vegetation exists within 15 km of intertidal communities and even closer to lush temperate rainforest with some of the world's largest trees (Buckingham and others, 1995).

The geologic and glacial histories of the Peninsula and western Washington provide a diversity of parent materials for soil formation. The ocean floor contributed sedimentary and marine-deposited basaltic bedrock. The continental glaciers deposited a variety of soil material including granitic rocks from the Cascade Range along the east and north sides of the Peninsula. Mass wasting and glaciers have mixed, washed, and eroded all three materials, creating a complex of montane and riverine soil materials (Tabor, 1987). The continental glaciers are considered to be young and, in general, are relatively infertile, except in the lower Dungeness River Valley. Local soil characteristics (for example, soil moisture, sub-surface flow, soil temperature, and chemical properties) vary greatly, being influenced by the parent material, climate, and biotic communities of the area. Common soil orders include spodosols, inceptisols, entisols, histosols, and andisols (Henderson and others, 1989).

Vegetation reflects the diverse physical environment. West-side lowland forests are in the Sitka Spruce (Picea sitchensis) Zone, including the temperate coniferous rainforest for which ONP is famous. Here, massive Sitka spruce trees grow to 90 m, and deciduous bigleaf maples (Acer macrophyllum) are laden with epiphytes. Lowland and mid-elevation forests on the drier east side and mid-elevation forests on the west side are in the Western Hemlock (Tsuga heterophylla) Zone. This is the most widespread zone and it is dominated by Douglas-fir (Pseudotsuga menziesii) and western hemlock, with red cedar (Thuja plicata) as a fairly common constituent. Montane forests are in the Pacific Silver Fir (Abies amabilis) Zone on the cool, moist slopes of much of the Peninsula, whereas Douglas-fir inhabits south-facing montane slopes in the northeast. Subalpine areas are a matrix of tree islands and meadows at high elevation. Subalpine areas with snow packs deeper than 3 m are in the Mountain Hemlock Zone (Tsuga mertensiana) and include mountain hemlock, subalpine fir (Abies lasiocarpa), and sometimes Pacific silver fir. The Subalpine Fir Zone occurs in areas with snowpacks less than 3 m deep and may also include lodgepole pine (Pinus contorta) or whitebark pine (P. albicaulis). Treeline occurs at 1,615 m in wetter areas and 1,890 m in drier zones where trees finally give way to alpine meadows (Henderson and others, 1989).

The glacial history, geographic isolation, and steep climatic gradients have important consequences for the biogeography of the area. First, the Peninsula was never completely covered by ice during the last glaciation at least, when a complex of ridges and mountains were above ice. Moreover, when glacial ice was thick, sea level was lower, exposing considerable new lands along the coast for a long period of time (Booth, 1987; Tabor, 1987). The role of the OP as a glacial refugium is conjecture, but the theory is well supported by its biogeography (Buckingham and others, 1995). The OP is home to a surprising number of endemic and disjunct vascular species whose distribution patterns are consistent with the refugium theory. Not enough is known about the distribution of non-vascular species to reach conclusions, but the disjunct distribution patterns of several species support the theory (for example, Rhytidium rugosum and Vulpicida tilesii are both arctic Tertiary relics now disjunct from their main distributions).

Significance of Cryptogams for ONP

Non-vascular cryptogams (mosses, liverworts, and lichens) make up a significant portion of the biomass and annual production in temperate rainforests (Vitt and others, 1988), and are known to play important ecological roles in hydrologic (Norris, 1990; Boucher and Nash, 1990) and nutrient cycling (Nadkarni, 1985). They are also known to be sensitive to precipitation chemistry and air quality (Hawksworth and Hill, 1984). Consequently, non-vascular cryptogams are crucial components of the long-term ecological monitoring program currently under development in ONP. Cryptogams require management attention because they are harvested illegally for sale to the floral industry, and because some rare species may require special protection.

Additionally, mosses, liverworts, and lichens were included in the list of Survey and Manage species identified in the Record of Decision (U.S. Department of Agriculture and U.S. Department of the Interior, 1994) for the Northwest...
Forest Plan, to which the National Park Service (NPS) is a party. The Northwest Forest Plan was adopted by the BLM and USFS in 1994 to guide forest management in the range of the northern spotted owl after the owl’s designation as endangered under the Endangered Species Act. Part of the plan required the Forest Service to survey for certain species (in other words, Survey and Manage Species) before allowing ground-disturbing activities. The Survey and Manage List included a large number of bryophytes and lichens, among other taxa, and was based on minimal knowledge of the distribution and abundance of these species. ONP can fulfill its obligation to aid regionally based management of bryophytes and lichens mandated by the USFS and BLM Sensitive Species Programs by providing information about the status of bryophyte and lichen populations within its borders.

**Project Description**

There have been few previous attempts to systematically describe the biodiversity of cryptogams in ONP. Collectors have explored specific areas or places within short walking distance of parking lots. Consequently, the authors strove to expand collections to as many park environments as feasible and distribute them along important environmental gradients in different regions of the park using vascular vegetation as an environmental indicator. They also collected opportunistically when interesting habitats or microhabitats were encountered. Finally, the authors updated the nomenclature in the Park’s previous collection of non-vascular plants. Because of the size of this collection (approximately 5,000 specimens), only obvious misidentifications were corrected. The outcome of this project is a more comprehensive survey and more complete species list than previously available, documentation of cryptogam communities, and improvement of the Park’s herbarium collection.

**Methods**

**Field Methods**

Two types of field methods were employed over three field seasons during this project. In 1999 data were collected intuitively, by searching for specific types of microhabitats. Select diversity hot spots were visited to collect and photograph rare cryptogams. A more systematic inventory of selected major vegetation types was begun in 2000 of Sitka Spruce, Douglas-fir, dry Western Hemlock, moist Western Hemlock, dry Silver Fir, moist Silver Fir, Mountain Hemlock, and Subalpine Fir Zones and alpine parkland throughout the Park. Data were collected according to a modified U.S. Department of Agriculture (USDA) Forest Service Forest Health Monitoring (FHM) protocol (U.S. Forest Service, 1999, described below). Incidental collections and observations using the intuitive approach were also made in 2000. Field methods in 2001 were the same as during 2000, but data were collected in only a few plots.

- **Modified FHM Method**

Survey sites were selected to include major environmental gradients in ONP and to achieve a distributed geographic sample by using vascular vegetation to indicate environmental conditions. Because there is no map of ONP vegetation at the desired plant-community scale, the Potential Natural Vegetation Map (Henderson and Peters, 2000) and the Park’s geographic information system (GIS) were used to stratify ONP by selected major vegetation types. Foot trails that pass through areas of the park having the highest diversity of major vegetation types were selected as sampling routes. The authors planned to complete three plots in each selected vegetation type during the field season. Plots were selected by locating five random points (changed to 10 later in field season) within 200 m of the trail in the section with the target vegetation types. Areas having slopes of more than 35° were rejected at this stage for safety reasons. The Universal Transverse Mercator (UTM) coordinates of the random points were plotted on maps along with an associated random priority ranking for each. A two-person field crew used a global positioning system (GPS) unit to locate collection points. Data were collected at the highest priority UTM point if actual vegetation type matched projected vegetation type and if the collection site was safe to sample. If the vegetation was incorrect or the site unsafe, the crew continued to the next priority site until the target number of plots was completed. The final selection of plots produced a well-distributed and diverse sample of the Park (fig. 1).
• Intuitively Controlled Method

Many bryophytes and lichens are highly microhabitat-specific. Whereas microhabitats are easily targeted when encountered in the field, they are often missed in a sampling method based on more general macrohabitats. Consequently, an intuitively controlled sampling method is more effective in locating certain rare microhabitat- and substrate-specific species. For example, some species of cyano-lichens are found nearly exclusively on semi-exposed conifer twigs in perennially cool and moist microhabitats. Typically, they are further restricted to older forest, in areas where the common cyano-lichens are particularly abundant. When such places were encountered en route between randomly selected plots in the back country, they were checked for the presence of such specialized species if time allowed.

Data were collected using the lichen protocol employed by USFS for the FHM plots. It is a time-constrained search method for epiphytic macrolichens in 36.6-m radius plots for up to 2 hours (U.S. Forest Service, 1999) or until no new species have been found in 10 minutes. The authors modified this approach in several ways.

1. Instead of limiting the sample to epiphytic lichens, field observers searched for all macrolichens, including terrestrial lichens; crustose lichens were collected only accidentally or randomly. Although this modified method leads to a somewhat larger sampled community than the FHM method, the diversity of terrestrial lichens is not high in most heavily forested vegetation types. Within parkland plots, essentially all species are terrestrial, so parklands were a significant departure
6. It would have been impossible to pack out voucher specimens for all species on longer trips. Therefore, the authors allowed observational data to be collected for species that can be identified with confidence in the field. Nevertheless, if an easily identified species was interesting for any reason (for example, rare, elevation minimum or maximum, or a first collection in a geographic area in ONP), a voucher specimen was collected.

Processing of Specimens

Upon returning from the field, specimens were air dried. Some liverwort genera with ephemeral identification characters (for instance, oil bodies) were placed in a refrigerator, but refrigeration capacity was quickly exceeded. As a result, many liverworts had to be identified without oil-body characteristics. Specimen data were entered into a database. Dried vouchers were filed alphabetically in their respective taxonomic group (lichens, mosses, and liverworts/hornworts). Specimens were placed in a temporary holding area in the ONP herbarium, in bryophyte boxes with labeled tabs marking genera and species.

Identification Methods

- Equipment and Chemicals

Standard tools and methods were used to identify bryophytes (Schofield, 1985) and lichens (McCune and Geiser, 1997; White & James, 1988). Identifications were made by M. and K. Hutten, with some specimens sent to taxonomic experts for verification.

- Processing Method

Cryptogam specimens were grouped by genus and identified one genus at a time. This allowed the determinations to proceed efficiently, building familiarity with the diversity of characteristics within each genus and the available generic key. Importantly, this processing method increased the determination accuracy, especially for difficult genera. Associated species frequently were identified as well. Many of the smallest lichens and liverworts overlooked in the field are often associated with larger species in voucher specimens. In some plots the associated species contributed 30 percent to the overall plot list. When an interesting associated species was found during determinations, the voucher would be refiled under the generic name of the associate, and identified later with others of that genus. Identifications within previously completed genera were made without delay.

- Identification Literature

Initially, “Moss Flora of the Pacific Northwest,” by Elva Lawton (1971), was the basis for specimen identification. All
other literature was acquired as the project continued and the need for better keys arose.

**Mosses**

Subclass *Sphagnidae*: Crum (1984)

In 2004 a new key became available (Zander, 2004), which includes at least two species not reported in Crum that are found on the OP: *Sphagnum pacificum* (Flatberg, 1989) and *Sphagnum alaskense* (Andrus & Jenssens, 2003). Using the old keys, *S. pacificum* would key to *S. recurvum* s.l. During this project we often determined *S. recurvum* var. *brevifolium*. This is a problematic taxon for western North America (W. B. Schofield, written commun., 2004). For these reasons, all collections in the *S. recurvum* group need to be re-determined. *S. alaskense* was recently reported from ONP, but it is not likely the authors overlooked this species in their collections. *S. cuspidatum*, determined twice in this project, is misidentified (W. B. Schofield, written commun., 2004).

Subclass *Andreaeidae*: Lawton (1971); Murray (1986, 1988)

The authors initially used Lawton (1971) but later switched to Murray (1986, 1988). At some time in the future, the *Andreaea* identifications should be verified, identifying any newer species not included in Lawton (1971) that may have been overlooked. This probably resulted in the mis-determination of *A. megistospora* as *A. rothii* (W. B. Schofield, written commun., 2004). A subset of the substantial Harthill collections, predating this project and kept at ONP, should also be re-determined.

Subclass *Bryidae*: Lawton (1971)

For the following select genera in this large subclass we used more recent keys as listed after each genera: *Pohlia* (Shaw, 1982), and *Didymodon* (Zander, 1999). The complex genus *Racomitrium* was started using Lawton (1971), but later the authors switched to Frisvoll (1983, 1988), in which several species aggregates are differentiated. As a result, a portion of the *Racomitrium* collections should be re-examined at some time in the future, as well as a subset of the substantial Harthill collections predating this project that are kept at ONP. The Frisvoll volumes do not cover all species in the genus *Racomitrium*, so we used Lawton (1971) for the remainder of the species. At present Norris and Shevock (2004a) should be considered (see also Bednarek-Ochyra, 2000). *Dicranum* species were verified using Lawton (1971), and for Washington this key is probably adequate. Rare species were verified using a recently published key (Zander 2004), which is more up to date. The many ONP *Dicranum bonjeanii* collections in the ONP Herbarium submitted by Harthill and others are probably *Dicranum howellii* and *D. scoparium*. These should be verified using the new *Dicranum* key in Zander (2004). Some species concepts/groups have been revised fairly recently and our ONP specimens should therefore be re-examined (in part) at some point in the future, including *Hedwigia ciliata*; ours is now called *H. stellata* (Buck & Norris, 1996).

**Liverworts**

A complete key to liverworts and hornwort (hepatics) genera recently became available (Schofield, 2002). Unfortunately, this work does not contain keys to the species level. At present there is no single work that can be used to identify all hepatic species that occur in ONP. For keys and descriptions of most species found at ONP, one of the best single resources is Judith Godfrey’s thesis (1977). The authors used this work extensively, along side updated versions of the Christy and Wagner (1996) keys, the Schuster volumes (1966-1992), and versions of hepatic keys by Dan Norris (unpublished). Rather late in the identification process the authors acquired “The Liverwort Flora of the British Isles” (Paton, 1999), which helped resolve many problems in segregating taxa using the keys in the resources listed above. The “Illustrated Flora of Nordic Liverworts and Hornworts” (Damsholt 2002) would also be useful for some genera, but unfortunately was unavailable. None of the above resources cover all species found in ONP, consequently a myriad of additional literature is needed to identify some of the lesser-known species. Some of this literature was not available to this project.

**Lichens**

Fortunately, the literature relevant to macrolichens is much more consolidated than is the bryophyte literature. The keys in McCune and Geiser (1997) cover all but a few macro lichens. In general, the omitted lichens are more northern species that can be found in Goward (1999) and Goward and others (1994). For *Leptogium*, *Pseudocyphellaria*, *Usnea*, and *Xanthonia* (McCune, 2000), the authors used updated keys available from Bruce McCune (2000),’s website: (http://oregonstate.edu/~mccuneb/getkeys.htm). Some species concepts/groups have been revised fairly recently and ONP specimens should therefore be re-examined (in part) at some point in the future, including *Pannaria/Fuscopannaria*, *Menegazzia*, *Physconia* (*P. fallax* is a species now known from the ONP, but was not in the keys used by the authors for the ONP material), *Pyrrophospora*, and so forth. Most crustose lichens were omitted in this project, but can be keyed to genus using McCune (2002). Many crustose lichens can be keyed to species using Noble (1982) and Purvis and others (1992).
• Names and Titles of Experts Who Were Consulted
The following people have verified specimens during this project. Bruce McCune provided the majority of lichen verification.

1. Dr. Rick Dewey, USFS Botanist: *Riccia, Tritomaria*

2. Chiska Derr, USFS lichen Taxa Expert: Survey and Manage lichens

3. Dr. Linda Geiser, USFS Ecologist and Air Quality Specialist: *Bryoria capillaris*

4. Dr. Katie Glew, University of Washington Herbarium (WTU): *Alectoria samentosa subsp. vexillifera*

5. Dr. Judith Harpel, Regional Interagency Bryologist: Survey and Manage bryophytes

6. Sarah Jovan, Ph.D. candidate, student under McCune: *Physconia fallax*

7. Dr. Bruce McCune, Professor, Oregon State University (OSU): lichens

8. Dr. Wilfred Schofield, Professor, University of British Columbia (UBC): bryophytes

Curatorial Methods

• Archival-Quality Voucher Envelopes
Archival-quality voucher envelopes were produced showing standard collection information for each species (fig. 2). A map of the plot locality is also printed on the inside of each voucher envelope. Both the label and the map are printed on the laserprinter in grayscale on acid-free paper.

Figure 2. Example of the information on a typical voucher envelope generated during this project.
• Database
A back-end database retains and provides for the integrity of all raw data. See metadata for a detailed description of back-end database structure (http://mercury.ornl.gov/nbii/full.jsp?index=0&recidx=0&pageMax=1, November 2005). A front-end database was developed by M. Hutten to create data summaries and additional utilities.

• Quality Assurance/Quality Control for Data Entry
Various database tools were employed to ensure accurate and complete data entry. For example, certain minimum collection-site data are required before the database will connect voucher data to that site. Similarly, certain collector data must be entered before a collector can be connected to a voucher. A voucher record that lacks these and other critical fields cannot be saved until problems are corrected. The user will be prompted to add the missing data. In several fields, such as the abundance rating, the entry is limited to pre-defined valid entries. The data entry in such fields is usually via drop-down lists from which the applicable entry is selected, expediting the data-entry process, and reducing data-entry errors. These drop-down lists can be embedded directly into the definition of the data table or be associated with specific data-entry forms. More extensive, dynamic drop-down lists are easier to handle as a (lookup) data table. When the specimens had been identified and the data entered, new voucher labels were printed on acid free paper. If key fields are lacking or out of bounds (for example, elevations above 3,000 m), the database does not allow the label to be printed. Printed label data were compared and verified with the field label and associated identification notes before transferring the specimens in the new archival-quality envelope.

• Storage
Specimens are stored at Olympic National Park, 600 Park Avenue, Port Angeles, WA 98362-6798, USA (fig. 3).

Results
Bryophyte and lichen data were collected from 65 modified FHM-style plots throughout ONP (fig. 1) as the main focus of the project. Less formal data collection occurred opportunistically and intuitively from other localities in ONP during the project. The bulk of the opportunistic collections were made near trails and roads while traveling to plot locations. The scope of these collection efforts ranged from a single interesting species found along a trail, to substantial collections from an area of interest. Many of the ‘other protocol plots’ indicated on figure 1 are localities that were visited by M. and K. Hutten during trips not related to this project. These data are included in the species list and map because they provide additional documentation of the OP bryophyte and lichen flora.

Species List
During the course of this study, some 13,200 bryophyte and lichen species were identified (table 1), adding approximately 425 new species to the ONP Herbarium. These data, combined with select literature reports and personal data from M. and K. Hutten, added more than 350 species to the already extensive OP lichen and bryophyte list compiled from literature by Fred Rhoades (written comm., 1997). A few species were removed from Rhoades’ list because the reports were not based on actual collections, or they were based on misidentifications (for example, all reports of Scouleria marginata; J. Harpel, oral commun., 2002). Verification of literature reports requires finding and verifying the determinations of voucher specimens that the literature reports were based on. This was beyond the scope of this project, and it is therefore conceivable that some species listed on the Rhoades’ list are in error. Species such as Rhizomnium appalachianum, Scapania nemorosa, and Telaranea nematodes were removed, as they are known exclusively from eastern North America. Currently, more than 1,280 non-vascular plant species, subspecies, and varieties have been documented from the OP (table 1). Some reports still may contain errors, but the authors made no attempt to verify any specimens that were not available at ONP. Only a number of the approximately 5,000 non-vascular plants in the OP collections predating this project were verified. Checking previous collections was not a goal of this project, and typically records were examined only when errors were suspected. Therefore, many determinations in the ONP collection still need verification. Moreover, some of our determinations need further work for several reasons. Some groups of non-vascular plants were challenging to identify, in part due to the lack of complete and accurate keys for all species in the Pacific Northwest (PNW). Ecological and distributional information for many species, especially bryophytes, is still very incomplete. Plot work often yields many imperfect specimens, which may be small, lack needed structures (for example, sexual), or specimens were not examined when sufficiently fresh (for instance, some liverworts have ephemeral characters), making identification especially challenging.
Figure 3. Part of the lichen collection at the Olympic National Park curatorial facility.
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<thead>
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Table 1.—continued (Footnotes on page 52.)
<p>| Scientific name | Substrate category | Major vegetation type (FHM-style sampling protocol) | Source/comment | Elevation range (meters) | Parkland | ISME | ABIA | ABAM dry | ABAM wet | PSME dry | PSME wet | TSHE dry | TSHE wet | PISI | ALRU | ABLA | BOG | Bare Soil | Ennphyle | Fine Organic | Wood Debris |
|-----------------|--------------------|----------------------------------------------------|----------------|-------------------------|-----------|------|------|---------|---------|---------|---------|---------|---------|-----|------|------|-----|----------------|------------|---------------|-------------|----------------|
| Haematoma persoonii |                |                                                   | specimen at ONP herbarium, not verified | 16-1624 | 10 | 2 | 2 | 1 | 3 | 1 | 7 |         |     |      |      |    |                 |            |               |             |                |
| Halecania viridescens |            |                                                   | Rhoades 1998, WNHP Clallam | 900-1624 | 2 |   |   |   | 2 |   |   |       |     |      |      |    |                 |            |               |             |                |
| Heteroderma leucococa |           |                                                   | L. Grisez 2000 | 618-1629 | 5 | 1 | 2 |   |   |   |   | 2 | 2 |       |     |      |      |    |                 |            |               |             |                |
| Hydrothrya venosa |               |                                                   |             | 5-1627 | 67 | 5 | 3 | 2 | 11 | 3 | 3 | 1 | 2 | 6 | 1 | 3 | 1 | 3 | 64 | 1 | 1 |         |            |               |             |                |
| Hypocenomyce castaneocinerea | |       |                                                   |             | 1958 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |               |             |                |
| Hypocenomyce frisia |               |                                                   |             | 8-1627 | 48 | 4 | 1 | 1 | 2 | 3 |   | 1 | 110 | 1 | 5 |       |     |      |      |    |                 |            |               |             |                |
| Hypocenomyce leucococca |           |                                                   | Tentative ONP spec. | 0-1629 | 81 | 11 | 3 | 4 | 14 | 8 | 14 | 4 | 4 | 8 | 3 | 4 | 1 | 110 | 1 | 5 |       |            |               |             |                |
| Hypocenomyce scalaris |               |                                                   |             | 123-2032 | 49 | 1 | 6 | 12 | 2 | 4 | 1 | 2 | 2 | 3 | 3 | 1 | 2 | 49 | 1 | 26 |       |            |               |             |                |
| Hypogymnia australis |               |                                                   |             | 5-1261 | 33 | 2 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Hypogymnia biterni |                |                                                   |             | 618-1620 | 21 | 3 | 6 | 1 | 2 | 2 | 1 | 1 |     | 16 | 1 | 2 |       |     |      |      |    |                 |            |               |             |                |
| Hypogymnia duplicata |              |                                                   |             | 177-1886 | 21 | 3 | 4 | 2 | 4 | 1 |   |   | 17 | 1 | 2 |       |     |      |      |    |                 |            |               |             |                |
| Hypogymnia talloides |               |                                                   |             | 190-822 | 5 | 1 |   | 1 | 1 | 1 | 1 |   | 1 |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Hypogymnia physodes |               |                                                   |             | 0-1807 | 51 | 2 | 3 | 1 | 1 | 1 | 6 | 1 | 2 | 3 | 2 | 2 |   | 1 | 38 | 1 | 3 |       |            |               |             |                |
| Hypogymnia rugosa |                 |                                                   |             | 624-2032 | 36 | 8 | 8 | 3 | 2 | 2 | 1 | 2 |   | 1 | 27 | 3 | 1 |   | 9 | 1 |   |       |            |               |             |                |
| Hypogymnia tubulosa |               |                                                   |             | 0-1299 | 14 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Hypogymnia vittata |                |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Hypotrichyna sinuosa |              |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Icmadophila ericetorum |           |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Ionaclis lacustris |                |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Japewia subaurifera |              |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Koerberia californica |           |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Koerberia merrillii |                |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Koerberia sanoensis |               |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Lecanactis abietina |              |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |
| Lecanactis cyrtella |                |                                                   |             |       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |            |               |             |                |</p>
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Table 1. — continued (Footnotes on page 52.)
### Table 1. Inventory of the Mosses, Liverworts, Hornworts, and Lichens of Olympic National Park, Washington: Species List

**Scientific name**

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<tr>
<th>Common Name</th>
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**Footnotes:**

1. OLYM det. B. Ryan, WNHP Clall, Jeff

2. Tønsberg 1998, WNHP Clallam

3. Tønsberg 1999a, Tønsberg 1999b, Tønsberg 1997


5. Tanner 1958

6. O.B.R.M. det. B. Ryan, WNHP Clall, Jeff

7. O.B.R.M. det. B. Ryan, WNHP Clall, Jeff

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**Table 1.**—continued (Footnotes on page 52.)
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| Tremella cladoniae | ✔️ | | | | | Bare Soil
| Tremolecia atrata | ✔️ | | OLYM coll. Verif. B. Ryan | 1886-1958 | 3 | 1 |
| Tuckermannopsis chlorophylla | ✔️ | | OLYM specimen at BG Herbarium | 4-1678 | 59 | 2 | 10 | 1 | 5 | 3 | 5 | 2 | 3 | 3 | 4 | 1 | 1 |
| Tuckermannopsis orbata | ✔️ | | OLYM specimen at BG Herbarium | 3-1476 | 30 | 1 | 2 | 1 | 2 | 5 | 2 | 1 | 1 |
| Tuckermannopsis platyphylla | ✔️ | | OLYM specimen at BG Herbarium | 419-2032 | 28 | 3 | 5 | 3 | 4 | 3 | 3 | 1 | 3 |
| Tuckermannopsis subalpina | ✔️ | | OLYM specimen at BG Herbarium | 822-1807 | 22 | 2 | 10 | 5 | 3 |
| Umbilicaria angulata | ✔️ | | WNHP Jefferson | 624 | 1 |
| Umbilicaria arctica | ✔️ | | OLym coll. Verif. B. Ryan | 1886-1958 | 3 | 1 |
| Umbilicaria cylindrica | ✔️ | | | 1150-2032 | 5 | 1 |
| Umbilicaria decussata | ✔️ | | sent. B. McCune, WNHP Clallam | 1950-1958 | 2 | 1 |
| Umbilicaria deusta | ✔️ | | | 1347-1807 | 3 |
| Umbilicaria havaasii | ✔️ | | sent. B. McCune, WNHP Clallam | 948-2032 | 5 | 2 |
| Umbilicaria hirsuta | ✔️ | | | 1134 | 1 |
| Umbilicaria hyperborea | ✔️ | | | 948-2032 | 12 | 9 |
| Umbilicaria krascheninnikovii | ✔️ | | Glew 1998, WNHP Clallam, Jefferson | 1886-2032 | 4 | 1 |
| Umbilicaria lambi | ✔️ | | sent. B. Ryan | | |
| Umbilicaria lyngei | ✔️ | | | 1950 | 1 | 3 |
| Umbilicaria nylanderiana | ✔️ | | | 1958 | 1 |
| Umbilicaria phaea | ✔️ | | | | |
| Umbilicaria polyrhyzta | ✔️ | | | | |
| Umbilicaria proboscidea | ✔️ | | sent. B. McCune, WNHP Clallam | 1930-2032 | 4 | 4 |
| Umbilicaria rigida | ✔️ | | | 1807-2032 | 5 |
| Umbilicaria scholanderi | ✔️ | | | | |
| Umbilicaria torrefacta | ✔️ | | Glew 1998 | 728-2032 | 9 | 6 | 14 |
| Umbilicaria velea | ✔️ | | | 1982 | 1 | 1 |
| Umbilicaria virginis | ✔️ | | Glew 1998 | 1325-2032 | 5 | 2 | 4 |
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| Usnea ceratina | ✔️ | | | | |
| Usnea chaetophora | ✔️ | | | 69-1271 | 9 | 2 | 1 | 1 | 2 |
| Usnea comuta | ✔️ | | | | 9 | 1 | 9 | 1 |
| Usnea cornuta | ✔️ | | | 5-69 | 8 |
| Usnea diplotypus | ✔️ | | | | 5-452 | 1 |

Table 1.—continued (Footnotes on page 52.)
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463 LICHEN species on Rhoades list (1997)

150 LICHENS in ONP Herbarium (OLYM) (1997)

711 LICHEN species found on OP (2004)

### LIVERWORTS

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Table 1.—continued (Footnotes on page 52.)
**Scientific name**

- **Fossombronia foveolata**
- **Fossombronia longiseta**
- **Frullania bolanderi**
- **Frullania californica**
- **Frullania franciscana**
- **Frullania nisquallensis**
- **Geocalyx graveolens**
- **Gymnocolea inflata**
- **Gymnomitrium concinnatum**
- **Gyrothyra underwoodiana**
- **Harpanthus floiovianus**
- **Herbertus aduncus**
- **Hygrobiella laxifolia**
- **Jamesoniella autumnalis**
- **Jungermannia atrorubens**
- **Jungermannia confertissima**
- **Jungermannia exsertifolia subsp. cordifolia**
- **Jungermannia gracillima**
- **Jungermannia hyalina**
- **Jungermannia leiantha**
- **Jungermannia pumila**
- **Jungermannia rubra**
- **Jungermannia sphaerocarpa**
- **Kurzia pauciflora**
- **Kurzia sylvatica**
- **Lepidozia filamentososa**
- **Lepidozia reptans**
- **Lophocolea bidentata**
- **Lophocolea heterophylla**
- **Lophozia ascendens**

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Table 1.—continued (Footnotes on page 52.)
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118 LIVERWORT species on Rhoades list (1997)

84 LIVERWORTS in ONP Herbarium (OLYM) (1997)

151 LIVERWORT species found on OP (2004)

### MOSSES

| Alisia californica              | 43                          | 1 | 1 |
| Amblystegium serpens           | 134-265                     | 2 | 1 |
| Amphidium californicum         | 47-1048                     | 6 | 1 |
| Amphidium iaponicum            | 179-1685                    | 6 | 1 |
| Amphidium mougeoti             | 5-1621                      | 4 | 1 |
| Anacolia menziesii             | 47-1150                     | 10| 1 |
| Andreaea alpestris             | 1163                        | 1 | 1 |
| Andreaea blyttii               | 1163                        | 1 | 1 |
| Andreaea heinemannii           | OLYM coll Norris (verify)    | 1 | 1 |
| Andreaea rivalis               | 1061-1620                   | 7 | 1 |
| Andreaea rupestris             | 581-1807                    | 19| 2 |
| Antitrichia aestivum           | Schofield 1967              | 1 | 2 |
| Antitrichia californica        | 43-861                      | 12| 1 |
| Antitrichia curtipendula       | 8-1299                      | 57| 3 |

Table 1.—continued (Footnotes on page 52.)
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Table 1.—continued (Footnotes on page 52.)
| Scientific name                        | Source/comment | Major vegetation type | Substrate category | OP | elevation range (meters) | Parkland | FSLME | ABAM | ABAM dry | ABAM wet | FSLME dry | FSLME wet | TSHE dry | TSHE wet | PISI | ALRU | BOG | ROCK | FINE ORGANIC | EPIPHYTE | BARE SOIL | ROCK | EPIPHYTE | FINE ORGANIC | BARE SOIL |
|---------------------------------------|----------------|----------------------|-------------------|----|--------------------------|----------|------|------|---------|---------|----------|-----------|-----------|---------|------|-----|-----|--------|--------|--------|------|--------|----------|----------|
| Ceratodon purpureus                   |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Cirriphyllum citriodorum              |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Claopodium bolanderi                 |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Claopodium crispifolium              |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Claopodium whippleanum               |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Climacium dendroides                 |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Conostomum tetragonum                |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Cynodonon calyptratus                |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Cratoneuron filicinum                |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Cusma latifolia                      |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Cynodontium jenneri                  |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Cynodontium strumulosum              |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dendroalsia abietina                 |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Desmatodon latifolius                |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dichelyma falcatum                   |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dichelyma uncinatum                  |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dichodontium olympicum               |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella crispa                    |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella grevilleana               |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella heteromalla               |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella howei                     |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella pacifica                  |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella palustris                 |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella rufescens                 |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella schreberiana              |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella varia                     |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranella cirrata                   |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranoweisia cirrata var. contemina |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranoweisia crispula var. contemina|                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranoweisia crispula var. crispula |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |
| Dicranus fusescens                   |                |                      |                   |    |                          |          |      |      |         |         |          |           |           |         |      |     |     |        |        |        |      |        |           |          |

Table 1.—continued (Footnotes on page 52.)
| Scientific name                      | Substrate category | Major vegetation type | Source/comment | OP elevation range (meters) | OP localities | Parkland | ABAM | ABAM dry | ABAM wet | TSHE | TSHE dry | TSHE wet | PSME | PSME dry | PSME wet | PISI | PISI dry | PISI wet | AILU | AILU dry | AILU wet | BOC | Rock | Fine Debris | Wood Debris |
|--------------------------------------|--------------------|-----------------------|-----------------|--------------------------|--------------|----------|------|---------|---------|------|---------|---------|------|---------|---------|------|---------|---------|-----|------|-----------|----------|
| Dicranum howellii                    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dicranum majus                       |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dicranum pallidisetum                |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dicranum polysetum                   |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dicranum rhabdocarpum                |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dicranum scoparium                    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dicranum tauricum                    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dicranum undulatum                   |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Didymodon rigidulus var. gracilis    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Didymodon tophaceous                 |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Didymodon vinealis                   |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Didymodon vinealis var. brachyphyllus|                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Didymodon vinealis var. flaccidus    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Didymodon vinealis var. vinealis     |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Discellium nudum                     |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Distichium capillaceum               |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Ditrichium ambiguum                  |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Ditrichium flexicaule                |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Ditrichium heteromallum              |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Ditrichium montanum                  |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Ditrichium pusillum                  |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Ditrichium schimperi                 |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Ditrichium zonatum var. scabrifolium|                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Drepanocladus aduncus var. aduncus   |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Drepanocladus aduncus var. kneiffii  |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Drepanocladus sendinieri             |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Dryopteris patens                    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Encalypta affinis                    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Encalypta ciliata                    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Encalypta procera                    |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |
| Encalypta rhapsocarpa                |                    |                       |                 |                          |              |          |      |         |         |     |         |         |      |         |         |     |       |           |          |     |

Table 1.—continued (Footnotes on page 52.)
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<td>Warnstorfia exannulata</td>
<td>1 2 1 2 1 1</td>
<td>Fine Organic</td>
<td>Norris 1997, WSHP Chelfin 5-157-289</td>
</tr>
<tr>
<td>Warnstorfia fluitans</td>
<td>1 2 1 2 1 1</td>
<td>Fine Organic</td>
<td>Norris 1997, WSHP Chelfin 5-157-289</td>
</tr>
<tr>
<td>Weissia controversa</td>
<td>1 2 1 2 1 1</td>
<td>Fine Organic</td>
<td>Norris 1997, WSHP Chelfin 5-157-289</td>
</tr>
<tr>
<td>Zygodon viridissimus</td>
<td>1 2 1 2 1 1</td>
<td>Fine Organic</td>
<td>Norris 1997, WSHP Chelfin 5-157-289</td>
</tr>
</tbody>
</table>

Table 1.—continued (Footnotes on page 52.)
Inventory of the Mosses, Liverworts, Hornworts, and Lichens of Olympic National Park, Washington: Species List
Other products

Several products resulted from this project in addition to a significantly enhanced list and herbarium of cryptogam species for ONP.

• Field Guide

A field guide entitled “101 Common Mosses, Liverworts, and Lichens of the Olympic Peninsula” (Hutten and others, 2001) is a pocket-sized, waterproof guide to cryptogams of the Olympic Peninsula, and it is also useful throughout western Washington. It is easy to use, with close-up color photos and non-technical descriptions that offer tips for identification. Species are grouped by substrate, and elevational range is indicated for each. It includes a glossary and diagrams to teach new terms, and differentiates 140 species. This field guide is for sale to the public and will also be used to train vegetation-monitoring crews in the future.

• Illegal Commercial Moss Harvests

Images and reports describing two significant incidents of illegal harvest of cryptogams from the Park are available to ONP staff members at the park-accessible network address I:\all\crypto\Commercial Moss Harvest\ (restricted access).

• Fact Sheet

A four-page fact sheet describing cryptogams, their ecological role, and their need for conservation is available from USGS as a PDF file at http://fresc.usgs.gov/products/fs/fs-154-02.pdf, November 2005. This fact sheet is also available in hard copy from USGS-FRESC, 777 NW 9th St., Suite 400, Corvallis, OR 97330.

Images that have been provided to other agencies can be seen at http://www.or.blm.gov/surveyandmanage/about.htm, temporarily unavailable November 2005 and http://www.fs.fed.us/pnw/pubs/gtr573.pdf, November 2005. Other images have been requested for use in a general biology textbook, and 50 images have been published (Hutten, 2003; http://www.cnps.org/publications/fremontia/Fremontia_Vol31-No3.pdf, November 2005).

• Websites

General project information is available at http://fresc.usgs.gov/olympic/research/indivproj.asp?OFSProj_ID=12, November 2005. Results from the ONP non-vascular plant inventory through 2001 can be found at http://ocid.nacee.org/nbii/crypto/, November 2005. This is an online database searchable by watershed (to generate species lists), genus, species (to generate locality listings), and so forth. Several hundred low-resolution photographs can be viewed and downloaded from this site (higher resolution cryptogam images are accessible to ONP employees at the ONP network drive address I:\all\crypto\images, restricted access).

• GIS Layer

All records of cryptogam species and their locations are available as a data layer in the ONP GIS system.

• Metadata

Metadata for this project and the resulting database can be found at http://mercury.ornl.gov/nbii/full.jsp?index=0&recidx=0&pageMax=10, November 2005.

• Collaboration with Other Agencies

Data of federally listed Survey and Manage species found in ONP have been shared with the Northwest Forest Plan Interagency Bryologist and Lichen Coordinator with permission of the ONP Chief of Natural Resource Management. Species included in the Survey and Manage List required special surveys in areas on USFS and BLM land where ground-disturbing activities are planned. Sharing data contributed to the understanding of the habitat requirements and distribution of these species, which is used to refine search protocols. ONP data were included in species habitat models, which predict likely sites for rare species (R. Lesher, written commun., 2002). Some species (such as Leptogium brebissonii, Ptilidium californicum, and Ulota megalospora) were dropped from the former Survey and Manage List because they were either common or because habitat data showed that they were not exclusively associated with old-growth forests, a requirement for the federal listing associated with the Northwest Forest Plan. Some former Survey and Manage species are locally common in ONP and rare elsewhere in the PNW (for instance, Schistostega pennata, Tetraphis giguliculata, Diplophyllum plicatum [fig. 4], Kurzia spp., and Herbertus aduncus [fig. 5]). Botanists of several agencies have visited populations of former Survey and Manage species in ONP to improve their ability to locate these species elsewhere in the region.

Washington State Department of Natural Resources, USFS (http://www.fs.fed.us/pnw/pubs/gtr573.pdf, November 2005), and BLM (http://www.or.blm.gov/surveyandmanage/about.htm, temporarily unavailable November 2005) have also used images generated during this project.

Some rare species found in ONP were new to Washington and have been proposed and subsequently added to the Washington Natural Heritage Program (WNHP) list. Thus far, the authors have proposed the lichens Bunodophoron melanolcarpum (fig. 6), Spilonema sp.1 (Goward, 1999), and Pseudocyphellaria mallota (fig. 7). Suggested for listing review is Bryoria tenuis, a very rare species in Washington (possibly new to Washington), with only one or two sites on the OP. Proposed mosses include several species in the Splachnaceae, including Splachnum ampullaceum (fig. 8). To date, the WNHP list has not included liverworts, but a working list is currently being compiled and ONP data can be made available to support this effort.

ONP has made its data available to other agencies, but informal data requests by ONP are not always answered.
As a result, ONP has no information on the location of the following critically endangered species: *Brachyodontium olympicum* (WNHP G3S1; see Appendix A for explanation of species status), *Dermatocarpon luridum* (WNHP G?S2), and *Umbillicaria scholarnderi* (WNHP G1S1).

**Discussion**

**Cryptogam Diversity of the Olympic Peninsula**

Because of its tremendous habitat complexity, pristine condition, and moderate maritime climate, ONP has an astonishing diversity of non-vascular plants. In the Hoh rainforest, a single old-growth Sitka spruce may support more than 60 bryophyte and lichen species and a few epiphytic vascular plants (Hutten, unpub. data, 2001). More than 1,280 species of mosses, liverworts, hornworts, and lichens have been catalogued from the OP (Rhoades, 1997, supplemented with data from this project), and species new to the area are still frequently discovered. Within ONP, collections and locality data are available for some 900 species. The sheer biomass of bryophytes and lichens is as impressive as the species diversity. ONP is internationally known for the “Hall of Mosses”, one of few places in the world where one cannot see the forest for the moss carpets.

It is not just the lush rainforests that support a high abundance and diversity of cryptogams. The unique biogeo-graphy of the OP includes a variety of other habitats with large numbers of species, including many rare and endemic vascular plants, relative to its geographic area (Houston and others, 1994; Buckingham and others, 1995). In fact, the OP has the greatest number of rare vascular plant taxa listed by WNHP as compared to any geographic area within Washington (http://www.nps.gov/olymp/eal/Fmp2/fmpaf2.htm, November 2005). The number of rare non-vascular plants is even higher than vascular plants, and can also be attributed to the broad range of habitats on the OP. Intact examples of many of these habitats are rare elsewhere due to human activity.

Bryophytes and lichens have a high degree of habitat and substrate specificity, which also contributes to the high diversity and frequency of rare taxa on the OP. Though some species are clearly generalists, many bryophytes and lichens are decidedly microhabitat specific. For example, *Splachnum ampullaceum* and *S. sphaericum* are mosses found only on excrement in open and perennially moist *Sphagnum*-dominated coastal bogs. Both species were proposed for listing in WNHP, as there are few, if any, other known occurrences in Washington. Occurrences of *Tetraplodon mniodes* (G5 S1) and *Tayloria serrata* (G4? S1; fig. 9) on the OP are primarily on moist and exposed xylophore excrement. The widespread crustose lichen *Fellhanera bouteillei* is one of the few epiphylls found in this area and lives on live needles of conifers in moist forests. With species occupying such small ecological niches, the wide variety of habitats on the OP could indeed be expected to harbor a multitude of cryptogams.

**Rare Species on the Olympic Peninsula**

Determining whether a given species is common, infrequent, or rare requires a large amount of distributional data. Despite having access to more than 20,000 data points for non-vascular plants on the OP, the data are still inadequate for determining the status of a flora of more than 1,250 species, forcing reliance on data from elsewhere in the region. The most relevant source is the list of endangered, threatened, and sensitive plants in Washington, produced by the Washington Natural Heritage Program (WNHP) (1997), a Washington State Department of Natural Resources project. Documents associated with the former Survey and Manage program of the Northwest Forest Plan provide information on species thought to be rare due to their association with old-growth forests. The authors also included the British Columbia (BC) listing of red- and blue-listed mosses and lichens. The BC status data are particularly relevant for those species at the northern extent of their range in this area.

The current list of rare species reported from the OP (Appendix A) includes data from this project, supplemented with select literature reports and personal communications with other lichenologists and bryologists. More than 220 bryophytes and lichens found on the ONP are listed as rare in the Washington and Oregon Heritage Plans (ONHIC, 2004) and in former Survey and Manage documents (about 18 percent of the OP flora). The authors expect that the total number of rare species will increase in the future for a number of reasons.

1. There is currently no status information for Washington liverwort species, despite a recent catalog (Hong, 2002). Liverworts, therefore, have not yet been incorporated into the WNHP. The authors used data from ONHIC as an indicator of liverwort rarity (Appendix A), but these Oregon data cannot be used for Washington without caution. There are several OP species that do not occur in Oregon (such as *Odontoschisma denudatum* and *Blepharastoma arachnoideum* [fig. 10]). For lack of Washington distribution data, such species were omitted from our list, although they almost certainly belong on it.

2. Some species are so poorly known that their distributional status cannot yet be determined. Such species are omitted from this list of rare species (Appendix A). For example, *Stigonema* sp. 1, (Goward, 1999) probably is genuinely rare, but lichenologists have not been aware of this species for very long.

3. The ONP/OP inventory is far from complete, and many crustose lichens and less common bryophytes and macro-lichen species are yet to be recorded.

There are also species on the WNHP list that appear to be quite frequent on the OP (such as the lichens *Ahtiana pal-lidula* and *Usnea wirthii* and the liverworts *Douinia ovata* and *Diplophyllum albicans*). The status of these lichens may be
updated if evidence shows that they are also frequent elsewhere in Washington. Both liverworts were removed recently from the former Survey and Manage list. The moss *Racomitrium aquaticum* is now considered to be the distinct species *Racomitrium ryssardi*, an endemic to the PNW found mainly on the western part of the OP (Bednarek-Ochyra, 2000). The lichen *Karnefeltia californica* is apparently over-reported in Washington because of mis-identifications; there are perhaps only four or five accepted locations in Washington (L. Geiser, written commun., 2004), hence its status should be G2S1.

Surveyor attention often focuses on species listed as rare. The Survey and Manage species in particular receive much more attention than other species and are specifically sought in the field. On the OP, for example, the authors have collected the rare lichen *Pseudocyphellaria rainierensis* (fig. 11) from more locations than the common *P. anthrapsis*. It is therefore necessary to use caution in drawing conclusions from the collection frequency of these species on the OP, as indicated in Appendix A. However, a few species do appear to be more frequent here than elsewhere in Washington and Oregon, and future work may demonstrate that they are not truly rare on the OP (for example, *Metzgeria temperata* and *Platismatia lacunosa*).

**Endemic Species**

Clues from biogeography help us to understand patterns of endemism. Endemic species are those with narrow distributional ranges, and are considered special for being unique to a region. Endemism may occur when an area has been isolated for a significant time or serves as a refuge for relict populations of a formerly common species following widespread extinction. Vascular plants endemic to OP were thought to have been isolated by its island-like geography and its potential to have been a refuge during the last ice age (Buckingham and others, 1995). Whether the distribution of non-vascular endemic plants supports this hypothesis remains to be seen.

Among the non-vascular flora, approximately 105 moss species and varieties are endemic to western North America, representing about 18 percent of the moss flora (Lawton, 1971; Schofield, 1985). Of these, some 20 mosses are found west but not east of the Cascade Range (Lawton, 1971). The proportion of endemic liverworts is similar, about 16 percent (Schofield, 1985). Nine moss and three (monotypic) liverwort genera are endemic to Pacific North America (Schofield, 1985; 2002). The proportion of the lichen flora that is endemic to western North America is high, but the number is unknown to the authors. At present, no mosses, liverworts, or lichens are known to be endemic exclusively to the Olympic Mountains. In Pacific North America, almost all endemic bryophytes occupy geographic areas that are larger than the OP, hence the Peninsula may not be sufficiently isolated to produce endemic bryophytes. With respect to lichen endemism on the OP, Rhoades (1997) comments that “the general response from lichenologists concerning endemism is that the Olympic Peninsula has a diverse and abundant lichen flora but that, with perhaps a few exceptions, the flora is no different from that of nearby areas.”

Even though there is no current evidence of endemism in the OP non-vascular flora, it may be too early to draw a firm conclusion. Many of the areas suspected of having been glacial refugia in ONP have not been surveyed. The state of knowledge of cryptogam distribution is also still dynamic, as new species are frequently added to the non-vascular plant lists of the OP, Washington, and North America. Species altogether new to science are described frequently, particularly among the crustose lichens. Often, with the increased attention brought on by the publication of a new species description, the species is soon reported from other areas. For example, the moss *Brachydontium olympicum* was initially believed to be restricted to the Olympics when discovered by Dr. Frye in 1907. It was later found in Oregon, Washington, British Columbia, and Japan. The small fruticose lichen *Spilome-llya americana* was recently described and placed in a new genus. Originally collected adjacent to the Hoh River (type locality), it is now also known from other areas in Pacific North America (Henssen and Tønsberg, 2000). The ‘arboreal hairball,’ another fruticose lichen species, tentatively called *Stigonema* sp. 1, was included in a species key for British Columbia by Goward (1999). During this project it was found on Sitka spruce branches from the upper canopy in the Hoh and Quinault rainforests, and it was also found in Oregon (B. McCune, written commun., 2002). During this project, two macro-lichens in the genus *Dermatocarpon* were found in ONP that are thought to be undescribed. One liverwort in the genus *Scapania* did not fit any key we had available. If these are undescribed, these species may be endemics, or they may be found elsewhere now that taxonomists are aware of them.

**Conservation of Cryptogams**

- **Regional Context for Rare Species**

Bryophytes and lichens fulfill many important roles in the ecosystem and are a major component of the floristic biodiversity of the Olympics. In turn, the OP is of major floristic importance to the region because of its large habitat diversity and because of the occurrence of many species that are known from only a few localities in the PNW (such as *Vulpicida tilesii*), the conterminous 48 States (such as *Bunodophoron melanocarpum*, fig. 6), or Washington (such as *Sphalchnum sphaericum*, fig. 12). The liverwort *Tritomaria exsectiformis* (ONHIC list 2; SEIS J2-8a) occurs in a single site (on Olympic National Forest land), which represents the only known site in Washington and Oregon west of the Cascade Range for this species (J. Harpel, oral commun., 2003). The preservation of biological diversity is becoming increasingly important with the advance of anthropogenic habitat conversion. It seems inevitable that the main reservoir of diversity is going to be the National Park system and other unmanaged areas. ONP is essentially an unmanaged island in a managed
landscape. Species associated with old-growth forests in Washington and Oregon, such as the mosses Schistostega pennata (WNHP G4 S2, fig. 13), Tetraphis geniculata (WNHP G5 S2, fig. 14), and Iwatsukiella leucotricha (WNHP G2/3 S1) were once more widespread, and generally only occur in the managed landscape on legacy substrates from the original old-growth forest. Schistostega requires large, shaded, upturned, soil-clad root wads. Tetraphis geniculata requires large, shaded wood debris in an advanced state of decay. After these legacies have been depleted, commercial forests are unlikely to provide a spatially and temporally continuous habitat for these species. Their persistence may only be guaranteed in large tracts of old-growth forest, where their microhabitats have greater temporal and spatial continuity.

Although some species of cryptogams seem to disperse easily via light-weight, airborne spores, many spores are not robust to long distance/time travel (Tan and Pocs, 2000). Most species depend on vegetative propagation and slow dispersal through forests (Tan and Pocs, 2000). Consequently, if populations of rare species are lost, they would probably return slowly, if ever. Attempts to revitalize managed landscapes will need to restore the ecological infrastructure and the connectivity to centers of diversity that still remain on the landscape. The large relatively pristine ecosystems in ONP are some of the last few places that still harbor healthy and extensive populations of some of these obligate old-growth associated species. Because of the island-like nature of the OP, species cannot easily recolonize the area once extirpated. A comprehensive list of ‘special concern species’ for ONP is unavailable as there is insufficient information to adequately assess the frequency of many species. Nevertheless, some candidate species can be identified. The macro-lichen Platismatia stenophylla is common in Oregon and other parts of Washington, including the San Juan Islands, and is hence not listed on any State or federal list. However, this distinctive species is known from a few thalli on a single ridge on the northern OP, and hence may represent a critically endangered element of the flora. The southern OP is less well explored, but our limited fieldwork there did not yield additional records of this species. Other examples of species that are apparently rare on the OP, but may be more frequent elsewhere in Washington, are the PNW endemic mosses Bryolawtonia vancouveriensis and Alsia californica and the lichen Ramalina subleptocarpha.

• Threats

People often assume National Parks are in little need of active management, but human impacts are far reaching and will continue to increase and affect the National Parks. The direct threats are easiest to control and many activities are already regulated or prohibited in National Parks: commercial and scientific collection of bryophytes and lichens, construction of human infrastructure such as trails, roads (runoff), parking lots, and buildings. The indirect effects of fire suppression, air pollution, the introduction of invasive exotic organisms, and rapid climate change induced by global warming all can have major impacts on natural systems in the long term.

Wildfire and fire suppression. In the event of wildfire, Park management may attempt to protect critical locations of rare organisms. Periodic fire, on the other hand, maintains habitat diversity and continuity at the landscape level. Low-intensity fires help create open-forest conditions where many lichens and bryophytes thrive. For example, the Blue Mountain fire in ONP eliminated many corticolous lichens, but favored others, including some thriving Bryoria cf. fremontii (fig. 15). A rare PNW endemic lichen, Sulcaria badia (WNHP G? S1), formerly known from a single locality in Washington on the Dungeness Spit, may have gone extinct from the OP as a result of habitat conversion and the effects of fire suppression (Peterson and others, 1998). Other lichens grow exclusively on charred wood (for instance, Hypocymenyes species), which is still a common sight in many areas of the ONP. However, a policy of fire suppression in National Parks may jeopardize the long-term supply of charred wood.

Air pollution. Air quality is generally good on the OP, but this may change with increasing human population. Pollutants from Asia are now periodically measurable in ONP (Edmonds and others, 1998), and may increase in the future, eventually to a level where they are harmful to pollution-sensitive lichens. This effect can be monitored in the critically endangered Usnea sphaecelata (WNHP Priority 1, G?S1, fig. 16). It is found in only a few places in Washington, and was recently discovered in ONP. The high fog-bound peaks and ridges favored by this species intercept aerosols, which present a serious threat to this pollution-intolerant species. Much could be learned from mapping the population of this rare species and seeking other populations on nearby ridges. If the population size is sufficient, pollutant concentrations in its tissue could be monitored periodically along with tissue from common species nearby. Although only an informal survey was conducted, many other rare species were found in the immediate vicinity, making a pollutant monitoring effort even more worthwhile. Examples include Alectoria nigricans (Priority 1 G4 S1), A. ochroleuca (Priority 1 G4 S2), Ahtiana sphaerosporella (Priority 2, G? S?), Brodoa oroarctica (Priority 1, G2 S1), Bryoria nitidula (to be verified, possibly new to Washington), Collema undulatum var. granulosum (Washington status unknown), Cornicularia norvegica (Priority 2, G? S2), Leptogium minutissimum (Washington status unknown), Leptogium platnum (Washington status unknown), Lobaria limita (Priority 2 G? S?), Nodobryoria subdivergens (Washington status unknown), Umbilicaria cilindrica (Priority 2 G3 S1), U. havaasi (Priority 2 G3 S1), U. kraschenin- nikovii (Priority 2 G3 S1), U. proboscidea (Priority
Figure 9. *Tayloria serrata* (composite photograph).

Figure 10. *Blepharostoma arachnoideum*.

Figure 11. *Pseudocyphellaria rainierensis*.

Figure 12. *Splachnum sphaericum*.

Figure 13. *Schistostega pennata*.

Figure 14. *Tetraphis geniculata*.
Exotic cryptogams. The introduction of exotic species of non-vascular plants is not yet a major problem, though it seems inevitable that parks will see them in the future. *Orthodontium lineare* (fig. 18), a Southern Hemisphere species, was accidentally imported to Europe, apparently via raw log transports. It has proved an aggressive, invasive species and is now widely distributed in western Europe (Schofield, 1985; van Dort and others, 1998). It may have contributed to the decline of a related species native to England, now critically endangered (http://www.ukbap.org.uk/UKPlans.aspx?ID=485, access restricted, November 2005). Another moss, *Campylopus introflexus* (fig. 19), has spread across western Europe and now is also spreading rapidly in California and Oregon (Christy and Wagner, 1996). In 2001, it was found on the OP for the first time, along the Moclips highway in Grays Harbor County. In 2004 it was found in ONP on Tivoli Island, Lake Ozette. This species grows in thick sods and can replace native vegetation on sandy soils (van Dort and others, 1998). The European species *Pseudoscleropodium purum* is one of at least six introduced mosses that are now established in British Columbia (http://srmapps.gov.bc.ca/apps/neswp/, November 2005). It is common in lawns of south coastal British Columbia (Schofield, 1992) and Seattle. It has also been found on the San Juan Islands (Harpel, 1997) and recently in Port Angeles and Quilcene, Washington. It grows in forests of western Europe, but so far has not been detected growing in forested habitats on the OP. Other introduced mosses, liverworts (such as *Lunularia cruciata*) and lichens (such as *Xanthoria parietina* and *Phaeophyscia rubrapulchra*; McCune and Geiser, 1997, and possibly *Scolicosporum sarothamni*; Tønsberg, 1995) have established and are spreading in the PNW.

Other exotic species. Exotic species can exert a major influence on pristine ecosystems from another angle as well. White pine blister rust (*Cronartium ribicola*) has decimated white bark pine (*Pinus albicaulis*) in ONP and is also taking a toll on western white pine (*P. monticola*). Species associated with white bark pine also undergo population declines, but these may have gone unnoticed or undocumented. The lichen ‘whitebark candlewax’ (*Ahtiara spheroesporella*; WNHP Priority 2, G? S?, fig. 20) was found in the park in only two places, once on dead whitebark pine and once on dead western white pine (*Pinus monticola*).

Climate change. Humans are influencing ecosystems in major ways. Spatial and temporal patterns of the landscape composition and process are very different than those a few hundred years ago due to human activities. Specifically, continuous mosaics of ecosystems have been disrupted so that habitat continuity and connectivity have been diminished. This will be of major concern in light of climate change (whether natural or anthropogenic) and the need for species to migrate. Most plants and animals cannot evolve fast enough to adapt apace with the changing conditions, so they must survive by migrating to new habitats. Those species that cannot migrate or adapt along with the rate of environmental change will likely be out-competed by other species moving into their habitats. The cascading effects of rapid climate change could have a major impact on an island-type flora where species may be more easily lost than replaced. Especially if climate is changing at an unprecedented rate, it will be necessary to restore the ecological infrastructure of the landscape to accommodate the migration of species.

Further Work in Olympic National Park

Bryophytes and lichens are an important component of the ecosystem, fulfilling many roles in nutrient and hydrologic cycles and providing nesting material for many animals and birds and housing for numerous invertebrates. Bryophytes and lichens are used as powerful tools in biomonitoring, have commercial value, are a major component of the biodiversity, and in many areas define the aesthetic appearance of ONP. Consequently, there are many kinds of research into ecosystem function that could benefit ONP and the scientific community, but because of the taxonomic focus of our project, this section is devoted to suggestions for additional floristic work.

- **Needs for Existing Bryophyte and Lichen Data**

  Complete the identification and verification of difficult and interesting specimens. It is important that the identity of some of the most interesting taxa be verified, either by taking specimens to a regional herbarium, by requesting reference specimens, or by sending specimens to taxonomic specialists. Specific needs include the following.

  - **Chilocyphes gemmiparous** (G2 S1), a liverwort collected from a high mountain basin. If verified, it would be new to Washington. This species requires work at an herbarium where it can be compared with a specimen, or it could be sent to Dr. D. H. Wagner (Northwest Botanical Institute).
  - **Dermatocarpon aff. luridum** in ONP. One came from near the Hurricane Ridge Visitor Center; the other specimen came from the park interior and differs from the first. McCune tentatively examined both specimens and recommended that they be sent to Starri Heiðmarsson.
Figure 15. **Bryoria** cf. **fremontii**.

Figure 16. **Usnea sphaecelata**.

Figure 17. **Umbilicaria rigida**.

Figure 18. **Orthodontium lineare** (photographed in The Netherlands).

Figure 19. **Campylopus introflexus** (photographed in Coos Bay, Oregon).

Figure 20. **Ahtiana sphaerosporella**.
(Icelandic Institute of Natural History), a taxonomic expert on *Dermatocarpon*.

- There may be an undescribed liverwort in the genus *Scapania* that was collected from a few localities in ONP. Further work could elucidate whether this species is undescribed, or perhaps is one of the more recently described species from the region. Additional literature will be needed.

**Correcting problems in ONP non-vascular plant herbarium.** During the past century, independent of this project, some 55 collectors deposited more than 5,000 non-vascular plant collections at ONP. Recently, the outdated nomenclature of many of these collections was revised: the lichen nomenclature during this project and the bryophyte nomenclature with support from ONP Cultural Resources Management (CRM) where the collection facility is housed. K. Hutten, with support of CRM, determined 400 specimens with incomplete identifications, collected by N. Buckingham. Only specimens with obvious identification errors were re-determined. Other obvious identification errors have been identified, but at present no funds are allocated for work on the historic collections (for example, most if not all *D. bonjeanii* are probably *D. scoparium/D. howellii*, many *Claopodium whippleanum* are *Pseudoleskea patens*; the determinations in the genus *Sphagnum* have proved unreliable). Some species concepts have been modified recently, requiring work on all previously determined collections of *Pyrrhospora cinnabarina* for instance, as many pertain to the recently described *P. gowardiana* (Spribille and Hauck, 2003); similarly, most of the *Menegazzia terebrata* are *M. subsimilis* (Bjerke, 2003), several species groups in the lichen genus *Fuscopannaria* have recently been reworked (Jørgensen, 2000), and so forth.

**Generating spatial data from ANCS+ records.** Bryophyte and lichen data from other collectors are stored in ANCS+, the NPS-mandated curatorial database. Because of major inadequacies of the spatial component of ANCS+, these historic data cannot easily be mapped. With some further effort, however, one could generate coordinates for the roughly 600 different localities where these 5,000+ specimens were collected. These spatial data would allow the addition of thousands of data points to the cryptogam distribution maps of the OP. Geographic and elevational distribution maps also provide a useful tool for identifying outliers that often signal misdeterminations.

**Obtain data from other sources.** The diverse and abundant non-vascular plant flora of ONP has inspired considerable interest. In the last 30 years, 25 researchers were issued a collecting permit for lichen and bryophyte work in Olympic National Park. Several workers renewed their permits for several years, sometimes accompanied by peer scientists. Apparently, some researchers worked in ONP without a permit or with oral permission, leaving no records at the Park. Although the combined effort was substantial, it left a comparatively small research legacy at ONP. Many researchers did not deposit voucher specimens at ONP, or deposited few specimens while making sizeable collections. Many researchers apparently did not submit an informal collection report, and only one researcher submitted electronic records. Only a limited amount of the gathered data was published in the scientific literature, and few researchers sent copies of their published work to ONP. Therefore, databases are missing data for thousands of specimens collected in ONP. ONP lacks locality data on hundreds of species known from the ONP and OP, including:

- *Dermatocarpon luridum* WNHP Priority 1, G? S2 lichen, Clall, Jeff County,
- *Thulurna dissimilis* WNHP Priority 1, G? S2 lichen, Hurricane Ridge,
- *Umbilicaria scholanderi* WNHP Priority 1, G1 S1 lichen, Mason County,
- *Brachydontium olympicum* WNHP G3 S1 moss, Clallam County,
- *Brotherella roellii* WNHP G4 S1 PNW endemic moss, Clallam, Jefferson Counties,
- *Sphagnum alaskense* newly described moss, not yet listed, Cape Alava
- *Gymnomitrion concinnatum* Anordus & Jannsen 2003, Clallam County,
- *Gymnomitrion concinnatum* WNHP G5 S2, liverwort, park interior Jefferson County? (Christy and Wagner, 1996; fig. 21),
- and possibly other rare species.

Although a portion of these missing specimens may be adequately cared for in a university or agency collection, the data are effectively inaccessible to ONP, because most facilities do not have their herbarium data available electronically. The storage of all inventory data in an appropriate database is a critical component in ONP’s mandate to protect its floristic diversity. From such databases, researchers can begin to understand how species are distributed in the park and where rare species are located. Rapid assessments can be made using GIS in the event of environmental or human-induced impacts. ONP could considerably advance its baseline cryptogam data by requesting and compiling data published in the scientific literature, from ONP collections deposited in regional herbaria, from other agencies, and from previous collectors.

- **Needed Field Work**

  **Geographic areas.** The cryptogam diversity encompassed within the boundaries of ONP is not fully known because there are still many areas that remain unexplored or under-explored by bryologists or lichenologists. Entire river drainages have not been visited (for instance, Bogachiel, Queets, Skokomish, Duckabush; fig. 1). The focus of the largely plot-based
work described here was on specific forest types, therefore many other areas were not surveyed, examples of which are addressed below.

Ecological zones. Some ecological zones have not been adequately surveyed. Significantly, the importance of a high-elevation, hyper-maritime (fog-intercepting) belt to bryophytes and lichens was not fully appreciated until 2002. A USFS project in this zone yielded the first record in Washington of a particularly interesting disjunctive moss, *Iwatsukiella leucotricha* (fig. 22), just outside of the Park. In North America, this arboreal moss is known only from a few locations along the West Coast. It is considered critically endangered in Washington, and was listed WNHP G2/3 S1 in 2004 (J. Harpel, written commun., 2004). In Oregon and Washington, its high-elevation, ocean-influenced habitat has been nearly completely logged. The remaining populations, including some that predictably exist in ONP, are of vital importance for the westward reintroduction of this species, should habitats become suitable again.

Other rare taxa also exist in the hyper-maritime zone. The lichen *Bryoria tenuis* is new to the OP and possibly Washington (suggested for listing WNHP), and *B. bicolor* is listed in Oregon. The former Survey and Manage moss *Racomitrium aquaticum* (WNHP G5 S3, fig. 23), considered rare throughout the PNW, is frequent on fog-intercepting ridges on the OP. It has recently been reclassified as *R. ryzsardii*, and in that interpretation is a PNW endemic. At least four other regionally rare former Survey and Manage species were frequently encountered in this zone (these occur outside the zone as well), including the endemic lichen *Pseudocyphellaria rainierensis* (WNHP Priority 2, G? S2, fig. 11) and the yet unlisted *P. mallota* (Tønsberg, 1999b; fig. 7), called “one of our rarest lichens” (http://www.proaxis.com/~mccune/mallota.htm, November 2005). The number and relative abundance of rare taxa in this high-elevation belt suggest that further surveys would be appropriate.

Macrohabitats. Several habitat types remain underexplored.

- Mountain ridges provide habitat for many rare species and should be surveyed using an intuitively controlled method (see “Air Pollution” under subsection “Threats” for an example of the number of rare species that may be found on some high-elevation ridges in ONP).

- Deciduous forests have a diverse lichen and bryophyte flora. Some types that have not been explored during this project include forest types dominated by *Acer* spp., *Alnus sinuata*, *Arbutus menziesii*, *Salix* spp., *Populus trichocarpa*, *P. tremuloides*, or *Prunus emarginata*.

- *Alnus rubra*-dominated riparian and floodplain forests bear diverse lichen floras when old and not too shaded, particularly on nutrient rich soils (Tønsberg, oral commun., 2003). Several rare lichens are known from these habitats, for example *Szczawinskaia tsugae* (WNHP G? S1) and *Spilomenella americana* (not yet listed, recently described from type locality at the Hoh River).

- *Quercus garryana* forests are becoming exceedingly rare on the northern OP. The authors have only examined a polluted fragment, slated for development, near the city center of Sequim. It contains our only collection of the moss *Alsia californica*, blue listed in BC (S2S3). A recently described lichen species, *Physcionia fallax*, is found on oak trunks and is known from only one other place in Washington (S. Jovan, oral commun., 2003). The oak trunks also support *Pyrhospora querneia* (WNHP, G? S?; S&M ‘E’). A ceder fencepost in the area supports *Thelomma occidentale* (WNHP G? S1). The oaks also support a large population of another rare lichen, *Ramalina subleptiocarpa*, on the OP. It reaches the north end of its range here and is listed in British Columbia (S1), but not in Washington. The moss *Tortula laevipila var. meridionalis* (WNHP G3/G4 T1, S1; J. Harpel, written commun., 2004) was reported by Lawton (1971) from only one locality in North America, on oak in Victoria, British Columbia. It is now known from a few additional localities in the PNW, and it should also be sought in the few oak stands remaining on the Peninsula.

- The immediate coast needs further surveys. Several rare lichens are exclusively coastal and are expected to occur on the OP coast but have not yet been found (for example, *Hypogymnia heterophylla* and *Heteroderma sitchensis*). These and several others are expected because they have been found farther north and south along the coast. The critically rare coastal species *Heteroderma leucomelos*, and *Bryoria subcrea* were recently found on Mt. Walker on USFS land (L. Geiser, written commun., 2003), but their distribution along the OP coast is unknown. Because many of these lichens are arboreal, they are more likely to be found after high winds when freshly fallen branches are common. An opportunistic project after a major wind event would be ideal to assay these lichens. One liverwort that may be found this way on the immediate coast is *Scapania scandica* (only two records in Washington).

- Bogs in ONP urgently need detailed surveys to detect and protect rare species. *Sphagnum ampullaceum* (fig. 8) and *S. sphaericum* (fig. 12) are new to Washington, per this project, and hence are not on the Washington list. The former is known from a single historic locality in Oregon, the latter appears to be new to the PNW. Both species are known from only one coastal bog complex on the OP. *Tetraplodon mnioides* (WNHP G5 S1; see figure 30) is known from six forested bogs, all outside of the Park, but Christy and Wagner (1996) show a record within ONP (details not known).
Tayloria serrata (WNHP G4? S1; fig. 9) is a rare PNW species in the Splachnaceae that on the OP is less restricted to bogs than the other species. It has been found in five localities, including an alpine location. Another bog associated moss Tetraplodon cf. angustatus (blue listed in BC: G4, S2S3), if verified, would also be new to the PNW. Of the 25 Splachnaceae collections, only two were found during the systematic sampling effort, indicating that these distinctive species are more easily detected by an intuitively controlled sampling method. It is very easy, however, to unwittingly damage these populations by trampling and indiscriminate collecting. Any future surveys of ONP coastal bogs should have the important goal of treading especially lightly, and all surveyors should be aware of the fragile and critical habitats of the Splachnaceae.

- Some mountain and ridge tops are floristically very interesting and may be impacted by view-seeking visitors. One of the most frequently visited peaks in ONP supports the only known Washington population of the moss Rhytidium rugosum (G4 S1; fig. 24). Its presence provides support for the glacial refugia hypothesis. Spence (1983) indicated that the population was quite large in 1983, but this population was not relocated during an informal survey in 2000. A detailed survey to relocate and map the population would enable it to be monitored and protected in the future. The lichen Leptogium saturnicum is also restricted to this mountain on the OP.

Microhabitats. Bryophytes and lichens often occur on specific substrates or in specific microhabitats. Because such places are not evenly distributed on the landscape, such species cannot be adequately sampled with a stratified random sampling scheme based on vascular plant associations. Instead, they must be found by seeking specific microhabitats in the field using an intuitively controlled sampling method. Many habitats, microhabitats, and substrates have been underexplored.

- Areas in and around waterfalls, streams, springs, and other wet areas typically have a diverse bryoflora that differs markedly from nearby floras not influenced by flowing water. Several rare species are known from these habitats. Crumia latifolia (WNHP G3 S1; fig. 25) is a moss that is known from only four places in Washington, three of which are on the OP. Fissidens grandifrons (WNHP G4 S2; fig. 26) is found on rock in seeps or in gentle streams that are always calcium-enriched including several watersheds on the OP. Preissia quadrate (ONHIC List 3, G5 S2) is known from a single locality near a calcium-enriched waterfall in ONP. There are also lichens that are associated with wet areas. Hydrothyria venosa (WNHP G7 S2; fig. 27) is known from one alpine wetland in ONP.

- Rock and rocky outcrops often have stable exposure and moisture regimes on which diverse bryophyte and lichen communities develop. Many rare non-vascular plants are known from such habitats. Pilophorus nigricalvis (WNHP Priority 1, G?, S2; fig. 28), for example, has recently been found (new to OP list) when surveyors passed through areas with exposed rock on Colonel Bob and the Skyline trail. Myurella julacea (WNHP Priority 2 G4 S1) is a rare moss that in Washington is only known from rock crevices on the OP. Radula obtusiloba subsp. polyclada is a rare liverwort that has been found on rock walls on the OP. Neither bryophyte has been collected in the past two decades. The authors suspect that these species still occur, but their habitats have not been surveyed.

- Mineral soil habitats (roadcuts, stream/creek banks, floodplain) are very common but have not been surveyed. Discelium nudum (WNHP G5 S1; fig. 29) in Pacific North America occurs on steep (vertical) stream banks in the Hoh and the Bogachiel Rivers and may be under-reported.

- Animal waste provides a nutrient-enriched growth substrate for a number of non-vascular plants. Several lichens grow on exposed rocks where raptors perch, and a handful of moss species grow exclusively on coyote or elk excrement (and possibly owl pellets; fig. 30). All of these mosses are very rare.

- Dermatocarpon sp. nov., a lichen possibly new to science, is known only from natural drainages that now receive runoff from the NPS Visitor Center parking lot. Surveys of similar drainages would ascertain the status of this suspected new lichen species. Additional species of interest occur on soil nearby, including the liverworts Riccia sp., Athalamia hyalina (fig. 31), and Asterella saccata, known only from this location in ONP. The liverworts can only be detected shortly after snowmelt in spring, and may be more widespread than we realize, considering the strong summer bias in the present data. Surveys after snowmelt are recommended to find additional populations of these rare alpine liverworts in ONP.

- There are other rare species needing further surveys, but are not mentioned here. For a more exhaustive list, see Appendix A.

Species-specific surveys. There are a number of critical species for which more detailed surveys are particularly needed.

- Relocate populations of rare species. Several rare species were collected from ONP many years, even decades ago. If general collection localities can be determined, it would be important to attempt to relocate populations of these taxa (see examples in section “Obtain data from other sources”).
Figure 21. *Gymnomitrion obtusum* is very similar to *G. concinnatum* and occurs in the same habitat.

Figure 22. *Iwatsukiella leucotricha*

Figure 24. *Rhytidium rugosum* (photograph of specimen from Denali National Park, Alaska).

Figure 25. *Crumia latifolia*.

Figure 23. *Racomitrium aquaticum*.
The only known locality for the lichen *Karnefeltia californica* is adjacent to an NPS sewage-evaporation field. The species is currently listed in WNHP as G2 S2. The State listing should probably be S1, however, (see “Rare species on the OP”) since there are only five collections in Washington. Many early reports of this species are the more inland species *Karnefeltia merrillii*. Because the species is also federally listed, a USFS crew has surveyed for this and other rare coastal lichens on the OP as part of a project ranging from California to Washington in 2000. These surveys did not yield further detections of this species (L. Geiser, written commun., 2004). Surveys of adjacent forest bogs would put the status of this population into perspective in advance of the planned expansion of the sewage facility and the presumed increase in human impacts around the evaporation field.

The only known population of the rare moss *Rhytidium rugosum* may be declining and may be affected by Park visitors (see mountain tops, under macrohabitats). Surveys are needed to locate and assess the population and the potential for impacts.

A lichen species in the genus *Dermatocarpon*, suspected to be new to science, was found in a natural drainage area receiving runoff from an NPS parking lot. Further surveys are needed to assess the extent of the population in nearby drainages.

The lichen *Bunodophoron melanocarpum* (fig. 6) was not previously known from the lower 48 States, and it was proposed for listing by WNHP in 2003. A few years after its initial discovery, it is still known from only four or five sites on the OP. Locations near Ozette are the only known locations of this lichen on federal land. The ONP therefore has considerable responsibility for the protection of this species, yet the extent of the population and the existence of other populations is unknown.

*Splachnum ampullaceum* (fig. 8), *S. sphaericum* (fig. 12), *T. minioides* (fig. 30), and *T. cf. angustatus* are species that occur on elk excrement deposited in coastal bogs. Several species are new to Washington and so far are known only from one coastal bog complex on private land. Elk herds may be diminishing in the coastal zone, providing added reason for concern.

*Sulcaria badia* (WNHP G? S1) may be extinct from the Dungeness (Peterson and others, 1998), the only known site in Washington. It is one of the region’s rarest lichens and one of few that has been placed as critically endangered on the global red list (Peterson and others, 1998). Surveys conducted in other suitable areas, in especially the northeast OP, may locate extant populations. In Oregon and California it has been found most often on oak, but also on bigleaf maple, Douglas fir, Oregon ash, and ponderosa pine (http://www.fs.fed.us/r5/mendocino/projects/hfi/docs/sulcaria-badia.pdf, November 2005).

*Brotherella roelli* (WNHP G3 S2, Survey and Manage) is a PNW endemic moss that was found in the Dosewallips decades ago. Relocation efforts have not been successful (J. Harpel, written commun., 2004), but surveys of adjacent ONP may locate more populations.

A rare liverwort, *Marsupella emarginata var. aquatica* (ONHIC G5 S1; S&M ’B’), was collected in association with another species from the Park interior. A better specimen and a population survey are needed.

Only a few populations of *Discelium nudum* (WNHP G5 S1; fig. 29) are known from the lower 48 States, two in the Hoh River valley, the other along the Bogachiel River. The specialized sites that this species occupies are often eroded or quickly invaded by vascular plants, so the sites are often quite ephemeral. In British Columbia, where the species is red-listed, there are no known currently occupied sites (W. Schofield, written commun., 2004) and the only other site known in Pacific North America is in California (Norris and Shevock, 2004b). Notably, the Pacific Coast population of *Discelium nudum* bears sporophytes that are often four to five times the size noted in the rest of its world range. The capsules are often elongate rather than subspheric, and setae can exceed 3 cm, compared to less than 1 cm elsewhere in its range (Schofield, 2003). If the Pacific Coast population is isolated enough to be genetically distinct, the global ranking in the WNHP would increase considerably.

The Olympics are suspected to provide good habitat for a number of regionally rare species that have not yet been recorded. Christy and Wagner (1996) and Harpel (oral commun., 2000) predicted that *Iwatsukiella leucotricha* (fig. 22), one of the region’s rarest species, would likely occur in the Olympics. When the USFS ordered a survey for this species, several populations were detected from areas on the west OP. Although it is not yet known from ONP, it is likely to be there. Other rare species suspected to occur in the Olympics include *Bartramioptis leucotricha* (R. Lesher, oral commun., 2000), *Pleuroziopsis rutherenica*, and *Radula brunnea* (Christy and Wagner, 1996; http://www.or.blm.gov/surveyandmanage, temporarily unavailable November 2005).

Request specimens and data from future collectors. As mentioned previously (under: Obtain data from Other Sources), valuable information has been lost to ONP or is essentially inaccessible, because many collectors did not deposit voucher specimens at ONP. The authors have been unable to find locations for rare species documented from ONP, and verifying a rare species is
Figure 26. *Fissidens grandifrons*.

Figure 27. *Hydrothyria venosa* inspection by James Walton.

Figure 28. *Pilophorus nigricaulis*.

Figure 29. *Discelium nudum*.

Figure 30. cf. *Tetraplodon mniodes* (WNHP GS S1) on an owl pellet or coyote scat.

Figure 31. *Athalamia hyalina*. 
difficult without a voucher specimen. Furthermore, a good reference collection makes specimen identification easier and increases confidence in identifications. Travel to other herbaria for reference material can be costly, leaving some very interesting specimens unidentified. Moreover, data deposited at the University of Washington (WTU) and many other herbaria are not yet entered electronically, making it very time-consuming for ONP staff to locate any quantity of ONP data in the large WTU collection. It may not be necessary to retain every specimen of the most common species at ONP, and certainly not type specimens, but ONP should at least retain those data electronically. North Cascades National Park already requires scientists to submit delimited electronic collection data from collectors, relieving curatorial staff from cumbersome data entry. Because data deposited at ONP are entered electronically, they can easily be made available to researchers elsewhere. The ONP collection is particularly deficient in crustose lichens, such that they were excluded from the present project because they could not be efficiently identified. Requesting duplicate specimens of crustose lichens from future collectors is an important need for ONP. Considering the importance of having distributional data on any species, collectors should be encouraged to deposit all data at ONP. Storage space at ONP is not a limitation, because a new facility is planned.

Conclusions

The importance and uniqueness of the non-vascular flora of ONP are hard to exaggerate. Not only are cryptogams key to the ecosystem function and aesthetic appeal of ONP forests, they represent a biogeographically significant array of rare and endemic species and a sizable component of the Park’s biodiversity. This project has made important steps toward a comprehensive survey of these organisms. It has put the Park’s resources in a regional context by documenting rare species, some for the first time in the conterminous United States, and a few species that are apparently undescribed. ONP has healthy populations of some species that are rare outside of the Park, where habitats have been destroyed. This data set can form the basis for further research on community stucture and successional patterns, and could be used as a tool for eventual restoration efforts outside of the Park.

Forests are one of the most important habitats for bryophytes and lichens globally, and conservation of forests is key to maintaining their biodiversity (Tan and Pocs, 2000). The NPS has had a long-standing mandate to protect habitats and a more recent mandate to inventory its resources so it can better protect biodiversity (National Park Service, 2001). Conservation of bryophytes and lichens worldwide has usually been a by-product of saving habitat for larger flagship, charismatic, or keystone species (Tan and Pocs, 2000). ONP is one of few places in the world where bryophytes and lichens, collectively, are conspicuous flagship organisms themselves. Consequently, ONP has the opportunity to bring them to the attention of the public, government, and other conservation agencies. The inventory described here is a tool to help ONP understand and conserve its non-vascular resources.

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Appendix A

Rare bryophytes and lichens known from Olympic Peninsula.

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Appendix A—continued (Footnotes on page 78.)
### Inventory of the Mosses, Liverworts, Hornworts, and Lichens of Olympic National Park, Washington: Species List

#### Appendix A—continued (Footnotes on page 78.)

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**(Total 100 MOSES)**

### LIVERWORTS

- **Anastrophyllum minutum**
- **Barbilophozia lycopodioides**
- **Calypogeia sphagnicola**
- **Diplophyllum albicans**
- **Diplophyllum plicatum**
- **Gymnomitrion concinnatum**
- **Harpanthus flotovianus**
- **Herbertus aduncus**
- **Jamesioniella autumnalis**
- **Lophozia gillmanii**
- **Marsupella condensata**
- **Marsupella emarginata var. aquatica**
- **Marsupella sparsifolia**
- **Metzgeria temperata**
- **Nardia japonica**
- **Preissia quadrata**
- **Ptidium pukherrimum**
- **Radula obtusiloba subsp. polyclada**
- **Scapania obscura**
- **Schofeldia monticola**
- **Tritomaria exsectiformis**
- **Tritomaria quinquedentata**

**(Total 22 LIVERWORTS)**

### LICHENS

- **Ahtiana pallidula**
- **Ahtiana sphaerosporella**
- **Alectoria lata**

**Priority 2 G7? S?**
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(Total 103 LICHENS)

Appendix A—continued (Footnotes on page 78.)
Indexes created over all recent 1998-current data (USGS/ONP data, M. Hutten personal data), but excluding ANCS data because of several problems associated with that dataset. These data are provided as an indicator of the relative frequency of the species collected. The OP localities count is generated from unique sites only, i.e. duplicate collections from a single site are excluded. Such unique sites however may occasionally be in close proximity to each other.

Note that the Washington Natural Heritage Program has not yet included liverworts in their listings.

1WNHP= Washington Natural Heritage Program
2ONHP= Oregon Natural Heritage Program
3ROD= Record of Decision; applicable to Forest Service and Bureau of Land Management forest management in range of the Northern Spotted Owl.
4WHER= Washington Heritage Endangered Species
5SM= Survey and Manage: the program implementing the ROD was amended several times, and revisions were made to the status of ROD species (USDA and USDI 2001). In 2001 a Supplemental Environmental Impact Statement (SEIS) was released.
6USFS R6: OR/WA= United States Forest Service (USFS) Special Status Species Rating
7BC rating= British Columbia (Goward 1996): 1 = Critically imperiled because of extreme rarity (5 or fewer occurrences, or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extirpation or extinction.
8Special Status
9BS = Bureau Sensitive
10British Columbia (Goward 1996):

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<tr>
<td>E = Rare, Status Undetermined</td>
<td>F = Uncommon Or Concern for Persistence Unknown, Status Undetermined</td>
<td>X = Species removed from list</td>
<td>+1: A – WA OP, WA W Lowlands, WA W Cascades, OR W Cascades, OR Coast Range, OR Willamette Valley, and CA Coast Range</td>
<td>+2: F – OR, (Curry, Josephine, Jackson)</td>
<td>+3: A – OR, E – OR (Coos, Douglas, Curry, Josephine, Jackson)</td>
<td>+4: E – WA (W-Cascades outside GPNF), E – Cascades, OP)</td>
<td>X – Removed elsewhere</td>
<td>1 = Critically imperiled because of extreme rarity (5 or fewer occurrences, or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extirpation or extinction.</td>
<td>2 = Imperiled because of rarity (6 to 20 extant occurrences or very few remaining individuals), or because of other factors demonstrably making it vulnerable to extirpation or extinction.</td>
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