OREGON DEPARTMENT OF AGRICULTURE

NATIVE PLANT CONSERVATION PROGRAM

Developing population density estimates for nine rare Willamette Valley prairie species

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Chapter I. Project Overview

Introduction

The Willamette Valley prairie habitat is one of the most imperiled ecosystems in the United States (Noss et al. 1995). Once common throughout the region, today prairie habitat is restricted, for the most part, to small, disturbed, and fragmented parcels (Altman et al. 2001). This decline in prairie habitat has inevitably resulted in the decline of prairie-associated species, including the nine rare plant species examined in this study. The Recovery Plan for Prairie Species of Western Oregon and Southwest Washington, currently in preparation by U.S. Fish and Wildlife Service and cooperators, will identify recovery objectives for all nine of these species (as well as one additional species, *Castilleja levisecta*, which no longer occurs in Oregon). The amount of occupied habitat needed for the development of self-sustaining populations of these species, and consequently for achieving the planned recovery objectives, can be calculated using data on the density of plants (number of individuals/m^2) in currently established populations. The goal of this study is to develop current population density estimates for each of the nine rare prairie species still found in Oregon.

Study species

Population density estimates were developed for the following nine rare Willamette Valley prairie-associated species: *Delphinium leucopheum*, *Delphinium pavonaceum*, *Erigeron decumbens* var. *decumbens*, *Horkelia congesta* ssp. *congesta*, *Lathyrus holochlorus*, *Lomatium bradshawii*, *Lupinus sulphureus* ssp. *kincaidii*, *Sericocarpus rigidus* (*Aster curtus*), and *Sidalcea nelsoniana*. Detailed information about each of these species may be found in their respective chapters.

Study site selection

In order to develop an accurate and current estimate of population densities for each study species, approximately 10% of the known, locatable populations of each species were visited (Table 1.1). Known population sites were obtained from the Oregon Natural Heritage

Table 1.1. Summary of known and visited populations of nine Willamette Valley prairie species used in study.

Species	Total # known or historic populations*	Total # current, locatable populations*	10% of current, locatable populations	# populations visited by ODA staff	# populations used in study
Delphinium leucophaeum	24	18	1-2	5	4
Delphinium pavonaceum	30	29	2-3	15	4
Erigeron decumbens var. *decumbens*	48	30	3	6	6
Horkelia congesta ssp. *congesta*	38	29	2-3	7	5
Lathyrus holochlorus	84	64	6-7	14	7
Lomatium bradshawii	48	45	4-5	6	6
Lupinus sulphureus ssp. *kincaidii*	59	52	5-6	14	11
*Sericocarpus rigidus (*was *Aster curtus)*	30	27	2-3	8	7
Sidalcea nelsoniana	91	84	8-9	22	14
Totals	**452**	**378**	**33-41**	**97**	**64**

* Total number of populations listed in Oregon Natural Heritage Information Center database as of June 2005

Information Center's database in June of 2005 (ORNHIC 2005). Populations that were presumed extirpated or extinct were removed from the list of current known sites. Populations which did not have sufficient location information to relocate the population (i.e. a record from 1918 with the location description "Salem") were also removed from the list of potential sites to visit. The remaining sites were counted to obtain the total number of current and locatable populations. Additional population information was obtained from the Oregon Flora Project (Oregon Flora Project 2005), the Oregon Department of Transportation's list of Special Management Areas (ODOT 2006) and conversations with federal, state and local land managers. When appropriate, these new populations were added to the list of potential study sites. For a complete list of sites visited during the course of this study, refer to Appendix 1.

Site selection criteria

The following criteria were employed to select the populations used in this study:

- ODA was able to relocate population
- ODA was able to obtain permission to visit the population and collect data
- Population was large enough to obtain a meaningful population density estimate
- Populations represented the geographical and ecological range of the species
- Population was natural (not introduced)

1. ODA able to relocate population: As already stated above, ODA did not attempt to visit populations for which there was not enough location information available to find the population. There were cases, however, where ODA visited the locations of previously known (although sometimes historic) study species populations, but was unable to relocate the populations themselves. These locations were not included in the study, but a summary of all populations visited is listed in Appendix 1.

2. ODA was able to obtain permission to visit the population: Because a large number of site visits needed to be conducted during a narrow window of time (when plants were in bloom and identifiable), and obtaining permission to visit sites required a fair amount of logistical coordination, we focused on populations where land ownership was already known, and access was likely to be granted. These sites were primarily located either on public lands or on land privately managed for conservation (i.e. by The Nature Conservancy). ODA did not collect data at sites where land owner or land manager permission was not obtained prior to the visit.

3. Population was large enough to obtain a meaningful population density estimate: In general, small populations (i.e. populations containing <10 individuals) were not visited. However, ODA staff did visit some populations where the actual number of individuals counted was much less than previous population estimates (obtained from the ORNHIC database or land managers), and some of those sites were included in the study.

4. Populations represented the geographical and ecological range of the species: An attempt was made to visit populations representing the geographical range of each species (in Oregon). Figure 1.1 shows the overall range of sites visited for this project. In addition, if a species appeared to have populations located in distinct habitat types, an attempt was made to include populations from each habitat type in the study.

5. Population was natural: Several sites visited during the course of this study contained both natural and introduced/reintroduced/augmented populations. Most of the introduced populations were relatively newly established (< five years old). There was a strong possibility that these experimental populations were distributed or functioning differently than natural populations. Because their population densities might be different than those of natural populations, ODA decided to only use natural populations in this study.

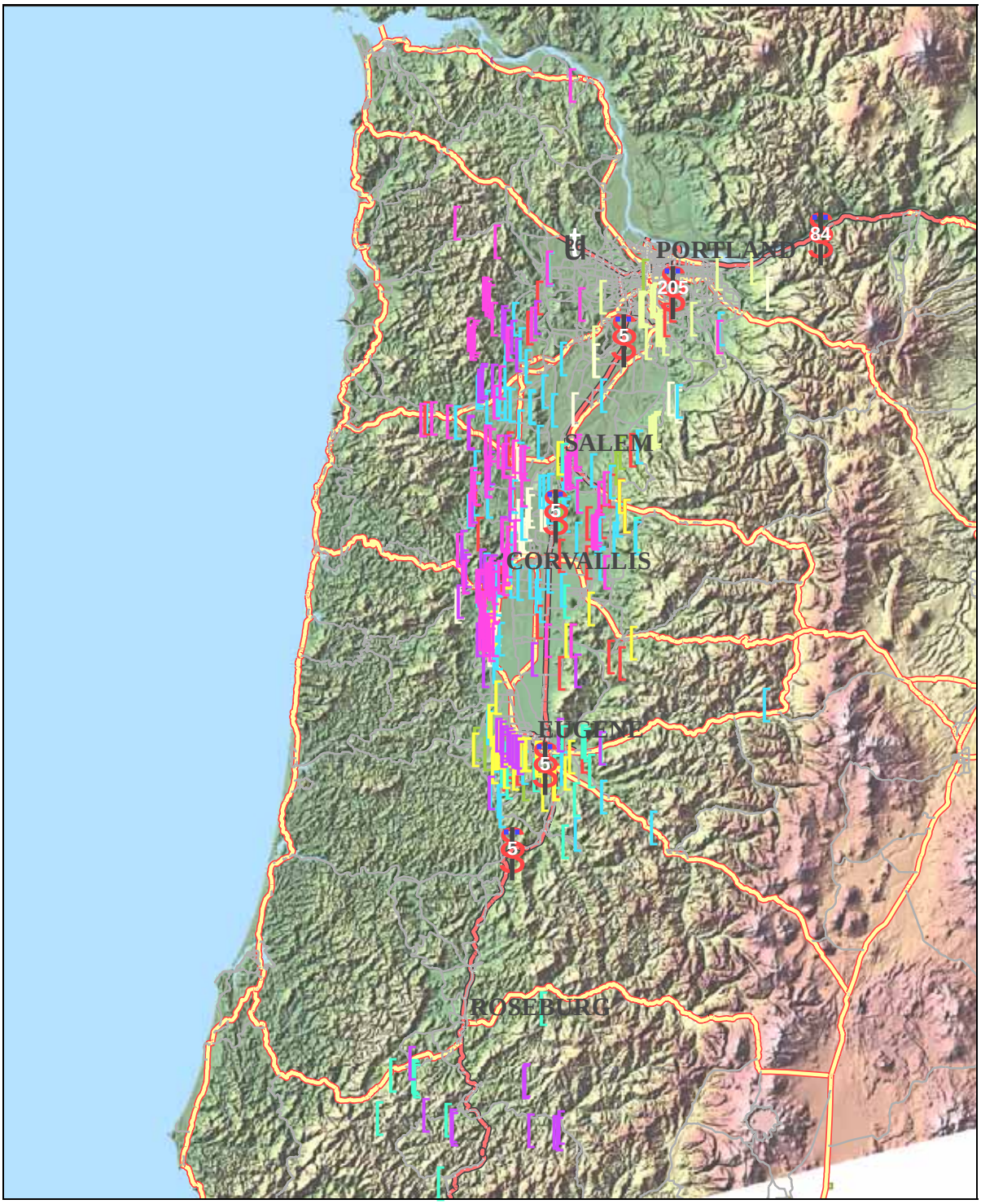

Figure 1.1. Oregon range of the nine Willamette Valley prairie species used in this study. Stars indicate known population locations.

Determining counting unit (What is an individual?)

One of the initial challenges encountered during the course of this study was deciding what an "individual" was for each species. Many of the study species are capable of reproducing vegetatively, creating clonal groups through the spread of underground root systems and making it impossible to determine whether or not a group of stems are, in fact, one individual. Other species (i.e. the *Delphiniums*) have distinct life history stages (such as seedlings vs. reproductive stems) that are not always visible above ground at the same time (B. McKernan-Stout, graduate student, personal communication on March 25, 2006).

ODA examined the ORNHIC database records and found that the counting unit used to determine population numbers for each of the study species varied from site to site, and from observer to observer. When available, we also reviewed monitoring reports for each study species. We found that many of the species had been counted using a variety of methods. Sometimes the "individual" was defined, and sometimes not. When an individual of a given species had been defined in more than one way, we selected the definition that seemed to be the most consistent and easy to apply in the field, and used that definition for our study. When no previous definition of an "individual" could be found, we visited a site and examined plants of the target species itself before creating an optimal definition.

Table 1.2 summarizes the definitions of an individual for each of the study species. For a detailed description of how these definitions were derived, see the *Methodology* section in each of the species chapters.

Table 1.2: Study species life history and counting unit. For a description of how counting unit was determined for each species, see *Methodology* section within each species chapter.

Species	Bloom time	Description	Counting Unit
Delphinium leucophaeum	Late May-June	Herbaceous perennial, not clonal, vegetative plants often dormant by the time reproductive plants flower	Flowering stem
Delphinium pavonaceum	May-June	Herbaceous perennial, not clonal, vegetative plants often dormant by the time reproductive plants flower	Flowering stem
Erigeron decumbens var. *decumbens*	June-July	Herbaceous perennial, taproot, appears to spread vegetatively over short distances, forming clumps	Flowering clumps separated by at least 6 cm
Horkelia congesta	Late June-early July	Herbaceous perennial, taprooted, does not reproduce vegetatively, can have multiple rosettes from same branched caudex	Rosette
Lathyrus holochlorus	Late April – June	Herbaceous perennial, rhizomatous	Stem
Lomatium bradshawii	April-May	Herbaceous perennial, taproot, does not reproduce vegetatively	Stem
Lupinus sulphureus ssp. *kincaidii*	May-June	Herbaceous perennial, from branched crown, numerous unbranched stems, clonal	Area cover
Sericocarpus rigidus (was *Aster curtus*)	August	Herbaceous perennial, clonal, creeping rhizomes	Stem
Sidalcea nelsoniana	Late June-July	Herbaceous perennial, sometimes rhizomatous/clonal	Clumps separated by at least 30 cm

Defining population area

The second challenge faced when developing the methodology used in this study was determining how to define the population area. There are two general approaches to answering this question. The first is to define the area of the population as the area of the appropriate habitat at the site hosting the population. Many of our populations occupied small prairie remnants, fields or meadows, with relatively clear boundaries (i.e. a road or the

edge of a forested area). However, after visiting several sites it became apparent that we often did not have enough information to define "appropriate habitat" in a consistent manner. Some populations occupied only a small portion of a meadow, although it appeared that the entire meadow contained "appropriate habitat." It became clear that "appropriate habitat" was defined by multiple factors, many of which were difficult to see or quickly assess in the field. In addition, there were many sites where no clear habitat "edge" existed. While some sites were bounded by forest, agricultural fields, or roads, others were not, and determining where the habitat ended was difficult.

The second approach is to define the area of the population as the actual area occupied by the species of interest. However, populations frequently occurred in patchy distributions over large areas. Should the unoccupied areas in the middle of the overall distribution be excluded from the calculation of population area? If so, how large must the unoccupied patch be to be excluded? Once again, it proved difficult to make these decisions quickly and consistently when in the field.

Finally, many populations were too large and/or geographically spread out to census (or even sample) the entire population in the time available. In these cases, a subset of the population was either censused or sampled. The population area definition challenges mentioned above were also present in these situations, and any method for determining population area selected had to work for these populations as well.

Ultimately, we wanted a method for determining population area that could be consistently and quickly applied to a wide variety of sites. After visiting several sites to test methodology, we settled upon a method for determining the area of a population which included elements from both of the previously discussed approaches. In general, the area of the population was defined as the area contained within the perimeter of the population. Upon arriving at a site, field staff surveyed the area and marked the individuals along the edges of the population with pinflags, establishing a population perimeter. The entire area within that perimeter was counted, whether or not there were patches of inappropriate habitat (i.e. a thicket of blackberry or a large tree) present. How this definition was applied to each

type of population encountered is described in detail in the *Methodologies for estimating population densities* section below.

Overview of site protocol

In order to complete this study, a large number of sites were visited in a relatively short period of time. The following protocol was developed to maximize the time and efforts of the field staff. In general, this protocol was followed at each site.

1. Locate the site: Sometimes this first step was the most time-consuming piece of the process. Staff drove to the general vicinity of the population, following directions obtained from the ORNHIC records or the land manager. Once at the site, staff located the general area where the plants occurred.

2. Conduct site orientation: If necessary, all field crew members demonstrated that they could correctly identify the species. Staff then conducted an overall site assessment, marking patches and/or borders of population with pinflags in order to determine the extent of the population.

3. Determine the appropriate methodology for the site: After assessing the extent of the population, staff selected the methodology to be used at that site (i.e. census vs. sample, whole population vs. subset).

4. Determine overall population (or subset of the population) area: An area of the population (or subset of the population) was determined, either by measuring with 100-meter tapes or by recording GPS coordinates around the perimeter to be used for future area calculations.

5. Determine area to be sampled (if relevant): When the population was too large or geographically spread out to census/sample the entire area, a subset of that population was selected for use in the study.

6. Collect data: Staff collected and recorded all relevant data (i.e. population count data, GPS points, photo documentation, site notes, methodology notes, etc.)

Population density methodology overview

This purpose of this section is to describe the four basic methodologies used for determining population density estimates at each site, and explain how a given method was selected. Information provided in this section is not site specific – these general descriptions of methodology are applicable for each site where that methodology was used. For information about site specific methodologies, see the *Methodology* section in each species chapter.

Issues to address

The large number of variables involved in this study made it impossible to use just one method to develop population density estimates. Nine species were included in the study. Each species had its own set of characteristics and challenges, and the methodology that worked best for one species was not always appropriate for the rest. Plants of some species were relatively large and easy to locate (i.e. *Sidalcea nelsoniana* or *Lupinus sulphureus* ssp. *kincaidii*). Others were quite difficult to distinguish from the other vegetation at the site (i.e. vegetative *Lomatium bradshawii* or *Erigeron decumbens* var. *decumbens*). These differences impacted the amount of area that could be covered and the number of individuals that could be counted in a given amount of time.

Secondly, the configuration of the populations varied greatly, even among populations of the same species. Some populations were large, containing thousands of individuals, while others were quite small, with only a handful of plants present. Some populations were concentrated within a relatively small geographical area, and others were spread out over a large area. Some populations were patchily distributed, with large areas of inappropriate habitat (sometimes containing barriers to walking or sampling, such as large thickets of

Himalayan blackberry, poison oak, or forested areas with heavy undergrowth) located between areas containing individuals of the study species.

Finally, sometimes it was difficult to even determine what a "population" was. Some sites contained several smaller areas occupied by the study species, separated by distances of varying lengths. Depending on the site, ORNHIC database records described these areas as separate populations (each with their own element occurrence identification number, or EO ID#), subpopulations within the same population (all under one EO ID#), or patches within a population or subpopulation (also under one EO ID#).

Four general approaches

Four general approaches were used to determine the population density estimates for the nine study species:

- Census the entire population
- Census a subset of the population
- Sample the entire population
- Sample a subset of the population

The overall goal at each site was to develop a population density estimate using the best data possible (i.e. count as many of the individuals present in the population as possible, in as large a percentage of the population area possible). In order to achieve this, a census of the entire population was completed whenever possible. When a census could not be completed, we sampled as much of the population as we could in the time available. We found systematically sampling the entire population using either belt transects or plots to be the most effective way to do this. Systematic sampling involves the regular placement of quadrats along a transect, where the starting point for the regular placement is selected randomly. The advantage of this method is that it allows the researcher to sample evenly across the entire area of a population or subpopulation (Elzinga et al. 1998).

When possible, we sampled using belt transects, rather than square quadrats. In general, belt transects allowed us to sample more efficiently, covering a larger area in a given amount of time. Also, the use of rectangular plots such as belt transects can potentially reduce the amount of variance between plots, especially if the transects are aligned parallel to the major environmental gradient at the site, such as slope or distance from the edge of the water (Kershaw 1973, Greig-Smith 1983, Barbour et al. 1999). In situations where our sites contained irregularly shaped populations/habitat, we used the variable-lengthed belt transects sampling method developed by Stehman and Salzer (2000). This enabled us to sample these irregular shapes and calculate appropriate standard errors. (NOTE: Whether using belt transects or quadrats, individuals located along the borders of the plots were recorded when 51% or more of the plant was within the plot.)

Each of the four general approaches to collecting data is described in more detail below.

1. Census entire population

A population was censused when one or more of the following criteria were in place:

- Population contained a small number of individuals
- Population covered a small geographical area
- Individuals of the species were relatively easy to locate and count

If the population covered a small geographical area, a rectangular macroplot was installed encompassing the entire population. Meter tapes were used to establish the borders of the macroplot, and the area of the population was considered to be the area of the macroplot. The macroplot was subsequently divided into appropriate units (usually transects or one-meter^2 plots) to aid in the systematic search for individuals. With several of the species (i.e. *Lomatium bradshawii* and *Lathyrus holochlorus*), individuals within a given unit were first marked with pinflags. Once all individuals were marked, the pinflags were collected and counted to get the total number of individuals for that area.

If the population covered a larger area and had an irregular shape, an x-transect was installed running the length of the population. Y-transects (typically three meters in width) were established perpendicular to the x-transect to assist in the systematic search for individuals. The length of each y-transect was recorded, and the areas of all of the y-transects were added together to calculate the total population area. Field crew members walked the lengths of each transect, calling out the number of individuals when they were encountered to the person recording the data.

2. Sample entire population

A population was sampled when the following criteria were in place:

- Population contained a large number of individuals
- Population covered a relatively small geographical area
- Individuals were either too densely clustered or too difficult to locate and count (or both) to census

There were two general types of sampling used, depending upon the configuration of the population. If the population consisted of multiple patches scattered across a relatively large geographic area, with some type of barrier (i.e. trees and heavy undergrowth) in between, a subset of the patches was randomly selected, and all plants within those patches were counted. The area of these populations was usually calculated by using the mapping program ArcGIS to draw a polygon encompassing all patches and calculate the area of that polygon.

If the population was not scattered in a patchy distribution with barriers to sampling/walking in between patches, a systematic sampling scheme was employed. If the individuals were relatively large and easy to identify, and the population was not dense, then the population was systematically sampled using belt transects. If the population occupied a relatively square- or rectangular-shaped area, a macroplot encompassing the population was installed to facilitate the installation of the belt transects. If the population was irregularly shaped, variable-length belt transects were installed perpendicular to a central transect running the

length of the population. Once the length of the population was measured, the number of belt transects to be sampled was determined (with an attempt made to sample as many belt transects as possible in the time available). Belt transects were spaced systematically along the central transect running the length of the population, with the location of the first transect randomly determined.

Finally, when populations were very dense or the species was difficult to locate in the habitat, we systematically sampled using one-meter^2 or ½ x one meter^2 quadrats. Belt transects were first located perpendicular to the central transect, as discussed above. Quadrats were then systematically placed along each belt transect, with the location of the first quadrat randomly determined.

3. Census a subset of the population

A subset of a population was censused when the following criteria were in place:

- Population covered a large geographical area or was divided into subpopulations/patches
- Individuals of the species were relatively easy to locate and count

At some of the sites visited, we calculated population density using a subset of the overall population. This was done in one of two ways. The first was by using a macroplot encompassing as much of the population as possible. This method was employed when the population covered too large of an area to effectively census or sample in the time available. Once the macroplot was established, it was censused as if it were the entire population.

Some populations were made up of several subpopulations or patches located too far apart from each other to census or sample them together. When limited time prevented the censusing or sampling of all of the subpopulations/patches, one or more of the subpopulations or patches were selected to represent the population for the purposes of estimating density.

4. Sample subset of population

A subset of the population was censused when the following criteria were in place:

- Population contained a large number of individuals
- Population covered a large geographical area or was divided into subpopulations/patches
- Individuals were either too densely clustered or too difficult to locate and count (or both) to census

With very dense populations, or species that were more difficult to locate, sometimes even a subpopulation or a patch contained too many individuals to census in the available time. In those instances, the subpopulation or patch was sampled using one of the techniques described in the *Sample entire population* section above.

Recording site data

Overall site data (directions to site, GPS points, maps and notes on methodology, etc.) were recorded on a pre-printed Site Information Sheet (Appendix 2). All population data were recorded on a pre-printed datasheet (Appendix 3). GPS points were recorded with a Magellan Explorer 600, set on datum WGS 1984.

Analysis

Population data was analyzed using Microsoft Excel. Population area for several of the larger sites was calculated using ArcGIS 9.2.

Chapter II. *Delphinium leucophaeum*

Introduction

Delphinium leucophaeum (white rock larkspur, Figure 2.1), a member of the buttercup family (Ranunculaceae), is the rarest and most geographically restricted larkspur species in the Pacific Northwest. It is one of two rare white-flowered larkspur species found in the Willamette Valley (*D. pavonaceum*, addressed in the following chapter, is the other). It is found in Oregon, where the majority of populations occur, and Washington, and is listed as Endangered by both states.

Species information

Species status: *Delphinium leucophaeum* is recognized as a Species of Concern by the U.S. Fish and Wildlife Service (USFWS), and is listed as Endangered by the State of Oregon. It is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G2/S2 (imperiled throughout its range/imperiled in Oregon) (ONHP 2001). The species is listed as Endangered by the State of Washington, though this status designation provides no administrative protection because Washington currently has no state regulatory authority for listed plants (Florence Caplow, Washington Natural Heritage Program, Olympia, Washington, personal communication). *Delphinium leucophaeum* is ranked S1 (critically imperiled in Washington) by the Washington Natural Heritage Program (WNHP 2007).

Figure 2.1. *Delphinium leucophaeum* inflorescence.

Species description: *Delphinium leucophaeum* is an erect perennial, usually leafy up to the raceme, arising from a small cluster of globose tubers each about 5-8 (15) mm across. Stems are slender, 30-75 cm tall, glabrous below, villous pubescent above with curling hairs, occasionally wholly puberulent. Leaves are mostly cauline, not withering at anthesis, long-petioled, 4.5-9.0 cm wide, and the 3 (or 5) chief divisions pinnatifid or simply trifid into short acute segments. Racemes are open, especially below, 6-12-flowered, with flowers on ascending bracteate pedicels. Sepals are creamy white, ovate, umbonate, closely puberulent, 9-14 mm long, the lower petals are the same color as sepals, but upper petals are bright blue. Follicles are short, 8-10 (18) mm long, erect, with filiform and prickle-like cusps. Seeds are prismatic, 1.5-2.0 mm, truncate depressed, and all the angles distinctly winged (Ewan 1945).

The white flowers of *Delphinium leucophaeum* readily distinguish it from its many blue-purple flowered relatives. Taxonomic distinction is more difficult, however, between *D. leucophaeum* and its white-flowered relative, *D. pavonaceum* (Figure 3.1), another rare larkspur occurring in the Willamette Valley. *Delphinium pavonaceum* is essentially parapatric with *D. leucophaeum*, insofar that its primary distribution is situated farther south in the Willamette Valley than that of *D. leucophaeum*. However, the two species' ranges may overlap somewhat in northern Marion and southern Clackamas counties. *Delphinium pavonaceum* can be distinguished from *D. leucophaeum* by the former species' larger (11-18 mm), broadly ovate sepals, conical racemes that are wider below (due to long and spreading pedicels) and tapered above, and its spreading, often glandular-pubescent follicles (Darr 1980). See the following chapter for a more detailed description of *D. pavonaceum*.

Habitat/range: *Delphinium leucophaeum* was first collected by Thomas Nuttal in 1834, on "open prairies and along the banks of the Wahlamet" (Goodrich 1983). As of June 2005, the Oregon Natural Heritage Information Center (ORNHIC) database listed 24 populations of *D. leucophaeum* occurring in Oregon, all within Clackamas, Marion, Multnomah, and Washington counties except for one historic occurrence (made by Nelson in 1919) from Yamhill County, Oregon, though this site has never been successfully relocated (ORNHIC 2005). The only population in Washington State occurs on private land in Lewis County

(Joseph Arnett, Washington Natural Heritage Program, Olympia, Washington, personal communication on December 14, 2007).

According to Darr (1980), *Delphinium leucophaeum* occurs in a variety of habitat types, including: edges of *Quercus garryana* woods, dry roadside ditches, along river banks and bluffs, on moist rocky slopes, in moist lowland meadows, in dirt at cliff bases, and in open, moist areas atop basaltic shelves.

Species commonly associated with *Delphinium leucophaeum* include: *Anthoxanthum odoratum, Arbutus menziesii*, *Aquilegia formosa, Bromus* sp., *Collinsia parviflora*, *Comandra umbellata*, *Camassia quamash*, *Cynosurus echinatus*, *Cytisus scoparius*, *Danthonia californica, Elymus glaucus*, *Eriogonum* sp., *Festuca rubra*, *Galium* sp., *Holcus lanatus*, *Holodiscus discolor*, *Hypericum perforatum*, *Plectritis congesta*, *Polypodium glycyrrhiza, Quercus garryana*, *Rosa* spp., *Rubus* sp., *Sedum* sp., *Symphoricarpos alba*, *Toxicodendron diversilobum*, and various unidentified mosses, lichens, and liverworts (Darr 1980, Goodrich 1983, Anonymous 1986, ONHP 2002, and OSU herbarium specimen labels). Elevations of extant sites range from 50 to 1050 ft (ORNHIC 2005).

Goodrich (1983) analyzed soils at several extant *Delphinium leucophaeum* populations and concluded that the species occupies very distinctive substrates that are notably black in color (due to high content of organic matter), loose in texture, and very shallow (only 5-7 cm in most places). Particle size analysis of soils indicated a high percentage of sand relative to soils occupied by other Pacific Northwest *Delphinium* species, and low percentages of clay and silt. Specifically, soil analyses yielded a mean pH of 4.93, 33.47 percent organic matter, and particle sizes of 15.1 percent gravel, 58.6 percent sand, 20.0 percent silt, and 6.3 percent clay. May-June soil moisture was also higher (50.7 percent) at *D. leucophaeum* sites compared to those of the other *Delphinium* species (the latter typically ranging from 10.6-22 percent).

Given the apparent significance of edaphic factors on *Delphinium leucophaeum* distribution, Hoegler (1997) conducted soil analyses at the Camassia Natural Area and found that the

"healthiest" *D. leucophaeum* patches (those with positive increase in numbers over time) occupied sites with a mean soil depth of 7.7 cm, 54.1 percent organic matter, and 1.57 percent nitrogen. Soils occupied by declining patches tended to be slightly deeper, more organic, and contain more nitrogen, though these relationships were only weakly statistically significant.

Threats: Like many of the native prairie species included in this report, *Delphinium leucophaeum* is threatened by loss of its unique habitat to urban and agricultural development, especially in the Portland metropolitan area. In addition to anthropogenic land use threats, invasive species, roadside maintenance, and small population sizes pose risks for *Delphinium leucophaeum* (Darr 1980). Furthermore, the genetic integrity of the species is potentially threatened by hybridization. *Delphinium* species are "notorious hybridizers" (Lynda Boyer, Heritage Seedlings Inc., Salem, Oregon, personal communication on March 23, 2003), and crosses between *D. leucophaeum* and two other species (*D. nuttallii*, a blue-flowered species, and *D. pavonaceum*, the rare white-flowered species also found in the Willamette Valley) have produced viable seeds (Goodrich 1983). Hybridization, particularly between two rare species, may further complicate species management and recovery.

Study sites

Four study sites were used to determine density estimates for *D. leucophaeum*: Willamette Narrows, Willamette Falls, Cooper Mountain and Camassia Natural Area (Figure 2.2). For a complete list of all sites visited during the course of the study, as well as directions and GPS points for those sites, see Appendix 1.

Figure 2.2. *Delphinium leucophaeum* study sites.

Willamette Narrows: The Willamette Narrows population of *Delphinium leucophaeum* is located along the western bank of the Willamette River near Wilsonville (Figure 2.3). Owned by Metro, the regional government for the Portland metropolitan area, this site is being managed for what is believed to be the largest known population of this species. The site has two main population areas. The larger area (subpopulation 1) is located on a large, open, grassy slope close to Little Rock Island. The smaller area (subpopulation 2) is located just up river, and is separated from the larger subpopulation by a narrow strip of trees and shrubs. In 1998, it was estimated that both subpopulations combined had 4,500 flowering individuals (Salzer 1998). Current threats to *D. leucophaeum* at this site include invasion by non-native species like Scotch broom (*Cytisus scoparius*) and velvet grass (*Holcus lanatus*) (Salzer 1998).

Figure 2.3. *Delphinium leucophaeum* habitat at Willamette Narrows.

Willamette Falls: This small population of *D. leucophaeum* is located on a rocky outcrop next to the Oregon Department of Transportation-managed viewpoint of Willamette Falls near West Linn (off of I-205; Figure 2.4). This site is a very narrow remnant of Oregon white oak (*Quercus garryana*) woodland that is now dominated by non-native grasses. Current associated species include *Bromus diandrus*, *Lolium perenne*, *Camassia quamash*, *Toxicodendron diversilobum*, *Symphoricarpos albus*, *Polypodium glycyrrhiza* and *Sedum*

Figure 2.4. *Delphinium leucophaeum* habitat at Willamette Falls.

spathulifolium. In 2003, there were an estimated 10-15 flowering individuals at this site (ORNHIC 2005).

Cooper Mountain: Cooper Mountain is home to oak and madrone woodlands with pockets of remnant upland prairie and wetlands. Located in one of the fastest growing areas of the greater Portland region, 256 acres of this site were acquired in 1995 by Metro, and are currently being managed for wildlife habitat and recreation (Metro 2005). There are an estimated 4,500 individuals of *D. leucophaeum* at this site, primarily distributed between two main population areas (Metro 2005). The larger population (subpopulation 1) occurs in a shallow-soiled, open meadow surrounded by oak and Douglas fir woodland (Figure 2.5). The smaller population (subpopulation 2) is located in a patch of remnant prairie next to the access road, not far from the fire gate on the north edge of the site. Threats at this site include encroachment by the surrounding oak woodland habitat, competition from non-native invasive species, and disturbance from recreational users.

Figure 2.5. *Delphinium leucophaeum* habitat at Cooper Mountain.

Camassia Natural Area: Located in the hills of West Linn, The Nature Conservancy's Camassia Natural Area is a 26 acre rocky plateau which hosts an unusually diverse array of wetland and grassland communities (The Nature Conservancy 2005; Figure 2.6). *Delphinium leucophaeum* occurs in small patches along the edges of clumps of trees throughout this site.

Figure 2.6. *Delphinium leucophaeum* habitat at Camassia Natural Area.

Sites visited but not used in this study: Some of the current or historic sites visited by ODA during the course of this study did not prove to be suitable for use in the development of population density estimates. A complete list of the sites visited is available in Appendix 1.

Methodology

Overview

Deciding what to count: In general, once a population of *Delphinium leucophaeum* is in flower, most of the vegetative individuals have already gone dormant and are no longer visible above ground (B. McKernan-Stout, graduate student, personal communication on March 25, 2006). Because *D. leucophaeum* frequently occurs in tall grass and shrubs, flowering individuals of this species are much easier to locate and identify than vegetative individuals. Due to the large number of sites visited, and the narrow window of time available for each species (when plants were in flower and fruit), most sites were visited only once. Consequently, an individual of *D. leucophaeum* was defined as a flowering stem (which may or may not have branches).

Willamette Narrows

Willamette Narrows was visited on June 6, 2007. The population was too large to census in the time available, so the largest subpopulation was sampled using unequal-area belt transects. Two 100-meter tapes were used to establish a central transect (the x-transect) through the middle of the subpopulation, with the origin located at the southern edge of the grassy exposed slope (Figure 2.7). The x-transect was roughly parallel to the river, running 140 m to the northwest (at approximately 301°) along the slope to the tree line at the northern edge of the subpopulation. A one-meter-wide y-transect (perpendicular to the x-transect) was established for each 10 m section of the x-transect (for a total of 14 y-transects; Figure 2.7). The location of each y-transect was determined by randomly selecting a number between zero and nine. Another 100-meter tape was then placed perpendicular to the x-transect, crossing at the randomly determined number (i.e., for the 10 m – 20 m section of the x-transect, the number four was randomly selected, causing the y-transect for that section to

cross the x-transect at 14). All flowering plants were counted within each belt transect. If a plant was on the border of the transect, and more than 50% of the plant was within the transect, it was counted as being within that transect.

Figure 2.7. (Left) Establishing the x-transect through the center of the Willamette Narrows population of *Delphinium leucophaeum*. (Right) Y-transect running down the slope (perpendicular to the x-transect) at Willamette Narrows.

Willamette Falls

The Willamette Falls *D. leucophaeum* was visited on June 5, 2006. All likely habitat (along both sides of the viewpoint) was thoroughly searched for flowering stems. *Delphinium leucophaeum* plants were found on the west side of the viewpoint only. Located plants were were marked with pinflags and at the end of the search, flags were collected and counted. The overall area occupied by the plants was measured with a 100-meter tape.

Cooper Mountain

Cooper Mountain was visited on June 14, 2006. As with Willamette Narrows, this population of *D. leucophaeum* was too large to census. The density of this population was estimated by sampling subpopulation one, located in the central meadow surrounded by oak/douglas fir woodlands. While a few of the *D. leucophaeum* individuals were distributed throughout the open meadow at Cooper Mountain, most of the plants were found along the edges, next to and among the shrubs right at the tree line (Figure 2.8). The uneven distribution of plants throughout the meadow (indicating an environmental gradient) and the irregular shape of the habitat led to the selection of unequal belt transects as the sampling method for this site.

Figure 2.8. *Delphinium leucophaeum* plants along the edge of the meadow at Cooper Mountain.

The entire meadow was surveyed initially to determine the extent and distribution of the subpopulation. Plants at the perimeter of the subpopulation were marked with pinflags. A dirt trail runs through the middle of the meadow. A 100-meter-long central x-transect was established with endpoints on each side of the meadow where the trail leaves the trees and enters the meadow (Figure 2.9). Ten one-meter-wide y-transects were established perpendicular to the x-transects. Each y-transect spanned the width of the meadow, ending just inside the tree line, far enough in so that any outlier *D. leucophaeum* plants were included in the transect. For each 10 m section of the x-transect, a number between zero and nine was randomly selected to determine the point where the y-transect would cross the x-transect.

Figure 2.9. Central x-transect running though subpopulation one of *Delphinium leucophaeum* at Cooper Mountain. ODA volunteer Gerry Carr and ODA botanist Rebecca Currin are counting flowering stems along one of the y-transects.

Camassia Natural Area

ODA visited The Nature Conservancy's Camassia Natural Area on June 5, 2006. The configuration of the *D. leucophaeum* population at this site was different from that of the other three sites used in this study. Rather than having one or more distinct populations which were relatively easy to locate and either census or sample, small patches of *D. leucophaeum* are scattered throughout the 26 acre site (Figure 2.10). According to Dr. Keith Karoly, there are 22 known patches of *D. leucophaeum* at the Camassia Natural Area (although not all of these patches have been relocated in recent years; Dr. Keith Karoly, Associate Professor, Reed College, Portland, Oregon, personal communication on December 3, 2007). The topography and vegetation at the site made it impossible to run an x-transect that would include all of the known patches of *D. leucophaeum*. In addition, members of the 2006 field crew were unable to locate all of the previously found patches. Consequently, the data used for this site includes both data collected by ODA staff and data provided by Dr. Karoly.

When ODA staff located a patch of *D. leucophaeum*, each individual was marked with a pinflag. Once all individuals were located, the area of the patch was measured and the pinflags were collected and counted for that patch. Density could be calculated in several ways at this site, depending upon how the "population area" is defined. If the population area is defined as the sum of the areas of the patches where *D. leucophaeum* plants are located, the calculated density for this site would be much higher than that of the other three sites used in this study. Alternatively, the population area could be defined as the entire Camassia Natural Area, since patches of *D. leucophaeum* were scattered throughout the entire site.

Figure 2.10. Patch of *D. leucophaeum* at Camassia Natural Area (under oak tree). This site was characterized by small patches scattered throughout the area.

Although using the entire Camassia Natural Area as the "population area" underestimates the density of the population, it is felt that this method yields a density estimate closer to that of the other *D. leucophaeum* sites (since patches of non-habitat that fell within the overall population boundaries were included when calculating the area covered by the populations at these other sites).

Results

Willamette Narrows

Plants were counted within fourteen transects at the Willamette Narrows site. Transects ranged from 15 m to 41 m long, and transect plant counts ranged from zero to 114 plants. The estimated density for *D. leucophaeum* at this site is 0.797 flowering stems per m^2 (SE = 0.236). The total subpopulation area (for the larger subpopulation) is estimated to be 4,750 m^2, and the estimated size of this subpopulation is 3,788 flowering stems.

Willamette Falls

Thirteen flowering *D. leucophaeum* plants were found within a 34 m x 2 m occupied area at Willamette Falls. Twelve of the plants were located within a 15 m x 2 m area. The density of the population at this site was 0.191 flowering stems per m^2.

Cooper Mountain

Y-transects varied in length from 14 to 82 m long, and the number of flowering stems present in each y-transect ranged from two to 92. A total of 287 plants were counted in 10 transects (total sampled area = 441 m^2). The estimated population density for this site was 0.651 flowering stems per m^2 (SE=0.199).

Camassia Natural Area

Twenty-two patches of *D. leucophaeum* have been documented at Camassia Natural Area between 1981 and 2006. ODA field crew members were able to re-locate and census nine of these patches. Nine of the patches were either not located or had no plants in 2006. Counts for the remaining four patches were obtained from Dr. Keith Karoly (see *Methods* section above). Patches containing plants ranged in size from one to 142 flowering stems. Table 2.1 summarizes the number of *D. leucophaeum* individuals counted in each patch. The overall area of the Camassia Natural Area is 26 acres, or 105,218 m^2 (The Nature Conservancy

2005). Using the site area as the population area, the estimated density for this *D. leucophaeum* population is 0.004 flowering stems per m^2.

Table 2.1. Number of flowering *D. leucophaeum* stems counted at each patch in the Camassia Natural Area in 2006. Non-italicized numbers were obtained from ODA field crew counts. Italicized numbers were obtained from Dr. Keith Karoly of Reed College in Portland, Oregon.

Patch	# Flowering stems
1	4
2	*3*
3	*47*
4	31
5	1
6	*0*
7	*0*
8	1
9	*0*
10	*0*
11	36
12	*0*
13	*142*
14	38
15	*0*
16	-
17	55
18	*113*
19	-
20	1
21	1
22	0
Total	**473**

Summary

Overall, *D. leucophaeum* population densities ranged from 0.004 to 0.797 flowering stems per m^2. Table 2.2 summarizes the population density estimates for the four *D. leucophaeum* sites used in this study.

Table 2.2. Summary of estimated population densities for *Delphinium leucophaeum* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# flowering stems)	Total population area (m^2)	Total # flowering stems	Population density stems/m^2 (SE)
Willamette Narrows	Sample total subpopulation	475	378	*4,750*	*3,786*	*0.797* (0.236)
Willamette Falls	Census total population	n/a	n/a	68	13	0.191 (n/a)
Cooper Mountain	Sample total subpopulation	441	287	*4,410*	*2,871*	*0.651* (0.199)
Camassia Natural Area	Census total population	n/a	n/a	105,218 (26 acres)	473	0.004 (n/a)

Discussion

There was a wide range of population densities among the four *D. leucophaeum* sites visited for this study. The most dense subpopulation was located at Willamette Narrows (0.797 stems/m^2), followed closely by the subpopulation at Cooper Mountain (0.651 stems/m^2). Both of these populations are found in open clearings surrounded by trees (and in the case of Willamette Narrows, water on one side). The populations with lower density were located within a more patchy landscape, where suitable habitat was found in very small areas. The Willamette Falls site is most likely a remnant population, surviving in the one small area of remaining habitat, bordered by concrete sidewalks and a hillside almost completely dominated by blackberry (*Rubus* sp.). The Camassia Natural Area site is more wooded, and *D. leucophaeum* survives in small open patches or along the fringes of larger open areas (where the bulk of the open area is almost completely exposed rock). When determining the amount of habitat needed to support a *D. leucophaeum* population of a given size, it will be important to determine the nature of that habitat.

Chapter III. *Delphinium pavonaceum*

Introduction

Delphinium pavonaceum (peacock larkspur, Figure 3.1), a member of the buttercup family (Ranunculaceae), is one of two rare white-flowered larkspur species found in the Willamette Valley (*D. leucophaeum*, the other, is treated in the preceding chapter). Occurring only in Oregon, *Delphinium pavonaceum* is one of the most imperiled of the Willamette Valley native prairie species.

Species information

Species status: *Delphinium pavonaceum* is recognized as a Species of Concern by the U.S. Fish and Wildlife Service, and is listed as Endangered by the State of Oregon. It is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G1/S1 (critically imperiled throughout its range/critically imperiled in Oregon) (ORNHIC 2007).

Figure 3.1. *Delphinium pavonaceum* inflorescence.

Species description: *Delphinium pavonaceum* is an herbaceous perennial, 30-45 (90) cm tall, arising from a cluster of globose tubers. Flowering stems are erect, rather stout, with soft to hirsute pubescence. Leaves are mostly cauline, hirsute above and sparingly so below, persistent at anthesis, and extend up to the raceme as diminishing foliar bracts. Racemes are pyramidal (the lower pedicels

much longer than upper ones), with large foliar bracts in the axils. Flowers are showy, with sepals that are broadly ovate, acute, 11-18 mm long, and creamy white with blue or green umbos; the lower petals are rounded distally, 8 mm wide, shallowly emarginated, and the upper petals dark blue distally. Follicles are nearly erect, 12 mm long, and exhibit viscid-pubescence (Ewan 1945, Goodrich 1983).

Delphinium pavonaceum is very similar in appearance to another rare, white-flowered *Delphinium* species that occurs in the Willamette Valley, *D. leucophaeum* (see previous chapter, Figure 2.1). *Delphinium leucophaeum* can be distinguished from *D. pavonaceum* by the former species' shorter sepals (9-14 mm), its columnar (non-tapering) rather than conical raceme, and its follicles, which are shorter (8-12 mm) and non-glandular-puberulent (Darr 1980). The primary range of *Delphinium leucophaeum* is the northern Willamette Valley; it is only believed to spatially overlap with *D. pavonaceum* in northern Marion and southern Clackamas Counties.

Habitat/range: The type specimen of *Delphinium pavonaceum* was collected by H.C. Gilbert in 1916 from "fields west of Corvallis" (Goodrich 1983). As of June 2005, the Oregon Natural Heritage Program lists 30 known populations of *D. pavonaceum* in the state, at least one of which is known to be extirpated. The species occurs in Benton, Clackamas, Marion, Multnomah, and Polk Counties (ORNHIC 2005).

Habitat of *Delphinium pavonaceum* consists of undeveloped native wet prairie communities and shady edges of Oregon ash and Oregon white oak woodlands located in wildlife refuges and along roadsides and fence rows, usually at elevations of 150-450 ft (Darr 1980, ORNHIC 2005). Species typically associated with *D. pavonaceum* include: *Achillea millefolium*, *Alepocuris pratensis*, *Allium amplectens*, *Cammasia quamash*, *Delphinium menziesii*, *Deschampsia cespitosa*, *Fraxinus latifolia*, *Geum macrophyllum*, *Geranium oreganum*, *Holcus lanatus*, *Hypericum perforatum*, *Lomatium utriculatum*, *Lupinus polyphyllus*, *Phlox gracilis*, *Plectritis congesta*, *Poa pratensis*, *Potentilla gracilis*, *Rosa* spp., *Sidalcea campestris*, *S. nelsoniana*, *Spiraea douglasii*, *Symphoricarpos albus*, *Toxicodendron*

diversilobum, *Vicia* sp., and *Wyethia angustifolia* (Darr 1980, Finley and Ingersoll 1994, ONHP 2002, OSU herbarium specimen labels).

According to Goodrich (1983), Finley and Ingersoll (1994) and ONHP (2002), *Delphinium pavonaceum* often inhabits slightly higher, drier, more well-drained microsites within native wet prairies, rather than wetter depressions dominated by *Deschampsia caespitosa*. The species can, however, tolerate seasonal inundation (Goodrich 1983). Goodrich (1983) measured soil moisture at several *D. pavonaceum* populations and found the mean value for May and June to be about 30 percent by volume (as opposed to 19.53 percent for *D. nuttallii*, 50.66 percent for *D. leucophaeum*, 10.6 percent for *D. oreganum*, and about 22 percent for *D. menziesii*). Soil analyses for *D. pavonaceum* conducted by Goodrich (1983) showed a mean pH of 5.38, 11.28 percent organic matter, and particle size of: 5.8 percent gravel, 37.5 percent sand, 40.0 percent silt, and 18.7 percent clay.

Threats: As with other native species endemic to Willamette Valley grassland habitats, *Delphinium pavonaceum* has been severely impacted by habitat loss due to urban expansion and agricultural development (Darr 1980, USFWS 1995). Most extant populations are very small and occur along roadsides where they are continually threatened by road maintenance activities and herbicide application from adjacent agricultural fields (Darr 1980, USFWS 1995, Bender 1997, Bender 1998, ONHP 2002). Additional threats to this species include habitat degradation by invasive weeds and successional encroachment of shrubs (Finley and Ingersoll 1994), and herbivory by rodents (Goodrich 1983), deer, and slugs (B. McKernan, OSU graduate student, personal communication on April 3, 2006).

Although many of the known extant *Delphinium pavonaceum* populations occur on public lands (i.e., state and county road right-of-ways and federal wildlife refuges), many of these populations continue to face serious threats to their survival. For example, within Polk County road right-of-ways, two *D. pavonaceum* populations were destroyed by herbicides over the last 10 years (in both cases herbicides were applied by adjacent private landowners), a third roadside population was destroyed in 1997 during an emergency culvert replacement project resulting from a flood event, and a fourth roadside population was disturbed in 2002

when adjacent private landowners mowed occupied habitat during the flowering period. In Benton County, one roadside population was disturbed in 2001 by intentional trespass, mowing, and uprooting of plants. And on the Finley National Wildlife Refuge, home of the largest known *D. pavonaceum* population, at least two dozen individuals were destroyed in 2002 during placement of a native prairie habitat viewing platform.

However, although publicly owned *Delphinium pavonaceum* populations continue to face a variety of threats, public land managers are simultaneously striving to conserve this rare species. For example, in recognition of the extreme vulnerability of small roadside populations, counties are undertaking efforts to protect roadside *D. pavonaceum* populations by identifying their locations on maps and defining their boundaries with permanent metal signs. At Finley National Wildlife Refuge, important efforts are being made to maintain populations and their prairie habitat with prescribed fire, mowing, and brush clearing.

As with *Delphinium leucophaeum*, hybridization poses a potential threat to the genetic integrity of *D. pavonaceum*, as well. *Delphinium* species are "notorious hybridizers" (Lynda Boyer, Heritage Seedlings Inc., Salem, Oregon, personal communication on March 23, 2003), and crosses between *D. pavonaceum* and *D. leucophaeum* have produced viable seeds (Goodrich 1983). Hybridization, particularly between two rare species, may further complicate species management and recovery.

Study sites

Four study sites were used to determine density estimates for *D. leucophaeum*: Decker Road /Highway 34, Buena Vista Road/Davidson Road, Highway 22 (between Highway 99W and Greenwood Road) and Finley National Wildlife Refuge (Figure 3.2).

Figure 3.2. *Delphinium pavonaceum* sites visited for this study. Because there were taxonomic questions regarding the *Delphinium* species found at the northernmost two populations (Walker Prairie and Champoeg State Park), they were not included when calculating population density estimates.

Decker Road & Highway 34: The Decker Road/Highway 34 *D. pavonaceum* population is jointly managed by Oregon Department of Transportation (Hwy 34) and Benton County (Decker Road). Plants are found along the ditch and slope behind the ditch in the right-of-way (Figure 3.3). A few plants occur along the fencerow on private land. Current threats include roadside maintenance and potential development of the corner property (the owner applied to install a second driveway on Decker Road in 2007).

Figure 3.3. *Delphinium pavonaceum* population at Decker Road and Highway 34. Orange flags indicate location of plants in 2007.

Buena Vista Road & Davidson Road: The Buena Vista Road/Davidson Road population of *D. pavonaceum* is another roadside population located in the right-of-way. This population is managed by Polk County. Associated species include *Anthoxanthum odoratum*, *Camassia* sp., *Daucus carot*a, *Lolium* sp., *Rosa* sp., *Rubus armeniacus*, *Rumex crispus*, and another listed species, *Sidalcea nelsoniana*. As with most roadside populations of rare plants, the primary threat is roadside maintenance.

Highway 22 (between 99W and Greenwood Road): The *D. pavonaceum* population along Highway 22 (near its intersection with Highway 99W) is managed by the Oregon Department of Transportation (Figure 3.4). This broad right-of-way prairie remnant is designated as a Special Management Area and managed for multiple plant species (the site contains *Sidalcea nelsoniana* as well as *D. pavonaceum*). The bulk of the *D. pavonaceum* plants occur within the right-of-way, but approximately 10% of the population does occur on the other side of the fence, on private land. A small population of *D. menziesii* co-occurs with *D. pavonaceum*, but there does not appear to be hybridization between the two species at this location (ORNHIC 2005). Threats to this population include invasion of the habitat by

non-native exotics such as Himalayan blackberry (which is very prevalent on the privately-owned side of the fencerow) and dense weedy grasses, and roadside maintenance.

Figure 3.4. Highway 22 (near junction with Highway 99W) population of *Delphinium pavonaceum*. A small portion of the population does occur on the far side of the fence, on private property, but the invasion of Himalayan blackberry on the private side of the fence limits suitable habitat.

Finley National Wildlife Refuge:

The U.S. Fish and Wildlife Service's Finley National Wildlife Refuge supports the largest known population of *D. pavonaceum* (Figure 3.5). According to Oregon Natural Heritage Information Center records, there are several subpopulations of *D. pavonaceum* at Finley, with the largest (McFaddon Marsh) containing approximately 100,000

Figure 3.5. *Delphinium pavonaceum* at the Finley National Wildlife Refuge. Finley supports the largest known population of this rare prairie species.

plants. In recent years refuge biologists have been actively restoring the prairie through controlled burns and alteration of hydrology (several areas were leveled for crop cultivation in the past). Current threats include encroachment of shrubs and non-native exotics and deer grazing.

Methodology

Overview

Deciding what to count: In general, once a population of *Delphinium pavonaceum* is in flower, most of the vegetative individuals have already gone dormant and are no longer visible above ground (B. McKernan-Stout, OSU graduate student, personal communication on March 25, 2006). Because *D. pavonaceum* frequently occurs in tall grass and shrubs, flowering individuals of this species are much easier to locate and identify than vegetative individuals. Due to the large number of sites visited, and the narrow window of time available for each species (when plants were in flower and fruit), most sites were visited only once. Consequently, an individual of *D. pavonaceum* was defined as a flowering stem (which may or may not have branches).

Decker Road & Highway 34

ODA visited the Decker Road population of *D. pavonaceum* on May 25, 2007. Because this population is fairly small and occupies a limited geographical area, the whole population was censused, rather than sampled. Field crew members thoroughly surveyed the site, marking all *D. pavonaceum* plants with pinflags (Figure 3.6). Once the extent of the population was determined, the area of the population was measured using 100 m tapes. A one-meter buffer was included at each end of the population. Plants occurring on private land (on the other side of the fence, see Figure 3.6) were not included in the density estimate calculations.

Figure 3.6. *Delphinium pavonaceum* plants marked with pinflags along Decker Road. Each pinflag represents one reproductive plant.

Buena Vista Road & Davidson Road

The Buena Vista Road/Davidson Road *D. pavonaceum* population was visited on May 24, 2007. This roadside population was also small enough to be censused. As with the Decker Road population, individual plants were marked with pinflags and then counted. The overall population area was measured with 100 m tapes. Population density was calculated by dividing the number of plants by the area (m^2).

Highway 22 (between 99W and Greenwood Road)

The Highway 22 population of *D. pavonaceum* was visited on May 24 and May 25, 2007. This population was also small enough to be censused. The height of the grasses at this site made it difficult to see the *D. pavonaceum* individuals from a distance (Figure 3.7). In addition, the right-of-way was fairly broad along this stretch of the highway (ranging from 9.5 m to 17.5 m in width). Consequently, the site was divided into approximately 10-meter-

wide transects running perpendicular to the highway. Each transect was then systematically searched for flowering *D. pavonaceum* plants. All flowering individuals within the right-of-way were counted. In addition, flowering individuals occurring on the private property on the other side of the fence were also counted, although these plants were not included in the population density calculations.

Figure 3.7. ODA botanist counting *Delphinium pavonaceum* plants along Highway 22.

Finley National Wildlife Refuge

The Finley National Wildlife Refuge population was visited on May 24, 2006. The Oregon Natural Heritage Information Center's database lists four populations of *D. pavonaceum* occurring at Finley. However, maps provided by Finley biologists indicated that the refuge supports two large subpopulations of this species. Because these subpopulations were too large and geographically diffuse to census in the time available, a 100 m x 80 m macroplot encompassing the bulk of one of the subpopulations (and representative of the habitat occupied by this subpopulation) was established, and all plants were counted within that macroplot (Figure 3.8). The estimated population density was then calculated by dividing the total number of plants counted within the macroplot by the area of the macroplot.

Figure 3.8. *Delphinium pavonaceum* macroplot at Finley Wildlife Refuge. Flags in the foreground indicated the macroplot corner. Each flag in the background represents one plant.

Results

Decker Road & Highway 34

There were a total of 269 flowering *Delphinium pavonaceum* plants occurring in the right-of-way at the junction of Decker Road and Highway 34. The total area of the population was 946 m^2. The population density for this site was 0.284 flowering stems per m^2. In addition to the plants found on the right-of-way, 32 flowering plants were observed on the adjacent private property. These plants were not included in the population density calculations. This was the only *D. pavonaceum* site visited where field crew members encountered vegetative *D. pavonaceum* plants (at other sites, vegetative plants had already gone dormant by the time the reproductive plants were flowering). The presence of vegetative individuals later in the season could be due to the higher levels of shade experienced at this site, caused by the large conifer trees along the fence at the edge of the right-of-way (see Figure 3.3). Over 135

vegetative individuals were counted during the site visit. However, in order to maintain consistent population density calculation methods between sites, these were also not included when calculating population density at this site.

Buena Vista Road & Davidson Road

A total of 70 flowering plants were found at the Buena Vista Road and Davidson Road *D. pavonaceum* population. The population covered an area of 95 m^2. The population density for this site was 0.737 flowering stems per m^2.

Highway 22 (between 99W and Greenwood Road)

The Highway 22 population of *D. pavonaceum* contained 573 plants scattered over an area of 4,873 m^2. The density calculated for this population was 0.118 flowering stems per m^2. An additional 71 flowering plants were observed occurring on private land adjacent to the right-of-way, but these individuals were not included when calculating population density for this site.

Finley National Wildlife Refuge

A total of 582 flowering *D. pavonaceum* plants were counted in the 80 m x 100 m (8,000 m^2) macroplot at Finley. The macroplot population density was 0.073 flowering stems per m^2.

Summary

Overall, *D. pavonaceum* population densities ranged from 0.073 to 0.737 flowering stems per m^2. Table 3.1 summarizes the population density estimates for the four *D. pavonaceum* sites used in this study.

Table 3.1. Summary of estimated population densities for *Delphinium pavonaceum* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# flowering stems)	Total population area (m^2)	Total # flowering stems	Population density stems/m^2 (SE)
Decker Rd/ Hwy 34	Census total population	n/a	n/a	946	269	0.284
Buena Vista Rd/ Davidson Rd	Census total population	n/a	n/a	95	70	0.737
Hwy 22/ 99W	Census total population	n/a	n/a	4,873	573	0.118
Finley	Census macroplot	8,000	582	n/a	n/a	0.073

Discussion

Delphinium pavonaceum population densities ranged from 0.073 flowering plants per m^2 to 0.737 flowering plants per m^2. The population with the fewest individuals (Buena Vista Road/Davidson Road) had the highest population density, while the populations with the largest number of individuals (Finley and Highway 22) had the lowest population densities. This is most likely due to the fact that the larger populations had more microhabitat diversity, with more areas of unsuitable habitat located amongst the patches of suitable habitat. This increase in uninhabited area within the overall population area would obviously decrease the population density. In contrast, the smallest population was located along a narrow county road right-of-way, bounded on one side by the shoulder of the road and on the other by private land with little suitable habitat. Within the Buena Vista Road/Davidson Road population area, there was little unsuitable habitat present. Consequently, the density was much higher for this population.

When calculating the amount of habitat need to support a *D. pavonaceum* population of a certain size, it will be important to determine the nature of that habitat. Ideally, habitat set aside for *D. pavonaceum* would not be limited to narrow strips along roads which are vulnerable to many types of disturbances. If protected habitat is of a more open and

extensive nature, then the lower density estimates should be used to estimate the amount of habitat needed.

Chapter IV. *Erigeron decumbens* var. *decumbens*

Introduction

Once thought to be extinct, *Erigeron decumbens* var. *decumbens* (Figure 4.1) was rediscovered in 1980. Since then, additional populations of this rare member of the sunflower family (Asteraceae) have been reported from small native prairie sites, all occurring in the Willamette Valley of Oregon.

Species information

Species status: This rare daisy is listed as Endangered by both the U.S. Fish and Wildlife Service and the State of Oregon, is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G4T1/S1 (the variety of this species is critically imperiled throughout its range/critically imperiled in Oregon) (ORNHIC 2007).

Figure 4.1. *Erigeron decumbens* var. *decumbens* flowering heads.

Species description: *Erigeron decumbens* var. *decumbens* (Figure 4.1) is a taprooted perennial, with decumbent stems that are often purplish at the base and 1.5-7 dm tall. Basal leaves and some or most of the cauline leaves are triple-nerved, the basal leaves up to 25 cm long and 1 cm wide and cauline leaves becoming only gradually

reduced above. Flowering heads typically number from 1-20, with 20-50 purple to pale pink ray flowers (6-12 mm long, 1-2 mm wide), yellow disk corollas (2.5-4.5 mm long), and pappus consisting of 12-16 fragile bristles (Hitchcock *et al*. 1955).

According to Kagan and Yamamoto (1987), *Erigeron decumbens* var. *decumbens* is the only pink-purple rayed *Erigeron* that occurs in the grassland habitats of the Willamette Valley, and is further distinguished by its gradually reduced cauline leaves, triple-nerved basal leaves, and decumbent, spreading habit.

Habitat/range: Herbarium collections from such notable early botanists as Louis Henderson, Thomas Howell, Morton Peck, James Nelson, Wilhelm Suksdorf, Thomas Nuttal, and J.W. Thompson collectively indicate that *Erigeron decumbens* var. *decumbens* was once fairly common and widely distributed in the wetland and upland prairies of Oregon's Willamette Valley (OSU herbarium records and ONHP 2002). After 1934, however, the species was not collected and was believed extinct until it was finally relocated near Eugene, Oregon, in 1980 (Clark et al. 1993). The Oregon Natural Heritage Information Center (as of June 2005) lists records for 48 *Erigeron decumbens* var. *decumbens* populations, many of which are likely extirpated, as they have not been observed for over 70 years. Currently, the species is known from Benton, Lane, Linn, Marion, and Polk Counties, Oregon (ORNHIC 2005). Historic populations in Clackamas, Washington and Yamhill Counties have never been relocated.

Habitat for *Erigeron decumbens* var. *decumbens* consists of undeveloped native wetland and upland prairies at elevations typically ranging from 240-950 ft (ORNHIC 2005). Commonly associated prairie species include: *Achillea millefolium*, *Allium amplectens*, *Anthoxanthum odoratum*, *Brodiaea hyacinthina*, *Bromus carinatus*, *B. japonicus*, *Carex* spp., *Camassia leichtlinii*, *Crataegus douglasii*, *Danthonia californica*, *Deschampsia caespitosa*, *Elymus glaucus*, *Eriophyllum lanatum*, *Festuca arundinaceae*, *F. roemeri*, *Fragaria virginiana*, *Fraxinus latifolia*, *Grindelia integrifolia*, *Holcus lanatus*, *Juncus* spp., *Lomatium bradshawii*, *Panicum occidentale*, *Poa nevadensis, Potentilla gracilis*, *Prunella vulgaris*, *Quercus garryana*, *Ranunculus occidentalis*, *Rosa* spp., *Saxifraga integrifolia*, *Sericocarpus rigidus*,

Sidalcea campestris, *Spiraea douglasii*, and *Symphyotrichum hallii* (Kagan and Yamamoto 1987, Clark et al. 1993, 1995, USFWS 2000, ONHP 2002).

Threats: Widespread loss of native Willamette Valley prairie habitat to agricultural and urban development is the primary threat to *Erigeron decumbens* var. *decumbens*. As with many other rare prairie species, *E. decumbens* var. *decumbens* faces the additional threats of successional encroachment of prairie habitat by trees and shrubs, competition with invasive weeds, and possible inbreeding depression arising from small population sizes (Kagan and Yamamoto 1987, Clark et al. 1993, USFWS 2000, ONHP 2002).

With the majority of extant populations of *Erigeron decumbens* var. *decumbens* occurring on privately owned lands (USFWS 2000), land ownership presents a serious obstacle to conservation and recovery of the species. Populations occurring on private lands are the most vulnerable to threats of development, since state and federal plant protection laws do not apply to private lands. However, publicly owned populations are still at risk. For instance, Clark et al. (1993) identified four populations protected from development on public lands (Willow Creek, Basket Slough NWR, Bald Hill Park, and Fisher Butte RNA) that were threatened by the proliferation of non-native weeds and successional encroachment of brush and trees. Likewise, vulnerability arising from small population sizes and inbreeding depression may be a concern for the species, regardless of land ownership, especially among the 20 remaining *E. decumbens* var. *decumbens* sites that are less than 3.4 hectares in size (USFWS 2000).

Study sites

Six study sites were used to determine density estimates for *E. decumbens* var. *decumbens*: Kingston Prairie, McClun Road, Willow Creek Preserve, Muddy Creek, Bald Hill and Basket Slough National Wildlife Refuge (Figure 4.2).

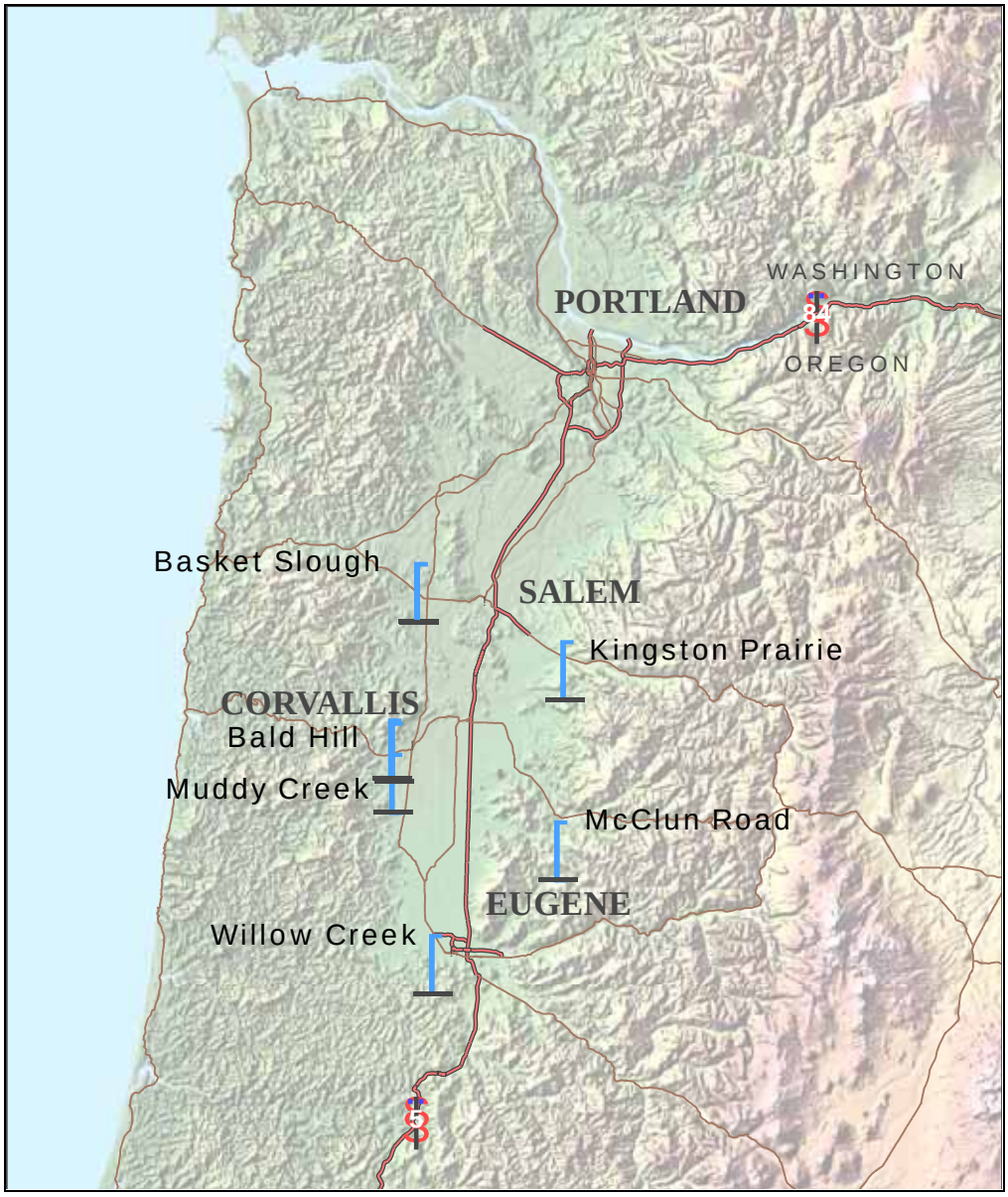

Figure 4.2. *Erigeron decumbens* var. *decumbens* populations visited during the course of this study.

Kingston Prairie Preserve: Owned and managed by The Nature Conservancy, Kingston Prairie is a small, relatively high quality remnant of prairie which supports several rare Willamette Valley species, including *Erigeron decumbens* var. *decumbens*, *Sericocarpus rigidus* (*Aster curtus*), and *Lomatium bradshawii* (Figure 4.3). This site is located in Linn County near Stayton. The primary threat to the rare species that inhabit this site is competition from non-native plants species.

Figure 4.3. *Erigeron decumbens* var. *decumbens* habitat at Kingston prairie.

McClun Road: The McClun Road *E. decumbens* var. *decumbens* population was only recently discovered in 2002. This population is located on private property outside of the tiny town of Holley (near Sweet Home). The current landowner is actively working with U.S. Fish and Wildlife to restore this piece of prairie. Grazing no longer occurs at the site and non-native invasive weeds such as ox-

Figure 4.4. *Erigeron decumbens* var. *decumbens* population on private property near McClun Road. Each pink and green pinflag represents one reproductive individual. Plants are confined to the bottom and sides of the shallow ditch running through the property. The large white patches in the background are ox-eye daisy flowers.

eye daisy (*Leucanthemum vulgare*) are being removed. The *E. decumbens* var. *decumbens* population is confined to the bottom and sides of the drainage ditch which runs through the property, and along the path of an old railroad track where the tracks have been removed (Figure 4.4). Despite the attempts to remove weeds, the biggest threat facing this population is the invasion of non-native plant species. Additionally, because it is located on private property, future changes of ownership or management practices might also threaten this population.

Willow Creek Preserve: The Willow Creek Preserve (Figure 4.5) is owned and managed by The Nature Conservancy. This preserve is part of the greater West Eugene Wetlands, a network of private and publicly-owned lands being managed for wetland function and rare species. In addition to *E. decumbens* var. *decumbens*, this preserve also supports populations of *Horkelia congesta* ssp. *congesta, Lomatium bradshawii*, *Sericocarpus rigidus* (*Aster curtus*) and *Lupinus sulphureus* ssp. *kincaidii*. The primary threat to this population is competition from invasive weeds and encroachment of shrubs and trees.

Figure 4.5. *Erigeron decumbens* var. *decumbens* (foreground) habitat at Willow Creek Preserve.

Muddy Creek: The Muddy Creek population of *E. decumbens* var. *decumbens* (also known as the Allen and Allen property) is located on a privately-owned farm south of Corvallis. This site is another example of a small patch of remnant prairie that supports multiple rare plant species, including *Sidalcea nelsonia*, *Lomatium bradshawii*, *Lathyrus holochlorus* and *Delphinium pavonaceum* (Salix Associates 2004). Like the McClun Road population of *E.*

Figure 4.6. *Erigeron decumbens* var. *decumbens* plants following the ditch at Muddy Creek. Each pinflag marks one reproductive plant.

decumbens var. *decumbens*, the Muddy Creek population is confined to the banks of the rather deep drainage ditch which runs through the center of an open field (Figure 4.6). Although the field was formerly cultivated, it is no longer being used for agriculture. Unfortunately, reed canary grass (*Phalaris arundinacea*) has invaded the site, and this aggressive weed poses a substantial threat to rare prairie species found here.

Bald Hill: Bald Hill is a Corvallis city park located west of Oregon State University's campus on the outskirts of town. This park has a well maintained network of trails that are heavily used by walkers, joggers, cyclists and horseback riders. The Bald Hill *E. decumbens* var. *decumbens* population is divided into three small subpopulations. Subpopulation one is on an open slope about 50 m above a main trail and subpopulation two is adjacent to a gravel trail (Figure 4.7). ODA field crew members were unable to locate subpopulation three. The City of Corvallis is working with the Institute for Applied Ecology to improve the *E. decumbens* var. *decumbens* habitat at the park. Current threats include encroachment of shrubs and trees, invasive weeds and trampling caused by people (whether on foot, bicycle or horse) who do not remain on the trails.

Figure 4.7. *Erigeron decumbens* var. *decumbens* habitat at Bald Hill. Subpopulation one (left) is located on an open slope. Subpopulation two (right) is found adjacent to a park trail. Each pinflag marks one reproductive individual.

Basket Slough National Wildlife Refuge: Part of the Willamette Valley Wildlife Refuge complex managed by the U.S. Fish and Wildlife Service, Basket Slough National Wildlife Refuge is located just north of Highway 22 and just west of Highway 99. Established in 1965 to provide winter habitat for dusky Canada geese, this 2,493 acre refuge is a patchwork of farmed fields, oak woodlands, grass fields and wetlands (USFWS 2007). In addition to *E. decumbens var. decumbens*, this refuge supports the largest remaining population of Fender's blue butterfly, a federally endangered butterfly which lays its eggs exclusively on *Lupinus sulphureus* ssp. *kincaidii*, another rare prairie species (USFWS 2007; see Chapter VIII). The bulk of the

Figure 4.8. *Erigeron decumbens* var. *decumbens* habitat at Basket Slough National Wildlife Refuge. Pinflags mark locations of individual plants.

Basket Slough *E. decumbens* var. *decumbens* population is found on or near the summit of a grassy hill dotted with patches of oak woodland (Figure 4.8).

Methodology

Overview

Deciding what to count: Because *Erigeron decumbens* var. *decumbens* is able to reproduce vegetatively, it is difficult to determine if closely placed clumps of plants are connected underground, or if they are genetically distinct individuals. Researchers conducting previous monitoring efforts have assumed that plants separated by five to seven cm were distinct individuals (Finley and Ingersoll 1995, Kaye 2000). For the purposes of this study, ODA defined an individual plant as any plant separated from its neighbors by six cm or more (Figures 4.9 and 4.10). Depending on the associated plants species, vegetative individuals were difficult to locate and identify as *E. decumbens* var. *decumbens* at some of the populations. Consequently, during this study ODA staff counted reproductive individuals only.

Figure 4.9. Closely spaced clumps of *Erigeron decumbens* var. *decumbens*. Each blue pinflag marks an individual plant, defined as any plant separated from its neighbors by six cm or more.

Figure 4.10. One ODA field crew member was able to determine if the distance between clumps of *Erigeron decumbens* var. *decumbens* was greater than six cm by using his hand (the width of his three fingers at the first knuckle was exactly six cm).

Kingston Prairie Preserve

The Kingston Prairie population of *E. decumbens* var. *decumbens* was visited on June 16, 2006. Although The Nature Conservancy (TNC) owns several parcels of land at Kingston Prairie which support patches of *E. decumbens* var. *decumbens*, the boundaries for several of the areas were unclear. Rather than inadvertently trespass on private property, ODA staff chose to look at the subpopulation located within the area clearly belonging to TNC. Upon arrival at the site, field crew members briefly surveyed the area containing the subpopulation, marking the perimeter of the *E. decumbens* var. *decumbens* population with pinflags. Because this population is relatively small and covers a small geographical area, it was censused rather than sampled. In order to ensure that no individuals were missed, a 68 m x 50 m macroplot encompassing the entire population was demarcated with 100 m tapes. This macroplot was then divided into 3 m x 50 m transects (Figure 4.11). Field crew members

walked the length of each transect, recording the number and location of *E. decumbens* var. *decumbens* plants.

Figure 4.11. Counting *Erigeron decumbens* var. *decumbens* plants at Kingston Prairie. The subpopulation was divided into transects to facilitate counting.

McClun Road

The McClun Road population of *E. decumbens* var. *decumbens* was visited on June 19, 2007. Upon arrival at the site, field crew members briefly surveyed the area containing the population, marking the perimeter of the *E. decumbens* var. *decumbens* population with pinflags. Because this population is relatively small and covers a small geographical area, it was censused rather than sampled. The two patches of *E. decumbens* var. *decumbens* are confined to bottom and edges of a drainage ditch and the ditch next to an old railroad grade, which cross at one end and gradually veer away from each other. In order to ensure that no individuals were missed, a 200-meter-long x-transect was installed running the length of the area containing *E. decumbens* var. *decumbens* habitat, and one-meter-wide y-transects (up to 65 m in length) were established perpendicular to the x-transect. Each y-transect was surveyed for *E. decumbens* var. *decumbens* plants (Figure 4.12). The area of the population

was calculated by measuring the area of the polygon that encompassed all patches of the plants.

Figure 4.12. ODA staff counting *Erigeron decumbens* var. *decumbens* along a the drainage ditch at the McClun Road population. Transects were installed to ensure that all of the population area was surveyed, and that no plants were missed or double counted.

Willow Creek Preserve

The Nature Conservancy's Willow Creek Preserve was visited on June 30, 2006. TNC has permanent monitoring plots encompassing the vast majority of the *E. decumbens* var. *decumbens* population established at the Preserve (Figure 4.13). These plots also cover the bulk of the *Horkelia congesta* ssp. *congesta* population. In order to maximize the use of staff time, TNC staff collected *E. decumbens* var. *decumbens* data, and ODA staff collected *H. congesta* ssp. *congesta* data (see Chapter V). The permanent monitoring plots are set up in a 100 m x 100 m grid, with an additional 10 m x 60 m "arm" extending off from the primary square, for a total monitored area of 10,060 m^2. Staff walked back and forth within each 10

m x 10 m macroplot, recording the number of reproductive and vegetative individuals found. In order to maintain consistent methodology between sites, this study only used the number of reproductive individuals to calculate density. TNC provided a complete summary of their *E. decumbens* var. *decumbens* monitoring data at Willow Creek, so the population density within the monitored area was calculated for the last five years at this site.

Figure 4.13. *Erigeron decumbens* var. *decumbens* macroplot at The Nature Conservancy's Willow Creek Preserve. Blue pinflags mark the corners of the 10 m x 10 m microplots within the overall 100 m x 100 m macroplot.

Muddy Creek

The Muddy Creek population of *E. decumbens* var. *decumbens* was visited on June 27, 2006. Because of the relatively small size of this population and the fact that plants were limited to the edges of the large ditch running through the middle of the field at this site, ODA was able to census the population. After ODA field crew members walked the length of the ditch to

determine the extent of the population, a 180 m x-transect was established running through the middle of the ditch (Figure 4.14), with the origin at the southern end of the population. Four-meter-wide y-transects were then temporarily installed by stretching two 100 m tapes perpendicular to the x-transect (and then leap-frogging them over each other along the x-transect) to facilitate searching for the *E. decumbens* var. *decumbens* plants (Figure 4.15). The y-transects were 22 meters long (long enough to include all patches of *E. decumbens* var. *decumbens*). The population area was calculated by multiplying the length of the x-transect (180 m) by the length of the y-transects (22 m).

Figure 4.14. X-transect running through the center of the Muddy Creek *Erigeron decumbens* var *decumbens* population.

Figure 4.15. Oregon Department of Agriculture botanist counting reproductive *Erigeron decumbens* var. *decumbens* plants at Muddy Creek.

Bald Hill

The Bald Hill population of *Erigeron decumbens* var. *decumbens* was visited on July 3, 2006. ODA staff located and censused two of the three subpopulations at this site. The surrounding habitat at both sites was thoroughly surveyed for additional plants as well. Both vegetative and reproductive individuals were counted, but only the reproductive individuals were used to calculate population densities. Each subpopulation area was determined by calculating the area of a rectangle which encompassed all individuals of that subpopulation (Figure 4.16). Because of the considerable distance between the two areas, density was calculated separately for each subpopulation.

Figure 4.16. ODA botanist mapping the location of *Erigeron decumbens* var. *decumbens* plants at Bald Hill.

Basket Slough

The Basket Slough population of *E. decumbens* var. *decumbens* was visited on July 6, 2006. This population was too large and geographically spread out to census within the time

available. The area was canvassed to determine the extent and perimeter of the population. Three rectangular macroplots encompassing the three patches of *E. decumbens* var. *decumbens* were established using 100-meter tapes. Macroplot one was 69 m x 36 m. Macroplot two was 17 m x 10 m. Macroplot three was 36 m x 28 m. Each macroplot was censused. Macroplots were divided into three-meter-wide transects to facilitate thorough searching (Figure 4.17). An overall population area was also estimated in ArcGIS using the GPS points for the outside corners of each macroplot. Population densities were calculated for each macroplot, as well as for the overall site. However, it is important to remember that the entire site was not censused, and it is possible that there were a few plants located between macroplots which were not included. This potential undercounting of the population would make the overall estimated density of this population slightly lower than its actual density.

Figure 4.17. *Erigeron decumbens* var. *decumbens* population (macroplot one) at Basket Slough. Meter tapes helped delineate the area being searched.

Results

Kingston Prairie Preserve

A total of 98 flowering individuals of *E. decumbens* var. *decumbens* were counted at Kingston Prairie. The population covered an area of 3,400 m^2. The density of this population was 0.029 flowering individuals per m^2.

McClun Road

A total of 477 flowering individuals of *E. decumbens* var. *decumbens* were counted at Kingston Prairie. The population covered an area of 12,200 m^2. The density of this population was 0.039 flowering individuals per m^2.

Willow Creek Preserve

A total of 860 flowering individuals of *E. decumbens* var. *decumbens* were counted at Willow Creek. The population covered an area of 10,060 m^2. The density of this population was 0.085 flowering individuals per m^2 in 2006. Between 2001 and 2006, the density of the Willow Creek Preserve population of *E. decumbens* var. *decumbens* ranged from 0.057 to 0.149 flowering individuals per m^2. Table 4.1 summarizes the change in population density during that time period.

Table 4.1. Change in density of Willow Creek Preserve *Erigeron decumbens* var. *decumbens* population over time.

Year	# Flowering Plants	Area Monitored (m^2)	Population Density (# Flowering Plants/m^2)
2001	589	10,060	0.059
2002	1077	10,060	0.107
2003	1172	10,060	0.117
2004	1499	10,060	0.149
2005	578	10,060	0.057
2006	860	10,060	0.085

Muddy Creek

A total of 135 flowering individuals of *E. decumbens* var. *decumbens* were counted at Muddy Creek. The area of this population was 3,690 m^2. The density of this population was 0.034 flowering individuals per m^2.

Bald Hill

Subpopulation one contained 13 reproductive individuals of E. decumbens var. decumbens, covering an area of four m^2. Five vegetative individuals were also found. The density of this subpopulation was 3.25 flowering individuals per m^2. Subpopulation two contained 12 reproductive individuals and three vegetative individuals within an area of 10 m^2. The density of this subpopulation was 1.2 flowering individuals per m^2.

Basket Slough

Table 4.2 summarizes the data collected at Basket Slough. A total of 112 flowering plants were present in macroplot one. The area of macroplot one was 2,484 m^2. The density *E. decumbens* var. *decumbens* in macroplot one was 0.045 flowering individuals per m^2. Twenty-nine flowering plants were found in macroplot two. The area of the second macroplot was 170 m^2. The density *E. decumbens* var. *decumbens* in macroplot two was 0.171 flowering individuals per m^2. The third macroplot contained 75 flowering individuals within an area of 1008 m^2. The density *E. decumbens* var. *decumbens* in the final macroplot was 0.074 flowering individuals per m^2. The overall area of the site was estimated to be 10,792 m^2. Therefore, the estimated density at of the *E. decumbens* var. *decumbens* population at the Basket Slough observation deck is 0.020 flowering individuals per m^2.

Table 4.2. Individual macroplot densities for the Basket Slough population of *Erigeron decumbens* var. *decumbens*.

Macroplot	# Flowering Plants	Area Monitored (m^2)	Population Density (# Flowering Plants/m^2)
Macroplot 1	112	2,484	0.045
Macroplot 2	29	170	0.171
Macroplot 3	75	1,008	0.074
Total site	216	10,792	0.020

Summary

Overall, *E. decumbens* var. *decumbens* population densities ranged from 0.029 to 3.25 flowering stems per m^2. Table 4.3 summarizes the population density estimates for the six *E. decumbens* var. *decumbens* sites used in this study.

Table 4.3. Summary of population densities for *Erigeron decumbens* var. *decumbens* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# flowering individauls)	Total (sub) population area (m^2)	Total # individuals	Population density flowering indls/m^2 (SE)
Kingston Prairie	Census subpopulation	n/a	n/a	3,400	98	0.029
McClun Road	Census population	n/a	n/a	12,200	477	0.039
Willow Creek	Census macroplot	n/a	n/a	10,060	578-1499	0.057-0.149
Muddy Creek	Census population	n/a	n/a	3,960	135	0.034
Bald Hill	Census 2 subpopulations	n/a	n/a	4, 10	13, 12	3.25-1.2
Basket Slough	Census 3 macroplots	n/a	n/a	3,878 (3 macroplots)	216	0.045-0.171 (0.056 ave)

Discussion

Erigeron decumbens var. *decumbens* population densities ranged from 0.029 flowering plants per m^2 to 3.25 flowering plants per m^2. As with *Delphinium pavonaceum* (see Chapter III), the population with the fewest individuals (Bald Hill) had the highest population density. When Bald Hill is removed from the group of populations studied, the population density range is much narrower (0.029-0.171 flowering individuals per m^2). Once again, this is primarily due to the fact that the small populations generally consist of a single patch of plants in a very limited area, whereas the larger populations are made up of multiple patches scattered across variable habitat. The areas of these larger populations tend to have more unsuitable habitat located amongst the patches of suitable habitat, and the resulting larger area decreases the population density.

It was also interesting to note the range of plant counts over time at the Willow Creek population. Flowering individual counts ranged from just under 600 to almost 1500 (see Table 4.1), an almost three-fold difference between certain years.

When calculating the amount of habitat need to support a *E. decumbens* var. *decumbens* population of a certain size, it will be important to determine the nature of that habitat. Ideally, protected habitat will be of a more open and extensive nature, with patches of suitable microhabitat scattered throughout. If this is the case, then the lower density estimates should be used to estimate the amount of habitat needed. Finally, the variability of population sizes from year to year also indicate that, in order to increase the likelihood of achieving protection of the minimum population desired, conservative estimates of population density should be used as guidance for designating protected habitat.

Chapter V. *Horkelia congesta* ssp. *congesta*

Introduction

Horkelia congesta ssp. c*ongesta* (Figure 5.1), a rare member of the rose family (Rosaceae), is restricted to small native wetland and upland prairie remnants in the Willamette and Umpqua River Valleys of western Oregon. The limited range of this naturally rare species has been further reduced by ongoing habitat loss and degradation.

Species information

Species status: The U.S. Fish and Wildlife Service categorizes *Horkelia congesta* ssp. *congesta* as a Species of Concern, and the Oregon Department of Agriculture designates it a Candidate species for state protection. This species is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G4/T2/S2 (the subspecies is imperiled throughout its range/imperiled in Oregon) (ORNHIC 2007).

Figure 5.1. *Horkelia congesta* ssp. *congesta* inflorescence.

Species description: *Horkelia congesta* ssp. *congesta* is a taprooted perennial with erect 1-4 dm tall flowering stems (usually simple but sometimes dichotomously branched) arising from few-leaved rosettes. Basal leaves are 5-15 cm long, with pilose or hirsute petioles and silky-villous leaf blades,

possessing 2-5 pairs of leaflets. Flowering heads (cymes) are congested and capitate, terminating the mostly simple or sparingly branched stems. Hypanthia are hemispheric, 3-4 mm wide, and glabrous within. Petals are creamy white, rotund, and exceed the lanceolate sepals. The 10 stamens are obscurely biseriate and anthers are broader than long (0.4-0.7 mm long) (Keck 1938).

To help discriminate *Horkelia congesta* ssp. *congesta* from two other congeners occurring within the species' range (*H. tridentata* and *H. congesta* ssp. *nemorosa*), Kaye (1995) conducted a morphometric analysis using 18 morphological traits. Results of this study indicate that stipule shape is the most useful trait for distinguishing *H. congesta* ssp. *congesta* from *H. congesta* ssp. *nemorosa*, with those of the former taxon being markedly dissected into linear segments and those of the latter being only shallowly divided with broad segments. *Horkelia tridentata* can be distinguished by having much narrower petals (more than twice as long as wide) than *H. congesta* ssp. *congesta*, and having stems almost completely red-brown pigmented, as opposed to only partial and/or weak pigmentation of stems in *H. congesta* ssp. *congesta*.

Habitat/range: The type specimen of *Horkelia congesta* ssp. *congesta* was collected by northwest explorer David Douglas "…on the low hills of the Umpqua River [Douglas County] upon the North-west coast of America" (Hooker 1829). Currently, there are 38 populations of this species reported by the Oregon Natural Heritage Information Center (as of June 2005), though some of these are historic occurrences. *H. congesta* ssp. *congesta* is known to be extant in four counties, Douglas, Benton, Lane, and Linn, with historic occurrences in Marion and Washington Counties (ORNHIC 2005). The lack of recent sightings of the species in the latter two counties may indicate that *H. congesta* ssp. *congesta* has been extirpated from the northern portion of its range.

The habitat of *Horkelia congesta* ssp. *congesta* is described by Kaye and Gisler (1993) as "grassland and oak savannah remnants in the Willamette Valley and…grassy balds in the Umpqua Valley." Within Willamette Valley prairies, populations occupy a variety of microsites, ranging from slight topographic rises within wet prairies to distinctly dry uplands,

and from completely open areas (i.e., grassy balds) to shady understories of oak/fir woodlands. Extant populations range in elevation from 275-1760 feet, with higher elevation sites located in the southern portion of the species' range (ORNHIC 2005).

According to herbarium label and Oregon Natural Heritage Program sighting report information, *Horkelia congesta* ssp. *congesta* is commonly associated with the following native and introduced species: *Agrostis tenuis*, *Allium amplectens*, *Brodiaea congesta*, *Camassia quamash*, *Centaurium umbellatum*, *Chrysanthemum leucanthemum*, *Cynosurus echinatus*, *Cytisus scoparius*, *Dactylis glomerata*, *Danthonia californica*, *Deschampsia caespitosa*, *Daucus carota*, *Eriophyllum lanatum*, *Festuca arundinaceae*, *F. rubra*, *Fragaria virginiana*, *Fraxinus latifolia*, *Holcus lanatus*, *Hypericum perforatum*, *Lathyrus holochlorus*, *Lomatium utriculatum*, *Lotus micranthus*, *Potentilla gracilis*, *Prunella vulgaris*, *Pseudotsuga menziesii*, *Quercus garryana*, *Q. kelloggii*, *Rosa eglanteria*, *R. nutkana*, *Rubus procerus*, *R. discolor*, *Sanicula crassicaulis*, *Saxifraga oregana*, *Sidalcea campestris*, *S. virgata*, *Symphyotrichum hallii*, and *Toxicodendron diversilobum* (OSU herbarium records, ONHP 2002).

Threats: Aside from the obvious threats of habitat loss and invasive weeds, *Horkelia congesta* ssp. *congesta* is threatened by successional changes to its grassland habitat. According to Kaye and Gisler (1993), "Succession of woody plants in the habitat is cause for concern. In the absence of fire, woody shrubs and trees may shade and outcompete many prairie plant species, resulting in a conversion of prairie/savannah habitat to woody thicket or riparian forest." Kaye (1999) also lists grazing by deer as a potential threat to *H. congesta* ssp. *congesta*.

Study sites

Five study sites were used to determine density estimates for *H. congesta* ssp. *congesta*: Long Tom Area of Critical Environmental Concern, Willow Creek Preserve, Speedway (part of the West Eugene Wetlands), Dorena Reservoir, and the Ben Irving Reservoir (Figure 5.2).

For a complete list of all sites visited during the course of the study, as well as directions and GPS points for these sites, see Appendix 1.

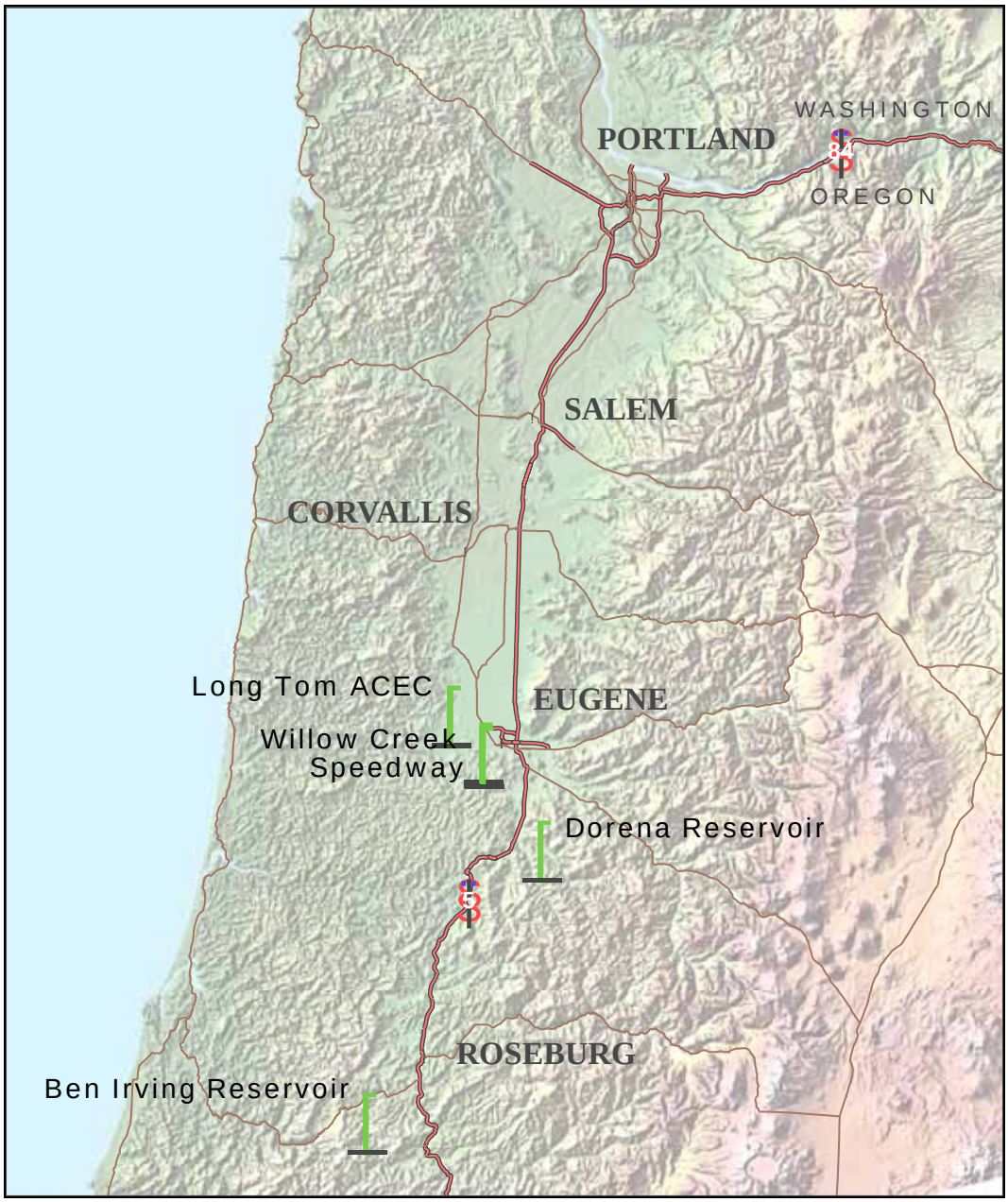

Figure 5.2. *Horkelia congesta* ssp. *congesta* populations visited during the course of this study.

Long Tom Area of Critical Environmental Concern: The Long Tom Area of Critical Environmental Concern (ACEC), owned by the Bureau of Land Manangement (Eugene District, Coast Range Resource Area), is located slightly northwest of Eugene. The ACEC covers approximately two acres located along the Long Tom River, nestled between private lands currently used for agricultural purposes. This site is part of the greater West Eugene Wetlands, a network of private and publicly-owned lands being managed for wetland function and rare species. The *Horkelia congesta* ssp. *congesta* population at this site consists of three distinct patches located on the south side of the Long Tom River, separated by scattered clumps of Oregon white oak (*Quercus garryana*) and shrubs. *Horkelia congesta* ssp. *congesta* plants are found in the small clearings between the trees (Figure 5.3). Current threats to this population include encroachment of trees and shrubs and competition from non-native invasive plant species.

Figure 5.3. *Horkelia congesta* ssp. *congesta* habitat at the Long Tom Area of Critical Environmental Concern. Orange flags indicate the presence of clumps of *H. congesta* ssp. *congesta* plants.

Speedway: The Speedway population of *H. congesta* ssp. *congesta* is located in West Eugene. Although at one time this site was privately owned and had an active racetrack, it is now managed by the Bureau of Land Management as part of the West Eugene Wetlands complex. This site is a relatively high quality prairie remnant, and in addition to the population of *Horkelia*, populations of *Erigeron decumbens* ssp. *decumbens*, *Lomatium bradshawii* and *Sericocarpus rigidus* are also found here. The *H. congesta* ssp. *congesta* population is scattered throughout the eastern portion of this property in an open *Deschampsia* meadow (Figure 5.4) and along the bank of Amazon Creek, which runs along the southern edge of the property. Current threats to this site are invasion of non-native plant

species (especially *Rubus armeniacus* or Himalayan blackberry), encroachment of woody species, and changes in hydrology from surrounding development (a new Walmart was recently built immediately to the south of the Speedway site).

Figure 5.4. *Horkelia congesta* ssp. *congesta* habitat at the Speedway site in West Eugene. Pink flags indicate the presence of individual plants. Directly to the south of this site is a new Walmart store and parking lot.

Willow Creek Preserve: The Willow Creek Preserve is owned and managed by The Nature Conservancy. This preserve is also part of the greater West Eugene Wetlands network, and as such is being managed for rare species. The *H. congesta* ssp. *congesta* population is located in three patches within the preserve. In addition to *H. congesta* ssp. *congesta*, this preserve also supports populations of *Erigeron decumbens* var. *decumbens, Lomatium bradshawii*, *Sericocarpus rigidus* (*Aster curtus*) and *Lupinus sulphureus* ssp. *kincaidii*. The primary threat to this population is competition from invasive weeds and encroachment of shrubs and trees (Figure 5.5).

Figure 5.5. *Horkelia congesta* ssp. *congesta* plant growing next to encroaching shrub at Willow Creek Preserve.

Dorena Reservoir: The Dorena Reservoir population of *H. congesta* ssp. *congesta* is located along the Row River Trail on the north side of the reservoir. Although the reservoir and its associated dam are managed by the Army Corps of Engineers, portions of the Row River Trail run through land managed by the Bureau of Land Management and the City of Cottage Grove. The *H. congesta* ssp. *congesta* population occurs on both sides of the BLM-managed section of the trail, primarily along the ecotone between the meadow and the *Quercus garryana*/*Pseudotsuga menziesii* forest (Figure 5.6). Additional associated species include *Agrostis* sp., *Brodiaea coronaria*, *Calochortus uniflorus*, *Camassia quamash*, *Centaurium muehlenbergii*, *Cynosurus echinatus*, *Dactylis glomerata*, Danthonia californica, *Daucus carota*, *Dodecatheon pulchellum*, *Fragaria virginiana*, *Hypochaeris radicata*, *Linum bienne*, *Plantago lanceolata*, *Sanguisorba occidentalis*, *Satureja douglasii* and *Zigadenus venosus*.

Figure 5.6. *Horkelia congesta* ssp. *congesta* habitat at Dorena Reservoir. Plants were found either in the open meadow next to the reservoir (left) or in small patches among the trees along the path that runs around the edge of the reservoir (right).

Ben Irving Reservoir: The Ben Irving Reservoir population of *H. congesta* ssp. *congesta* is located on land owned and managed by the Roseburg District of the Bureau of Land Management. The population occurs on the thinly-soiled slope above and to the west of the reservoir. In general, plants are located along the edge of an open meadow, right where the trees begin (Figure 5.7).

Figure 5.7. *Horkelia congesta* ssp. *congesta* habitat at the Ben Irving Reservoir population. Plants occur along the edge of the meadow where the trees begin.

Sites visited but not used in this study: Some of the current or historic sites visited by ODA during the course of this study did not prove to be suitable for use in the development of population density estimates. A complete list of the sites visited is available in Appendix 1.

Methodology

Overview

Deciding what to count: *Horkelia congesta* ssp. *congesta* is a taprooted perennial that does not reproduce vegetatively. Although this species is capable of producing multiple rosettes from the same branched caudex, it is often impossible to tell if closely placed rosettes are connected underground. Therefore, during the course of this study an individual plant was defined as a single rosette. Both reproductive and nonreproductive individuals were counted.

Long Tom ACEC

The Long Tom ACEC population of H. congesta ssp. congesta was visited on July 2, 2007. The fenced area south of the river was surveyed for plants, with special attention paid to areas marked as supporting individuals of *Horkelia* in previous years. Plants were initially flagged to determine the perimeter of the patches, and 100-meter tapes were used to create grids to methodically count the number of plants within each patch (Figure 5.8). The area of the population was determined by using ArcGIS to calculate the area of the polygon formed by the outside corners of each patch.

Figure 5.8. Hundred-meter tapes outlining one patch of *Horkelia congesta* ssp. *congesta* at the Long Tom ACEC. Orange pinflags show the location of clumps of *H. congesta* ssp. *congesta*. The fence indicates the eastern boundary of the ACEC.

Speedway

The Speedway population of *H. congesta* ssp. *congesta* was visited on July 3, 2007. This population was too large to census in the time available, and large patches of blackberries

made sampling the population difficult. Therefore, a 50 m x 120 m macroplot encompassing one large patch of *H. congesta* ssp. *congesta* was established, and divided into 5-meter-wide transects to facilitate counting (Figure 5.9). All *Horkelia* plants within the macroplot were censused.

Figure 5.9. Hundred-meter tapes mark the boundaries of the macroplot established to facilitate censusing a subset of the Speedway population of *Horkelia congesta* ssp. *congesta*.

Willow Creek Preserve

The Willow Creek Preserve population of *H. congesta* ssp. *congesta* was visited on June 30, 2006. This population was too large to census. The Nature Conservancy (TNC) already had three permanent macroplots encompassing the majority of the area inhabitated by *H. congesta* ssp. *congesta* installed at the site (Figure 5.10). In order to assist TNC with their monitoring while collecting data for this study, ODA counted all *H. congesta* ssp. *congesta* plants within these permanent macroplots. Two of TNC's macroplots were adjacent to each other, and ODA counted them as one subpopulation for the purposes of this study. The third

macroplot was located some distance away from the other two, through a dense patch of trees. As such, it was counted as a distinct subpopulation with its own subpopulation density.

Figure 5.10. Blue flags mark corners of permanent *Horkelia congesta* ssp. *congesta* monitoring plots at The Nature Conservancy's Willow Creek Preserve.

Dorena Reservoir

Dorena Reservoir was visited on July 5, 2007. Once the area where the *H. congesta* ssp. *congesta* plants occurred was located, field staff flagged the perimeter of the population with pinflags, and then set up a 12 m x 25 m grid encompassing the population. The gridded area was then systematically searched for *H. congesta* ssp. *congesta* plants (Figure 5.11).

Figure 5.11. Counting the *Horkelia congesta* ssp. *congesta* population at Dorena Reservoir.

Ben Irving Reservoir

The Ben Irving Reservoir was visited on June 29, 2006. It took some time to locate the *H. congesta* ssp. *congesta* population due to the imprecision of the directions. Once the population was found, field crew members marked the perimeter with pinflags. Because the population occupied a relatively small area, it was censused. A 24 m x 8 m grid encompassing the entire population area was established along the edge of the meadow (Figure 5.12). Because of the denseness of some of the patches of *H. congesta* ssp. *congesta* at this population, the population area was examined for plants one meter at a time, using a one-meter^2 PVC plot frame.

Figure 5.12. Counting *Horkelia congesta* ssp. *congesta* plants at Ben Irving Reservoir. Orange flags indicate the perimeter of the population. Because of the denseness of this population, each meter was examined with the help of a one-meter^2 plot frame.

Results

Long Tom ACEC

Three patches of *H. congesta* ssp. *congesta* were located within the Long Tom ACEC. The total number of individuals (rosettes) counted at this population was 182 (131 reproductive, 51 vegetative). The overall area of the population (the area included within the polygon encompassing all three patches) was 9,394 m^2. The overall population density of *H. congesta* ssp. *congesta* at Long Tom was 0.019 rosettes per m^2.

Because data were collected for each patch, it was also possible to calculate the individual patch densities at this site. The first patch contained a total of 71 rosettes (58 reproductive, 13 vegetative), and had an area of 400 m^2 (20 m x 20 m). The density of *H. congesta* ssp *congesta* was 0.118 rosettes per m^2 for the first patch. Forty-six rosettes (24 reproductive, 22

vegetative) were located in the second patch, within an area of 1,350 m^2 (45 m x 30 m), giving this patch a density of 0.034 rosettes per m^2. The third patch had 65 rosettes (49 reproductive, 16 vegetative), an area of 375 m^2 (15 m x 25 m), and a density of 0.173 rosettes per m^2.

Speedway

A total of 96 *H. congesta* ssp. *congesta* rosettes were counted within the 6,000 m^2 macroplot at Speedway. The density of the *Horkelia* within the macroplot was 0.016 rosettes per m^2.

Willow Creek Preserve

A total of 97 individuals (74 reproductive, 23 vegetative) of *H. congesta* ssp. *congesta* were counted within the two adjoining macroplots (treated as one subpopulation by ODA) at the Willow Creek Preserve. The combined area of these two macroplots was 13,500 m^2. The density of the *H. congesta* ssp. *congesta* for this first subpopulation was 0.007 rosettes per m^2. An additional 44 individuals (38 reproductive, six vegetative) were counted in the third macroplot (which encompasses a second, disjunct subpopulation). The area of this macroplot was 3,000 m^2. The density of this second subpopulation was 0.015 rosettes per m^2.

Dorena Reservoir

A total of 32 individuals (six reproductive, 26 vegetative) of *H. congesta* ssp. *congesta* were counted at the Dorena Reservoir population. The population covered an area of 300 m^2. The population density of *H. congesta* ssp. *congesta* at this site was 0.107 rosettes per m^2.

Ben Irving Reservoir

A total of 431 individuals of *H. congesta* ssp. *congesta* were counted at the Ben Irving Reservoir population. The area of the population was 192 m^2. The population density of *H. congesta* ssp. *congesta* at this site was 2.24 rosettes per m^2.

Summary

The population densities of *H. congesta* ssp. *congesta* ranged from 0.007 rosettes per m^2 to 2.24 rosettes per m^2. Table 5.1 summarizes the population density estimates for the five *H. congesta* ssp. *congesta* sites used in this study.

Table 5.1. Summary of population densities for *Horkelia congesta* ssp. *congesta* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# flowering stems)	Total (sub) population area (m^2)	Total # rosettes	Population density rosettes/m^2 (SE)
Long Tom ACEC	Census	n/a	n/a	9,394	182	0.019
Speedway	Census one macroplot	n/a	n/a	6,000	96	0.016
Willow Creek	Census two macroplots	n/a	n/a	13,500 and 3,000	97 and 44	0.007-0.015
Dorena Reservoir	Census	n/a	n/a	300	32	0.107
Ben Irving Reservoir	Census	n/a	n/a	192	431	2.24

Discussion

Horkelia congesta ssp. *congesta* population densities ranged from 0.007 rosettes per m^2 to 2.24 rosettes per m^2. However, the Ben Irving Reservoir population had a much higher density than any of the other populations visited, and when this population is removed from consideration, the population density range is much narrower (0.007-0.107 rosettes per m^2). The *H. congesta* ssp. *congesta* population at Ben Irving Reservoir differed from the other populations in several ways. It was the southernmost population visited. The population was on a thinly-soiled slope at a higher elevation than the other populations, which were all in or along the edges of more open meadow habitat on the Willamette Valley floor. Plants at this site were more densely distributed, but tended to be smaller in stature, while the Valley floor populations tended to have larger and more sparsely distributed plants or patches of plants. The areas of these more sparsely distributed populations tend to have more unsuitable habitat

located amongst the patches of suitable habitat, and the resulting larger area decreases the population density.

When calculating the amount of habitat needed to support a *H. congesta* ssp. *congesta* population of a certain size, it will be important to determine the nature of that habitat. In the Willamette Valley, ideal habitat will probably be of a more open and extensive nature, with patches of suitable microhabitat scattered throughout. If this is the case, then the lower density estimates should be used to estimate the amount of habitat needed.

Chapter VI. *Lathyrus holochlorus*

Introduction

Lathyrus holochlorus (Figure 6.1) is a rare papilionaceous member of the pea family (Fabaceae). It occurs in Oregon, which hosts the majority of *L. holochlorus* populations, and Washington.

Species information

Species status: The U.S. Fish and Wildlife Service categorizes *Lathyrus holochlorus* as a Species of Concern. It is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range) and has a Natural Heritage Network Rank of G2/S2 (imperiled throughout its range/imperiled in Oregon) (ORNHIC 2007). The State of Washington recognizes *L. holochlorus* as Endangered and the Washington Natural Heritage Program designates it with a rank of S1 (critically imperiled in Washington) (WNHP 2007).

Figure 6.1. *Lathyrus holochlorus* inflorescence.

Species description: *Lathyrus holochlorus* is a rhizomatous perennial herb that is 1-8 dm. tall with well developed tendrils. Climbing stems are strongly angled but not winged. Stipules are ovate to ovate-lanceolate, mostly 1/5-1/2 the length of the leaflets, sometimes constricted into 2 lobes but more usually not, with a coarsely dentate or dentate-lobed margin. Leaves

are composed of (6) 8-12 leaflets that are ovate or oblong-ovate to elliptic, 2-5 cm long, and 0.7-3 cm wide. The calyx is 9-12 mm long with ciliate teeth, the upper two teeth deltoid-lanceolate and about 1/2 the length of the lateral pair, which are linear to lanceolate and somewhat broader but shorter than the lowest calyx tooth, which is about equal to the tube. Flowers, 13-17 mm long and born 5-15 in racemes, have a whitish to creamy-yellow corolla. The banner, pale greenish-cream with faint purplish-rose lines, is 14-17 mm long. The wings of the corolla are pale lemon, about equal in overall length to the banner, the claw nearly equaling the blade. The keel is nearly white, slightly shorter than the wings, with a strongly recurved tip. Flowers fade to orange to yellow-brown with age. Pods are 3-5 cm long and 4-7mm wide (Hitchcock et al. 1961).

Habitat/range: The type specimen of *Lathyrus holochlorus* in the Oregon State University herbarium was collected by H. C. Gilbert in 1916 on the "road to the south farm" of the then Oregon Agriculture College in Corvallis, Oregon. Currently (as of June 2005), the Oregon Natural Heritage Information Center lists 84 occurrences of *L. holochlorus* in Oregon, though many of these populations are small and have poor estimated viability. The species is distributed among Benton, Clackamas, Douglas, Lane, Linn, Marion, Polk, Washington, and Yamhill Counties (ORNHIC 2005, ORNHIC 2007). There is only one population of *L. holochlorus* in Washington State, located in Lewis County on private land (Joseph Arnett, Washington Natural Heritage Program, Olympia, Washington, personal communication).

Lathyrus holochlorus typically grows along roadsides or fence rows, in grasslands, in woodlands at the base of *Quercus garryana,* or climbing in low scrubby vegetation. Species commonly associated with *L. holochlorus* include: *Camassia leichtlinii*, *Delphinium pavonaceum*, *Fraxinus latifolia*, *Holodiscus discolor*, *Quercus garryana*, *Rosa nutkana*, *Rubus* spp., *Symphoricarpos albus*, *Symphyotrichum hallii*, *Toxicodendron diversilobum*, and *Vicia* spp. (Meinke 1982, WNHP 1999, ORNHIC 2005, OSU Herbarium specimen labels).

Threats: The most common threats to *L. holochlorus* involve the loss of its unique habitat due to agricultural and urban conversions. Roadside herbicide application, grazing, and

weed invasion pose threats as well. Further compounding these pressures is evidence that *L. holochlorus* reproduces poorly (Meinke 1982).

Study sites

Seven study sites were used to determine density estimates for *L. holochlorus*: Freeway Lakes Park, Three Lakes Road, Muddy Creek, Ankeny National Wildlife Refuge, Finley National Wildlife Refuge, Highway 226 (outside of Scio) and Wisner Cemetery (Figure 6.2). See Appendix 1 for information about *L. holochlorus* sites that were visited but not used in this study.

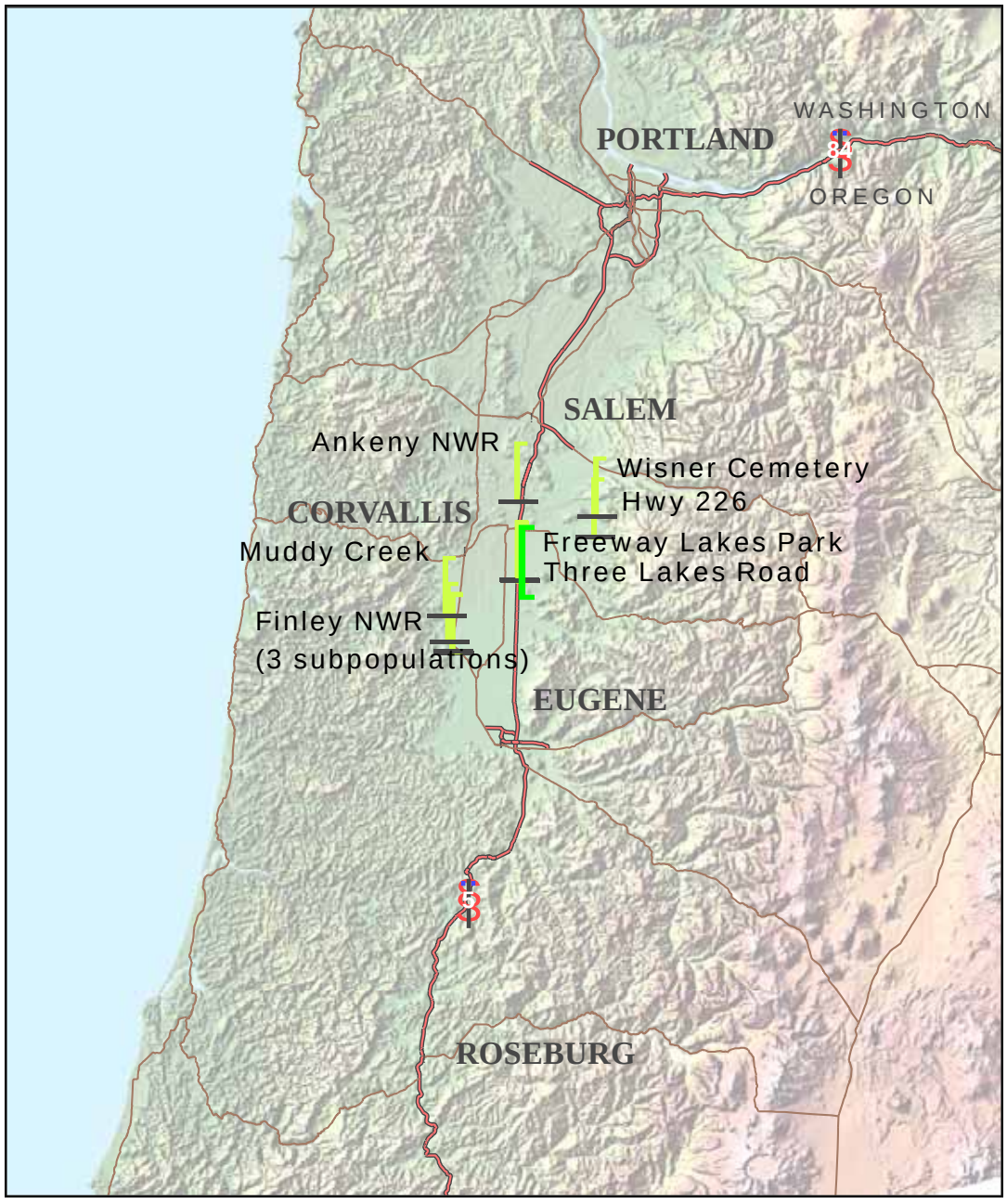

Figure 6.2. *Lathyrus holochlorus* populations visited during the course of this study.

Freeway Lakes Park: Freeway Lakes Park is owned and managed by Linn County Parks and Recreation Department. The park is made up of a series of three connected lakes located on either side of I-5, just south of Albany. Linn County currently manages this park for its primary recreational use - fishing. The *L. holochlorus* population is located within a small grove of Oregon white oaks (*Quercus garryana*), scattered around the bases of the trees and shrubs on the bank of one of the lakes (Figure 6.3), and along one end of the fence separating the County property from the ODOT I-5 right-of-way. In addition to the oak, associated species include *Galium aparine*, *Geranium molle*, *Oemleria cerasiformis, Prunus* sp., *Symphoricarpos albus*, *Tellima grandiflora* and *Toxicodendron diversilobum*. The primary threats to this population are non-native invasive weeds and disturbances caused by park users.

Figure 6.3. (Left) Looking across the lake at *Lathyrus holochlorus* habitat at Freeway Lakes Park. (Right) Green flags mark the location of individual stems of *L. holochlorus*. Most individuals are found growing up through shrubs around the bases of the trees.

Three Lakes Road: The Three Lakes Road population of *L. holochlorus* is located along the Linn County right-of-way directly south of Freeway Lakes Park (Figure 6.4). Individual plants are found within 1.5 m of the fence which separates the right-of-way from private land. On the other side of the fence is a small wooded area. Across the road is a large agricultural field, and no *L. holochlorus* plants were found along that right-of-way. Associated species include *Claytonia sibirica*, *Corylus cornuta*, *Galium* sp., *Pteridium*

aquilinum, *Ranunculus uncinatus*, *Rubus armeniacus* and *Vicia americana*. The primary threats to this population are roadside maintenance and potential future clearing (of trees and shrubs) of the adjoining private property.

Figure 6.4. *Lathyrus holochlorus* habitat along Three Lakes Road in Linn County. The small patches of white and yellow along the barbed wire fence are *L. holochlorus* flowers.

Muddy Creek: The Muddy Creek (also known as Allen and Allen) population of *L. holochlorus* is located on a privately-owned farm south of Corvallis. This site is another example of a small patch of remnant prairie that supports multiple rare plant species, including *Erigeron decumbens* var. *decumbens*, *Sidalcea nelsonia*, *Lomatium bradshawii* and *Delphinium pavonaceum* (Salix Associates 2004). A thorough rare plant survey of the property was conducted in 2004, and 30 patches of *L. holochlorus* were found at that time. It is a challenging site to survey, since the *L. holochlorus* patches are found in the thick underbrush (much of it poison oak) of the wide strip of woodland on either side of Muddy Creek, which winds its way through the property (Figure 6.5). The primary threat to this population is invasion of non-native weeds.

Figure 6.5. *Lathyrus holochlorus* habitat at Muddy Creek. Plants are found growing up through shrubs in the oak woodland strip running along the banks of the creek (left). Red flags (right) indicate individual stems of *L. holochlorus*.

Ankeny National Wildlife Refuge: The Ankeny National Wildlife Refuge population of *L. holochlorus* is located along the fencerow that separates the Refuge from the Marion County right-of-way along Buena Vista Road. As with other populations of this species, *L. holochlorus* stems are found growing up through the shrubs (especially the poison oak!) found along the fence (Figure 6.6). Some stems are also found in the grassy area immediately adjacent to the shrubs. Associated species at this site include *Acer macrophyllum*, *Camas leichtlinii*, *Heracleum lanatum*, *Hypochaeris radicata*, *Quercus garryana*, *Rosa nutkana*, *Rubus armeniacus*, *Salix* sp., *Sidalcea campestris*, *Tellima grandiflora*, *Toxicodendron diversiloba* and *Vicia americana*. Although the

Figure 6.6. *Lathyrus holochlorus* habitat along Buena Vista Road at the border of the Ankeny National Wildlife Refuge.

Refuge is managed for rare species, including *L. holochlorus*, the County right-of-way is not. The primary threat to this population is roadside maintenance activities such as herbicide spraying.

Finley National Wildlife Refuge: According to Oregon Natural Heritage Information Center records (ORNHIC 2005), the Finley National Wildlife Refuge supports eight subpopulations or patches of *L. holochlorus*. These subpopulations are grouped under three ORNHIC element occurrence identification numbers. Descriptions of subpopulation locations indicate that they are all located along the edge of forested areas, next to an opening such as a marsh (Figure 6.7), Muddy Creek (Figure 6.8), a road (Figure 6.8) or an open field. The Refuge is managed for many rare species, including *L. holochlorus*.

Figure 6.7. Looking across a marsh from Finley Refuge Road toward *Lathyrus holochlorus* subpopulation at Finley National Wildlife Refuge.

Figure 6.8. *Lathyrus holochlorus* habitat at Finley National Wildlife Refuge. Plants are found along forest edges such as near the bank of Muddy Creek (right) or along the roadside (left).

Highway 226 (Scio): The Highway 226 population of *L. holochlorus* is located along the ODOT right-of-way approximately three miles east of Scio, in Linn County (Figure 6.9). Like many of the other visited L. holochlorus populations, plants at this site are growing up through relatively thick vegetation, dominated by *Sericocarpus albus* and various grasses. Threats to this site include roadside maintenance activities (especially herbicide spraying) and potential management activities on the privately owned property adjacent to the right-of-way.

Figure 6.9. *Lathyrus holochlorus* habitat along Highway 226.

Wisner Cemetery (Kingston-Jordan Drive): The Wisner Cemetery population of *L. holochlorus* is located along the Linn County Kingston-Jordon Drive right-of-way (Figure 6.10). This small population is actually situated across the road from the cemetery, in a patch of *Rosa* sp. The primary threat to this population is roadside maintenance activities, including mowing and spraying.

Figure 6.10. *Lathyrus holochlorus* habitat along Kingston-Jordan Drive, across from Wisner Cemetery.

Sites visited but not used in this study: Some of the current or historic sites visited by ODA during the course of this study did not prove to be suitable for use in the development of population density estimates. A complete list of the sites visited is available in Appendix 1.

Methodology

Overview

Lathyrus holochlorus was one of the more challenging plants to count in the field, due to the fact that its preferred habitat is dense thickets and brush (often consisting of poison oak and thorny shrubs). This species is rhizomatous, and sends up stems which can be over a meter in height. Because it is impossible to determine if stems are connected underground by rhizomes, an "individual" was defined as a single stem (whether branched or unbranched) coming from the ground. In cases where the vegetation prevented the tracing of individual stems back to the ground, researchers differentiated between connected branches on one stem and single stems by gently moving the stem in question and observing the movement (or lack thereof) of nearby stems. This process was carefully conducted, since stems were fragile and easily broken.

Freeway Lakes Park

Freeway Lakes Park was visited on May 8, 2006. The site was surveyed for L. holochlorus and the perimeter of the population was marked with pinflags. A 40 m x 23 m rectangle encompassing the population was installed using 100-meter tapes. There were too many stems to count in the time available, so the population was sampled. The large

Figure 6.11. *Lathyrus holochlorus* growing up through *Sericocarpus albus* at the base of a tree at Freeway Lakes Park.

number of trees (and the fact that most of the stems were around the base of the trees, see Figure 6.11) made installation of transects difficult, so the population area was instead divided into eight 10 m x 11.5 m quadrats. Four of these quadrats were randomly selected, and all *L. holochlorus* stems were counted within those quadrats (Figure 6.12).

Figure 6.12. Quadrats used for sampling *Lathyrus holochlorus* population at Freeway Lakes Park. Red lines approximate quadrat locations. All *L. holochlorus* stems were counted in four (out of eight total) randomly selected quadrats.

Three Lakes Road

The Three Lakes Road population of *L. holochlorus* was visited on May 15, 2006. Two field crew members started at the center of the population and walked away from each other along the side of the road surveying for plants, stopping when the habitat ended (the private property on the other side of the fence transitioned from wooded habitat to an agricultural field with no brush along the fence). Population GPS endpoints were recorded. The two staff members then walked back towards the center of the population, counting each *L.*

holochlorus stem seen as they walked Figure 6.13). The GPS endpoints were used to determine the length of the population. The width (distance from fence within which *L. holochlorus* occurred) was measured with a meter stick.

Figure 6.13. Counting *Lathyrus holochlorus* stems along Three Lakes Road. All plants were found within a two-meter-wide strip of shrubs and brambles hugging the fence that separates the right-of-way from private property.

Muddy Creek

The Muddy Creek population of *L. holochlorus* was visited on May 10 and May 12, 2006. This population was too large, spread out and difficult to access to census. A previous survey located 30 patches scattered throughout the woods on this property. A sample of five of these patches (I, K, L, Z and AB; see Salix Associates 2004 for patch descriptions and locations) was randomly selected and censused (Figure 6.14). An estimate of the total number of *L. holochlorus* stems present at Muddy Creek was derived from the sample patch counts. The GPS points for all of the patches were mapped, and the overall population area

was considered to be the area of the polygon encompassing all patches (whether or not they were to counted). The area of this polygon was calculated using ArcGIS.

Figure 6.14. Oregon Department of Agriculture botanist Troy Maddux counting *Lathyrus holochlorus* stems in one of the patches sampled at Muddy Creek.

Ankeny National Wildlife Refuge

Ankeny National Wildlife Refuge was visited on May 15, 2006. The *L. holochlorus* plants were located along the fence separating the Refuge from the right-of-way along Buena Vista Road. ODA surveyed both sides of the fence (Figure 6.15). No plants were found on the Refuge side of the fence. However, because most plants were located in dense patches of poison oak, it is possible that small

Figure 6.15. Surveying for *Lathyrus holochlorus* at Ankeny National Wildlife Refuge.

vegetative stems were present but not counted. The area was calculated by measuring the length and the width of the population using meter tapes.

Finley National Wildlife Refuge

Finley National Wildlife Refuge was visited on May 17, 2006. Although ORNHIC records indicated that there were eight subpopulations (grouped under three ORNHIC element occurrence numbers) of *L. holochlorus* at the Refuge, ODA staff were only able to access and locate three of these subpopulations. Because of the large distance and patchy habitat between subpopulations, the density of each subpopulation was calculated independently. The first subpopulation is located along the edge of the strip of trees separating the marsh on the south side of Finley Refuge Road from Muddy Creek (Figure 6.16), and consists of two small patches of plants separated from each other by approximately six meters. The second subpopulation is located along a hedgerow along Bruce Road. The third subpopulation is located to the west of the dirt road running between McFadden Marsh and Muddy Creek, growing in dense vegetation near the bank of the creek. Each located subpopulation was censused. The area of each subpopulation was considered to be the area of the rectangle which encompassed the entire subpopulation. The length and width of these rectangles were measured using meter tapes.

Figure 6.16. Counting *Lathyrus holochlorus* stems at the first subpopulation at Finley National Wildlife Refuge. Each pink flag represents one stem.

Highway 226

The Highway 228 population of *L. holochlorus* was visited on May 22, 2006. The roadside right-of-way was surveyed. Because the population was very small, a census was completed at this site. The population area was calculated by measuring the length and width with meter tapes.

Wisner Cemetery

The Wisner Cemetery population of *L. holochlorus* was visited on May 22, 2006. The area was surveyed for plants. Because the population was quite small, it was censused. The area of the population was calculated by measuring the length and the width of a rectangle that encompassed all plants with a meter stick.

Results

Freeway Lakes Park

A total of 302 stems of *L. holochlorus* were counted in the four quadrats sampled at Freeway Lakes Park (Table 6.1). The total area sampled was 460 m^2. The population density at this site was 0.657 stems per m^2 (SE=0.313).

Table 6.1. Number of *Lathyrus holochlorus* stems counted in each of four randomly selected quadrats at Freeway Lakes Park.

Quadrat #	# Stems	Area (m^2)
1	161	115
4	35	115
6	0	115
8	106	115
Total	302	460

Three Lakes Road

A total of 177 *L. holochlorus* stems were counted at the Three Lakes Road population. These plants stretched along the side of the road for 122 m. The plants were all found within a strip of fencerow habitat that was approximately two meters wide. The total area for this population was 244 m^2. The population density of *L. holochlorus* at the Three Lakes Road site was 0.725 stems per m^2.

Muddy Creek

The number of stems counted in each of the six patches of *L. holochlorus* sampled at the Muddy Creek population is summarized below in Table 6.2. The average number of *L. holochlorus* stems per patch is estimated to be 76 stems per patch (SE = 36). The estimated total number of *L. holochlorus* stems at Muddy Creek is 2,280 stems (76 stems/patch x 30 patches). The total area (calculated from GPS points at corners of the polygon) is 159,750 m^2. The estimated population density of *L. holochlorus* at Muddy Creek is 0.014 stems per m^2(SE=0.007).

Table 6.2. Number of stems counted at five randomly sampled patches of *Lathyrus holochlorus* at Muddy Creek.

Patch	# Stems (SE)
I	140
K	11
L	186
Z	26
AB	18
Total	381
Average # Stems/Patch (SE)	76 (36)

Ankeny National Wildlife Refuge

A total of 26 *L. holochlorus* stems were counted at this population. The area of the population was 54 m^2 (18 m x 3 m). The population density of *L. holochlorus* at Ankeny National Wildlife Refuge was 0.481 stems per m^2.

Finley National Wildlife Refuge

A summary of the data collected for the three Finley National Wildlife Refuge subpopulations of *L. holochlorus* is located below in Table 6.3. A total of 130 stems were counted in subpopulation one. The area of this subpopulation was 85 m^2. The density of subpopulation one was 1.53 stems per m^2. The second subpopulation consists of two very small patches of *L. holochlorus*, one with five stems and the second with four stems, for a total of nine stems. The area of this subpopulation was nine m^2. The density of subpopulation two was 1.00 stems per m^2. Subpopulation three consisted of four stems in a two m^2 area, and the density of this subpopulation was 2.00 stems per m^2.

Table 6.3. Size and area of Finley National Wildlife Refuge subpopulations of *Lathyrus holochlorus*.

Subpopulation	# Stems	Area (m^2)	Density (stems/m^2)
1	130	85	1.53
2	9	9	1.00
3	4	2	2.00

Highway 228

A total of seven stems were located within a 15 m^2 area at Highway 226. The population density of *L. holochlorus* at this population is 0.467 stems per m^2.

Wisner Cemetery

A total of five stems of *L. holochlorus* were counted at the Wisner Cemetery population. The population area was two m^2. The density of this population was 2.50 stems per m^2.

Summary

The population densities of *L. holochlorus* ranged from 0.014 stems per m^2 to 2.00 stems per m^2. Table 6.4 summarizes the population density estimates for the seven *L. holochlorus* sites used in this study.

Table 6.4. Summary of population densities for *Lathyrus holochlorus* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# stems)	Total (sub) population area (m^2)	Total # stems	Population density stems/m^2 (SE)
Freeway Lakes Park	Sample	460	302	920	*604*	*0.657 (0.313)*
Three Lakes Road	Census	n/a	n/a	244	177	0.725
Muddy Creek	Census 5 of 30 patches	5 patches	381	*159,750* (30 patches)	*2,280*	*0.014 (0.007)*
Ankeny NWR	Census	n/a	n/a	54	26	0.481
Finley NWR	Census 3 subpopulations	n/a	n/a	1 = 85 2 = 9 3 = 2	1 = 130 2 = 9 3 = 4	1 = 1.53 2 = 1.00 3 = 2.00
Hwy 226	Census	n/a	n/a	15	7	0.467
Wisner Cemetery	Census	n/a	n/a	2	4	2.00

Discussion

There appear to be two distinct types of habitat preferred by *L. holochlorus*, both of which provide some structure for *L. holochlorus* "vines" to climb. The first type is fencerows, which are typically located along roadsides. These populations of *L. holochlorus* tend to grow in the midst of the vegetation hugging the fence (and somewhat protected from mowing), straddling the public right-of-way and the often privately-owned adjacent property. The second type of habitat is found along the edge of forests or woodland, whether riparian or otherwise, where the *L. holochlorus* prefers the company of shrubs (i.e. poison oak, rose and snowberry) growing around the bases of trees.

Due to the nature of the second type of *L. holochlorus* habitat, this species presented the greatest challenge when attempting to develop meaningful population density estimates (which could then be used to make management decisions such as determining the area of protected habitat needed to support viable populations of this species). In particular, it was

difficult to determine what the "area" of a given population should be, since plants were typically found in small patches scattered throughout woodlands. Whether or not the area is defined as the habitat occupied by a patch of *L. holochlorus*, or the overall habitat encompassing multiple patches of this species, greatly impacts the estimated density of that population. ODA used the broader definition of "area" in cases where a population consisted of multiple patches located relatively closely to each other.

Lathyrus holochlorus population densities ranged from 0.014 stems per m^2 to 2.00 stems per m^2. The Muddy Creek site had the lowest population density, due to the fact that it had the largest area (the site consists of 30 patches spread over almost 160,000 m^2 (almost 40 acres) of potential *L. holochlorus* habitat. When calculating the amount of habitat need to support a *L. holochlorus* population of a certain size, it will be important to determine the nature of that habitat. Since roadside habitats of rare plants are by their very nature vulnerable to disturbance and extinction, one might expect that future protection of *L. holochlorus* habitat would focus on sites more closely resemble the second type of habitat discussed above. If this is the case, then the lower density estimates should be used to estimate the amount of habitat needed.

Chapter VII. *Lomatium bradshawii*

Introduction

Lomatium bradshawii. (Figure 7.1) was once found throughout the extensive native prairies of the Willamette Valley of Oregon, as well as in southwestern Washington (Kagan 1980, WNHP 1999). Habitat loss and degradation have caused severe declines in this native member of the carrot family (Apiaceae), prompting action from federal and state governments to protect the species.

Species information

Species status: *Lomatium bradshawii* is listed as endangered by both the U.S. Fish and Wildlife Service and the State of Oregon. It is on the Oregon Natural Heritage Information Center List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G2/S2 (imperiled throughout its range/imperiled in Oregon) (ORNHIC 2007). *Lomatium bradshawii* is listed as Endangered by Washington State, though this status carries no legal mandate for protection on state or other public lands (Florence Caplow, Washington Natural Heritage Program, Olympia Washington, personal communication). The species is assigned a rank of S1 (critically imperiled in Washington) by the Washington Natural Heritage Program (WNHP 2007).

Figure 7.1. *Lomatium bradshawii* umbel.

Species description: *Lomatium bradshawii* is a low, erect perennial arising from a long slender taproot. Overall, the plant is glabrous and has leaves 4-12 inches long which are dissected into linear or filiform segments. *Lomatium bradshawii* has small light yellow flowers that occur in umbels (umbellets are rarely larger than 1 cm across). Generally, only 2-5 flowers in each umbel are actually fertile. The fruit of this *Lomatium* is oblong, 1/4-1/2 inch long and glabrous with thickened, corky wings and inconspicuous dorsal ribs (Hitchcock 1961). The plant's blooming period peaks around the end of April and beginning of May, but flowers may be observed as early as the first week of April through the end of May (Kagan 1980).

This species is distinguished from other species of *Lomatium* by its conspicuously ternately divided free involucel bracts. *L. utriculatum*'s range overlaps with that of *L. bradshawii*, but its involucels are shallowly cleft and its fruit is thinly winged (WNHP 1999).

Habitat/range: For many years *Lomatium bradshawii* was considered a Willamette Valley endemic, its range limited to the area between Salem and Creswell, Oregon (Kagan 1980). However, in 1994 two populations (now considered to be one large population) of the species were discovered in Clark County, Washington (CPC 2007, Joseph Arnett, Washington Natural Heritage Program, Olympia, Washington, personal communication). The Oregon Natural Heritage Information Center currently lists 48 occurrences of *L. bradshawii* (as of June 2005) distributed in Benton, Lane, Linn, and Marion Counties, Oregon. Most of these populations are small, ranging from about 10 to 1,000 individuals, although the largest site contains approximately 30,000 plants (ORNHIC 2005). The single Washington population is larger than all the Oregon populations combined, however, it occurs on private land and therefore lacks protection (WNHP 2004, CPC 2007).

According to Siddall and Chambers (1978), the species was first collected in Salem by Nelson in 1916. Bradshaw collected the type specimen a few years later, in 1921, in "low swales near the high school, Eugene, Oregon." Siddall and Chambers describe *L. bradshawii*'s habitat as undisturbed sites of native Willamette Valley grassland, with associated species including: *Carex* spp., *Deschampsia caespitosa*, *Eryngium petiolatum*,

Galium cymosum, Grindelia integrifolia, *Hordeum brachyantherum*, *Juncus* spp., *Microseris laciniata*, *Perideridia* sp., and *Poa pratensis*. Kagan (1980) further elaborates that the *Lomatium* occurs on and around the small mounds created by senescent *Deschampsia caespitosa* plants, and lists the following additional associates: *Carex aurea*, *C. lasiocarpa*, *C. lanuginose*, *C. obnupta*, *Danthonia californica*, *Juncus patens*, *J. acuminatus* and *Luzula campestris*. All of the populations studied by Kagan occur within 500 meters of the banks of creeks or small rivers, where soils largely consist of clay, and are shallow and poorly drained. These sites often have standing water until late spring or early summer. In populations near the Santiam River in Marion and Linn Counties, Kaye and Kirkland (1994) found that *L. bradshawii* plants occupy thin, seasonally saturated soils overlying basalt.

Threats: The historical and continuing loss and degradation of Willamette Valley prairie habitat is a pressing concern for *Lomatium bradshawii*. Agricultural, commercial and residential development has almost completely eliminated the native grasslands of this area; currently less than one percent of the Willamette Valley prairie remains intact (CPC 2007). Pesticides, encroachment of woody and invasive species, herbivory, and grazing are also threats to remaining *L. bradshawii* populations.

The majority of Oregon's *Lomatium bradshawii* populations are located within a ten mile (16 km) radius of Eugene. The continued expansion of this city is a potential threat to the persistence of the species at these sites. Even when the sites themselves are protected, the resultant changes in hydrology caused by surrounding development can alter the species' habitat (Meinke 1982, USFWS 1988, WNHP 1999, CPC 2007). Siddall and Chambers (1978) state that the majority of sites from which herbarium specimens have been collected are within areas of Salem or Eugene which are now developed for housing and agriculture.

Many *L. bradshawii* populations occur near roadways and other areas that are sprayed with pesticides. There is concern that these pesticides will kill the pollinators necessary for plant reproduction. Because *L. bradshawii* does not form a seed bank, any loss of pollinators (and subsequent lack of successful reproduction) could have an immediate effect on population numbers (Kaye and Kirkland 1994).

The final rule granting *L. bradshawii* federal endangered status (USFWS 1988) states that one of the most significant threats to *L. bradshawii* is encroachment of its habitat by woody vegetation. Historically, Willamette Valley prairies were periodically burned, either by wildfires or by fires set by Native Americans (Johannessen et al. 1971). Since European settlers arrived, fire suppression has allowed shrubs and trees to invade grassland habitat (USFWS 1988, Kaye 1993).

Robinson (1998) indicated that "vole herbivory at some sites is a major threat to local species viability." Studies of the effects of cattle grazing on *L. bradshawii* populations have had mixed results. Grazing in the springtime, when *L. bradshawii* plants are growing and reproducing, can negatively impact the plants by biomass removal, trampling, and soil disturbance (CPC 2004). However, late-season livestock grazing, after fruit maturation, led to an increase in emergence of new plants, and the density of plants with multiple umbels, although it did not alter survival rates or population structure (Drew 2000).

Study sites

Six study sites were used to determine density estimates for *L. bradshawii*: Muddy Creek, Kingston Prairie Preserve, Jackson-Frazier Wetland, Oak Creek Easement, Sublimity Grassland and the Willow Creek Preserve (Figure 7.2). For a complete list of all sites visited during the course of the study, as well as directions and GPS points for those sites, see Appendix 1.

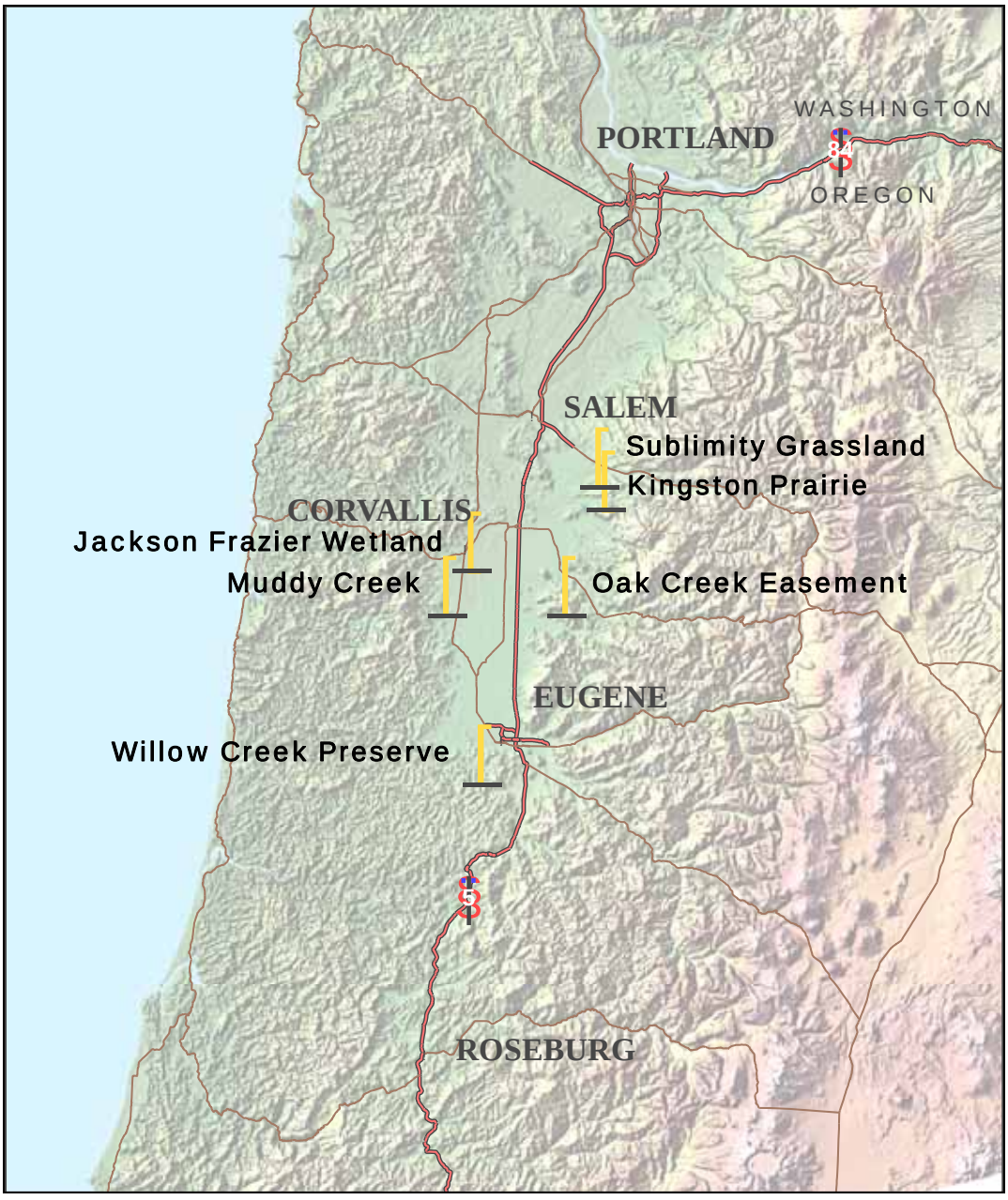

Figure 7.2. *Lomatium bradshawii* populations visited during the course of this study.

Muddy Creek: The Muddy Creek (also known as Allen and Allen) population of *L. bradshawii* is located on a privately-owned farm south of Corvallis. This property contains a small patch of degraded prairie that supports multiple rare plant species, including *Delphinium pavonaceum*, *Erigeron decumbens* var. *decumbens*, *Lathyrus holochlorus* and *Sidalcea nelsonia* (Salix Associates 2004). A thorough rare plant survey of the property was conducted in 2004, and 45 "patches" of *L. bradshawii* were found at that time. The patches were rather arbitrarily assigned, since many of them were quite close together. The bulk of the population was located within approximately 20 m of the ditch that runs through the middle of the field (Figure 6.3). However, some plants were also located in small clearings amongst the trees directly to the north of the ditch. The primary threat to this population is invasion of non-native weeds, particularly reed canary grass (*Phalaris arundinacea*).

Figure 6.3. *Lomatium bradshawii* habitat at Muddy Creek. Plants are located in the field along either side of the ditch that runs through the middle of the property.

Jackson-Frazier Wetland: The Jackson-Frazier Wetland is owned by Benton County. Established as a park in 1992, the site managed for the protection of the natural features of the area (including wetlands and rare plants). County-sanctioned activities at this site include education, research and public use (Benton County 2007). This site's small population of *L. brandshawii* is located along the edge of a seasonally wet remnant of prairie (Figure 6.4), not far from residential development. Threats to this population include encroachment of woody species (although Benton County currently controls encroachment with targeted burning) and disturbance by recreational users who stray from the designated paths.

Figure 6.4. *Lomatium bradshawii* habitat at Jackson-Frazier wetland. Plants are located in a small patch not far from the parking lot. Pink flags indicate patches of L. brandshawii. Flagging and tapes show the boundaries of the population.

Kingston Prairie Preserve: Owned and managed by The Nature Conservancy, Kingston Prairie is a small, relatively high quality remnant of prairie which supports several rare Willamette Valley species, including *Erigeron decumbens* var. *decumbens*, *Lomatium bradshawii*, and *Sericocarpus rigidus* (*Aster curtus*). This site is located in Linn County near Stayton. The *L. bradshawii* population is located in the seasonally wet open area adjacent to a small stream that runs through the property (Figure 6.5). The primary threat at this site is invasion of non-native exotic plants species.

Figure 6.5. *Lomatium bradshawii* habitat at the Kingston Prairie Preserve. Plants are located in the seasonally wet prairie remnant on the far side of the stream in the foreground.

Oak Creek Easement: The Oak Creek Easement population of L. bradshawii is located slightly to the east of Lebanon, in Linn County. Although this site is privately owned, a portion of the property does have a permanent conservation easement. The site is currently managed by the U.S. Fish and Wildlife Service's Finley National Wildlife Refuge staff for wetland function and the conservation of *L. bradshawii*. The bulk of the population is located in an open wet meadow, in patches where the competition with the grass is less severe (Figure 6.6). Patches of *L. bradshawii* are also located in clearings scattered along the edge of the small woodland at the western edge of the field (Figure 6.7).

Figure 6.6. *Lomatium bradshawii* habitat at the Oak Creek Easement site.

Figure 6.7. A small portion of the Oak Creek Easement *Lomatium bradshawii* population is located in small clearings scattered in the trees along the edge of the meadow.

Sublimity Grassland: The Sublimity Grassland site is located on a privately-owned farm just outside of Sublimity, in Marion County. This site consists of open grassland separated by small patches of shrubs and an interrupted strip of riparian woodland (Figure 6.8). The soil at this site varies in depth, and during the winter a patchwork of vernal pools is present. Associated species include *Juncus patens*, *Saxifraga integrifolia*, *Mimulus guttatus*, *Trifolium variegatum*, *Plagiobothrys figuratus* and *Isoetes nuttallii*. The primary threats to this population include trampling by cattle (the site is currently lightly grazed), invasion of non-native invasive weeds (the site is considerably more degraded than the adjacent site, which up until recently was managed by The Nature Conservancy and presumably does not have as extensive of a grazing history), disturbance to the vegetation caused by geese that are attracted to the nearby pond (Alverson 1990) and disturbance caused by local children playing paintball (Lynda Boyer, horticulturist, Heritage Seedlings, Inc., Salem, Oregon, personal communication on May 8, 2006).

Figure 6.8. *Lomatium bradshawii* habitat at Sublimity Grassland. The site consists of a mosaic of more shallowly-soiled patches interspersed with deeper deposits (left). White flags (right) represent patches of *L. bradshawii*.

Willow Creek Preserve: The Willow Creek Preserve is owned and managed by The Nature Conservancy. This preserve is part of the greater West Eugene Wetlands network, and as such is being managed for rare species. The *L. bradshawii* population is located in three

patches within the preserve. In addition to *Lomatium bradshawii*, this preserve also supports populations of *Erigeron decumbens* var. *decumbens, H. congesta* ssp. *congesta*, *Sericocarpus rigidus* (was *Aster curtus*) and *Lupinus sulphureus* ssp. *kincaidii*. The primary threat to this population is invasive weeds and encroachment of shrubs and trees (Figure 6.9).

Figure 6.9. *Lomatium bradshawii* habitat at Willow Creek Preserve. Blue flags (right) indicate location of permanent monitoring plots used by The Nature Conservancy.

Methodology

Overview

Lomatium bradshawii is an herbaceous, taprooted perennial. Although this species is not known to spread vegetatively, it is possible for a single taproot to produce more than one stem. Without digging up the entire plant, it is difficult to tell if individual stems are part of the same plant, or if they are discrete, closely- spaced individuals. Consequently, for this study ODA defined an "individual" as a single stem arising directly from the ground.

Due to the difficulty of locating nonreproductive individuals of *L. bradshawii* within the grassland habitat preferred by this species and the high density of the patches, all visited *L. bradshawii* populations except the one at the Jackson-Frazier Wetland were sampled, rather than censused. When sampling, the microplot size was one meter x ½ meter, rather than one m^2 (as was used when sampling populations of the other species in this study).

Muddy Creek

The Muddy Creek population of *L. bradshawii* was visited on April 19, 2007. This population was too numerous (and scattered throughout an area to large) to census. Two population density estimates were derived for this site. The first was an overall site population density estimate, using the population size estimate developed by Salix Associates in their 2004 survey of the site. The overall population area was determined by using ArcGIS to draw a polygon around all of the *L. bradshawii* patches located and mapped in 2004 and calculate the area of that polygon. This method has several potential sources of error. First, the 2004 population count was derived by counting all of the individuals in each located patch of *L. bradshawii*; however, it is possible that not all vegetative individuals were counted (Dick Brainard, Salix Associates, personal communication on January 15, 2008). Secondly, depending on the accuracy of the GPS readings, there is some variability associated with the population area estimate.

The second population density estimate was derived from sampling a subset of the population (Patch A, see Salix Associates 2004). A 130-meter-long x-transect was established running through the middle of the patch (Figure 6.10). Seven y-transects were established running perpendicular to the x-transect every 20 m. The placement of the first y-transect (the point at which it crossed the y-transect) was randomly determined. The y-transects ranged in length from 13-28 m long. One meter x ½ meter plots were placed every five meters on the y-transects, with the first plot's y-transect location randomly determined. An estimate of the population density of the sampled subset was then calculated.

Figure 6.10. A 100-meter tape was used to establish an x-transect through the center of a subset of the Muddy Creek population of *Lomatium bradshawii*.

Jackson-Frazier Wetland

The Jackson-Frazier Wetland population of *L. bradshawii* was visited on April 14, 2006. This population was small enough to census. The area was surveyed for *L. bradshawii*, and the perimeter of the population was flagged. A 6 m x 9.2 m rectangle encompassing the population was established using meter tapes (Figure 6.11). The rectangle was gridded to assist with counting the individual plants. The population density was calculated from the measured area (6 m x 9.2 m) and the total number of individuals counted at the site.

Figure 6.11. Counting individuals of *Lomatium bradshawii* at the Jackson-Frazier Wetland.

Kingston Prairie Preserve

The Kingston Prairie Preserve population of *L. bradshawii* was visited on May 5, 2006. The population was too large to census. An 84 m x 68 m macroplot encompassing the bulk of the population was established and 56 one meter x ½ meter microplots were sampled on a grid within the macroplot. Microplot location was determined by selecting one of the 68-meter-long sides of the macroplot as the x-axis, and then selecting four y-transects to run the length of the macroplot (Figure 6.12). Y-transects were spaced 17 meters apart, with the location of the first one randomly determined. Microplots were located every six meters along the y-transects, with the location of the first microplot (from 0-6) randomly determined. All vegetative and reproductive plants were counted within each microplot (Figure 6.13).

Figure 6.12. The Kingston Prairie Preserve population of *Lomatium bradshawii* was sampled. The x-transect is running left to right in the foreground, and the two tapes stretching away from the x-transect are two of the y-transects. The pink flags mark the location of the microplots.

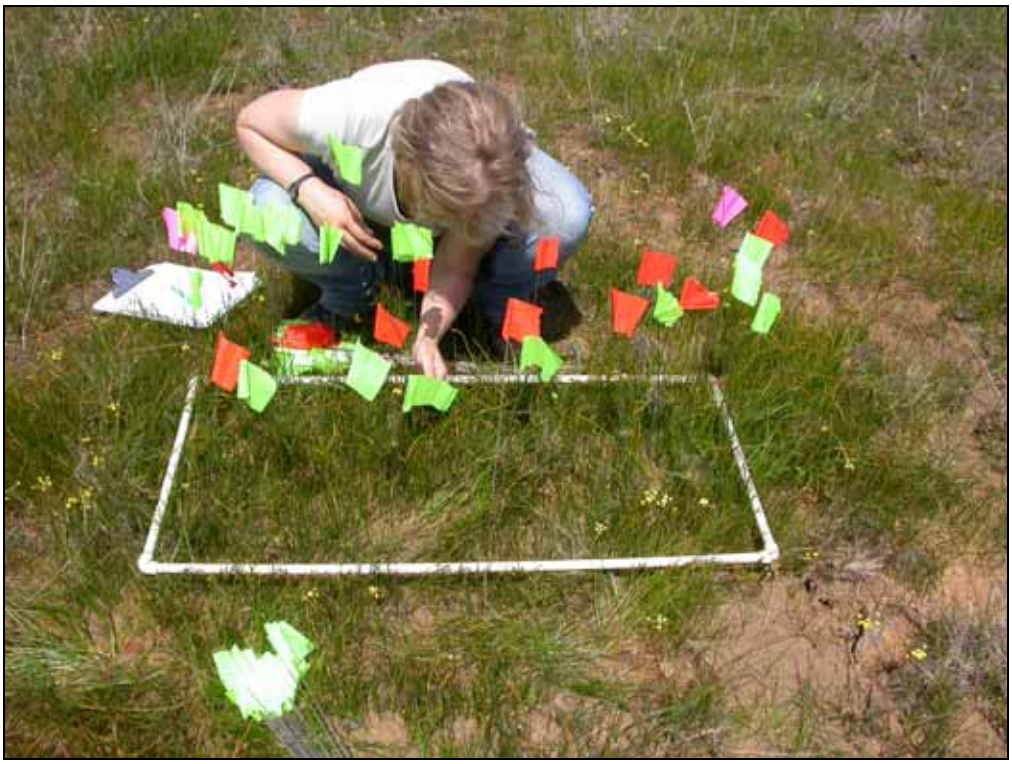

Figure 6.13. Counting *Lomatium bradshawii* plants in a one meter x ½ meter microplot at Kingston Prairie Preserve. Orange flags represent reproductive individuals, while green flags represent vegetative individuals.

Oak Creek Easement

The Oak Creek Easement population of *L. bradshawii* was visited May 1-2, 2006. This population was too large and geographically spread out to census. A 335 m x 95 m macroplot encompassing the vast majority of the population was established and sampled using a systematic sampling technique. Five transects were established running lengthwise along the macroplot (Figure 6.14). The starting point of the first transect was randomly selected, and the starting point of each additional transect was located 19 meters after that of the previous transect. Twenty microplots were located evenly along each transect, with the starting place of the first microplot randomly selected. Microplots were one meter x ½ meter. All vegetative and reproductive plants were counted within each microplot (Figure 6.15).

Figure 6.14. Laying out microplots along a transect at the Oak Creek Easement population of *Lomatium bradshawii*. Pink pinflags mark the location of microplots along the transect.

Figure 6.15. Oregon Department of Agriculture staff and volunteer counting *Lomatium bradshawii* plants at Oak Creek Easement (left). A completed microplot with pinflags marking the location of each individual of *L. bradshawii* (right).

Sublimity Grassland

The Sublimity Grassland population of *L. bradshawii* was visited May 11, 2006. This population was too large and dense to census, and a systematic sampling scheme was used to estimate the population density. The site was surveyed for *L. bradshawii*, and the perimeter of the population was flagged (Figure 6.16). A 28 m x 40 m encompassing the population was established. Four 40-meter-long transects were installed within the macroplot, with the starting point of the first transect randomly determined. Thirteen microplots were located along each of the transects, with the starting point of the first microplot randomly determined. Microplots were one meter x ½ meter. All vegetative and reproductive plants were counted within each microplot (Figure 6.17).

Figure 6.16. Botanists from the Oregon Department of Agriculture, The Nature Conservancy, and Heritage Seedlings, Inc. look for *Lomatium bradshawii* at Sublimity Grasslands.

Figure 6.17. One of the more densely populated microplots at Sublimity Grasslands. Each pinflag represents an individual of *Lomatium bradshawii*.

Willow Creek Preserve

The Willow Creek Preserve population of *L. bradshawii* was visited on May 16, 2006. The Nature Conservancy has established four permanent macroplots at this site (Macroplots 3, 4, 7 and 8), encompassing the bulk of the *L. bradshawii* population, which are monitored (sampled) annually. All macroplots are 50 m x 100 m, and each macroplot was systematically sampled by placing 10 transects, one transect randomly located within each 10 meter segment, in the macroplot. All *L. bradshawii* individuals found within those transects were recorded. In Macroplots 3, 7 and 8, the transects were 50 m long. In Macroplot 4, the transects were 25 m long (Jason Nuckols, The Nature Conservancy, personal communication on May 16, 2007). A subpopulation density for each macroplot was calculated using TNC's 2006 data. ODA staff sampled an additional two small patches of *L. bradshawii* at the Preserve (Figure 6.18); however these patches were two small to use for developing population (or subpopulation) density estimates.

Figure 6.18. A small (2 m x 2 m) patch of *Lomatium bradshawii* found at Willow Creek Preserve.

Results

Muddy Creek

Method 1 (Density calculated using 2004 population data): A total of 7600 individuals of *L. bradshawii* were counted in 45 patches at Muddy Creek in the spring of 2004 (Salix Associates 2004). The overall area of the population (the area of the polygon encompassing all 45 patches) was 28,228 m^2. The overall density for this population is 0.269 individuals per m^2.

Method 2 (Density calculated using 2007 sampled subpopulation data): The overall area of Patch A was 2,340 m^2. Twenty-nine ½ meter plots in Patch A were sampled. Fifty *L. bradshawii* individuals were counted within these 29 plots. The estimated density of Patch A was 1.72 individuals per ½ m^2, or 3.44 individuals per m^2 (SE = 3.32).

Jackson-Frazier Wetland

A total of 102 individuals of *L. bradshawii* were counted at the Jackson-Frazier Wetland population. The population inhabited an area of 55.2 m^2. The density of this population was 1.85 individuals per m^2.

Kingston Prairie Preserve

A total of 385 individuals of *L. bradshawii* (38 reproductive, 347 vegetative) were counted in the 56 ½-m^2 microplots sampled. The average number of individuals per ½-m^2 microplot was 6.875 (SE=1.90). The area of the macroplot was 5,712 m^2. The estimated population density was 13.75 individuals per m^2 (SE = 3.79).

Oak Creek Easement

A total of 282 individuals of *L. bradshawii* were counted in the 104 ½-m^2 microplots sampled at the Oak Creek Easement population. The average number of individuals per ½-m^2 microplot was 2.71 (SE=0.984). The area of the macroplot was 31,825 m^2. The estimated population density was 5.42 individuals per m^2 (SE = 1.97).

Sublimity Grassland

A total of 287 individuals (51 reproductive, 236 vegetative) of *L. bradshawii* were counted in the 52 ½-m^2 microplots sampled at the Sublimity Grassland population. The average number of individuals per ½-m^2 microplot was 5.52 (SE = 2.63). The area of the macroplot was 1,120 m^2. The estimated population density was 11.0 individuals per m^2 (SE = 5.26).

Willow Creek Preserve

Table 6.1 summarizes the data collected by The Nature Conservancy staff at the Willow Creek Preserve population of *L. bradshawii* in 2006. The estimated macroplot densities ranged from 0.04 stems per m^2 to 1.11 stems per m^2.

Table 6.1. 2006 *Lomatium bradshawii* sample data from four macroplots at the Willow Creek Preserve. Data was collected by The Nature Conservancy staff in 2006, and shared with the Oregon Department of Agriculture for use in this study. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Macroplot	Method	Sample area (m^2)	Sample count (# stems)	Total (sub) population area (m^2)	Total # stems	Population density stems/m^2 (SE)
3	Sample macroplot	250	10	5,000	*200*	*0.04 (0.02)*
4	Sample macroplot	125	66	5,000	*2,640*	*0.53 (0.25)*
7	Sample macroplot	500	23	5,000	*230*	*0.046 (0.02)*
8	Sample macroplot	250	278	5,000	*5,560*	*1.11 (0.44)*
Total		1,125	377	20,000	*8,630*	*0.04-1.11*

Summary

The population densities of *L. bradshawii* ranged from 0.040 stems per m^2 to 13.8 stems per m^2. Table 6.2 summarizes the population density estimates for the six *L. bradshawii* sites used in this study.

Table 6.2. Summary of population densities for *Lomatium bradshawii* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# stems)	Total (sub) population area (m^2)	Total # stems	Population density stems/m^2 (SE)
Muddy Creek	Census (2004)	n/a	n/a	*28,228*	7,600	*0.269*
	Sample subpopulation	14.5	50	*2,340*	*8,069*	*3.44 (3.32)*
Jackson-Frazier	Census	n/a	n/a	55.2	102	1.85
Kingston Prairie	Sample macroplot	23	385	5,712	*78,540*	*13.8 (3.79)*
Oak Creek Easement	Sample macroplot	52	282	31,825	*172,492*	*5.42 (1.97)*
Sublimity Grassland	Sample population	26	287	1,120	*12,320*	*11.0 (5.26)*
Willow Creek	Sampled 4 macroplots	1,125	377	20,000	*8,630*	*0.040-1.11 (0.020-0.440)*

Discussion

Lomatium bradshawii population densities ranged from 0.040 stems per m^2 to 13.8 stems per m^2. Unlike some of the other species in this study, the *L. bradshawii* populations visited appeared to inhabit a more consistent type of habitat – open, wet fields and/or meadows with limited competing vegetation. Even so, there was a considerable range in then estimated densities of these populations. When calculating the amount of habitat need to support a *Lomatium bradshawii* population of a certain size, it would be most prudent to use a more conservative population density estimate.

Methodolgy note: Plant counts for this study included seedlings and very small (having 1-2 leaves) vegetative individuals. Locating and counting these smallest individuals made the process extremely labor intensive. For larger populations, this reduced the total area that our field crew was able to sample, and increased the standard errors of the sample counts.

Chapter VIII. *Lupinus sulphureus ssp. kincaidii*

Introduction

Lupinus sulphureus ssp. *kincaidii* (Figure 8.1), a rare member of the pea family (Fabaceae), is found in Oregon, where the majority of populations occur, and Washington. It is the primary host plant for the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*). At most of the sites in which this butterfly occurs, adults of the species lay their eggs exclusively on *L. sulphureus* ssp. *kincaidii* plants, which then provide the sole source of food for the developing Fender's blue larvae (USFWS 2000).

Species information

Species status: *Lupinus sulphureus* ssp. *kincaidii* is listed as threatened by both the U.S. Fish and Wildlife Service and the State of Oregon. It is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G5/T2/S2 (subspecies imperiled throughout its range/imperiled in Oregon) (ORNHIC 2007). In Washington, *L. sulphureus* ssp. *kincaidii* is listed by the State as Endangered, though this status carries no legal mandate for protection on state or other public lands (Florence Caplow, WNHP, Olympia, Washington, personal communication). The species is assigned a rank of S1 (critically imperiled in Washington) by the Washington Natural Heritage Program (WNHP 2007).

Figure 8.1. *Lupinus sulphureus* ssp. *kincaidii* inflorescence.

Species description: *Lupinus sulphureus* ssp. *kincaidii* is an herbaceous perennial from a branched crown, usually with numerous unbranched stems 4-10 dm tall, with whitish or brownish stiff to silky pubescence. Basal leaves are usually persistent until after flowering, the lowermost petioles (2) 3-5 times as long as the blades, the upper cauline leaves with petioles sometimes shorter than the blades. Leaflets usually number from 7-12, are rather narrowly oblanceolate, usually acutish, and 2.5-5 cm long. The flowers are numerous but not crowded on the stem, and range in color from bluish or purple to yellowish or creamy white. The banner is distinctively ruffled and not very reflexed, the upper calyx lip short, bidentate, and not concealed by the reflexed sides of the long-clawed banner. Fruit pods are 3-4 cm long, with 1-6 pinkish-brown to black seeds. The species is distinguished from other relatives by its ruffled banner on light-colored flowers, its unbranched inflorescences, and its low-growing habit (Hitchcock 1961, Kaye and Kuykendall 1993).

Habitat/range: The earliest collections of what is now considered *Lupinus sulphureus* ssp. *kincaidii* were made in the early 1900's, in the vicinities of Corvallis and Eugene, Oregon (Wilson et al. 2003). Subsequent collections have documented the occurrence of this species at over 60 locations, distributed from Lewis County, Washington, south through the Willamette Valley to Douglas County, Oregon—a latitudinal span of over 400 km (USFWS 2000). The cumulative area of habitat occupied by *L. sulphureus* ssp. *kincaidii* has been estimated at 160 hectares (Kaye and Kuykendall 1993). Currently, the Oregon Natural Heritage Information Center (as of June 2005) recognizes 59 occurrences of the species in Oregon, distributed in Benton, Douglas, Lane, Linn, Marion, Polk, Washington, and Yamhill Counties (ORNHIC 2005). The Washington Natural Heritage Program recognizes three occurrences of Kincaid's lupine in Washington, located mostly on private lands, all within Lewis County (Joseph Arnett, Washington Natural Heritage Program, Olympia, Washington, personal communication).

Lupinus sulphureus ssp. *kincaidii* is primarily restricted to undisturbed remnants of upland prairie and ecotones between grasslands and forests (Kaye and Kuykendall 1993). Most Willamette Valley populations occur in association with well-drained soils classified as Ultic

Haploxerolls, Ultic Argixerolls, and Xeric Palehumults (Wilson et al. 2003), and in Benton County the species exhibits a strong affinity to the Dixonville soil series, and a positive association with the Witzel, Hazelhair, Briedwell, and Price soil series (A.F. Robinson, unpublished, in Wilson et al. 2003). Commonly associated native plant species are those typical of intact upland prairie habitats, including: *Agoseris grandiflora*, *Arbutus menziesii*, *Balsamorhiza deltoidae*, *Brodiaea coronaria*, *Bromus carinatus*, *Calochortus tolmiei*, *Cryptantha intermedia*, *Danthonia californica*, *Delphinium menziesii*, *Elymus glaucus*, *Eriophyllum lanatum*, *Festuca idahoensis*, *F. roemeri*, *Fragaria vesca*, *F. virginiana*, *Holodiscus discolor*, *Iris tenax*, *Lomatium triternatum*, *L. utriculatum*, *Luzula comosa*, *Madia gracilis*, *Potentilla gracilis*, *Pseudotsuga menziesii*, *Pteridium aquilinium*, *Sanicula crassicaulis*, *Silene hookeri*, *Symphoricarpos mollis*, *Toxicodendron diversilobum*, and *Whipplea modesta* (Kaye and Kuykendall 1993, Wilson et al. 1997).

Threats: As with most rare plants in the Willamette Valley, Kincaid's lupine faces pressure from the destruction of its prairie habitat. Urbanization and intensive agriculture have permanently altered many of the suitable sites for this species, and have contributed to degradation of existing habitat. Wilson et al. (2003) identify three major threats to Kincaid's lupine: habitat loss, invasion by non-natives, and elimination of disturbance regimes.

More than 95% of the prairie habitat in the Willamette Valley has now been converted to farming and urban uses. Due to this loss, prairie species that were formerly widespread (including Kincaid's lupine) are now rare. Additionally, remaining prairie fragments have been further impacted by invasions of exotic weeds. Non-native vegetation often forms tall, dense stands around lupine plants, shading them and leading to dramatic changes in the structure of upland prairie communities. These weed invasions (especially of *Arrhenatherum elatius* and *Cytisus scoparius*) threaten many sites, as does fire suppression and the resultant succession of the species' preferred grassland habitat to woody shrubs. Prior to European settlement, intentional burning by Native Americans kept prairies open – lack of periodic fires has altered these habitats. Fortunately, several substantial populations of *Lupinus sulphureus* ssp. *kincaidii* occur on federally owned wildlife refuges, where burning and mowing have improved prairie habitat for native species (Wilson et al. 2003).

Insect predation and inbreeding depression also impacts the viability of Kincaid's lupine. Kaye and Kuykendall (1993), and Schultz (1995) observed many parasites plaguing the species, including gall-forming insects in unopened flowers and around the base of woody stems, and seed predation by weevils and bruchid beetles. Work by Severns (2003) indicates inbreeding depression may limit seed set and seed fitness in smaller populations of Kincaid's lupine.

Additionally, research suggests that hybridization may occur, or have the potential to occur, in *Lupinus sulphureus* ssp. *kincaidii*, posing another possible threat to the species. Liston et al. (1995) showed isozyme evidence of past hybridization between Kincaid's lupine and sympatric *L. arbustus* at Basket Slough NWR, possibly explaining the presence of morphologically intermediate individuals and sterile clones at the site. Liston reports that hybridization is a very widespread phenomenon in the genus *Lupinus*.

Study sites

Eleven study sites were used to determine density estimates for *L. sulphureus* ssp. *kincaidii*: Oak Creek Road, Camp Adair, Willow Creek Preserve, Philomath Prairie, McDonald Forest (Butterfly Meadows), Lupine Meadows, Loose Laces, China Ditch, Dickerson Heights, Stouts Creek, and Callahan Meadows (Figure 8.2). For a complete list of all sites visited during the course of the study, as well as directions and GPS points for those sites, see Appendix 1.

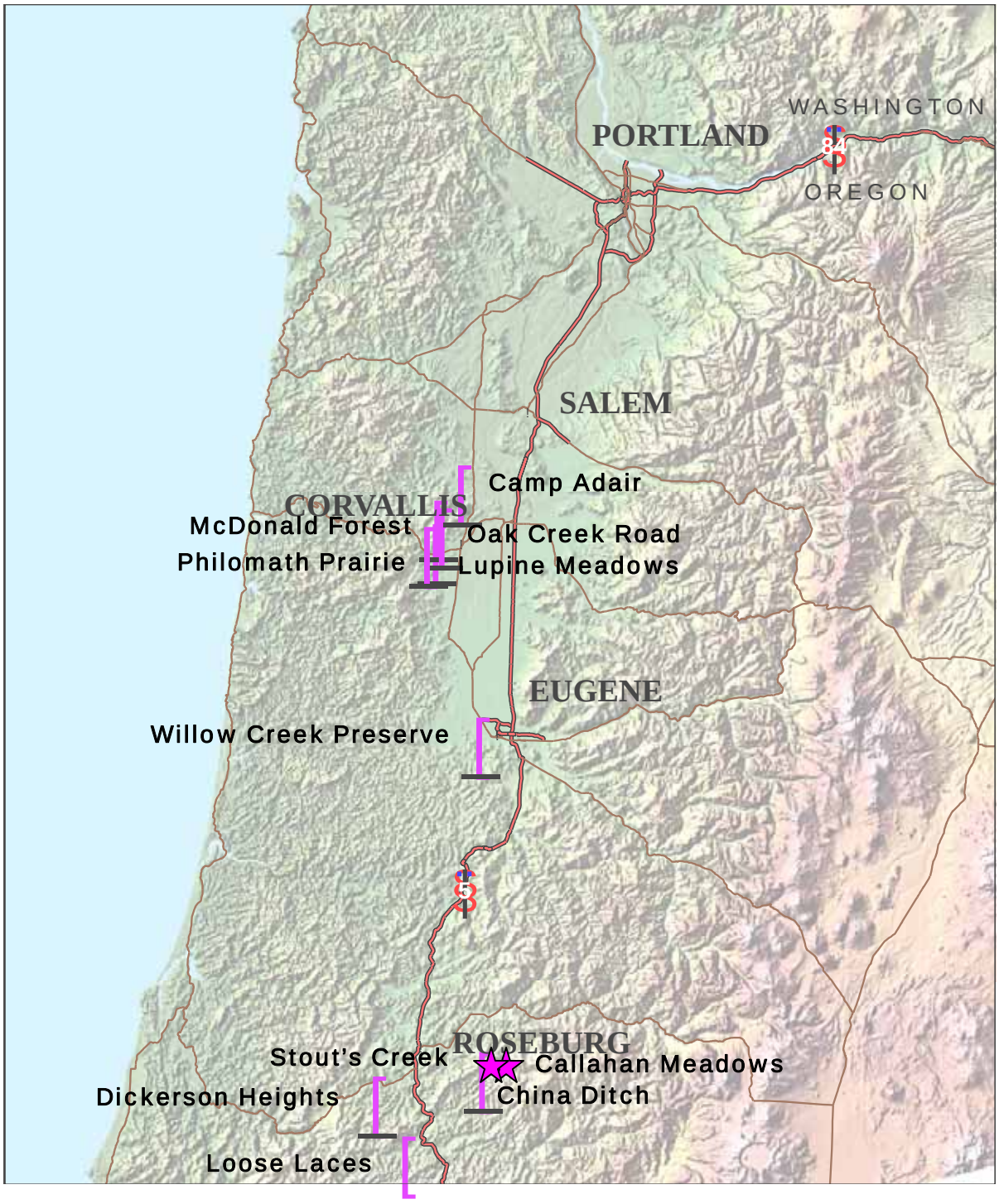

Figure 8.2. *Lupinus sulphureus* ssp. *kincaidii* populations visited during the course of this study.

Oak Creek Road: The Oak Creek Road population of *L. sulphureus* ssp. *kincaidii* is located along a roadside right-of-way (ROW) located just west of Corvallis (Figure 8.3). Plants are located along the back of the ditch that runs along the side of the road, and continue up the back of the ditch to the Douglas fir trees at the edge of the ROW. Associated species primarily consist of non-native grasses. This site is managed by the Benton County, which is currently in the process of developing a Habitat Conservation Plan for all of the County's rare prairie species populations. Threats to this population include disturbance from road maintenance activities (such as spraying and ditching) and competition from non-native, invasive species.

Figure 8.3. ODA staff establishing the boundaries of the Oak Creek Road population of *Lupinus sulphureus* ssp. *kincaidii*.

Camp Adair: Once part of one of the largest military installations in Oregon, the portion of Camp Adair that hosts a population of *L. sulphureus* ssp. *kincaidii* is currently managed by the Oregon Military Department (OMD), and primarily used for military training exercises. Individuals of *L. sulphureus* ssp. *kincaidii* are clumped in eight patches scattered across a hillside overlooking a rifle range (Figure 8.4). The

Figure 8.4. One of the patches of *Lupinus sulphureus* ssp. *kincaidii* found at Camp Adair. White flags mark the location of clumps of plants.

patches are located in small clearings between clumps of Oregon white oak, Douglas fir and various shrubs. With assistance from U.S. Fish and Wildlife, OMD manages the site for *L. sulphureus* ssp. *kincaidii* (not only for the rare plant species itself, but also as potential habitat for the federally listed Fender's blue butterfly). Threats to this population include encroachment from woody plant species, accidental disturbance during the course of military training activities, and invasion of non-natives such as scotch broom.

Willow Creek Preserve: The Willow Creek Preserve is owned and managed by The Nature Conservancy. This preserve is also part of the greater West Eugene Wetlands network, and as such is being managed for rare species. The *L. sulphureus* ssp. *kincaidii* population is located in several large patches within the preserve (Figure 8.5). In addition to *L. sulphureus* ssp. *kincaidii*, this preserve also supports populations of *Erigeron decumbens* var. *decumbens, Lomatium bradshawii*, *Horkelia congesta* ssp. *congesta*, and *Sericocarpus rigidus* (*Aster curtus*). The primary threat to this population is invasive weeds and encroachment of shrubs and trees.

Figure 8.5. *Lupinus sulphureus* ssp. *kincaidii* habitat at Willow Creek Preserve.

Philomath Prairie: The Philomath Prairie population of *L. sulphureus* ssp. *kincaidii* is located in an open meadow in the hills just outside of Philomath (Figure 8.6). Although the site is privately owned by Weyerhaeuser (a large timber company), The Nature Conservancy has a conservation easement on a portion of the site, and manages it for the lupine.

Figure 8.6. *Lupinus sulphureus* ssp. *kincaidii* habitat at Philomath Prairie.

McDonald Forest – Butterfly Meadow: This population of *L. sulphureus* ssp. *kincaidii* population is located just west of Corvallis, in an area of McDonald Forest known as Butterfly Meadow (Figure 8.6). The population spans both public and private land – McDonald Forest is managed by Oregon State University (OSU), but a portion of the meadow habitat is owned by the Starker family. OSU is actively managing the site for the conservation of *L. sulphureus* ssp. *kincaidii* and Fender's blue butterfly, and is expected to sign on as a partner in the Benton County Habitat

Figure 8.6. *Lupinus sulphureus* ssp. *kincaidii* habitat at Butterfly Meadow in McDonald Forest.

Conservation Plan. Although clumps of *L. sulphureus* ssp. *kincaidii* are found scattered throughout the open meadow, the most densely populated areas are found along the edge of the meadow (Figure 8.7). Current threats to the site include invasion of non-native invasive species, especially false-brome (*Brachypodium sylvaticum*) along the tree line, and disturbance from logging operations (on the Starker property).

Figure 8.7. At Butterfly Meadow, the densest clumps of *Lupinus sulphureus* ssp. *kincaidii* were found along the edge of the meadow, near the tree line (red circle).

Lupine Meadow: Lupine Meadow (Figure 8.8) is an approximately 20 acres of upland prairie owned and managed by the Greenbelt Land Trust (GBLT), a non-profit, conservation-oriented, land trust organization based in Corvallis. GBLT manages this property for the conservation the rare species found here, including a large population of *L. sulphureus* ssp. *kincaidii* that hosts a population of Fender's blue butterfly. A previous survey of this site estimated that approximately two-thirds of the population was located on GBLT land, while the remaining one-third was located on the adjacent Benton County right-of-way (Institute for Applied Ecology 2003). Currently, the greatest threat to this population is the invasion of non-native weeds, including both grasses and forbs.

Figure 8.8. *Lupinus sulphureus* ssp. *kincaidii* habitat at the Greenbelt Land Trust's Lupine Meadow.

Loose Laces: Loose Laces is one of five *L. sulphureus* ssp. *kincaidii* sites owned and managed by the Bureau of Land Management (BLM) that were used in this study. Located approximately seven miles south of Riddle, Oregon, this population is composed of four subpopulations. All of these subpopulations are associated with BLM roads: subpopulations one and two are located on overgrown skid roads (Figure 8.9), subpopulation three occurs along the bank of a maintained road (Figure 8.10), subpopulation four is located above a road cut bank (Figure 8.11). Unlike some of the other sites visited during the course of this study, three out of the four Loose Laces subpopulations are found in relatively shady areas, in dappled light.

Figure 8.9. An example of *Lupinus sulphureus* ssp. *kincaidii* habitat at Loose Laces. Subpopulation one is located on an abandoned skid road.

Figure 8.10. An example of *Lupinus sulphureus* ssp. *kincaidii* habitat at Loose Laces. Subpopulation three is located along a cut bank next to a road maintained by the Bureau of Land Management.

Figure 8.11. Another example of *Lupinus sulphureus* ssp. *kincaidii* habitat at Loose Laces. Subpopulation four is located under trees, in a relatively flat area immediately above a roadcut.

China Ditch: China Ditch is another one of the five *L. sulphureus* ssp. *kincaidii* sites owned and managed by the Bureau of Land Management (BLM) that were used in this study. This site is located roughly 14 miles east and slightly north of Myrtle Creek, Oregon. The population is divided into three subpopulations, all of which are located along roadsides (Figures 8.12).

Figure 8.12. Subpopulation one (left) and two (right) of the China Ditch population of *Lupinus sulphureus* ssp. *kincaidii*.

Dickerson Heights: Also owned by the BLM, the Dickerson Heights population of *L. sulphureus* ssp. *kincaidii* is approximately nine miles southwest of Winston, Oregon. Like the other BLM-managed *L. sulphureus* ssp. *kincaidii* visited during this study, this population is located along the side of a BLM road, along the edge of a relatively dense stand of Douglas fir (Pseudotsuga menziesii), madrone (*Arbutus menziesii*) and incense cedar (*Calocedrus decurrens*) (Figure 8.13). Potential threats to this population include disturbance from road maintenance and logging, and the invasion of non-native weeds.

Figure 8.13. A large *Lupinus sulphureus* ssp. *kincaidii* plant growing along the side of a Bureau of Land Management road at Dickerson Heights.

Stout's Creek: The Stout's Creek population of *L. sulphureus* ssp. *kincaidii* is located roughly three miles south of Milo, Oregon. This large population spans both BLM and privately-owned land.

Callahan Meadows: The last of the BLM-owned populations of *L. sulphureus* ssp. *kincaidii* used in this study, Callahan Meadows is located approximately 29 miles east of Canyonville, Oregon, just south of Tiller. Unlike the other BLM-managed populations of *L. sulphureus* ssp. *kincaidii*, this site is not located along a roadside. Instead, two small subpopualtions are found in a meadow. A fence separates the area populated by the *L. sulphureus* ssp. *kincaidii* from the larger meadow, which is privately grazed.

Sites visited but not used in this study: Some of the current or historic sites visited by ODA during the course of this study did not prove to be suitable for use in the development of population density estimates. A complete list of the sites visited is available in Appendix 1.

Methodology

Overview

Deciding what to count: Because *L. sulphureus* ssp. *kincaidii* is highly rhizomatous, spreading vegetatively by underground rhizomes to form large mats of vegetation, in many of the populations it is extremely difficult to identify an "individual" of this species. The monitoring trend for *L. sulphureus* ssp. *kincaidii* is to look at area cover, rather than number of individuals (Institute for Applied Ecology 2006, USFWS 2007). Therefore, ODA decided to also use area covered when developing density estimates for this species. The amount of area covered was determined by laying down a square meter plot, and having two staff people estimate the area using plastic squares representing five percent of a square meter (Figure 8.14). The two estimates of area covered were then averaged for each square meter plot, and the average was converted from percent cover (which was easier to work with in the field) to area cover. There are two general ways to determine "cover" when looking at plants. The first is to consider cover the area of influence of the plant, and to draw a theoretical line around the outside border of a plant or clump, and count everything inside that perimeter as "cover." The second method defines "cover" as the area on the ground that would be in shadow if a light was shone directly above the plant. In this second method, the spaces between leaves, stems and clumps are excluded from the cover estimation. For the purposes of this study, the second approach was used.

Figure 8.14. Oregon Department of Agriculture botanists estimating the amount of area covered by *Lupinus sulphureus* ssp. *kincaidii* at Philomath Prairie. The small plastic squares represent five percent of a square meter.

Oak Creek Road

The Oak Creek Road population of *L. sulphureus* ssp. *kincaidii* was visited on June 1, 2007. After establishing the extent of the population by walking the site and placing pinflags at the edges, it was determined that this population was too dense to census. A 30 m x 6 m rectangle encompassing the entire population was established, with the 30 m side running parallel to the road (Figure 8.15). A total of 12 six-meter-long transects were randomly established along the 30 m axis. Cover was estimated for each of the six square meter plots within each transect.

Figure 8.15. The Oak Creek Road population of *Lupinus sulphureus* ssp. *kincaidii* was sampled by establishing 10 five-meter-long transects perpendicular to the road, and estimating the area covered by *L. sulphureus* ssp. *kincaidii* in each transect.

Camp Adair

The Camp Adair population of *L. sulphureus* ssp. *kincaidii* was visited on May 25, 2006. This population is divided into eight patches scattered across the hill. Because this population was too large and geographically spread out to census, we developed density estimates for two randomly selected patches (one and seven). Patch one was too large to census, and was sampled (Figure 8.16). A 17 m x 11 m (187 m^2) rectangle was established encompassing the entire patch. Sixteen one-$meter^2$ plots were randomly selected within this rectangle, and the area covered by *L. sulphureus* ssp. *kincaidii* was recorded for each plot. Patch seven was smaller, and therefore censused, rather than sampled. A 5 m x 6 m rectangle was established encompassing the entire patch, and the area covered by *L. sulphureus* ssp. *kincaidii* was recorded for each one-$meter^2$ plot within the rectangle (Figure 8.17).

Figure 8.16. Meter tapes form a rectangle encompassing the first patch of *Lupinus sulphureus* ssp. *kincaidii* at Camp Adair. White flags represent clumps of lupine within the patch.

Figure 8.17. Oregon Department of Agriculture staff estimating area covered by *Lupinus sulphureus* ssp. *kincaidii* in Patch seven at Camp Adair. Orange flags represent clumps of lupine.

Willow Creek Preserve

The Willow Creek Preserve population of *L. sulphureus* ssp. *kincaidii* was visited on June 2, 2006. There are several large patches of lupine at the Preserve. However, some of them have been augmented with introduced plants. We decided to focus on one of the largest patches, but to exclude the area where augmentation had occurred. A 27 m x 78 m macroplot was established encompassing the majority of the patch (Figure 8.18). Because this patch was too large and dense to census, it was systematically sampled instead. Fifteen transects were established parallel to the 27-meter-long side of the macroplot. The location of the first transect was randomly selected, and the subsequent transects were placed every five m after that. A series of nine plots were located along each transect. The placement of the first plot was randomly determined, and the subsequent plots were placed every 3 m along the transect. A total of 135 plots were sampled at this site.

Figure 8.18. Looking at the Willow Creek Preserve subpopulation of *L. sulphureus* ssp. *kincaidii* from the origin of the macroplot. White flags represent clumps of *L. sulphureus* ssp. *kincaidii*.

Philomath Prairie

The Philomath Prairie population of *L. sulphureus* ssp. *kincaidii* was visited on June 8, 2006. The population was small enough to be censused. A 9 m x 10 m grid encompassing the population was laid out with meter tapes, and the area covered by *L. sulphureus* ssp. *kincaidii* was recorded for each one-meter^2 plot within the grid (Figure 8.19).

Figure 8.19. Meter tape outlines the boundaries of the Philomath Prairie population of *Lupinus sulphureus* ssp. *kincaidii*.

McDonald Forest – Butterfly Meadow

The McDonald Forest-Butterfly Meadow population of *L. sulphureus* ssp. *kincaidii* was visited on June 9, 2006. Although a section of this population is found on private land, ODA staff only had access to the publically-owned portion of the population, and that was what was used in this study. This population was too large to be censused. Instead, it was systematically sampled. An 80-meter-long x-axis was established running through the middle of the meadow containing *L. sulphureus* ssp. *kincaidii*. A one-meter-wide y-transect was established perpendicular to the x-axis within each 10-meter portion of the x-axis, for a total of eight y-transects (Figure 8.20). The point at which the y-transect crossed the x-axis was randomly determined for each section. Because of the roughly oval shape of the meadow, the y-transects were variable in length. The area of *L. sulphureus* ssp. *kincaidii* cover for each one-meter-squared plot along each transect was estimated using the methods described in the introductory chapter.

Figure 8.20. Sampling layout at the McDonald Forest population of *Lupinus sulphureus* ssp. *kincaidii*. This population is scattered throughout a clearing in the surrounding Douglas fir-dominated forest, although most individuals are concentrated along the meadow's edge. Pink flags represent clumps of *L. sulphureus* ssp. *kincaidii*.

Lupine Meadows

Lupine Meadows was visited on June 13, 2006. This population was too large to census, and too geographically spread out to sample the entire population in the time allowed. Instead, a 180 m x 100 m macroplot was established encompassing the bulk of the population, and this macroplot was systematically sampled. Nine 100-meter-long y-transects were located along the 180-meter-long x-axis, one in each 20-meter section. The point where the y-transect crossed the x-axis was randomly determined for each section. Twenty one-meter^2 plots were located along each y-transect, one every five meters, with the location of the first plot randomly determined. In each plot, the percentage the area covered by of *L. sulphureus* ssp. *kincaidii* was estimated to the nearest percentage (Figure 8.21). The percentage cover numbers were later converted to area covered. A total of 180 plots were sampled.

Figure 8.21. Estimating the *Lupinus sulphureus* ssp. *kincaidii* cover in a one-meter2 plot at the Greenbelt Land Trust's Lupine Meadows.

Loose Laces

The Loose Laces population of *L. sulphureus* ssp. *kincaidii* was visited on June 7, 2007. This population had been monitored in 2006 by the Institute for Applied Ecology (IAE). Rather than re-census the population, ODA used the data collected by IAE to develop population density estimates for the four subpopulations at this site. Because IAE did not measure the area of each subpopulation, ODA staff calculated the area covered by each subpopulation during our visit to the site (Figure 8.22). Due to the natural boundaries of the habitat (subpopulations was confined to old skid roads and cut banks), an assumption was made that the areas of the subpopulationse remained the same from 2006 to 2007.

Subpopulation one: IAE censused this population. IAE staff established a 110-meter-long transect along the edge of the subpopulation, which followed the curve of an old skid road, and marked each 20-meter segment with rebar (the last segment was only 10 m long). The area of *L. sulphureus* ssp. *kincaidii* cover was determined in five-meter-long segments on either side of the central transect (Institute for Applied Ecology 2006).

Figure 8.22. Measuring the area of subpopulation one at the Loose Laces population of *L. sulphureus* ssp. *kincaidii*.

Subpopulation two: IAE censused this subpopulation (Institute for Applied Ecology 2006) by establishing a 15-meter-long transect, and recording the area covered by *L. sulphureus* ssp. *kincaidii* on either side of the transect in one-meter segments.

Subpopulation three: IAE censused this subpopulation (Institute for Applied Ecology 2006) by establishing a 150-meter-long transect, and recording the area covered by *L. sulphureus* ssp. *kincaidii* on either side of the transect in five-meter segments.

Subpopulation four: IAE censused this subpopulation (Institute for Applied Ecology 2006) by establishing a 15 m x 16 m rectangle that encompassed the entire subpopulation. This rectangle was then divided into 12 segments, each measuring 2 m x 5 m, and the area covered by *L. sulphureus* ssp. *kincaidii* within each segment was recorded.

China Ditch

The China Ditch population of *L. sulphureus* ssp. *kincaidii* was visited on June 7, 2007. This population had been monitored in 2006 by the Institute for Applied Ecology (IAE). Rather than re-collect data for this population, ODA used the data collected by IAE to develop population density estimates for the three subpopulations at this site. Because IAE did not measure the area of each subpopulation, ODA staff calculated the area covered by each subpopulation during our visit to the site (Figure 8.23). Due to the natural boundaries of the habitat (subpopulations was confined to old skid roads and cut banks), an assumption was made that the areas of the subpopulations remained the same from 2006 to 2007.

Subpopulation one: IAE did not census this subpopulation. Instead, they established a 75-meter-long transect spanning the bulk of subpopulation, marking every 15 m with rebar. The area of *L. sulphureus* ssp. *kincaidii* cover was determined in five-meter-long segments on either side of the central transect (Institute for Applied Ecology 2006). ODA calculated the area of the population by measuring the width of the population at each rebar marker, averaging the width of each 15-meter-long segment, calculating the area of each segment by multiplying the average width by 15 m, and adding the segment areas together.

Subpopulation two: IAE did not census this subpopulation. Instead, they established a 42 m x 3 m macroplot encompassing the bulk of the subpopulation, and recorded the *L. sulphureus* ssp. *kincaidii* within that macroplot (Institute for Applied Ecology 2006).

Subpopulation three: IAE did not census this subpopulation. Instead, they established a 70-meter-long transect encompassing the bulk of the subpopulation, and recorded the *L. sulphureus* ssp. *kincaidii* cover along both sides of that transect (Institute for Applied Ecology 2006). ODA calculated the area of this subpopulation by measuring the width of the population along each segment of the transect.

Figure 8.23. Calculating the area of subpopulation one at the China Ditch population of *Lupinus sulphureus* ssp. *kincaidii*.

Dickerson Heights

The Dickerson Heights population of *L. sulphureus* ssp. *kincaidii* was visited on June 8, 2007. This population had been censused in 2006 by the Institute for Applied Ecology (IAE). Rather than re-collect data for this population, ODA used the data collected by IAE to develop population density estimates for this population. Because IAE did not provide a measure of the total area of this population, ODA staff calculated the population area during our visit to the site (Figure 8.24). An assumption was made that the area of the population remained the same from 2006 to 2007.

Figure 8.24. Establishing the boundaries of the Dickerson Heights population of *Lupinus sulphureus* ssp. *kincaidii*.

Stout's Creek

Density estimates for the Stout's Creek population of *L. sulphureus* ssp. *kincaidii* was estimated from data collected by the Institute for Applied Ecology (IAE) in 2006. This population was not visited by ODA staff. IAE divided the first subpopulation into three patches, and measured the area covered by *L. sulphureus* ssp. *kincaidii* for each patch. ODA calculated the density for each patch in this subpopulation. ODA did not use IAE's data from Stout Creek's second subpopulation in this study.

Callahan Meadows

Density estimates for the Callahan Meadows population of *L. sulphureus* ssp. *kincaidii* was estimated from data collected by the Institute for Applied Ecology (IAE) in 2006. This population was not visited by ODA staff.

Subpopulation one: IAE established a 12 m x 12 m plot encompassing this entire subpopulation, and measured the area covered by *L. sulphureus* ssp. *kincaidii* in each 2 m x 2 m cells within this plot (Institute for Applied Ecology 2006).

Subpopulation two: IAE established a 6 m x 4 m plot encompassing this entire subpopulation, and measured the area covered by *L. sulphureus* ssp. *kincaidii* in each 2 m x 4 m cell within this plot (Institute for Applied Ecology 2006).

Results

Oak Creek Road

The total area of the population is 180 m^2 (30 m x 6 m). The estimated total cover of *L. sulphureus* ssp. *kincaidii* at this site is 27.9 m^2 (SE = 9.17). The estimated density of *L. sulphureus* ssp. *kincaidii* at the Oak Creek Road population is 0.155 m^2 of cover per m^2 (SE = 0.051).

Camp Adair

Patch one: A total of 0.245 m^2 of *L. sulphureus* ssp. *kincaidii* was recorded in the 16 one-$meter^2$ plots sampled in patch one. The estimated total cover of *L. sulphureus* ssp. *kincaidii* in this patch is 2.55 m^2 (SE = 1.49). The estimated density of *L. sulphureus* ssp. *kincaidii* for patch one at Camp Adair is 0.013 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2 (SE = 0.008).

Patch seven: The total area of patch seven is 30 m^2. The total area covered by *L. sulphureus* ssp. *kincaidii* is 1.84 m^2. The density of *L. sulphureus* ssp. *kincaidii* in this patch is 0.061 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Willow Creek Preserve

A total of 2.24 m^2 of *L. sulphureus* ssp. *kincaidii* cover was recorded in the 135 m^2 that was sampled at Willow Creek. The estimated density of *L. sulphureus* ssp. *kincaidii* in this subpopulation is 0.017 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2 (SE = 0.005).

Philomath Prairie

A total of 2.41 m^2 of *L. sulphureus* ssp. *kincaidii* was recorded within the 90 m^2 that the Philomath Prairie population inhabits. The density of this population is 0.027 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2

McDonald Forest – Butterfly Meadow

A total of 3.78 m^2 of *L. sulphureus* ssp. *kincaidii* was recorded within the eight belt transects (totaling 519 m^2) that were sampled. The estimated density of this population is 0.00728 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2

Lupine Meadows

A total of 2.45 m^2 of *L. sulphureus* ssp. *kincaidii* cover was recorded in the 180 m^2 that was sampled at Lupine Meadows. The estimated density of *L. sulphureus* ssp. *kincaidii* in this subpopulation is 0.014 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2 (SE = 0.003).

Loose Laces

Subpopulation one: IAE recorded a total of 3.3 m^2 of *L. sulphureus* ssp. *kincaidii* cover at the first Loose Laces subpopulation (Institute for Applied Ecology 2006). The area of this subpopulation was 990 m^2. The density of this subpopulation was 0.003 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Subpopulation two: IAE recorded a total of 2.53 m^2 of *L. sulphureus* ssp. *kincaidii* cover at the second Loose Laces subpopulation (Institute for Applied Ecology 2006). The area of this

subpopulation was 105 m^2. The density of this subpopulation was 0.024 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Subpopulation three: IAE recorded a total of 14.96 m^2 of *L. sulphureus* ssp. *kincaidii* cover at the second Loose Laces subpopulation (Institute for Applied Ecology 2006). The area of this subpopulation was 1,050 m^2. The density of this subpopulation was 0.014 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Subpopulation four: IAE recorded a total of 4.69 m^2 of *L. sulphureus* ssp. *kincaidii* cover at the second Loose Laces subpopulation (Institute for Applied Ecology 2006). The area of this subpopulation was 240 m^2. The density of this subpopulation was 0.020 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

China Ditch

Subpopulation one: IAE recorded a total of 10.12 m^2 of *L. sulphureus* ssp. *kincaidii* cover along the transect established at the first China Ditch subpopulation (Institute for Applied Ecology 2006). The area of the examined portion of this subpopulation was 375 m^2. The density of this subpopulation (the portion measured) was 0.027 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Subpopulation two: IAE recorded a total of 3.35 m^2 of *L. sulphureus* ssp. *kincaidii* cover within the macroplot established at the second China Ditch subpopulation (Institute for Applied Ecology 2006). The area of the macroplot established at this subpopulation was 126 m^2. The density of this subpopulation (the portion measured) was 0.027 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Subpopulation three: IAE recorded a total of 11.1 m^2 of *L. sulphureus* ssp. *kincaidii* cover along the transect established at the first China Ditch subpopulation (Institute for Applied Ecology 2006). The area of the examined portion of this subpopulation was 350 m^2. The

density of this subpopulation (the portion measured) was 0.032 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Dickerson Heights

IAE recorded a total of 17.26 m^2 of *L. sulphureus* ssp. *kincaidii* cover at the Dickerson Heights population (Institute for Applied Ecology 2006). The area of this population was 449 m^2. The density of this population was 0.038 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Stout's Creek

Patch densities at subpopulation one ranged from 0.004 to 0.012 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2. IAE recorded a total of 0.97 m^2 of *L. sulphureus* ssp. *kincaidii* cover in the first patch. The area of patch one was 230 m^2. The density of patch one was 0.004 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2. IAE recorded a total of 0.88 m^2 of *L. sulphureus* ssp. *kincaidii* cover in the second patch. The area of patch two was 220 m^2. The density of patch two was 0.004 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2. IAE recorded a total of 1.00 m^2 of *L. sulphureus* ssp. *kincaidii* cover in the third patch. The area of patch three was 84 m^2. The density of patch three was 0.012 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Callahan Meadows

Subpopulation one: IAE recorded a total of 8.2 m^2 of *L. sulphureus* ssp. *kincaidii* cover in the first patch. The area of patch one was 144 m^2. The density of patch one was 0.057 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Subpopulation one: IAE recorded a total of 0.3 m^2 of *L. sulphureus* ssp. *kincaidii* cover in the first patch. The area of patch one was 24 m^2. The density of patch one was 0.013 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2.

Summary

Overall, *L. sulphureus* ssp. *kincaidii* population densities ranged from 0.003 to 0.155 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2. Table 8.1 summarizes the population density estimates for the eleven *L. sulphureus* ssp. *kincaidii* sites used in this study.

Table 8.1. Summary of estimated population densities for *Lupinus sulphureus* ssp. *kincaidii* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (m^2 area cover)	Total (sub) population area (m^2)	Total area cover (m^2)	Population density area cover/m^2 (SE)
Oak Creek Road	Sample population	72	1.86	180	*27.9*	*0.155 (0.051)*
Camp Adair	Sample patch (Patch 1)	16	0.245	187	*2.55*	*0.014 (0.008)*
	Census patch (Patch 7)	n/a	n/a	30	1.84	0.061
Willow Creek Preserve	Sample subpopulation	135	2.24	2,106	*34.9*	*0.017 (0.005)*
Philomath Prairie	Census population	n/a	n/a	90	2.41	0.028
McDonald Forest	Sample subpopulation	519	3.78	*5,190*	*37.8*	*0.007*
Lupine Meadow	Sample macroplot	180	2.45	1,800	*24.4*	*0.014 (0.003)*
Loose Laces	Census each subpopulation	n/a	n/a	990	3.3*	0.003
		n/a	n/a	105	2.53*	0.024
		n/a	n/a	1,050	14.96*	0.014
		n/a	n/a	240	4.69*	0.020
China Ditch	Census a macroplot at each subpopulation	n/a	n/a	375	10.12*	0.027
		n/a	n/a	126	3.35*	0.027
		n/a	n/a	350	11.1*	0.032
Dickerson Heights	Census population	n/a	n/a	449	17.26*	0.038
Stout's Creek	Census three patches at subpopulation one	n/a	n/a	230*	0.97*	0.004
		n/a	n/a	220*	0.88*	0.004
		n/a	n/a	84*	1.00*	0.012
Callahan Meadow	Census two sub-populations	n/a	n/a	144*	8.2*	0.057
		n/a	n/a	24*	0.3*	0.013

* *Lupinus sulphureus* ssp. *kincaidii* cover data at Bureau of Land Management populations from Institute for Applied Ecology monitoring report (Institute for Applied Ecology 2006).

Discussion

There was a wide range of population densities among the eleven *L. suphureus* ssp. *kincaidii* sites visited for this study (0.003 to 0.155 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2). As with several of the other species in this study, the densest population (Oak Creek Road) was found along a roadside. In general, the smallest populations tend to have the highest population densities, due to the fact that their population areas are very small and do not incorporate inappropriate habitat. (The larger population areas do include patches of inappropriate habitat, lowering the population density.) Although there were several other small populations visited, both along roadsides and in small clearings, none of them were as dense as the Oak Creek Road population. This may be due in part to the fact that many of these other small populations occupied relatively shady habitat, and it is possible that having less access to light leads to less dense growth. When the Oak Creek Road population is removed, the range of population densities for this species becomes narrower - 0.003 to 0.061 m^2 of *L. sulphureus* ssp. *kincaidii* cover per m^2. When determining the amount of habitat needed to support a *L. sulphureus* ssp. *kincaidii* population of a given size, it will be important to determine the nature of that habitat. If protected habitat is of a more open and extensive nature, then the narrower range of population density estimates should be used to estimate the amount of habitat needed.

Chapter IX. *Sericocarpus rigidus* (*Aster curtus*)

Introduction

Exhibiting a strict ecological association with native prairie habitats, *Sericocarpus rigidus* (Figure 9.1) has experienced rapid declines in the wake of expanding urban and agricultural development and the proliferation of invasive weeds. Due to this unfortunate demographic trend, this increasingly rare member of the sunflower family (Asteraceae) has special conservation status throughout its range from British Columbia south to Oregon.

Species information

Species status: *Sericocarpus rigidus* is recognized as a Species of Concern by the U.S. Fish and Wildlife Service and is listed as Threatened by the State of Oregon. It is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G3/S2 (rare, threatened or uncommon throughout its range/imperiled in Oregon) (ORNHIC 2007). In Washington, home of the largest number of extant *Sericocarpus rigidus* populations, the species is listed as Sensitive, though this status designation provides no administrative protection, as Washington currently has no state regulatory authority for listed plants (Florence Caplow, WNHP, Olympia, Washington, personal communication).

Figure 9.1. *Sericocarpus rigidus* inflorescence.

Sericocarpus rigidus is assigned a rank of S3 (rare or uncommon in Washington) by the Washington Natural Heritage Program (WNHP 2007). On Vancouver Island, British Columbia, the northernmost extent of the species' geographic range, *Sericocarpus rigidus* is listed as Threatened (Schedule 1) by the Canadian Federal Species at Risk Act (SARA). Under this act, *S. rigidus* is protected on all Canadian federal lands, and in the absence of a provincial protection plan in British Columbia, the species could even gain federally-mandated protection on both provincial and private lands (Laura Telford, Canadian Nature Federation, Ottawa, Ontario, personal communication).

Species description: *Sericocarpus rigidus* is a perennial herb with slender creeping rhizomes and generally unbranched stems, topped by terminal clusters of flowering heads. Flowering stems are 1-3 dm tall (non-flowering stems about half as tall), and glabrous, except for the scabrous-ciliolate margins of leaves. Leaves are alternate and evenly distributed along the stem, oblanceolate and tapering to an essentially sessile base, the lowermost leaves reduced and the largest leaves (2.5-3.5 cm long) occurring along the center third of the stem. Flowers are inconspicuous, occurring in compact clusters of 5-20 small heads. Ray flowers are typically two (1-3), 1-3 mm long, and shorter than the pappus, and disk flowers are pale yellow with purple anthers. Involucres are 7-9 mm high, narrow, the bracts imbricate in several series, with a strong midrib or slight keel, chartaceous below and with spreading light green herbaceous tips (Hitchcock *et al.* 1955, Gamon and Salstrom 1992).

Sericocarpus rigidus is distinguishable from other related species (most notably *S. oregonensis*) by its more compact cluster of flower heads, fewer (1-3) and smaller (shorter than the pappus) ray flowers, and the abundance of creeping rhizomes (Hitchcock and Cronquist 1973, Gamon and Salstrom 1992). Moreover, *S. rigidus* is restricted to prairie habitats, while *S. oregonensis* tends to occupy more upland, woodland habitats. *Sericocarpus rigidus* does co-occur locally with *Symphyotrichum hallii* (=*Aster hallii*), but the latter can be readily distinguished by its much larger and more numerous ray flowers.

Habitat/range: *Sericocarpus rigidus* was first described by John Lindley in 1834 from a collection made by John Scouler, who found it "abundant on undulating, dry, gravelly soils

near Fort Vancouver, and low hills of the interior" (Lindley 1834). Since its initial discovery, over 100 populations have been identified, ranging from southwestern Vancouver Island, British Columbia (and several smaller surrounding islands), south through the Puget Trough of western Washington and into the southern Willamette Valley near Eugene, Oregon (Alverson 1983, Clampitt 1987, Gamon and Salstrom 1992, ORNHIC 2005, F. Caplow, personal communication). The Oregon Natural Heritage Information Center lists 30 occurrences of *S. rigidus* in Oregon (as of June 2005) distributed in Clackamas, Lane, Linn, and Marion Counties, with one historic occurrence in Multnomah County (ORNHIC 2005). The Washington Natural Herritage Program recognizes over 80 populations of the species, many very small and some quite large, on a mixture of public and private lands (Joseph Arnett, WNHP, Olympia, Washington, personal communication).

The majority of known *S. rigidus* populations (those occurring in western Washington) are found primarily on gravelly, glacial outwash soils, as originally described by Scouler. The exceptions to this edaphic generalization occur at the species' latitudinal extremes; the southernmost populations (in Oregon) are found on deep, poorly drained clayey soils, and the northernmost occurrences (in British Columbia) occupy very shallow soils overlying bedrock (Alverson 1983, Clampitt 1984, Alverson 1991, Douglas and Illingworth 1997).

In Oregon and Washington, habitat for *Sericocarpus rigidus* has been described as open, grassy, seasonally moist prairie and savannah habitats, at elevations ranging from 90 to 525 feet (Alverson 1983). Although typically not found in forested areas, plants at one location in Washington (the DuPont population) predominantly occur in proximity to *Quercus garryana*, where the shade of the leafy canopy apparently inhibits expansion of scotch broom (ACOE 1979). Likewise, sites in British Columbia are sometimes partially shaded by canopies of *Quercus garryana* and *Arbutus menziesii* (Douglas and Illingworth 1997).

Plant species frequently associated with *S. rigidus* include various grasses (*Agrostis tenuis*, *Aira praecox*, *Anthoxanthum odoratum*, *Cynosurus echinatus*, *Dactylis glomerata*, *Deschampsia cespitosa*, *Festuca idahoensis*, and *Poa pratensis*), forbs (*Symphyotrichum hallii*, *Camassia leichtlinii*, *Campanula rotundifolia*, *Chrysanthemum leucanthemum*,

Erigeron decumbens var. *decumbens*, *Eriophyllum lanatum*, *Fragaria vesca* var. *crinita*, *Hypochaeris radicata*, *Juncus patens*, *J. tenuis*, *Plantago lanceolata*, *Potentilla gracilis*, *Prunella vulgaris* var. *lanceolata*, *Sidalcea campestris*, and *Viola adunca*), shrubs (*Cytisus scoparius*, *Holodiscus discolor*, and *Symphoricarpos albus*) and trees (*Arbutus menziesii*, *Fraxinus latifolia*, and *Quercus garryana*) (compiled from Alverson 1983, Clampitt 1993, ONHP 2002, and OSU herbarium specimen labels).

Threats: Habitat loss to urban and agricultural development, and habitat degradation by invasive species and anthropogenic hydrologic alterations, pose the greatest threats to *Sericocarpus rigidus*. According to Giblin and Hamilton (1999), over 95 percent of this species' gravelly prairie habitat in western Washington has been destroyed or altered. Habitat loss is also identified as the primary threat to populations in Oregon (Siddall *et al*. 1978, Alverson 1983) and British Columbia (Douglas and Illingworth 1997).

Even when habitats are not directly destroyed by development, habitat disturbance can encourage colonization by invasive weeds. At the DuPont population in Washington, *Sericocarpus rigidus* is mainly restricted to areas not occupied by scotch broom (ACOE 1979). Based upon competition experiments, Clampitt (1987) stated that competition with non-native species is probably the most important factor restricting population recruitment in *S. rigidus*, more important even than low levels of seed production. Specifically, Clampitt (1993) found that habitat disturbance favors replacement of native bunchgrasses with non-native sod-forming grasses, and that *S. rigidus* tends to be present only where cover of native bunchgrasses exceeds 32 percent.

Continued *S. rigidus* population declines are expected in the future as development on private lands continues. State or federal endangered species laws do not protect populations of listed plants on private lands. Fortunately, however, many of the largest remaining and most ecologically pristine *S. rigidus* populations are located on public (primarily federal) lands in Oregon and Washington, where the species is afforded some degree of insulation from development pressures affecting private lands.

In addition to anthropogenic threats, the species is also impacted by seed predation (by beetle and fly larvae), which has been reported to destroy as many as 12 percent of *S. rigidus* seeds (Bigger 1999).

Study sites

Seven study sites were used to determine density estimates for *S. rigidus*: Vinci, Spectra Physics, Hansen, Isabelle, Speedway, Willow Creek Preserve, and Camassia Natural Area (Figure 9.2). For a complete list of all sites visited during the course of the study, as well as directions and GPS points for those sites, see Appendix 1.

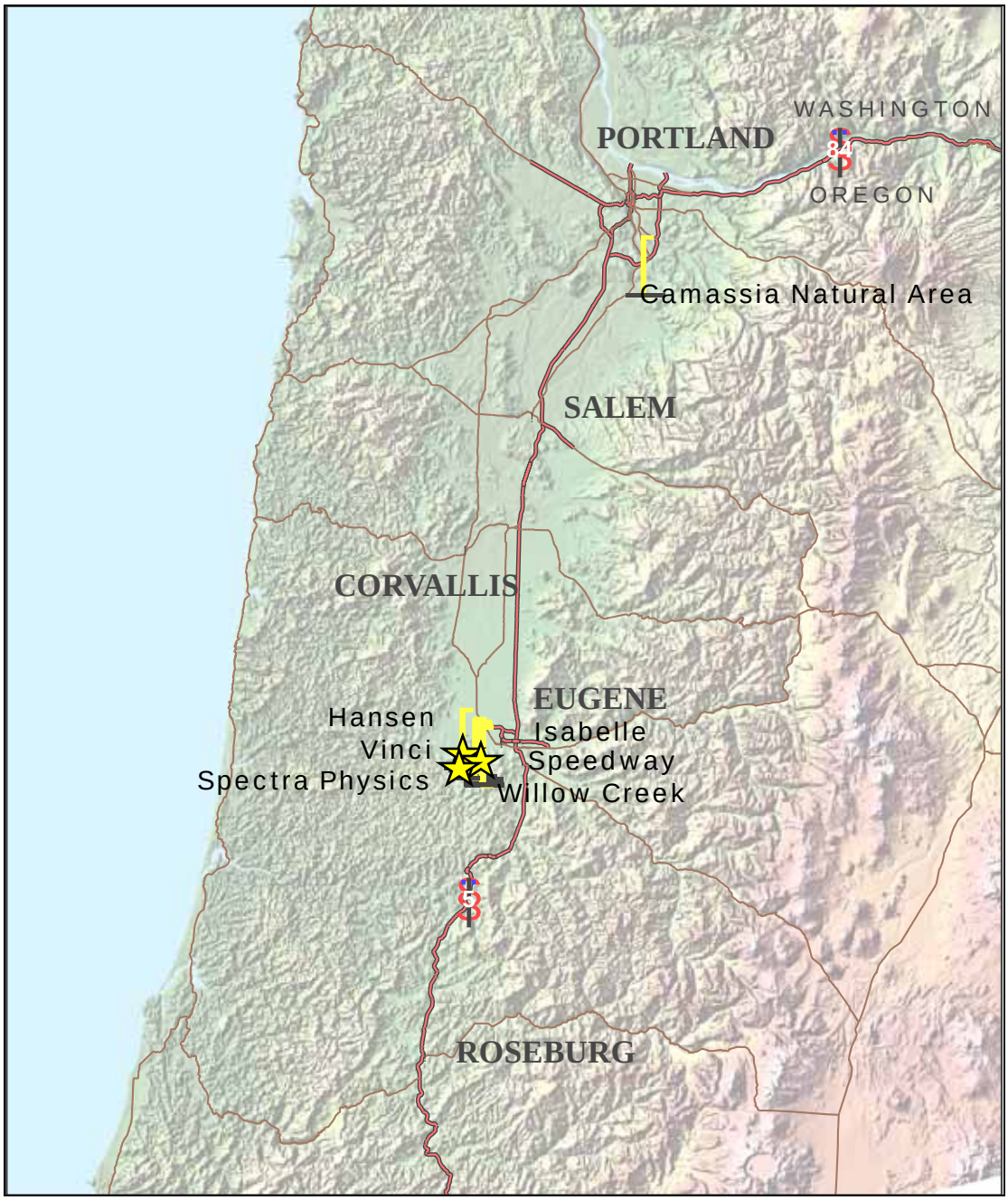

Figure 9.2. *Sericocarpus rigidus* sites visited for this study.

Vinci: The Vinci population of *S. rigidus* is located in West Eugene. This site is managed by the Bureau of Land Management as part of the West Eugene Wetlands complex. This site is a relatively high quality prairie remnant, and in addition to the *Sericocarpus* populations it supports populations of *Erigeron decumbens* ssp. *decumbens* and *Horkelia congesta* ssp. *congesta*. The *S. rigidus* population is scattered throughout the eastern portion of this property in an open field (Figure 9.3). Current threats to this site are invasion of non-native invasive plant species (especially Himalayan blackberry), encroachment of woody species, and potential changes in hydrology from surrounding development (a large business complex was fairly recently built to the east of the Vinci site).

Figure 9.3. *Sericocarpus rigidus* habitat at the Vinci site in West Eugene.

Spectra Physics: The Spectra Physics population of *S. rigidus* is also managed by the Bureau of Land Management as part of the West Eugene Wetlands complex (Figure 9.4). This site was recently purchased as a wetland mitigation site, and in addition to *Sericocarpus*, it supports a population of *Lomatium bradshawii*. As with other sites in this area, primary threats to this population include invasion

Figure 9.4. *Sericocarpus rigidus* habitat at the Spectra Physics mitigation site in West Eugene. Pink flags represent patches of *S. rigidus*.

of non-native weeds and encroachment of woody species.

Hansen: The Hansen population of *S. rigidus* is another West Eugene Wetlands site managed by the Bureau of Land Management. This site is largely forested, but supports multiple patches of *S. rigidus* in the small clearings and meadows scattered throughout the site (Figure 9.5).

Figure 9.5. *Sericocarpus rigidus* habitat at the Hansen site in West Eugene. Patches of *S. rigidus* are found throughout the site in small clearings.

Isabelle: The Isabelle population of *S. rigidus* is located on a small piece of property located to the east of the BLM office in West Eugene (Figure 9.6). Part of the West Eugene Wetlands complex, this site is managed by the Bureau of Land Management.

Figure 9.6. *Sericocarpus rigidus* habitat at the Isabelle site in West Eugene.

Speedway: The Speedway population of *S. rigidus* is located in West Eugene. Although at one time this site was privately owned and had an active racetrack, this site is now managed by the Bureau of Land Management as part of the West Eugene Wetlands complex. This site is a relatively high quality prairie remnant, and in addition to *Sericocarpus* it supports populations of *Erigeron decumbens* ssp. *decumbens*, *Lomatium bradshawii* and *Horkelia congesta* ssp. *congesta.* There are several patches of *S. rigidus* at this site. The bulk of the plants are located at the northern edge of the site, near W. 11th Street (Figure 9.7). There is an additional small patch along the southeastern edge of the property as well, along the bank of Amazon Creek, which runs along the southern edge of the property. Current threats to this site are invasion of non-native invasive plant species (especially Himalayan blackberry), encroachment of woody species, and changes in hydrology from surrounding development (a new Walmart was recently built immediately to the east of the Speedway site).

Figure 9.7. *Sericocarpus rigidus* habitat at the Bureau of Land Management's Speedway site.

Willow Creek Preserve: The Willow Creek Preserve is owned and managed by The Nature Conservancy. This preserve is part of the greater West Eugene Wetlands, a network of private and publicly-owned lands being managed for wetland function and rare species. In addition to *S. rigidus*, this preserve also supports populations of *Horkelia congesta* ssp. *congesta, Lomatium bradshawii*, *E. decumbens* var. *decumbens*, and *Lupinus sulphureus* ssp. *kincaidii*. The primary threat to this population is invasive weeds and encroachment of shrubs and trees (Figure 9.8).

Figure 9.8. *Sericocarpus rigidus* habitat at the Willow Creek Preserve in West Eugene.

Camassia Natural Area: Located in the hills of West Linn, The Nature Conservancy's Camassia Natural Area is a 26 acre rocky plateau which hosts an unusually diverse array of wetland and grassland communities (The Nature Conservancy 2005). In addition to *S. rigidus*, this site also contains a population of *Delphinium leucophaeum*. The primary threats to this population are invasion of non-native weeds and accidental trampling by recreational users.

Figure 9.9. *Sericocarpus rigidus* habitat at the Camassia Natural Area.

Methodology

Overview

Deciding what to count: Because *S. rigidus* stems are often connected underground by slender creeping rhizomes, it is impossible to tell which stems are connected without excavating the entire plant. Therefore, for the purposes of this study an "individual" was defined as a single stem, reproductive or vegetative, arising from the ground.

Vinci

ODA visited the Vinci population of *S. rigidus* on August 8, 2007. This population was too large and geographically spread out to census. Instead, a 175 m x 65 m macroplot was established encompassing the bulk of the population. Thirty-five one-meter-wide belt transects were installed every five meters along the 175-meter-long side of the macroplot. The position of the first belt transect was randomly determined, and each additional transect was spaced five meters from the last in a systematic sampling configuration. Each transect was surveyed in one meter segments, and all *S. rigidus* stems (vegetative and reproductive) were counted and recorded (Figure 9.10). The site was dotted with several large thickets of Himalayan blackberry. If a transect crossed a blackberry thicket, the center of the thicket was not surveyed for *S. rigidus*.

Spectra Physics

The Spectra Physics population of *S. rigidus* was visited on August 7, 2007. The entire area was surveyed and pinflags were used to mark clumps of *S. rigidus*. Because the population was too large to census, it was systematically sampled. An 195-meter-long x-axis was established parallel to the fence marking the southern edge of the population. Because the area covered by this population was unevenly shaped, variable length one-meter-wide y-transects were installed every five meters along the x-axis, with the location of the first y-transect randomly determined. A total of 39 y-transects were sampled, one meter at a time, and all reproductive and vegetative *S. rigidus* stems were recorded for each y-transect (Figure 9.11).

Figure 9.10. Looking for *Sericocarpus rigidus* along a one-meter-wide belt transect at the Vinci site in West Eugene.

Figure 9.11. Sampling the Spectra Physics population of *Sericocarpus rigidus* using one-meter-wide belt transects established every five meters along an x-axis.

Hansen

The Hansen population of *S. rigidus* was visited on August 17, 2006 and on August 6, 2007. This population was too large to census, and covered too large of an area to completely sample. At this site, several patches of *S. rigidus* were used to develop patch density estimates for the population.

Subpopulation one: Subpopulation one was located along the trail, and was small enough to census. An 8 m x 2 m plot was established encompassing the entire patch. All stems were counted within this plot, and the density was calculated.

Subpopulation two: The second subpopulation of *S. rigidus* used for this study was located in a small meadow. This subpopulation was also censused. An 60-meter-long x-axis was established along the footpath running along one side of the meadow. The subpopulation was censused by establishing one-meter-wide y-transects running perpendicular to the x-axis, and counting all stems of *S. rigidus* along each y-transect (Figure 9.12). The lengths of the y-transects were variable, ending at the edge of the meadow. The density of this subpopulation was calculated by dividing the total number of stems counted by the area of the subpopulation.

Figure 9.12. Counting *Sericocarpus rigidus* along a y-transect at subpopulation two at Hansen.

Subpopulation three: The third subpopulation at Hansen also occupied a small meadow. A 114-meter-long x-axis was established roughly parallel to the path bisecting the meadow (Figure 9.13). The population was divided into one-meter-wide y-transects running parallel to the x-axis. All *S. rigidus* stems were counted within each y-transect. The lengths of the y-transects were variable, ending at the edges of

the meadow. The density of this subpopulation was calculated by dividing the total number of stems counted by the area of the subpopulation.

Figure 9.13. An x-axis was established running through the third subpopulation of *Sericocarpus rigidus* at the Hansen site in Eugene.

Isabelle

The Isabelle population of *S. rigidus* was visited on August 3, 2007. This population was censused. A 4 m x 4 m macroplot was established encompassing the entire population. The macroplot was divided into one-meter^2 plots, and all *S. rigidus* stems were counted within each plot (Figure 9.14. Where stems were very dense, the one-meter^2 plot was further subdivided into quarters to facilitate counting.

Figure 9.14. The small population of *Sericocarpus rigidus* at the Isabelle site was bounded by a 4 m x 4 m macroplot (left). All stems within the macroplot were counted, one meter^2 plot at a time (right).

Speedway

The Speedway population of *S. rigidus* was visited on August 16, 2006. This site contains three subpopulations. Two of these subpopulations were used for this study.

Subpopulation one: This subpopulation is located on the north side of the Speedway property, and was small enough to census. A 3 m x 3 m macroplot encompassing the entire subpopulation was established. All *S. rigidus* stems within each plot were counted, with several transects established with flagging to facilitate counting (Figure 9.15).

Figure 9.15. ODA staff counting *Sericocarpus* stems within subpopulation one at the Speedway population in West Eugene.

Subpopulation two: The second Speedway subpopulation is located along the east side of the site. This subpopulation was also small enough to census. A 6 m x 3 m macroplot encompassing the entire subpopulation was established. The macroplot was further divided into 18 one-meter^2 plots to facilitate counting, and all *S. rigidus* stems within each plot were counted (Figure 9.16).

Figure 9.16. Subpopulation two at Speedway. A 6 m x 3 m macroplot was established encompassing this entire subpopulation, and all *Sericocarpus rigidus* stems within the macroplot were counted.

Willow Creek Preserve

The Willow Creek Preserve population of *S. rigidus* was visited on August 9-10, 2006. At this site, two subpopulations of *S. rigidus* were used for this study.

Subpopulation one: The first subpopulation was too large to census, and was systematically sampled instead. A 100 m x 50 m macroplot encompassing the entire subpopulation was established. Ten 50-meter-long transects were installed, one running the width of each 10-meter-wide section of the plot. The location of the first transect was randomly determined, and each subsequent transect was spaced 10 meters after the previous one. Ten one-meter^2 plots were located along each transect. The location of the first plot was randomly determined, and each subsequent plot was placed along the transect, five meters after the previous one. A total of 100 one-meter^2 plots were sampled. All *S. rigidus* stems were counted and recorded within each plot (Figure 9.17).

Figure 9.17. Laying out sampling plots within the first subpopulation of *Sericocarpus rigidus* at the Willow Creek Preserve.

Subpopulation two: The second Willow Creek Preserve subpopulation was also too large to census, and was systematically sampled. A 90 m x 28 m macroplot encompassing the entire subpopulation was established (Figure 9.18). Nine 30-meter-long transects were installed, one running the width of each 10-meter-wide section of the plot. The location of the first transect was randomly determined, and each subsequent transect was spaced 10 meters after the previous one. Seven one-meter^2 plots were located along each transect. The location of the first plot was randomly determined, and each subsequent plot was placed along the transect, four meters after the previous one. A total of 56 one-meter^2 plots were sampled. All S. *rigidus* stems were counted and recorded within each plot.

Figure 9.18. Looking down the 90-meter side of the macroplot encompassing the second subpopulation of *Sericocarpus rigidus* at Willow Creek Preserve.

Camassia Natural Area

The Camassia Natural Area population of *S. rigidus* was visited on August 18, 2006. This population is divided into two subpopulations.

Figure 9.19. The first subpopulation of *Sericocarpus rigidus* covered an area of less than one meter^2. Orange flags mark the corners of this subpopulation.

Subpopulation one: This subpopulation was small enough to census. However, because the entire area of this subpopulation was less than one m^2, this subpopulation was not used to estimate density (Figure 9.19).

Subpopulation two: The second Camassia Natural Area subpopulation was also small enough to census. A 5 m x 3 m macroplot encompassing the entire subpopulation was

established. The macroplot was further divided into 15 one-meter^2 plots to facilitate counting, and all *S. rigidus* stems within each plot were counted and recorded (Figure 9.20).

Figure 9.20. A 5 m x 3 m macroplot encompassed the second subpopulation of *Sericocarpus rigidus* at The Nature Conservancy's Camassia Natural Area.

Results

Vinci

A total of 1524 stems (118 reproductive, 1406 vegetative) of *S. rigidus* were counted in the 35 one-meter-wide belt transects sampled at the Vinci population. The estimated total number of stems within the macroplot is 7,620 (SE = 2,185). The estimated density of *S. rigidus* at this site is 0.670 stems per m^2 (SE=0.192).

Spectra Physics

A total of 2,126 stems (251 reproductive and 1,875 vegetative) of *S. rigidus* were counted in the 39 one-meter-wide variable length belt transects sampled at the Spectra Physics population. The estimated density of the population is 0.792 stems per m^2 (SE=0.201).

Hansen

Subpopulation one: A total of 265 stems (6 reproductive and 259 vegetative) of *S. rigidus* were counted within the first subpopulation at Hansen. The area of this subpopulation was 16 m^2. The density of *S. rigidus* in subpopulation one is 16.6 stems per m^2.

Subpopulation two: A total of 1,768 stems (33 reproductive and 1,735 vegetative) of *S. rigidus* were counted within the second subpopulation at Hansen. The area of this subpopulation was 1,007 m^2. The density of *S. rigidus* within this subpopulation is 1.76 stems per m^2.

Subpopulation three: A total of 5,893 stems (259 reproductive and 5,634 vegetative) of *S. rigidus* were counted within the third subpopulation at Hansen. The area of this subpopulation was 4,026 m^2. The density of *S. rigidus* within this subpopulation is 1.46 stems per m^2.

Isabelle

A total of 910 stems (199 reproductive and 711 vegetative) of *S. rigidus* were counted at the Isabelle population. The area of this population was 16 m^2. The density of *S. rigidus* within this subpopulation is 56.9 stems per m^2.

Speedway

Subpopulation one: A total of 645 stems (41 reproductive and 604 vegetative) of *S. rigidus* were counted within the first subpopulation at Speedway. The area of this subpopulation was nine m^2. The density of *S. rigidus* within this subpopulation is 71.7 stems per m^2.

Subpopulation two: A total of 400 stems (1 reproductive and 399 vegetative) of *S. rigidus* were counted within the second subpopulation at Speedway. The area of this subpopulation was 18 m^2. The density of *S. rigidus* within this subpopulation is 22.2 stems per m^2.

Willow Creek Preserve

Subpopulation one: A total of 812 stems (51 reproductive, 762 vegetative) of *S. rigidus* were counted in the 100 one-$meter^2$ plots sampled in the first Willow Creek subpopulation. The estimated total number of stems within the macroplot is 40,600 (SE = 8,850). The estimated density of *S. rigidus* at this site is 8.12 stems per m^2 (SE=1.78).

Subpopulation two: A total of 209 stems (4 reproductive, 205 vegetative) of *S. rigidus* were counted in the 56 one-$meter^2$ plots sampled in the second Willow Creek subpopulation. The estimated total number of stems within the macroplot is 8,958 (SE = 3,186). The estimated density of *S. rigidus* at this site is 3.32 stems per m^2 (SE=1.18).

Camassia Natural Area

Subpopulation one: A total of 50 stems (1 reproductive, 49 vegetative) of *S. rigidus* were counted at the first Camassia Natural Area subpopulation. Because the area of this subpopulation was less than one m^2, no density was calculated.

Subpopulation two: A total of 202 stems (1 reproductive and 201 vegetative) of *S. rigidus* were counted within the second subpopulation at Camassia Natural Area. The area of this subpopulation was 15 m^2. The density of *S. rigidus* within this subpopulation is 13.5 stems per m^2.

Summary

Overall, *S. rigidus* population densities ranged from 0.670 to 71.7 stems per m^2. Table 9.1 summarizes the population density estimates for the seven *S. rigidus* sites used in this study.

Table 9.1. Summary of estimated population densities for *Sericocarpus rigidus* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# stems)	Total (sub) population area (m^2)	Total # stems	Population density stems/m^2 (SE)
Vinci	Sample macroplot	2,275	1,524	11,375	*7,620 (2,185)*	*0.670 (0.192)*
Spectra Physics	Sample population	2,684	2,126	*13,420*	*10,631*	*0.792 (0.201)*
Hansen	Census three sub-populations	n/a	n/a	16	265	16.6
		n/a	n/a	1,007	1,768	1.76
		n/a	n/a	4,026	5,893	1.46
Isabelle	Census population	n/a	n/a	16	910	56.9
Speedway	Census two sub-populations	n/a	n/a	9	645	71.7
				16	400	22.2
Willow Creek	Sample two sub-populations	100	812	5,000	*40,600 (8,850)*	*8.12 (1.78)*
		56	209	2,700	*8,957 (3,187)*	*3.32 (1.18)*
Camassia Natural Area	Census one subpopulation	n/a	n/a	15	202	13.5

Discussion

There was a wide range of population densities among the seven *S. rigidus* sites visited for this study. As with several other species in this study, the populations with the smallest areas tended to be the densest. Overall, the population densities ranged from 0.670 to 71.7 stems per m^2. However, when the five populations or subpopulations with very small areas (less than 20 m^2) are removed from consideration, the variation between population densities is considerably reduced (0.670 to 8.12 stems per m^2). The populations with the lowest density estimates (Vinci and Spectra Physics) were those covering the largest areas. Individuals of *S.*

rigidus were found in patches scattered throughout large open areas. The overall landscape was patchier, with small areas of suitable habitat distributed among larger areas of apparently unsuitable habitat. When determining the amount of habitat needed to support a self-sustaining population of *S. rigidus* at a given size, it will be important to determine the nature of that habitat. Since networks of subpopulations covering larger areas tend to be less vulnerable to extirpation, it is probably better to use the smaller population density estimates when determining the amount of protected *S. rigidus* habitat needed to achieve recovery goals.

Chapter X. *Sidalcea nelsoniana*

Introduction

Sidalcea nelsoniana (Figure 10.1) is one of three rare checkermallows (along with *S. campestris* and *S. cusickii*) that occur in the Willamette Valley of Oregon. All three of these members of the mallow family (Malvaceae) have dwindled to an alarming paucity of mostly small, fragmented populations. *Sidalcea nelsoniana* is the rarest of these three species, with populations restricted to the Willamette Valley and flanking higher elevation meadows in Oregon, along with two populations in Washington.

Figure 10.1. *Sidalcea nelsoniana* inflorescence.

Species information

Species status: *Sidalcea nelsoniana* is listed as threatened by the U.S. Fish and Wildlife Service and by the State of Oregon. It is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G2/S2 (imperiled throughout its range/imperiled in Oregon) (ORNHIC 2007). It is listed as Endangered by the State of Washington, though the state lacks regulatory authority for listed plants (Florence Caplow, WNHP, Olympia, Washington, personal communication). The Washington Natural Heritage Program designates *S. nelsoniana* with a rank of S1 (critically imperiled in Washington) (WNHP 2007).

Species description: *Sidalcea nelsoniana* is an herbaceous perennial arising from a stout, often somewhat rhizomatous and laterally spreading rootstock that can form multiple crowns. It produces numerous, erect flowering stems ranging from 5 to 15 decimeters in height. Basal leaves are palmately lobed, with upper leaves and stem leaves becoming deeply divided. *S. nelsoniana* usually exhibits sparse, short, simple stem and upper leaf surface hairs. Fruits are 7-9 seeded schizocarps, with single-seeded, beaked carpels that form a ring, like the segments of an orange. Carpels separate at maturity and simply fall from the parent plant. Flowers vary considerably in size due to sexual dimorphism, with larger flowers formed on hermaphroditic individuals and smaller flowers formed on female (male-sterile) individuals. Although flower color can vary dramatically (Gisler 2003), flower color is *usually* pink to rose in *S. nelsoniana*. For further descriptive information see Hitchcock and Kruckeberg (1957), Peck (1961) and Halse et al. (1989).

Because of pronounced intraspecific variability, it can be very difficult to delimit Willamette Valley checkermallow species using single morphological traits. Instead, accurate identification often rests on a combination of characters. In general, *S. cusickii* can usually be discerned from its congeners by its glabrous (and typically non-glaucous) stems and leaves, dark pink flowers (though some populations contain white to pale pink flowers), sepals that are frequently widened above the base (and purple-tinged) before they taper to a point, bluntly terminated inflorescences (rather than tapered to a point) when in bud, and by its more southerly geographic distribution. *Sidalcea campestris* can usually be recognized by its white flowers (though some populations contain darker pink flowers), stem hairs that are typically long, dense, and forked (or simple and forked together), and basal leaves that are often more deeply dissected than those of the other congeners. *Sidalcea nelsoniana* typically has glaucous stems, pink flowers (though sometimes very pale pink to white in some populations in the southern portion of its range), sparse and short-simple stem and upper leaf pubescence, and a distribution entirely north of southern Benton County. *Sidalcea nelsoniana* and *S. cusickii* are the two most difficult species to distinguish from one another, though fortunately they are not known to overlap in the wild (Steve Gisler, ODOT Biologist, personal communication on February 10, 2004).

Another more common and widespread *Sidalcea* species, *S. virgata*, also occurs in the Willamette Valley. This species can be distinguished from its congeners by its more decumbent and rhizomatous habit, stellate stem pubescence, shorter flowering stems, sparser inflorescences, longer sepals that are rolled along the margins, and an earlier phenology (flowering is usually completed by early June, when the other congeners are just starting to flower) (Gisler 2003 and personal communication on February 10, 2004).

Habitat/range: *Sidalcea nelsoniana*, ranges from southern Benton County, Oregon, northward through the central and western Willamette Valley, to Cowlitz and Lewis Counties, Washington. (City of McMinnville 1997, USFWS 1998, ORNHIC 2005). Additionally, this species occurs in several higher elevation Coast Range meadows that flank the western Willamette Valley. The Oregon Natural Heritage Information Center (as of June 2005) lists 91 occurrences of *S. nelsoniana* in Oregon, distributed in Benton, Clackamas, Columbia, Linn, Marion, Polk, Tillamook, Washington, and Yamhill Counties (ORNHIC 2005). Only two populations occur in Washington, one each in Lewis and Cowlitz Counties, both on private land (Joseph Arnett, Washington Natural Heritage Program, Olympia, Washington, personal communication). Known populations range in elevation from 145-1,960 ft (ORNHIC 2005).

Sidalcea nelsoniana occupies grasslands (wet and dry prairie), wetlands, and edges of woodlands and riparian areas, sites that frequently exist as small habitat remnants located along roadsides. OSU herbarium specimen labels variously describe these habitats as: "dry prairies," "grassy fencerows," "moist, open ground and thickets," "overgrown drainage ditches," "roadside ditch with tall grasses," "wet, grassy openings along right-of-ways," "lightly wooded ash swales," and "moist flats with adobe soil." Although *S. nelsoniana* tends to occupy sites that are relatively undisturbed, such as parks and wildlife refuges and the undeveloped margins of fields and roads, it appears capable of colonizing (or at least persisting within) some disturbed sites (City of McMinnville 1986, Halse and Glad 1986, Glad et al. 1994). It is uncertain, however, to what degree seedling recruitment occurs in

weedy sites, and how long populations can persist under such conditions after mature plants with large, established root systems die.

Glad et al. (1994) reported 111 species associated with *Sidalcea nelsoniana*, about half of which were non-native. Some of the species most commonly associated with *S. nelsoniana* include: *Achillea millefolium*, *Agrostis tenuis*, *Alopecuris pratensis*, *Arrhenatherum elatius*, *Brodiaea hyacinthina*, *Carex* spp., *Cirsium* spp., *Chrysanthemum leucanthemum*, *Crataegus* spp., *Dactylis glomerata*, *Daucus carota*, *Deschampsia caespitosa*, *Equisetum arvense*, *Festuca arundinaceae*, *Fragaria virginiana*, *Fraxinus latifolia*, *Galium aparine*, *Geum macrophyllum*, *Heracleum lanatum*, *Holcus lanatus*, *Hordeum brachyantherum*, *Hypericum perforatum*, *Hypochaeris radicata*, *Juncus* spp., *Lotus corniculatus*, *Lupinus polyphyllus*, *Madia sativa*, *Parentucellia viscosa*, *Phalaris arundinaceae*, *Prunella vulagris*, *Pteridium aquilinum*, *Quercus garryana*, *Rubus* spp., *Rosa* spp., *Spiraea* douglasii, *Symphoricarpos albus*, *Vicia* spp., (Kemp et al. 1978, Siddall 1979, Halse and Glad 1986, USFWS 1993, 1998, Gisler and Meinke 1995, ONHP 2002, OSU herbarium specimen label information).

As indicated, *Sidalcea nelsoniana* is frequently associated with various trees, especially *Fraxinus latifolia* and *Quercus garryana*. These trees frequently occur as small woodlands, with *S. nelsoniana* typically occupying small clearings and edges with fairly open canopies. Although the species is sometimes found under closed canopies, plants frequently become etiolated under such conditions and it is uncertain how long they can persist in the shade. It is likewise unknown if these shaded plants colonized habitats that were originally wooded, or if they pre-date canopy closure and simply persist in areas that have become overgrown by trees and shrubs through successional encroachment of previously open habitat. Such encroachment is considered a primary threat to the species.

Soils found in habitats occupied by *Sidalcea nelsoniana* are variable, ranging from gravelly, well-drained loams, to poorly drained, hydric clay soils (City of McMinnville 1986, Glad et al. 1994). Generally, it is found in soils that become saturated during the rainy season, with plants frequently inundated for several weeks or longer (Steve Gisler, ODOT Biologist, personal communication on February 10, 2004).

Threats: *Sidalcea nelsoniana* faces overwhelming threats posed by widespread habitat loss to agricultural and urban development, ecological succession that results in shrub and tree encroachment of open prairie habitats, and competition with invasive weeds (Kemp et al. 1978, Siddall 1979, Scofield and Sawtelle 1985, ONRC 1986, Robinson and Parenti 1990, USFWS 1993, ODA 1995, USFWS 1998, Steve Gisler, Oregon Department of Transportation biologist, personal communication on February 10, 2004). Additional threats include pre-dispersal seed predation by weevils (USFWS 1993, Gisler and Meinke 1997, USFWS 1998, Gisler and Meinke 1998), and the potential threats of inbreeding depression due to small population sizes and habitat fragmentation, and interspecific hybridization (Gisler 2003).

The two overriding factors favoring the persistence and eventual recovery of *Sidalcea nelsoniana* are the occurrence of several large "stronghold" populations on public lands, and the very promising cultivation and re-introduction potential this species exhibits.

Study sites

Fourteen study sites were used to determine density estimates for *S. nelsoniana*: Walker Flat, Barney Reservoir, Salem Airport, Camp Adair, E.E. Wilson Wildlife Refuge, OSU Horse Farm, OSU Poultry Farm, Finley National Wildlife Refuge, I-5 and Highway 22 Junction, Highway 22 (Milepost 18), Highway 223 and Cooper Hollow Road, Highway 99 (Milepost 57), and Highway 99 (Milepost 56) (Figure 10.2). For a complete list of all sites visited during the course of the study, as well as directions and GPS points for those sites, see Appendix 1.

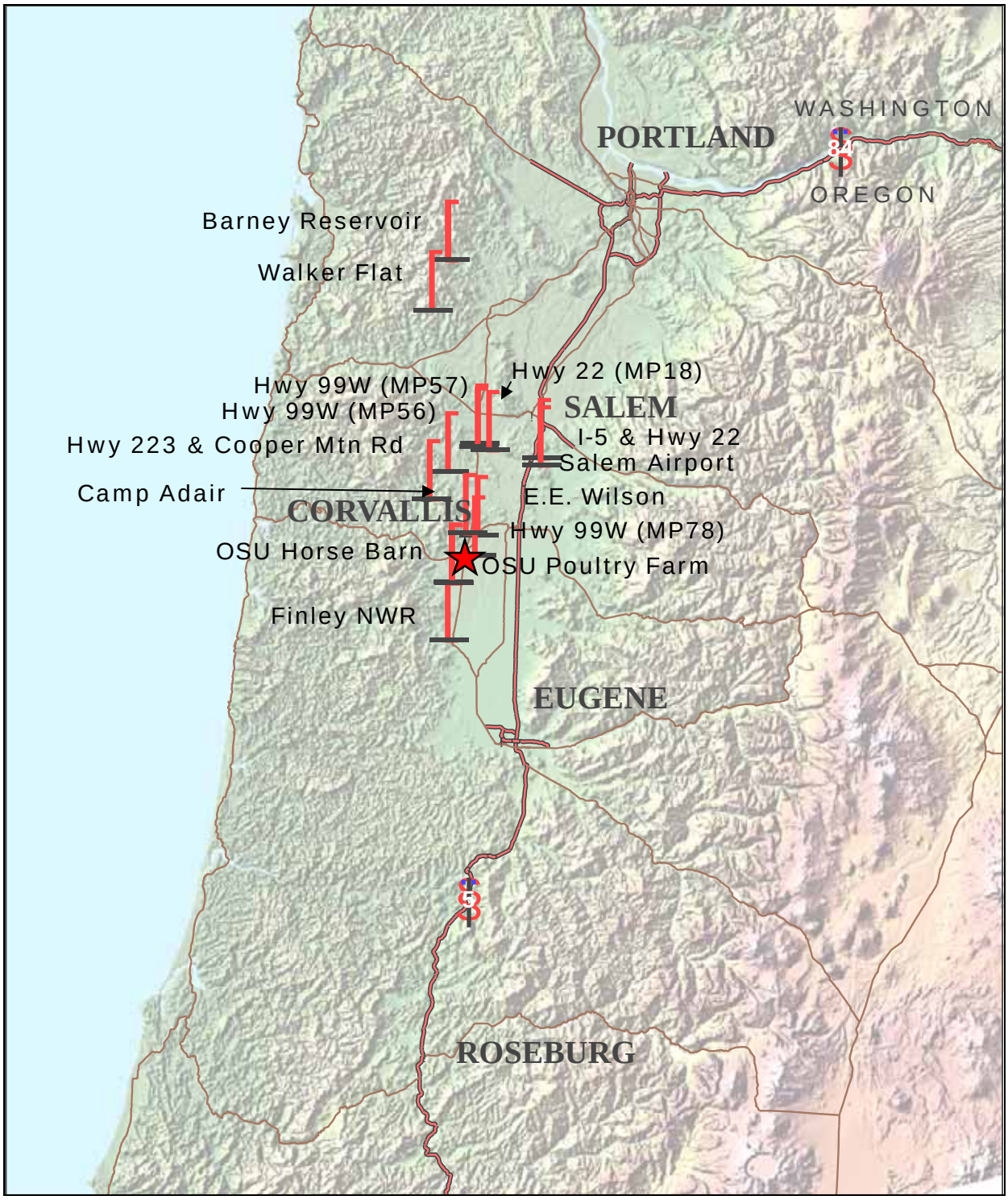

Figure 10.2. *Sidalcea nelsoniana* sites visited for this study.

Walker Flat/McGuire Reservoir: The Walker Flat/McGuire Reservoir population of *S. nelsoniana* was discovered when surveys were conducted prior to constructing a new reservoir in Yamhill County to meet the City of McMinnville's increasing water needs. While some of the population was destroyed during the construction of McGuire Reservoir, a portion still remains. Part of the remaining population's habitat was designated as an Area of Critical Environmental Concern (ACEC) in 1995, and is owned and managed by the Bureau of Land Management. The remaining part of this population is on land adjoining the ACEC, and is owned and managed by the City of McMinnville. This population is one of several found in meadows located at higher altitudes within the eastern edge of the Coast Range (rather than on the Willamette Valley floor, where most of the *S. nelsoniana* populations are found). Individuals of *S. nelsoniana* are scattered throughout a large open wet meadow (Walker Flat) dominated by grasses and sedges (Figure 10.3). This meadow is surrounded by forested areas dominated by either red alder (in the riparian areas) or Douglas fir (Bureau of Land Management 1998). Threats to this population include encroachment of woody species, invasion of non-native weeds, changes in vegetation and hydrology due to land use practices on nearby land (i.e. clear cutting timber on land adjacent to the southern boundary of the ACEC), and potential future expansion of the reservoir by the City of McMinnville (Kurt Heckeroth, botanist, Bureau of Land Management, personal communication on July 9, 2007).

Figure 10.3. *Sidalcea nelsoniana* habitat at Walker Flat in Yamhill County.

Barney Reservoir: The Barney Reservoir population of *S. nelsoniana* is located in Washington County, on land owned and managed by the City of Hillsboro. This is another

of the "Coast Range" populations of *S. nelsoniana*, found at higher elevations in the hills to the west of the Willamette Valley. Although historically there were several populations on land surrounding the reservoir, ODA staff was only able to locate one population, which is found in a small open wet meadow near a series of small ponds on the southeast end of the reservoir (Figure 10.4). It is possible that several of the other populations were destroyed when the reservoir's water level was raised in 1997 (Carl Borg, District Supervisor of Management Operations, City of Hillsboro, personal communication on June 15, 2007). Threats to this population include encroachment of woody species, invasion by non-native weeds, and potential changes in hydrology due to reservoir operations.

Figure 10.4. *Sidalcea nelsoniana* habitat at Barney Reservoir. Individuals are primarily found in the lower part of the meadow, nearer to the water.

Salem Airport: The Salem Airport population of *S. nelsoniana* is owned and managed by the City of Salem. This population stretches throughout the western edge of the airport property, with individuals found primarily along the banks of a ditch and the seasonally wet flat areas nearby (Figure 10.5). The ditch runs primarily north-south along the property through a currently unused field divided by several unmaintained roads. *Sidalcea campestris*, another rare Willamette Valley *Sidalcea*, is also found at this site. Current threats to this population

include invasion by non-native weeds (in particular scotch broom), fire (a portion of the site was accidentally burned in 2006), disturbance due to airport operations and potential future expansion, and hybridization with *S. campestris*.

Figure 10.5. *Sidalcea nelsoniana* habitat at the Salem Airport.

Camp Adair: Once part of one of the largest military installations in Oregon, the portion of Camp Adair that hosts a population of *S. nelsoniana* is currently managed by the Oregon Military Department (OMD), and is primarily used for military training exercises. Individuals of *S. nelsoniana* are found in the southeastern corner of the property, either in a small wet meadow or in tiny clearings scattered throughout the adjoining woodland (Figure 10.6). This property also supports a population of the federally and state

Figure 10.6. *Sidalcea nelsoniana* habitat at Camp Adair. Plants are found in clearings and along the edge of a small woodland, as well as in an adjoining wet meadow.

listed *L. sulphureus* ssp. *kincaidii*, as well as a population of the rare *Sidalcea campestris*. With assistance from U.S. Fish and Wildlife, OMD manages the site for both *S. nelsoniana* and *L. sulphureus* ssp. *kincaidii* (not only for the rare plant species itself, but also as potential habitat for the federally listed Fender's blue butterfly). Threats to this population include encroachment from woody plant species in the meadow, invasion of non-native species (especially Himalayan blackberry in the meadow), loss of habitat within the woodland as the canopy closes in, mowing during the growing season, accidental disturbance during the course of military training activities, and herbicide drift from county roadway maintenance activities along the adjoining road.

E.E. Wilson Wildlife Management Area: The E.E. Wilson Wildlife Management Area is owned by the Oregon Department of Fish and Wildlife. Although this 1,700-acre site is primarily managed for bird habitat, it also supports populations of *S. nelsoniana* and *Lupinus sulphureus* ssp. *kincaidii*. Historic records indicate that the *S. nelsoniana* population consists of four to five subpopulations (Figure 10.7). The primary threats to this population are encroachment of woody species and invasion by non-native weeds.

Figure 10.7. *Sidalcea nelsoniana* habitat at the E.E. Wilson Wildlife Management Area. The subpopulation used in this study is located along the edge of an old road (left). Another large subpopulation is found in a large wet meadow (right).

OSU Horse Barn: Historic records indicated that the OSU Horse Barn population of *S. nelsoniana* existed not only along Walnut Street in Corvallis, but also in the adjoining

pasture area. ODA staff did not find *S. nelsoniana* plants within the fenced pasture area adjacent to the Benton County right of way (ROW); however, only a cursory survey of the pasture area was conducted, and it is possible that plants were missed. For the purposes of this study, the OSU Horse Barn site consists of the portion of the population located along Walnut Street on the banks of the ditch in the Benton County ROW (Figure 10.8). Threats to this population include invasion by non-native weeds and County roadside maintenance activities such as ditching, mowing, spraying with herbicide, and maintenance of the adjoining bike path. However, Benton County is currently working with U.S. Fish and Wildlife Service to develop a Habitat Conservation Plan to assist in the conservation and management of listed species populations found on County lands.

Figure 10.8. *Sidalcea nelsoniana* growing up through a patch of vetch (*Vicia* sp.) along the Oregon State University Horse Farm property.

OSU Poultry Farm: The Oregon State University Poultry Farm is located in West Corvallis, just north of Harrison Street. Although historically this site hosted a large population of *S. nelsoniana* (in 1995 the estimated population size was over 1,700 individuals), it appears that land use practices (possible conversion of an open meadow to a grass field) have considerably reduced the size of this population. ODA staff located the remaining portion of the population between the edge of grass field/pasture and the adjacent strip of ash (*Fraxinus latifolia*) woodland (Figure 10.9). Individuals of *S. nelsoniana* at this site were primarily vegetative, and more spindly in habit than those at other sites used in this study. This may be due to the fact that the habitat was shadier at this site. Threats to this population include mowing, plowing, and grazing (the site has recently been used to graze sheep).

Figure 10.9. *Sidalcea nelsoniana* habitat at the Oregon State University Poultry Farm. Individuals are currently found along the edge of a strip of *Fraxinus latifolia* woodland (left). Orange flags (right) represent individual *S. nelsoniana* plants.

Finley National Wildlife Refuge: Finley National Wildlife Refuge is located approximately 10 miles south of Corvallis in Benton County (Figure 10.10). In addition to several populations of *S. nelsoniana*, the Refuge also supports populations of *Delphinium pavonaceum*, *Lomatium bradshawii*, and *Lathyrus holochlorus*. *Sidalcea campestris* is also found co-occurring with at least one of the *S. nelsoniana* populations. In addition to actively managing for these species, Refuge biologists have

Figure 10.10. *Sidalcea nelsoniana* habitat at Finley National Wildlife Refuge. Individuals are found scattered throughout a wet meadow near Muddy Creek.

planted an experimental population of *S. nelsoniana* at another site containing appropriate wet prairie habitat at the Refuge. Threats to the *S. nelsoniana* populations on the Refuge include encroachment of woody species, invasion of non-native weeds, and hybridization with *S. campestris*.

I-5 & Hwy 22 (Salem): The Salem cloverleaf interchange of Interstate 5 and Highway 22 is located in Marion County and is owned and managed by the Oregon Department of Transportation (ODOT). The *S. nelsoniana* plants are found in the open grassy area between two small clumps of ash/oak trees (Figure 10.11). In addition to *S. nelsoniana*, several plants with intermediate (between *S. nelsoniana* and *S. campestris*) characteristics occur at this site. Threats to this site include disturbance caused by road maintenance activities and invasion of non-native weeds.

Figure 10.11. *Sidalcea nelsoniana* habitat at the interchange of I-5 and Highway 22 in Salem.

Hwy 22 (MP 18): The Highway 22 population of *S. nelsoniana* is located in several patches along a wide ODOT right-of-way (ROW) between Salem and the interchange with Highway 99W, in Polk County. The *S. nelsoniana* habitat is bounded by the highway on one side, and a hedgerow and cultivated fields on the other (Figure 10.12). In addition to *S. nelsoniana*, this site supports a population of *Delphinium pavonaceum*. *Sidalcea campestris* is also present at this site, and individuals exhibiting characteristics intermediate between the two species were observed. One small patch of *S. nelsoniana* was observed on private land along the boundary between the ROW and the cultivated fields. Threats to this population include heavy competition with grasses, disturbance from roadside maintenance activities, invasion of non-native weeds, and potential drift from herbicide application on the adjoining private land.

Figure 10.12. Looking west along Highway 22 at the *Sidalcea nelsoniana* population located in the Oregon Department of Transportation right-of-way.

Hwy 223 & Cooper Hollow Rd: The Highway 223/Cooper Hollow Road population of *S. nelsoniana* is located south of Dallas in Polk County. This population is also located within an ODOT right-of-way (Figure 10.13). Much like other ROW populations of rare plants, threats to this site include disturbance from roadside maintenance activities, invasion by non-native weeds, and encroachment by woody species.

Figure 10.13. *Sidalcea nelsoniana* habitat along Highway 223.

Hwy 99W (MP 77-78): There are multiple small populations of *S. nelsoniana* along Highway 99W in Benton and Polk Counties. This particular population is located between Corvallis and Monmouth, just north of Lewisberg, and has individuals on both side of the highway (Figure 10.14). Like other roadside populations, maintenance activities and non-native weed invasion competition are the primary threats to this population.

Figure 10.14. An ODOT biologist surveys for *Sidalcea nelsoniana* along Highway 99.

Hwy 99W (MP 57): Located just north of the junction with Highway 22, this small Highway 99 population of *S. nelsoniana* is managed by ODOT. This site is across the highway from Baskett Slough National Wildlife Refuge, which also supports a population of *S. nelsoniana*. The primary threats to this population are competition with non-native grasses and drift from herbicide sprayed on the adjacent private agricultural fields.

Hwy 99W (MP 56): Just a mile up the highway from the previous population, this *S. nelsoniana* population is also owned and managed by ODOT. As with the previous site, the primary threats to this population are competition with non-native grasses and drift from herbicide sprayed on the adjacent private agricultural fields (Figure 10.15).

Figure 10.15. *Sidalcea nelsoniana* habitat along Highway 99. These roadside populations are commonly threatened by the non-native grasses and herbicide drift from adjacent agricultural fields.

Sites visited but not used in this study: Some of the current or historic sites visited by ODA during the course of this study did not prove to be suitable for use in the development of population density estimates. A complete list of the sites visited is available in Appendix 1.

Methodology

Overview

Deciding what to count: Like several of the other species in this study, *S. nelsoniana* is capable of reproducing vegetatively, through the spread of underground rhizomes which can produce multiple crowns. In dense populations it becomes impossible to determine whether or not stems are connected to each other via these rhizomatous roots. Several methods have been used to quantify populations of this species, including determining presence/absence in each square meter, estimating overall cover, and labeling clumps or stems which are separated by a designated amount as separate individuals. For the purposes of this study, we followed the third method, and required that stems or clumps be separated from each other by at least 30 cm in order to be considered separate individuals. This distance was measured at ground level between stem bases.

Distinguishing between Willamette Valley* Sidalcea *species: *S. nelsoniana* often grows with the closely related species *S. campestris* and *S. virgata*. These species look very similar, and field guide showing the differences between the three species was developed for field use using keys from Hitchcock and Cronquist (1974), Gilkey and Dennis (2001) and Kozloff (2005), as well as information in the thesis of Steve Gisler (see Willamette Valley *Sidalcea* characteristics in Appendix 1). With practice, field workers were able to distinguish between the three species, even in bud. At several of the sites used in this study, ODA encountered both *S. nelsoniana* and *S. campestris* occurring sympatrically. These populations often contained individuals exhibiting intermediate characteristics (between those of *S. nelsoniana* and *S. campestris*; Figure 10.16). These potential hybrids were recorded as "unknown species" and were not included when calculating of population densities. Vegetative

individuals of *Sidalcea* were recorded as non-reproductive, and were assumed to be *S. nelsoniana* in sites where no *S. campestris* or *S. virgata* were present.

Figure 10.16. Intermediate *Sidalcea* sp. flowers at Camp Adair.

Walker Flat (McGuire Reservoir)

The Walker Flat population of *S. nelsoniana* was visited on July 9, 2007. This population was too large and geographically spread out to census, and was instead systematically sampled using varable-length one-meter-wide belt transects. One portion of this site was previously used for an experimental augmentation of the population. However, as with other sites that had introduced or augmented populations, we did not use the area where the introduced individuals were planted for our study. A 150-meter-long x-axis was established running through the center of the population (roughly following the ditch which bisects the meadow). Fifteen y-transects were established running parallel to the x-axis. The location of the first y-transect was randomly determined within the first 10-meter section, and subsequent y-transects were placed along the x-axis every 10 meters after the first. The number of *S. nelsoniana* individuals (either vegetative or reproductive) in each y-transect was recorded (Figure 10.17).

Figure 10.17. Oregon Department of Agriculture botanists counting individuals of *Sidalcea nelsoniana* along a one-meter-wide transect at Walker Flat.

Barney Reservoir

The Barney Reservoir population of *S. nelsoniana* was visited on June 29, 2007. There are two subpopulations at this site – one natural and one introduced. We only used the natural subpopulation for the purposes of estimating population density, but we did estimate the number of individuals present at the introduced site as well. The natural populations was censused by establishing a 42 m x 23 m macroplot encompassing the entire population, and recording the number of individuals found. Three-meter-wide transects were installed parallel to the 22-meter side of the macroplot to facilitate counting (Figure 10.18).

Figure 10.18. Counting *Sidalcea nelsoniana* at the natural population at Walker Flat.

Salem Airport

The Salem Airport was visited on May 30, 2007. Initially, ODA staff was told that *S. nelsoniana* only occurred in the southeastern corner of the property, south of an abandoned road. This area was censused. A 101 m x 100 m macroplot encompassing all of the area (with the exception of one outlying plant approximately 20 m to the southwest of the plot) was established. The macroplot was divided into three-meter-wide transects to facilitate counting (Figure 10.19). All *S. nelsoniana* plants were counted within the macroplot. *Sidalcea campestris* also occurs at this site; however, most of the individuals of *S. campestris* were located north of the abandoned road (only one *S. campestris* was found within the macroplot). Once the macroplot census was completed, staff surveyed the area north of the abandoned road, and discovered that additional *S. nelsoniana* individuals occurred all along the ditch that runs north-south along the eastern edge of the airport property. There was not enough time to incorporate the northern part of the population into our study. Individuals exhibiting intermediate (between *S. nelsoniana* and *S. campestris*) characteristics were also observed north of the abandoned road.

Figure 10.19. *Sidalcea nelsoniana* habitat at the Salem Airport. Picture taken standing at the edge of the road bordering the north side of the 101 m x 100 m macroplot, looking south.

Camp Adair

The Camp Adair population of *S. nelsoniana* was visited on July 11, 2006. Calculating the population density posed several difficulties at this site. First, there was the issue of species identification – in addition to *S. nelsoniana*, both *S. campestris* and individuals exhibiting intermediate characteristics were also present at the site. Secondly, the perimeter of the population (an approximately two to three-meter-wide swathe running along the property boundary) had already been mowed when we visited the site. Although members of the field crew identified *Sidalcea* leaves in the mowed area, the flowering stalks were gone and we were unable to identify the species. Thirdly, while most of the *Sidalcea* plants were located the small meadow at the southeastern corner of the property, patches of *Sidalcea* were also scattered throughout the small woodland adjacent to the meadow, in clearings and along paths (Figure 10.20).

Figure 10.20. *Sidalcea* habitat at Camp Adair. Individuals of *S. nelsoniana* and *S. campestris* were found in both the meadow (foreground) and in clearings in the adjacent woodland (background).

When determining the total number of *S. nelsoniana* plants at this site, the population was divided into two subpopulations – the meadow and the woods. The meadow subpopulation

was censused by dividing the open area into three-meter-wide transects to facilitate counting. All *Sidalcea* plants were counted, and each individual was identified as *S. nelsoniana*, *S. campestris*, vegetative, or intermediate. A ratio of known individuals of *S. nelsoniana* to known individuals of *S. campestris* was calculated, and the vegetative plants were assigned a species according to that ratio. The woodland subpopulation was censused by thoroughly surveying the roads, paths and clearings found inside the trees. The ratio of *S. nelsoniana* to *S.*
campestris was different than that of the meadow. A new ratio was calculated, and the same process of assigning unknown *Sidalceas* was followed. The area of the population was determined by recording GPS points around the edge of the population boundary, and calculating the area of the resulting polygon using the mapping program ArcGIS.

E.E. Wilson Wildlife Management Area

The E.E. Wilson Wildlife Management Area population of *S. nelsoniana* was visited on June 14, 2007. There are four subpopulations at this site. ODA staff censused two of the four subpopulations at this site. However, the second subpopulation was too small to use in this study, and the population density was calculated for the first subpopulation only. At the first subpopulation, a 53-meter-long x-transect was established running through the middle of the population. Three-meter-wide y-transects were installed parallel to the x-transect to facilitate counting. All individuals of *S. nelsoniana* were recorded within the subpopulation (Figure 10.21).

Figure 10.21. Counting *Sidalcea nelsoniana* at E. E. Wilson Wildlife Area. Orange flags represent clumps of *S. nelsoniana*.

OSU Horse Barn

The Oregon State University Horse Farm population of S. nelsoniana was visited on June 11, 2007. This population was censused. The area of the population was small enough to be measured using 100-meter tapes (Figure 10.22). All plants were recorded. No *S. campestris* was observed at this site.

Figure 10.22. *Sidalcea nelsoniana* habitat along the edge of the Oregon State University Horse Barn. Plants were located along the ditch which runs between the OSU property and the bike path.

OSU Poultry Farm

The Oregon State University Poultry Farm population of *S. nelsoniana* was visited on July 12, 2006. This population was censused. After surveying the entire area for *S. nelsoniana*, a 45 m x 26 m macroplot encompassing the entire population was established. Three-meter-wide transects were installed perpendicular to the long side of the macroplot to facilitate counting (Figure 10.23). No *S. campestris* plants were found at this population.

Figure 10.23. Establishing a macroplot encompassing the entire population of *Sidalcea nelsoniana* at the Oregon State University Poultry Farm.

Finley National Wildlife Refuge

The Finley National Wildlife Refuge was visited on June 26, 2007. Due to time constraints, only one of the several Finley subpopulations of *S. nelsoniana* was used for this study. This subpopulation was censused. Two adjacent macroplots (one 100 m x 35 m and one 60 m x 29 m) were established, and three-meter-wide transects were installed to facilitate counting. There were several challenges at this population. First, in addition to *S. nelsoniana*, *S. campestris* was present at this site, and individuals exhibiting intermediate characteristics were also observed. Secondly, many of the flowering stalks were grazed, making species determination difficult. When conducting the census, all plants were recorded as *S. nelsoniana*, *S. campestris*, or unknown (if no flowers were present or if the individual exhibited intermediate morphology). Plants which had been grazed were marked with flagging tape, and ODA returned on July 13, 2007 to check these individuals for new flowering stalks in order to assign the correct species identification (Figure 10.24). Once the census was completed, a proportion of *S. nelsoniana* individuals:*S. campestris* individuals was calculated, and all unknown individuals with no flowers (either vegetative or grazed)

were assigned a species identification using the same proportion as the known individuals. Individuals exhibiting intermediate flower characteristics and individuals of *S. campestris* were not used to calculate the subpopulation density.

Figure 10.24. Grazed *Sidalcea* individual at the Finley National Wildlife Refuge, marked with flagging for future attempt at species identification. Because both *S. nelsoniana* and *S. campestris* were present at this site, flowering stalks were needed to correctly identify the species.

I-5 & Highway 22 (Salem)

The I-5 and Highway 22 population of *S. nelsoniana* was visited on June 16, 2007. This population was censused. A 58 m x 26 m macroplot encompassing the entire population was established (Figure 10.25). All *Sidalcea* plants were counted within the macroplot.

Figure 10.25. Surveying for *Sidalcea nelsoniana* within the I-5 and Highway 22 junction cloverleaf.

Highway 22 (MP 18)

The Highway 22 (MP 18) population of *S. nelsoniana* was visited on June 12, 2007. This population was censused. Five patches of *S. nelsoniana* were found along a approximately one-kilometer-long stretch of the highway. *S. campestris* was also present at this site. Individuals in the first patch were difficult to identify, with many of the plants exhibiting characteristics intermediate between *S. nelsoniana* and *S. campestris* (Figure 10.26). Because of the question regarding species identification at this patch, it was not used to estimate density. The second, third and fourth patches were very small (patch 4 contained only one individual) and were also not used to determine population density. The fifth (easternmost) patch was separated from the other four patches by a stream and heavy riparian vegetation. All plants within this patch appeared to be *S. nelsoniana*. This patch was used to calculate a population density estimate for the site (Figure 10.27). A 90 m x 14 m macroplot

was established encompassing the entire fifth patch, and three-meter-wide transects were installed to facilitate counting. All *S. nelsoniana* individuals were recorded.

Figure 10.26. Attempting to determine *Sidalcea* species at one of the Highway 22 patches. Many individuals within the first patch exhibited characteristics intermediate between *S. nelsoniana* and *S. campestris*.

Figure 10.27. Looking west along the length of the easternmost patch of *Sidalcea nelsoniana* at the Highway 22 population.

Highway 223 & Cooper Hollow Road

The Highway 223 and Cooper Hollow Road population of *S. nelsoniana* was visited on June 21, 2007. This population was censused. Both sides of Highway 223 were surveyed for *Sidalcea* between Cooper Hollow Road and Guthrie Road. An 223-meter-long x-transect was established along the west side of the highway, with the origin placed just south of the southernmost *S. nelsoniana* plant (Figure 10.28). The overall area of the population was determined by dividing the x-transect into sections, and measuring the width for each section. The same x-transect was also used to determine the length of the sections on the east side of the highway. Fern Creek crosses the highway through the middle of this population. The creek and its associated riparian vegetation were excluded from the overall area calculation (no *S. nelsoniana* plants were observed in the riparian areas, and the habitat was inappropriate for this species). One individual of *S. campestris* was observed some distance to the south of the southernmost *S. nelsoniana* plant (near Cooper Hollow Road), but was not included in the study.

Figure 10.28. *Sidalcea nelsoniana* habitat along Highway 223 near Fern Creek.

Highway 99W (MP 77-78)

The Highway 99W (MP77-78) population of *S. nelsoniana* was visited on July 14, 2006 (Figure 10.29). The population was censused. The population consisted of two patches of plants. Because of the distance between the two patches, the area of each patch was measured and the density was calculated separately for each patch.

Figure 10.29. Oregon Department of Agriculture and Oregon Department of Transportation botanists looking for *Sidalcea nelsoniana* plants along Highway 99w.

Hwy 99W (MP 57)

The Highway 99W (MP 57) population of *S. nelsoniana* was visited on June 5, 2007. This very small population was censused, and the area occupied by *S. nelsoniana* was measured with a meter tape. No *S. campestris* was observed at this site.

Highway 99W (MP 56)

The Highway 99W (MP 56) population of *S. nelsoniana* was visited on June 5, 2007 (Figure 10.30). This very small population was censused, and the area occupied by *S. nelsoniana* was measured with a meter tape. No *S. campestris* was observed at this site.

Figure 10.30. Clumps of *Sidalcea nelsoniana* along Highway 99W (red circles). This site is managed by the Oregon Department of Transportation.

Results

Walker Flat (McGuire Reservoir)

A total of 204 individuals of *S. nelsoniana* (115 vegetative and 89 reproductive) were counted in the 15 transects sampled at Walker Flat. The area sampled was 591 m^2. The estimated density of this population was 0.345 individuals per m^2 (SE = 0.055).

Barney Reservoir

A total of 42 individuals of *S. nelsoniana* (26 vegetative and 16 reproductive) were counted at the natural population at Barney Reservoir. The area of the population was 966 m^2. The density of this population was 0.043 individuals per m^2.

NOTE: The bulk of this population consisted of many vegetative plants clumped together forming mats of leaves all closer than 30 cm to each other. This population did not lend itself to the definition of an "individual" used for the other populations. Therefore, there is a strong possibility that our count of "individuals" at this site is low, and that the population density is higher than what we calculated.

Salem Airport

A total of 657 individuals of *S. nelsoniana* (608 vegetative and 49 reproductive) were counted within the macroplot established at the Salem Airport. The area of the population was 10,100 m^2. The density of this population was 0.065 individuals per m^2.

Camp Adair

A total of 58 individuals of *S. nelsoniana* were counted at the Camp Adair population (18 in the meadow and 40 in the woodland). In addition to the *S. nelsoniana*, 110 individuals of *S. campestris* were also located at the site, although they were not included in this study. The area of the population was 118,683 m^2. The density of this population was 0.0004 individuals per m^2.

E.E. Wilson Wildlife Management Area

A total of 185 individuals of *S. nelsoniana* (43 vegetative and 142 reproductive) were counted at subpopulation one at E.E. Wilson. The area of the population was 706 m^2. The density of this population was 0.201 individuals per m^2.

OSU Horse Barn

A total of 41 individuals of *S. nelsoniana* (20 vegetative and 21 reproductive) were counted at the OSU Horse Barn population. The area of the population was 576 m^2 (96 m long x 6 m wide). The density of this population was 0.071 individuals per m^2.

OSU Poultry Farm

A total of 46 individuals of *S. nelsoniana* (40 vegetative and 6 reproductive) were counted at the OSU Horse Barn population. The area of the population was 1,170 m^2 (45 m long x 26 m wide). The density of this population was 0.039 individuals per m^2.

Finley National Wildlife Refuge

A total of 52 reproductive individuals of *S. nelsoniana* were found at the Finley NWR subpopulation used for this study. Nine individuals of *S. campestris* were also found. The ratio of known *S. nelsoniana*:*S. campestris* was approximately 6:1. A total of 73 individuals (43 reproductive with flowering stalks grazed and 30 vegetative) were recorded as unknown. Using the known ratio, 62 of these were assigned to *S. nelsoniana*, and 11 were assigned to *S. campestris*, giving a total of 114 individuals of *S. nelsoniana* for this subpopulation. Two reproductive individuals displayed intermediate morphology, and were not included in the population density estimate calculations. The area of the subpopulation was 5,240 m^2. The estimated density of this subpopulation was 0.022 individuals per m^2.

I-5 & Highway 22 (Salem)

A total of 95 individuals of *S. nelsoniana* (21 vegetative and 74 reproductive) were counted at the I-5 and Highway 22 population. One individual of *S. campestris* and one individual exhibiting intermediate characteristics were also observed at the site. Because the ratio of known *S. nelsoniana* to known *S. campestris* was so large (74:1), it was assumed that all of the vegetative *Sidalceas* were *S. nelsoniana*. The area of the population was 1,508 m^2. The density of this population was 0.063 individuals per m^2.

Highway 22 (MP 18)

A total of 25 individuals of *S. nelsoniana* (2 vegetative and 23 reproductive) were counted at Highway 22 (MP18) population. The area of the population was 1,260 m^2. The density of this population was 0.020 individuals per m^2.

Highway 223 & Cooper Hollow Road

A total of 98 individuals of *S. nelsoniana* (37 vegetative and 61 reproductive) were counted at the Highway 223 and Cooper Hollow Road population. The area of the population was 2,009 m^2. The density of this population was 0.049 individuals per m^2.

Hwy 99W (MP 77-78)

A total of five individuals of *S. nelsoniana* (2 vegetative and 3 reproductive) were counted at first patch of the Highway 99W (MP 77-78) population. The area of this patch was four m^2. The density of this patch was 1.25 individuals per m^2. Sixteen individuals of *S. nelsoniana* (12 vegetative and 4 reproductive) were counted at second patch of the Highway 99W (MP 77-78) population. The area of the population was eight m^2. The density of this population was two individuals per m^2.

Hwy 99W (MP 57)

A total of four large individuals of *S. nelsoniana* (all reproductive) were counted at the Highway 99W (MP 57) population. The area of the population was three m^2. The density of this population was 1.33 individuals per m^2.

Hwy 99W (MP 56)

A total of 10 large individuals of *S. nelsoniana* (all reproductive) were counted at the Highway 99W (MP 56) population. The area of the population was 30 m^2. The density of this population was 0.333 individuals per m^2.

Summary

Overall, *S. nelsoniana* population densities ranged from 0.0004 to 2.00 individuals per m^2. Table 10.1 summarizes the population density estimates for the fourteen *S. nelsoniana* sites used in this study.

Table 10.1. Summary of estimated population densities for *Sidalcea nelsoniana* sites. Italicized numbers are estimated values. Non-italicized numbers are measured values.

Site	Method	Sample area (m^2)	Sample count (# plants)	Total (sub) population area (m^2)	Total # plants	Population density plants/m^2 (SE)
Walker Flat	Sample population	591	204	*5,910*	*2,040*	*0.345 (0.055)*
Barney Reservoir	Census population	n/a	n/a	966	42	0.043
Salem Airport	Census macroplot	n/a	n/a	10,100	657	0.065
Camp Adair	Census population	n/a	n/a	*118,683*	*58*	*0.0004*
E.E. Wilson	Census subpopulation	n/a	n/a	706	185	0.201
OSU Horse Barn	Census population	n/a	n/a	576	41	0.071
OSU Poultry Farm	Census population	n/a	n/a	1,170	46	0.039
Finley NWR	Census subpopulation	n/a	n/a	5,240	*114*	*0.022*
I-5 & Hwy 22	Census population	n/a	n/a	1,508	95	0.063
Hwy 22 (MP 18)	Census patch	n/a	n/a	1,260	25	0.020
Hwy 223 & Cooper Hollow Rd	Census population	n/a	n/a	2,009	98	0.049
Hwy 99 (MP 77)	Census 2 patches	n/a	n/a	4, 8	5, 16	1.25-2
Hwy 99 (MP 57)	Census population	n/a	n/a	3	4	1.33
Hwy 99 (MP 56)	Census population	n/a	n/a	30	10	0.333

Discussion

There was a wide range of population densities among the fourteen *S. nelsoniana* sites visited for this study (0.0004 to 2.00 individuals per m^2). The two densest populations were both small roadside populations: Highway 99 (MP 77) with a population density of 1.25-2 individuals per m^2 and Highway 99 (MP 57) with a population density of 1.33 individuals per m^2. These two populations each consist of just a few individuals along the highway right-of-way. The small population areas result in very high population densities. Conversely, the least dense population, Camp Adair (0.0004 individuals per m^2) is also unusual. Many of the individuals in this population are located in atypical habitat, in small clearings dotted throughout a wooded area. The large amount of inappropriate habitat between the clearings increases the overall population area, and decreases the population density. When these three sites are removed, the range of population densities for this species becomes much narrower - 0.020 to 0.345 individuals per m^2.

When determining the amount of habitat needed to support a *S. nelsoniana* population of a given size, it will be important to determine the nature of that habitat. Ideally, habitat set aside for *S. nelsoniana* would not be limited to narrow strips along roads which are vulnerable to many types of disturbances, or to clearings or edges of wooded areas where this species can persist, but does not thrive. If protected habitat is of a more open and extensive nature, then the narrower range of population density estimates should be used to estimate the amount of habitat needed.

Finally, a short discussion of methodology is warranted for this species. Initially, the decision was made to count individuals of *S. nelsoniana*, with an "individual" being defined as a stem or a clump of stems separated from other stems/clumps by at least 30 cm. However, during the second year of the study we encountered several populations where this method did not prove to be effective. The populations had large mats of vegetative S. nelsoniana stems, all within 30 cm of each other. In order to be able to accurately compare all populations of *S. nelsoniana*, we recommend that area cover be used as a measurement of the size of a population, rather than number of individuals.

Chapter XI. Conclusion and Recommendations

Conclusion

Precise estimates of plant density within currently occupied sites provide valuable information to be used by researchers and land managers as they work toward the recovery of rare species. Population density can be an effective monitoring parameter when the anticipated change in a population is recruitment or loss of individuals, although this method is not sensitive to changes in a population that are vigor-related (Elzinga et al. 1998). Once population densities are calculated for a species, the number of individuals within a population occupying a known area can be estimated (especially if the habitat of the new population is similar to that of the population used to develop the density estimate). Finally, population densities can be used to determine the amount of protected habitat that is needed to sustain a population of a given size. All of the species addressed in this study are quite rare, and several are considered highly endangered. The use of inaccurate data (such as inaccurate population density estimates) can easily lead to a skewing of conservation priorities, placing these species at greater risk of extinction. Decisions concerning site maintenance, additional habitat acquisition, and population augmentation or reintroduction can all be affected by data and models describing the expected size and density of populations.

The goal of this study was to develop current population density estimates for nine rare Willamette Valley prairie species. The data provided within this report will assist in evaluating the progress made toward the recovery of these species. During the course of this study, 97 (21%) of the 452 known populations of these species (26% of the 378 current, locatable populations) were visited. Of these, 64 sites (17% of the known, locatable populations) were used to develop these population density estimates. The population density estimates for all of the study species are summarized in Table 11.1.

Table 11.1. Summary of population density estimates for nine rare Willamette Valley prairie plant species.

Species	# Sites	Units	Population density estimate range	Recommended population density estimate range*
Delphinium leucophaeum	4	# Flowering stems/m^2	0.004 - 0.797	0.004 - 0.797
Delphinium pavonaceum	4	# Flowering stems/m^2	0.073 - 0.737	0.073 - 0.737
Erigeron decumbens var. *decumbens*	6	# Clumps separated by 6 cm or more/m^2	0.029 - 3.25	0.029 - 0.171
Horkelia congesta ssp. *congesta*	5	# Rosettes/m^2	0.007 - 2.24	0.007 - 2.24
Lathyrus holochlorus	7	# Stems/m^2	0.014 - 2.00	0.014 – 1.53
Lomatium bradshawii	6	# Stems/m^2	0.040 - 13.8	0.040 - 13.8
Lupinus sulphureus ssp. *kincaidii*	11	m^2 of *Lupinus sulphureus* ssp. *kincaidii* cover/m^2	0.003 - 0.155	0.003 - 0.155
Sericocarpus rigidus (was *Aster curtus)*	7	# Stems/m^2	0.670 - 71.7	0.670 – 8.12
Sidalcea nelsoniana	14	# Clumps separated by 30 cm or more/m^2	0.0004 - 2.00	0.0004 – 0.333

*Recommended ranges remove the population density estimates of the smallest populations. It was felt that the calculated density of an extremely small (occupying an area of <20 m^2), isolated population does not accurately reflect the actual population density of the target species.

With each of the study species, we found that the population density varied greatly between sites. As might be expected, populations occupying very small areas tended to be denser, simply because the area of the population was defined as the area within a polygon encompassing the population, and small populations had few or no "blank spaces" or patches of unsuitable or unoccupied habitat within the polygon. However, these populations were often located along roadside right-of-ways, and caution should be exercised when using these densities to calculate the size of a population occupying a different kind of habitat, or the amount of habitat needed to support a population of a given size.

In general, when determining the amount of habitat needed to support a population of a given size (for any of the study species), it will be important to determine the nature of that habitat. If the protected habitat is of a more open and extensive nature, then the narrower range of population density estimates should be used to estimate the amount of habitat needed. Ideally, these estimates will assist in the designation of larger parcels of high quality, protected prairie as critical habitat for each species. This information will help land managers identify and protect self-sustaining populations of these species, which is a critical component of recovery planning and implementation.

There were several challenges faced in this study. First of all, much of the population information available for the study species was out-of-date or inaccurate. Some of the populations listed in the Oregon Natural Heritage Information Center (ORNHIC) database were not locatable in the field, either due to incomplete or incorrect directions, or because the population was extirpated. In order for the ORNHIC database information to be useful for recovery planning and implementation, populations need to be monitored regularly, and monitoring data need to be submitted to ORNHIC.

Secondly, review of known population data and monitoring methodologies highlighted a need for clear and consistent survey and monitoring protocols for the study species. In order to assess the current status and future progress towards recovery of these species, the following terms need to be defined and applied consistently while monitoring populations: counting unit/individual, population/subpopulation/patch, and population area.

Finally, this study emphasized the need for protected prairie habitat that is not along roadsides. Many of the historic roadside populations visited during the course of this study are severely threatened or extirpated. The small size, isolation, and extreme vulnerability to disturbance of these populations make their long-term survival questionable. While these roadside populations may be critical for providing connectivity between larger populations, as well as helping to maintain genetic diversity within the species, meeting recovery goals will require that larger areas of protected habitat be set aside and managed for these species.

Management Recommendations

• When determining the amount of protected habitat needed to support self-sustaining populations of a given size, use the more conservative population density estimates provided in Table 11.1.

• Develop standardized survey and monitoring protocols for each of the rare Willamette Valley prairie species. Within these protocols, define terms such as the counting unit/individual, population, subpopulation, patch, and population area.

• Monitor known populations of rare Willamette Valley species regularly, and ensure that monitoring results are provided to and entered into the Oregon Natural Heritage Information Center database. Make standardized monitoring protocols available to land managers engaging in rare plant monitoring and encourage their use.

• Designate, protect and/or acquire non-roadside prairie habitat for the conservation of rare Willamette Valley prairie species.

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Appendices

Appendix 1: List of all sites visited by ODA

Abbreviations used in site list table

BLM = Bureau of Land Management
Bldg = building
Btwn = between
Crk = creek
E = east
Fwy = freeway
ID-spp = Target species indistinguishable from similar species present at site
ID-phen = Target species unidentifiable due to phenology at time of visit
Indls = individuals
Jct = junction
N = north
NWR = NationalWildlife Refuge
ODOT = Oregon Department of Transportation
OMD = Oregon Military Department
OPRD = Oregon Parks and Recreation Department
Pkg = parking
Pop, subpop = population, subpopulation
Prop = property
S = south
SMA = Special Management Area
Sp. = species
TNC = The Nature Conservancy
Twd = toward
USFWS = U.S. Fish and Wildlife Service
W = west
WMA = Wildlife Management Area

Delphinium leucophaeum			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Willamette Narrows **20007** 45.31395N 122.66548W	Metro Angie Kimpo, Site Mgr 541-797-1919 kimpoa@metro.dst.or.us TNC (monitors) Jonathan Sols 503-802-8199	Exit 283 (Wilsonville) from I-5. E on Wilsonville Rd, go 1.8 mi. R on Advance Rd, go 2.6 mi. R on SW Mountain Rd, go 0.5 mi. L on SW Hoffman Rd, go 0.7 mi. R on Riverwood Dr. L on SW Forest Cove Rd (private property on both sides). L at 1st fork. L at "Rowen on River" sign, park at gravel pullout immediately to L (private property, Metro has permission, room for 2 vehicles, leave note on dash). Follow trail to Willamette River, L along bank ~100 m to 1st patch. Plants between the river & the tree line on shallow-soiled slope.	Yes
Willamette Falls **14758** 45.35107N 122.62763W	ODOT Chris Maguire, Terrestrial Biology Coordinator, Christine.C.MAGUIRE@odot.state.or.us	I-205 N from I-5. Viewpoint between Exit 6 & Exit 8. Plants on stone outcrop to west of parking area, behind chain link fence.	Yes
Cooper Mountain **10037** 45.44925N 122.86787W	Metro Curt Zonick, Site Mgr 541-797-1729 zonickc@metro.dst.or.us	Exit 289 (Sherwood) from I-5. W on SW Nyberg Rd, curves to L to get on SW Tualatin-Sherwood Rd, go ~4.5 mi. Rd curves to R, crosses 99W, becomes Roy Rogers Rd, go 4.5 mi. L on Scholls Ferry Rd. R on Tile Flat Rd. R on SW Grabhorn Rd. L on Stone Creek Dr. **Subpop 1:** Park at fire gate on R just before Stone Cr Dr curves 90°to L, plants on L just past gate. **Subpop 2:** Plants a little further down road in meadow on slope. **Subpop 3:** Continue on Stone Cr Dr. R on Whispering Fir Dr. R on Suncrest. R on SW 190th, go to end of road & park at gate. Cut straight across field on L to tree line, find trail that heads E & then S ~0.5 mi to open clearing.	Yes
Camassia Natural Area Preserve **24580** 45.36069N 122.61837W (patch 11)	TNC Jason Dumont 503-802-8100 jdumont@tnc.Org	Exit 8 (West Linn) from I-205 N. Turn R at end of exit ramp & go under hwy. Turn R (uphill) onto Willamette Falls Dr (just before gas station). After 1 block, Willamette Falls Dr turns L 90°; continue on rd for ¼ mi. Veer R onto Sunset Ave. Take 1st R onto Walnut St, which ends at preserve entrance. Contact TNC for directions to plant locations.	Yes

***Delphinium leucophaeum*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Champoeg State Park **17612** DEPA **15845** DELE 45.25160N 122.88992W	OPRD Dennis Wiley, Park Mgr 503-678-1251 ext 230 dennis.wiley@ state.or.us	I-5 N to Exit 278. L onto Ehlen Rd NE, go 2.6 mi until it turns into Yergen Rd NE; continue on this for 0.9 mi. R onto Case Rd NE, go 1.3 mi. Slight L onto Champoeg Rd NE, go 1.5 mi. R into Champoeg State Park (visitor center 1st R). Continue past visitor center to pay booth. R after booth. L to Oak Grove Area, park btwn Oak Grove Area 2-3. Walk NE (to L of bathroom, btwn Oak Grove Area 2&3 signs) through Oak Grove to meadow. Plants in ditch on L side of meadow. NOTE: Unable to identify species – plants have intermediate characteristics between *D. pavonaceum* and *D. leucopheum*	No ID-spp
Total *Delphinium leucophaeum* populations visited: 5 **Total *Delphinium leucophaeum* populations used in study: 4**			

Delphinium pavonaceum			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Hwy 34 & Decker Rd **22100** 44.48907N 123.44987W	Benton County	Head W on Hwy 20/34 through Philomath. L (SW) onto Hwy 34 twd Alsea/Waldport & go ~4.9 mi. Park on R side of Hwy 34 at junction w/ Decker Rd. Go to S corner of jct. Plants are located along SE side of Hwy 34 extending~200m SW from the jct corner. There are also plants along SW side of Decker Rd extending ~80 m from the jct corner. Only 1 plant is located on NW side of Hwy 34.	Yes
Buena Vista Rd & Davidson Rd **17502** 44.80718N 123.15982W	Polk County	Go 3 mi N of Buena Vista on Buena Vista Rd to its intersection with Davidson Rd. Plants located on E side of Buena Vista Rd along E bank of roadside ditch & fence. Plants found along 47 m of fence S of the NE fence corner.	Yes
Hwy 22 between Hwy 99W & Greenwood Rd (Rickreal) **14141** 44.93382N 123.18510W	ODOT Chris Maguire, Terrestrial Biology Coordinator, Christine.C.MAGUIRE@odot.state.or.us	From Hwy 99W, go E on Hwy 22 for 2.5 mi to its intersection with Greenwood Rd. Make a U-turn & travel 0.3 mi W on Hwy 22 from Greenwood Rd & park in dirt pullout on N side of hwy. Most plants located between rd & fence line in the grass W of the pullout; few plants found E of pullout. SMA sign to W is at MP 18. Located 2 mi E of Rickreall.	Yes
Finley NWR observation deck **21941** 44.42348N 123.30480W	USFWS Jock Beall/Chris Seal 541-757-7236	S on Hwy 99W, turn R (W) onto Finley Rd. L (S) onto Finley Refuge Rd (at refuge entrance). Park by observation station (where rd takes 90° turn to R). Plants are in prairie surrounding observation deck.	Yes
Hwy 99 (1.25 mi S of Finley) **3893**	Benton County	Unable to relocate population	No sp. not found

Delphinium pavonaceum, continued			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Hwy 99 (btwn MP 92-93) **15069**	ODOT	NOTE: No plants found	No sp. not found
Corvallis bike path / Hwy 99 **18855**	ODOT	NOTE: No plants found	No sp. not found
Buena Vista Rd /Wells Landing **21438**	Polk County	NOTE: No plants found	No sp. not found
Parker Rd / Buena Vista Rd **1232**	Polk County	NOTE: No plants found	No sp. not found
Dawson Rd / Hwy 99 **2102**	Polk County	NOTE: No plants found	No sp. not found
Buena Vista Rd / Prather Rd **16451**	Polk County	NOTE: No plants found	No sp. not found
Ankeny Wildlife Refuge **12696**	USFWS Jock Beall/Chris Seal 541-757-7236	NOTE: No plants found	No site not found
Independence Hwy (Hwy 51) **9566**	ODOT	NOTE: No plants found	No private land

***Delphinium pavonaceum*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Walker Prairie **9782** 45.46555N 122.15412W	USFS, Mt. Hood NF David Lebo 503-668-1671 503-668-1700 dlebo@fs.fed.us	From I-5 N, take I-205 N to Exit 12. R onto OR-212 E. Slight R onto Hwy 26 E (Mt Hood Hwy), go for ~3 mi. Slight R onto Champion Way to NF headquarters. To Prairie, continue E on Hwy 26. L onto Ten Eyck Rd, go for ~3.3 mi. R onto Bull Run Rd, go ~3 mi to jct w/ Warriner Rd; continue straight onto Warriner Rd. After ~1 mi, follow rd as it bends L & go through yellow gate onto NF Rd 1010. After ~0.3 mi rd forks; take center rd (1010) through large locked yellow gate. Go 1.2 mi to another locked gate w/ closed to public sign. Go through gate & proceed to paved pullout loop on L. Walker Prairie is series of clearings on L side of rd & back into woods. Pop located from pullout to ~400 m beyond. (If get to jct w/ Rd 1008, gone too far.)	No ID-spp
Buena Vista Rd / Springhill Dr **5211**	Polk County	NOTE: Only a small leaves present, unable to confirm species.	No ID-phen
Total *Delphinium pavonaceum* populations visited: 15 **Total *Delphinium pavonaceum* populations used in study: 4**			

Erigeron decumbens* var. *decumbens			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
McClun Road **24874** 44.33032N 122.74712W	Dave Rand (private)	I-5 Exit 216, take Hwy 228 (Sweet Home Hwy) E though Brownsville & Crawfordsville to Holley. R on Calapooia Dr just past Holley Mkt. Go 2.1 mi to McClun Rd on L. L over one lane bridge, R on private gravel drive. (Need land owner permission to visit this site.)	Yes
Kingston Prairie **11171** 44.77993N 122.74310W	TNC Greg Fitzpatrick 541-757-0833 gfitzpatrick@ tnc.org Jason Nuckols, Preserves Mgr 541-343-1010 ext 301	I-5 N, Exit 238 to Jefferson. L onto Jefferson Hwy. Just after bridge at Jefferson, turn R onto Jefferson-Scio Dr & go 5.7 mi. L on Shelburn Drive, go 3.1 mi. L on Stayton-Scio Rd, go 5 mi. R on Kingston-Jordan Dr for 1.1 mi. L on Kingston-Lyons Dr (just past RR track), go 1.6 mi to where rd makes 90° turn to R. There is a gravel rd straight ahead & sign for Kingston Prairie. Park in turn-off at jct. Cross fence into Ralph & Florence Roberts Memorial Tract. Plants along fence away from pkg area.	Yes
Muddy Creek (was Allen & Allen) **17197** 44.48593N 123.32730W	Mike Robinson (private)	S on 99W; R (W) on Airport Rd for 2.7 mi. L onto Cutler Lane (gravel), go ~0.7 mi to S end; go straight past farm bldgs. Park to R of rd just before Muddy Cr (across from horse corral).	Yes
Willow Creek Preserve **13984** 44.03732N 123.16825W	TNC Jason Nuckols, Preserves Mgr 541-343-1010 ext 301 Gil Voss gvoss@tnc.org	I-5 S to exit 195B. Take Beltline Hwy W to its end. R onto W 11th Ave (OR-126) for 0.2 mi. L onto Willow Creek Rd. There is a stop sign & a 90° turn where Willow Creek Rd dead ends into 18th. Turn L (E) onto 18th & take the next R (S) onto Willow Creek Rd again. Take 1st L (S) onto Rathbone Rd, following it to the end & bearing R (W) into office pkg lot.	Yes
Bald Hill **15268** 44.56397N 123.32958W	City of Corvallis Steve DeGhetto, Parks Operations Mgr 541-754-1738	Head W on NW Harrison Blvd through Corvallis. Rd becomes NW Oak Creek Dr W of intersection with 53rd St. Continue 0.8 mi on Oak Cr Dr & turn L into pkg lot for Bald Hill. Walk ~0.4 mi on main trail from pkg lot, turn R onto trail that leads uphill past barn, go for ~0.3 mi to just past private property sign. Plants located on L side of trail.	Yes
***Erigeron decumbens* var. *decumbens*, continued**			

Site name/ ORNHIC EO_ID#/ GPS (DD)	Land ownership/ Contact	Directions to site (R=Right, L=Left)	Used in study?
Basket Slough **14153** 44.96390N 123.26185W (patch2)	USFWS Jock Beall/Chris Seal 541-757-7236	From I-5 N, take exit 253, & proceed W through Salem, toward Dallas, Oregon. Travel W on Hwy 22 from the intersection of Highways 22 & 99W, N of Rickreall, Oregon. Proceed ~2 mi & watch for the information & wildlife viewing area on the R.	Yes
Total *Erigeron decumbens* var. *decumbens* populations visted: 6 **Total *Erigeron decumbens* var. *decumbens* populations used in study: 6**			

Horkelia congesta* ssp. *congesta			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Long Tom ACEC **7121** 44.14145N 123.29507W (patch3)	BLM (Eugene) Sally Villegas, BLM WEW 541-683-6790	Hwy 99W S to Monroe. Before 99W crosses river, turn R onto Territorial Hwy. At T-jct in Cheshire, turn R onto Hwy 36, then L onto Territorial Hwy again after ~1 mi. Go 1.7 mi, then turn L onto Franklin Rd. At 0.8 mi from turnoff, cross bridge over Long Tom River. Park & walk S along river for ~1-1.5 mi to site/contact owner for driving access.	Yes
Dorena Reservoir **2166** 43.78830N 122.94478W	ACOE? Wes Messinger, Wes.Messinger @usace.army.mil	I-5 S, Exit 174 (Cottage Grove). L (E) at first signal onto Row River Rd, twd Dorena Lake At 4.4 mi from fwy offramp, turn L to continue on Row River Rd. At 6.0 mi from offramp, park at Row Point Park. Walk across bike path S to trailhead. Go ~30m to take the leftmost trail fork twd lake. Plants are ~20m past the fork.	Yes
Speedway **19487** 44.04667N 123.17243W	BLM (Eugene) Sally Villegas 541-683-6790 sally_villegas@or.blm.gov	I-5 S to Exit 195B. Take Beltline Hwy W to its end. R on W 11th Ave & get in L lane. Turn L into driveway @ speedway just after crossing creek. Park at pullout by gate, less than 0.1 mi W from Beltline. Walk through gate 50 m S, turn L (SE) & walk 80 m SE along old rd to reach SW corner of pop.	Yes
Ben Irving Reservoir **n/a** 43.04325N 123.55320W	BLM (Roseburg) Susan Carter 541-440-4930 Susan_Carter@blm.gov	I-5 S to Exit 119. W onto Hwy 42 through Winston. L onto County Rd 125/Hoover Hill Rd. Bear L as Hoover Hill turns into Olalla Rd (County Rd 38). L onto Upper Olalla Rd. R onto Coarse Gold Rd, ending at reservoir entrance gate. Walk up rd to pkg area if gate closed, walk down onto "beach" from L side of fence at pkg area. Follow N side of reservoir until past cliffs where you can climb up. Head uphill twd ridge along drainage, into meadow on R, angle L at top of meadow through trees to higher meadow.	Yes
Willow Creek Preserve **11487** 44.03500N 123.16825W (MP4)	TNC Jason Nuckols, Preserves Mgr 541-343-1010 ext 301 Gil Voss gvoss@tnc.org	I-5 S to exit 195B. Take Beltline Hwy W to its end. R onto W 11th Ave (OR-126) for 0.2 mi. L onto Willow Creek Rd. There is a stop sign & a 90° turn where Willow Creek Rd dead ends into 18th. Turn L (E) onto 18th. U-turn to park across street from field where population resides.	Yes

***Horkelia congesta* ssp. *congesta*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Irish Bend School **20829** No new GPS	Private	S on 99W from Corvallis. L at Bellfountain Jct. onto Hubbard Rd. R on Old River Rd. 26192 Old River Rd. on left. Old yellow school building with "Irish Bend" sign. Surrounded by ag fields & residences w/lawns. No suitable habitat seen from road.	No, private prop, unable to locate pop
Balboa **20059**? 44.05362N 123.18195W	BLM (Eugene) Sally Villegas 541-683-6790 Sally_Villegas@blm.gov	I-5 S to exit 195a. Take Beltline Hwy W to its end & turn R on 11th Ave. R onto Danebo Ave to BLM "Red House" (751 S Danebo). Park in BLM office pkg lot, cross Danebo & follow walking trail. When trail makes sharp curve to L, head out into meadow to the N. Plants in several small clumps just W of ox-eye daisy line. Found 23 plants (5 reproductive, 18 vegetative) in 2007.	No, pop too small
Total *Horkelia congesta* ssp. *congesta* populations visited: 7 **Total *Horkelia congesta* ssp. *congesta* populations used in study: 5**			

Lathyrus holochlorus			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Freeway Lakes Park **17591** 44.59051N 123.06128W	Linn County Parks & Recreation Brian Carroll 541-967-3917	E on Hwy 34; just past I-5, turn L (N) onto 7 Mile Ln. Before rd crosses I-5, turn R (N) onto 3 Lakes Rd; go 0.5 mi to pkg lot on R. Cross rd from lot & follow path along N edge of middle lake. As path curves to L (S), there is an oak grove on R of path; plants located at base of trees. Where path goes under I-5, just as fence starts on R side of path is another small group of plants.	Yes
Three Lakes Rd **n/a** 44.58922N 123.05910W	Linn County	E on Hwy 34; just past I-5, turn L (N) onto 7 Mile Ln. Before rd crosses I-5, turn R (N) onto 3 Lakes Rd; go 0.5 mi to Freeway Lakes Park pkg lot on R. Plants are just S of park along fence on E edge of rd.	Yes
Robinson Property (was Allen & Allen / Muddy Cr) **27169** 44.48823N 123.32920W	Mike Robinson (private)	S on 99W; R (W) on Airport Rd for 2.7 mi. L onto Cutler Lane (gravel), go ~0.7 mi to S end; go straight past farm bldgs. Park to R of rd just before Muddy Cr (across from horse corral).	Yes
Ankeny NWR **24294** 44.80158N 123.07322W	USFWS Jock Beall/Chris Seal 541-757-7236	I-5N, ~5-6 mi N of Albany, take Talbot Rd Exit (#242). Circle around overpass over I-5 (to W). Take 1st R onto Jorgenson Rd, go ~0.4 mi. Turn L (W) onto Wintel Rd (at T), go ~2.9 mi. Turn R onto Buena Vista Rd (at T), go ~2.4 mi to pkg spot on E side of rd. Plants are along hedgerow on W side of Buena Vista Rd.	Yes

***Lathyrus holochlorus*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Finley NWR **24563** **9980** 44.393283N 123.2993W (3rd subpop)	USFWS Jock Beall/Chris Seal 541-757-7236	S on Hwy 99W, R (W) onto Finley Rd. L (S) on Finley Refuge Rd (at refuge entrance). Go ~1.0 mi from this 90° L turn (passing the bathrooms). Park on L side of rd, just before "Narrow Bridge" sign before rd crosses Muddy Creek. Walk around marsh on S side of rd to reach **1st subpop**. Plants are at edge of oak & ash trees bordering Muddy Crk & where a narrow strip of water & cattails extends S from the marshy pond twd the crk. To access **2nd subpop**, return to Hwy 99W & head S. R (W) onto Bruce Rd; follow it as it bends 90° to L (S), then 90° to R (W). Park in gravel lot on R side of Bruce Rd at this 90° R curve. Plants are in hedgerow (dense poison oak, rose, & ash) openings N of pkg spot & facing Bruce Rd, along the N-S stretch btwn the 90° turns. To reach **3rd subpop**, continue W on Bruce Rd, turn R into next pkg lot by a dirt rd closed to vehicle traffic leading N btwn McFadden Marsh & Muddy Crk. Walk N on this rd; search in wooded area to W for LAHO 1 subpops (see GPS coordinates). Plants growing in thick blackberry, snowberry, & tall grass cover ~20m from Muddy Crk in opening in the oak & ash canopy.	Yes
Hwy 226 (Scio) **8539** 44.71187N 122.77930W	Linn County	Take Hwy 226 (Albany-Lyons Hwy) E from Scio ~3 mi. Plants are on S (R) side of hwy along fence, just W of where power lines cross Hwy 226.	Yes
Wisner Cemetery (Kingston-Jordan Dr) **5269** 44.76788N 122.77395W	Linn County	Take Hwy 226 E from Scio, turn L onto Richardson Gap Rd. R onto Ridge Dr. L (N) onto Gisler Rd. R onto Sandner Dr (which becomes Kingston-Jordan Dr when rd bends N). Continue to Wisner Cemetery (on E side of rd). Plants are on W (L) side of Kingston-Jordan Dr, across from cemetery, just S of intersection with Hecht Dr/Queener Dr.	Yes

***Lathyrus holochlorus*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
MacDonald Forest/Oak Creek Entrance **16096** No GPS taken	Benton County or OSU	Oak Cr, along road both inside & outside of Oak Cr Lab, MacDonald Forest Notes: no plants found, doesn't appear to have suitable habitat where directions stated (around lab bldgs all blackberry), GPS coordinates given appear to be private property	No No sp. found
East of Crabtree **4010** No GPS taken	County	Directions: 4 miles E of Crabtree on Rd to Roaring River State Fish Hatchery Notes: No plants found 5/22/06	No No sp. found
Driver Rd **25864** No GPS taken	Private	Hwy 99E 2.4 mi S of Albany. L on Driver Rd, go 1.6 mi to Calapooia R bridge. Pop N of bridge & W of Driver Rd, at edge of narrow path btwn the S edge of cultivated fescue field & N edge of remnant riparian fringe, primarily growing in dense vegetation beneath trees. Easternmost indls ~ 128 ft W of pavement edge (~6 ft W of OBEC survey stake #1007). Majority btwn ~128 feet (39 m) & 148 ft W of W edge of pavement. A few more indls noted ~157 ft W of pavement, under N edge of blackberry thicket. Note: private prop, can't see plants from Driver Rd	No
LBCC **2017**	Linn County	Fencerow on 99E opp LBCC Note: plants present 5/19/06	No (no time)
Jefferson-Scio Rd **21188** 444226N 1225642W (from ORNHIC	Linn County	Scattered along both sides of Jefferson-Scio Rd, along S side of NW4NE4 of section Note: no plants found, dense blackberry on both sides of road in this vicinity 5/22/06	No No sp. found

***Lathyrus holochlorus*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Jefferson Scio Rd/Miller Cemetery Rd **21425**	Linn County	½ mi W of Scio on Jefferson-Scio Rd. 500 yds W of Miller Cem Rd on S side of street, big oak directly across street. Note: 5/22/06 no plants found, no habitat found across from oak	No No sp. found
Ridge Drive **1575**	Linn County	Stayton-Scio Rd N from Scio, turn E onto Ridge Dr. Along N side of Ridge Dr just W of section line. Note: visited 5/22/06, lots of plants present (some in fruit) on both N & S of Ridge Dr, over long way, have picture of habitat but didn't count. Would need adjoining landowner permission to access plants to do census.	No
Total *Lathyrus holochlorus* populations visited: 14 **Total *Lathyrus holochlorus* used in study: 7**			

Lomatium bradshawii			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Muddy Creek (also known as Allen & Allen) **21054** 44.48317N 123.32752W	Mike Robinson (private)	S on 99W; R (W) on Airport Rd for 2.7 mi. L onto Cutler Lane (gravel), go ~0.7 mi to S end; go straight past farm bldgs. Park to R of rd just before Muddy Cr (across from horse corral).	Yes
Jackson-Frazier Wetland **15569** 44.60438N 123.23972W	Benton County Corvallis Natural Areas & Parks Dept. 541-766-6871	From 99W (N-bound), R onto Conifer. L onto Lancaster (at sign for wetland) to end of street. Park at cul-de-sac. Just N of pkg area, climb over fence on L side of path leading to the boardwalk. Cross ditch – pop boundary is marked with T-stakes.	Yes
Oak Creek Easement **2228** 44.49355N 122.88127W	USFWS Jock Beall/Chris Seal 541-757-7236	Take Hwy 20 E from Lebanon, turn R onto Sodaville Rd at the sign for Mtn Home & Sodaville (~2.2 mi from intersection of Airport Rd & Hwy 20) & go S ~0.7 mi to locked orange gate on R. There are a series of 4 additional gates before the site.	Yes
Kingston Prairie **22909** 44.77993N 122.74310W	TNC Greg Fitzpatrick 541-757-0833 gfitzpatrick@ tnc.org Jason Nuckols, Preserves Mgr 541-343-1010 ext 301	I-5 N, Exit 238 to Jefferson. L onto Jefferson Hwy. Just after bridge at Jefferson, turn R onto Jefferson-Scio Dr & go 5.7 mi. L on Shelburn Drive, go 3.1 mi. L on Stayton-Scio Rd, go 5 mi. R on Kingston-Jordan Dr for 1.1 mi. L on Kingston-Lyons Dr (just past RR track), go 1.6 mi. to where rd makes 90° turn to R. There is a gravel rd straight ahead & sign for Kingston Prairie. Park in turn-off at junction. Cross fence into Ralph & Florence Roberts Memorial Tract, head S, & cross stream to reach plants.	Yes
Sublimity Grassland **1851** 44.84088N 122.76933W	Private Lynda Boyer/Heritage Seedlings has permission 503-585-9835 503-932-5490 Tom Sanak, owner	I-5 N to Exit 253, R on OR-22 E/N Santiam Hwy SE for ~11.9 mi. Take exit 13 (Stayton/Sublimity), turn L onto Cascade Hwy & travel N ~1.6 mi (through Sublimity). Turn R onto Triumph Rd (~0.1 mi after leaving Sublimity city limits) & travel E for 1.6 mi. Property is on R (S) side of rd. There is a house just off the rd & a bldg with an American flag painted on the side facing the rd. Park on shoulder of Triumph Rd.	Yes

Lomatium bradshawii			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Willow Creek Preserve **17509** 44.03278N 123.17560W (patch1)	TNC Jason Nuckols, Preserves Mgr 541-343-1010 ext 301 Gil Voss gvoss@tnc.org	I-5 S to exit 195B. Take Beltline Hwy W to its end. R onto W 11th Ave (OR-126) for 0.2 mi. L onto Willow Creek Rd. There is a stop sign & a 90° turn where Willow Creek Rd dead ends into 18th. Turn L (E) onto 18th & take the next R (S) onto Willow Creek Rd again. Take 1st L (S) onto Rathbone Rd, following it to the end & bearing R (W) into office parking lot.	Yes
Total *Lomatium bradshawii* populations visited: 6 **Total *Lomatium bradshawii* populations used in study: 6**			

Lupinus sulphureus* ssp. *kincaidii			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Stout's Creek **27140**	BLM (Roseburg) Susan Carter 541-440-4930 Susan_Carter@blm.gov	I-5 Exit 98 (Canyonville). Head E out of Canyonville on SE 3rd (becomes OR-227), go ~16.6 mi (just before Milo). Turn R onto Stout's Creek Rd, go ~1 mi, then veer R. Stay on this rd for ~2.75 mi to reach **subpop 1** (above rd on R). Then at 2.9 mi (total) turn L & at ~3.1 mi reach **subpop 2** (above & below rd).	Yes
Callahan Meadows **10165 (or 12787? or 769?)**	BLM (Roseburg) Susan Carter 541-440-4930 Susan_Carter@blm.gov	I-5 Exit 98 (Canyonville). Head E out of Canyonville on SE 3rd (becomes OR-227), go ~25.9 mi. Turn R over bridge onto rd 3230, go 3 mi. R on rd 3220, go 1.5 mi. R onto rd 3220-300, go 0.2 mi. Veer R onto dirt (rd 3220-320), go 0.8 mi. Pass through gate & continue. Rd veers R after 0.6 more miles. Park at end of rd & head down slope, following W (L) edge of large meadow. Pop occurs under drip line of black oak trees on edge of meadow. A smaller subpop occurs just N of this location.	Yes
Loose Laces **9813 or 21722** 42.90057N 123.38895W	BLM (Roseburg) Susan Carter 541-440-4930 Susan_Carter@blm.gov	I-5S to Exit 103; go W twd Riddle for 2.4 mi. L onto Main St, go 0.7 mi. R onto Glenbrook Lp, go 1.8 mi. L onto Shoestring Rd, go 1.2 mi. R onto Silver Butte Rd (BLM #30-6-35.1), go 1.2 mi to pullout on R. Park & walk around brushy area onto old skid rd to reach **subpop 1**. Continue on 30-6-35 rd for 0.7 mi, to pullout on R (just below where rd forms a "Y"). **Subpop 2** is on the R, ~10-15 m below rd, on small, flat area that may be an old skid rd**.** Continue up the 30-6-35.1 rd to the "Y". The fork to the E is BLM #31-6-3. Continue on the W fork of rd (30-6-35.1). **Subpop 3** begins on L (E) side of rd. **Subpop 4** is on L (E) side of rd fork to the W (R), above the cut bank & ~100 m from the "Y" intersection.	Yes
China Ditch **16265? 11548?** 43.13578N 123.11640W	BLM (Roseburg) Susan Carter 541-440-4930 Susan_Carter@blm.gov	I-5 S to Exit 108 (Myrtle Ck) & follow it into town. L onto 3rd St (start odometer) at Chevron gas station on L, go 0.1 mi. R onto Division St (1st stop sign), go 0.7 mi. Veer L onto N. Myrtle (county rd 15), go ~12.4 miles & pass over bridge, then at 12.7 mi, turn L onto rd 28-4-13.2. At about 13.1 mi (1st split in rd), L onto rd 28-4-13.3. **Subpop 1** is located on R at ~13.6 mi. Continue up rd <1/4 mi to **subpop 2**. Continue up rd & park by spur rd off to the R. Walk down rd ~1/8 mi to **subpop 3**.	Yes

***Lupinus sulphureus* ssp. *kincaidii*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Dickerson Heights **n/a** 43.05962N 123.50428W	BLM (Roseburg) Susan Carter 541-440-4930 Susan_Carter@ blm.gov	I-5 S to Exit 119, head W twd Winston on Hwy 42/Hwy 99; turn R to stay on Hwy 42 in Winston (where the 2 hwys split). Go on hwy for 7.2 mi (from fwy). L onto Hoover Hill Rd, go 2 mi. L at stop sign onto Ollala Rd, go 0.6 mi. L onto BLM rd 29.7.3 (sign says 2880), go 3.4 mi. Pop. on L (E) side of rd.	Yes
Oak Creek Rd & Tanager Dr **3148** 44.59838N 123.33397W	Benton County	W on Harrison Blvd through Corvallis. Cross intersection with 53rd St & continue on Oak Creek Dr. At jct with Cardwell Hill Dr, turn R (N) & continue N on Oak Cr Dr 0.7 mi (just past Tanager Dr). Park at small pullout on R (E). Plants located on cut bank on E side of Oak Cr Dr & extend 30 m N along the rd from the pullout.	Yes
Camp Adair **5020** 44.71642N 123.26699W	OMD Jeff Mach 503-584-3493 jeff.mach@ us.army.mil Terry Larson 541-749-3569	On hwy 99W, travel ~6 mi N of Lewisburg Rd. L onto Robison Rd. L onto Rifle Range Rd. Pass US Federal Gov't. fencing, turn R at gate, & go twd bldgs. R just before bldgs, go through fenced compound & uphill. Plants are in patches on hillside to L.	Yes
Willow Creek Preserve **13394** 44.03778N 123.16657W	TNC Jason Nuckols, Preserves Mgr 541-343-1010 ext 301 Gil Voss gvoss@tnc.org	I-5 S to Exit 195B (Junction City/Florence); merge onto Beltline Hwy W. Turn slight R onto Beltline Rd, go ~1.1 mi. R onto W 11th Ave/OR-126, go 0.2 mi. L onto Willow Creek Rd. There is a stop sign & a 90° turn where Willow Creek Rd dead ends into 18th. Turn L (E) onto 18th & take the next R (S) onto Willow Creek Rd again. Take 1st L (S) onto Rathbone Rd, following it to the end & bearing R (W) into office parking lot.	Yes
Philomath Prairie **n/a** 44.54712N 123.38760W	Private Greg Fitzpatrick, TNC 541-757-0833 gfitzpatrick@ tnc.org	W on Hwy 34 from Corvallis. Drive almost through Philomath, then R on 7th. Go 2 blocks, L onto Pioneer; follow it to "Y" near top of hill. R onto gravel, then dirt, rd. Pass denuded landscape on R. Pass paved rd on L. Dirt rd ends at gate; park L of gate. Walk along rd past gate to where it opens into a meadow. Veer L to power lines. Follow power lines L (twd Corvallis), up one hill, down, then uphill again. Power lines take R turn (big oak right there, clump of trees straight ahead). Walk to L of tree clump; near top of hill look for T-post & old pin flags marking the pop.	Yes
McDonald Forest –	OSU	W through Corvallis on Harrison Blvd. Cross 53rd St. & continue on Oak Creek Dr. R (N) on Oak Cr Drive	Yes

***Lupinus sulphureus* ssp. *kincaidii*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Butterfly Meadow **24270** 44.61868N 123.35223W	Debbie Johnson, College Forests Info Mgr 541-737-6388	to Oak Cr Lab/gate to McDonald Forest. (Obtain access for locked gates.) Past gate, go straight on gravel rd for ~0.5 mi. L at 1st branch (W Fork Oak Cr Rd), then almost immediately L again onto 6021. Follow rd uphill 0.2 mi, R at next branch to continue on 6021 (main rd turns R, smaller rd goes straight). Go uphill ~2 mi. Park at top of ridge, sign on L "Trail closed, do not use" (rd turns R almost immediately). Hike in on trail ~1/3 mi to open meadow on steep slope.	
Lupine Meadows **16235** 44.55490N 123.35523W	Greenbelt Land Trust Claire Fiegener 541-752-9609 Claire@ greenbeltlandtrust.org	W on Philomath Blvd from Corvallis, R onto 53rd. L onto West Hills Rd. At intersection with Reservoir Ave, turn L to stay on West Hills Rd. L at gravel rd just before W Hills Rd bends sharply to L, just past Bailey St (on R). Gate is unlocked, follow gravel rd to site.	Yes
Mill Creek SMA **10933** 45.01954N 123.42187W	ODOT Steve Gisler Biologist Steven.Gisler@state.or.us	W on Hwy 22 to Mill Creek Rd, both sides of Hwy (MP 4.5). Note: Part of population accidentally herbicided in 2007.	No
Elkins Rd & Helmick Rd **456**	Polk County	Unable to locate population	No
Parker Rd **n/a** 44.80333N 123.22958W	Polk County	N on Hwy 99 from Corvallis. W on Parker Rd. Plants along right-of-way on N side of Parker Rd, ~150 m W of intersection with Hwy 99, and on adjacent private land. Note: Discovered this population while looking for EO_ID 456. Bulk of plants on private land. No time to collect data on ROW portion of population.	No
Total *Lupinus sulphureus* ssp. *kincaidii* populations visited: 14 **Total *Lupinus sulphureus* ssp. *kincaidii* populations used in study: 11**			

***Sericocarpus rigidus* (was *Aster curtus*)**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Vinci **4736 ?** 44.05413N 123.19850W	BLM (Eugene) Sally Villegas 541-683-6790 541-729-3953 sally_villegas@or.blm.gov	Take 99W to Beltline exit. Head W on Beltline for 3.5 mi. R (W) onto W 11th Ave (Hwy 126) for ¾ mi. R (N) onto Terry for 1/3 mi. L (W) onto Ed Cone Blvd until T-junction. Turn R & park at gravel dead end. Walk W along dirt track through a field for 0.1 mi & climb fence to reach plants.	Yes
Spectra Physics **4736 ?** 44.05812N 123.19438W	BLM (Eugene) Sally Villegas 541-683-6790 541-729-3953 sally_villegas@or.blm.gov	I-5 S to Exit 195a. Head W on Beltline Hwy & turn R onto W 11th (where Beltline ends). R onto Terry St & park. Follow bike path to train tracks. Turn L & walk ~300 m W along tracks, past mixed riparian grove (with *Populus trichocarpa*) to meadow on R where the plants are. Cross ditch & climb fence to access.	Yes
Hansen **n/a** 44.08027N 123.24572W	BLM (Eugene) Sally Villegas 541-683-6790 541-729-3953 sally_villegas@or.blm.gov	I-5 S to exit 195B (Beltline W). Exit to Barger Dr & head W. L onto Green Hill Rd. R onto Royal. Just before Royal ends, there is a padlocked gate on the R. Unlock gate & drive on mowed grass rd to wooded area. Park by trail. **Patch 1:** To R of trail as enter woods.	Yes
Isabelle **4736 ?** 44.05112N 123.17332W	BLM (Eugene) Sally Villegas 541-683-6790 541-729-3953 sally_villegas@or.blm.gov	I-5 S to exit 195a. Take Beltline Hwy W to its end & turn R on 11th Ave. R onto Danebo Ave. R onto Isabelle St. Go to end of st (it curves to R). Park & walk into field on L. Small patch of plants at opposite (E side) of field, near Beltline, in middle.	Yes
Willow Creek Preserve **19968** 44.03493N 123.16792W	TNC Jason Nuckols, Preserves Mgr 541-343-1010 ext 301 Gil Voss gvoss@tnc.org	I-5 S to exit 195B. Take Beltline Hwy W to its end. R onto W 11th Ave (OR-126) for 0.2 mi. L onto Willow Creek Rd. There is a stop sign & a 90° turn where Willow Creek Rd dead ends into 18th. Turn L (E) onto 18th & take the next R (S) onto Willow Creek Rd again. Take 1st L (S) onto Rathbone Rd, following it to the end & bearing R (W) into office parking lot.	Yes

***Sericocarpus rigidus* (was *Aster curtus*)**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Speedway **11061** 44.04730N 123.17362W	BLM (Eugene) Sally Villegas 541-683-6790 sally_villegas@or.blm.gov	I-5 S to exit 195B. Take Beltline Hwy W to its end. R on W 11th Ave & get in L lane. Turn L into driveway @ speedway just after crossing creek. Park & walk into site. **Patch 1:** Cut over L to Amazon Creek (twd Wal-Mart). **Patch 2:** In middle of meadow on the way to Wal-Mart, about even with 2 wood posts on entry road. **Patch 3:** Continue W on W 11th. L on Willow Creek Rd. L on 18th & make U-turn to park in first parking pullout. Walk N along the W side of Amazon Creek for ~0.1 mi; plants are across from gray barn on Willow Creek Dr & between the path & the creek.	Yes
Camassia Natural Area Preserve **12953** 45.2140N 122.3701W	TNC Jason Dumont 503-802-8100 jdumont@tnc.org	Exit 8 (West Linn) from I-205 N. Turn R at end of exit ramp & go under hwy. Turn R (uphill) onto Willamette Falls Dr (just before gas stn). After 1 block, Willamette Falls Dr turns L 90°; continue on rd for ¼ mi. Veer R onto Sunset Ave. Take 1st R onto Walnut St, which ends at preserve entrance. **Pop 1:** At entrance, go L on path, pass through long narrow meadow, pass pond & narrow strip of trees, to reach 2nd meadow. Take R turn on path, which drops a few feet into a swale. There is a large *Fraxinus latifolia* tree on L; *Sericocarpus* is at base of tree. **Pop 2:** From Pop 1, continue on path E to next meadow (with a quarry). There's a side trail that goes to a pond & a large clump of *Spirea douglasii* ahead. To L (E) of SPDO there is an area w/ low vegetation & moss over rocks, before ground drops to pond. Sericocarpus plants are scattered there.	Yes
Kingston Prairie **7265**	TNC	Unable to locate population	No
Total *Sericocarpus rigidus* populations visited: 8 **Total *Sericocarpus rigidus* populations used in study: 7**			

Sidalcea nelsoniana			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
EE Wilson WMA **15574** 44.70502N 123.21737W	ODFW Mike Moore (acting mgr) 541-745-5334	N on Hwy 99 W, R (E) onto Camp Adair Rd. L at sign "EE Wilson Wildlife Area" to park headquarters (HQ), past maintenance yard on L. Take 1st L past the HQ. Turn R onto the 2nd paved rd on the R (0.4 mi from HQ). Go past electrical transformer station to **site 1** on L (0.6 mi from HQ). Park near intersection with the gravel rd on the R. Plants are located across the rd to the SW.	Yes
Finley NWR **11692** 44.42042N 123.31703W	USFWS Jock Beall/Chris Seal 541-757-7236	S on Hwy 99W, turn R (W) onto Finley Rd. L (S) onto Finley Refuge Rd (at refuge entrance). Continue on rd past the observation deck on the L (rd bends 90° to R), then past the restrooms on the R. Park just before reaching the forested area along Muddy Creek. Walk out on track leading off to the R of the rd along the tree line (there's a "no vehicles" sign). Plants are just past the reed canary grass, concentrated along the edges of the meadow to the L twd Muddy Creek.	Yes
McGuire Reservoir **22371** 45.30308N 123.42040W	BLM/City of McMinnville Kurt Heckeroth 503-815-1132 Kurt_Heckeroth @blm.gov	N on hwy 99W, L(N) onto OR 47 just N of McMinnville, go ~5 mi to Carlton. OR 47 jogs L then R; instead of jogging R, go straight (W) on Meadow Lake Rd for ~13.6 mi to McGuire Reservoir on L. Continue on rd past reservoir ~0.5 mi to large gravel area on L. L onto gravel rd & over bridge, go ~0.5 mi to Y-jct. Park at gravel pullout to R. Walk up R-handed rd ~300 m, then cut to L through forest to creek. Cross creek, continue to meadow ~50m. Plants located throughout meadow.	Yes

Sidalcea nelsoniana, continued			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Barney Reservoir **2595** 45.43800N 123.36467W	City of Hillsboro Kevin Henway 503-615-6585 Carl Borg, Dist. Supervisor of Mgmnt Ops 503-614-6725	N on hwy 99W; just N of Amity, go R (E) onto OR 233 twd Dayton. Rd curves to L on Starr Quarry Rd. Stay to R at jct to McMinnville; L (N) onto Lafayette Hwy at power stn (4-way stop) twd Lafayette. Cross Hwy 18. Rd becomes Madison St when enter Lafayette. L (W) onto Hwy 99W twd McMinnville, go ~2 mi. R (N) onto OR 47. Go through Carlton where hwy makes a L, then a R turn to Yamhill. In Yamhill, turn L onto Pike Rd (where OR 47 bends 90° to R). Follow Pike; it becomes Turner Creek Rd, then turns into gravel rd; stay on main gravel rd. Zero odometer when rd becomes gravel. At 0.9 mi, there is a fenced area on L; stay R, go through gate. At 1.3 mi stay straight (rd to R). At 2.5 mi, stay L (rd to R). At 3.2 mi stay L (rd to R). At 3.4 mi, stay L (rd to R). At 3.6 mi, stay R (dirt rd to L). At 4.0 mi, go R (rd to L—MP 3). At 4.3 mi, stay R. At 4.4 mi, stay L. At 4.6 mi, go straight, downhill (rds to R & L). At 5.8 mi, R. At 6.6 mi, L. At 6.7 mi, L. At 7.0 mi, R (gate to L). At 7.4 mi, there is a gate & the reservoir is on the L.	Yes
I-5 & Hwy 22 (Salem) **17325** 44.91638N 122.99022W	ODOT Chris Maguire, Terrestrial Biology Coordinator, Christine.C.MAGUIRE@odot.state.or.us	I-5 N, exit 253 (Hwy 22), L at end of offramp. Cross overpass & take I-5 S exit twd Eugene. As you follow the onramp, the lane you are in becomes separated from adjacent (on your L) I-5 S offramp by a grassy area. Park here. Plants are located across the I-5 onramp in middle of cloverleaf (NW quadrant).	Yes
Hwy 223 & Cooper Hollow Rd **16257** 44.87310N 123.33732W	ODOT	From Monmouth, W on Monmouth Hwy. R (N) onto Hwy 223. Plants are located on both sides of hwy between Cooper Hollow Rd & Guthrie Rd, about halfway between Dallas & the Hwy 223/Monmouth Hwy intersection. Fern Creek passes under hwy between Cooper Hollow & Guthrie rds.	Yes
Hwy 99W (MP57) **16805** 44.94175N 123.22847W	ODOT	N on Hwy 99W to Hwy 22 near Salem. Cross Hwy 22 & park 100m past MP 57. Plants are on the E side of Hwy 99W, marked with SMA sign.	Yes

***Sidalcea nelsoniana*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Hwy 99W (MP56) **16805** 44.95040N 123.22835W	ODOT	N on Hwy 99W to Hwy 22 near Salem. Cross Hwy 22, pass MP 57, & drive 0.7 mi. Park at SMA sign & walk N 100m. Plants located 20 m S of small bridge.	Yes
Hwy 22 (MP18) **20529** 44.93380N 123.18635W	ODOT	From jct of Hwys 22 & 99W in Rickreal, go E on Hwy 22 for 2.5 mi to Greenwood Rd. Make a U-turn at Greenwood Rd & travel 0.3 mi back W to pullout on N side of hwy that leads through riparian vegetation to agricultural land. Park here. **1st pop**. extends 60 m W of pullout. A few clumps of plants are at the end of pullout near ag land (probably private) & to E of pullout before Basket Slough bridge. **2nd pop.** starts ~100 m W of the Greenwood Rd intersection.	Yes
OSU Horse Farm **12127** 44.57568N 123.30978W	Benton County (+ OSU?)	W on Harrison Blvd through Corvallis. R onto 53rd St. L at Horse Farm entrance (park to side). Pop. along ditch to N of entrance ~20 m.	Yes
OSU Poultry Farm **12127** 44.57430N 123.30758W	OSU Irene Pilgrim 753-8807 Irene.pilgrim@ gmail.com	W on Harrison Blvd through Corvallis, past dairy farm. R at 4545 NW Harrison. Go past bldgs, turn L on rd as it curves 90° to L. Pass westernmost bldg. Park before gate. Climb over gate, walk through strip of woods to field, go R & follow tree line. Plants located from tree edge to middle of woods strip, about halfway down.	Yes
Camp Adair **2210** 44.70972N 123.26306W	OMD Jeff Mach 503-584-3493 jeff.mach@ us.army.mil Terry Larson 541-749-3569	On hwy 99W, travel ~6 mi N of Lewisburg Rd. L onto Robison Rd. L onto Rifle Range Rd. Plants are at SE corner of Camp Adair in field N of forested wetlands & along fence.	Yes

***Sidalcea nelsoniana*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Hwy 99W (MP77-78) **15210** 44.65060N 123.22647W	ODOT Nick Testa 541-757-4155	N on Hwy 99 W twd Monmouth. After MP 76, go 0.8 mi & park on E side of rd. Blue ODOT sign on W side of hwy should be directly across the rd. Follow roadside 0.14 mi to south-most sign on W side of rd (western area). Cross hwy, walk to fence to north-most sign on E side & walk S for 0.10 mi (eastern area). Plants between miles 77.2 & 77.9.	Yes
Salem Airport **18617** 44.89730N 122.98998W	City of Salem Tom Franklin 503-589-2058 tfranklin@ cityofsalem.net	I-5 N to exit 253. L (W) onto Hwy 22, be in L lane. L onto Turner Rd (to R of intersection it's Airport Rd), go 4.1 mi. R onto Airway Dr, go 0.4 mi to gate on R (need code to enter gate)	Yes
Hwy 223 (MP13) **n/a** 44.79672N 123.40327W	ODOT Nick Testa 541-757-4155	Go W on Hwy 20/Philomath Blvd from Corvallis to ~4 mi past town of Philomath. R (N) onto Hwy 223. Go past town of Pedee. Zero odometer at MP 13. Go 0.2 mi & park where Shady Lane crosses hwy. Southernmost blue ODOT sign is on fence on E side of rd. NOTE: Population too small to use in study + unable to identify majority of individuals to species. Three small patches along ~ 0.6 miles: Total plants observed: 5 *S. nelsoniana*, 2 *S. campestris*, 9 unknown.	No
Hwy 22 & Van Well Rd **8847** 44.58.937'N 123.19.549'W	Railroad ROW?	W from Salem on Hwy 22 ~6 mi to Van Well Rd. Turn N on Van Well Rd, cross small bridge and park. Two clumps: #1: Walk ~100 m W to plants located 10 m S of rd under small power lines along RR track. #2 Small clump located at NW intersection of Hwy 22 and Van Well Rd. NOTE: Approximately 16 clumps of plants seen from road, uncertain of land ownership	No
Hwy and Ridge Dr **18108** 44.72571N 122.87462W	Linn County	NW of Scio. SE area of junction of Ridge Dr and RR tracks. NOTE: one plant found, population too small to use in study	No
I-5 and Hwy 22, SE Cloverleaf **17325**	ODOT	NOTE: No plants found	No

***Sidalcea nelsoniana*, continued**			
Site name/ ORNHIC EO_ID#/ GPS (DD)	**Land ownership/ Contact**	**Directions to site (R=Right, L=Left)**	**Used in study?**
Hwy 223 & Ash Cr **6466**	Private	From Dallas: Follow Hwy 223 S for ~1 mi to where N Fork of Ash Cr crosses Hwy (o.2 mi N of Jct 223 and Liberty Rd). Plants are in meadow between Hwy and creek. NOTE: private property, unable to count	No
Bridgeport School **6555**	Private	NOTE: private property, no plants seen from road	No
Mill Creek Staging Barn **27066**	ODOT	Hwy 22, ~300m NW of bridge over Mill Cr (MP4.71) and ~7 m E of Hwy between Hwy and barn. NOTE: Spoke with ODOT biologist and *Sidalcea* expert Steve Gisler, this population not *Sidalcea nelsoniana*	No
Hwy 22 (MP 11.8-12) **10761**	ODOT	Near jct of Hwy 22 and Perrydale Rd, S side of hwy. NOTE: No plants found	No
Total *Sidalcea nelsoniana* populations visted: 22 **Total *Sidalcea nelsoniana* populations used in study: 14**			

Appendix 2: Site Information Sheet

Species: _____ Date: _____ Observer: _____

Location: _____ Sub-location: _____

Directions to site:

ORNHIC Database Record? Yes__ No__ EO# _____ EO ID_____

Est Size of Popn _____ (from ORNHIC records) Est Area _____ (from ORNHIC)

Date last observed _____ Contacted ORNHIC with updated info? Yes ___ No ___

Owner/contact person permission needed? Yes___ No___

Contact Info: _____

_____

_____

Parking Spot GPS coordinates (decimal min): _____N _____W

Population Area Information (circle one): GPS Points / Measurements / Both

Method (circle one): Census / Sampling

Circle method and complete appropriate column:

Census	Sampling
OCCUPIED AREA: _____m^2	**OCCUPIED AREA: _____m^2**
TOTAL # PLANTS: _____	**Projected TOTAL # PLANTS: _____**

Sketch location—address the following:

1. **Access points**
2. **Macroplot/transect locations w/ plot #s and names**
3. **Approximate bounds of population**
4. **Show placement of sampling units if using transects (direction/positioning)**
5. **Provide approximate scale and north arrow**

Appendix 3: Datasheet

Species: _____ Date: _____ Observer: _____

Location: _____ Sub-location: _____ Page ____ of ____

Plot #	Plot coordinates N / E / S / W m from origin (if NW, circle N&W)	Plot coordinates N / E / S / W m from origin	# individuals	Notes	Plot #	Plot coordinates N / E / S / W m from origin (if NW, circle N&W)	Plot coordinates N / E / S / W m from origin	# individuals	Notes

Appendix 4: Sidalcea identification characteristics matrix

Characteristic/Source	*S. nelsoniana*	*S. campestris*	*S. virgata*
Stem Hairs			
Gilkey and Dennis (2001)	lower stem simple		
Hitchcock and Cronquist (1973)	stem glab - sparsely hirsute w.short appressed simple hairs	gen hirsute with simple (forked) hairs	gen stellate
Gisler (2003)	glaucous stem		
Hairs of upper leaf surface			
Gisler (2003)	sparse, simple hairs	densely hairy	
Petals			
Hitchcock and Cronquist (1973)	deep pink-pinkish lav, 5-15 mm	white-pale pink to pinkish orchid	deep pink-pinkish lav. 15-30mm
Gilkey and Dennis (2001)	deep pink-reddish purple, 5-15 mm	white-pale pink	
Kozloff (2005)	bright to deep pink or pinkish lavendar, often not more than 1.2 cm long	pale pink to pinkish lavender, to 2 cm long	bright to deep pink to 25mm long
Racemes			
Hitchcock and Cronquist (1973)		elongate/loosely flowered	elongate
Gilkey and Dennis (2001)	spikelike	loosely flowered	
Kozloff (2005)	congested		
Calyx			
Hitchcock and Cronquist (1973)	4-6 mm, sub-glab to thickly stellate hairs, gen purplish		< 9mm, gen densely hairy
Kozloff (2005)	5-7 mm long, usually purplish	to 9 mm	at least 8mm long
Phenology			
Gisler (2003)	beginning in June	beginning in June	completing in June