OREGON DEPARTMENT OF AGRICULTURE

NATIVE PLANT CONSERVATION PROGRAM

Developing standardized survey and monitoring protocols for four threatened and endangered Willamette Valley prairie plant species

Final Report

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1. Introduction

Oregon's Willamette Valley prairie habitat is one of the most endangered 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). Many of these remaining prairie fragments are heavily disturbed, facing threats from agriculture, invasion of non-native exotics, and encroachment of woody species. As one would expect, this extreme loss of prairie habitat has resulted in the decline of prairie-associated species.

The Recovery Plan for Prairie Species of Western Oregon and Southwest Washington (USFWS 2010) identifies recovery objectives for the most critically imperiled of these species, with the goal of achieving recovery to a level sufficient to prevent listing of the species of concern, downlist the endangered species, and eventually delist all listed species. However, achieving this goal depends upon obtaining data regarding the current status of each species and how that status is changing over time. Unfortunately, the status of many of these species' populations is not well documented. Many sites have not been visited in decades, and their status (including whether or not the population is even extant) is unknown. When populations have been visited, inventory and monitoring data collection has varied greatly in method and frequency, making it difficult to understand the current status of each species, and impossible to accurately interpret and compare population data between years and/or sites.

An accurate assessment of population size and structure is required to provide baseline information and determine when populations have achieved the size and structure stipulated by recovery criteria (and subsequently become eligible for downlisting or delisting). This information is also necessary to evaluate the effectiveness of management actions and implement adaptive management strategies. Consequently, the Western Oregon and Southwestern Washington Prairie Recovery Team has identified the development and implementation of a standardized population monitoring protocol for each species as one of the most pressing and important recovery actions which needs to occur (USFWS 2010).

The goal of this study is to develop standardized survey and monitoring protocols for the four prairie species found in Oregon which are currently listed by U.S. Fish and Wildlife Service (USFWS): Bradshaw's lomatium (*Lomatium bradshawii*), Kincaid's lupine (*Lupinus oregonus*, formerly *Lupinus sulphureus* ssp. *kincaidii*), Nelson's checkermallow (*Sidalcea nelsoniana*), and Willamette daisy (*Erigeron decumbens*). Survey protocols are designed to assess sites for the presence of the target species and, if found, to obtain simple estimates of population status, size, and threats in a relatively short period of time, in order to provide a maximum amount of data quickly and efficiently. Monitoring protocols are designed to facilitate population monitoring and comparison of data between years and sites. These protocols will facilitate the tracking of population abundance and evaluation of population trends, and will provide data useful for making management decisions and adjusting management strategies. Demographic study data collection protocols, although not the primary focus of this study, are provided to help those interested in assessing longer-term population structure and conducting species-specific modeling of population viability in order to have a better idea of the number and size of populations needed to ensure long-term persistence and recovery of the species.

Developing these protocols will be crucial for obtaining the data needed to assess these species' current status, their change in status over time, and ultimately their recovery. Having standardized protocols which are able to be consistently applied throughout the range of each species will allow for data to be compared between sites and years, and ultimately enable evaluation of population trends and status change for these species.

One note: The term "rare plant monitoring" has been used to describe a wide range of activities, including (but not limited to) looking for new populations, assessing the current status of populations (point-in-time), tracking changes in populations over time, evaluating the effects of management actions or disturbance on populations, and collecting data as part of a research study (Elzinga et al. 1998). However, for the purposes of this report, we will be discussing rare plant monitoring in the context of assessing the current status of a species and evaluating progress being made towards the recovery of that species. As such, the recommended monitoring protocols will be geared towards meeting the following goals:

- Determining the size, status and trend (increasing, stable, decreasing) of rare plant populations
- Identifying concerns about rare plant populations (i.e. declining population numbers or lack of reproduction) in the early stages, before they become a crisis

2. Background information

2.1 Study area (Willamette Valley prairies)

Western Oregon's Willamette Valley dominates the northwestern part of the state, running approximately 220 miles from its northern edge in Portland south to Eugene (Wilson et al. 1993). The alluvial flats of the valley are bordered to the west by Coast Range foothills, and to the east by the foothills of the Cascades. Although never glaciated, the Willamette Valley has been inundated many times by floods from both the Columbia and Willamette Rivers (Thilenius 1968, Savonen 1988). This periodic flooding has resulted in the valley floor being covered in silts, sands, and clays, which have poor drainage qualities and further contribute to the seasonal flooding that occurs to this day (Savonen 1988).

The prairie habitat of the Willamette Valley ranks as one of the United States' most at-risk ecosystems. While the interior valleys of western Oregon were once dominated by grasslands and oak savannas (Habeck 1961), it is estimated that less than one percent of the original western Oregon prairie habitat remains (Noss et al. 1995). Prior to settlement by Europeans, the prairies were maintained by frequent fires set by the Native Americans in the area (Johannessen et al. 1971). Today, the little remaining habitat is small, fragmented and severely disturbed. Much of the prairie has been lost to intensive agriculture, urban development and succession due to fire exclusion (Pendergrass et al. 1998). Ongoing threats include development, agricultural and pastoral practices, woody encroachment and invasion by non-native weeds.

2.2 Study species

Preliminary survey and monitoring methodology recommendations have been developed for the following four federally and state-listed Willamette Valley prairie species: Bradshaw's lomatium (*Lomatium bradshawii*), Kincaid's lupine (*Lupinus oregonus*), Nelson's checkermallow (*Sidalcea nelsoniana*) and Willamette daisy (*Erigeron decumbens*).

2.2.1 Bradshaw's lomatium

Bradshaw's lomatium (*Lomatium bradshawii*) is a low, erect perennial species in the carrot family (Apiaceae) arising from a long slender taproot. It is glabrous or slightly puberulent, with leaves 10-15 cm long on equally long (or longer) petioles. Leaves are ternate then pinnately dissected, the ultimate segments linear and 0.6-1.2 cm long. Small light yellow flowers (Figure 1) are arranged in umbels with 7-16 rays; umbellets are rarely larger than 1 cm across and generally only 1-4 of the rays are fertile. This species is distinguished from other species of *Lomatium* by its conspicuously ternately divided free involucel bracts. The glabrous fruit is oblong, 1.0-1.3 cm long, with thick, corky lateral wings (Peck 1961, Kagan 1980).

Figure 1. *Bradshaw's lomatium* flower. Photo by Melissa Carr.

Bradshaw's lomatium is listed as endangered by both the U.S. Fish and Wildlife Service and the State of Oregon. It is on the Oregon Biodiversity 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) (ORBIC 2013). Bradshaw's lomatium is listed as Endangered by Washington State, and is assigned a rank of S1 (critically imperiled in Washington) by the Washington Natural Heritage Program (WNHP 2010a).

The majority of the 45 known natural occurrences are located in the southern Willamette Valley in seasonally saturated or flooded prairies near creeks and small rivers, in moist, heavy clay soils. Some populations occur near the Santiam River in shallow, well-drained soils underlain by basalt, usually in vernal wetlands or along stream channels. Commonly associated species include *Carex* spp., *Danthonia californica*, *Deschampsia caespitosa*, *Eryngium petiolatum*, *Galium cymosum, Grindelia integrifolia*, *Hordeum brachyantherum*, *Juncus* spp., *Luzula campestris*, *Microseris laciniata*, *Perideridia* sp., and *Poa pratensis* (Meinke 1982, ORBIC 2012). Many of the Oregon populations are small, ranging from about 10 to 1,000 individuals. Although there are only two known occurrences of the species in Washington, they contain more plants than all of the Oregon populations combined.

2.2.2 Kincaid's lupine

Kincaid's lupine (*Lupinus oregonus*) is a showy herbaceous perennial in the pea family (Fabaceae). Numerous unbranched, pubescent, 4-10 dm tall stems arise from a branched crown (Figure 2). Basal leaves are usually persistent until after flowering, with the lowermost petioles (2) 3-5 times as long as the blades, and the upper cauline leaves with petioles sometimes shorter than the blades. Narrowly oblanceolate leaflets usually number from 7-12, and are 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).

Figure 2. *Kincaid's lupine* reproductive plant.

Kincaid's lupine 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) (ORBIC 2013). In Washington, *L. oreganus* is listed by the State as Endangered, and is assigned a rank of S1 (critically imperiled in Washington) by the Washington Natural Heritage Program (WNHP 2010).

Kincaid's lupine is primarily restricted to undisturbed remnants of upland prairie and ecotones between grasslands and forests at low elevations in the Willamette and Umpqua Valleys (Kaye and Kuykendall 1993, ORBIC 2012). Commonly associated native plant species include: *Agoseris grandiflora*, *Arbutus menziesii*, *Balsamorhiza deltoidea*, *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 and Clark 1997). As of 2012, ORBIC lists 112 known occurrences for this species.

2.2.3 Nelson's checkermallow

Nelson's checkermallow (*Sidalcea nelsoniana*) is an herbaceous, perennial member of the mallow family (Malvaceae). This showy prairie species has numerous erect flowering stems, ranging in height from 5-15 dm, which arise from a stout, often somewhat rhizomatous and laterally spreading rootstock that can form multiple crowns (Figure 3). Basal leaves are palmately lobed, with upper leaves and stem leaves becoming deeply divided. Stem and upper leaf surfaces often exhibit sparse, short, simple hairs. Fruits are 7-9 seeded schizocarps, with single-seeded, beaked carpels that form a ring, like the segments of an orange. 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*. (Hitchcock and Kruckeberg 1957, Peck 1961, Halse et al. 1989).

Figure 3. *Nelson's checkermallow* inflorescence.

Nelson's checkermallow 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) (ORBIC 2013). It is listed as Endangered by the State of Washington, and the Washington Natural Heritage Program designates *S. nelsoniana* with a rank of S1 (critically imperiled in Washington) (WNHP 2010a).

Nelson's checkermallow is typically found in both wet and dry prairie grasslands, wetlands, edges of woodlands and riparian areas, and small habitat remnants located along roadsides. Although *S. nelsoniana* tends to occupy (and probably prefers) 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). Associated species include *Achillea millefolium*, *Agrostis tenuis*, *Alopecuris pratensis*, *Arrhenatherum elatius*, *Carex* spp., *Cirsium* spp., *Leucanthemum vulgare*, *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*, *Tritelia hyacinthina*, and *Vicia* spp. (Kemp et al. 1978, USFWS 1993, Gisler and Meinke 1995, ORBIC 2012, OSU herbarium specimen label information).

The Oregon Biodiversity Information Center lists 100 occurrences (93 of which are considered extant) of Nelson's checkermallow in Oregon, distributed in Benton, Clackamas, Columbia, Linn, Marion, Polk, Tillamook, Washington, and Yamhill Counties (ORBIC 2012). 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).

2.2.4 Willamette daisy

Willamette daisy (*Erigeron decumbens*, Figure 4) is a tap-rooted perennial member of the sunflower family (Asteraceae). Growing from a crown or slightly branched caudex, stems are decumbent, 15-70 cm tall, and often purplish at the base. This species typically has numerous linear or linear-lanceolate leaves, with the basal leaves and most of the cauline leaves triple-nerved. Basal leaves are up to 25 cm long, including the long petiole, and 1 cm wide, with cauline leaves becoming gradually reduced above. Flowering heads number from 1-20, with 20-50 purple to pale pink ray flowers ranging from 6-12 mm long and 1-2 mm wide, yellow disk corollas 2.5-4.5 mm long, and the pappus consisting of 12-16 fragile bristles (Cronquist 1947, Hitchcock et al. 1955, Nesom 2006).

Figure 4. Flowering head of Willamette daisy. Photo by Melissa Carr.

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) (ORBIC 2013).

Willamette daisy inhabits both seasonally flooded bottomland prairies and well-drained upland prairies at elevations ranging from 70-290 m (240-950 ft). Commonly associated species include *Achillea millefolium*, *Allium amplectens*, *Anthoxanthum odoratum*, *Tritelia hyacinthina*, *Bromus carinatus*, *B. japonicus*, *Carex* spp., *Camassia leichtlinii*, *Crataegus douglasii*, *Danthonia californica*, *Deschampsia caespitosa*, *Elymus glaucus*, *Eriophyllum lanatum*, *Festuca arundinacea*, *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, USFWS 2000a, ORBIC 2012).

Willamette daisy is only known to occur in the Willamette Valley in northwestern Oregon. Though once found throughout the valley, the species is now restricted to scattered habitat remnants. Historic populations in Clackamas, Washington, and Yamhill Counties have not been relocated, and the species may no longer occur in these counties. The majority of the 37 extant populations are located on private lands vulnerable to development (ORBIC 2012).

3. Methodology

3.1 Target species literature review

During the first year of this study, a comprehensive literature search was conducted for each of the four target species (Bradshaw's lomatium, Kincaid's lupine, Nelson's checkermallow and Willamette daisy), and all current information regarding life history, identification, surveying, monitoring and demographic studies was assembled and reviewed. Because there were a limited number of survey and monitoring reports available for these four species, the

literature search was then expanded to include other rare members of the target genera (*Lomatium*, *Lupinus, Sidalcea* and *Erigeron*) in order to assess how other states are addressing the challenges inherent in monitoring similar rare species.

3.2 Target species survey and monitoring methodology review

In addition to reviewing all available monitoring reports during the literature review process, the Oregon Biodiversity Information Center's database was accessed for an updated list of land owners/managers with populations of the target species on their lands. A short survey requesting information regarding current monitoring practices was sent to accessible land managers. Follow-up contact (via phone or email) was made with those land managers who are actively managing populations of the target species to further clarify the methodologies used (and the rationale behind their selection) while monitoring populations found on their lands.

The following list of land managers (or their contractors) were contacted for information regarding the monitoring of rare plant species found on their lands: Benton County, Rae Selling Berry Seed Bank, Bureau of Land Management, City of Corvallis, City of Eugene, City of Salem airport, Institute for Applied Ecology, Lane County, Oregon Department of Forestry, Oregon Department of Transportation, The Nature Conservancy, and the U.S. Fish and Wildlife Service (Willamette Valley National Wildlife Refuges).

3.3 General rare plant survey and monitoring methodologies review

A general review of rare plant survey and monitoring methodology literature was conducted. Documents were compiled and reviewed for pertinent information and best practices. This information was synthesized with the species-specific information to result in preliminary recommendations for the four Willamette Valley prairie species addressed in this study.

3.4 Field site visits

Several populations of each species were visited to ground-test preliminary recommendations for monitoring methodology. We attempted to visit sites large enough to warrant sampling and potentially posing additional monitoring challenges (in order to address those challenges

in the recommended protocols). Table 1 lists the sites that were visited in 2011 and 2012 as part of this study.

Table 1. Summary of sites visited to test monitoring methodology.

Species	Site	Origin of population	Monitoring method tested
Bradshaw's lomatium	Finley NWR	Introduced	Sampled
	Sweet Home	Natural	Combination sampled and censused
	Short Mountain	Natural	Censused
	West Eugene	Natural	Combination sampled and censused
	Allen and Allen	Natural	Censused
Willamette daisy	Speedway	Natural	Censused
	Highway 126	Natural	Both sampled and censused
Kincaid's lupine	Lupine Meadows	Natural	Sampled
	Camp Adair	Natural	Censused
Nelson's checkermallow	Mary's River Natural Area	Introduced	Sampled
	Fort Hill	Introduced	Sampled
	Dhooghe	Introduced	Sampled
	Walker Prairie	Natural	Sampled
	Baskett Slough	Introduced	Censused

3.5 Previous monitoring data analysis

In addition to sites visited during the course of this two year study, monitoring data were available from previous years' visits to Willamette Valley prairie species sites. In many cases, these data were collected in such a way that we could evaluate the effectiveness of various theoretical sampling designs in the office, without having to recollect data. The results from these evaluations were also used to develop the final recommendations.

4. Summary of general and previously-used protocols

4.1 Overview

This section provides a summary of the survey and monitoring protocols that have been or are being used for the monitoring of rare plants in general, and the four target Willamette

Valley prairie species in particular. This information is provided to assist land managers and researchers in understanding the process followed to develop the recommended protocols presented later in this report.

4.2 Summary of field vegetation measurement techniques

Table 2 summarizes Elzinga et al.'s (1998) discussion of the techniques commonly used for vegetative monitoring. Many of these techniques have been used to monitor the four target species (Bradshaw's lomatium, Kincaid's lupine, Nelson's checkermallow, and Willamette daisy) in the past. These techniques were reviewed and, where appropriate, field tested before developing the recommended protocols for this report.

4.3 Summary of previously-used target species protocols

Tables 3-6 summarize survey and monitoring methodologies previously used by surveyors, researchers and land managers to document the presence and extent of Bradshaw's lomatium, Kincaid's lupine, Nelson's checkermallow and Willamette daisy. A more detailed description of the these methodologies and their sources can be found in Appendices A-D, which provide more information regarding how investigators have been quantifying population abundance, defining individuals of target species, assessing effects of management actions, determining census and sampling methodology, and addressing various challenges in the field when working with these four species.

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Table 2. Summary of field vegetation measurement techniques (from Elzinga et al. 1998).

Method	Pros	Cons
1. Presence/ absence	• The absolute minimum to determine if a population is still extant • Low cost: small amount of staff time, resources needed	• Provides no estimation of population size, information about population trends or threats, or guidance for management • Negative results (no plants seen) not conclusive indication that species not present • Methodology often poorly documented (Drive-by? Walk-through? # observers? Time spent looking?)
2. Visual estimate of population size	• Only a small amount of time more than just determining presence/absence of target species needed, but gain a very rough estimate of population size • Low cost: small amount of staff time, resources needed	• Provides only a rough estimation of population size, information about population trends only possible for large changes • High potential for variability among observers
3. Estimation of population condition	• Can gain a rough snapshot view of status of a population (i.e. estimated # individuals, estimated proportion of individuals in various age classes, phenology of individuals, evidence of herbivory, threats, etc.) • Still relatively low level of staff time and money needed	• Provides only a rough estimation of population size • High potential for variability among observers
4. Boundary mapping	• Gives a precise picture of where plants are located and if population area is increasing, stable or decreasing. • GPS equipment makes this relatively quick	• Does not provide population size information • Requires effective use of GPS equipment

Table 2, continued. Summary of field vegetation measurement techniques (from Elzinga et al. 1998).

Method	Pros	Cons
5. Photopoints	• Provides a substantial amount of visual information about a site/population with fairly little effort (if photopoints taken consistently over time), including: location of study site, overview of specific transects/macroplots, habitat conditions, and population conditions	• Does not provide population size information • Underreported method: data often collected but not analyzed/used (Allen 1993)
6. Photoplots	• Can reduce time in field (analysis of photos occurs in office) • Depending on species, can gather data on density, # individuals, change in age class/reproductive status, etc.	• Sometimes difficult and time-consuming to analyze photos (pilot study essential to determine if this method appropriate for species in question) • Dependent on equipment (camera working in field, pictures saved/labeled correctly, etc.) • Problems with method usually only detected once have returned to office and attempted to analyze data
7. Complete population counts	• Most precise method for knowing the size of the population • No statistical analysis needed and no sampling error	• Depending on species, habitat and size of population, this method can be very labor-intensive • Doesn't necessarily collect data on threats to or concerns about the population • Must have good quality control measures in place, or a "census" can miss hard-to-spot individuals
8. Density	• Allows for comparison between sites even if quadrat shape used for sampling differs from site to site • Most sensitive to changes caused by mortality or recruitment	• Unless combined with overall area measurement, does not result in estimation of population size • Sometimes difficult to quantify an "individual" (especially for species that spread underground); definition of individual must be consistently used by all observers • Less sensitive to changes that are sub-lethal or vigor-related, especially for longer-lived species

Table 2, continued. Summary of field vegetation measurement techniques (from Elzinga et al. 1998).

Method	Pros	Cons
9. Frequency	• Can be used with any species growth form • Most sensitive to changes in spatial arrangement • Can be useful for measurement of rhizomatous species, where individuals are difficult to define • Longer window of time available for monitoring (doesn't depend on the species phenology, only presence/absence in a plot) • Minimizes observer variability (only need to decide if target species in plot or not)	• Does not provide estimate of population size (# individuals) • Changes in frequency can be difficult to interpret biologically
10. Cover	• Allows for quantitative estimate of population size for rhizomatous species, where defining an individual is difficult	• Can have high levels of observer variability • Cover can change over the course of the growing season • Sensitive to changes in both numbers of plants and plant vigor, can be difficult to interpret trends in cover
11. Sampling	• Allows for development of population estimates using less time/fewer resources	• Requires statistical analysis • Subject to sampling errors

Table 3. Summary of previously used Bradshaw's lomatium survey and monitoring practices (see Appendix A for more details).

Suggested absence survey time period	Suggested presence survey time period	What has been counted in the past	Previous definitions of an individual	Survey challenges
Not applicable, too difficult to locate species from immature vegetative leaves	• When species is flowering • 4/10 – 6/24 • Mid-March – mid-June (most observations April – May)	• All plants (flowering and vegetative) • Just flowering individuals • All flowering plants and a sample of vegetative individuals	• Individual separated by at least 2 finger widths (~1.5 in, ~3.5 cm) • Individual with no additional definition • Individual = stem from the ground • Individual separated by at least 10 cm • Individual (separated into 7 age classes) • Individual separated by 1 finger width (~2 cm)	• Non-reproductive individuals (especially seedlings) are very difficult to find and monitor • Definition of individuals complicated due to potential for multiple stems arising from the same root

Table 4. Summary of previously used Kincaid's lupine survey and monitoring practices (see Appendix B for more details).

Suggested absence survey time period	Suggested presence survey time period	What has been counted in the past	Previous definitions of an individual	Survey challenges
March – July (when vegetative leaves of similar *Lupinus* species easily located and identified)	• When species is flowering • May – mid-July • 4/26 - 7/19 • Early May – mid-July (most observations mid-May - June)	• Individual plants/clumps • Presence/absence in plots • Area of foliar cover in m^2 • # of leaves + foliar cover • # of leaves + # of inflorescences • # of leaves • Area of foliar cover and # racemes • # of racemes, # patches	• No definitions of an "individual" found	• Potential for hybridization with similar species of *Lupinus* • Difficult to determine genetic individuals due to species spreading by underground rhizomes

Table 5. Summary of previously used Nelson's checkermallow survey and monitoring practices (see Appendix C for more details).

Suggested absence survey time period	Suggested presence survey time period	What has been counted in the past	Previous definitions of an individual	Survey challenges
April - August (when vegetative leaves of similar *Sidalcea* species easily located and identified, or when in fruit)	• When species is flowering • Mid-June – mid-July • 5/20 – 8/24 • Early May – early-August (most observations early June – mid-July)	• Individual plants • Area of foliar cover • # inflorescences • Type of inflorescence • Presence/absence in m2 plots • % cover	• Separated by at least 0.5 m between basal clumps, unless plants clearly distinct • Individual plant = 1 m^2 • Individual = all stems and leaves within 0.56 m radius of circular plot center, unless both pistillate and perfect flowers present • Individual separated by at least 30 cm communication • Individual = spatially distinct group of basal leaves and/or aerial stems	• Potential for hybridization with *Sidalcea campestris*, resulting in individuals with intermediate characteristics • Difficult to distinguish from *S. campestris* or *S. virgata* unless flowers present • Herbivory of flowers from deer and elk can make ID difficult • *S. nelsoniana* can spread rhizomatously, making differentiation of genetic individuals difficult

Table 6. Summary of previously used Willamette daisy survey and monitoring practices (see Appendix D for more details).

Suggested absence survey time period	Suggested presence survey time period	What has been counted in the past	Previous definitions of an individual	Survey challenges
Not applicable, too difficult to locate/identify species from vegetative leaves, multiple similar species that are easily confused with target species	• When species is flowering • May - July • Late May – early August • June - early July	• All plants (flowering and vegetative) • Just flowering individuals • All flowering plants and a sample of vegetative individuals	• Flowering clumps or plants • Basal clump at least 5 cm from nearest neighbor • Reproductive individual separated from neighbor by at least 6 cm • Individuals separated by at least 2 finger widths (~1.5 in, ~3.5 cm) • Individuals separated by at least 7 cm • Clump • Individual, no further definition • Separated by at least 10 cm • Plant separated by at least 3.5 cm	• Sporadic flowering from year to year • Non-reproductive individuals are very difficult to find and monitor • Definition of individuals complicated due to overlapping of flowering clumps

5. Recommended survey protocols

5.1 Overview

In general, rare plant surveys are conducted prior to some type of ground- or vegetation-disturbing land management action that has the potential to harm the target species or its habitat (including other organisms critical to the survival and reproduction of the species, such as pollinators or mycorrhizae). The purpose of these surveys is to locate, describe and ultimately conserve rare plant species and their habitats.

Ideally, the implementation of these recommended survey protocols will lead to a more consistent and systematic approach to the survey and assessment of the target species, in order to maximize the potential of locating these species and produce reliable information about their occurrences. Once new populations of the target species are located, these recommendations are designed to quickly and efficiently obtain simple estimates of population status, size and threats. (One note: if impacts to the population cannot be avoided and mitigation is required, a more thorough assessment of the population is necessary. See the section on monitoring for recommendations.)

The following general rare plant survey guidelines have been created with the help of information from the following sources: Whiteaker et al. 1998, USFWS 2000b, CNPS 2001, Cypher 2002, CDFG 2009, Kaye et al. 2009, Alberta Native Plant Council 2010, ODA 2010, ORBIC 2012, Penny and Klinkenberg 2010 and WNHP 2010b.

5.2 Determining if a rare plant survey is appropriate

In general, a rare plant survey should be conducted:

- When known rare plant sites exist in the proposed project impact area
- When the proposed project occurs within the known or suspected range of the species, and there is a potential for suitable habitat within the proposed project impact area

- Prior to commencement of any ground- or vegetative-disturbing activity (such as clearing, mowing, logging, grazing, ditching, or construction) in the proposed project area

5.3 Minimum survey requirements

- Surveys must be conducted during the appropriate season (when the target species can be identified, typically when it is in flower or fruit).
- Surveys should not target a single species, but rather aim to identify any and all rare species/plant communities in the area.
- Survey should thoroughly cover entire project area. If the size of the project area is too large for detailed inspections of the entire area, searches should concentrate on the likely potential habitat, while still sampling each habitat represented in the project area. Because rare plants tend to have small, discrete populations or to be thinly scattered on the landscape, traditional quantitative methods that focus on vegetation community classification are not appropriate for rare plant surveys.
- A site may need to be visited multiple times in a season if there is a possibility of more than one target species (with different bloom times) occurring there.
- Ideally, sites should be assessed over several growing seasons and moisture conditions, in order to address challenges such as annuals that may not germinate in dry years, perennials that may not produce flowers every year (making them difficult to identify), or plants with subterranean perennial organs where above-ground growth may be absent for one or more years. The four target species in this study do not typically fall within any of these categories; however, it is important to be aware of these potential challenges when planning rare plant surveys.
- Surveys must be conducted by qualified botanists with a knowledge of plant taxonomy and natural community ecology, a familiarity of plants in the survey area (including rare plants), an ability to use technical floras, experience conducting floristic field surveys, an understanding of how to contact taxonomic experts for species they can't identify, the ability to use maps and other tools (i.e. GPS) to adequately map rare plant populations, a familiarity with appropriate state and federal

statutes related to plants and plant collecting, and experience analyzing impacts of development or other activity on rare plant species and their habitat.

5.4 Pre-survey preparation

The effectiveness of rare plant surveys can be greatly increased by adequate pre-survey preparation. The following steps can make field work much more focused and efficient (see Appendix E for a sample survey data form that includes the following information in checklist format):

- Develop list of rare plant species that might be located in the survey area, based on range and habitat requirements. Include scientific name, habitat, and appropriate time period for successful identification.
- If not familiar with the species, study description of species from floristic keys, photos, illustrations and herbarium specimens. Once key characters for species identification have been determined, look at those characters in herbarium specimens. Note: most species cannot be identified from photos only, as many of the characters that separate species cannot be seen in photos.
- Get maps/aerial photos of survey area. Map special habitats, known rare plant locations and areas that will be disturbed during the project. If the project area is large, precluding detailed inspections of entire area, and surveys are focused on most likely potential habitat only, the larger area should not be mapped as having been surveyed.
- Include areas that might be directly or indirectly impacted by the project. Include adjacent properties if effects could potentially extend offsite (i.e. herbicide applications) in survey.
- Create field schedule that allows for visiting each habitat within the survey area at the appropriate time for identifying the species that might be found in that habitat.
- If planning on collecting voucher specimens, obtain necessary federal and/or state permits. Determine what to collect for voucher specimens before going into the field (i.e. is identification based on fruit characteristics?). Usually need flowers, seeds, stems, leaves and roots.

- Obtain written permission of the appropriate landowner or land-management agency before conducting surveys.
- If surveyors cannot determine extent of potential habitat in a proposed project area from other sources, a habitat reconnaissance trip to the field may be necessary. The purpose of this trip is to provide a general overview of the site and to see first-hand if any potential habitat occurs within the project area. This is not a thorough search of the project area, and the area should not be mapped as having been surveyed if no suitable habitat was encountered.
- Prior to conducting surveys in a given year, surveyors (or at least one member of the survey crew) should visit known populations of the target species that occur in areas similar in elevation, latitude, vegetation and topography to the survey area. This will enable field personnel to assess current phenology of the target species, and develop a search image for the target species and its habitat.

5.5 Survey field equipment list

The following is a list of recommended supplies/equipment to carry while conducting rare plant surveys:

- Aerial photos/maps outlining survey area and showing any known populations of target species
- GPS unit + extra batteries
- Camera + extra memory card/battery
- Write-in-rain notebook + pencils (extra pencils/lead)
- Plant key/information regarding key characteristics of target species
- Pinflags or flagging (to mark target plants if found)
- Copies of permits/access permission letters (if applicable)
- Meter^2 plot frame (to sample new population if needed, helpful if have a plot frame that collapses)

5.6 Survey protocols: all species

The level of effort required for survey depends on vegetation diversity and structural complexity, which determines distance at which plants can be identified. For example, it has

been estimated that at least one person-hour per eight acres per survey date is needed for a comprehensive field survey in grassland with medium diversity and moderate terrain, with additional time needed for species identification (CDFG 2009). For maximum likelihood of locating the target species, one of the following two types of survey protocols are recommended: systematic or intuitive controlled. The method used will depend on the size of the area to be surveyed; in general, sites of less than a hectare in size should be searched systematically, while those larger than a hectare should be covered using the intuitive controlled method. Table 7 summarizes the two types of survey methods recommended for rare plant surveys.

Table 7. Recommended rare plant survey methods.

Method	When to use	Description
Systematic search patterns/complete survey	• Typically used for search areas of less than one hectare (2.47 acres). • Use to minimize overlap and maximize coverage. • Reduces tendency to avoid difficult search terrain. • Results in 100% visual examination of the area.	• Walk a series of parallel transects in a search unit maximizes coverage of an area. • Spacing of transects depends on density of vegetation, visibility through vegetation, the size of the plants and the topography of the site (i.e. if target species is small and easily hidden by vegetation, transects should be spaced no more than 5-10 m apart).
Intuitive controlled survey	• Typically used for larger (> 1 hectare or 2.47 acres) areas.	• Complete surveys in habitats with highest potential for locating target species. • Surveyors traverse through project area enough to see representative cross section of all major habitats and topographical features, looking for target species while en route between focus areas. • When surveyor arrives at area of high potential habitat, a complete survey for target species conducted.

Note: Presence surveys vs. absence surveys: When target species can be confused with similar, more common species (as in the case of Kincaid's lupine or Nelson's checkermallow), two types of surveys can be used: presence surveys and absence surveys. Presence surveys are conducted when the species can be positively identified (i.e. while the plants are in flower or fruit). Absence surveys can be conducted when leaves of the target species are easily identifiable and reliably present so that if leaves are not encountered, the surveyor can be confident that neither the target species nor its lookalike(s) are present. Absence surveys can be conducted over a wider window of time than presence surveys. These two types of surveys can be used in conjunction with each other. If the absence survey does not locate the leaves of the species, no further survey is required. If an absence survey finds leaves that could potentially belong to the target species, a follow-up presence survey will be required for a positive identification.

5.7 Survey protocols: species-specific

See Table 8 for a summary of recommended species-specific survey methodology.

5.7.1 Bradshaw's lomatium

When to survey:

Because vegetative Bradshaw's lomatium plants (especially seedlings) are difficult to locate, surveys should be conducted when this species is in flower (see Appendix F for pictures of Bradshaw's lomatium). Although historical sighting reports and herbarium records show bloom times ranging from early April through late June (OFP 2005, ORBIC 2012), surveyors are most likely to encounter flowering plants from mid-April through late May.

What to count:

First-year vegetative individuals of Bradshaw's lomatium are very difficult to locate. When a new population of this species is located during survey efforts, we recommend counting non-seedling plants to get an accurate estimate of the new population size, and note the presence of seedlings if observed. Once again, there are times when it is difficult to determine if closely spaced plants are, in fact, connected underground. In previous work with this species, plants separated by distances of ~3.5 cm to 10 cm were reported as

individuals. Although these distances are somewhat arbitrary, the consistent application of one definition over time and across populations is the important factor. We recommend using a distance of 4 cm (approximately two finger widths) when differentiating between individuals (Table 8).

5.7.2 Kincaid's lupine

When to survey:

Without flowers, it can be difficult to differentiate Kincaid's lupine from several more commonly occurring look-alike lupine species. Therefore, surveys for this species should be conducted when it is in bloom (see Appendix G for pictures of Kincaid's lupine). Historic and herbarium records report bloom times ranging from late April through mid-July. However, surveyors are most likely to reliably encounter flowers from mid-May through early July (Table 8). Because Kincaid's lupine and its look-alikes have fairly distinct and easy to spot leaves, it is possible to do "absence surveys" during a wider window of time (March – July). Obviously, if lupine leaves are encountered during the absences survey, a follow-up presence survey is needed to determine the species. However, if no lupine leaves are encountered, the survey is complete.

What to count:

While previous studies have quantified populations of Kincaid's lupine in a variety of ways, the ability of this species to spread relatively large distances through underground rhizomes has always posed a challenge. This, combined with studies showing correlation between numbers of leaves and area cover, has led to most researchers using area of foliar cover (in square meters) as the standard method for estimating abundance of Kincaid's lupine. This is what is recommended here as well.

5.7.3 Nelson's checkermallow

When to survey:

Without flowers, it can be difficult to differentiate Nelson's checkermallow from several more commonly occurring look-alike checkermallow species. Therefore, surveys for this species should be conducted when it is in bloom (see Appendix H for pictures of Nelson's

checkermallow and Appendix I for a short key to Willamette Valley checkermallows). Historic and herbarium records show bloom times ranging from late May through mid-August. However, surveyors are most likely to reliably encounter flowers from mid-June through mid-July (Table 8). Because Nelson's checkermallow and its look-alikes have fairly distinct and easy to spot leaves, it is possible to do "absence surveys" during a wider window of time (April - August). Obviously, if checkermallow leaves are encountered, a follow-up survey to determine the species is needed. However, if no checkermallow leaves are encountered, the survey is complete.

What to count:

Like the other three species in this study, Nelson's checkermallow presents some challenges when determining an individual. Most investigators working with this species have counted individuals. Some have defined that term, and some have not. For most populations, plants are fairly distinct and easy to differentiate, and this is the appropriate unit for quantifying abundance. Because separate clumps of Nelson's checkermallow leaves/stems can be connected underground, and individuals are often not easily distinguished (except in cases where differentiation is obvious, such as when one plant has perfect flowers while the other has pistillate flowers), we recommend calling plants separated by 30 cm (~1 ft) or more separate individuals. We have encountered several populations or portions of populations, however, that consist of relatively larger areas covered with mats of vegetative Nelson's checkermallow leaves. In situations like this, almost none of the leaves are more than 30 cm apart from the others, and the previous definition of an "individual" would result in calling the whole area one plant! If this type of situation is encountered, we recommend quantifying the population size using area of foliar cover (in square meters).

5.7.4 Willamette daisy

When to survey:

Because vegetative Willamette daisy plants (especially small ones) are extremely difficult to locate and identify, surveys should be conducted when this species is in flower (see Appendix J for pictures of Willamette daisy). Although historical sighting reports and herbarium records show bloom times ranging from early May through early August (OFP

2005, ORBIC 2012), surveyors are most likely to encounter flowering plants from early June to mid-July (Table 8).

What to count:

Because vegetative individuals are difficult to locate, when a population of Willamette daisy is located during survey efforts, we recommend counting flowering plants to estimate population size. When clumps are more closely spaced, it can be difficult to determine if clumps are connected underground. Since actually determining the connectivity of clumps would involve disturbing and potentially damaging them (by digging them up), in the past investigators in the past have arbitrarily defined individuals as being separated by anywhere from ~3.5 to 10 cm. The distance is important, since the larger it is, the more likely it is that clumps will be lumped together as one "plant" and the lower the population count will be. However, what is most important is consistently using the same definition over time, and across populations. For that reason, we are recommending a standard distance of 7 cm (approximately in the middle of the range) be applied when differentiating between individuals.

Table 8. Summary of recommended target species survey protocols.

Species	Survey time period		What to count	What is an individual?
	Absence surveys	Presence surveys		
Bradshaw's lomatium	n/a	Mid-April – May (when flowering)	Individual non-seedling (reproductive and vegetative) plants	Individuals separated by 4 cm or more
Kincaid's lupine	March – July	May – mid-July (when flowering)	Area of foliar cover (m^2)	n/a
Nelson's checkermallow	April – August	Mid-June – mid-July (when flowering)	Individual plant (reproductive and vegetative) or area of foliar cover (m^2)	Clumps separated by 30 cm or more unless both pistillate and perfect flowers present
Willamette daisy	n/a	June – mid-July (when flowering)	Flowering plants	Individuals separated by 7 cm or more.

5.8 Documenting new populations

When a target species is found during a survey, the following steps should be followed to ensure that the new population is documented in a thorough and consistent manner:

1. Document location of population. Thoroughly survey area and mark boundaries of population (pinflags/flagging can be helpful). GPS a polygon boundary of population (and/or points for small patches/individuals, as appropriate). It can also be helpful to mark locations on field map.
2. Count/estimate the size of the population. See Section 5.9 below for more recommendations for quickly estimating population size. Note: When assessing potential impacts to the population (if there is a proposed land action that will be causing ground or vegetation disturbance), more accurate population counts need to be conducted. Large population census/sampling methodology can be more time consuming, and follow-up visits to the site will probably be needed. Refer to monitoring section of this report for more information on how to get baseline population data for a new site.
3. If appropriate (i.e. population is large enough to support the loss of one individual), obtain voucher specimen for each rare species found to provide verifiable documentation of species presence and identification (consult permitting agencies for guidelines). If unsure of whether or not to collect a voucher, collect only a few leaves/flowers or a single flowering branch with associated photos. Clonal/tufted plants can often withstand collection of part of a plant. If unable to collect voucher specimen, document target species presence with photographic close-ups of diagnostic features needed to identify species and surrounding habitat. State references used to key plant.
4. Take photos of target species and representative habitats to support information and descriptions.
5. Record information about habitat, threats, management.

5.9 Developing quick estimates of new population sizes

This section is intended to assist surveyors in developing quick and very rough estimates of population sizes. It assumes that the surveyor does not have time during the initial survey to stop and conduct a thorough monitoring effort at the newly discovered population. Information gathered and reported in this manner provides information about the presence and order of magnitude of the size of the population. This information allows USFWS and other partners to assess the role the new population might play in recovery of the species and make preliminary management recommendation, but is generally not sufficient to determine impacts from proposed projects that might disturb or destroy the population. Refer to Section 6 for more information about monitoring a population to get baseline data for the development of a project impact assessment.

- **Small populations**: Count all individuals (see Section 5.7 for what to count/definitions of an individual).
- **Large populations**: After completing surveys and mapping the location of a new population, visually estimate the population (or patch) size to the nearest order of magnitude (i.e. 0-10, 11-100, 101-1000, etc.).
- **Densely distributed populations/patches**: In cases where plants are densely distributed, visual population estimates are often low, and sometimes can be off by an order of magnitude. In this case, better estimates can be achieved by sub-sampling a population or patch by counting all of the individuals in one or more plots or patches (i.e. within several meter^2 plots). This is not meant to be a statistically rigorous sampling effort; rather, it is intended to give the surveyor "a better eye" for visually estimating the overall magnitude of the population or patch size. Once a good sense of what 10 plants (or 100 plants, etc.) looks like has been developed, the surveyor can extrapolate to the larger population in order to better estimate the magnitude of the population size.
- **Scattered distribution**: In cases where plants are sparsely scattered over a larger area, visual population estimates can often be high. In this case, better estimates can be achieved by counting all the individuals in one or more sub-sections of the

population. Once again, this provides the surveyor with a better sense of what 10 plants (or a 100 plants, etc.) look like on the site.

5.10 Survey reports

Reports documenting survey methods and results should contain the following information:

- Date of report
- Name of person writing report
- Contact information of reporter (phone, address, email, affiliation)
- Proposed project/land action description: type of project, anticipated impacts, proposed timeline, land owner/manager
- Directions to site (refer to roads, geographical features)
- Detailed map of project location that includes footprint of proposed project, topographic and landscape features, north arrow and bar scale
- Description of pre-field preparation/review, especially if the review results in a determination that no field survey is needed, including names of people contacted, herbaria visited, etc.
- Written description of biological setting (vegetation, geological and hydrological characteristics, current and historic land use, etc.)
- List of targeted rare plant species and methods used to develop list
- Location of reference population(s) visited, date visited, observability and phenology of target species on that date
- Date(s) of survey and rationale for timing and intervals
- Location(s) surveyed
- Name, contact information for and qualifications of surveyor(s)
- Total person hours spent on surveys
- Detailed description of survey methods for each habitat present and rationale for methods used
- Discussion of possibility of false negative survey, including conditions which might have prevented surveyors from determining presence of species in potential habitat (i.e. timing of survey, weather, disease, drought, herbivory)

- Comprehensive list of vascular plants for entire project site, identified by scientific name to species (or taxonomic level needed to determine rarity)
- Discussion of any use of data from previously conducted surveys
- Digital images of representative habitats in survey area
- Presence or absence of target species on adjacent land parcels (known or observed)
- References cited
- Copies of field survey forms (See Appendix E for an example)
- Sign-off sheet with signatures of the botanists who conducted the surveys should be present on the final document to ensure that findings are reported

If target species are found during the survey, the following information should also be included:

- Detailed information about any special status plant populations found, including scientific name, location and size of population (with description of method used to determine size), method used to identify species, phenology of target species, area occupied, evidence of reproduction (i.e. evidence of seed production and seedling recruitment)
- Source of GPS coordinates: GPS make/model or map, datum (NAD27, NAD83, other), coordinating system (UTM/Zone, Latitude/Longitude)
- Digital images of target species found
- Information on voucher collections and their storage
- Assessment of potential direct/indirect/cumulative impacts of the proposed project (both one-time and ongoing) on the target species or its occupied/unoccupied habitat
- Assessment of biological significance of the target species populations or their habitat in a local, regional or species range context
- Habitat description: plant communities/associated species, slope, aspect, topographic position, light, moisture/hydrology, elevation range, substrate/soil
- Discussion of threats to the target species population (management, disease, predation, invasive species, encroachment, land use, off-site hydrological influences, etc.), including assessment of immediacy of potential threats

- Recommended measures to avoid, minimize or mitigate impacts to target species and their habitat
- Comments on protection of target species at site (legal actions/strategies needed to secure protection of site, if applicable)

6. Recommended monitoring protocols

6.1 Developing a monitoring plan

A well-developed monitoring plan can greatly increase the efficiency and effectiveness of monitoring efforts, and help ensure that monitoring resources are well-spent and that the data collected will be useful and relevant to present and future land managers. There are many good references that go into great depth on this topic. This section summarizes some of the information found in the following sources: Elzinga et al. 1998, Beard et al. 1999, Vesely et al. 2006, and Hierl et al. 2007. It is meant to provide basic information about monitoring plan development, rather than be an exhaustive discussion. Each of the following topics is detailed in the sections below:

- Compile and review information about target species and sites
- Develop monitoring goals/objectives
- Assess resources available for monitoring
- Select methodology (including measures of population or habitat) to be used
- Determine intensity/method of monitoring
- Address how to control observer bias and maintain consistency
- Review monitoring plan with management and on the ground staff, solicit input

6.1.1 Compile and review target species/site information

Compile and review existing information on the target species and populations of interest. Review any planning documents related to the site and/or population of interest (i.e. site planning documents, regional environmental documents).

6.1.2 Develop monitoring goals and objectives

Whenever possible, all monitoring efforts should be designed to not only meet the objectives that prompted the monitoring to take place in the first place (i.e. assessing effects of management actions or disturbance), but also should achieve the following goals (if these are not already built into the study or monitoring plan) in order to contribute to assessment of progress towards recovery:

1. *Create a relatively accurate estimate of overall population size*. If estimating total population size is not already part of the monitoring plan, consider adjusting methodology so that developing this estimate is possible. The ability to assess the size and status (increasing, stable, decreasing) of rare plant populations is a critical element of assessing the state of the species as a whole, and determining progress towards recovery.
2. *Record evidence of recruitment, if present*. If monitoring does not include counting seedlings, at the very least an anecdotal account of the presence or absence of seedlings will help determine the potential of the site to contribute towards recovery of the species.
3. *Provide an assessment of current threats to the population*. This information, combined with data on population sizes and trends, allows for analysis of overall status of the species as a whole.
4. *Provide a quick assessment of habitat quality*. A model for rapid habitat assessment is currently being developed by Willamette Partnership with the help of Institute for Applied Ecology. Ideally, this tool will be used in conjunction with species-specific monitoring to determine whether a site may contribute towards recovery of the species. At the very least, though, a quick assessment of native forb/grass diversity (number of species), percentage of native cover (more or less than 50%), presence of noxious weeds (more or less than 5%, see Appendix K for list) and percentage of woody cover (more or less than 15%) should be estimated/recorded.
5. *Make recommendations for adaptive management techniques if population appears to be declining*. This enables land managers and government entities

(e.g. USFWS) to assess recovery implementation priorities, plan conservation efforts, allocate funds appropriately.

Ideally, land managers implementing monitoring efforts should consider themselves part of the larger recovery effort for the species in question. In the past, many dollars, staff hours and other resources have been spent monitoring rare plant populations without taking into consideration how individual monitoring efforts fit into the bigger picture of rare plant conservation and recovery. This resulted in the collection of monitoring data that was not comparable over time or between locations, and an inability to assess the status of a species. By implementing monitoring methods that address this issue, land managers will assist regulators in focusing recovery efforts and ultimately enable the downlisting or delisting of these rare plant species.

6.1.3 Assess resources available for monitoring

One of the key factors in determining the level of intensity at which a site may be monitored is the amount of resources available to do the monitoring. The amount of staff time (for field work, data entry, and data analysis and reporting), the type of equipment, and/or the amount of funding available will all play a role. It is important to assess the resources available before implementing a monitoring plan. When in doubt, err on the side of assuming fewer resources. It is more important to have a less complex or less resource-intensive (or even slightly less accurate) monitoring plan that **will be** implemented, rather than a highly accurate but labor-intensive monitoring plan that will not be implemented, or will be implemented inconsistently!

6.1.3 Select general approach/methodology to be used

During the process of answering the following questions, the parameters of the proposed monitoring will be established:

- Will your monitoring be qualitative or quantitative? Although qualitative monitoring (i.e. photopoints, presence/absence, visual estimate, etc.) can be useful, in general these methods do not result in sufficiently accurate estimations of plant population size and trends to assist in the assessment of the population's

(or species') status. As such, qualitative monitoring should be used in limited circumstances, such as:

  - Using presence/absence or visual estimates when initially attempting to ascertain status of a historic population that has not been seen for many years, especially if this "scouting" is being done by volunteers
  - Using presence/absence or visual estimates when describing status of a population on private land, where access is limited and ability to assess the population more thoroughly is hindered
  - Using photoplots in conjunction with quantitative methods to provide additional information and records of site conditions, etc.

- To what level of intensity will you monitor (Census? Sample?) This may need to be decided on site the first time you monitor, especially if you are not familiar with the site. See Section 6.5 for a census vs. sampling decision matrix.
- What will the measures of population and/or habitat be? (What will you count/measure?)

6.1.4 Maintain consistency in long-term monitoring

Because this study defines monitoring in the context of assessing the status and trends of rare plant populations in order to determine progress towards recovery of these species, we assume that target species populations will need to be monitored over longer periods of time. Therefore, ensuring the continuity and reliability of the information collected is critical. Methods for coping with measurement inconsistency can be classified as either protective or corrective (Beard et al. 1999). In general, corrective methods (where analysis is adapted to take account of measurement inconsistency) are only possible if sufficient information has been provided by the protective methods built into the monitoring plan. The following protective measures can help avoid inconsistencies to begin with, and aid in implementing corrective measures when unavoidable inconsistencies are encountered.

1. *Detailed protocols/methods*: The goal of thoroughly describing protocols in a detailed manner is to eliminate differences in interpretation and application of those protocols. All investigators should be briefed on the importance of

following methods exactly and reporting any unavoidable deviations from those methods (Beard et al. 1999). Protocols should include the following items (Vesely et al. 2006):

- Data collection methods
- How to locate sampling units (if applicable)
- Dimensions of sampling units and how they are/will be marked
- Observation techniques
- Duration of sampling
- Data recording methods (significant digits, units, taxonomic level, etc.)
- Plant marking techniques (if applicable)
- Instructions for operating equipment
- Collection of voucher specimens

2. *Trial run/pilot study*: When possible, a trial run of methodologies should be conducted with personnel who have not been involved with the development of the protocols, so that inconsistencies can be caught and questions can be addressed. (If no pilot study/trial run is conducted, investigators run the risk of having the first year becoming the de facto pilot study, and face the possibility of losing the first year of data if methodologies have to be changed greatly.)

3. *Detailed recording of methodology*: Thoroughly document all procedures and any changes to those procedures in writing. Include information on sources of equipment and materials (if applicable), location and timing of data collection, and personnel involved. The level of detail provided should allow the monitoring to be repeated exactly in subsequent monitoring periods by personnel that have not been involved in previous efforts.

4. *Quality control/quality assurance*: Some method for regularly checking the quality of data collected should be implemented. Techniques might involve periodic remeasurement of variables, having more than one investigator independently collect data for the same measurement, and review of collected

data before leaving site. If quality control measures are left until the end of the data collection efforts, investigators run the risk of not discovering quality issues until the opportunity for correction is past, especially if data is being collected in a limited window of time, or at locations some distance from where the data will be processed and analyzed.

5. *Overlap periods for changes in methods*: There are times when, in spite of the most careful planning, changes to methodology are unavoidable. When this is the case, both the old and new methods should be conducted concurrently for an overlap period of time to allow for calibration between the two. The length of the time period should be such that any factors likely to affect the calibration will be accurately estimated (Beard et al. 1999).

6. *External variables*: External factors which are not part of the actual study, but which may influence results, should be recorded. External variables might include weather, herbivory, disease or impacts from adjacent landowners.

7. *Measurement synchronization*: Efforts should be made to collect data during the same relative time of year, over the same length of time and at the same spatial location (Beard et al. 1999).

8. *Training of personnel*: The benefits of good project planning can be undermined by poorly trained personnel. For example, different levels of training and experience among survey personnel can result in significant observer variability (Vesely et al. 2006). Ensuring that staff is properly trained (ideally by conducting trial runs of the methodologies being used) is essential to quality data collection.

6.2 Monitoring pre-site visit checklist

This section provides a list of tasks to be completed before visiting the site to be monitored. (Note: Once this protocol has been fine-tuned for a particular site and implemented, some of

these steps can be skipped in subsequent monitoring trips.) See Appendix L for the following list (and the equipment list) in a removable checklist format.

Pre-site visit monitoring checklist

1. Contact land owner/manager to obtain permission to access site (if necessary)
2. Print aerial photos/maps with GPS layer of population locations (if known)
3. Obtain last counts from previous monitoring data (if known)
4. Gather equipment (see Section 6.3 Field equipment list)
5. Get specific directions to site (if necessary)
6. Develop monitoring plan if not already completed (see Section 6.1)

6.3 Monitoring field equipment list

Efficient monitoring can be conducted without having a long list of expensive equipment. However, there are some tools that make monitoring efforts much more effective and efficient (Figure 5). Table 9 provides a sample list of equipment and supplies recommended for use when monitoring rare plant populations. See Appendix L for this list (and the pre-site visit list) in a removable checklist format.

Figure 5. An example of monitoring field equipment.

Table 9. Monitoring field equipment list

- 100 meter tapes (at least 3)
- Meter tape chaining pins
- Meter sticks or meter-long plastic PVC pipe with 1/10s marked in sharpie (1/investigator)
- Pinflags (at least 300-500, at least 2-3 colors, orange and pink work best)
- Flagging (to put on equipment & mark transects/plots in tall vegetation where it is difficult to see pinflags)
- Square meter plot frame(s) (for estimating m^2 of coverage for Kincaid's lupine and Nelson's checkermallow
- 0.05 m^2 cover template (22.4 cm x 22.4 cm clear plastic square, for estimating coverage for Kincaid's lupine and Nelson's checkermallow)
- Camera + extra batteries/memory card
- GPS + extra batteries (if uses batteries)
- Tally counters (2/person)
- Waterproof knee-high boots (Bradshaw's lomatium often in/near standing water)
- Scientific calculator
- Write-in-rain notebooks
- Pencils
- Clipboard
- Sample size calculation worksheets (on write-on-rain paper if chance of rain)
- Pictures of species/identifying characteristics (if all field staff not familiar with species)
- Plant identification key/guides
- Method for generating random numbers (i.e. smartphone ap, random number sheet, stopwatch)
- Previous monitoring data (if available)
- Aerial photos/maps (with GPS layer of previously-mapped population locations)
- Directions to site (if haven't been there before)

6.4 General monitoring protocols: all species

The following recommended protocols assume that the general location of the population in question is already known. (See Section 5 for recommendations on how to survey for new populations.)

Before counting anything:

1. Consider establishing permanent macroplot(s) which encompass entire population or patch. Macroplot corners can be permanently marked with t-posts, rebar, or large nails with metal tags (to be found with metal detector), depending on the site. Macroplots can aid with relocation of the population over time, as well as providing a baseline structure for dividing the area into transects or subsections.

2. Review target species identification guidelines and definition of an individual for that species.
3. Arrive at site and locate area where plants are known to occur.
4. Walk area where target plants and potential habitat are located. Mark encountered plants with pinflags (or flagging if the vegetation is too high or dense to see pinflags). If the population is dense, do not mark every individual. Spend enough time to cover the entire area (usually 15 minutes to an hour, depending on the geographical area). The goal at this point is to get a general sense of the population size, density, and geographical distribution, rather than to mark every plant.
5. Establish a clear population boundary. Walk perimeter of marked plants, searching for more outlying plants and marking them when found.
6. Decide whether to census or sample the population (see Section 6.5 for the census vs. sampling decision matrix). Once the methodology has been determined, this step will not be necessary during subsequent monitoring visits, unless a large change to the size or distribution of the population has occurred.

After counting (before removing pinflags/flagging and preparing to leave site):

7. GPS population boundaries (or patch boundaries) to get polygon encompassing entire population or patch. In general, unless the goal is to map out exact locations of individuals/small patches of the target species (which takes considerably more time), we recommend only mapping individual patches when there are large distances (i.e. > 100 m) between them.
8. If you have permanent macroplots, adjust corners if population has expanded beyond original area.
9. Take pictures of overall site, distribution of plants, methodology used.
10. Conduct quick assessment of site habitat quality. Do a quick walk through the site and record number of native forbs and grasses, percentage of native cover (more or less than 50%), presence of noxious weeds (more or less than 5%, see Appendix K for list) and percentage of woody cover (more or less than 15%).
11. Make detailed notes regarding who conducted the monitoring, the time it took, and any deviations from the monitoring plan.

12. Check over data to make sure there are no gaps or unclear data entries.

6.5 Census vs. sampling decision matrix

When deciding whether to census or sample a population, the overall goal is to obtain the most accurate count of the population size possible given the time/staff/resources available to conduct the monitoring. In general, a complete census is the preferred method for determining the size and extent of rare plant population. Since there is a fair amount of time involved with setting up sampling transects and calculating sample sizes, it is often both faster and more accurate to census many populations. However, there are definitely instances where it is more appropriate to sample. It can be challenging to census populations of difficult-to-see species, populations in difficult-to-access or rugged terrain, numerous or very dense populations, and populations that cover a large geographical area. The ability to census will depend on all of these factors, as well as the amount of time, money and personnel available to conduct the monitoring. When limited resources preclude the ability to census a population, sampling is recommended. Each land manager will need to realistically assess the resources that are available for monitoring (both present availability and projected future availability, to the best of their ability), and select a method accordingly. When in doubt, it is better to select a less resource-intensive, easier to implement method that has a high likelihood of being consistently implemented over time.

A decision matrix for determining whether to census or sample a population is presented in Table 10; however, keep in mind that these are guidelines only, and that this decision should be made taking into consideration the specific site and species attributes and the resources available.

6.6 Monitoring frequency

Ideally, population monitoring will occur annually. Annual monitoring enables investigators to document the variation in population size from year to year, and to closely monitor site disturbances and environmental factors that might impact population numbers. Monitoring with less frequency makes it more difficult to document population size trends over time. The Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (USFWS 2010) states that populations used to meet recovery goals should have stable or

Table 10. Census vs. sampling decision matrix.

Estimated population size is LESS THAN 1000 individuals (Bradshaw's lomatium, Nelson's checkermallow, or Willamette daisy) or estimated habitat is less than 100 m x 100 m (Kincaid's lupine)			
Population distribution	**Population density**	**Ability to locate individuals**	**Recommended monitoring methodology**
Population covers large geographical area	Any density (dense, diffuse, or combination of dense patches and scattered individuals)	Easy	Census
		Difficult	Sample
Distinct patches or subpopulations	Option of either treating as one population covering large area (especially if many patches or each patch covers large area, see above) or multiple small area populations (especially if only a few patches, see below)		
In relatively small geographical area	Any density (dense, diffuse, or combination of dense patches and scattered individuals)	Easy	Census
		Difficult	Census*
Estimated population size is GREATER THAN 1000 individuals (Bradshaw's lomatium, Nelson's checkermallow, or Willamette daisy) or estimated habitat is greater than 100 m x 100 m (Kincaid's lupine)			
Population distribution	**Population density**	**Ability to locate individuals**	**Recommended monitoring methodology**
Population covers large geographical area	Dense	Easy	Sample
		Difficult	Sample
	Diffuse	Easy	Census
		Difficult	Sample
	Combination of dense patches and scattered individuals	Easy	Census**
		Difficult	Sample
Distinct patches or subpopulations	Option of either treating as one population covering large area (especially if many patches or each patch covers large area, see above) or multiple small area populations (especially if only a few patches, see below)		
In relatively small geographical area	Dense	Easy	Census
		Difficult	Sample
	Diffuse	Easy	Census
		Difficult	Sample
	Combination of dense patches and scattered individuals	Easy	Census**
		Difficult	Sample**

* Consider sampling if not confident that census methodology will locate all individuals.
**Consider using combination of census (scattered individuals) and sampling (dense patches estimated to contain ~1000 individuals or more)

increasing sizes over a period of 10 years, so monitoring with enough frequency to establish population trends over time is important. However, we recognize that land owners/managers do not always have the resources to monitor their populations every year. At a minimum, we recommend that every population with the potential to count towards recovery is monitored every three years.

6.7 Censusing protocols: all species

Census the entire population when it is relatively small (<1000 individuals or <100 m x 100 m) and easy to count. See Section 6.6 for more details on how to determine whether to census or sample.

Once the population has been located and marked with pinflags (see Section 6.4 General monitoring protocols: all species), assess target species and surrounding vegetation density in order to determine if transects or quadrats are needed to count plants. Transects are helpful for keeping track of what has already been counted and ensuring plants are not missed when vegetation is dense or the target species is difficult to see.

<u>If not using transects/subsections:</u>

- Start at one end of the population and methodically canvas the area. If counting individuals (as opposed to area of foliar cover), mark each individual with a pinflag when encountered. This enables field staff to determine which plants have already been located, and minimizes the chances of double counting or missing plants. (For specifics about conducting a census when using area cover as the unit of measurement, see Section 6.9.2.)
- If plants are particularly dense, consider using two colors of pinflags, where one color represents a single plant, and the second color represents 5 or 10 plants (see species-specific recommendations below for species that are quantified using area of foliar cover instead of individual counts).
- If counting more than one life stage (i.e. vegetative and reproductive), either use different colored pinflags for the different life stages, or write the counts for a cluster

of plants on the pinflag with a sharpie (i.e. write "3V/2R" for three vegetative and two reproductive individuals in a cluster).

- Once all individuals are marked, take digital photos of entire population to capture a visual representation of the size and extent of the population.
- If no further data needs to be collected for each individual, go back through the population collecting all pinflags, and total the number of pinflags (or the counts written on the pinflags) for a population count.

<u>If using transects/subsections to census:</u>

- Use meter tapes or survey flagging to subsection the population into manageable areas. For example, starting at one end of the population, create the first transect by laying out a meter tape along one edge of the population. If the population is more than 100 meters wide, either use an additional tape to encompass the entire width, or consider sampling. Lay a second meter tape parallel to the first. Appropriate transect width ranges from 1-10 meters wide (see species-specific recommendations below for more information) when censusing. Wider transects are more difficult to accurately census, especially if plants are dense in areas.
- Determine guidelines for plants occurring on line between subsections/transects, so that individuals are not missed or counted twice. The following are recommendations for each species:
    - Bradshaw's lomatium: rooted within transect
    - Kincaid's lupine: not applicable (measuring area of cover, not counting individuals)
    - Nelson's checkermallow: more than 50% of individual is located within transect
    - Willamette daisy: more than 50% of individual is located within transect
- Count all individuals of the target species within a transect. If plants are densely distributed, use pinflag method described above. Sometimes it is helpful to use meter stick or meter-long PVC pipe to further partition the transect while counting. If counting more than one life history stage and there are enough people, assign one person to be the recorder, and have the people counting call out the number and types

of individuals as they are encountered (i.e. 3 veg, 1 repro, 2 seedlings, etc.). If there are not enough people to have a designated recorder, each person counting can keep track of numbers and types of individuals in their own field notebook, and totals can be calculated at the end.

- "Leapfrog" the first tape over the second, and lay it down parallel and the desired transect width apart from the other tape so that a second transect is formed. Continue this way, counting plants in a transect then leapfrogging the tape to form the next transect until the entire population has been censused.
- If there are two people counting plants, they can either each start at opposite ends of the same transect and meet in the middle (which works best if one person is considerably faster than another), or two transects can be set up at the same time (Figure 6), and Person A can start at one end of Transect 1 and count the whole transect, while Person B counts Transect 2 starting from the opposite end. This positions both people such that they can easily leapfrog the tapes when they have completed their transects.

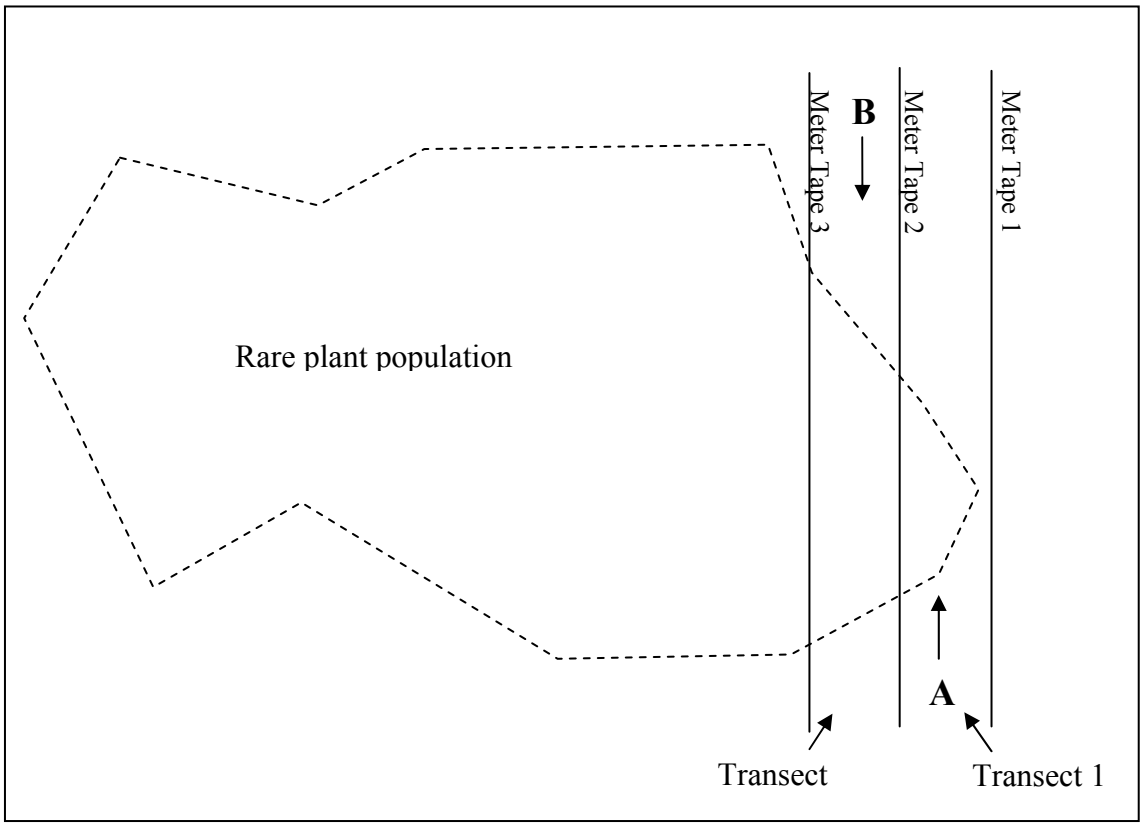

Figure 6. Diagram of how to use transects to census a rare plant population.

- Add up counts for each subsection/transect (and within each life history category, if appropriate) for a total population count.

6.8 Sampling protocols: all species

6.8.1 Overview

A population (or a portion of a population) is a good candidate for sampling when it:

- is larger than 1000 individuals
- is relatively contiguous on the landscape
- has individuals that are difficult to locate
- is spread over a large geographical area

6.8.2 General sampling design requirements

Section 6.6.3 outlines one recommended and fairly simple sampling approach. This approach has been field tested with all four target species at multiple sites. However, other sampling designs are acceptable as well, as long as:

1. The definition of an individual for the target species is consistent with this report's recommendations

2. The sampling methodology is thoroughly documented, and the following questions are answered:
    - What is the target population?
    - What are the spatial bounds of sample selection (i.e. did every spot in the entire population have a chance to be selected for sampling)?
    - What is the statistical scope of inference (i.e. will the resulting population size estimates be applicable to the whole population)?
    - How are sampling units selected?
    - What are the size, shape and spacing of sample units?
    - What is the desired level of precision?
    - What sample size is needed to meet desired level of precision?

- What is the desired power to detect change? (How much sensitivity to change is needed to determine if management changes are needed?)

6.8.3 Example sampling protocol

The following steps outline one fairly simple sampling approach. This approach may be used to sample an entire population, or to sample a portion of the population (in conjuction with censusing the remainder of the population).

1. Determine the extent and distribution of the population (see Section 6.5 for more information on how to go about this).

2. Determine the dimensions of a macroplot that encompasses the population or portion of the population to be sampled. The macroplot must be a quadrilateral (typically a square or rectangle, although in some cases a rhombus might be the most appropriate shape). Ideally, the macroplot will contain the entire population. However, the sampling works best if the population is fairly uniformly distributed (the more variation between sampling units, the larger number of sampling units needed). If there are outlier individuals that would create potential sampling units with zero or very few individuals, it is often better to exclude those from the macroplot and census them separately.

3. Determine which direction to orient the sampling quadrats/transects. Orient quadrats to minimize variability between them. For example, if plants are more densely clustered at one end of a rectangular macroplot (see Figure 7), quadrats should be oriented lengthwise so that each quadrat crosses through both the dense area and the more sparsely populated area. In general, place quadrats parallel to an environmental gradient (i.e. perpendicular to a stream/wet area). Whichever way the quadrat is oriented, it should run the entire length or width of the macroplot.

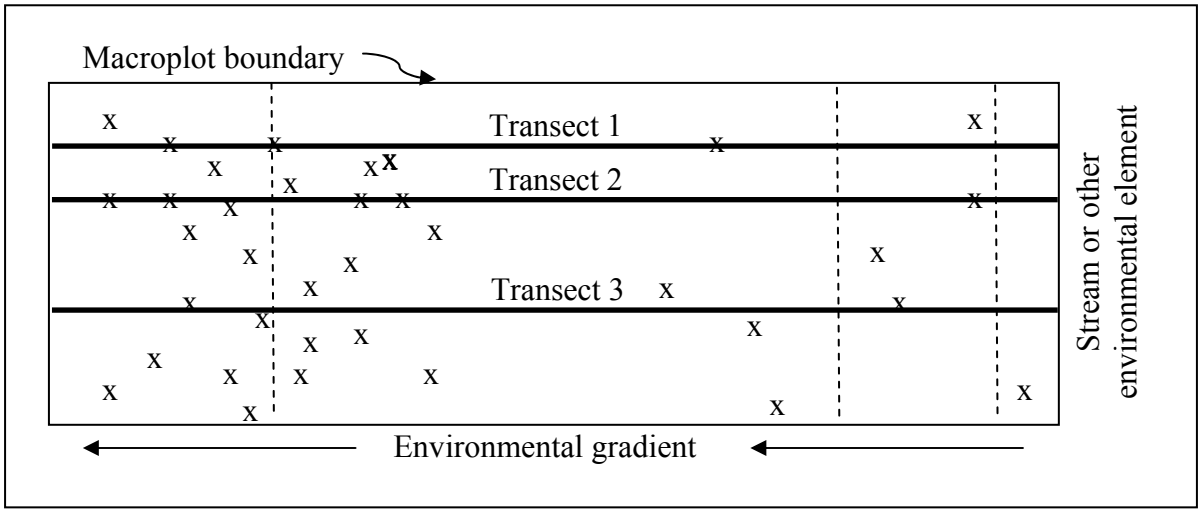

Figure 7. Sample diagram of quadrat (belt transect) orientation within a macroplot. Each x represents a cluster of plants. Quadrats are oriented lengthwise (solid lines labeled Transects 1-3) so that variability is captured within each transect (each transect passes through areas of greater and lesser density), rather than between transects (as it would be if transects were oriented the other way, as shown by the dotted lines). Orienting transects this way also places them parallel to the environmental gradient.

4. Determine length of macroplot. Lay one meter tape along an edge of the macroplot perpendicular to the transects. This is your baseline tape. If the macroplot is less than 100 meters long, simply note how long it is. If the macroplot is longer than 100 meters, measure the length by either 1) laying additional 100 meter tapes along the baseline edge or 2) approximating the length by pacing (trying to make each pace one meter long). The second method is usually necessary for very long (>200 meters) macroplots.

5. Determine width of quadrat/transect. Table 11 provides a range of recommended quadrat widths for each of the target species. In general, the more densely distributed the individuals, the narrower the quadrat. Once again, the goal is to have the quadrat be the smallest width possible (to reduce the amount of time counting) while still minimizing variability between quadrats (i.e. transect large enough to avoid samples with zero or very few individuals).

Table 11. Recommended range of widths for sampling quadrats/transects. Selection of width should depend upon population density and ease of locating individuals.

Species	Recommended sampling quadrat widths
Bradshaw's lomatium	¼ meter – 1 meter
Kincaid's lupine	1 meter -2 meters
Nelson's checkermallow	1 meter – 5 meters
Willamette daisy	1 meter – 5 meters

6. Generate randomly selected locations for ten sampling quadrats. Use a random number table or generator (stopwatch, smartphone ap, etc.). Figure out the total number of possible quadrats by multiplying the width of the macroplot in meters by the width of transect (if width of transect is less than one) or dividing the width of the macroplot by the width of the transect (if width of transect is greater than or equal to one).

******* FIELD TIP *******

If using a random number generating method that generates numbers between 0 and 1 (i.e. 100ths of seconds on a stopwatch), and you have less than 100 possible transect locations in your macroplot, multiply your randomly generated number by your total number of possible quadrats to get a random location for each quadrat. If there are more than 100 possible quadrats, you will need to randomly generate a number between 0-100, then randomly generate a third digit as well (i.e. if there are 152 possible quadrat locations, randomly generate 0-100, then randomly generate a 0 or 1 to put in front of the first randomly generated number. If your resulting number is too large, like 178, then continue generating numbers until you get one that is a possibility.)

7. Set up first quadrat. If available, lay a second 100 meter tape along the top edge of the macroplot, parallel to your baseline tape and perpendicular to the orientation of the sampling quadrats. Make sure the zero point for each tape is at the same end of the macroplot. Lay another 100 meter tape perpendicularly between the two baseline tapes, with each of its endpoints crossing the baseline tapes at the first randomly generated location.

8. If the macroplot is greater than 100 meters long, or if you do not have another 100 tape to use as a second baseline, then position the transect using a compass. Take a reading along the baseline tape. Add 90° to that number to get the orientation of the transect. Standing at the randomly generated starting point of the transect, use the compass to locate a target point on the other side of the macroplot along that orientation.

9. If the transect is one meter wide or less, determine if individuals of the target species are within the transect by using a meter stick. If the transect is 2 meters wide, place the transect meter tape in the middle, and use a meter stick to determine if plants are within a meter on either side. For transects wider than two meters, you will need two meter tapes to delineate the boundaries of the transect. Make sure that everyone is walking on the correct side of the meter tape when counting plants.

10. Count all plants in each quadrat, following the appropriate "what to count" guidelines for each species (Section 6.9). Walk along transect with a meter stick held in front of you. Record plants obviously located within transect area. When in doubt, use meter stick to measure distance from plant to meter tape. Determine a rule of thumb for handling plants that are only partially in the transect (see Field Tip below for guidelines). Record the totals for each life history stage separately, then total them for a single count for the quadrat.

****** *FIELD TIP* ******

Suggested rule of thumb for determining whether a plant is counted within a transect:

Bradshaw's lomatium……plant is rooted within transect

Kincaid's lupine…….not applicable (only counting area of foliar cover within the transect, not individuals)

Nelson's checkermallow……50% or more of foliage is located within transect
Willamette daisy……50% or more of foliage is located within transect

11. Repeat steps 7 through 10 with the remaining nine quadrats.

12. Calculate the number of transects needed to accurately sample the population within your desired margin of error. A field calculation sheet is provided in Appendix M. The lower the margin of error needed, the more transects will need to be sampled, and the longer monitoring effort will take. We recommend a margin of error of 30% or less.

13. If the sample size calculations result in a number of 10 or less, the 10 quadrats already sampled are sufficient. If the resulting number is greater than 10, subtract 10 from the suggested number of quadrats. The result is the number of additional quadrats needing to be sampled. Use the random number generator to determine the location of these additional quadrats, then follow steps 7 through 10 to get data for each additional quadrat.

    Note #1: If your calculated number of quadrats is quite large (i.e. greater than 20), we recommend sampling a second batch of 10 quadrats, then re-calculating the number needed. (Often, the number of quadrats needed decreases as more information becomes available with the sampling of the additional transects.) Since it takes ~30 minutes to run through the transect number calculations, you will have to weigh the time it takes to sample the additional transects needed vs. the time it takes to run the sample size calculations to determine which course is more time-efficient.

Note #2: If time is limited, figure out how many transects needed to sample 5% of the population. If less than 10, sample that number of transects, then stop and calculate needed sample size to see if the number of transects already sampled is sufficient.

14. Census all individuals of the target species that fall outside of the sampling macroplot. Add these to the estimated total.

15. Don't forget to take pictures showing the population, your methodology and monitoring efforts!

6.9 Monitoring protocols: species-specific

6.9.1 Bradshaw's lomatium

This section provides specific recommendations for monitoring Bradshaw's lomatium. General monitoring recommendations that apply to all four target species are discussed in Sections 6.1-6.8. A summary of species-specific monitoring recommendations can be found in Table 17 in Section 6.9.5.

When to monitor:

- Because vegetative plants are often very difficult to find, we recommend monitoring Bradshaw's lomatium when it is in flower, typically mid-April through May.

What to count:

- At a minimum: Non-seedling individuals (vegetative and reproductive) + presence/absence of seedlings. Bradshaw's lomatium seedlings are very difficult to find. If found, count as vegetative, and note their presence, but we do not recommend spending a huge amount of time looking for seedlings.
- If more time, see Section 7 for guidelines for collecting demographic data.
- Individual defined as being separated by 4 cm or more (see Section 5.7.1 for discussion about defining the individual).
- Seedlings are defined as a single leaf with cotyledons still present at the base.
- See Appendix F for pictures of Bradshaw's lomatium.

***Additional censusing recommendations*:**

- Because individuals of this species are often difficult to locate (especially if located in taller grass), dividing the population into transects or subsections to facilitate counting is recommended for Bradshaw's lomatium.

***Additional sampling recommendations*:**

- Recommended sampling quadrat/transect width range: 0.25-1 meter. When Bradshaw's lomatium is very densely distributed, it is difficult to keep track of what has/has not been counted if the transect is wider than half a meter.
- Count plant within transect if it is rooted in the transect.

Time estimates:

Table 12 provides estimates of the amount of time it takes to monitor different types of populations of Bradshaw's lomatium using the protocols described in this report. These are rough estimates, provided to assist with the development of monitoring plans.

Table 12. Examples of time needed to monitor Bradshaw's lomatium populations.

Population name	Allen and Allen	Short Mountain	Finley NWR (introduced)	Hobart
Population size (# individuals)	3356	405 (5 patches)	8700	8670
Acres of occupied habitat	0.23	0.24	0.77	~5
Monitoring method	Census	Census	Sample	Sample + Census
Number of investigators	3	3	4	6
Total person-hours	**19.5**	**18**	**30**	**72**
Notes	Familiar with site. Distribution did not lend itself to sampling.	Unfamiliar with site. Patches separated by large stretches of difficult-to-traverse terrain. Did not census smallest patches.	Two patches, plants easy to locate with no high competing vegetation.	Familiar with site.

6.9.2 Kincaid's lupine

This section provides specific monitoring recommendations for Kincaid's lupine. General monitoring recommendations that apply to all four target species are discussed in Sections 6.1-6.8. A summary of species-specific monitoring recommendations can be found in Table 17 in Section 6.9.5.

When to monitor:

- Because there are several similar-looking species of lupine located in similar habitat within the Willamette Valley, we recommend monitoring Kincaid's lupine when it is in flower, typically May through mid-July.

What to count:

- At a minimum: Area of foliar cover in m^2 + presence of seedlings. Because Kincaid's lupine is able to reproduce vegetatively, it is very difficult to determine whether clumps near each other are genetically distinct individuals. See Kaye and Benfield 2005 for a discussion of the correlation between number of leaves (a previously used metric) and area of foliar cover.
- If more time: # inflorescences. This provides information about reproduction in the population in question.
- For populations occupied by Fender's blue butterfly, see insert on next page for more information about working with two different recommended abundance metrics.
- See Appendix G for pictures of Kincaid's lupine.

MEASURING KINCAID'S LUPINE ABUNDANCE IN SITES OCCUPIED BY FENDER'S BLUE BUTTERFLY

The Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington provides habitat quality criteria for Fender's blue butterfly (USFWS 2010, p D-3; Figure 8). In this plan, sites providing breeding habitat for the butterfly should have a minimum of 30 lupine leaves/m^2 of habitat. However, the recovery plan also recommends that Kincaid's lupine abundance be measured in m^2 of foliar cover. This has resulted in two recommended ways to monitor Kincaid's lupine in sites that are occupied by Fender's blue butterfly.

Figure 8. Fender's blue butterfly. Photo by Nick Testa.

Because counting lupine leaves is a labor intensive process (and can cause more disturbance to the plants), Kaye and Benfield (2005) studied the correlation between number of leaves and area of foliar cover to see if the latter could be used as a surrogate of the former. While they found a strong correlation between these two metrics, there was substantial variation between populations (291– 986 leaves/m^2). Much, but not all, of this variation was explained by the amount of light the site received, with populations in full sun having more leaves/m^2 than those in partial sun.

Given this, we recommend that both metrics (total area of cover + a subsample of plots where leaves/m^2 are measured) are measured for at least one year at any FBB-occupied Kincaid's lupine site in order to develop a site-specific average number of leaves/m^2 for that site. Once that number has been determined, results from monitoring of either type can be translated into the other metric at that site. If immediate development of this site-specific average is not possible, Table 13 (from Kaye and Benfield 2005) can be used to roughly translate monitoring data so that it may be used for assessing both Kincaid's lupine abundance and Fender's blue butterfly habitat quality.

Table 13. Average number of leaves/m^2 in Kincaid's lupine populations with three different light exposures (adapted from Kaye and Benfield 2005).

Sun exposure of population	Average # leaves/m^2 (+/- 1 SE)	Correlation R^2
Full sun	870 (+/-34)	0.97-0.87
Sun to partial shade	500 (+/-30)	0.97-0.62
Partial shade	360 (+/-20)	0.75-0.73

***Additional censusing guidelines*:**

The following methodology has worked well for measuring Kincaid's lupine abundance (area of foliar cover in m^2).

1. Survey area and mark the extent and distribution of population (see Section 6.4 General monitoring protocols for more information).
2. Using flagging or 100 meter tapes, divide area being censused (whether an entire population or a discrete patch) into one-meter-wide transects. (Lay out the first transects, then leapfrog tapes to move across the population, just as you would with the other species.)
3. Walk along transect holding 1 $meter^2$ plot frame (Figure 9).

Figure 9. Investigators searching for Kincaid's lupine within two one-meter-wide transects. Photo by R. Currin.

4. When a patch of lupine is encountered, lay plot frame down so that one edge is touching the edge of the transect and the frame encompasses the entire patch (or the portion of the patch) that falls within that transect (Figure 10).

Figure 10. Investigators estimating area of foliar cover of Kincaid's lupine using square meter plot frames and .05m^2 plastic squares. Photo by R.Currin.

5. Estimate the area of foliar cover by visually "squishing" leaves together in one section of the plot frame so that there are no gaps in between, then estimating the percent of the square meter plot frame that is covered by the patch (i.e. 25% of the plot frame area = 0.25 m^2, etc.). Another way to estimate area cover is to visually manipulate the patch of lupine into a rectangle, calculate the length and width of the rectangle, then use those values to determine the rectangular area (from Thorpe and Kaye 2007b).

   Note: Estimating area cover is a notoriously subjective process. We recommend using tools like the 5% sheet (See Field Tip and Figure 11 below) to help. It is also a good idea to have all investigators calibrate themselves to each other by

independently estimating the area of cover in several 1 m^2 plots, then discussing their answers with each other, before beginning the actual monitoring. If staffing allows, have two investigators give area cover estimates for each plot, then average their estimates to get the recorded area cover for that plot.

******** *FIELD TIP* ********

A clear or semi-opaque, stiff, plastic sheet (report folder covers work well) cut into a square representing 5% of a square meter (0.05 m^2, 22.36 cm x 22.36 cm) is helpful for estimating area cover (Figure 11). A good rule of thumb for smaller patches is one closed fist = approximately .01m^2.

Figure 11. A transparent or semi-transparent square measuring 22.36 cm x 22.36 cm (representing 5% of a square meter or 0.05 m^2) can be helpful when estimating area cover.

6. If the patch is longer than 1 m^2, flip the plot frame upward along the transect so that what was the top edge of the frame now becomes the bottom edge of the new plot. Repeat as necessary in dense patches.
7. Add the area cover of all patches in a transect together to get the total area cover for each transect. Add transects together to get the total area cover for the population.

***Additional sampling guidelines*:**

- Recommended sampling quadrat/transect width range: 1-2 meters. Two-meter-side transects might be desirable if distribution is very patchy and you want to decrease the variability between transects. If two meter-wide transects are used, position 100-meter-tape in the middle of the transect, and estimate cover for the one-meter-wide transect on each side separately, then add the two one-meter-wide transect estimates together for a total area cover for the two-meter-wide transect.
- Count only foliage located within transect. In the case of Kincaid's lupine, where area of foliar cover is the measure of abundance, we are not concerned with whether or not a plant is rooted within the transect, or if greater than 50% of the foliage is within the transect.

Timing estimate:

Table 14 provides estimates of the amount of time it takes to monitor different types of populations of Kincaid's lupine using the methods described. These are rough estimates, provided to assist with the development of monitoring plans.

Table 14. Examples of time needed to monitor Kincaid's lupine populations.

Population name	Camp Adair	Lupine Meadows	McDonald Forest (OSU portion)
Population size (m^2)	~80 (in 8 patches)	~151	38
Acres of occupied habitat	~10	4.2	1.72
Monitoring method	Census	Sample	Sample
Number of investigators	3	3	2
Total person-hours	**23**	**21**	**26**
Notes	Familiar with site, corners of patches marked with t-posts (easy to locate)	Familiar with site. 3 hours to survey/flag and set up macroplot. It took 3 people ~13 min to set-up and estimate cover in a 144-meter-long transect.	Not familiar with site. High variance between transects required larger sample size.

6.9.3 Nelson's checkermallow

This section provides specific recommendations for Nelson's checkermallow. General monitoring recommendations that apply to all four target species are discussed in Sections 6.1-6.8. A summary of species-specific monitoring recommendations can be found in Table 17 in Section 6.9.5.

When to monitor:

- Difficult to differentiate Nelson's checkermallow from several more commonly occurring look-alike checkermallow species. Surveys for this species should be conducted when it is in bloom, typically mid-June through mid-July.

What to count:

- At a minimum: All (reproductive, vegetative and seedling) individuals (if distinct) or area of foliar cover in m^2 (if individuals are not, for the most part, distinct). In some cases, Nelson's checkermallow can form dense mats that cover an area larger than

what would traditionally be thought of as an individual plant (Figure 12). In these cases, measuring area of foliar cover is recommended..

Figure 12. Nelson's checkermallow plants at Barney Reservoir, where plants form large vegetative mats and it is difficult to separate out individuals. In cases like this, measuring area of foliar cover (m^2) is recommended.

- If time: see recommendations in Section 7.3 for collection of demographic data.
- Individual is defined as clump of leaves and/or stems separated from other clumps by at least 30 cm. For large plants situated fairly closely together, trace the curve of the stems back to the ground and assess the distance between two clumps where the stems emerge from the ground. See Section 5.7.3 for a discussion about defining an individual.
- Seedling defined as 1-2 leaved distinct individual with leaves < 2.5 cm in diameter.
- If monitoring a population that has both individual plants and large mats of coverage, count each area using the method most appropriate for that area. If a single number is desired for the population size, convert the area of cover to individuals using the formula 1 m^2 of cover = 2 individuals. This conversion is taken from the Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington

(USFWS 2010). Although the conversion does not provide a precise count, it does provide a consistent way of measuring these challenging populations.

- See Appendix H for pictures of Nelson's checkermallow, and Appendix I for a key to the four Willamette Valley checkermallow species.

Additional censusing guidelines:

- Because individuals of this species can be difficult to locate (especially if vegetative and located in taller grass), dividing the population into transects (5-10 meter-wide transects often works well) or subsections to facilitate counting is recommended for Nelson's checkermallow (Figure 13).

Figure 13. Oregon Department of Agriculture and Institute for Applied Ecology botanists searching transects for Nelson's checkermallow individuals. The pink flowered reproductive plants are easy to locate, even in the high grass, but vegetative individuals are more difficult to find. Tapes are leap-frogged over each other across the field to ensure that the entire area is searched.

***Additional sampling guidelines*:**

- Recommended sampling quadrat/transect width range: 1-2 meters. When Nelson's checkermallow is densely distributed, it is difficult to keep track of what has/has not been counted if the transect is wider than two meters.
- Count plant within transect if it is rooted more than halfway in the transect.

Time estimates:

Table 15 provides estimates of the amount of time it takes to monitor different types of populations of Nelson's checkermallow using the methods described. These are rough estimates, provided to assist with the development of monitoring plans.

Table 15. Examples of time needed to monitor Nelson's checkermallow populations.

Population name	Dooghe	Aleutian Prairie (Finley)	Fort Hill	Walker Flat
Population size (# individuals)	25,062 (+/-7851)	1283	107,339 (+/- 13,579)	4359 (+/-964) +40.8 m^2
Acres of occupied habitat	5.12 acres	1.67 acres	30.15 acres	1.52 acres
Monitoring method	Sample	Census	Sample	Census and Sample
Number of investigators	4	5	4	6
Total person-hours	**25.5**	**6.5**	**46**	**43**
Notes	Introduced population. Familiar with site.	Introduced population. Familiar with site.	Introduced population. Not familiar with site.	Natural population. Some areas very dense. Familiar with site.

6.9.4 Willamette daisy

This section is intended to provide specific recommendations for monitoring Willamette daisy. General monitoring recommendations that apply to all four target species are discussed in Sections 6.1-6.8. A summary of species-specific monitoring recommendations can be found in Table 17 in Section 6.9.5.

When to monitor:

- Because vegetative plants are often very difficult to find, we recommend monitoring Willamette daisy when it is in flower, typically June through mid-July.

What to count:

- At a minimum: Flowering individuals + presence/absence of seedlings. Because vegetative plants are often less common and quite difficult to find, we recommend counting them when found, but not spending a large amount of extra time searching for them. However, because having populations exhibiting recruitment is one of the criteria for recovery, any seedlings found should be noted as well. See Appendix J for pictures of vegetative and reproductive individuals.
- If more time: # of capitula (flowering heads)/plant and size of plant (see Section 7.4 for information on collecting demographic data for Willamette daisy). This gives an idea of the size/robustness and reproductive output of the individuals in a population.
- An individual is defined as being separated by 7 cm or more (see Section 5.7.4 for discussion about defining the individual).
- See Appendix J for pictures of Willamette daisy.

***Additional censusing guidelines*:**

- Because individuals of this species are often difficult to locate (especially if located in taller grass), dividing the population into transects or subsections to facilitate counting is recommended for Willamette daisy.

***Additional sampling guidelines*:**

- Most known Willamette daisy populations are not large enough to warrant sampling.
- Recommended sampling quadrat/transect width: two meters. This width allows those monitoring to easily see the plants and maximizes the ground sampled, but only requires one tape/transect, making installation easier and faster.
- Count plant within a transect 50% or more of the foliage is located within the transect.

Time estimates:

Table 16 provides estimates of the amount of time it takes to monitor different types of populations of Willamette daisy using the methods described. These are rough estimates, provided to assist with the development of monitoring plans.

Table 16. Examples of time needed to monitor Willamette daisy populations.

Population name	**Highway 126 (ODOT)***	**Highway 126 (ODOT)***	**Speedway (north side)**
Population size (# individuals)	418	418	165
Acres of occupied habitat	~0.64	~0.64	~6.9
Monitoring method	Census*	Sample	Census
Number of investigators	3	3	3
Total person-hours	**5**	**10.5**	**13.5**
Notes	Unfamiliar with site.	High variance between transects required large sample size.	Unfamiliar with site.

*In order to compare methodologies, we both censused and sampled the Highway 126 population. It took twice as long to sample the population, highlighting the argument for using the census methodology whenever feasible – often it results in better data in less time!

6.9.5 Summary of species-specific monitoring protocols

Table 17. Summary of recommended target species monitoring protocols.

Species	Monitoring time period	What to count (minimum)	What to count in addition if have time/resources (i.e. demographic data)	What is an individual?	What is a seedling?	Monitoring recommendations
Bradshaw's lomatium	Mid-April – May (when flowering)	Individual non-seedling plants (reproductive and vegetative) + presence/absence of seedlings	6 life stages: seedling, vegetative plant 1-2 leaves (V1-2), vegetative plant 3+ leaves (V3), reproductive plant with 1 umbel (R1), reproductive plant with 2 umbels (R2), reproductive plant with 3+ leaves (R3)	Individuals separated by 4 cm or more	Usually single leaf, cotyledons present at base (see Appendix F)	Census: use transects to partition area Sample: 25 cm wide sampling quadrats
Kincaid's lupine	May – mid-July (when flowering)	Area of foliar cover (m^2) + presence/absence of seedlings	# of inflorescences # leaves/m^2 (if FBB-occupied)*	n/a (measuring area cover, not # of individuals)	Usually 1-2 small leaves (see Appendix G)	Census: use one-meter-wide transects to census Sample: 1-2 meter wide sampling quadrats (might have to measure 2 meter quadrats 1 meter at a time).

Table 14, continued. Summary of recommended target species monitoring protocols.

Species	Monitoring time period	What to count (minimum)	What to count in addition if have time/resources (i.e. demographic data)	What is an individual?	What is a seedling?	Monitoring recommendations
Nelson's checkermallow	Mid-June – mid-July (when flowering)	Individual plants (reproductive, vegetative, seedling) or area of foliar cover (m^2) + presence/absence of seedlings	Area cover of plant** + # of inflorescences	Clumps separated by 30 cm or more unless both pistillate and perfect flowers present	Usually 1-2 leaves, each < 2.5 cm diameter (see Appendix H)	Census: 5-10 meter wide transects. Sample: 1-2 meter wide quadrats. Count plant in if more than ½ in the quadrat.
Willamette daisy	June – mid-July (when flowering)	Flowering plants + presence/absence of seedlings	Area cover of plant** + # flowering heads (capitula)	Individuals separated by 7 cm or more.	Unable to locate seedlings for this study	Census: use transects to facilitate locating plants Sample: 2 meter wide transects, count plants if more than ½ located in transect

*Fender's blue butterfly monitoring requires measuring number of leaves. Kaye and Benfield (2005) documented the correlation between number of leaves and area of foliar cover; however, the correlation varies from site to site, and it is recommended to develop a site-specific #leaves/m^2 conversion for each site when possible.

** To calculate area cover of Willamette daisy individual, measure plant at the widest point across, then measure the perpendicular width. Assume plant is an oval, and calculate are with the following formula: (0.5*widest)*(0.5*perpendicular)*∏ (from Giles-Johnson 2012).

7. Demographic monitoring

Demographic studies deal with the measurement of individuals: their birth, growth, reproductive output, and death (Elzinga et al.1998). They are helpful to gain a better insight into what is happening within a specific population, and for projecting what will happen to that population. Studies can be fairly simple (i.e. measuring the number of flowers/individual in a population and how that changes over time) or very complex (involving the study of transitions between multiple size or age classes).

Elzinga et al. (1998) discuss three types of demographic approaches: Population modeling and viability analysis, single age/state class investigations, and demographic structure. A brief description of each follows.

1. Population modeling and viability analysis (PVA): Tracks individual plants in a population, recording their fates in all stages of the species' life cycle, and using the data to construct a model for projecting population trends in the future.
2. Single age or stage class investigations: Focuses on one to several stages, often used to measure population "vigor" over time, especially for longer-lived species where number of individuals does not change greatly from year to year.
3. Demographic structure: Measures distribution of individuals in age or stage classes at a point in time.

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Demographic monitoring is very labor intensive (and therefore expensive). Although the information gathered can be very useful for estimating minimum viable population sizes and long-term prospects for populations, most land managers simply do not have the resources to be able to conduct demographic monitoring studies. Because of this, and the fact that the level of data collected in a demographic study is, for the most part, not needed to track population sizes and trends for the purpose of assessing progress towards recovery goals (the focus of these recommendations), we will not go into great detail about demographic monitoring in this report. However, this section does provide information on possible ways to collect demographic data for the four target species.

7.1 Bradshaw's lomatium

Bradshaw's lomatium demography has been studied extensively (Kaye et al. 1994, Caswell and Kaye 1996, Caswell and Kaye 2001. In general, the following size/age classes are recommended for demography studies involving this species:

1. Seeds/Seed bank (often not included)
2. Seedling
3. Vegetative plants with 1-2 leaves (V1-2)
4. Vegetative plants with 3 or more leaves (V3)
5. Reproductive plants with 1 umbel (R1)
6. Reproductive plants with 2 umbels (R2)
7. Reproductive plants with 3 or more umbels (R3)

7.2 Kincaid's lupine

Kincaid's lupine presents some challenges when it comes to demographic monitoring, due to the difficulty in determining what an "individual" is. Because of this, the recommended standard for measuring abundance of this species is area of foliar cover in square meters. For additional information about the reproductive vigor of the population, the number of inflorescences/m^2 can also be counted.

A study involving another federally-listed rhizomatous lupine species (*Lupinus tidestromii*) used the following classes when conducting a demography study: seeds that germinate after one year (seed bank 1), seeds that germinate after 2 years (seed bank 2), seedlings, vegetative plants, and reproductive plants (Dangremond et al. 2010). However, although *L. tidestromii* is rhizomatous, there was no discussion of having difficulty differentiating individuals, and a lot of discussion about seeds, the seed bank, and seedlings, which makes this methodology less useful for a more clonally reproducing species such as Kincaid's lupine. Silverton et al. (1993) looked at 66 published demography studies involving plant species with a variety of life histories, including clonal reproduction. They included clonal growth as one of the transitional elements in the matrices, but did not discuss individual species size or age

classes. They did, however, find a correlation between the elasticity[1] of clonal growth and the elasticity of fecundity in the demography of ramets (individuals arising from asexual reproduction, genetically identical individuals), and validated the approach of using ramet dynamics as an indirect measure of genet (individuals arising from sexual reproduction, genetically distinct individuals) fitness.

After reviewing literature and spending considerable time in the field documenting Kincaid's lupine abundance, we offer the following suggestions for those interested in pursuing demographic studies of Kincaid's lupine:

- Treat square meter plots as "individuals" and either look in the measures of area cover and/or number of inflorescences per plot, or
- Create the slightly artificial categories of seedling, vegetative and reproductive "individuals" for each square meter plot, or
- Do not use square meter plots at all, and go back to measuring clump/patch size and number of inflorescences per clump/patch (first determining the standard distance between clumps/patches to be used to separate two or more clumps/patches) and either assign patch size categories (starting with seedling, vegetative clump/patch, and reproductive clump/patch) or look at overall patch clonal growth

7.3 Nelson's checkermallow

There are three age/size classes recommended for demographic studies involving Nelson's checkermallow:

1. Seedling
2. Vegetative
3. Reproductive

In addition, number of inflorescences and area cover of an individual can also be recorded. To calculate the area cover of an individual, follow recommendations for Willamette daisy in

[1] Elasticity: proportional change in finite rate of increase (λ) resulting from proportional changes in individual demographic parameters (matrix elements) (Silverton 1996, Menges 2000).

Section 7.4 (from Giles-Johnson 2012). In populations/patches of Nelson's checkermallow where it is difficult to differentiate individuals, the same issues encountered with Kincaid's lupine demographic studies exist. See Section 7.2 above for ideas about how to handle this.

7.4 Willamette daisy

There are three age/size classes recommended for demographic studies involving Willamette daisy:

1. Seedling
2. Vegetative
3. Reproductive

In addition, number of capitula (flowering heads) and area cover of an individual can also be recorded. To calculate area cover of Willamette daisy individual, measure plant at the widest point across, then measure the perpendicular width. Assume plant is an oval, and calculate with the following formula: (0.5 x widest) x (0.5 x perpendicular) x π (from Giles-Johnson 2012).

8. Conclusion

There are many approaches to surveying and monitoring rare plants. This report is not meant to be an exhaustive summary of how to go about conducting rare plant surveys and monitoring efforts. Rather, it is an attempt to encourage land managers and other investigators to consistently collect data about the four Willamette Valley prairie species and their populations in such a way that 1) information can be compared between sites and years, and 2) USFWS and other partners can assess progress towards recovery, given the recovery goals outlined in the Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (USFWS 2010).

In order for these two goals to be achieved, it is critical that all investigators:

1. Use the same definition of an individual for each species

2. Count the same types or categories of individuals for a total population count (and if more categories are used, they are able to be collapsed into the recommended categories – i.e. several classes of vegetative Bradshaw's lomatium plants may all be combined into "vegetative")
3. Thoroughly document and report monitoring methodology, so that it is clear exactly what was counted and how it was counted
4. Provide USFWS with copies of monitoring data and/or reports

As partners and regulators work together to ensure monitoring is conducted following the recommendations laid out in this report, we will be taking a huge step forward in our ability to document the recovery work that has been done, and we will be that much closer to achieving the recovery of Bradshaw's lomatium, Kincaid's lupine, Nelson's checkermallow and Willamette daisy.

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Appendices

Appendix A: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Alverson, Ed (TNC), personal communication	Willow Creek	Monitoring to detect change in population and to assess effects of management	Individual plants (individual separated by at least 2 finger widths) + # flowering stalks	Annually (since 1993)	Sample	• Permanent 50m x 100m macroplots covering ~75% of population • Permanent belt transects (originally picked stratified random sampling, one transect in each 10 m segment • Transect size depends on density: most dense 25m x 1/2m, less dense 50m x 1m • Monitoring takes~ 40 hours staff time • Use age classes: seedlings, vegetative (1-2 leaves), veg (3+ leaves), flowering (1 inflorescence), flowering (2 inflorescence)
Alverson, Ed (TNC), personal communication	Kingston Prairie	Monitoring to get estimate of population size	Flowering plants + sample of all indls. Plants >2 finger widths (1.5 in).	One time so far	Census (reproductive) + sample (vegetative)	• Mark boundary of population w/pinflags • Split into ~2.5m wide transects using measuring tapes/string. • Count all flowering plants (include plants w/buds or old flowers). • Get estimate ratio of flowering:veg by haphazardly choosing twelve 90 cm^2 plots and counting all plants, developing ratio.

Appendix A, continued: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Argentea Environmental 2000	Camas Meadows	Monitoring for treatment effects	Nested frequency (presence/ absence)	Every 5 years	Sample	• Established macroplot covering almost entire habitat. • Systematic grid for sampling, using 30 transects spaced 12m apart. Random starting point of grid changes each year. • 1997 sampled 281 quadrats • Frequency data gathered using nested quadrat design: 2m x 2m, 1 m x 1 m, 31.6 cm x 31.6 cm, 10 cm x 10 cm to determine which size results in absolute frequency of at least 50%.
Caswell and Kaye 2001		Monitoring for treatment effects	Individual plants (no definition of separation distance)	Annually (1988-1993)	Sample	• Circular 2m diameter plots surrounded randomly selected mature individuals, 10 plots/treatment. • Individuals classified in 6 stages based on size and reproductive status: yearlings (1st yr veg 1-2 leaves), veg plants with 1-2 leaves, veg plants with 3+ leaves, repro w/1 umbel, repro with 2 umbels, repro with 3+ umbels.

Appendix A, continued: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Currin and Meinke 2008	Multiple	Developing density estimates	Individual = stem from ground	One time	Sample	•Establ boundary of pop with pinflags • Created rectangular macroplot encompassing all/most of population • Estimated # plots could sample in time available (usually 3-4 people in one day)• Stratified random sampling: randomly selected starting point for systematic grid of 1m x 0.5m plots • Counted all plants w/in sample plots
Drew 2000	Oak Creek	Monitoring for effects of grazing	Individual plants (vegetative and reproductive)	Before/after grazing treatment (2 years)	Census and sample (depending on patch size/density)	• Established 6 10x40 meter blocks with 4 10x10m grazing plots each • Monitored plants along two 10m transects randomly located w/in ea plot • Five 20cm x50cm plots were monitored along each transect • Plants counted, measured for vegetative height (not counting umbel), # seeds produced, elliptical canopy area. • Plants classified six categories
Gisler 1994	Multiple	Estimate population size	Individuals (vegetative and reproductive)	Once	Census/sample	• Entire property surveyed on foot, along regularly spaced transects. • Population size determined using 2 methods, depending on density of plants in a given patch (78 patches) • When feasible, absolute numbers of plants counted directly. When patch size large/dense, # plants est using a random quadrat and grid techniques.

Appendix A, continued: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Jackson 1996	Fern Ridge	Estimate "neighborhood size and neighborhood area"	Individual plant (no definition)	Once	Sample	• Macroplot established where density representative of density in study area • Subdivided into $1m^2$ subplots • All plants inside subplots counted, classified as vegetative, flowering but producing little or no seed, and flowering/producing strong seed crop
Kagan 1980	Multiple	Estimate population size	Individual plants (no definition)	Once	Sample or census	• Counted # repro/veg plants, # mature fruits, # aborted fruits. • Sampled ~50-75% of larger populations. Censused smaller ones.
Kaye 1992	Buford Park	Demography	Individual plant		Sample	• Established 6 permanent transects through population. • Mapped and measured every plant within 20 x 50 cm plots spaced along transects at each meter • Transects subjectively placed to represent range of habitat. Didn't say length of transects.
Kaye et al. 2003	Multiple	Monitor introduction study results	Individual plants (with 7 life stages)		Census	
Kaye et al. 2009	Benton County HCP	Monitor	Individuals separated by at least 10 cm		Census	• Denser or larger populations divided into grid to facilitate counting • 30% drop in population size will trigger consultation w/ USFWS/ODA

Appendix A, continued: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Koenig and Perkins 2005, Taylor, Trevor (City of Eugene), personal communication	Amazon Park	Monitor to get estimate of population size	Frequency + Count flowering plants. Individual = 1 finger width apart (~2 cm). Categories: 1, 2, or 3+ flowering stems	Every 5 years	Sample	• 2 permanent baselines (S & N ends) • 93 randomly located 1/2 meter wide transects located perpendicular to and running north from south baseline. 105 transects for north baseline. Transects vary in length to accommodate irregularly shaped area. • All flowering plants counted in transect. • Several transects had plants south of baseline, which were included in total count for that transect, indicated with a negative sign for the meter. • In 2010 took 2 city staff 1.5 weeks
USFWS 1993	All	Recommendations for recovery	Doesn't define individual			•Recommends annual sampling for at least 3 years to establish baseline #s. • If population stable (doesn't define), go to monitoring every three years. • If active threats/management occurring, monitor every year.
USFWS 2008	All	Status review	Doesn't define individual			• Survey protocols currently used include: counting plants by doing a complete census, sampling a portion of the population, or making visual estimates of the number of plants at a site. This includes all forms of the plant with an estimate of the percentage of flowering plants vs. vegetative plants

Appendix A, continued: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Kaye and Pendergrass 1998, Kaye et al. 1994, Kaye et al. 2001, Pendergrass et al. 1999	Fisher Butte, Rose Prairie	Monitor effects of fire on population density and demography	Individual plants (7 age classes)	Annually	Sample	• Randomly selected individuals tagged, subset selected to serve as center points for circular plots. • 1 umbeled plants rarely set seed, usually only have male flowers
Kaye and Kirkland 1994	Buford Park, Finley, Jackson-Frazier	Demographic monitoring	Individual plants (in 7 age classes)		Census and sample	•Permanent monitoring plots, size and shape varied to fit populations. • Grazed plants with uneaten stump of repro stalk recorded as R-1 (1 umbel). • J-F: mapped plants in all m^2 subplots • Finley: 14 patches within macroplot, 5 patches randomly selected for monitoring, subplot centered around each of 5 patches. For two largest subplots, set up 1 transect in each with 20 x 50cm sub-plots each meter. • BP: macroplot encompassed almost all individuals. Flagging used to make temp grid with 0.5m x 5m subplots. Meter tape used to describe X,Y coordinate system. 40 (of 330) subplots randomly sampled
USFWS 2010	All	Recommendations for recovery	Doesn't define individual			• Subpopulations should be within pollinator flight distance (2 mi). • #/size of popns should be stable/increasing for at least 10 years. • For downlisting: 12 populations of 5,000 plants in 8 zones • For delisting: 20 populations

Appendix A, continued: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
USACOE 2009	Fern Ridge (multiple sites)	Population estimate	Doesn't define individual	Annually	Census and sample	• Permanent plots set up at each RNA sit, monitored annually. • Small populations censused • For sampled populations, aim for 70% chance of detecting 30% change with 10% false-change risk. • Perm plots placed to capture the core of LOBR plants at each sites. 50m x 100m, with a 50 x 0.5m quadrat randomly selected from each 10m length of long axis.
Villegas, Sally (BLM), personal communication	West Eugene Wetlands	Population size	Doesn't define individual	Annually	Census	• Macroplot encompassing populations established, divided into one-m^2 plots. • Counted total # plants, leaves, and flowering stalks

Appendix A, continued: Summary of monitoring practices for Bradshaw's lomatium

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Wilson et al. 1993.	Fern Ridge (multiple)		Doesn't define individual			• Recorded height (from ground to tallest leaf extension), widest diameter of leaf material (W1), widest axis of leaf material perpendicular to W1 (W2), # umbels, #umbellets, # developed fruits. • Derived elliptical crown cover area (A) using formula A=pie x W1 x W2/4. • For response to treatments: tagged plants, measured data before/after treatments. 2-m-radius macroplots established around randomly selected tagged plants to determine recruitment. Indl plants tallied as repro or non-repro. 5 macroplots/treatment/site.

Appendix B: Summary of monitoring practices for Kincaid's lupine

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Alverson, Ed (TNC), personal communication	Willow Creek	Monitor introductions	Individual plants	Annually	Census	
Alverson, Ed (TNC), personal communication	Multiple	Monitor natural populations	Presence/ absence			• Mostly documenting where occurs, rather than monitoring. Grid of 12m x 12m plots, presence/absence in each cell.
BLM 2008	Douglas County	Monitor to estimate change in population size	Foliar cover (m^2)	Annually	Census/Sample	• Monitoring to conform to standardized population monitoring protocol developed by Willamette Prairie Species Recovery Team. • Abundance measured by total amount of cover (square meters of ground area covered by the species).
Currin and Meinke 2008	Multiple	Density estimate	Foliar cover (m^2)	Once	Sample	• If population large and in discrete patches: selected subsample of patches to count • Created temporary macroplot encompassing patch/population, divided into m^2 subplots using meter tapes and plot frames • 2 investigators visually estimated foliar cover within all or a sample of subplots

Appendix B, continued: Summary of monitoring practices for Kincaid's lupine

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Giles-Johnson et al. 2009	Oak Basin	Monitor to estimate population size	Foliar cover (m^2)	Annually (2006-2009)	Census	• Surveyed entire area for lupine. • Established permanent plots around each patch. Large plots rectangular, small plots monitored in either circle or belt transects. • Within each plot, recorded cover and # of mature/aborted lupine inflorescences. Cover determined by measuring the approximate rectangular area occupied by a lupine. Cover highly correlated with number of leaves. • In 2007-2008 also counted # leaves in subsample of plots.
Gisler 2008	Mill Creek	Monitor population size estimate, effects of management	# leaves, m2 foliage cover	Biennially	Census	• Occupied lupine habitat subjectively partitioned into manageable sections using meter tapes or ribbon, and square feet/meter foliar lupine cover is visually estimated within each section and then summed for entire population. Cover estimates are made by two monitoring biologists independently to promote consistency between observers.

Appendix B, continued: Summary of monitoring practices for Kincaid's lupine

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Kaye 1999, Kaye 2000b, Kaye and Cramer 2002	Fir Butte, Oxbow West (West Eugene)	Monitor population size	Number of leaves + # inflorescences	Annually	Sample/Census	• Method depends on popn size • For sampling: macroplot w/18 20m x 100m subplots with 2m wide buffer on long sides and 4 m wide buffer on narrow sides, permanently marked with fenceposts. Within these plots, 2 subplots randomly sampled (transects 2 m wide, 100 m long). Subplots =15.7% sample of total 230 possible subplot locations. Run tape down middle, count 1 m on either side in 5 m segments. • For census: established permanent macroplot. Break down into 1 m2 cells, measured variables in cell.
Kaye et al. 2003	Multiple	Monitoring introduction sites	Area of foliar cover (m^2)	Annually	Census	• Lupine foliar cover correlates with lupine abundance. • Should be minimum of 3 year monitoring cycle after outplanting.
Kaye et al. 2009	Benton County (HCP)	Proposed monitoring (estimate population size + effects of management)	Area of foliar cover (m^2)			• Conduct baseline monitoring, then monitor a minimum of every three years. • If significant management occurs, monitoring should be conducted at higher frequency. • Drop in abundance of 30% or more triggers consultation with USFWS/ODA.

Appendix B, continued: Summary of monitoring practices for Kincaid's lupine

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Kuykendall and Kaye 1993	Multiple	Survey, study reproduction	Area of foliar cover (m^2) (estimate to the nearest quarter m^2 + # racemes			• Surveyed between 5/1-6/2/92. • 2000 acres, walking in systematic fashion over designated acreage. • Study: 8 sites. Popn abundance measured by estimating total vegetative cover to the nearest quarter square meter, and counting total # racemes. Some sites distinguished between racemes with mature fruits vs. not.
Mitchell 2001, Mitchell 2002	Camp Adair	Monitor population size, effects of weed treatments	Presence/absence in m^2 plots	Every 3 years	Census (of a sort)	• Seven patches • Established permanent plots, marked corners with rebar and took UTMs. Plots larger than patches to allow for expansion. • Photographed from NW corner. • Determined # square m occupied by lupines and their reproductive (flowering, veg, both) state. (Used baseline tapes, measuring tapes, square meter plot frames. Total occupied square meters recorded. • Takes ~ four 8-hour days
ORBIC 2012	All	Estimate population size	Plants, clumps, flowering stalks, area occupied			• Data not comparable at all. • No definitions of units
Schultz 2001	Willow Creek, Royal	Monitor introduction, soil prep effects	Leaves counted on all plants			• Split-plot within randomized complete block design, each block had 5 soil preparations.

Appendix B, continued: Summary of monitoring practices for Kincaid's lupine

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Severns 2003	Multiple (6 in West Eugene)	Study link between population size an seed set	# racemes, raceme density, # lupine patches	Once?	Monitor	• Randomly selected 30 racemes each from 6 colonies to estimate maternal output. • Raceme density and # racemes were estimated by sampling 4-6 1x10m transects randomly placed across patches. • Lupine patch #, defined by a gap of at least 10 m between ramets, directly counted for each colony.
Thorpe and Kaye 2007b, Thorpe and Kaye 2008	Multiple (West Eugene Wetlands)	Monitor population size	Area of foliar cover (m^2)	Annually	Sample	• Plot setup from Kaye 1999 • Switched to foliar cover, # mature/aborted inflorescences. • Cover estimated by measuring the ~ rectangular area occupied by a clump of lupine. • Estimating foliar cover acceptable alternative to counting leaves when combined with flower stem counts, especially if objective is to measure trends in lupine abundance. Lupine leaf density positively correlated with foliar cover. Relationship is strongest in habitats with full sun. Regional differences make direct comparisons of lupine cover across sites unreliable in some cases (leaf density varies with the amount of sunlight reaching the habitat).

Appendix B, continued: Summary of monitoring practices for Kincaid's lupine

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Menke and Kaye 2005, Thorpe and Kaye 2008	Douglas County (6 sites)	Monitor population size	Area of foliar cover (m^2) + # racemes		Census (4 sites) + sample (2 sites)	• Measured length and width of each patch, used values to determine rectangular area. • Depending on configuration of site: established permanent transect or grid, divided into manageable segments • For sampling, established 3 subplots encompassing bulk of population (on public land). Subdivided plots to facilitate censusing within plot.
Thorpe et al. 2009	Eagle's Rest	Monitor population size, response to management and impacts of threats	# leaves (2003-2006), area of foliar cover m^2 (2004-2007), # inflorescences	Annually	Census	• Five permanent rectangular monitoring plots established in 2003 to include almost entire population. • Determined abundance and counted @ of mature/aborted inflorescences and FBB eggs. • Estimated foliar cover for each patch by visually manipulating into a rectangular shape, recorded length and width. Cover highly correlated with leaf number.
USFWS 2010	All	Estimate population size	Area of foliar cover (m^2)		Monitor	• Delisting goals: 20 populations in 9 recovery zones • Population = 2500 m^2 cover • Stable or increasing for 15 years

Appendix B, continued: Summary of monitoring practices for Kincaid's lupine

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Wilson and Clark 1997	Baskett Slough		Area of foliar cover (m^2)			• Replicated before-after-control-intervention design w/5 blocks. • Collected pre/post-treatment data on cover, post-manipulation data on height and number of inflorescences. • Divided each block into 4 cells, estimating cover for each cell. For estimating cover of other vegetation, 2 investigators reached a consensus value, using calibrated templates as standards.
Wilson et al. 2003	Multiple	Study of species biology	• Spatial extent, cover, leaf number, and leaf area should be evaluated			• Difficult to recognize, enumerate individuals due to spread from belowground vegetative parts. Indirect measures of abundance, like # inflorescences are unreliable. •Recommend evaluating different measurements for their efficiency and sensitivity to annual variation in weather and management actions

Appendix C: Summary of monitoring practices for Nelson's checkermallow

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Amsberry and Meinke 2005	Bonesteele	Monitor introduction	Individual plants	Annually	Census	Transplants monitored for survival, vegetative growth and reproduction during growing season.
Bartels 2000	Finley	Monitor effects of treatments	# plants, size (cover), # flowering stalks, # inflorescences, type of inflorescence (pistillate or perfect), height of tallest flowering stalk.	Pre/post treatment	Sample	112 permanent SINE-centered quadrats. SINE individuals tagged, 30 (~10%) repro plants sampled in each of three tmt strata, 0.5 m^2 quadrat centered on each indl. • Size measured as area cover, estimated by consensus of two investigators using calibration templates. • # Inflorescences = raceme branching off main flowering stalk
Center for Plant Conservation 2008	n/a	n/a	Important to count genets rather than ramets	n/a	n/a	
CH2M Hill 1986	Multiple	Species status	Plants, separated by at least 0.5m between 2 basal clumps, unless plants clearly distinct.	once	Census	• For one population: used 1 m^2 = 1 plant
CH2M Hill 1994	Barney Reservoir	Population size estimate + transplant survival	Plants (not defined), # leaves, height of foliage/flower, vigor	Annually for five years after transplanting	Census	• Annual photographs of grids taken from fixed spots

Appendix C, continued: Summary of monitoring practices for Nelson's checkermallow

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
CH2M Hill 1997	Multiple	Species status	All stems & leaves within 0.56m radius of circular plot considered indl, unless pistillate/ perfect flowers both present (then 2 plants)	Once	Sample	• All popns within proposed Recovery Zones 4 & 5 visited. • Plants counted at only 3 sites: Lewis Co, WA; Baskett Slough NWR, Meyer Rd. • Field personnel traversed site in parallel lines ~ 2m apart, counted all observed plants. • Random, stratified sampling approach used to estimate popn size at Walker Flat. Baselines laid out in grids as close to original baselines as could be approximated. Data from BLM portion separate from MWL portion. Sampling intensity slightly > 2% of total area encompassing the sample grids.
Currin and Meinke 2008	Multiple	Develop population density estimates	Plants, separated by at least 30 cm/12" (unless pistillate/perfect flowers present)	Once	Census or sample	• For census: pinflag all plants, go back and count. • For sample: survey population, establish perimeter, run baseline tape along one side, perpendicular transects (~10% area covered).
Jock Beal, USFWS, personal communication	Finley	Population size estimate + monitor introductions	Plants, separated by at least 30 cm/12" (unless pistillate/perfect flowers present)	Annually	Census	

Appendix C, continued: Summary of monitoring practices for Nelson's checkermallow

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Gisler 2003	Multiple	Reproduction/ hybridization study	Individuals (not defined), floral development	Once	n/a	• Floral development: recorded % of inflorescences with open flowers in each 2-week period
Gisler and Meinke 1998	Multiple	Levels of seed predation, population size	Individual = spatially distinct group of leaves and/or stems		Census (all but 2 of 16 popns)	• Salem airport and Walker Flat populations: used previously acquired population size estimates
Gisler and Meinke 1995	Multiple (48)	Species status review, population size	Individual = group of stems originating from its own basal cluster of leaves.	Once	Census	• 3-5 indls surveyed on foot, absolute counts of indl plants (ramets). • Closely spaced plants counted as separate plants to avoid underestimation of population size
Glad et al. 1994	Multiple	Survey	Plant=contained in 1 m diam circle, unless both types of flowers present			• Potential sites ID'd from aerial photos, searched by at least 2 indls walking parallel paths 2-5 m apart • Plant counts only done at new sites & sites w/disturbance since previous count. • At Walker Flat/Tillamook Burn: random stratified sampling of 1 m^2 quadrats included 1-3% of total quadrats. Frequency of SINE determined as a % of quadrats with at least one stem. Multi-stemmed plants within quadrat assumed to be 1 plant (unless diff sexes) • Ratios of pistillate to perfect flowers calculated.

Appendix C, continued: Summary of monitoring practices for Nelson's checkermallow

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Guerrant 2007 Guerrant 1998	Walker Flat/BLM	Estimate population size, change	Presence/absence of 3 categories: vegetative, flowering with pistillate flowers, flowering with perfect flowers or both in 1 m^2 quadrats	Varies	Sample	• Established permanent baseline, regular grid covering entire popn • Pilot study to establish quadrat and sample sizes. • Starting point chosen randomly ea year. Plot size = 1 m2. • Some plants recorded as just reproductive, couldn't determine type of flower because either in bud, past flowering, or eaten. • 2 pp searched ea quadrat
Halford 1994	California	Effects of vegetation removal treatments	Plant (both seedlings and mature plants)	Pre/post treatment	Sample	• Monitoring *Sidalcea covillei* • Established 4 permanent 15 m transects and 3 1.5 m plots/transect (12 plots total). • Plants counted in each plot using 1.5 x 1.5 m grid frame.
Kaye et al. 2009	Benton County	Estimate population size	Individual plant, plants are at least 30 cm (11.8") apart		Census	• Absence surveys April-July • Presence surveys must be conducted during the blooming period, mid-June through mid-July • Species abundance censused by counting individuals. When necessary, sites divided with a grid, marked with permanent or GPS markers as needed. • >=30% drop will trigger consultations with ODA/USFWS.

Appendix C, continued: Summary of monitoring practices for Nelson's checkermallow

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Mitchell 2001, Oregon Military Department 2007	Camp Adair		# stems (1999), occupied square meters (2001, 2007)	Every 3 years	Census (of a sort)	• Established 6 permanent plots • Photograph plots from NW corner • Determined # m^2 occupied + repro status (flowering, veg, both) • Made note whether repro plants were perfect or pistillate • Took about six person days to collect data for LUSUKI + SINE
Morré 2002	Marion County	Seed production proposal, estimating population size	# plants (no def given) or # flowering/ not flowering stems			
ODOT 2007	ODOT Right-of-ways	Estimate population size	Plants (not defined), phenology (bud/flower/fruit), age/size class	Biennially	Census	• Also gave population trend (stable, up, down, undetermined) • Age/size classes: seedlings, immature, 1st year, mature, senescent
USFWS 1998	All	Monitoring recommendations to determine size/stability of population	Doesn't say	Doesn't say	Doesn't say	• Monitoring should be sensitive enough to detect a 10% drop in frequency (although has 30% or 22% drop as trigger for change in management) • Should have demographic monitoring for selected popns in three areas (Coast, WV, Puget Trough) conducted annually to provide info on growth/decline, age structure to assess sustainability and project long-term trends.

Appendix C, continued: Summary of monitoring practices for Nelson's checkermallow

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
USFWS 2010	All	Monitoring to assess progress towards recovery	Area of foliar cover + # plants (doesn't define a plant)			• Need standardized monitoring protocol, or at least standardized set of features to be monitored to evaluate status of extant populations (currently data recorded are varied)
Zimmerman and Reichard (No date)	*Sidalcea oregana* var. *calva*	Study on pollination, seed predation, fire	% cover, # individuals (no definition), length of longest repro stem, # flowers/ fruits, length and width of 3rd leaf up from ground			• Seed predation: Randomly chose 10 plants from each site (from all indls with mature fruit). • Fire: Established 8 $2m^2$ plots along either side of 37 m transect.

Appendix D: Summary of monitoring practices for Willamette daisy

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Clark et al. 1993	Multiple (18)	Species status review	Flowering clumps or plants	n/a	Quantitative: census	• Did not count vegetative plants (inconspicuous) • Did not define what a plant was
Clark et al. 1995, Clark 2000, Finley 1998, Finley and Ingersoll 1995	Fisher Butte, Baskett Butte	Demographic analysis	Plants (defined as a basal clump at least 5 cm from nearest neighbor)		Demography	• Installed 1/2 m^2 permanent marked quadrats, located to include at least one randomly selected individual in each quadrat and to "represent the range of *Erigeron* densities across the site." • Flowering stems almost 1:1 with flowering heads, just counted flowering heads plus longest + perpendicular basal dimension
Currin and Meinke 2008	Multiple	Develop density estimates	Reproductive individuals (separated from neighbor by at least 6 cm)		Census or Sample	• Difficult to see/identify vegetative plants/seedlings • Sampled
Ed Alverson, The Nature Conservancy (personal communication)	Willow Creek	Detect change in response to management	All individuals (separated by at least 2 finger widths, ~1.5 inches, ~3-4 cm)	Annually	Sample	• ~75% population encompassed in permanent 50m x 100m macroplots. • Permanent transects (.5 – 1 m wide, 25-50 m long) established every 10 meters (stratified random sampling) • Count all indls, separate into veg classes (seedling, 1-2 lf veg, 3+ lf veg, flowering-1 infl, flowering-2 infl • 90% sure detecting 20% change

Appendix D, continued: Summary of monitoring practices for Willamette daisy

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Ed Alverson, The Nature Conservancy (personal communication)	Kingston Prairie	Estimate population size	Flowering individuals + sample of vegetative indls (indl > 2 finger widths)	One time	Census (flowering) + sample (vegetative)	• Mark population boundaries with pinflags, divide into 2.5 m strips • Count all flowering plants • Haphazardly select twelve 90 cm plots, count all plants to get veg: flowering ratio • Extrapolate for population count
Finley and Kauffman 1992	Fisher Butte	Monitor recruitment				• Established 55 permanent plots • Measured plant height, crown area, # flowers, percent mortality
Giles-Johnson 2012	FinleyNWR and Fern Ridge	Monitor effects of treatments	Size (area and height) and # capitula	2 times	Demography	•Measure plant at widest point, take width perpendicular to that, calculate area of oval using: (0.5*widest)*(0.5*perpendicular)*∏
Gisler and Kaye 2004, Thorpe and Kaye 2007a	Oxbow West	Monitoring for effect of mowing	Individuals (separated by at least 7 cm)			• Established macroplot encompassing most of population. • Twenty permanent subplots established within macroplot, randomly assigned treatments. • 1 m buffer noted with each plot. • 6 plots sub-sampled along transects (two 1x40m), rest censused and all plants measured. • Monitoring takes 6-7 days of field work with help of 4-5 people. • Calculated proportional changes in plant size and abundance variables before mowing and 2 years after mowing. • Compared using t-tests.

Appendix D, continued: Detailed summary of current monitoring practices for Willamette daisy

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Ingersoll et al. 1993	Fisher Butte NRA, Bald Hill, Baskett Butte	All individuals (difficult to distinguish)		Demography		• Density estimated • Approx boundaries of populations delineated • Permanent macroplots at 3 sites encompassing somewhat homogeneous vegetation and *Erigeron* density selected to represent the range of densities on the site • For each plot, # *Erigeron* indls estimated, then indl clumps selected at random. • A 1 m x 0.5 m permanent quadrat established around clump. • Censused Erigeron in each quadrat using PVC quadrat frame with 25 cm wire grid. • Measured longest basal dimension, basal dimension 90 deg from first dimension, stem height (to tallest head or leaf with stem stretched out), # flowering stems, # flowering heads, # flower buds, # damaged heads (grazed or aborted).
Kagan and Yamamoto 1987	Many	Status report	Individual = clump (not defined)		Varies	• Sampling difficult when plant scattered over large areas

Appendix D, continued: Summary of monitoring practices for Willamette daisy

Land Manager/ Information source	Population	Purpose	What was counted	Frequency	Type of monitoring	Methodology notes
Kaye 1999, Kaye 2000a	Oxbow West	Monitoring for treatment effects	Individual separated by at least 7 cm.		Sample	• Established macroplot containing twenty subplots selected to capture the greatest number of plants. • Count all plants in sampled subplots
Kaye and Brandt 2005, Kaye et al. 2003		Monitoring introduction results	Plants (no definition)		Census	• Transplant monitoring: measurement data (maximum and perpendicular widths, height) and # inflorescences/plant.
Kaye et al. 2006.	Multiple	Minimum population size for reproduction	Individuals (not defined), their area of foliar cover, height, # flowers	Once	Sample	
Kaye et al. 2009	All Benton County sites (part of HCP)	Population estimates, detect change to trigger consultation	Plant (separated by at least 10 cm)	Surveys should be conducted during bloom time (June1-July15)	Census	When necessary, sites divided with a grid, marked with permanent or GPS markers as needed. >=30% drop will trigger consultations with ODA/USFWS.
Sally Villegas, personal communication	West Eugene Wetlands	Population estimate	Plant (separated by at least 3.5 cm)		Census	Macroplot delineated around entire populations, then divided into 1m2 plots. All plots are counted. Total # crowns (>3.5 cm apart) counted. Also counted flowers, reproductive crowns.
USFWS 2010	All (Prairie Recovery Plan)	Population estimate	Plant (separated by 7 cm or more)			

Appendix E: Sample rare plant survey data sheet

Pre-survey Checklist

☐ Develop list of rare plant species potentially occurring in project area (scientific name, habitat, appropriate survey time)

☐ Study species descriptions, key characteristics for ID, herbarium specimens (if not familiar with species)

☐ Get maps and/or aerial photos of survey area (area directly or indirectly impacted by project)

☐ Create field schedule

☐ Obtain state/federal permits if planning on collecting voucher specimens

☐ Obtain written permission from landowner/manager before conducting surveys on their lands

☐ Conduct habitat reconnaissance at site to determine extent of potential habitat in project area (if unable to determine through study of aerial photos, etc.)

☐ Visit reference population(s) for target species to confirm phenology (i.e. species in bloom) and to develop site image for species and habitat

☐ Select survey method appropriate for site and survey goals

Survey Equipment Checklist

☐ Aerial photos/maps outlining survey area and showing any known populations of target species

☐ GPS unit + extra batteries

☐ Camera + extra memory card/battery

☐ Write-in-rain notebook + pencils (extra pencils/lead)

☐ Plant key/information regarding key characteristics of target species

☐ Pinflags or flagging (to mark target plants if found)

☐ Copies of permits/access permission letters (if applicable)

☐ Meter^2 plot frame (to sample new population if needed, helpful if have a plot frame that collapses)

Appendix E, continued: Sample rare plant survey data sheet

Rare Plant Survey Data Sheet

Survey Location/Project Name: _____

Directions to site/Location information (tax lot, GPS, etc.): _____
_____
_____

Date(s) of surveys: _____ Total survey hours: _____

Name(s) of surveyor(s):_____

Site Species List:_____
_____
_____

Target species: _____

Target species present? ☐ Yes ☐ No

If yes, which target species present? _____
Target species present on adjacent lands? ☐ Yes ☐ No

Target species mapped with GPS? ☐ Yes ☐ No

GPS make/model: _____
Datum: ☐ NAD27 ☐ NAD83 ☐ Other_____
Coordinating system: ☐ UTM/Zone ☐ Latitude/Longitude

Estimated size of population: _____

Size determined by (circle one): Census Sample Visual Estimate

Estimated area of population: _____

Describe census/sampling methodology:_____
_____
_____
_____
_____

Appendix E, continued: Sample rare plant survey data sheet

Conditions which might have prevented surveyors from locating target species? _____
_____

Phenology of target species (%): Vegetative_____ In flower_____ In fruit_____

Seedlings of target species observed? ☐ Yes ☐ No

Voucher specimen obtained? ☐ Yes ☐ No Stored where? _____

Site photo(s) taken? ☐ Yes ☐ No

Habitat description: _____
_____

Slope/topographical position: _____
Elevation range:_____
Exposure: _____
Hydrology: _____
Soils: _____
Associated species/vascular plant list (scientific names, to taxonomic level needed to determine rarity): _____
_____
_____
_____
_____
_____
_____

Threats (invasive species, land management practices, disease, predation, encroachment, adjacent property land management, etc.) and their immediacy: _____
_____
_____

Current use/management: _____
_____

Additional notes: _____
_____
_____
_____

Appendix F: Bradshaw's lomatium pictures

Clockwise from top left: Bradshaw's lomatium diagnostic bracts, seedling, flowering plant, and vegetative plant.

Appendix G: Kincaid's lupine pictures

Kincaid's lupine flowers with ruffled, reflexed banner (left) and back of Kincaid's lupine leaf with gray pubescence (right).

Kincaid's lupine reproductive plant (left) and seedling (right).

Appendix H: Nelson's checkermallow pictures

Nelson's checkermallow (left) and its vegetative look-alike, meadow checkermallow (*Sidalcea campestris*, right), with flowers in bud. Typically, Nelson's checkermallow buds are dark pink-purple and more pointed, while those of meadow checkermallow are pale green – pale pink and more rounded.

Left: Nelson's checkermallow (dark pink) and meadow checkermallow (light pink) in flower. Right: Nelson's checkermallow seedling.

Appendix I: Willamette Valley Sidalcea *key*

(Adapted from Halse et al. 1989 and Pendergrass and Gisler 2010)

1a. Petals white to pale pink; simple basal stem hairs; petals of perfect flowers 13-25 mm long, calyx 6-9 mm long; petals of pistillate flowers 9-12 mm long, calyx 5-7 mm long; if in bud, buds round, light green and more loosely distributed on the rachis…….. *S. campestris*

1b. Petals dark pink, red, lavender or purple

2a. Simple basal stem hairs; petals of perfect flowers 9-15 mm long, calyx 4.5-7 mm long; petals of pistillate flowers 5-9 mm long, calyx 4-6 mm long; if in bud, buds purple to green, more oval, and tightly clustered on the rachis……..*S. nelsoniana*

2b. Basal stem hairs forked to stellate

3a. Petals of perfect flowers 11-19 mm long, calyx 6-10 mm long; petals of pistillate flowers 8-12 mm long, calyx 6-8 mm long; calyx usually prominently veined, loves widened above base, +/- ovate-lanceolate; range does not extend north of Lane County in the Willamette Valley ……..*S. cusickii*

3b. Petals of perfect flowers 15-25 mm long, calyx 7-10 mm long; petals of pistillate flowers 9-13 mm long, calyx 5-7 mm long; calyx not prominently veined, lobes not widened above base, tapered evenly to the tip; tends to bloom earlier than *S. nelsoniana*.....……..*S. virgata*

Appendix J: Willamette daisy pictures

Willamette daisy vegetative (left) and reproductive (right) plants. Vegetative plants can be difficult to locate, especially if the surrounding vegetation is high.

Front view (left) and back view (right) of triple nerved basal leaves of Willamette daisy.

Appendix K: Partial List of invasive non-native plant species of concern

(From USFWS 2010)

Arrhenatherum elatius (tall oatgrass)

Brachypodium sylvaticum (false-brome)

Centaurea X *pratensis* (meadow knapweed)

Cytisus scoparius (Scotch broom)

Phalaris arundicacea (reed canary grass)

Pyrus communis (feral common pear)

Rubus armeniacus (Armenian blackberry)

Rubus vestitus (European blackberry)

Appendix L: Monitoring pre-site visit and equipment checklists

Pre-site visit monitoring checklist

- ☐ Contact land owner/manager to obtain permission to access site (if necessary)
- ☐ Print aerial photos/maps with gps layer of population locations (if known)
- ☐ Obtain last counts from previous monitoring data (if known)
- ☐ Gather equipment (see below)
- ☐ Get specific directions to site (if necessary)
- ☐ Develop monitoring plan if not already completed (see Section 6.1)

Monitoring field equipment list

- ☐ 100 meter tapes (at least 3)
- ☐ Meter tape chaining pins
- ☐ Meter sticks or meter-long plastic PVC pipe with 1/10s marked in sharpie (1/investigator)
- ☐ Pinflags (at least 300-500, at least 2-3 colors, orange and pink work best)
- ☐ Flagging (to put on equipment & mark transects/plots in tall vegetation where it is difficult to see pinflags)
- ☐ Square meter plot frame(s) (for estimating area for Kincaid's lupine & Nelson's checkermallow)
- ☐ 0.05 m^2 cover template (22.4 cm x 22.4 cm clear plastic square, for estimating coverage of Kincaid's lupine and Nelson's checkermallow)
- ☐ Camera + extra batteries/memory card
- ☐ GPS + extra batteries
- ☐ Tally counters (2/person)
- ☐ Waterproof knee-high boots (Bradshaw's lomatium often in/near standing water)
- ☐ Scientific calculator
- ☐ Write-in-rain notebooks
- ☐ Pencils
- ☐ Clipboard
- ☐ Sample size calculation worksheets (on write-on-rain paper if raining)
- ☐ Pictures of species/identifying characteristics
- ☐ Plant identification key/guides
- ☐ Method for generating random numbers
- ☐ Previous year's monitoring data
- ☐ Aerial photos/maps with GPS layer of previously-mapped target population locations, if available)
- ☐ Directions to site (if haven't been there before)

Appendix M. Sample size calculation sheet

(from Silvernail et al. 2012, adapted from Elzinga et al. 1998, p 349-350)

Site Name: _____
ORBIC EO_ID: _____
Date: _____
Observers: _____

1. Caclculate standard deviation: $(s)=\sqrt{\{[\sum(x-\mu)2]/(n-1)\}}$

   x = value/count associated with quadrat
   μ=mean
   n=number of sampled quadrats

Sample	x	μ	x- μ	$(x- \mu)^2$
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
∑				
[∑(x-μ)2]/(n-1)				
s = √{[∑(x-μ)2]/(n-1)}				

Standard deviation, s = _____

2. Initial, uncorrected sample size, $n =(Z_\alpha^2 * s^2)/(\mu*\beta)2$

   Z_α = standard normal coefficient (Elzinga et al. 1998 p 346)
   = 1.96 for 95% confidence level
   s = standard deviation calculated from pilot sampling
   β = desired precision level (maximum 30%, or 0.3)

	Value	Value2
Z_α	1.96	3.84
s		
μ		
β	0.3	
μ*β		
$Z_\alpha^2*s^2$		
$(Z_\alpha^2*s^2)/(\mu*\beta)^2$		

3. Sample size correction, n*
   (see Appendix N)

   Corrected sample size, n* = _____

Appendix M, continued. Sample size calculation sheet

4. Correct for a "finite population" if you have sampled more than 5% of the population: n'=n*/{1+(n*/N)}

   n'=the new, finite population corrected (FPC) sample size
   n*=the corrected sample size from #3

   N=the total number of possible quadrat locations in the population. To calculate, determine the total area of the population and divide by the size of one quadrat.

	Value
Quadrat length (m)	
Quadrat width (m)	
Quadrat size (m^2)	
Macroplot area (m^2)	
N	

	Value
N	
n*	
n*/N	
1+(n*/N)	
n' = n*/{1+(n*/N)}	

Finite population corrected (FPC) sample size, n' = _____

Appendix N: Sample size correction table for single parameters

(from Elzinga et al. 1998, p 350)

95% confidence interval[1]							
n	n*	n	n*	n	n*	n	n*
1	5	26	37	51	66	76	94
2	7	27	38	52	67	77	95
3	8	28	39	53	68	78	96
4	10	29	41	54	69	79	97
5	11	30	42	55	70	80	98
6	12	31	43	56	71	81	99
7	14	32	44	57	72	82	100
8	15	33	45	58	74	83	101
9	16	34	46	59	75	84	102
10	18	35	48	60	76	85	103
11	19	36	49	61	77	86	105
12	20	37	50	62	78	87	106
13	21	38	51	63	79	88	107
14	23	39	52	64	80	89	108
15	24	40	53	65	81	90	109
16	25	41	54	66	83	91	110
17	26	42	56	67	84	92	111
18	28	43	57	68	85	93	112
19	29	44	58	69	86	94	113
20	30	45	59	70	87	95	114
21	31	46	60	71	88	96	116
22	32	47	61	72	89	97	117
23	34	48	62	73	90	98	118
24	35	49	63	74	91	99	119
25	36	50	65	75	92	100	120

[1]for corrections based on a different confidence interval, see Elzinga et al. 1998, p 349-350