

**Species Status Assessment Report for
Bradshaw's lomatium
(*Lomatium bradshawii* (Rose ex. Math.) Mathias & Constance)
Version 1.0**



(Photo by Jeff Dillon, U.S. Fish and Wildlife Service)

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Throughout this document, words that appear in **bold type** are defined in the Glossary.

Suggested reference:

U.S. Fish and Wildlife Service. 2018. Species status assessment report for Bradshaw's lomatium (*Lomatium bradshawii*). Version 1.0. Oregon Fish and Wildlife Office, Portland, Oregon. 64 pp.

EXECUTIVE SUMMARY

This Species Status Assessment Report is a comprehensive review of the biology and status of Bradshaw's lomatium (*Lomatium bradshawii*), a perennial herb that was listed as endangered under the Endangered Species Act of 1973, as amended (Act), in 1988 (53 Federal Register 38448-38451). The purpose of this report is to evaluate the viability of Bradshaw's lomatium as indicated by measures of population resiliency, redundancy, and representation. This report was prepared for the purposes of conducting a 5-year review of the status of the species, as required by section 4(c)(2)(A) of the Act.

Bradshaw's lomatium is a plant in the parsley family endemic to the Willamette Valley of Oregon and southwest Washington. The species requires wet prairie habitats with intact wetland hydrology, high light availability, and the presence of pollinating insects in order to complete its life cycle. Periodic disturbance is required to reduce woody encroachment and maintain open conditions. Populations must be sufficiently large to withstand stochastic events. To maintain viability, a sufficient number of resilient Bradshaw's lomatium populations should be distributed across its range in order for the species to withstand catastrophic events.

Land use conversion, woody species encroachment following alteration of the historical fire regime, and the proliferation of nonnative invasive plant species had reduced the quantity and quality of Bradshaw's lomatium habitat over time, leading to the loss or diminishment of populations. These stressors, combined with concerns over potential genetic impacts associated with small populations and inbreeding depression, led to the decision to list Bradshaw's lomatium as endangered. At the time of listing, there were 11 small populations of the species known, totaling roughly an estimated 25,000 to 30,000 individuals.

Since the time of listing, significant efforts have been made to manage woody encroachment and invasive plants, to protect wet prairie habitat from development, and to augment or establish Bradshaw's lomatium populations throughout the species' known range. Increased survey efforts have also led to the discovery of previously unknown wild populations of Bradshaw's lomatium. At the time of this assessment there are 24 known populations of Bradshaw's lomatium. Of these, 23 are in the central to southern Willamette Valley and one disjunct population is in southwestern Washington. Ten populations are considered to have high resiliency, nine have moderate resiliency, and four have low resiliency. One population was not assessed due to insufficient data. A consideration of likely future conditions, including the status of known stressors, management trends, and possible impacts of climate change, finds that although populations may decline in abundance, at least 14 – 16 populations are expected to maintain high or moderate resiliency. The species is anticipated to retain appreciable levels of resiliency, redundancy, and representation over the 25 to 50 year timeframe projected into the future.

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I. INTRODUCTION

Bradshaw's lomatium (*Lomatium bradshawii*) is a perennial herb that occurs in wet prairie habitats in the Willamette Valley of western Oregon and adjacent southwestern Washington. This species was listed by the U.S. Fish and Wildlife Service (Service) as endangered under the Endangered Species Act of 1973, as amended (ESA) in 1988 (53 Federal Register (FR) 38448-38451).

This Species Status Assessment report (SSA) is a comprehensive review of Bradshaw's lomatium, which will be used to inform the 5-year review of the species' status under the ESA and to guide continued recovery efforts for the species. This SSA will also provide information to guide other potential future actions for Bradshaw's lomatium under the ESA, such as recovery plan revisions, if needed, and consultation with other Federal agencies.

The SSA framework summarizes the best available scientific and commercial data to conduct an in-depth review of a species' biology, needs, and the stressors it faces in order to evaluate its biological status and long-term **viability**. For the purpose of this assessment, we define viability of Bradshaw's lomatium as its ability to sustain multiple resilient populations distributed across its range in the wild over time. Using the SSA framework, we will evaluate viability in terms of **resiliency**, **redundancy**, and **representation** (Shaffer and Stein 2000, pp. 307-310; Wolf *et al.* 2015, pp. 204-5; U.S. Fish and Wildlife Service 2016, p. 21; Smith *et al.* 2018, p. 8).

- **Resiliency** refers to the ability of a population to endure or withstand stochastic disturbance events; thus, resiliency is related to the demographic ability of populations to absorb and rebound from disturbance and persist. Resilient populations are able to recover from losses due to demographic stochasticity (such as fluctuations in population growth rate) or environmental stochasticity (such as variations in annual weather patterns). Demographic factors (abundance, survival, productivity, and ultimately intrinsic population growth rate) are metrics commonly used to measure resiliency.
- **Redundancy** is assessed at the species level, and describes the ability of a species to withstand catastrophic events. Catastrophic events are typically rare and of finite duration, causing severe impacts to one or more populations. Redundancy is a measure of the number of populations, their resiliency, and their distribution (and connectivity). Spatial structure contributes to redundancy through increased distributional extent by

spreading risk across the broader landscape and adds to the resiliency by increasing connectivity among populations.

- **Representation** describes the ability of a species to adapt to changing conditions and is measured by the breadth of genetic or environmental diversity within and among populations. Representation uses diversity as a proxy for adaptive capacity. Diversity, as represented in genetic, geographic, or life-history variation, contributes to the evolutionary capacity of a species to adapt to change.

The SSA is intended to be a strictly scientific review of the conservation status of Bradshaw's lomatium, and does not pre-determine any decision by the Service in regards to protection under the ESA. Any decisions regarding a change in classification under the ESA will be made following a review of this document, any supporting analyses, other scientific information, and all applicable laws, regulations, and policies. Should a change in classification be recommended on the basis of the 5-year review, that change will be published in the *Federal Register* as a proposed rule and will be open for public comment. The results of any subsequent decision will be published in the *Federal Register*.

II. SPECIES INFORMATION

Bradshaw's lomatium or Bradshaw's desert-parsley is a perennial herb listed as endangered, without critical habitat, on September 30, 1988 (53 FR 38448-38451). A Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington, which included Bradshaw's lomatium, was published in 2010 (U.S. Fish and Wildlife Service 2010, entire). This recovery plan supersedes the original recovery plan for Bradshaw's lomatium, which was published in 1993 (U.S. Fish and Wildlife Service 1993, entire).

DESCRIPTION

Bradshaw's lomatium is an erect, **glabrous**, perennial herb that grows from a long, slender **taproot** to a height of 20 to 50 centimeters (cm) (12 to 20 inches (in)) with its **caudex** 3 to 5 cm (1 to 2 in) below the surface (Figure II-1). Leaves are typically 2 to 6, chiefly basal, 10 to 20 cm (4 to 8 in) in length, more vertical than horizontal (Jackson 1996), and ternately-pinnately divided into linear or filiform segments 2 to 12 mm (0.08 to 0.5 in) long. **Inflorescences** are flat-topped **umbels**, comprised of 5 to 14 **umbellets** less than 1 cm (0.4 in) across, supported by rays branching from a **peduncle**. Umbellets are subtended by ternately or bi-ternately divided

involucel bracts (Figure II-2). Flowers are light yellow, with petals approximately 1 mm long (Jackson 1996). Fruits are **glabrous schizocarps**, 8 to 13 mm (0.3 to 0.5 in) long by 5 to 7 mm (0.20 to 0.28 in) wide, with corky, thickened wings (Natural Resources Conservation Service 2010) (Figure II-3). Identification of Bradshaw's lomatium is most often confused with common lomatium (*Lomatium utriculatum*), which can be distinguished by the presence of well-developed involucel bracts (Natural Resources Conservation Service 2010).



Figure II-1. Bradshaw's lomatium – Photo by Jeff Dillon, U.S. Fish and Wildlife Service.



Figure II-2. Bradshaw's lomatium umbellet, with ternately and bi-ternately divided involucel bracts. Photo by Jeff Dillon, U.S. Fish and Wildlife Service.



Figure II-3. Bradshaw's lomatium fruits (schizocarps). Photo by Jeff Dillon, U.S. Fish and Wildlife Service

TAXONOMY

Bradshaw's lomatium is a member of the Apiaceae, the umbel or parsley family. The genus is a North American group with its center of distribution in the western United States, and is composed of taprooted or tuberous perennial herbs with large, winged fruits. Bradshaw's lomatium was first collected by J.C. Nelson near Salem, Oregon, in 1916. The type specimen was collected in 1920, in Eugene, by R.V. Bradshaw, for whom the species was named by Mildred Mathias in 1934. It was originally described as *Leptotaenea bradshawii* Mathias, and was renamed *Lomatium bradshawii* (Rose ex. Math.) Math. & Constance in a 1942 revision of the genus (Mathias and Constance 1942). The taxonomy of this species is well-accepted and not in dispute. The currently accepted classification is:

Clade: Asterids

Order: Apiales

Family: Apiaceae

Genus: *Lomatium*

Species: *L. bradshawii*

LIFE HISTORY

The leaves of Bradshaw's lomatium emerge as early as February. Plants bloom in the spring, usually in April and early May. The flowers have a spatial and temporal separation of sexual phases, presumably to promote outcrossing, resulting in **protandry** on a whole plant basis, and **protogyny** within the umbels. Bradshaw's lomatium produces both male-only and hermaphroditic flowers, and typically produces one or two umbels per year (Kagan 1980). The first umbel is typically composed of all male flowers, while the second contains some hermaphroditic flowers. On umbels with both hermaphroditic and male flowers, the hermaphroditic flowers bloom first. This results in a temporal separation of flower maturity between male and hermaphroditic flowers, reducing the likelihood of self-fertilization (Kaye 1992, pp. 2-3).

A typical population is composed of many more vegetative plants than reproductive plants (Silvernail *et al.* 2016). Plants commonly express dormancy for 1 to 4 growing seasons, though the stimulus is unknown (Drew 2000, p. 48). Mortality is most common at the seedling stage. The lifespan of Bradshaw's lomatium is unknown, though inspection of root crown scars on a single herbarium specimen indicated an age of approximately 15 years (Darrach, personal communication). Other *Lomatium* species in Oregon and Washington are estimated to live on average 5 to 20 years, with some individuals approaching 100 years old (Committee on the Status of Endangered Wildlife in Canada 2008, p. 13; Darrach and Wagner 2011, p. 433; Darrach 2014, p. 11; Darrach and Hinchliff 2014, p. 2).

In a pollinator exclusion experiment, Kaye and Kirkland (1994) observed that self-fertilization in Bradshaw's lomatium is rare, indicating that pollinator-mediated outcrossing is required for reproduction. Pollination of Bradshaw's lomatium is completed by a variety of insects. Over 30 species of solitary bees, flies, wasps and beetles have been observed visiting the flowers (Kaye 1992, p. 3; Kaye and Kirkland 1994, p. 9; Jackson 1996, pp. 72-76). The very general nature of the insect pollinators may help buffer Bradshaw's lomatium from the population swings of any one pollinator species. Kaye (1992, p. 3) observed a change in relative abundance of pollinator functional groups visiting Bradshaw's lomatium during years in which weather conditions favored one group over another.

Bradshaw's lomatium does not reproduce asexually and depends exclusively on seeds for reproduction (Kaye 1992, p. 2). Reproductive plants may produce 1 to 20 seeds per year, with variations by year, site conditions, and disturbance regime. Seeds mature in late May to June (Kagan 1980, pp. 4, 20-21) and may persist on the plant until October or November before

falling to the ground (Jackson 1996, p. 82). The large fruits have corky thickened wings, and usually fall to the ground fairly close to the parent. Fruits appear to float somewhat, and may be distributed by water. The fine-scale population patterns at a given site appear to follow seasonal microchannels, but whether this is due to dispersal, habitat preference, or both, is not clear. The seeds either germinate the following spring or die, and do not form a persistent seed bank (Kaye *et al.* 2001, p. 1376).

In a genetic study that included five populations of Bradshaw's lomatium, the species displayed little population differentiation but the level of diversity, measured in percent polymorphic loci, was only slightly lower than the more common cous biscuitroot (*Lomatium cous*) and Gray's lomatium (*L. grayi*) (Gitzendanner and Soltis 2001, p. 352), and was greater than that found in other rare *Lomatium* species (Gitzendanner and Soltis 2000, p. 787). Isolated populations in Washington appear to have lower levels of diversity, but they do not appear to be genetically differentiated from the other populations of the species, consistent with historical gene flow among all populations, and a recent bottleneck in the Washington populations.

The species generally responds positively to disturbance. Low intensity fire appears to stimulate population growth of Bradshaw's lomatium. The belowground portion of Bradshaw's lomatium is able to survive fires, allowing aboveground vegetation to resprout. One study showed that flower and seed production was 5 to 7 times higher on burned plants relative to unburned plants (Wilson *et al.* 1993, p. 44). Pendergrass *et al.* (1999, pp. 1422-1425) showed increased density and abundance of reproductive plants following fires, although monitoring showed that the effects dissipated after 1 to 3 years. Frequent burns may be required to sustain population growth, as determined from population models (Caswell and Kaye 2001, pp. 43-45, Kaye *et al.* 2001, pp. 1376-1377). Annual fall mowing has significantly increased the number of individual Bradshaw's lomatium plants persisting in the City of Eugene's Amazon Park, from 10,134 individuals in 1995 to 31,252 individuals in 2005 (Trevor Taylor, City of Eugene, *in litt.* 2008, p. 2).

HABITAT CHARACTERISTICS

Bradshaw's lomatium is mostly restricted to wet prairie habitats (Figure II-4). These sites have heavy, sticky clay soils or a dense clay layer below the surface that results in seasonal **hydric soils**. Most of the known Bradshaw's lomatium populations occur on seasonally saturated or flooded prairies, which are found near creeks and small rivers in the southern Willamette Valley (Kagan 1980, p. 4). The soils at these sites are dense, heavy clays with a slowly permeable clay

layer located between 15 and 30 cm (6 and 12 in) below the surface. This slowly permeable clay layer, which results in a perched water table in winter and spring, allows soils to be saturated to the surface or slightly inundated during the wet season. The soils include Dayton silt loams, Natroy silty clay loams or Bashaw clays; other soil series mapped where the species occurs include Amity, Awbrig, Coburg, Conser, Courtney, Cove, Hazelair, Linslaw, Oxley, Panther, Pengra, Salem, Willamette, and Witzel.



Figure II-4. Typical wet prairie habitat at Green Mountain site in southwestern Washington, May 2003; yellow flowers in this photo are Bradshaw's lomatium. Photo by Kathy Pendergrass, U.S. Fish and Wildlife Service.

Less frequently, Bradshaw's lomatium populations are found on shallow, basalt areas in Marion County and Linn County near the Santiam River. The soil type is characterized as Stayton Silt Loam; it is described as well drained, in alluvium underlain by basalt (U.S. Fish and Wildlife Service 1993, p. 8). The shallow depth to bedrock, 50 cm (20 in) or less, results in sites that are poorly suited to agriculture. This soil type occurs at scattered locations in a mosaic with deeper soils belonging to the Nekia-Jory association, which were originally vegetated by

grassland and oak savanna (Alverson 1990, p. 108). Bradshaw's lomatium at these sites occurs in areas with very shallow soil, usually in vernal wetlands or along stream channels.

POPULATION TRENDS AND DISTRIBUTION

Bradshaw's lomatium has a range extending from the southern Willamette Valley near Creswell, Oregon, north to southwestern Washington in the town of Camas. Populations are found in Lane, Linn, Benton, and Marion Counties in Oregon, and Clark County in Washington.

During the early stages of Euro-American migration to the Willamette Valley in the mid-19th century, wet prairie comprised approximately 137,277 hectares (ha) (339,219 acres (ac)), accounting for approximately 10 percent of the area in the Willamette Valley overall (Christy and Alverson 2011, pp. 100-101). Wetland prairie was more prevalent in the southern portion of the valley and west of the Willamette River, and patchier east of the river and north of the Santiam River (Taft and Haig 2003, pp. 54-55). Wet prairie in the Willamette Valley currently covers less than 2,024 ha (5,001 ac) (Christy and Alverson 2011, pp. 100-101), about 1.5 percent of its historical extent, and approximately 0.15 percent of the Willamette Valley overall. Conversion to agriculture has been the largest driver of loss of prairie habitats in the Willamette Valley (Johannessen *et al.* 1971, p. 292; Hulse *et al.* 2002, pp. 78-81). Approximately 50 percent of the modern Willamette Valley is in agricultural production (Morlan *et al.* 2011, p. 11). Residential, commercial, and infrastructure development have also contributed to the decline in wet prairie (Hulse *et al.* 2002, pp. 78-81).

On the remainder of wet prairie not yet converted to agriculture or subjected to urbanization or other development, natural succession to woody species contributes to a loss of this habitat type. Prior to Euro-American settlement in the Willamette Valley, widespread and frequent fires maintained a mosaic of prairie and open savannas and woodlands. Fires were caused by a combination of intentional burning by Native American peoples and lightning strikes. Johannessen *et al.* (1971, entire) compiled writings from early settlers and explorers detailing their observations of these fires. In the absence of disturbance cause by these fires, native and nonnative trees and shrubs encroach on prairies. Conversion of prairie to woodland habitat occurs as these woody species become dominant (Pendergrass *et al.* 1998, p. 303).

The historical range and abundance of Bradshaw's lomatium is unknown. The species has historically been overlooked and poorly documented. The earliest known databased collection of Bradshaw's lomatium was made in 1916 in the vicinity of Salem, Oregon. From 1920 through 1941, at least 10 unique collections of Bradshaw's lomatium were made at locations throughout Lane County (Consortium of Pacific Northwest Herbaria Database 2017). There were no known

collections of Bradshaw's lomatium between 1942 and 1964, contributing to the assumption that the taxon might have gone extinct. No record describing the search effort for Bradshaw's lomatium during this period is available, so it is difficult to draw reliable conclusions about population size and extent. By 1980, eight occurrences had been located, six of which contained greater than 100 plants each (Kagan 1980, pp. 9-11). When Bradshaw's lomatium was listed as endangered in 1988, 11 populations were known, including at least one with greater than 10,000 plants; the total population at the time of listing was estimated to be from 25,000 to 35,000 individuals (53 FR 38448-38451). When the first Recovery Plan for the species was completed in 1993, 14 sites were known with a total of 52,250 plants (U.S. Fish and Wildlife Service 1993, p. 6). When the current Recovery Plan was completed in 2010, the Service was aware of 62 sites containing greater than 1,000,000 plants total (U.S. Fish and Wildlife Service 2010; see Figure II-5). A new occurrence of Bradshaw's lomatium was discovered on private property in Linn County in 2010 (Jarod Jebousek, pers. comm. 2017), and it is likely more unknown occurrences exist. At present, 71 sites are known to the Service, with greater than 11,000,000 plants. The majority of plants are found in southwestern Washington, while the majority of sites are found toward the southern portion of the species' distribution in Oregon (Figure II-5).

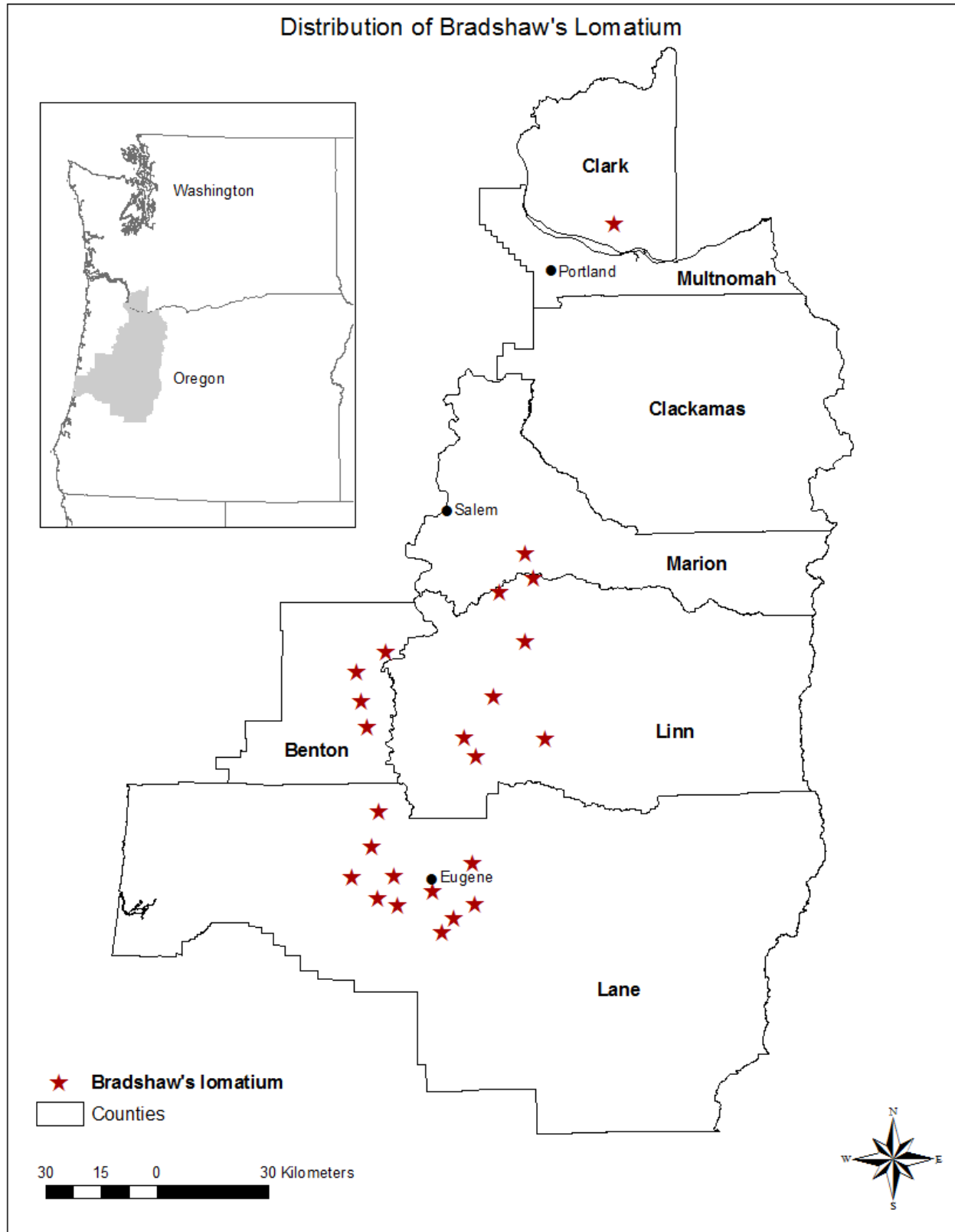


Figure II-5 – Distribution map of *L. bradshawii*.

III. SUMMARY OF INDIVIDUAL, POPULATION, AND SPECIES REQUIREMENTS

REQUIREMENTS OF INDIVIDUALS

Bradshaw's lomatium grows primarily in wet prairies. These seasonally wet habitats may be flooded in the spring, or have soils saturated at or near the surface. Seasonal moisture may be due to heavy precipitation in winter and spring, flooding, and poor drainage.

A high light environment is important for Bradshaw's lomatium to complete its life cycle and reproduce, as reduced sunlight is associated with lower flower and seed production (Alverson 1993, unpublished data). Sites with more open space and less canopy cover appear to support more robust populations.

Bradshaw's lomatium is often associated with tufted hairgrass (*Deschampsia cespitosa*), and frequently occurs on and around the small mounds created by senescent tufted hairgrass plants. In wetter areas, Bradshaw's lomatium occurs on the edges of tufted hairgrass hummocks or sedges in patches of bare or open soil. In drier areas, it is found in low areas, such as small depressions, trails or seasonal channels, with open, exposed soils.

REQUIREMENTS OF POPULATIONS

To be resilient, populations of Bradshaw's lomatium need sufficiently large numbers of individuals so that they are able to withstand stochastic events (expected levels of variation in environmental or demographic characteristics). For example, populations must be large enough to withstand annual variation in levels of vole (*Microtus* spp.) predation. No quantitative analysis has been completed to determine a minimum viable population size for Bradshaw's lomatium. Experts on the Recovery Team for the prairie species of western Oregon and southwestern Washington (Recovery Team) defined eight Recovery Zones within the range of Bradshaw's lomatium (Figure III-2), and set population level goals for each to achieve the desired distribution of the species across its known historical range (U.S. Fish and Wildlife Service 2010, entire; see Figure III-2). Within each Recovery Zone, they set a goal of at least 10,000 plants in a minimum of two populations, and at least two of the populations contain greater than 2,000 plants each. Smaller scattered populations of at least 200 plants within pollinator flight distance (3 kilometer [km] (2 miles [mi])) of each other were deemed stable enough to contribute to overall goals.

Sufficient annual seed production is necessary to offset mortality of mature Bradshaw's lomatium plants within a population. Bradshaw's lomatium does not maintain a persistent seed bank in the soil. Though some fruit survives in the soil for one year, the seeds are not viable under natural conditions in the wild (Kaye *et al.* 2001, p. 1376).

Open habitats with relatively high sunlight and low canopy cover are important for successful reproduction necessary to sustain Bradshaw's lomatium populations, due to the observed correlation between reduced sunlight and lowered flower and seed production (Alverson, unpublished data 1993). In the absence of disturbance to set back succession, wet prairies in the Willamette Valley are subject to woody species encroachment, gradually transitioning into shrub or woodland habitat. Periodic disturbance, such as fire or fall mowing, are necessary to maintain the open, high light wet prairie habitats Bradshaw's lomatium populations depend on. Flowering and seed production have been shown to be 5- to 7- times greater in plants that have been burned relative to those that have not (Wilson *et al.* 1993, p. 44). Pendergrass *et al.* (1999, pp. 1422-1425) also noted increased flower and fruit production by Bradshaw's lomatium in response to fire. Overall, fire has a substantially positive effect on population growth rate and population viability, though multiple studies show the magnitude of effect varies by site (Pendergrass *et al.* 1999, pp. 1422-1425; Caswell and Kaye 2001, pp. 43-45; Kaye *et al.* 2001, pp. 1376-1377).

Populations of Bradshaw's lomatium need habitat with intact wetland hydrology and protected from adjacent hydrological changes that may affect wet prairie characteristics. Land use changes on adjacent sites or flood control can alter the hydrology and soil conditions of nearby Bradshaw's lomatium populations. Bradshaw's lomatium requires a hydrologic regime of flooding, precipitation, poor drainage, and unaltered topography/hydrology (i.e. no development, no drainage ditches), resulting in seasonally wet prairie. Poorly draining soil types such as heavy clay or shallow soil with underlying basalt result in soil saturation, standing water, vernal pools, or a perched water table, providing the type of habitat required to support Bradshaw's lomatium. Population growth and reproduction are positively correlated with higher September to February precipitation at some sites (Drew 2000, p. 49). Both reproductive potential and plant height are higher on wetter sites (Drew 2000, p. 50).

High population densities on sites with poor soil may result in small plants, low seed production, and lower leaf length and umbel number. Lower plant densities with adequate soil tend to result in larger plants with high seed production (Kaye 1992, p. 2).

The floral phenology and breeding system of Bradshaw's lomatium seem to limit self-fertilization (Kaye and Kirkland 1994, p. 10), making it dependent on the presence of pollinators

during its early spring bloom period for successful sexual reproduction. In Bradshaw's lomatium populations composed of multiple discontinuous sites, insect pollinators are also important for ensuring gene flow between sites. Numerous species from multiple functional groups of insects have been observed pollinating Bradshaw's lomatium, and annual variations in weather appear to influence the relative abundance of certain insect pollinator functional groups (Kaye 1992, Kaye and Kirkland 1994, Jackson 1996). In order to ensure the presence of pollinators each year, it is important that habitats supporting Bradshaw's lomatium provide sufficient resources to support an abundance and diversity of pollinator species and functional groups. Native bee species have been observed showing preference for native plant species, and a diversity of native flowering plants is important for supporting pollinator populations (Morandin and Kremen 2013, pp. 28-31). Flowering plant richness is positively correlated with pollinator abundance, species richness, functional group diversity, and frequency of pollinator flower visits (Ebeling *et al.* 2008, pp 1810-1811; Orford *et al.* 2016, pp. 909-911).

Table III-1. Key life history and resource needs of Bradshaw's lomatium

<ul style="list-style-type: none"> • Pollinators (obligate outcrossing) • Bare substrate for seed germination • Open habitats (high levels of sunlight, low canopy, woody cover) • Water and nutrients • Seasonally moist, hydric soils; intact wetland hydrology
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Figure III-1 presents a conceptual model summarizing the key population needs for Bradshaw's lomatium. Additionally, this model incorporates stressors that may influence these resource needs, and thus affect the resiliency of Bradshaw's lomatium. These stressors are discussed further in Section IV of this document, Summary of Stressors Affecting the Species.

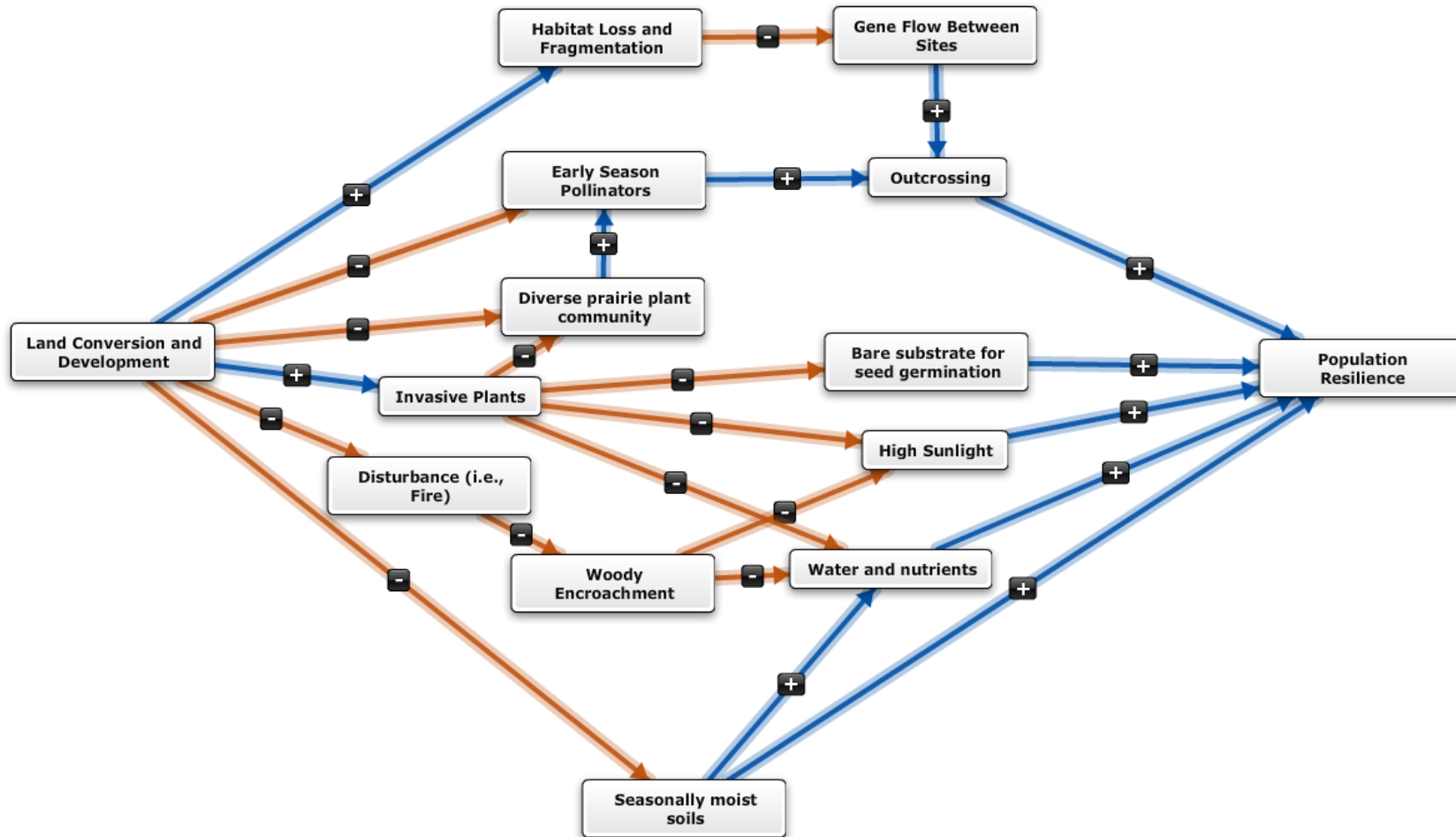


Figure III-1 – Conceptual model showing relationships of factors influencing *Lomatium bradshawii* population resiliency. Blue and Red arrows show the direction and type of relationship between two factors (red arrows represent reductions and blue arrows represent increases). For example, Land Conversion and Development increases Habitat Loss and Fragmentation, and reduces Disturbance.

REQUIREMENTS OF THE SPECIES

To be considered **viable**, Bradshaw's lomatium should have a sufficient number of secure, resilient populations well-distributed throughout its geographic range, and representing the range of ecological settings in which the species is known to exist. The number and distribution of resilient populations must be sufficient for the species to withstand catastrophic events.

Bradshaw's lomatium is endemic to the Willamette Valley of Oregon and Clark County in southwestern Washington. Though its historical extent and distribution are not precisely known, the species may have been more abundant, widespread, and contiguously distributed throughout the seasonally wet prairies of the region, many of which have been lost and fragmented due to land conversion and development. We do not have information to indicate that the species ever occurred in a diverse range of ecological environments, nor do we have information suggesting any differentiation of genetic structure between populations of Bradshaw's lomatium.

No quantitative analysis has been completed to determine the minimum number of populations necessary for Bradshaw's lomatium to be viable as a species, because we lack the data necessary to construct a meaningful model. However, experts on the Recovery Team delineated Recovery Zones throughout the range of Bradshaw's lomatium (Figure III-2), and set goals for the desired number of populations per Recovery Zone based upon a generic model of the relationship between number of populations and extinction risk (U.S. Fish and Wildlife Service 2010, pp. IV-18 – IV-20), the known historical distribution of the species, and their best professional judgment (Table III-2). The intent of these goals was to ensure the distribution of resilient populations of the species across its historical range and thus achieve redundancy in populations as well as adequate ecological and genetic representation. The Recovery Team did not set goals for the Portland and Salem West Recovery Zones, because we do not have any historical records to indicate that the species occurred in those zones, or if so, where they may have occurred. Although they do not have specific population targets, these zones were included because they are within the current range of Bradshaw's lomatium and may contain suitable habitat to support the species.

Table III-3 presents a summary of the fundamental requirements of Bradshaw's lomatium at the individual, population, and species level.

Recovery zones for Bradshaw's lomatium

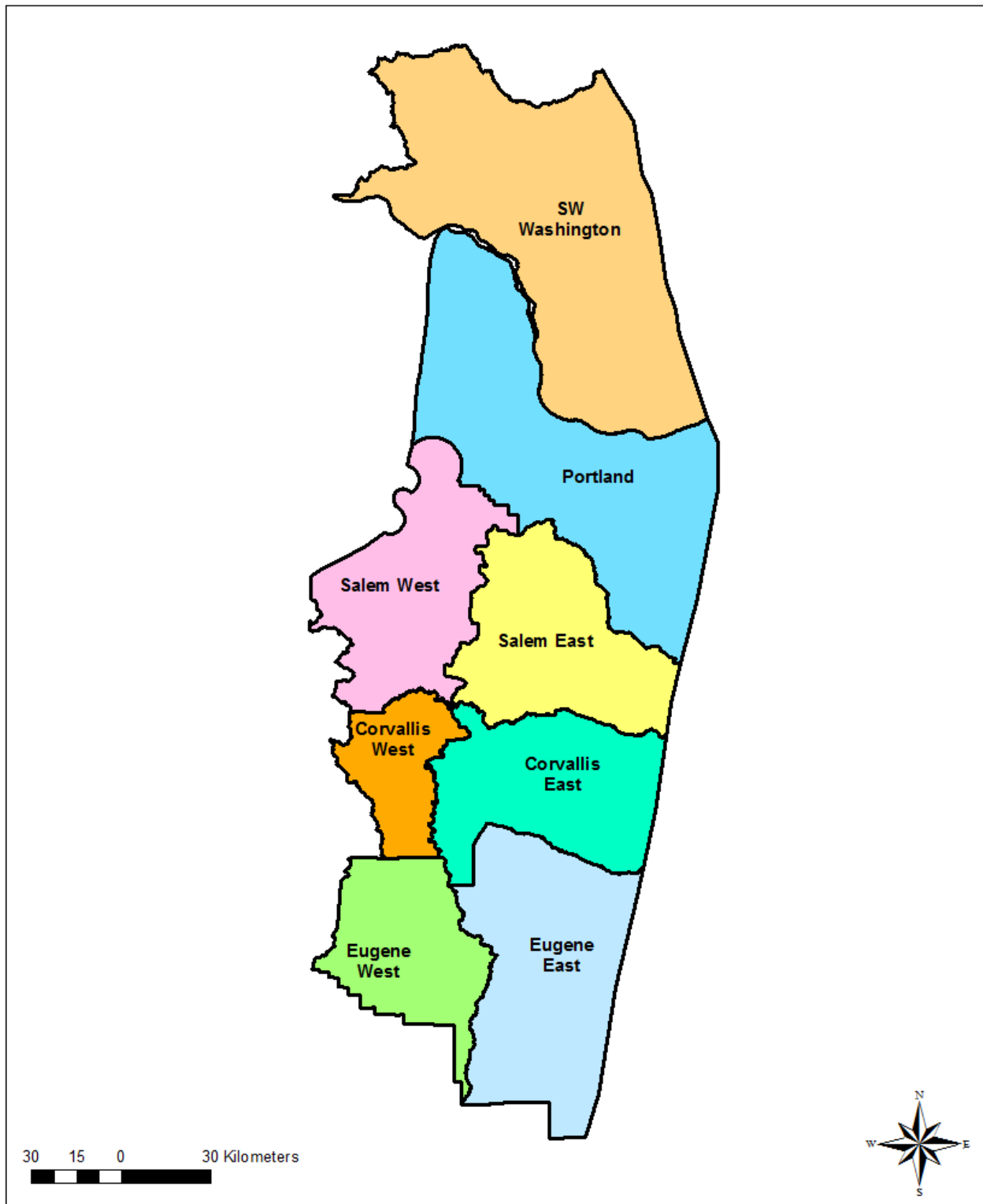


Figure III-2 – Map of Recovery zones for Bradshaw's lomatium .

Table III-2 – Recovery targets for number and distribution of Bradshaw's lomatium populations, as well as population size, as determined by the Recovery Team. Adapted from the Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (U.S. Fish and Wildlife Service 2010).

Distribution and Abundance Goals for Bradshaw's lomatium				
Recovery Zone	Downlisting Goals		Delisting Goals	
	Minimum # of Populations / Zone	Target # of Plants / Zone	Minimum # of Populations / Zone	Target # of Plants / Zone
SW Washington	1	5,000	2	10,000
Portland	0	0	0	0
Salem East	1	5,000	2	10,000
Salem West	0	0	0	0
Corvallis East	2	10,000	3	15,000
Corvallis West	2	10,000	2	10,000
Eugene East	1	5,000	3	15,000
Eugene West	3	15,000	3	15,000
+ Additional Populations (may occur in any Recovery Zone within range of <i>L. bradshawii</i>)	2	10,000	5	25,000
Total	12	60,000	20	100,000

Table III-3 – Summary of requirements of Bradshaw's lomatium at individual, population, and species levels.IV.

Requirements of Bradshaw's lomatium		
Individuals	Populations	Species
<ul style="list-style-type: none"> • Wet prairie habitat • High light environment 	<ul style="list-style-type: none"> • Sufficiently large populations to withstand stochastic events (at least 2,000 plants) • Sufficient annual seed production to offset mortality (no persistent seed bank) • High quality seasonally wet prairie habitat • Regular disturbance (fire, mowing) to maintain open conditions • Early season pollinators for outcrossing 	<ul style="list-style-type: none"> • Sufficient number of resilient populations well distributed across the range • Downlisting target in Recovery Plan: 12 populations / 60,000 plants • Delisting target: 20 populations, 100,000 plants • Sufficient genetic diversity to adapt to change over time

IV. SUMMARY OF STRESSORS AFFECTING THE SPECIES

At the time of listing, the primary threats identified to Bradshaw's lomatium were habitat loss due to land use conversion for agriculture or urbanization and invasion of prairie vegetation by various woody plant species. Several other potential threats were mentioned as well, including the negative effects of a parasitic fungus, spittle bug, and two aphids on smaller stressed populations, and possible inbreeding depression due to the geographic and thus possibly genetic isolation of remaining populations, with the caveat that further work was needed to assess the significance of any of these potential threat factors. Finally, the listing rule mentioned that existing State and Federal regulations did not adequately protect the plant from threats such as loss of habitat (53 FR 38449-38450; September 30, 1988). By the time the recovery plan was

developed in 1993, the same threats were still considered relevant (Service 1993; p. 12). Additional stressors not known or considered at the time of listing include competition from nonnative invasive plant species and potential impacts resulting from climate change. Predation by voles also was not accounted for at the time of listing, but has been observed within Bradshaw's lomatium sites.

At present, not all threats previously identified at the time of listing are still considered to be significant stressors to the species. We have no evidence that negative impacts due to parasitic organisms constitute a threat to the viability of the species. Concerns over inbreeding depression are now reduced relative to the time of listing due to subsequent studies indicating that overall genetic diversity in Bradshaw's lomatium is relatively high for a rare species (Gitzendanner and Soltis 2001, pp. 352-353) and is greater than that found in other rare *Lomatium* species (Gitzendanner and Soltis 2000, p. 787). The threat of inbreeding depression is further considered reduced due to studies indicating that Bradshaw's lomatium is primarily an outcrossing species, rather than being an obligate self-pollinating species as was believed at the time of listing (Kagan 1980, p. 59). Predation by voles appears to vary year to year, and can substantially reduce aboveground biomass and reproduction in years when vole abundance is high. However, the effect on populations is believed to be minimal over time as long as there is sufficient time for Bradshaw's lomatium to regenerate taproot reserves between vole outbreaks (Drew 2000, pp. 54-55), and no consistent long-term declines attributable to vole predation have been reported.

At the time of this assessment, the stressors most likely to affect the viability of Bradshaw's lomatium are habitat loss and fragmentation due to land conversion, woody encroachment resulting from vegetative succession in the absence of disturbance, and competition from nonnative invasive plants. The current impact of these stressors on Bradshaw's lomatium is incorporated into our assessment of the current condition of the species, especially in our evaluation of population resiliency, below. The potential effects of climate change are incorporated into our assessment of species viability in Section VII of this report, under "Consideration of Additional Stressors."

HABITAT LOSS AND FRAGMENTATION

The abundance and distribution of Bradshaw's lomatium prior to Euro-American settlement is not known, but may have been greater than at the present time. Historically, wet prairie habitat that could have supported Bradshaw's lomatium comprised approximately 10 percent of the Willamette Valley at an estimated 137,277 ha (339,219 ac) (Christy and Alverson 2011, pp. 100-101). Wet prairie currently occupies approximately 1.5 percent of its historic extent, at 2,024 ha (5,001 ac) (Christy and Alverson 2011, pp. 100-101). Conversion to agriculture has been the largest driver of loss of prairie habitats in the Willamette Valley (Johannessen *et al.* 1971, p. 296; Hulse *et al.* 2002, pp. 78-81). Approximately 50 percent of the modern Willamette Valley is

in agricultural production (Morlan *et al.* 2011, p. 11). Residential, commercial, and infrastructure development have also contributed to the decline in wet prairie (Hulse *et al.* 2002, p. 78-81).

Activities associated with land use change and development that impact Bradshaw's lomatium habitats are wetland draining, infill, paving, and other hydrologic alterations. These activities result in mortality of individuals, loss of habitat, and loss of genetic connectivity between remaining populations. This stressor occurs range-wide, and affects all life stages of Bradshaw's lomatium. The greatest exposure of Bradshaw's lomatium to habitat loss is historical, with only 1.5 percent of wet prairie habitat remaining in the Willamette Valley, though ongoing development pressure may cause additional periodic losses.

WOODY ENCROACHMENT

In the absence of certain types of disturbance, wet prairies in the Willamette Valley and southwestern Washington are subject to vegetative succession involving encroachment of trees and shrubs. Historically, wildfires and active burning by native peoples maintained open prairie habitats throughout the region. The end of native burning, as well as landscape fragmentation and active fire suppression, have allowed succession to shrub- and tree-dominated habitats to progress rapidly in prairie ecotypes.

Succession to woody species causes a shift in plant community structure and composition, and alters the light environment in the herbaceous layer. Substrate availability may be reduced for all life stages of Bradshaw's lomatium. Reductions in light availability may result in reduced flower and fruit production, causing a reduction in recruitment. The increased shading and resource competition associated with woody encroachment results in reduced growth, survival, and reproduction in Bradshaw's lomatium. Historically, woody encroachment was not likely a significant stressor to Bradshaw's lomatium populations due to the frequency of widespread fires prior to Euro-American settlement in the Willamette Valley. Presently, woody encroachment is a regular and recurring stressor to Bradshaw's lomatium throughout its range. Active management, such as prescribed fire and mowing, can help to reduce exposure of Bradshaw's lomatium to this stressor. Woody species of particular management concern were identified by the Recovery Team (U.S. Fish and Wildlife Service 2010, entire), and are listed in Table IV-1.

Table IV-1 – Select woody species of management concern in Bradshaw's lomatium habitats, as determined by the Recovery Team. Adapted from the Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (U.S. Fish and Wildlife Service 2010).

Woody Species of Management Concern	
Scientific Name	Common Name
<i>Crataegus monogyna</i>	oneseed hawthorn
<i>Crataegus suksdorfii</i>	Suksdorf's hawthorn
<i>Fraxinus latifolia</i>	Oregon ash
<i>Pyrus communis</i>	feral common pear
<i>Rosa eglanteria</i>	sweetbriar rose
<i>Rosa multiflora</i>	multiflora rose
<i>Rubus armeniacus</i>	Armenian blackberry
<i>Rubus laciniatus</i>	cutleaf blackberry
<i>Spiraea douglasii</i>	Douglas' spirea
<i>Toxicodendron diversilobum</i>	poison oak

INVASIVE PLANTS

Human-mediated dispersal of nonnative plant species has resulted in established populations of invasive plants. Though specific definitions vary, for our purposes an invasive plant is defined as a plant species not native to a specific geographic area, which is likely to cause ecological harm. At least 700 nonnative plant species are reported to occur in the Willamette Valley (Albert 2015), though the majority are not classified as invasive. A partial list of nonnative plants found in Willamette Valley can be found in Table IV-2.

Nonnative invasive plants have established and spread within many habitats supporting Bradshaw's lomatium, leading to increased direct competition for resources such as light, water, nutrients, and open substrate for germination. A decrease in available light, water, and nutrients results in reduced growth, survival, and reproduction in Bradshaw's lomatium. Exposure of Bradshaw's lomatium to invasive plants has occurred in the past, is ongoing, and is likely to continue into the future. In cases where invasive plants may be eliminated from within a Bradshaw's lomatium population, propagules from nearby source populations may continue to arrive. The degree of nonnative invasive plant infestations varies by site (Silvernail *et al.* 2016).

Table IV-2 – A partial list of non-native plants found in Willamette Valley wet prairies. Species of management concern are adapted from U.S. Fish and Wildlife Service (2010). Other non-native species are adapted from Wilson (1998) and Silvernail *et al.* (2016).

Non-native Plant Species in Willamette Valley Wet Prairies¹	
Invasive Plants of Management Concern	
Scientific Name	Common Name
<i>Agrostis capillaris</i>	colonial bentgrass
<i>Agrostis stolonifera</i>	creeping bentgrass
<i>Anthoxanthum odoratum</i>	sweet vernalgrass
<i>Arrhenatherum elatius</i>	tall oatgrass
<i>Brachypodium sylvaticum</i>	false-brome
<i>Centaurea jacea</i> nothosubsp. <i>pratensis</i>	meadow knapweed
<i>Cytisus scoparius</i>	Scotch broom
<i>Holcus lanatus</i>	common velvetgrass
<i>Hypochaeris radicata</i>	hairy cat's ear
<i>Leucanthemum vulgare</i>	oxeye daisy
<i>Phalaris arundinacea</i>	reed canarygrass
<i>Pyrus communis</i>	feral common pear
<i>Rubus armeniacus</i>	Armenian blackberry
<i>Rubus vestitus</i>	European blackberry
<i>Alopecurus pratensis</i>	meadow foxtail
<i>Briza minor</i>	little quakinggrass
<i>Centaureum erythraea</i>	European centaury
<i>Cerastium viscosum</i>	sticky chickweed
<i>Dipsacus fullonum</i>	Fuller's teasel
<i>Galium parisiense</i>	wall bedstraw
<i>Hypericum perforatum</i>	St. John's wort
<i>Leontodon nudicaulis</i>	lesser hawkbit
<i>Lolium perenne</i>	perennial ryegrass
<i>Lysimachia nummularia</i>	creeping jenny
<i>Mentha pulegium</i>	pennyroyal
<i>Myosotis discolor</i>	changing forget-me-not

¹ Partial listing

Other Common Non-native Plants	
Scientific Name	Common Name
<i>Parentucellia viscosa</i>	yellow glandweed
<i>Plantago lanceolata</i>	narrowleaf plantain
<i>Prunella vulgaris</i> ssp. <i>vulgaris</i>	common self-heal
<i>Schedonorus arundinaceus</i>	tall fescue
<i>Senecio jacobaea</i>	tansy ragwort
<i>Trifolium dubium</i>	suckling clover
<i>Vicia sativa</i>	garden vetch
<i>Vicia tetrasperma</i>	lentil vetch

A summary of the stressors that may influence the viability of Bradshaw's lomatium are summarized in Table IV-3.

Table IV-3. Stressors that have a negative effect on the individual, population, and species-level needs of Bradshaw's lomatium.

Factors affecting survival of Bradshaw's lomatium		
Individuals	Populations	Species
<ul style="list-style-type: none"> • Shade from encroaching trees likely reduces vigor and reproduction • Competition from invasive plants likely reduces survival • Alterations to wet prairie hydrology degrades habitat quality or renders it unsuitable 	<ul style="list-style-type: none"> • Habitat loss and fragmentation causes reduced availability of habitat, reduced connectivity • Ongoing development pressure may threaten some sites • Natural succession in the absence of active management causes loss of habitat • Invasive plants reduce habitat quality 	<ul style="list-style-type: none"> • Habitat loss and fragmentation reduces number and connectivity of populations throughout the range • Habitat degradation due to invasive plants or succession to woody species reduces resilience of populations

V. CONSERVATION EFFORTS

Extensive research has been conducted on the ecology and population biology of Bradshaw's lomatium, effective methods for habitat enhancement, and propagation and reintroduction techniques (Kagan 1980, Kaye 1992, Kaye and Kirkland 1994, Caswell and Kaye 2001, Kaye and Kuykendall 2001, Kaye *et al.* 2003). The results of these studies have been used to direct the management of the species at sites managed for wet prairies.

Propagation studies have found that long-term (8 weeks) cold stratification was necessary to fully break dormancy in this species (Kaye *et al.* 2003b). Bradshaw's lomatium plants can be grown from seed in a greenhouse environment (Kaye *et al.* 2003b). Plants may be successfully established at existing populations or new locations through outplanting of greenhouse-grown plants. Fertilizing transplants may have a negative effect on survival in some cases. Direct seeding has a relatively high success rate (17 to 38 percent), and is improved by removal of competing vegetation (Kaye and Kuykendall 2001, Kaye *et al.* 2003). Seeds of this species have been banked at the Rae Selling Berry Seed Bank at Portland State University, as well as the University of Washington Botanic Garden.

Studies of the effects of cattle grazing on Bradshaw's lomatium populations show mixed results. Grazing in the springtime, when the plants are growing and reproducing, can harm the plants by biomass removal, trampling and soil disturbance; however, late-season livestock grazing, after fruit maturation, has been observed to lead to an increase in emergence of new plants, and the density of plants with multiple umbels, although it did not alter survival rates or population structure (Drew 2000). Observed increases in seedlings may be due to small disturbances in the soil, a reduction of shading by nearby plants, and reduced herbivory by small mammals.

Populations of Bradshaw's lomatium occur on public lands or lands that are managed by a conservation organization at many sites including, but not limited to, the Service's William L. Finley and Oak Creek units of the Willamette Valley National Wildlife Refuge Complex, the U.S. Army Corps of Engineers at Fern Ridge Reservoir, the Bureau of Land Management at the West Eugene Wetlands, The Nature Conservancy at Willow Creek Natural Area and Kingston Prairie Preserve, Lane County at Howard Buford Recreation Area, Greenbelt Land Trust at Courtney Creek, and McKenzie River Trust at Coyote-Spencer Wetlands. All of these parcels have some level of management for native prairie habitat values (for example, regular mowing or prescribed burning to control woody succession). A number of privately-owned sites are also enrolled in the Natural Resources Conservation Service's Wetland Reserve Program, the Service's Partners for Fish and Wildlife Program, or both.

A habitat conservation plan that addresses conservation of Bradshaw's lomatium within Benton County was completed in 2010 (Benton County 2010, entire). Habitat conservation plans are also in place for Yamhill County road maintenance activities (Yamhill County 2013, entire) and routine road maintenance by the Oregon Department of Transportation (Oregon Department of Transportation 2015, entire). The Oregon Department of Transportation also manages a number of Special Management Areas (SMAs) where Bradshaw's lomatium sites are present in rights-of-way.

A rangewide assessment of Bradshaw's lomatium was completed by the Institute for Applied Ecology in 2016 (Silvernail *et al.* 2016), providing more current data on abundance and habitat quality at many sites considered important for recovery of the species.

Under a cooperative agreement with the Service, the Institute for Applied Ecology also maintains an active seed production program to provide seeds of Bradshaw's lomatium and other native prairie plant species to land managers for population augmentation and restoration projects. In 2016, this program produced 17,300 Bradshaw's lomatium plugs that were outplanted at two sites (Getty 2017, p. 14). The non-governmental organization Friends of Buford Park also produces Bradshaw's lomatium seed sourced from a population in the Eugene East Recovery Zone.

VI. ASSESSMENT OF CURRENT CONDITION

ANALYTICAL APPROACH

Delineation of Populations

Sites of Bradshaw's lomatium, which are typically delineated by ownership or management unit, are distributed across a highly fragmented landscape. After over 150 years of habitat loss, suitable wet prairie habitat is discontinuous throughout the Willamette Valley.

A population of a species is a group of individuals of that species that are demographically and/or genetically connected with each other, and are disjunct from other groups or individuals of that species. In previous assessments of Bradshaw's lomatium, the individual site has commonly been the unit of analysis, without consideration of proximity and potential connectivity to other nearby sites. Analysis at the site level is useful for recovery planning due to differences in ownership and management of nearby sites. The Recovery Team for the Prairie Species of Western Oregon and Southwestern Washington determined that a population of Bradshaw's lomatium may be composed of several smaller subpopulations if they are within

pollinator distance of one another, which they defined as 3 km (2 mi) (U.S. Fish and Wildlife Service 2010). Frequent pollinator-mediated genetic exchange between subpopulations may not be necessary, as models have shown that in general as little as one migrant per generation may be sufficient to prevent the negative effects of inbreeding in disjunct subpopulations of sites (Newman and Tallmon 2001, p. 59; Wang 2004, entire). For the purposes of this SSA, a population of Bradshaw's lomatium is defined as any number of Bradshaw's lomatium sites within the previously agreed-upon pollinator flight distance of 3 km (2 mi) of each other, regardless of site ownership.

Analysis of Population Condition

No quantitative population viability assessment models currently exist that calculate extinction probabilities for Bradshaw's lomatium populations. In this SSA, we utilize the best available scientific data to score the current condition of each population as High, Moderate, or Low based upon our assessment of how well the needs of the population are being met, as detailed here. We evaluated each population in a two-stage process considering overall wet prairie habitat condition, management, site protection, and abundance of Bradshaw's lomatium (see Figure VI-1).

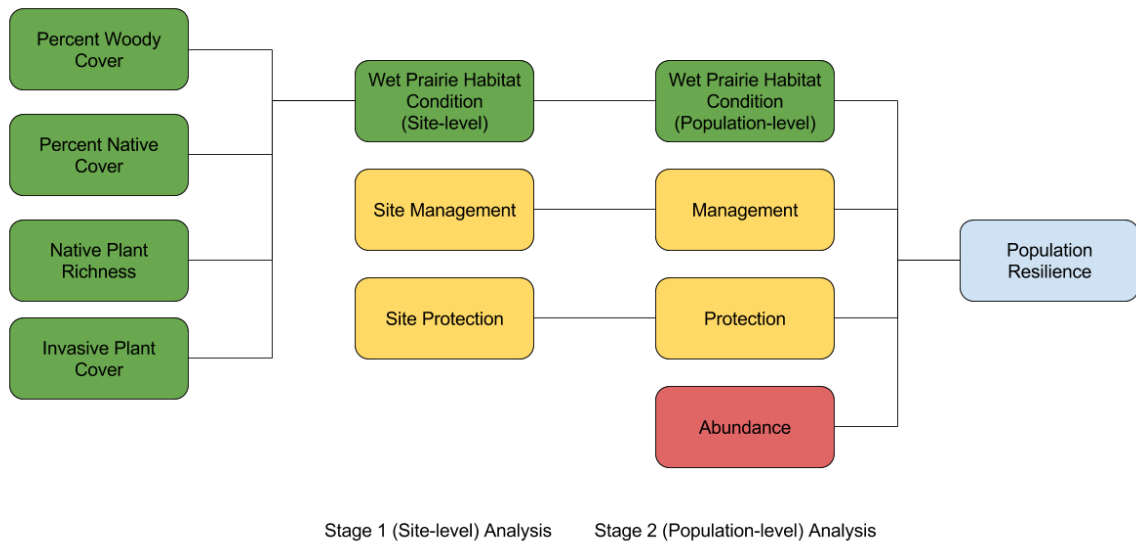


Figure VI-1. Factors used to assess resiliency of Bradshaw's lomatium populations. Green boxes are for factors related to habitat condition. Yellow boxes reflect ownership and management factors. Red represents plant abundance.

The evaluation at Stage 1 is at the site level, and includes an assessment of wet prairie habitat condition, management, and protection. Wet prairie habitat condition is scored based upon the following measurable factors that are likely to influence Bradshaw's lomatium population resiliency: percent woody cover, percent native cover, native plant richness, and invasive plant

cover. These factors were selected as important habitat quality criteria due to their effects on Bradshaw's lomatium as described in Sections III and IV of this SSA. For each site where data on these criteria are available, a score of 1 (Poor), 2 (Fair), or 3 (Good) was assigned for each habitat criterion. Overall wet prairie habitat condition for each site was determined by calculating the mean score across individual habitat criteria for that site. If some data were present for the site but missing for one or more of the factors, that factor was excluded from the calculation of the mean score. Site-level habitat scoring criteria are based upon guidelines for assessing prairie quality developed by the Recovery Team (U.S. Fish and Wildlife Service 2010, pp. D-1 – D-2), the best available scientific data, and the best professional judgment of Service staff. A summary of the site-level habitat scoring criteria we used is presented in Table VI-1.

Table VI-1. Summary of site-level habitat analysis criteria.

Site-Level Habitat Quality Analysis Criteria				
Score	Woody cover	Native cover	Native Richness	Invasive Plants
3 (Good)	<5% woody cover	Relative cover $\geq$ 50%	Total native species richness >10	0 Invasive species of concern* $\geq$ 5% cover -AND- No single non-native plant species >50% cover
2 (Fair)	5-15% woody cover	Relative cover 25-50%	Total native species richness 5-10	1 Invasive species of concern* $\geq$ 5% cover -OR - Any single non-native plant species >50%
1 (Poor)	>15% woody cover -OR- Any woody species of management concern* >5% cover	Relative cover <25%	Total native species richness <5	1 Invasive species of concern* $\geq$ 5% cover and any single non-native plant species >50%; -OR- $\geq$ 2 Invasive species of concern* $\geq$ 5% cover

* A list of invasive species of concern can be found in Table IV-2 of this document

Due to the potential losses of Bradshaw's lomatium populations to development or natural succession to woody habitats in the absence of disturbance, management and site protection that serve to offset the negative effect of these stressors are included in this analysis of current population condition. Because these factors vary within populations based upon ownership, initial analysis is conducted at the site-level. Management and protection at the site-level are each scored as 1 (Poor), 2 (Fair), or 3 (Good) based upon their level of management for the open wet prairie habitat required by Bradshaw's lomatium and type of land protection in place. A summary of site-level management and site protection criteria is available in Table VI-2 below.

Table VI-2. Summary of site-level management and site protection criteria used in this analysis.

Site-Level Management and Protection Analysis Criteria		
Score	Management	Site Protection
3 (Good)	Managed for prairie conditions, management plan in place	Public or Private Conservation Organization ownership, or Public Right-of-Way
2 (Fair)	Generally managed for prairie, management plan not in place	Private with conservation easement or similar program (i.e., the Service's Partners for Fish and Wildlife Program, Natural Resources Conservation Service Wetland Reserve Program)
1 (Poor)	Not managed for prairie conditions -OR- Unknown	Private with no conservation easement

Stage 2 is a population-level analysis, and evaluates the current condition of Bradshaw's lomatium populations. In this stage, a mean of site-level scores for habitat quality, management, and site protection is calculated across all sites within a population. If site protection or habitat

quality is unknown, then that factor is excluded from the calculation of the mean of that factor's site-level scores. For each of these criteria, the population condition is classified as High (mean score ≥ 2.5), Moderate (mean score 1.75-2.49), or Low (mean score < 1.75). Abundance is scored based upon the total number of plants across all sites within a population at the most recent survey as High ($\geq 5,000$ plants), Moderate (2,000-4,999 plants), or Low ($< 2,000$ plants), and assigned scores of 3, 2, or 1, respectively. Abundance data and survey year for sites are available in Appendix A. Overall condition is determined as an average of the individual factors (Wet Prairie Habitat Condition, Management, Protection, and Abundance), with Management weighted twice as much as the other factors due to its relative importance to long-term population resiliency (U.S. Fish and Wildlife Service 2010, pg. IV-5).

Except where otherwise noted, data for this analysis are sourced from the Threatened and Endangered Plant Geodatabase (Version 05/16/2017), developed by the Institute for Applied Ecology under a cooperative agreement with the Service to track the status of ESA-listed species in the Willamette Valley. The details for the analysis of each site are provided in Appendix A.

RESULTS

Southwest Washington Recovery Zone

In the Southwest Washington Recovery Zone (Table VI-3), two adjacent sites comprise one population (WA1) in Moderate condition. This population contains the largest number of Bradshaw's lomatium individuals of any population (10,790,640 plants), with the vast majority occurring in one site (Camas Meadows). The Camas Meadows site is privately-owned, not protected by a conservation agreement, and does not have a management plan, but it is currently being managed in a way that is compatible with maintenance of Bradshaw's lomatium. The second, smaller site (Lacamas Prairie Natural Area Preserve) is owned and managed by the Washington Department of Natural Resources and is actively managed for wet prairie conditions, but no formal management plan is in place (Carlo Abbruzzese, pers. comm. 2017).

Table VI-3. Summary of current condition of Bradshaw's lomatium in the Southwest Washington Recovery Zone.

Population	# of Sites	Abundance	Habitat	Protection	Management	Current Condition
WA1	2	10,790,640	2.875	2	2	Moderate
		High	High	Moderate	Moderate	

With one population and over 10 million plants, the Southwest Washington Recovery Zone currently meets the downlisting goal for minimum number of populations (1) and exceeds the downlisting goal for number of plants (5,000).

Salem East Recovery Zone

The Salem East Recovery Zone (Table VI-4) currently contains three known Bradshaw's lomatium populations. Population SE1 is comprised of a single site and occurs on private property. Though no formal management plan is in place for the property, the owners have begun proactively managing (i.e., mowing, manual removal of invasive plants) for Bradshaw's lomatium (Jeff Dillon, pers. comm. 2017; Chris Seal, pers. comm. 2017). Population SE2 is owned and managed by The Nature Conservancy, and has a management plan in place; and SE3 is protected by a permanent conservation easement. A fourth population, where the species was originally collected in 1916, is considered extirpated.

Table VI-4. Summary of current condition of Bradshaw's lomatium in the Salem East Recovery Zone.

Population	# of Sites	Abundance	Habitat	Protection	Management	Current Condition
SE1	1	10,680 (Jeff Dillon, pers. comm. 2017)	No Data	1	2	Moderate
		High		Low	Moderate	
SE2	1	46,385	2.5	3	3	High
		High	High	High	High	
SE3	2	5,539	2.5	2	3	High
		High	High	Moderate	High	

The Salem East Recovery Zone currently has three populations and more than 60,000 plants, which exceeds the delisting goals for minimum number of populations (2) and target number of plants (10,000). Two of the three populations are permanently protected, and positive management is underway at the third population site.

Corvallis East Recovery Zone

The Corvallis East Recovery Zone (Table VI-5) contains four known Bradshaw's lomatium populations, each of which is composed of a single site. Abundance is relatively low at population CE1, but habitat quality is high, there is a management plan in place, and the site

though privately owned is protected by a Wetland Reserve Program conservation easement. In 2016, 15,500 Bradshaw's lomatium plugs were planted in this population (Getty 2017, p. 14), but establishment has not yet been monitored. Populations CE2 and CE3 are publicly owned, have high habitat quality and a management plan in place, and so score high for all categories of this assessment. For population CE4, no data are currently available to evaluate current condition.

Table VI-5. Summary of current condition of Bradshaw's lomatium in the Corvallis East Recovery Zone.

Population	# of Sites	Abundance	Habitat	Protection	Management	Current Condition
CE1	1	1,535	2.5	2	3	Moderate
		Low	High	Moderate	High	
CE2	1	169,254	2.75	3	3	High
		High	High	High	High	
CE3	1	8,673	2.75	3	3	High
		High	High	High	High	
CE4	1	No Data	No Data	No Data	No Data	No Data

The Corvallis East Recovery Zone contains four Bradshaw's lomatium populations and nearly 180,000 plants. Of these four populations, three are permanently protected and are managed for habitat conditions that support Bradshaw's lomatium. This Recovery Zone meets the delisting goals for number of populations (3) and exceeds delisting goals for number of plants (15,000).

Corvallis West Recovery Zone

The Corvallis West Recovery Zone (Table VI-6) contains four populations across 11 sites. Population CW1 contains two sites in protected ownership (one is publicly owned, the other is managed by a conservation organization), and both sites have management plans. However population CW1 has low abundance. A third site within pollinator flight distance of these two sites is presumed extirpated. Population CW2 has low abundance and is in private ownership with no known management or protection. Population CW3 contains two sites, with the majority of plants (all but one) occurring at a privately-owned site and is enrolled through the Partners for Fish and Wildlife program. The second site in population CW3 is also privately owned, but is protected by a Wetland Reserve Program conservation easement. The abundance is very low and contained a single Bradshaw's lomatium plant at the most recent survey, but has a

management plan in place. Population CW4 contains six sites, five of which occur on William L. Finley National Wildlife Refuge and have a management plan in place. Few data are available for the sixth site in population CW4, which occurs on private land.

Table VI-6. Summary of current condition of Bradshaw's lomatium in the Corvallis West Recovery Zone.

Population	# of Sites	Abundance	Habitat	Protection	Management	Current Condition
CW1	2	166	2.375	3	3	Moderate
		Low	Moderate	High	High	
CW2	1	20	No Data	1	1	Low
		Low		Low	Low	
CW3	2	3445	2.25	2	2.5	Moderate
		Moderate	Moderate	Moderate	High	
CW4	6	14040	2.75	2.67	2.67	High
		High	High	High	High	

The Corvallis West Recovery Zone contains four Bradshaw's lomatium populations and two of these populations contain nearly 17,500 plants. Of these two, one is protected because it is public land managed by William L. Finley National Wildlife Refuge; the other is privately owned, but is partly protected by a conservation easement. Bradshaw's lomatium abundance is too low at the remaining two populations to reliably contribute to recovery criteria outlined in the Recovery Plan, which treats populations with fewer than 200 plants as too vulnerable to stochastic events. This Recovery Zone meets the delisting goals for number of populations (2) and exceeds delisting goals for number of plants (10,000).

Eugene East Recovery Zone

The Eugene East Recovery Zone (Table VI-7) contains three Bradshaw's lomatium populations. Population EE1 is made up of two separate sites owned and managed by Lane County, and a management plan is in place for these sites. A third site in the vicinity of EE1 had been reported at Mt. Pisgah Arboretum, but this report is considered erroneous (Ed Alverson, pers. comm. 2017). Population EE2 contains a single site in private ownership and is protected by a Wetland Reserve Program conservation easement and is enrolled in the Partners for Fish and Wildlife program. The population has very low abundance, but the habitat quality is high and a management plan in place. Population EE3 was recently discovered (Jarod Jebousek, pers. comm. 2017) and is protected because it has been acquired by Greenbelt Land Trust for the purpose of conserving Bradshaw's lomatium; however, no management plan is currently in place. The habitat quality is unknown but there is a substantial population estimated at approximately 25,000 plants.

Table VI-7. Summary of current condition of Bradshaw's lomatium in the Eugene East Recovery Zone.

Population	# of Sites	Abundance	Habitat	Protection	Management	Current Condition
EE1	2	9,451	3	3	3	High
		High	High	High	High	
EE2	1	10	2.75	2	3	Moderate
		Low	High	Moderate	High	
EE3	1	25,000	No Data	3	2	High
		High		High	Moderate	

The Eugene East Recovery Zone contains three populations and nearly 35,000 plants. Two of these populations are large enough to exceed downlisting goals for number of populations (1) and number of plants (5,000), but not to meet delisting goals for number of populations (3).

Eugene West Recovery Zone

The Eugene West Recovery Zone (Table VI-8) contains nine Bradshaw's lomatium populations, made up of 43 sites. Population EW1 is estimated at over 100,000 plants and contains 25 sites with a mix of ownership, including the U.S. Army Corps of Engineers, Bureau of Land Management, Oregon Department of Transportation, City of Eugene, The Nature Conservancy, and private landowners. Of the 25 extant sites in this population, 23 are in ownership that confers some degree of protection and management. Four additional sites within pollinator flight distance are presumed extirpated. Overall current condition of population EW1 is high. Population EW2 is composed of four sites, three of which are protected because they are publicly owned and have management plan in place. Bradshaw's lomatium at one of these sites had been reduced to a single plant, but has recently been planted with 1,750 Bradshaw's lomatium plants by the U.S. Army Corps of Engineers (Wes Messinger, pers. comm. 2017). The other site is privately owned and has a conservation easement in place, but no management plan. The overall current condition of population EW2 is high. Population EW3 contains a single site owned by the City of Veneta and is enrolled in the Partners for Fish and Wildlife Program. This population was augmented with 1,800 Bradshaw's lomatium plugs in 2016 (Getty 2017), but establishment has not been monitored yet. Population EW4 contains two sites owned and managed by McKenzie River Trust, one of which has a management plan in place. The other site is in private ownership with no conservation easement and no known management for prairie conditions. Population EW5 contains two privately owned sites with low abundance, no known management

or protection, and no available habitat data. Population EW6 contains three sites, two of which are owned by the City of Eugene and generally managed for prairie condition. The other site is privately owned, is not protected by a conservation easement or similar program, and management for prairie conditions is unknown. Population EW7 consists of a single site with low abundance, and for which no habitat, ownership, or management data are available. Population EW8 consists of two sites, one of which is within an Oregon Department of Transportation Special Management Area and the other of which is owned and managed by Lane County. Population EW9 consists of three sites, one of which is owned by the City of Creswell, but its management is unknown. The other two sites are privately owned. One of the privately owned sites is enrolled in the Wetland Reserve Program and has a management plan in place, and contains the majority of individuals in this population (1,091 plants). The other privately owned site has no conservation easement, and its management is unknown.

Table VI-8. Summary of current condition of Bradshaw's lomatium in the Eugene West Recovery Zone.

Population	# of Sites	Abundance	Habitat	Protection	Management	Current Condition
EW1	25	141,978	2.68	3	2.54	High
		High	High	High	High	
EW2	4	7,924	2.67	2.67	2.67	High
		High	High	High	High	
EW3	1	3,690	No Data	3	2	Moderate
		Moderate		High	Moderate	
EW4	3	3,769	2.38	2.33	2	Moderate
		Moderate	Moderate	Moderate	Moderate	
EW5	2	28	No Data	1	1	Low
		Low		Low	Low	
EW6	3	32,225	2.5	2.33	1.67	Moderate
		High	High	Moderate	Low	
EW7	1	21	No Data	No Data	1	Low
		Low			Low	
EW8	2	2,007	2.75	3	2.5	High
		Moderate	High	High	High	
EW9	3	1,116	3	1.5	1.67	Low
		Low	High	Low	Low	

The Eugene West Recovery Zone contains nine Bradshaw's lomatium populations and greater than 190,000 plants. Six of these populations contain sufficiently high abundance of plants to exceed delisting criteria (5 populations; 25,000 plants). These six populations are composed of 37 sites with diverse ownership, 33 of which are in protective ownership or have a conservation easement.

SUMMARY OF CURRENT RESILIENCY, REDUNDANCY, AND REPRESENTATION

Resiliency and Redundancy

Resiliency refers to the ability of populations to withstand stochastic events, and is commonly determined as a function of metrics such as population size, growth rate, or habitat quality and quantity. In this assessment, we determined the resiliency of Bradshaw's lomatium populations using measures of population size, current habitat conditions, protections from loss to development, and whether the site is managed to restore and maintain appropriate habitat condition. Long-term monitoring data are not currently available for the majority of Bradshaw's lomatium populations, and was not a component of our resiliency assessment. However, consistent long-term data are available for a limited number of sites (eight; see Appendix B). A visual assessment of these data show apparently stable or increasing trends over the most recent 10 survey years for all but one of these sites (note this should not be interpreted as a rigorous statistical analysis). One site shows an apparent declining trend, but appears to have increased in abundance in the most recent survey after a single year with a substantial decline. Future monitoring of this site would be required to determine any shifts in trend. Sites for which sufficient data are available to evaluate a general trend over time thus generally demonstrate resiliency over at least the last 10 survey years.

Redundancy is defined as a species' ability to withstand catastrophic events, and is measured by the number of populations, their resiliency, and their distribution and connectivity. The Recovery Plan (U.S. Fish and Wildlife Service 2010, entire) established recovery criteria of 12 populations and 60,000 individuals for the species to be downlisted to threatened, and 20 populations and 100,000 individuals for the species to be considered for delisting, with criteria for distribution as well to be achieved on the basis of setting population goals across Recovery Zones. The Recovery Plan also set habitat quality targets, which we have incorporated here into our evaluation of current condition for each population (see Table VI-1; also U.S. Fish and Wildlife Service 2010, pp. D-1 – D-2).

There are currently approximately 11,277,596 Bradshaw's lomatium individuals across 24 known populations, made up of 71 known sites with multiple different ownerships. Of the 71 known sites, 51 are in either public ownership, public right-of-way, or are owned by a conservation-oriented non-governmental organization. Of the 20 remaining sites, 9 are under conservation easement or are enrolled in the Service's Partners for Fish and Wildlife Program, which provides technical and financial assistance to private landowners to restore, enhance, and manage private land to improve native habitat and conserve listed species. The vast majority of known Bradshaw's lomatium individuals (10,790,000 plants) occur at a single site, Camas Meadows, in the WA1 population. Outside of this site, there are approximately 487,596 Bradshaw's lomatium plants at the most recent count, distributed across 70 sites in Washington and Oregon. We considered only populations currently in moderate or high condition, and with at least 200 plants, as contributing to recovery of the species. Including only populations counting toward recovery, there is a total of 11,276,234 individuals of Bradshaw's lomatium in 17 populations in Washington and Oregon, and a total of 485,594 in 16 populations in Oregon alone (Table VI-9).

Table VI-9. Summary of recovery goals and current condition of known Bradshaw's lomatium populations.
Populations with overall low current condition or with fewer than 200 plants are considered likely not stable enough to qualify toward recovery of the species, and are not included here. Recovery zones highlighted in grey meet or exceed downlisting and delisting goals in terms of numbers of populations and target number of plants.

Distribution and Abundance of Bradshaw's lomatium						
Recovery Zone	Downlisting Goals		Delisting Goals		Current Condition	
	Minimum # of Populations / Zone	Target # of Plants / Zone	Minimum # of Populations / Zone	Target # of Plants / Zone	# Populations Qualifying Toward Recovery Criteria	# of Plants in Populations Qualifying Toward Recovery Criteria
OREGON						
Portland	0	0	0	0	0	0
Salem East	1	5,000	2	10,000	3	62,604
Salem West	0	0	0	0	0	0
Corvallis East	2	10,000	3	15,000	3	179,462
Corvallis West	2	10,000	2	10,000	2	17,484
Eugene East	1	5,000	3	15,000	2	34,451
Eugene West	3	15,000	3	15,000	6	191,593
					Subtotal	485,594
WASHINGTON						
SW Washington	1	5,000	2	10,000	1	10,790,640
					Subtotal	10,790,640
+ Additional Populations (may occur in any Recovery Zone within range of Bradshaw's lomatium)	2	10,000	5	25,000		
Total	12	60,000	20	100,000	17	11,276,234

Of the 24 total known populations, 4 are currently in low condition, 9 are in moderate condition, and 10 are in high condition. One population, CE4, had no available data on which to analyze current condition. Populations occur from Camas, Washington, at the northern extent of the range, to Creswell, Oregon, at the southern extent, and occur in all Recovery Zones for the species that have population goals (Figure VI-1). Populations with low condition (CW2, EW5, EW7, and EW9) are concentrated in the southwestern portion of the species' range, including the southernmost known population (EW9). Low abundance, unprotected ownership, and lack of management for prairie conditions are the main drivers of low condition for these populations. Populations with moderate and high condition are fairly evenly distributed throughout the range, with the exception of the Portland and Salem West Recovery Zones which contain no known Bradshaw's lomatium populations. Though within the range of Bradshaw's lomatium, as noted earlier, we have no historical documentation of the occurrence of Bradshaw's lomatium within these two Recovery Zones and they were not assigned specific targets by the Recovery Team.

Our analysis indicates the threat posed by known stressors to Bradshaw's lomatium has decreased relative to the time of listing. In Oregon, where 69 of the 71 sites of Bradshaw's lomatium are found, nearly 99 percent of Bradshaw's lomatium individuals now receive some degree of protection from further habitat loss and fragmentation due to land ownership by Federal, State, or other public entities, non-governmental conservation organizations, or protections through management agreements or conservation easements on private lands. Woody encroachment and competition from invasive plant species continue to act as stressors, but are being addressed by management actions at many sites. Approximately 75 percent of known sites comprising greater than 99 percent of Bradshaw's lomatium individuals receive some degree of habitat management, such as mowing, prescribed burning, or invasive plant treatments. Regular ongoing management is necessary to prevent a decline in habitat quality, and therefore population resiliency, into the future. Appendix A contains the assessed scores for levels of protection and management on a site by site basis which form the foundation of our analysis.

For recovery purposes, our assessment is informative in terms of understanding what would be needed to increase the resiliency of some populations of Bradshaw's lomatium, as no single factor stands out as a primary driver of reduced condition populations throughout the range of the species. For populations CE1, CW1, and EE2, increasing the population size to above 2,000 individuals each would be sufficient to improve their overall condition from moderate to high. For WA1, EW3, and EW4, improvements to management and site protection could change their condition to high. Populations CW2, CW3, EW4, EW5, EW7, and EW9 would require improvements across multiple factors to receive a high condition score.

In assessing the current condition of Bradshaw's lomatium relative to Recovery Plan goals, to be conservative we considered only populations ranked as high or moderate in condition, and with abundance greater than 200 plants. When we apply these criteria, we found that at present, four of the six Recovery Zones with population targets (all except SW Washington and Eugene East) support population numbers that meet or exceed both the downlisting and delisting criteria for the species (Table VI-9). In SW Washington, the abundance criterion is exceeded by more than 10,000,000 plants, but all of these occur in a single large population, and the Recovery Team established a target of two populations in this zone as the delisting goal. In Eugene East, the abundance criterion for delisting is exceeded by more than 15,000 plants. There are three populations in this zone, but one population contains only 10 plants and is vulnerable to stochastic events. The SW Washington and Eugene East populations do meet the downlisting criteria for number of populations and abundance; both populations have the same downlisting criteria of 1 population and 5,000 plants.

Current Condition and Distribution of Bradshaw's Lomatium Populations

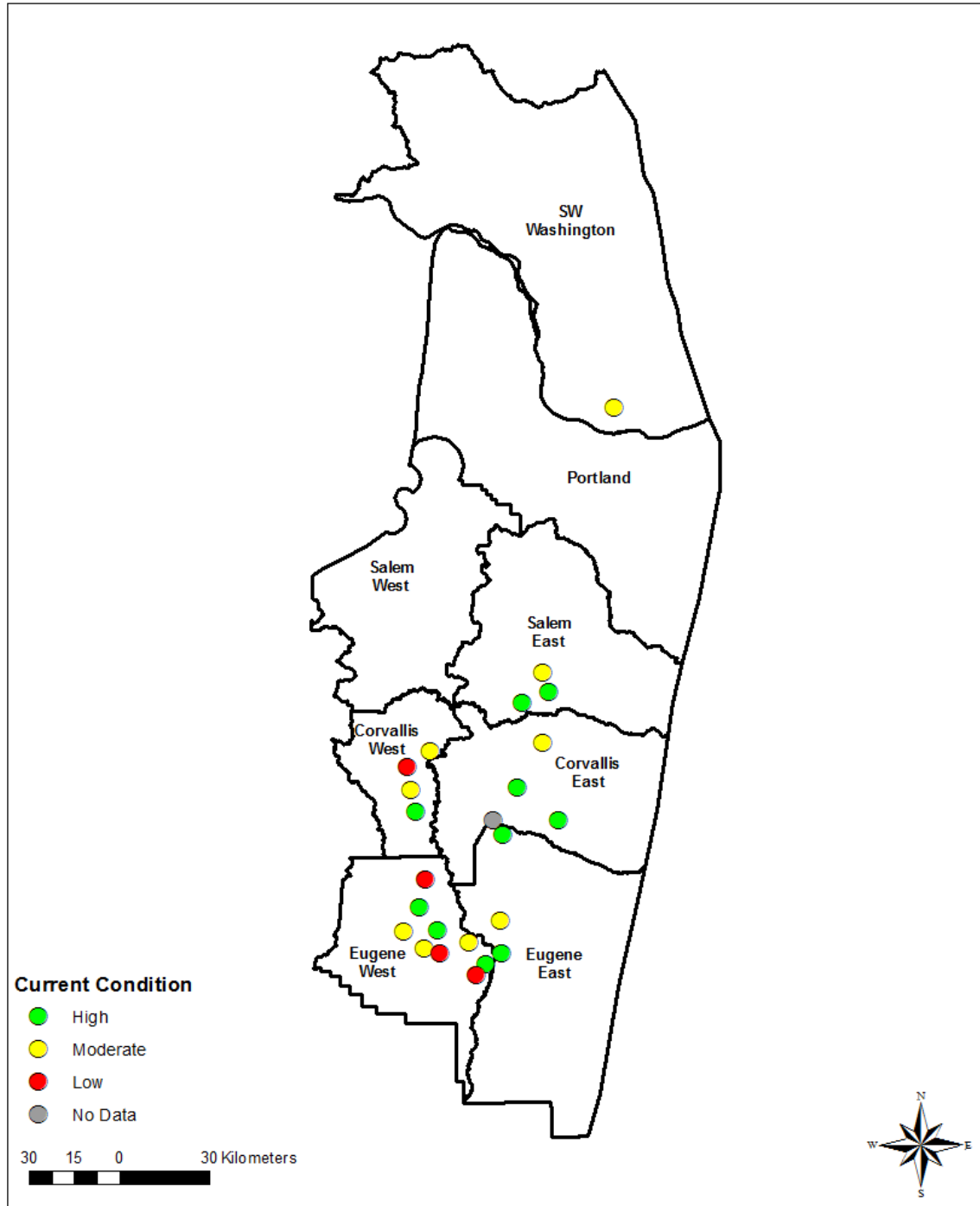


Figure VI-1. Map showing the distribution and current condition of known Bradshaw's lomatium populations.

Representation

Representation refers to the evolutionary capacity of a species to adapt to environmental change, and is measured by the breadth of genetic or ecological diversity within and among populations, as well as geographic distribution of populations.

The 24 known populations of Bradshaw's lomatium span approximately 196 km (122 mi) from Camas, Washington in the north to Creswell, Oregon in the south. Populations are more prevalent west of the Willamette River and south of Salem in Oregon. Populations are more dispersed east of the Willamette River in Oregon, and only one population is known in Washington. The historical distribution of populations is largely unknown.

Throughout its range, Bradshaw's lomatium is restricted to remnant wet prairie habitats, which are highly fragmented due to a history of land conversion and natural succession following alterations to disturbance cycles. The species is sensitive to any hydrologic alterations that reduce early season moisture, as well as to shading due to encroachment of woody species. Overall, ecological diversity is naturally low for the species. Bradshaw's lomatium grows only in wet prairie habitats with either a slowly permeable clay layer or shallow soils overlaying basalt, and appears unable to colonize other habitats. Bradshaw's lomatium thus appears to retain the breadth of its historical ecological representation.

Genetic diversity of Bradshaw's lomatium is relatively high, being comparable to the much more widespread *Lomatium* species cousin biscuitroot. Genetic diversity was lowest (approximately half the percent polymorphic loci and expected heterozygosity compared to the most diverse site sampled) at a site in the WA1 population, which is the most isolated Bradshaw's lomatium population, at approximately 100 km (62 mi) from the nearest population (Gitzendanner and Soltis 2001, pp. 351-353). Based on the data available to us, it appears that Bradshaw's lomatium has retained relatively high genetic diversity, and so we conclude that it also retains its genetic representation.

Summary – Current Condition

The current conditions of Bradshaw's lomatium are summarized in Table VI-10, below. Overall, most populations show good resiliency, with abundant numbers of individuals. Redundancy is good, with multiple populations occurring in all Recovery Zones for the species. Representation is also good, with populations distributed across the historical range of the species and showing relatively high genetic diversity. There is a large gap between the extremely large population in southwest Washington and the remainder of the populations in Oregon's Willamette Valley, but

we have no data to indicate the potential historical occurrence or distribution of the species across the Portland and Salem West Recovery Zones.

Current conditions of Bradshaw's lomatium		
Individuals	Populations	Species
<ul style="list-style-type: none"> • Greater than 11,000,000 individuals across the range of the species • Invasive plants and woody encroachment likely causing mortality and reduced reproduction at some sites • Data lacking on seed production / reproductive rates 	<ul style="list-style-type: none"> • Habitat data lacking for 27 of 71 sites, and for seven entire populations • Some degree of habitat management within 57 of 71 sites at 20 populations • Seven populations rated low for abundance (<2,000 plants), making them more susceptible to stochastic events; of these, five have <200 plants 	<ul style="list-style-type: none"> • 24 populations (10 high condition, 9 moderate, 4 low, 1 not analyzed) • Downlisting recovery targets for minimum number and size of populations met or exceeded in each recovery zone • Genetic diversity relatively high for a rare species

VII. VIABILITY

In this section, we consider the viability of Bradshaw's lomatium 25 to 50 years into the future, taking into consideration the current condition of the species and the identification of any new stressors not considered at the time of listing or recovery plan development. Viability is then assessed in terms of anticipated population resiliency, redundancy, and representation under these future conditions.

ASSUMPTIONS

Conservation Support

Conservation support for Bradshaw's lomatium is high among government agencies, non-governmental conservation organizations, and some private landowners. Partner organizations

meet and interact regularly to coordinate on projects related to recovery of Bradshaw's lomatium and restoration and maintenance of high quality prairie habitat. In general, interest in restoring and conserving prairie habitats in the Willamette Valley appears to be on the rise, based on our own experience with private landowners entering into conservation agreements and reports from multiple conservation partners of insufficient resources to respond to the increasing number of private landowners expressing interest in conservation actions to benefit listed prairie species (e.g., USFWS 2018 *in litt.*, p. 11). Though funding levels may fluctuate over time, it is expected that execution of priority recovery and management actions will at least continue at approximately the current pace.

Management

Management of existing sites for the restoration or maintenance of habitat conditions necessary to support Bradshaw's lomatium (e.g., removal of invasive plants and encroaching woody vegetation) are expected to continue at the same level. Efforts to formalize management plans will continue where they are not currently in place, and to update them as necessary into the future based upon new information and changing conditions.

Site Protection

Sites currently in public or non-governmental conservation organization ownership or under long-term or permanent conservation easements are expected to remain so. Ongoing efforts by government agencies and non-governmental conservation organizations to acquire existing sites on unprotected lands or to establish additional conservation easements are expected to continue. Such efforts could possibly leading to higher degrees of protection. Although it is difficult to predict the future of sites that are currently unprotected, it is reasonable to assume that some of these sites may face development pressure in the future.

CONSIDERATION OF ADDITIONAL STRESSORS

Climate Change

In the Pacific Northwest, temperature increases of 3 to 6°C (5.4 to 10.8°F) are predicted by the end of the 21st century. Winter precipitation is predicted to increase, though increased summer temperatures are expected to cause increased evapotranspiration, thus causing reduced growing season soil moisture (Bachelet *et al.* 2011, p. 414). Bradshaw's lomatium is hydrologically sensitive, and reduced soil moisture could stress individuals and populations of the species. Existing climate vulnerability assessments of Bradshaw's lomatium have rated it as moderately

vulnerable (Steel *et al.* 2011, pp. 25, 89) or moderately- to highly vulnerable (Kaye *et al.* 2013, p. 20) to the effects of climate change. We therefore evaluated the viability of Bradshaw's lomatium over a range of time 25 to 50 years into the future, which is the length of time over which we conclude we can make reliable predictions about the anticipated effects of climate change. We do not have any quantitative estimates of how climate change may affect populations of Bradshaw's lomatium, only the aforementioned assessments that estimate the species will be moderately to moderately-to-highly vulnerable to its effects. Possible effects of climate change on Bradshaw's lomatium include increased reproduction after increased early precipitation, temporal shifts in life cycle completion to earlier in spring (earlier germination and seed set), and increased mortality and decreased recruitment due to alterations in hydrology. To be conservative in our projections, we assumed that under the anticipated effects of climate change and the assumptions outlined above, all populations of Bradshaw's lomatium would be reduced by 50 percent within a period of 25 to 50 years. We then reassessed population condition applying the same methodology we used for assessing current condition.

RESULTS

Resiliency

Five populations (CW1, CW2, EE2, EW5, EW7) have very low abundance of Bradshaw's lomatium plants, and are highly vulnerable to stochastic events. These populations carry a relatively higher risk of extirpation in the future due simply to their small size and subsequent vulnerability to both stochastic and catastrophic events. Climate change impacts compound the risk to these populations and have the potential to negatively affect habitat quality and abundance at all Bradshaw's lomatium populations, leading to reductions in resiliency throughout the range of the species. Populations with very high abundance, such as SE2 (46,386 plants) and CE2 (169,254 plants) are likely to maintain higher resiliency into the future than those with fewer plants such as SE3 (5,539 plants), as their higher numbers buffer them from stochastic variation in environmental conditions and potential extirpation from catastrophic events.

A significant point of uncertainty is the future status of those populations currently rated as moderate condition. Declines in abundance and habitat quality due to climate change impacts and stochastic events may drive some of these populations to low condition in the future, though active adaptive management may help mitigate some declines.

A high degree of uncertainty surrounds the magnitude of impacts that can be expected due to climate change. Due to this uncertainty, we do not seek to predict a distinct magnitude of decline for each population. Rather, as described above, to be conservative we use a standard 50 percent reduction in individuals for forecasted future abundance predictions.

Redundancy

The possible extirpation of five populations (CW1, CW2, EE2, EW5, EW7), combined with the possible decline of some populations from moderate to low condition due to climate change impacts, may reduce the number of known Bradshaw's lomatium populations from the current condition of 19 in moderate or high condition to 14 to 16 in moderate or high condition throughout the range. The Corvallis West recovery zone would be left with only two known populations, one of which (CW3) is at risk of declining to low condition overall. Future losses could be offset by active augmentation of existing populations or the establishment of new populations in high quality habitats where Bradshaw's lomatium is currently absent. There is also the potential for more Bradshaw's lomatium populations to be discovered, as has happened in recent years (Jarod Jebousek, pers. comm. 2017). Estimates of the possible future abundance and distribution of Bradshaw's lomatium under the assumptions described above for assessing the potential effects of climate change are presented in Table VII-1.

Representation

No major changes are predicted regarding the genetic or ecological diversity of Bradshaw's lomatium as a result of the effects of climate change. The species is likely to continue to occupy wet prairie habitats throughout its range, though some degree of range contraction may occur if wet prairie conditions are altered in some areas as a result of climate change. The five populations that we identified as potentially vulnerable to extirpation under such a scenario (CW1, CW2, EE2, EW5, EW7) are relatively small and distributed across multiple recovery zones, thus we anticipate that any range contraction that might occur will not be concentrated in any particular area of the species' range and therefore will not have a disproportionate impact on representation.

Viability

Under the possible effects of climate change as evaluated here, Bradshaw's lomatium may experience some reductions in resiliency and redundancy. We concluded that populations currently in low condition or with very low abundance may be extirpated due to the combined effects of climate change impacts and stochastic events; this translates to an estimated loss of up to 5 small populations, with other populations reduced in size. However, even with a 50 percent reduction in abundance under the conditions of climate change, at least 14 to 16 populations in moderate or high condition are expected to persist on the landscape with ongoing management.

We do not anticipate any significant effect on representation as described above. In addition, to be conservative, we did not consider that ongoing efforts to improve population sizes and habitat quality have the potential to increase the number of resilient populations of Bradshaw's lomatium. Many stressors to the species are being addressed through habitat management and population augmentation, but ongoing management is necessary to maintain resilient populations throughout the species' range.

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Table VII-1. Distribution and abundance goals for Bradshaw's lomatium recovery, along with current and predicted future abundance and distribution of populations rated as moderate or high condition. *Populations with overall low current condition or with fewer than 200 plants are not likely stable enough to qualify toward recovery of the species, and are not presented here.*

Recovery Zone	Downlisting Goals		Delisting Goals		Current Condition		Predicted Future Condition	
	Minimum # of Populations / Zone	Target # of Plants / Zone	Minimum # of Populations / Zone	Target # of Plants / Zone	# Populations Qualifying Toward Recovery Criteria	# of Plants in Populations Qualifying Toward Recovery Criteria	# Populations Qualifying Toward Recovery Criteria	# of Plants in Populations Qualifying Toward Recovery Criteria
SW Washington	1	5,000	2	10,000	1	10,790,640	1	>5,000,000
Portland	0	0	0	0	0	0	0	0
Salem East	1	5,000	2	10,000	3	62,604	3	>30,000
Salem West	0	0	0	0	0	0	0	0
Corvallis East	2	10,000	3	15,000	3	179,462	2 -3	>90,000
Corvallis West	2	10,000	2	10,000	2	17,484	1	>9,000
Eugene East	1	5,000	3	15,000	2	34,451	2	>17,000
Eugene West	3	15,000	3	15,000	6	191,593	5-6	>95,000
+ Additional Populations (may occur in any Recovery Zone within range of Bradshaw's lomatium)	2	10,000	5	25,000				
Total	12	60,000	20	100,000	17	11,276,234	14-16	>5,241,000

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GLOSSARY

Caudex – A short, vertical stem at or just below the surface of the ground

Filiform – Slender, threadlike

Glabrous – Smooth, without glands or hairs

Hydric soils – Soils formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

Inflorescence – The floral cluster of a plant

Peduncle – The stalk of a solitary terminal flower, or of an inflorescence

Protandry – Maturation of male flowers before female flowers on a single plant

Protogyny – Maturation of female flowers before male flowers on a single plant

Redundancy – Having a sufficient number of populations for the species to withstand occasional catastrophic events. Redundancy is a function of the number and resilience of populations, as well as their distribution and connectivity.

Representation – The capacity of a species to adapt to environmental change, based upon considerations of geographic, genetic, ecological, and niche diversity. Representation overlaps with the measure of redundancy.

Resiliency – Having sufficiently large populations to withstand stochastic events (random variation in environmental or demographic factors, such as variability in rainfall or changes in sex ratios).

Schizocarp – A fruit which splits into its separate carpels at maturity

Taproot – A large, main root

Umbel – A flat-topped or convex inflorescence with pedicels arising from a common point

Umbellet – An ultimate umbellate cluster of a compound umbel

Viability – The ability of a species to maintain multiple (redundant) self-sustaining (resilient) populations distributed across a range that captures the ecological and genetic diversity of the species (representation).

APPENDIX A – Site level analysis for current condition; sites that are blacked out are presumed extirpated. (Abbreviations: BLM- Bureau of Land Management; GLT – Greenbelt Land Trust; MRT – McKenzie River Trust; ODOT – Oregon Department of Transportation; PFW – Partners for Fish and Wildlife; TNC – The Nature Conservancy; USACE – U.S. Army Corps of Engineers; USFWS – U.S. Fish and Wildlife Service; WNHP – Washington Natural Heritage Program; WRP – Wetland Reserve Program)

Population	Site	Count	Habitat	Protection	Management	Ownership	Easement, Other	Count source
WA1	Camas Meadows	10790000	2.75	1	2	Private		Report 2010
	Lacamas Prairie Natural Area Preserve	640	3	3	2	WNHP		Field Survey 2016
SE1	Sublimity Grasslands	10,680	No Data	1	2	Private		Field Survey 2017 (Jeff Dillon, p.c.)
SE2	Kingston Prairie Preserve	46385	2.5	3	3	TNC		Report 2008
SE3	SE3 WRP NE	1797	2.5	2	3	Private	WRP	Field Survey 2016
	SE3 WRP SW	3742	No Data	2	3	Private	WRP	Field Survey 2014
CE1	CE1 WRP	1535	2.5	2	3	Private	WRP	Field Survey 2016
CE2	Oak Creek	169254	2.75	3	3	USFWS		Report 2007
CE3	Sweet Home - Hobart Park	8673	2.75	3	3	City of Sweet Home		Field Survey 2012
CE4	Brownsville	No Data	No Data	No Data	No Data	Private		No Survey data

Population	Site	Count	Habitat	Protection	Management	Ownership	Easement, Other	Count source
CW1	Jackson-Frazier Wetland	165	2	3	3	Benton Co., City of Corvallis		Field Survey 2012
	Owens Farm	1	2.75	3	3	GLT		Field Survey 2012
	Conifer Blvd	0	ORBIC 2005					
CW2	Holmes	20	No Data	1	1	Private		FWS data 2008
CW3	Cutler Lane	3444	2.75	2	2	Private	PFW	Field Survey 2016
	CW3 WRP	1	1.75	2	3	Private	WRP	Field Survey 2012
CW4	Buchanan Rd	20	No Data	1	1	Private		IAE data 2007
	Finley NWR Field 1	4106	2.75	3	3	USFWS		Field Survey 2016
	Finley NWR, Field 31	7573	2.75	3	3	USFWS		Field Survey 2016
	Finley NWR, Muddy Creek Middle	50	No Data	3	3	USFWS		ORBIC 2005
	Finley NWR, North Road	2251	2.75	3	3	USFWS		Field Survey 2016
	Finley NWR, Willamette Floodplain RNA	40	No Data	3	3	USFWS		ORBIC 2005

Population	Site	Count	Habitat	Protection	Management	Ownership	Easement, Other	Count source
EE1	Buford Park Main Patch	1996	3	3	3	Lane Co.		Field Survey 2016
	Buford Park Satellite Patches	7455	3	3	3	Lane Co.		Field Survey 2013
EE2	EE2 WRP	10	2.75	2	3	Private	WRP, PFW	Field Survey 2013
EE3	Courtney Creek	25000	No Data	3	2	GLT		Field Survey 2015

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Population	Site	Count	Habitat	Protection	Management	Ownership	Easement, Other	Count source
EW1	Amazon Dike #2 (Fern Ridge Reservoir)	21236	2.5	3	3	USACE		Field Survey 2014
	Balboa	234	3	3	3	BLM		Field Survey 2015
	Fern Ridge East Coyote Dikes	2180	2.25	3	3	USACE		Field Survey 2014
	Amazon Canal ROW (Fir Butte)	446	No Data	3	1	City of Eugene		Report 2012
	Fisher Butte (Fern Ridge)	11113	3	3	3	USACE		Field Survey 2014
	Fisher Butte - ODOT SMA East	62	2.25	3	3	ODOT		Field Survey 2014
	North Fisher Butte	211	3	3	3	USACE		Field Survey 2014
	North Greenhill - Ash Grove	83	2.75	3	3	BLM		Field Survey 2015
	North Greenhill - IAE Introduced	593	2.75	3	3	BLM		Field Survey 2015
	Oak Patch	370	2.75	3	2	City of Eugene		Report 2014
	Fern Ridge Rose Prairie	5456	2.25	3	3	USACE		Field Survey 2014
	Rosy	562	3	3	3	BLM		Field Survey 2015
	Royal Amazon RNA	74433	3	3	3	USACE		Field Survey 2014
	Fern Ridge Green Oaks South	2086	2.25	3	3	USACE		Field Survey 2014

Population	Site	Count	Habitat	Protection	Management	Ownership	Easement, Other	Count source
EW1, cont.	Speedway East / Cuddeback Unit	423	2.75	3	3	TNC		Field Survey 2015
	Dragon Fly Bend	1	No Data	3	1	BLM		ORBIC 2000
	Greenhill / Royal	18270	2.5	3	3	TNC		Report 2011
	Bertelsen Road	23	No Data	No Data	1			ORBIC 1991
	Greenhill / Royal	0				City of Eugene		ORBIC 2005
	Wallis St	450	No Data	No Data	1	Private		ORBIC 2005
	Neilsen Road Substation	160	No Data	No Data	1	USACE		ORBIC 2005
	Fern Ridge Fisher Butte West ²					USACE		
	Vinci	2	No Data	No Data	3	BLM		ORBIC 2004
	Nielson	2	No Data	No Data	3	BLM		ORBIC 2004
	Spectra Physics	0			3	BLM		Field Survey 2015
	Oxbow East	1	No Data		3	BLM		ORBIC 2003
	Oxbow West	0			3	BLM		Report 2010
	Fisher Butte - ODOT SMA West	3573	2.75	3	2	ODOT		Field Survey 2012
	Willow Corner Annex	8	No Data	3	3	BLM		Field Survey 2015

² Presumed extirpated based on anecdotal information (as opposed to survey data)

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Population	Site	Count	Habitat	Protection	Management	Ownership	Easement, Other	Count source
EW2	Lomatium Prairie	5814	2.75	2	2	Private	MRT, PFW	Report 2013
	Long Tom River ACEC	1440	2.75	3	3	BLM		Field Survey 2014/5
	North Taylor	670	2.5	3	3	BLM		Field Survey 2015
	Fern Ridge Reservoir - Kirk Pond	0	No Data	3	3	USACE		ORBIC 2002
EW3	Veneta	3690	No Data	3	2	City of Veneta	PFW	Field Survey 2016
EW4	Bloomer	311	2.5	3	2	MRT		Field Survey 2014
	Coyote-Spencer Wetlands	3371	2.25	3	3	MRT		Field Survey 2012
	Petzold Road	87	No Data	No Data	1	Private		ORBIC 1990
EW5	Spencer Creek North	28	No Data	No Data	1	Private		ORBIC 1991
	Spencer Creek South	No Data	No Data	No Data	1	Private		ORBIC 1990

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Population	Site	Count	Habitat	Protection	Management	Ownership	Easement, Other	Count source
EW6	Amazon Park	31200	2.5	3	2	City of Eugene		Report 2012 (In Silvernail 2016)
	19th & Pearl	25	No Data	1	1	Private		ORBIC 2005
	Amazon & 35th	1000	No Data	3	2	City of Eugene		Steeck, p.c. 2017
EW7	High Pass Road	21	No Data	No Data	1	Unknown		ORBIC 2005
EW8	Camas Swale	1375	3	3	3	ODOT		Field Survey 2014
	Short Mountain Landfill	632	2.5	3	2	Lane Co.		Field Survey 2016
EW9	Creswell (Wastewater Treatment Plant)	20	No Data	No Data	1	City of Creswell		ORBIC 2005
	Danville Rd	5	No Data	1	1	Private		ORBIC 1990
	EW9 WRP	1091	3	2	3	Private	WRP	Field Survey 2014

APPENDIX B – Long-term population trends at all sites with sufficient survey data available over time. Blue markers and lines indicate survey data in a given year. Red dotted lines indicate trends over the most recent 10 survey years. Horizontal green lines represent median population size over the period for which survey data exist.

