Developing biogeographically based population introduction protocols for at-risk plant species of the interior valleys of southwestern Oregon:

Fritillaria gentneri (Gentner's fritillary)
Limnanthes floccosa ssp. *bellingeriana* (Bellinger's meadowfoam)
Limnanthes floccosa ssp. *grandiflora* (big-flowered wooly meadowfoam)
Limnanthes floccosa ssp. *pumila* (dwarf wooly meadowfoam)
Limnanthes gracilis var. *gracilis* (slender meadowfoam)
Lomatium cookii (Cook's desert parsley)
Perideridia erythrorhiza (red-rooted yampah)
Plagiobothrys hirtus (rough popcorn flower)
Ranunculus austro-oreganus (southern Oregon buttercup)

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Report format:

The following species are presented in alphabetical order: *Fritillaria gentneri* (Gentner's fritillary), *Limnanthes floccosa* ssp. *bellingeriana* (Bellinger's meadowfoam), *Limnanthes floccosa* ssp. *grandiflora* (big-flowered wooly meadowfoam), *Limnanthes floccosa* ssp. *pumila* (dwarf wooly meadowfoam), *Limnanthes gracilis* var. *gracilis* (slender meadowfoam), *Lomatium cookii* (Cook's desert parsley), *Perideridia erythrorhiza* (red-rooted yampah), *Plagiobothrys hirtus* (rough popcorn flower), and *Ranunculus austro-oreganus* (southern Oregon buttercup). Each species' section consists of segments covering Conservation Status, Range and Habitat, Species Description, Seed Production, Seed Germination, Vegetative Reproduction, Breeding System, Hybridization, Cultivation, Transplanting and Introduction Attempts, Population Monitoring, and Land Use Threats and other Limitations, followed by a final segment outlining a specific Population Introduction/Augmentation Strategy.

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Developing biogeographically based population introduction protocols for at-risk plant species of the interior valleys of southwestern Oregon:

Lomatium cookii
(Cook's desert parsley)

Lomatium cookii. ODA photo.

Lomatium cookii (Cook's desert parsley)

Conservation status

Lomatium cookii Kagan, or Cook's desert parsley (Figure 14), is a rare member of the carrot family (Apiaceae). This inconspicuous plant is listed as endangered by both the U.S. Fish and Wildlife Service (USFWS) and the state of Oregon. It is on the Oregon Natural Heritage Information Center (ORNHIC) List 1 (endangered or threatened throughout its range), and has a Natural Heritage Network Rank of G1/S1 (critically imperiled throughout its range/critically imperiled in Oregon) (ORNHIC 2004a). It is closely related to *Lomatium bradshawii* (Rose) Math. & Const., another endangered species found in the Willamette Valley of western Oregon.

Figure 14. *Lomatium cookii* flowers. Oregon Department of Agriculture file photo.

Lomatium cookii's range is limited to two population centers in southwestern Oregon, located in Josephine and Jackson Counties. As with many rare and endangered plants, the loss and deterioration of habitat poses the largest threat to *L. cookii*'s continuing survival and well-being. In the Illinois Valley in Josephine County, much of *L. cookii*'s original and potential habitat has been lost to rural development and agriculture. Several sites within the Bureau of Land Management's (BLM) French Flat Area of Environmental Concern (ACEC) have been severely damaged by unauthorized off-road vehicle use, and active mining concerns have permanently altered much of the meadow hydrology, further degrading the habitat (Kaye 2003). Without steps taken to protect existing sites and develop new populations, *L. cookii* has a very good chance of becoming extinct in the near future.

Range and habitat

Lomatium cookii is endemic to southwestern Oregon (Figure 15), occurring only in the Rogue River basin. Its two distinct population centers are located about 30 miles apart (Kagan 1994). The Oregon Natural Heritage Information Center (ORNHIC 2004b) lists 38 populations in its database, although some of these populations were very small (50 plants or less) and their current status is not known.

In Jackson County, *L. cookii* inhabits seasonally wet areas known as vernal pools. This habitat occurs in patches throughout an area of approximately 83 km^2 in the Agate Desert, located north of Medford (USFWS 2002b). The Agate Desert is characterized by

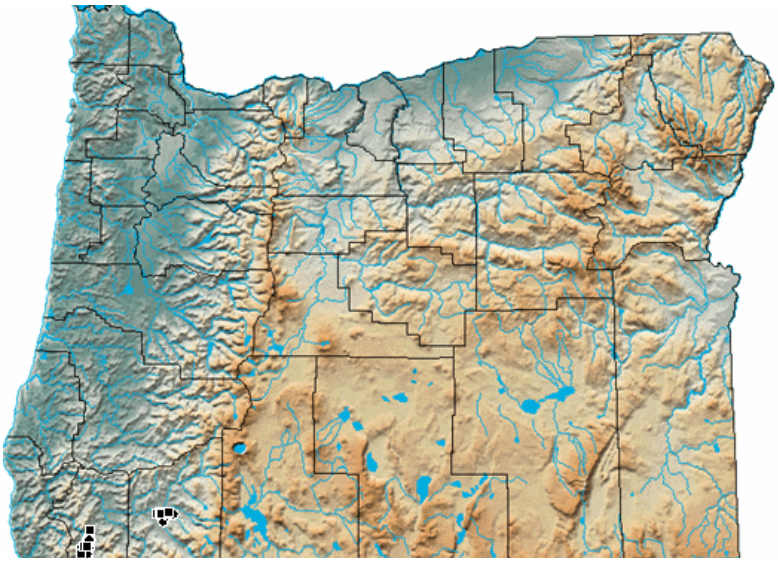

Figure 15. Map showing locations of populations in Jackson and Josephine Counties. Map courtesy of the Oregon Flora Project's Plant Atlas.

shallow, Age-Winlow complex soils, sparse prairie vegetation with relatively few trees and, as might be surmised from its name (Agate Desert), agates frequently present on the soil surface. The landscape consists of a low mound-swale topography, where shallow pools develop in the swales from about December through April or May. These pools vary in size from 1 to 30 meters across, with their depth no greater than 30 cm (USFWS 2002a). The pools themselves usually have stony bottoms, while the mounds are relatively rock-free, with clay-loam soils (NatureServe 2003). Plant species native to these pools are often adapted to grow, flower and set seed during the short time that water is available in the spring, finishing their life cycle before the dry hot summers. Some of the associated plants that occur with *L. cookii* in these vernal pools include: *Limnanthes floccosa* ssp. *grandiflora* (also listed as endangered), *Plagiobothrys bracteatus*, *Juncus uncialis*, *Navarretia* spp., *Limnanthes floccosa* ssp. *floccosa*, *Deschampsia danthonioides*, and *Triteliea hyacinthina* (USFWS 2002a).

Two of the fifteen Agate Desert *L. cookii* populations occur at least partially within the Agate Desert Preserve, owned by The Nature Conservancy (TNC). The Preserve contains the only large populations on private land specifically managed for the protection of these species. Several of the populations reside at least in part on public lands, with two occurring on State land (primarily in the Ken Denman Wildlife Area), two located on land managed by Jackson County, and two on lands owned by the City of Medford (within an area designated as the Whetstone Industrial Park). Portions of two sites are located in highway or powerline rights-of-way (ORNHIC 2004b).

In Josephine County, the populations are located in the Illinois Valley near the Siskiyou Mountains, where they tend to occur in seasonally wet grassy meadows on alluvial floodplains. The underlying soil forms a clay pan 60-90 cm below the surface, which causes the meadows to retain water in the winter, mimicking the vernal pool habitat (without the accompanying mounds) found in the Agate Desert. These meadows are dominated by California oatgrass (*Danthonia californica*), and other associated species include *Deschampsia cespitosa*, *Festuca rubra*, *Stipa lemmonii*, *Plagiobothrys bracteatus*, *Camassia quamash*, *Ranunculus occidentalis*, *Downingia yina*, *Horkelia*

daucifolia, *Calochortus nudus* and *Viola hallii*. One clump of *L. cookii* was observed growing up through a dense ground-cover of poison oak (*Toxicodendron diversiloba*) at the Rough and Ready Creek Botanical Wayside. The meadow habitat is frequently bordered by *Pinus ponderosa*, *Pinus jeffreyi*, *Arctostaphylos* spp. and *Ceanothus cuneatus* (Kaye 2003).

Currently, the Illinois Valley *L. cookii* populations lie in an area that encompasses roughly 10 km^2. The 21 sites listed in the Oregon Natural Heritage Program's database (ORHNIC 2004b) are found at the following locations: French Flat (south central Josephine County), Rough and Ready Creek Forest Wayside State Park (southwestern Josephine County), both east and west of Cave Junction, east and southeast of Woodcock Mountain near Woodcock Creek, and a few scattered sites are northeast of Kerby near Reeves Creeks (USFWS 2002a). Fifteen of these sites are located partially or entirely on land managed by the BLM. The remaining sites occur predominately on private land.

Species description

Lomatium cookii (Figure 16) was relatively recently described by Kagan (1986) as an inconspicuous perennial forb that grows anywhere from 1.5 – 5 dm (although usually less than 3 dm) tall. It has a slender twisted taproot from which a basal rosette of smooth, finely dissected leaves arise. Creamy yellow flowers are produced in compound umbels on leafless stems (Figure 17). The taproot can often branch at ground level to produce multiple stems. Fruits are boat-shaped, 8-13 mm long and have thickened margins.

There are several *Lomatium* species which are closely related to *L. cookii* and occur in a similar range or habitat, but they are fairly easy to distinguish in the field. *Lomatium cookii*'s branching taproot separates it from its closest relative, the Willamette Valley endemic *L. bradshawii*, and the northern California vernal pool dweller *L. humile*. *L. urtriculatum* (fine-leaved desert parsley), is found on the mounds scattered among the vernal pools in the Agate Desert, and may be distinguished from *L. cookii* by its more vibrant yellow flowers, the shape of its involucel bracklets (broad as opposed to narrow),

Figure 16. *Lomatium cookii* plant habit. Oregon Department of Agriculture file photo.

Figure 17. *Lomatium cookii* umbels. Oregon Department of Agriculture file photo.

and its thin-winged fruits (Kagan 1986). The range of *L. tracyi* (Tracy's lomatium) extends up from California into the Illinois Valley. While *L. tracyi* has a similar appearance to *L. cookii*, it has slender-margined fruits and is able to grow on drier sites (Kagan 1986, USFWS 2002a). At the seedling stage, *L. cookii* can be identified by its lack of a reddish, scabrous petiole and its fewer and more linear ultimate leaf segments (NatureServe 2003).

There are slight morphological differences between the Agate Desert and Illinois Valley populations of *L. cookii*, but these differences are not considered significant enough to separate the species into subspecies. Recent genetic research supports this conclusion, finding no evidence of significant genetic differences between plants in the two populations centers that would warrant the separation of species into subspecies (Gitzendanner and Soltis 2001).

Seed production

Lomatium cookii's flowering stems begin to emerge from the rosette of leaves toward the end of winter, and the flowers start to open in mid-March and continue blooming into May (Kagan 1986). Like several other species of *Lomatium*, the majority of *L. cookii*'s earliest umbels are staminate, whereas umbels produced later in the season tend to have both staminate and perfect flowers. Typically, these *Lomatium* species produce very few, if any, fruits on the plants that have only one umbel. Individuals with two or three umbels can produce several to many fruits (Kaye 2003). Brock (1987) found that mature *L. cookii* individuals usually produced 2-5 flowering umbels (8-20 umbellets) with a total of 100-250 flowers per plant.

L. cookii flowers are protogynous, with the stigmas receptive before anthers on the same flower dehisce (Kagan 1986). Fruits begin development 14-20 days after stigma exsertion, and mature in 4-5 weeks (Brock 1987). In spite of the fairly large number of individual flowers, seed production does not appear to be prolific. While there is little information available regarding seed production of *Lomatium cookii*, Kagan (1980) sampled seed production of the closely related (and also rare), *L. bradshawii*. He found

the mean number of fruits per plant to range from 7.2-18.5. Other *L. bradshawii* studies found similar numbers of fruits per plant, although fruit production did vary in response to location, year and burning regime (Pendergrass et al. 1999, Kaye 2003).

Seed germination

In the field, *Lomatium cookii* seed germination begins around the first week of February, with most seeds sprouting simultaneously, although sporadic germination continues for the next month or so. Seeds in pools germinate about a week later than those on pool margins or mounds (Brock 1987). It is no surprise, then, that preliminary germination studies indicate that *L. cookii* seeds require a period of cold stratification in order to germinate. Brock (1987) found that seeds required 7 weeks to 4 months of stratification at cool temperatures to germinate. In another study, the Berry Botanic Garden (BBG) conducted a series of germination trials, using three batches of seed which had been stored in their seed bank. These 11, 12 and 16-year-old seeds were subjected to four sets of environmental conditions with two variables: length of cold stratification and growth chamber temperature regime. Cold stratification for 8-16 weeks followed by a 68° F (20°C) or 50°F/68°F (10°/20°C) temperature treatment resulted in 20-100% germination, depending on the parent plant. BBG found that no one treatment was consistently better than the others, but the 16-year-old seeds did yield a maximum of 90% germination after 8 weeks of cold stratification followed by alternating 50°F/68°F (10°/20°C) temperatures (Gasser 1999). The Nature Conservancy (TNC) also conducted germination trials (Preszler and Nitsos 1984), and found *L. cookii* seed viablility to be quite high (88.5%) when seeds were treated with tetrazolium chloride.

Because of the close relationship between *L. cookii* and *L. bradshawii*, it is of interest to note that the most recent *L. bradshawii* seed germination attempts, performed by Lynda Boyer of Heritage Seedlings Inc. (pers. comm. 2004), yielded nearly 100 percent germination by mixing seeds with pre-moistened vermiculite inside sealed plastic bags and cold stratifying the mixture at 1°C for 11 weeks. This seed/vermiculite mixture was then sown into soil-filled flats and covered with a "light dusting of soil." Using this method, germination typically occurred within 7 days of sowing.

Vegetative reproduction

Lomatium cookii has a long, slender taproot (Kagan 1986), and, like other tuberous species in the genus, is not capable of spreading vegetatively (Kaye 1999).

Breeding system

Several pollinators have been observed visiting *Lomatium cookii*, including a small bee in the Andrenae family and a small black moth (Kaye 2003, Kagan 1986). During monitoring visits to the French Flat population in 1994 and 1995, numerous bumblebees (*Bombus* sp.) were observed making repeated visits to the flowers of *L. cookii* (Kaye 1999). In a general study of pollination in the genus *Lomatium*, Schlessman (1982) found that insects visiting tuberous *Lomatium* species were found to represent 19 families in the orders Diptera, Hymenoptera and Coleoptera, with examination of the pollen loads confirming that all the insects carried *Lomatium* pollen.

It has been speculated that *L. cookii*, like other species of the Apiaceae family, is self-compatible (Kagan 1994). It is clear, however, that the pollination biology of this species has not been sufficiently studied, and the conflicting reports regarding the self-compatibility of *L. cookii*'s closest relative, *L. bradshawii*, only add to the confusion. Kaye (1999) showed, through a pollinator exclusion experiment, that autogamy was not likely because protogyny completely separated the sexual phases of flowers within an inflorescence. As a result, outcrossing rates were very high within populations, and insects were thought to be required for fruit production. Twenty-six of the 38 observed insect visitors had *Lomatium* pollen on their bodies. On the other hand, Kagan (1980) showed that the *L. bradshawii* is completely self compatible, and suggested that plants were capable of seed production through selfing in the absence of pollinators. Kagan observed very few insects acting as pollinators, and he speculated that some between-umbel pollination could occur through wind dispersal of pollen. He also noted that higher fruit set among plants more distant from their nearest neighbors may indicate some inbreeding depression.

Hybridization

To date, no hybridization research has been conducted regarding potential hybridization between *L. cookii* and other *Lomatium* species. None of the literature reviewed mentions hybridization as a possibility or concern.

Cultivation

Once again, there is little information available on the cultivation of *L. cookii*. In the field, *L. cookii* plants do most of their growth in the late fall (after the winter rains start but before limiting temperature decreases occur) and late winter (when temperatures start to warm up) (Brock 1987). Smaller (non-flowering) plants seem to initiate growth in February, rather than November, and two-year-old plants do not appear to flower. Apparently, plants usually don't produce their first umbel until their third or fourth year of growth, and seed production may not occur until a year or two after that. Seedlings in the Agate Desert germinated in early February, and grew rapidly, but produced only one true leaf during their first growing season. First year seedling mortality rates were as high as 51% in the naturally-occurring Agate Desert populations (Brock 1987).

More cultivation work has been done with *Lomatium bradshawii*. Lynda Boyer of Heritage Seedlings, Inc., Salem, Oregon (personal communication, 2004) reported successfully cultivating seedlings by following the seed germination protocols listed above (seeds were mixed with pre-moistened vermiculite and cold stratified at 1°C inside sealed plastic bags for 11 weeks), then sowing the seed/vermiculite mixture into flats filled with a planting medium consisting of bark, compost, peat, perlite, and Philip's pre-mix (crabmeal, 3 kinds of lime, micronutrients, Actino-iron, and a wetting agent). Following establishment in flats, seedlings were transplanted into 5 inch x 2 3/8 inch pots. Boyer reported very high (nearly 100 percent) establishment and survival rates, and noted that although *L. bradshawii* did not produce many leaves in the first 60 days, the root system was well established by that time. Kaye et al. (2003) also cultivated *L. bradshawii* from seed in the greenhouse; germinated seeds were potted in 5" pots, watered daily and fertilized monthly with liquid fertilizer.

Transplanting and introduction attempts

Although there have been no transplanting or introduction research done with *Lomatium cookii*, an introduction study involving the outplanting of both seeds and transplants of *Lomatium bradshawii* at two sites was completed in 2003. According to Kaye et al. (2003), direct seeding of *L. bradshawii* was highly effective at both locations. At the first site, seeds collected in July of 1999 were sown in 10 one-meter-square plots (60 seeds/plot) in mid-November of the same year. Half of the plots were randomly selected to have established vegetation removed before seeding, and seedling emergence ranged from 17 to 38% for undisturbed and bare soil plots, respectively. Soil in the plots at the second study site were ammended with a variety of soil amendments (compost, fertilizer, mycorrhizae, or mycorrhizae mixed with compost); however, seedling emergence (19-30%) was not significantly affected by the amendments.

Greenhouse-cultivated *Lomatium bradshawii* plants (grown from seed) were transplanted to research plots in both the fall and spring of 2000. Seeds were collected in late June or July of 1999, and potted (in 5" or 9" pots) in mid-December of the same year. Half of the plants were outplanted in March of 2000. The rest remained in the greenhouse throughout the summer, where they were watered daily and fertilized with liquid fertilizer monthly. The fall transplants were outplanted in late October of 2000. All transplants were given 1-2 teaspoons of 17-17-17 slow release fertilizer at the time of outplanting. Two years later, approximately 40 and 75 percent of the transplants had survived at the two sites, respectively, although as of 2002 very few of the survivors were reproductive. Survival of *L bradshawii* transplants appeared to be greater for unfertilized transplants and transplants planted in the autumn. The effect of fertilizer was not seen in the first year, but became significant in the second and third years of monitoring (Kaye et al. 2003).

Population monitoring

Population monitoring has occurred at both of *Lomatium cookii*'s population centers. The Illinois Valley monitoring focused on the populations which reside on BLM land, while the Agate Desert Preserve monitoring was conducted by The Nature Conservancy.

The Illinois Valley monitoring projects involved 3 sets of subpopulations: French Flat, Rough and Ready Creek and Indian Hill. In 1993, BLM Medford District staff installed long-term monitoring plots and transects in the three largest sub-populations of *Lomatium cookii* in the French Flat area. Additional plots were added at French Flat and Rough and Ready Creek in 1994, and at Indian Hill in 1997. These plots have been monitored annually since their establishment. As of the spring of 2002, French Flat is estimated to have slightly under 203,000 *L. cookii* plants (Kaye 2003). Overall, the population appears to be stable, with the year-to-year variation attributed to environmental variability, time of observation and possible herbivore interactions (Kaye 2001). Rough and Ready Creek's subpopulations have increased or remained stable since 1994. This site had roughly 1,000 plants in 2002, located in eight small patches which are traversed by dirt roads, although recently there has been little vehicular use of these roads. Indian Hill numbers have declined since 1997 (when monitoring began), going from 11,177 to the most recent count (in 2002) of 6,477 plants (Kaye 2003).

As part of the process of federally listing *L. cookii*, a survey of all populations was completed in 2000-2001. During the course of this study, the estimated number of plants at one privately-owned *L. cookii* site was revised to 500,000 flowering individuals - an increase from the historical estimate of 6,000 plants at that site. Another population, located on Medford airport property, previously estimated at 1,000 plants, was found to have over 5,000 flowering plants. However, this large population was partially destroyed by the development of a new taxiway shortly after the survey was completed (USFWS 2002b).

Although TNC routinely monitors some of the Agate desert populations of *L. cookii*, these data have not been published (Kagan 1994). Surveys for both *L. cookii* plants and

the vernal pool habitat in which they reside have also been completed by TNC (USFWS 2002b). According to TNC reports, no intact vernal pool habitat remains in the Agate Desert. Habitat with vernal pool hydrology has been invaded by weedy competitors, and TNC has observed a decrease in populations in habitat not controlled for annual grasses.

Land use threats and other limitations

The historical and continuing loss and degradation of appropriate habitat is a pressing concern for *Lomatium cookii*. In the Agate Desert, the vernal pools favored by *L. cookii*, previously widespread south of the Rogue River, are now virtually eliminated (Brock 1987, USFWS 2002a). One survey estimated that, between 1998 and 2002, the remaining *L. cookii*-inhabited vernal pool system in the Agate Desert decreased by almost 50%, going from 54 to 28 hectares. In addition, many of the populations (especially in the Illinois Valley) are fragmented along roads or on private land, and almost 80% of the extant populations occur on sites which cover 2 hectares or less (USFWS 2002a). Stochastic simulations based on observed environmental variability in French Flat subpopulations indicate that the risk of a 50% decline over a 20 year period is 100% (Kaye 2003). Development, off-road vehicles (ORVs), mining, grazing, hydrologic disruption, exotic weeds and fire suppression have all negatively impacted *L. cookii*'s habitat. This section discusses these factors in more detail.

1. Development: Within the Illinois Valley in Jackson County, *L. cookii* populations tend to occur on the only arable lands available in the area. Much of the potential *L. cookii* habitat has been converted to farmland. Those sites with soils too shallow for farming have frequently been grazed by cattle, sheep and horses. In addition, Jackson County continues to experience increased rates of residential development, which not only cause direct disturbance, but often result in increased grazing and plowing as well (Kagan 1994). Public ownership of a site does not guarantee safety for the plant. One *L. cookii* population, located on land managed by Jackson County, was extirpated by construction of a baseball sports complex in 1992. Many of the known French Flat sites are found directly adjacent to roads and powerline right-of-ways, making them more

vulnerable to roadside maintenance activities (such as herbicide spraying), human-caused wildfire and other effects commonly associated with roads (USFWS 2002a).

The only *L. cookii* site which is currently protected and managed for the plant, TNC's Agate Desert Preserve, is becoming surrounded by commercial and industrial developed land, which could disrupt the hydrologic processes within the Preserve. This vulnerability was demonstrated in 1988, when the ditch alongside a new road built on southern edge of the Preserve drained several of the Preserve's southern vernal pools, destroying even more of this rare habitat. It has been estimated that over 60% of *L. cookii*'s Agate Desert habitat has been destroyed by leveling and development of structures, roads and other impermeable surfaces (USFWS 2002a).

2. Recreation/Off-Road Vehicles (ORVs): Although ORVs were banned on *L. cookii* sites managed by the BLM in Josephine County, illegal ORV use still occurs. In 1992, ORVs damaged a large wet meadow at French Flat; the ruts created by the vehicles punctured the clay pan and caused the draining of at least 6 ha (20% of remaining habitat on federally-managed land) of the meadow. Restricting access to this large, open area is difficult, and in the last several years, gates erected by the BLM to direct ORV traffic away from *L. cookii* habitat have been repeatedly vandalized (EPA Comments 1).
At another Josephine County site, the Oregon Parks and Recreation Department was forced to undertake protective measures for the Illinois River Forks State Park population of *L. cookii*. Their entrance road was recently fenced to exclude ORV use from areas near the road where the plant occurs. In addition, general recreational use (hiking biking, camping, horseback riding) may also cause damage to *L. cookii* plants and habitat (Kagan 1994, USFWS 2002a).

3. Invasive weeds: In the Agate Desert area, none of the remaining hydrologically intact vernal pool habitat has escaped the invasion of invasive weeds. Recent evidence indicates that non-native annual grasses, particularly medusahead (*Taeniatherum caput-medusae*) are a greater problem than previously believed. Unlike the area's original native perennial bunchgrasses, annual grasses die back each year, creating a buildup of

thatch that interferes with germination of *L. cookii* seeds. TNC staff have observed that without control of annual grasses through mowing, grazing, or prescribed burns, *L. cookii* populations tend to decrease over time, and could be extirpated within a relatively short time frame (USFWS 2002b). In many cases, these non-native grasses have been purposefully planted for livestock grazing and other reasons. For example, the Ken Denman Wildlife Reserve, which covers roughly 720 hectares of Agate Desert land, is managed by the State primarily for waterfowl production. Much of this Reserve has been covered with log deck debris, plowed in strips and planted with non-native wildlife food plants (Brock 1987).

Results from a study looking at the effects of prescribed burning in the Agate Desert showed that early summer fire is beneficial for *Lomatium cookii*. Seedling recruitment in the two years following burning was much higher in the burned areas, when compared to that in unburned units. Older *L. cookii* plants die back by the time fire can carry through such stands, and the roots are insulated from the heat generated by the short duration of a grassland fire (USFWS 2002a).

4. Mining: Historically, placer gold mining has occurred on or near many of the *L. cookii* sites in the Illinois Valley. Currently, there are nine active mineral mining claims on the French Flat ACEC. Not only does working these mines directly damage the habitat, but the indirect impacts (roads and slag piles) are also harmful. If existing mining claims on French Flat are pursued, habitat destruction would be increased by at least an additional 20 percent (EPA 2). In 1993 a mining plan was filed at the Medford District of the BLM; the proposed plan involved the destruction of the majority of a large subpopulation of *L. cookii* (Kagan 1994). At the present time, no safeguards exist to protect habitat from mining.

5. Grazing: Cattle, sheep and horses all browse *L. cookii*, and populations of this plant have been eradicated by heavy grazing (Kagan 1994). Recent Agate Desert Preserve research conducted by TNC showed an increase in *L. cookii* populations in areas where livestock grazing was excluded. However, first year population gains were lost by the

third year due to thatch build-up impeding plant growth and seedling recruitment. In light of this, it is possible that the benefits of light grazing (reduction of non-native competitor populations) in the late summer to early fall, when *L. cookii* plants are dormant, may balance the negative impacts of trampling (USFWS 2002a). No grazing of *L. cookii* populations on BLM lands in the Illinois Valley occurs, although two privately owned sites are grazed. At the Woodcock Creek site, grazing has almost completely eliminated the *L. cookii* population (Kagan 1994).

6. Fire suppression: In the past, much of southern Oregon (including the Illinois Valley) was subject to frequent wildfires during the summer months. Since the time of European settlement, a fire suppression regime has been instituted. This exclusion of fire has changed the character of much of the potential *L. cookii* habitat, causing forest encroachment of previously open areas (Kagan 1994). Several sites at Indian Hill and Rough and Ready Creek are currently threatened by this encroachment of woody species. Furthermore, a recent large wildfire in the Kalmiopsis Wilderness Area, just west of the Illinois Valley, has raised the possibility of new threat. Fire suppression activities, such as fireline construction or the use of heavy equipment, could potentially cause damage to *L. cookii* populations on the west side of the Illinois Valley (USFWS 2002a).

Population introduction/augmentation strategy

Based upon the biogeographical data compiled and described above for *Lomatium cookii*, there do not appear to be any insurmountable ecological, life history, anthropogenic, or administrative obstacles to the successful implementation of population introduction and augmentation projects for this rare species. Although many *L. cookii* populations face imminent threats on private lands, and native vernal pool and wet meadow habitats have been reduced to a small fraction of their former abundance, there are still several extant *L. cookii* populations that occur on public or otherwise secure landholdings. As such, pending interagency cooperation and funding availability, a few sites are available for collection of seeds for use in off-site cultivation projects, and open locations are also available for population augmentation and introduction purposes.

The biology and life history of *Lomatium cookii* likewise pose no unavoidable hurdles to successful implementation of population introduction and augmentation projects. Although the relatively low seed production of *L. cookii* poses a potential limitation to the number of seeds that can be collected and used in a single year for off-site cultivation projects, this complication can be overcome, if necessary, by using sustainable seed collecting practices over multiple years prior to project implementation. Seed germination was fairly high for seed that had been stored for up to 16 years at the Berry Botanic Garden. The closely related *Lomatium bradshawii* has been successfully cultivated in the greenhouse, and there is no reason to think that cultivation of *L. cookii* would not be similarly successful. As far as it is known, the species exhibits no unique propagation or soil symbiont requirements. Once adequate seed supplies are available, there are no apparent cultivation-related obstacles to implementation of introduction projects.

Based upon the information provided in this manual, the following procedures are recommended for *Lomatium cookii* population introductions:

1. Select population introdution/augmentation target sites. Several factors should be considered when selecting target sites for *Lomatium cookii* population introduction and augmentation projects. First, target sites should contain suitable habitat, keeping in mind the variation found between populations located in the Agate Desert (vernal pool-swale complex) and the Illinois Valley (wet meadows). Because of the potential problems with non-native grass thatch build-up, transplant site vegetation communities should retain as high a percentage of native species as possible. Although habitat descriptions have been provided in this manual, it is extremely helpful to visit extant populations and actually see the habitat in which the plant grows. Such visits provide a better idea of the types of microsites occupied by *L. cookii* individuals within their larger vernal pool or wet meadow habitat context.

Given the lack of long-term protection of *L. cookii* on private lands, inventories for suitable sites should focus on publicly owned or otherwise secure lands. Selection and use of sites should be coordinated with public landowners or agencies to ensure administrative protection and management of populations following introductions. This is especially important in areas in the Illinois Valley, where mining is such an imminent threat to much of the BLM-owned habitat. Both field observations and research have indicated that grazing has a negative impact on *L. cookii* populations, so it is important to ensure that no grazing is allowed to occur on the on the proposed target sites. Also, for sites located in the Illinois Valley, an attempt should be made to locate areas where off-road vehicle use is not prevalent.

2. Collect *Lomatium cookii* seeds for off-site cultivation of introduction stock. Introduction efforts involving *L. bradshawii* indicate that both direct sowing of seed and transplanting plugs are successful ways to introduce new propagules into a site. Normally, if recruitment from directly-sown seed is high, this is the best way to introduce new plants – the cost is often lower and the genetic diversity of the new population is higher. However, since there have been no introduction studies involving *L. cookii*, initial introduction efforts should include the transplanting of both cultivated plants and seeds. Source material for off-site cultivation should be collected from the extant population(s) located nearest to the introduction target sites to maximize conveyance of potential local adaptations. At the very least, it is recommended that Illinois Valley introduction efforts use stock collected from existing populations in the Illinois Valley, , and Agate Desert introduction efforts use stock collected from the Agate Desert. When collecting seed, an effort should be made to collect seeds from as large a sample of genetically variable individuals as possible, in an effort to elevate seed production, fitness and adaptive genetic variability within the introduced population.

3. Cultivate *Lomatium cookii*. *L. cookii* has been successfully cultivated from seed. Previous studies suggest that seeds should be cold stratified for at least 8 weeks, followed by an alternating 10°/20°C (50°F/68°F) temperature treatment. Under these conditions, germination rates can be quite high (up to 90%). Once germinated, seedling survival rates appear to be fairly high as well; although no percentages were given in previous studies, no mention of high seedling mortality rates was made, either. Once seeds are germinated, they can be potted in 5" pots, watered daily and fertilized monthly.

4. Introduce cultivated plugs and seeds into the target site(s). Once again, since there are no *Lomatium cookii* introduction studies, information from *L. bradshawii* studies is helpful. *Lomatium cookii* has two growth seasons - late fall and late winter/early spring. Like *L. bradshawii*, *L. cookii* propagules will probably do their best if planted in the late fall, after the arrival of the fall rains. Seed plots should have the vegetation cleared before sowing, and no fertilizer should be used with plug transplants. Although no research on the effect of population size on *L. cookii*'s ability to attract pollinators or produce viable seed and robust progeny has been completed, small populations may attract few pollinators, and be more vulnerable to extinction due to stochastic events or inbreeding depression. Therefore, it is recommended that introduced populations consist of many individuals planted in large clusters.

5. Monitor introduced populations. Introduced *L. cookii* populations should be monitored annually to evaluate project success. These evaluations should take place in the late spring, when fruits are mature and it is possible to assess reproductive success. Monitoring should, at least in the first several years, consist of demographic monitoring of individuals in order to yield data on the survival and performance of individual plants over time.

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