DEVELOPING REINTRODUCTION TECHNIQUES FOR *LOMATIUM COOKII*

2013

Report to the Bureau of Land Management, Medford District

Report prepared by Thomas N. Kaye, Ian A. Pfingsten, Denise E. L. Giles-Johnson, and Ian S. Silvernail
Institute for Applied Ecology

PREFACE

This report is the result of a cooperative Challenge Cost Share project between the Institute for Applied Ecology (IAE) and the Bureau of Land Management. IAE is a non-profit organization whose mission is conservation of native ecosystems through restoration, research and education. IAE provides services to public and private agencies and individuals through development and communication of information on ecosystems, species, and effective management strategies. Restoration of habitats, with a concentration on rare and invasive species, is a primary focus. IAE conducts its work through partnerships with a diverse group of agencies, organizations and the private sector. IAE aims to link its community with native habitats through education and outreach.

Institute for Applied Ecology

Questions regarding this report or IAE should be directed to:

Thomas Kaye (Executive Director)

Institute for Applied Ecology

PO Box 2855

Corvallis, Oregon 97339-2855

phone: 541-753-3099

fax: 541-753-3098

email: tom@appliedeco.org

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Cover photos: Seeding plots at French Flat (above) and *Lomatium cookii* (below). Photos by T.N. Kaye.

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REPORT TO THE BUREAU OF LAND MANAGEMENT, MEDFORD DISTRICT

INTRODUCTION

Lomatium cookii (Figure 1), Cook's desert-parsley, is listed as endangered by the State of Oregon and the U.S. Fish and Wildlife Service (USFWS). The species is endemic to southwestern Oregon in two population centers, one in Josephine County in the Illinois Valley and one in Jackson County in the Agate Desert north of the Medford Plains (Kagan 1994). The species is closely related to *L. bradshawii*, an endangered species found in the Willamette Valley of western Oregon.

Figure 1. *Lomatium cookii* at French Flat.

Population augmentation and reintroduction are identified in the Draft Recovery Plan for the species as necessary steps toward recovery. Specific Recovery Actions target development of offsite and onsite cultivation and propagation techniques (priority 1, Action 4.12), and reintroduction of the species to suitable habitat (Action 2.4.4). This project contributes to these recovery actions by conducting research into field cultivation of *Lomatium cookii*.

Background

Lomatium cookii was first discovered in 1981 in the Agate Desert in the Rogue River Valley. Habitats for the species in this area are characterized patterned ground in the form of a series of vernal pools and mounds. *Lomatium cookii* occupies a seasonally wet zone on the margins of the vernal pools. The dominant vegetation consists of annual grasses (*Deschampsia danthonioides*, *Bromus hordeaceus*, *Alopecurus saccatus*, and *Taeniatherum caput-medusae*) and herbaceous annuals and perennials (*Lasthenia californica*, *Plectritis congesta*, *Collinsia grandiflora*, and *Limnanthes flocossa* ssp. *grandiflora*). The largest populations of this species are on lands managed by The Nature Conservancy and the Medford Airport.

The largest federally-owned population of *L. cookii* occurs in the Illinois Valley at French Flat on the Medford District BLM. Areas around this population were placer-mined for many years. Populations in this area have been monitored annually since 1993 (Giles-Johnson et al. 2012). These populations are often found in moist, grassy meadows dominated by *Danthonia californica* (Kaye and Blakeley-Smith 2002). Other associated species include *Deschampsia cespitosa*, *Camassia quamash*, *Ranunculus occidentalis*, *Hesperochiron occidentalis*, *Horkelia daucifolia*, *Isoetes nuttallii*, *Calochortus nudus*, and *Viola* *hallii*. Trees and shrubs, such as *Pinus ponderosa*, *Pinus jeffreyi*, *Arctostaphylos* spp., and *Ceanothus cuneatus* border these grassy meadows. Populations of *L. cookii* are also found in the Illinois Valley in grass-dominated gaps within oak woodland, especially in the Reeves Creek area. These habitats have upland soils and are on hillsides which are substantially different in character than the wet sites in the Illinois Valley lowlands. The soils at French Flat are moderately serpentine, which restricts the growth of many plant species. In contrast, the soils Reeves Creek and in Agate Desert populations of *L. cookii* are non-serpentine in origin.

Previous cultivation research

Lomatium cookii greenhouse cultivation practices were investigated by Silvernail (2008), who found that seed dormancy was broken after 12 weeks of cold stratification followed by warm conditions to promote germination. Seeds collected from wild plants in the Agate Desert had higher germination rates and plants grown from them were larger than those from Illinois Valley populations (Silvernail 2008). Plants from both seed sources grew best on well drained potting soil augmented with native soil and fertilizer (Silvernail and Meinke 2008). We used the plants grown by Silvernail (2008) for his research in our study to compare field survival and growth of greenhouse grown plants with different cultivation histories.

Goal and Objectives

The goal of this project was to develop reintroduction techniques for *Lomatium cookii* to support recovery of the species. The specific objectives were to:

1. Determine seedling emergence and subsequent survival rate for seeds sown into suitable habitat and document variation among years, sites, and preparation conditions.
2. Measure field survival and growth of bare root plugs grown under various greenhouse conditions.
3. Test for local adaptation of seed sources for population reintroduction and augmentation.
4. Compare emergence and survival rates to wild populations as a measure of reintroduction success.
5. Collect seeds and establish a seed increase program for *L. cookii* to support future population augmentations and reintroductions.

METHODS

Seeding

Direct seeding was conducted at four locations: two at French Flat ACEC (North and South), Reeves Creek, and Agate Desert Preserve. French Flat ACEC and Reeves Creek are on land managed by the Medford District BLM. Agate Desert Preserve is owned and managed by The Nature Conservancy. Seeds were sown in 2006, 2007 and 2009 (Table 1). Seeds were sown into 1 m^2 plots marked with gray PVC conduit in two corners, one of which was tagged with an aluminum tag (Figure 2). Results from sowing events in 2006, 2007 and 2009 are analyzed here. Seeds sown in 2006 and 2007 were collected by Silvernail while those sown in 2009 were collected by Kaye and others. Prior to field sowing, all seeds were cleaned and backlit to ensure they were filled with an embryo.

Figure 2. Example of a gray conduit post with aluminum tag used to mark 1 m^2 plot corners.

French Flat

2006 – On December 1, 2006, 30 1 m^2 plots (3 rows of 10 plots each) were established at the south end of the south meadow at French Flat (Figure A15). Plots were spaced 1 m apart and were marked in the northwest and southeast corners with gray PVC conduit, emerging from the soil 10 – 20 cm aluminum tags (#901-930). Ten plots were randomly assigned to receive seeds from the Medford Airport population and 20 plots received seed from the local population at French Flat (Figure A16). Seventy-five seeds were sown by hand, scattered evenly over each plot. In 2012, some plot markers were removed due to vandalism, but the markers were relocated and plots were reestablished.

2007 – On December 3, 2007, 20 1 m^2 plots (2 rows of 10 plots each) were established at the south end of the south meadow at French Flat adjacent to the 2006 seeding plots. Rows were established approximately perpendicular to the 2006 seeding plots (Figure A17). Plots were spaced 1 m apart and were marked in the northeast and southwest corners with gray PVC conduit, emerging from the soil 12 – 20 cm. Posts in the northeast corner were marked with a yellow cap and pre-numbered round aluminum tags #61-80. All plots received seventy-five seeds collected from French Flat. An even distribution of seeds across each plot was attempted. However, areas of the plot where water was actively flowing were avoided (at the time of seeding standing water was pooled on the soil surface in places and it was raining). In 2012, some plot markers were removed due to vandalism, but the markers were relocated and plots were reestablished.

2009 – Seeding was conducted on November 16, 2009 at the French Flat North area (Figure 3). Experimental plots were placed on the perimeter of the existing population of *Lomatium cookii* at this location. Sixteen 1 m^2 plots were placed in three rows 1 m apart (Figure A18). We put the plots adjacent to an oak (*Quercus kelloggii*) tree that had dropped leaves over the soil surface (Figure 3). To test the effects of tree litter removal on seedling establishment, we removed all litter from 8 randomly selected experimental plots prior to seeding, leaving the remaining 8 plots as undisturbed controls (Figure 4). Litter was removed by scraping the soil surface with the side of a boot, which was very effective despite its low-tech characteristic. A total of 100 seeds were sown by hand into each 1 m^2 plot. All seeds sown in the plots were collected from the French Flat Middle subpopulation in 2009 (a bulk collection from over 40 plants).

Table 1. Summary of seeding and transplanting information for each site and year.

Site	Year planted	Seed source	No. seeds or plants per plot	No. plots (1 m^2)
	Seeding			
	French Flat ACEC, South Area			
	2006	French Flat	75	20
	2006	Medford Airport	75	10
	2007	French Flat	75	20
	French Flat ACEC, North Area			
	2009	French Flat (Middle)	100	14
	Reeves Creek			
	2009	Reeves Creek & French Flat	60	26
	Agate Desert Preserve			
	2007	Medford Airport	75	20
	Transplants			
	French Flat ACEC, South Area			
	2008	French Flat	≤20	20
	Agate Desert Preserve			
	2008	Medford Airport	≤20	20

Figure 3. Site photo at French Flat North showing 2009 plot locations.

Figure 4. Examples of 2009 seeding plots at French Flat North showing control (left) and litter removal (right) treatments.

Reeves Creek

2009 – Seeding at Reeves Creek was conducted on November 17, 2009. A total of 26 1 m^2 plots were sown with 60 seeds each. Seeds were available from the local Reeves Creek population of *Lomatium cookii* sufficient to seed 6 plots. The remaining 20 plots were sown with seed from French Flat ACEC collected in 2009. Habitat at this site consists of hill slopes with patchy forested vegetation and small openings. *Lomatium cookii* occurs naturally in this area in forest openings as well as under trees. Seeding plots were placed in both habitat types. To test for the effect of leaf litter on seedling establishment, plots were randomly assigned to a litter removal treatment or undisturbed control. Litter removal was conducted by scraping the soil surface with the side of a boot, and/or manually to remove most litter. Existing vegetation on the soil surface was not removed. Finally, plots were placed in six general groups adjacent to one another and surrounding an existing patch of *L. cookii* (Table 1, Figure A20). Three reproductive plants were located inside the plots prior to seeding and these were noted during seedling sampling.

Agate Desert

2007 – On 4 December, 2007, twenty 1 m^2 plots on the perimeter of four vernal pools were established in The Nature Conservancy's Agate Desert Preserve. Plots were located on the margins of Pools Z, 2, A1, and AD22 near UTM 10T 0508947E, 4697130N, NAD27 (Figure A21). At this site, *L. cookii* occurs on upper margins of vernal pools. As this habitat type is not linearly distributed, we did not establish rows of plots as at French Flat, but instead placed plots along the edges of the pools in habitats where *L. cookii* is typically found (Figure 5). Similar to French Flat, we chose an area of Agate Desert that has habitat apparently suitable for *L. cookii*, but was unoccupied. Plots were spaced in order to have sufficient habitat available for 2008 transplant plots. Plots were marked in two diagonal corners with gray PVC conduit, emerging from the soil 12 – 20 cm. The corner on the left closest to the pool was marked with a yellow cap and pre-numbered oblong aluminum tags #81-100. All plots received seventy-five seeds collected from a population at the Medford Airport in summer 2007. Seeds were scattered evenly over each plot. However, areas of the plot where water was actively flowing were avoided (the water table was fairly high and it was raining heavily).

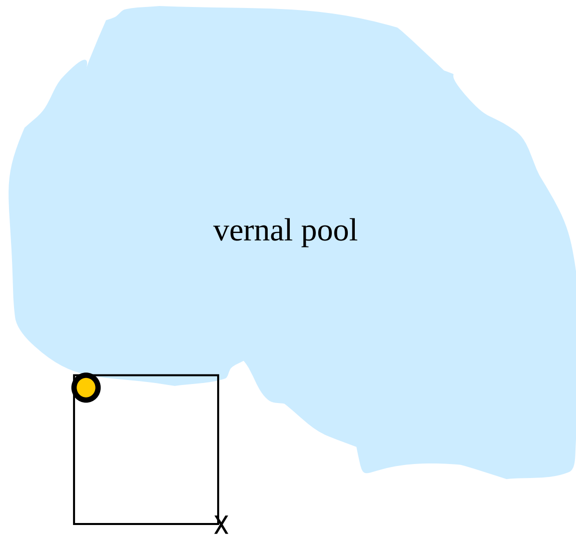

Figure 5. Example of orientation of labeled and unlabeled plot markers at Agate Desert. As you are facing the pool, the labeled post (yellow circle) is in the pool-side left corner; the unlabeled post is in the right corner closer to the mound.

Transplanting

Transplanting was conducted at French Flat ACEC and Agate Desert Preserve in 2008 with plants grown from 0 to 3 years in the greenhouse. At both sites, twenty 1 m^2 plots were established in appropriate habitat adjacent to or within established wild populations (Table 1). Each plot was subdivided into twenty planting locations (Figure 6). Position 1 was located 20 cm to the right of the edge of the plot and 10 cm below the top of the plot.

Plants with different greenhouse cultivation histories were distributed across all plots. In total, plants from seven different cultivation categories were used. Full details of cultivation history can be found in Silvernail and Meinke (2008).

Cultivation categories were as follows:

1. 3 week old seedlings
2. 1 year old tap-roots cultivated in 3:3:2 (coir fiber:compost:perlite) nursery mix
3. 2 year old tap-roots cultivated in 3:3:2 nursery mix
4. 2 year old taproots cultivated in Illinois Valley soil with monthly supplemental fertilization
5. 2 year old taproots cultivated in Illinois Valley soil without supplemental fertilization
6. 2 year old taproots cultivated in Rogue Valley soil with monthly supplemental fertilization monthly
7. 2 year old taproots cultivated in Rogue Valley soil without supplemental fertilization

Because there were different numbers of plants in each greenhouse cultivation category, the sequence in which plots were planted was randomized in order to avoid the last plots having numerous empty positions. The cultivation history of a plant placed in a particular position within a plot was randomized as well. The cultivation history of all individual plants within all plots at French Flat can be found in Appendix A. See Figure 7 for images of transplanting activities.

French Flat

Transplanting occurred on March 11, 2008. One row of ten plots was located immediately south of and parallel to the 2006 direct seeding plots. Another row of ten plots was located immediately west of and adjacent to the 2007 direct seeding plots (Figure A15). Plots were spaced 1 m apart and each was labeled with a pre-numbered tag. Plots #601-610 were marked in the northeast and southwest corners with gray PVC conduit, emerging from the soil 12 – 20 cm. Posts in the northeast corner were marked with a yellow cap. Plots #611-620 were marked in the northwest and southeast corners with gray PVC conduit, with the posts in the northwest corner receiving a yellow cap. In 2012, some plot markers were removed due to vandalism, but the markers were relocated and plots were reestablished.

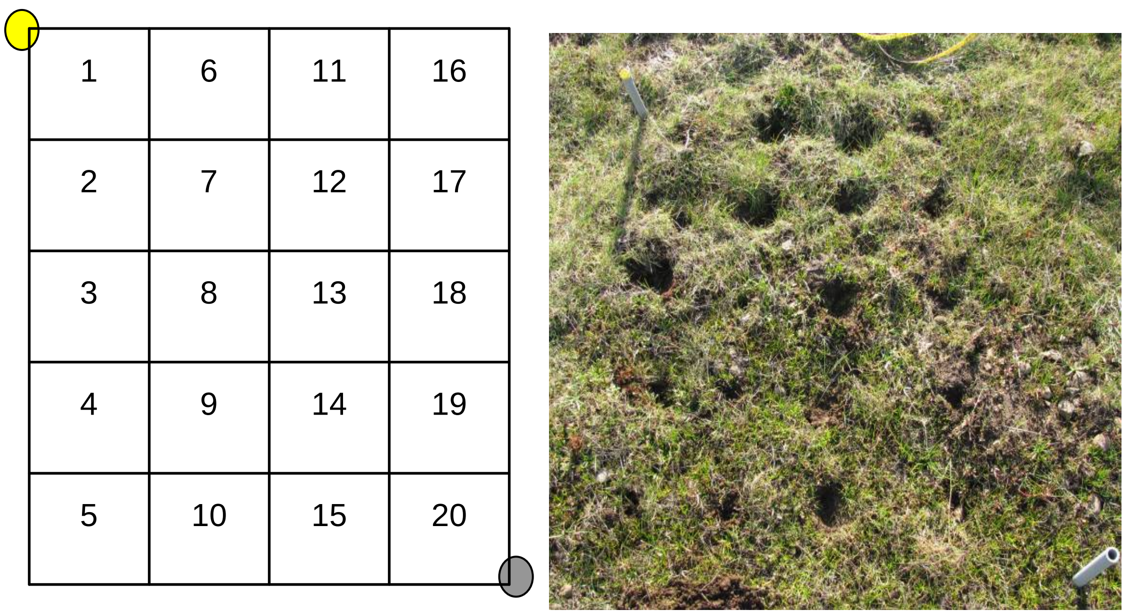

Figure 6. Orientation of twenty planting locations within 1 m^2 transplant plots at French Flat and Agate Desert. Left: diagram showing planting locations. The yellow circle represents the post containing a yellow plastic cap. Right: plot with posts in opposite corners and holes dug with dibble prior to planting.

Agate Desert Preserve

Transplants were planted on March 10, 2008. Since *L. cookii* habitat is not linearly distributed at Agate Desert, plots were placed along the margins of vernal pools in appropriate habitat.

Vernal pools were chosen in the immediate vicinity of other pools where direct seeding plots were located (Figure A21). Plots were marked with pre-numbered aluminum tags #621-640 placed on gray PVC conduit, emerging from the soil 12 – 20 cm. Refer to Appendix A for the cultivation histories of plants within each planting position across all plots.

Plot sampling

Direct Seeding

The number of plants found in each plot at French Flat (North and South) was recorded in late April or early May 2007-2013. Agate Desert plots were visited on April 21, 2008 and 2009, May 3, 2010, and April 19, 2011, and the same information was recorded. Monitoring of the Agate Desert plots was discontinued after 2011 due to low seedling survival. Reeves Creek plots were sampled for the first time in late April or early May 2010-2013. The location of each plant was also mapped during the 2008-2013 monitoring dates to track individual plants through time. In 2009-2013 additional data recorded included the number of leaves and length of the longest leaf for each plant.

Because seedlings were not mapped in 2007 at French Flat, all plants mapped in 2008 from the 2006 seeding were assumed to be second year small vegetative plants. In 2009-2013 some additional small vegetative plants were discovered that had not been previously mapped (seedlings of *L. cookii* are difficult to locate because of their small size), and these were assumed to have established in their first spring after seeding, unless specifically noted otherwise on the datasheets. As of 2013, seedlings near reproductive plants were assumed to be from hand seeding and not wild recruits. This assumption was corroborated during plot sampling, although it should change in future monitoring as more seeded plants mature to large (> 1 umbel) reproductive plants, produce seeds, and recruit seedlings nearby.

Transplanting

Transplants were monitored on in late April or early May 2008-2013 at French Flat and 2008-2011 at Agate Desert. Monitoring of the Agate Desert plots was discontinued after 2011 due to low seedling and transplant survival. For each plant, the leaf number, maximum leaf length, presence of herbivory, and number of reproductive stems was recorded. See Appendix B for a copy of the data sheets used for gathering this information. New seedlings were mapped and recorded as wild recruits, but not included in the survival analysis. However, they were used as a measure of reproductive plant fecundity in demographic analyses of the transplanted populations.

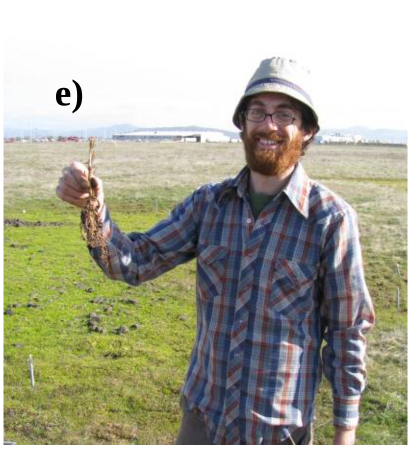

Figure 7. Scenes from *Lomatium cookii* reintroduction experiments: a) a three week old seedling immediately prior to planting at French Flat ACEC in 2008, b) transplant emerging at Agate Desert Preserve in 2009, c) transplanting at Agate Desert Preserve, d) TNC staff assisting with transplanting at Agate Desert, e) Ian Silvernail with bare root plant ready for planting in 2008.

Analysis

Direct Seeding – Environmental Factors and Local Adaptation

We used Chi-squared analysis of deviance for generalized linear models with quasi-binomial error distribution (Hastie and Pregibon 1992) to test for an effect of seed source (French Flat South), litter removal (French Flat North), and seed source and litter removal each stratified by light exposure (Reeves Creek) on seedling establishment with data from 2013.

Transplanting – Plant Size Effects

We used the same analysis as with direct seeding treatments to test for an effect of cultivation history on transplant survival with data from 2013.

Comparing augmented to wild populations

To compare seeded populations to wild populations, we used log-linear analysis (Anderson and Goodman 1957, Caswell 2001) to test the null hypothesis that annual life history stage transitions from seed sown at French Flat, Agate Desert, and Reeves Creek are equal to those of plants sampled in wild populations at French Flat South and Middle (combined) from 2007-2013 (see Pfingsten et al. [2013] for source of demographic data from wild populations). We matched years between wild and seeded population plant stage transitions to control for environmental variability across time. We excluded transitions to seedlings and transitions from reproductive plants because these transitions were not possible or were rare in seeded plots (<10 observations), respectively.

We also used log-linear analysis (Anderson and Goodman 1957, Caswell 2001) to compare life history stage fates of transplants at French Flat and Agate Desert with stage fates from all plants sampled in wild populations at French Flat South and Middle from 2009-2013 (Giles-Johnson et al. 2011). The 2008-2009 plant stage transitions were excluded to account for transplant shock after the first year of planting. As in the seeding analysis, we matched years between wild and planted populations, and we excluded transitions to seedlings and to plant stages with <10 observations in transplant plots.

All analyses were done in R version 3.0.2 (R Core Team 2013).

Seed collection and increase

Seed collection

L. cookii occurs on both moist serpentine and dry non-serpentine soil types, with the potential for differing selective pressures in these contrasting edaphic environments, and much of the landscape in which it occurs is claimed for mining, restricting which sites can be used to host new populations. Seed collection was conducted in 2009 and 2011 to develop a plant materials program that creates a large and steady seed supply and reduces pressure on wild sources. Since 2009, 15 seed accessions have been collected from 13 sites (Table 2, Figure 8) with special attention to unprotected sites on private lands, and have been placed into isolated productions for two soil types. Seeds were collected and stored in paper envelopes.

Table 2. *Lomatium cookii* seed collection sites and dates, number of maternal source plants, and habitat type.

site	collection date	source plants	Habitat type
Reeve's Creek 802	7/6/2011	10	Upland/oak gaps
Reeve's Creek 803	7/6/2011	25	Upland/oak gaps
Reeve's Creek 804	7/6/2011	25	Upland/oak gaps
Reeve's Creek 805	7/7/2011	90	Upland/oak gaps
Reeve's Creek 821	7/6/2011	2	Upland/oak gaps
Reeve's Creek 822	7/6/2011	5	Upland/oak gaps
Caves Highway ROW	7/7/2011	40	Low/serpentine
French Flat Middle	7/6/2011	70	Low/serpentine
French Flat Middle	6/23/2009	50	Low/serpentine
French Flat North	7/6/2011	3	Low/serpentine
French Flat Piney Woods	7/6/2011	45	Low/serpentine
French Flat South	7/6/2011	100	Low/serpentine
French Flat South	6/23/2009	25	Low/serpentine
Indian Hill	7/7/2011	50	Low/serpentine
Rough and Ready	7/7/2011	50	Low/serpentine

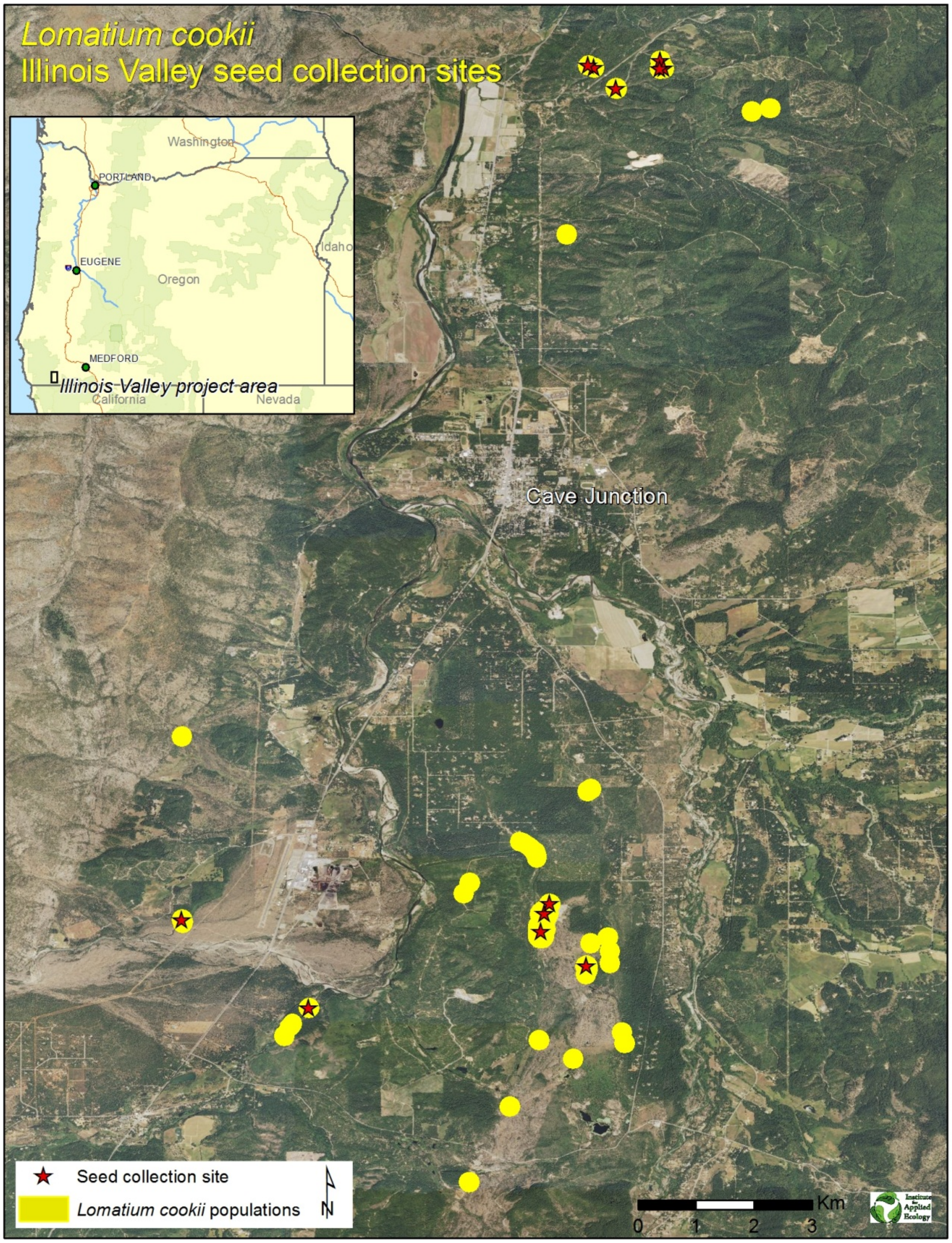

Figure 8. Known populations of *Lomatium cookii* in the Illinois Valley, Oregon. Sites from which seeds have been collected for a seed increase program are indicated with red stars. Seed collection occurred in 2009 and 2011. Reeves Creek area populations occur in gaps in oak forest while the southern populations are primarily on serpentine grasslands and openings. The two source areas are in production in isolated fields at the NRCS Corvallis Plant Materials Center.

Seed increase

Seeds collected in 2009 and 2011 from the Illinois Valley area have been placed into isolated production fields for each of the two source habitat types, upland oak gaps and low serpentine soils. These fields are located at the NRCS Corvallis Plant Materials Center. Prior to outplanting, seeds were given dormancy breaking treatment (10 weeks of cold stratification) in flats, germinated and grown in a greenhouse (Figure 9), then stored until fall of 2012 when they were planted into the production fields.

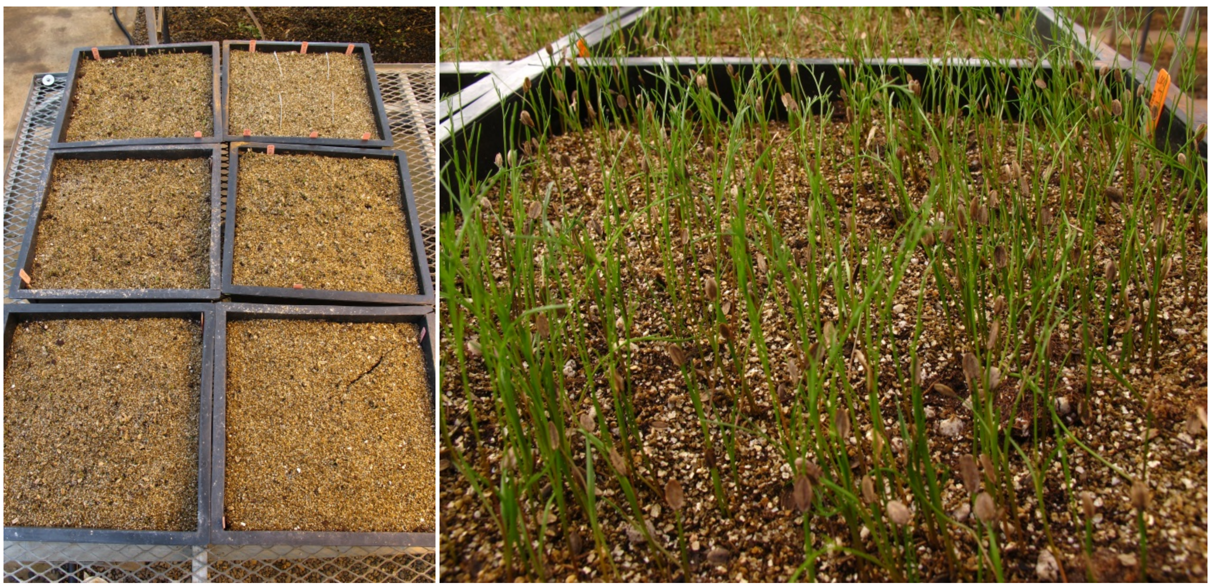

Figure 9. *Lomatium cookii* seedlings in production at the NRCS Corvallis Plant Materials Center. Left: Flats with germinating seeds in a greenhouse. Right: close-up of seedlings growing in flats soon after germination in spring 2012.

RESULTS

Direct seeding – Local Adaptation and Environmental Factors

Seeding resulted in establishment of plants at French Flat ACEC, Reeves Creek, and Agate Desert Preserve. As of 2013, the total number of seedlings established through these experimental efforts was 271 at French Flat South, 486 at French Flat North, 201 at Reeves Creek, and 37 at Agate Desert Preserve, which was last monitored in 2011. Overall, the average annual rate of seedling survival was 41% at Agate Desert, 86%-90% at French Flat South and North with locally sourced seed, and 72% at French Flat South with Agate Desert seed, while seedlings at Reeves Creek survived at a mean annual rate of 64% with local seed and 69% with French Flat seed.

French Flat South

In 2007, first-year seedling emergence at French Flat South was 15.1% from the local source seed, and 12.5% for seed from Medford Airport/Agate Desert (Figure 10). By 2013, plant establishment and subsequent survival in the seeding plots had declined because of mortality to 7.1% for plants from French Flat and 2.7% from Medford Airport seed. 2013 survival for Medford Airport seeds was significantly (p=0.008) lower than establishment of local seeds. 2012 was the only other year where seed source significantly affected establishment (p=0.034). In 2013, most plants had two or three leaves, and leaf number ranged from 1 to 8. A total 27 reproductive plants were observed in 2013 in these seeded plots, of which 6 had more than one umbel.

Seeds sown in 2007 had a first-year emergence rate in 2008 of 22.0%. Survival dropped gradually each year to 11.5% in 2013.

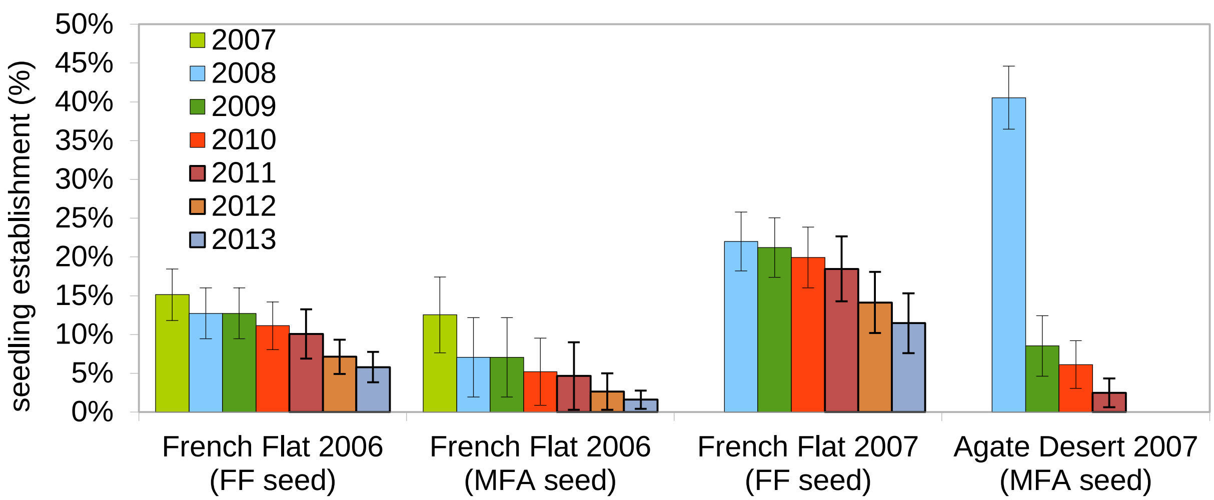

Figure 10. Seedling emergence and survival of 2006 and 2007 experimental cohorts at French Flat South and Agate Desert. Error bars represent 90% confidence intervals.

Agate Desert

First year establishment in 2008 at Agate Desert was 40.5%, substantially higher than at French Flat in the same year. By 2011, however, survival in these plots declined to 2.5% (Figure 10). In 2011, most plants remained small (1-3 leaves) and thirteen were reproductive.

French Flat North

Litter removal significantly ($p<0.001$) improved seedling establishment at the French Flat North site in all years since sowing. Seed sown in 2009 at French Flat North had a first year establishment rate in 2010 of 57.9% where litter was removed and 35.4% in control plots where litter was undisturbed (Figure 11). This trend remained through 2013 ($p<0.001$) where seedling establishment was 45.0% for where litter was removed and 24.4% in control plots.

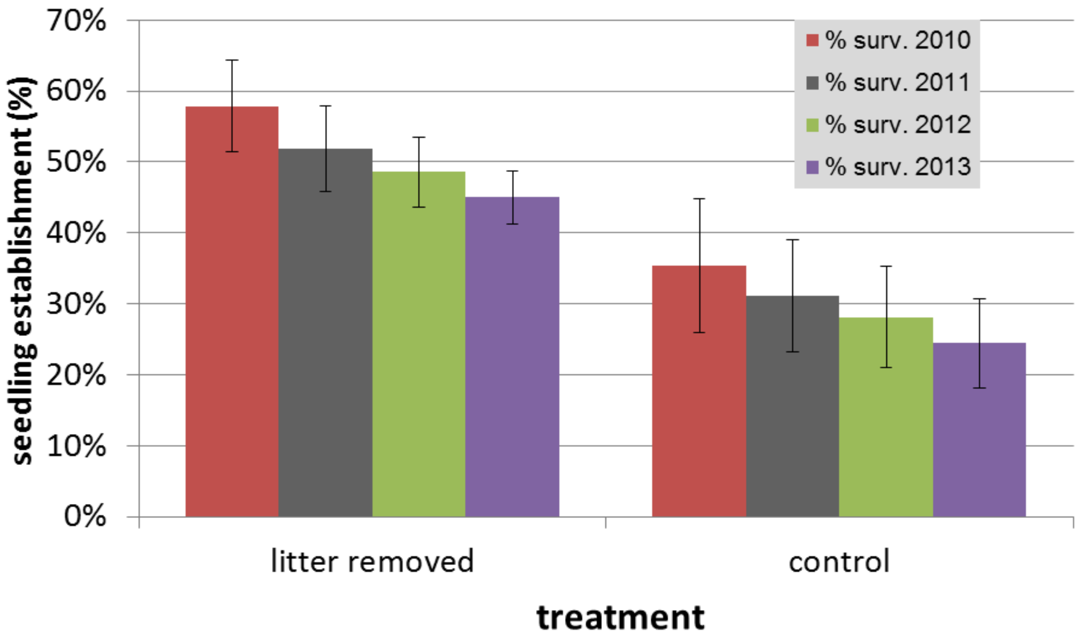

Figure 11. First three years seedling emergence and establishment at French Flat North with and without litter removal. Treatments differed significantly ($p<0.001$). Error bars represent 95% confidence intervals. Leaf litter was heavy at this site due to the presence of trees surrounding the seeded area, and was primarily composed of oak leaves and pine needles. Removal of leaf litter exposed the organic soil horizon, increasing seed to soil contact. Seeds were sown in 2009.

Reeves Creek

First year seedling establishment in 2010 at Reeves Creek was 34.0% overall, but decreased to 23.8%, 18.1%, and 12.9% in 2011-2013 respectively. Habitat type did not have a significant ($p=0.265$) effect on seedling establishment at Reeves Creek in 2013; in gaps with full sun, 15.5% of seeds established while in the shade under oak canopy 9.9% established. We found no significant ($p=0.941$) effect of litter removal on seedling establishment at this site.

Establishment rates varied among seed sources, but although there was a trend toward better establishment with locally collected seeds, this effect was not significant (p=0.253), possibly due to a low ability to detect differences because of the small sample size (seven plots) coupled with high variation in survival among plots of local seed. Seeds from French Flat established at 10.7% while those collected from the Reeves Creek site established at 18.8% (Figure 12). There were no significant two or three-way interactions between habitat type, litter removal, or seed source (p=0.956).

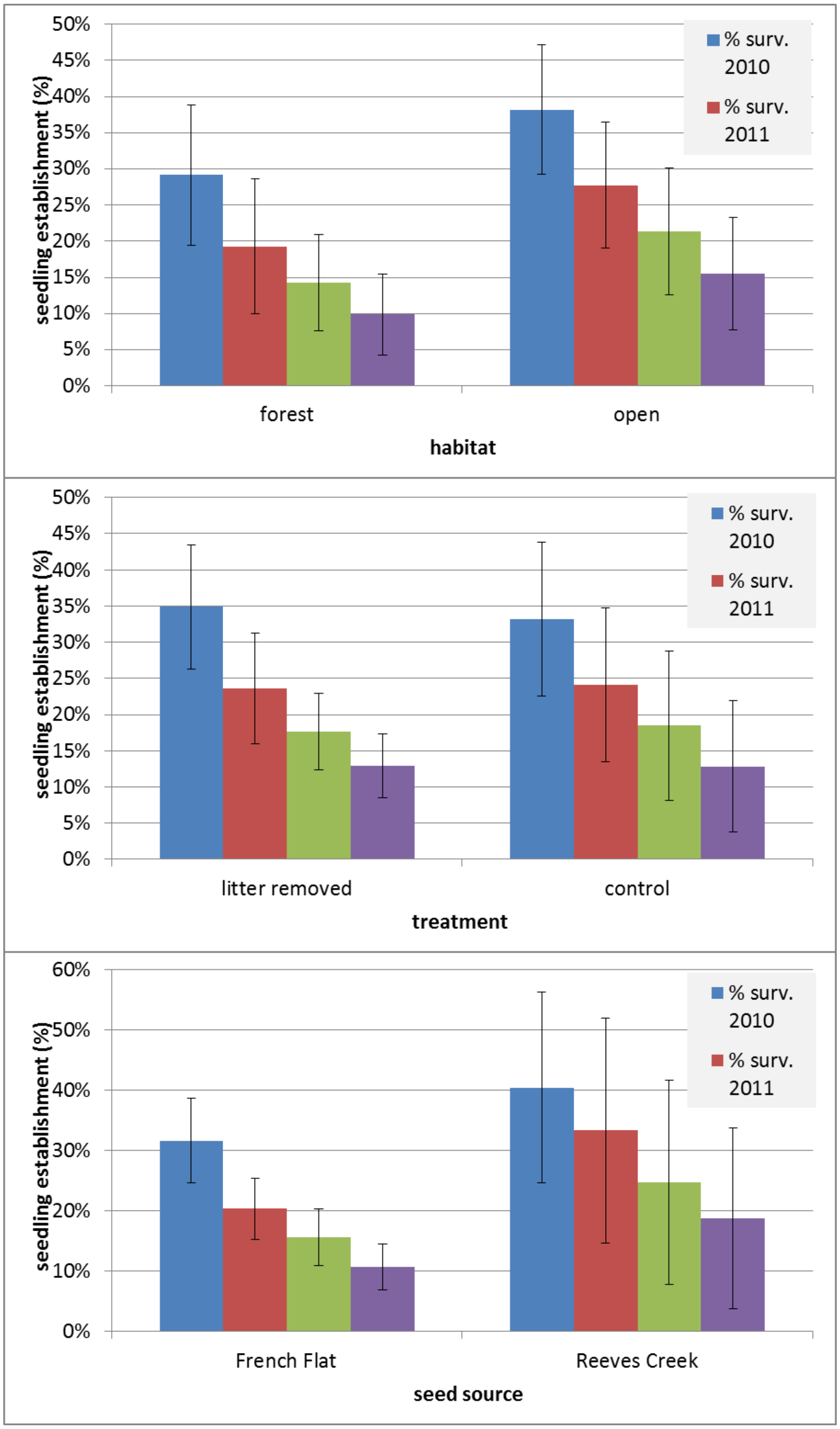

Figure 12. First four years seedling establishment at Reeves Creek. Error bars represent 95% confidence intervals. Establishment was not significantly higher in full sun (Open) than under forest canopy (Forest). There was no significant effect of litter removal (LR; Control = C) at this site.

Transplanting

French Flat

At French Flat in 2013, cultivation history did not have a statistically significant effect on plant survival (p=0.523). Seedlings and one year old plants had approximately 18-23% survival, while most two-year-old tap roots fared somewhat better, with 18-38% surviving, depending on the cultivation conditions. Two-year-old plants grown in 3:3:2 mix potting soil had only 18% survival (Table 3, Figure 13).

Most mortality occurred in the first month after transplanting in 2008. Mortality remained low from 2009 to 2011, with a few seedlings reappearing after being missed in 2009-2011 (Table 3). However, 2012 had losses in all transplant types, mostly from seedlings and two-year-old plants in Illinois Valley soil with fertilizer. In 2013, those two-year-old plants in native soil with fertilizer were the only type to have no mortality. Despite poor survival years in 2012 and 2013, these results suggest that after initial mortality, possibly due to transplant shock, established plants may persist at high rates. A total of 87 transplants remained alive in 2013.

Agate Desert

This site was not visited after 2011 due to low survival rates of transplants. In previous years, transplant survival at Agate Flat was much lower than at French Flat (Table 3). Cultivation history did not have a significant effect on transplant survival in 2011 (p=0.503). Only 10 seedlings (2.5%) remained in 2009, down from 90 in 2008, but 6 reappeared in 2011. No one-year old tap-roots survived and only 5.1% to 11.1% of two year old plants could be relocated in 2011 (Table 3). Cultivation histories with the highest survival rates were the two year old plants in Rogue Valley soil with fertilizer (11.1%, 4 out of 36) and two year old plants in 3:3:2 soil mix (10.0%, 1 out of 10). Only 17 transplants were still present in 2011.

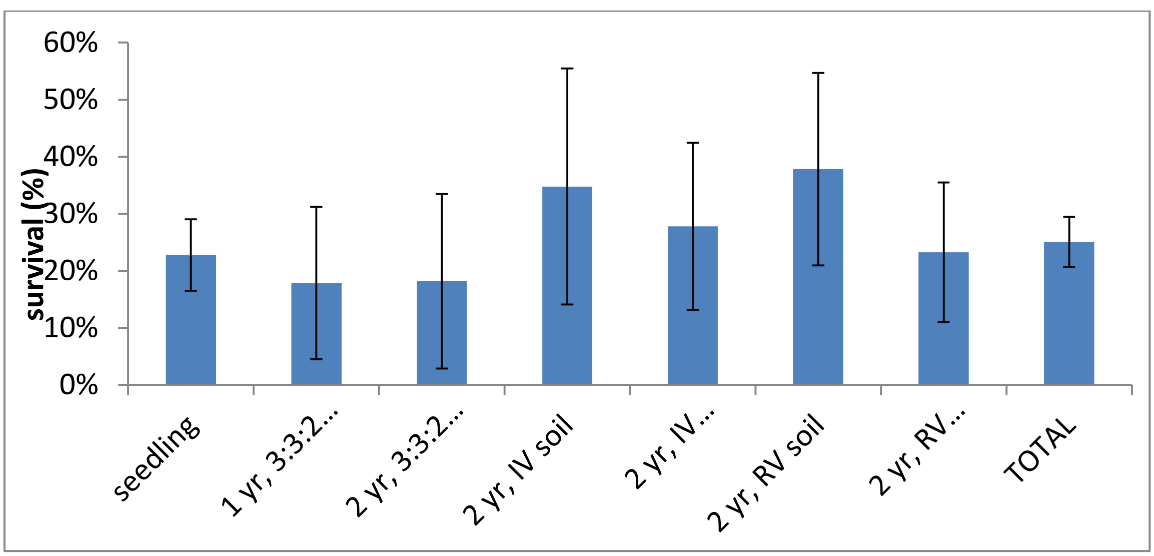

Figure 13. Survival of transplants at French Flat in 2013, six years after planting. Differences in average survival between cultivation histories were not significant. Error bars are 90% confidence intervals.

Table 3. Number of transplants, number surviving (2008-2013), and total percentage survival to 2013 (Agate Desert monitoring stopped in 2011) of transplants within seven different cultivation histories at French Flat ACEC and Agate Desert Preserve (IV = Illinois Valley and RV = Rogue Valley).

	Seedling	1 yr, 3:3:2 soil	2 yr, 3:3:2 soil	2 yr, IV soil	2 yr, IV soil fertilized	2 yr, RV soil	2 yr, RV soil fertilized	Total
# planted	158	28	22	23	36	37	43	347
2008 survival	118	15	12	15	21	27	22	230
2009 survival	90	13	10	15	21	23	20	192
2010 survival	77	12	10	12	18	19	18	166
2011 survival	70	12	10	11	17	19	18	157
2012 survival	55	9	7	10	10	17	13	121
2013 survival	36	5	4	8	10	14	10	87
Total % 2013 survival	*23%*	*18%*	*18%*	*35%*	*28%*	*38%*	*23%*	*25%*
# planted	160	29	10	39	36	37	36	347
2008 survival	90	3	6	24	26	28	29	206
2009 survival	10	0	2	3	8	4	7	34
2010 survival	9	0	1	3	7	3	6	29
2011 survival	6	0	1	2	2	2	4	17
Total % 2011 survival	*4%*	*0%*	*10%*	*5%*	*6%*	*5%*	*11%*	*5%*

Comparing Augmented to Wild Populations

French Flat South

Plants seeded in 2006 and 2007 from local seed differed significantly ($p<0.001$) in their vital rates from wild French Flat plants in vegetative stage transitions (Table 4). From 2007-2013 (2006 seeded cohort) or 2008-13 (2007 cohort), seeded plants had lower mortality and more transitions to small vegetative plants than did wild French Flat plants ($p<0.001$). Only the behavior of large vegetatives was the same in reintroduced and wild plants ($p=0.507$). Small reproductive plants also behaved similarly in wild and seeded populations ($p=0.686$); this was comparable for only the 2006 cohort from local origin because no plants had become reproductive from the Medford Airport seed or the 2007 cohort by 2013.

Transplants at French Flat behaved similarly to wild French Flat plants in all size classes except small vegetative plants (Table 4), which had lower mortality and higher transitions from small vegetative plants to large vegetative plants than plants in the wild population ($p=0.004$). Plants established as seedlings or large vegetative or reproductive classes did not differ in behavior from wild plants ($p>0.2$).

Seed from the Agate Desert area (Medford Airport population) planted at French Flat also produced plants that differed from the wild population at French Flat in their survival and growth ($p<0.001$, Table 4). For example, planted seedlings had lower mortality and higher transitions to small the vegetative stage, small vegetative plants had higher rates of stasis, and large vegetative plants had higher rates of regression to small vegetative plants than those in the wild population. Agate Desert transplants also had higher rates of stasis of small vegetative plants ($p<0.001$) and lower growth of small and large vegetative plants than plants in wild populations ($p<0.011$).

French Flat North

Plants seeded at French Flat North in 2009 had lower mortality and higher transitions to large vegetative plants than did wild French Flat plants from 2010-2013, regardless of whether litter had been removed from the plots prior to seeding or not ($p\leq0.005$, Table 4).

Agate desert

Seeded plants at the Agate Desert Preserve differed from wild French Flat plants in seedling and large vegetative stage transitions (Table 4). This difference was due to higher mortality in seeded plots than in wild populations from 2008-2011.

Transplants at Agate Desert only differed from wild French Flat plants in small and large vegetative and large reproductive plant transitions (Table 4). However, survival of transplants at Agate Desert was so low that many plant transitions had too few observations to notice significant differences from wild plants as of 2009-2011.

Reeves creek

Seeded plants at Reeves Creek differed from wild French Flat plants in vegetative stage transitions ($p<0.001$, Table 4), mostly due to more transitions to small vegetative plants in seeded plots from 2010-2013.

Table 4. Log-linear analysis of *Lomatium cookii* population stage fates by wild or reintroduced origin for each stage. Only transitions from stages with more than ten observations were evaluated. LR is the likelihood ratio between the saturated model, fate X origin, and the null model, fate + origin. P-values < 0.05 are in bold, and indicate significant differences among reintroduced and wild populations. Degrees of freedom for all models were 5. Veg=Vegetatives. Rep=Reproductives.

	Seedlings		Small Veg.		Large Veg.		Small Rep.		Large Rep.	
Seedling cohort	**LR**	***p***	**LR**	***p***	**LR**	***p***	**LR**	***p***	**LR**	***p***
French Flat South										
seeded 06 (FF seed)	165	**< 0.001**	30	**< 0.001**	5	0.507	3	0.686	-	-
seeded 06 (AD seed)	62	**< 0.001**	23	**< 0.001**	13	**0.011**	-	-	-	-
seeded 07	36	**< 0.001**	36	**< 0.001**	22	**< 0.001**	-	-	-	-
planted 08	7	0.245	17	**0.004**	6	0.327	5	0.472	1	0.952
French Flat North										
seeded 09 (litter removed)	31	**< 0.001**	34	**< 0.001**	27	**< 0.001**	-	-	-	-
seeded 09 (control)	28	**< 0.001**	31	**< 0.001**	15	**0.005**	-	-	-	-
Agate Desert Preserve										
seeded 07	40	**< 0.001**	4	0.444	17	**0.002**	-	-	-	-
planted 08	-	-	11	**0.044**	17	**0.004**	-	-	11	**0.048**
Reeves Creek										
seeded 09	37	**< 0.001**	36	**< 0.001**	21	**< 0.001**	-	-	-	-

Seed Collection and Increase

Seed collection has been completed from 15 sites over two collection years. Plants are currently in their first year of field growth at the NRCS Corvallis Plant Materials Center. Because the plants mature to a reproductive size relatively slowly, the first seed crop can be expected no sooner than 2014 or 2015. Our most recent report from the NRCS Corvallis Plant Materials Center suggests that the field grown with plants from serpentine soils may have failed, so we will evaluate the need to recollect seeds of this ecotype in 2014.

Once seeds are available from this field, sites for outplanting will need to be identified and prepared for planting. Site selection for outplantings will emphasize suitable habitats that are protected, compatible with mining claims, and anticipate climate change.

DISCUSSION

Seeding and transplanting

Seeding

Direct seeding and transplanting appear to be useful methods for reintroducing populations of *Lomatium cookii*. The augmentations conducted in this study at three locations, French Flat ACEC, Reeves Creek, and Agate Desert Preserve resulted in establishment, survival, and growth of substantial numbers of plants in some cases, although subsequent mortality at Agate Desert was relatively high: by 2011 only 17 of 347 transplants remained.

First year seedling emergence varied from 12.5% at French Flat to 40.5% at Agate Desert. Mortality of seedlings after the first year was much lower at French Flat than Agate Desert. While survival to two years declined slightly to about 13% at French Flat (FF seed), it dropped to about 9% at Agate Desert. The average annual survival rate of Agate Desert seed was higher at French Flat (72%) than at Agate Desert (41%), suggesting that site conditions are important drivers of seedling establishment. Strong competition with annual plants, herbivory by voles, and dry soil conditions in 2008 may explain the rapid decline at Agate Desert. Seedling survival to 2011 at Agate Desert was 2.5%, lower than any other site over that amount of time.

Plants reintroduced through direct seeding may take longer than six years to behave comparably to wild *L. cookii* populations. Most plant stages had lower mortality in seeded plots 3 to 6 years after seeding than in wild French Flat populations, with the exception of plants in plots seeded with Agate Desert seed. Seeded plots also had more plants grow to or remain small vegetative plants, with a few plants becoming reproductive only at French Flat South and Agate Desert. The high stasis in small vegetative plants and very low reproductive transitions may be due to the life history of this relatively long-lived perennial. *L. cookii* needs at least three years for about 9% of plants to become reproductive (Giles-Johnson et al. 2012). This absence of reproduction explains why we have yet to observe new recruitment within seeded plots.

Transplants

Transplants fared better at French Flat than Agate Desert from 2008 to 2011. In general, older and larger plants survived better, especially if they had been fertilized while grown in the greenhouse (and therefore had higher biomass) or were grown in potting soil inoculated with local soil. Much of the difference between the two planting sites was attributable to planting challenges at Agate Desert in cobbly soil. Other factors, such as plant competition, herbivory, and dry soils later in the season (as mentioned above) may also have affected the plants at that site. Transplants at Agate Desert had less than 5% survival by 2011. After 2011, monitoring was ceased at this site.

More transplants grew to large reproductive plants, and in a shorter time frame, than seeded plants. Transplants from French Flat produced a total of 193 (61 large) reproductive plants from 2008-2013, while seeded *L. cookii* at French Flat produced only 70 (15 large) reproductive plants from 2006-2013. Recruitment of seedlings was also observed in many transplant plots at French Flat (and Agate Desert) by 2010.

Environmental factors affecting seedling establishment

Leaf litter and planting habitat appear to affect seedling establishment at some sites. At French Flat North, removal of leaf litter increased first year seedling establishment from 35% in control plots to 58% in plots where bare soil was exposed. Two and three-year survival also differed across treatments from 31% and 28% in control plots to 52% and 49% in bare soil plots, respectively. Leaf litter at this site was relatively thick because the plots were adjacent to large oak and pine trees that shed substantial leaf loads annually. At Reeves Creek, in contrast, removal of leaf litter had no effect on seedling establishment in the first and second years. Seed source had no effect in both years either, although there was a suggestion that locally collected seed established better than seed from French Flat; variance among the few plots with local seed was too high to detect a significant difference. Also, habitat in which seeds were sown appeared to affect establishment at Reeves Creek, but this apparent effect was not statistically significant. Seeds sown under tree canopies had lower survival (29%, 19%, 14%, and 10% in years 1-4) than those sown in gaps with full sun (38%, 28%, 21%, and 16%). At this site, wild *L. cookii* plants occur in both habitat types, but densities are highest in openings.

Is there evidence for local adaptation in *L. cookii*?

When seeds from French Flat and Agate Desert were both sown at French Flat on serpentine-influenced soils, first year establishment was nearly equal (13-15%). However, mortality after 2007 was higher for seeds from Agate Desert, suggesting that there may be some local adaptation of French Flat plants to the serpentine environment. This result is in contrast to some previous findings from a greenhouse experiment that showed Agate Desert plants achieved *better* growth (height) on serpentine-influenced soils compared to the local genotype from French Flat (Silvernail 2008). In the same study, Agate Desert plants had higher survival overall than plants from French Flat. The interaction between genotype and the serpentine environment, which is characterized by soils that have low concentrations of essential nutrients, low calcium:magnesium ratios, and high concentrations of heavy metals, may result in effects at different life history stages. Seedling survival may be reduced for nonlocal genotypes, while growth of larger plants may be unaffected. Other factors may also be at play, such as herbivory from voles, which is frequently very high at French Flat (Pfingsten et al. 2013). If nonlocal plants are more palatable to voles at French Flat then seedling survival could be reduced relative to the local genotype. Regardless of the mechanisms involved, at this time it appears that there is some evidence for local adaptation of *L. cookii* to conditions at French Flat. Results from Reeves Creek comparing establishment of local genotypes with those from French Flat are suggestive but inconclusive at this time. Seedling emergence was higher for the local genotype (41%) compared to French Flat seed (32%) in the first year, but local seed mortality than French Flat seed from 2012-2013 (48% vs. 33%).

Setting reintroduction targets from wild population behavior

Reintroductions can be informed by wild populations to set success criteria. For example, density of plants in wild populations, observed population structures, rates of survival and reproduction, as well as population growth can inform the reintroduction process and assist in measuring project accomplishments.

Wild plant density in the Illinois Valley ranges from a low of 1.2-2.8 plants m^{-2} at the Indian Hill population to a high of 7-42 plants m^{-2} at the French Flat populations. This range can be used to develop a target for reintroduction seeding rates based on observed seedling survival after seeding. For example, in the present study, four years after seeding, overall survival was 2.5% at Agate Desert, while six years after seeding at French Flat it ranged from 2.7% to 7.1%. Based on this, if we conservatively assume four-year survival to be about 3%, the one-time seeding rate needed to establish plants with a density similar to wild populations would be roughly 30 to 1400 seeds m^{-2}. This wide range could accommodate a flexible approach to establishing wild-type densities based on local site characteristics, seed availability, and opportunities for multiple seeding events spread over several years. Resulting densities would need to be monitored to help managers decide when sufficient seeding has occurred.

Our comparison of reintroduced plants two those in wild populations showed that seedlings from broadcast seed tended to have higher survival than wild seedlings, but subsequent poor growth compared to wild plants. Transplants behaved similarly to wild *L. cookii* populations only after four years of growth, excluding the first year (due to the potential for transplant shock). In general, transplants had lower mortality and higher transitions from small to large vegetative plants than did wild plants. This suggests that reintroduction of *L. cookii* by transplanting results in population dynamics similar to wild *L. cookii* at a faster rate than by direct seeding. However, seeding may be more economical and may achieve desired results in the long run.

Continuing tasks

- Experimental reintroduction plots at all sites should continue to receive annual monitoring to document plant survival, growth and reproduction.
- Propagation fields for seed production of *Lomatium cookii* have only been recently established. These fields must be continued for several more years to allow all the plants to mature and produce harvestable quantities of seeds.
- Site selection for reintroduction of *L. cookii* to suitable sites in the Illinois Valley should be implemented in 2014.

Implications for recovery

A necessary step to restore and recover populations of *L. cookii* is to evaluate cultivation and propagation techniques and establish standard procedures and protocols (USFWS 2006). Doing so will enable a larger number of partners to participate in successful recovery through plant production and outplanting. Our results to date suggest the following implications for *L. cookii* recovery:

- Both direct seeding and transplanting of greenhouse-grown bare root stock are feasible methods for establishing *Lomatium cookii*.
- We recommend combining direct seeding with transplanted plugs to establish large

numbers of plants while simultaneously establishing bigger plants that will reproduce quickly.

- Transplants may be most successful with larger individuals grown with native soil and/or fertilizer in a greenhouse potting mix, but all life-history stages may perform well.
- Transplanting may also be most successful at sites without large rocks in the soil and/or high cover from competing vegetation (which also provides cover for voles).
- Direct seeding with large numbers of seeds may be the most cost-effective method for establishing new populations. Production of *L. cookii* seeds in cultivation will release wild populations from seed collection pressure and provide large numbers of seeds for restoration.
- Evidence to date of local adaptation in this species suggests that reintroduction success on sites with serpentine-influenced soils may be higher with seed from serpentine sites.
- Planting efforts at the Agate Desert Preserve have not been as successful as those at French Flat. Some reintroductions may be unsuccessful for unknown reasons, suggesting that multiple reintroduction sites should be included in any recovery or mitigation actions to increase the likelihood that plants will establish and grow well at some sites (a bet-hedging strategy).

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APPENDIX A. CULTIVATION HISTORY OF TRANSPLANTED *LOMATIUM COOKII*

Cultivation history of individual plants transplanted at French Flat on March 10, 2008, plots 601-610. All plants were grown from Illinois Valley seed. A blank cell indicates that no plant was placed in that planting position. Seedling = plants transplanted three weeks after emergence. 1-332 = One-year tap-root cultivated in 3:3:2 soil. 2-332 = 2-year tap-root cultivated in 3:3:2 soil. 2SOILivFERTmo = 2-year taproot cultivated in Illinois Valley soil fertilized monthly. 2SOILivFERT0 = 2-year taproot cultivated in Illinois Valley without supplemental fertilization. 2SOILrvFERTmo = 2-year taproot cultivated in Rogue Valley soil fertilized monthly. 2SOILrvFERT0 = 2-year taproot cultivated in Rogue Valley without supplemental fertilization.

French Flat plot numbers and cultivation history of plants in each planting position

Planting position	601	602	603	604	605	606	607	608	609	610
1	seedling	seedling	2SOILivFERTmo	1-332	2-332	2SOILrvFERTmo	seedling	2SOILrvFERT0	2SOILivFERTmo	2SOILrvFERTmo
2	seedling	seedling	2SOILrvFERT0	2SOILrvFERT0	2SOILrvFERTmo	seedling	2SOILivFERTmo	seedling	seedling	seedling
3	2SOILrvFERTmo	1-332	2SOILrvFERT0	seedling		seedling	seedling	2SOILivFERT0	2SOILrvFERT0	seedling
4	seedling	seedling	seedling	2-332	2SOILivFERTmo	seedling		seedling	2SOILivFERT0	2SOILrvFERTmo
5	2SOILivFERTmo	seedling	2-332	2SOILrvFERTmo	seedling	2SOILivFERTmo	2SOILivFERTmo	seedling		seedling
6	2SOILivFERTmo	seedling	2SOILrvFERTmo	seedling	seedling	seedling	seedling	seedling	seedling	2SOILivFERT0
7		2SOILrvFERTmo	2-332	seedling	1-332	seedling	seedling	seedling	seedling	2SOILivFERTmo
8		2SOILivFERT0	seedling	seedling		seedling	2-332	2SOILrvFERT0	2SOILrvFERTmo	2-332
9	seedling	1-332	1-332	2SOILivFERTmo	seedling	2SOILivFERTmo	seedling	2SOILivFERT0	2SOILivFERTmo	seedling
10	seedling	2-332	seedling	1-332	2SOILivFERTmo			1-332		1-332
11		seedling	2SOILrvFERTmo	seedling	seedling		seedling	seedling	seedling	
12		seedling	2SOILivFERTmo	seedling	2SOILrvFERT0	2SOILrvFERT0	2SOILivFERT0	2-332	seedling	seedling
13	1-332	2SOILivFERTmo	2SOILivFERT0	2SOILivFERT0		seedling	seedling	2SOILrvFERTmo	1-332	seedling
14	2SOILrvFERT0	2SOILrvFERTmo	seedling	2SOILivFERTmo	2SOILivFERT0	2SOILrvFERT0	1-332		seedling	seedling
15	2SOILivFERT0	2-332	seedling	2SOILrvFERT0	2SOILrvFERTmo	1-332	2SOILrvFERTmo	2SOILivFERTmo	seedling	1-332
16	seedling	2SOILrvFERT0	seedling	2-332	seedling		2SOILrvFERTmo	seedling	seedling	2SOILrvFERT0
17	2SOILivFERT0	2SOILrvFERT0	1-332	2SOILivFERT0	seedling	2SOILivFERT0		2SOILivFERTmo		seedling
18	seedling	2SOILivFERT0	seedling	seedling	2SOILrvFERT0	seedling	2SOILrvFERT0		2SOILrvFERT0	2SOILrvFERT0
19	seedling	seedling	2SOILivFERT0	2SOILrvFERTmo	seedling	2-332	seedling	2SOILrvFERTmo	2SOILivFERTmo	2-332
20	2SOILrvFERTmo	2SOILivFERTmo	seedling	seedling	seedling	2SOILrvFERTmo	2SOILrvFERT0	seedling	2-332	2SOILivFERTmo

Cultivation history of individual plants transplanted at French Flat on March 10, 2008, plots 611-620. All plants were grown from Illinois Valley seed. A blank cell indicates that no plant was placed in that planting position. Seedling = plants transplanted three weeks after emergence. 1-332 = One-year tap-root cultivated in 3:3:2 soil. 2-332 = 2-year tap-root cultivated in 3:3:2 soil. 2SOILivFERTmo = 2-year taproot cultivated in Illinois Valley soil fertilized monthly. 2SOILivFERT0 = 2-year taproot cultivated in Illinois Valley without supplemental fertilization. 2SOILrvFERTmo = 2-year taproot cultivated in Rogue Valley soil fertilized monthly.

French Flat plot numbers and cultivation history of plants in each planting position

Planting position	611	612	613	614	615	616	617	618	619	620
1	seedling	seedling	2SOILrvFERTmo	2SOILivFERTmo	seedling	seedling		seedling	2SOILrvFERTmo	
2	1-332	2SOILivFERTmo	seedling	2SOILivFERT0	2SOILivFERTmo	2SOILivFERTmo	2SOILrvFERT0	2-332	seedling	seedling
3	seedling	2SOILivFERT0		2SOILrvFERT0	seedling	seedling	seedling	2SOILrvFERT0	2SOILrvFERTmo	seedling
4	seedling	seedling	seedling	seedling	2SOILivFERT0	2SOILivFERT0	2SOILrvFERTmo	seedling	2SOILrvFERT0	
5	seedling	seedling	2SOILrvFERTmo	1-332			seedling	2SOILivFERTmo	seedling	seedling
6	2SOILrvFERT0	seedling	seedling	seedling	seedling	seedling		2SOILivFERTmo	seedling	2SOILrvFERTmo
7	seedling	2SOILrvFERT0		seedling	2SOILrvFERT0	2SOILrvFERT0	seedling	seedling	2SOILrvFERTmo	
8	seedling	2SOILivFERTmo		2SOILivFERTmo		2-332		1-332	2SOILrvFERT0	seedling
9	2SOILrvFERTmo	1-332	seedling	1-332	2-332	2-332		seedling	seedling	seedling
10	2SOILivFERT0	2-332	seedling	2-332	seedling	seedling		seedling	2SOILrvFERTmo	seedling
11	2SOILivFERTmo	2SOILrvFERT0		2SOILrvFERTmo		1-332		2SOILivFERT0	seedling	2SOILrvFERT0
12	2SOILrvFERTmo	seedling	seedling	seedling	2SOILrvFERTmo	2SOILrvFERTmo			2SOILrvFERT0	1-332
13		seedling		seedling	seedling	seedling	2SOILrvFERTmo	seedling	seedling	
14	seedling	2-332	seedling	2-332	seedling	seedling	seedling	2SOILrvFERTmo	seedling	
15	2-332	seedling		seedling	seedling	seedling	1-332	seedling	1-332	2SOILrvFERTmo
16	seedling	2SOILrvFERTmo	1-332	seedling	seedling	seedling	seedling	2SOILrvFERT0	2SOILrvFERTmo	2SOILivFERTmo
17		seedling	2SOILrvFERT0	2SOILrvFERT0	1-332	1-332	seedling		seedling	
18		2SOILrvFERTmo	seedling	2SOILrvFERTmo	2SOILrvFERT0	2SOILrvFERT0	seedling	2SOILrvFERTmo	1-332	
19	2SOILrvFERT0	2SOILivFERT0	2SOILivFERTmo	seedling	2SOILivFERTmo	2SOILivFERTmo	seedling		2SOILrvFERTmo	
20	2SOILivFERTmo	1-332		2SOILivFERT0	2SOILrvFERTmo	2SOILrvFERTmo	2SOILivFERTmo	seedling		

Cultivation history of individual plants transplanted at Agate Desert on March 11, 2008, plots 621-630. All plants were grown from Medford Airport and Agate Desert seed. A blank cell indicates that no plant was placed in that planting position. Seedling = plants transplanted three weeks after emergence. 1-332 = One-year tap-root cultivated in 3:3:2 soil. 2-332 = 2-year tap-root cultivated in 3:3:2 soil. 2SOILivFERTmo = 2-year taproot cultivated in Illinois Valley soil fertilized monthly. 2SOILivFERT0 = 2-year taproot cultivated in Illinois Valley without supplemental fertilization. 2SOILrvFERTmo = 2-year taproot cultivated in Rogue Valley soil fertilized monthly. 2SOILrvFERT0 = 2-year taproot cultivated in Rogue Valley without supplemental fertilization.

Agate Desert plot numbers and cultivation history of plants in each planting position

Planting position	621	622	623	624	625	626	627	628	629	630
1	seedling	seedling	2SOILivFERTmo	1-332		2SOILrvFERTmo	seedling	2SOILrvFERT0	2SOILrvFERTmo	2SOILrvFERTmo
2	seedling	seedling	2SOILrvFERT0	2SOILrvFERT0	2SOILrvFERTmo	seedling	2SOILivFERTmo	seedling	seedling	seedling
3	2SOILrvFERTmo	1-332	2SOILrvFERT0	seedling		seedling	seedling	2SOILivFERT0	2SOILrvFERT0	seedling
4	seedling	seedling	seedling		2SOILivFERTmo	seedling	1-332	seedling	2SOILivFERT0	2SOILrvFERTmo
5		seedling	2-332	2SOILrvFERTmo	seedling	2SOILivFERTmo	2SOILivFERTmo	seedling	1-332	seedling
6	2SOILivFERTmo	seedling	2SOILrvFERTmo	seedling	seedling	seedling	seedling	seedling	seedling	2SOILivFERT0
7	1-332	2SOILivFERTmo		seedling	1-332	seedling	seedling	seedling	seedling	2SOILivFERTmo
8		2SOILivFERT0	seedling	seedling	2SOILivFERT0	seedling		2SOILrvFERT0	2SOILrvFERTmo	
9	seedling	1-332	1-332	2SOILivFERTmo	seedling	2SOILivFERTmo	seedling	2SOILivFERT0	2SOILivFERTmo	seedling
10	seedling		seedling	1-332	2SOILivFERTmo	1-332	2SOILivFERT0	1-332		1-332
11	2-332	seedling	2SOILrvFERTmo	seedling	seedling		seedling	seedling	seedling	2SOILivFERT0
12	2SOILrvFERT0	seedling	2SOILivFERTmo	seedling	2SOILrvFERT0	2SOILrvFERT0	2SOILivFERT0		seedling	seedling
13	1-332	2SOILivFERTmo	2SOILivFERT0	2SOILivFERT0	1-332	seedling	seedling	2SOILrvFERTmo	1-332	seedling
14	2SOILrvFERT0	2SOILrvFERTmo	seedling	2SOILivFERTmo	2SOILivFERT0	2SOILrvFERT0	1-332	2-332	seedling	seedling
15	2SOILivFERT0	2-332	seedling	2SOILrvFERT0	2SOILrvFERTmo	1-332	2SOILrvFERTmo	2SOILivFERTmo	seedling	1-332
16	seedling	2SOILrvFERT0	seedling		seedling	2SOILivFERT0	2SOILrvFERTmo	seedling	seedling	2SOILrvFERT0
17	2SOILivFERT0	2SOILrvFERT0	1-332	2SOILivFERT0	seedling	2SOILivFERT0		2SOILivFERTmo	2SOILivFERT0	seedling
18	seedling	2SOILivFERT0	seedling	seedling	2SOILrvFERT0	seedling	2SOILrvFERT0	1-332	2SOILrvFERT0	2SOILrvFERT0
19	seedling	seedling	2SOILivFERT0	2SOILrvFERTmo	seedling	2-332	seedling	2SOILrvFERTmo	2SOILivFERTmo	2-332
20		2SOILrvFERTmo	seedling	seedling	seedling	2SOILrvFERTmo	2SOILrvFERT0	seedling	2-332	2SOILivFERTmo

Cultivation history of individual plants transplanted at Agate Desert on March 11, 2008, plots 631-640. All plants were grown from Medford Airport and Agate Desert seed. A blank cell indicates that no plant was placed in that planting position. Seedling = plants transplanted three weeks after emergence. 1-332 = One-year tap-root cultivated in 3:3:2 soil. 2-332 = 2-year tap-root cultivated in 3:3:2 soil. 2SOILivFERTmo = 2-year taproot cultivated in Illinois Valley soil fertilized monthly. 2SOILivFERT0 = 2-year taproot cultivated in Illinois Valley without supplemental fertilization. 2SOILrvFERTmo = 2-year taproot cultivated in Rogue Valley soil fertilized monthly. 2SOILrvFERT0 = 2-year taproot cultivated in Rogue Valley without supplemental fertilization.

Agate Desert plot numbers and cultivation history of plants in each planting position

Planting position	631	632	633	634		636	637	638	639	640
1	seedling	seedling	2SOILrvFERTmo	2SOILivFERTmo	seedling	seedling		seedling	seedling	
2	1-332	2SOILivFERTmo	seedling	2SOILivFERT0	2SOILivFERTmo	2SOILivFERTmo	2SOILrvFERT0	2SOILivFERTmo	2SOILrvFERT0	seedling
3	seedling	2SOILivFERT0		2SOILrvFERT0	seedling	seedling	seedling	2SOILrvFERT0		seedling

4	seedling	seedling	seedling	seedling	2SOILivFERT0	2SOILivFERT0	2SOILrvFERTmo	seedling		
5	seedling	seedling		1-332	2SOILivFERT0	2SOILivFERT0	seedling	2SOILivFERTmo	seedling	seedling
6	2SOILrvFERT0	seedling	seedling	seedling	seedling	seedling		2SOILivFERTmo	seedling	
7	seedling	2SOILrvFERT0	2SOILivFERT0	seedling	2SOILrvFERT0	2SOILrvFERT0	seedling	seedling		2SOILivFERT0
8	seedling	2SOILivFERTmo	2SOILrvFERT0	2SOILivFERTmo						seedling
9	2SOILrvFERTmo	1-332	seedling	1-332			2SOILivFERT0	seedling	seedling	seedling
10	2SOILivFERT0		seedling		seedling	seedling	2SOILivFERT0	seedling	2SOILrvFERTmo	seedling
11	2SOILivFERTmo	2SOILrvFERT0	1-332	2SOILrvFERTmo	1-332			2SOILivFERT0	seedling	
12	2SOILrvFERTmo	seedling	seedling	seedling	2SOILrvFERTmo	2SOILrvFERTmo				
13		seedling		seedling	seedling	seedling		seedling	seedling	
14	seedling	2-332	seedling		seedling	seedling	seedling	2SOILrvFERTmo	seedling	seedling
15	2-332	seedling	2SOILivFERT0	seedling	seedling	seedling		seedling		
16	seedling	2SOILrvFERTmo	1-332	seedling	seedling	seedling	seedling	2SOILrvFERT0	2SOILivFERTmo	2SOILivFERTmo
17	1-332	seedling	2SOILrvFERT0	2SOILrvFERT0			seedling	2SOILivFERT0	seedling	
18	2SOILivFERT0	2SOILrvFERTmo	seedling	2SOILrvFERTmo	2SOILrvFERT0	2SOILrvFERT0	seedling	2SOILrvFERTmo	2SOILivFERT0	2SOILrvFERTmo
19	2SOILrvFERT0	2SOILivFERT0	2SOILivFERTmo	seedling	2SOILivFERTmo	2SOILivFERTmo	seedling		2SOILrvFERTmo	2SOILrvFERT0
20	2SOILivFERTmo	1-332	2-332	2SOILivFERT0	2SOILrvFERTmo	2SOILrvFERTmo	2SOILivFERTmo	seedling	2SOILivFERT0	Seedling

APPENDIX B. BLANK DATASHEETS

Lomatium cookii direct seeding plots

Site:

Name(s):

Date:

Plot number:

plant #	# lvs	length

Plot number:

plant #	# lvs	length

French Flat
Lomatium cookii transplantings
Name(s):______________________________ Date:______________

Planting position	Plot # 601	leaf #/ length (cm)	# repro stems	Plot # 602	leaf #/ length (cm)	# repro stems	Plot # 603	leaf #/ length (cm)	# repro stems	Plot # 604	leaf #/ length (cm)	# repro stems
1	seedling			seedling			2SOILivFERTmo			1-332		
2	seedling			seedling			2SOILrvFERT0			2SOILrvFERT0		
3	2SOILrvFERTmo			1-332			2SOILrvFERT0			seedling		
4	seedling			seedling			seedling			2-332		
5	2SOILivFERTmo			seedling			2-332			2SOILrvFERTmo		
6	2SOILivFERTmo			seedling			2SOILrvFERTmo			seedling		
7				2SOILrvFERTmo			2-332			seedling		
8				2SOILivFERT0			seedling			seedling		
9	seedling			1-332			1-332			2SOILivFERTmo		
10	seedling			2-332			seedling			1-332		
11				seedling			2SOILrvFERTmo			seedling		
12				seedling			2SOILivFERTmo			seedling		
13	1-332			2SOILivFERTmo			2SOILivFERT0			2SOILivFERT0		
14	2SOILrvFERT0			2SOILrvFERTmo			seedling			2SOILivFERTmo		
15	2SOILivFERT0			2-332			seedling			2SOILrvFERT0		
16	seedling			2SOILrvFERT0			seedling			2-332		
17	2SOILivFERT0			2SOILrvFERT0			1-332			2SOILivFERT0		
18	seedling			2SOILivFERT0			seedling			seedling		
19	seedling			seedling			2SOILivFERT0			2SOILrvFERTmo		
20	2SOILrvFERTmo			2SOILivFERTmo			seedling			seedling		

French Flat *Lomatium cookii* transplantings
Name(s):______________________________ Date:______________

Plot #	leaf #/	# repro	Plot #	leaf #/	# repro	Plot #	leaf #/	# repro	Plot #	leaf #/	# repro

Planting position	605	length (cm)	stems	606	length (cm)	stems	607	length (cm)	stems	608	length (cm)	stems
1	2-332			2SOILrvFERTmo			seedling			2SOILrvFERT0		
2	2SOILrvFERTmo			seedling			2SOILivFERTmo			seedling		
3				seedling			seedling			2SOILivFERT0		
4	2SOILivFERTmo			seedling						seedling		
5	seedling			2SOILivFERTmo			2SOILivFERTmo			seedling		
6	seedling			seedling			seedling			seedling		
7	1-332			seedling			seedling			seedling		
8				seedling			2-332			2SOILrvFERT0		
9	seedling			2SOILivFERTmo			seedling			2SOILivFERT0		
10	2SOILivFERTmo									1-332		
11	seedling						seedling			seedling		
12	2SOILrvFERT0			2SOILrvFERT0			2SOILivFERT0			2-332		
13				seedling			seedling			2SOILrvFERTmo		
14	2SOILivFERT0			2SOILrvFERT0			1-332					
15	2SOILrvFERTmo			1-332			2SOILrvFERTmo			2SOILivFERTmo		
16	seedling						2SOILrvFERTmo			seedling		
17	seedling			2SOILivFERT0						2SOILivFERTmo		
18	2SOILrvFERT0			seedling			2SOILrvFERT0					
19	seedling			2-332			seedling			2SOILrvFERTmo		
20	seedling			2SOILrvFERTmo			2SOILrvFERT0			seedling		

French Flat *Lomatium cookii* transplantings

Name(s):____ Date:____________________

Planting position	Plot # 609	leaf #/ length (cm)	# repro stems	Plot # 610	leaf #/ length (cm)	# repro stems	Plot # 611	leaf #/ length (cm)	# repro stems	Plot # 612	leaf #/ length (cm)	# repro stems
1	2SOILrvFERTmo			2SOILrvFERTmo			seedling			seedling		
2	seedling			seedling			1-332			2SOILivFERTmo		
3	2SOILrvFERT0			seedling			seedling			2SOILivFERT0		
4	2SOILivFERT0			2SOILrvFERTmo			seedling			seedling		
5				seedling			seedling			seedling		

6	seedling			2SOILivFERT0			2SOILrvFERT0			seedling		
7	seedling			2SOILivFERTmo			seedling			2SOILrvFERT0		
8	2SOILrvFERTmo			2-332			seedling			2SOILivFERTmo		
9	2SOILivFERTmo			seedling			2SOILrvFERTmo			1-332		
10				1-332			2SOILivFERT0			2-332		
11	seedling						2SOILivFERTmo			2SOILrvFERT0		
12	seedling			seedling			2SOILrvFERTmo			seedling		
13	1-332			seedling						seedling		
14	seedling			seedling			seedling			2-332		
15	seedling			1-332			2-332			seedling		
16	seedling			2SOILrvFERT0			seedling			2SOILrvFERTmo		
17				seedling						seedling		
18	2SOILrvFERT0			2SOILrvFERT0						2SOILrvFERTmo		
19	2SOILivFERTmo			2-332			2SOILrvFERT0			2SOILivFERT0		
20	2-332			2SOILivFERTmo			2SOILivFERTmo			1-332		

French Flat *Lomatium cookii* transplantings

Name(s):____ Date:____________________

Planting position	Plot # 613	leaf #/ length (cm)	# repro stems	Plot # 614	leaf #/ length (cm)	# repro stems	Plot # 615	leaf #/ length (cm)	# repro stems	Plot # 616	leaf #/ length (cm)	# repro stems
1	2SOILrvFERTmo			2SOILivFERTmo			seedling			seedling		
2	seedling			2SOILivFERT0			2SOILivFERTmo			2SOILivFERTmo		
3				2SOILrvFERT0			seedling			seedling		
4	seedling			seedling			2SOILivFERT0			2SOILivFERT0		
5	2SOILrvFERTmo			1-332								
6	seedling			seedling			seedling			seedling		
7				seedling			2SOILrvFERT0			2SOILrvFERT0		
8				2SOILivFERTmo						2-332		
9	seedling			1-332			2-332			2-332		
10	seedling			2-332			seedling			seedling		

11				2SOILrvFERTmo						1-332		
12	seedling			seedling			2SOILrvFERTmo			2SOILrvFERTmo		
13				seedling			seedling			seedling		
14	seedling			2-332			seedling			seedling		
15				seedling			seedling			seedling		
16	1-332			seedling			seedling			seedling		
17	2SOILrvFERT0			2SOILrvFERT0			1-332			1-332		
18	seedling			2SOILrvFERTmo			2SOILrvFERT0			2SOILrvFERT0		
19	2SOILivFERTmo			seedling			2SOILivFERTmo			2SOILivFERTmo		
20				2SOILivFERT0			2SOILrvFERTmo			2SOILrvFERTmo		

French Flat *Lomatium cookii* transplantings

Name(s):____ Date:________________

Planting position	Plot # 617	leaf #/ length (cm)	# repro stems	Plot # 618	leaf #/ length (cm)	# repro stems	Plot # 619	leaf #/ length (cm)	# repro stems	Plot # 620	leaf #/ length (cm)	# repro stems
1				seedling			2SOILrvFERTmo					
2	2SOILrvFERT0			2-332			seedling			seedling		
3	seedling			2SOILrvFERT0			2SOILrvFERTmo			seedling		
4	2SOILrvFERTmo			seedling			2SOILrvFERT0					
5	seedling			2SOILivFERTmo			seedling			seedling		
6				2SOILivFERTmo			seedling			2SOILrvFERTmo		
7	seedling			seedling			2SOILrvFERTmo					
8				1-332			2SOILrvFERT0			seedling		
9				seedling			seedling			seedling		
10				seedling			2SOILrvFERTmo			seedling		
11				2SOILivFERT0			seedling			2SOILrvFERT0		
12							2SOILrvFERT0			1-332		
13	2SOILrvFERTmo			seedling			seedling					
14	seedling			2SOILrvFERTmo			seedling					
15	1-332			seedling			1-332			2SOILrvFERTmo		
16	seedling			2SOILrvFERT0			2SOILrvFERTmo			2SOILivFERTmo		
17	seedling						seedling					
18	seedling			2SOILrvFERTmo			1-332					
19	seedling						2SOILrvFERTmo					
20	2SOILivFERTmo			seedling								

Agate Desert *Lomatium cookii* transplantings

Name(s):____ Date:________________

Plot #	leaf #/	# repro	Plot #	leaf #/	# repro	Plot #	leaf #/	# repro	Plot #	leaf #/	# repro

Planting position	621	length (cm)	stems	622	length (cm)	stems	623	length (cm)	stems	624	length (cm)	stems
1	seedling			seedling			2SOILivFERTmo			1-332		
2	seedling			seedling			2SOILrvFERT0			2SOILrvFERT0		
3	2SOILrvFERTmo			1-332			2SOILrvFERT0			seedling		
4	seedling			seedling			seedling					
5				seedling			2-332			2SOILrvFERTmo		
6	2SOILivFERTmo			seedling			2SOILrvFERTmo			seedling		
7	1-332			2SOILivFERTmo						seedling		
8				2SOILivFERT0			seedling			seedling		
9	seedling			1-332			1-332			2SOILivFERTmo		
10	seedling						seedling			1-332		
11	2-332			seedling			2SOILrvFERTmo			seedling		
12	2SOILrvFERT0			seedling			2SOILivFERTmo			seedling		
13	1-332			2SOILivFERTmo			2SOILivFERT0			2SOILivFERT0		
14	2SOILrvFERT0			2SOILrvFERTmo			seedling			2SOILivFERTmo		
15	2SOILivFERT0			2-332			seedling			2SOILrvFERT0		
16	seedling			2SOILrvFERT0			seedling					
17	2SOILivFERT0			2SOILrvFERT0			1-332			2SOILivFERT0		
18	seedling			2SOILivFERT0			seedling			seedling		
19	seedling			seedling			2SOILivFERT0			2SOILrvFERTmo		
20				2SOILrvFERTmo			seedling			seedling		

Agate Desert *Lomatium cookii* transplantings

Name(s):______________________________ Date:____________________

Planting position	Plot # 625	leaf #/ length (cm)	# repro stems	Plot # 626	leaf #/ length (cm)	# repro stems	Plot # 627	leaf #/ length (cm)	# repro stems	Plot # 628	leaf #/ length (cm)	# repro stems
1				2SOILrvFERTmo			seedling			2SOILrvFERT0		
2	2SOILrvFERTmo			seedling			2SOILivFERTmo			seedling		
3				seedling			seedling			2SOILivFERT0		
4	2SOILivFERTmo			seedling			1-332			seedling		
5	seedling			2SOILivFERTmo			2SOILivFERTmo			seedling		
6	seedling			seedling			seedling			seedling		
7	1-332			seedling			seedling			seedling		
8	2SOILivFERT0			seedling						2SOILrvFERT0		
9	seedling			2SOILivFERTmo			seedling			2SOILivFERT0		
10	2SOILivFERTmo			1-332			2SOILivFERT0			1-332		
11	seedling						seedling			seedling		
12	2SOILrvFERT0			2SOILrvFERT0			2SOILivFERT0					
13	1-332			seedling			seedling			2SOILrvFERTmo		
14	2SOILivFERT0			2SOILrvFERT0			1-332			2-332		
15	2SOILrvFERTmo			1-332			2SOILrvFERTmo			2SOILivFERTmo		
16	seedling			2SOILivFERT0			2SOILrvFERTmo			seedling		
17	seedling			2SOILivFERT0						2SOILivFERTmo		
18	2SOILrvFERT0			seedling			2SOILrvFERT0			1-332		
19	seedling			2-332			seedling			2SOILrvFERTmo		
20	seedling			2SOILrvFERTmo			2SOILrvFERT0			seedling		

Agate Desert *Lomatium cookii* transplantings

Name(s):______________________________ Date:____________________

Planting position	Plot # 629	leaf #/ length (cm)	# repro stems	Plot # 630	leaf #/ length (cm)	# repro stems	Plot # 631	leaf #/ length (cm)	# repro stems	Plot # 632	leaf #/ length (cm)	# repro stems
1	2SOILrvFERTmo			2SOILrvFERTmo			seedling			seedling		
2	seedling			seedling			1-332			2SOILivFERTmo		
3	2SOILrvFERT0			seedling			seedling			2SOILivFERT0		
4	2SOILivFERT0			2SOILrvFERTmo			seedling			seedling		
5	1-332			seedling			seedling			seedling		
6	seedling			2SOILivFERT0			2SOILrvFERT0			seedling		
7	seedling			2SOILivFERTmo			seedling			2SOILrvFERT0		
8	2SOILrvFERTmo						seedling			2SOILivFERTmo		
9	2SOILivFERTmo			seedling			2SOILrvFERTmo			1-332		
10				1-332			2SOILivFERT0					
11	seedling			2SOILivFERT0			2SOILivFERTmo			2SOILrvFERT0		
12	seedling			seedling			2SOILrvFERTmo			seedling		
13	1-332			seedling						seedling		
14	seedling			seedling			seedling			2-332		
15	seedling			1-332			2-332			seedling		
16	seedling			2SOILrvFERT0			seedling			2SOILrvFERTmo		
17	2SOILivFERT0			seedling			1-332			seedling		
18	2SOILrvFERT0			2SOILrvFERT0			2SOILivFERT0			2SOILrvFERTmo		
19	2SOILivFERTmo			2-332			2SOILrvFERT0			2SOILivFERT0		
20	2-332			2SOILivFERTmo			2SOILivFERTmo			1-332		

Agate Desert *Lomatium cookii* transplantings

Name(s):____ Date:________________

Planting position	Plot # 633	leaf #/ length (cm)	# repro stems	Plot # 634	leaf #/ length (cm)	# repro stems	Plot # 635	leaf #/ length (cm)	# repro stems	Plot # 636	leaf #/ length (cm)	# repro stems
1	2SOILrvFERTmo			2SOILivFERTmo			seedling			seedling		
2	seedling			2SOILivFERT0			2SOILivFERTmo			2SOILivFERTmo		
3				2SOILrvFERT0			seedling			seedling		
4	seedling			seedling			2SOILivFERT0			2SOILivFERT0		
5				1-332			2SOILivFERT0			2SOILivFERT0		
6	seedling			seedling			seedling			seedling		
7	2SOILivFERT0			seedling			2SOILrvFERT0			2SOILrvFERT0		
8	2SOILrvFERT0			2SOILivFERTmo								
9	seedling			1-332								
10	seedling						seedling			seedling		
11	1-332			2SOILrvFERTmo			1-332					
12	seedling			seedling			2SOILrvFERTmo			2SOILrvFERTmo		
13				seedling			seedling			seedling		
14	seedling						seedling			seedling		
15	2SOILivFERT0			seedling			seedling			seedling		
16	1-332			seedling			seedling			seedling		
17	2SOILrvFERT0			2SOILrvFERT0								
18	seedling			2SOILrvFERTmo			2SOILrvFERT0			2SOILrvFERT0		
19	2SOILivFERTmo			seedling			2SOILivFERTmo			2SOILivFERTmo		
20	2-332			2SOILivFERT0			2SOILrvFERTmo			2SOILrvFERTmo		

Agate Desert *Lomatium cookii* transplantings

Name(s):____ Date:________________

Plot #	leaf #/	# repro	Plot #	leaf #/	# repro	Plot #	leaf #/	# repro	Plot #	leaf #/	# repro

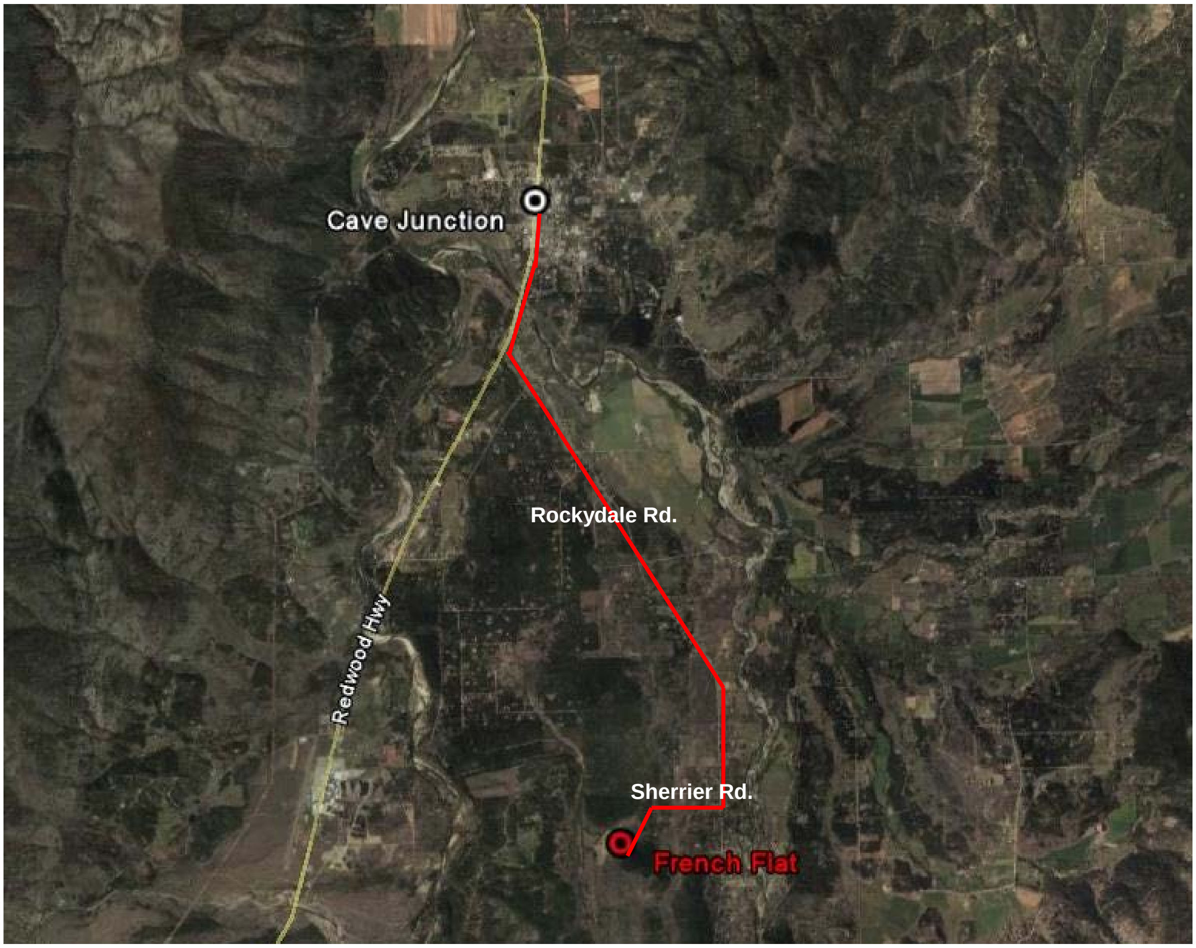
Planting position	637	length (cm)	stems	638	length (cm)	stems	639	length (cm)	stems	640	length (cm)	stems
1				seedling			seedling					
2	2SOILrvFERT0			2SOILivFERTmo			2SOILrvFERT0			seedling		
3	seedling			2SOILrvFERT0						seedling		
4	2SOILrvFERTmo			seedling								
5	seedling			2SOILivFERTmo			seedling			seedling		
6				2SOILivFERTmo			seedling					
7	seedling			seedling						2SOILivFERT0		
8										seedling		
9	2SOILivFERT0			seedling			seedling			seedling		
10	2SOILivFERT0			seedling			2SOILrvFERTmo			seedling		
11				2SOILivFERT0			seedling					
12												
13				seedling			seedling					
14	seedling			2SOILrvFERTmo			seedling			seedling		
15				seedling								
16	seedling			2SOILrvFERT0			2SOILivFERTmo			2SOILivFERTmo		
17	seedling			2SOILivFERT0			seedling					
18	seedling			2SOILrvFERTmo			2SOILivFERT0			2SOILrvFERTmo		
19	seedling						2SOILrvFERTmo			2SOILrvFERT0		
20	2SOILivFERTmo			seedling			2SOILivFERT0			seedling		

APPENDIX C. DIRECTIONS TO SITES AND SITE MAPS

French Flat

From the Junction of Hwy 199 and Hwy 46 in the town of Cave Junction, Oregon, travel south on Hwy 199 0.7 miles to Rockydale Road. Turn left on Rockydale Road and travel 3.8 miles to Sherier Road. Turn right. At this point the road becomes gravel. Travel just under 1 mile to a yellow, locked BLM gate on the left. Over this distance on Sherier Road, the road quality degrades and there are often large puddles in the road in the spring, though it usually remains passable with most vehicles. There are also several driveways on Sherier Road, some of which are marked and some of are not. Be certain to follow what appears to be the main road. Park at the yellow gate (Map 1).

From here, the seeded and transplanted populations must be reached on foot as the BLM does not allow vehicle access beyond the gate. Walk past the gate and follow the main road. Once out of the trees (approx. 200 meters), the road will veer right and up a small hill. At the top of the hill, continue to follow the road downhill. On the left is a denuded hillside covered in mine tailings. Continue to follow the road. The north meadow will not be visible from this road. The first meadow encountered on the right is the middle meadow. Continue to follow the road south to the south meadow, the next meadow encountered on the right. A pond, not shown on the sketch map, separates the middle and south meadows. A smaller pond, also not shown on the sketch map, is located at the northern terminus of the south meadow. From this pond, cross the south meadow, walking toward the most obvious and largest *Pinus jeffreyi* on the southwest border of the meadow. Seed and transplant plots are located to the northeast of this tree on the edge of the meadow.



Map 1. Aerial photograph of French Flat and surrounding area, including Cave Junction and driving route to sit

Figure A14. Aerial photo of French Flat showing locations of planting and seeding areas at the North and South subpopulations of *Lomatium cookii*. The map scale is 1:7,000.

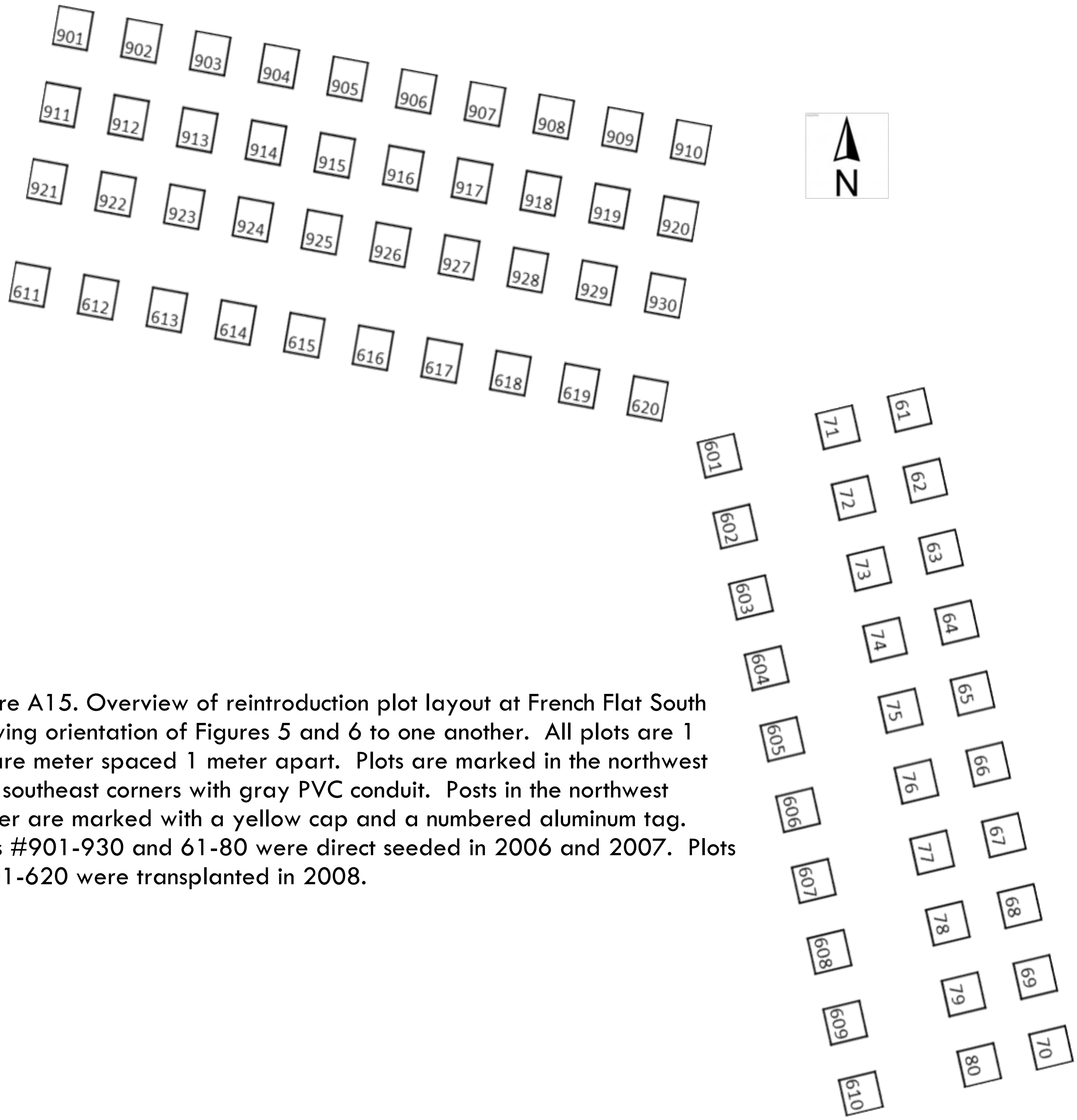


Figure A15. Overview of reintroduction plot layout at French Flat South showing orientation of Figures 5 and 6 to one another. All plots are 1 square meter spaced 1 meter apart. Plots are marked in the northwest and southeast corners with gray PVC conduit. Posts in the northwest corner are marked with a yellow cap and a numbered aluminum tag. Plots #901-930 and 61-80 were direct seeded in 2006 and 2007. Plots #601-620 were transplanted in 2008.

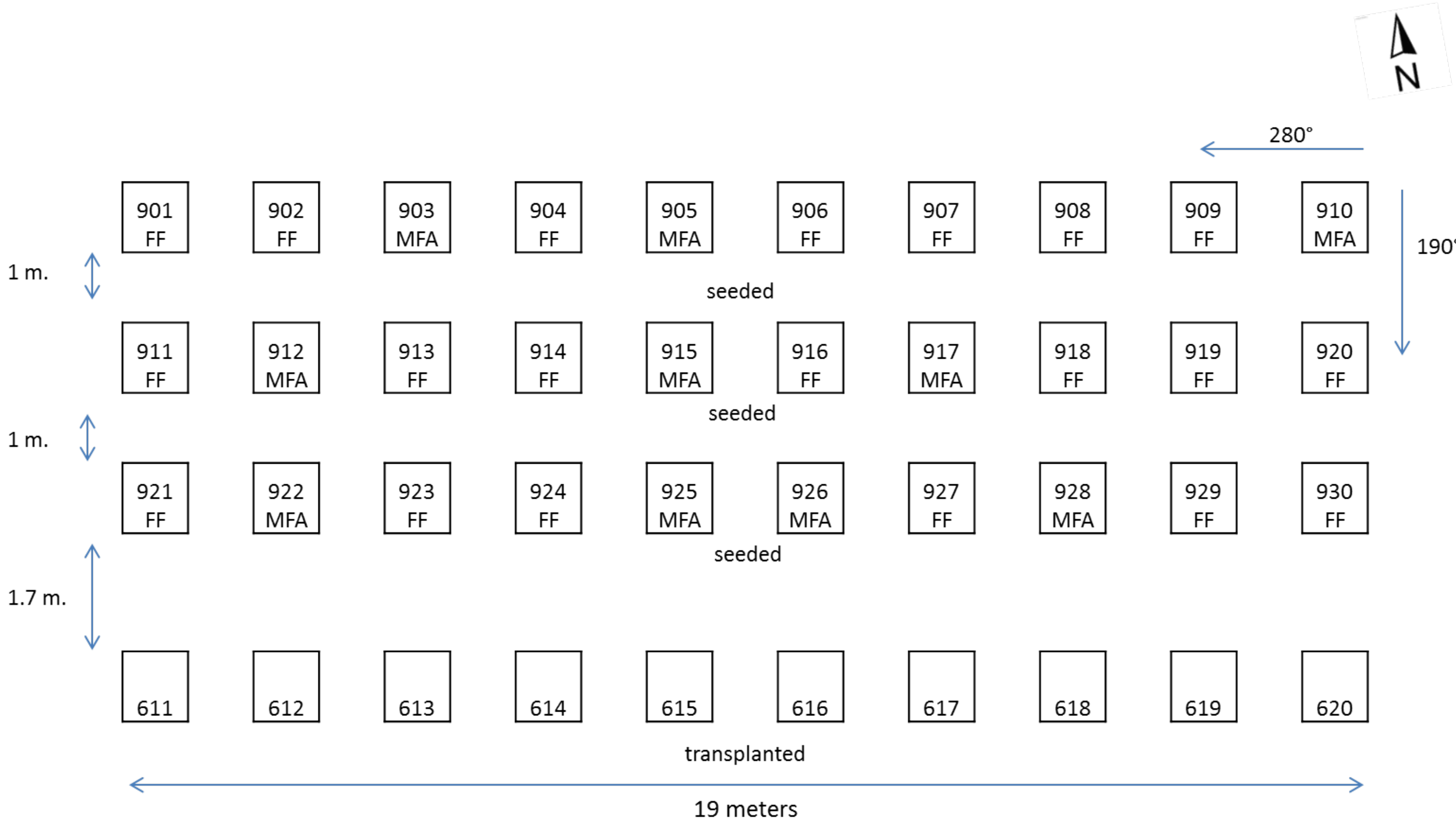


Figure A16. *Lomatium cookii* direct seeding and planting plots at French Flat, 2006. Plots are numbered with printed metal tags in the northwest corner. Plots #901-930 were seeded plots and #611-620 were transplanted. FF indicates plots that received French Flat seeds; MFA indicates plots that received Medford Airport seeds.

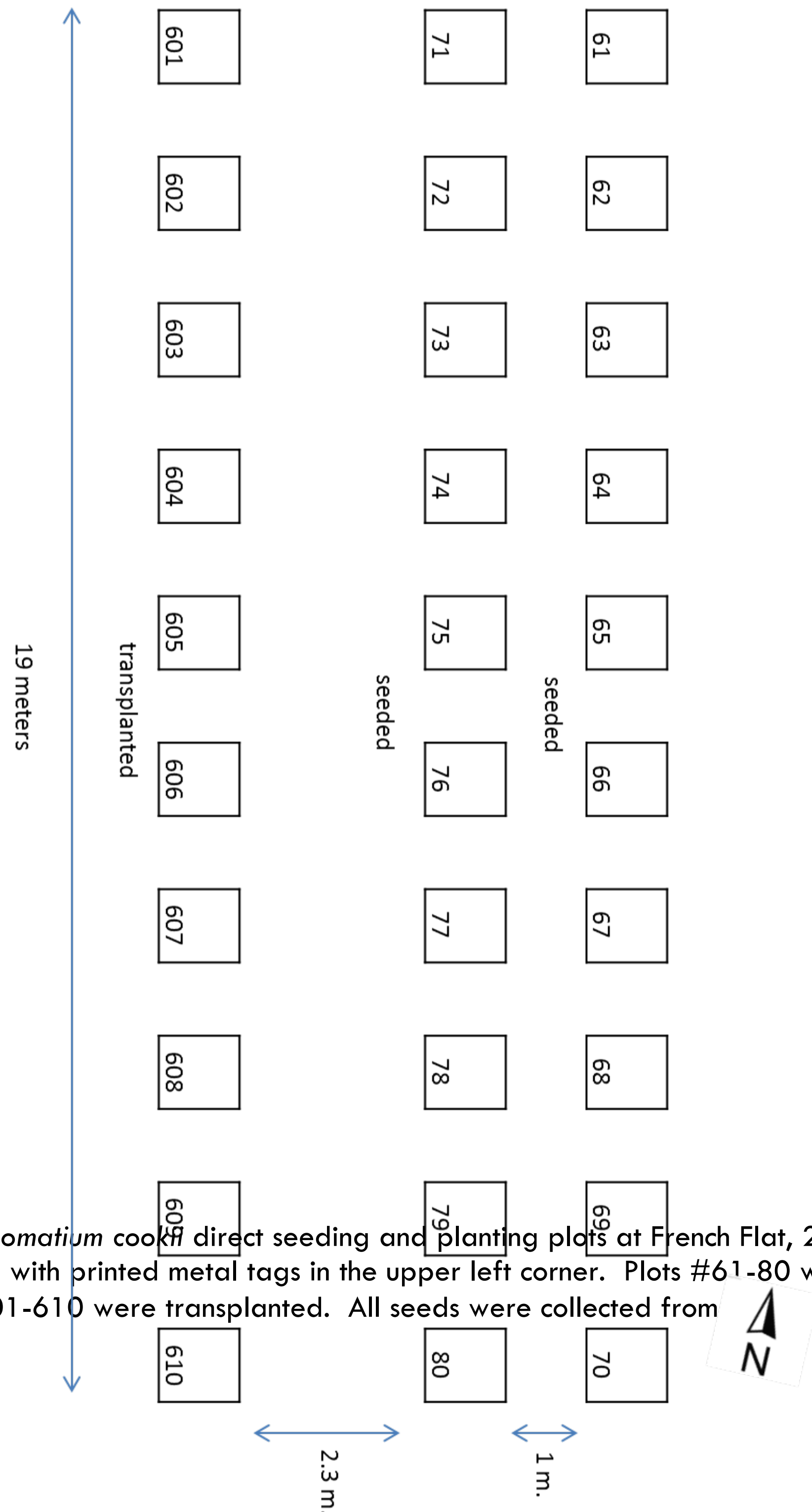


Figure A17. *Lomatium cookii* direct seeding and planting plots at French Flat, 2007. Plots are numbered with printed metal tags in the upper left corner. Plots #61-80 were seeded plots and #601-610 were transplanted. All seeds were collected from Flat.

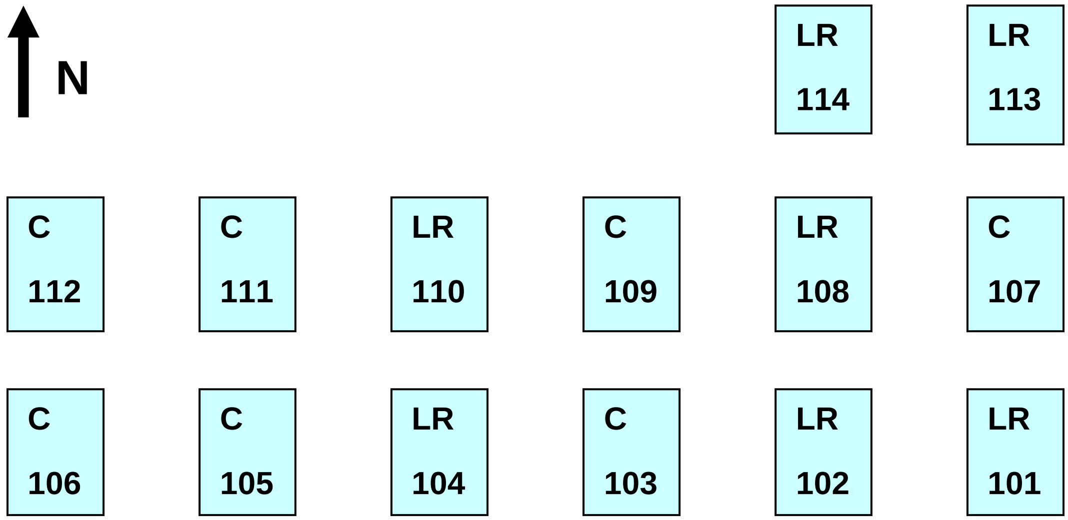
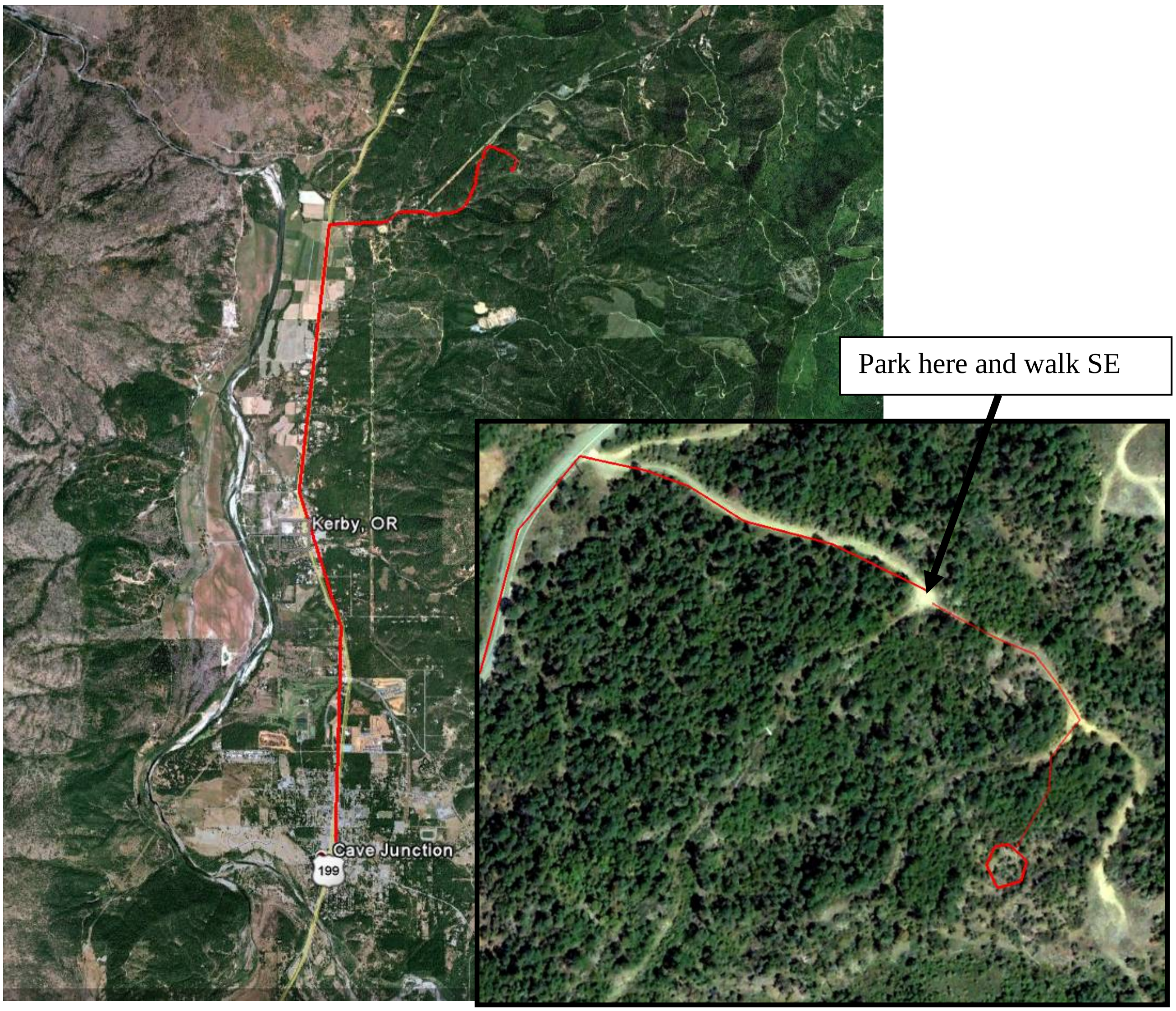


Figure A18. Plot layout at French Flat North, 2009. Plots were 1 m^2 and spaced 1 m apart. Treatment type (LR=litter removed, C=control) and tag number are shown for each plot.

Reeves Creek

From Cave Junction, drive 3.9 miles north on Hwy 199 to Reeves Creek Rd. turn east and travel 1.4 miles to Road 38-8-27.8. Turn right a go 0.1 mile and park at wide place in the road (with large pile of garbage present in 2009). Continue on road SE past blocked area approximately 0.1 mi and watch for spur road on right. Travel route to plots is flagged from here.

Map 2. Aerial photograph of Reeves Creek and surrounding area, including Cave Junction and driving route to site. Inset shows walking route from parking spot.



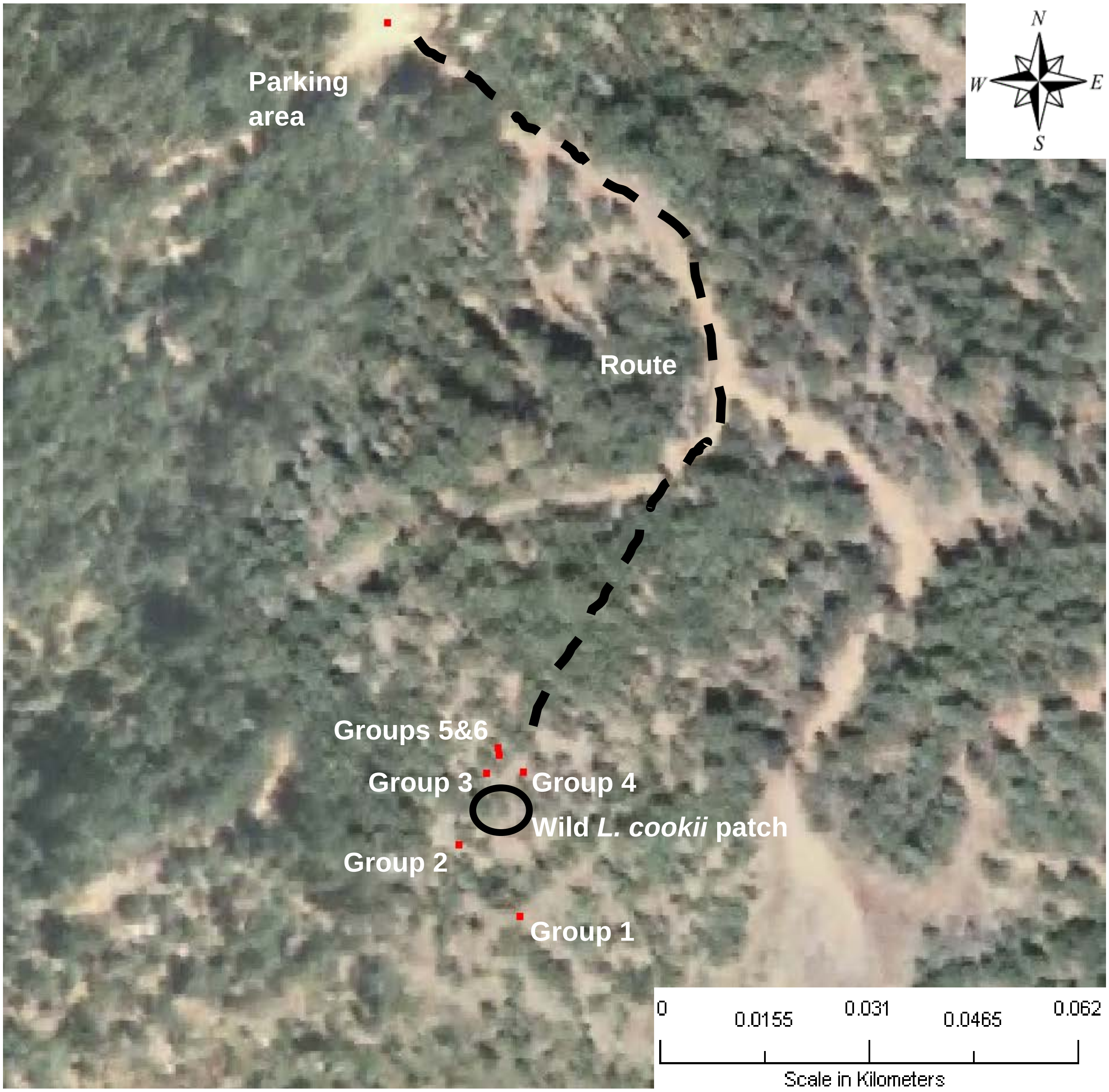


Figure A19. Aerial photo of the Reeves Creek area showing general GPS locations of seeding plots in six adjacent groups surrounding a wild patch of *Lomatium cookii*. The map scale is 1:1000.

Table A5. Plot group, number, seed source and litter treatment at the Reeves Creek site. Seed source codes are FF=French Flat (Middle subpopulation) and RC=Reeves Creek.

Group	Plot (tag no.)	Seed source	Litter removal	Habitat

1	115	FF	N	open
1	116	FF	Y	open
1	117	RC	N	open
1	118	FF	Y	open
2	119	FF	N	forest
2	120	FF	Y	forest
2	121	FF	N	forest
2	122	FF	Y	forest
2	123	RC	N	forest
3	124	FF	Y	forest
3	125	RC	N	forest
3	126	FF	Y	forest
3	127	FF	N	forest
4	128	FF	Y	open
4	129	FF	N	open
4	130	FF	Y	open
4	131	RC	N	open
4	132	FF	Y	open
5	133	FF	N	open
5	134	FF	Y	open
5	135	RC	N	open
5	136	RC	Y	open
5	137	FF	N	open
6	138	FF	Y	forest
6	139	FF	N	forest
6	140	RC	Y	forest

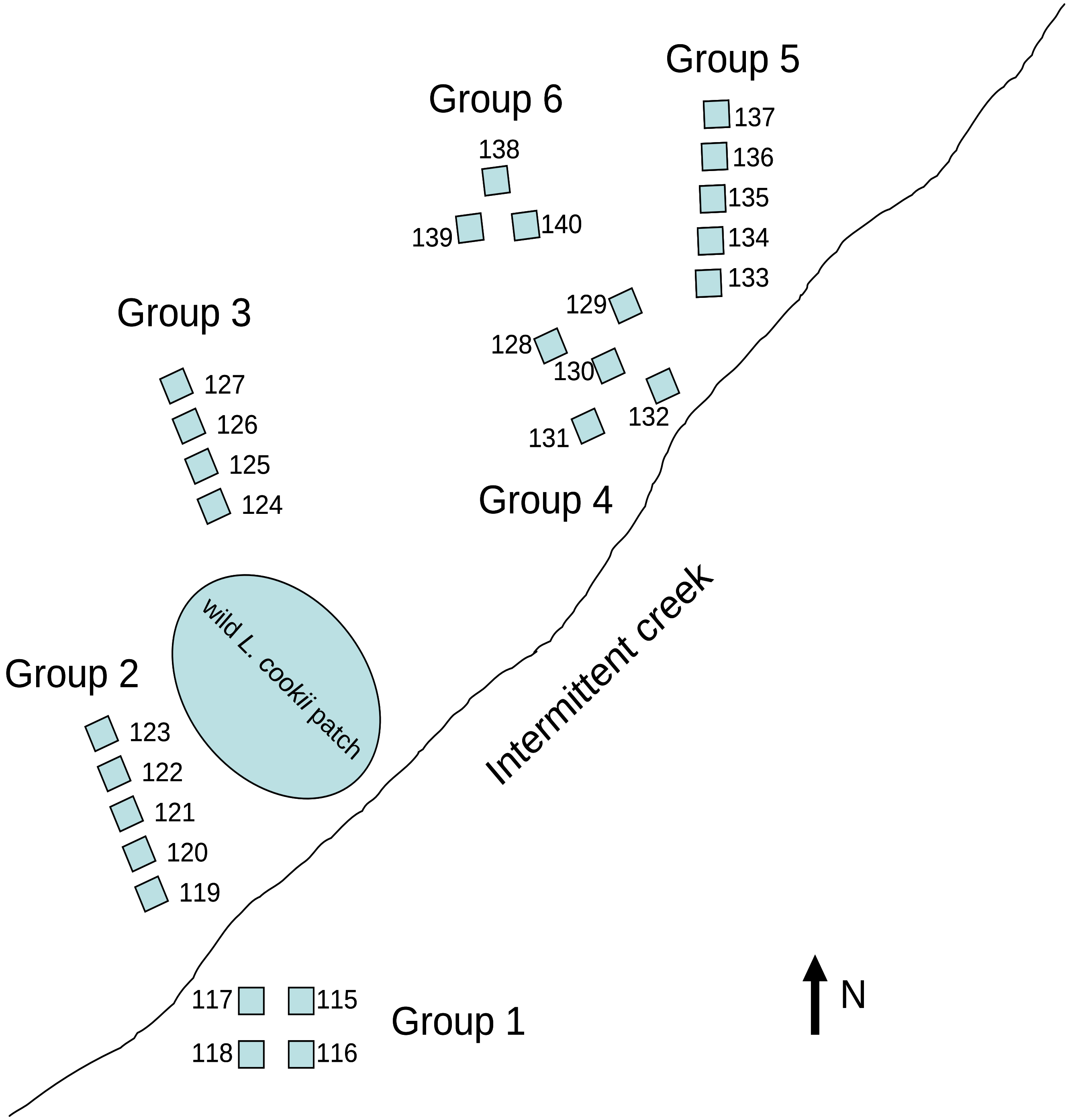


Figure A20. Plot layout at Reeves Creek. Six groups of plots were distributed across the site. Each plot was 1 m X 1 m in size, and in most groups the plots were 1 m apart. Each plot was marked in the lower right and upper left corners (facing uphill) with gray PVC conduit. The upper left post was tagged with a pre-numbered aluminum tag. Tag numbers are shown next to each plot. The map is not to scale.

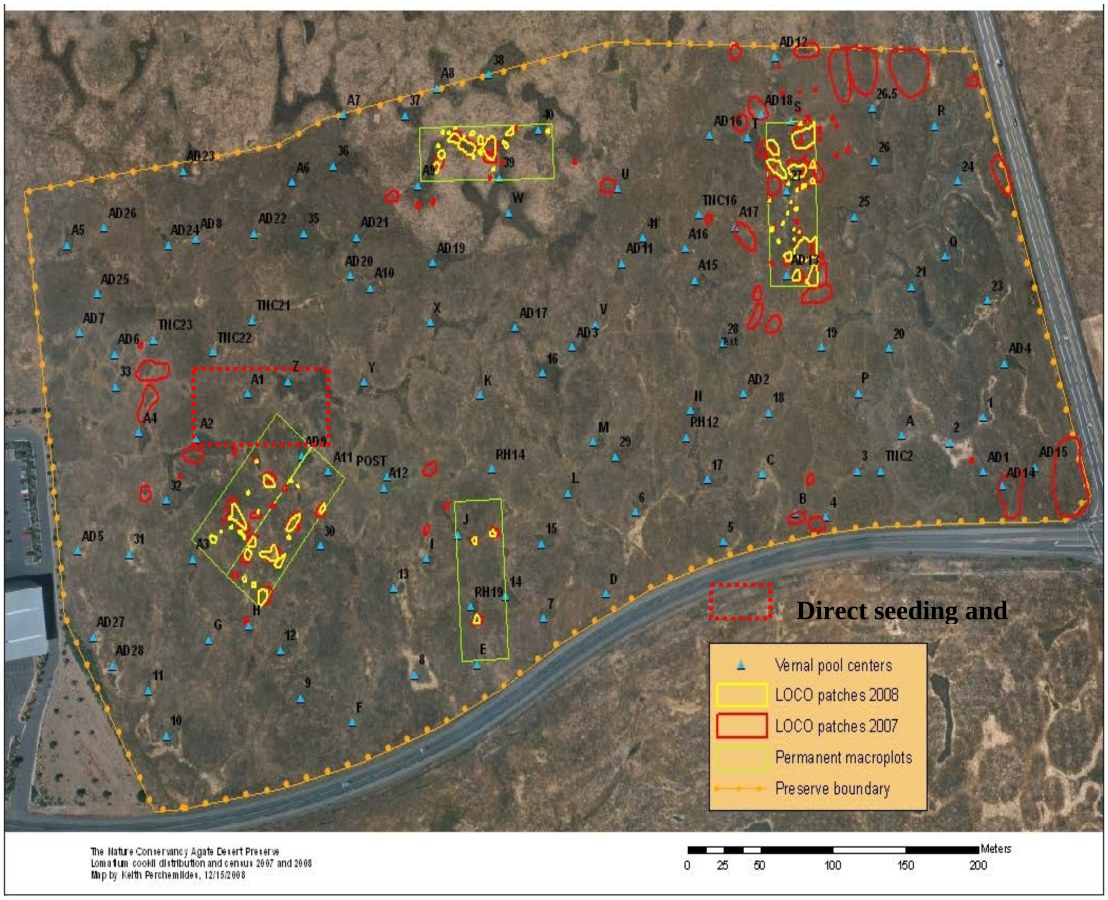
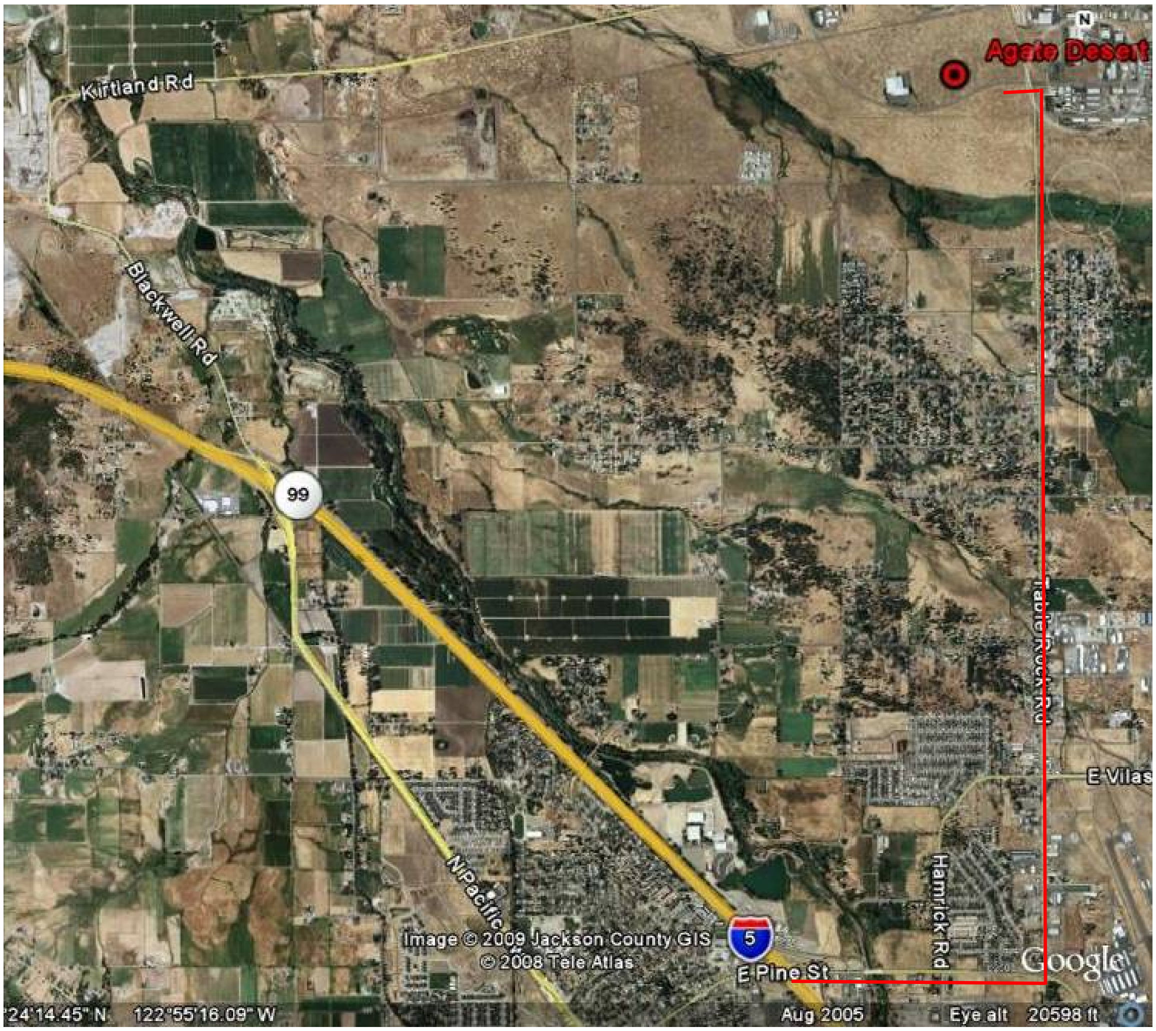


Figure A21. Aerial photo of Agate Desert Preserve, with *Lomatium cookii* populations and vernal pools.

Agate Desert

The Nature Conservancy's Agate Desert Preserve is located on the northwest corner of the intersection of Table Rock Road and Antelope Road in White City, Oregon, just NE of Medford. From I-5, take the Central Point Exit #33 and travel east on E Pine St. (becomes Biddle St.) approximately one mile to Table Rock Road. Turn left and travel north approximately 3.5 miles to the intersection with Antelope Road. Turn left and park on the right side of the road where the shoulder widens enough to accommodate a few vehicles.



Map 3. Aerial photograph of Medford and surrounding area. The Agate Desert site is in the upper right corner; the red line indicates a driving route from I-5 to the site.