ASSESSING MANAGEMENT TECHNIQUES FOR *LOMATIUM COOKII* (COOK'S DESERT-PARSLEY)

2016

Report to the Bureau of Land Management, Medford District

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Institute for Applied Ecology

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PREFACE

This report is the result of a cooperative 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.

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EXECUTIVE SUMMARY

This document summarizes results from two studies involving habitat management techniques for *L. cookii* to support recovery of the species. The studies include 1) an evaluation of herbicide effects at Illinois Forks State Park, and 2) the effects of prescribed fire on *L. cookii* and the surrounding plant community at French Flat Middle and French Flat South.

Illinois Forks

There were no clear differences in survivorship or size of *L. cookii* by treatment at Illinois Forks State Park in 2015 or 2016 (one year and two years post-treatment). There were changes in the plant community observed from 2014-2016, however treatment effects were not significant.

French Flat

Density (and population size) of *L. cookii* at French Flat Middle and French Flat South in 2014 and 2015 have been among the lowest recorded at these sites since monitoring began in 1993. While the cause of this decline is unclear, competition with non-native species, increasing litter and thatch, disturbance by off-road vehicles and climatic factors may be playing a role. In the fall of 2015, approximately half of the occupied portion of each meadow was burned under the supervision of BLM staff.

In the first year post-burn there were no differences in population structure (proportion of individuals in each size class) between the burned and unburned portions of the habitat. At French Flat Middle a larger proportion of the plants were grazed in the burned than unburned portions of the population (49% vs. 29%). At both French Flat Middle and French Flat South, the density of plants in the burned portion was slightly lower (7.9 and 9.1 plants per m^2) than that of the unburned portion (12.6 and 13.9 plants per m^2), however the difference was not significant. Results in 2017 are expected to be more informative, particularly if there are differences in recruitment, or other changes in population structure that were not immediately evident.

The cover of invasive graminoids is so low in the portions occupied by *L. cookii* that differences between burned and unburned portions were negligible. In burned plots there was higher cover of bareground and gravel than in unburned portions. Native graminoid cover was lower in burned plots, due to decreases in the size of *Danthonia unispicata* bunches.

ASSESSING MANAGEMENT TECHNIQUES FOR *LOMATIUM COOKII*

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) (ORBIC 2016). *L. cookii* is a member of the Apiaceae (parsley family). 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 plants are usually less than 3 dm tall and inconspicuous except when in flower. Ternately divided leaves feature many narrow leaflets and creamy yellow flowers are produced in compound umbels on leafless stems (Figure 1). Fruits are flattened and oblong. The species was originally described by Kagan in 1986 from specimens collected in the Medford area. 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.

Background

L. cookii was first discovered in 1981 in the Agate Desert in the Rogue River Valley. Habitats for the species in this area are characterized by patterned ground in the form of a series of vernal pools and mounds. *L. cookii* occupies a seasonally wet zone on the margins of the vernal pools. The dominant vegetation at Agate Desert 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 (Kagan 1994).

The largest federally-owned population of *L. cookii* occurs in the Illinois Valley at the French Flat Area of Critical Environmental Concern (ACEC) managed by the Medford District Bureau of Land Management. Areas around this population were placer-mined for many years. Populations in this area have been monitored annually since 1993 (Pfingsten et al. 2016). These populations are often found in moist, grassy meadows dominated by *Danthonia californica* (Kaye and Blakeley-Smith 2002). Other associated species at French Flat include *Danthonia unispicata,*

Deschampsia cespitosa, *Camassia quamash*, *Ranunculus occidentalis*, *Hesperochiron occidentalis*, *Horkelia daucifolia*, *Isoetes nuttallii*, *Calochortus uniflorus*, and *Viola hallii*. Trees and shrubs, such as *Pinus ponderosa*, *Pinus jeffreyi*, *Arctostaphylos* spp., and *Ceanothus cuneatus* border these grassy meadows (Mousseax 1993). 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. In addition to French Flat and Reeves Creek, population monitoring of *L. cookii* by IAE is also conducted at the Rough and Ready ACEC and at Indian Hill, also managed by the Medford District BLM. For more information about these populations see Pfingsten et al. 2016.

Mining activities continue to threaten *L. cookii*. Placer gold mining has restricted the population at French Flat and permanently altered much of the natural hydrologic patterns through the meadows. Some of the French Flat subpopulations monitored and discussed in this report are located on BLM managed lands adjacent to the Hillside Placer No. 1 and No. 3 mines owned and operated by a local resident. A proposed mining plan filed in 1993 would involve destruction of a significant portion of this subpopulation. Recently, mining plans have been filed with BLM that will alter habitat immediately adjacent to *L. cookii* at French Flat ACEC.

L. cookii habitat in the Illinois Valley is threatened not only by invasion of non-native species, but also by rural development and abuse by recreational users in the area. At Illinois Forks State Park, an unofficial trail cuts through one of the populations of *L. cookii* at the site. Unoccupied plots close to the river were disturbed by recreational users between 2014 and 2015 when a bulldozer (or other heavy equipment) was used to create a path to the river from the adjacent private property. French Flat has been repeatedly damaged by ORV use, where we observed fresh vehicle tracks from 2002-2007.

The 2012 USFWS Recovery Plan for the Rogue and Illinois Valley Vernal Pool and Wet Ecosystems states the following regarding the recovery priority and necessary habitat requirements for the species:

> **"Recovery priority.** *Lomatium cookii* has a recovery priority number of 2C, based upon a high degree of threat, a high potential for recovery, and a taxonomic classification as a species. The "C" indicates the potential for conflict between the species and construction, development, or other economic activities."
>
> "The primary constituent elements for *L. cookii* critical habitat include vernal pools, seasonally wet meadows within oak and pine forests, sloped mixed conifer openings, and shrubby plant habitats, the dominant native plant association of these habitats, and intact hydrology and soils that provides for adequate soil moisture. Enhancement and protection of these elements is critical to recovering the species."

Goal and Objectives

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

1. Study the effects of herbicide at sites occupied and unoccupied by *L. cookii,* and the surrounding plant community. (Illinois Forks State Park)
2. Study the effects of fire on *L. cookii* and surrounding the plant community. (French Flat Middle and French Flat South)

METHODS

Herbicide

Treatments included glyphosate, imazapic and fluazifop, as well as an untreated control. Plots were sprayed with glyphosate on 7 November 2014 and imazapic on 10 November 2014, and fluazifop was sprayed on 9 March 2015 and all herbicide applications included a non-ionic surfactant (Table 1).

Plots were monitored by IAE staff prior to treatment application in May 2014, and post-treatment in May 2015 and 2016. Plant species were identified to species level in all plots, and percent cover estimated. Additionally, demographic information was recorded for each *L. cookii* individual in the occupied plots.

Table 1. Herbicide application rates and dates of application at Illinois Forks State Park.

Chemical	Trade Name	Target species	Rate (oz/gal)	Surfactant (Activator 90)	Spray Volume	Time
Fluazifop	Fusilade DX	Grass specific, post-emergence	0.75	0.64 oz/gal	30 gal/acre	3/9/2015, 2:30 pm
Glyphosate	Roundup Custom	Broad spectrum, post-emergence	1.28	0.64 oz/gal	30 gal/acre	11/7/14, 3:00 pm
Imazapic	Plateau	Broad spectrum, pre-emergence	0.16	0.64 oz/gal	30 gal/acre	11/10/14, 1:30 pm

Unoccupied

To assess herbicide as a potential tool to control annual grasses and other noxious weeds in the presence of *L. cookii*, IAE worked with Oregon State Parks and the Medford BLM to conduct herbicide trials at Illinois River Forks State Park. In May 2014, 12 plots were established by IAE in areas not occupied by *L. cookii*. Plots are 2 x 8 meters (divided into four 2m x 2m treatment squares) marked at the corners with 8 yellow capped PVC pipes (Figure 3). The northwest corner is marked with the first plot tag in the series and the opposite corner (southeast) is marked with the next consecutively numbered plot tag. Four 1-m^2 plots are marked in the middle of each 2m x 2m plot with nails and hot pink washers in the northwest (has plot id tag) and southeast corners (Figure 3). For plot coordinates and schematics, see Appendix A and Appendix B.

Figure 2. Photo of an unoccupied plot at Illinois Forks State Park. In this photo, the 1m x 1m frames are in the center of each 2m x 2m treatment plot.

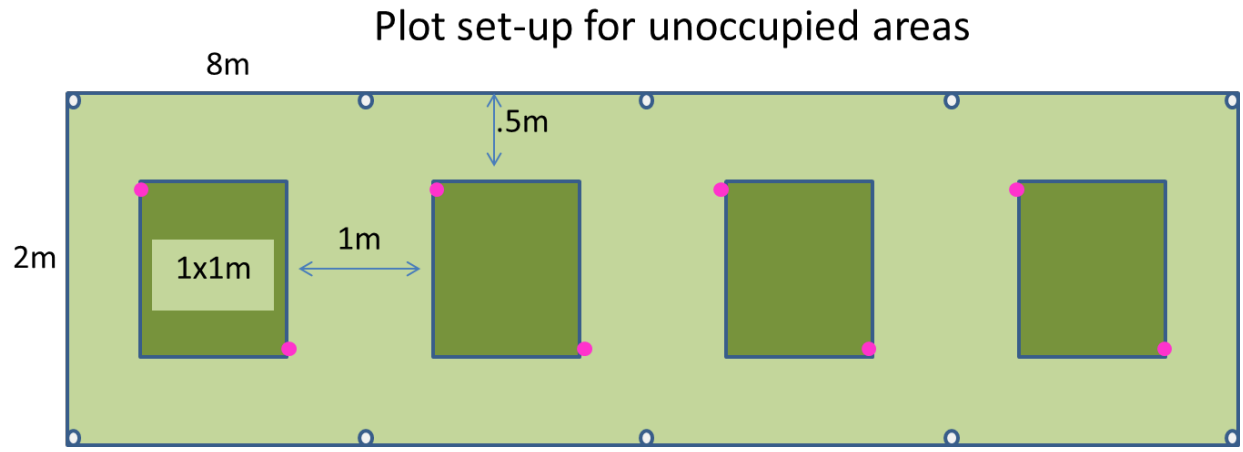

Figure 3. Plot setup for areas not occupied by *Lomatium cookii*. Plots are 2m x 8m, and each treatment block is 2m x 2m. Only the central $1m^2$ of each treatment plot was monitored for community composition.

Occupied

In May of 2014, 40 0.5m x 0.5m plots occupied by *L. cookii* at Illinois River Forks State Park were established in a patch of *L. cookii* approximately 20m x 15m wide. A 25 meter baseline was established running roughly N/S along the eastern edge of the *L. cookii* population and is marked with concrete markers placed flush with the ground at both ends. The head of the transect is at the N end, and is marked with tag #801 (end tag #802). See Appendix A for plot locations and Appendix B for schematic of plot layout.

The 40 plots monitored for both demography and plant community were established on transects that run perpendicular to this baseline (the longest of these transects is 15m). Within each demographic plot, all *L. cookii* plants were mapped, given unique numbers (beginning with #1), assigned to the life history categories discussed in the density section below, the length of the longest leaf was measured, and the presence or absence of grazing was recorded.

Fire

To study the effects of fire on *L. cookii* and the plant community, French Flat South and French Flat Middle were chosen for an experimental burn treatment. In the fall of 2015, portions of French Flat South and French Flat Middle were burned under the supervision of BLM Medford staff (Appendix C). In addition to fire, some trees were removed or girdled and shrubbery encroaching along the edges of the meadow was thinned. Existing plots established by IAE were chosen in both burned areas and unburned areas to collect plant community data, as well as demographic information. Plant species were identified to species level in all plots, and percent cover estimated. Additionally, the number of *L. cookii* were counted along transects in both burned and unburned areas. Details on the longer term history of the established plots at French Flat can be found in Pfingsten et al. 2016.

Density plots

In the 40m x 0.10m density plots, all *L. cookii* were counted and assigned to a specific life-history category, as follows:

S seedling

V1/2 vegetative with 1 or 2 leaves

V3 vegetative with 3 or more leaves

R1 reproductive with 1 umbel

R2 reproductive with 2 umbels

R3 reproductive with 3 or more umbels

Life-history categories were originally developed for *Lomatium bradshawii* monitoring in the Willamette Valley (Kaye et al. 2001). The similarities of the life-history characteristics of these species cause the categories to be applicable to *L. cookii* as well. Reproductive plants were segregated by umbel number because studies of *L. bradshawii* have shown that one-umbel plants rarely produce seed, while two-umbel plants produce seed on the second umbel, and three umbel plants may produce many seeds (Kaye and Kirkland 1994).

Demographic plots and analysis

At French Flat Middle and French Flat South, 20-30 existing 0.5m x 0.5m demographic plots were monitored to assess effects of burning on these plots. Approximately half of the plots in each meadow were burned (Appendix C). Similar to the demographic plots at Illinois Forks, within each demographic plot, all *L. cookii* plants were mapped, given unique numbers (beginning with #1), assigned to the life history categories discussed earlier, and the presence or absence of grazing was recorded. For details regarding the longer term history of these plots see Pfingsten et al. 2016.

RESULTS

Herbicide

L. cookii survivorship

In order to evaluate the treatment effects on *L. cookii*, the percent survivorship of original plants and average size were compared by treatment type (Table 2 and Figure 4.). Two plots were not included in analysis due to their proximity to a heavily used trail (use increased over the course of the study), these are plots #831-fluazifop, and #812-glyphosate). Fluctuations in plant numbers of more 10 individuals in these plots were noted in the portions of the plots most heavily trampled. See Appendix E for more detailed plot information.

There were no effects of treatment on survivorship of *L. cookii* in the herbicide plots. In the first year post-treatment, survivorship in the treatment plots ranged from 78%-92%, and in 2016 survivorship of original plants ranged from 63%-76% (Table 2). In both 2015 and 2016, the highest survivorship was noted in the plots treated with fluazifop. In addition to survivorship, the number of new plants in 2015 and 2016 are reported in Table 2. In each year, new plants were noted in all treatment plots resulting in an increase of 15%-27% in 2015 and 9%-28% in 2016.

In each year post-treatment, there were no differences in treatment plots between average *L. cookii* size in the control plots, or the density of plants (Table 3 and Figure 4). Since 2014, plant size has shown a general downward trend (2014 range 12.0cm -13.5 cm, 2016 range 9.5cm-10.8cm), however this slight decline is independent of treatment (Figure 4).

Table 2. Total number of plants in each treatment plot, number and percent of original plants present, and the number of new recruits from 2014-2016 at Illinois Forks State Park.

	Total # of plants present in treatment plots		
Treatment	**2014**	**2015**	**2016**
Control	49	47	45
Fluazifop	25	29	31
Glyphosate	56	59	64
Imazapic	55	51	50

	Number and % of original plants present				
	2014		**2015**		**2016**
Control	49	39	80%	31	63%
Fluazifop	25	23	92%	19	76%
Glyphosate	56	44	79%	38	68%
Imazapic	55	43	78%	38	69%

	Number of new plants in each year		
	2014	**2015**	**2016**
Control	-	8	8
Fluazifop	-	6	7
Glyphosate	-	15	12
Imazapic	-	8	5

Table 3. Average number of plants in demographic plots by treatment with 95% confidence intervals.

Treatment	**Average Number of Plants**					
	2014	95%C.I.	2015	95%C.I.	2016	95%C.I.
Control	4.9	3.2	4.7	2.5	4.5	1.9
Fluazifop	2.7	1.4	3.2	1.8	3.4	2.3
Glyphosate	6.2	2.4	6.5	2.9	7.1	3.3
Imazapic	5.5	3.1	5.1	2.8	5.0	2.5

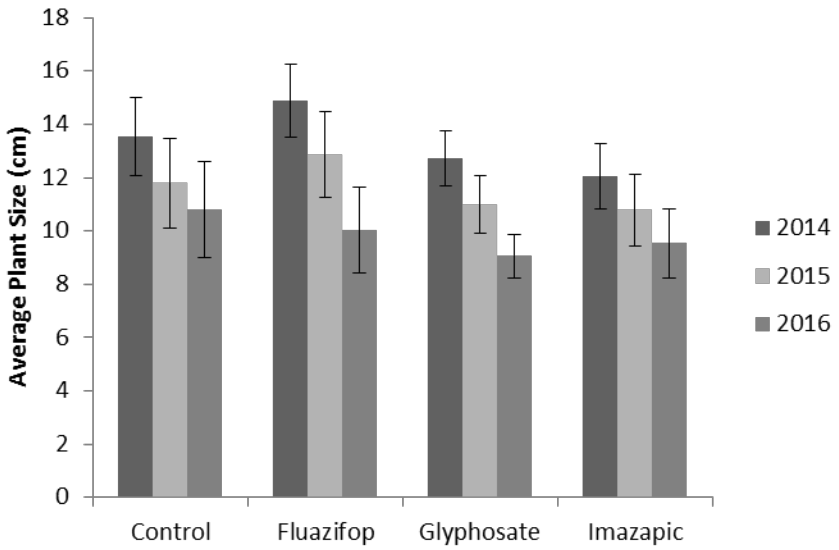

Figure 4. Average size of *L. cookii* in demographic plots at Illinois Forks State Park. Error bars represent 95% confidence interval.

Plant Community

Results are reported separately for the two groups, occupied and unoccupied plots, as the initial plant community differed between the two areas. The initial composition of areas occupied with *L. cookii* generally had less forbs (both native and invasive) and more graminoids, with a large proportion of the graminoids present classified as native perennials (often *Danthonia* sp.).

The plant community in the unoccupied area had higher cover of forbs (28% versus 13%) with a similar proportion of native to invasive cover of forb species. Graminoid cover in 2014 in both occupied and unoccupied areas was similar (28% and 34%, respectively), however, in the occupied areas, native graminoids dominated, whereas in the unoccupied areas invasive annual grasses are the dominant graminoid species. Common invasive annual grasses include *Bromus* spp., *Cynosurus echinatus*, *Vulpia bromoides* and *Taeniatherum caput-medusae*.

Occupied Habitat

Forbs

Average cover of forbs in 2014 ranged from 9.8%-16.3%, and native forb cover increased across all treatments to 28.9%-40.8% in 2016. In 2014, native forb cover ranged from 5.2% - 8.3%. Native cover increased in 2016 to a range of 23.7% - 30.2% in 2016 (Figure 5). Cover of invasive forbs has remained relatively low since 2014 (range 1.4%-11.0%), ranging from 5.2%-10.6% in 2016.

Graminoids

Graminoid cover decreased in all occupied plots from 2014-2016, with no significant differences found between treatments for any of the graminoid categories (Figure 6). In 2014, total graminoid cover was 48.8%-60.0%, and native graminoid cover ranged from 17.9%-30.8%. In

2016, this had declined to 10.7-22.6%, and native graminoids just 1.1%-5.2%. The changes in cover of the perennial *Agrostis* sp. and *Danthonia californica*, were the largest contributors to these decreases between 2014 and 2016 (Figure 7). Both species remain present at the site, but have shifted out of the plot area. Invasive graminoid cover in 2014 ranged from 22.9-33.9% and declined in 2016 to 9.6%-17.6% (Figure 6). As previously stated, the decreases in invasive (and native) graminoid cover from 2014 to 2016 can be contributed to declines in the perennial *Agrostis* sp. and *Danthonia* sp.

Native annual grasses increased from a low of 0.3%-0.9% in 2014 to 1.1%-5.1% in 2016 (Figure 7), although there were no statistically significant differences between treatments. In 2014, cover of invasive annual grasses ranged from 5.5%-12.9%, with *Bromus* spp. contributing the most to total cover. In 2016, invasive annual grasses ranged from 9.6-17.6% (Figure 7) with increases in the cover of annuals, *Aira caryophyllea* and *Vulpia bromoides*. All treatments showed high variability in cover of invasive grass species, and no statistical differences were observed.

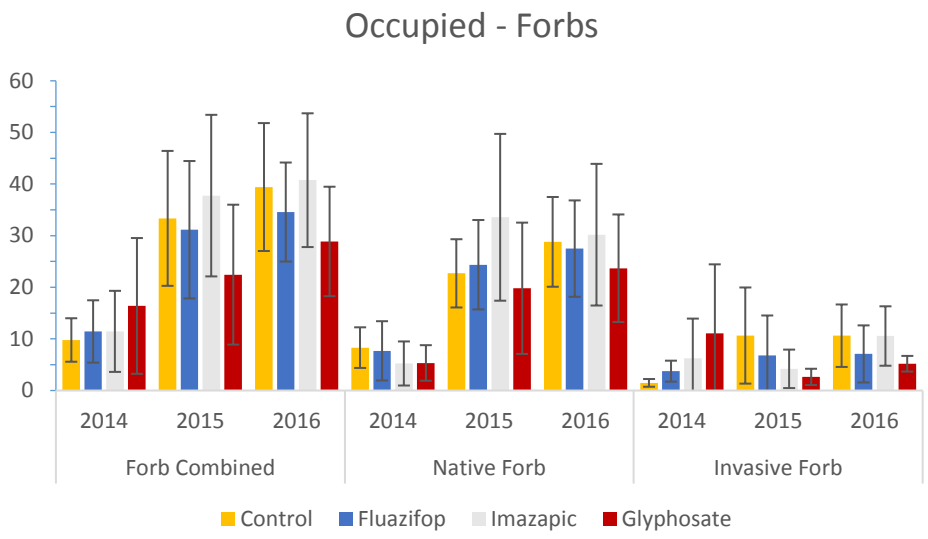

Figure 5. Average percent cover of forbs by treatment in the occupied habitat. Error bars represent 95% confidence interval.

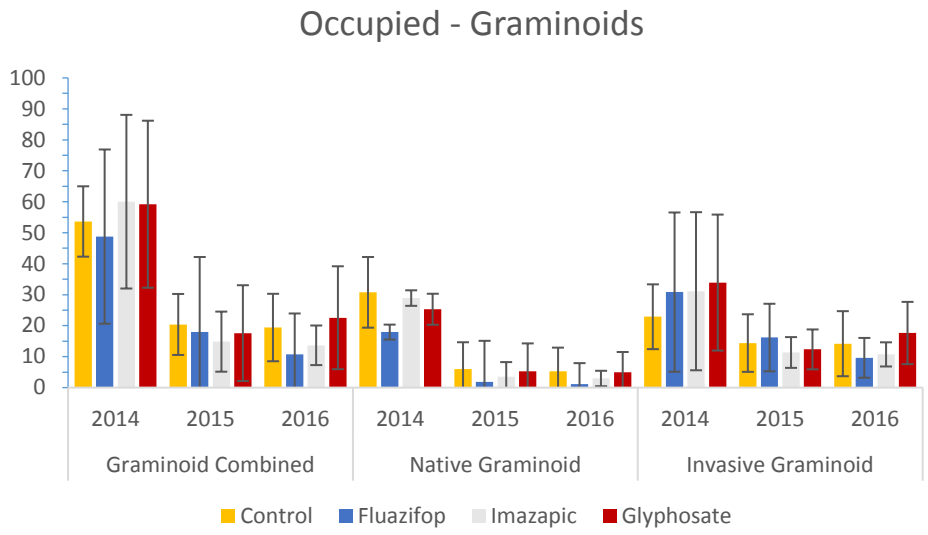

Figure 6. Average percent cover of graminoids by treatment in the occupied habitat. Error bars represent 95% confidence interval.

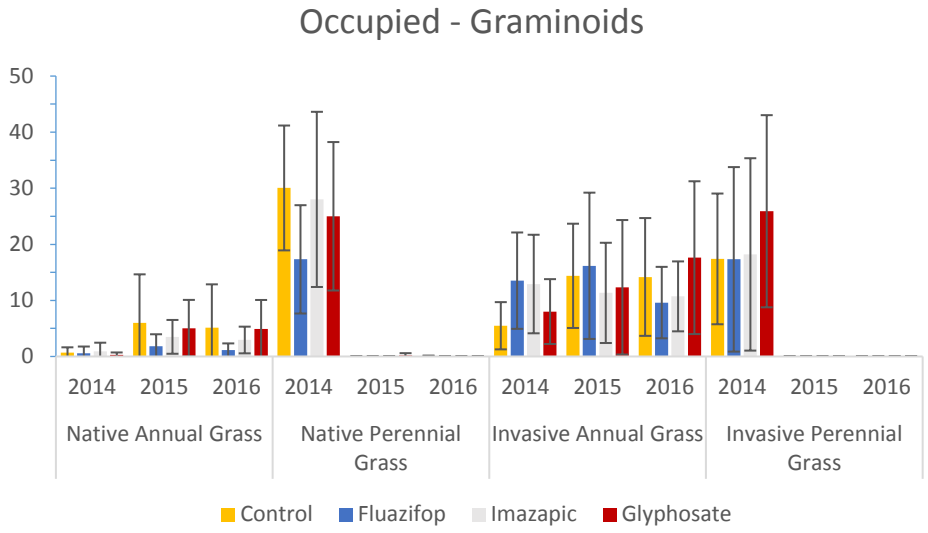

Figure 7. Average percent cover of annual and perennial graminoids. Error bars represent 95% confidence interval.

Unoccupied Habitat

Forbs

There was no statically significant effect of treatments on forb cover (Figure 8). Forb cover decreased across all treatments (including control) in the unoccupied plots from 2014-2016, ranging from 21.6%-31.2% and 7.6%-16.2%, respectively. These decreases were observed in

native (11.6-20.7% in 2014 to 5.0%-13.0% in 2016) and invasive forbs (6.9-11.1% in 2014 to 2.6%-3.3%).

Graminoids

Total graminoid cover in the unoccupied plots in 2014 ranged from 25.3%-28.1%, with native graminoids comprising only 2.4%-5.0% and invasive graminoids 21.8%-25.7% (Figure 9). In 2016, total graminoid cover ranged from 6%-17%, with native graminoids ranging from 3%-7% and invasive graminoids ranging from 4%-10% (Figure 9). The decrease in total graminoid cover was observed across all treatments, including the control, and no statistical differences were found. Annual grasses (both native and invasive) showed a similargeneral downward trend, with no significant differences between treatments on annualgraminoid cover (Figure 10).

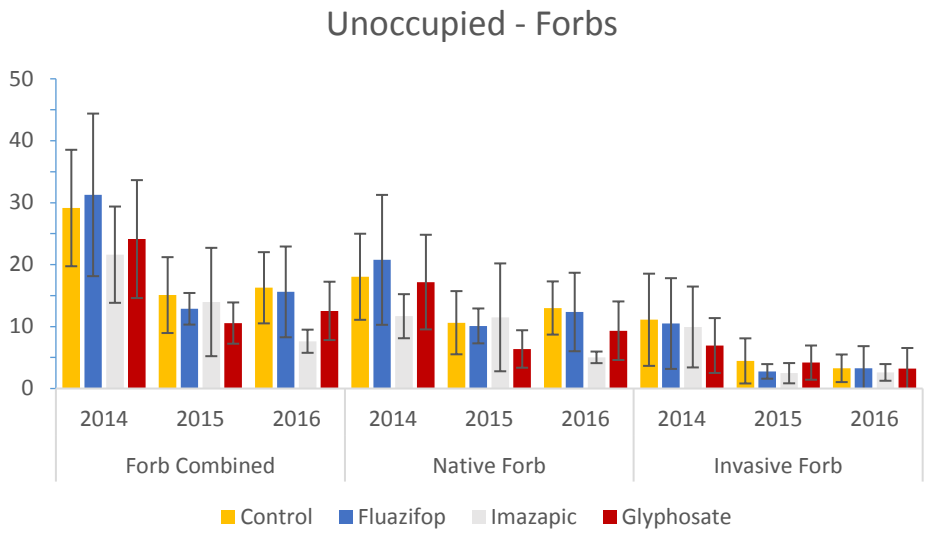

Figure 8. Average percent cover of forbs in unoccupied habitat. Error bars represent 95% confidence interval.

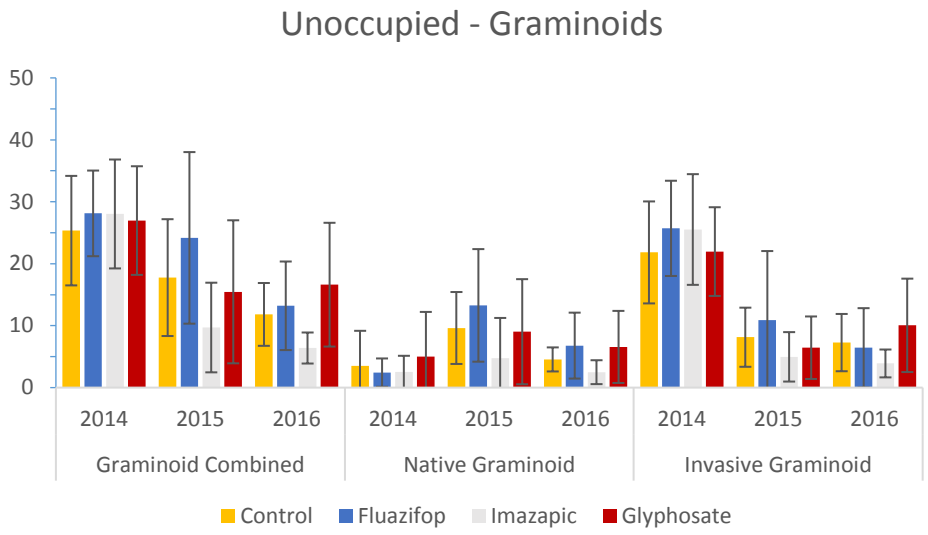

Figure 9. Average percent cover of graminoid species in unoccupied habitat. Error bars represent 95% confidence interval.

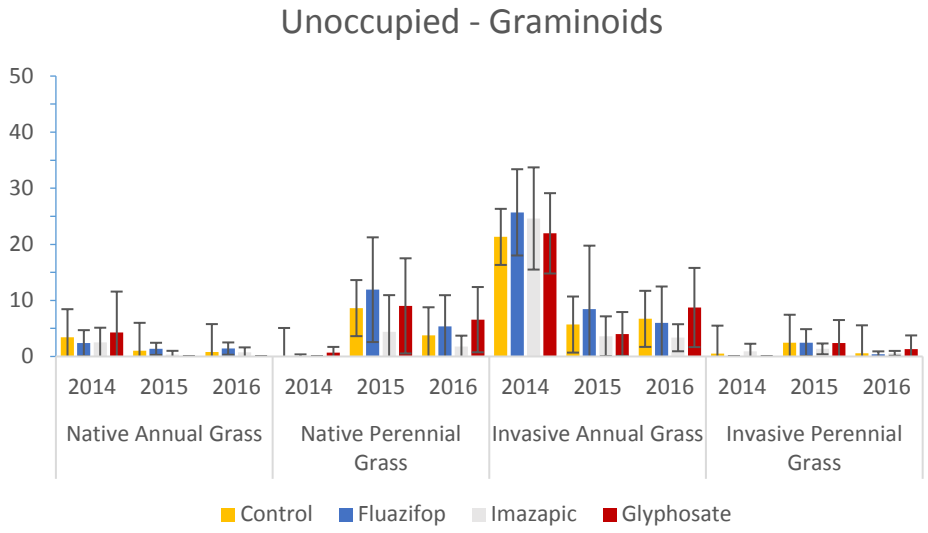

Figure 10. Average percent cover of annual and perennial graminoids in unoccupied habitat. Error bars represent 95% confidence interval.

Fire

Plant Community

Results are reported here for French Flat Middle and French Flat South by functional group and ground cover class. At both sites, the burned plots had significantly lower litter cover than unburned plots, 45% vs. 6% at French Flat Middle and 51% vs. 14% at French Flat South (Figure 11). Bareground cover is significantly higher in the burned plots at French Flat South (57% vs.

24%), whereas at French Flat Middle, there was not a difference in bareground cover in the burned vs unburned plots, instead differences in the "Rock/Gravel" cover were noted in the burned plots (Figure 11).

There was no significant difference between burned and unburned plots on the cover of native forb species in either meadow. Native graminoid cover was significantly lower in the burned plots at both sites with cover of 32% vs 15% at South, and 38% vs. 13% at Middle (Figure 12). Cover of invasive grasses in both areas is low (<1%), thus differences between burned and unburned plots are negligible with respect to total cover.

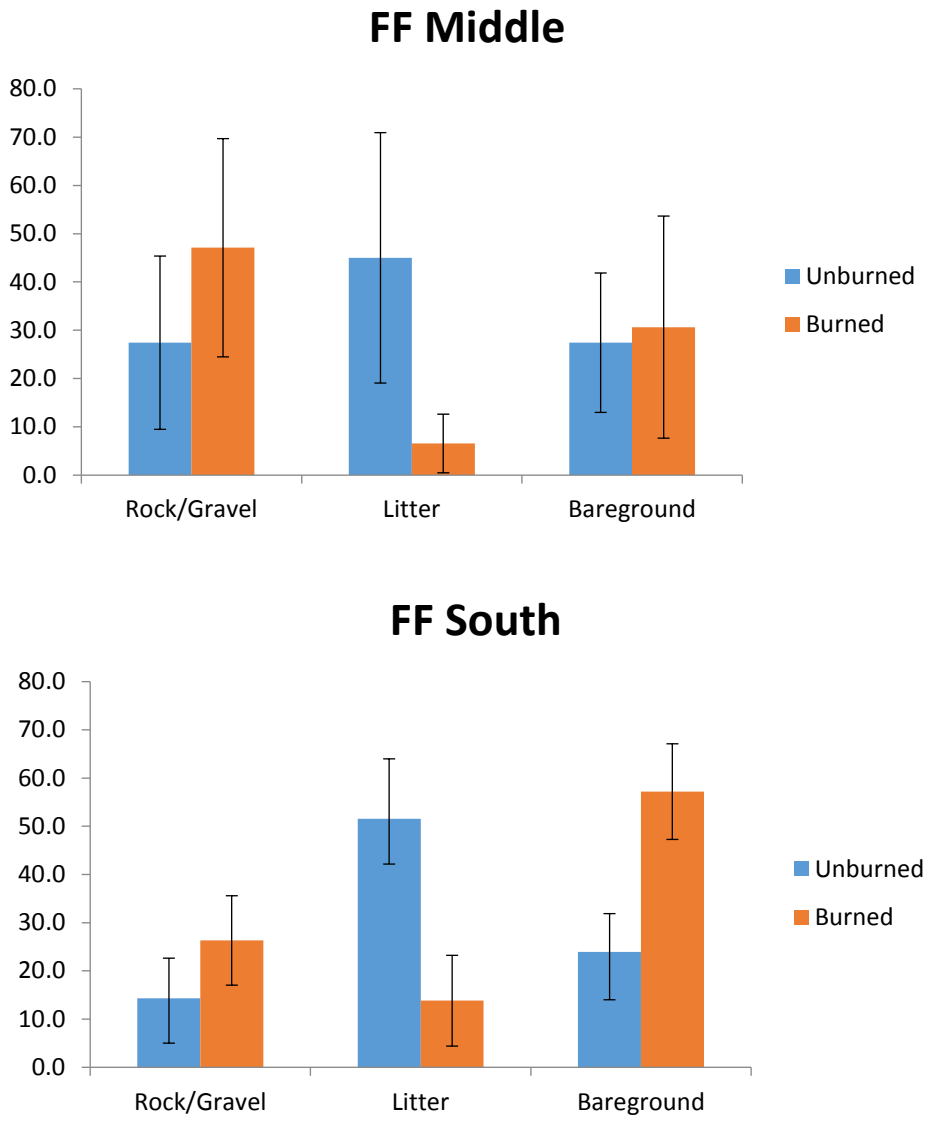

Figure 11. Ground cover at French Flat Middle and French Flat South in 2016. Error bars represent 95% confidence interval.

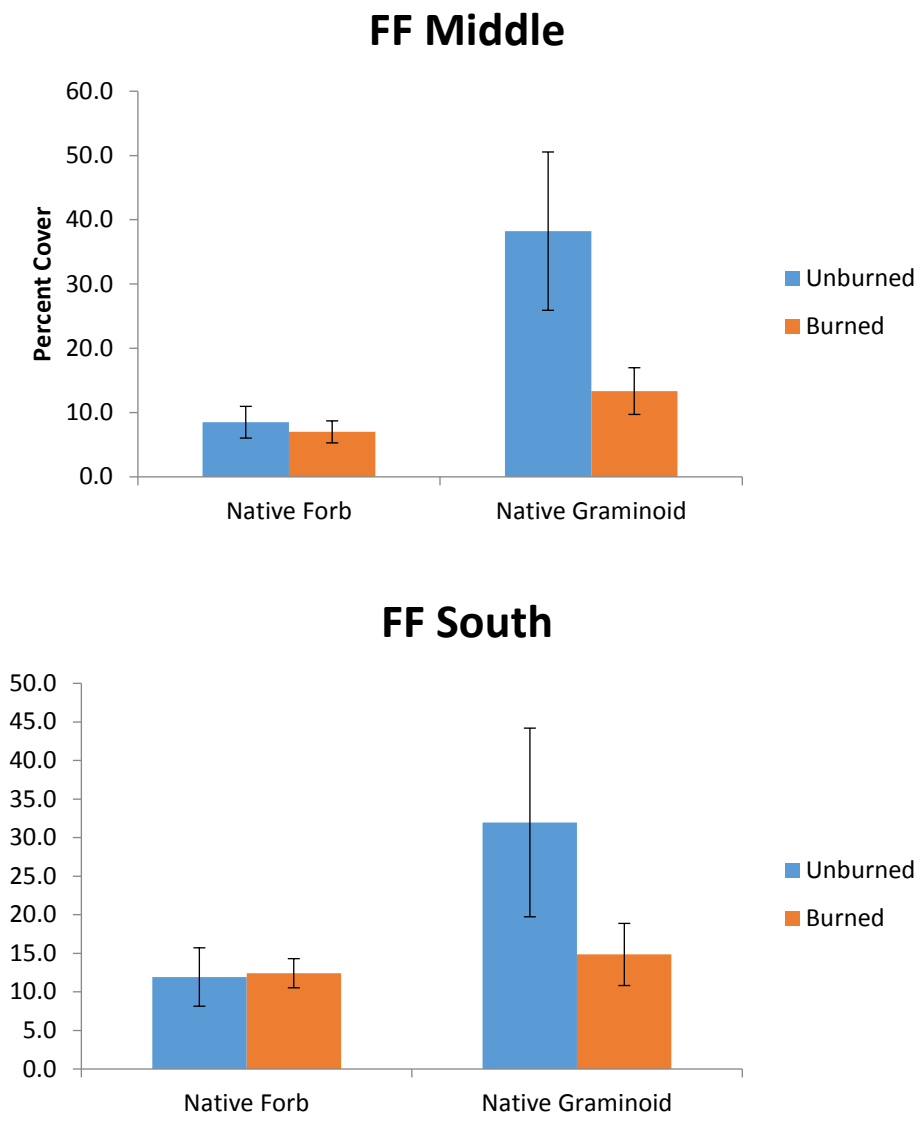

Figure 12. Native forb and graminoid cover at French Flat Middle and French Flat South in 2016. Error bars represent 95% confidence interval.

Lomatium cookii

Density

Since 1993 at French Flat Middle and South, the density of plants has ranged from 6.8-33.4 plants per m^2 at South, with some of the lowest densities observed in 2014 and 2015. Similar trends have been observed at French Flat Middle, where densities have ranged from 7.9 to 41.7 plants per m^2 with densities in 2014 and 2015 among the lowest observed (8.5 and 9.9 respectively). See Pfingsten et al. 2016 for details on long term density and population trends.

In 2016, density of *L. cookii* was higher in the unburned plots (12.6 and 13.9 plants per m^2) than in the burned plots (7.9-9.1 plants/m^2) at both sites, however this difference is not significant (Figure 13).

There were no differences in the population structure between the treatments. The size class "V3" (non-reproductive plants with three or more leaves), is the most abundant representing approximately half of the plants monitored in both treatments (Figure 14). Monitoring in 2017 will allow us to evaluate the longer-term effects of fire on this population.

Although the proportion of each size class is consistent between treatments, there are differences in the amount of grazing observed in burned and unburned treatments at one of the sites. At French Flat Middle 29% of the plants in the unburned portion showed signs of grazing whereas 49% showed signs of grazing in the burned portion. At French Flat South, there was no difference between grazing in the burned or unburned portions, with 43% and 40% of plants showing signs of grazing respectively (Figure 15).

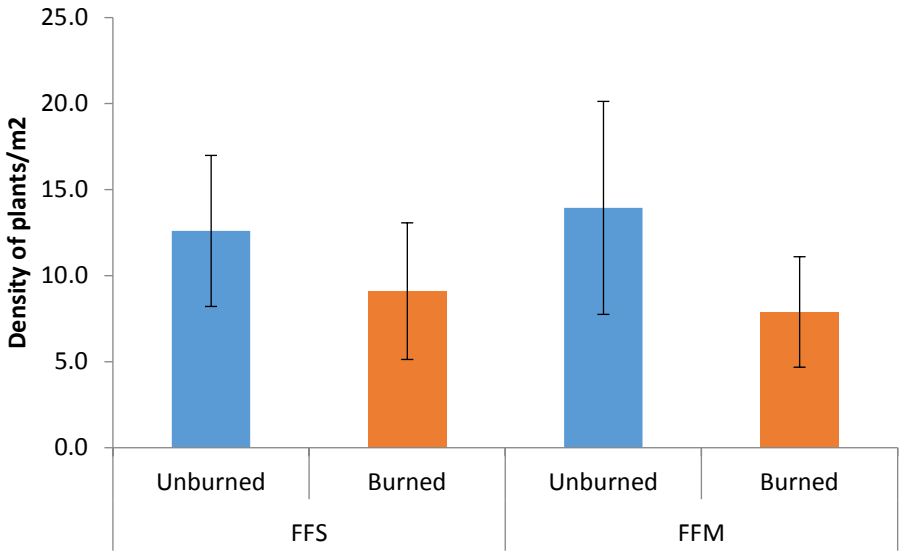

Figure 13. Density of *L. cookii* in 2016 in the burned and unburned portions of French Flat Middle and French Flat South.

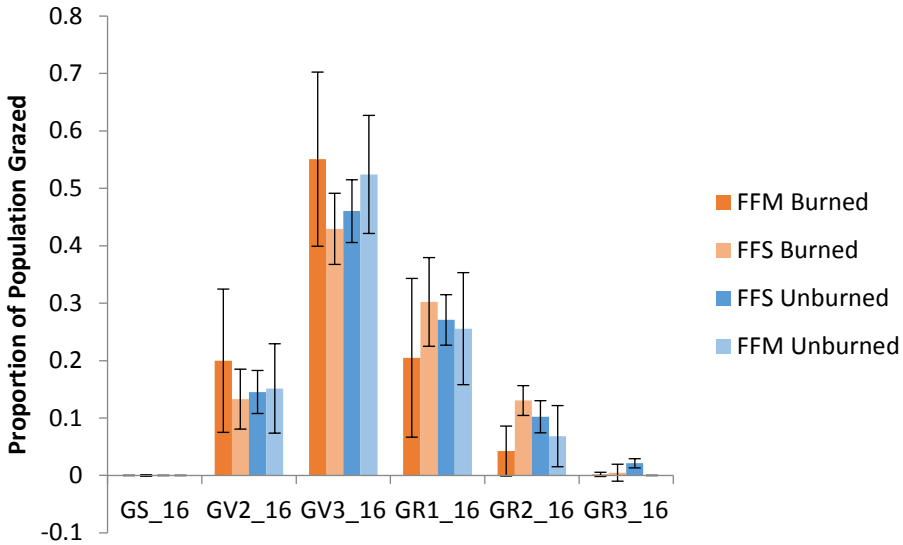

Figure 14. Proportion of plants grazed in the burned and unburned portions of French Flat Middle and French Flat South by size class in 2016.

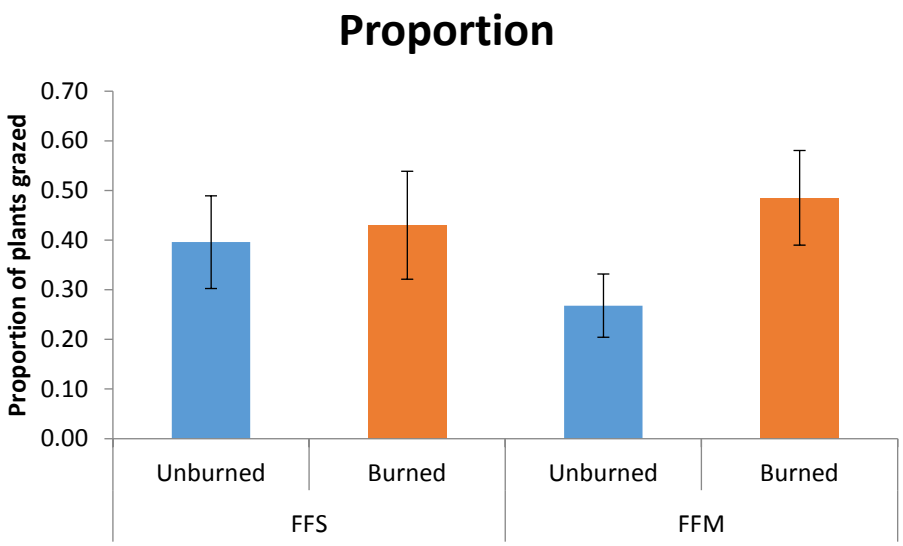

Figure 15. Proportion of plants grazed in burned and unburned portions of French Flat South and French Flat Middle.

DISCUSSION

Plant Community Response to Habitat Management Treatments

At Illinois Forks State Park in the unoccupied (and weedy) habitat, although there were visual differences between the herbicide-treated plots even in the second year post-treatment, these differences were not detected in the measured plant community composition. Previous studies have shown that fall application of imazapic (pre-emergent herbicide) and spring application of fluazifop (grass-specific herbicide), alone and in combination, reduced exotic annual grasses for two years after treatment (Menke and Kaye 2016), however due to the variability observed between our plots, our results were inconclusive. In the occupied and unoccupied habitats, invasive graminoids decreased across all treatments (including controls), and there was not a consistent treatment effect. Because these vegetation changes were observed even in the controls, these changes could be in part due to annual (and seasonal) differences between water levels, or other climatic factors in this ephemeral vernal pool environment. Additionally, our monitoring only occurred in the spring (May) of each year and thus we did not necessarily detect changes to the annual grass community in other parts of the year. For example, *T. caput-medusae* germinates in the early fall, and it is possible that due to the timing of our monitoring we did not detect changes in this species.

At French Flat, in the area occupied with *L. cookii*, cover of invasive grasses is so low that we were not able to distinguish any effects of the fire on these problematic species in our community data. However, invasive annual grasses (in particular *T. caput-medusae*) are becoming more common, and encroaching from the edges of the meadow (and along the road) into the portions of the meadow occupied by *L. cookii* (although not within our current monitoring area). While native graminoid cover was lower in the first year post-fire at both French Middle and French Flat South,

this was mostly related to decreases in the size of bunches of *Danthonia* sp. which will likely rebound in 2017. The longer-term effects of burning on *T. caput-medusae* and other invasive species at this otherwise relatively pristine location can inform future management actions.

At Illinois Forks State Park, in occupied habitat, plots have had a general shift (independent of treatment) away from perennial graminoids towards more annual grasses (both native and invasive). Continued habitat monitoring at French Flat will allow us to see if these changes are also occurring at French Flat.

Lomatium cookii Response to Habitat Management Treatments

Since 2014, densities at both French Flat Middle and French Flat South have been among some of the lowest recorded at these sites since monitoring began in 1993. Competition from other (non-native) species, changes in soil pH and composition from needle and litter cast, encroachment by shrubby and woody species, as well as climatic and other factors at French Flat may be contributing to these declines. While burned plots had slightly lower densities of *L. cookii* than unburned plots in the first season, this difference was not statistically significant, and it will be valuable to observe the longer term effects of these treatments. It is predicted that there will be increases in seedling recruitment and potentially an increase in reproductive effort into the future in the burned plots.

Additionally, expansion of the population into the newly cleared meadow edges is anticipated, though it is possible that seed addition (or transplanting) as well as litter removal of *Pinus* (and less so *Quercus*, *Ceanothus* and *Arctostaphylos*) may be recommended to accelerate the colonization of the newly created meadow edges at both French Flat South and Middle, and to increase connectivity between the two populated areas.

During monitoring of the *L. cookii* populations at French Flat in the recent past, an increase in the presence of *T. caput-medusae* into the occupied habitat at French Flat Middle and French Flat South has been noted. The presence of this weed species is particularly alarming, as the meadows of the French Flat Area of Criticial Environmental Concern are otherwise dominated by native species. Aggressive control of this invasive species is recommended.

Differences were observed in the proportion of plants grazed between burned and unburned at French Flat Middle (but not at French Flat South). At both French Flat South and French Flat Middle, the proportion of plants that were grazed in each size class mirrored its proportion within the ungrazed population, indicating that there was not an apparent preference by grazers for certain age classes in 2016 (Figure 16).

At Illinois Forks State Park, no significant differences were between survivorship or recruitment between treated and control plots. Additionally, recruitment was noted in all plots. Although none of the treatments resulted in satisfactory changes in the targeted species, the recruitment of new *L. cookii* individuals at least shows that the treatments did not appear to do harm. These results are encouraging from a land management perspective, as it indicates that careful, appropriate and well-timed habitat management can be performed in *L. cookii* occupied populations for the control of troublesome species.

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APPENDIX A. COORDINATES FOR UNOCCUPIED AND OCCUPIED HABITAT PLOTS AT ILLINOIS FORKS STATE PARK.

Unoccupied Habitat

River/ Road	Block tag #s NW/SE corners	Meter sq. Plot tag#				Coordinates of NW corner tag (NAD 83)
Road	901/902	903	904	905	906	42.15844011 -123.65429099
Road	907/908	909	910	911	912	42.1582578 -123.65404523
Road	913/914	915	916	917	918	42.15818086 -123.65393442
Road	919/920	21	22	23	24	42.15805706 -123.65332036
Road	925/926	927	928	929	930	42.15771742 -123.65269465
Road	931/932	933	934	935	936	42.15699775 -123.65173870
Road	937/938	939	940	941	942	42.15760075 -123.65262156
River	943/944	945	946	947	948	42.15576972 -123.65672392
River	949/950	951	952	953	954	42.15575723 -123.65665460
River	955/956	963	964	965	966	42.15552061 -123.65664622
River	961/962	963	964	965	966	42.15518818 -123.65698258
River	967/968	969	970	971	972	42.15531668 -123.65685635

[1] The occupied plots can be found near Plots 901/902. The 25m baseline runs roughly North-South from #801 to #802 and is marked with concrete markers on both ends.

Occupied Habitat

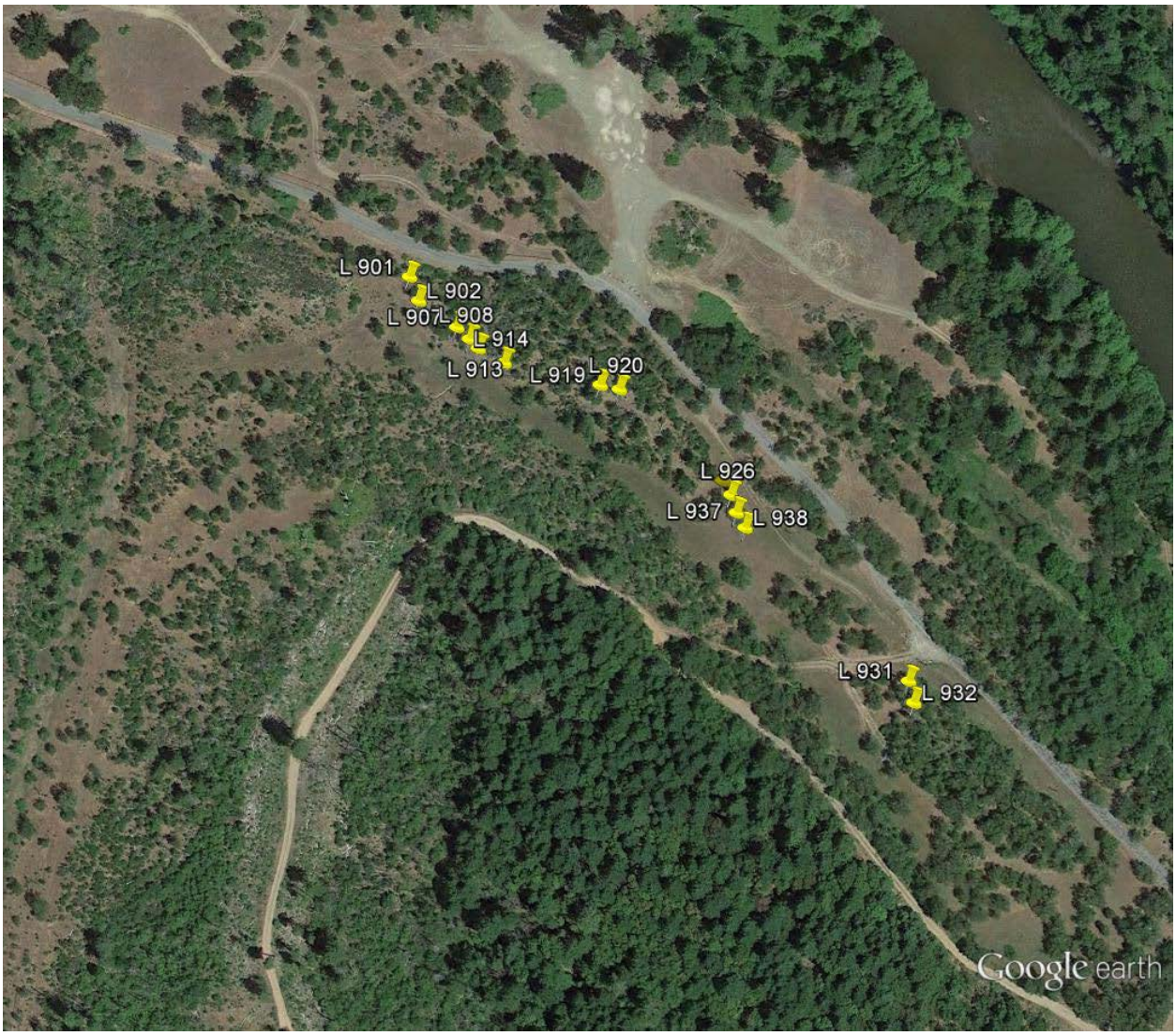
Plot#	Treatment	Transect #/Baseline Meter	Location of Demography Plot (m)
803	Control	843/21.5m	5.45
804	Fluazifop	843/21.5m	6.5
806	Imazapic	844/20.5m	4.6
807	Glyphosate	844/20.5m	5.6
808	Fluazifop	844/20.5m	7.5
809	Imazapic	845/19.5m	5.3
810	Control	845/19.5m	7.1
811	Imazapic	846/ 18.5m	6.15
812	Glyphosate	846/ 18.5m	7.4
813	Control	846/ 18.5m	6
814	Fluazifop	847/17.5m	15.15
815	Glyphosate	847/17.5m	7
816	Imazapic	847/17.5m	8.5
817	Control	848/16.5m	5.9
818	Glyphosate	848/16.5m	6.7
819	Fluazifop	848/16.5m	7.7
820	Glyphosate	849/ 15.5m	9.7
821	Control	849/ 15.5m	6.6
822	Imazapic	849/ 15.5m	7.8
823	Glyphosate	849/ 15.5m	9
824	Fluazifop	850/14.5	10.1
825	Control	850/14.6	7.8
826	Glyphosate	850/14.7	9.8
827	Fluazifop	850/14.8	10.85
828	Imazapic	850/14.9	13
829	Imazapic	851/13.5m	1.4
830	Fluazifop	851/13.5m	7.3
831	Fluazifop	851/13.5m	10.8
832	Control	852/13m	3.9
833	Glyphosate	852/13m	8.3
834	Imazapic	853/12.5m	4.4
835	Fluazifop	854/12m	3.5
836	Glyphosate	854/12m	5
837	Control	854/12m	7.3
838	Imazapic	855/11.5m	5.6
839	Control	856/11m	3.25
840	Fluazifop	856/11m	13.1
841	Glyphosate	858/9.5m	5.8
842	Imazapic	859/8.5m	3.7
401	Control	859/8.5m	5.9

APPENDIX B. AERIAL PHOTOS AND SCHEMATICS OF PLOTS IN THE UNOCCUPIED AND OCCUPIED HABITATS AT ILLINOIS FORKS STATE PARK.

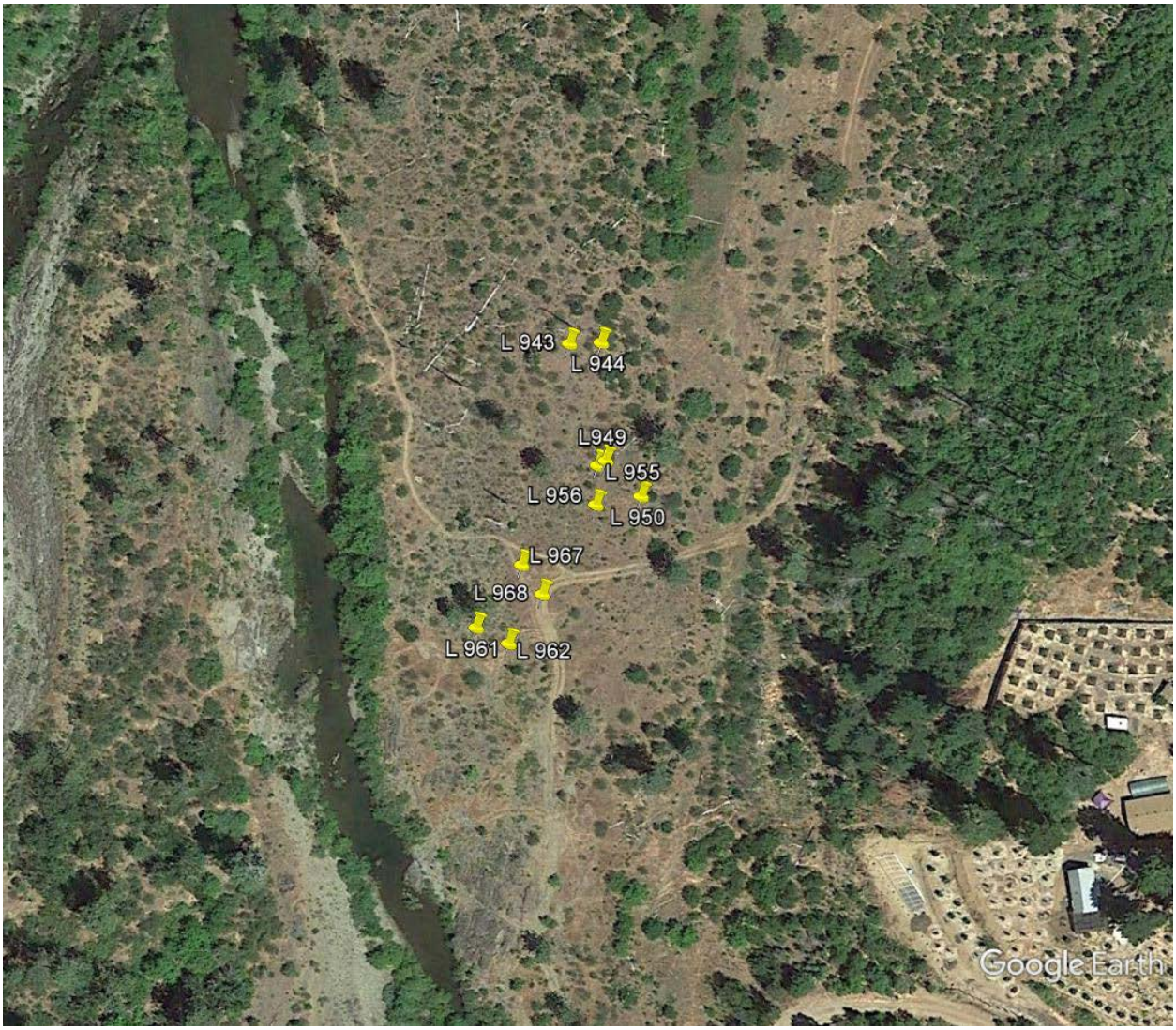
Unoccupied Habitat

There are a total of 12 macroplots, 7 near the entrance road to the park and 5 to the west closer to the Illinois River. The baseline marking the occupied plots can be found near Plot 901/902. GPS points are marked at opposite corners for each plot.

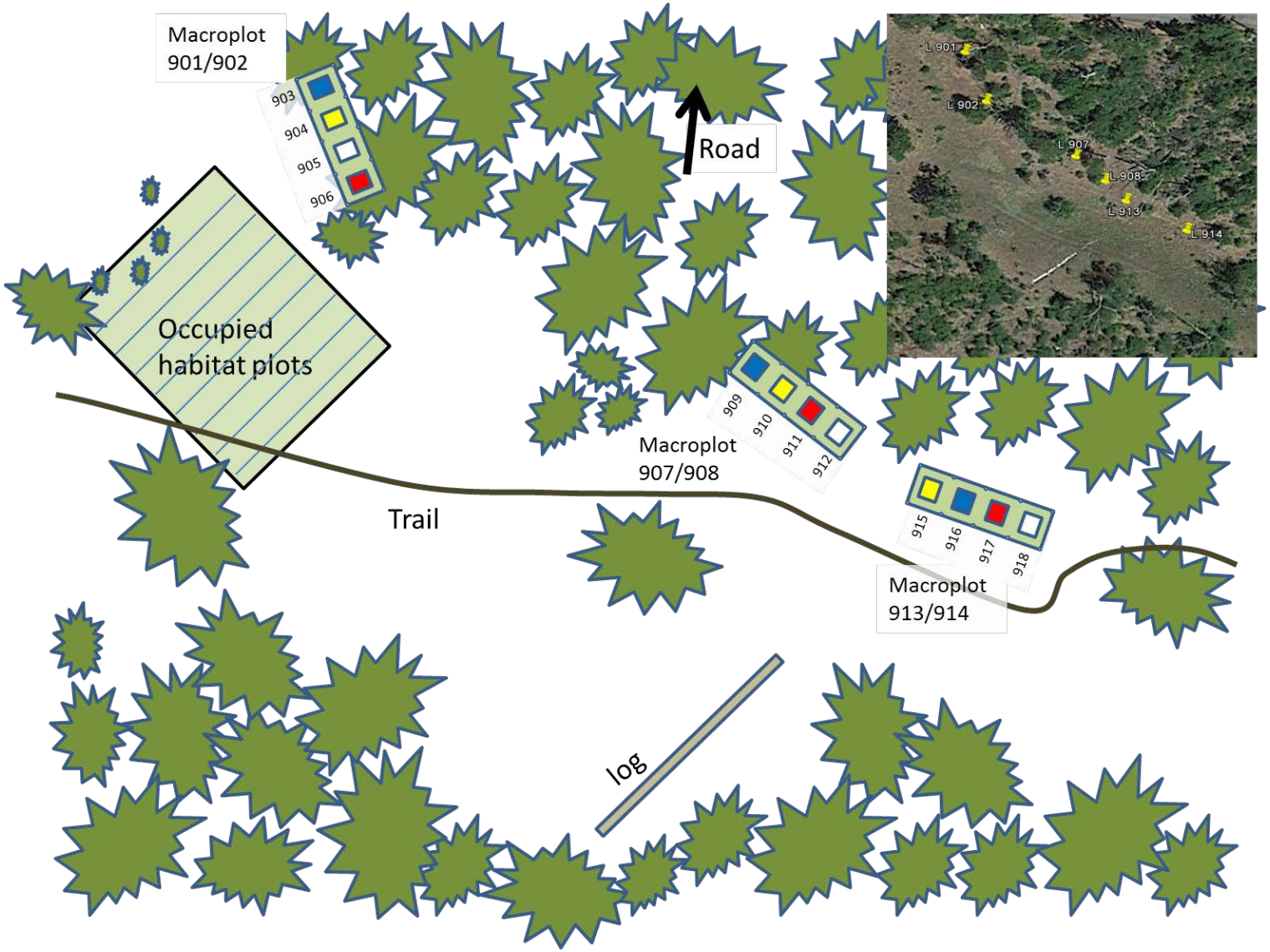
Overview of plots near the road.



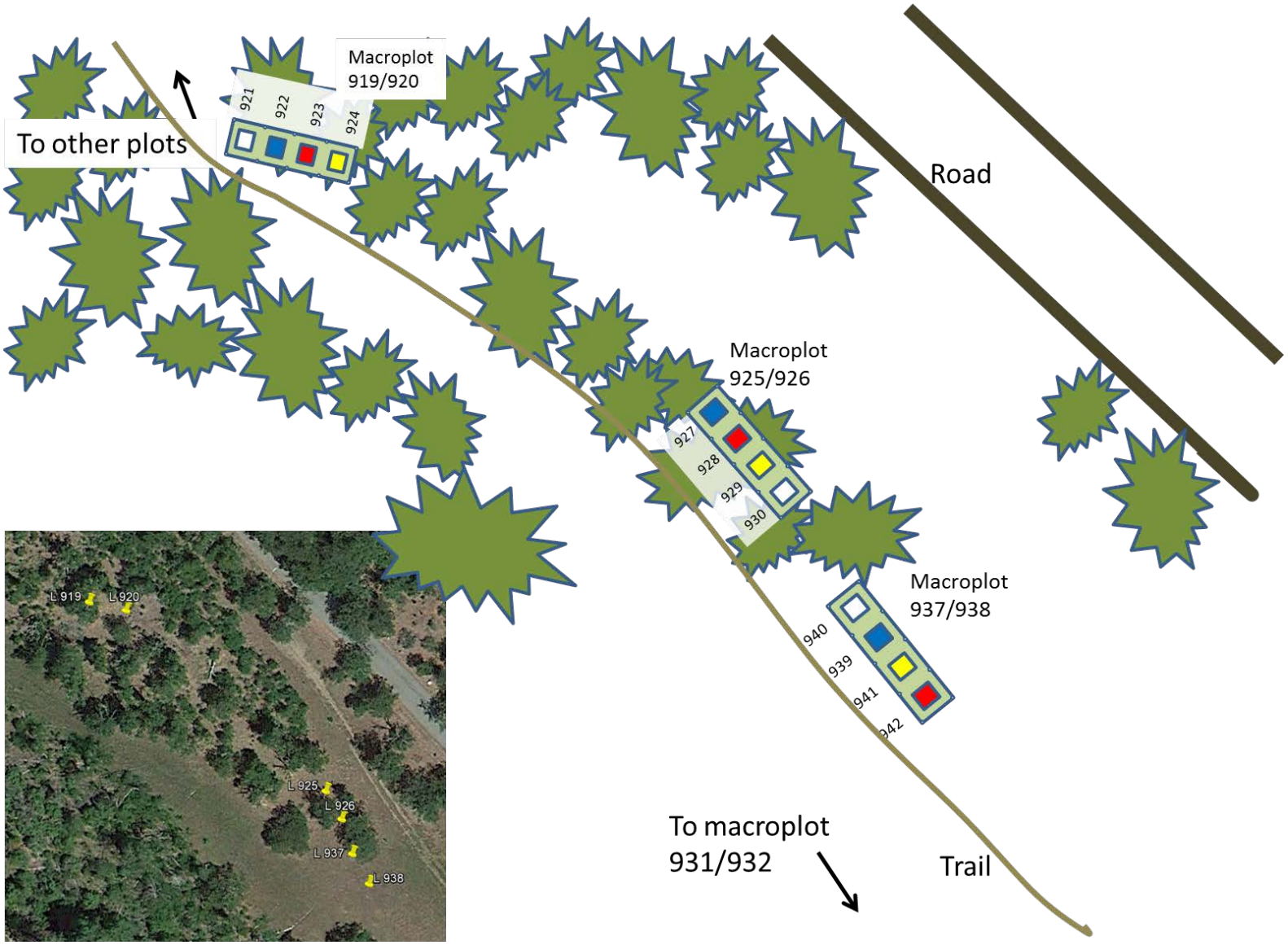
Overview of plots near the river.



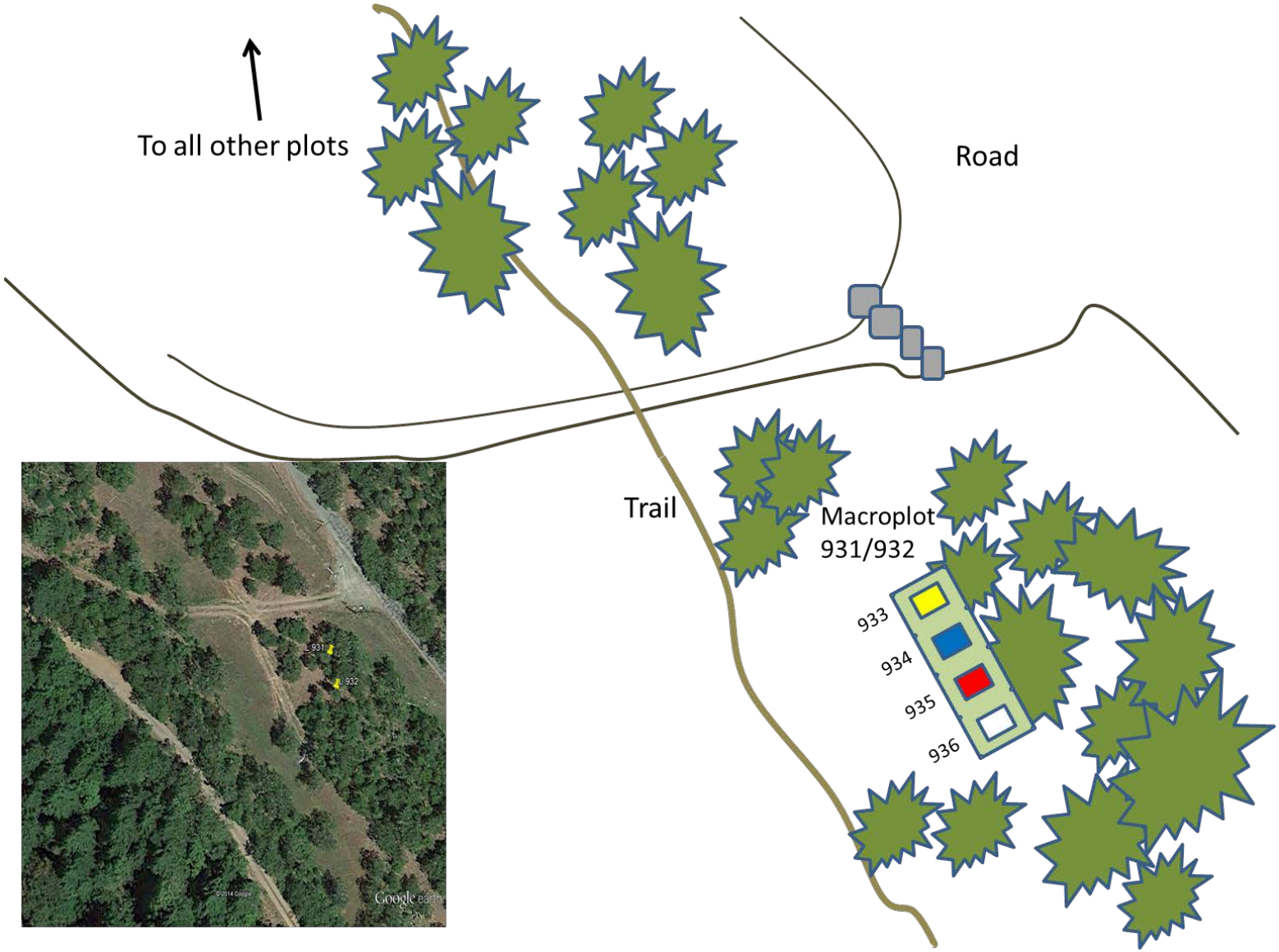
Schematic of macroplots #901, #907 and #913, as well as general location of occupied plots.



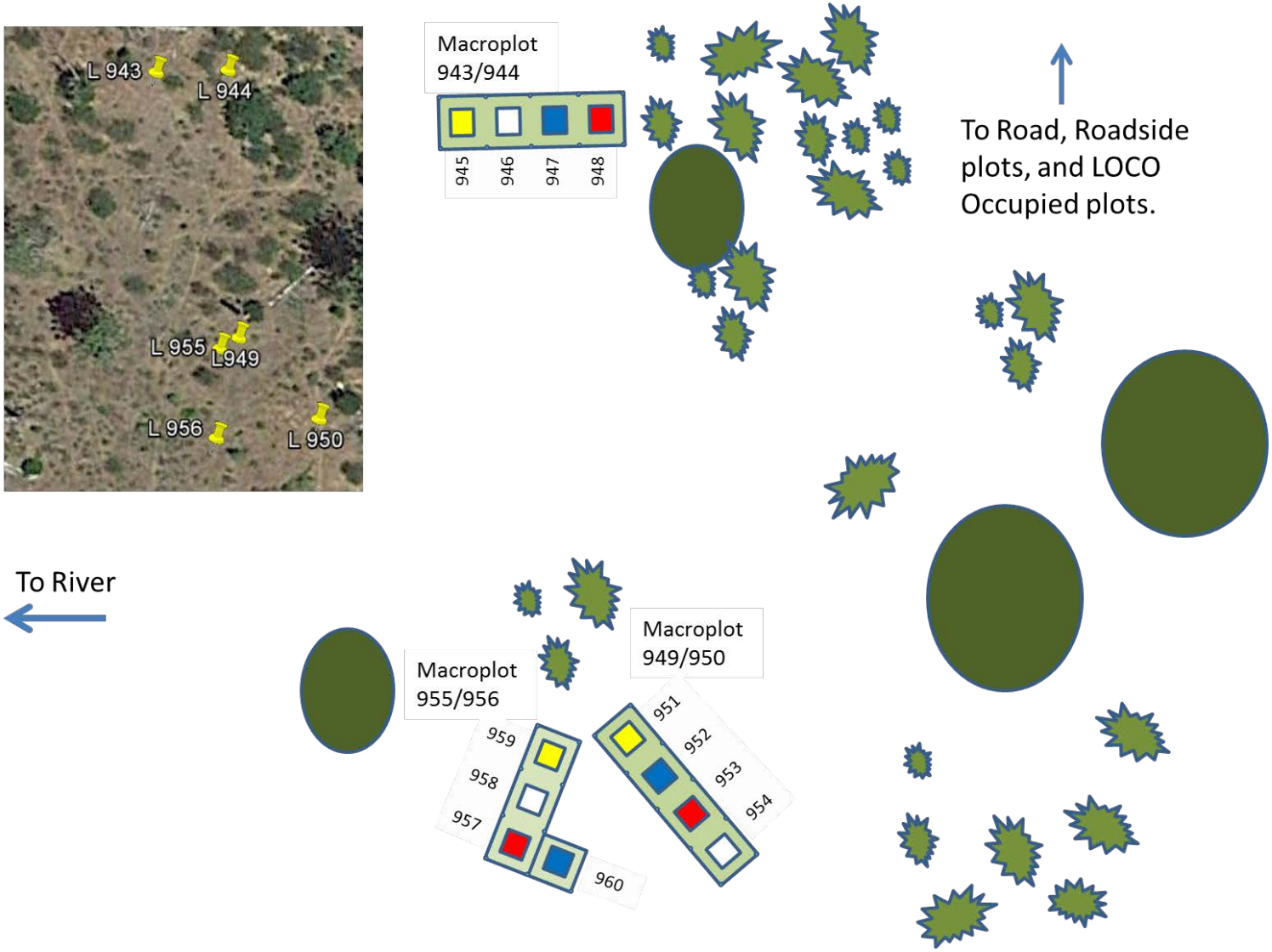
Schematic of macroplots #919, #925 and #937 in the unoccupied area.



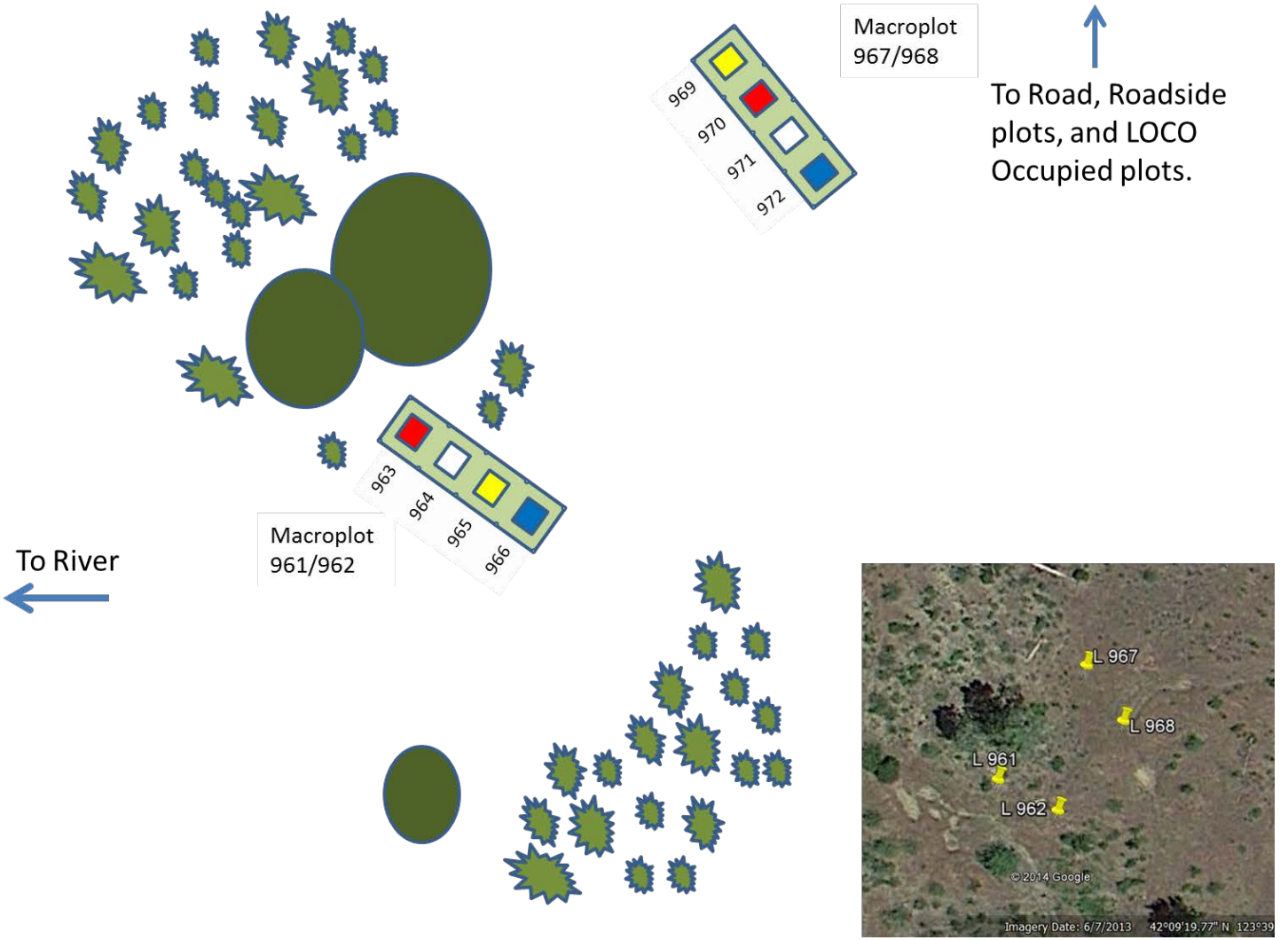
Schematic of macroplot #931.



Schematic of macroplots #943, #949 and #955.

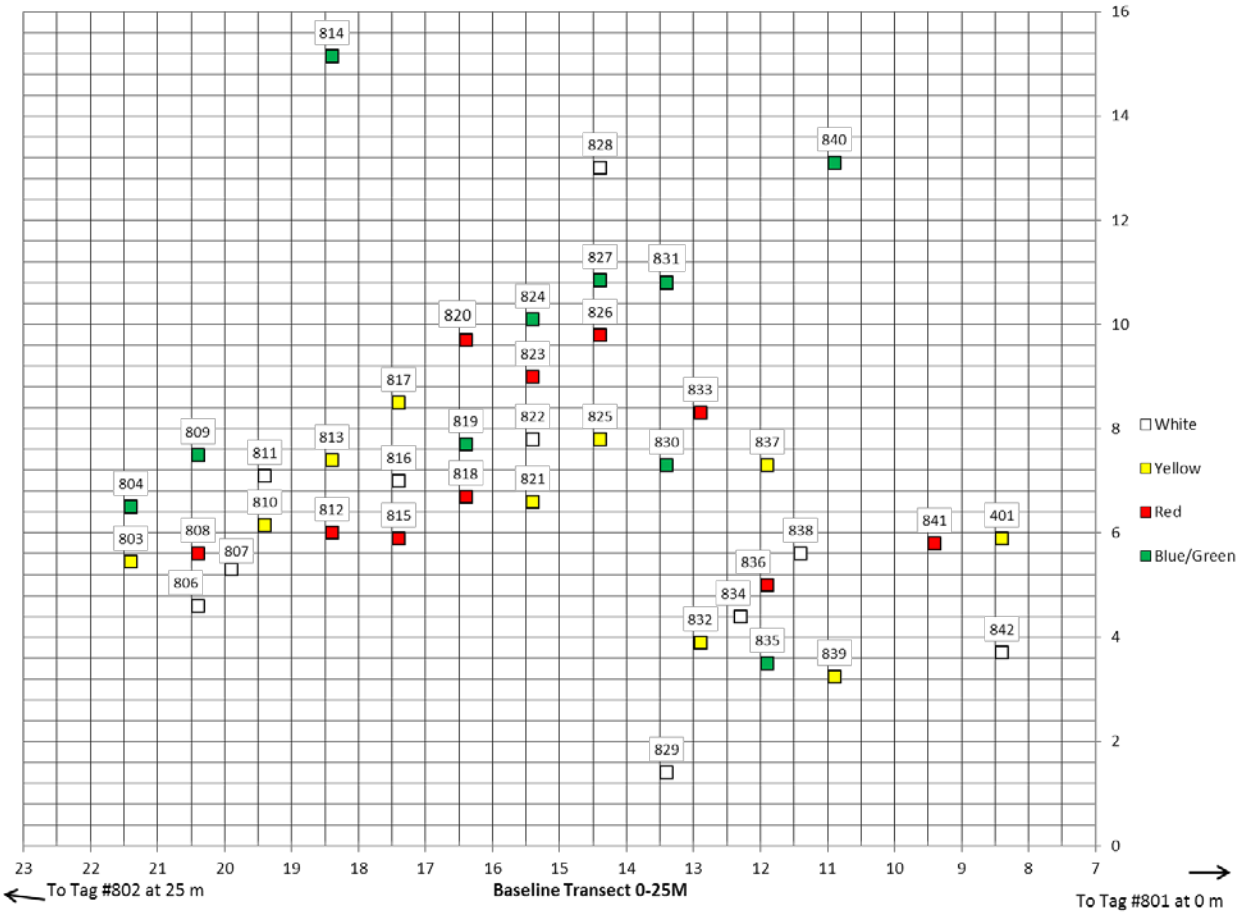


Schematic of macroplots #961 and #967.



Occupied Habitat

There are 40 0.5mx0.5m plots established along 15m transects that run perpendicular to the 25m baseline (#801-802). Location along the baseline, and location of the demography plot(s) along the transects are recorded in the following table. The perpendicular transects are marked at both ends with tagged 18" PVC, capped with IAE labels, and pounded into the ground with ~3-6" exposed. The placement of the perpendicular transects and the location of the demographic plot (s) along these transects were selected using a random number generator. If the randomly selected target location did not have at least three *L*. cookii, the next closest suitable area along the transect (with at least three *L. cookii*) was selected[1]. Demographic plots are marked with nails and (hot pink) washers on opposite corners (NE – with tag and SW).



Schematic of plots established in the occupied habitat. In this diagram, white = fluazifop, yellow = control , red =glyphosate and blue/green = imazapic .

[1] Due to the limited size of the population, one to three plots in each treatment have only one or two plants instead of the targeted minimum of three plants.

APPENDIX C. LOCATIONS OF DENSITY AND DEMOGRAPHY PLOTS AT FRENCH FLAT MIDDLE AND FRENCH FLAT SOUTH.

French Flat Middle

Established in 2013.

2013 New Plot #	Side of Tape	Location on Baseline (m)	End Rebar at (m)	End Rebar Tag	2013 Last Plant Found at (m)	Demo g. Tag	Demog. Plot Location (NE Corner)	Demog. Plot Location (End)
165	W	2.8	30	166	25.95	33	11.43	10.9
154	W	6.5	37	153	34	1	11.2	10.75
155	E	6.5	37	156	26.5	3	18.05	18.55
161	E	9.1	40	162	35.2	8	23.25	23.75
163	E	9.7	40	164	39.55	7	15.5	16
163	E	9.7	40	164	38.05	10	33.25	33.75
28	W	15	37	29	35.7	876	18.55	19.05
167	E	17.5	40	166	38.05	-	-	-
30	E	19	39.3	31	35.1	-	-	-
33	W	22	40	34	28.1	877	23.45	23.95
169	W	25	40	170	38.7	37	22.24	21.71
171	E	27.1	33.5	172	33	38	2.4	2.9
199	W	31	30	200	29.3	-	-	-
35	E	35	40	36	38.6	-	-	-
173	E	36.6	40	174	36.6	874	20.5	30
173	E	36.6	40	174	36.6	875	11.2	11.7
175	W	40.2	35	176	31.85	167	23.45	23.95
158	W	43.1	30	157	20.6	18	13.2	12.7
159	E	43.5	30	160	28.25	28	5.2	5.7
177	E	46.6	35.5	178	33.9	29	5.1	5.6
179	E	55.1	15.4	180	13.7	31	4.75	5.25
181	W	56	20.4	182	19	-	-	-
183	E	60	11.3	184	11.05	-	-	-
185	E	62	10.8	186	9.7	-	-	-
187	W	67	9.9	188	6.7	-	-	-
189	E	72	15	190	14.9	168	6.5	7
37	W	74	16	38	6.9	-	-	-
191	W	82	15.5	192	11.4	169	2.5	2
193	W	86	10.5	194	3.5	-	-	-
195	E	89	21.4	196	19.5	170	-	-
197	W	95	15	198	10.5	-	-	-
39	W	98	15	40	8.7	-	-	-

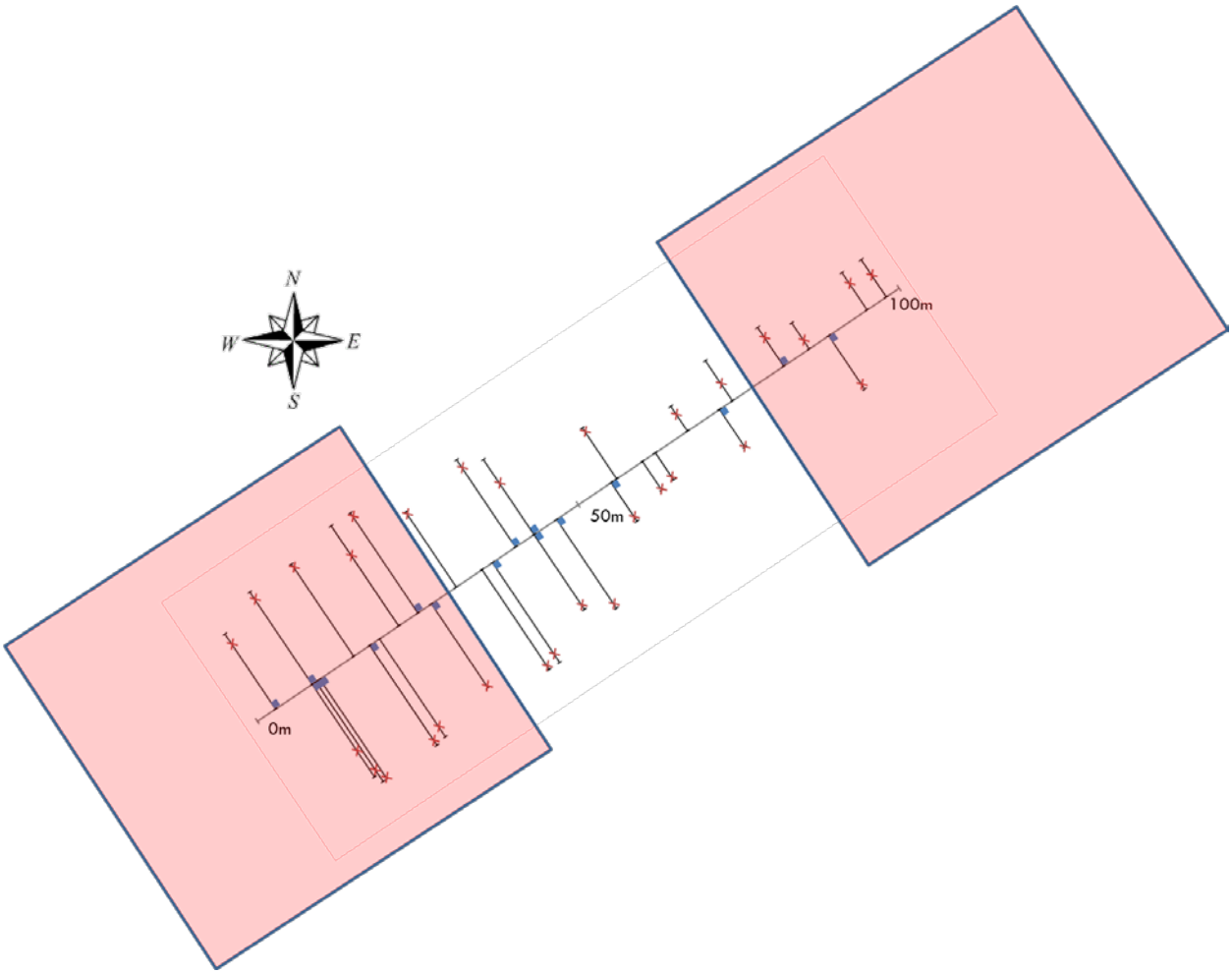
French Flat South

Established in 2012.

2012 New Plot #	Side of Tape	Location on Baseline (m)	End Rebar at (m)	End Rebar Tag	2012 Last Plant Found at (m)	Demo g. Tag	Demog. Plot Location (NE Corner)	Demog. Plot Location (End)
362	E	13	23	363	9.3	-	-	-
364	W	27	30	365	10.4	-	-	-
366	W	30	33	367	6.9	-	-	-
707	W	36	21	708	15.9	329	10.5	11
709	W	38	21	710	15.8	330	6.5	7
711	W	42	21	712	12.7	331	4	4.5
749	E	45	40	750	23.6	353	15.5	15
713	E	52	37	714	25.8	332	17.5	17
741	E	57	35	742	27.1	352	20.5	20
743	E	59	40	744	30.1	354	21.5	21
753	E	61	36	754	31.8	357	23	22.5
745	W	65	39	746	23.9	361	13.5	14
747	E	70	40	748	32.1	360	8.5	8
751	E	72	40	752	22.8	355	5.5	5
725	W	79	40	726	11.8	338	3	3.5
715	E	81	40	716	30.4	333	11.5	11
717	W	94	40	718	28.7	334	13.5	14
719	E	95	40	720	30.9	335	19	18.5
721	E	97	40	722	30.6	336	15.5	15
723	W	99	32	724	31.0	337	16	16.5
727	W	107	28	728	24.6	339	13	13.5
701	E	109	40	702	27.2	326	24.5	24
703	E	111	40	704	28.3	327	23	22.5
705	W	116	32	706	23.0	328	19	19.5
729	W	119	33	730	22.8	340	24	24.5
755	E	125	40	756	27	356	16.5	16
731	E	126	40	732	19.1	341	5.5	5
733	W	128	35.5	734	29.2	342	20	20.5
735	E	129	40	736	23.6	343	9	8.5
737	W	136	40	738	31.5	344	15	15.5
757	W	142	33	758	32.8	358	5	5.5
759	W	144	34	760	32.6	359	9.5	10
739	W	154	40	740	32.8	345	18	18.5

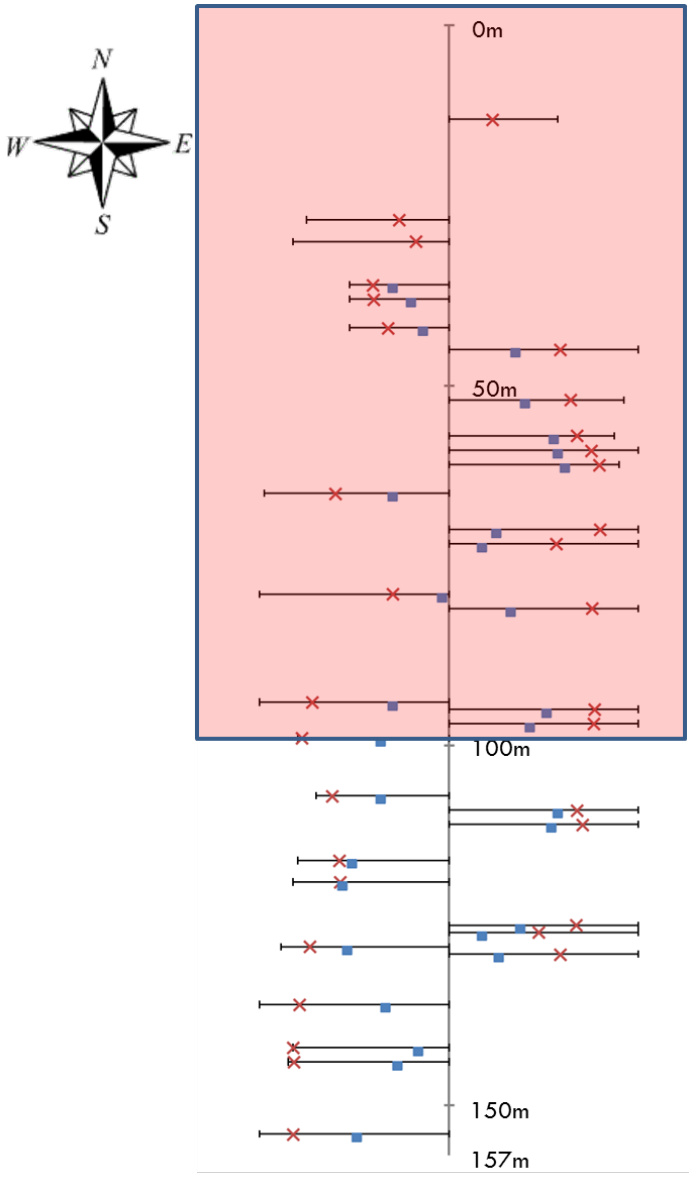
APPENDIX D. SCHEMATIC OF DENSITY AND DEMOGRAPHY PLOTS AT FRENCH FLAT MIDDLE AND FRENCH FLAT SOUTH.

French Flat Middle



Demography and density plots were established in 2013. Baseline transect is 100m with a bearing of 034° (northeast). Last plants located on density plots are indicated by red crosses. Demography plots are indicated by blue squares and are not located along the baseline transect as shown here. The shaded areas were burned in the fall of 2015.

French Flat South



Demography and density plots were established in 2012. Baseline transect is 157m with a bearing due south. Last plants located on density plots are indicated by red crosses. Demography plots are indicated by blue squares. The shaded areas were burned in the fall of 2015.

APPENDIX E. NUMBER OF L. COOKII IN EACH DEMOGRAPHIC PLOT AT ILLINOIS FORKS STATE PARK, 2014-2016.

Treatment[1]	Plot #	2014	2015	2016	Notes
CONTROL TOTAL		49	47	45	
Control	401	3	3	3	
Control	803	3	4	5	
Control	810	17	15	12	
Control	813	1	1	1	
Control	817	3	3	3	
Control	821	12	7	6	
Control	825	3	3	4	
Control	832	3	3	3	
Control	837	2	2	2	
Control	839	2	6	6	
FLUAZIFOP TOTAL		25	29	31	
Fluazifop	804	3	6	10	* new plants are V1/V2s
Fluazifop	808	1	1	1	
Fluazifop	814	2	3	2	
Fluazifop	819	1	1	1	
Fluazifop	824	1	1	1	
Fluazifop	827	4	4	3	
Fluazifop	830	3	3	3	
(Fluazifop)	831	17	27	27	* new plants were big plants, along edge of trail likely related to trampling
Fluazifop	835	8	9	9	
Fluazifop	840	2	1	1	
GLYPHOSATE TOTAL		56	59	64	
Glyphosate	807	4	3	3	
(Glyphosate)	812	17	20	14	*adjacent to trail, 'new' plants in 2015 and 'gone' plants in 2016 were large
Glyphosate	815	8	10	16	*2015 one seedling, 2016 new small plants
Glyphosate	818	5	8	8	
Glyphosate	820	5	4	5	
Glyphosate	823	12	14	14	
Glyphosate	826	11	9	7	
Glyphosate	833	8	9	8	
Glyphosate	836	2	1	2	
Glyphosate	841	1	1	1	

Treatment[1]	Plot #	2014	2015	2016	Notes
IMAZAPIC TOTAL		55	51	50	
Imazapic	806	1	1	2	
Imazapic	809	12	10	8	
Imazapic	811	3	3	4	
Imazapic	816	9	11	10	
Imazapic	822	7	5	5	
Imazapic	828	1	1	1	
Imazapic	829	3	3	3	
Imazapic	834	15	13	13	
Imazapic	838	1	1	1	
Imazapic	842	3	3	3	

[1]Plots in parentheses were not included in analysis in 2016.