

Population and habitat monitoring for Kincaid's lupine and Hitchcock's blue-eyed grass at Oak Basin



2017

Report to the Bureau of Land Management,
Eugene District

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PREFACE

This report is the result of an agreement between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization whose mission is conservation of native ecosystems through restoration, research and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.



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Cover photograph: Kincaid's lupine (*Lupinus oregonus*) and Oak Basin from Meadow A.

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EXECUTIVE SUMMARY

This report documents monitoring conducted on population characteristics and habitat of Kincaid's lupine (*Lupinus oreganus*), a threatened species, and Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*), a federal species of concern, at Oak Basin. Kincaid's lupine serves as the primary larval host plant for the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*). Both species are endemic to western Oregon prairies. In 2017, the twelfth year of monitoring occurred at Oak Basin, which is managed by the Eugene District Bureau of Land Management.

- **Kincaid's lupine:** In 2017, Kincaid's lupine cover doubled from 2016 in all meadows to 152m². The total number of mature racemes increased to over 3,600 mature racemes, while the number of aborted racemes decreased from 18% in 2016 to 3%. Despite these increases, the cover and reproduction of Kincaid's lupine at Oak Basin have varied substantially from year to year and should be continually monitored to decipher the factors impacting the fluctuations which could include climate differences, competition from invasive species and/or habitat degradation. Population monitoring inside and outside of management treatment areas can inform habitat management for this, and other species which share this unique upland prairie habitat.
- **Habitat quality:** In 2017, as in previous years, there was high cover of exotic grasses (>75% cover) including *Schedonorus arundinaceus*, *Dactylis glomerata*, and *Cynosurus echinatus*. These non-native species were the most prevalent while the exotic forb, *Leucanthemum vulgare*, encompassed over 15% cover. Cover of native forbs remained relatively stable with <20% cover, with *Eriophyllum lanatum* the dominant species. Species richness decreased from 2011-2015 with 105 species observed in 2011, 82 in 2015, and 66 species observed in 2017. Meadows A has seen the largest decrease in species richness from 85 to 38 species.
- **Management treatments:** Management treatments conducted in 2013-2017 included mowing to control exotic perennial grasses and shrubs, flame weeding, limbing of larger trees, and removal of conifers <4" DBH to increase meadow connectivity and reduce encroachment. In 2015 and 2016, it was observed that flame-weeded areas had lower cover of invasive graminoid species, and higher native graminoid cover than adjacent untreated areas. In Meadow B, areas that had been flame-weeded had higher cover of native forb species than untreated areas. Mowing treatments in Meadow A in 2015 and 2016, did not have a clear effect on cover of native or exotic grasses or forbs. Mowing treatments in all meadows appeared to result in higher foliar cover and raceme production in all meadows. Monitoring in 2018 will inform longer term effects of flame weeding, mowing, and other management treatments.
- ***Sisyrinchium hitchcockii*:** Long-term monitoring plots for *S. hitchcockii* were added to Meadow C in 2012, and monitoring has been conducted from 2012-2017. Since 2012, the population declined from a total of 122 to just 42 in 2016. In 2017, numbers increased to 66 individuals. The number of reproductive stems has also decreased from 128 in 2012 to 19 in 2016. The decline in reproductive effort of both *L. oreganus* and *S. hitchcockii*, and subsequent increase in 2017 for both species, suggest that some shared factor, such as climate factors and/or competition with exotic species could be impacting the success of these populations. Continued monitoring will be essential to document annual population variability to inform future management activities and the perpetuation of these rare species.

Population and habitat monitoring for Kincaid's lupine and Hitchcock's blue-eyed grass at Oak Basin

REPORT TO THE BUREAU OF LAND MANAGEMENT, EUGENE DISTRICT

INTRODUCTION

This report documents rare plant and community monitoring at Oak Basin, a site managed by the Eugene District Bureau of Land Management. Oak Basin supports the largest known Kincaid's lupine (*Lupinus oregonus*; Figure 1) population in the Upper Willamette Resource Area. Monitoring at Oak Basin is focused on documenting the population size and reproduction of Kincaid's lupine and habitat quality of the site. This information will be used to determine effectiveness of habitat treatments at the site and document long-term population trends. In addition to Kincaid's lupine, we also monitor to document trends in a population of *Sisyrinchium hitchcockii* (Hitchcock's blue-eyed grass).

Species status

Kincaid's lupine, a member of the legume family (Fabaceae), is listed by the Oregon Department of Agriculture and the U.S. Fish and Wildlife Service as a threatened species (ORBIC 2013, Figure 1). Kincaid's lupine serves as the primary host plant for larvae of Fender's blue butterfly (*Icaricia icarioides fenderi*), which is listed as an endangered species by the U.S. Fish and Wildlife Service (ORBIC 2013; Figure 2). *Sisyrinchium hitchcockii* (Hitchcock's blue-eyed grass) is listed as a federal species of concern by the U.S. Fish and Wildlife Service (ORBIC 2013) and is a Bureau Sensitive Species for the BLM.

Background information

Kincaid's lupine is found in native prairie remnants in the Willamette Valley and southwestern Washington and in forest openings in Douglas County, Oregon. Because Kincaid's lupine serves as the primary host for Fender's blue butterfly larvae, conservation of the lupine is a common goal for the protection of both species.



FIGURE 1. KINCAID'S LUPINE (*LUPINUS OREGANUS*).



FIGURE 2. FENDER'S BLUE BUTTERFLY (*ICARICIA ICARIOIDES FENDERI*).

Oak Basin has been identified as a potential Functioning Network to meet the de-listing goals for Fender's blue butterfly and the population of Kincaid's lupine currently meets the minimum local population size standard of at least 60 m² of foliar cover (USFWS 2008). Management and Implementation Plans have been developed for Oak Basin, and restoration began in the fall of 2012. Several patches of Kincaid's lupine occur on the adjacent Oak Basin Tree Farm that is currently being restored through a cooperative agreement between private landowners, The Nature Conservancy, Oregon Department of Fish and Wildlife, and the United States Fish and Wildlife Partners for Fish and Wildlife Program.

Reproduction and population biology of Kincaid's lupine

Kincaid's lupine is an herbaceous perennial that reproduces by seed. Plants form clumps of basal leaves and eventually produce one or more flowering stems. This species also spreads vegetatively, though it is unknown to what extent vegetative growth may result in the formation of physiologically distinct clones. Kincaid's lupine requires insects for successful fertilization and seed formation (Kaye 1999).

Fender's blue butterfly life cycle

Fender's blue butterflies are mature adults in May and June, when they fly, eat nectar, and mate. The females oviposit their eggs on the underside of lupine leaves. Eggs are identifiable as small (0.5–1.0 mm) white spheres (Figure 3a). The eggs hatch in a few weeks; hatched eggs resemble unhatched eggs except they are burst in the center, making them look like little white "donuts." The larvae subsequently feed on the lupine leaves (Figure 3b, 3c) until late June or early July, when they crawl under nearby vegetation and plant litter and enter diapause. They remain in a dormant state until February or early March, when they begin feeding again on the newly emerging lupines. Near the end of April they pupate and reemerge as butterflies (Schultz and Crone 1998).

Objectives

The objectives of this study were to monitor the population of Kincaid's lupine at Oak Basin and examine overall Kincaid's lupine habitat quality over time, particularly paired with restoration activities that have been occurring on site. Additionally, two plots were established in 2012 to monitor *Sisyrinchium hitchcockii*, another rare species that occurs at Oak Basin. An initial goal of this study was to estimate the number of Fender's blue butterfly eggs at the site; however, these surveys were discontinued in 2010 due to concerns over negative impacts to the species (Giles-Johnson et al. 2009). Surveys of adult butterflies at Oak Basin were conducted by Dana Ross and are reported elsewhere. Surveys for nectar species occurred in 2011 (Giles-Johnson et al. 2011). For discussion on the relationship between Kincaid's lupine cover and number of leaves, and trends in Fender's blue butterfly egg counts, see Giles-Johnson et al. 2009.

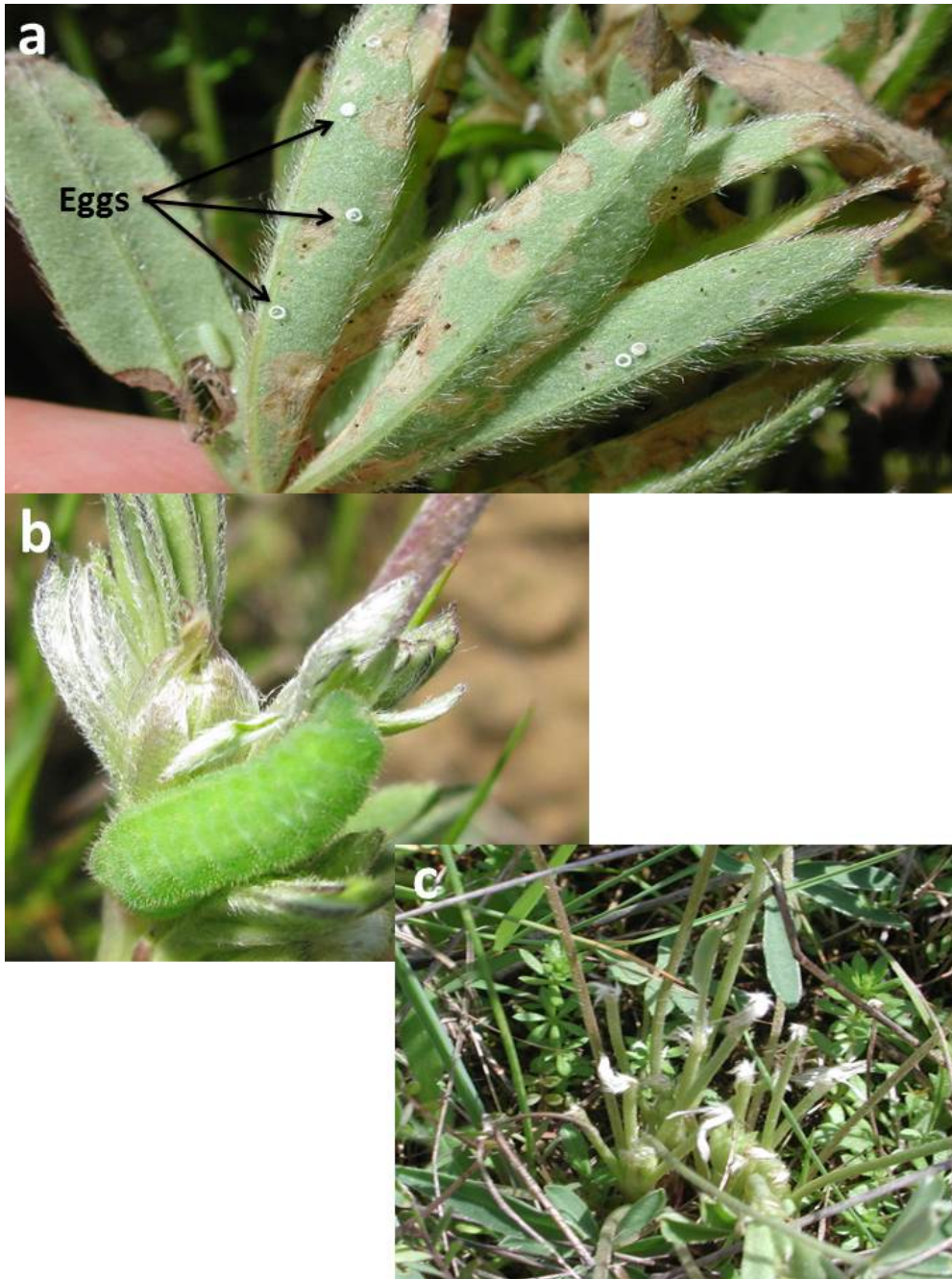


FIGURE 3. FENDER'S BLUE BUTTERFLY ON KINCAID'S LUPINE. (A) FEMALE FENDER'S BLUE BUTTERFLIES OVIPOSIT SMALL WHITE EGGS ON THE UNDERSIDES OF LUPINE LEAVES. HERBIVORY OF KINCAID'S LUPINE BY LARVAE (B) OF FENDER'S BLUE BUTTERFLY RESULTS IN CLUSTERS OF DAMAGED STEMS, LEAVES, AND GROWING POINTS (C) BECAUSE THE LARVAE TYPICALLY FEED ON YOUNG LEAVES AND APICAL MERISTEMS.

METHODS

Study site

Oak Basin is located south of Brownsville in Linn County, Oregon. The site includes upland prairie and oak, maple, and Douglas-fir woodlands and includes three meadows (Meadows A, B, and C; Appendix A). In 2006, the entire area was surveyed for the presence of Kincaid's lupine. Plots were then established around each original lupine patch, and additional plots have been added as new lupine patches have been located to conduct a complete census of *L. oregonus* on the site (Table 1, Appendix A, Appendix B). Larger plots are rectangular and marked with fiberglass posts, rebar, or conduit in all four corners. Smaller lupine patches are monitored in either circle or belt transects. Circular plots were marked in the center and all plants were included by setting an appropriate radius. Belt transects were marked on opposite ends, a tape was stretched between the posts, and all of the lupine on either side of the tape was recorded. Each plot origin was tagged with a pre-numbered aluminum tag. Plot notes can be found on the plot maps (Appendix A).

The overall habitat quality at the site is poor to moderate, with heavy infestations of invasive, exotic plants such as Himalayan blackberry (*Rubus armeniacus*), invasive, exotic grasses including tall fescue (*Schedonorus arundinaceus*), orchard grass (*Dactylis glomerata*) and bristly dogtail (*Cynosurus echinatus*), and the invasive, exotic forb, oxeye daisy (*Leucanthemum vulgare*).

Kincaid's lupine population monitoring

The monitoring at Oak Basin is meant to be a complete census of the *Lupinus oregonus* population. Plots were established such that all lupine at the site is monitored for foliar cover as well as the count of mature and aborted racemes. Lupine foliar cover was determined by measuring the approximate rectangular area occupied by a lupine. Foliar cover of lupine (as opposed to counting 'individual' plants, of this often rhizomatous species), is the standard for lupine monitoring as recommended by the Draft Recovery Plan (USFWS 2008).

When plants are found outside of existing plots, plot boundaries are modified, or new plots added to accommodate these plants. See Appendix A and Table 1 for details about plot sizes, locations and schematics.

Table 1. Location, dimensions, and monitoring notes for Kincaid's lupine and Hitchcock's blue-eyed grass (in bold) plots at Oak Basin.

Meadow	Plot Number	Dimensions	origin (Nad27)	Notes
A	7	23m x 12m	504288 E 4906986 N	measured in 2m increments
A	8	Circular, 2m radius	504259 E 4907001 N	fallen tree covering part of plot
A	9	18m x 14m	504286 E 4906960 N	measured in 2m increments
A	10	Circular, 2m radius	504312 E 4906952 N	
A	459	13m x 12m	504246 E 4906964 N	measured in 3m increments
A	454	20m x 13m	504210 E 4906979 N	3 individuals 8m and 48° from origin
A	464	20m x 26m	504183 E 4906999 N	measured in 2m increments
A	450	90m x 7m	504232 E 4907030 N	measured in 5m increments
A	451	8m x 7m	504132 E 4906987 N	measured in 2m increments
A	452	25m x 35m	504156 E 4907003 N	measured in 2m increments
A	460	22m x 16m with extension	504274 E 4906955 N	measured in 4m increments
A	406	Circular, 2m radius	504101 E 4907056 N	
A	509	Circular, 1.5m radius	504199 E ¹ 4907048N ¹	new in 2011
A	510	8m x 6m	503967 E ¹ 4907105 N ¹	new in 2011, measured in 1m increments N-S
A	511	3m x 1m	504702 E ¹ 4907160 N ¹	new in 2011, measured in 1m segments N-S

(Cont.). Table 1. Location, dimensions, and monitoring notes for Kincaid's lupine and Hitchcock's blue-eyed grass (in bold) plots at Oak Basin.

B	1	60m x 18m+	504420 E 4906668 N	measured in 5m increments
B	2	Circular, 2.5m radius	504503 E 4906649 N	
B	3	12m x 18m (20m)	504514 E 4906646 N	measured in 2m increments
B	4	Circular, 3m radius	504545 E 4906630 N	
B	5	12m x 9m	504597 E 4906570 N	measured in 2m increments
B	6	11m belt transect	504628 E 4906559 N	measured 2m to each side
B	399**	11m belt transect	504326 E 4906806 N	measured to E and W, in 1-2m increments.
B	558	2m radius	504413 E ¹ 4906842 N ¹	new in 2014
C	594	12m belt	See map	New in 2017
C	233	1m radius	See map	New in 2017
C	1(185) ²	15m x 4m	504639 E ¹ 49065659N ¹	measured in 1m increments
C	2 (186) ²	2m radius	504655 E ¹ 4906555N ¹	divided into NW, NE, SW, and SE sections
C	433	8m belt transect	504712 E 4906379 N	measured to E and W, in 2m increments
C	432	8m x 9m	504649 E 4906401 N	measured in 2m increments
C	431	18m belt transect	504732 E 4906378 N	measured to N and S, in 1m increments
C	400	1m radius	504609 E ¹ 4906553 N ¹	new in 2012; along tree line in <i>Rupertia physodes</i>

¹ Coordinates are in NAD83 instead of NAD27.

² Plots 1 (185) and Plot 2 (186) in Meadow C are SIHI plots.

** There is a large patch of lupine on the SW end of Meadow B which is on private property. Plot 399 captures the lupine nearest the public/private boundary.

Habitat assessment

In 2017 habitat monitoring focused on assessing the quality of lupine habitat in all meadows; areas treated with flame-weeding and mowing are scheduled to be re-sampled in 2018. In 2016, plant community monitoring focused on the assessment of areas treated for habitat management and adjacent untreated areas: community monitoring in 2011-15 included evaluation of areas designated as Kincaid's lupine habitat and areas that were not occupied by lupine ("non-lupine" habitat). Random points were generated across all meadows and loaded into a handheld GPS unit. Each point was then visited and a 1m² plot was sampled. An ocular estimation of percent cover was performed for each species and the habitat type (lupine or non-lupine) was noted. Lupine habitat/non-lupine habitat was designated based on presence (or absence) of lupine within ~10m, unless habitat characteristics indicated otherwise. These data have been used as a baseline to target and test restoration efforts at the site and to understand changes in the plant community over time.

The purpose of the community assessment is to:

1. Quantify recovery targets for associated prairie species: percent native vs. percent exotic.
Accomplished by quantifying percent cover of all plant species and ground cover types (litter, bare ground, moss, and rock) in 10-30 randomly placed plots in each meadow.
2. Assess pre- and post-treatment effects (could be fire, mowing, herbicides, etc. in the future).
Accomplished by quantifying percent cover of all plant species and ground cover types (litter, bare ground, moss, and rock) in 10-30 randomly placed plots in each meadow.

Details on timing and implementation of management treatments can be found in "Restoration of Upper Oak Basin and Oak Basin Tree Farm: 2016 Annual Report to the Bureau of Land Management" (Silvernail 2016). Data are reported in Appendix E. Mean Percent cover of species encountered in habitat management assessment in 2015 and 2016 by meadow and treatment..

Oak Basin Management Actions, 2016

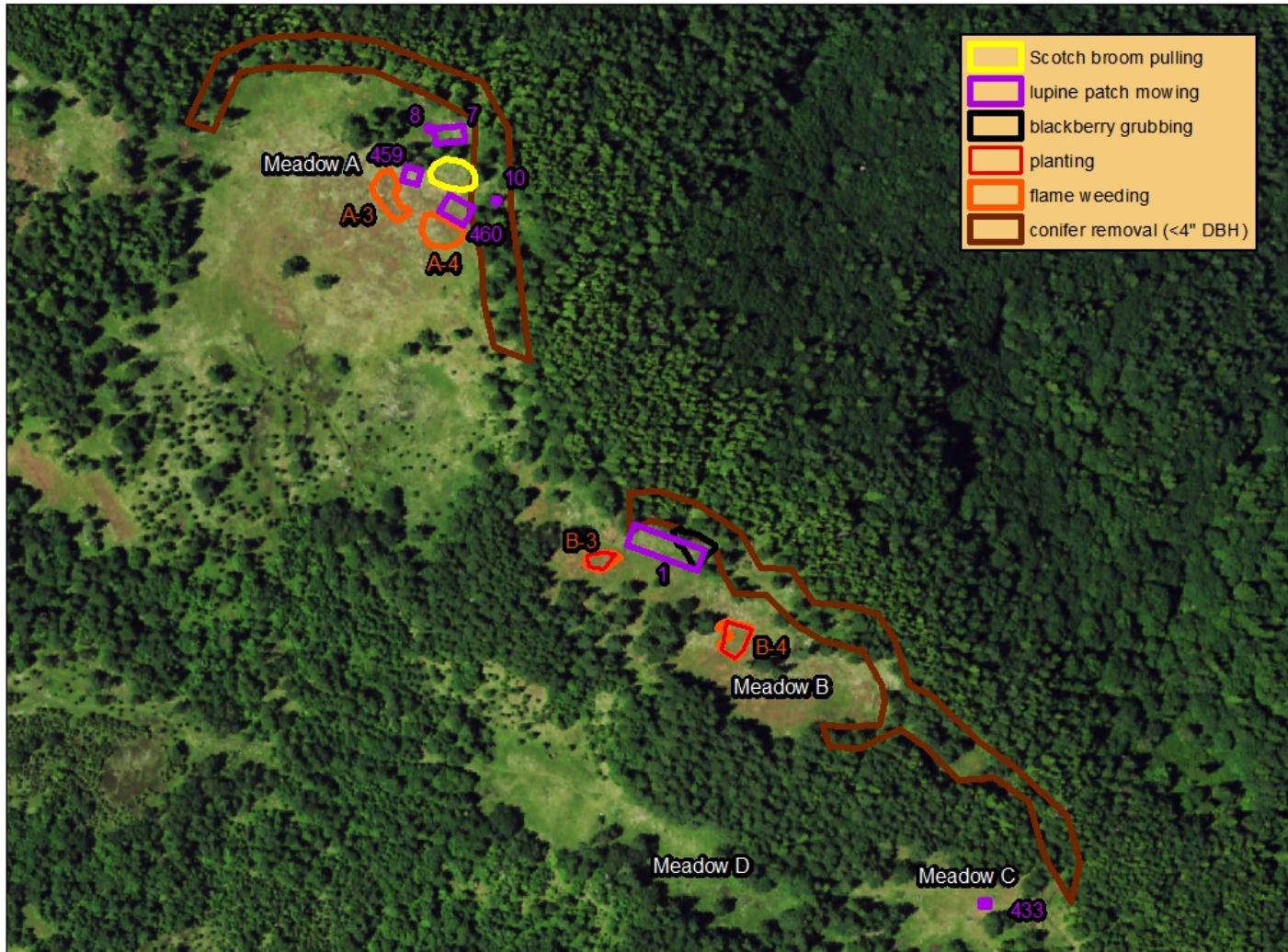
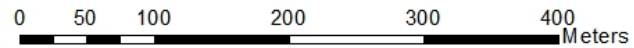


FIGURE 4. MANAGEMENT ACTIONS THAT OCCURRED IN 2016 AT OAK BASIN.

Oak Basin Management Actions, 2015

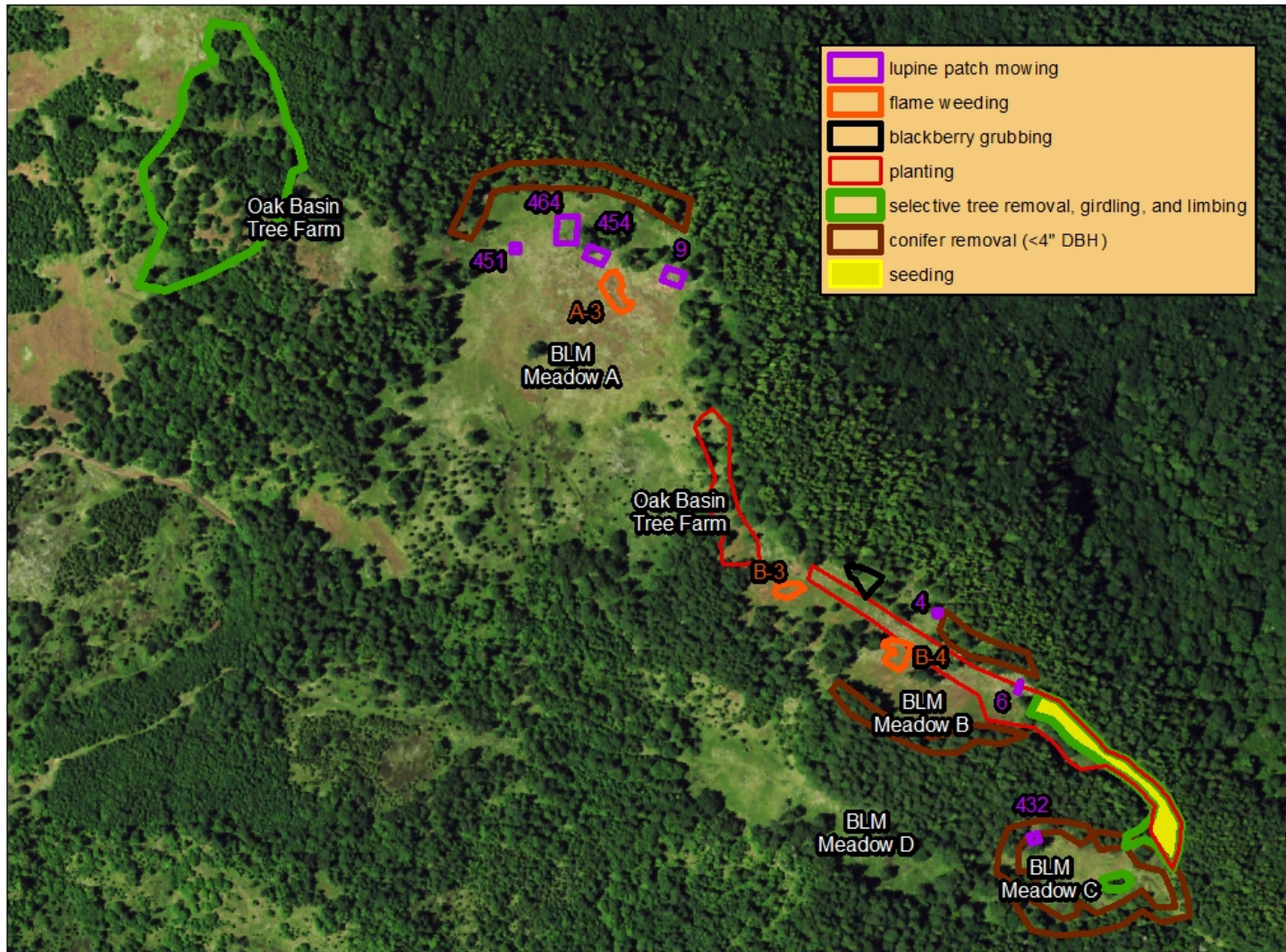
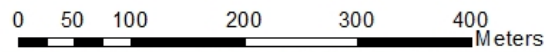


FIGURE 5. MANAGEMENT ACTIONS COMPLETED AT OAK BASIN IN 2015. NUMBERS INDICATE LUPINE AND FLAME WEEDING PATCH IDENTITY (FROM SILVERNAIL 2016).

Sisyrinchium hitchcockii monitoring

Two permanent monitoring plots were established in 2012 to monitor the small population of the Bureau Sensitive species, *S. hitchcockii*, in Meadow C at Oak Basin (Figure 6). The first was a 15m long transect with rebar marking both ends. Plants were found in an ~4m belt (with most plants within 2m). The plot was monitored in 1m sections on the east and west side of the tape. The origin of the transect was on the south end, tagged with #185. The plot extended at a bearing of 340° for 15m; the end rebar was not tagged. The second plot was a circular plot with the rebar placed in the center and tagged with #186; plants were measured in four quadrants and were found within 2 meters of the central rebar. (There is a small patch of lupine in this same area, and the circular plot #186 serves as a marker for both *L. oregonus* and *S. hitchcockii*).

Sisyrinchium bellum is also present in the area, so monitoring should occur at the time of flowering to ensure proper identification of the species. *Sisyrinchium hitchcockii* has a dark filament >6mm with narrower tepals than *S. bellum*. *S. bellum* can also be distinguished morphologically from *S. hitchcockii* by having two-toned tepals, with a prominent yellow 'eye' at the center; this feature is absent or small if present on *S. hitchcockii* (Groberg et al. 2013). Herbarium samples were collected and brought to the Oregon State University Herbarium.



FIGURE 6. HITCHCOCK'S BLUE-EYED GRASS. (A) LONG AND NARROW LEAVES WITH PARALLEL VEINS THAT ARE MOSTLY BASAL (B) 3-CHAMBERED CAPSULES UP TO 6 MM LONG CONTAINING BLACK SEEDS (C) FLOWERS HAVE BLUE TO BLUISH-PURPLE TEPALS WITH A FAINT (OR ABSENT) YELLOW "EYE" IN CENTER.

Due to the rhizomatous growth of *Sisyrinchium*, plants greater than 20cm apart were deemed to be distinct individuals unless there was clear evidence otherwise (e.g. exposed rhizomes). This methodology was consistent with that used by other *Sisyrinchium* sp. studies (Groberg et al. 2013).

Plants were noted to be either vegetative, R1, R2, R3 etc. depending on the number of inflorescences, however individual stems may have more than one flower. In addition, a reproductive plant is likely to have vegetative stems associated with it.

Climate data

To make inferences about the effects of climate on longer-term trends at Oak Basin, climate data from 2011- 2017, as well as mean values for these attributes from 1981-2010 were acquired from The PRISM Climate Group, hosted by Oregon State University. This group, “gathers climate observations from a wide range of monitoring networks, applies sophisticated quality control measures, and develops spatial climate datasets to reveal short- and long-term climate patterns (<http://www.prism.oregonstate.edu/>.” The data we downloaded for comparison were monthly mean precipitation (in), monthly maximum precipitation (in), monthly average temperature (F), monthly minimum temperature (F), and monthly maximum temperature (F).

RESULTS AND DISCUSSION

Kincaid’s lupine population monitoring

At the initiation of this study, cover of lupine across all three meadows was just over 100m². Since that time, both foliar cover and count of racemes has fluctuated. From 2006 to 2012, this value steadily increased to a high of 165m². Cover dropped to the lowest values recorded in 2013 (74 m²). Values doubled in 2014 (149m²), decreasing again in 2015- a year of both high temperatures and low precipitation. In 2016, Kincaid’s lupine cover decreased in all meadows (79 m²), and then increased in 2017 (152 m²) (Table 2, Table 3, Figure 7).

The total number of racemes has followed a similar pattern as the lupine foliar cover at Oak Basin (Figure 7, Figure 8). The number of racemes fluctuated, but showed a general increase, from 2006 to 2012 (range 864-4,168 racemes), experienced a dramatic decline in 2013 (195 racemes), rebounded in 2014 (2,046 racemes), and then declined into 2015 and 2016 (460 and 528 racemes respectively) (Figure 8, Table 2, Table 3). Raceme counts increased in 2017 to the second highest value since monitoring began (3,613 racemes, Table 3).

While Kincaid’s lupine is a long-lived species that can also spread vegetatively, successful sexual reproduction and survival of new genets will be important for the population’s long-term viability. Over the course of the study there have been periodic fluctuations in Kincaid’s lupine total cover, however decreases in foliar cover, combined with low raceme production should trigger a re-evaluation of management actions may be warranted.

The recent observed increases in cover and reproductive effort of Kincaid’s lupine could be caused by a number of potential factors, including habitat management and removal of invasive grasses, climatic factors, increases in pollinator access, or other factors. Direct competition from invasive grasses which have been steadily increasing in recent years could lead to reduced cover of Kincaid’s lupine, while the tall stature of those species could potentially reduce reproduction by limiting access for pollinators (Sletvold et al. 2013). Nectar surveys in 2011 indicate that while nectar species are present at the site, there may not be adequate nectar species (both in number and nectar resources) through the duration of the flight period for Fender’s blue butterfly (Giles-Johnson et. al 2011), and this is could also be true for other pollinators.

The percentage of aborted racemes has varied from 3%-59% over the course of this study (Table 3). We have noted an inverse relationship between production of mature racemes and the percentage of aborted racemes; years that produced a large quantity of mature racemes tend to be associated with low percentages of aborted racemes. Conversely, in years when few racemes are produced, as in 2013 and 2015, the percent of aborted racemes was 59% and 29% respectively (Table 3).

TABLE 2. KINCAID'S LUPINE COVER, TOTAL MATURE RACEMES, MEAN MATURE RACEMES PER M², AND PERCENT ABORTED RACEMES AT OAK BASIN FROM 2005-2017.

Meadow	Year	Lupine Cover (m²)	Total Mature Racemes [Mean Mature Racemes (m²)]	% Aborted Racemes
A	2006	39.34	245 (6.2)	13
	2007	35.13	813 (23.1)	28
	2008	45.46	891 (19.6)	21
	2009	49.53	348 (8.3)	35
	2010	65.31	1860 (28.5)	3
	2011	86.89	2,191 (25.2)	3
	2012	86.53	1,357 (15.7)	3
	2013	42.46	70 (1.6)	55
	2014	80.41	1,108 (13.8)	4
	2015	49.22	129 (2.6)	43
	2016	47.30	209 (4.4)	2
B	2017	87.50	1,996 (22.8)	3
	2006	44.86	375 (8.4)	9
	2007	37.69	1,482 (39.3)	7
	2008	45.92	1,027 (22.4)	13
	2009	50.06	1,004 (20.1)	17
	2010	49.55	1,678 (33.9)	2
	2011	55.83	1,791 (32.1)	3
	2012	64.89	924 (14.2)	1
	2013	20.61	81 (3.9)	65
	2014	51.60	627 (12.2)	1
	2015	21.38	154 (7.2)	37
C	2016	15.19	102 (6.7)	4
	2017	34.67	736 (21.2)	2
	2006	17.55	244 (13.9)	5
	2007	21.19	810 (38.2)	4
	2008	10.59	432 (40.8)	3
	2009	10.72	55 (5.1)	38
	2010	12.04	108 (9.0)	5
	2011	15.06	186 (12.4)	6
	2012	13.52	127 (9.4)	0
	2013	11.14	44 (4.0)	46
	2014	17.80	311 (17.5)	0
2015	21.60	177 (8.2)	2	
2016	14.02	217 (15.5)	37	
2017	29.49	881 (29.9)	3	

TABLE 3. TOTAL LUPINE COVER IN ALL MEADOWS FROM 2006-2017.

Year	Lupine Cover (m²)	Total Mature Racemes [Mean Mature Racemes (m²)]	% Aborted Racemes
2006	101.75	864 (8.5)	9
2007	94.01	3,105 (33.0)	13
2008	101.97	2,350 (23.0)	15
2009	110.31	1,407 (13.4)	23
2010	126.91	3,646 (28.7)	3
2011	157.78	4,168 (26.4)	3
2012	165.04	2,408 (14.6)	3
2013	74.20	195 (2.6)	59
2014	149.81	2,046 (13.7)	3
2015	92.21	460 (5.0)	29
2016	79.27	528 (6.9)	20
2017	151.64	3,613 (23.8)	3

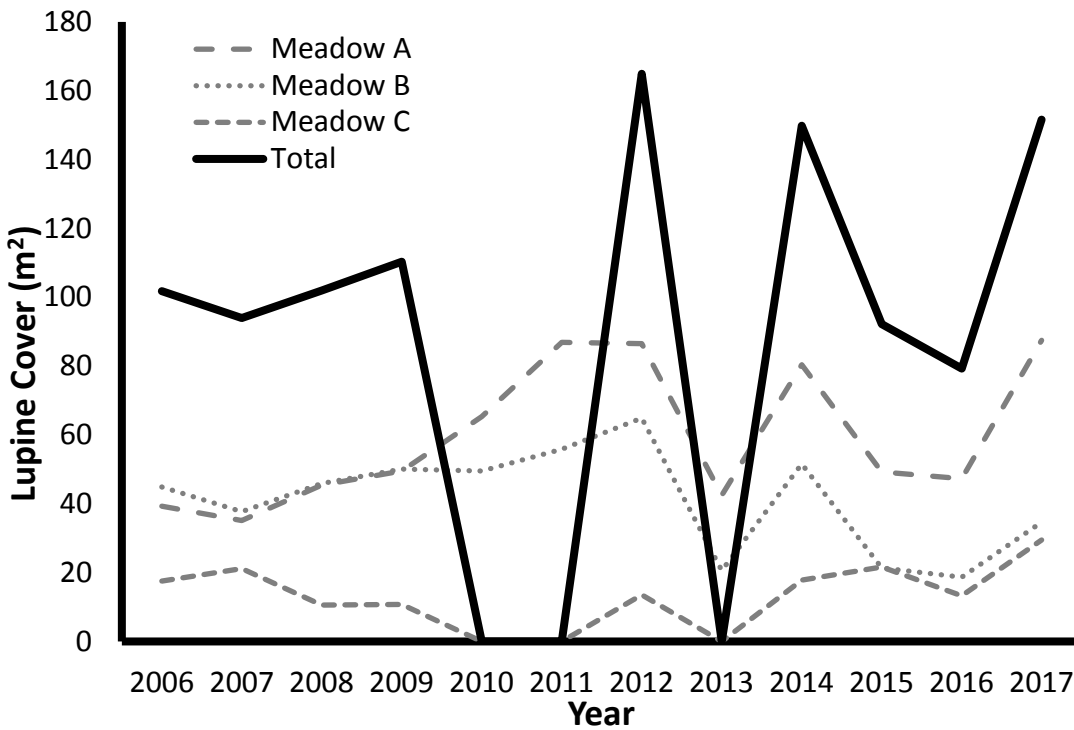


FIGURE 7. LUPINE COVER (M²) IN EACH MEADOW AND TOTAL COVER FOR ALL MEADOWS AT OAK BASIN FROM 2006-2017.

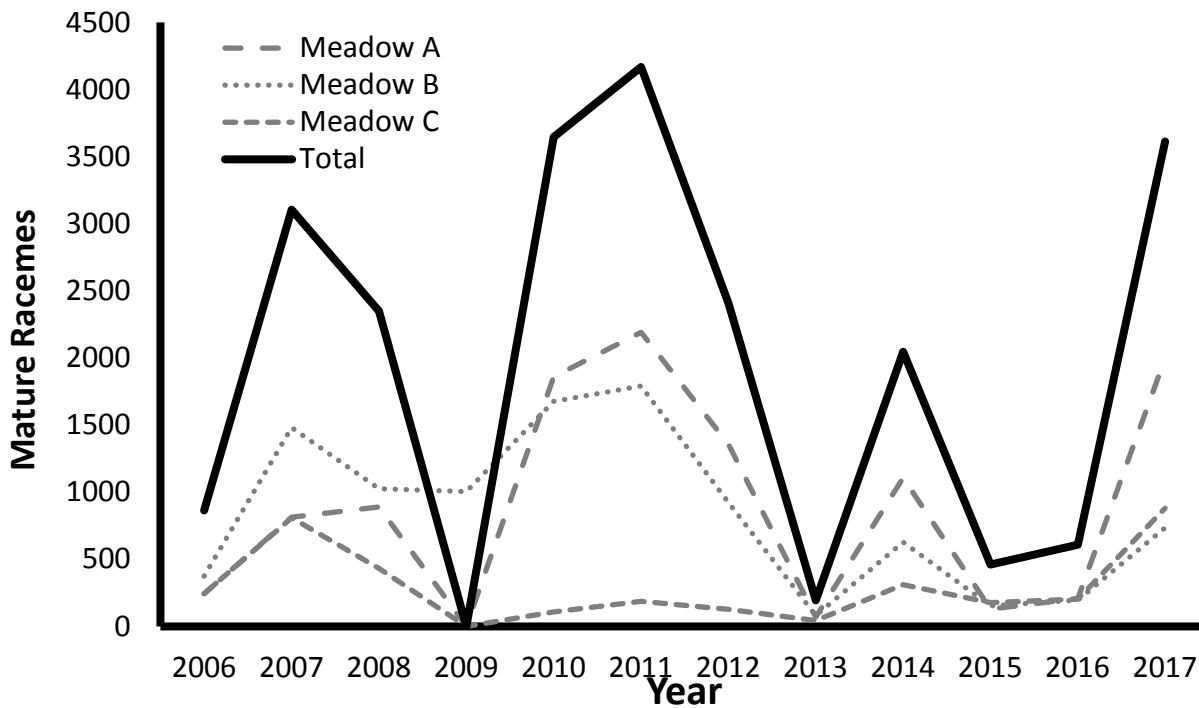


FIGURE 8. TOTAL MATURE RACEMES COUNTED IN EACH MEADOW AT OAK BASIN FROM 2006-2017.

Habitat assessment

Pre-treatment

From 2011-2015 cover of invasive graminoid species showed an increase in all meadows in both lupine and non-lupine habitat (Figure 9, Figure 10, Appendix C). Meadows A, B and C increased in exotic graminoid cover with an increase from 36% to 88% in Meadow A, 42% to 98% in Meadow B, and 44% to more than 100% in Meadow C from 2011-2015. Additionally, the cover of native forb species declined in Meadow C lupine habitat from a high of 30% in 2014 to just 3.5% in 2015. Cover of native forbs in Meadows A and B, have ranged from 7-30% across all years. In each year, the cover of exotic forb species in Meadow C has been consistently lower (range 7%-15%) than the cover of exotic forb species in Meadows A and B (range 10%-31% and 15%-37% respectively). Native graminoid cover is low in all three meadows, with a range of 3%-16% across all years. Similar patterns are noted in non-lupine habitat, with all meadows trending towards increasing cover of invasive graminoids and Meadow C showing a decrease in native forb cover (Figure 10).

Exotic grasses, including *Schedonorus arundinaceus*, *Dactylis glomerata* and *Cynosurus echinatus*, were most prevalent across all meadows, while the exotic forb, *Leucanthemum vulgare*, comprised almost 6% in 2015 of the total cover in these habitats (Appendix C). *S. arundinaceus* is an especially competitive invasive species and dominated lupine and non-lupine habitats with a total average cover ranging from 40-93% in all monitored areas in 2015.

In Kincaid's lupine habitat, the native forbs, *Pteridium aquilinum*, *Sidalcea virgata*, and *Eriophyllum lanatum* were the most abundant. Despite the presence of these native species, the invasive, exotic forb *L. vulgare* dominated total forb cover (Appendix C). Exotic grasses, *S. arundinaceus*, *D. glomerata*, and *C. echinatus*, and the native grasses, *Festuca roemerii* and *Bromus carinatus*, were the most abundant grasses across all three meadows in Kincaid's lupine habitat, and graminoid cover is higher than forb cover in all meadows (Appendix C).

Total species richness for all meadows declined from 2011-2015 (from a high of 105 in 2011 to 82 in 2015). Species richness in Meadow A, decreased from 85 species in 2011 to only 46 in 2015; Meadow C followed a similar downward trend with a high of 66 in 2011 to only 44 species in 2015 (Table 4). The observed range of species richness from 2011-2017 has been the lowest in Meadow C (44-66 species); the range for Meadow A is 46-86 species and Meadow B 54-70 species (Table 4). In 2015, Meadow B contained the highest species richness with 70 total species (40 non-native) (Table 4).

Invasive species competition with Kincaid's lupine, Hitchcock's blue-eyed grass and other native species should be monitored closely given the observed increases in exotic species cover, particularly exotic graminoid species. Exotic species have potential to outcompete native species by limiting available space, nutrients, and water (Corbin and D'Antonio 2004; D'Antonio and Mahall 1991; Hejda et al. 2009; Melgoza et al. 1990).

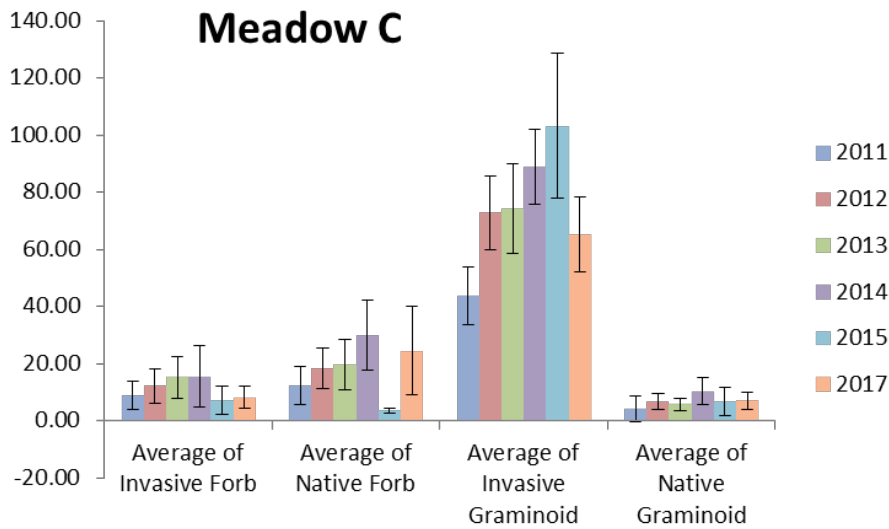
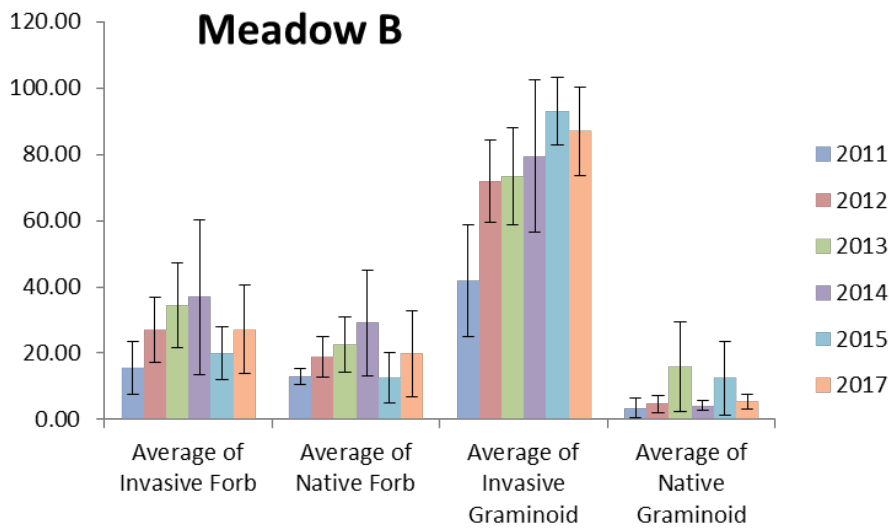
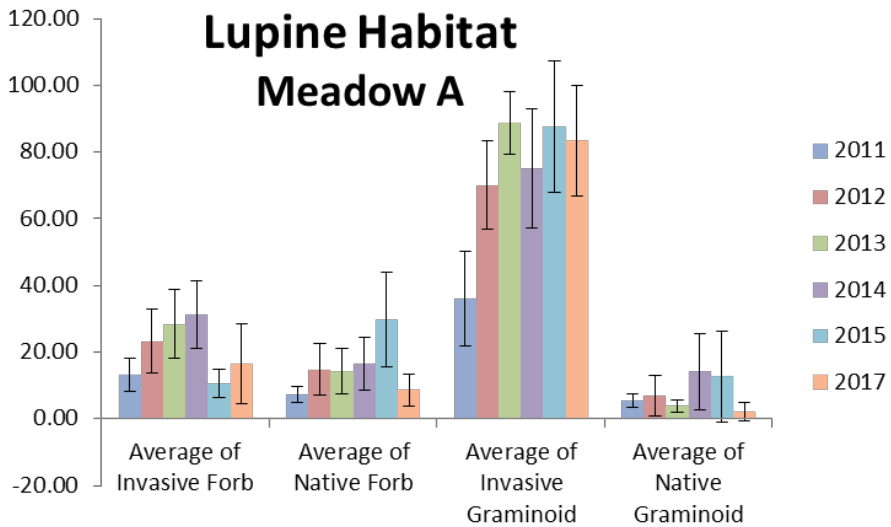


FIGURE 9. AVERAGE PERCENT COVER OF INVASIVE AND NATIVE FORB AND GRAMINOID SPECIES IN LUPINE HABITAT FROM 2011-2015, AND 2017 IN MEADOWS A, B AND C. ERROR BARS REPRESENT 95% CI.

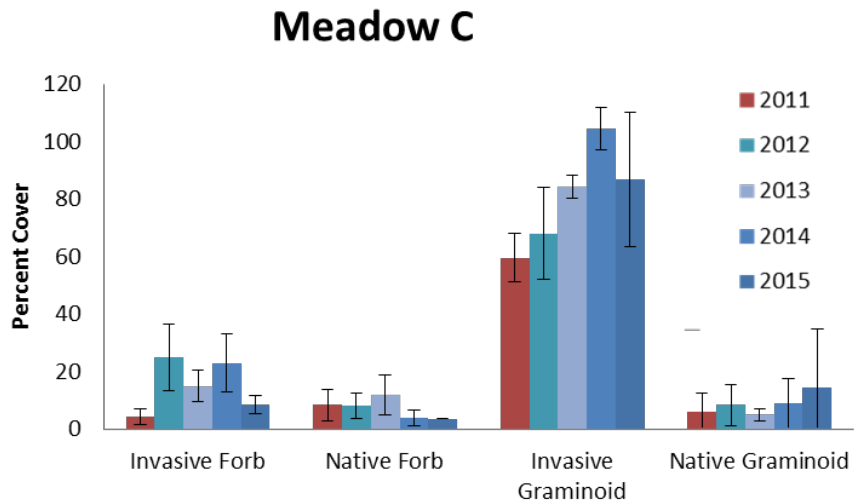
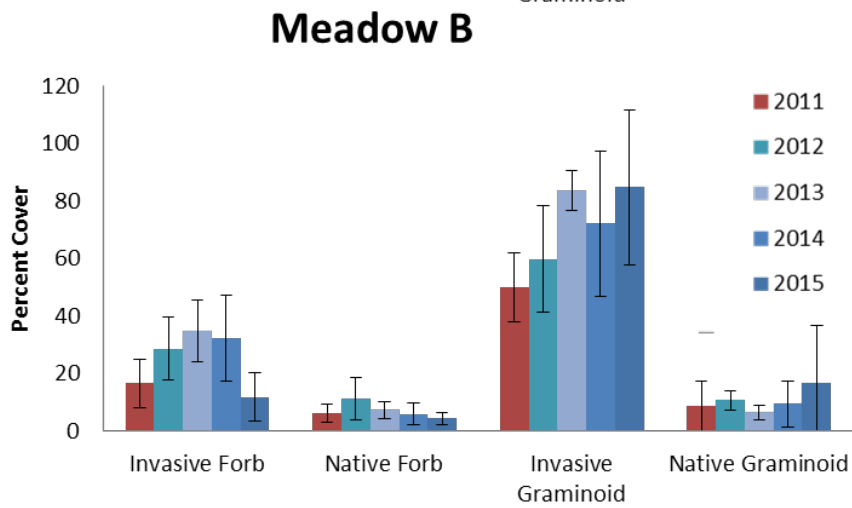
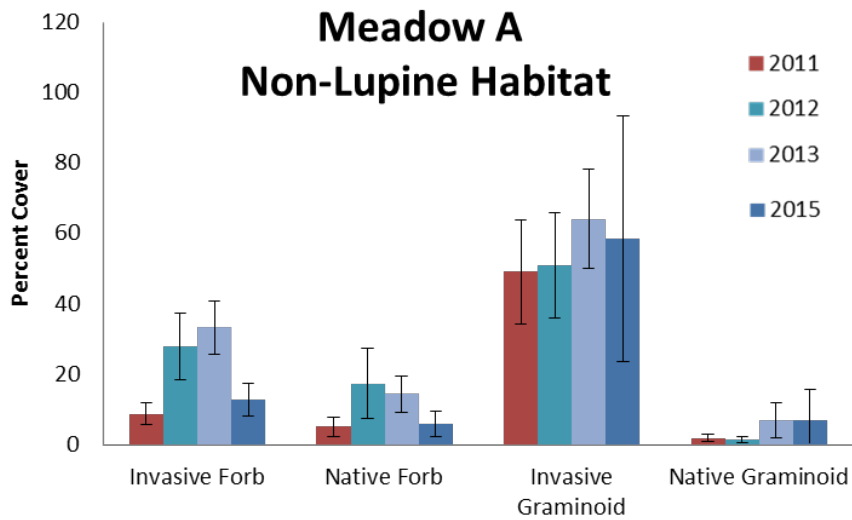


FIGURE 10. AVERAGE PERCENT COVER OF INVASIVE AND NATIVE FORB AND GRAMINOID SPECIES FROM 2011-2015 AT OAK BASIN, MEADOWS A, B, AND C. NO NON-LUPINE PLOTS WERE MEASURED IN 2017 OR IN MEADOW A IN 2014. NO ERROR BARS REPRESENT 95% CI.

TABLE 4. TOTAL (AND NATIVE) SPECIES RICHNESS IN MEADOWS A, B AND C FROM 2011-2015. VALUES REPORTED HERE ARE FOR BOTH LUPINE AND NON-LUPINE HABITATS.

	All meadows	Meadow A	Meadow B	Meadow C
2011	105 (45)	85 (42)	67 (33)	66 (28)
2012	97 (39)	80 (34)	70 (33)	68 (31)
2013	87 (34)	64 (28)	62 (31)	59 (24)
2014	89 (37)	60 (27)	54 (28)	64 (25)
2015	82 (33)	46 (24)	70 (30)	44 (20)
2017	68 (35)	38 (18)	51 (29)	66 (35)

Habitat Management Treatment Assessment

SOLARIZATION

Pre-treatment data was collected in 2015 in the northeast portion of Meadow A along the tree line in an area that is scheduled to be solarized in 2016. Details on timing and implementation of treatments can be found in Silvernail 2015. Plant community was measured in the area to be treated, as well as in the adjacent (and similar) untreated habitat. These measurements will be repeated after the removal of the shade-cloth to assess the efficacy of this treatment in decreasing cover of invasive, exotic species (in particular invasive, exotic perennial grasses).

FLAMEWEEDING

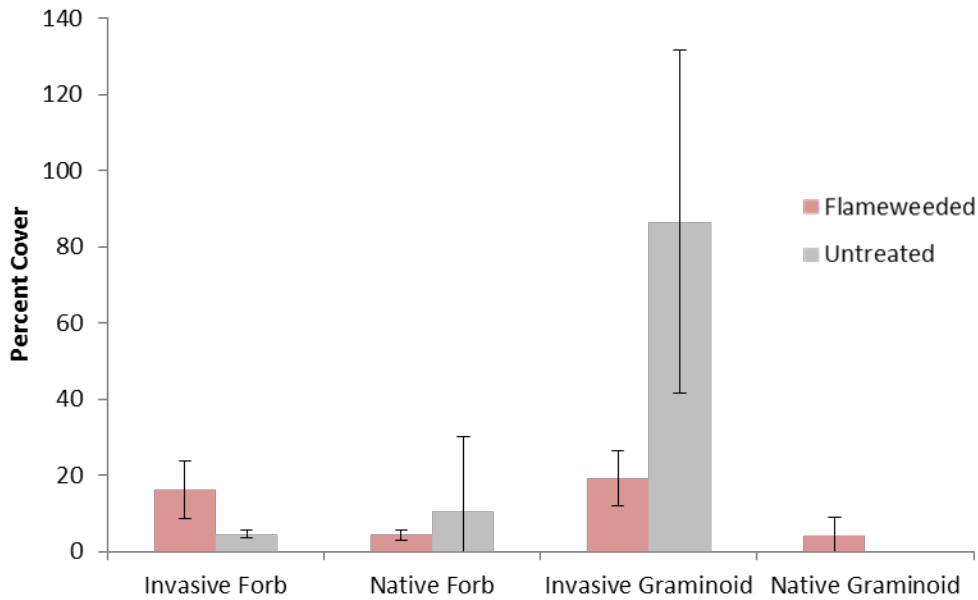
On 4/8, 4/14, and 12/16/2015, selected areas were flame weeded at Meadow A and B (Figure 5, Figure 11, Figure 16). In 2015 and 2016, plant community was measured in areas that had been flame weeded and adjacent areas with similar soil structure and initial plant community that had not been treated. These measurements will be repeated in 2018. Initial results show that cover of invasive grasses was higher in the untreated areas than in the flame weeded areas for both Meadow A and B; untreated areas at Meadow A had 2.5 times higher invasive grass cover than untreated areas at Meadow B (86.5% versus 32.7%) (Figure 12, Figure 13, Figure 15, Figure 16, Appendix C, Appendix E).

In both 2015 and 2016, the cover of exotic grasses was higher in areas that had not been flame-weeded. This was particularly true for exotic, annual species (particularly *Taeniatherum caput-medusae*) (Appendix E, Figure 12, Figure 13, Figure 14, Figure 15). Cover of exotic forbs only differed slightly between flame-weeded and untreated areas in both 2015 and 2016 (Figure 12, Figure 13, Figure 14, Figure 15). In both years, the response of native forb cover in flame-weeded areas varied. At Meadow A, native forb cover was higher in untreated areas, while in Meadow B native forb cover was higher in flame weeded areas (Figure 16). These measurements will be repeated in the future as management continues at the site, and additional management actions are implemented (including seeding and outplanting of native species.)



FIGURE 11. PIN FLAGS MARK THE BOUNDARY BETWEEN UNTREATED (LEFT) AND FLAME-WEEDED (RIGHT) IN MEADOW A IN 2015. COVER OF BOTH ANNUAL AND PERENNIAL EXOTIC GRASSES WERE HIGHER IN UNTREATED AREAS.

Meadow A, 2015, Flame



Meadow A, 2016, Flame

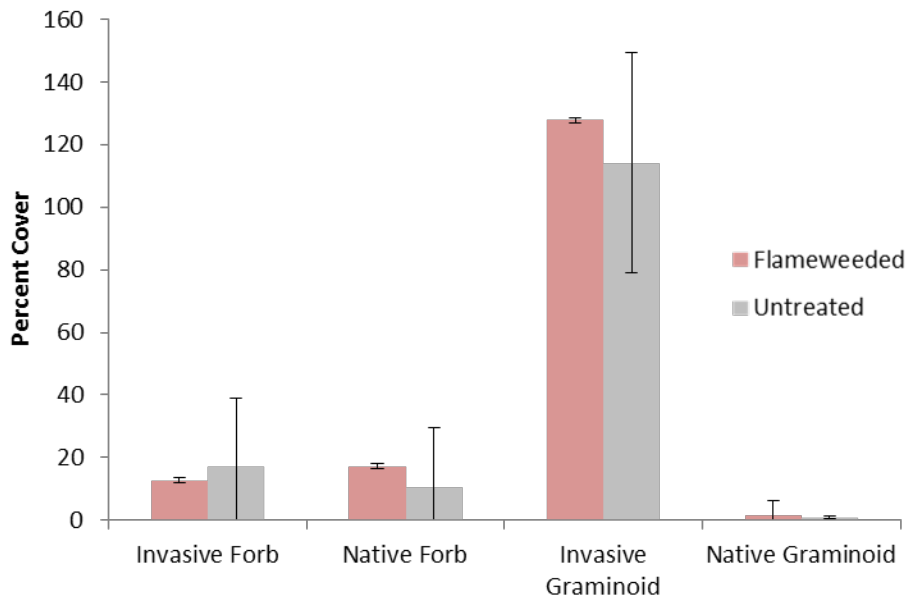
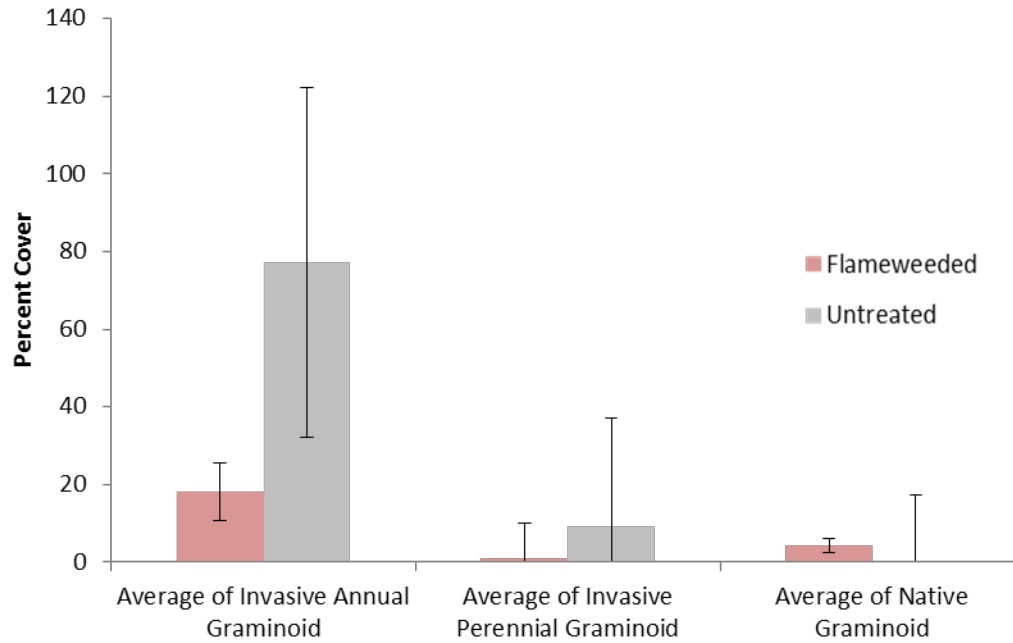


FIGURE 12. PERCENT COVER BY FUNCTIONAL GROUP FOR FLAMEWEEDED AND UNTREATED AREAS IN MEADOW A FOR BOTH 2015 AND 2016. ERROR BARS REPRESENT 95% CI.

Meadow A, 2015, Flame, Graminoids



Meadow A, 2016, Flame, Graminoids

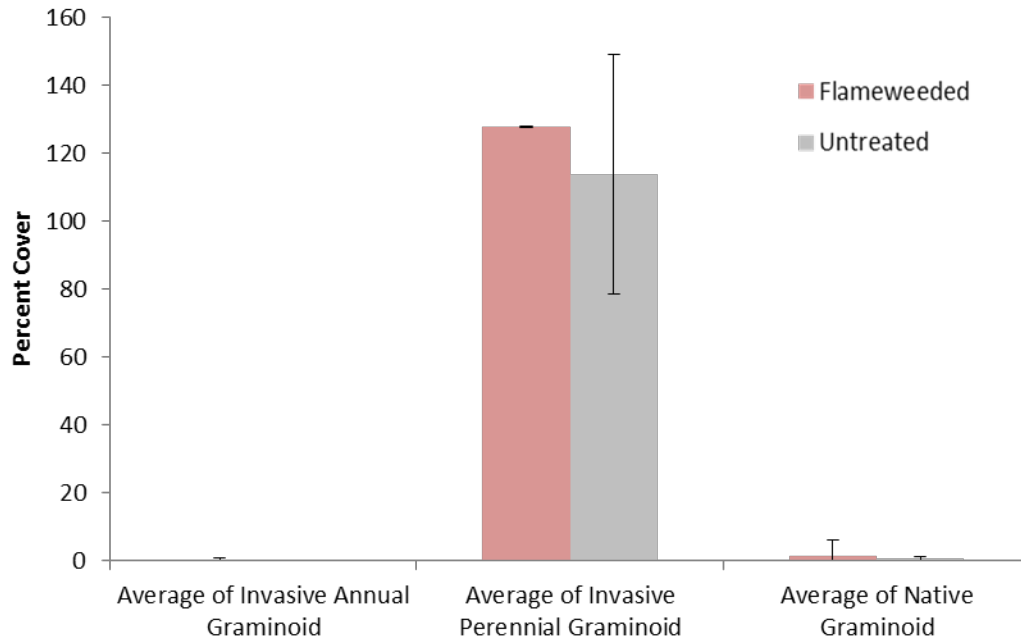


FIGURE 13. PERCENT COVER OF GRAMINOIDS BY NATIVITY FOR FLAMEWEEDED AND UNTREATED AREAS IN MEADOW A FOR BOTH 2015 AND 2016. ERROR BARS REPRESENT 95% CI.

Meadow B, 2016, Flame

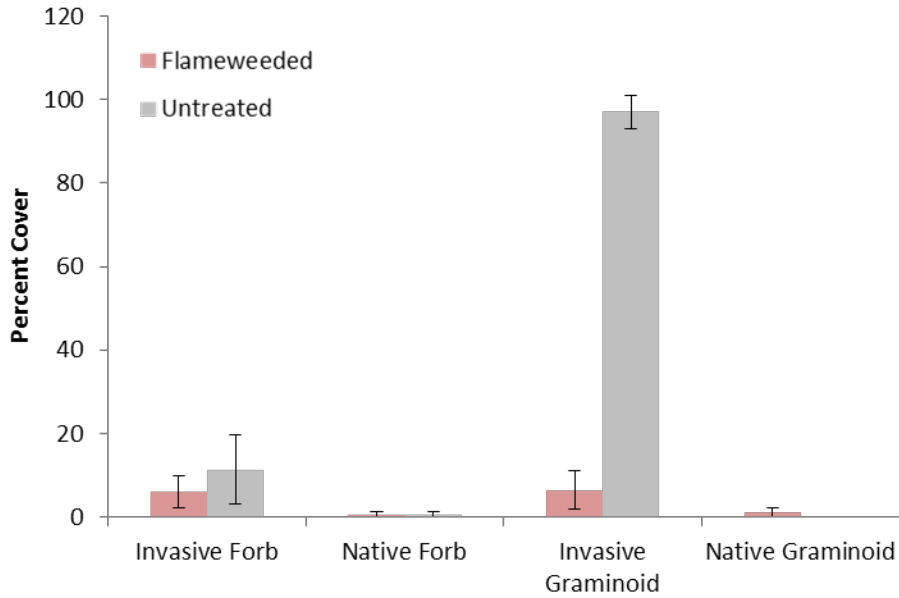


FIGURE 14. AVERAGE PERCENT COVER BY FUNCTIONAL GROUP OF FLAMEWEEDED AND UNTREATED AREAS IN MEADOW B IN 2016. ERROR BARS REPRESENT 95% CI.

Meadow B, 2016, Flame, Graminoids

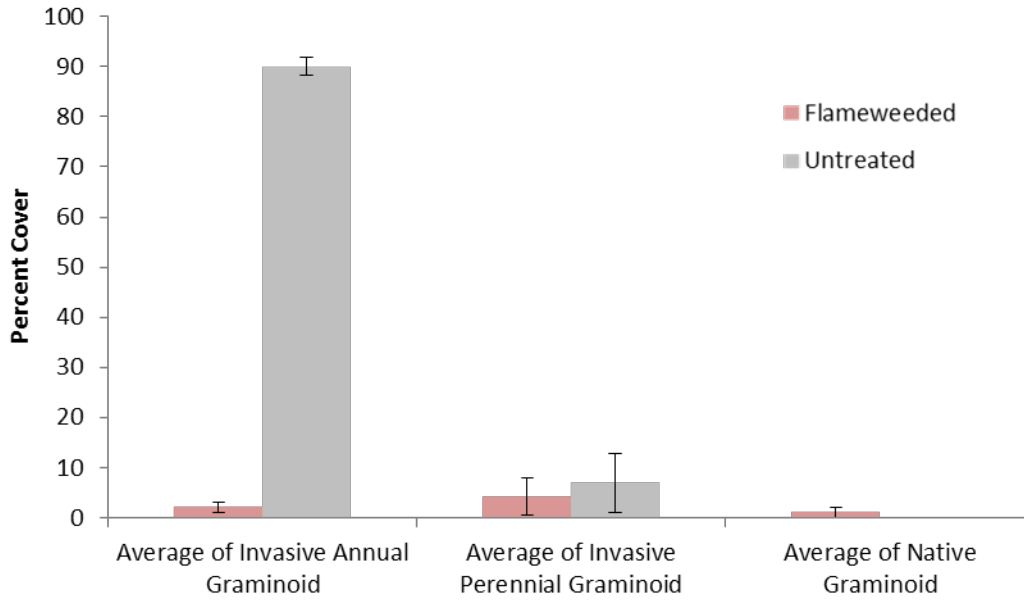


FIGURE 15. PERCENT COVER OF ANNUAL AND PERENNIAL GRAMINOID SPECIES IN FLAMEWEEDED AND UNTREATED AREAS OF MEADOW B IN 2016. ERROR BARS REPRESENT 95% CI.

MOWING

Large areas adjacent to existing lupine patches were mowed in Meadow A in the summer of 2015, in an attempt to decrease seed set of exotic species, as well as improve pollinator access to lupine (Severns 2008). Monitoring in 2016 found little difference in plant community between mowed and unmowed portions in Meadow A (Figure 14, Figure 15). Mowing will likely need to continue over time to see any potential impact to targeted species (in this case *L. oreganus* and indirectly the Fender's blue butterfly), however, mowing will only temporarily reduce cover of *S. arundinaceous* and may actually stimulate new vegetative and rhizomatous growth.

In 2017, the foliar cover and raceme count was higher in mowed vs unmowed patches in all meadows, but more data should be collected before conclusions/management actions can be developed. The total area mowed and unmowed are not equal in areal coverage, and are not directly comparable, thus the proportion of cover relative to 2012 totals in each year will be reported after future data collection efforts to gain a more complete picture of the effects of mowing. Despite apparent increases in raceme count and foliar cover, mowing is not recommended as a long-term solution for control of invasive perennial grasses, as many have been selected for traits that allow recovery following defoliation. *S. arundinaceous* must be consistently mowed to <1.5 inches for control efforts (USDA 2001), which would likely negatively impact the native plant community as well. Grass-specific herbicide application could provide more targeted control, but must be timed to not interfere with the Fender's blue butterfly and meet all necessary permitting requirements.

Meadow A, 2016, Mow

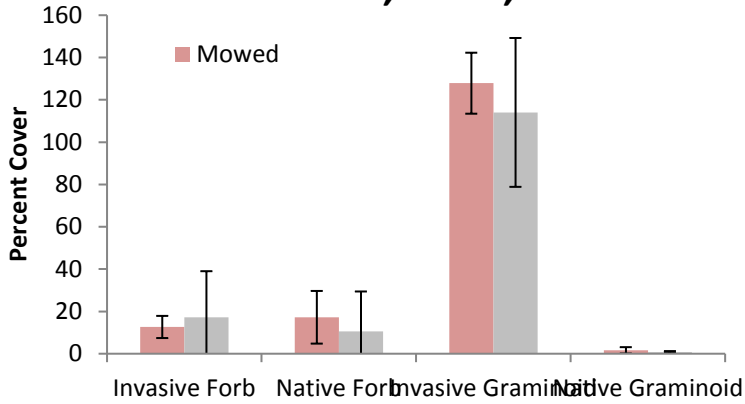


FIGURE 16. NATIVE AND EXOTIC PLANT COVER BY FUNCTIONAL GROUPS IN MOWED AND UNTREATED (“UNMOWED”) AREAS AT OAK BASIN IN 2016 IN MEADOW A. ERROR BARS REPRESENT 95% CI.

Meadow A, 2016, Mow, Graminoids

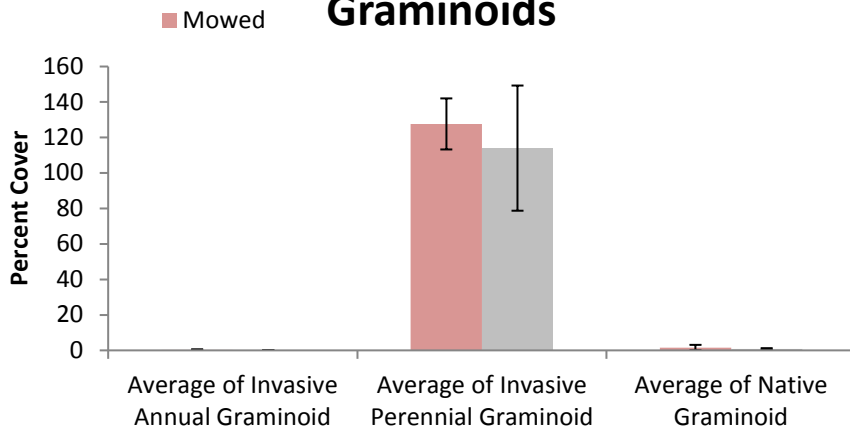


FIGURE 17. PERCENT COVER OF ANNUAL AND PERENNIAL GRASSES AT OAK BASIN MEADOW A IN MOWED AND UNTREATED (“UNMOWED”) AREAS. ERROR BARS REPRESENT 95% CI.

Sisyrinchium hitchcockii monitoring

Since initiation of monitoring in 2012, the population of *S. hitchcockii* has been in decline (Figure 19, Table 5). In 2012 a total of 122 plants were observed, with a total of 128 reproductive stems. In 2017 the fewest number of vegetative plants was recorded (15, range: 15-47), with just 66 total plants and 89 reproductive stems. While these values are higher than those observed in 2016 (Figure 19, Table 5), they represent a nearly 50% decrease in the number of plants since 2012.

Despite the fact that we follow methodology consistent with that used by other *Sisyrinchium* sp. studies (Groberg et al. 2013), it is acknowledged by Groberg et. al. that this methodology, may under-represent the true number of individuals present. *S. hitchcockii* plants may spread through rhizomatous growth into neighboring plants, potentially resulting in the grouping of separate individuals during



FIGURE 18. SISYRINCHIUM HITCHCOCKII (HITCHCOCK'S BLUE-EYED GRASS) AT OAK BASIN.

monitoring. Measurements are taken each year following the same monitoring protocol, despite the potential limitations of the sampling method discussed above, there is not an effect on the total count of reproductive stems; the number of reproductive stems (and the number of plants) has decreased over the course of the study (Figure 15, Table 5).

We have been monitoring *S. hitchcockii* for six years, and our data show that the *S. hitchcockii* population has been in decline. Reproductive effort in this *S. hitchcockii* population has followed similar trends to Kincaid's lupine at this site. The fact that the reproductive effort and growth of the Kincaid's lupine population followed the same trend suggests that a ubiquitous factor (i.e. climate, competition with exotic species)

could be affecting these populations. It remains vital to monitor the *S. hitchcockii* population to track population variability in coming years to ensure that these populations are remaining viable. Despite the increase in the number of plants from 2016-2017, the decrease in the number of reproductive could be a concern for the longevity of this population.

Sisyrinchium hitchcockii, Meadow C

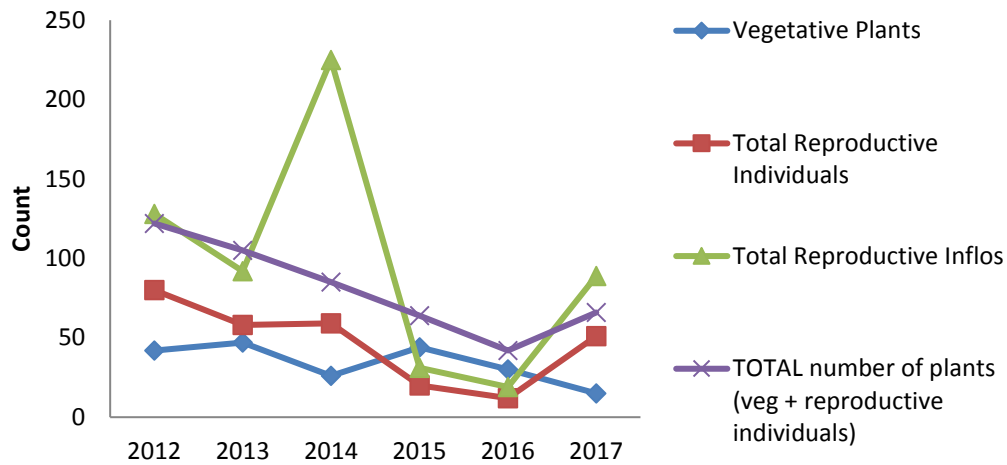


FIGURE 19. POPULATION TRENDS FOR *S. HITCHCOCKII* IN MEADOW C.

TABLE 5. COUNT OF NUMBER OF *S. HITCHCOCKII* BY SIZE CLASS IN MEADOW C.

Size Class	2012	2013	2014	2015	2016	2017
Vegetative	42	47	26	44	30	15
R1	55	40	17	13	8	21
R2	14	10	9	5	2	20
R3	7	5	5	1	1	8
R4	1	1	7	0	1	1
R5	1	1	0	1	0	1
R6	1	0	12	0	0	0
R7	0	0	7	0	0	0
R8	0	1	0	0	0	0
R9	1	0	0	0	0	0
R10	0	0	0	0	0	0
R11	0	0	0	0	0	0
R12	0	0	1	0	0	0
R13	0	0	0	0	0	0
R14	0	0	1	0	0	0
Total Reproductive Individuals	80	58	59	20	12	51
Total Reproductive Stems	128	92	225	31	19	89
Total number of plants	122	105	85	64	42	66

Synthesis

The foliar cover and raceme count of Kincaid's lupine has fluctuated dramatically since monitoring began in 2006. Inter-annual fluctuations in raceme count and foliar cover highlight the need for ongoing monitoring of extant populations in order to assess the status of these populations. In order to reach recovery goals for this species, continued monitoring of both Kincaid's lupine and the associated plant community will be vital. Since 2012, we have documented a decline in reproductive effort for *S. hitchcockii*. While both *L. oreganus* and *S. hitchcockii* species increased in 2017 from 2016 values, the inter-annual fluctuation is cause for concern. The fluctuations in population dynamics of both of these species during the study might be partially due to changes in climate factors observed over recent years (Figure 20).

Large declines in foliar cover, lupine raceme counts, and increases in cover of invasive grasses particularly in 2013 and 2015 could have been related to temperature and precipitation fluctuations. In 2012, the early winter (Oct-Dec) was wetter than average, and then transitioned to a drier than average winter/spring (Dec-Mar). This relatively dry winter coupled with higher than average temperatures throughout the spring (Feb-June) of 2013 may have contributed to the observed declines of both *L. oreganus* and *S. hitchcockii*, both of which do much of their growth in the early spring. A similar pattern was observed in 2015, with low precipitation and high temperatures, particularly during the spring growing season. Long-term stresses on the plants, as related to extremes in temperatures and moisture conditions, may also be contributing to observed declines (Figure 7, Figure 8, Figure 20).

The plant community from 2011-2017 has experienced significant changes that could negatively impact the rare species present, in particular Kincaid's lupine. All meadows have experienced large increases in invasive grasses from 2011-2017 (Figure 9, Figure 10, Appendix C, Appendix E). Meadows A, B and C have shown increases in exotic graminoid cover with an increase from 36% to 88% in Meadow A, 42% to 98% in Meadow B, and 44% to more than 100% in Meadow C from 2011-2015. Management activities focused on targeting invasive species in Kincaid's lupine habitat, as well in the area occupied by *S. hitchcockii* will be necessary to prevent further declines of these rare species.

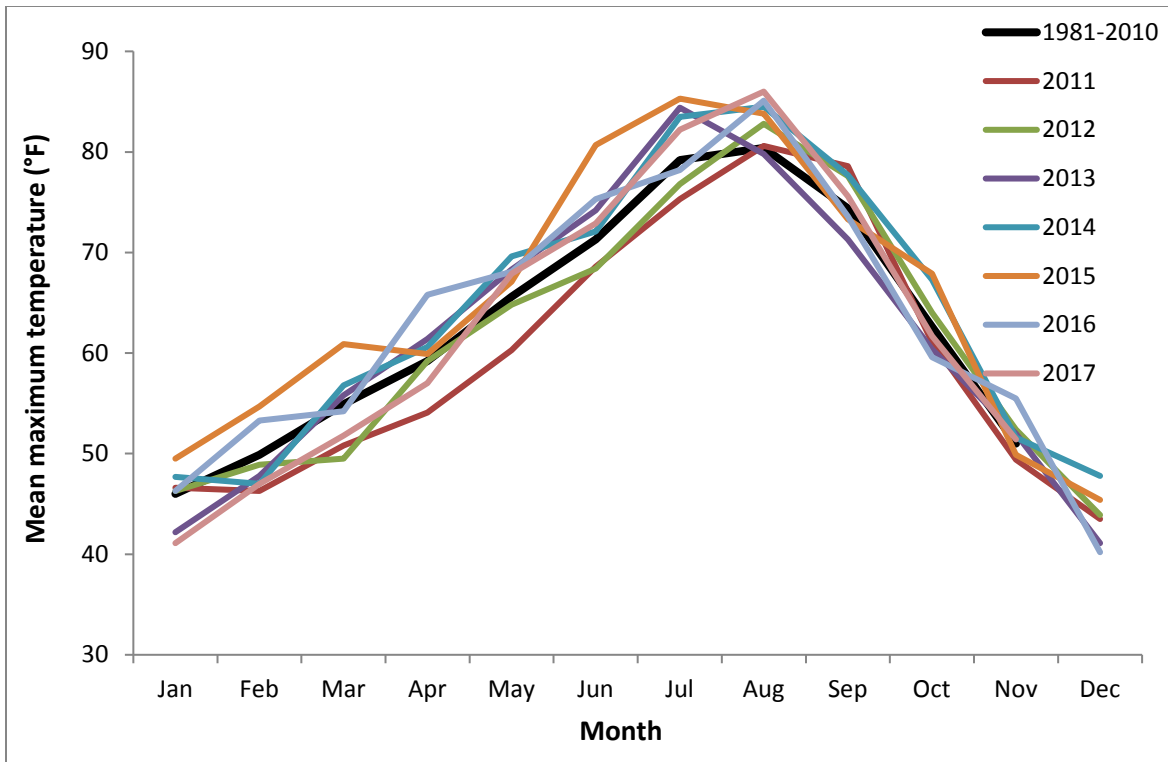
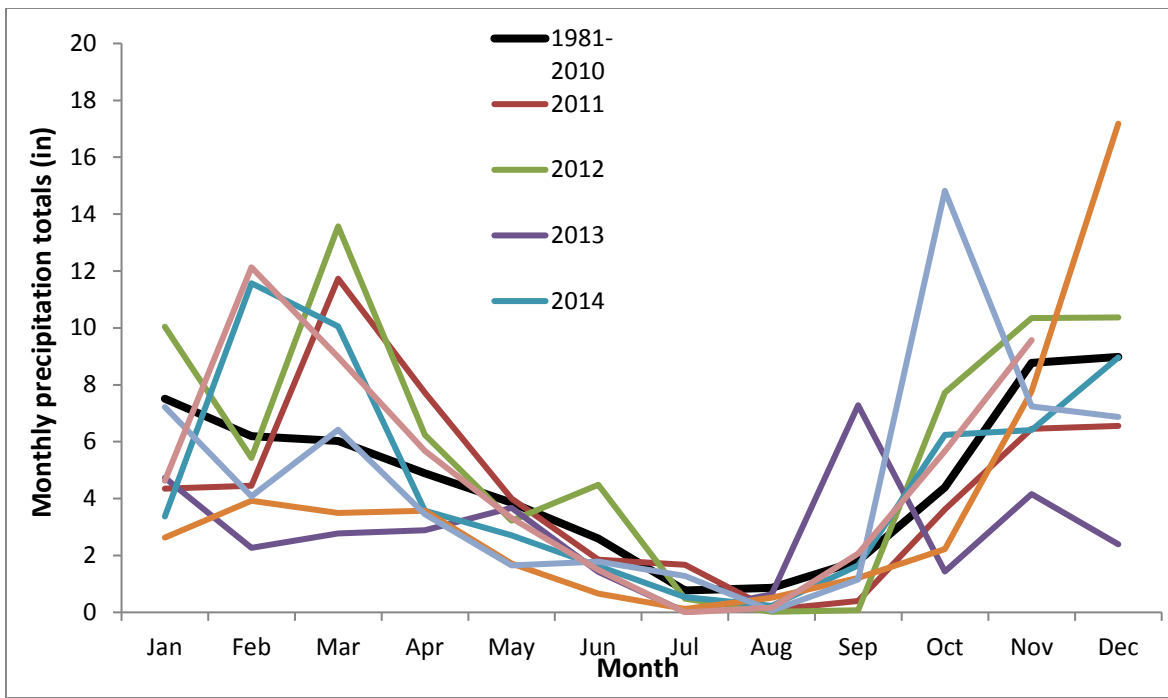


FIGURE 20. MONTHLY PRECIPITATION (TOP) AND MEAN MAXIMUM TEMPERATURE (BOTTOM) AT OAK BASIN FROM 2011-2016. MEAN VALUES FROM 1981-2010 ARE REPORTED AS THE BLACK DOTTED LINE. ALL DATA FROM PRISM CLIMATE GROUP, OREGON STATE UNIVERSITY.

RECOMMENDATIONS

Based on results from 2017, and the continued management activities at the site, we recommend the following actions at Oak Basin in 2018:

1. Continued population monitoring will be essential to document population trends for both species, especially in response to restoration activities occurring on site. Long-term monitoring of threatened species is important to inform management and restoration treatments, especially in the face of climate change.
2. Targeted community monitoring of areas pre- and post-management treatments.
3. Quantification (e.g. area covered) of any future ATV (or other anthropogenic) damage to lupine populations.
4. Documentation of which plots may contain Kincaid's lupine, spurred lupine, and hybrids between the two species.
5. Continued management treatments targeting both annual and perennial invasive grasses, increasing meadow connectivity by reducing encroachment through the removal of trees and control of invasive forb and shrub species.

The Institute for Applied Ecology is working in partnership with the BLM and TNC to coordinate restoration efforts in the area. Ongoing community, Kincaid's lupine, and Hitchcock's blue-eyed grass monitoring will enable us to assess the effects and success of ongoing restoration at the site.



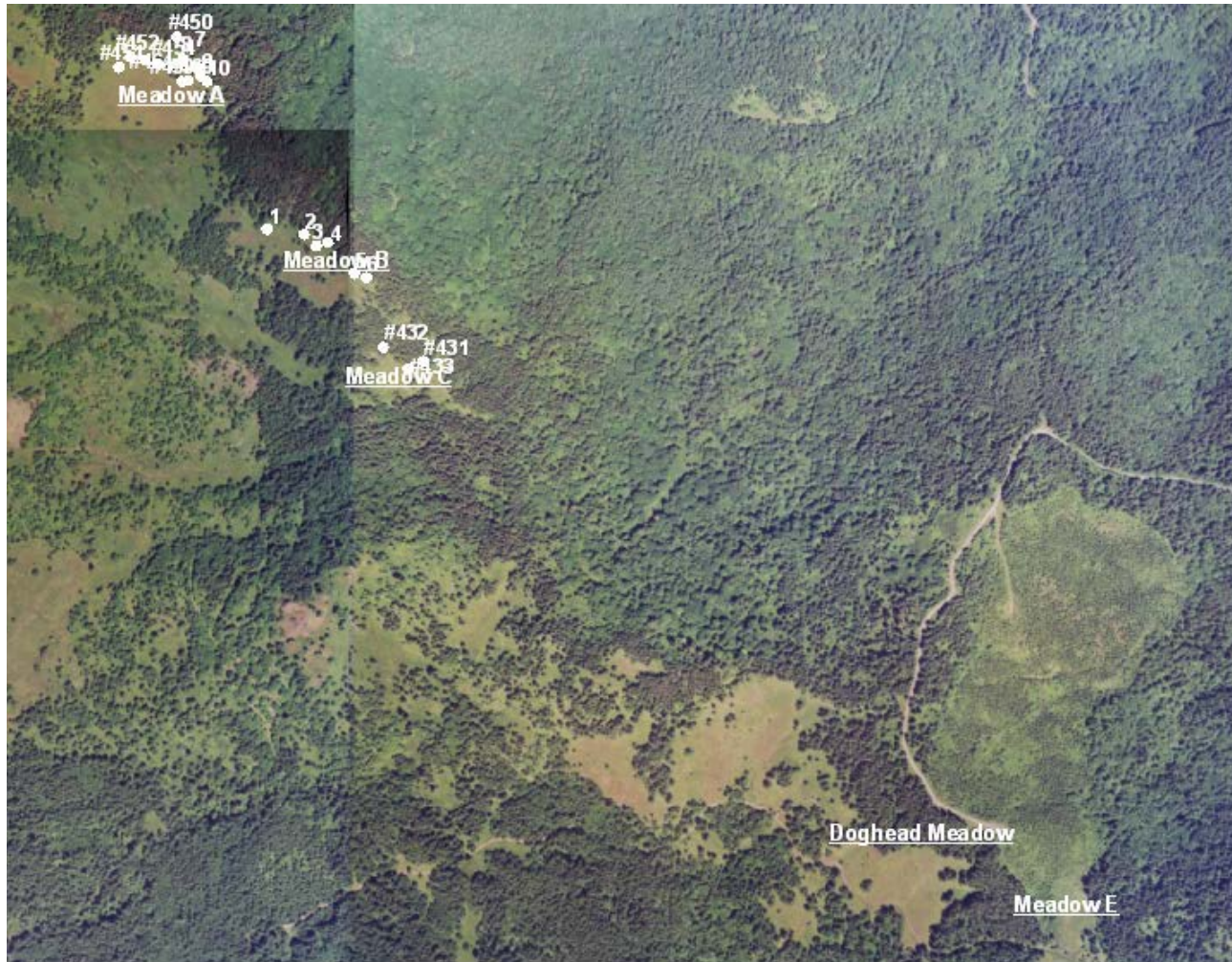
FIGURE 21. 2012 IAE INTERN EDDIE RAMIREZ IN MEADOW A, WHICH HAS A DENSE COVER OF OXEYE DAISY.

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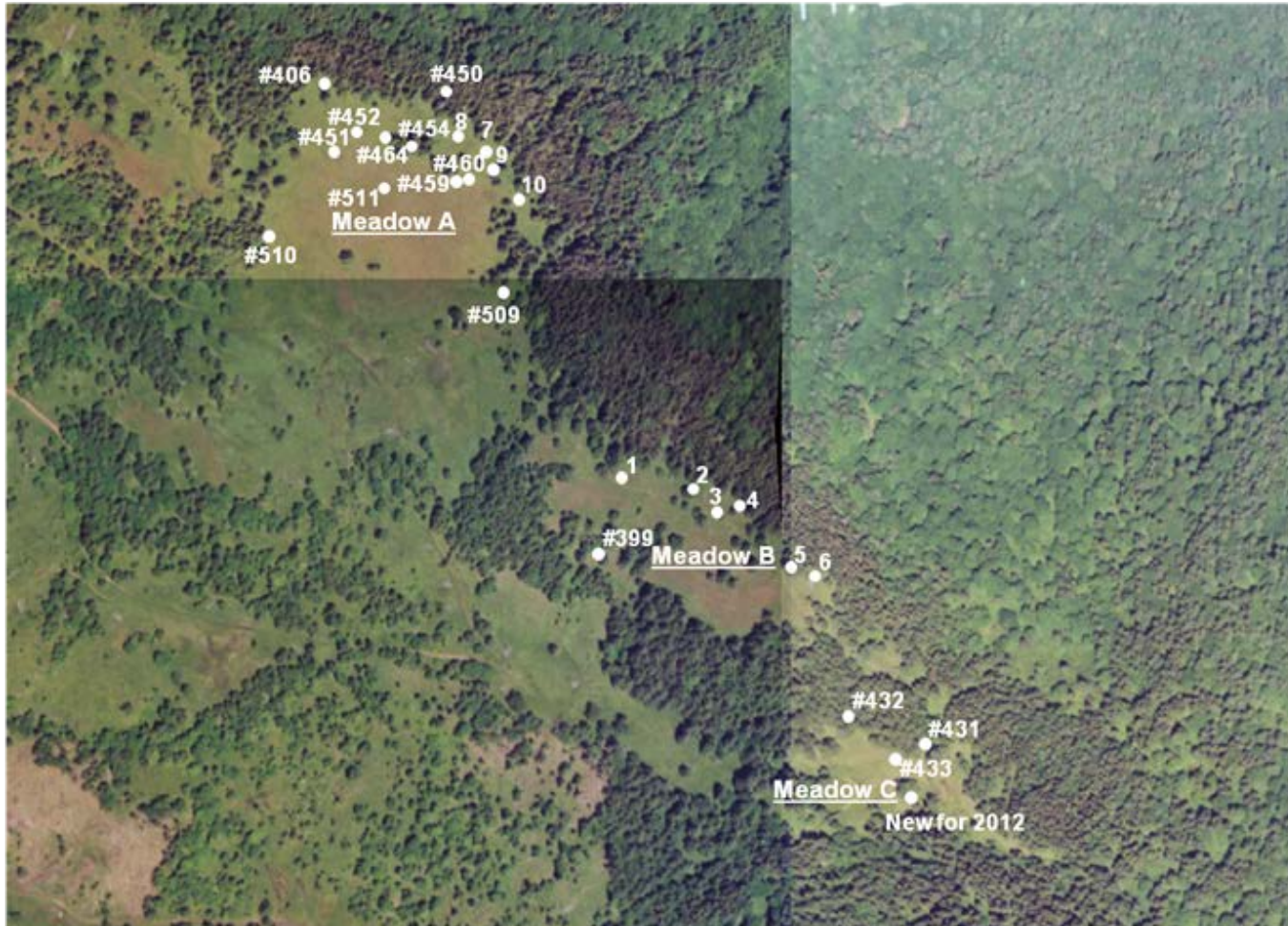
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APPENDIX A. AERIAL PHOTOS AND PLOT DIAGRAMS OF OAK BASIN.



AERIAL PHOTO WITH AN OVERVIEW OF THE OAK BASIN STUDY AREA, INCLUDING MEADOW NAMES. DETAILED MAPS OF EACH MEADOW AND PLOT NUMBERS FROM OUR STUDY ARE INCLUDED BELOW.



AERIAL PHOTO OF THE THREE MEADOWS AT OAK BASIN THAT CONTAIN PATCHES OF KINCAID'S LUPINE. PLOT NUMBERS AND MEADOW NAMES ARE INDICATED.

Meadow A

Plots established in 2011: 509, 510 and 511

509: East population on skid road

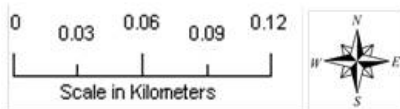
~1.5m radius around rebar

510: West population on tree line at 179 degrees from big PSME around center of hill

~8m x 1m strip going N to S

511: Center population in middle of hill at 230 degrees from westernmost PSME of PSME island on top of hill near plot 459.

5 plants in 3m x 0.5m going N to S

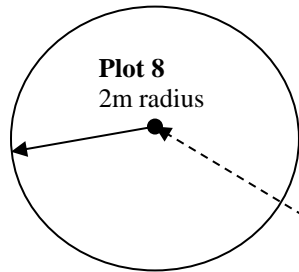


DIAGRAMS OF KINCAID'S LUPINE MONITORING PLOTS AT OAK BASIN MEADOW A.

Meadow A

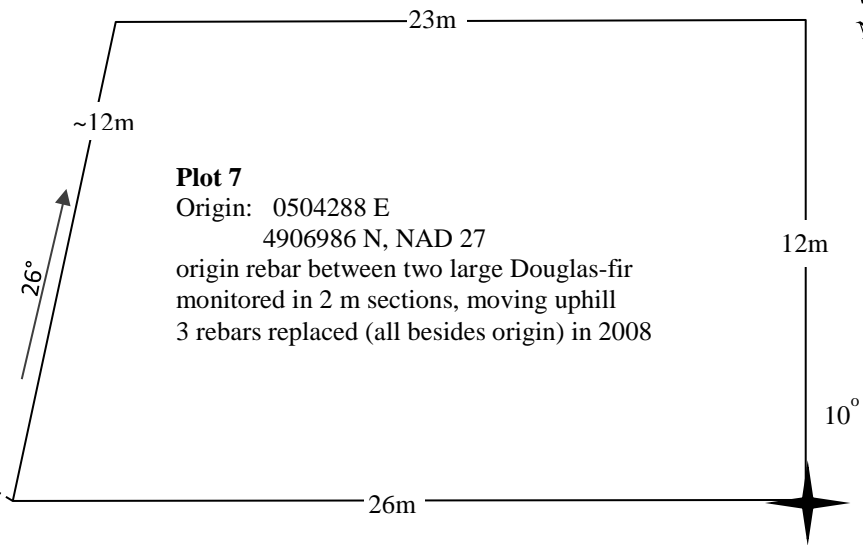
Plot 8

Rebar 4.5m to NW (356°) from
plot 7, tree has fallen across plot
Origin: 0504259 E
4907001 N; NAD 27



Plot 7

Origin: 0504288 E
4906986 N, NAD 27
origin rebar between two large Douglas-fir
monitored in 2 m sections, moving uphill
3 rebars replaced (all besides origin) in 2008

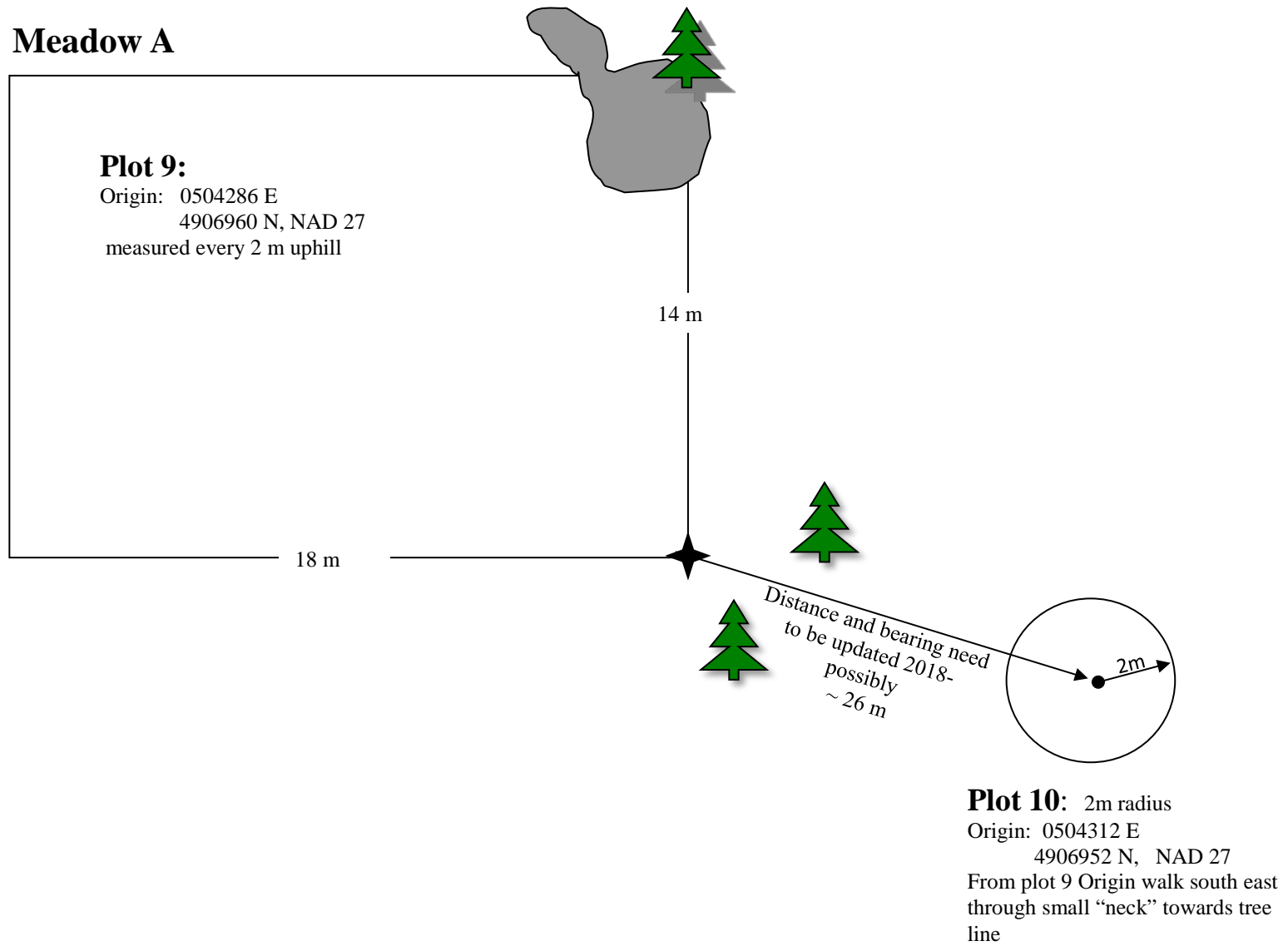


Unrelated rebar

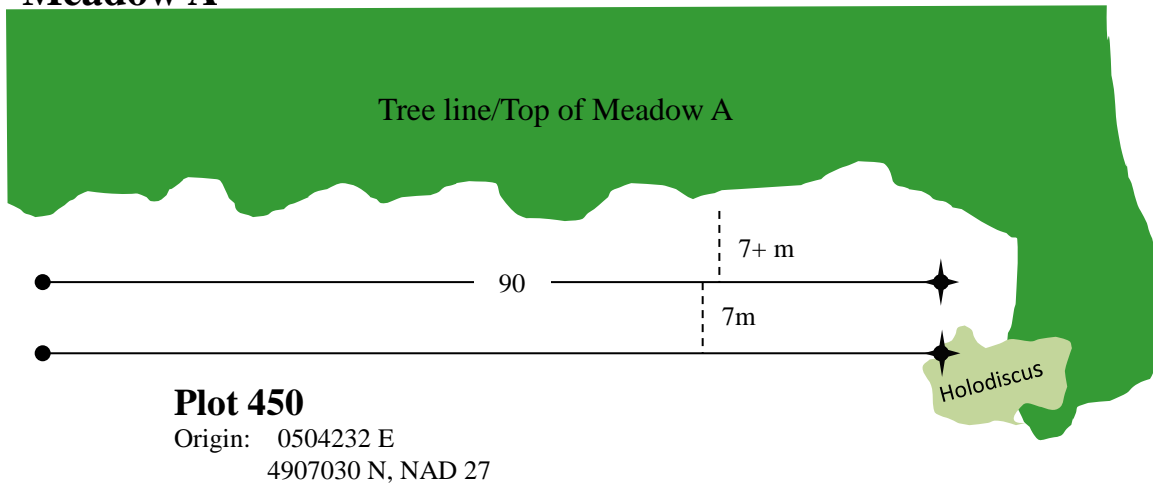
Tree

Tree

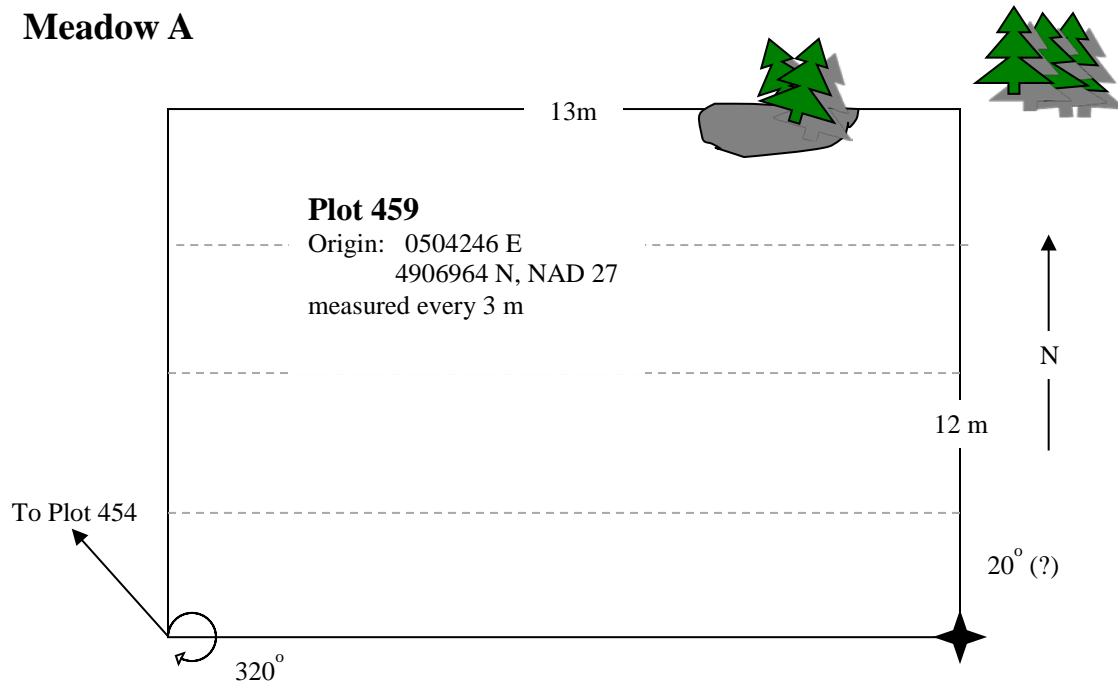
Meadow A



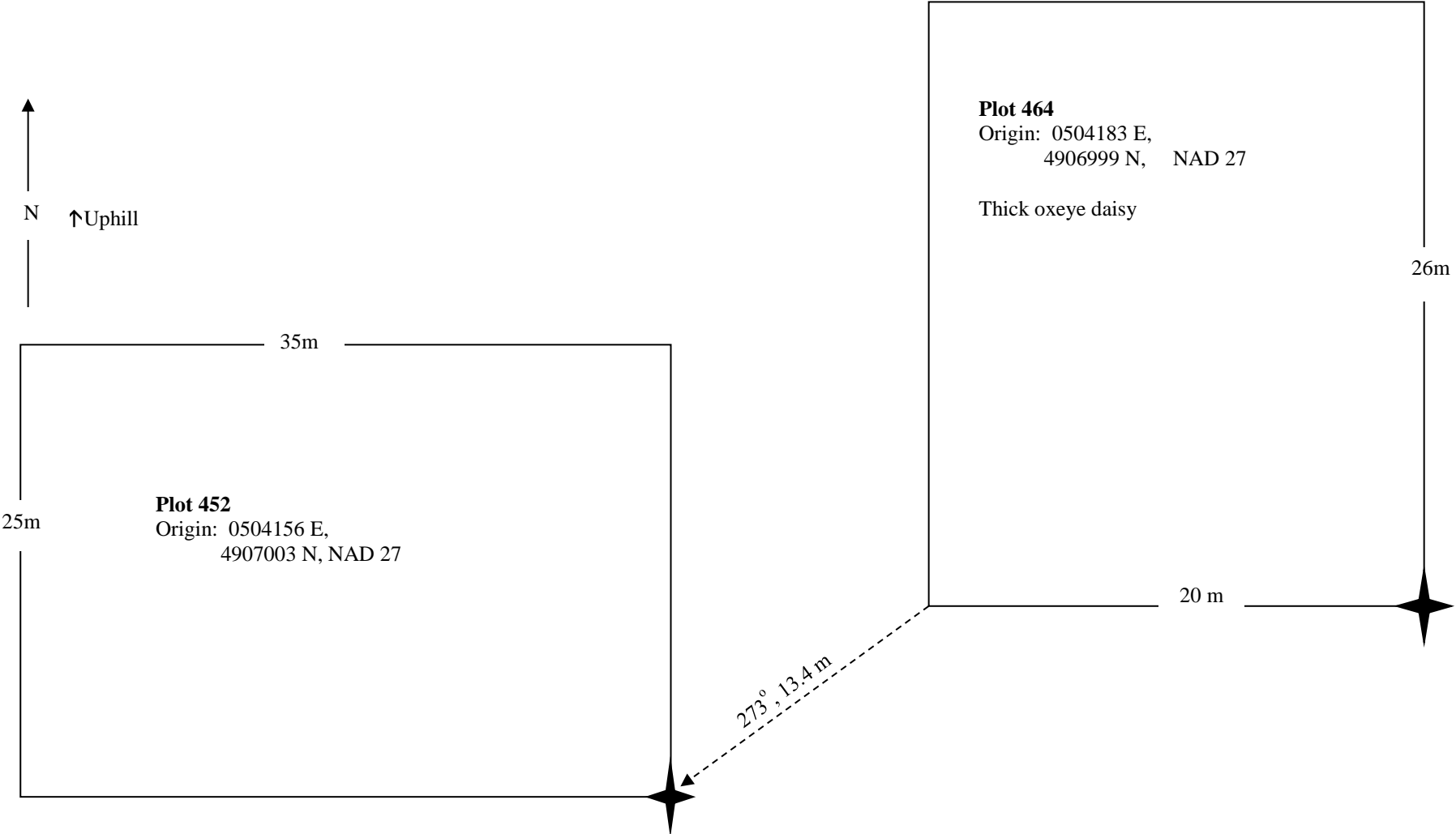
Meadow A



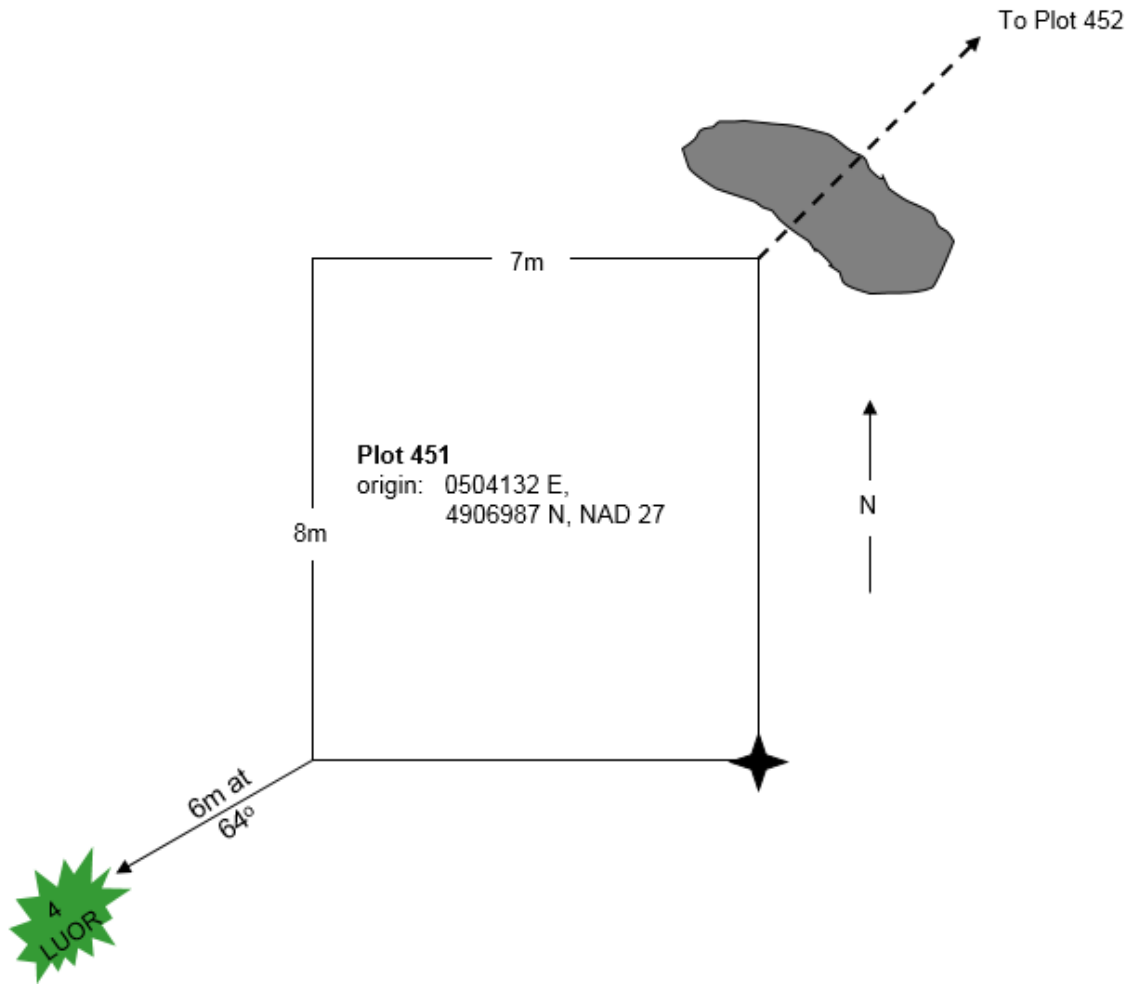
Meadow A



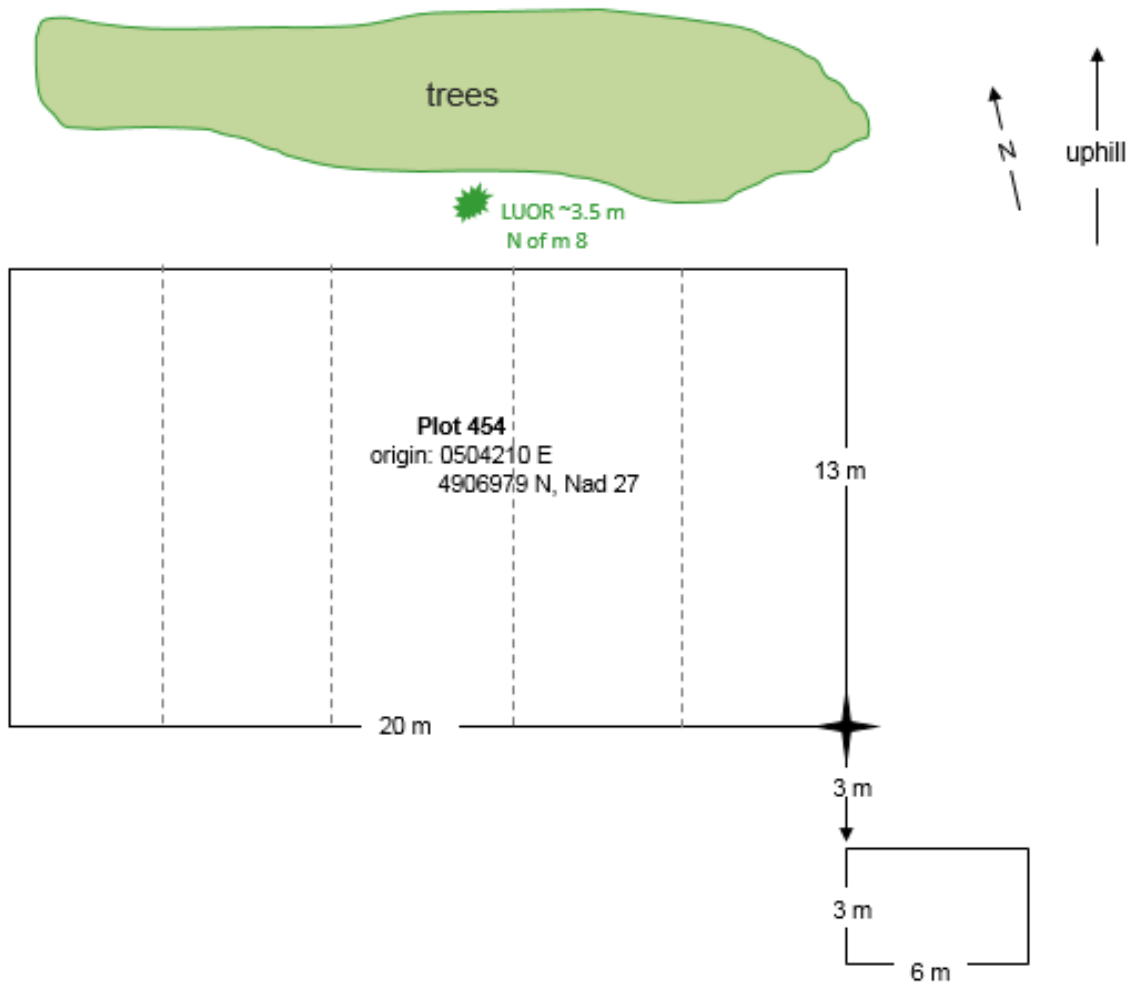
Meadow A



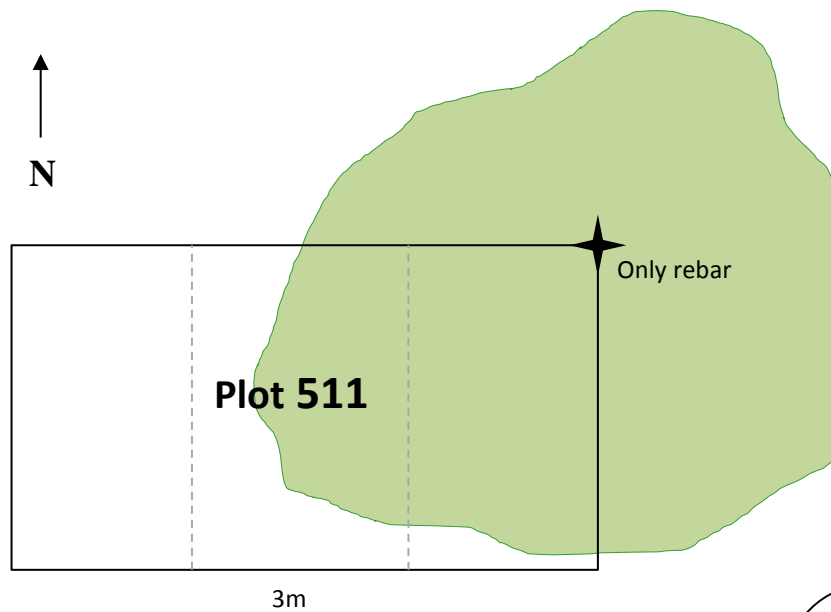
Meadow A



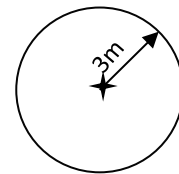
Meadow A



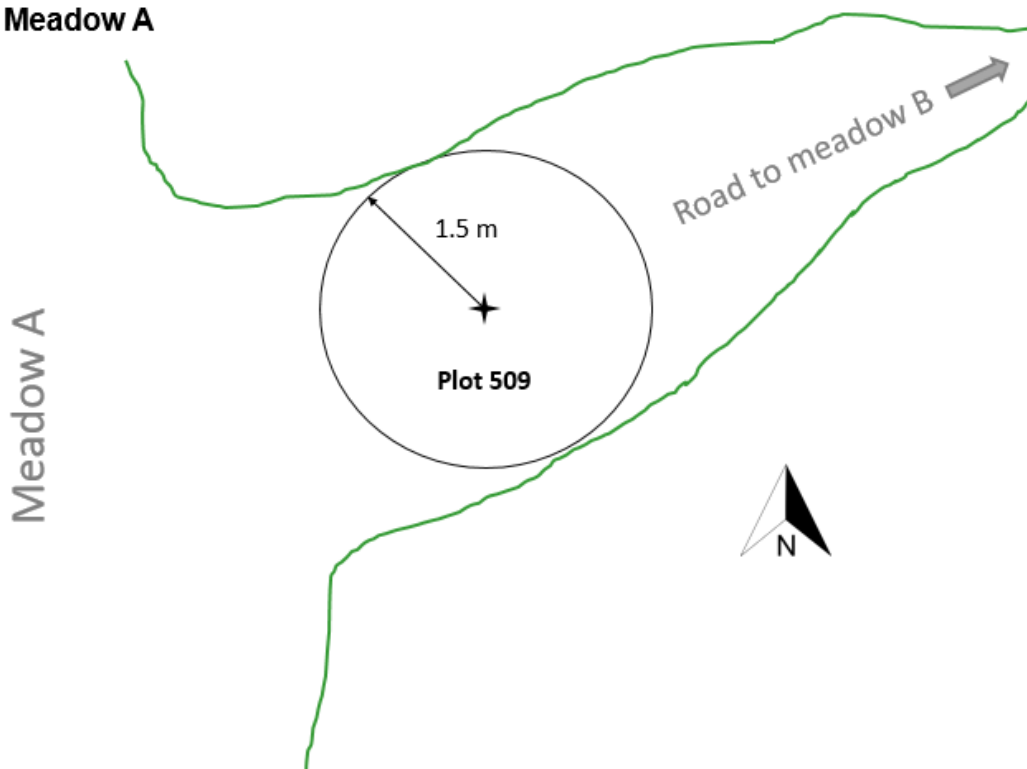
Meadow A



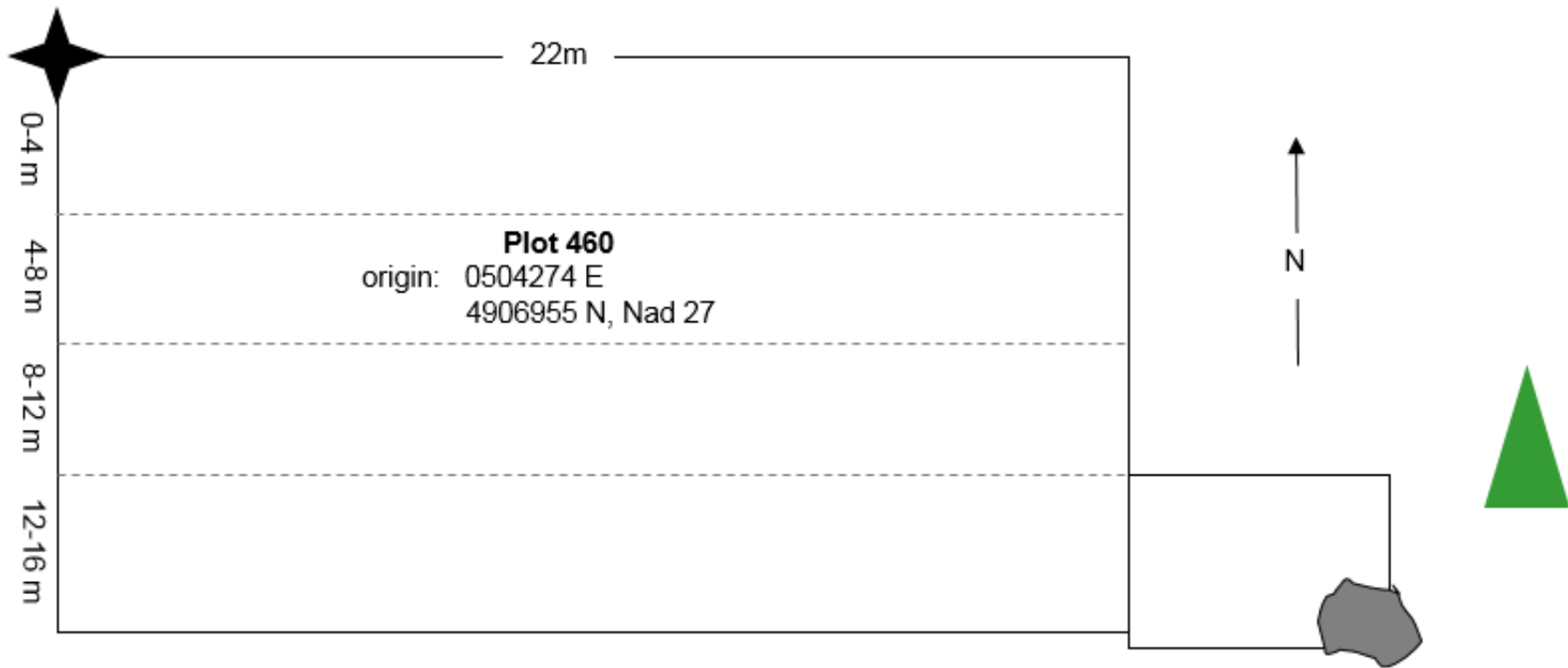
Plot 511 as established in 2011 (3 x 0.5 meter belt transect) no longer encompasses population. Left map shows the plot as monitored in 2017: 3 m x 1m with the origin in the NE corner (monitored this way to correlate with data sheet). Suggest creating new data sheets and re-establishing in 2018 as a 3m radius plot with the rebar in the center:

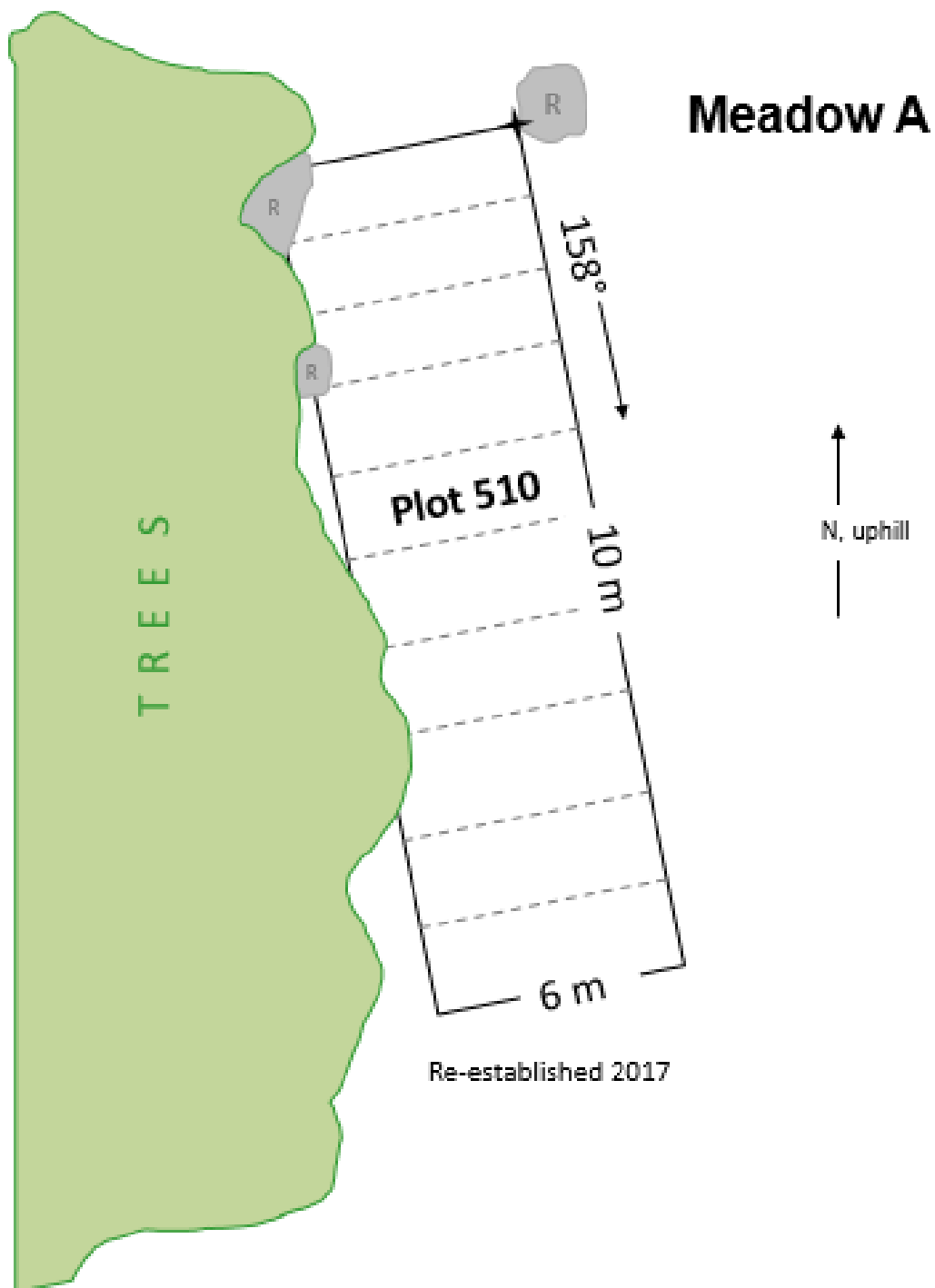


Meadow A

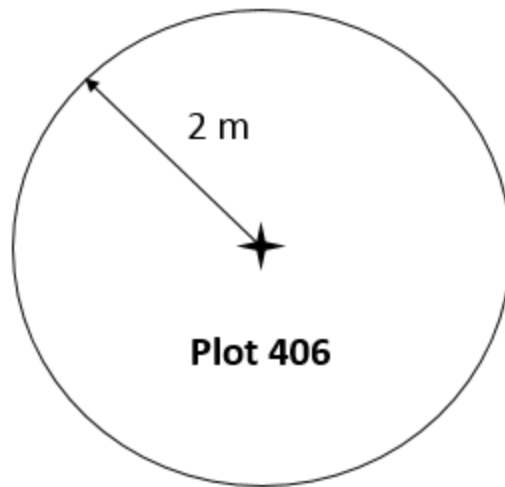


Meadow A



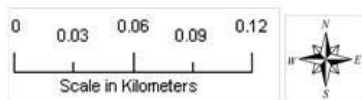


Meadow A



NW of Plot 450

Meadows B and C



To reach plot 399**:

From Origin of plot 1, bearing 178, ~40 meters.

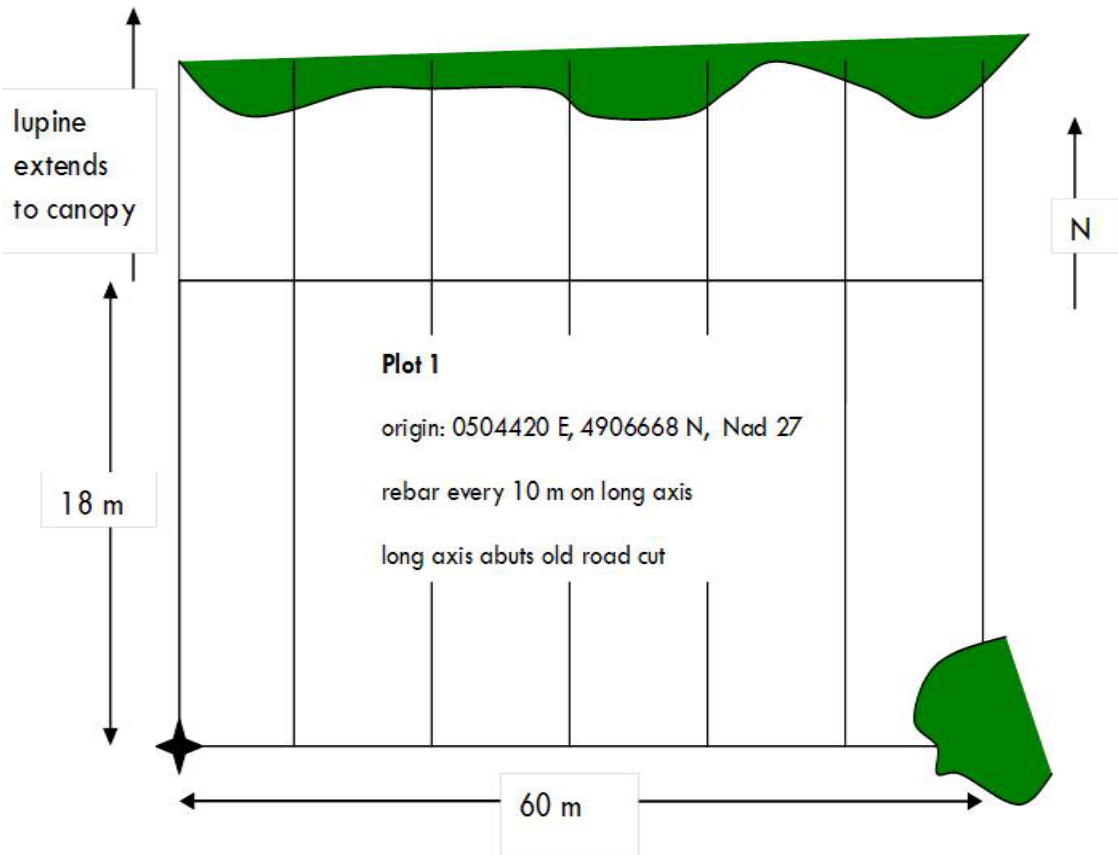
Near PSME with ACMA growing with it where hill steeply drops off.

Population has been captured in a rectangle plot with 14m x 11m sides. Origin is in NE corner and has conduit, the other corners have rebar with yellow caps.

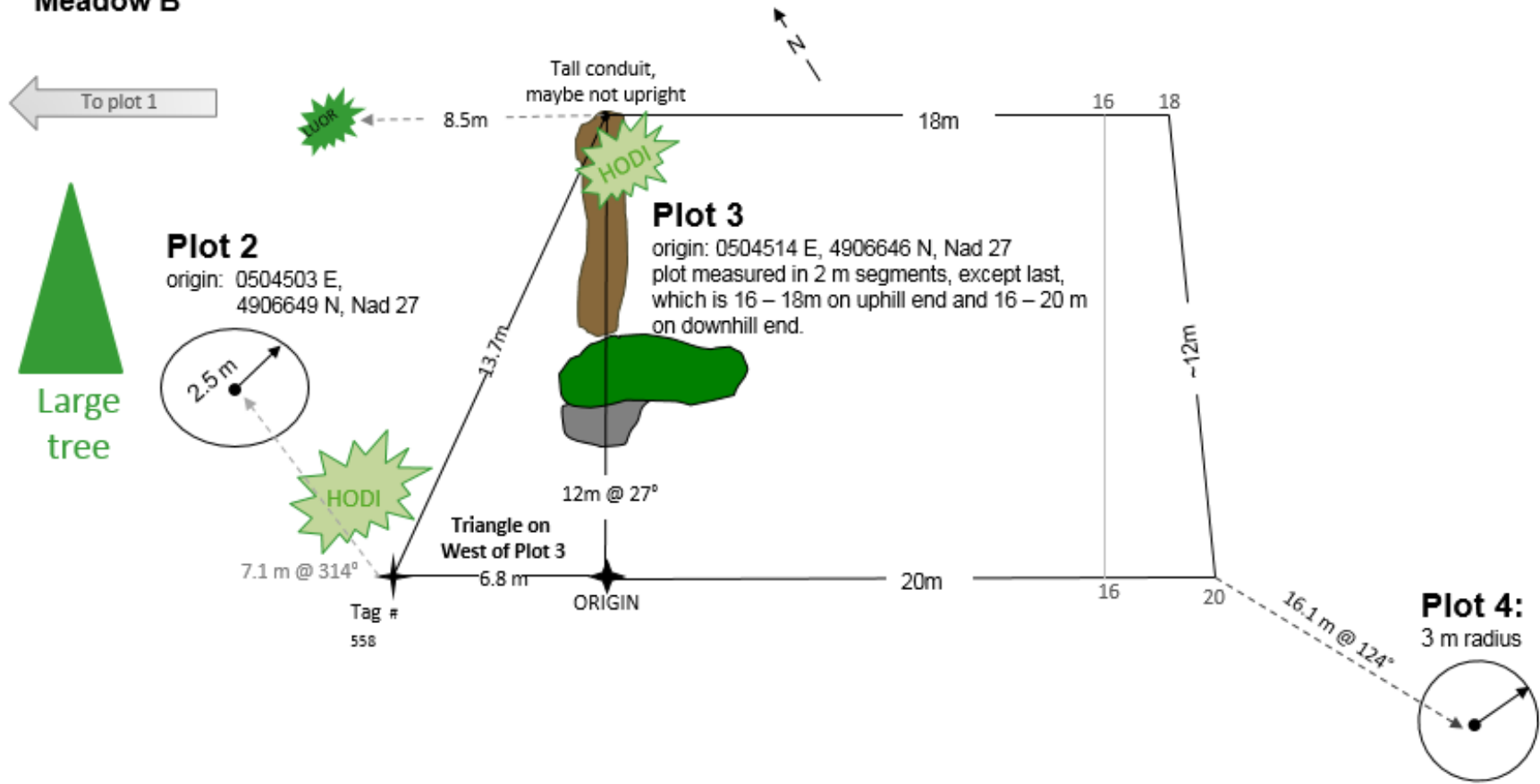
This population MAY be on private land and thus was not included in our cover estimate totals

OVERVIEW OF PLOTS IN MEADOWS B AND C.

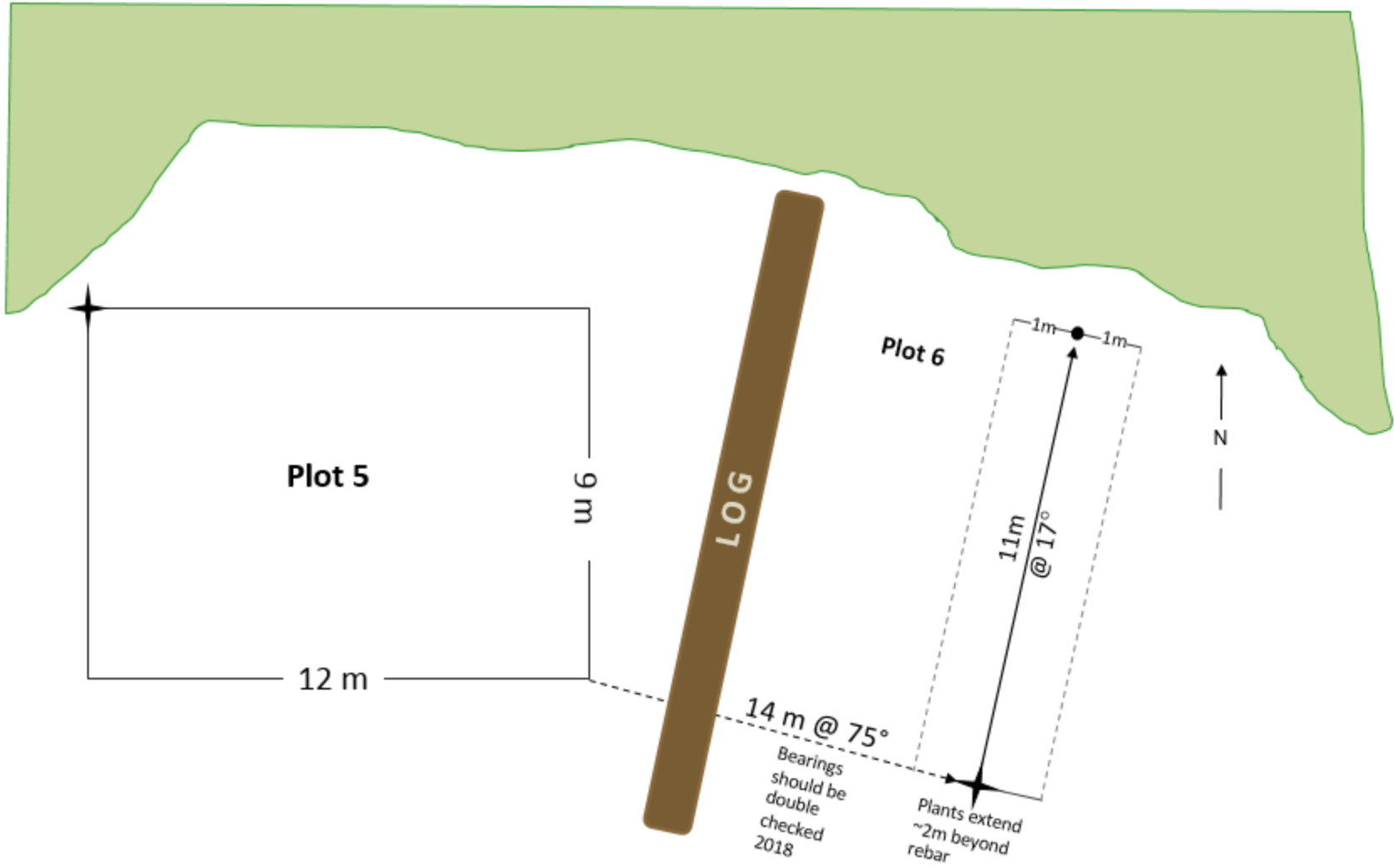
Meadow B



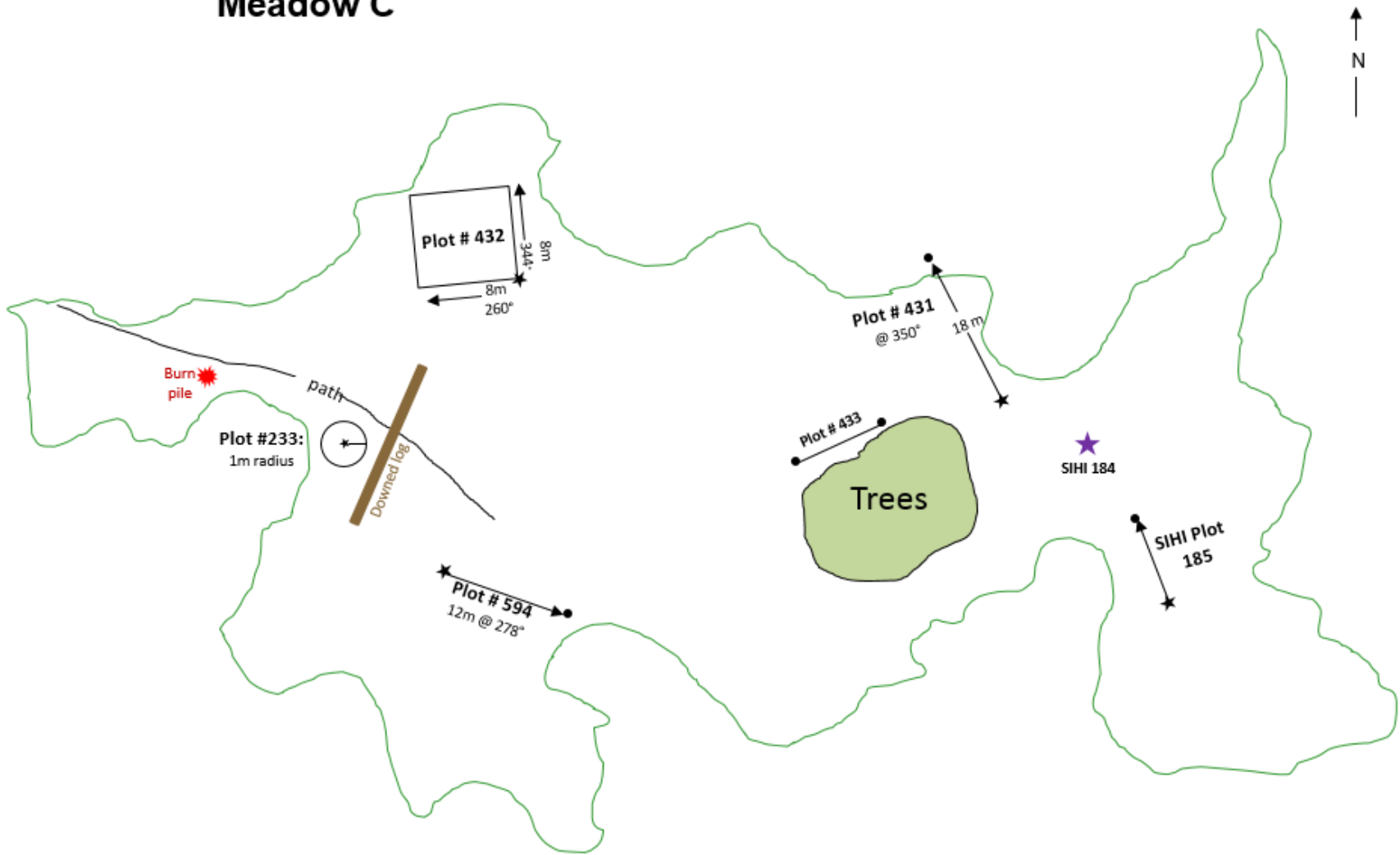
Meadow B



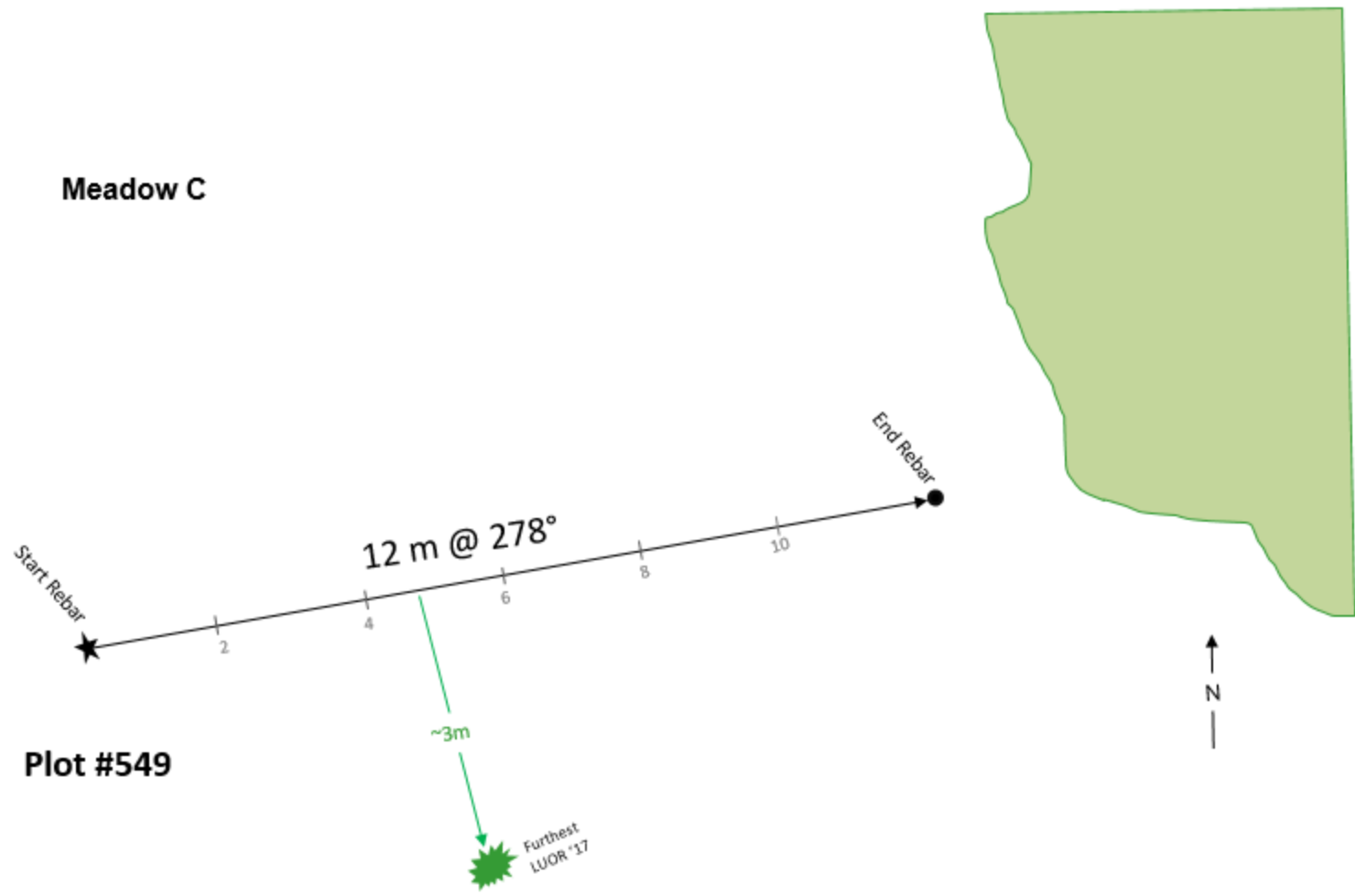
Meadow B



Meadow C







APPENDIX B. CONTACTS, DIRECTIONS, AND GEAR LIST FOR OAK BASIN

Private Landowner contact

(access is through his property, *but you do not need to contact*)

Jim Merzenich
Oak Basin Tree Farm
7410 Oleson Road, PMB #319
Portland, OR 97223
503.246.4202
cell: 503.799.6772
merzenich@comcast.net

Directions:

To Meadows A, B, and C

South on I-5, take exit 209

Head east on Diamond Hills Road towards the Coburg Hills and stay north at 2.8 miles when the road semi-forks and becomes Gap Road.

Continue North for a few miles, then turn east on Northernwood Rd. (5.8 miles from the freeway.)
Reset the mileage as you turn onto Northernwood.

At the end of Northernwood Rd, the road turns to gravel and forks. Take the left gated fork. (0.7 miles)

At 1.0 miles stay right (don't go to the barn/equipment area).

At 1.2 go right.

At 1.6 go right (road is more grassy and rough)

Park at 2.3 miles and walk up the road to the base of Meadow A.

See maps and photos for directions to meadows.

Alternative Directions:

Take Peoria to American Drive. In Brownsville turn right just past the Chevron gas station onto Gap Rd. From Gap Road, turn left onto Northernwood and follow directions above.

To Doghead Meadow

South on I-5 to Brownsville/Hwy 228 exit

Take HWY 228 east, just over 6 miles, to Courtney Creek Road.

(Start mileage once turn onto Courtney Creek Road)

Courtney Creek Road becomes Timber Road at ~2.5 miles

Continue past gravel pile (on left) to total of 7.3 miles

Park at (mostly) blocked road, 14-2.34 (signed). Walk in to end of road (approx. 1.5 - 2 miles).

Old ATV trail to right through trees to meadow (flagged and sign saying no motorized traffic).

Equipment needed:

Eugene BLM Key for Oak Basin Site/Data sheets

Last year's report

Last year's data

6 rulers

2 tatums and extra pencils

Meter tapes: 2 - 100m tapes, 4 medium tapes

Tecnu

First aid kit

10 candy canes

Pin flags

Compass

Flagging (white with orange polka-dots)

Rebar, conduit, or fiberglass x3 (for replacement, if necessary)

Plot tags and wires x3 (for replacement, if necessary)

Extra water

Health and Safety Box

Maps and Gazetteer

APPENDIX C. MEAN PERCENT COVER OF SPECIES ENCOUNTERED IN HABITAT ASSESSMENT IN 2015, CALCULATED BY HABITAT TYPE (LUPINE OR NON-LUPINE), AND BY MEADOW.

Species	All meadows		Meadow A		Meadow B		Meadow C	
	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat
Forbs								
<i>Achillea millefolium</i>	0.43	0.28	0.05	0.6	0.47	0.34	0.23	0.25
<i>Agoseris grandiflora</i>	0.04	0	0	0	0.08	0	0	0
<i>Aster hallii</i>	0.09	0.04	0.03	0.17	0.09	0.04	0.02	0
<i>Brodiaea</i> sp.	0.01	0.05	0.03	0.03	0	0.05	0	0.05
<i>Calochortus tolmiei</i>	0	0	0	0	0	0	0.02	0
<i>Centaurium erythraea</i>	0	0	0	0	0	0	0.02	0
<i>Cerastium fontanum</i> ssp. <i>vulgare</i>	0	0.01	0	0	0	0.01	0	0
<i>Cirsium arvense</i>	0.12	0.65	2.75	0	0.23	0	0	0
<i>Cirsium</i> sp.	0	0.03	0	0	0	0.04	0	0
<i>Clarkia amoena</i>	0	0.05	0	0.02	0	0.07	0	0
<i>Crepis setosa</i>	0	0.09	0.13	0.02	0	0.09	0	0
<i>Daucus carota</i>	0	0	0	0	0.01	0	0	0
<i>Daucus pusillus</i>	0	0	0	0	0.01	0	0	0
<i>Dianthus armeria</i>	0.05	0.06	0.03	0.02	0	0	0.18	0.5
<i>Dichelostemma congestum</i>	0	0.03	0	0	0.01	0.04	0	0
<i>Erigeron speciosus</i> var. <i>speciosus</i>	0.96	0	0	0	1.92	0	0	0
<i>Eriophyllum lanatum</i>	1.88	1.57	1.28	3	1.69	1.3	1.5	3
<i>Fragaria vesca</i>	0.27	0	0	0	0.54	0	0	0
<i>Fragaria virginiana</i>	2.5	0.06	0	0.5	4.69	0.08	0.17	0
<i>Galium aparine</i>	0	0.03	0.13	0.02	0	0	0	0
<i>Geranium dissectum</i>	1.72	1.97	1.38	0.42	2.55	2.42	1.33	0
<i>Geranium oreganum</i>	0	0	0	0	0.01	0	0	0
<i>Githopsis specularioides</i>	0	0.01	0	0	0	0.02	0	0
<i>Hypericum perforatum</i>	0.47	0.11	0.15	0.1	0.65	0.14	0.42	0
<i>Hypochaeris radicata</i>	0.65	0.18	0.25	2.5	0.15	0.08	0	0.5
<i>Iris tenax</i> var. <i>tenax</i>	2.5	0.06	0.25	1.85	3.92	0	0.5	0
<i>Lathyrus nevadensis</i> var. <i>nevadensis</i>	0.04	0	0	0	0	0	0.18	0

Appendix C. Continued

Species	All meadows		Meadow A		Meadow B		Meadow C	
	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat
<i>Lathyrus sphaericus</i>	0	0.03	0	0	0	0	0	0.25
<i>Leucanthemum vulgare</i>	13.19	5.07	7.5	6	18.77	5.76	8	1.05
<i>Linanthus bicolor</i>	0	0.01	0	0	0	0.01	0	0
<i>Linum bienne</i>	0.15	0.93	1.53	0.12	0.01	0.14	0.5	4
<i>Lupinus oregonus</i>	1.23	0	0	0.85	2.08	0	0	0
<i>Madia gracilis</i>	0.05	0.72	0.05	0.2	0	1	0.02	0
<i>Madia madioides</i>	0.02	0	0	0	0	0	0.08	0
<i>Madia</i> sp.	0	0.04	0	0	0	0.05	0.02	0.05
<i>Marah oregonus</i>	0.12	0	0	0	0.23	0	0	0
<i>Myosotis discolor</i>	0.01	0.01	0	0	0.02	0.02	0	0
<i>Plantago lanceolata</i>	0.54	0.89	0.25	1.35	0.46	0.76	0	2.5
<i>Potentilla gracilis</i>	0.15	0	0	0	0.31	0	0	0
<i>Prunella vulgaris</i> var. <i>lanceolata</i>	0.04	0	0	0	0.08	0	0	0
<i>Pteridium aquilinum</i>	5.65	0.47	10	9	2.69	0.67	3	0
<i>Rumex acetosella</i>	0.1	0.18	0.03	0.25	0.08	0.25	0	0
<i>Sanicula graveolens</i>	0	0.01	0	0	0	0	0	0.05
<i>Satureja douglasii</i>	0.15	0	0	0	0.31	0	0	0
<i>Sherardia arvensis</i>	0.18	0.28	0.13	0.13	0.1	0.39	0.35	0
<i>Sidalcea virgata</i>	3.19	0.59	2.53	2	0.85	0	10	0
<i>Sisyrinchium</i> sp.	0	0	0	0	0.01	0	0	0
<i>Synthyris reniformis</i>	0.12	0	0	0	0.24	0	0	0
<i>Torilis arvensis</i>	0.69	0.59	0.25	0.5	0.15	0.79	2.02	0.25
<i>Tragopogon dubius</i>	0	0.06	0.25	0	0	0	0	0
<i>Veronica americana</i>	0	0.01	0	0	0.01	0.01	0	0
<i>Vicia americana</i>	0.15	0	0	0	0.31	0	0	0
<i>Vicia gigantea</i>	0	0	0	0	0	0	0.02	0
<i>Vicia sativa</i>	0.22	0.21	0.25	0.05	0.3	0.3	0.1	0
<i>Viola praemorsa</i>	0.01	0.06	0	0	0.02	0.08	0	0
<i>Wyethia angustifolia</i>	0.46	0	0	0	0	0	2	0
Grasses								
<i>Agrostis capillaris</i>	0.12	0	0	0	0.24	0	0	0
<i>Aira caryophylla</i>	0.12	0.06	0.03	0.5	0.01	0.08	0.02	0
<i>Bromus carinatus</i>	4.92	3.12	1.25	7.5	2.15	1.58	9.17	14.5
<i>Bromus hordeaceus</i>	0.06	0.24	0.03	0.03	0.1	0.31	0.02	0.1
<i>Bromus rigidus</i>	0	0.65	0	0	0	0.93	0	0

Appendix C. Continued

Species	All meadows		Meadow A		Meadow B		Meadow C	
	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat
<i>Bromus</i> sp.	0.08	0.14	0	0	0.15	0.18	0	0.05
<i>Carex tumulicola</i>	2.39	0	0	0.68	4.46	0	0.02	0
<i>Cynosurus echinatus</i>	0.79	14.14	1	1	0.35	13.86	1.68	35
<i>Dactylis glomerata</i>	13.27	4.94	2.5	14.5	17.24	5.5	5.67	4
<i>Danthonia californica</i>	0.7	0.77	0.03	2.83	0.09	1.08	0	0
<i>Elymus glaucus</i>	1.04	0.06	0	2	1.08	0.08	0.17	0
<i>Elymus trachycaulus</i>	0.08	0.54	0	0.17	0.08	0.75	0	0.05
<i>Schedonorus arundinaceus</i>	73.12	47	78.75	55.33	69.92	42	93.33	40
<i>Festuca roemerii</i>	4.31	10.62	11.38	6.75	5.51	11.25	0	0
<i>Holcus lanatus</i>	1.62	2.71	10	0.17	3.15	0.5	0	0
<i>Juncus patens</i>	0.01	0.35	0	0.02	0.01	0.5	0	0
<i>Luzula</i> sp.	0.03	0.01	0	0.02	0.04	0.01	0.03	0
<i>Phleum pratense</i>	2.28	0.18	0	2.67	3.31	0.25	0.03	0
<i>Poa compressa</i>	0.27	2.97	10.03	0	0.54	0.86	0.02	0.05
<i>Poa pratensis</i>	0	3.94	0	0	0	5.58	0	0
<i>Taeniatherum caput-medusae</i>	0.05	7.77	0	0.2	0.01	10.84	0	1
<i>Vulpia bromoides</i>	0.38	4.01	1.5	1.67	0	4.01	0	7
Shrubs								
<i>Rosa</i> sp.	0.38	1.18	5	0	0.77	0	0	0
<i>Rubus ursinus</i>	1.38	2.06	8.75	0	2.77	0	0	0
Trees								
<i>Malus</i> sp.	0.15	0	0	0	0.31	0	0	0

APPENDIX D. AVERAGE PERCENT COVER OF SPECIES ENCOUNTERED IN HABITAT MANAGEMENT ASSESSMENT IN LUPINE HABITAT IN 2017. NON-LUPINE HABITAT WAS NOT MEASURED IN 2017.

Species	2017 Lupine Habitat			
	All Meadows	Meadow A	Meadow B	Meadow C
Ground Cover				
Bare ground	0.1	0.1	0.2	0.1
Litter	94.8	98.1	98.2	87.3
Moss	4.1	0.8	1.8	10.4
Rock	0.6	0.0	0.4	1.6
Basal vegetation	55.7	51.5	57.5	58.3
Graminoids				
<i>Agrostis capillaris</i>	0.1	0.0	0.2	0.0
<i>Aira caryophylla</i>	0.0	0.0	0.0	0.1
<i>Briza minor</i>	0.1	0.0	0.0	0.4
<i>Bromus carinatus</i>	0.7	0.4	0.3	1.6
<i>Bromus hordeaceus</i>	0.5	0.0	0.2	1.4
<i>Bromus rigidus</i>	0.1	0.0	0.2	0.0
<i>Carex tumulicola</i>	0.5	0.1	1.0	0.6
<i>Cynosurus echinatus</i>	3.2	0.1	0.7	9.6
<i>Dactylis glomerata</i>	13.2	17.9	12.3	9.1
<i>Danthonia californica</i>	1.3	0.2	1.4	2.3
<i>Elymus glaucus</i> Buckley	0.7	0.3	1.3	0.4
<i>Elymus trachycaulus</i>	0.0	0.0	0.1	0.0
<i>Festuca arundinacea</i>	59.3	65.5	67.0	43.9
<i>Festuca roemerii</i>	1.2	1.1	0.6	1.9
<i>Holcus lanatus</i>	0.3	0.3	0.7	0.0
<i>Luzula</i> sp.	0.3	0.1	0.6	0.1
<i>Lolium perenne</i>	0.0	0.0	0.0	0.0
<i>Melica subulata</i>	0.0	0.0	0.0	0.1
<i>Phleum pratense</i>	0.8	0.7	1.4	0.2
<i>Poa compressa</i>	0.2	0.1	0.2	0.3
<i>Taeniatherum caput-medusae</i>	0.0	0.0	0.0	0.1
<i>Vulpia bromoides</i>	0.0	0.0	0.0	0.0
Forbs				
<i>Achillea millefolium</i>	0.2	0.3	0.2	0.2
<i>Aster halii</i>	0.5	0.3	1.0	0.2
<i>Calochortus tolmiei</i>	0.0	0.0	0.0	0.0
<i>Centaurium erythraea</i>	0.0	0.0	0.0	0.1
<i>Clarkia amoena</i>	0.0	0.0	0.0	0.1
<i>Daucus carota</i>	0.0	0.0	0.1	0.0
<i>Dianthus armeria</i>	0.0	0.1	0.0	0.0
<i>Erigeron speciosus</i>	0.2	0.0	0.6	0.0
<i>Eriophyllum lanatum</i>	6.9	3.3	5.4	12.5
<i>Fragaria virginiana</i>	3.0	0.2	6.8	1.9
<i>Galium parisiense</i>	0.0	0.0	0.0	0.0
<i>Geranium dissectum</i>	0.5	0.5	0.7	0.3
<i>Hypericum perforatum</i>	0.1	0.1	0.2	0.0

2017 Lupine Habitat				
Species	All Meadows	Meadow A	Meadow B	Meadow C
<i>Hypochaeris radicata</i>	0.3	0.0	0.0	1.1
<i>Iris tenax</i>	1.6	1.8	2.9	0.0
<i>Lathyrus sphaericus</i>	0.0	0.0	0.0	0.0
<i>Leucanthemum vulgare</i>	14.8	15.2	23.1	5.1
<i>Ligusticum apifolium</i>	0.1	0.0	0.2	0.0
<i>Linum bienne</i>	0.0	0.1	0.0	0.1
<i>Lotus micranthus</i>	0.0	0.0	0.0	0.0
<i>Lupinus oregonus</i>	1.5	1.2	2.6	0.7
<i>Madia gracilis</i>	0.5	0.0	0.0	1.7
<i>Myosotis discolor</i>	0.0	0.0	0.0	0.0
<i>Plantago lanceolata</i>	0.6	0.4	0.5	0.9
<i>Potentilla gracilis</i>	0.1	0.0	0.1	0.3
<i>Prunella vulgari</i>	0.2	0.0	0.5	0.2
<i>Pteridium aquilinum</i>	0.7	0.8	0.8	0.3
<i>Ranunculus occidentalis</i>	0.1	0.0	0.0	0.2
<i>Rumex acetosella</i>	0.1	0.0	0.3	0.0
<i>Sanicula graveolens</i>	0.0	0.0	0.0	0.0
<i>Sherardia arvensis</i>	0.2	0.0	0.5	0.0
<i>Sidalcea virgata</i>	0.8	1.5	0.4	0.7
<i>Synthyris reniformis</i>	0.0	0.0	0.1	0.0
<i>Taraxacum officinale</i>	0.0	0.0	0.1	0.0
<i>Torilis arvensis</i>	0.1	0.1	0.2	0.0
<i>Trifolium dubium</i>	0.1	0.0	0.0	0.4
<i>Veronica americana</i>	0.0	0.0	0.0	0.0
<i>Vicia gigantea</i>	0.1	0.0	0.2	0.0
<i>Vicia hirsuta</i>	0.0	0.0	0.0	0.0
<i>Vicia sativa</i>	0.2	0.3	0.1	0.1
<i>Viola praemorsa</i>	0.0	0.0	0.1	0.0
<i>Wyethia angustifolia</i>	1.7	0.0	0.0	5.3
Shrubs				
<i>Rosa</i> sp.	0.8	2.3	0.0	0.0
<i>Rubus ursinus</i>	1.3	1.3	2.5	0.0
Trees				
<i>Acer</i> seedling	0.0	0.0	0.1	0.1
Functional Groups				
Native Graminoid	4.7	2.1	5.3	7.0
Invasive Graminoid	78.0	84.6	82.9	65.1
Native Forb	18.3	9.4	21.7	24.4
Invasive Forb	17.1	16.6	25.6	8.1
Native Shrub	1.3	1.3	2.5	0.0
Invasive Shrub	0.8	2.3	0.0	0.0
Native Tree	0.0	0.0	0.1	0.1
Invasive Perennial Graminoid	74.0	84.5	82.0	53.6
Invasive Annual Graminoid	4.0	0.1	0.9	11.6

APPENDIX E. MEAN PERCENT COVER OF SPECIES ENCOUNTERED IN HABITAT MANAGEMENT ASSESSMENT IN 2015 AND 2016 BY MEADOW AND TREATMENT.

Meadow Treatment Year	A				B		
	Flameweed	Untreated	Flameweed	Mowed	Untreated	Flameweed	Untreated
	2015	2015	2016	2016	2016	2016	2016
Bare ground	11.2	1.5	82	0	0	32.8	0.5
Litter	83	99	18	98	99	67	99.5
Moss	9.6	7	0	0	0	8.42	2
Rock	0.46	0.25	0.2	0	0	6.6	0.05
Basal vegetation	-	-	12.4	75	-	10.2	10
Graminoids							
<i>Aira caryophylla</i>	0	0.25	0	0	0	0	0.05
<i>Alopecurus pratense</i>	0	0	0	7.04	1.5	0	0
<i>Bromus carinatus</i>	1.2	0	0	0.3	0	0	0
<i>Bromus hordeaceus</i>	0.54	2	0.42	0	0	0.6	6
<i>Bromus rigidus</i>	0.1	0	0.1	0	0	0.1	0
<i>Bromus sp.</i>	0	0	1.82	0	0	0	0
<i>Carex tumulicola</i>	0	0	0	0	0.5	0	0
<i>Cynosurus echinatus</i>	1.42	15	1	0.22	0.05	1	6.5
<i>Dactylis glomerata</i>	0.2	0	0	27	20	4	0
<i>Danthonia californica</i>	0.6	0	0	0.2	0	0.2	0
<i>Elymus glaucus</i>	0	0	0	1	0	0	0
<i>Festuca arundinacea</i>	0.8	9	0	93	92.5	0	7
<i>Festuca roemeri</i>	2.2	0	0.6	0	0	0.4	0
<i>Juncus bufonius</i>	0	0	0	0	0	0.02	0
<i>Koeleria macrantha</i>	0	0	2	0	0	0.1	0
<i>Luzula sp.</i>	0	0	0	0.1	0.25	0	0
<i>Phleum pratense</i>	0	0	0	0	0	0.2	0
<i>Poa compressa</i>	0	0.25	0	0.6	0	0	0
<i>Poa scabrella</i>	0.2	0	0	0	0	0	0
<i>Poa secunda</i>	0	0	0.5	0	0	0.4	0
<i>Taeniatherum caput-medusae</i>	15.62	60	0.14	0	0	0.54	77.5
<i>Vulpia bromoides</i>	0.5	0	0	0	0	0	0
Forbs							
<i>Achillea millefolium</i>	0.7	0.25	0.12	0.72	0.05	0.22	0

Appendix E. Continued

Meadow Treatment Year	A				B		
	Flameweed	Untreated	Flameweed	Mowed	Untreated	Flameweed	Untreated
	2015	2015	2016	2016	2016	2016	2016
<i>Aster halii</i>	0.1	0	0	0	0	0	0
<i>Centaurium erythraea</i>	0	0	0	0	0	0.12	0
<i>Clarkia amoena</i>	0	1.05	0	0	0	0	0
<i>Crepis setosa</i>	0.04	0	0	0	0	2.6	0
<i>Dianthus armeria</i>	0	0	0	0	0	0.2	0
<i>Eriophyllum lanatum</i>	3.4	9.25	0.72	0.1	0	0.1	0
<i>Erodium cicutarium</i>	0	0	0.02	0	0	0.02	0
<i>Fragaria virginiana</i>	0	0	0	0.4	0	0	0
<i>Geranium dissectum</i>	0	0	0	2.4	6	0	3.5
<i>Geranium molle</i>	0	0	0	0	0	0.4	0
<i>Hypericum perforatum</i>	0.04	0.05	0	0.02	0	0	0
<i>Hypochaeris radicata</i>	5.8	0	9.6	0	0	0.82	0.5
<i>Iris tenax</i>	0	0	0	1.8	0	0	0
<i>Leucathemum vulgare</i>	4	4	1	7.4	9.5	1.3	1
<i>Linanthus bicolor</i>	0	0	0.2	0	0	0	0
<i>Linum bienne</i>	0.06	0.5	0	0.22	0.05	0	4
<i>Lupinus oreganus</i>	0	0	0	1	0	0	0
<i>Lythrum hyssopifolia</i>	0		0	0	0	0.12	0
<i>Madia gracilis</i>	0	0	0.1	0	0	0.2	0.5
<i>Madia sp.</i>	0.82	8.05	0	0	0	0	0
<i>Myosotis discolor</i>	0	0	0	0	0.05	0	0
<i>Oenanche sarmentosa</i>	0	0	0	0.8	0	0	0
<i>Peplis portula</i>	0	0	0	0	0	0.02	0
<i>Plantago lanceolata</i>	6.2	0	2.8	0.8	1.5	1.4	2
<i>Pteridium aquilinum</i>	0	0	0	3.2	10	0	0
<i>Ranunculus occidentalis</i>	0.1	0	0	0	0	0	0
<i>Rumex acetosella</i>	0	0	0	1.2	0	1.6	0
<i>Rupertia physodes</i>	0	0	0	8	0	0	0
<i>Sherardia arvensis</i>	0.02	0	0	0.2	0.05	0	0
<i>Sidalcea virgata</i>	0	0	0	0.2	0	0	0
<i>Sonchus asper</i>	0	0	0	0	0	0	0.25
<i>Taraxacum officinale</i>	0	0	0.2	0	0	0	0
<i>Torilis arvensis</i>	0	0	0	0.5	0.5	0	0.05
<i>Tragopogon dubius</i>	0.02	0	0	0	0	0	0
<i>Trifolium dubium</i>	0	0	0	0	0	0	0.05

Appendix E. Continued

Meadow Treatment Year	A				B		
	Flameweed	Untreated	Flameweed	Mowed	Untreated	Flameweed	Untreated
	2015	2015	2016	2016	2016	2016	2016
<i>Vicia sativa</i>	0	0	0	0.4	0	0	0
<i>Viola praemorsa</i>	0	0	0	0.4	0	0	0
<i>Wyethia angustifolia</i>	0.02	0	0	0	0	0	0
Shrubs							
<i>Rosa sp.</i>	0	0	0	0.4	0	0	0
<i>Rubus ursinus</i>	0	0	0	7.2	0	0	0
Functional Groups							
Native Graminoid	4.2	0	4.92	1.6	0.75	1.12	0
Invasive Graminoid	19.18	86.5	1.66	127.86	114.05	6.44	97.05
Native Forb	4.34	10.55	1.14	17.22	10.6	0.52	0.6
Invasive Forb	16.14	4.55	13.62	12.64	17.15	6	11.3
Native Shrub	0	0	0	7.2	0	0	0
Invasive Shrub	0	0	0	0.4	0	0	0
Invasive Perennial Graminoid	1.1	9.25	0.1	127.64	114	4.3	7
Invasive Annual Graminoid	18.08	77.25	1.56	0.22	0.05	2.14	90.05