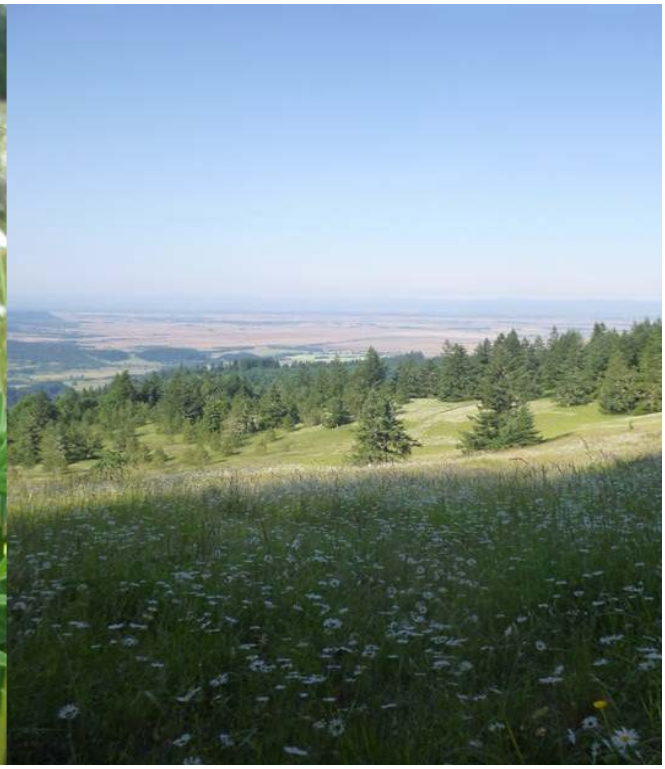
Population and habitat monitoring for Kincaid's lupine and Hitchcock's blue-eyed grass at Oak Basin



2016

Report to the Bureau of Land Management Eugene District

Report prepared by Denise Giles, Andrew Esterson, and Matt A. Bahm

Institute for Applied Ecology

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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 oreganus*) and Oak Basin from Meadow A.

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EXECUTIVE SUMMARY

This report documents research 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 2016, the eleventh year of monitoring occurred at Oak Basin, which is managed by the Eugene District Bureau of Land Management.

- Kincaid's lupine: In 2016, Kincaid's lupine cover decreased from 2015 totals and reached the second lowest recorded value (76m^2) since monitoring began. The total number of mature racemes increased by 15% while the number of aborted racemes decreased by 30% from 2015 values, which were low at all sites monitored by IAE in 2015. 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.

- Habitat quality: In 2016, the Oak Basin habitat once again had high proportions of exotic species cover, and habitat monitoring was focused on assessing cover in treated vs. untreated areas. In 2015, exotic grasses including *Dactylis glomerata*, *Schedonorus arundinaceus*, and *Cynosurus echinatus*, were the most prevalent species in lupine and non-lupine habitat, while the exotic forb, *Leucanthemum vulgare*, encompassed over 20% cover in both habitats. Species richness decreased from 2011-2015 with 105 species observed in 2011 and just 82 in 2015. Meadows A and C have seen the largest decreases in species richness from 85 to 46 species and Meadow A and 66 to 44 species in Meadow C in that same time period.

- Management treatments: Management treatments conducted in 2013-2016 included mowing to control exotic perennial grasses and shrubs, flame weeding, limbing of larger trees, and removal of smaller trees to increase meadow connectivity and reduce encroachment. Flame weeding was utilized to control both annual and perennial exotic species, followed by plug planting and direct seeding in treated areas. Hand removal of weedy species including grubbing of blackberries also occurred. 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, did not have a clear effect on cover of native or exotic grasses or forbs.

- *Sisyrinchium hitchcockii:* Long-term monitoring plots for *S. hitchcockii* were added to Meadow C in 2012, and monitoring has been conducted from 2012-2016. Since 2012, the population has declined from a total of 122 to just 42 in 2016. The number of reproductive stems has also decreased from 128 in 2012 to just 19 in 2016. The decline in reproductive effort of both *L. oreganus* and *S. hitchcockii* 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 oreganus*; 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).

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

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

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.

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 m^2 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.

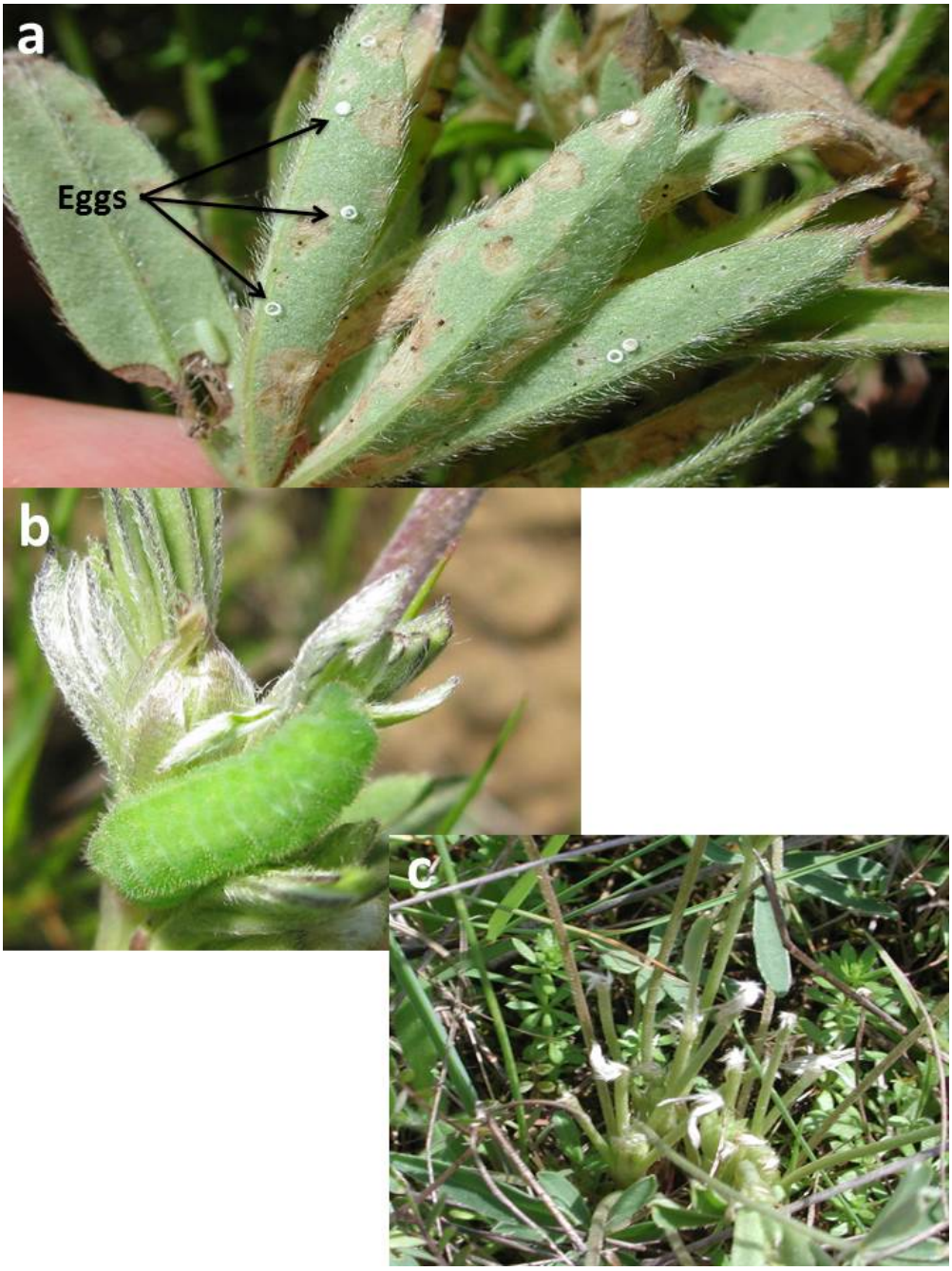


FIGURE 3. FENDER'S BLUE BUTTERFLY ON KINCAID'S LUPINE. (A) FEMALE FENDER'S BLUE BUTTERFLIES OVIPOSIT SMALL WHITE EGGS ON THE UNDERSIDES OF LUPINE LEAVES. HERBIVORY OF KINCAID'S LUPINE BY LARVAE (B) OF FENDER'S BLUE BUTTERFLY RESULTS IN CLUSTERS OF DAMAGED STEMS, LEAVES, AND GROWING POINTS (C) BECAUSE 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 (Table 1, Appendix A, Appendix B). Larger plots were rectangular and marked with fiberglass posts, rebar, or conduit in all four corners. Smaller lupine patches were 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 oreganus* 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 1m	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, in1-2m increments.
B	558	2m radius	504413 E[1] 4906842 N[1]	new in 2014
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 *Rupertia physodes*

[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 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 $1m^2$ 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 15-30 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 15-30 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: 2015 Annual Report to the Bureau of Land Management" (Silvernail 2016). Data are reported in Appendix D.

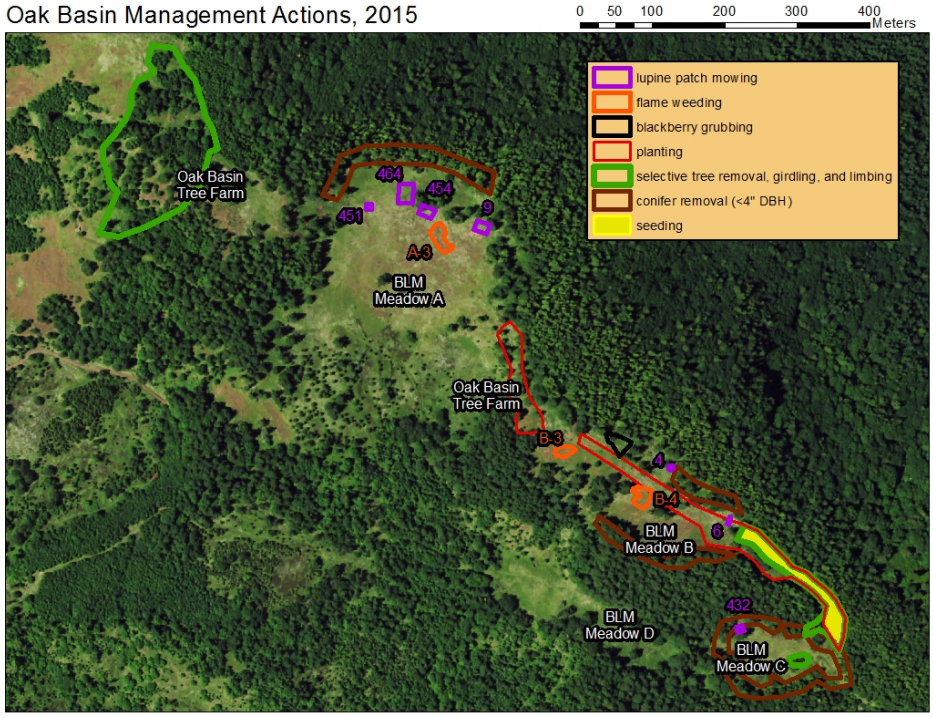


FIGURE 4. MANAGEMENT ACTIONS COMPLETED AT OAK BASIN IN 2015. NUMBERS INDICATE LUPINE AND FLAME WEEDING PATCH IDENTITY (FROM SILVERNAIL 2016).

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 5). 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. oreganus* 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 with narrower petals than *S. bellum*, while *S. bellum* is morphologically different than *S. hitchcockii* by having two-toned tepals (Groberg et al. 2013). Herbarium samples were collected and brought to the Oregon State University Herbarium.

FIGURE 5. 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 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- 2016, 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. From 2006 to 2012, this value steadily increased to a high of 165m^2. Cover took a drop to a low of just 74.2 m^2 in 2013, and after rebounding in 2014 to 149m^2, has again decreased over the last two years. Cover values in 2016 (76.5 m^2) are the second lowest ever recorded since the initiation of this study in 2006 (Table 2, Table 3, Figure 6). In 2016, Kincaid's lupine cover decreased in all meadows from 2015 cover values. Kincaid's lupine cover in the largest Meadow A (47m^2) remained the highest, whereas cover at meadows B and C was relatively low (14-15m^2).

The total number of racemes has followed a similar (but more pronounced) pattern as the lupine foliar cover at Oak Basin; the number of racemes generally increased from 2006 to 2012 (range 864-4,168 racemes), experiencing a dramatic decline in 2013 (195 racemes), and slightly rebounding in 2014 (2,046 racemes), and then continuing a downward decline into 2015 and 2016 (460 and 528 racemes respectively) (Figure 7, Table 2, Table 3).

Even more so than the decline in foliar cover, the decline in reproductive effort since 2012 is cause for alarm. 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, if total cover continues to decrease, combined with low raceme production a re-evaluation of management actions may be warranted.

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 aborted racemes; years that produced a large quantity of mature racemes tend to be associated with low numbers of aborted racemes, and vice-versa, as was particularly the case in 2013, 2015 (and less so 2016) where the percent of aborted racemes was 59% and 29% (and 20%) respectively (Table 3).

The decrease in cover and reproductive effort of Kincaid's lupine could be caused by a number of potential factors, including invasive grasses and/or pollinator limitation. Direct competition from invasive grasses could be leading 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 true for other pollinators.

TABLE 2. KINCAID'S LUPINE COVER, TOTAL MATURE RACEMES, MEAN MATURE RACEMES PER M², AND PERCENT ABORTED RACEMES AT OAK BASIN FROM 2005-2016.

Meadow	Year	Lupine Cover (m^2)	Total Mature Racemes [Mean Mature Racemes (m^2)]	% 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	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
	2016	15.19	102 (6.7)	4
C	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

TABLE 3. TOTAL LUPINE COVER IN ALL MEADOWS FROM 2006-2016.

Year	Lupine Cover (m^2)	Total Mature Racemes [Mean Mature Racemes (m^2)]	% 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	76.52	528 (6.9)	20

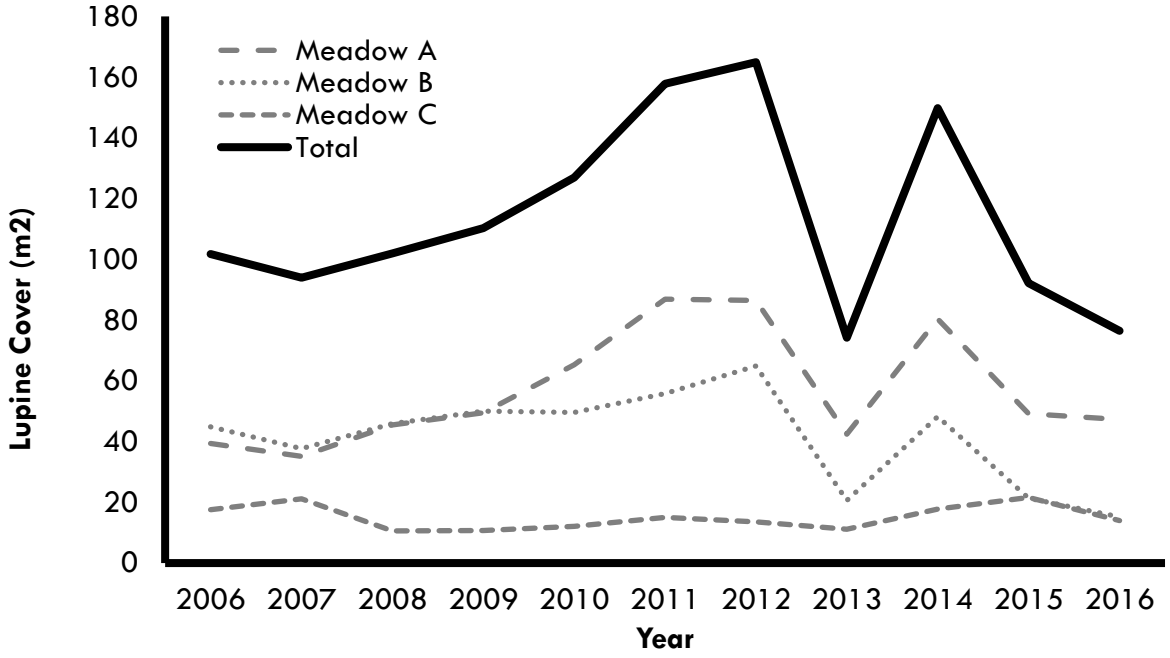


FIGURE 6. LUPINE COVER (M^2) IN EACH MEADOW AND TOTAL COVER FOR ALL MEADOWS AT OAK BASIN FROM 2006-2016.

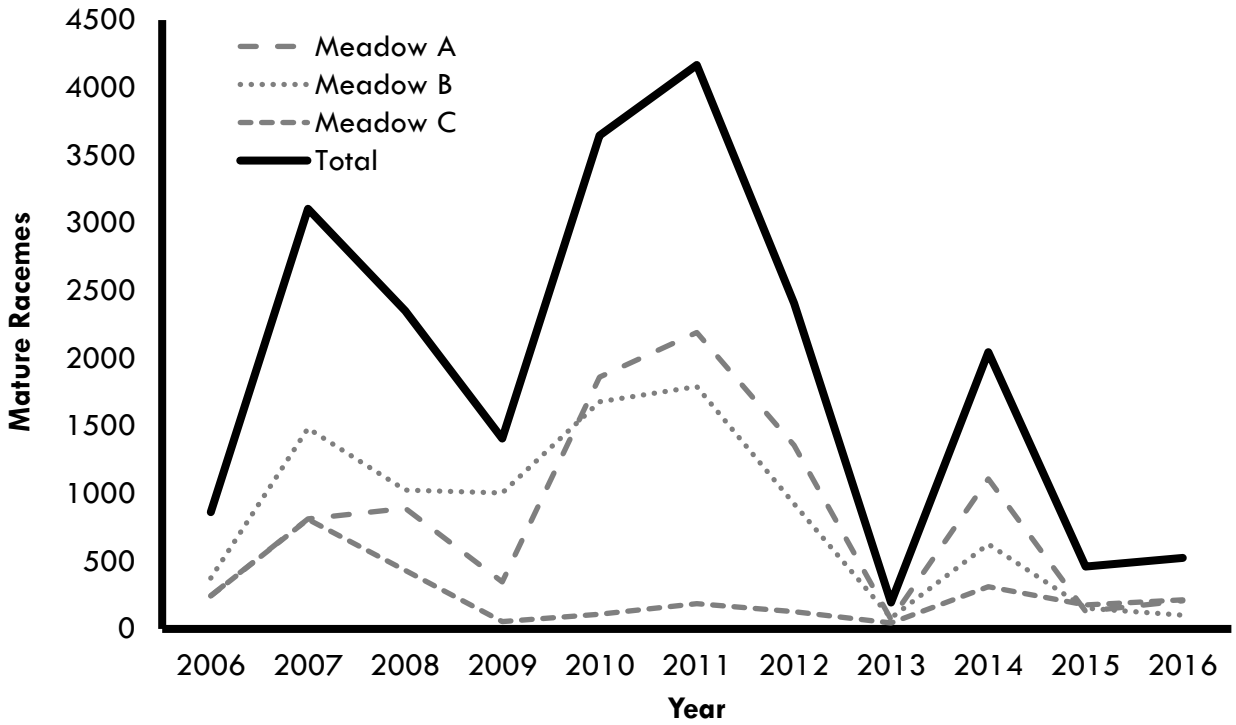


FIGURE 7. TOTAL MATURE RACEMES COUNTED IN EACH MEADOW AT OAK BASIN FROM 2006-2016.

Habitat assessment

Pre-treatment

From 2011-2015 cover of invasive graminoid species has shown an increasing trend in all meadows in both lupine and non-lupine habitat (Figure 8, Figure 9, Appendix C). 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. Additionally, the cover of native forb species has 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 9).

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 roemeri* 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 has declined from 2011-2015 (from a high of 105 in 2011 to 82 in 2015). Species richness in Meadow A, has decreased from 85 species in 2011 to only 46 in 2015, and Meadow C has followed a similar downward trend with a high of 66 in 2011 to only 44 species in 2015 (Figure 10, Table 4). The observed range of species richness from 2011-2015 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, Figure 10). In 2015, Meadow B contained the highest species richness with 70 total species (40 non-native)(Table 4).

Competition from invasive species 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. Even though there was a slight increase in species richness at Oak Basin in 2015 from 2014 (from 80 to 82), this may be short-lived as there was a concurrent increase in exotic species cover. Increasing species richness may not have as much of a positive impact if some of those species are invasive (Hejda et al. 2009). 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; Melgoza et al. 1990). Oak Basin has exhibited a decline in total species richness since the study began. The decline in species richness, in combination with the decline in Kincaid's lupine experienced in 2015 and continuing into 2016 and the increase in exotic graminoid cover across all meadows, is cause for serious concern at Oak Basin.

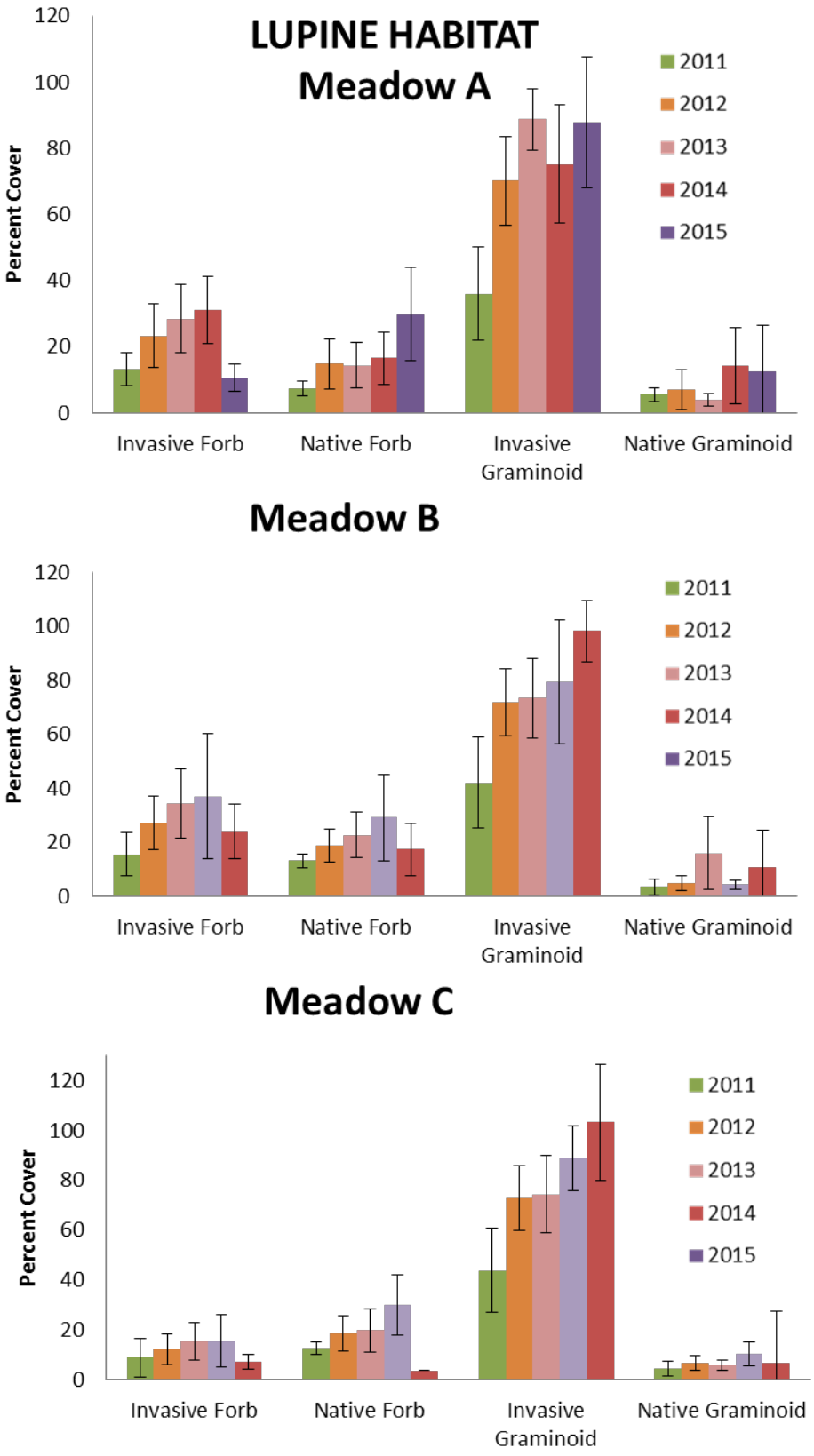


FIGURE 8. AVERAGE PERCENT COVER OF INVASIVE AND NATIVE FORB AND GRAMINOID SPECIES FROM 2011-2015 IN MEADOWS A, B AND C. ERROR BARS REPRESENT 95% CI.

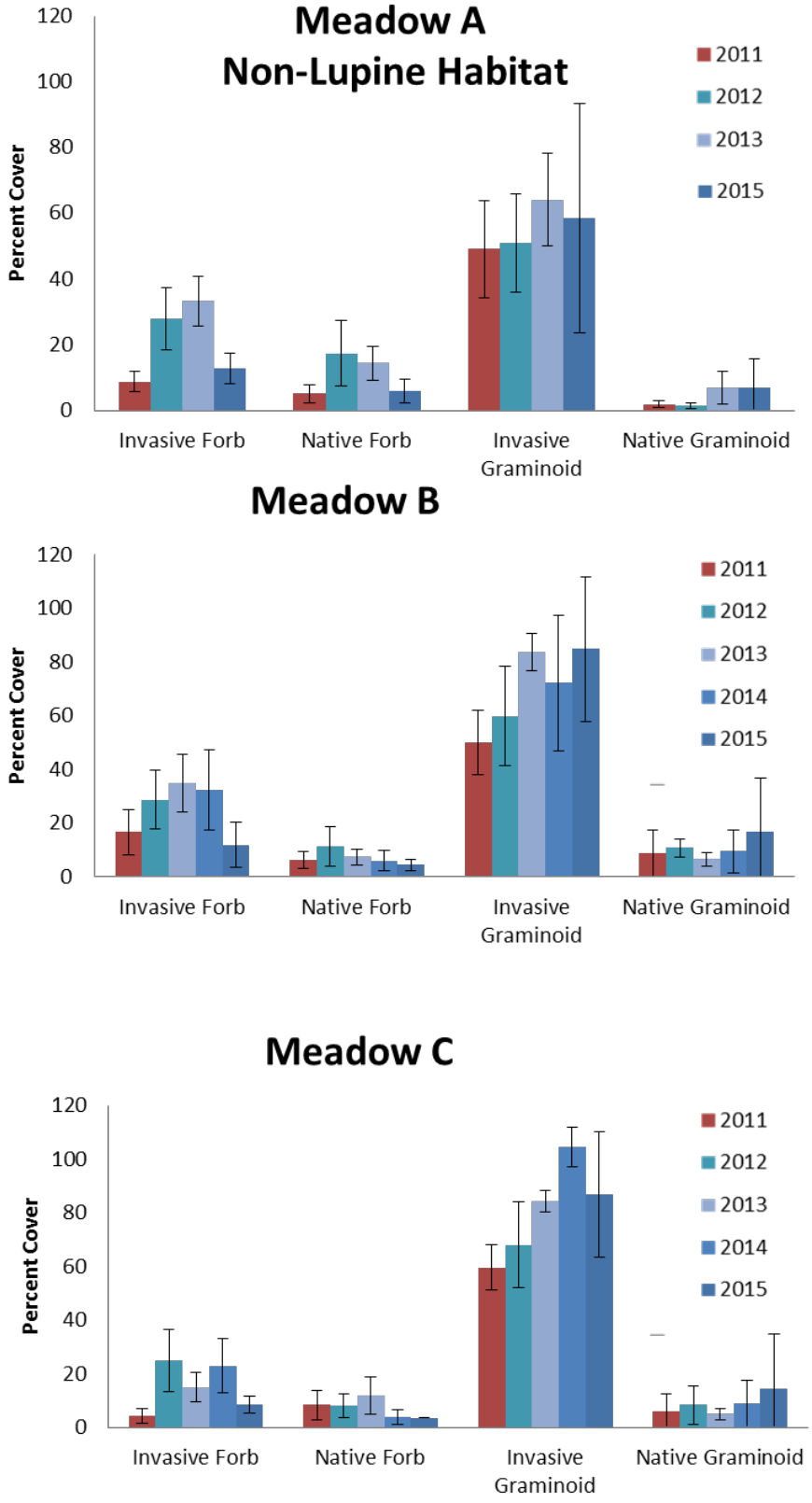


FIGURE 9. AVERAGE PERCENT COVER OF INVASIVE AND NATIVE FORB AND GRAMINOID SPECIES FROM 2011-2015 AT OAK BASIN, MEADOWS A, B, AND C. NO NON-LUPINE PLOTS WERE MEASURED IN MEADOW A IN 2014. ERROR BARS REPRESENT 95% CI.

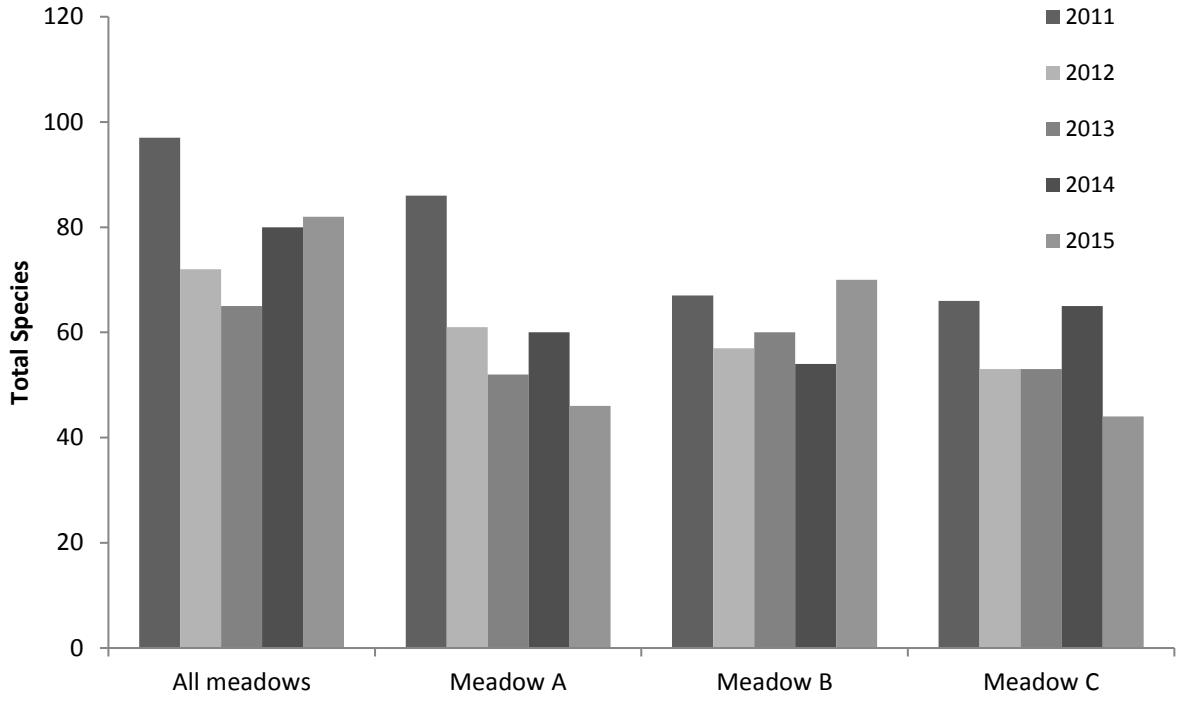


FIGURE 10. SPECIES RICHNESS ACROSS ALL MEADOWS AND INDIVIDUAL MEADOWS A, B, AND C FROM 2011-2015.

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)

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 4, 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. 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 D).

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 D, 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 into 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.

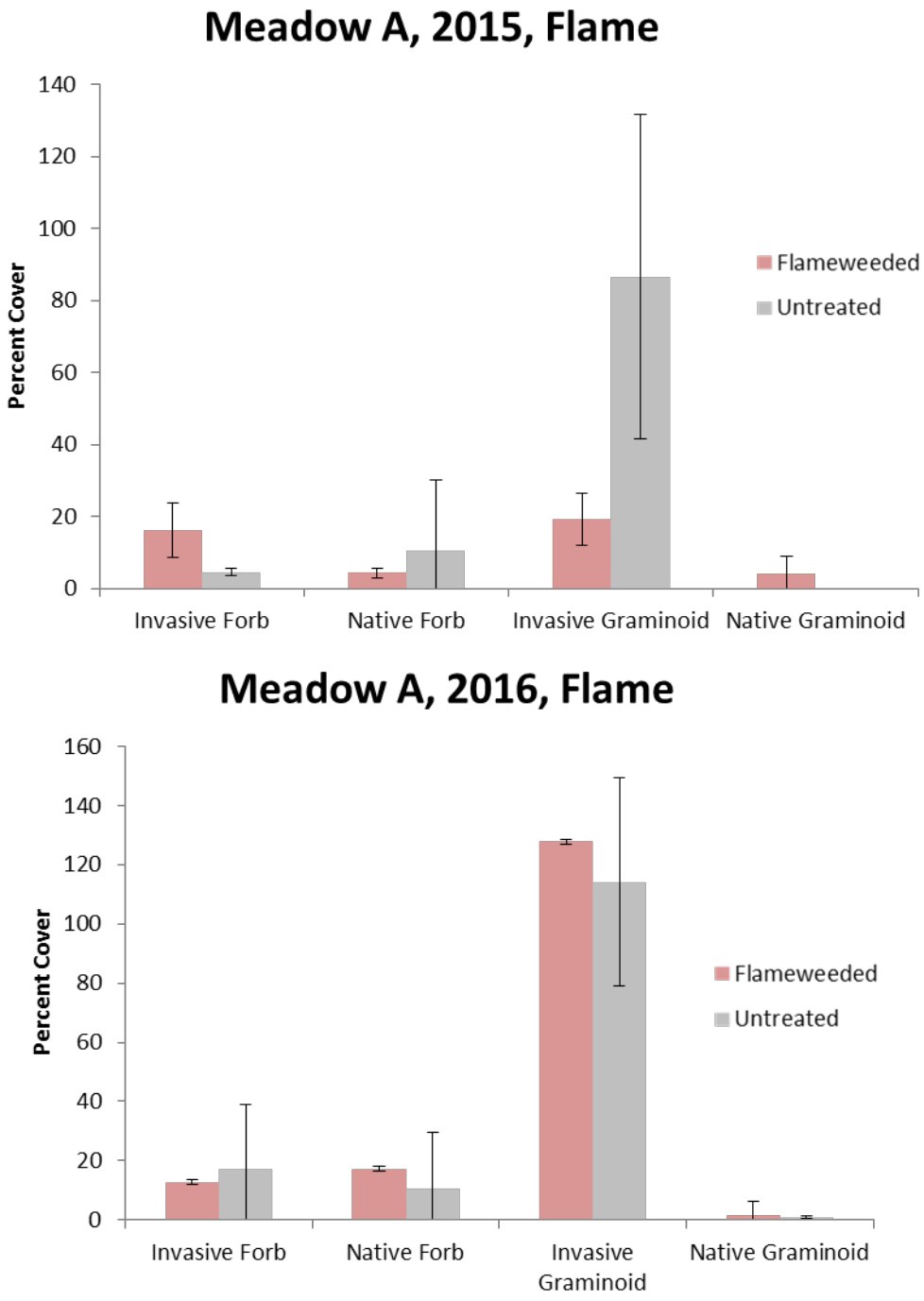
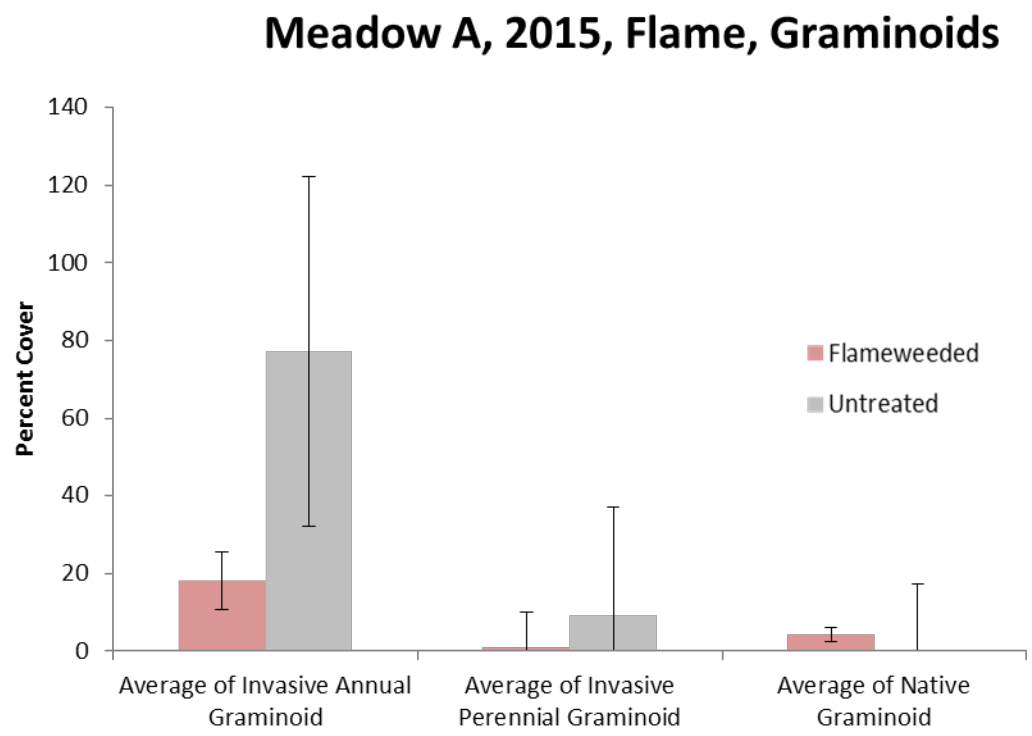


FIGURE 12. PERCENT COVER BY FUNCTIONAL GROUP FOR FLAMEWEEDED AND UNTREATED AREAS IN MEADOW A FOR BOTH 2015 AND 2016. ERROR BARS REPRESENT 95% CI.



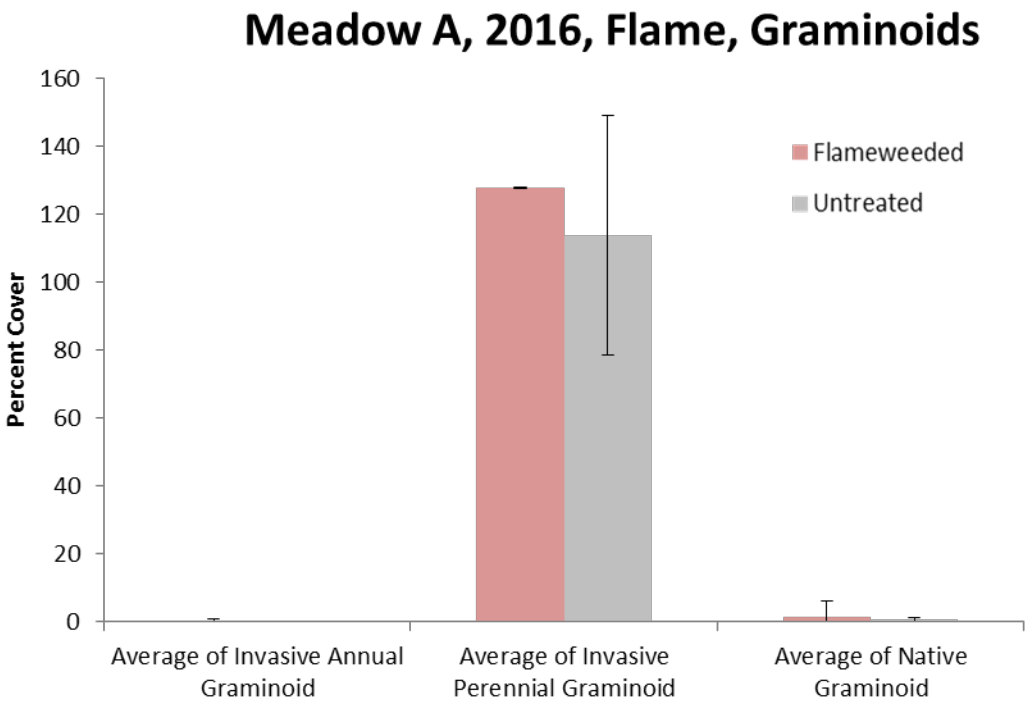


FIGURE 13. PERCENT COVER OF GRAMINOIDS BY NATIVITIY FOR FLAMEWEEDED AND UNTREATED AREAS IN MEADOW A FOR BOTH 2015 AND 2016. ERROR BARS REPRESENT 95% CI.

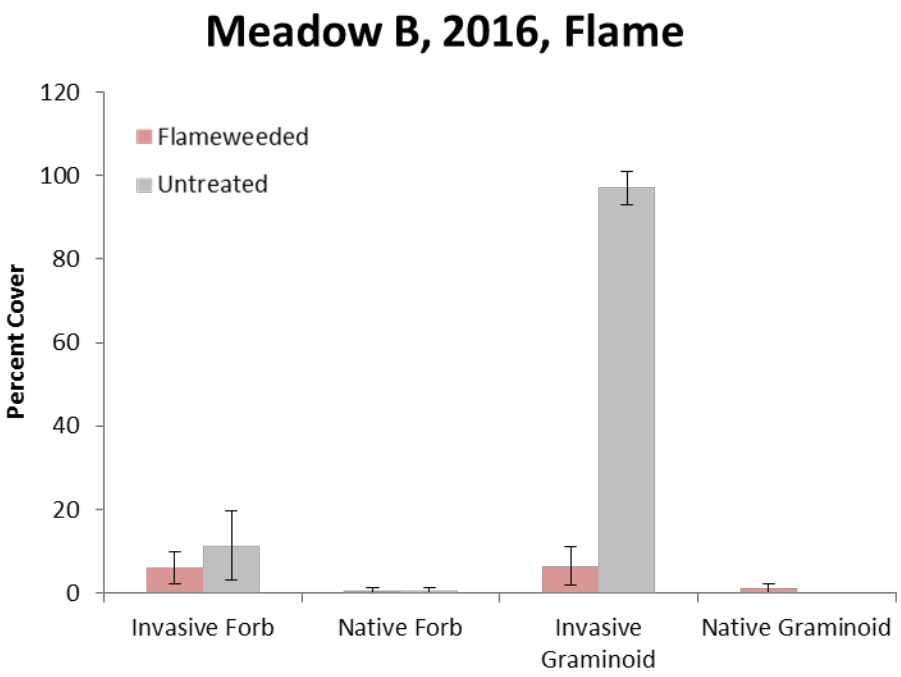


FIGURE 14. AVERAGE PERCENT COVER BY FUNCTIONAL GROUP OF FLAMEWEEDED AND UNTREATED AREAS IN MEADOW B IN 2016. ERROR BARS REPRESENT 95% CI.

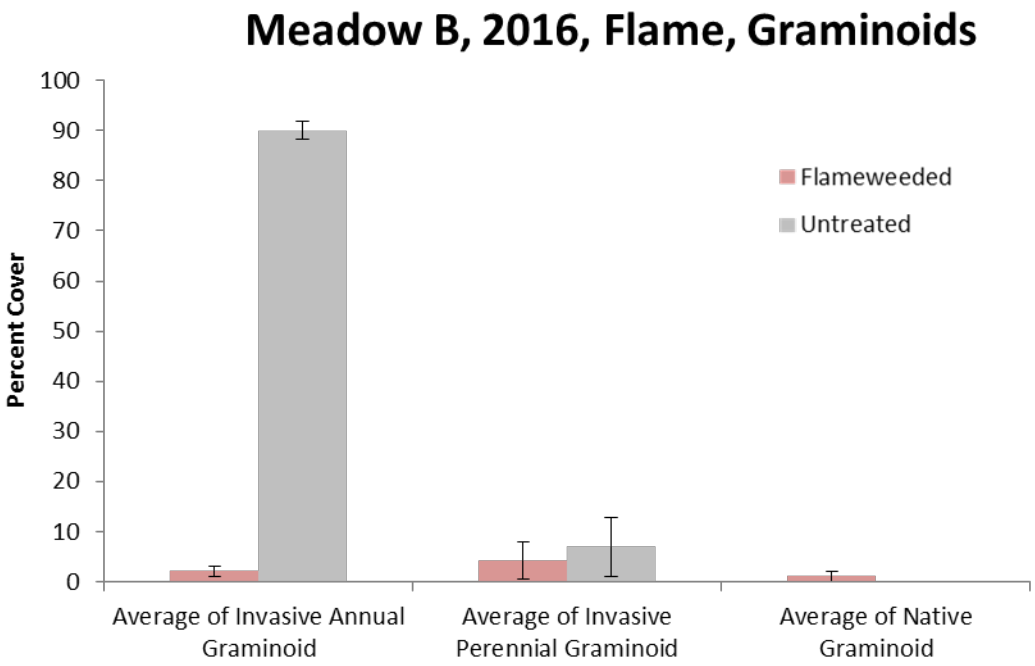


FIGURE 15. PERCENT COVER OF ANNUAL AND PERENNIAL GRAMINOID SPECIES IN FLAMEWEEDED AND UNTREATED AREAS OF MEADOW B IN 2016. ERROR BARS REPRESENT 95% CI.

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. 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 negatively impact the native plant community as well.

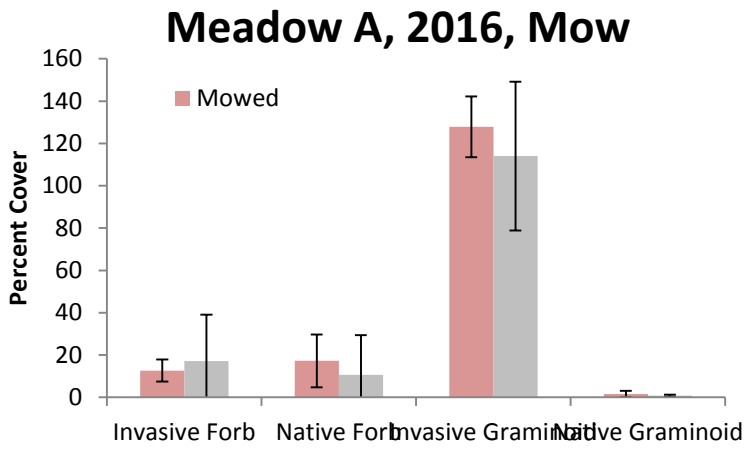


FIGURE 16. NATIVE AND EXOTIC PLANT COVER BY FUNCTIONAL GROUPS IN MOWED AND UNTREATED ("UNMOWED") AREAS AT OAK BASIN IN 2016 IN MEADOW A. ERROR BARS REPRESENT 95% CI.

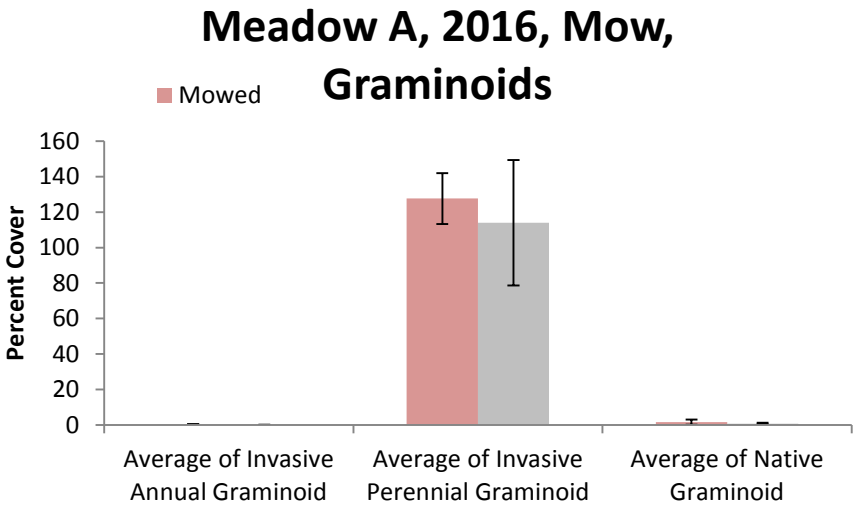


FIGURE 17. PERCENT COVER OF ANNUAL AND PERENNIAL GRASSES AT OAK BASIN MEADOW A IN MOWED AND UNTREATED ("UNMOWED") AREAS. ERROR BARS REPRESENT 95% CI.

Sisyrinchium hitchcockii monitoring

Since initiation of monitoring in 2012, the population of *S. hitchcockii* has been in steady decline (Figure 19, Table 5). In 2012 a total of 122 plants were observed, with a total of 128 reproductive stems. In 2016, these numbers had dwindled to 42 plants and only 19 reproductive stems. Between 2015 and 2016, the total number of reproductive individuals decreased from 20 to 12, the total number of reproductive stems decreased from 31 to 19, and the number of vegetative individuals decreased by from 44 to 30.

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 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 been decreasing over the course of the study (Figure 15, Table 5).

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

We have been monitoring *S. hitchcockii* for five 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.

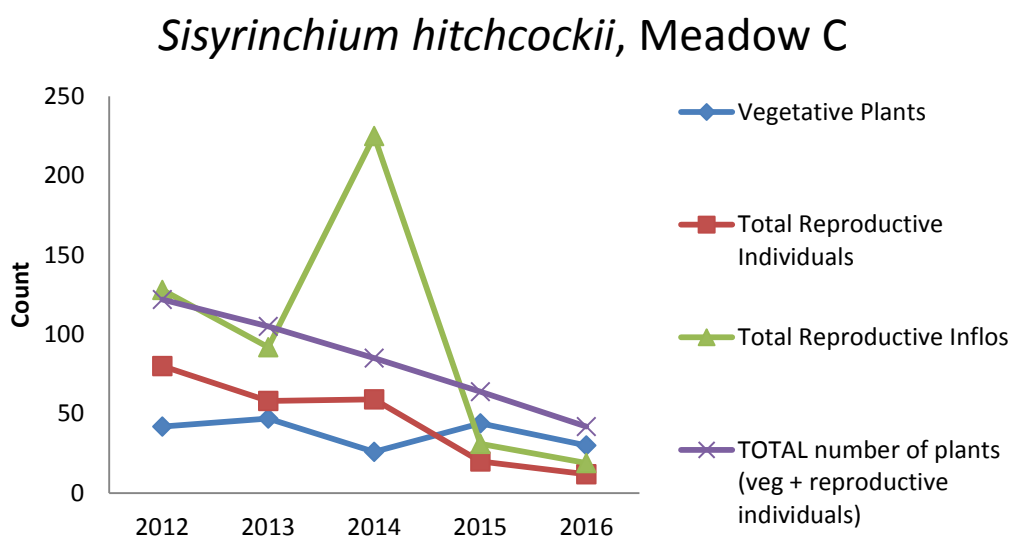


FIGURE 19. POPULATION TRENDS FOR *S. HITCHCOCKII* IN MEADOW C.

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

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

Synthesis

The decline of Kincaid's lupine foliar cover and reproductive effort at Oak Basin since 2011 is cause for serious concern. During this same time period, we also documented a decline in reproductive effort for *S. hitchcockii*. This decline was followed by a substantial increase of both species in 2014, however, in 2015 and 2016, both Kincaid's lupine and *S. hitchcockii* declined once again. The major 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 in 2013 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 of 2012/2013, 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, and would have been affected by these higher than average temperatures combined with lower than average precipitation.

The observed 'rebound' of *L. oreganus* and *S. hitchcockii* in 2014, could be related to higher precipitation in Feb-Mar and average temperatures for that same period. The subsequent decreases observed in 2015 and 2016 may be related to higher than average temperatures experienced by these plants in the prior summer. Long-term stresses on the plants (as related to extremes in temperatures and moisture conditions, may also be contributing to observed declines) (Figure 6, Figure 7, Figure 20).

The plant community from 2011-2016 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 2011-2016 (Figure 8, Figure 9, Appendix C, Appendix D). 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.

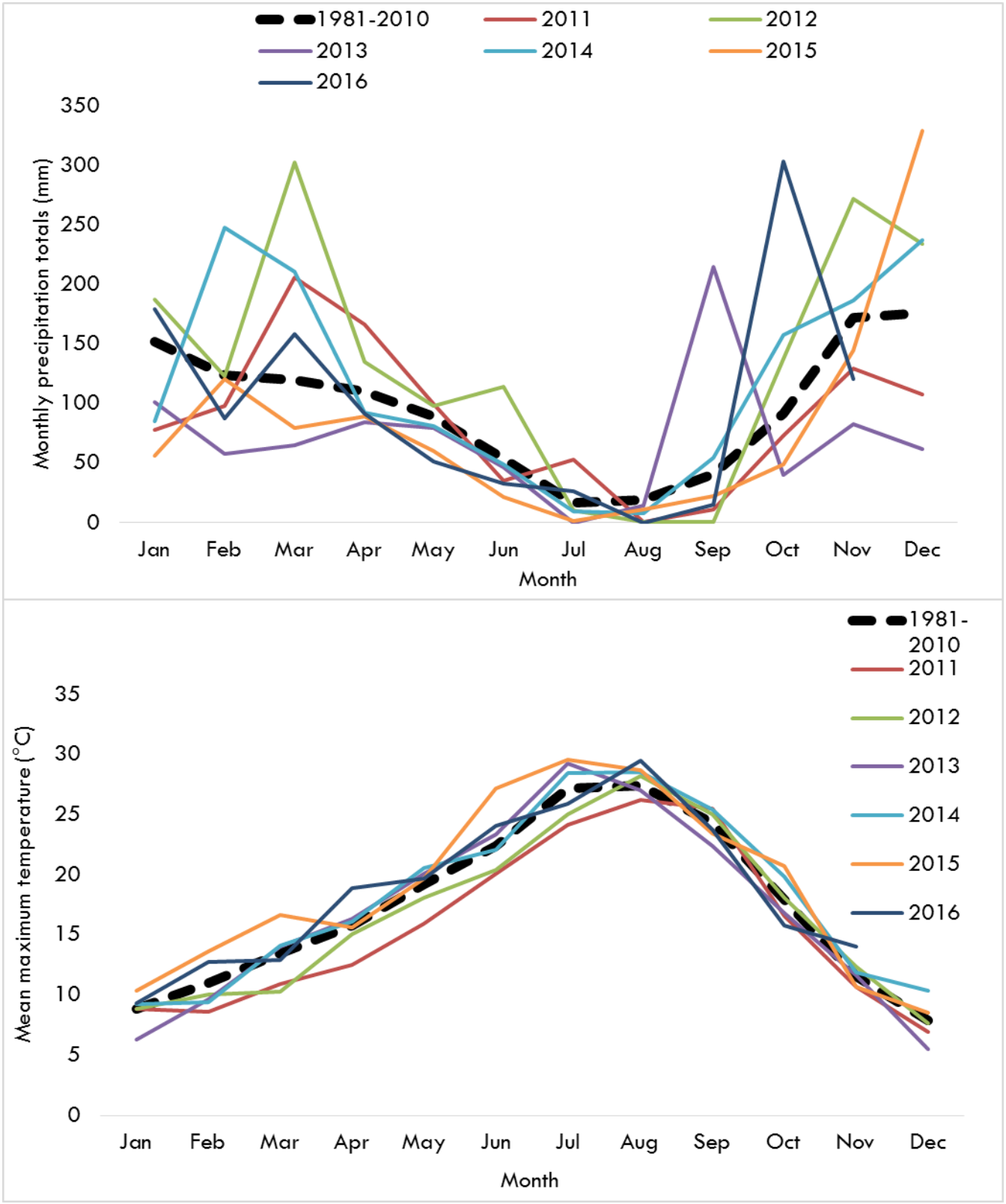


FIGURE 20. MONTHLY PRECIPITATION (TOP) AND MEAN MAXIMUM TEMPERATURE (BOTTOM) AT OAK BASIN FROM 2011-2016. MEAN VALUES FROM 1981-2010 ARE REPORTED AS THE BLACK DOTTED LINE. ALL DATA FROM PRISM CLIMATE GROUP, OREGON STATE UNIVERSITY.

RECOMMENDATIONS

Based on results from 2016, we recommend the following actions at Oak Basin in 2017:

1. Continued population monitoring will be essential to document population trends for both species, especially with 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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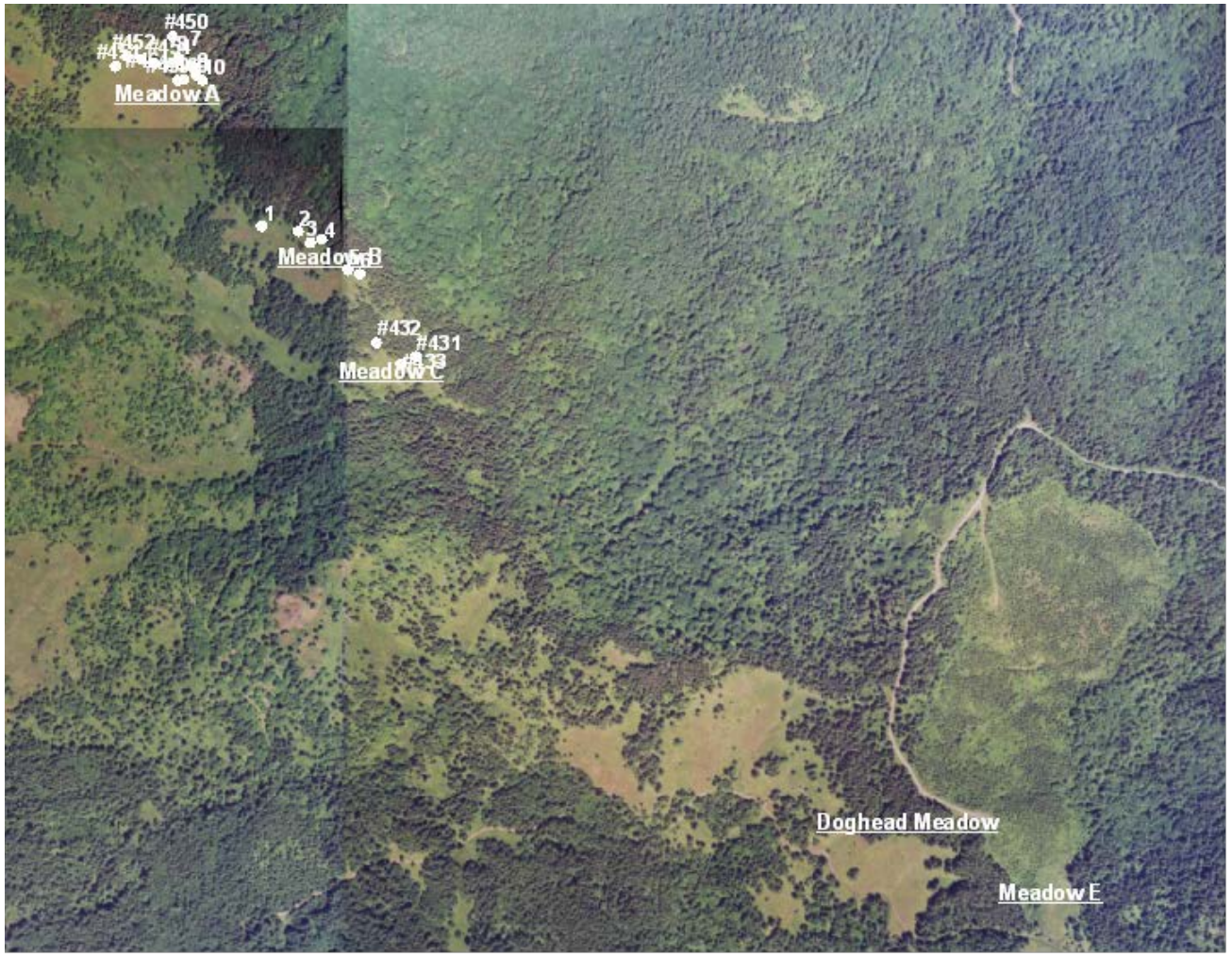
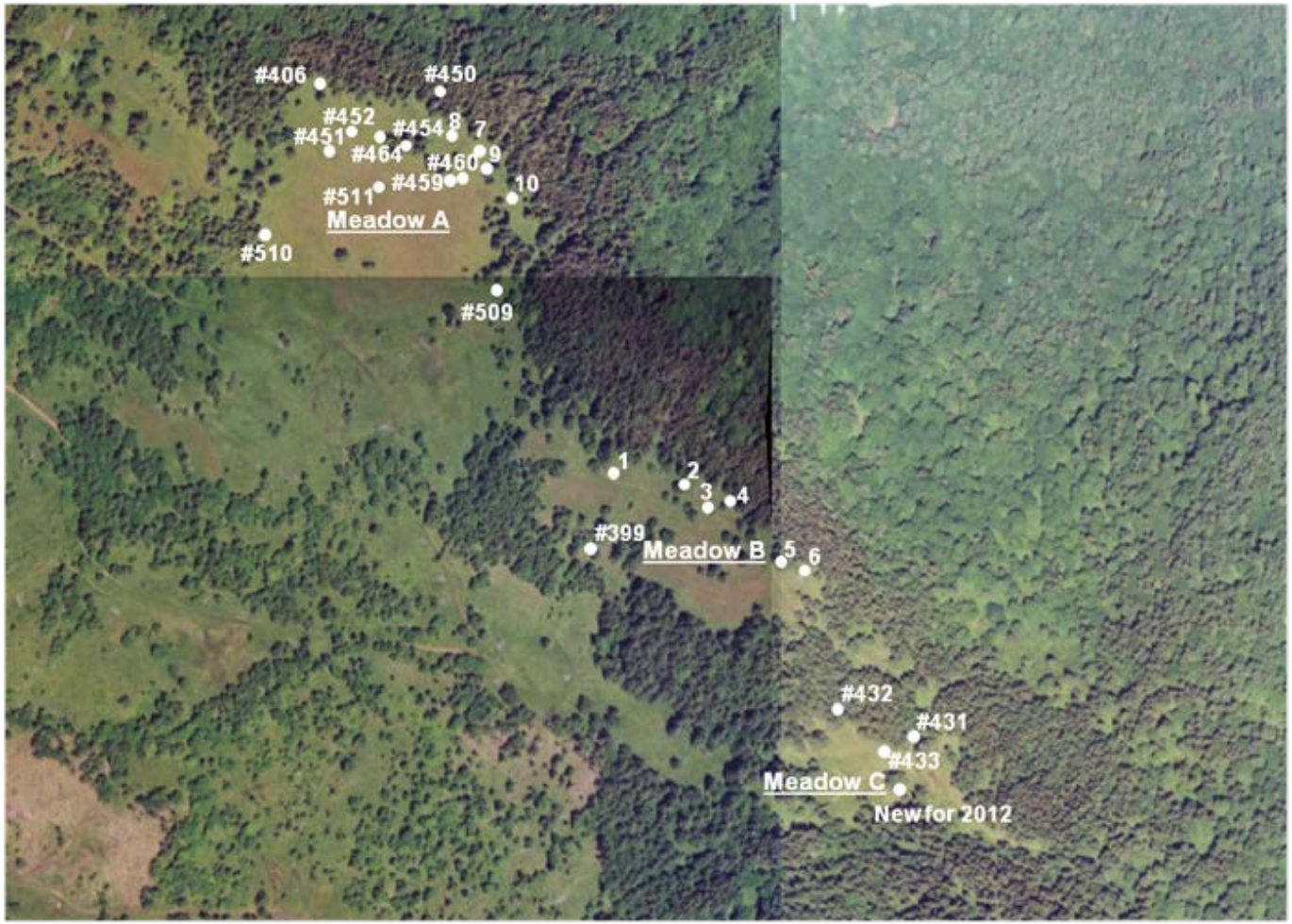
APPENDIX A. AERIAL PHOTOS AND PLOT DIAGRAMS OF OAK BASIN.



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

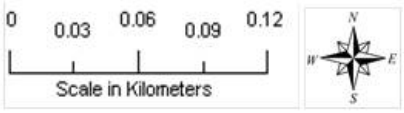
~1.5m radius around rebar

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

~8m x 1m strip going N to S

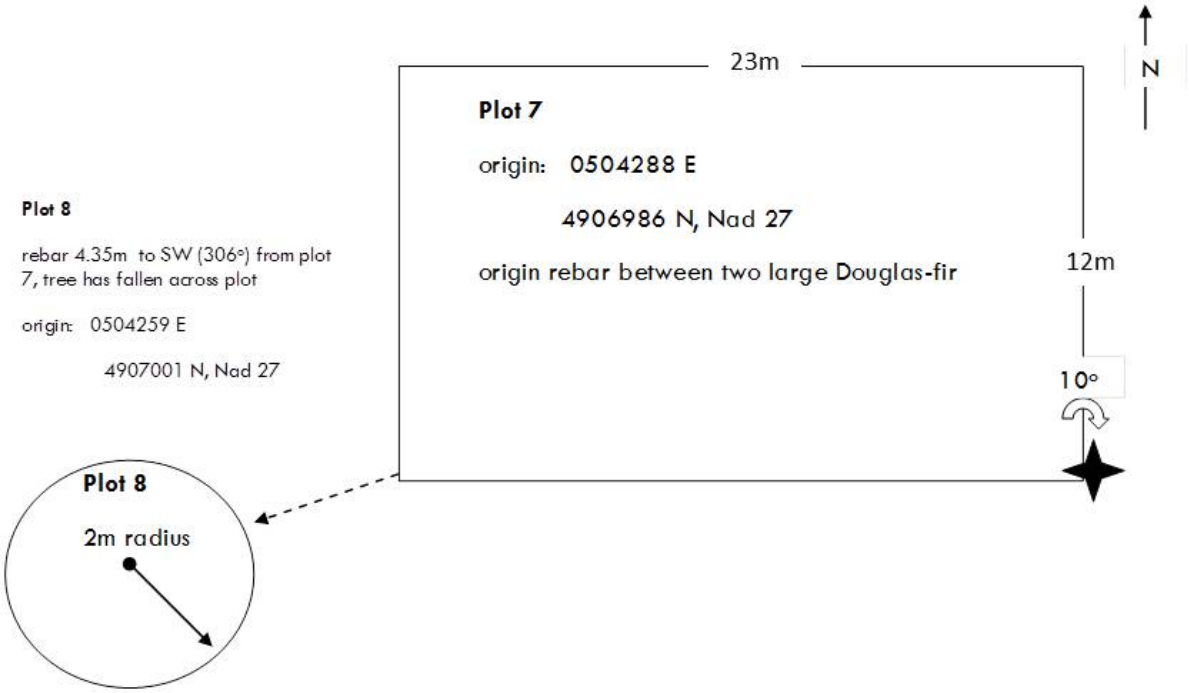
511: Center population in middle of hill at 230 degrees from westernmost PSME of PSME island on top of hill near plot 459.

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

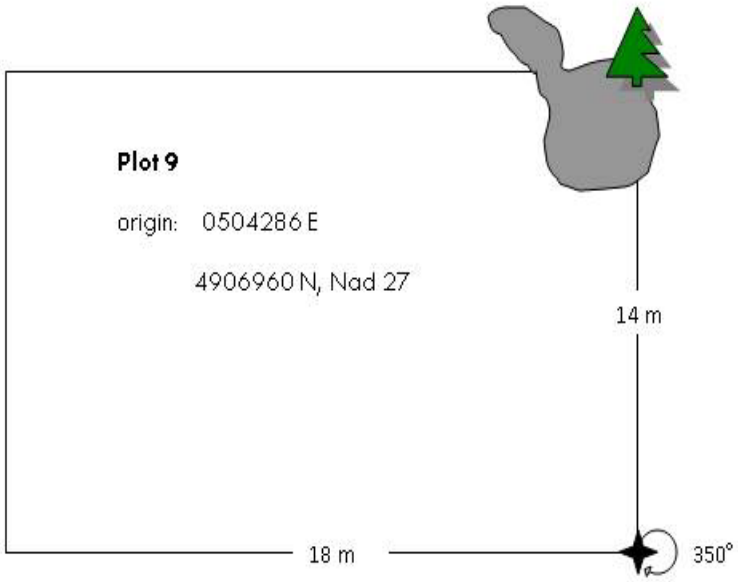


DIAGRAMS OF KINCAID'S LUPINE MONITORING PLOTS AT OAK BASIN MEADOW A.

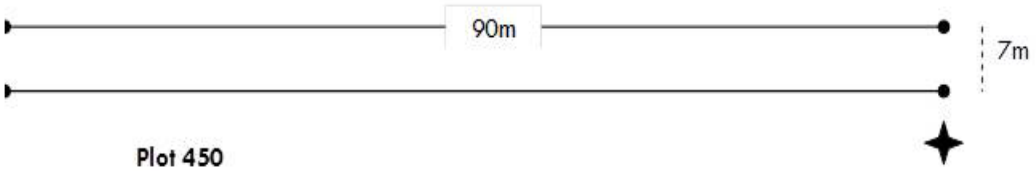
Meadow A


23m
N
Plot 7
origin: 0504288 E
4906986 N, Nad 27
origin rebar between two large Douglas-fir
12m
10°
Plot 8
rebar 4.35m to SW (306°) from plot 7, tree has fallen across plot
origin: 0504259 E
4907001 N, Nad 27
Plot 8
2m radius

Meadow A



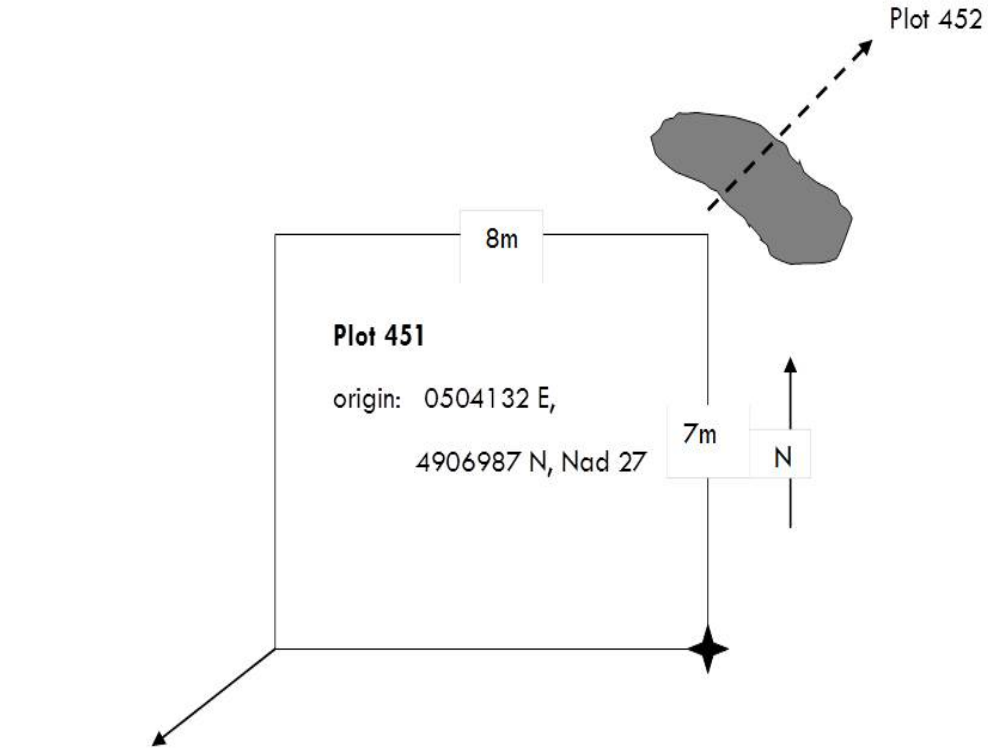
Tree line/Top of Meadow A



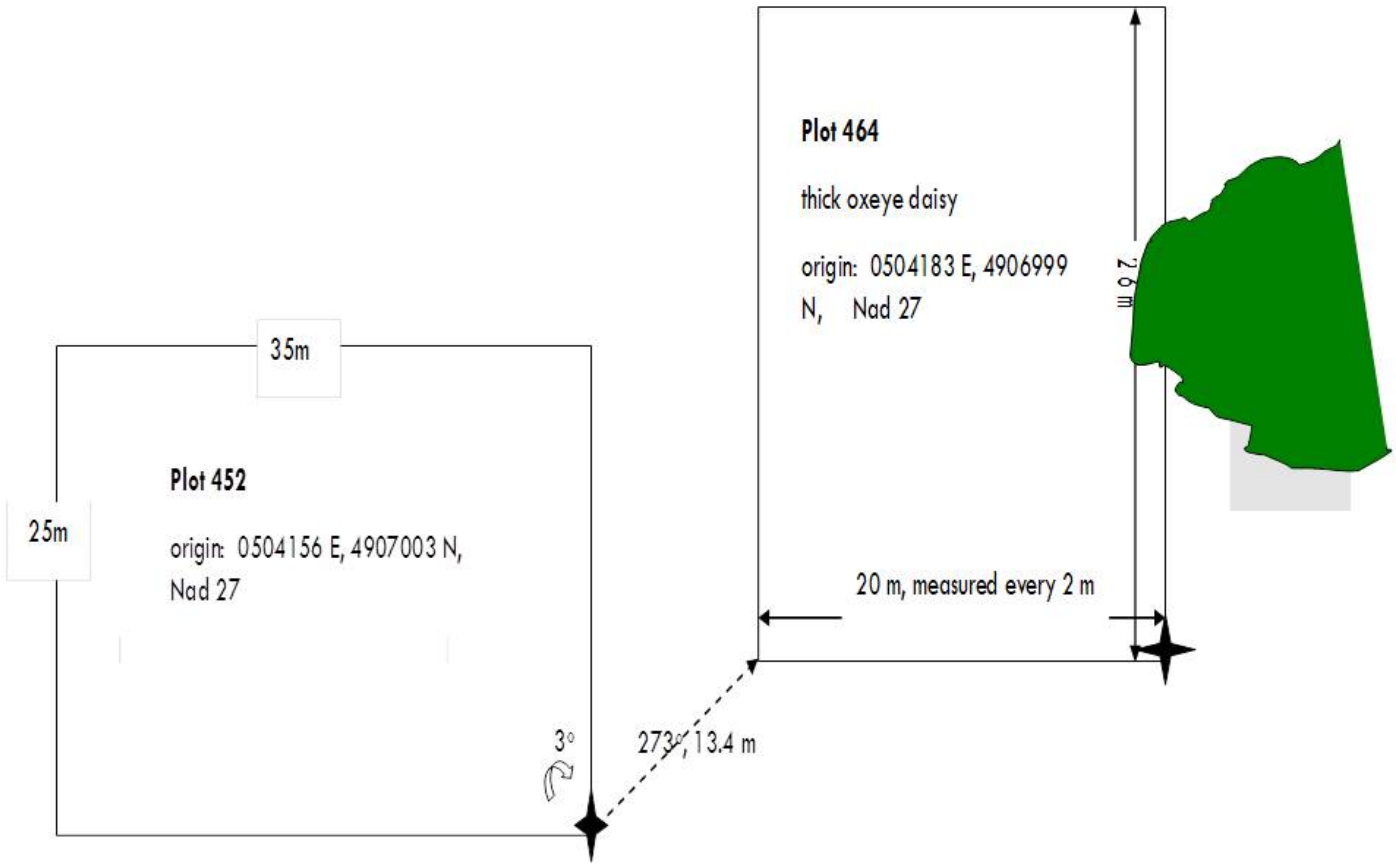
Plot 450

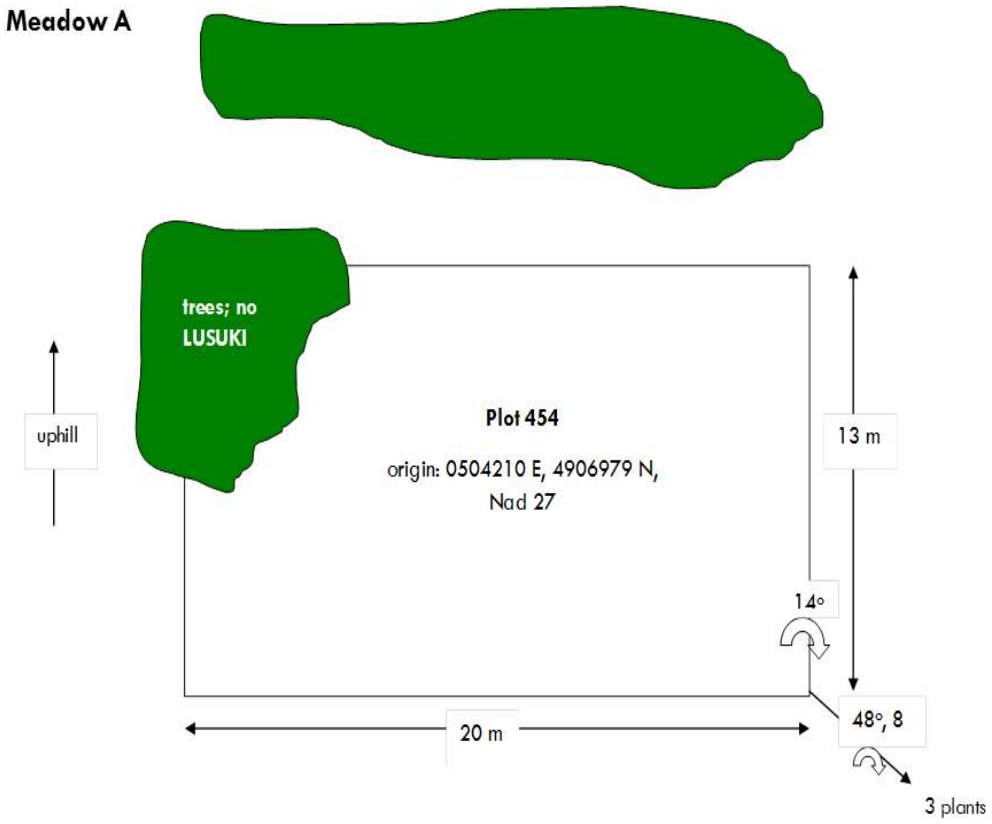
origin: 0504232 E

Meadow A

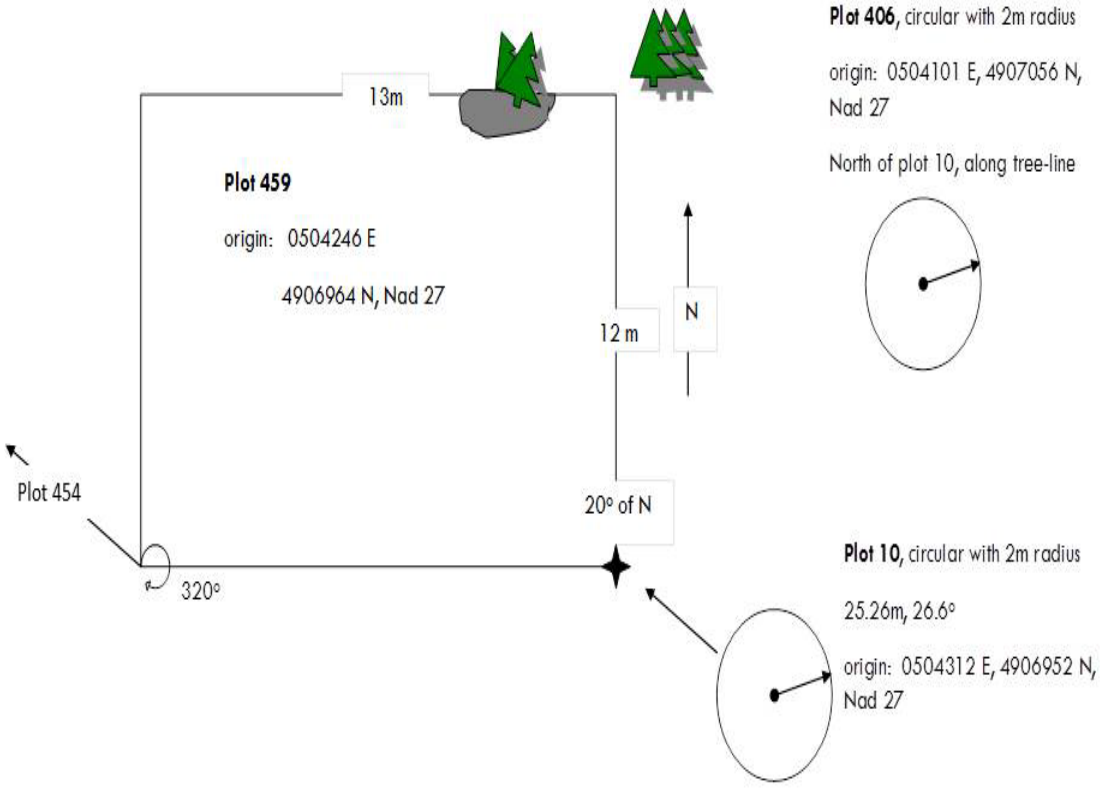

Plot 452
8m
Plot 451
origin: 0504132 E,
4906987 N, Nad 27
7m
N
2 plants outside plot,
6m at 64°

Meadow A

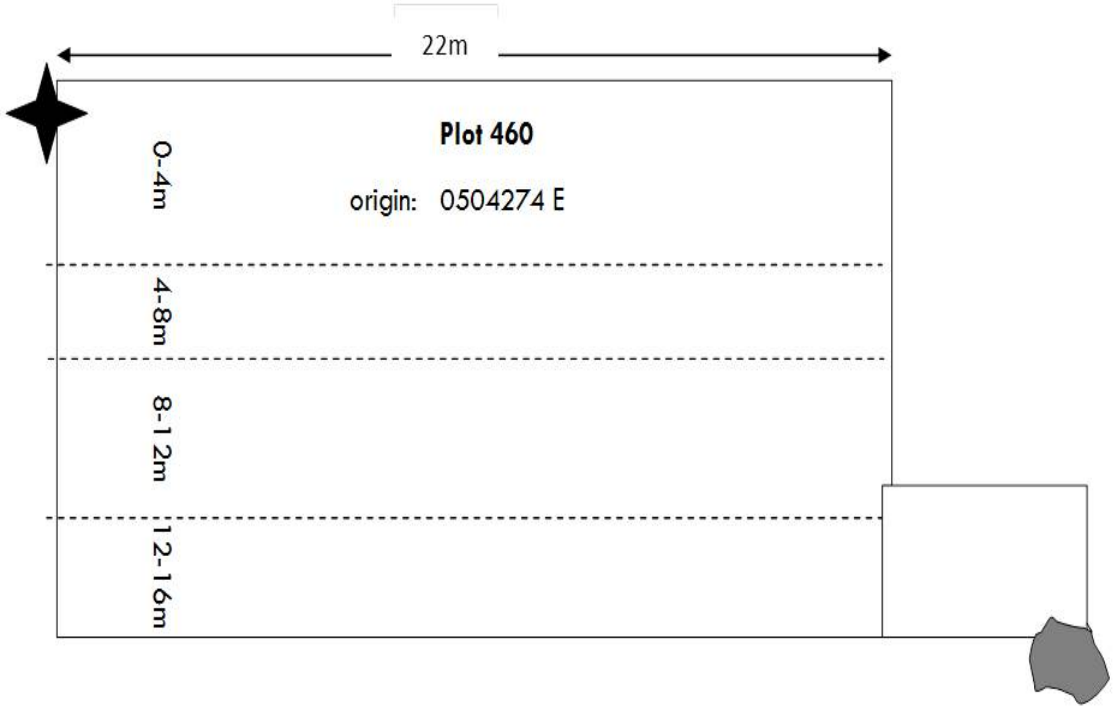

Plot 464
thick oxeye daisy
origin: 0504183 E, 4906999 N, Nad 27
26 m
35m
Plot 452
25m
origin: 0504156 E, 4907003 N, Nad 27
20 m, measured every 2 m
3°
273°, 13.4 m


Meadow A
trees; no
LUSUKI
uphill
Plot 454
origin: 0504210 E, 4906979 N,
Nad 27
13 m
14°
48°, 8
20 m
3 plants

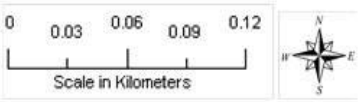
Meadow A


13m
Plot 459
origin: 0504246 E
4906964 N, Nad 27
12 m
N
Plot 454
320°
20° of N
Plot 406, circular with 2m radius
origin: 0504101 E, 4907056 N, Nad 27
North of plot 10, along tree-line
Plot 10, circular with 2m radius
25.26m, 26.6°
origin: 0504312 E, 4906952 N, Nad 27

Meadow A



Meadows B and C



To reach plot 399**:

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

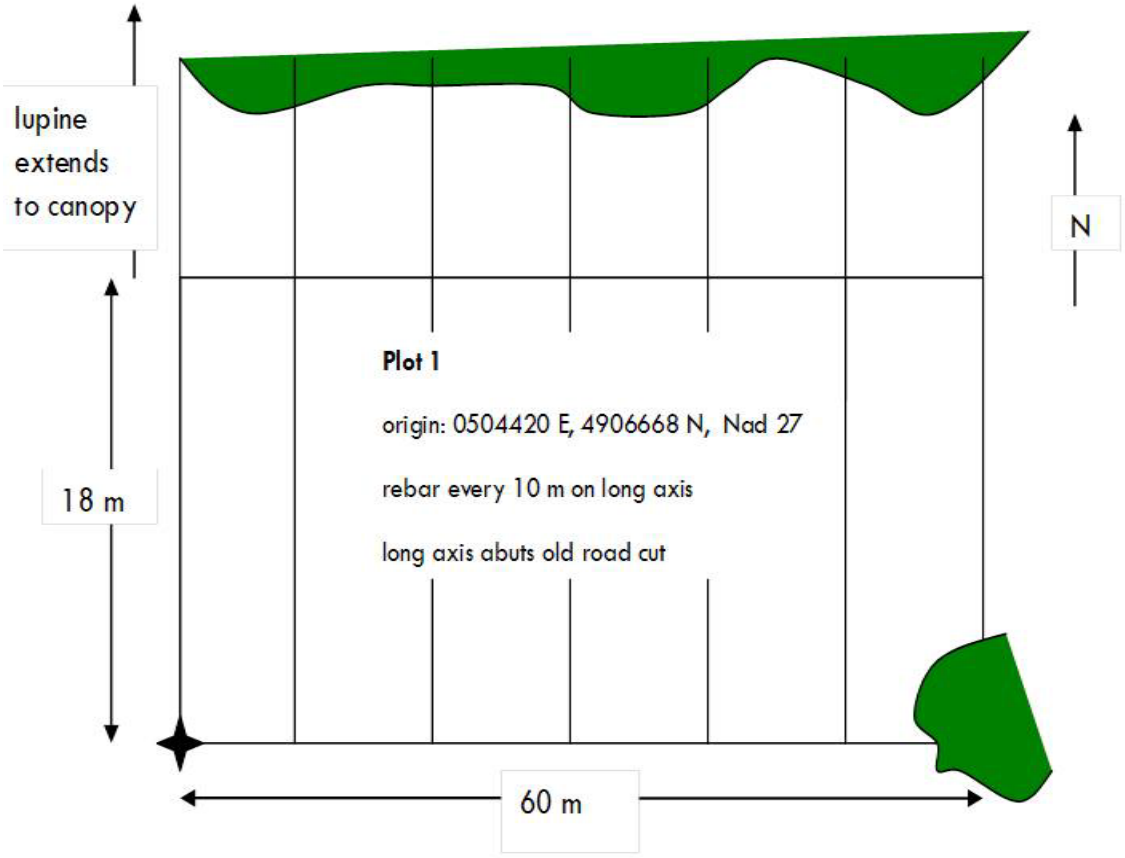
Near PSME with ACMA growing with itwhere hill steeply drops off.

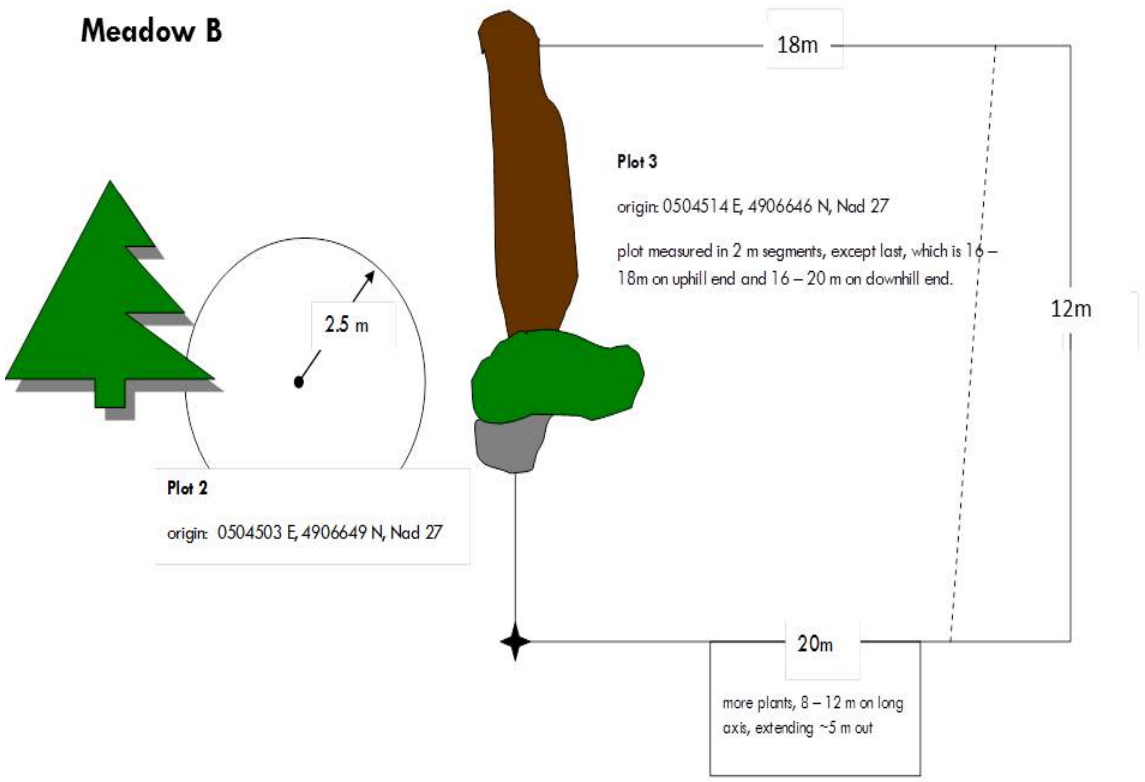
Population has been captured in a rectangle plot with 14m x 11m sides. Origin is in NE corner and has conduit, the other corners have rebar with yellow caps.

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

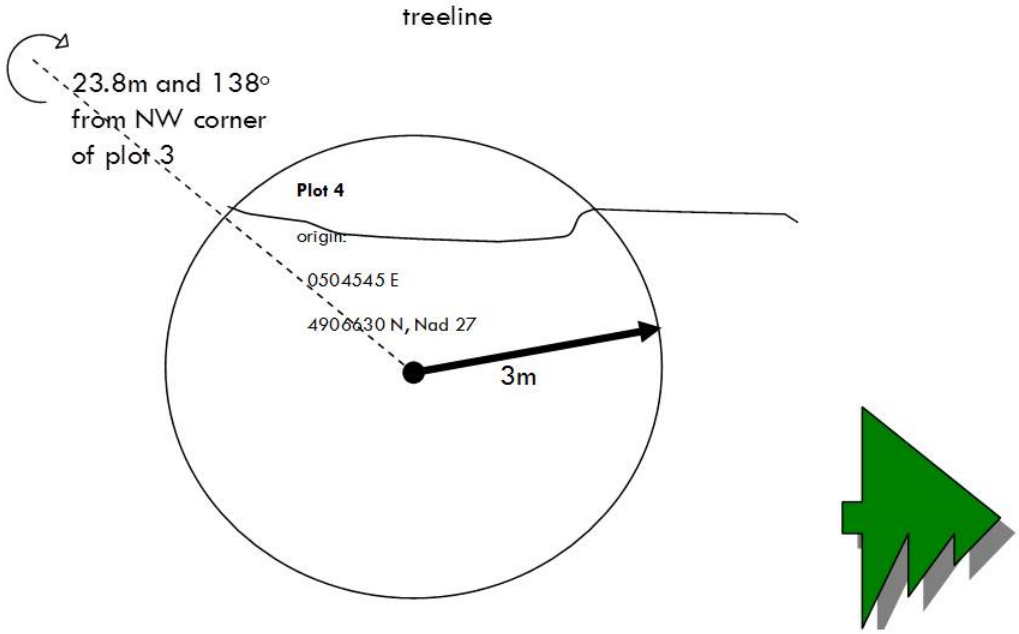
OVERVIEW OF PLOTS IN MEADOWS B AND C.

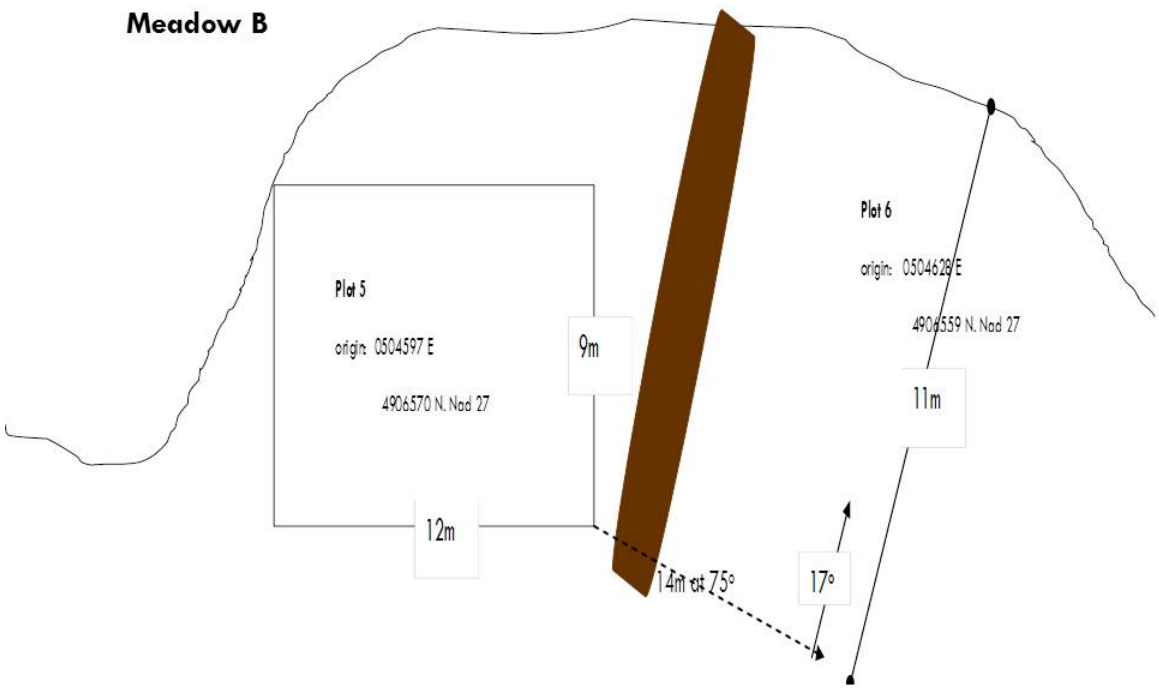
Meadow B

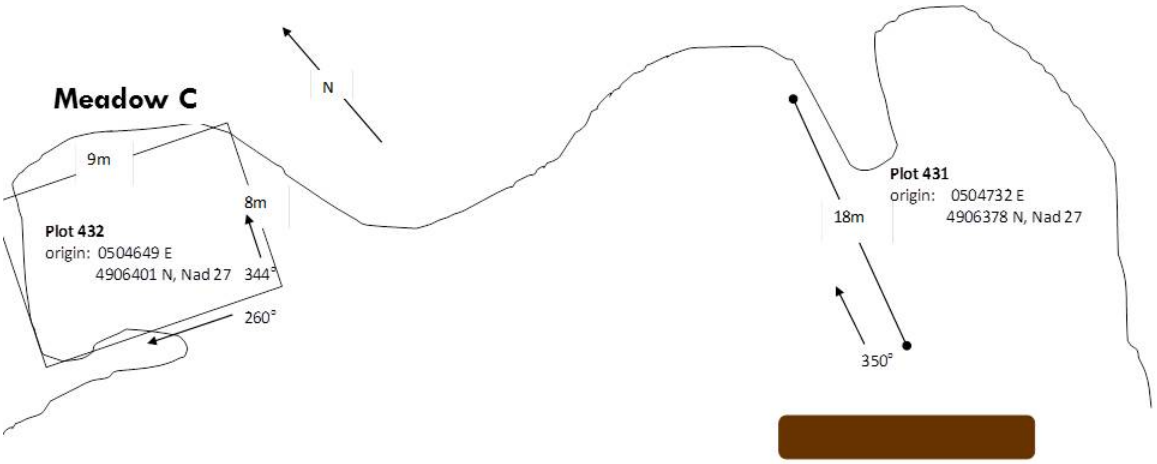

lupine
extends
to canopy
18 m
N
Plot 1
origin: 0504420 E, 4906668 N, Nad 27
rebar every 10 m on long axis
long axis abuts old road cut
60 m

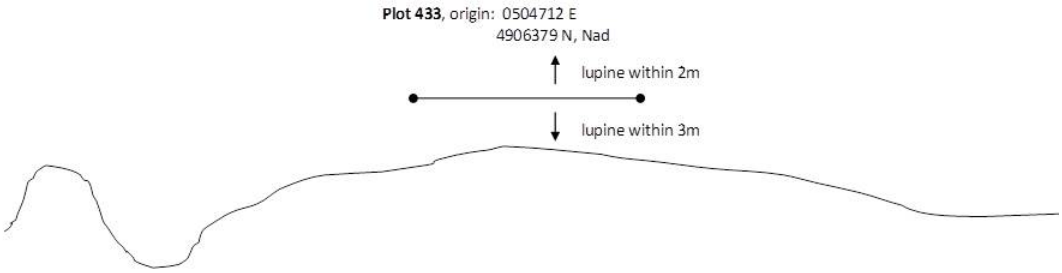

Meadow B
18m
Plot 3
origin: 0504514 E, 4906646 N, Nad 27
plot measured in 2 m segments, except last, which is 16 – 18m on uphill end and 16 – 20 m on downhill end.
12m
2.5 m
Plot 2
origin: 0504503 E, 4906649 N, Nad 27
20m
more plants, 8 – 12 m on long axis, extending ~5 m out

Meadow B


treeline
23.8m and 138°
from NW corner
of plot 3
Plot 4
origin:
0504545 E
4906630 N, Nad 27
3m


Meadow B
Plot 5
origin: 0504597 E
4906570 N. Nad 27
9m
12m
14m at 75°
Plot 6
origin: 0504628 E
4906559 N. Nad 27
11m
17°


Meadow C
N
9m
8m
Plot 432
origin: 0504649 E
4906401 N, Nad 27
344°
260°
Plot 431
origin: 0504732 E
4906378 N, Nad 27
18m
350°


Plot 433, origin: 0504712 E
4906379 N, Nad
lupine within 2m
lupine within 3m

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								
Achillea millefolium	0.43	0.28	0.05	0.6	0.47	0.34	0.23	0.25
Agoseris grandiflora	0.04	0	0	0	0.08	0	0	0
Aster hallii	0.09	0.04	0.03	0.17	0.09	0.04	0.02	0
Brodiaea sp.	0.01	0.05	0.03	0.03	0	0.05	0	0.05
Calochortus tolmiei	0	0	0	0	0	0	0.02	0
Centaurium erythraea	0	0	0	0	0	0	0.02	0
Cerastium fontanum ssp. *vulgare*	0	0.01	0	0	0	0.01	0	0
Cirsium arvense	0.12	0.65	2.75	0	0.23	0	0	0
Cirsium sp.	0	0.03	0	0	0	0.04	0	0
Clarkia amoena	0	0.05	0	0.02	0	0.07	0	0
Crepis setosa	0	0.09	0.13	0.02	0	0.09	0	0
Daucus carota	0	0	0	0	0.01	0	0	0
Daucus pusillus	0	0	0	0	0.01	0	0	0
Dianthus armeria	0.05	0.06	0.03	0.02	0	0	0.18	0.5
Dichelostemma congestum	0	0.03	0	0	0.01	0.04	0	0
Erigeron speciosus var. *speciosus*	0.96	0	0	0	1.92	0	0	0
Eriophyllum lanatum	1.88	1.57	1.28	3	1.69	1.3	1.5	3
Fragaria vesca	0.27	0	0	0	0.54	0	0	0
Fragaria virginiana	2.5	0.06	0	0.5	4.69	0.08	0.17	0
Galium aparine	0	0.03	0.13	0.02	0	0	0	0
Geranium dissectum	1.72	1.97	1.38	0.42	2.55	2.42	1.33	0
Geranium oreganum	0	0	0	0	0.01	0	0	0
Githopsis specularioides	0	0.01	0	0	0	0.02	0	0
Hypericum perforatum	0.47	0.11	0.15	0.1	0.65	0.14	0.42	0
Hypochaeris radicata	0.65	0.18	0.25	2.5	0.15	0.08	0	0.5
Iris tenax var. *tenax*	2.5	0.06	0.25	1.85	3.92	0	0.5	0
Lathyrus nevadensis var. *nevadensis*	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
Lathyrus sphaericus	0	0.03	0	0	0	0	0	0.25
Leucanthemum vulgare	13.19	5.07	7.5	6	18.77	5.76	8	1.05
Linanthus bicolor	0	0.01	0	0	0	0.01	0	0
Linum bienne	0.15	0.93	1.53	0.12	0.01	0.14	0.5	4
Lupinus oreganus	1.23	0	0	0.85	2.08	0	0	0
Madia gracilis	0.05	0.72	0.05	0.2	0	1	0.02	0
Madia madioides	0.02	0	0	0	0	0	0.08	0
Madia sp.	0	0.04	0	0	0	0.05	0.02	0.05
Marah oreganus	0.12	0	0	0	0.23	0	0	0
Myosotis discolor	0.01	0.01	0	0	0.02	0.02	0	0
Plantago lanceolata	0.54	0.89	0.25	1.35	0.46	0.76	0	2.5
Potentilla gracilis	0.15	0	0	0	0.31	0	0	0
Prunella vulgaris var. *lanceolata*	0.04	0	0	0	0.08	0	0	0
Pteridium aquilinum	5.65	0.47	10	9	2.69	0.67	3	0
Rumex acetosella	0.1	0.18	0.03	0.25	0.08	0.25	0	0
Sanicula graveolens	0	0.01	0	0	0	0	0	0.05
Satureja douglasii	0.15	0	0	0	0.31	0	0	0
Sherardia arvensis	0.18	0.28	0.13	0.13	0.1	0.39	0.35	0
Sidalcea virgata	3.19	0.59	2.53	2	0.85	0	10	0
Sisyrinchium sp.	0	0	0	0	0.01	0	0	0
Synthyris reniformis	0.12	0	0	0	0.24	0	0	0
Torilis arvensis	0.69	0.59	0.25	0.5	0.15	0.79	2.02	0.25
Tragopogon dubius	0	0.06	0.25	0	0	0	0	0
Veronica americana	0	0.01	0	0	0.01	0.01	0	0
Vicia americana	0.15	0	0	0	0.31	0	0	0
Vicia gigantea	0	0	0	0	0	0	0.02	0
Vicia sativa	0.22	0.21	0.25	0.05	0.3	0.3	0.1	0
Viola praemorsa	0.01	0.06	0	0	0.02	0.08	0	0
Wyethia angustifolia	0.46	0	0	0	0	0	2	0
Grasses								
Agrostis capillaris	0.12	0	0	0	0.24	0	0	0
Aira caryophyllea	0.12	0.06	0.03	0.5	0.01	0.08	0.02	0
Bromus carinatus	4.92	3.12	1.25	7.5	2.15	1.58	9.17	14.5
Bromus hordeaceus	0.06	0.24	0.03	0.03	0.1	0.31	0.02	0.1
Bromus rigidus	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
Bromus sp.	0.08	0.14	0	0	0.15	0.18	0	0.05
Carex tumulicola	2.39	0	0	0.68	4.46	0	0.02	0
Cynosurus echinatus	0.79	14.14	1	1	0.35	13.86	1.68	35
Dactylis glomerata	13.27	4.94	2.5	14.5	17.24	5.5	5.67	4
Danthonia californica	0.7	0.77	0.03	2.83	0.09	1.08	0	0
Elymus glaucus	1.04	0.06	0	2	1.08	0.08	0.17	0
Elymus trachycaulus	0.08	0.54	0	0.17	0.08	0.75	0	0.05
Schedonorus arundinaceus	73.12	47	78.75	55.33	69.92	42	93.33	40
Festuca roemeri	4.31	10.62	11.38	6.75	5.51	11.25	0	0
Holcus lanatus	1.62	2.71	10	0.17	3.15	0.5	0	0
Juncus patens	0.01	0.35	0	0.02	0.01	0.5	0	0
Luzula sp.	0.03	0.01	0	0.02	0.04	0.01	0.03	0
Phleum pratense	2.28	0.18	0	2.67	3.31	0.25	0.03	0
Poa compressa	0.27	2.97	10.03	0	0.54	0.86	0.02	0.05
Poa pratensis	0	3.94	0	0	0	5.58	0	0
Taeniatherum caput-medusae	0.05	7.77	0	0.2	0.01	10.84	0	1
Vulpia bromoides	0.38	4.01	1.5	1.67	0	4.01	0	7
Shrubs								
Rosa sp.	0.38	1.18	5	0	0.77	0	0	0
Rubus ursinus	1.38	2.06	8.75	0	2.77	0	0	0
Trees								
Malus sp.	0.15	0	0	0	0.31	0	0	0

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

Meadow	A				B		
Treatment	Flameweed	Untreated	Flameweed	Mowed	Untreated	Flameweed	Untreated
Year	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							
Aira caryophyllea	0	0.25	0	0	0	0	0.05
Alopecurus pratense	0	0	0	7.04	1.5	0	0
Bromus carinatus	1.2	0	0	0.3	0	0	0
Bromus hordeaceus	0.54	2	0.42	0	0	0.6	6
Bromus rigidus	0.1	0	0.1	0	0	0.1	0
Bromus sp.	0	0	1.82	0	0	0	0
Carex tumulicola	0	0	0	0	0.5	0	0
Cynosurus echinatus	1.42	15	1	0.22	0.05	1	6.5
Dactylis glomerata	0.2	0	0	27	20	4	0
Danthonia californica	0.6	0	0	0.2	0	0.2	0
Elymus glaucus	0	0	0	1	0	0	0
Festuca arundinacea	0.8	9	0	93	92.5	0	7
Festuca roemeri	2.2	0	0.6	0	0	0.4	0
Juncus bufonius	0	0	0	0	0	0.02	0
Koeleria macrantha	0	0	2	0	0	0.1	0
Luzula sp.	0	0	0	0.1	0.25	0	0
Phleum pratense	0	0	0	0	0	0.2	0
Poa compressa	0	0.25	0	0.6	0	0	0
Poa scabrella	0.2	0	0	0	0	0	0
Poa secunda	0	0	0.5	0	0	0.4	0
Taeniatherum caput-medusae	15.62	60	0.14	0	0	0.54	77.5
Vulpia bromoides	0.5	0	0	0	0	0	0
Forbs							
Achillea millefolium	0.7	0.25	0.12	0.72	0.05	0.22	0

Appendix D. Continued

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

Appendix D. Continued

Meadow	A					B	
Treatment	Flameweed	Untreated	Flameweed	Mowed	Untreated	Flameweed	Untreated
Year	2015	2015	2016	2016	2016	2016	2016
Vicia sativa	0	0	0	0.4	0	0	0
Viola praemorsa	0	0	0	0.4	0	0	0
Wyethia angustifolia	0.02	0	0	0	0	0	0
Shrubs							
Rosa sp.	0	0	0	0.4	0	0	0
Rubus ursinus	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