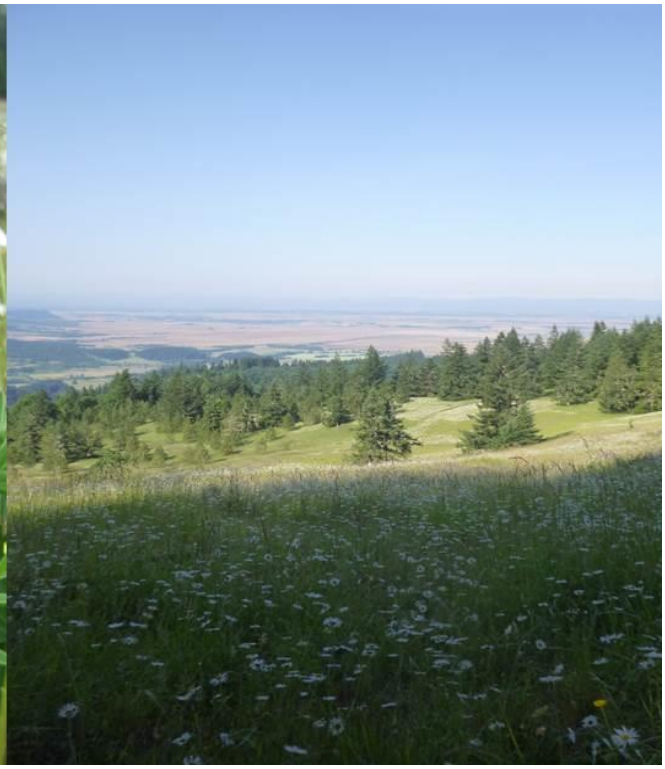
Population and habitat monitoring for Kincaid's lupine and Hitchcock's blue-eyed grass at Oak Basin



2014

Report to the Bureau of Land Management Eugene District

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Institute for Applied Ecology

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PREFACE

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

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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 dynamics and habitat for of Kincaid's lupine (*Lupinus oreganus*), a threatened species in the legume family, 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 prairies. In 2014, the ninth year of monitoring occurred at Oak Basin, which is managed by the Eugene District Bureau of Land Management.

- Kincaid's lupine: After the alarming decline observed in 2013, lupine cover and mature inflorescences recovered to pre-crash levels in 2014. Lupine cover improved considerably to 150m² (in 2014) from 74m² (in 2013); coinciding with elevated cover, total mature inflorescences increased greatly from 195 (in 2013) to 2,046 (in 2014). Mature racemes per m² increased in all meadows, while aborted inflorescences plummeted to only 3% in 2014. The population dynamics 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 2014, the Oak Basin habitat once again had high proportions of exotic species cover with 79% exotic and only 21% native cover. While the percent cover of native and exotic species has not fluctuated greatly over the years, functional group cover has varied from 2011-2014. Dominance by exotic species was most evident in the grass functional group comprising 59% of the total cover, followed by 19% exotic forb cover, in comparison to 12% native forb and 7% native grass cover in 2014. Exotic grasses including *Dactylis glomerata*, *Festuca arundinacea*, 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 increased 21% across all three meadows, with 80 species present as compared to only 72 and 65 species in 2012 and 2013, respectively. Meadow C contained the highest species richness with 65 total species, and Meadow A and B had slightly lower total species with 60 and 54, respectively.

- *Sisyrinchium hitchcockii:* Long-term monitoring plots for *S. hitchcockii* were added to Meadow C in 2012; monitoring was conducted in 2012, 2013, and 2014 and will continue annually. In 2014, a total of 225 inflorescences and 26 vegetative plants were recorded. Overall, reproductive effort was much greater in 2014 than in 2013, while vegetative plants decreased 45% from 2013 to 2014. A favorable year for the reproductive effort of both *L. oreganus* and *S. hitchcockii* suggest that some shared factor, such as climate 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.

- Management treatments: Management treatments conducted in 2013 and 2014 included mowing to control exotic perennial grasses and shrubs, limbing up 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. Personal observations from the 2014 crew witnessed lupine proliferation occurring under recently opened up meadows via limbing and mowing. In future years, a community monitoring scheme targeted at areas of management will be essential to track plant community response from such actions.

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 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 dynamics. In 2012, we added a permanent plot 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*; Figure 2) an endangered species. *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 (Figure 12). 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 specie (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, for more information see Giles-Johnson et al. 2011. For discussion on the relationship between Kincaid's lupine cover and number of leaves (2006), and trends in Fender's blue butterfly egg counts, see Giles-Johnson et al. 2009.

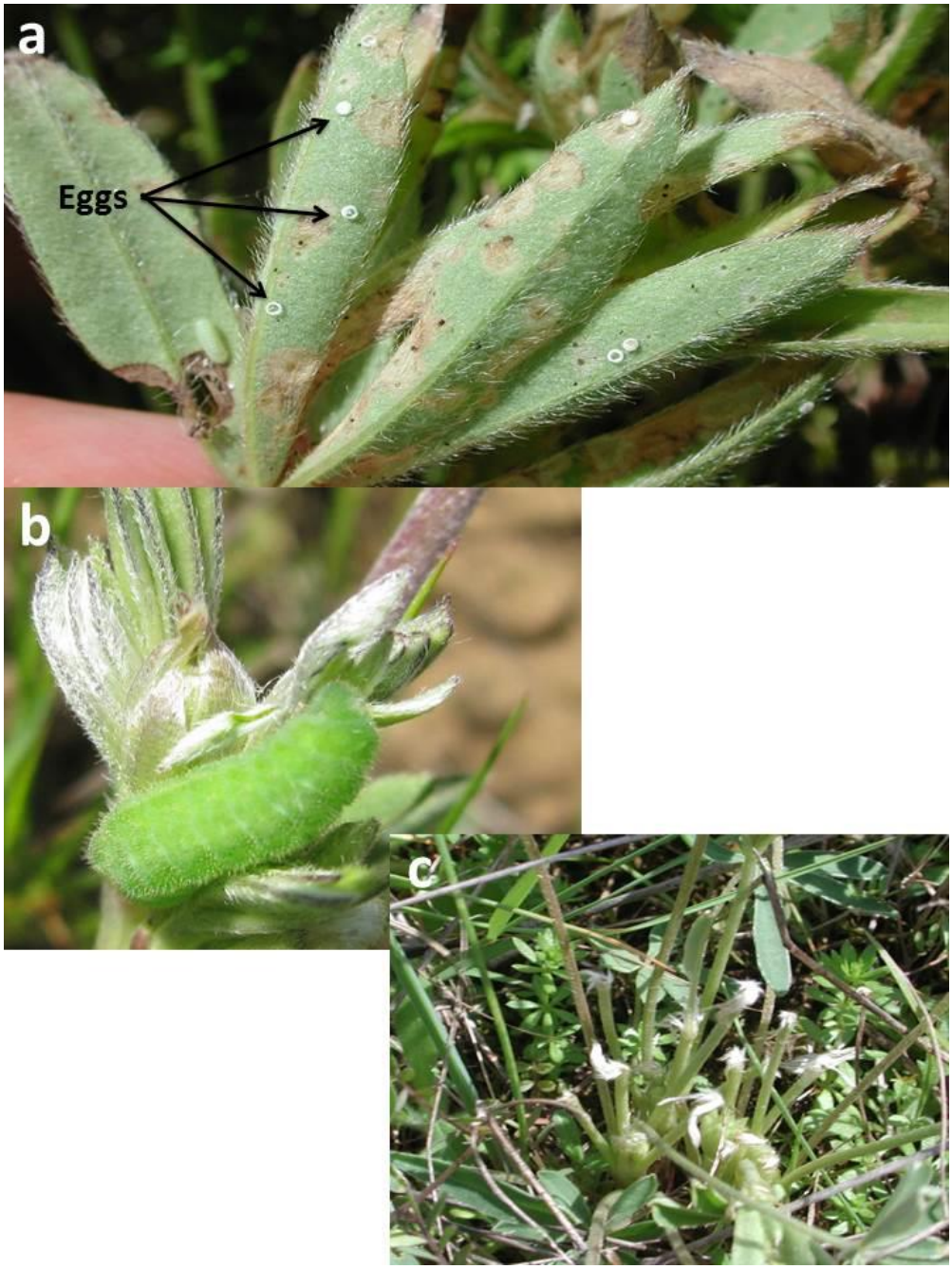


FIGURE 3. FENDER'S BLUE BUTTERFLY ON KINCAID'S LUPINE. (A) FEMALE FENDER'S BLUE BUTTERFLIES OVIPOSIT SMALL WHITE EGGS ON THE UNDERSIDES OF LUPINE LEAVES. HERBIVORY OF KINCAID'S LUPINE BY LARVAE (B) OF FENDER'S BLUE BUTTERFLY RESULTS IN CLUSTERS OF DAMAGED STEMS, LEAVES, AND GROWING POINTS (C) BECAUSE 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 lupine patch; 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 previous year's data sheets and in the plot maps (Appendix A).

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

Kincaid's lupine population monitoring

Within each plot, we recorded the cover of Kincaid's lupine as well as the number of mature and aborted Kincaid's lupine inflorescences. Lupine cover was determined by measuring the approximate rectangular area occupied by a lupine. Cover of lupine is highly correlated with the number of leaves (Kaye and Benfield 2005) and is the standard for lupine monitoring as recommended by the Draft Recovery Plan (USFWS 2008). In 2007-2008, we also counted the number of leaves in a subsample of the plots to determine the site-specific relationship between leaves and cover. The relationship between lupine cover and the number of leaves was determined using linear regression, for more information see Giles Johnson et al. 2009. In 2010- 2014, eggs were not counted at Oak Basin.

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
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	

[1] Coordinates are in NAD83 instead of NAD27.

** 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.

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)**	15m x 4m	504639 E[1] 49065659N[1]	measured in 1m increments
C	**2 (186)**	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*

Habitat Assessment

Community monitoring in 2011-14 included evaluation of areas designated as Kincaid's lupine habitat and areas that were not occupied by lupine. 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. 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.

In 2011, in addition to community sampling, the abundance and phenology of nectar species utilized by Fender's blue and Taylor's checkerspot was evaluated. Nectar species were surveyed by systematically walking through Meadows A, B, and C, estimating the abundance of each nectar species, their phenology, and noting their location. For more information, see Giles-Johnson et al. 2011.

The purpose of both the community and nectar species assessments is to:

1. Quantify recovery targets for associated prairie species; percent native vs. percent exotic. Accomplished by quantifying percent cover of all species and plant 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 species and plant cover types (litter, bare ground, moss, and rock) in 15-30 randomly placed plots in each meadow.
3. Quantify available nectar species for Fender's blue butterfly, Taylor's checkerspot butterfly, and other butterfly species of concern. Accomplished by systematically surveying all meadow areas and estimating abundance of all species known to be utilized by Fender's blue and Taylor's checkerspot butterflies in 2011.

Sisyrinchium hitchcockii

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 4). The first was a 15m long transect with rebar marking both ends. Plants were found in a ~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*).

FIGURE 4. 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.

S. bellum is also present in the area, so monitoring should occur at the time of flowering to ensure proper identification of the species. *S. 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.

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.

RESULTS AND DISCUSSION

Kincaid's lupine population monitoring

Total cover of Kincaid's lupine at Oak Basin had crashed in 2013 to its lowest total cover at 74m² representing a loss of 55% (Table 2, Figure 5). The population has since rebounded in 2014 with a 51% increase in total cover from 2013 values reaching 150m². In 2014, Meadow A had a significant increase in cover (90%) of Kincaid's lupine to 80m², almost doubling the cover after the decline witnessed in 2013 (42m²; Table 2, Figure 5). Total cover of lupine in Meadow B more than doubled from an all-time low of 21m² in 2013 to 52m² (in 2014). For Meadow C, lupine cover increased to the second highest value found from 2006-2014 (17.8m²) after a dismal total cover in 2013 (11m²). Meadow C, the smallest meadow, had the fewest number of lupine patches (four), the lowest foliar cover, and the fewest mature inflorescences (Table 2). The increase in total cover in all meadows is a positive sign that the population may be rebounding after the severe decline in 2013. Many factors could have contributed to observed population variability including climatic fluctuations, meadow encroachment by trees and shrubs, and competition by invasive species. Annual monitoring will be necessary to elucidate whether patterns in recent years are related to typical annual variability or are cause for more serious concern.

Similar to lupine cover results, the total number of mature inflorescences experienced a 950% increase to 2,046 (in 2014) from the 2013 value of 195 inflorescences (Table 2, Figure 6). Mature racemes per m² increased to 13.8, 12.2, and 17.5 in Meadows A, B and C, respectively. From the 2011 apex, mature racemes per m² had been steadily decreasing in all meadows to an all-time low in 2013. Mature racemes per m² rebounded at Meadow A, with 1,108 inflorescences (in 2014) from an all-time low of 70 (in 2013); Meadow B had 627 after only 81 inflorescences (in 2013). Finally, in 2014 Meadow C had 311 inflorescences recorded after the low of 44 (in 2013). The percentage of aborted inflorescences decreased considerably between 2013 and 2014 (Figure 7), with an extremely low range for all meadows of 0-4%; contrary to 2014 values where the percent of aborted inflorescences in Meadows A, B and C in 2013 ranged 46-65%. We have noted an inverse relationship between production of mature inflorescences and aborted inflorescences; years that produced a large quantity of mature inflorescences tend to be associated with low numbers of aborted inflorescences, and vice-versa (Table 2, Figure 7, Figure 8).

Table 2. Lupine cover, total mature inflorescences, mean mature inflorescences per m^2, percent aborted inflorescences, and the number of butterfly eggs at Oak Basin from 2006-2014.

Meadow	Year	Lupine Cover (m^2)	Mature Inflorescences (m^{-2})	% Aborted Inflorescences	Butterfly Eggs*
A	2006	39.34	245 (6.2)	13	424
	2007	35.13	813 (23.1)	28	3,728
	2008	45.46	891 (19.6)	21	2,686
	2009	49.53	348 (8.3)	35	1,956
	2010	65.31	1860 (28.5)	3	N/A
	2011	86.89	2,191 (25.2)	3	N/A
	2012	86.53	1,357 (15.7)	3	N/A
	2013	42.46	70 (1.6)	55	N/A
	2014	80.41	1,108 (13.8)	4	N/A
B	2006	44.86	375 (8.4)	9	77
	2007	37.69	1,482 (39.3)	7	159
	2008	45.92	1,027 (22.4)	13	526
	2009	50.06	1,004 (20.1)	17	244
	2010	49.55	1,678 (33.9)	2	N/A
	2011	55.83	1,791 (32.1)	3	N/A
	2012	64.89	924 (14.2)	1	N/A
	2013	20.61	81 (3.9)	65	N/A
	2014	51.60	627 (12.2)	1	N/A
C	2006	17.55	244 (13.9)	5	13
	2007	21.19	810 (38.2)	4	0
	2008	10.59	432 (40.8)	3	3
	2009	10.72	55 (5.1)	38	34
	2010	12.04	108 (9.0)	5	N/A
	2011	15.06	186 (12.4)	6	N/A
	2012	13.52	127 (9.4)	0	N/A
	2013	11.14	44 (4.0)	46	N/A
	2014	17.80	311 (17.5)	0	N/A
Total	2006	101.75	864 (8.5)	9	514
	2007	94.01	3,105 (33.0)	13	3,887
	2008	101.97	2,350 (23.0)	15	3,215
	2009	110.31	1,407 (13.4)	23	2,234
	2010	126.91	3,646 (28.7)	3	N/A
	2011	157.78	4,168 (26.4)	3	N/A
	2012	165.04	2,408 (14.6)	3	N/A
	2013	74.20	195 (2.6)	59	N/A
	2014	149.81	2,046 (13.7)	3	N/A

*From 2007-2009 scaled egg values are determined by counting the number of eggs per m^2 of lupine cover in a subsample of the population and then extrapolating for the number of eggs based on the lupine cover in the entire area. See text for a discussion of how egg values were scaled in 2006.

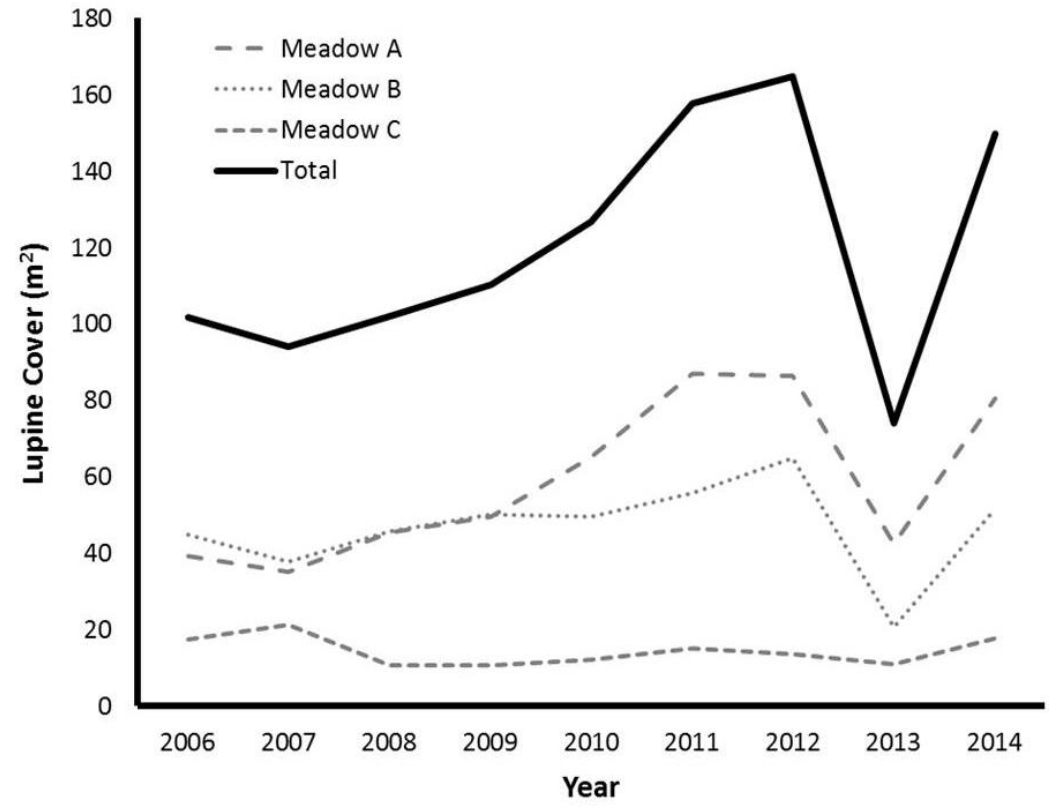


FIGURE 5. LUPINE COVER (M²) IN EACH MEADOW AND TOTAL COVER FOR ALL MEADOWS AT OAK BASIN FROM 2006-2014.

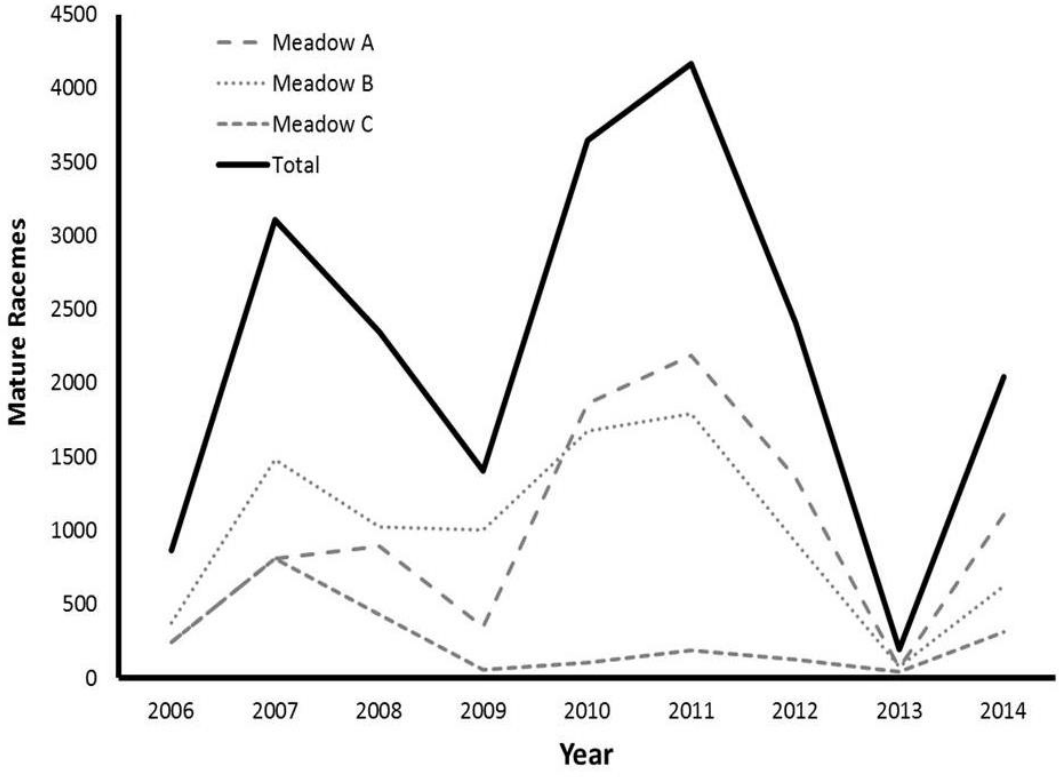


FIGURE 6. TOTAL MATURE RACEMES COUNTED IN EACH MEADOW AT OAK BASIN FROM 2006-2014.

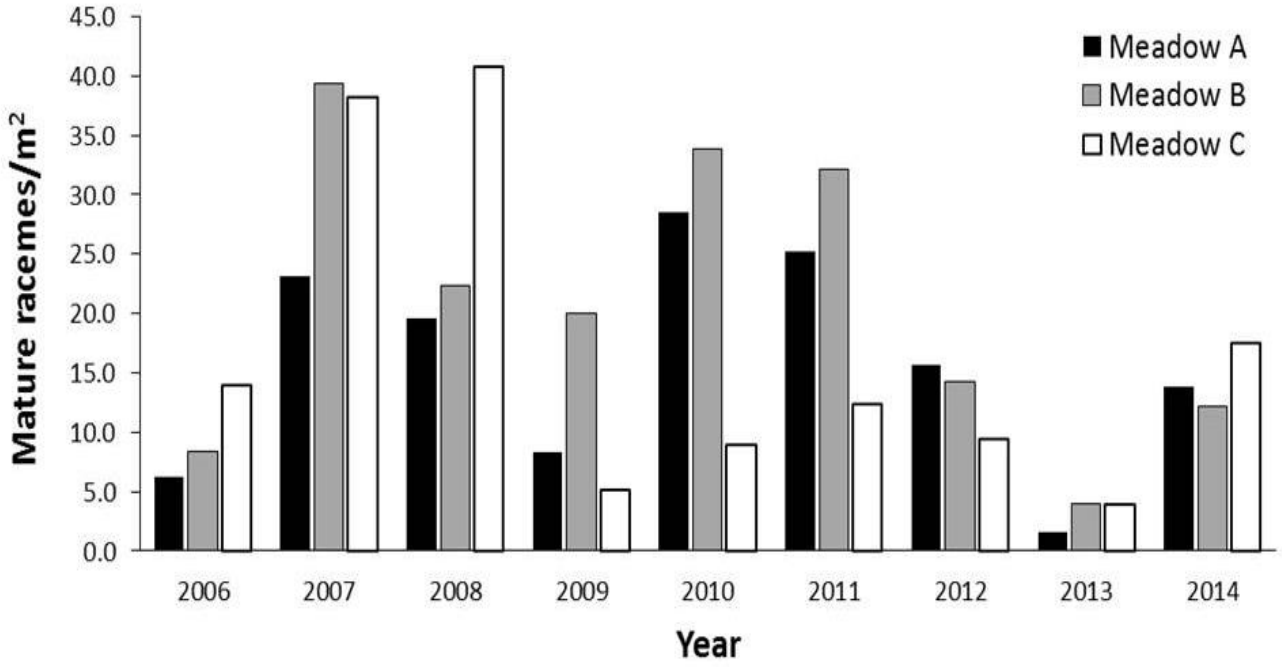


FIGURE 7. MATURE RACEMES PER M² AT OAK BASIN BY MEADOW FROM 2006-2014.

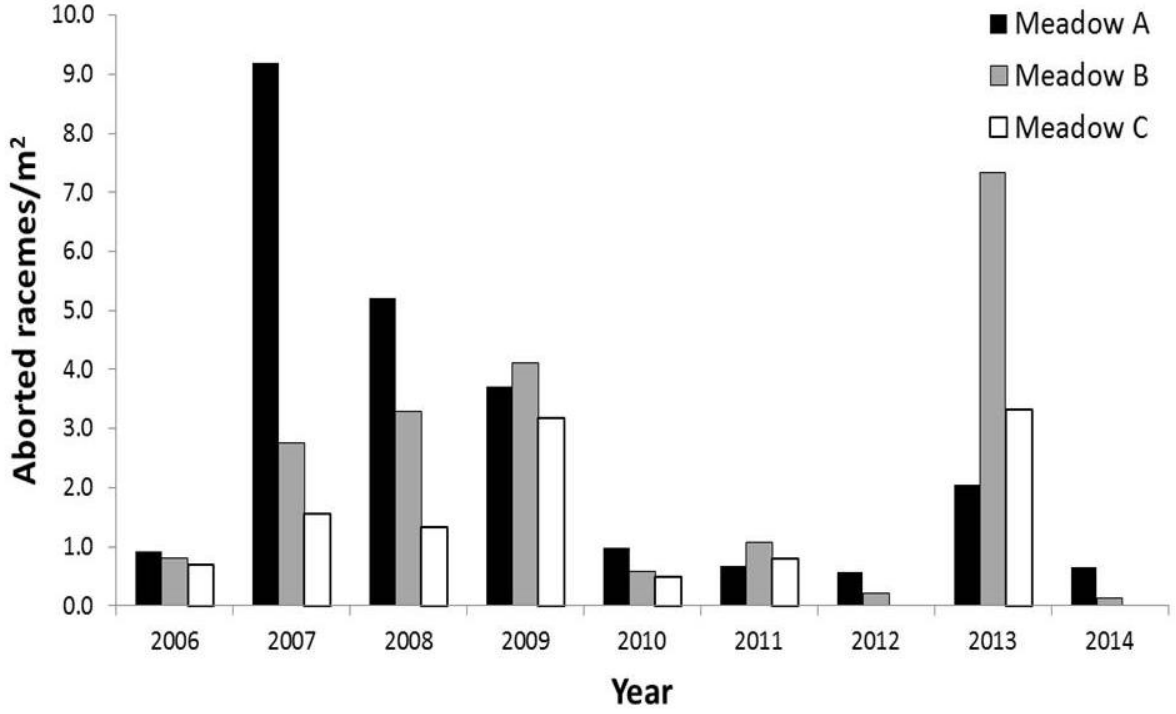


FIGURE 8. ABORTED RACEMES PER M² AT OAK BASIN FROM 2006-2014.

Habitat assessment

In 2014, all three meadows had similar cover of exotic species to that of 2013 with 79% exotic and only 21% native cover; percent cover of exotic species for Meadows A, B, and C was 76%, 82% and 78%, respectively. While 2014 values were similar to last year, cover of exotic species experienced an increasing trend from 2011 to 2014 (Figure 9). Dominance by exotic species was most evident in the grass functional group comprising 59% of the total cover followed by 19% exotic forb cover, whereas natives forbs composed 12% cover, and with only 7% native grass cover. From 2013 to 2014, Meadow C exhibited a large increase in exotic grass cover (Figure 9), while Meadow A had a slight decrease and Meadow B had a slight increase from 2013 values. Exotic grasses, including *F. arundinacea*, *D. glomerata* and C. *echinatus,* were most prevalent in across all meadows, while the exotic forb, *L. vulgare*, comprised of over 20% cover in these habitats (Appendix C, Figure 10). *F. arundinacea* is an especially aggressive invasive species and has dominated lupine and non-lupine habitats with a total cover ranging from 31-97% in all monitored areas.

In Kincaid's lupine habitat, the native forbs, *Eriophyllum lanatum, Pteridium aquilinum* and *Lupinus oreganus*, and the exotic forb, *L. vulgare*, were the most abundant; despite these native species, the exotic forb *L. vulgare* dominated total forb cover (Appendix C, Figure 10). Exotic grasses, *D. glomerata*, *F. arundinacea* 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. *Festuca arundinacea* was the most abundant composing 55% of total cover in Kincaid's lupine habitat. Competition by exotic species, including tall fescue (*F. arundinacea),* orchard grass (*D. glomerata)* and oxeye daisy (*L. vulgare*) continues to be a threat to Kincaid's lupine and other native species at Oak Basin.

In 2014, species richness increased 21% across all three meadows, with 80 species present as compared to only 65 and 72 species in 2013 and 2012, respectively (Appendix C, Figure 11). This reversed trend was especially promising as years 2012 and 2013 had excessive declines in species richness across all meadows. While species richness was not as abundant as in 2011, the documented increase has shown improvement in heterogeneity of species, however these increases could reflect increases in both exotic and native species. In 2014, Meadow C contained the highest species richness with 65 total species, and Meadow A and B had slightly lower richness totals with 60 and 54, respectively. Meadow C exhibited a 23% increase in species richness from 2013 to 2014, which contributes greatly to the overall increased trend in increased richness across all sites (Figure 11).

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. Even though there was greater species richness at Oak Basin in 2014, this may be short-lived as there still was a growth in exotic species cover. Likewise, increasing species richness and species heterogeneity may not have as much of a positive impact if those species are invasive. Exotic species have potential to outcompete native species by limiting available space, nutrients, and water. Oak Basin has exhibited a decline in total species richness since the study began, with a slight increase in 2014. Although species richness increased overall in 2014, the decline in Kincaid's lupine experienced in 2012- 2013, coupled with the increase in exotic graminoid cover, is cause for serious concern.

The size of this Kincaid's lupine population and utilization by Fender's blue butterfly make Oak Basin an essential site for conservation, thus maintaining the health of the lupine population and management of aggressive exotic species should be the utmost priority. The trends in plant community composition in recent years indicate that one of the greatest threats to Kincaid's lupine at Oak Basin is competition with

exotic species. Exotic grasses, including tall fescue (*F. arundinacea)*, orchard grass (*D. glomerata*), and the exotic forb, oxeye daisy (*L. vulgare*), are a threat to all patches of lupine. *F. arundinacea* should be targeted by management treatments due to its presence in both lupine and non-lupine habitat in all three meadows (Figure 10). These species may be competing with Kincaid's lupine and preventing population growth or reducing existing populations. Active management as suggested in the draft Oak Basin Management and Implementation Plans will be required in the future in order to prevent the competitive exclusion of lupine.

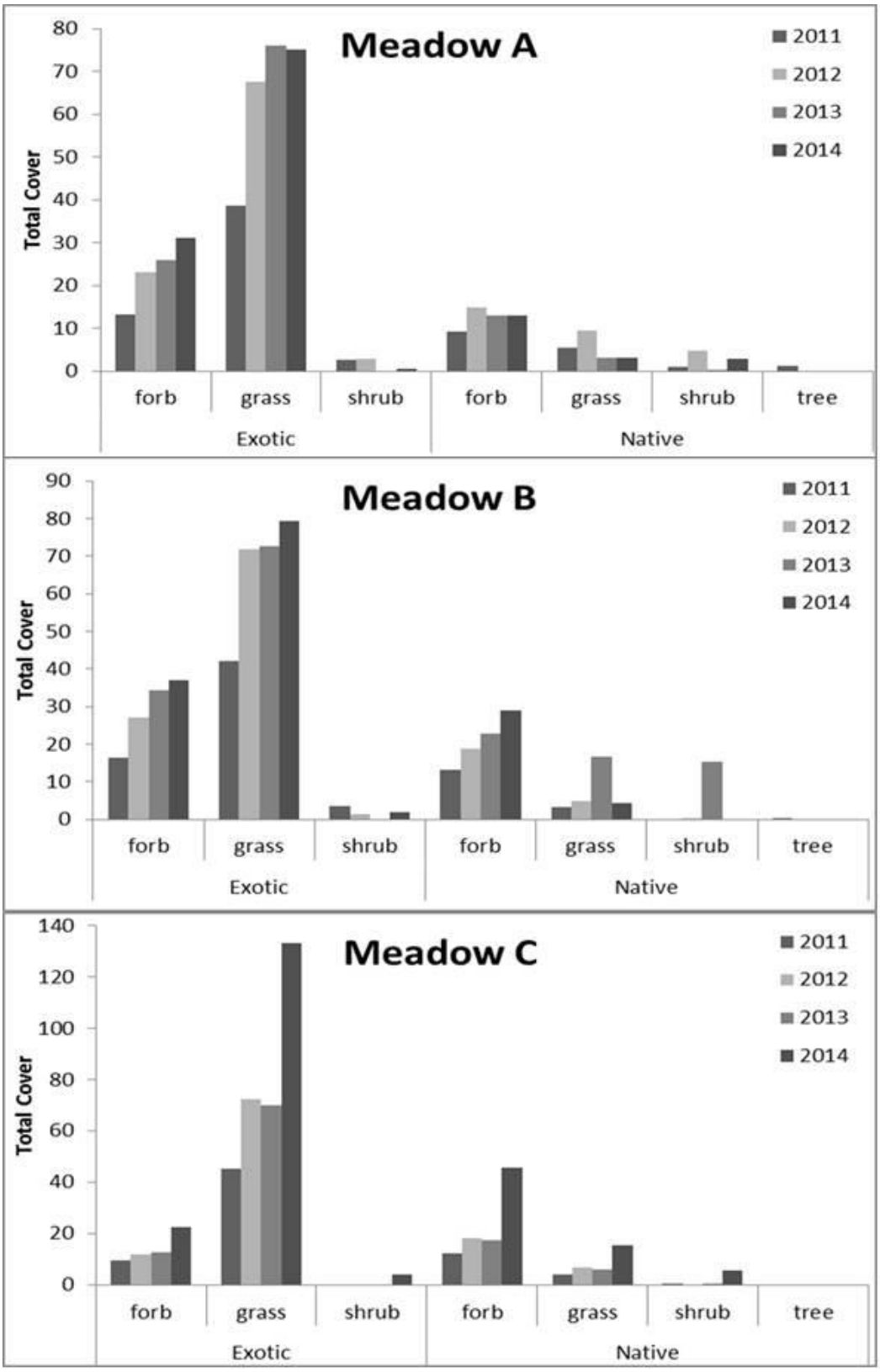


FIGURE 9. TOTAL NATIVE AND EXOTIC PLANT COVER SEPARATED INTO FUNCTIONAL GROUPS AT OAK BASIN IN 2011, 2012, 2013, AND 2014 IN MEADOWS A, B, AND C.

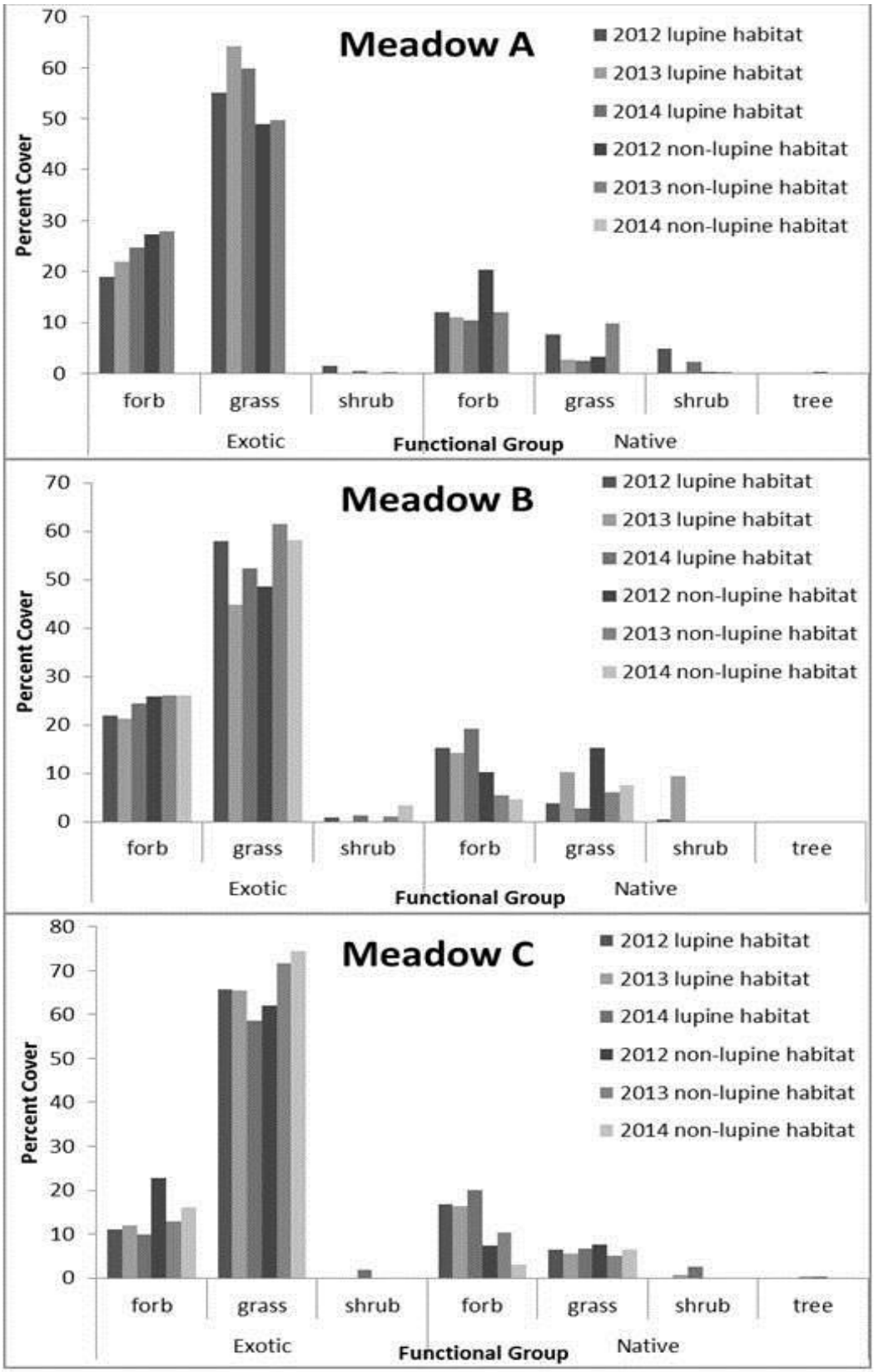


FIGURE 10. TOTAL NATIVE AND EXOTIC PLANT COVER SEPARATED INTO FUNCTIONAL GROUPS IN LUPINE AND NON-LUPINE HABITAT AT OAK BASIN IN 2012, 2013, AND 2014 IN MEADOWS A, B, AND C.

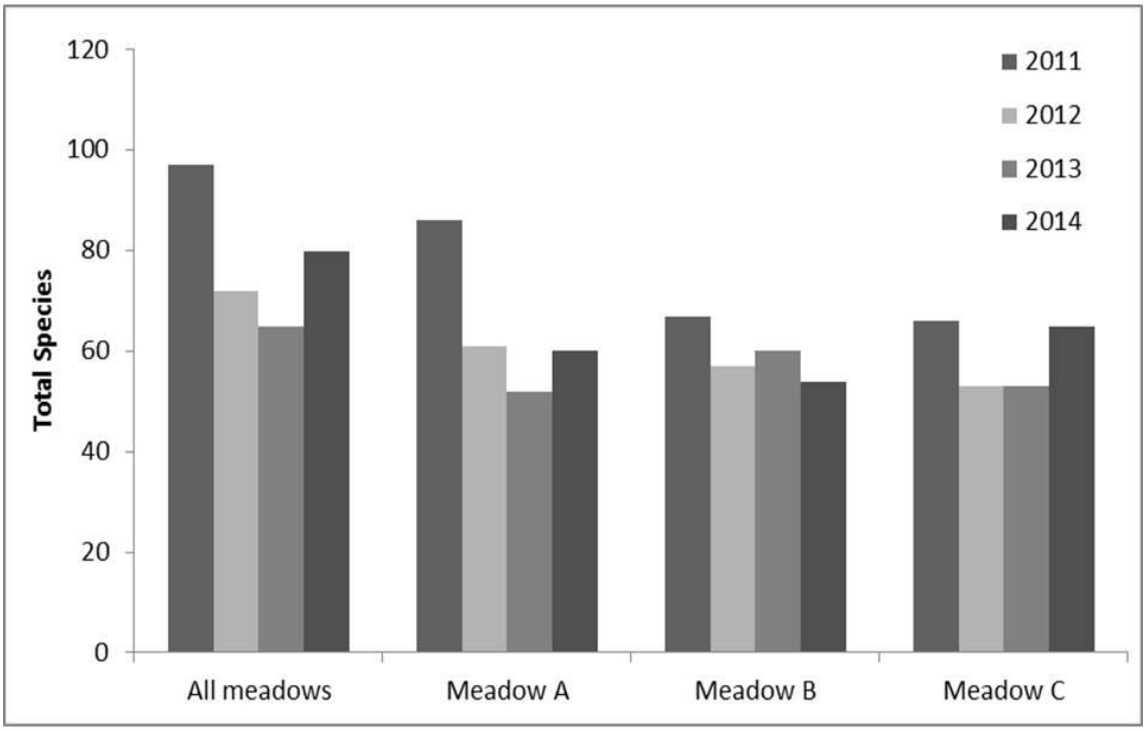


FIGURE 11. SPECIES RICHNESS ACROSS ALL MEADOWS AND INDIVIDUAL MEADOWS A, B, AND C FROM 2011-2014.

Sisyrinchium hitchcockii monitoring

In 2014, reproductive effort of *S. hitchcockii* increased greatly, though this increase was not consistent across all reproductive stem classes (Figure 13). Between 2012 and 2014, there were reductions in totals stems for reproductive stem classes, R1, R2 and R3 with the R1stem class decreasing by 69% (from 55 to 17, respectively). This decline has continued since 2012, when monitoring was initiated. However, despite these declines, we observed a pronounced increase of reproductive individuals in the higher reproductive stem classes, predominantly in R6 and R7. Overall, the reproductive effort in 2014 increased greatly by 145% from 2013 to 2014, from 92 to 225 total inflorescences, respectively.

FIGURE 12. *SISYRINCHIUM HITCHCOCKII* (HITCHCOCK'S BLUE-EYED GRASS) AT OAK BASIN.

In 2013, the opposite findings of 2014 were recorded with a 28% decline in reproductive effort, while vegetative individuals increased 45% in 2013 (Figure 13). Between 2012 and 2013, there was a decline in reproductive effort from 128 to 92 inflorescences and total vegetative individuals increased from 42 to 47, respectively.

Due to the rhizomatous growth of *S. hitchcockii* (Figure 13), plants greater than 20 cm apart were deemed to be distinct individuals unless there was clear evidence otherwise (ex. exposed rhizomes). While this methodology was consistent with that used by other *Sisyrinchium* sp. studies (Groberg et al. 2013), we may have under-represented the true number of individuals present; plants may spread through growth, thus causing groupings of separate individuals during monitoring. This drawback is practical because the overall goal was to determine the reproductive effort of this species, and the sampling method does not affect the total inflorescence count.

We have been monitoring *S. hitchcockii* for three years (2012-2014), from these data it has become evident that the *S. hitchcockii* population has undergone some high annual variability relating to the number of vegetative vs. reproductive individuals. Reproductive effort in this *S. hitchcockii* population increased greatly in 2014, possibly due to a favorable growth year. The fact that the reproductive effort and growth of the lupine population also improved greatly in 2014 suggests that a ubiquitous factor such as climate could be affecting these trends. It remains vital to monitor the *S. hitchcockii* population to track population variability in coming years in insure that these populations are remaining viable.

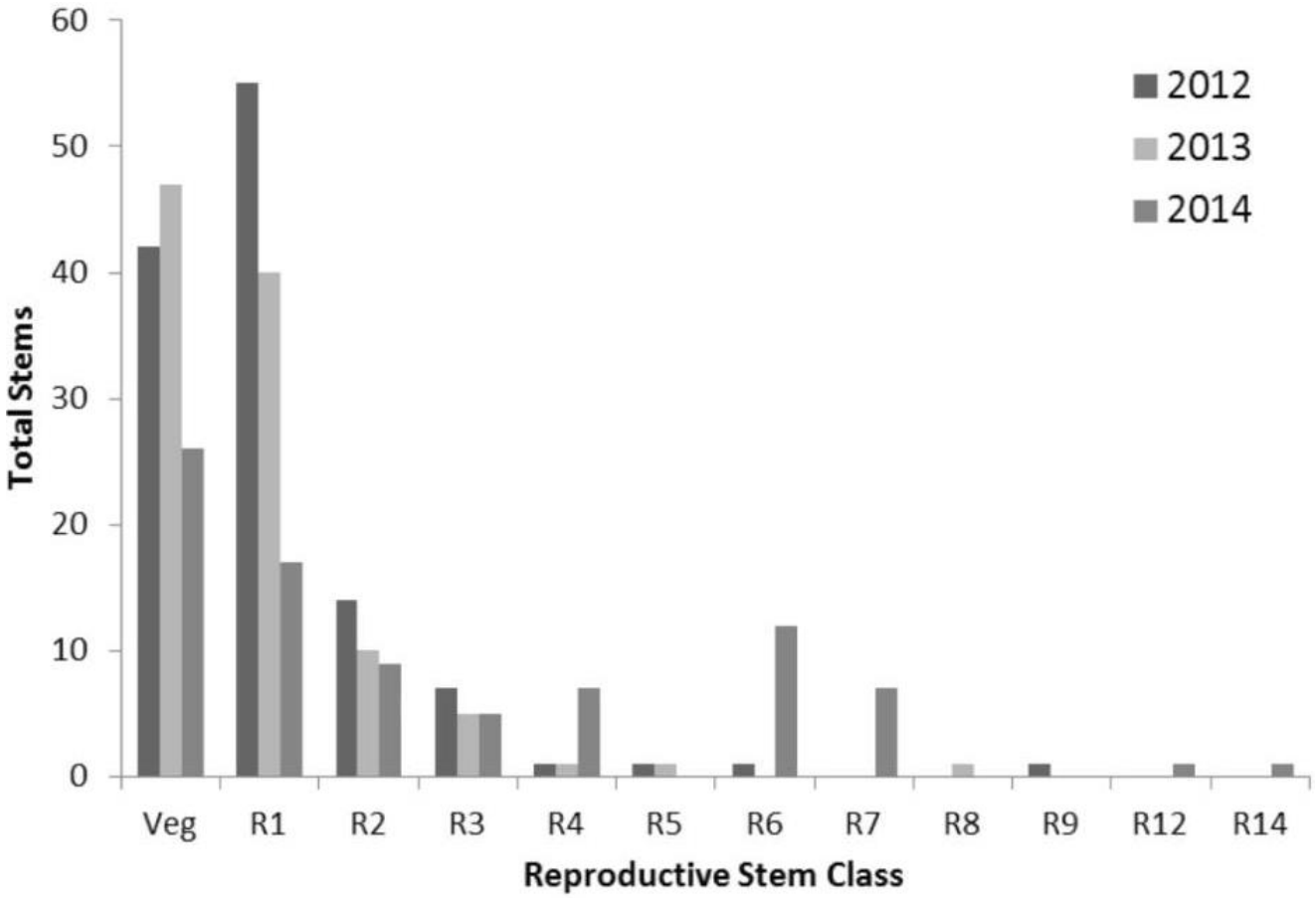


FIGURE 13. TOTAL STEMS OF *SISYRINCHIUM HITCHCOCKII* FOR EACH REPRODUCTIVE STEM CLASS IN 2012-2014 AT OAK BASIN MEADOW C. PLANTS WERE NOTED TO BE EITHER VEG (VEGETATIVE INDIVIDUALS WITH NO FLOWERS) OR R (SIGNIFYING A REPRODUCTIVE INDIVIDUAL) WITH A NUMBER AFTER REPRESENTING THE NUMBER OF REPRODUCTIVE STEMS FOR THAT INDIVIDUAL.

Synthesis

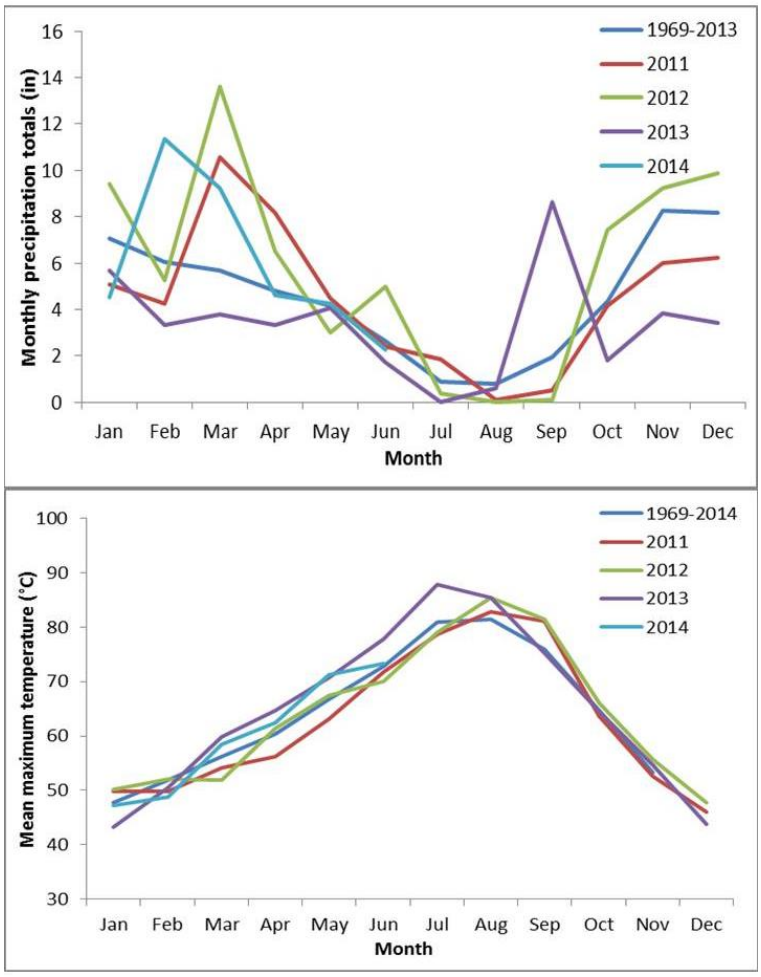


FIGURE 14. CLIMATE SUMMARIES FOR MONTHLY PRECIPITATION (ABOVE) AND MEAN MAXIMUM TEMPERATURE TOTALS (BELOW) AT OAK BASIN.

Population dynamics of Kincaid's lupine and *S. hitchcockii* have been variable in recent years. The dramatic decline observed in 2013 of Kincaid's lupine foliar cover and reproductive effort at Oak Basin was 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. The major differences in population dynamics of both of these species during the study might be partially changes in climate observed over recent years.

Climate in 2011-2014 differed in comparison to long-term averages, but 2013 varied greatly from other years (Figure 14, Western Regional Climate Center 2008). This difference in climate might be attributed to the low foliar cover and reproductive effort, and increased aborted inflorescences observed (Table 2). Compared to the long-term averages, 2013 experienced much lower precipitation during from January-March as well as much higher than average mean maximum temperatures from March-July (Figure 14). Consequently, 2014 was much wetter and temperatures were more similar to other years, which could be attributed to increases observed in 2014.

In closing, the plant community from 2011-2014 has experienced significant changes that could negatively impact the rare species present, in particular Kincaid's lupine. All meadows have experienced large increases in both invasive forbs and grasses from 2011-2014. Invasive grasses and forbs can compete with Kincaid's lupine for nutrients, light availability, and space (Figure 9). Management activities focused on targeting invasive species in Kincaid's lupine habitat will be necessary to perpetuate this rare species. Continued monitoring of *S. hitchcockii* will enable us to see if the decline of reproductive effort in 2013 and subsequent recovery in 2014 is a short-term or long-term trend. Restoration efforts implemented at Oak Basin in 2013 may have had a positive impact based on personal observations, but continued monitoring will be essential to document its response to these efforts.

Recommendations

Based on the results from 2014, we recommend the following actions at Oak Basin:

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 15. 2012 IAE INTERN EDDIE RAMIREZ IN MEADOW A, WHICH HAS A DENSE COVER OF OXEYE DAISY.

LITERATURE CITED

Bureau of Land Management, Eugene District (BLM) 2008. Western Oregon Plan Revision Record of Decision and Resource Management Plan.

Giles-Johnson, D. E. L., A.S. Thorpe and R.T. Massatti. 2009. *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's lupine) and *Icaricia icarioides fenderi* (Fender's blue butterfly) at Oak Basin. Prepared by the Institute for Applied Ecology for the USDI Bureau of Land Management, Eugene District. Corvallis, OR. v + 29.

Giles-Johnson, Thorpe, A.S., Newton, R.E.., and T.N. Kaye. 2010. *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's lupine) and *Icaricia icarioides fenderi* (Fender's blue butterfly) in the West Eugene Wetlands: Population monitoring, reintroduction success, and an evaluation of experimental treatments. 2010 Report. Prepared by the Institute for Applied Ecology for the USDI Bureau of Land Management, Eugene District. Corvallis, OR..

Giles-Johnson, D. E.L., E.C. Gray, A.S. Thorpe, and T.N. Kaye. 2011. Population monitoring for *Lupinus oreganus* var. *kincaidii* (Kincaid's lupine) at Eagle's Rest. Prepared by the Institute for Applied Ecology for the USDI Bureau of Land Management, Eugene District. Corvallis, Oregon. iii + 11.

Groberg, M.G., S.C. Meyers, P.M. Severns, and K. Amsberry. 2013. Systematic evaluation of *Sisyrinchium hitchcockii* (Iridaceae): A rare, endemic species of North America. Phytoneuron 2013-88: 1-7.

Kaye, T.N. 1999. Obligate insect pollination of a rare plant, *Lupinus sulphureus* ssp. *kincaidii*. Northwest Science 73:50-52.

Kaye, T.N. and A. Brandt. 2005. Seeding and transplanting rare Willamette Valley prairie plants for population restoration, Fifth Year (2004) Report. Prepared by Institute for Applied Ecology for the USDI Bureau of Land Management, Eugene District. Corvallis, OR.

Schultz, C.B. and E.E. Crone. 1998. Burning prairie to restore butterfly habitat: a modeling approach to management tradeoffs for the Fender's blue. Restoration Ecology 6:244-252.

Severns, P.M. 2006. 2006 Fender's blue butterfly season summary for Oak Basin. Report submitted to the Eugene District BLM.

Oregon Biodiversity Information Center. 2013. Rare, Threatened and Endangered Species of Oregon. Institute for Natural Resources, Portland State University, Portland, Oregon. 111 pp.

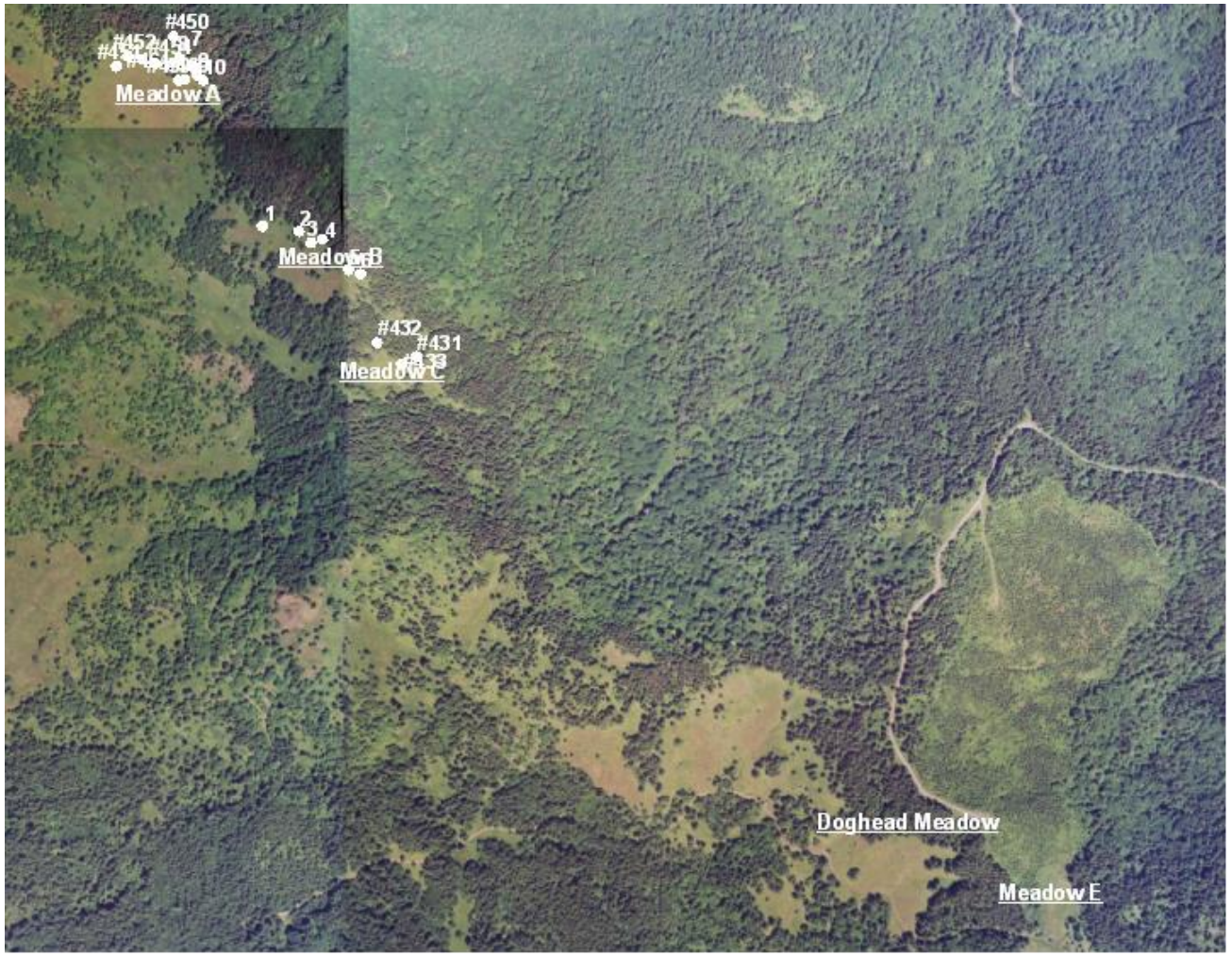
U.S. Fish and Wildlife Service. 2000. Endangered and threatened wildlife and plants; Endangered status for *Erigeron decumbens* var. *decumbens* (Willamette daisy) and Fender's blue butterfly (*Icaricia icarioides fenderi*) and proposed threatened status for *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's lupine). Federal Register 65:3875-3890.

U.S. Fish and Wildlife Service. 2008. Draft Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington. U.S. Fish and Wildlife Service, Portland, Oregon. x + 212 pp.

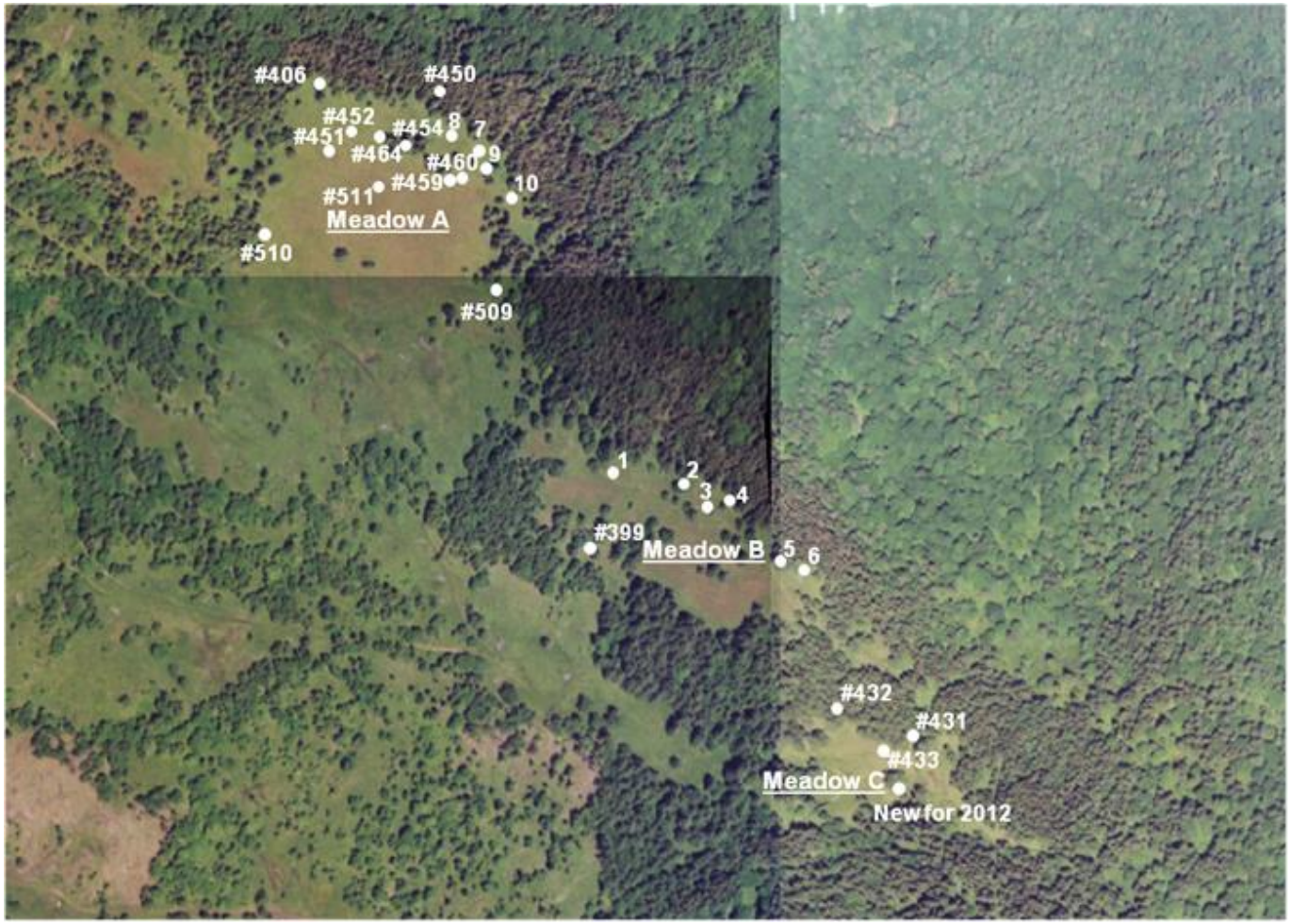
Western Regional Climate Center. 2008. Corvallis, Eugene, and Douglas County (RAWS), Monthly Climate Summary: 1965-2013. Available at: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?orcowb. Accessed July 18, 2014.

Wilson, M.V., T. Erhart, P.C. Hammond, T.N. Kaye, K. Kuykendall, A. Liston, A.F. Robinson Jr., C.B. Schultz, and P.M. Severns. 2003. Biology of Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii* [Smith] Phillips), a threatened species of western Oregon native prairies, USA. Natural Areas Journal 23:72-83

APPENDIX A. AERIAL PHOTOS AND PLOT DIAGRAMS OF THE OAK BASIN STUDY AREA.



AERIAL PHOTO OF THE OAK BASIN STUDY AREA. PLOT NUMBERS AND MEADOW NAMES ARE INDICATED.



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

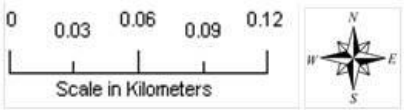
~1.5m radius around rebar

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

~8m x 1m strip going N to S

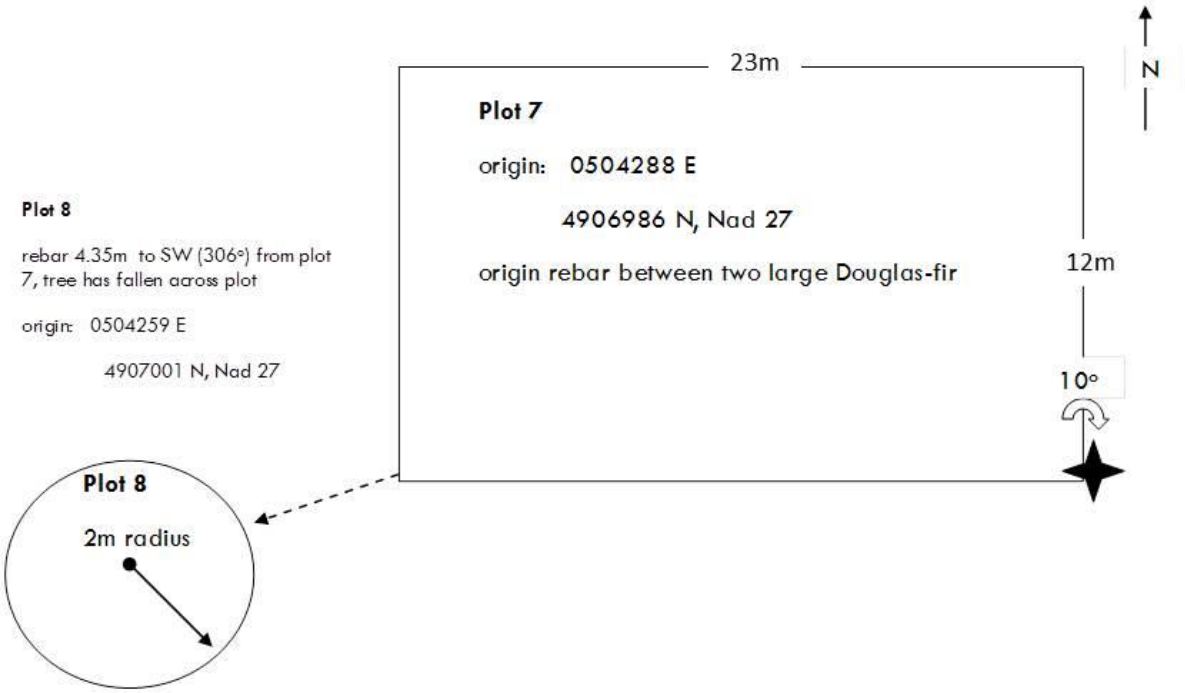
511: Center population in middle of hill at 230 degrees from westernmost PSME of PSME island on top of hill near plot 459.

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

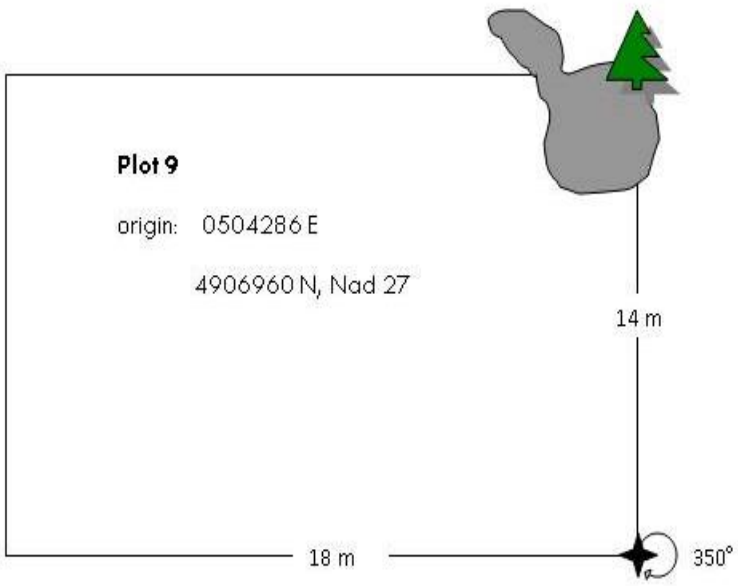


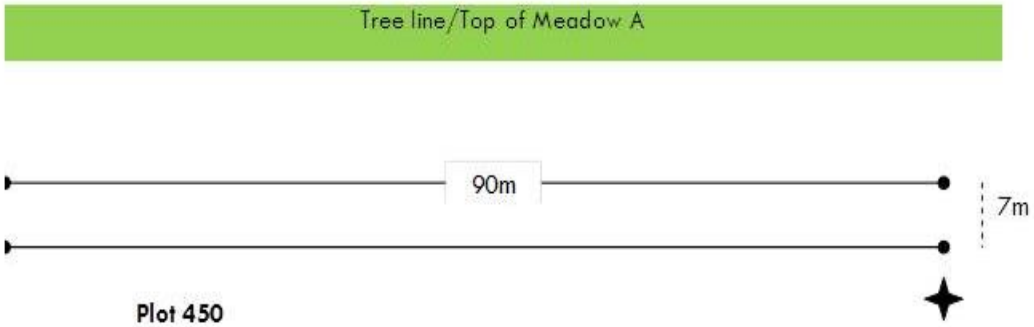
DIAGRAMS OF KINCAID'S LUPINE MONITORING PLOTS AT OAK BASIN MEADOW A.

Meadow A

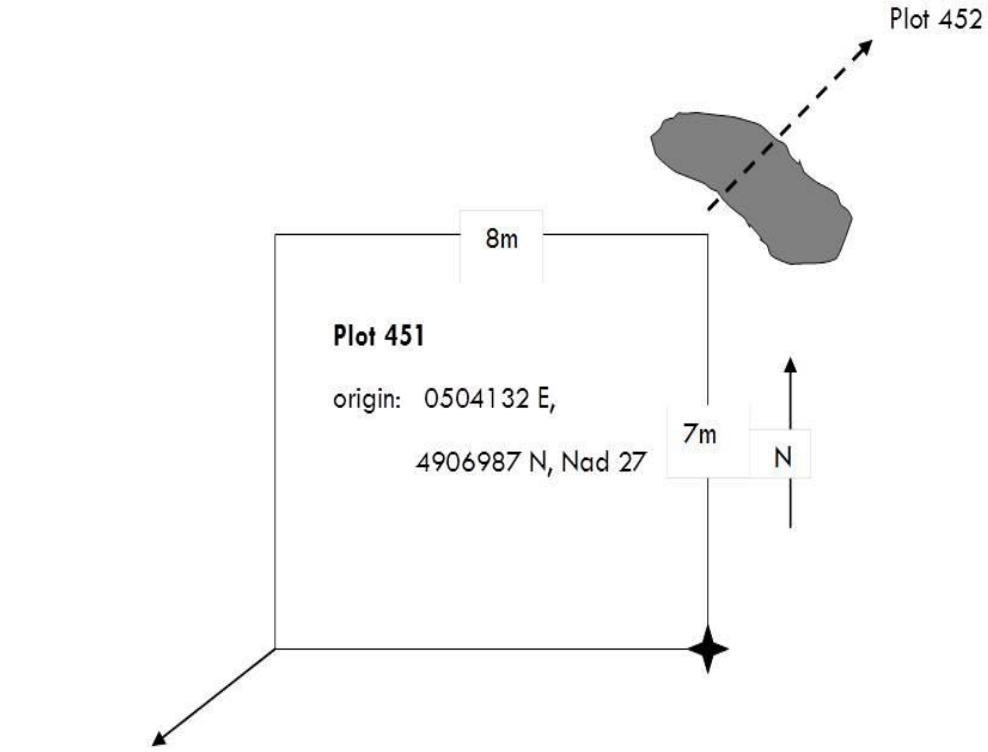

23m
N
Plot 7
origin: 0504288 E
4906986 N, Nad 27
origin rebar between two large Douglas-fir
12m
10°
Plot 8
rebar 4.35m to SW (306°) from plot 7, tree has fallen across plot
origin: 0504259 E
4907001 N, Nad 27
Plot 8
2m radius

Meadow A

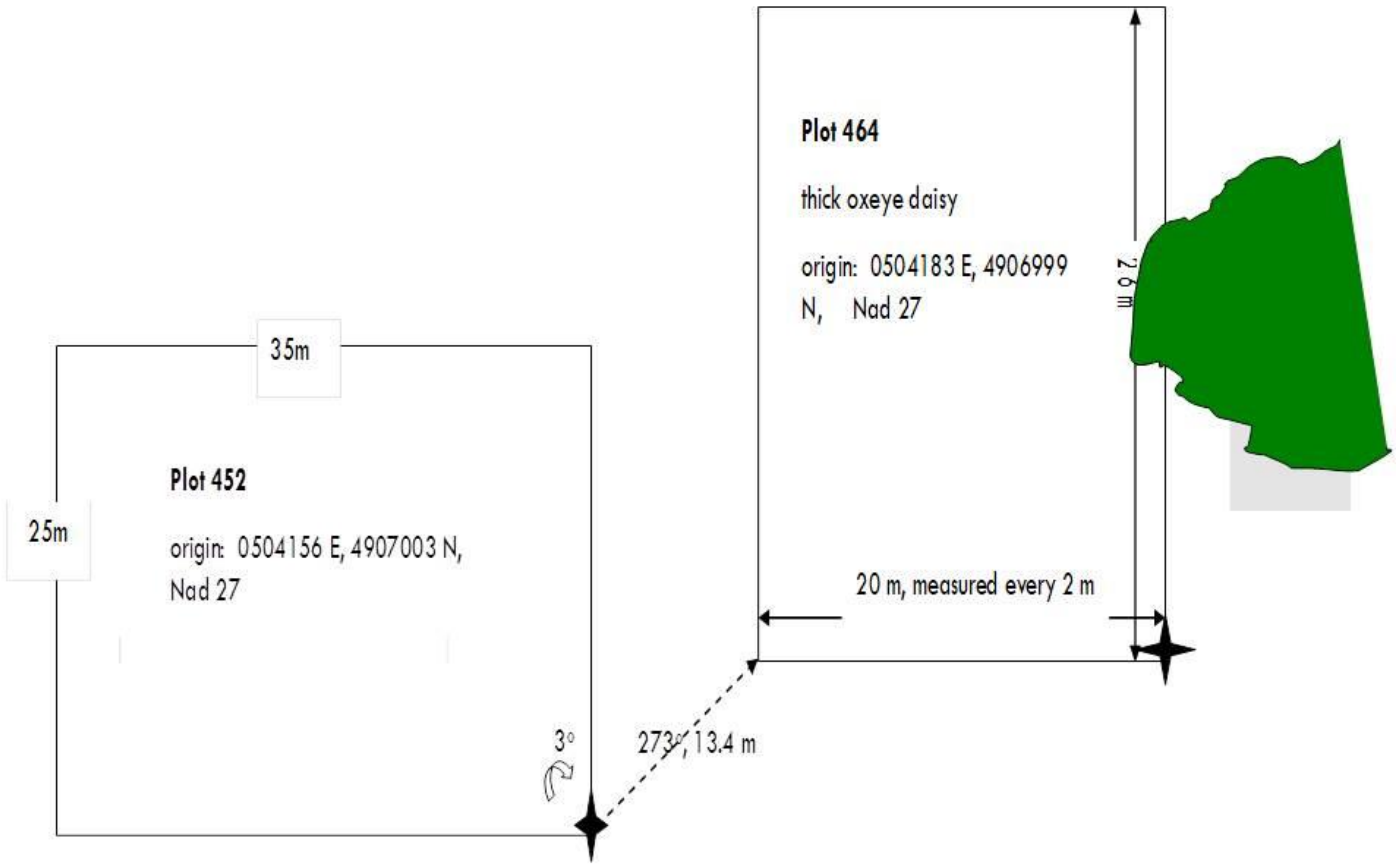

Plot 9
origin: 0504286 E
4906960 N, Nad 27
14 m
18 m
350°

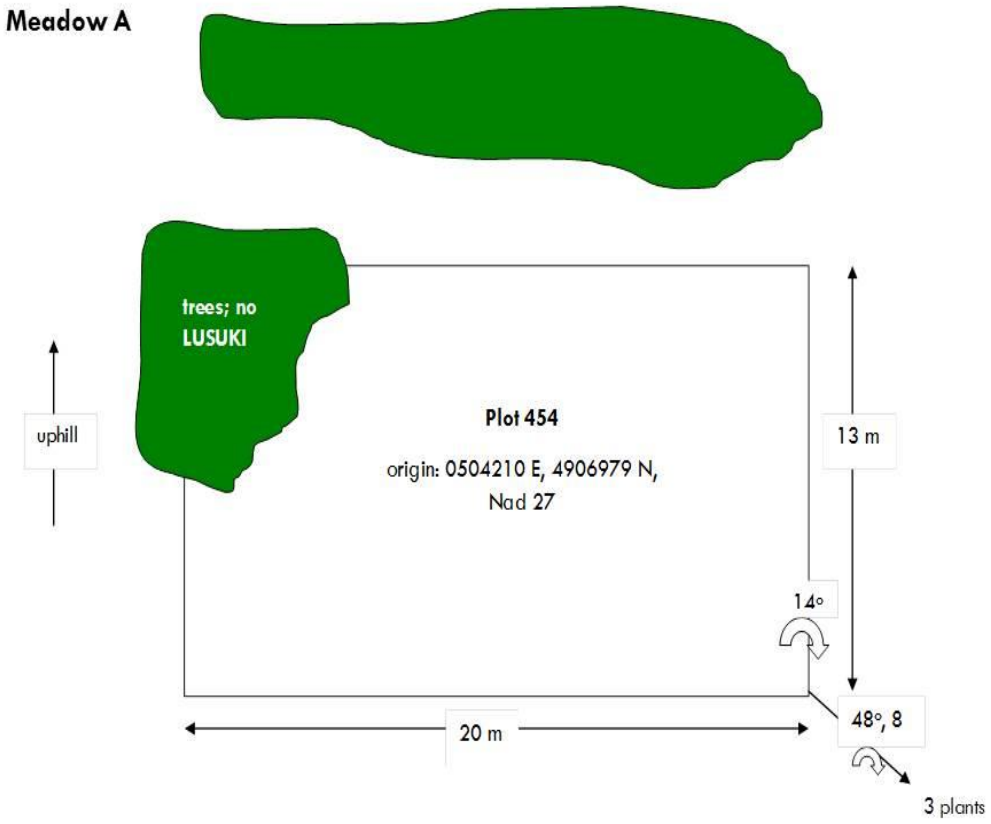

Tree line/Top of Meadow A
90m
7m
Plot 450
origin: 0504232 E

Meadow A

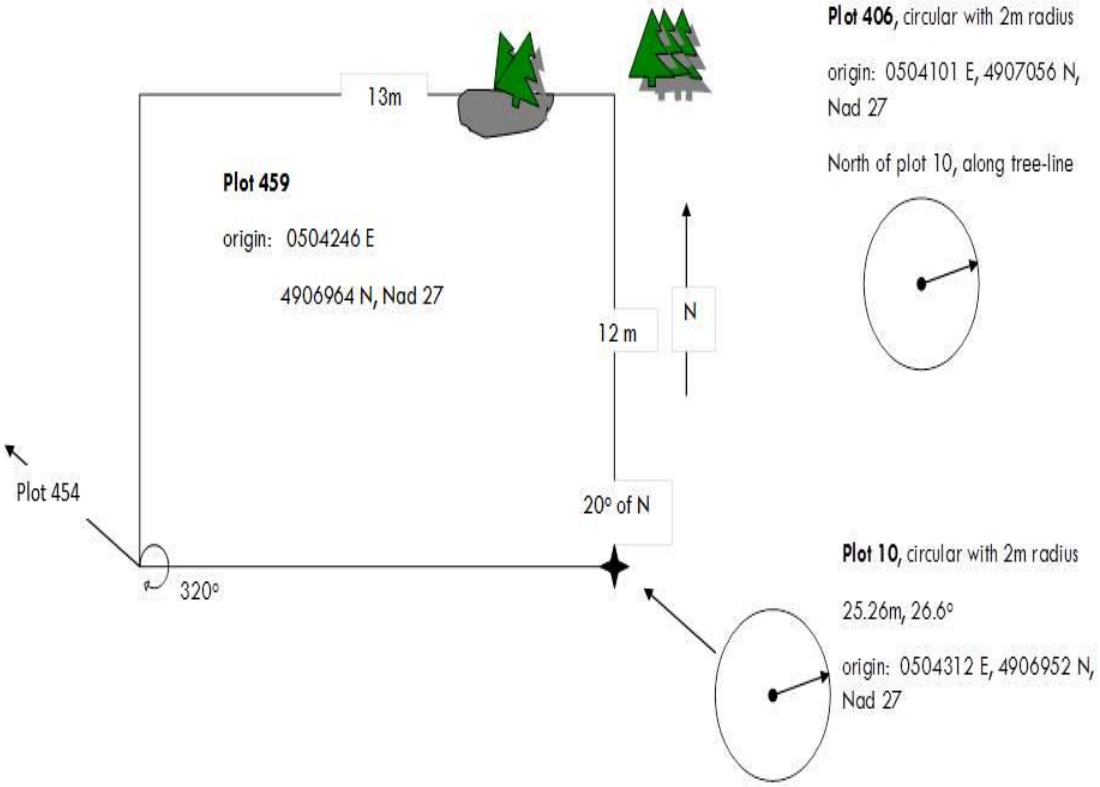

Plot 452
8m
Plot 451
origin: 0504132 E,
4906987 N, Nad 27
7m
N
2 plants outside plot,
6m at 64°

Meadow A

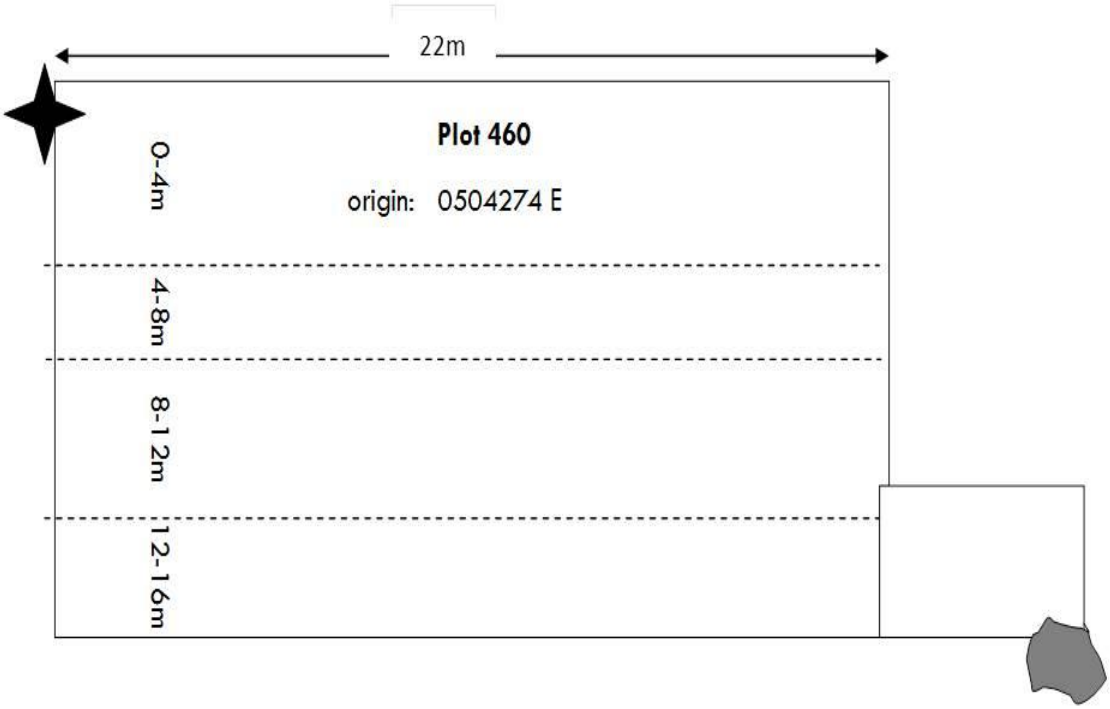

Plot 464
thick oxeye daisy
origin: 0504183 E, 4906999 N, Nad 27
26 m
35m
Plot 452
25m
origin: 0504156 E, 4907003 N, Nad 27
20 m, measured every 2 m
3°
273°, 13.4 m


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

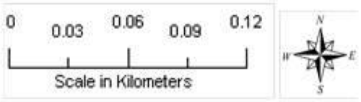
Meadow A


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.

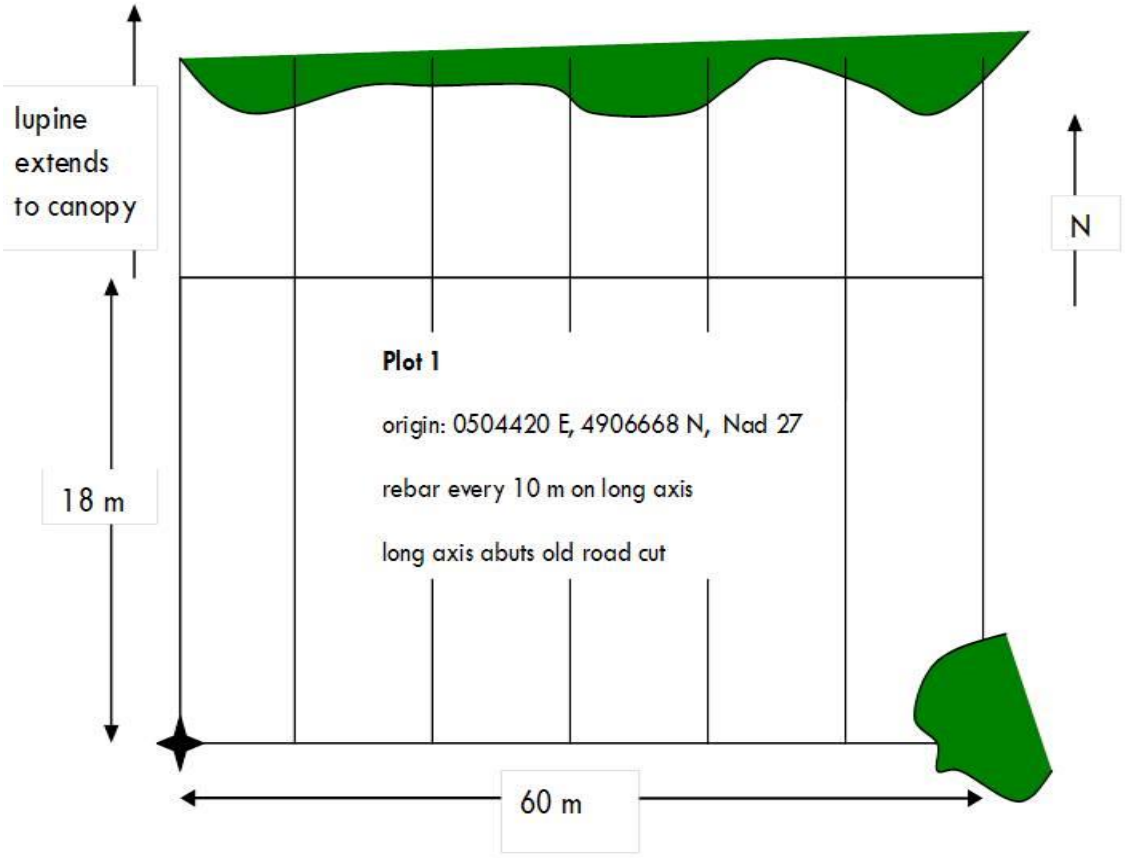
Near PSME with ACMA growing with itwhere hill steeply drops off.

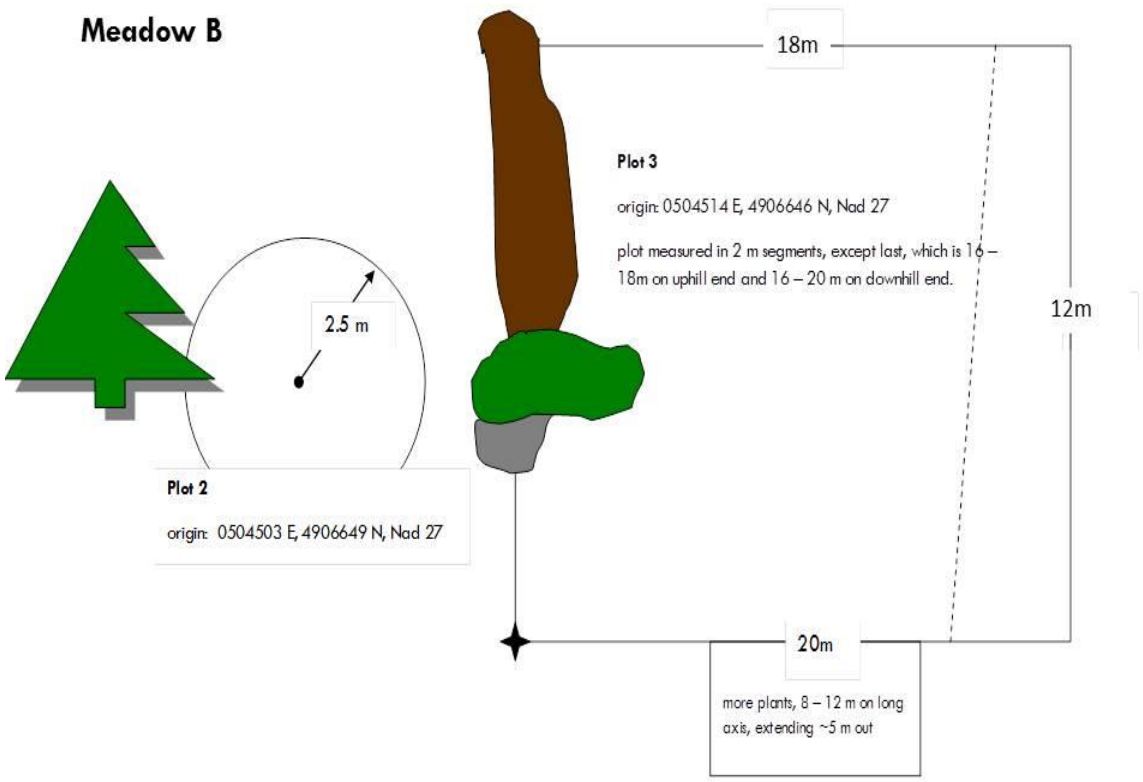
Population has been captured in a rectangle plot with 14m x 11m sides. Origin is in NE corner and has conduit, the other corners have rebar with yellow caps.

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

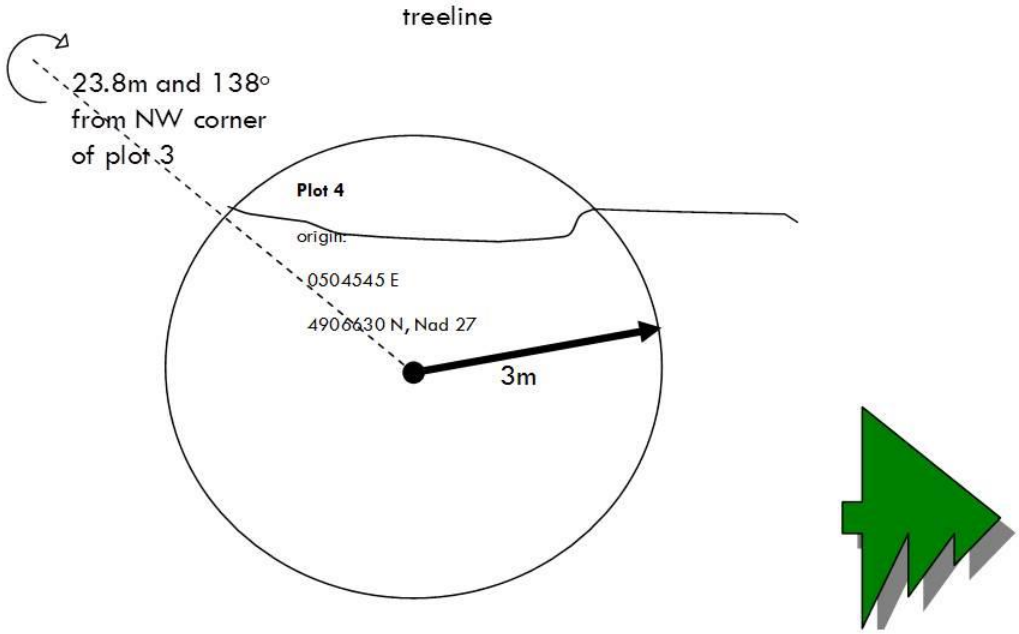
OVERVIEW OF PLOTS IN MEADOWS B AND C.

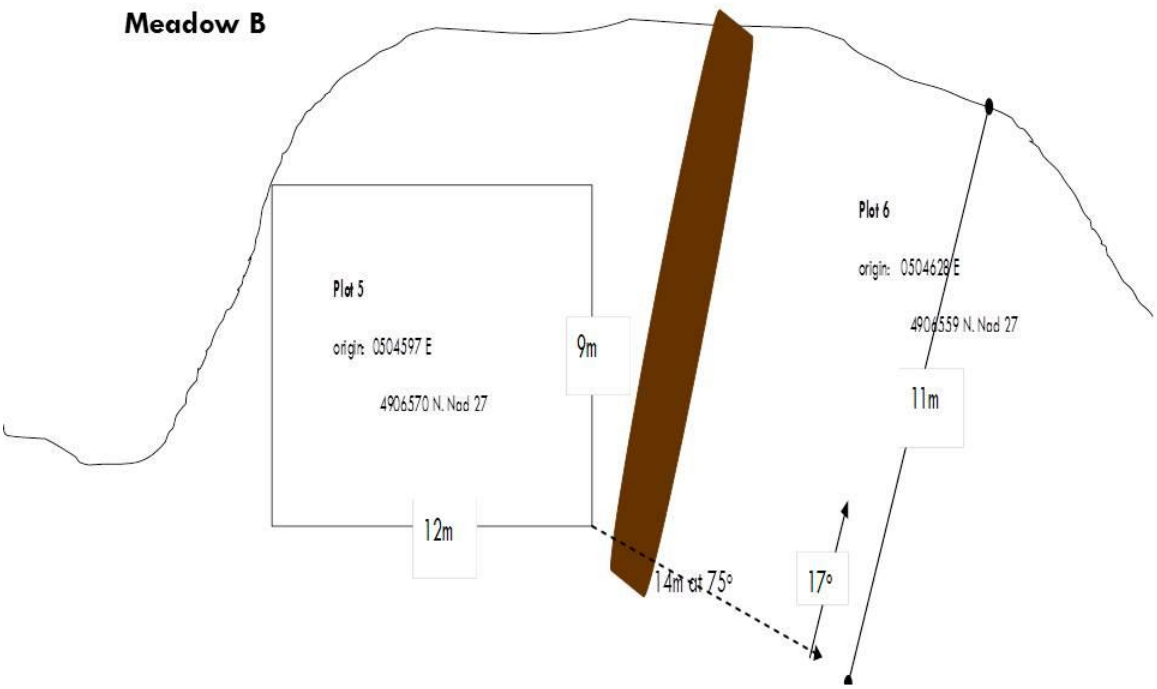
Meadow B

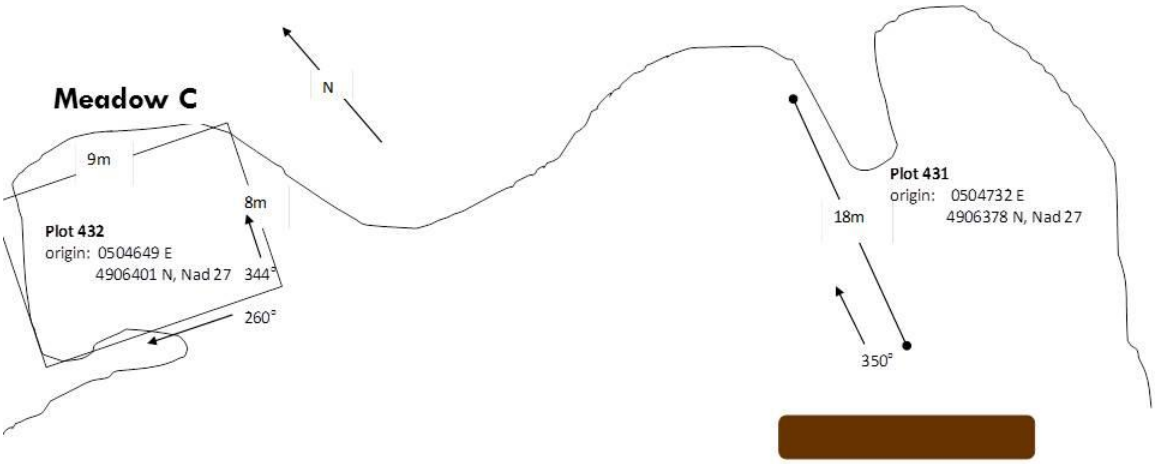

lupine
extends
to canopy
N
Plot 1
origin: 0504420 E, 4906668 N, Nad 27
rebar every 10 m on long axis
long axis abuts old road cut
18 m
60 m

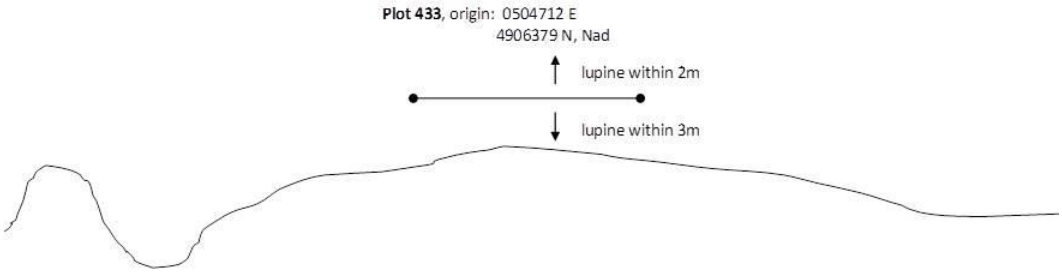

Meadow B
18m
Plot 3
origin: 0504514 E, 4906646 N, Nad 27
plot measured in 2 m segments, except last, which is 16 – 18m on uphill end and 16 – 20 m on downhill end.
12m
2.5 m
Plot 2
origin: 0504503 E, 4906649 N, Nad 27
20m
more plants, 8 – 12 m on long axis, extending ~5 m out

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
Plot 6
origin: 0504628 E
4906559 N. Nad 27
9m
11m
12m
14m at 75°
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 2014, CALCULATED BY HABITAT TYPE (LUPINE OR NON-LUPINE), AND BY MEADOW.

	All meadows		Meadow A		Meadow B		Meadow C	
Species	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat
Forbs								
Achillea millefolium	1.08	1.52	1.81	0.00	0.45	1.80	0.28	1.20
Adenocaulon bicolor	0.03	0.00	0.00	0.00	0.00	0.00	0.11	0.00
Aster hallii	0.19	0.01	0.17	0.00	0.25	0.00	0.18	0.02
Brodiaea coronaria	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.00
Brodiaea sp.	0.03	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Calochortus tolmiei	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Centaurium erythraea	0.05	0.08	0.07	0.00	0.02	0.00	0.03	0.18
Cerastium glomeratum	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Cirsium sp.	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.08
Cirsium vulgare	0.20	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Clarkia amoena	0.24	0.31	0.43	0.00	0.12	0.29	0.01	0.33
Dianthus armeria	0.02	0.01	0.04	0.00	0.00	0.01	0.30	0.00
Dichelostemma sp.	0.11	0.08	0.03	0.00	0.00	0.00	0.00	0.17
Epilobium brachycarpum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Erigeron speciosus var. *speciosus*	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Eriophyllum lanatum	3.59	1.93	2.18	0.00	3.67	2.29	5.89	1.52
Fragaria vesca	0.13	0.00	0.00	0.00	0.67	0.00	0.00	0.00
Fragaria virginiana	0.74	0.00	0.01	0.00	0.00	0.00	2.44	0.00
Galium aparine	0.24	0.09	0.47	0.00	0.00	0.17	0.01	0.00
Geranium dissectum	1.04	1.58	1.03	0.00	1.67	2.29	0.62	0.77
Hypericum perforatum	0.40	1.09	0.09	0.00	1.33	1.71	0.29	0.37
Hypochaeris radicata	1.08	0.00	1.13	0.00	0.00	0.00	1.72	0.00
Iris tenax var. *tenax*	1.00	0.00	0.03	0.00	3.83	0.00	0.73	0.00
Lapsana communis	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Lathyrus sp.	0.08	0.04	0.00	0.00	0.00	0.00	0.28	0.08
Leucanthemum vulgare	20.89	21.38	23.83	0.00	29.17	23.86	10.46	18.50
Linanthus bicolor	0.06	0.00	0.04	0.00	0.18	0.00	0.00	0.00
Linum bienne	0.42	0.18	0.67	0.00	0.12	0.17	0.20	0.20
Lotus formosissimus	0.03	0.00	0.00	0.00	0.00	0.00	0.11	0.00
Lotus micranthus	0.36	0.00	0.25	0.00	0.00	0.00	0.79	0.00
Lupinus oreganus	3.02	0.00	4.03	0.00	3.83	0.00	0.78	0.00
Madia gracilis	2.02	0.00	3.82	0.00	0.50	0.00	0.02	0.00

	All meadows		Meadow A		Meadow B		Meadow C	
Appendix C continued	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat
Myosotis discolor	0.01	0.02	0.03	0.00	0.00	0.03	0.00	0.00
Navarretia squarrosa	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Oenanthe sarmentosa	0.80	0.00	1.60	0.00	0.00	0.00	0.00	0.00
Osmorhiza berteroi	0.20	0.00	0.00	0.00	0.00	0.00	0.68	0.00
Plantago lanceolata	2.53	2.15	2.97	0.00	3.50	2.00	1.17	2.33
Potentilla gracilis	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Prunella vulgaris var. *lanceolata*	0.80	0.12	0.27	0.00	0.33	0.14	2.00	0.08
Pteridium aquilinum	4.23	0.38	0.13	0.00	5.17	0.14	10.44	0.67
Ranunculus occidentalis	0.05	0.00	0.01	0.00	0.02	0.00	0.12	0.00
Ranunculus repens	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Rumex acetosella	0.08	0.31	0.09	0.00	0.17	0.57	0.00	0.00
Rupertia physodes	1.40	0.00	0.13	0.00	6.67	0.00	0.00	0.00
Sanicula graveolens	0.25	0.00	0.00	0.00	0.00	0.00	0.83	0.00
Satureja douglasii	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Senecio jacobaea	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Sherardia arvensis	0.16	0.04	0.29	0.00	0.03	0.04	0.02	0.03
Sidalcea virgata	1.18	0.00	0.40	0.00	3.35	0.00	1.02	0.00
Synthyris reniformis	0.33	0.00	0.00	0.00	0.00	0.00	1.11	0.00
Taraxacum officinale	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Torilis arvensis	0.07	0.47	0.08	0.00	0.03	0.86	0.07	0.02
Tragopogon dubius	0.07	0.04	0.00	0.00	0.33	0.07	0.00	0.00
Trifolium dubium	0.05	0.01	0.00	0.00	0.00	0.00	0.17	0.02
Veronica americana	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.02
Vicia gigantea	0.10	0.00	0.20	0.00	0.00	0.00	0.00	0.00
Vicia hirsuta	0.00	0.15	0.00	0.00	0.00	0.29	0.00	0.00
Vicia sativa	0.44	0.82	0.45	0.00	0.52	1.21	0.38	0.35
Vicia tetrasperma	0.02	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Viola praemorsa	0.00	0.04	0.00	0.00	0.00	0.07	0.00	0.00
Wyethia angustifolia	0.67	0.04	0.00	0.00	0.00	0.00	2.22	0.08
Zigadenus venenosus	0.14	0.00	0.27	0.00	0.00	0.00	0.00	0.00
Grasses								
Agrostis capillaris	1.50	1.46	2.47	0.00	0.33	2.14	0.67	0.67
Aira caryophyllea	0.59	0.39	1.17	0.00	0.00	0.71	0.03	0.02
Alopecurus pratensis	0.27	0.00	0.53	0.00	0.00	0.00	0.00	0.00
Briza minor	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.03
Bromus carinatus	4.18	2.38	5.27	0.00	1.17	2.00	4.39	2.83
Bromus hordeaceus	1.41	1.98	2.44	0.00	0.67	3.64	0.18	0.03
Bromus vulgaris	0.23	0.62	0.23	0.00	0.58	1.14	0.00	0.00
Carex tumulicola	0.20	0.92	0.07	0.00	0.17	0.00	0.44	2.00
Cynosurus echinatus	4.95	1.00	7.33	0.00	0.70	1.21	3.82	0.75
Dactylus glomerata	8.57	12.62	7.47	0.00	15.33	20.57	5.89	3.33

	All meadows		Meadow A		Meadow B		Meadow C	
Appendix C continued	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat	lupine habitat	non-lupine habitat
Danthonia californica	1.64	0.52	2.27	0.00	0.50	0.00	1.34	1.12
Deschampsia danthonioides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elymus glaucus	0.30	1.25	0.07	0.00	0.33	2.30	0.67	0.02
Elymus trachycaulus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca arundinacea	55.47	61.23	42.33	0.00	55.83	30.57	77.11	97.00
Festuca sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca roemeri	4.37	4.08	6.20	0.00	1.17	5.00	3.44	3.00
Festuca rubra var. commutata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Holcus lanatus	0.87	0.38	1.20	0.00	1.33	0.71	0.00	0.00
Koeleria macrantha	0.30	0.00	0.27	0.00	0.83	0.00	0.00	0.00
Luzula sp.	0.02	0.02	0.01	0.00	0.03	0.01	0.03	0.02