Monitoring and restoration of Kincaid's lupine (*Lupinus oreganus*) and Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) at Oak Basin: 2019 Annual Report

3/31/2020

Report to the Bureau of Land Management, Upper Willamette Resource Area: Northwest Oregon District, L16AC00241 and L18AC00073

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Institute for Applied Ecology

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PREFACE

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 photographs: Kincaid's lupine (*Lupinus oreganus*) and Oak Basin Meadow A.

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EXECUTIVE SUMMARY

This report documents the seventh year of restoration activities and fourteenth year of monitoring conducted by the Institute for Applied Ecology (IAE) at Oak Basin, an upland prairie managed by the Northwest Oregon District of the Bureau of Land Management (BLM). This site is home to Kincaid's lupine (*Lupinus oreganus*), a threatened species, and Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*), a federal Species of Concern. Kincaid's lupine serves as the primary larval host plant for the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*). The small population of Fender's blue butterfly on BLM lands at Oak Basin has been on the decline since 2015, and only 25 individuals were documented in 2019. All three species are endemic to western Oregon prairies.

Management treatments

Management treatments conducted in 2019 included mowing in lupine patches to reduce invasive perennial grass and shrub cover, flame weeding patches of non-native grass near Kincaid's lupine patches, removal of conifers between meadow cooridors to increase meadow connectivity and reduce woody encroachment around lupine patches, and hand pulling/grubbing of noxious weeds including Himalayan blackberry (*Rubus bifrons*), Scotch broom (*Cytisus scoparius*), and Italian plumeless thistle (*Carduus pycnocephalus*).

Kincaid's lupine

In 2019, total Kincaid's lupine foliar cover at Oak Basin was 168.6 m^2, an increase of 5.2 m^2 from 2018. The total number of racemes was the highest ever counted at the site for both mature and aborted racemes (4,563 and 1,244 respectively). Since the initiation of management, Meadows A and C have returned to cover and raceme counts similar to those observed prior to 2013; however, Meadow B has continued to decline in both foliar cover and raceme count. A subset of transplanted Kincaid's lupine plants was also monitored for survival at Oak Basin Tree Farm, a neighboring private property. Of the 50 plugs monitored, 27 (54%) were still alive two years after transplanting.

Hitchcock's blue-eyed grass

The number of Hitchcock's blue-eyed grass individuals and reproductive stems have both increased since 2016 and in 2019, 160 reproductive stems were counted, though this remains below the high of 225 observed in 2015. Hitchcock's blue-eyed grass and Kincaid's lupine have followed roughly parallel trajectories in population size at Oak Basin, both declining from 2012 to 2016, and it is likely that some shared factor(s), such as climate and/or competition with exotic species, could be impacting the success of these populations.

Recommendations

Based on effects of management actions and the importance of this site for reaching recovery goals for Fender's blue butterfly and Kincaid's lupine, continued management for introduced species, particularly introduced perennial and annual graminoids, is recommended. Activities in 2020 should include continued control of introduced species and tree removal around the forest-meadow edge and in corridors to increase connectivity between meadows. More specifically, if prescribed burning and herbicide treatments become options for weed control at Oak Basin, we recommend that the meadows and especially the corridors between meadows be treated for weeds using all available tools, followed by

and heavily seeding and planting treated areas with a mix of native nectar species and perennial grasses. In addition, Kincaid's lupine should be put into production for mid-elevation prairies in preparation for the opening of corridors and the exposed ground that will be created when herbicide and broadcast burning become available at Oak Basin.

Monitoring and restoration of Kincaid's lupine (*Lupinus oreganus*) and Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) at Oak Basin: 2019 Annual Report

INTRODUCTION

This report documents rare plant and community monitoring and restoration activities conducted by the Institute for Applied Ecology (IAE) at Oak Basin in 2019. Oak Basin, a site managed by the Upper Willamette Field Office in the Northwest Oregon District of the Bureau of Land Management (BLM), supports the largest known Kincaid's lupine (*Lupinus oreganus*; Figure 1) population in the Upper Willamette Field Office, and is home to a population of the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*, Figure 1). The Oak Basin Fender's blue butterfly is relatively small, with only 25 butterflies documented in 2019 (Ross 2019), and it remains sensitive to complete sub-population collapse.

Figure 1. Kincaid's lupine (*Lupinus oreganus*, top) and Fender's blue butterfly (*Icaricia icarioides fenderi*, bottom).

Vegetation monitoring by IAE at Oak Basin is focused on documenting the population size and reproduction of Kincaid's lupine, as well as assessing habitat quality at the site. This information is used to determine the effectiveness of restoration treatments at the site and to document long-term population trends in support of meeting recovery goals as outlined in the Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (Recovery Plan; U.S. Fish and Wildlife Service 2010). In addition to monitoring Kincaid's lupine, IAE also monitors a population of the rare Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) to document population trends.

Oak Basin is a BLM-owned property located in Linn County, approximately six miles southeast of Brownsville, Oregon. IAE has been partnering with the BLM to monitor rare plant and animal populations since 2006 and to restore and manage prairie habitat since

2012. Management actions at the site are consistent with those necessary to support populations of these rare species.

Species status and information

Kincaid's lupine is a member of the legume family (Fabaceae). It 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 (Severns et al. 2011). Kincaid's lupine requires insects for successful fertilization and seed formation (Kaye 1999). It 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 the federally endangered Fender's blue butterfly larvae (Oregon Biodiversity Information Center 2016), conservation of lupine populations is a common goal for the protection of both species. Kincaid's lupine is listed by the Oregon Department of Agriculture and the U.S. Fish and Wildlife Service as a threatened species (Oregon Biodiversity Information Center 2016).

Hitchcock's blue-eyed grass is a rhizomatous perennial forb in the Iris family (Iridaceae; Figure 2). This species reproduces by seed as well as by clonal vegetative growth. It is listed as a federal Species of Concern by the U.S. Fish and Wildlife Service (Oregon Biodiversity Information Center 2016) and is a Bureau Sensitive Species for the BLM.

Figure 2. Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*); (a) long and narrow leaves with parallel veins that are mostly basal (b) 3-chambered capsules up to 6 mm long containing black seeds (c) flowers have blue to bluish-purple tepals with a faint (or absent) yellow "eye" in center.

Oak Basin has been identified as a potential Functioning Network to meet the downlisting goals for Fender's blue butterfly. The site also contributes to the recovery of Kincaid's lupine; the population currently meets the minimum local foliar cover of 100 m^2 recovery criterium (U.S. Fish and Wildlife Service 2010) in Meadow A, one of the three main meadows at the site. Additionally, large patches of Kincaid's lupine occur on the adjacent, privately-owned 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 U.S. Fish and Wildlife's Partners for Fish and Wildlife Program.

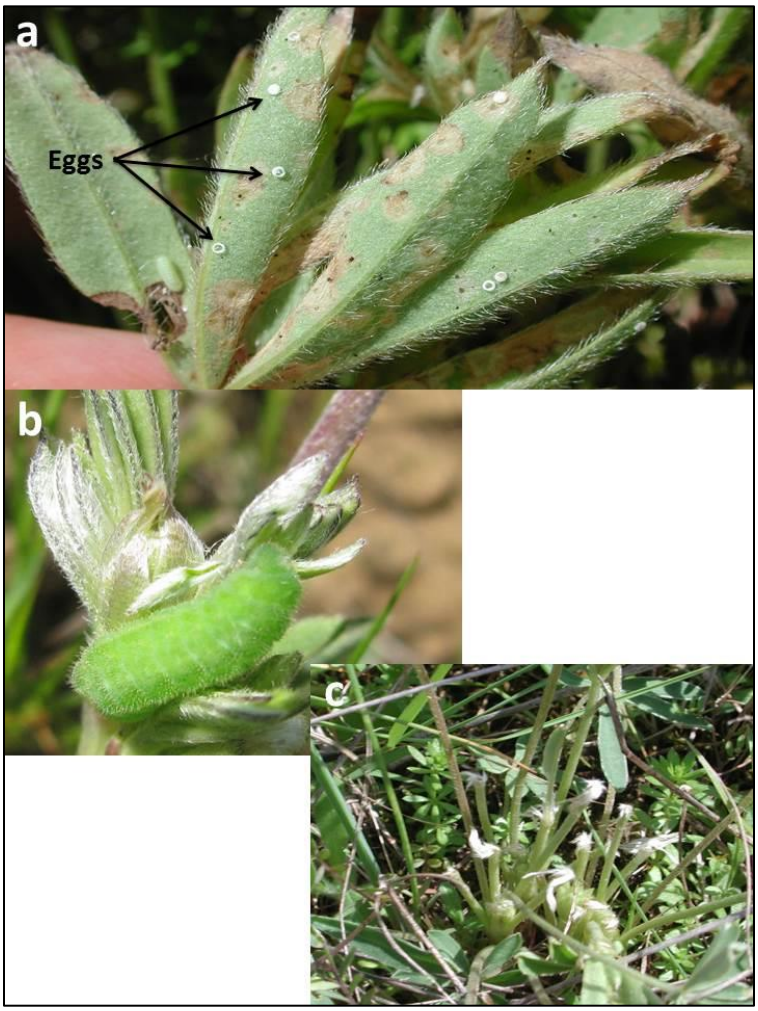

Figure 3. Fender's blue butterfly (*Icaricia icarioides fenderi*) on Kincaid's lupine (*Lupinus oreganus*); (a) female Fender's blue butterflies oviposit small white eggs on the undersides of lupine leaves. Herbivory of Kincaid's lupine by larvae (b) of Fender's blue butterfly results in clusters of damaged stems, leaves, and growing points (c) because the larvae typically feed on young leaves and apical meristems.

Fender's blue butterfly life cycle

Fender's blue butterflies (FBB) are mature adults in May and June. This is 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 and 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).

The 2019 range-wide FBB population estimate was 24,196, an increase of 57% from 2018 (Menke 2019). At Oak Basin, however, the small FBB population in Meadow A has been in decline since 2015, and the current population estimate is 25 butterflies.

GOALS AND OBJECTIVES

Habitat restoration

The goals of restoration actions at Oak Basin are to maintain and improve prairie habitat in support of Kincaid's lupine and its associated Fender's blue butterfly populations. The four primary objectives of this project are to:

1. Maintain/improve quality prairie habitat by removing non-native invasive plants
2. Prevent encroachment of woody species into the prairie
3. Increase diversity and abundance of the native plant community
4. Improve connectivity between meadows at Oak Basin

Monitoring

The objectives of the monitoring portion of this project are to monitor the population of Kincaid's lupine at Oak Basin and examine overall Kincaid's lupine habitat quality over time. Specifically, we aim to link these data with habitat restoration activities occurring on-site, conducted and facilitated by IAE, and to document population size and trends to ensure that the population remains stable or increasing, with area of foliar cover being maintained at or above the minimum targets as laid out in the Recovery Plan and listed below (U.S. Fish and Wildlife Service 2010). Additionally, a second objective is to assess the status of the Hitchcock's blue-eyed grass population and to help guide restoration activities therein.

Recovery goals

- Increase the Fender's blue butterfly population to a minimum of 200 individuals, with the population remaining stable or increasing over a period of 10 years
- Maintain Kincaid's lupine foliar cover at a minimum area of 100m^2 in each meadow, with the population remaining stable or increasing over a period of 15 years. Ideally, this population will increase in size beyond the minimum area necessary to count towards recovery. The Oak Basin site is within the Eugene East Recovery Zone. This zone has a target of supporting at least two populations with total foliar cover of 5000 m^2.
- Kincaid's lupine populations must show evidence of reproduction by seed set or through the presence of seedlings.
- Increase cover of native prairie species to at least 50%.
- Decrease woody species cover to less than 15%.
- Increase prairie species diversity so that there are at least 10 native prairie species including seven or more forbs and at least one native bunchgrass (within a representative 25 m^2 area).
- Decrease non-native vegetation such that no single non-native plant has more than 50% cover.
- Increase nectar species abundance at the site. Sufficient abundance of nectar species should be available at the site throughout the Fender's blue butterfly flight season, with sufficient abundance of nectar (20 mg nectar sugar/m^2) and at least five native nectar species present (within a 25 m^2 area).

METHODS

Habitat restoration

Oak Basin habitats include upland prairie and oak (*Quercus garryana*), maple (*Acer macrophyllum*), and Douglas-fir (*Pseudotsuga menziesii*) woodlands. Restoration efforts focus on three meadows (Meadows A, B, and C; Figure 4 and 5). In 2019, IAE coordinated and implemented a variety of activities to support restoration and conservation efforts at Oak Basin. Major activities included flame weeding of several key areas, Himalayan blackberry (*Rubus bifrons*)/Scotch broom (*Cytisus scoparius*) grubbing, hand pulling of Italian plumeless thistle (*Carduus pycnocephalus*) populations, mowing in Kincaid's lupine patches, removal of conifers along the north edge of Meadow B and between Meadows A and B and seeding in areas disturbed by tree removal activities. Restoration actions are detailed in Table 1. See Figure 4 and Figure 5 for the geographic locations of 2019 management actions. Appendix A includes a summary of restoration activities conducted at Oak Basin from 2012 to 2019.

Table 1. On-the-ground restoration activities completed at Oak Basin in 2019.

Date	Activity	Who	Notes
2/21	Site Visit	IAE and BLM	Initial site visit for the year and introduction of Oak Basin to John Klock (Upper Willamette Field Office Botanist).
3/21 and 5/2	Weed treatment	IAE	Hand pulled Italian plumeless thistle, Scotch broom, and removed Douglas-fir and grand fir (*Abies grandis*) seedlings and saplings from edges of Meadow A.
5/07	Weed treatment and monitoring	IAE and Walama Restoration Project	Grubbed Himalayan blackberry in Meadows C and B. Handpulled Italian plumeless thistle populations in Meadow B.
6/11	Weed treatment and monitoring coordination	IAE	Hand weeded Italian plumeless thistle and coordinated monitoring efforts with Denise Giles.
7/24 and 8/7	Seed collection	IAE	East Eugene Kincaid's lupine seed collection at Oak Basin and Eagle's Rest.
10/9 and 10/10	Mowing	IAE	Mowed Kincaid's lupine plots in Meadows A, B, and C.
10/15	Flame weeding	IAE and Walama Restoration Project	Flame weeded five different patches of annual and perennial grasses covering approximately 0.75 acres in Meadows A and C.
10/21and 11/13	Tree removal prep	IAE, BLM, and Jim Merzenich	Prepare for tree removal in November.
11/18	Tree removal	IAE and Oregon Woods	Cut 60 trees between Meadows A and B and along the northern edge of Meadow B.
11/27 12/0412 /11 and 12/18	Brush piling and clearing	IAE and Americorps Blue 5 Team (12)	The Americorp crew cleaned up tree removal efforts from Oregon Woods work. Smaller branches were piled in preparation for burning. Larger logs were moved into the woods. Seeding on 12/18.

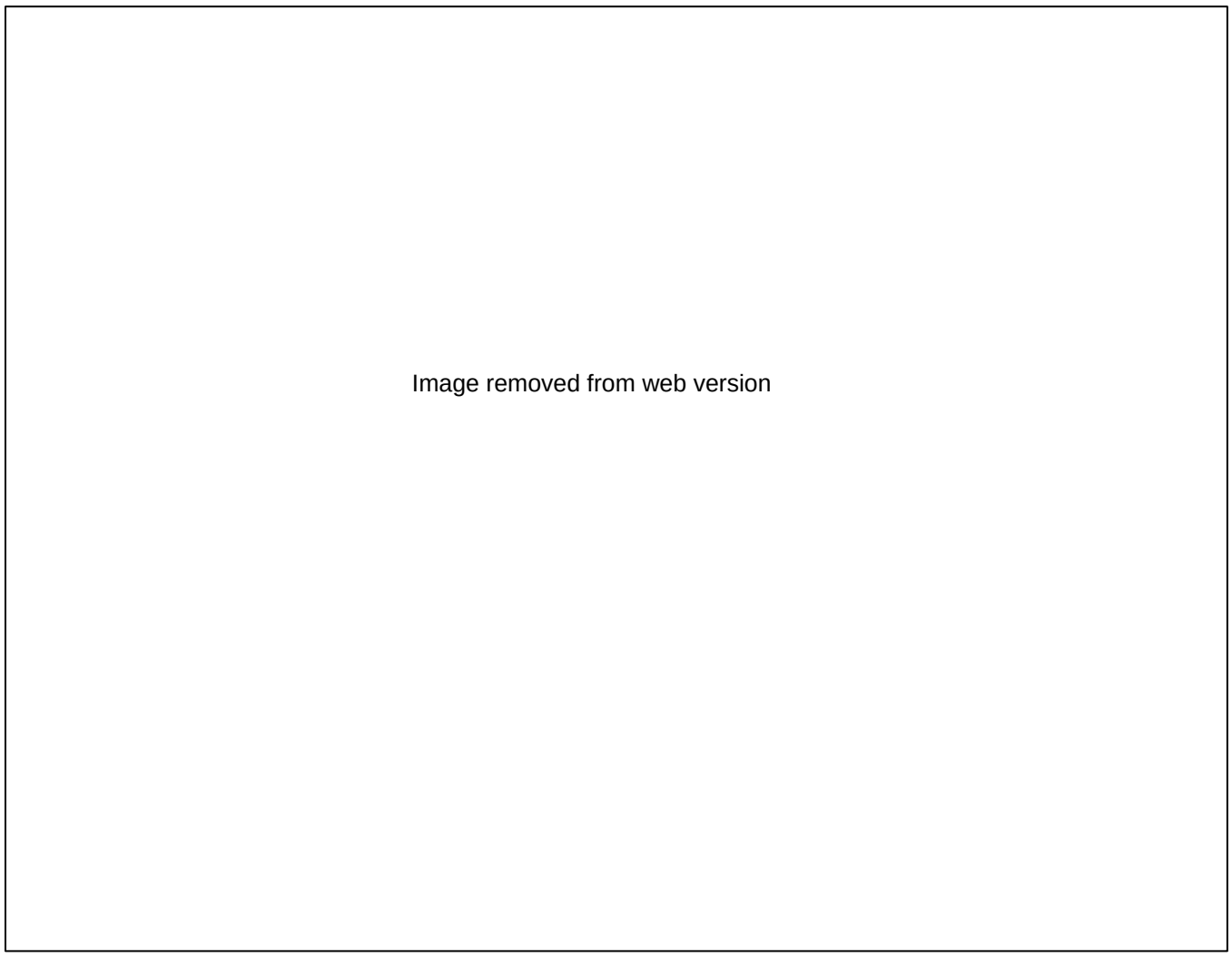

Figure 4. Management actions completed in Meadow A at Oak Basin in 2019.

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Figure 5. Management actions completed in Meadows B and C at Oak Basin in 2019.

Mowing

On October 9 and 10, 2019 the area in and around six Kincaid's lupine patches was mowed using a string trimmer to reduce standing thatch and remove competing non-native perennial grasses (Figure 4, Figure 5, and Figure 6). The goal is to mow competing vegetation within approximately 1/3 of the area occupied by Kincaid's lupine in each of the three meadows annually; these patches rotate so that each patch is mowed every three years. Appendix B indicates the cover and raceme count of Kincaid's lupine patches and the years in which each patch has been mowed.

Figure 6. Kincaid's lupine (*Lupinus oreganus*) patch #1 in Meadow B before mowing (left) and after mowing (right).

Hand pulling of weeds

IAE staff and subcontractor Walama Restoration Project hand pulled several invasive species at Oak Basin: Himalayan blackberry, Scotch broom, and Italian plumeless thistle (Table 1). A large patch of Himalayan blackberry in Meadow B, located above Kincaid's lupine patch 001, and a patch in Meadow C were grubbed out of the ground using shovels (Figure 5 and Figure 7). The Himalayan blackberry patch in Meadow B has been grubbed annually since 2013. Kincaid's lupine Patch 001 and this population of blackberry overlap; individual lupine plants are marked with pin flags to allow grubbing to occur while avoiding damage to the threatened plants. In Meadow A, a Scotch broom population and Italian plumeless thistle population were hand pulled before the plants produced reproductive parts (Figure 4). In Meadow B, two populations of Italian plumeless thistle were hand pulled. The eastern population was newly discovered this year and should be monitored/treated yearly before flowering (Figure 5).

Figure 7. Walama Restoration Project removing a patch of Himalayan blackberry (*Rubus bifrons*) from Meadow C. The left photo shows the patch before treatment and the right shows it after.

Flame weeding

Although we had planned to flame weed in the spring to reduce cover of and competition from non-native grasses and thatch, hazardous fire conditions prevented these plans. Therefore, all flame weeding occurred in the fall of 2019 (Table 2). A total of 0.75 acres were burned. Four patches of dense annual and perennial grass in Meadow A (A3.5, A5, A6, and A 7) were flame weeded (October 15, 2019; see Figure 4 and 5). Three of these patches are new in the flame weeding rotation: A5, A6, and A7. Additionally, the Hitchcock's blue-eyed grass patch located in Meadow C was flame

Figure 8. Rolando Beorchia (IAE) flame weeding in October 2019.

weeded in an effort to reduce competition by densely established perennial non-native grasses for this Bureau-sensitive species (Figure 8).

Table 2. Management (mgmt) and monitoring (monitor) carried out in flame weeded patches from 2013 to 2019 at Oak Basin. Treatments for management are abbreviated: flame weeded (fw), handpulled (hp), planted with plugs (p), and seeded (s). Monitoring took place in late June/early July of each year and is summarized by the number of 1m^2 plant community plots surveyed within each patch. Seasons denoted as fall (Fa), spring (Sp), and summer (Su).

	Year	2013	2014	2015			2016			2017			2018			2019		
Patch	**Season**	**Fa**	**Fa**	**Sp**	**Su**	**Fa**	**Sp**	**Su**	**Fa**	**Sp**	**Su**	**Fa**	**Sp**	**Su**	**Fa**	**Sp**	**Su**	**Fa**
A1	Mgmt	FW/S	FW/P/S															
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A2	Mgmt	FW/S	FW/P/S															
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A3	Mgmt			FW			M/FW		FW	M/FW		FW/S	HP					
	Monitor	-	-	-	*5*	-	-	*5*	-	-	-	-	-	*7*	-	-	4	-
A3.5	Mgmt												FW		FW/S			FW
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	*7*	-	-	4	-
A4	Mgmt						FW		FW			FW	FW		FW/S			
	Monitor	-	-	-	-	-	-	1	-	-	-	-	-	8	-	-	4	-
A4N	Mgmt														FW			
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*5*	-
A5	Mgmt																	FW
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*5*	-
A6	Mgmt																	FW
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
A7	Mgmt																	FW
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
B1	Mgmt	FW/S	FW/S/P															
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	Mgmt	FW/S	FW/S/P															
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	Mgmt			FW		FW	FW		FW/P			FW/S			FW/S			
	Monitor	-	-	-	-	-	-	*5*	-	-	-	-	-	*7*	-	-	*5*	-
B4	Mgmt			FW		FW	FW		FW/P			FW/S			FW/S			
	Monitor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-

Tree removal

In early spring conifer seedlings and saplings were cut from along the north and east edges of Meadow A (Figure 4). Through a coordinated planning effort between the BLM, Oak Basin Tree Farm, and IAE on November 18th, Oregon Woods (subcontracter) removed approximately 35 conifers that were blocking light and preventing easy access for Fender's blue butterfly between meadows A and B (Figure 9). Additionally, Oregon Woods cut 25 trees along the north end of Meadow B to improve lupine habitat (Figure 5). Subsequently, a 12-person Americorps crew and IAE staff spent three days (11/27, 12/4, and 12/11) removing all the fallen tree debris by piling branches and leaves into the middle of the corridor and moving larger bucked rounds into the forest. On December 12, IAE staff completed piling efforts in Meadow B and broadcast seed into areas disturbed by tree removal activities.

Figure 9. Before (left column) and after photos (right column) of the corridor between Meadows A and B on 11/18/2019 when Oregon Woods spent the day cutting trees.

Seed collection

Wild collections of East Eugene Kincaid's lupine seed were collected from Oak Basin in late July and from Eagle's Rest in early August. This seed will be used to start a seed amplification bed at the IAE farm in spring of 2020.

Seeding

On December 18, 2019 a native grass and forb seed mix was broadcast onto areas disturbed by tree removal activities (Figures 4 and 5). A total of 4.5 lbs of native seed were sown in the corridor between Meadows A and B. See Table 3 for species included in the seed mix.

Table 3. Species seeded in those areas disturbed by tree removal activities on November 27, 2019.

Species	Growth form	Quantity (lbs)
Danthonia californica	Graminoid	0.87
Elymus glaucus	Graminoid	1.10
Festuca roemeri	Graminoid	0.34
Wyethia angustifolium	Forb	2.20

Monitoring methods

Flame weeding monitoring

Treatment history for the patches flame weeded from 2013 to 2019 is listed in Table 2. In 2015 and/or 2016, plant community data were collected from five 1m^2 plots in each of the areas that had been flame weeded (A3 – 2015 and 2016, B4 – 2016 only) and two 1m^2 plots in adjacent, untreated areas with similar soil structure and plant community. Means and 95% confidence intervals (CI) were calculated for these groups (burned and unburned) and compared visually using bar graphs. In 2019, vegetation community cover data were further collected in nine flame weeded patches; six of which were flame weeded in previous years (A3, A3.5, A4, A4N, B3, B4) and three new to the flame weeding rotation (A5, A6, A7). Monitoring data in new patches were collected in the summer, before the fall 2019 treatment (Table 2). In 2019, four to five 1m^2 quadrats were placed within each of the nine patches, for a total monitored area of 41m^2.

For all community monitoring, we used an ESRI ArcGIS random point generator tool to place quadrats within patch boundaries. Within each quadrat percent cover to the nearest 1% was visually estimated for vascular plant species and ground cover classes (basal vegetation, bare bround, rock, litter, moss). Due to the overlapping nature of vegetation, the total cover of all plant species combined with ground cover classes commonly exceeded 100%. For analysis, results were combined by plant management groups (native/inasive forbs, native/invasive graminoids, and shrub/tree species). Means and 95% confidence intervals (CI) were calculated for these groups and compared visually using bar graphs. For the purpose of this report, overlapping CI's are interpreted as indicating no change in management groups from one year to the next, whereas non-overlapping CI's indicate a change in management groups from year to year. No formal statistical analyses were run to compare means.

Habitat quality

Habitat monitoring data were collected in 2013-2018 to assess the quality of lupine habitat in all meadows and to determine whether or not the site meets recovery targets. In 2019, habitat quality monitoring methods were re-evaluated; new monitoring methods have been proposed for Oak Basin so that data are directly applicable to habitat quality criteria measurements outlined in the Recovery Plan (USFWS 2010). Therefore, habitat quality was not assessed this year beyond the effects of flame weeding on the plant community. Habitat quality results from 2011-2018 are available in Appendix H and are discussed at length in prior years' reports (Giles et al. 2017, Celis et al. 2018).

Kincaid's lupine

The monitoring at Oak Basin is meant to be a complete census of the Kincaid's lupine population. In 2006, Meadows A, B, and C were surveyed for the presence of Kincaid's lupine. Plots were then established around lupine patches. Additional plots have been added as new patches have been located. Larger plots are rectangular and marked with fiberglass posts, rebar, or conduit in all four corners. Smaller patches are monitored in either circle or belt transects. Circular plots were marked in the center and all plants were included by setting an appropriate radius. Belt transects were marked on opposite ends, a tape was stretched between the posts, and all of the Kincaid's 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 in Appendix C Figure 3 and Appendix C Figure 4. When plants are found outside of existing plots, plot boundaries are either modified or new plots added to accommodate these plants.

Kincaid's lupine is censused by measuring foliar cover (m^2) as well as the count of mature and aborted racemes in each plot. Specfically, lupine foliar cover is measured by taking the approximate length (cm) and width (cm) of area occupied by a lupine using standard rulers. Foliar cover of lupine (as opposed to counting 'individual' plants of this rhizomatous species) is the standard metric for lupine monitoring in the Recovery Plan (U.S. Fish and Wildlife Service 2010). The percentage of aborted racemes is calculated by dividing the number of aborted racemes by the sum of mature and aborted racemes and multiplying by 100.

Oak Basin Tree Farm plug survival

In the spring of 2017, 68 plugs of Kincaid's lupine were planted on Oak Basin Tree Farm property (Appendix E Figure 5). Plugs were grown by IAE from seed collected at Oak Basin Tree Farm the previous summer. In May of 2019, we monitored survivorship of outplanted Kincaid's lupine plugs in 15 outplanted plots (encompassing 50 of the 68 original plugs). These plots were sprayed with Fusilade, a grass specific herbicide (dates unknown), to treat non-native perennial grasses surrounding the lupine by landowner Jim Merzenich.

Hitchcock's blue-eyed grass

Two permanent plots were established in 2012 to monitor the small population of Hitchcock's blue-eyed grass in Meadow C at Oak Basin. These same plots were monitored in 2019. The first is a 15m long x 8m wide belt transect with rebar marking both ends. The plot was monitored in 1m sections on the east and west sides of the tape. The origin of the transect is on the south end, tagged with an aluminum tag with #185 stamped on it. The second plot is a 2m radius circular plot with the rebar placed in the center and

tagged with #186; plants in this plot are measured in four quadrants. There is a small patch of Kincaid's lupine in this same area, and the circular plot #186 serves as a marker for both the lupine and the blue-eyed grass. Western blue-eyed grass (*Sisyrinchium bellum*) is also present in the area; for this reason monitoring occured at the time of flowering (late June/early July) to ensure proper identification of each species.

Due to the rhizomatous growth of Hitchcock's blue-eyed grass, plants greater than 20cm apart were counted as distinct individuals unless there was clear evidence otherwise (e.g. exposed rhizomes; Groberg et al. 2013). Plants were noted to be either vegetative (V) or reproductive (R). Those that were reproductive were also given a number to represent the number of flowering stems of each plant (R1 has one flowering stem, R2 has two flowering stems, R3 etc.); individual stems may have more than one flower. In addition, a reproductive plant is likely to have multiple vegetative stems as well.

RESULTS

Flame weeding monitoring

Since the initial burn, the mean cover of plant management groups has varied within patches and between meadows. Flame weeding treatments appeared to initially reduce overall invasive graminoid cover in patches A3 and B4 when compared to areas with similar plant community composition and soils (we do not have pre-treatment data for direct and robust comparison; top graphs in Figure 10 and Figure 11). This reduction appears to be driven primarily by a decrease in the cover of annual invasive grasses (top graphs in Figure 10 and Figure 11). In patch A3, percent cover within management groups appears to remain unchanged between monitoring years after initial treatment (bottom graph in Figure 10). However, in patch B4, cover within some management groups appears to have changed over time (bottom graph in Figure 11). For example, invasive forbs appear to have declined in cover, whereas native forb and graminoid cover have increased. These are visual observations from group means and CI's and are not interpretations of formal statistical analyses. Pre-treatment conditions for new flame weeded patches are summarized in Table 4. Both invasive graminoid and forb cover were high, accounting for ~50% of total vegetation cover in each patch.

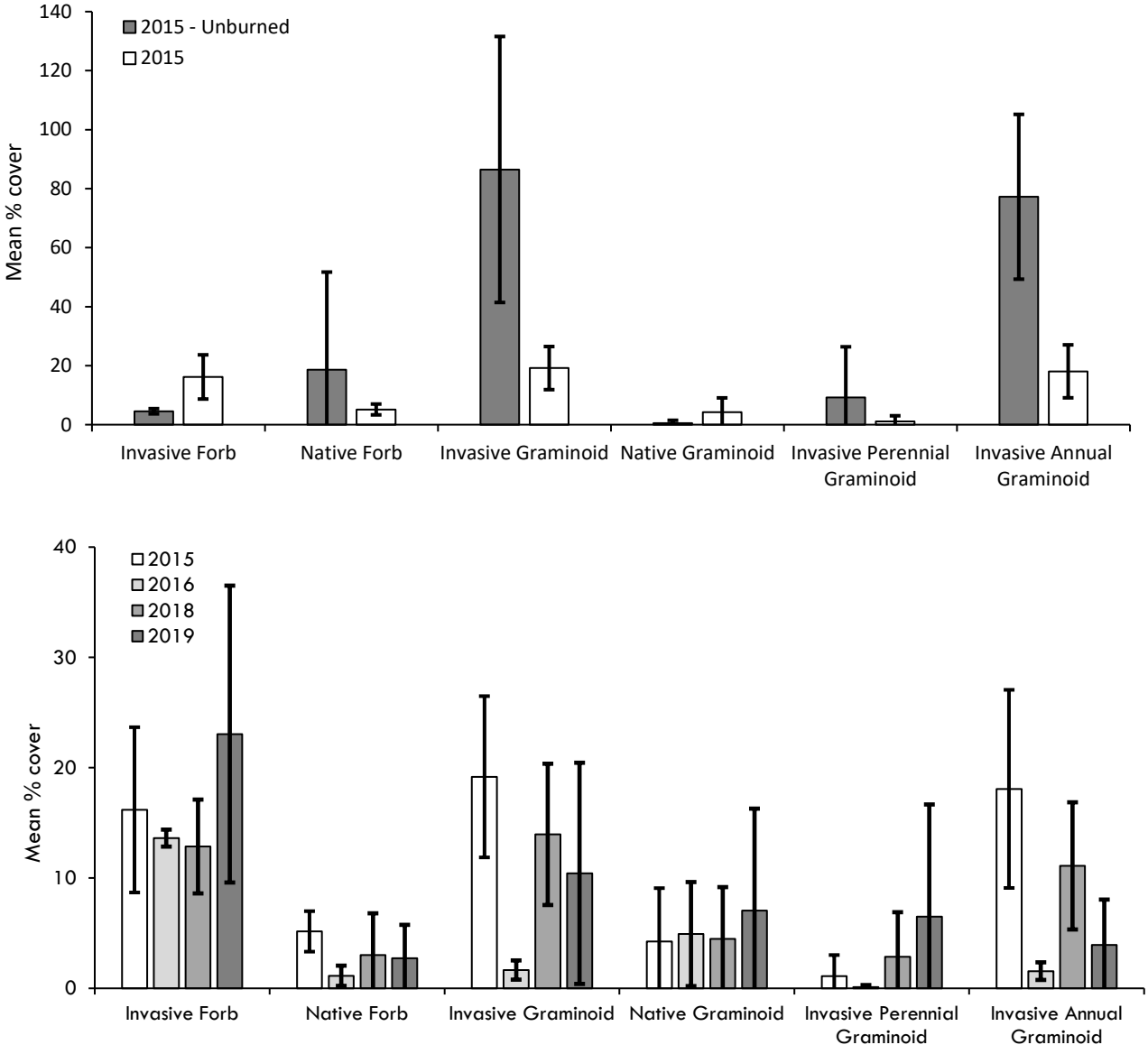

Figure 10. Mean percent cover (y-axis) by plant management group (x-axis) for the flame weeded patch A3. A3 was flame weeded in the spring of 2015 and then in the spring and fall of 2016 and 2017. Top bar graph shows untreated areas in similar habitat (n = 2, grey bars) and the flame weeded patch A3 (n = 5, white bars) in 2015. Bottom bar graph shows data from only flame weeded patch A3 (n = 5) from 2015 to 2019. Error bars represent 95% confidence intervals.

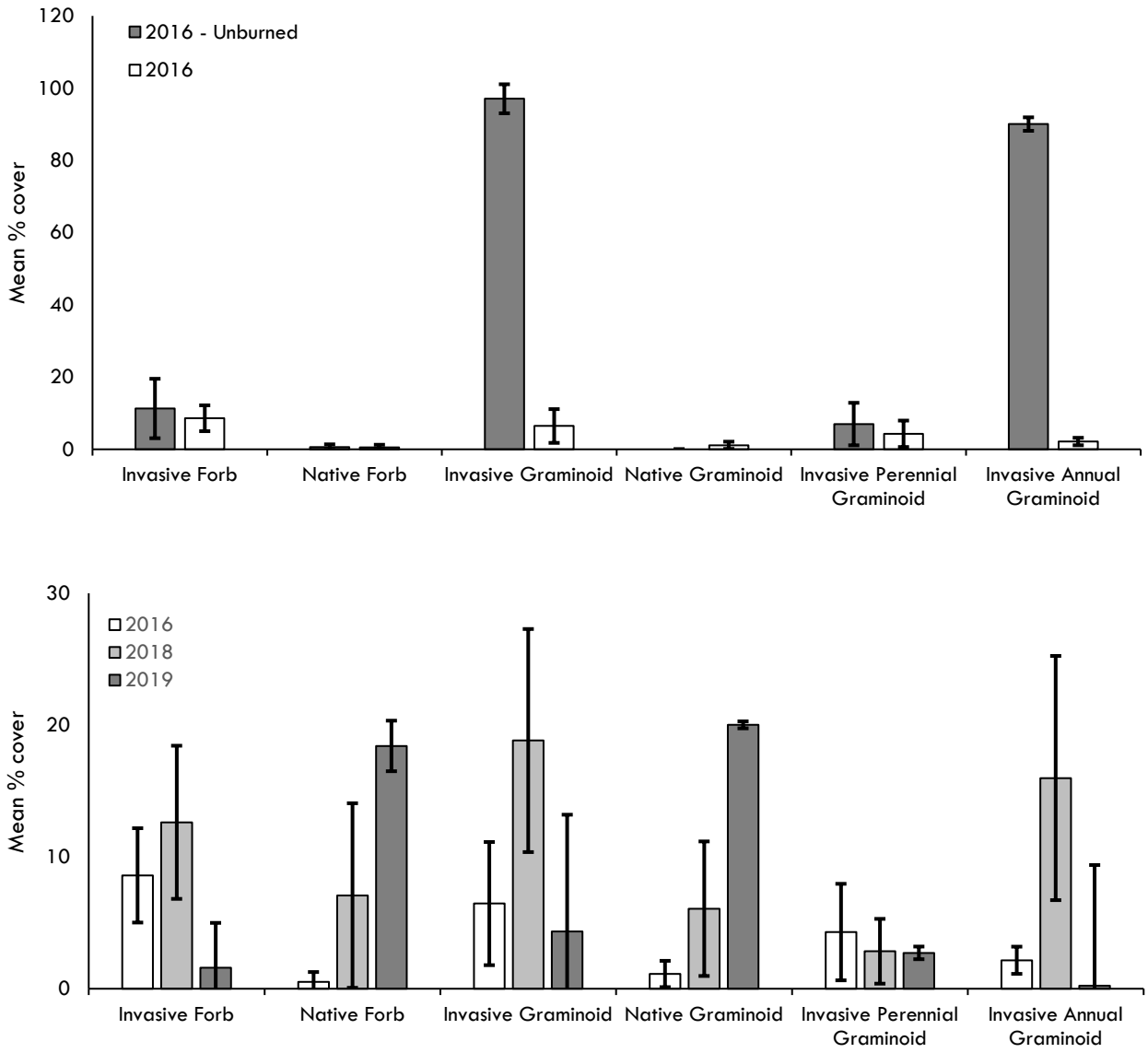

Figure 11. Mean percent cover (y-axis) by plant management group (x-axis) for the flame weeded patch B4. B4 was flame weeded in the spring and fall in 2015 and 2016, and then in the fall only in 2017 and 2018. Top bar graph shows untreated areas in similar habitat (n = 2, grey bars) and the flame weeded patch B4 (n = 5, white bars) in 2016. The bottom graph shows data collected from only the flame weeded patch B4 (n = 5) from 2016 to 2019. Error bars represent 95% confidence intervals.

Table 4. 2019 baseline plant community data collected from 1 m² plots at each of three new flame weeding areas: patch A5 (n=5), patch A6 (n=4), and patch A7 (n=4).

		Average cover (± 95% CI)					
Patch	**Year**	**Invasive Forb**	**Native Forb**	**Invasive Graminoid**	**Native Graminoid**	**Invasive Perennial Graminoid**	**Invasive Annual Graminoid**
A5	2019	1.9 (0.5)	1.9 (2.1)	13.1 (3.0)	0.7 (0.7)	2.9 (2.2)	10.1 (2.7)
A6	2019	19.8 (17.4)	4.4 (0.6)	1.7 (0.8)	7.4 (3.6)	0.8 (0.8)	0.9 (0.3)
A7	2019	22.5 (9.9)	2.2 (0.7)	52.7 (27.4)	1.5 (1.2)	51.9 (28.2)	0.8 (0.8)

Kincaid's lupine

In 2019, total Kincaid's lupine foliar cover was 168.6m² across all meadows (Figure 12, Appendix F Table 4) and there were 4,563 flowering racemes, 1,124 (21%) of which were aborted (Figure 13, Appendix F Table 3). This was the highest raceme count on record, and the secondest highest record of foliar cover.

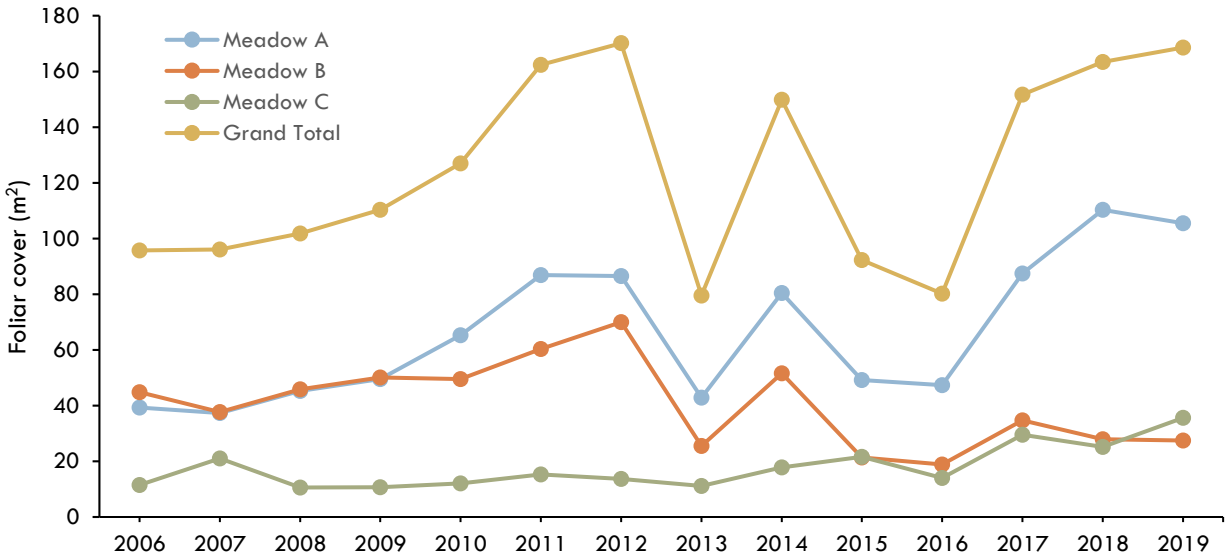

Figure 12. Kincaid's lupine (*Lupinus oreganus*) foliar cover (m²) in each meadow and total cover for all meadows at Oak Basin from 2006 to 2019.

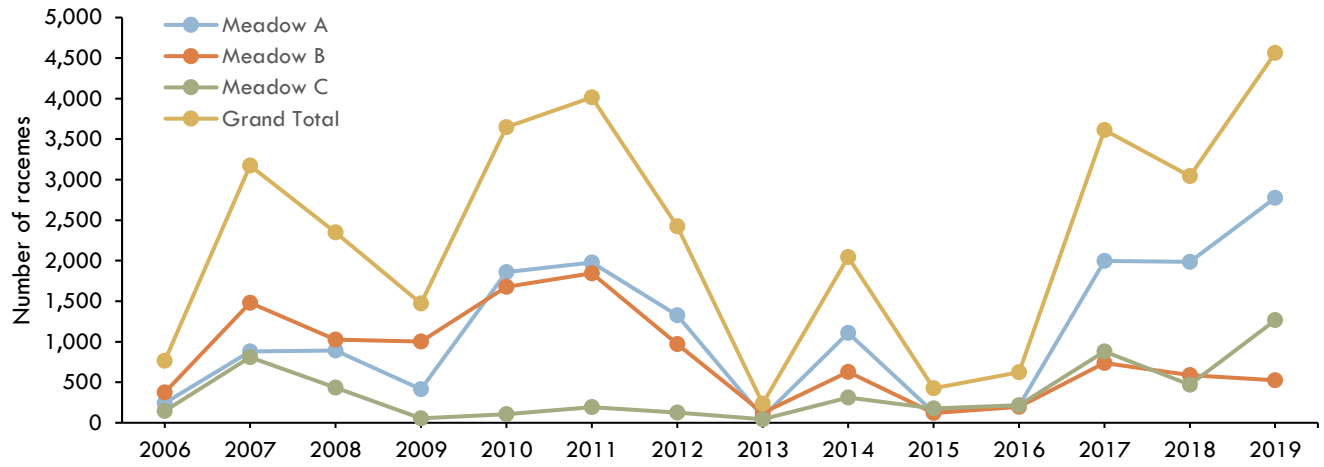

Figure 13. Total mature Kincaid's lupine (*Lupinus* oreganus) racemes counted in each meadow at Oak Basin from 2006 to 2019.

Oak Basin Tree Farm plug survival

Of the 50 outplanted lupine plugs monitored at the Oak Basin Tree Farm in 2019, 27 plants (54%) had survived two years after outplanting.

Kincaid's lupine seed collection

The total amount of wild seed collected from Oak Basin and Eagle's rest was 16.02 grams (Table 5).

Table 5. East Eugene Recovery Zone Kincaid's lupine (*Lupinus oreganus*) wild seed collection results for 2019.

Date Collected	Site	Amount collected (g)
7/24/2019	Oak Basin	7.18
8/7/2019	Eagle's Rest	8.84
	Total	16.02

Hitchcock's blue eyed grass

In 2019, a total of 70 plants were observed with a total of 160 reproductive stems (Figure 14). Most plants observed in the 4-meter-wide belt transect were found within two meters of the transect tape.

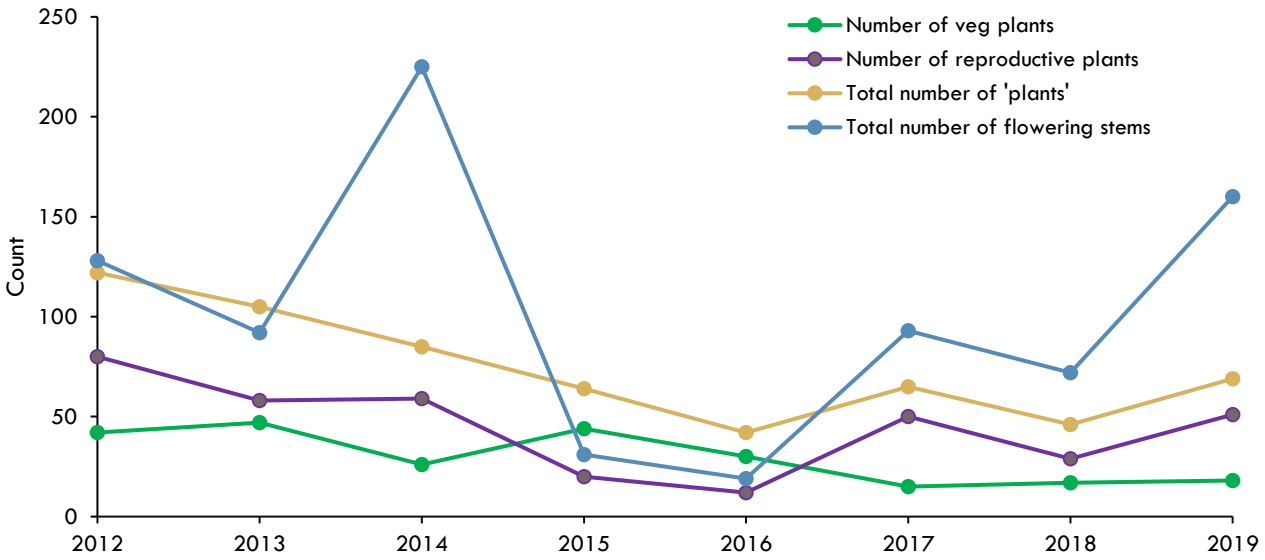

Figure 14. Population trends for Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) in Meadow C at Oak Basin from 2012 to 2019.

DISCUSSION

Monitoring trends

Flame weeding

Although not directly comparable in space, cover of invasive graminoids, particularly annual graminoids, was lower in flame weeded patches than those areas with similar plant community composition and soils as measured in 2015 and 2016. This could indicate that while flame weeding is not effective at eradicating annual grasses, it might have the capacity to lessen their cover and competitive impact on the native plant community. Trends for other plant management groups were variable between meadows and years. In flame weeded patch B4, there appears to be an increase in two native plant management groups, graminoids and forbs. This trend was not seen in patch A3. When comparing the two patches it is worth noting that invasive forbs in A3 had an average cover of 16% from 2015 to 2019 compared to B4 which had an average cover of 8%. It could be that competition from invasive forbs in Meadow A hindered the recovery of the native plant community. However, other differences between meadows including but not limited to micro-topography, and soil moisture, depth, and type, could be influencing this discrepancy. Overall, invasive species have the potential to outcompete native species by limiting available space, nutrients, and water (Melgoza et al. 1990, D'Antonio and Mahall 1991, Corbin and D'Antonio 2004, Hejda et al. 2009), and the potential negative impacts of invasive species to the Kincaid's lupine and Hitchcock's blue-eyed grass populations is an ongoing threat.

Kincaid's lupine

Over the course of the study there have been periodic fluctuations in Kincaid's lupine foliar cover and raceme counts (range; 79.6m^2 - 170.1m^2, 237- 4,563 racemes) (Appendix F Table 3 and Appendix F Table 4). Some of these fluctuations could be linked to climatic stresses; for instance, 2015 and 2016 had high temperatures and drought conditions and we observed low cover and raceme counts in those years. However, a number of potential factors, including habitat management (removal of introduced grasses, limbing of trees adjacent to existing patches of lupine), pollinator access, and others not currently measured or identified are likely impacting the fluctuations we are seeing in lupine cover and reproduction. That said, the overall decrease in foliar cover from 2012 to 2016 led to a re-evaluation of management actions, and these changes may be one of the factors leading to the subsequent rebounding of lupine foliar cover from 2017-2019.

The total number of racemes has followed a similar pattern to lupine foliar cover at Oak Basin (Figure 12, Figure 13). The 2013 season marked a low point in both raceme production and lupine cover; management actions were initiated in the fall of 2013. Since that time, Meadows A and C have returned to cover and raceme counts similar to those prior to 2013, however Meadow B has continued to decline in both foliar cover and raceme count. The percentage of aborted racemes (flowering stems that do not fully mature) has varied from 1% to 55% of the total number of racemes counted over the course of this study (Appendix F Table 3). As with foliar cover, climate differences, competition from exotic species, and other factors related to habitat degradation may contribute to observed fluctuations in raceme count and flowering success.

Direct competition from introduced grasses, which have steadily increased in cover in recent years, may be a key driver of reduced lupine foliar cover over the long term. Additionally, the tall stature of these perennial grass species could potentially reduce reproductive success by limiting pollinator access (Sletvold et al. 2013). Furthermore, lupine plants growing in competition with introduced perennial grasses often have fewer leaves and larger gaps between leaves (personal observation); leaves are the crucial egg-laying zones for the Fender's blue butterfly. Nectar surveys in 2011 indicated that while nectar species were present at the site, there may not have been enough available (both the number of species and the amount of flower production) through the duration of the flight period for Fender's blue butterfly to thrive (Giles-Johnson et al. 2011); this could also be true for other pollinators.

Oak Basin Tree Farm plug survival

Survival of planted lupine plugs increased from 47.4% in 2018 (one year after planting) to 54% in 2019. This increase in survival is primarily due to changes in the sampling effort, rather than an indication of plants resprouting from plugs that were lost in the first year post-planting. In 2018, not all planted plots were surveyed, and in 2019, plots were surveyed earlier in the season under wetter conditions. Private landowner Jim Merzenich maintains these plots by spraying Fusilade, a grass-specific herbicide, to reduce non-native perennial grasses.

Hitchcock's blue-eyed grass

Over six years of monitoring, our data show a general downward trend in the Hitchcock's blue-eyed grass population at Oak Basin, despite some expected annual fluctuation. As a caveat, it is acknowledged by Groberg et. al. (2013) that the methodology we currently use may under-represent the true number of individuals present. Hitchcock's blue-eyed grass individuals may spread through rhizomatous growth into neighboring plants, potentially resulting in the grouping of separate individuals which are then counted as one during monitoring. Despite the potential limitations of the sampling method in regards to the total number of individuals, this does not affect the total count of reproductive stems of the population, which is an important indicator of population health. The total number of plants has decreased over the course of the study, but reproductive stems have fluctuated more widely, increasing in 2019 to the second highest recorded count (Figure 14, Appendix G Table 5). These fluctuations in reproductive stem counts may be influenced by acute environmental factors and booms in reproductive effort may not always correspond to overall population success, but alternate methods of monitoring (e.g. counting all reproductive and non-reproductive stems) could be employed to address these challenges of interpretation.

Monitoring of the Hitchcock's blue-eyed grass remains vital to ensure its continued viability and to illustrate the need for active management of the population. Despite increases in the number of plants and reproductive stems in 2017 and 2019, the overall decrease in plants over the course of study could be a concern for the longevity of this population (Figure 14).

Synthesis

The foliar cover and raceme count of Kincaid's lupine has fluctuated periodically since monitoring began in 2006. Inter-annual fluctuations in raceme count and foliar cover highlight the need for ongoing monitoring of extant populations in order to assess the status and overall trend of these populations. In order to reach recovery goals for this species, continued monitoring of both Kincaid's lupine and the associated plant community will be vital. Since 2012, we have documented a general trend of decline in reproductive effort for Hitchcock's blue-eyed grass. The fluctuations in population size of both of these species over the course of the study may be due to increases in competitive, non-native species (i.e. invasive perennial grasses), but other factors not measured here (e.g. climate) likely play key roles. The prevelance of these introduced grasses in the community continues to pose a great challenge for restoration. To assess the progress that has been made towards the Kincaid's lupine recovery goals, we've summarized data for 2019 in Table 6 to compare current conditions to the habitat quality targets listed in the Recovery Plan (U.S. Fish and Wildlife Service 2010).

Table 6. Summary of current Oak Basin prairie habitat quality compared to recovery goals. This summarizes 14 years of population and community monitoring data from 2006 to 2019.

Prairie Quality and Diversity Summary*			
Criteria	**Data**	***Recovery Plan* threshold**	**Meets *Recovery Plan* objectives?**
Fender's blue butterfly population size (M = male, F = female)	BLM land: 17M 8F Private land: 8M 4F	Minimum population size of 200 individuals over 10 years	No
Trend for Kincaid's lupine foliar cover (m^2): 14 years of monitoring as of 2019	Increased on average 3.6 m^2/year	Increasing (+ slope) or stable (0 slope) over 15 years	Yes
Target foliar cover for Kincaid's lupine downlisting	Total: 168 m^2 Meadow A: 105 m^2 Meadow B: 27 m^2 Meadow C: 35 m^2	100m^2 in each meadow	No
Evidence of reproduction	7.18 g seed collected on BLM land only	Seedset or presence of seedlings	Yes
Native herbaceous species cover	13.9%	50% min	No
Woody species cover	0%	15% max	Yes
Do any woody species of management concern exceed 5% cover?	No	5% max	Yes
Prairie diversity: Native forb richness	21	7	Not restricted to 25m^{2**}
Prairie diversity: Native bunchgrass richness	1	1	Not restricted to 25m^{2**}
Prairie diversity: Total native herbaceous species richness	29	>10	Not restricted to 25m^{2**}
Sufficient abundance of nectar species	3 Native, 2 Non-native	5 native species	Not restricted to 25m^{2**}

*From the *Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington* (USFWS 2010).
** The Recovery Plan specifies that prairie diversity measurements need to be measured within a 25m^2 area to count towards recovery

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Annual monitoring data show that recent restoration efforts at Oak Basin have put the site on the right trajectory with regard to increased Kincaid's lupine foliar cover and evidence of reproduction. However, Oak Basin is still falling short of meeting several aspects of the criteria outlined in the Recovery Plan, including the overall population size of Fender's blue butterfly, Kincaid's lupine foliar cover targets, and several measures of habitat quality. These data highlight where to focus future restoration efforts at Oak Basin as well as guide future monitoring methods.

Emphasis for continued restoration needs to be placed on increasing the population size of Kincaid's lupine at Oak Basin and improving habitat quality. To accomplish this, larger areas of meadow need to be treated using fire and herbicides. As an example, although we have consistently mowed lupine patches as a means of combating tall fescue, it is not recommended as a long-term solution for control of introduced perennial grasses, as many have been selected for traits that allow recovery following defoliation. Tall fescue must be treated using herbicides or through tillage (Indiana Division of Fish and Wildlife 2006) which would negatively impact the native plant community. Alternatively, prescribed fire followed by spot herbicide application could provide more targeted control of this and other non-native species. These treated areas would need to be subsequently seeded and outplanted with native graminoids and forbs, including Kincaid's lupine and others that serve as nectar species for the Fender's blue butterfly. It will still be important to use an integrated management approach at this site by continuing to hand-pull small, isolated noxious weed populations such as Scotch broom, Himalayan blackberry, and Italian plumeless thistle. Additionally, conifer recruitment should be addressed early by lopping seedlings and saplings rather than allowing trees to grow in size. Furthermore, to address the problem of low Fender's blue butterfly counts at the site, we recommend that particular effort go into increasing meadow connectivity between all BLM owned meadows (A, B, and C) and those located on Oak Basin Tree Farm through the creation of corridors. These corridors need to be heavily treated for the forest-adapted and non-native species that dominate the herbaceous understory and subsequently seeded heavily with those species that the Fender's blue butterfly will use: Kincaid's lupine and nectar species.

The following habitat management, monitoring activities, and recovery actions are recommended at Oak Basin in 2020 and beyond:

- Continue to treat non-native species using all available methods.
- Pending authorization of the use of prescribed fire, initiate fire treatments.
- Pending authorization of use of herbicides, consider implementation of spot applications and post-fire herbicide application.
- Continue to increase nectar availability for Fender's blue butterfly and native species cover and diversity by augmenting native forb resource plants through seeding and/or plug outplanting.
- Continue to monitor and assess efficacy of management treatments to reduce abundance of introduced species via appropriate weed control measures.
- Remove more trees in corridors between meadows to increase connectivity of meadows for FBB.
- Establish and maintain Eugene East Recovery Zone Kincaid's lupine seed production beds (0.03 acres).

- Augment Kincaid's lupine population with transplants or seeds from appropriate seed sources.
- Monitor Kincaid's lupine outplanting at Oak Basin Tree Farm.
- Initiate active restoration of Hitchcock's blue eyed grass habitat and augment population in Meadow C by putting this species into production (wild-collecting seed and growing plugs and/or amplifying seed).

Continued population monitoring will be essential to document population trends for both species, especially in response to restoration activities occurring on site, and to track whether the Kincaid's lupine population is meeting recovery goals. Targeted community monitoring of areas pre- and post-treatment will be used to further guide management and restoration treatments. In 2020 we plan to establish relevé plots to monitor species richness in the target reference 25 m^2 area (as recommended in the Recovery Plan).

The Institute for Applied Ecology is working in partnership with the BLM and Oak Basin Tree Farm 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 this site.

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APPENDIX A: SUMMARY OF RESTORATION ACTIVITIES AT OAK BASIN

2012

- Site inspection and partner coordination.

2013

- Site inspection and partner coordination.
- Mapped *Taeniatherum caput-medusae* (medusahead) locations.
- Mowed around perimeter of all lupine patches and inside 1/3 of all lupine patches.
- Mowed all major *R. bifrons* patches.
- Grubbed several *R. bifrons* patches.
- Flame weeded patches for *T. caput-medusae* control and site preparation for planting/seeding.

2014

- Site inspection and partner coordination.
- Flame weeded patches for medusahead control and site preparation for planting/seeding.
- Planted 882 bulbs plus 2 15"x15" trays of *Allium amplectens*, 784 rhizomes of *Iris tenax*, 670 plugs of *Eriophyllum lanatum*, and 8 *Balsamorhiza deltoidea* plants.
- Seeded 7.14 lbs *Bromus carinatus*, 4.83 lbs *Elymus glaucus*, 1.27 lbs *Elymus trachycaulis*, 0.50 lbs *Eriophyllum lanatum*, 1.50 lbs *Festuca roemeri*, 0.70 lbs *Plectritis congesta*, 1.14 lbs *Prunella vulgaris* var. *lanceolata*, 1.71 lbs *Sidalcea malviflora* ssp. *virgata*.
- Nectar plant availability assessment.
- Hand weeded of *Cirsium vulgare* and *Cytisus scoparius*.
- Mowed 1/3 of all lupine patches and some *R. bifrons* patches.
- Grubbed *R. bifrons*.

2015

- Site inspection and partner coordination.
- Grubbed of *R. bifrons*.
- Removed small diameter conifer around perimeter of meadows.
- Removed, limbed or girdled trees around edges of meadows and in corridors between meadows. Similar work also done on adjacent Merzenich property.
- Flame weeded patches for medusahead control and site preparation for planting/seeding.
- Planted native plugs: 280 *Danthonia californica*, 100 *Elymus trachycaulis*, 150 *Festuca californica*, 200 *Festuca roemeri*, 1200 *Geranium oreganum*, 2000 *Iris tenax*, 120 *Lomatium dissectum* and 5600 *Sidalcea malviflora* ssp. *virgata*.
- Seeded 3.15 lbs *Danthonia californica*, *1.5* lbs *Eriophyllum lanatum*, 9.40 lbs *Festuca californica*, 6.0 *Festuca roemeri*, 3.0 lbs *Prunella vulgaris* var. *lanceolata* and 3.0 lbs. *Sidalcea malviflora* ssp. *virgata*.
- Mowed 1/3 of all lupine patches.

2016

- Site inspection and partner coordination.

- Flame weeded medusahead control and site preparation for planting/seeding.
- Grubbed *R. bifrons*.
- Removed small diameter conifer around perimeter of meadows.
- Hand weeded *Cytisus scoparius*.
- Mowed 1/3 of all lupine patches.
- Planted plugs: 40 *Danthonia californica*, 50 *Iris tenax* and 400 *Sidalcea malviflora* ssp. *virgata*.

2017

- Site inspection and partner coordination.
- Outplanted 68 plugs of *Lupinus oreganus* on neighboring private land, Oak Basin Tree Farm.
- Flame weeded patches for medusahead control and site preparation for seeding.
- Grubbed *R. bifrons*.
- Seeded *Danthonia californica* 2.37 lbs, *Elymus trachycaulis* 2.0 lbs, *Eriophyllum lanatum* 1.28 lbs, *Festuca roemeri* 3.41lbs, *Plectritis congesta* 1.18 lbs, *Prunella vulgaris* var. *lanceolata* 0.75 lbs and *Sidalcea malviflora* spp. *virgata 1.0 lbs*.
- Mowed approximately one-third of lupine patches after senescence of *L. oreganus*.
- Hand mowed flame weeded plots A3, A4, B3 and B4 in Meadows A and B.

2018

- Site inspection and partner coordination.
- Monitored 38 outplanted plugs of *Lupinus oreganus* on neighboring private land, Oak Basin Tree Farm; 18 survived.
- Flame weeded patches for medusahead control and site preparation for seeding in Meadows A and B.
- Grubbed *R. bifrons*.
- Pulled Scotch broom Italian thistle, and shining geranium (geranium pulled near lupine patch 460 in Meadow A only)
- Cut seedlings and saplings from edges of all meadows. It was partidularly concentrated in Meadow C.
- Mowed approximately one-third of lupine patches after senescence of *L. oreganus*.
- Seeded flame weeded areas (~0.67 acres) with a native forb and grass mix: *Danthonia californica* (1.87), *Elymus glaucus* (1.45), *Eriophyllum lanatum* (0.28), *Koelaria micrantha* (0.09), *Plectritis congesta* (0.46), *Prunella vulgaris* (0.38), and *Wyethia angustifolium* (3.27)

2019

- Site inspection and partner coordination.
- Monitored 50 outplanted plugs of *Lupinus oreganus* on neighboring private land, Oak Basin Tree Farm; 18 survived.
- Cut seedlings and saplings from edges of Meadow A and between Meadows A and B.
- Grubbed *R. bifrons* in Meadows B and C.
- Pulled Scotch broom and Italian thistle in Meadows A and B.
- Flame weeded patches for non-native annual and perennial graminoid control in all meadows including three new flame weeded patches and the *Sisyrinchium hitchcockii* population.

- Subcontracted the cutting of 60 trees between and along the edges of Meadows A and B ranging in size from 10 to 20 inches in diameter.
- Led an Americorps Blue 5 Team in the piling and moving of downed trees from the meadows and meadow corridor.
- Seeded areas disturbed by tree removal with a native forb and grass mix: *Danthonia californica* (0.87), *Elymus glaucus* (1.10), *Festuca roemeri* (0.34), and *Wyethia angustifolium* (2.20)

2020 (recommended)

- Site inspection and partner coordination.
- Monitor outplanted plugs of *Lupinus oreganus* on neighboring private land, Oak Basin Tree Farm.
- Continue to increase nectar availability for Fender's blue butterfly by augmenting native forb resource plants through seeding and/or plug outplanting.
- Continue to monitor and assess efficacy of management treatments to reduce abundance of introduced species via appropriate weed control measures.
- Remove more trees in corridors between meadows to increase connectivity of meadows for FBB.
- Pending authorization of the use of prescribed fire, initiate fire treatments.
- Pending authorization of use of herbicides, consider implementation of spot applications and post-fire herbicide application.
- Initiate Eugene East Recovery Zone Kincaid's lupine seed production.
- Augment Kincaid's lupine population with transplants or seeds from appropriate seed sources.
- Monitor Kincaid's lupine outplanting at Oak Basin Tree Farm.
- Initiate active restoration of *S. hitchcockii* population in Meadow C by putting this species into production and augmenting restoration disturbance.

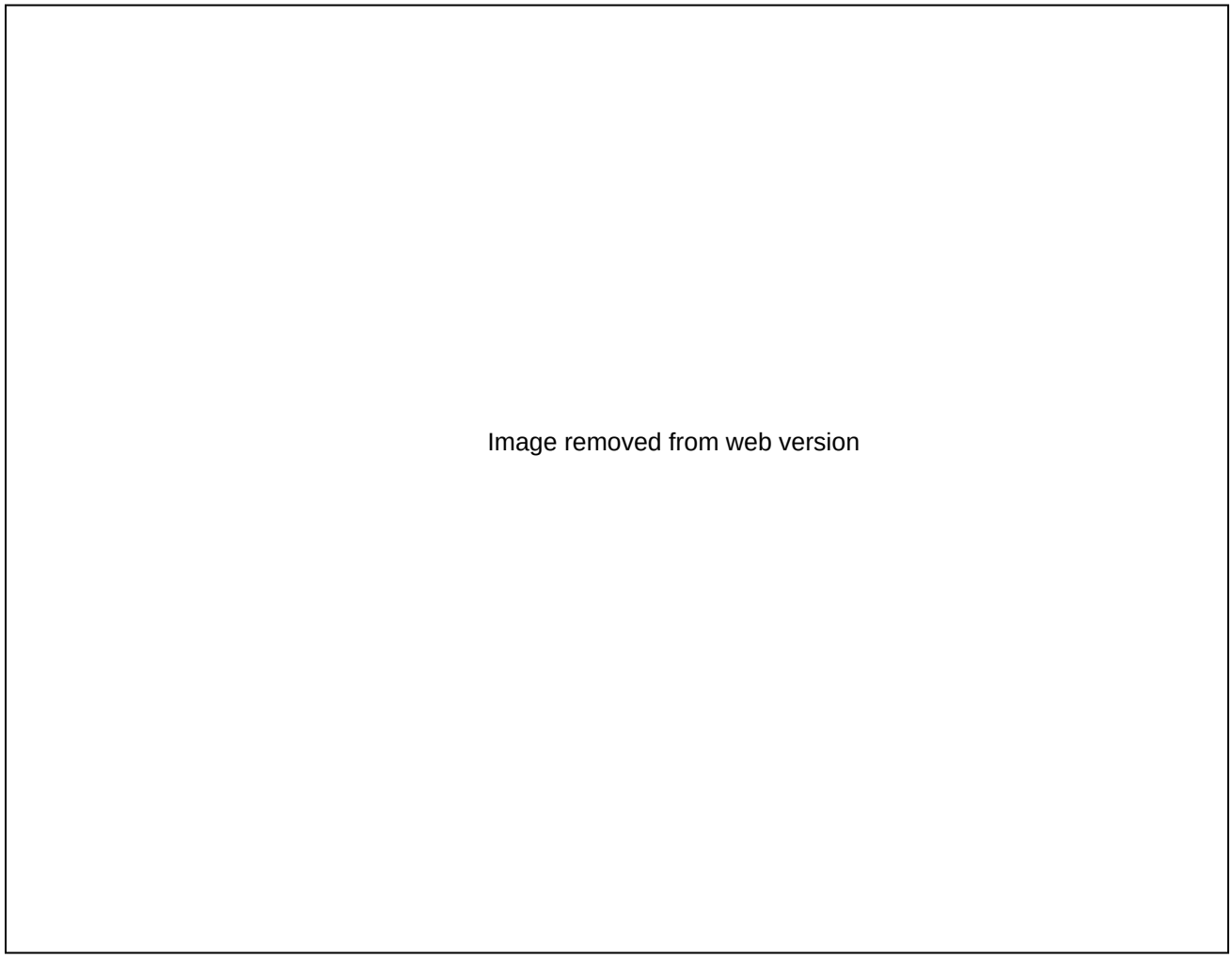
APPENDIX B: LUPINE COVER AND RACEME COUNTS BY PLOT (2013-2019)

Appendix B Table 1. Kincaid's lupine (*Lupinus oreganus*) cover and raceme counts by plot from 2013-2019. Shaded cells indicate which plots were mowed in the preceding fall.

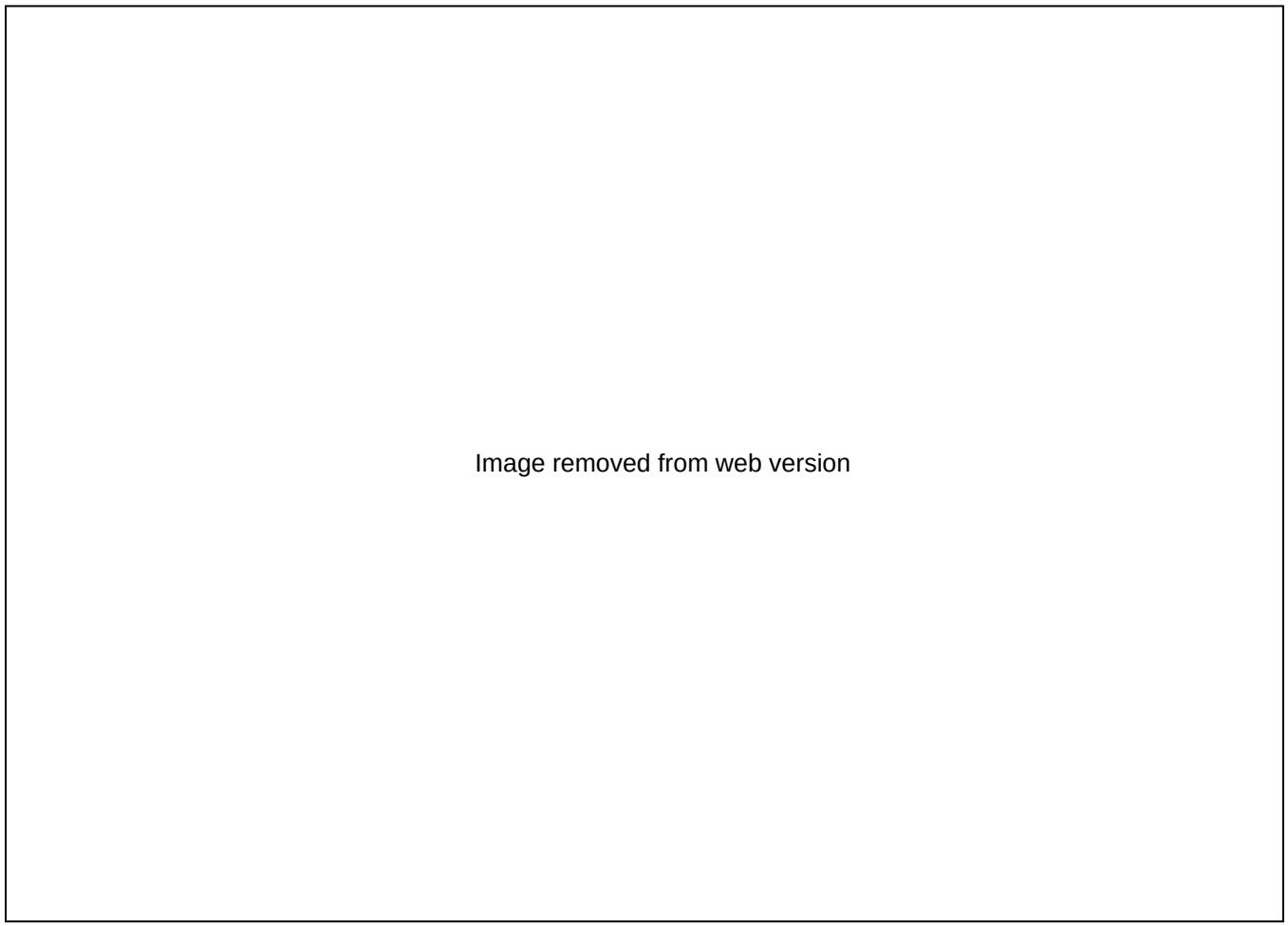
	2013		2014		2015		2016		2017		2018		2019	
Plot	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes
Meadow A	42.9	71	80.4	1108	49.2	129	47.3	209	87.5	1996	110.3	1984	103.4	2775
7	1.1	10	**2.9**	**36**	1.8	10	1.9	12	**2.8**	**201**	1.8	62	2.1	145
8	0.3	3	**0.2**	**1**	0.1	0	0.1	0	**0.3**	**4**	0.4	6	0.3	9
9	4.7	2	6.4	146	3.2	24	**2.2**	**5**	4.7	49	6.0	30	**4.3**	**25**
10	0.4	0	**0.8**	**18**	0.4	3	0.6	0	**0.5**	**8**	0.6	3	0.5	3
369	-	-	-	-	-	-	-	-	-	-	10.9	50	7.8	0
406	0.7	1	0.3	0	0.0	0	0.1	2	0.3	1	0.4	0	0.5	1
450	10.8	23	11.3	30	**7.5**	**21**	3.9	22	6.2	29	**7.4**	**7**	15	93
451	0.7	0	1.6	4	0.6	0	**0.9**	**0**	1.4	16	1.4	0	**0.5**	**0**
452	3.4	6	10.0	93	**8.5**	**9**	3.8	0	11.1	129	**10.4**	**34**	8.0	25
454	1.8	4	5.7	10	2.6	0	**1.3**	**0**	6.8	36	6.4	3	**4.7**	**27**
459	9.7	6	**19.3**	**361**	11.9	9	16.8	0	**26.3**	**1069**	39.3	669	25.1	1142
460	2.4	2	**4.8**	**192**	3.0	12	2.5	117	**6.5**	**206**	6.4	785	**10.1**	**589**
464	5.3	4	13.8	118	6.4	2	**7.9**	**0**	17.4	126	12.0	23	**14.9**	**90**
509	1.0	8	1.5	52	1.6	30	0.7	51	2.3	56	5.0	239	7.1	462
510	0.3	0	1.4	14	1.3	4	0.0	0	0.1	1	0.8	8	1.6	14
511	0.4	2	0.5	33	0.3	5	4.5	0	0.8	65	1.2	65	1.2	127
Meadow B	25.5	122	51.6	627	21.4	120	18.9	197	34.7	736	27.9	587	27.4	523
1	8.6	20	**31.3**	**309**	11.8	31	8.8	43	**23.2**	**441**	12.1	379	13.5	198
2	0.5	1	0.5	1	**0.1**	**1**	0.0	0	0.1	3	**0.0**	**1**	0.02	0
3	2.0	5	3.2	21	**1.6**	**7**	1.5	13	1.3	15	**0.5**	**5**	1.0	16
4	1.7	2	2.5	23	0.7	7	**0.9**	**0**	1.5	40	0.4	2	**1.1**	**6**
5	4.3	2	6.2	114	**4.3**	**50**	1.7	25	1.6	19	**4.5**	**22**	3.8	67
6	3.6	51	4.6	125	2.9	24	2.3	21	2.5	51	4.3	107	1.9	36
399	4.9	41	3.3	34	0.0	-	3.7	95	4.6	167	6.1	71	6.1	200
Meadow C	11.2	44	17.8	311	21.7	177	14.0	217	29.5	881	25.2	471	35.6	1265

	2013		2014		2015		2016		2017		2018		2019	
Plot	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes	Cover (m^2)	Mature Racemes
400	0.1	0	0.1	1	**0.04**	**1**	0.04	3	0.05	0	**0.1**	**0**	0.1	2
431	1.8	0	2.7	20	**3.1**	**8**	1.6	0	3.9	62	2.6	32	4.4	99
432	5.1	42	10.1	173	9.4	86	**7.4**	**187**	12.2	408	12.4	322	**20.4**	**741**
433	4.2	2	**4.8**	**117**	9.1	82	4.3	14	**12.3**	**408**	8.7	78	9.1	372
594	-	-	-	-	-	-	0.7	13	0.9	1	1.3	38	1.5	44
TOTAL	**79.6**	**237**	**149.8**	**2046**	**92.3**	**426**	**80.2**	**623**	**151.7**	**3613**	**163.4**	**3042**	**166.4**	**4540**

APPENDIX C. AERIAL OVERVIEWS



Appendix C Figure 1. Aerial overview of the Oak Basin study area, including meadow names. Detailed maps of each meadow and plot numbers from our study are included below.



Appendix C Figure 2. Aerial photo of the three meadows at Oak Basin that contain patches of Kincaid's lupine (*Lupinus oreganus*). Plot numbers and meadow names are indicated.

Meadow A overview

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Appendix C Figure 3. Meadow A overview. Plots established in 2011 = 509, 510, 511. The 509 east population is on the skid road and exists within a 1.5m radius of the rebar. The 510 west population is on the tree line at 179° from large Douglas-fir (*Pseudotsuga menziesii*) around center of hill and extends in a 8m x 1m strip going north-south. The 511 center population is in the middle of the hill at 230° from the westernmost Douglas-fir of Douglas-fir island on top of hill near plot 459; consists of 5 plants in a 3m x 0.5m strip going north-south.

Meadows B and C overview

Image removed from web version

Appendix C Figure 4. Meadows B and C overview. To reach plot 399 (this population may be on private land and thus was not included in our cover estimate totals): from origin of plot 1, bearing 178°, ~40m. Near Douglas-fir (*Pseudotsuga menziesii*) with big leaf maple (*Acer macrophyllum*) growing with it, where hill steeply drops off. Population has been captured in a rectangular plot with 14m x 11m sides. Origin is in ne corner and has conduit (other corners have rebar with yellow caps).

APPENDIX D. LOCATION, DIMENSIONS, AND MONITORING NOTES FOR PLOTS AT OAK BASIN

Appendix D Table 2. Location, dimensions, and monitoring notes for Kincaid's lupine (*Lupinus oreganus*) and Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*; 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	Measured entire plot as one. Fallen log partially on plot
A	9	18m x 14m	504286 E 4906960 N	Measured in 2m increments
A	10	Circular, 2m radius	504312 E 4906952 N	Measured in 4 quadrats: NW, NE, SW, SE
A	459	13m x 12m	504246 E 4906964 N	Measured in 3m increments
A	454	20m x 13m	504210 E 4906979 N	Measured in 4m increments. 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 (E-W)
A	451	8m x 7m	504132 E 4906987 N	Measured in 2m increments (N-S)
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	Measured in 4 quadrants: NW, NE, SW, SE
A	509	Circular, 1.5m radius	504199 E[1] 4907048N[1]	New in 2011. Measured in 4 quadrats: NW, NE, SW, SE
A	510	6m x 10m	503967 E[1] 4907105 N[1]	New in 2011. Measured in 1m increments N-S 1m segment measured from E-W
A	511	3m radius	504702 E[1] 4907160 N[1]	Changed plot to 4 quadrants (NW, NE, SW, SE) in 2018
A	369	14m x 12m		New in 2018 Measured in 2m increments N-S

Meadow	Plot Number	Dimensions	origin (Nad27)	Notes
A	653	16m x 11m	504136 E 4907160 N	New 2019, Measured in 2m segments N-S.
B	1	60m x 18m+	504420 E 4906668 N	Measured in 5m increments
B	2	Triangular adjacent to Plot 3	504503 E 4906649 N	Measure entire plot as 1
B	3	12m x 18m (20m)	504514 E 4906646 N	Measured in 2m increments
B	4	Circular, 3m radius	504545 E 4906630 N	Measured in 4 quadrats: NW, NE, SW, SE
B	5	12m x 9m	504597 E 4906570 N	Measured in 2m increments, except the last, which was 3m
B	6	11m belt transect	504628 E 4906559 N	Measured in 2m increments to each side until last plant
B	399**	11m x 14m-16m plot	504326 E 4906806 N	Measured E-W in 2m increments
B	Plot 2 Tag 558	12m x 6.8m x 13.7m	504413 E[1] 4906842 N[1]	New in 2014, plot is triangular directly adjacent to Plot 3
C	594	12m belt	See map	New in 2017. Measured in 2m increments on each side (N&S)
C	233	1m radius	See map	New in 2017. Measured entire plot as one
C	**1(185)[2]**	**14m belt transect**	**504639 E[1] 49065659N[1]**	**Measured in 1m increments on each side (E&W)**
C	**2 (186)[2]**	**2m radius**	**504655 E[1] 4906555N[1]**	**Measured in 4 quadrats: NW, NE, SW, SE**
C	433	8m belt transect	504712 E 4906379 N	Measured in 2m increments on each side (N&S)
C	432	8m x 9m	504649 E 4906401 N	Measured in 2m increments
C	431	18m belt transect	504732 E 4906378 N	Measured in 1m increments on each side (E&W)
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 Kincaid's lupine on the SW end of Meadow B which is on private property. Plot 399 captures the lupine nearest the public/private boundary.

APPENDIX E. LOCATIONS OF KINCAID'S LUPINE PLANTINGS

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Appendix E Figure 5. Locations of Kincaid's lupine (*Lupinus oreganus*) plantings (orange polygons planted in 2017) on Merzenich property. Survivorship of transplants was monitored in 2018 and 2019.

APPENDIX F. MATURE AND ABORTED RACEMES (2006-2019)

Appendix F Table 3. Total number of mature racemes and percent racemes aborted of Kincaid's lupine (*Lupinus oreganus*) at Oak Basin from 2006 to 2019.

	Meadow A		Meadow B		Meadow C		Grand Total	
	Mature Racemes	Percent Aborted	Mature Racemes	Percent Aborted	Mature Racemes	Percent Aborted	Mature Racemes	Percent Aborted
2006	245	9%	375	13%	145	21%	765	14%
2007	881	9%	1,482	4%	810	5%	3,173	6%
2008	891	9%	1,027	6%	432	9%	2,350	8%
2009	415	18%	1,004	7%	55	42%	1,474	12%
2010	1,860	5%	1,678	4%	108	28%	3,646	5%
2011	1,978	5%	1,845	4%	192	18%	4,015	5%
2012	1,328	7%	969	7%	127	24%	2,424	8%
2013	71	59%	122	39%	44	50%	237	49%
2014	1,108	8%	627	11%	311	12%	2,046	10%
2015	129	47%	120	35%	177	11%	426	32%
2016	209	42%	197	31%	217	20%	623	32%
2017	1,996	8%	736	11%	881	6%	3,613	8%
2018	1,984	8%	587	14%	471	11%	3,042	10%
2019	2,775	31%	523	35%	1,265	16%	4,563	27%

Appendix F Table 4. Total Kincaid's lupine (*Lupinus oreganus*) cover and number of racemes per m^2 of Kincaid's lupine foliar cover at Oak Basin from 2006 to 2019.

	Meadow A		Meadow B		Meadow C		All Meadows	
	Cover (m^2)	Mature racemes/m^2	Cover (m^2)	Mature racemes/m^2	Cover (m^2)	Mature racemes/m^2	Cover (m^2)	Mature racemes/m^2
2006	39.3	6	44.9	8	11.5	13	95.7	8
2007	37.3	24	37.7	39	21.1	38	96.1	33
2008	45.3	20	45.9	22	10.6	41	101.8	23
2009	49.5	8	50.1	20	10.7	5	110.3	13
2010	65.3	28	49.6	34	12.0	9	126.9	29
2011	86.8	23	60.3	31	15.2	13	162.3	25
2012	86.5	15	70.0	14	13.6	9	170.1	14
2013	42.9	2	25.5	5	11.2	4	79.6	3
2014	80.4	14	51.6	12	17.8	17	149.8	14
2015	49.2	3	21.4	6	21.7	8	92.3	5
2016	47.3	4	18.9	10	14.0	15	80.2	8
2017	87.5	23	34.7	21	29.5	30	151.7	24
2018	110.3	18	27.9	21	25.2	19	163.4	19
2019	105.5	26	27.4	19	35.6	36	168.5	27

APPENDIX G. *SISYRINCHIUM HITCHCOCKII* SIZE CLASS AND REPRODUCTIVE SUMMARY

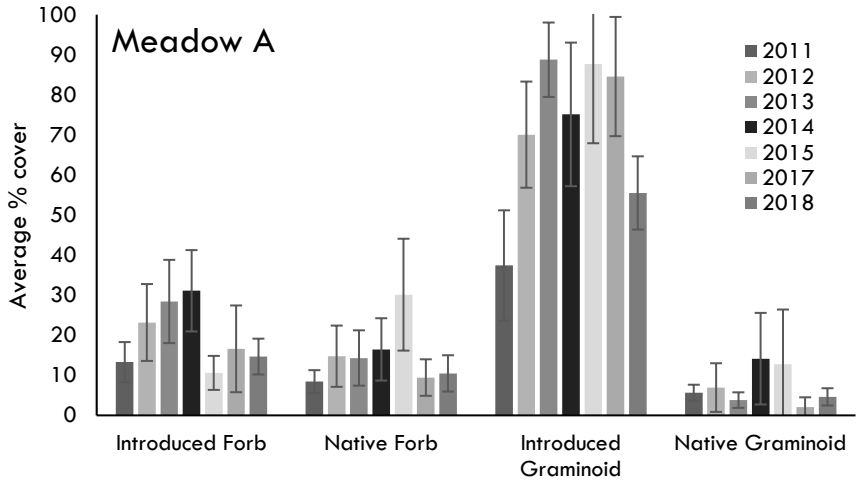
Appendix G Table 5. Count of number of Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) stems by size class in Meadow C at Oak Basin from 2012 to 2019. 'R' numbers represent the number of inflorescences recorded per stem (R1, R2, R3, etc.).

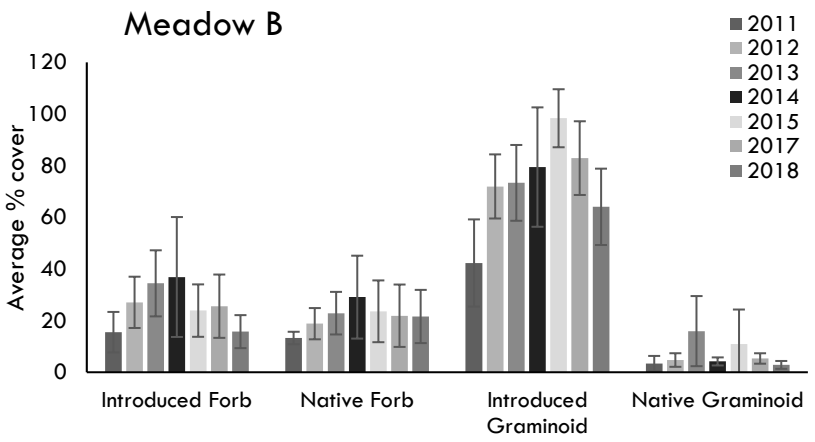
Size Class	2012	2013	2014	2015	2016	2017	2018	2019
Vegetative	42	47	26	44	30	**15**	17	18
R1	55	40	17	13	8	21	12	17
R2	14	10	9	5	2	20	10	9
R3	7	5	5	1	1	8	4	15
R4	1	1	7	0	1	1	1	3
R5	1	1	0	1	0	1	1	1
R6	1	0	12	0	0	0	0	0
R7	0	0	7	0	0	0	0	1
R8	0	1	0	0	0	0	0	0
R9	1	0	0	0	0	0	0	1
R10	0	0	0	0	0	0	0	1
R11	0	0	0	0	0	0	0	1
R12	0	0	1	0	0	0	0	1
R13	0	0	0	0	0	0	0	0
R14	0	0	1	0	0	0	0	1
R19	0	0	0	0	0	0	1	0
R21	0	0	0	0	0	0	0	1
Total Reproductive Individuals	**80**	**58**	**59**	**20**	**12**	**51**	**29**	**52**
Total Reproductive Stems	128	92	225	31	19	89	72	160
Total number of plants	**122**	**105**	**85**	**64**	**42**	**66**	**46**	**70**

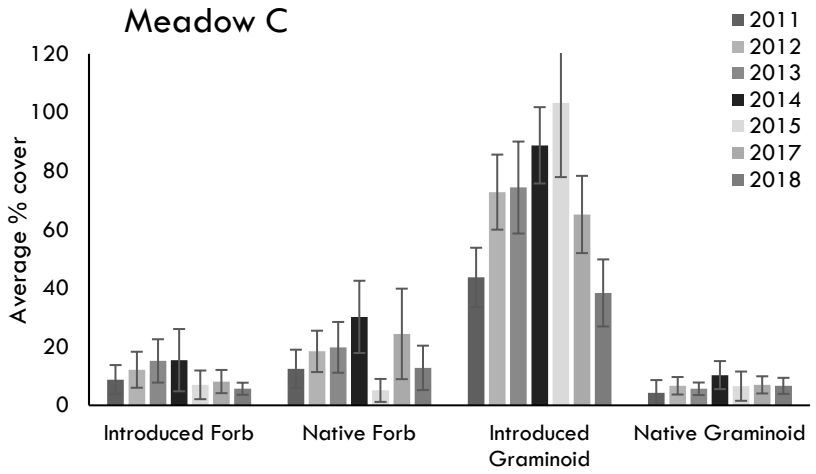
APPENDIX H. FORB AND GRAMINOID COVER BY MEADOW

Appendix H Table 6. Average percent cover and 95% confidence interval (CI) by plant management group at Oak Basin in Kincaid's lupine (*Lupinus oreganus*) habitat from 2011 to 2018.

		Introduced Forb		Native Forb		Introduced Graminoid		Native Graminoid		Introduced Perennial Graminoid		Introduced Annual Graminoid	
		% Cover	95% CI	% Cover	95% CI	% Cover	95% CI	% Cover	95% CI	% Cover	95% CI	% Cover	95% CI
Meadow A	2011	13.3	5.0	8.4	2.9	37.4	13.8	5.7	2.0	34.4	14.5	3.0	3.1
	2012	23.2	9.6	14.8	7.6	70.1	13.3	6.9	6.1	69.1	13.9	1.0	0.9
	2013	28.4	10.4	14.3	6.9	88.8	9.3	3.8	1.9	86.8	9.7	2.0	1.4
	2014	31.1	10.2	16.5	7.8	75.1	17.9	14.2	11.4	56.9	24.2	18.2	13.8
	2015	10.6	4.2	30.1	14.0	87.7	19.7	12.7	13.7	85.8	20.8	1.9	2.2
	2017	16.6	10.8	9.4	4.6	84.6	14.9	2.1	2.5	84.5	14.9	0.1	0.1
	2018	14.7	4.5	10.5	4.5	55.5	9.1	4.6	2.2	54.1	9.6	1.4	0.8
Meadow B	2011	15.5	7.9	13.3	2.4	42.3	16.9	3.3	3.0	41.0	17.8	1.4	1.7
	2012	27.1	9.9	18.8	6.1	72.0	12.4	4.7	2.6	71.5	12.5	0.5	0.3
	2013	34.4	12.8	22.9	8.2	73.3	14.7	15.9	13.6	72.6	15.0	0.7	0.6
	2014	36.9	23.2	29.1	16.1	79.5	23.1	4.2	1.6	75.5	28.7	4.0	6.3
	2015	23.9	10.2	23.6	12.0	98.4	11.2	10.9	13.4	97.9	11.6	0.4	0.5
	2017	25.6	12.3	21.9	12.1	82.9	14.3	5.3	2.0	82.0	14.5	0.9	1.3
	2018	15.7	6.4	21.6	10.3	64.1	14.8	2.8	1.5	61.3	16.4	2.8	3.6
Meadow C	2011	8.8	4.9	12.5	6.5	43.7	10.1	4.3	4.4	42.4	10.3	1.2	1.0
	2012	12.2	6.1	18.4	7.1	72.8	12.8	6.7	3.0	69.9	12.4	2.9	1.6
	2013	15.2	7.4	19.8	8.7	74.4	15.7	5.7	2.1	72.8	15.6	1.6	0.9
	2014	15.4	10.6	30.2	12.3	88.8	13.0	10.3	4.8	84.6	13.4	4.2	4.7
	2015	7.0	4.9	5.1	3.9	103.2	25.3	6.6	5.0	102.6	24.4	0.7	0.9
	2017	8.1	4.0	24.4	15.5	65.2	13.2	7.0	2.9	53.6	14.7	11.6	9.2
	2018	5.7	2.1	12.8	7.6	38.4	11.4	6.7	2.7	34.1	11.9	4.3	2.9







Appendix H Figure 6. Average percentages of introduced and native forb and graminoid species in Kincaid's lupine (*Lupinus oreganus*) habitat from 2011 to 2019 in Meadows A, B, and C. Error bars represent 95% confidence intervals.

APPENDIX I. 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 216

Head East towards Brownsville. Turn right (at Chevron Station), onto Washburn Road, this will become Gap Road.

Turn left onto 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 (use key if necessary). (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 grassier 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.

To Doghead Meadow

South on I-5 to Brownsville/Hwy 228 exit 216

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
Maps and Gazetteer

Rulers – 1 per person
2 tatums and extra pencils
Meter tapes: Minimum 6 tapes, (more is better- at least 3- 100m tapes)
$1m^2$ plot frame (for community monitoring)
1m poles – 2 per person (for measuring/sectioning large patches)
Candy canes (at least 2x the number of tapes)
Pin flags – white (marks lupine), pink (marks plot corners), other color (for various other uses)
Compass
Flagging
Rebar, conduit, or fiberglass x3 (for replacement, if necessary)
Plot tags and wires x3 (for replacement, if necessary)

Extra water
Health and Safety Box
Tecnu
First aid kit