Upper Oak Basin Kincaid's lupine and Hitchcock's blue-eyed grass monitoring and restoration: 2022 annual report

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Report to the Bureau of Land Management, Upper Willamette Resource Area: Northwest Oregon District, L21AC10022, L21AC10456, L20AC00228, and L21AC10117

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PREFACE

IAE is a non-profit organization whose mission is the 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: Looking East from Meadow A at the newly established corridor connecting Meadow B. Photo taken by Tyler Roberts on 09/19/2022.

SUGGESTED CITATION

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EXECUTIVE SUMMARY

This report documents habitat restoration and vegetation monitoring activities conducted by the Institute for Applied Ecology (IAE) in partnership with the Bureau of Land Management's (BLM) Upper Willamette Field Office (UWFO), Northwest Oregon District, at Oak Basin, a complex of upland meadows. Oak Basin is home to Kincaid's lupine (*Lupinus oreganus*), a federally 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 threatened Fender's blue butterfly (*Icaricia icarioides fenderi*). The small population of Fender's blue butterfly at Oak Basin has been on the decline since 2015, and only 10 individuals were documented in 2022 at Oak Basin on BLM-administered land. All three species are endemic to western Oregon prairies.

Management treatments

Restoration activities conducted in 2022 included mowing Kincaid's lupine patches to reduce invasive perennial grass thatch and shrub cover; removal and limbing of conifers between meadow corridors to increase meadow connectivity and reduce woody encroachment around Kincaid's lupine patches; hand-pulling or grubbing invasive plants, including Himalayan blackberry (*Rubus bifrons* syn. *Rubus armeniacus*), false brome (*Brachypodium sylvaticum*), and Italian plumeless thistle (*Carduus pycnocephalus*); chemical treatments of Himalayan and evergreen blackberry (*Rubus laciniatus*); and collecting native seed including blue wildrye (*Elymus glaucus*), Columbia brome (*Bromus vulgaris*), common woolly sunflower (*Eriophyllum lanatum*), woodrush (*Luzula comosa*), and Kincaid's lupine; and starting seed amplification beds for dwarf checkermallow (*Sidalcea malviflora ssp. virgata*) and toughleaf iris (*Iris tenax*).

Kincaid's lupine

In 2022, total Kincaid's lupine foliar cover at Oak Basin was 243.3 m^2, continuing the generally positive trend that started in 2016 coincident with more active management of the site. The count of racemes in 2022 was 9,639, more than double the count in any previous year. Since the initiation of more active management practices in 2016, all meadows have shown a positive trend in foliar cover and count of mature racemes.

Hitchcock's blue-eyed grass

The number of Hitchcock's blue-eyed grass individuals and reproductive stems at Oak Basin's Meadow C has generally decreased since monitoring began in 2016. In 2022, 32 stems from 52 total plants were observed. Of particular concern was that no plants were observed in the small patch peripheral to the main population.

Recommendations

Activities in 2023 should include continued control of non-native plants. We recommend treating non-native plants in the meadows and corridors using all available tools (e.g., herbicide, fire, mechanical treatment), followed by the seeding and planting treated areas with a mix of native nectar species and native perennial grasses. We suggest implementing a research and demonstration project to assess the use of grass-specific herbicides to control tall fescue (*Schedonorus arundinaceus*). In 2023, site preparation will begin in meadow D to convert two acres of low-quality habitat to resource-rich habitat for Fenders blue butterfly. Coordination with adjacent landowners will leverage management actions by both parties to increase connectivity between Kincaid's lupine and Fender's blue butterfly populations in the meadow complex.

1. INTRODUCTION

This report documents habitat restoration and rare plant and community monitoring activities conducted by the Institute for Applied Ecology (IAE) at Oak Basin in 2021. Oak Basin, managed by the Northwest Oregon BLM (Bureau of Land Management) District's Upper Willamette Field Office, is about six miles southeast of Brownsville, Oregon (Figure 1). The site includes upland prairie and oak (*Quercus garryana*), maple (*Acer macrophyllum*), and Douglas-fir (*Pseudotsuga menziesii*) woodlands. Oak Basin supports the largest known population of Kincaid's lupine (*Lupinus oreganus*; Figure 2) in the Upper Willamette Field Office's management area and is home to a population of the threatened Fender's blue butterfly (*Icaricia icarioides fenderi*; Figure 2). The Oak Basin Fender's blue butterfly population is relatively small, with an estimated population of 10 butterflies in 2022, and remains vulnerable to extirpation (Diaz and Harris 2022).

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Figure 1. The location of Oak Basin within the Willamette Valley and a close-up of the project area.

Vegetation monitoring by IAE at Oak Basin is focused on documenting the size and reproduction of the Kincaid's lupine population and assessing habitat quality. This information is used to determine the effectiveness of restoration treatments 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 (U.S. Fish and Wildlife Service, 2010). In addition to monitoring Kincaid's lupine, IAE monitors a small population of the rare Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*).

Figure 2. Fender's blue butterfly (*Icaricia icarioides fenderi*) and Kincaid's lupine (*Lupinus oreganus*). Photos taken on May 5, 2021 in Meadow B.

1.1. 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. The 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 larval host for the federally threatenend Fender's blue butterfly (Oregon Biodiversity Information Center 2016), conservation of Kincaid's lupine populations is the primary 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 (USFWS) 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 3). The species reproduces by seed and 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.

The site contributes to the recovery of Kincaid's lupine since the population currently meets the minimum foliar cover of 100 m^2 needed for the site to count towards recovery (Figure 1). 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, Greenbelt Land Trust, Oregon Department of Fish and Wildlife, and U.S. Fish and Wildlife's Partners for Fish and Wildlife Program.

Figure 3. 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; and (c) flowers with blue to bluish-purple tepals with a faint (or absent) yellow "eye" in the center.

1.2. Fender's blue butterfly life cycle

Fender's blue butterflies become mature adults in May and June at which time they fly, consume nectar, and mate. The females oviposit their eggs on the underside of Kincaid's lupine leaves. Eggs are identifiable as small (0.5–1.0 mm) white spheres. The eggs hatch in a few weeks; hatched eggs resemble

unhatched eggs except that they are burst in the center, making them look like little white "donuts." The larvae subsequently feed on Kincaid's lupine leaves until late June or early July, at which time they crawl under nearby vegetation and plant litter and enter diapause. They remain in a dormant state until February or early March when they then begin feeding again on the newly emerging Kincaid's lupine leaves. Near the end of April, they pupate and reemerge as butterflies (Schultz and Crone 1998).

2. GOALS AND OBJECTIVES

2.1. Monitoring

The goals of the monitoring are to track the size and reproductive status of the Kincaid's lupine population at Oak Basin and examine overall Kincaid's lupine and Fender's blue butterfly 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 increases, with area of foliar cover being maintained at or above the minimum targets as laid out in the Recovery Plan (U.S. Fish and Wildlife Service 2010). Secondary goals are to assess the status of the Hitchcock's blue-eyed grass population and to help guide restoration activities at the site.

2.2. Habitat restoration

Habitat restoration goals are to maintain or improve prairie habitat in support of Kincaid's lupine and its associated Fender's blue butterfly populations.

This project has four primary objectives:

1) Maintain and improve quality prairie habitat by removing non-native invasive plants;
2) Prevent encroachment of woody species into the prairie;
3) Increase diversity and the areal extent of the native plant community; and
4) Improve connectivity between meadows.

3. METHODS

3.1. Monitoring methods

Habitat quality

In 2022, we continued habitat monitoring efforts begun in 2020 that are directly applicable to the habitat quality criteria as outlined in the Recovery Plan (U.S. Fish and Wildlife Service 2010). Standard relevé plots (5m x 5m) were established in each meadow, two in Meadow A and one each in Meadows B and C. Within each plot, we estimated percent cover by species and then calculated species richness and cover by plant functional group.

Restoration experiment

In addition to the relevé plots, in 2020 a new experimental restoration project was installed to assess the efficacy of utilizing various combinations of mowing, fire, application of glyphosate, and seeding over time (one, two, and four years after treatment). Plots were first sampled in 2021 and repeated in 2022. Future sampling will take place in 2023 and 2024. Two different treatment combinations, hereafter referred to as treatments, are being evaluated that include the following components: mowing (M) in the spring to prevent seed set and to reduce stored reserves of non-native perennial grasses; flame weeding (B) in the fall to reduce thatch build-up and prep the site for seeding; a post-burn spot application of 1.5% glyphosate (G) to reduce the abundance of non-native herbaceous perennials; and the application of seed (S). Mowing height will be 3-10 cm and the biomass will be left in place. In addition to the experimental treatments, a "no treatment" regime was included as a control.

A total of 10 experimental plots (10m x 30 m) were established in occupied Kincaid's lupine habitat in three BLM meadows: four in Meadow A and three in each of meadows B and C (Figure 4). Plots were divided into three 100m^2 (10m x 10m) subplots: control, GBGS, and MBGS. The control subplot was further subdivided into two 10m x 5m plots, one that will be seeded using the same mix as the treated subplots and one that will be left unseeded (Figure 5).

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Figure 4. Experimental plot and Kincaid's lupine (*Lupinus oreganus*) patch locations at Oak Basin.

Data are collected from four 1m^2 quadrats randomly placed within each of the subplots in June. Percent cover is visually estimated to the nearest 1% for all vascular species. Ground cover classes will be divided into the following: basal vegetation, bare ground, rock, moss, and thatch (defined as non-living vegetative matter). Photos of each subplot are taken from the south-central edge of the plot before sampling the quadrats.

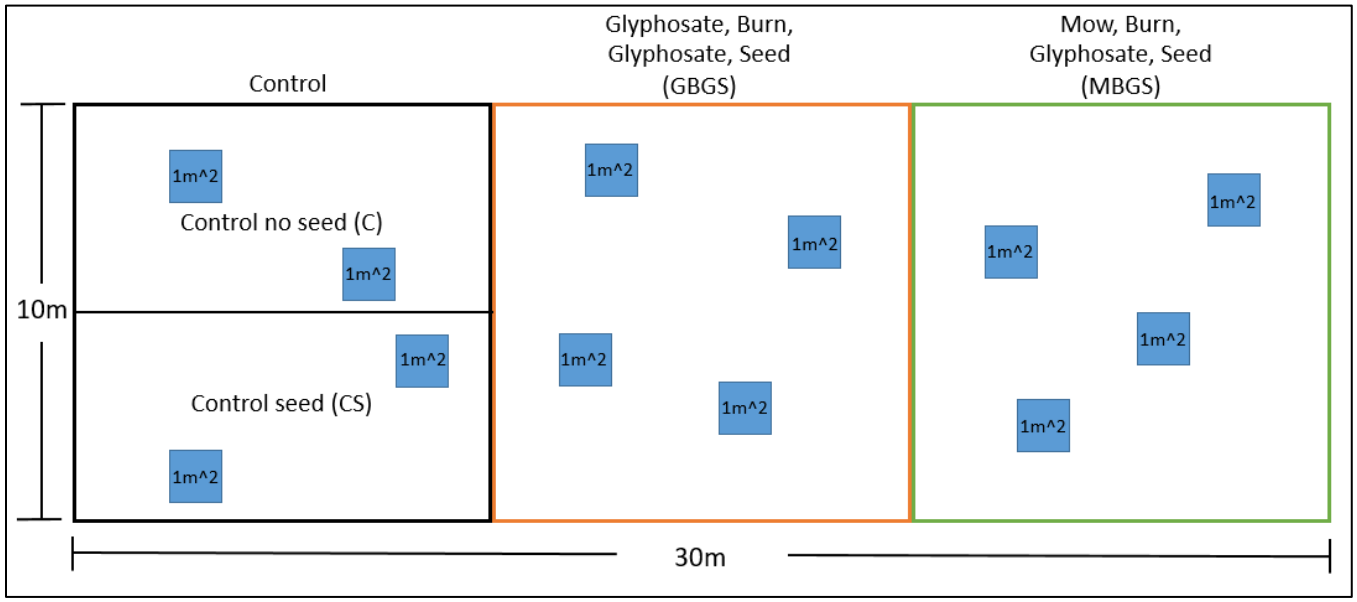

Figure 5. Diagram of oak basin experimental design. One plot is 10m x 30m. Plots are divided into three subplots (10m x 10m). Treatments for each subplot include (1) control, (2) GBGS (glyphosate-flame weed-glyphosate-seed), and (3) MBGS (mow-flame weed-glyphosate-seed). The control is divided further into two subplots: one seeded, one left unseeded. Each subplot was sampled by visually estimating species and ground cover types in four 1m^2 quadrats.

Kincaid's lupine

Monitoring Kincaid's lupine at Oak Basin is considered to be a complete census of the population. In 2006, Meadows A, B, and C were surveyed for the presence of Kincaid's lupine. Plots were then installed around Kincaid's lupine patches. Additional plots have been added as new patches have been located, and all plots are sampled annually. Larger plots are rectangular and marked with fiberglass posts, rebar, or conduit at 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 the Kincaid's lupine on either side of the tape were recorded. Each plot origin was tagged with a pre-numbered aluminum tag. Plot notes can be found on the plot maps in Appendix F. When plants are found outside of existing plots, plot boundaries are either modified or new plots added to accommodate these plants in the census.

Kincaid's lupine is monitored by measuring the area of foliar cover (m^2) and counting mature and aborted racemes in each plot. Specifically, Kincaid's lupine foliar cover is measured by taking the approximate length (cm) and width (cm) of area occupied by Kincaid's lupine using standard rulers and meter poles.

Foliar cover of Kincaid's lupine (as opposed to counting 'individual' plants of this rhizomatous species) is the standard metric for Kincaid's 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 all mature and aborted racemes and multiplying by 100.

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 2022. 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 Kincaid's lupine and the Hitchcock's blue-eyed grass. Western blue-eyed grass (*Sisyrinchium bellum*) is also present in the area; for this reason, monitoring occurs 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 (e.g., R1 has one flowering stem; R2 has two flowering stems, etc.); individual stems may have more than one flower. In addition, a reproductive plant is likely to have multiple vegetative stems as well.

4. HABITAT RESTORATION ACTIONS

In 2022, IAE coordinated and implemented a variety of activities to support restoration and conservation efforts in Meadows A, B, C, and D (Figure 6, Table 1). Restoration actions included manual and chemical invasive plant treatments, mowing around Kincaid's lupine plots, removing conifers between meadows, collecting seed, and establishing and maintaining seed amplification beds. Appendix A includes a summary of completed restoration activities conducted at Oak Basin from 2012 to 2022. Restoration actions proposed for 2023 and beyond are listed under the Conclusions and management recommendations.

Table 1. Habitat restoration actions completed at Oak Basin in 2022.

Date	Personnel	Tasks
9-Feb	IAE, contractor	Troy Danks (contractor) limbed 17 trees and felled one.
11-Feb	IAE, Lane County Youth Services Crew	Lane County Youth Services crew swamped limbs and created burn piles.
12-Feb	IAE, Lane County Youth Services Crew	Lane County Youth Services crew swamped limbs and created burn piles.
1-Apr	IAE, Lane County Youth Services Crew	Lane County Youth Services crew swamped limbs and created burn piles. IAE staff scouted seed collection spots and took photos at all 10 experimental plots.
2-Apr	IAE, Lane County Youth Services Crew	Lane County Youth Services crew swamped limbs and created burn piles.
14-Apr	IAE, BLM	Site visit with Jessica Celis (UWFO BLM botanist) and project lead handover from Celeste Lebo to Tyler Roberts.

Date	Personnel	Tasks
17-May	IAE, BLM, Anna Merzenich	Hand pulled Italian plumeless thistle (*Carduus pycnocephalus*)
13-Jun	IAE, BLM, Jim Merzenich	Hand pulled Italian plumeless thistle (*Carduus pycnocephalus*).
5-Jul	IAE, Jim Merzenich	Assessment of weeds in the corridor between meadow A and B.
26-Jul	IAE	Grubbing false brome (*Brachypodium sylvaticum*) from a patch in meadow B.
30-Aug	IAE	Spot sprayed Himalayan and evergreen blackberry (*Rubus bifrons* and *Rubus laciniatus*) with Triclopyr (Garlon 3A) in meadows A-B.
19-Sep	IAE	Spot sprayed Himalayan and evergreen blackberry (*Rubus bifrons* and *Rubus laciniatus*) with Triclopyr (Garlon 3A) in meadows B-D.
28-Sep	IAE	Mowed the edges of Kincaid's lupine (*Lupinus oreganus*) plots and blackberry patches in meadow A.
6-Oct	IAE	Mowed lupine patches in meadow C and Himalayan blackberry (*Rubus bifrons*) in meadow D

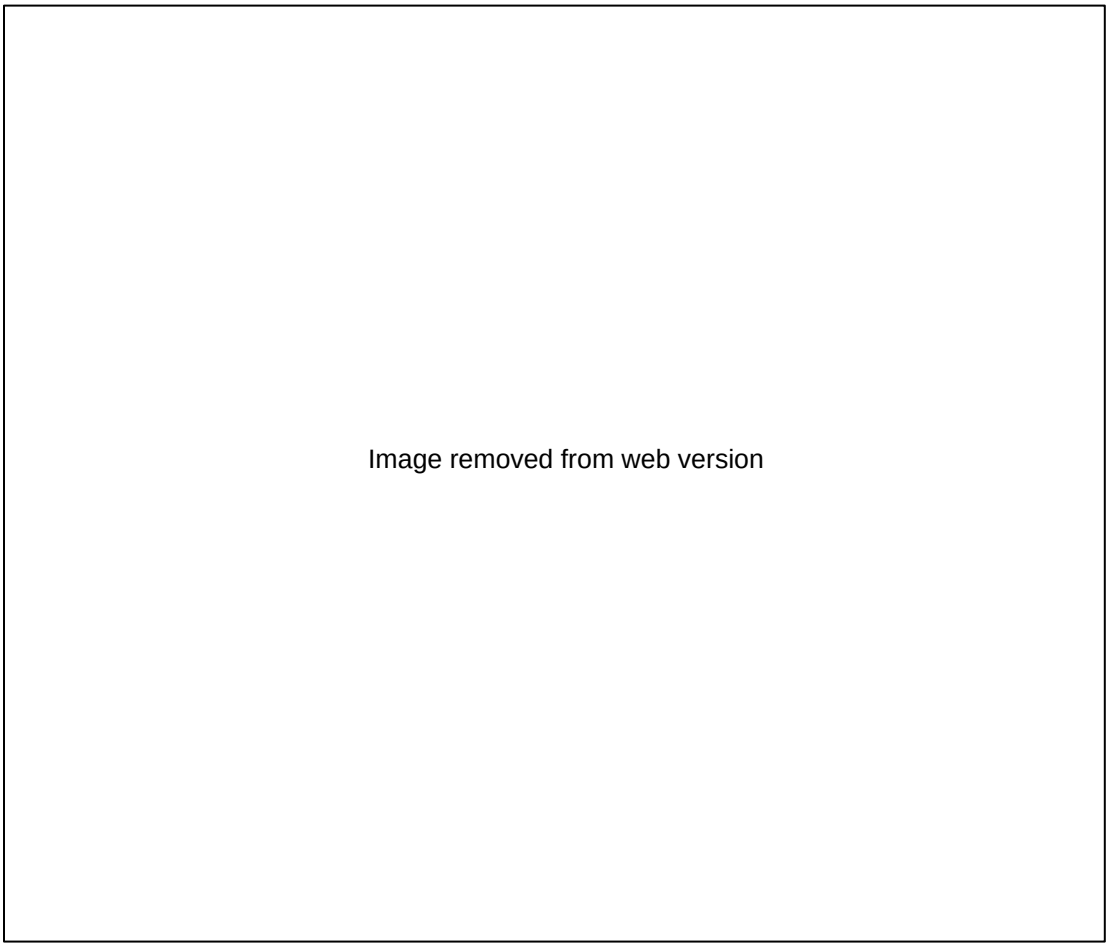

Figure 6. Restoration actions completed at Oak Basin in 2022.

4.1. Invasive plant treatments

Manual treatments

The purpose of manually removing invasive species by hand is to reduce ground cover and seed maturation while minimizing the use of herbicide. IAE and BLM staff and private landowners pulled populations of Italian plumeless thistle (*Carduus pycnocephalus*) by hand from meadows A and B during the Fender's flight season, April 15 to June 30 (Table 1, Figure 6, Figure 7). In July, IAE staff grubbed out a small and isolated patch of false brome (*Brachypodium sylvaticum*) in meadow B to reduce seed set and further expansion (Figure 7). The disturbed ground will be planted with native species in 2023.

Figure 7. Photos of invasive species and tree removal. **A.** private landowner and BLM staff hand pulling Italian plumeless thistle (*Carduus pycnocephalus*). **B.** IAE ecologist, Paul Reed, grubbing false brome (*Brachypodium sylvaticum*) from meadow B. **C.** Lane County Youth Services crew after swamping and piling woody debris. **D.** Contractor, Troy Danks, Limbing a large Douglas-fir (*Pseudotsuga menziesii*) tree between meadows A and B.

Mowing

IAE mowed seven Kincaid's lupine plots using a string trimmer to reduce thatch build up (Figure 6). The goal is to mow competing vegetation within approximately 1/4 of the area occupied by Kincaid's lupine in each of the three meadows annually; management of the patches rotates so that each patch is mowed every three years. In 2022, this pattern of mowing was not followed due to the low survey count of Fender's blue butterfly. Instead, the perimeter of four Kincaid's lupine patches in meadow A were mowed to support the core habitat and reduce unintended impacts of mowing occupied areas. Additionally, IAE fully mowed three Kincaid's lupine patches in meadow C, where Fender's blue butterfly have not been observed since 2016. Appendix C indicates the cover and raceme count of Kincaid's lupine patches and the years in which each patch has been mowed.

Herbicide

The purpose of spot spraying at Oak Basin is to reduce cover of noxious weeds while minimizing negative impacts to surrounding vegetation. In fall 2022, Triclopyr (Garlon 3A) herbicide was spot sprayed on Himalayan and evergreen blackberry across seven acres of BLM meadows and surrounding habitat (Figure 6). Particular attention was given to treating connectivity corridors, which are expected to experience a surge of Himalayan blackberry growth in response to increased sun exposure following tree removal and limbing.

Tree removal

IAE contracted a specialist to remove and limb large trees in three corridors connecting BLM and privately owned meadows (Figure 6). Reducing the cover of trees and woody vegetation in corridors promotes connectivity of Fender's blue butterfly habitat and increases opportunity for population growth and dispersal. After felling and limbing, IAE staff and a Lane County Youth Services crew swamped limbs and consolidated woody debris into burn piles (Figure 7).

4.2. Revegetation actions

In 2022, Oak Basin revegetation actions included collecting wild native seed and starting seed amplification beds. Wild seed was collected from populations of blue wildrye (*Elymus glaucus*), Columbia brome (*Bromus vulgaris*), common woolly sunflower (*Eriophyllum lanatum*), woodrush (*Luzula comosa*), and Kincaid's lupine. In the fall of 2022, dwarf checkermallow (*Sidalcea malviflora ssp. virgata*) and toughleaf iris (*Iris tenax*) seed amplification beds were started. Additionally, funds from a complimentary BLM agreement (#L21AC10385) were used to start mid-elevation sourced seed amplification beds of California fescue (*Festuca californica*), white-topped aster (*Sericocarpus rigidus*), and Hitchcock's blue-eyed grass. Seed from these beds may be used in any of the UWFO managed mid-elevation restoration projects, including Oak Basin.

5. RESULTS

5.1. Habitat quality

In each meadow, a 25 m^2 relevé plot was permanently installed in 2020 and surveyed for species richness. Observations are summarized in Table 2. A full list of observed species is provided in Appendix H. Plots are scheduled to be monitored on a three year cycle to assess changes in plant community. In 2020 a total of 15 native species were observed and 23 non-native species. Plots will be resampled in 2023.

Table 2. Number of species observed within a 5 x 5 m plot in each meadow in 2020, summarized by plant functional group and nativity. Plots will be monitored again in 2023.

	Number of species observed							
	Forbs		Graminoids		Tree/Shrubs		Total	
Meadow	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native
A (plot #696)	9	13	6	8	0	0	15	21
B (plot #691)	8	14	4	9	2	0	14	23
C (plot #690)	10	14	6	9	0	0	16	23
Average	**9**	**14**	**6**	**9**	**1**	**0**	**15**	**23**

5.2. Experimental treatment plots

When plots were established, cover of each plant functional group was similar (Table 3, Figure 9). In the second-year post-treatment (2022), introduced graminoids were significantly lower in the treated plots compared to the controls ($p<0.01$). The remaining functional groups including native and introduced forbs, and native graminoids remained similar to the control plots (Table 3, Figure 8, Figure 9). Bareground increased in the first year post-treatment compared to the controls with the flame-weeded plots having higher bareground than control or mow plots. This trend continued in 2022, with the GBGS treatment continuing to have more bareground than the controls ($p<0.01$) and more than the MBGS ($p<0.01$), (Table 3). Photo points of all 10 experimental plots were taken in April 2022 (Appendix B).

Table 3. Mean plant functional group cover (%) by treatment in 2020 (pre-treatment), 2021, and 2022. Each experimental plot contains 3 treatments, and twelve 1x1m subplots in which percent cover was visually estimated for all species and ground cover classes. Results are reported here as an average for each treatment by year.

	2020 – Pre-treatment			2021- First year post-treatment			2022 – Second year post-treatment		
	Control	GBGS	MBGS	Control	GBGS	MBGS	Control	GBGS	MBGS
Native Forbs	15.4 (3.3)	16.3 (5.2)	13.7 (4.6)	8.7 (2.8)	10.5 (6)	13.4 (5.4)	12.5 (3.6)	17.0 (7.2)	13.9 (3.6)
Native Graminoids	1.5 (0.5)	1.6 (0.5)	3.2 (1.6)	1.8 (0.7)	0.9 (0.4)	4.6 (2.9)	2.2 (.06)	0.8 (0.5)	3.3 (1.6)
Introduced Forbs	18.8 (4.2)	17.4 (4.7)	12.4 (3.9)	6.7 (2.2)	14.4 (4.7)	3.1 (1.1)	13.4 (3.2)	18.8 (4.5)	12.9 (3.1)
Introduced Graminoids	42.5 (7.4)	49.2 (8.3)	52.5 (6.9)	44.4 (7)	10.9 (3.5)	34.2 (6.9)	51.7 (7.9)	19.1 (5.3)	25.2 (6.5)
Bare Ground	1.4 (0.6)	0.6 (0.4)	0.5 (0.3)	1.2 (0.9)	10.4 (3.9)	5.4 (3.5)	0.8 (0.6)	10.6 (4.6)	2.8 (1.9)
Litter	62.1(3)	56.2 (6.1)	65.2 (2.9)	66 (4)	58.1 (7.7)	55.5 (7.1)	54.9 (6.1)	58.8 (5.2)	64.1(3.4)
Moss	1.4 (0.7)	10.1 (7.4)	1.5 (0.6)	1.5 (1.6)	6.3 (5.5)	1.5 (2)	2.3 (1.7)	6.2 (4.1)	1.5 (1.4)
Rock	0.1(0.1)	0.1(0.2)	0.5 (0.3)	0.3 (0.3)	2.7 (3.7)	0.8 (0.4)	0.2 (0.3)	1.5 (1.5)	2.0 (2.0)
Basal Vegetation	30.8 (2.9)	25 (3.5)	36.7 (3.0)	30.8 (3.6)	25 (4.5)	36.7 (6.3)	42.0 (6.6)	22.7 (4.4)	29.6 (3.8)

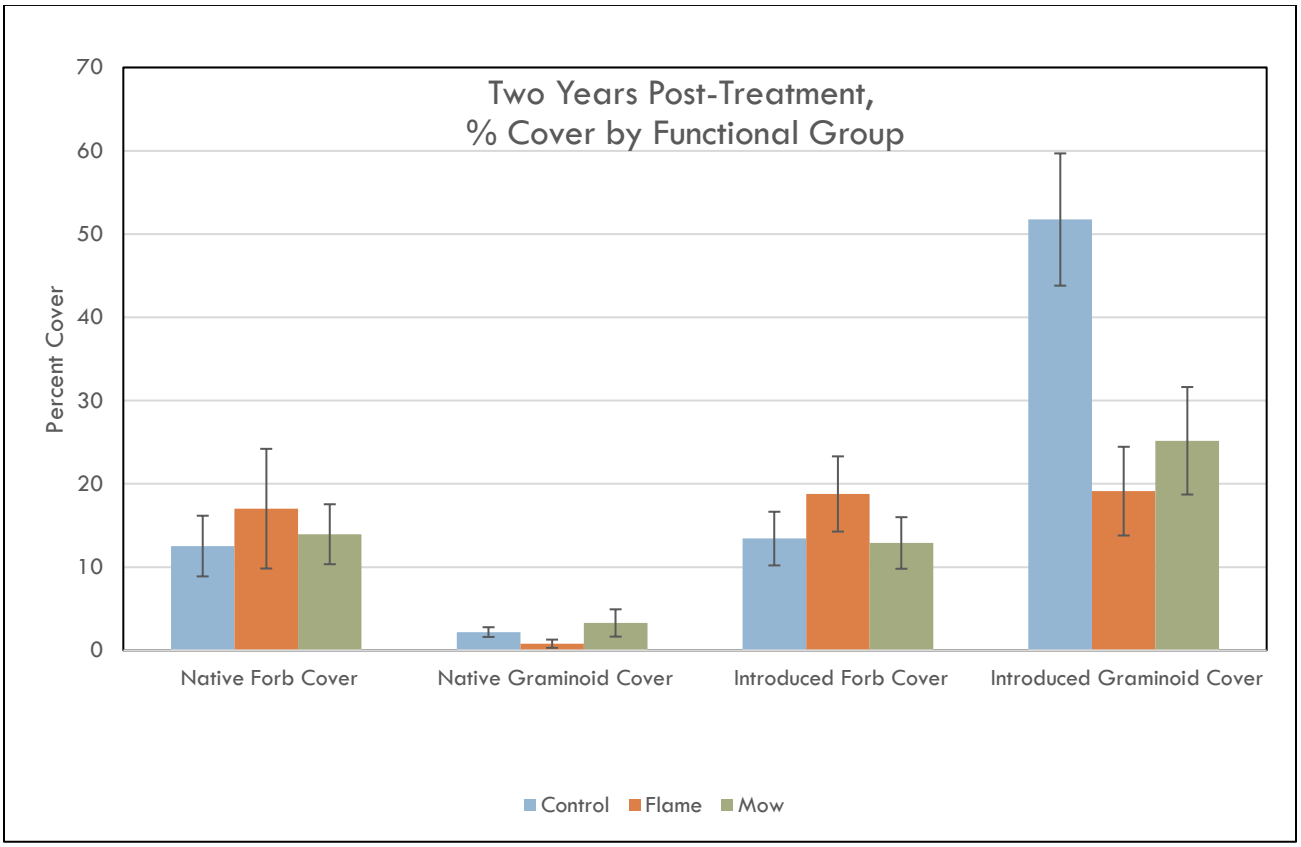

Figure 8. Percent cover by functional group two years post-treatment (2022). Treatments include control, flame weeding (GBGS), and mowing (MBGS). Error bars represent 95% confidence intervals.

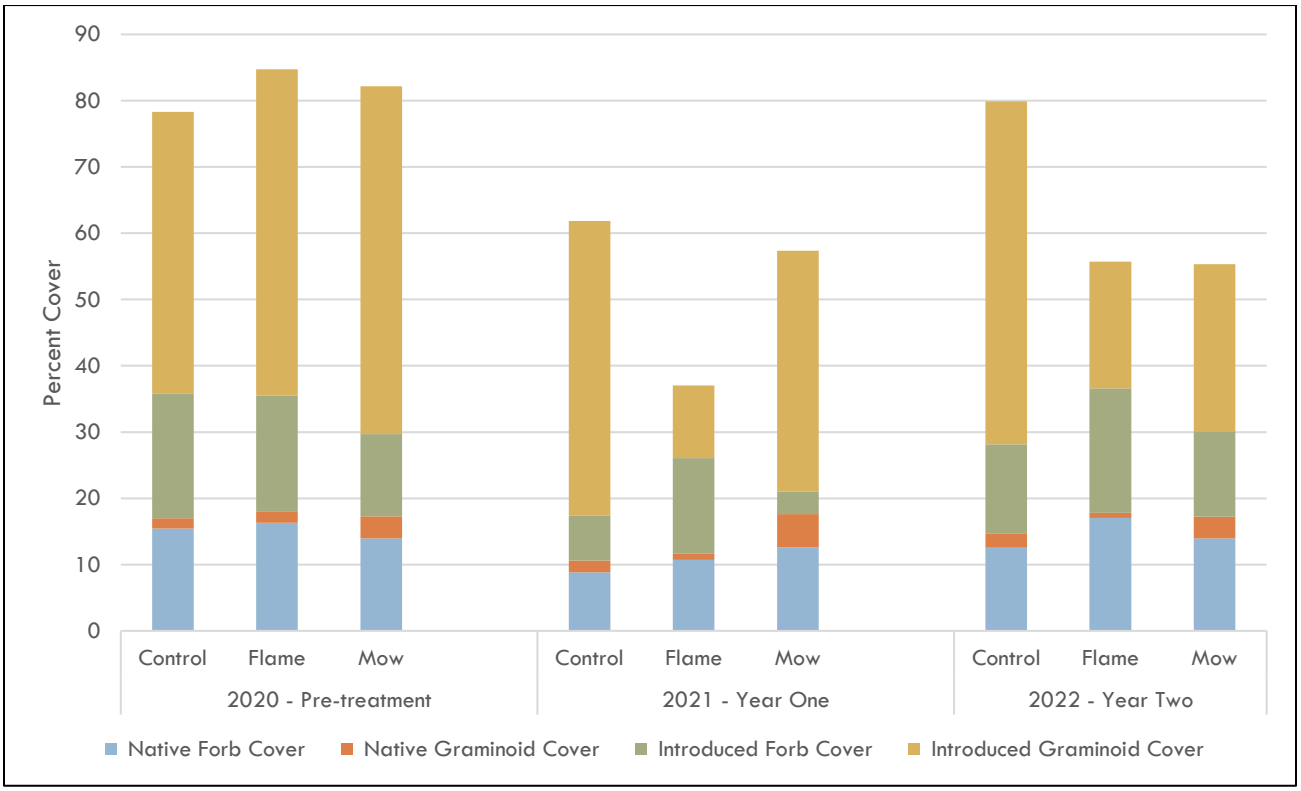

Figure 9. Percent cover of species by treatment, colored by functional group. Pre-treatment (left) and one and two years post-treatment (right): control, flame weeding (GBGS), and mowing (MBGS).

5.3. Kincaid's lupine

Kincaid's lupine cover and raceme count increased in 2022 in all meadows. Total Kincaid's lupine foliar cover was 247.3m^2 across all meadows (Figure 10; Table C-2). There were 9,639 mature racemes and 531 aborted racemes (5.2%) (Figure 11, Table D- 1).

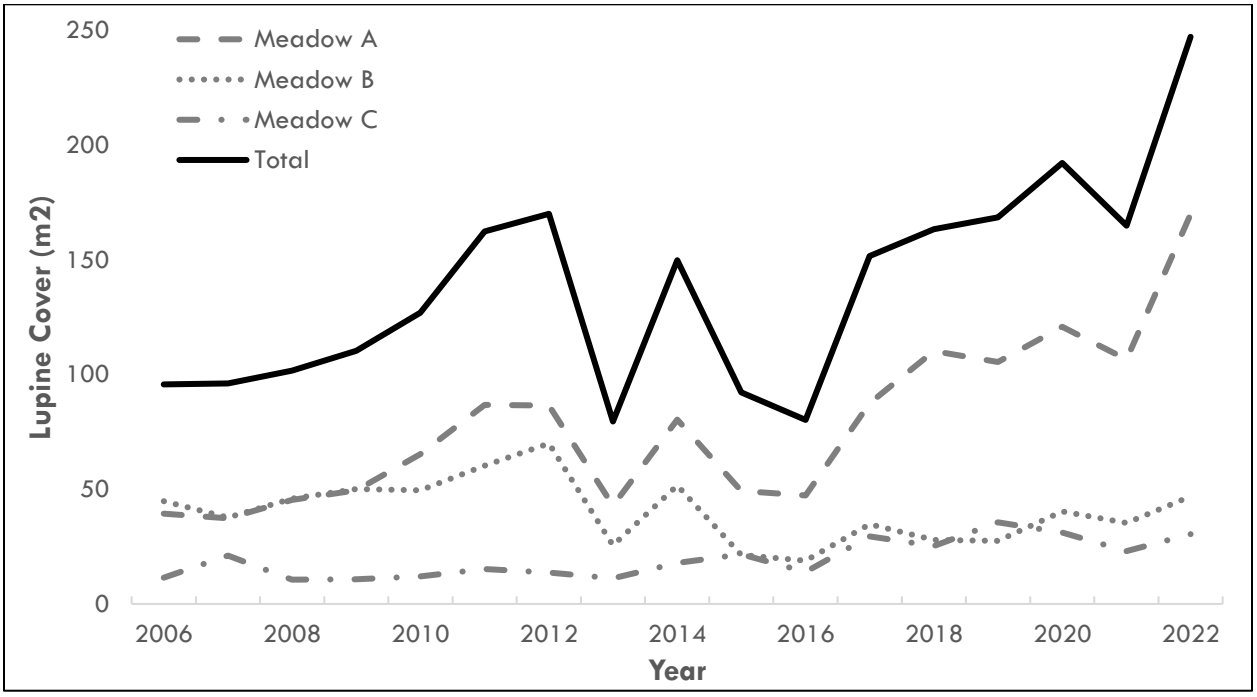

Figure 10. Kincaid's lupine (*Lupinus oreganus*) foliar cover (m^2) in each meadow and total cover for all meadows at Oak Basin from 2006 to 2022.

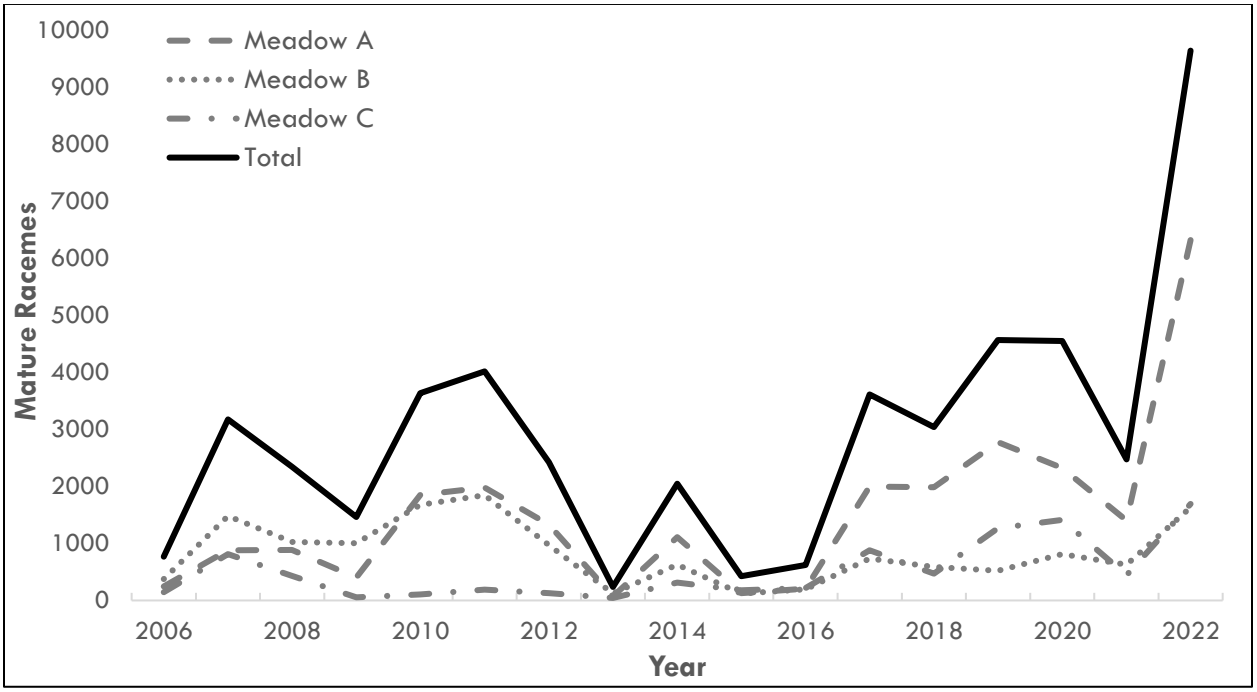

Figure 11. Total mature Kincaid's lupine (*Lupinus oreganus*) racemes counted in each meadow at Oak Basin from 2006 to 2022.

5.4. Hitchcock's blue-eyed grass

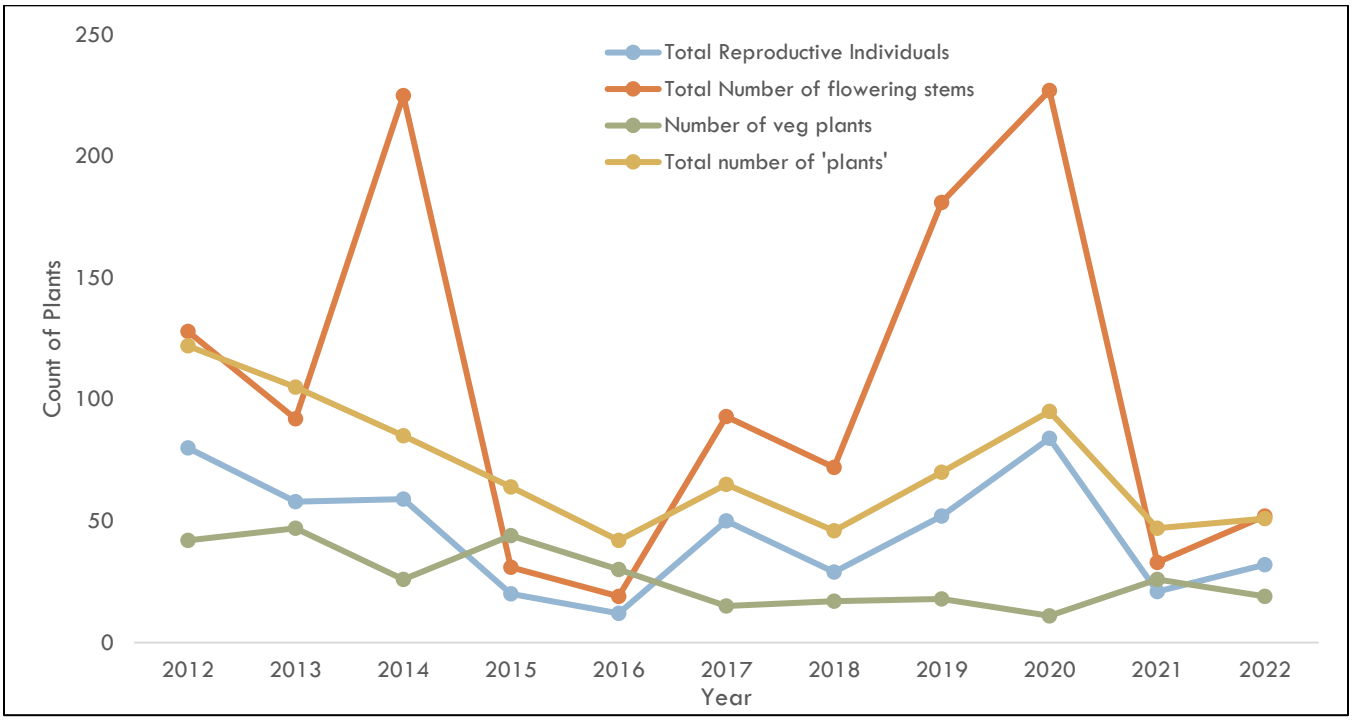

Figure 12. Count of Hitchcock's blue-eyed grass at Oak Basin from 2012-2022.

In 2022, a total of 51 Hitchcock's blue-eyed grass plants were observed, with a total of 52 reproductive stems (Appendix E). This count was the second lowest since monitoring of this species began in 2012. As in previous years, most plants observed in the 4-meter-wide belt transect were found within two meters of the transect tape.

6. DISCUSSION

6.1. Monitoring trends

Kincaid's lupine

Over the course of this project there have been periodic fluctuations in Kincaid's lupine foliar cover and raceme counts (Figure 10, Figure 11, Table D- 1, Table D- 2). Some of these fluctuations could be linked to climatic stresses and ongoing modeling conducted by IAE may help to elucidate these trends. In addition to links to climatic factors, habitat management (including removal of introduced grasses and limbing of trees adjacent to existing patches of lupine) likely contribute to these fluctuations. For example, increases in cover of Kincaid's lupine in Meadow A were largely from increases from the plot along the north end of the Meadow where ongoing management has been conducted to treat introduced graminoids and to expand meadow habitat. The overall decrease in foliar cover from 2012 to 2016 led to a re-evaluation of management actions. Kincaid's lupine cover has generally increased from 2016 to the present concurrent with increased management activities at the site.

The total number of racemes has followed a similar pattern to Kincaid's lupine foliar cover (Figure 10, Figure 11). As with foliar cover, climate differences, competition from non-native plants, 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 Kincaid's 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, Kincaid's lupine plants growing in competition with introduced perennial grasses often have fewer leaves and larger gaps between leaves (Giles, 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 number of flowers) through the duration of the butterfly's flight period for Fender's blue butterflies to thrive (Giles-Johnson et al. 2011), a condition that may also be true for other pollinators.

Hitchcock's blue-eyed grass

Over the past nine years of monitoring, our data show a general downward trend in the Hitchcock's blue-eyed grass population, 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 that are then counted as one during monitoring. Despite the potential limitations of the sampling method with regard 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 vegetative plants has decreased over the course of the study, but reproductive stems have fluctuated more widely, decreasing in 2021 to the second lowest recorded count (Figure 12, Appendix E). These fluctuations in reproductive stem counts may be influenced by environmental factors, and booms in reproductive effort may not always correspond to overall population success.

Monitoring Hitchcock's blue-eyed grass remains vital to ensure its continued viability and to illustrate the need for active management of the population. The general downward trend and the extremely small size of the population merits continued monitoring efforts and habitat management to improve habitat quality to ensure the longevity of this small population, which occupies less than 50m^2 in Meadow C.

Experimental treatment plots

In the first and second-year post-treatment, the glyphosate-flame weeding-glyphosate-seed (GBGS) resulted in increased bare ground and lower cover of introduced graminoids compared to other treatments (Table 3, Figure 8). In the first-year post-treatment, GBGS resulted in higher cover of introduced forb species, however in the second year post-treatment differences in introduced forb cover were not significantly different between treatments (Table 3). It is anticipated that seeding efforts conducted in 2021 and 2022 will contribute to increased cover of native species in the future as germinated seeds mature.

6.2. Synthesis

To reach recovery goals for Kincaid's lupine, continued monitoring of both this species and its associated plant community will be vital. Annual fluctuations in raceme count and foliar cover of Kincaid's lupine highlight the need for ongoing monitoring of extant populations in order to assess the status and overall trend of these populations to meet recovery goals (USFWS 2010). The prevalence of introduced grasses in the plant community continues to pose a challenge for the restoration of both Kincaid's lupine and Hitchcock's blue-eyed grass. To assess the progress that has been made towards the Kincaid's lupine

recovery goals, we have summarized data for 2022 to compare current conditions to the habitat-quality targets listed in the Recovery Plan (Table 4; USFWS 2010).

Table 4. Summary of current Oak Basin prairie habitat quality compared to recovery goals. Trends summarize 14 years (2006-2022) of population and community monitoring data.

Prairie Quality and Diversity Summary*			
Criteria	**Oak Basin**	***Recovery Plan* threshold***	**Meets *Recovery Plan* objectives?**
Fender's blue butterfly population size**	BLM-administered land: 10;	Minimum population size of 200 individuals over 10 years	No
Trend of Kincaid's lupine population size (foliar cover, m^2)	Generally increasing since 2006	Increasing (+ slope) or stable (0 slope) over 15 years	Yes
Target foliar cover for Kincaid's lupine downlisting	Total: 247.3[2] Meadow A: 169.9 m^2 Meadow B: 46.9 m^2 Meadow C: 30.5 m^2	5,000 m^2 in Eugene East Recovery Zone; minimum of 100m^2 in each meadow to count towards recovery	Mixed
Evidence of lupine reproduction	7.18 g seed collected on BLM-adminstered land only	Seedset or ~~presence of seedlings~~	Mixed – no seed set in some meadows
Native herbaceous species relative cover	15%	50% min	No
Woody species cover	8%	15% max	Yes
Do any woody species of management concern exceed 5% cover?	No	5% max	Yes
Prairie diversity: Native forb richness	9	7	Yes
Prairie diversity: Native bunchgrass richness	1	1	Yes
Prairie diversity: Total native herbaceous species richness	15	>10	Yes
Sufficient abundance of nectar species	2 Native, 5 Non-native	5 native species	No

*From the *Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington* (USFWS 2010).
** Data from Diaz 2022

7. 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, and several measures of habitat quality. These data highlight where to focus future restoration efforts at Oak Basin and also guide future monitoring methods.

Continued restoration needs to be a priority, with the goals of increasing the population size of Kincaid's lupine and improving habitat quality. To accomplish these goals, larger areas of meadow need to be treated using fire and herbicides. As an example, although we have consistently mowed Kincaid's lupine patches as a means of controlling 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. We suggest the use of grass-specific herbicides such as fluazifop or sethoxydim, currently restricted from use at Oak Basin, as the most effective means of controlling tall fescue. Alternatively, prescribed fire followed by spot herbicide application could provide more targeted control of tall fescue and other non-native plants. These treated areas would need to be subsequently seeded and planted with native graminoids and forbs, including Kincaid's lupine and others that serve as nectar species for Fender's blue butterfly. It will still be important to use an integrated management approach at the site and to continue to hand-pull small, isolated populations of non-native invasive plants such as Scotch broom, Himalayan blackberry, and Italian plumeless thistle. Additionally, conifer recruitment should be addressed by cutting saplings rather than allowing trees to grow larger. To address the problem of low Fender's blue butterfly counts at the site, a large number of trees have been removed, girdled, or limbed since 2015 to increase connectivity between meadows; and treatments to control introduced graminoids are being implemented and tested. Once corridors are opened up, follow-up treatments are necessary to prevent non-native shrubs from colonizing the site.

The following habitat management and monitoring activities are recommended at Oak Basin in 2023 and beyond:

- Monitor outplanted Kincaid's lupine plugs at Oak Basin Tree Farm.
- Monitor Fender's blue butterfly nectar availability at least once every three years.
- Initiate active restoration of Hitchcock's blue-eyed grass habitat and augment population in Meadow C by putting this species into production (collecting seed in the wild and growing plugs and/or increasing seed).
- Continue to monitor and assess efficacy of management treatments to reduce abundance of non-native species through appropriate weed-control measures.
- Continue to treat non-native species using all available methods, including spot-spraying non-native perennial species with herbicide.
    - Continue treatment of non-native species between meadows, particularly in newly created corridors
    - Hand-pull all populations of Italian plumeless thistle annually.
    - Spot-spray Himalayan blackberry in all meadows.
- Implement a research and demonstration project using grass-specific herbicides to determine the effectiveness and degree of tall fescue control.
- Pending authorization of the use of prescribed fire, initiate fire treatments in 2023-2024 in Meadow A.
- 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 outplanting of plugs.
    - Seed/plant nectar and host plant species in experimental plots.
    - Maintain Eugene East Recovery Zone seed-production beds for Kincaid's lupine.
    - Collect wild native seed from Oak Basin and other mid-elevation sites for starting seed-increase beds, growing plugs for introduction, and/or direct sowing in disturbed areas.

- Maintain mid-elevation seed-production beds (funded through a separate agreement).
- Augment the Kincaid's lupine population with plugs or seed from appropriate seed sources.

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APPENDIX A. SUMMARY OF RESTORATION ACTIONS AT OAK BASIN (2012-2022)

2012 Management Actions

- Site inspection and partner coordination.

2013 Management Actions

- Site inspection and partner coordination.
- Mapped *Taeniatherum caput-medusae* locations.
- Mowed around perimeter of all *Lupinus oreganus* patches and inside 1/3 of all *Lupinus oreganus* patches.
- Mowed all major *Rubus armeniacus* patches.
- Grubbed several *Rubus armeniacus* patches.
- Flame-weeded patches for *Taeniatherum caput-medusae* control and site preparation for planting/seeding.

2014 Management Actions

- Site inspection and partner coordination.
- Flame-weeded patches for *Taeniatherum caput-medusae* 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*, and 1.71 lbs. *Sidalcea malviflora* ssp. *virgata*.
- Nectar plant availability assessment.
- Hand-weeded *Cirsium vulgare* and *Cytisus scoparius*.
- Mowed 1/3 of all *Lupinus oreganus* patches and some *Rubus armeniacus* patches.
- Grubbed *Rubus armeniacus*.

2015 Management Actions

- Site inspection and partner coordination.
- Grubbed *Rubus armeniacus*.
- Removed small-diameter conifers 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 *Taeniatherum caput-medusae* 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 *Lupinus oreganus* patches.

2016 Management Actions

- Site inspection and partner coordination.
- Flame-weeded *Taeniatherum caput-medusae* control and site preparation for planting/seeding.
- Grubbed *Rubus armeniacus*.
- Removed small-diameter conifers around perimeter of meadows.
- Hand-weeded *Cytisus scoparius*.
- Mowed 1/3 of all *Lupinus oreganus* patches.
- Planted plugs: 40 *Danthonia californica*, 50 *Iris tenax*, and 400 *Sidalcea malviflora* ssp. *virgata*.

2017 Management Actions

- Site inspection and partner coordination.
- Outplanted 68 plugs of *Lupinus oreganus* on neighboring private land (Oak Basin Tree Farm)
- Flame-weeded patches for *Taeniatherum caput-medusae* control and site preparation for seeding.
- Grubbed *Rubus armeniacus*.
- 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 *Lupinus oreganus* patches after senescence.
- Hand-mowed flame-weeded plots A3, A4, B3, and B4 in Meadows A and B.

2018 Management Actions

- 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 *Taeniatherum caput-medusae* control and site preparation for seeding in Meadows A and B.
- Grubbed *Rubus armeniacus*.
- Pulled *Cytisus scoparius, Carduus pycnocephalus*, and *Geranium lucidum* (geranium pulled near lupine patch 460 in Meadow A only).
- Cut seedlings and saplings from edges of all meadows. They were particularly concentrated in Meadow C.
- Mowed approximately one-third of *Lupinus oreganus* patches after senescence.
- Seeded flame-weeded areas (~0.67 acres) with a native forb and grass mix: *Danthonia californica* (1.87 lbs.), *Elymus glaucus* (1.45 lbs.), *Eriophyllum lanatum* (0.28 lbs.), *Koelaria micrantha* (0.09 lbs.), *Plectritis congesta* (0.46 lbs.), *Prunella vulgaris* (0.38 lbs.), and *Wyethia angustifolium* (3.27 lbs.).

2019 Management Actions

- 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 *Rubus armeniacus* in Meadows B and C.
- Pulled *Cytisus scoparius* and *Carduus pycnocephalus* 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 Five 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 lbs.), *Elymus glaucus* (1.10 lbs.), *Festuca roemeri* (0.34 lbs.), and *Wyethia angustifolium* (2.20 lbs.).

2020 Management Actions

- Site inspection and partner coordination.
- Tree removal between Meadows B and C.
- Hand-pulled *Carduus pycnocephalus* from Meadow B, *Cytisus scoparius* from Meadow A, and grubbed *Rubus armeniacus* from Meadow C.
- Installed restoration experimental plots.
- Collected *Lupinus oreganus* seed.
- Mowed *Lupinus oreganus* plots in Meadows A, B, and C, the furthest east subplot of all 10 experimental plots and a six-foot-wide path between Meadows A and B using a weed trimmer.
- Spot-sprayed non-native species in all experimental plots with Glyphosate.
- Removed a large tree in corridor between Meadows A and B.
- Flame-weeded two patches of annual grasses (A5 and A6) and all experimental plots in Meadow A. Activity approved by BLM fire duty officer Sean Sheldon.
- Took photo points.
- Broadcast a seed mix in flame-weeded patches A5 and A6.
- Cut down approximately 35 conifers along the forest/meadow edge in Meadow C.
- Established Eugene East Recovery Zone seed-production beds for *Lupinus oreganus*.
- Monitored *Lupinus oreganus* and *Sisyrinchium hitchcockii*.

2021 Management Actions

- Site inspection and partner coordination.
- Tree removal over four acres of meadow between Meadows A and B and between Meadow A and the Oak Basin Tree Farm.
- Limbed 18 large conifers.
- Piled limbs into brush piles for burning.
- Hand-pulled *Carduus pycnocephalus* and *Cirsium vulgare* from Meadows B and C; cut *Rubus armeniacus* from Meadows B and D.
- Collected *Lupinus oreganus* seed.
- Mowed *Lupinus oreganus* plots in Meadows A, B, and C.
- Spot-sprayed non-native species in all experimental plots with glyphosate.
- Took photo points in experimental plots.
- Broadcast seed in experimental plots.

- Continued Eugene East Recovery Zone seed-production beds for *Lupinus oreganus*.
- Monitored *Lupinus oreganus* and *Sisyrinchium hitchcockii*.
- Planted 495 plugs at the top of Meadow A.

2022 Management and Monitoring Actions

- Limbed 17 large conifers and felled one.
- Swamped limbs and created burn piles.
- Hand-pulled *Carduus pycnocephalus* from Meadows A and B; cut *Rubus armeniacus* from Meadows A and D
- Mowed *Lupinus oreganus* plots in meadow C and perimeter of plots in meadow A.
- Mowed *Rubus armeniacus* in meadows A and D.
- Spot-sprayed *Rubus armeniacus* and *Rubus laciniatus* with Triclopyr (Garlon 3A) in meadows A, B, C, and D.
- Collected wild seed for *Elymus glaucus*, *Bromus vulgaris*, *Eriophyllum lanatum*, *Luzula comosa*, *Lupinus oreganus*.
- Established seed-production beds for *Sidalcea malviflora ssp. virgata* and *Iris tenax*.
- Continued Eugene East Recovery Zone seed-production beds for *Lupinus oreganus*.
- Monitored Kincaid's lupine *Lupinus oreganus* and *Sisyrinchium hitchcockii*.
- Took photo points in experimental plots
- Monitored outplanting of Kincaid's lupine plugs at Oak Basin Tree Farm.

APPENDIX B. EXPERIMENTAL PLOT PHOTO POINTS (2022)

Figure B-1. Plot A1: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-2. Plot A2: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-3. Plot A3: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-4. Plot A4: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-5. Plot B1: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-6. Plot B2: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-7. Plot B3: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-8. Plot C1: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-9. Plot C2: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

Figure B-10. Plot C3: (left to right) control, GBGS (glyphosate-flame weed-glyphosate-seed), MBGS (mow-flame weed-glyphosate-seed)

APPENDIX C. KINCAID'S LUPINE COVER AND RACEME COUNTS BY PLOT (2013-2022)

Table C- 1. Count of Kincaid's lupine racemes by plot from 2013-2022.

	Plot	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Meadow A	7	10	36	10	12	201	62	145	164	7	40
	8	3	1	-	-	4	6	9	19	-	0
	9	2	146	24	5	49	30	25	162	14	56
	10	-	18	3	-	8	3	3	29	4	0
	369						50	-	8	14	96
	406	1	-	-	2	1	-	1	12	-	6
	450	23	30	21	22	29	7	93	251	111	1000
	451	-	4	-	-	16	-	-	-	-	5
	452	6	93	9	-	129	34	25	116	67	433
	454	4	10	-	-	36	3	27	42	15	322
	459	6	361	9	-	1,069	669	1,142	555	517	2968
	460	2	192	12	117	206	785	589	223	365	753
	464	4	118	2	-	126	23	90	83	12	315
	509	8	52	30	51	56	239	462	550	176	190
	510	-	14	4	-	1	8	14	43	15	51
	511	2	33	5	-	65	65	127	56	86	65
	653							23	7	-	18
Meadow A Total		**71**	**1,108**	**129**	**209**	**1,996**	**1,984**	**2,775**	**2,320**	**1,403**	**6,318**
Meadow B	1	20	309	31	43	441	379	198	222	175	542
	2	1	1	1	-	3	1	-	-	-	0
	3	5	21	7	13	15	5	16	49	72	131
	4	2	23	7	-	40	2	6	-	6	28
	5	2	114	50	25	19	22	67	134	184	181
	6	51	125	24	21	51	107	36	80	71	339
	399	41	34		95	167	71	200	330	119	408
Meadow B Total		**122**	**627**	**120**	**197**	**736**	**587**	**523**	**815**	**627**	**1,629**
Meadow C	184	-	-	-			1	3	7	13	4
	233			-		2	-	4	2	8	12
	400	-	1	1	3	-	-	2	7	-	222
	431	-	20	8	-	62	32	99	162	70	777
	432	42	173	86	187	408	322	741	1,010	251	596
	433	2	117	82	14	408	78	372	213	94	81

	Plot	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	594				13	1	38	44	12	6	4
Meadow C Total		**44**	**311**	**177**	**217**	**881**	**471**	**1,265**	**1,413**	**442**	**1,692**
Grand Total		**237**	**2,046**	**426**	**623**	**3,613**	**3,042**	**4,563**	**4,548**	**2,472**	**9,639**

Table C- 2. Kincaid's lupine (*Lupinus oreganus*) foliar cover (m^2) by plot from 2013 to 2022.

	Plot	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Meadow A	7	1.1	2.9	1.8	1.9	2.8	1.8	2.1	4.1	0.4	2.2
	8	0.3	0.2	0.1	0.1	0.3	0.4	0.3	0.5	0.0	0.0
	9	4.7	6.4	3.2	2.2	4.7	6.0	4.3	7.4	1.8	7.6
	10	0.4	0.8	0.4	0.6	0.5	0.6	0.5	0.8	0.5	0.1
	369						10.9	7.8	13.8	14.0	21.5
	406	0.7	0.3	0.0	0.1	0.3	0.4	0.5	0.4	0.2	0.4
	450	10.8	11.3	7.5	3.9	6.2	7.4	15.0	10.5	13.5	22.4
	451	0.7	1.6	0.6	0.9	1.4	1.4	0.5	0.9	0.6	1.6
	452	3.4	10.0	8.5	3.8	11.1	10.4	8.0	8.3	12.8	20.2
	454	1.8	5.7	2.6	1.3	6.8	6.4	4.7	5.7	6.9	8.1
	459	9.7	19.3	11.9	16.8	26.3	39.3	25.1	35.2	29.9	38.2
	460	2.4	4.8	3.0	2.5	6.5	6.4	10.1	8.7	9.9	10.8
	464	5.3	13.8	6.4	7.9	17.4	12.0	14.9	9.6	7.3	20.9
	509	1.0	1.5	1.6	0.7	2.3	5.0	7.1	10.4	5.3	9.2
	510	0.3	1.4	1.3	0.0	0.1	0.8	1.6	2.2	1.3	3.0
	511	0.4	0.5	0.3	4.5	0.8	1.2	1.2	1.4	1.5	1.2
	653							2.1	0.9	0.6	2.4
Meadow A Total		**42.9**	**80.4**	**49.2**	**47.3**	**87.5**	**110.3**	**105.5**	**120.8**	**106.6**	**169.9**
Meadow B	1	8.6	31.3	11.8	8.8	23.2	12.1	13.5	16.9	18.9	21.3
	2	0.5	0.5	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0
	3	2.0	3.2	1.6	1.5	1.3	0.5	1.0	3.6	2.6	2.9
	4	1.7	2.5	0.7	0.9	1.5	0.4	1.1	0.7	0.9	0.8
	5	4.3	6.2	4.3	1.7	1.6	4.5	3.8	5.9	4.8	5.8
	6	3.6	4.6	2.9	2.3	2.5	4.3	1.9	3.8	4.2	7.2
	399	4.9	3.3	0.0	3.7	4.6	6.1	6.1	9.4	3.9	8.9
Meadow B Total		**25.5**	**51.6**	**21.4**	**18.9**	**34.7**	**27.9**	**27.4**	**40.3**	**35.3**	**46.9**

	Plot	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Meadow C	184	0.0	0.0	0.0			0.1	0.2	0.4	0.6	0.0
	233			0.0		0.1	0.0	0.1	0.1	0.0	0.2
	400	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	5.9
	431	1.8	2.7	3.1	1.6	3.9	2.6	4.4	6.1	4.8	14.4
	432	5.1	10.1	9.4	7.4	12.2	12.4	20.4	16.1	8.2	7.0
	433	4.2	4.8	9.1	4.3	12.3	8.7	9.1	6.6	7.3	3.1
	594				0.7	0.9	1.3	1.5	1.8	2.2	0.0
Meadow C Total		**11.2**	**17.8**	**21.7**	**14.0**	**29.5**	**25.2**	**35.6**	**31.1**	**23.1**	**30.5**
Grand Total		**79.6**	**149.8**	**92.3**	**80.2**	**151.7**	**163.4**	**168.6**	**192.3**	**164.9**	**247.3**

***Values with 0.0 do not show due to rounding. Some lupine is present. Blanks indicate that the plot was not monitored or established in that year.**

APPENDIX D. TOTAL NUMBER OF MATURE RACEMES AND PERCENT RACEMES ABORTED OF KINCAID'S LUPINE (*LUPINUS OREGANUS*) AT OAK BASIN FROM 2006 TO 2022

Table D- 1. Total number of mature racemes and percent racemes aborted of Kincaid's lupine (*Lupinus oreganus*) at Oak Basin from 2006 to 2022.

	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	13%	375	9%	145	6%	765	10%
2007	881	28%	1,482	7%	810	4%	3,173	13%
2008	891	21%	1,027	13%	432	3%	2,350	15%
2009	415	31%	1,004	17%	55	38%	1,474	23%
2010	1,860	5%	1,678	4%	108	28%	3,646	5%
2011	1,978	3%	1,845	3%	192	6%	4,015	3%
2012	1,328	3%	969	2%	127	0%	2,424	3%
2013	71	58%	122	55%	44	46%	237	55%
2014	1,108	4%	627	1%	311	0%	2,046	2%
2015	129	46%	120	35%	177	11%	426	32%
2016	209	2%	197	3%	217	37%	623	18%
2017	1,996	2%	736	3%	881	2%	3,613	2%
2018	1,984	1%	587	2%	471	1%	3,042	1%
2019	2,775	24%	523	26%	1,265	13%	4,563	24%
2020	2,320	8%	815	10%	1,413	4%	4,548	7%
2021	1,403	12%	627	13%	442	13%	2,472	12%
2022	6,318	5%	1,629	6%	1,692	6%	9,639	5%

Table D- 2. 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 2022.

	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
2020	120.8	19	40.0	20	31.1	45	192.3	24
2021	106.6	13	35.3	18	23.1	19	164.9	15
2022	169.9	37	46.9	35	30.5	55	247.3	39

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

Table E- 1. Count of number of Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) stems by size class in Meadow C at Oak Basin from 2012 to 2020. "R" numbers represent the number of inflorescences recorded per stem (R1, R2, R3, etc.).

Size Class	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Vegetative	42	47	26	44	30	15	17	18	11	26	19
R1	55	40	17	13	8	21	12	17	29	14	21
R2	14	10	9	5	2	20	10	9	19	22	7
R3	7	5	5	1	1	8	4	15	15	5	1
R4	1	1	7	0	1	1	1	3	8	0	1
R5	1	1	0	1	0	1	1	1	6	0	2
R6	1	0	12	0	0	0	0	0	3	0	0
R7	0	0	7	0	0	0	0	1	2	0	0
R8	0	1	0	0	0	0	0	0	0	0	0
R9	1	0	0	0	0	0	0	1	0	0	0
R10	0	0	0	0	0	0	0	1	1	0	0
R11	0	0	0	0	0	0	0	1	1	0	0
R12	0	0	1	0	0	0	0	1	0	0	0
R13	0	0	0	0	0	0	0	0	0	0	0
R14	0	0	1	0	0	0	0	1	0	0	0
R19	0	0	0	0	0	0	1	0	0	0	0
R21	0	0	0	0	0	0	0	1	0	0	0
Total Reproductive Individuals	**80**	**58**	**59**	**20**	**12**	**51**	**29**	**52**	**84**	**21**	**32**
Total Reproductive Stems	128	92	225	31	19	89	72	160	206	33	52
Total number of plants	**122**	**105**	**85**	**64**	**42**	**66**	**46**	**70**	**95**	**47**	**51**

APPENDIX F. PLOT LOCATION MAPS BY MEADOW

Meadow A

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Figure F- 1. Map of lupine monitoring plots in Meadow A.

Meadow B

Figure F- 2. Map of lupine monitoring plots in Meadow B.

Meadow C

Image removed from web version

Figure F- 3. Map of lupine and blue-eyed grass monitoring plots in Meadow C.

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

Table G- 1. 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, and 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, and SE
A	509	Circular, 1.5m radius	504199 E[1] 4907048N[1]	New in 2011. Measured in 4 quadrats: NW, NE, SW, and 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, and SE) in 2018
A	369	14m x 12m		New in 2018. Measured in 2m increments N-S.
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

Meadow	Plot Number	Dimensions	origin (Nad27)	Notes
	2	Triangular adjacent to Plot 3	504503 E 4906649 N	Measured 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, and 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, and 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 at the SW end of Meadow B, which is on private property. Plot 399 captures the lupine nearest the public/private boundary.

APPENDIX H. HABITAT QUALITY SPECIES LISTS

Table H- 1. Relevé plots were surveyed on June 30, 2020 and will be surveyed again in 2023.

	Meadow (plot #)		
	A (696)	**B (691)**	**C (690)**
Non-native forbs	*Cerastium glomeratum* *Dianthus armeria* *Galium parisiense* *Hypericum perforatum* *Leucanthemum vulgare* *Linum bienne* *Myosotis discolor* *Plantago lanceolata* *Sherardia arvense* *Taraxacum officinale* *Tragopogon dubius* *Comandra umbellata* *Veronica arvensis*	*Cerastium glomeratum* *Geranium dissectum* *Hypericum perforatum* *Leucanthemum vulgare* *Linum bienne* *Medicago lupulina* *Plantago lanceolata* *Prunella vulgaris* *Rumex acetosella* *Sherardia arvense* *Torilis arvensis* *Tragopogon dubius* *Unk. forb 1* *Vicia sativa*	*Centaurium erythrea* *Dianthus armeria* *Geranium dissectum* *Hypericum perforatum* *Hypochaeris radicata* *Leucanthemum vulgare* *Linum bienne* *Lotus micranthus* *Medicago lupulina* *Plantago lanceolata* *Sherardia arvense* *Torilis arvensis* *Veronica arvensis* *Vicia sativa*
Native forbs	*Achillea millefolium* *Brodiaea coronaria* *Calochortus tolmiei* *Clarkia amoena* *Clarkia purpurea* *Eriophyllum lanatum* *Fragaria virginiana* *Leptosiphon bicolor* *Madia gracilis*	*Achillea millefolium* *Clarkia amoena* *Dichelostemma capitatum* *Eriophyllum lanatum* *Fragaria vesca* *Fragaria virginiana* *Iris tenax* *Viola nuttallii*	*Achillea millefolium* *Balsamorhiza sagittata* *Calochortus tolmiei* *Clarkia amoena* *Eriophyllum lanatum* *Fragaria virginiana* *Madia elegans* *Polygonum* sp. *Potentilla gracilis* *Ranunculus occidentalis*

Non-native graminoids	*Agrostis capillaris* *Aira caryophyllea* *Bromus hordeaceus* *Bromus sterilis* *Cynosurus echinatus* *Dactylis glomerata* *Schedonorus arundinaceus* *Vulpia bromoides*	*Agrostis capillaris* *Aira caryophyllea* *Bromus hordeaceus* *Bromus sterilis* *Cynosurus echinatus* *Dactylis glomerata* *Phleum pratense* *Schedonorus arundinaceus* *Vulpia bromoides*	*Agrostis capillaris* *Briza minor* *Bromus hordeaceus* *Cynosurus echinatus* *Dactylis glomerata* *Holcus lanatus* *Phleum pratense* *Schedonorus arundinaceus* *Taeniatherum caput-medusae*
Native graminoids	*Bromus carinatus* *Danthonia californica* *Elymus trachycaulus* *Festuca roemeri* *Koeleria macrantha* *Luzula comosa*	*Bromus carinatus* *Danthonia californica* *Elymus glaucus* *Luzula comosa*	*Bromus carinatus* *Danthonia californica* *Elymus glaucus* *Elymus trachycaulus* *Festuca roemeri* *Luzula comosa*
Shrub/tree		*Crataegus suksdorfii* *Quercus garryana*	