Habitat restoration and monitoring for Kincaid's lupine at Fir Butte: 2021 annual report

3/31/2022

Report for the Bureau of Land Management, Northwest Oregon District, Agreement #L20AC00014, #L21AC10189 and #L19AC00166

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Institute for Applied Ecology

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 photograph: Kincaid's lupine (*Lupinus oreganus*) at Fir Butte on May 25, 2021. *Photo by Julia Fields.*

SUGGESTED CITATION

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EXECUTIVE SUMMARY

This report documents habitat restoration and monitoring work conducted in 2021 by the Institute for Applied Ecology (IAE) at Fir Butte, an 18-acre site located in Eugene, Oregon that is owned and managed by the Bureau of Land Management, Northwest Oregon District (BLM). Fir Butte hosts a large population of the federally endangered Fender's blue butterfly (*Icaricia icarioides fenderi*) and its host plant, the federally threatened Kincaid's lupine (*Lupinus oreganus*), along with other Bureau sensitive species.

To conserve and bolster populations of critical species at Fir Butte, the BLM has partnered with IAE since 2012 to conduct habitat restoration activities. In 2021, IAE planned and implemented a variety of activities to support restoration and conservation efforts including weed control, seeding nectar plants and Kincaid's lupine, and monitoring Kincaid's lupine and the effects of habitat restoration at the site.

2021 monitoring results indicate that:

- Kincaid's lupine foliar cover decreased from 2020 to 2021 from an estimated 5,931m^2 (±1,515 m^2) to 4,678(±1,214m^2), respectively;
- The estimated number of mature racemes decreased from 196,011 (±61,004) in 2020 to 108,279(±29,463) in 2021;
- In 2021, the average Himalayan blackberry cover was the lowest it has been since plant community monitoring was initiated in 1998 with only 0.4% (±0.1%) cover. This is well under the 5% threshold allowed for species of particular concern in the Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (Recovery Plan, USFWS 2010);
- In the treated areas of the southeast corner, the percent cover of introduced perennial graminoids decreased from 2020 to 2021 from an average of 17% to 2%;
- Introduced forbs are now the dominant vegetation in the treated southeast corner with a cover of 23% up from 16% in 2020. (In 2020, introduced graminoids were the dominant vegetation class with a cover of 18%);
- Bareground increased in the southeast corner from 2020 to 2021 from 15% to 20% respectively. Litter also increased from 34 to 54% but remains below that observed in 2018 (65%);
- From 2011 to 2021, relative cover of introduced species in occupied Kincaid's lupine habitat ranged from 80-90%, far exceeding the 50% threshold set in the Recovery Plan. In 2021, relative cover of introduced species was 82% in the treated southeast corner.

1. INTRODUCTION

1.1 Site background

Fir Butte is an 18-acre site owned and managed by the Bureau of Land Management, Northwest Oregon District (BLM) and located in Lane County, Oregon, in the West Eugene Wetlands (WEW). Fir Butte is part of a network of sites in the Eugene West Recovery Zone within the Willamette Valley that supports a large population of the federally endangered Fender's blue butterfly (*Icaricia icarioides fenderi*) and the federally threatened Kincaid's lupine (*Lupinus oreganus*; Figure 1). Bureau-Sensitive species including white-topped aster (*Sericocarpus rigidus*) and three rare bryophyte species have been observed at Fir Butte as well. Populations of listed species at Fir Butte are critical for meeting U.S. Fish and Wildlife Service (USFWS) delisting goals referenced in the 2010 Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (Recovery Plan, USFWS 2010).

Figure 1. Kincaid's lupine (*Lupinus oreganus*).

Prior to purchase by the BLM, Fir Butte was used as a horse pasture and hay field. The site includes both upland and wetland prairie habitats. The overall habitat quality at the site is poor, with heavy infestations of introduced plants such as tall oatgrass (*Arrhenatherum elatius*) and annual grasses.

The BLM began partnering with the Institute for Applied Ecology (IAE) in the early 2000s to monitor the Kincaid's lupine population and in 2012 to perform habitat restoration actions at Fir Butte. Since restoration actions were initiated, the Fender's blue butterfly population has remained relatively stable or increased, although there is some annual fluctuation with numbers decreasing in 2021 generally across all occupied sites (Appendix 5). In general, habitat restoration conducted by IAE has improved habitat conditions at Fir Butte and, while the site does not yet meet all habitat quality and listed species population benchmarks identified in the Recovery Plan, conditions at this site are moving in the right direction to meet benchmark recovery goals (USFWS 2010).

1.2 Species background

Kincaid's lupine, a rare member of the legume family (Fabaceae), is listed as threatened by the Oregon Department of Agriculture (ODA) and USFWS (Figure 1). Kincaid's lupine is found in remnant prairies in the Willamette Valley and southwestern Washington, as well as forest openings in Douglas County, Oregon. In the Willamette Valley, Kincaid's lupine serves as a larval host plant for the federally endangered Fender's blue butterfly, making conservation of Kincaid's lupine a common strategy for the success of both species.

Figure 2. Herbivory of Kincaid's lupine by Fender's blue butterfly larvae results in clusters of damaged stems, leaves, and growing points (left) because the larvae (right) typically feed on young leaves and apical meristems.

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

Fender's blue butterfly oviposits small white eggs on the undersides of Kincaid's lupine leaves in late spring. After eggs hatch, larvae emerge and feed on Kincaid's lupine leaves before overwintering in the soil near the base of plants (Figure 2).

2. GOALS AND OBJECTIVES

The goals of this project are to improve habitat quality such that Kincaid's lupine and Fender's blue butterfly populations contribute to USFWS delisting, decrease abundance of non-native species, and increase abundance and diversity of native plants.

Specific objectives for restoration and maintenance of this sensitive habitat include:

- maintain or increase Kincaid's lupine foliar cover;
- reduce blackberry to below 5% absolute cover;
- remove all meadow knapweed (*Centaurea pratensis*) and Scotch broom (*Cytisus scoparius*); and
- increase native species relative cover to 50% or greater.

Specific monitoring goals include:

- determine the abundance of Kincaid's lupine and summarize long term population trends;
- summarize plant community composition to assess whether habitat quality thresholds for delisting are met; and
- obtain pre-treatment data for planned prescribed fire and herbicide treatments.

This report summarizes results of Kincaid's lupine and plant community monitoring at Fir Butte in 2021 to assess the effects of management treatments.

2. RESTORATION ACTIVITIES

2.1 2021 overview

In 2021, IAE planned and implemented a variety of restoration and conservation activities at Fir Butte. Activities included weed control (via hand pulling and herbicide application), site preparation, seeding Kincaid's lupine and nectar plants, and monitoring Kincaid's lupine and the plant community. Monitoring also included Fender's blue butterfly surveys; however, Fender's blue butterfly survey results are described in a separate report (Diaz 2021). Table 1 summarizes restoration actions completed at Fir Butte in 2021. See Appendix 1 for a summary of all management actions completed from 2008 to the present and Appendix 6 for photopoints.

Table 1. Management actions completed at Fir Butte in 2021.

Date	Action	Personnel*	Description
1/14/2021	Weed control	IAE	Spot sprayed SE corner with glyphosate.
3/16/2021	Weed control	IAE	Site visit to assess conditions. Flagged lupine in SE corner.
4/14/2021	Weed control	IAE	Spot sprayed meadow knapweed and SE corner.
5/3/2021	Weed control	IAE	Spot sprayed meadow knapweed and SE corner.
5/13/2021	Site visit	IAE	Site visit to assess herbicide treatment and take photopoints.
5/26/2021	Site visit	IAE	Finished flagging lupine in SE corner.
6/15-18/2021	Monitoring	IAE	Monitoring of lupine and plant community
6/18/2021	Weed control	IAE	Spot sprayed SE corner.
6/21-23/2021	Monitoring	IAE	Monitoring of lupine and plant community
7/12/2021	Site visit	IAE/BLM	Site visit to discuss treatment options and seeding.
8/5/2021	Mapping	IAE	Mapped tall oatgrass population.
8/18/2021	Weed control	IAE	Spot sprayed bracken fern throughout meadow, hand pulled meadow knapweed.
9/14/2021	Woody species control	IAE/IRM	Treated woody plants throughout meadow.
9/29/2021	Site visit	IAE/USACE	Site visit to discuss use of seed drill.
10/4/2021	Weed control	IAE	Broadcast glyphosate to SE corner.
10/14/2021	Seeding	IAE/BLM	Seeded SE corner with dew drop drill borrowed from USACE.

*Institute for Applied Ecology (IAE); Bureau of Land Management (BLM); Integrated Resource Management (IRM); US Army Corps of Engineers (USACE)

2.2 Post-burn site preparation and seeding

Prescribed burns are an important habitat management tool at Fir Butte. Portions of the site were burned in 2008, 2009, 2012, 2014, 2016, 2017, and 2018 (Appendix 2). All burns complied with guidelines from the Biological Opinion (USFWS 2014; standards 9 and 36). Standard 36 limits burning to no more

than one third Fender's blue butterfly habitat in a given year if more than 100 Fender's blue butterflies occupy the site; therefore, burn units in the WEW are typically less than five acres unless they are not Fender's blue butterfly habitat (e.g. wet prairie). Burn units are rotated annually and not burned again for at least three years.

The most recent prescribed burn at Fir Butte was conducted on October 13th, 2018. Approximately five acres in the southeast (SE) corner and all nectar islands except those installed in 2017 and 2018 in the southwest corner were burned. BLM and IAE agreed to put 3.5 acres of the burn area in chemical fallow to reduce cover of non-native species (SE corner and nectar island 8a; Figure 3).

Figure 3. Nectar islands and treatment types at Fir Butte.

Kincaid's lupine was present throughout the prairie so broadcast chemical applications were limited to between September and February. Regular spot and broadcast glyphosate treatments were applied to the SE corner and nectar island 8a from December 7, 2018 to October 4, 2021 to control non-native grasses and forbs.

The SE corner and nectar island 8a were seeded with a diverse mix of nectar plants and six pounds of Eugene West Kincaid's lupine seed on October 14, 2021 (Table 2). The seed mix was bulked up with rice hulls to achieve the appropriate rate. Nectar island 8a was hand broadcast with a belly seeder and the SE corner was seeded using a Dew Drop Drill borrowed from the US Army Corps of Engineers and operated by Colin Sayre, BLM restoration technician (Figure 4). Discs on the Dew Drop Drill can be raised and lowered with a remote switch and were calibrated to till only the top ¼ inch of soil. Kincaid's lupine areas were flagged before operating the drill and the discs were raised when driving over Kincaid's lupine patches to avoid ground disturbance in areas with Fender's blue butterfly. See Appendix 3 for a summary of nectar island establishment and treatments.

Table 2. Seed mix broadcast in the southeast corner and nectar island at Fir Butte on October 14, 2021.

Scientific name	**Common name**	**Habit**	**Quantity (lbs)**
Achillea millefolium	common yarrow	Forb	0.17
Allium amplectens	narrow-leaf onion	Forb	1.39
Camassia quamash	common camas	Forb	4.88
Carex tumulicola	splitawn sedge	Sedge	1.88
Clarkia purpurea ssp. *quadrivulnera*	winecup clarkia	Forb	0.26
Collomia grandiflora	large-flowered collomia	Forb	3.01
Danthonia californica	California oatgrass	Grass	4.36
Epilobium densiflorum	denseflower willowherb	Forb	0.43
Eriophyllum lanatum	woolly sunflower	Forb	0.42
Festuca roemeri	Roemer's fescue	Grass	1.22
Hordeum brachyantherum	meadow barley	Grass	3.25
Iris tenax	toughleaf iris	Forb	7.95
Leptosiphon bicolor	true babystars	Forb	0.15
Lomatium nudicaule	barestem biscuitroot	Forb	6.17
Lupinus oreganus*	**Kincaid's lupine**	**Forb**	**6.00**
Luzula comosa	woodrush	Rush	0.52
Madia elegans	showy tarweed	Forb	1.14
Microseris laciniata	cutleaf silverpuffs	Forb	1.54
Perideridia oregana	Oregon yampah	Forb	0.77
Plectritis congesta	shortspur seablush	Forb	0.46
Potentilla gracilis	slender cinquefoil	Forb	0.26
Prunella vulgaris var. *lanceolata*	common selfheal	Forb	0.91
Ranunculus occidentalis	western buttercup	Forb	1.83
Sidalcea malviflora ssp. *virgata*	dwarf checkermallow	Forb	4.59
Sisyrinchium idahoense	Idaho blue-eyed grass	Forb	2.01
Wyethia angustifolia	mule ears	Forb	3.67
Total			**59.2**

* Kincaid's lupine is a Federally threatened plant and host plant for the endangered Fender's blue butterfly.

Figure 4. BLM technician Colin Sayre seeding the SE corner at Fir Butte with a Dew Drop Drill on October 1, 2021.

The northeast corner was scheduled to be burned in fall 2021 however conditions did not allow the prescribed burn to take place. No prescribed burns were conducted on BLM lands in the West Eugene Wetlands in 2021.

2.3 Invasive species control

In 2021, invasive species management primarily targeted meadow knapweed and woody species such as blackberry, hawthorn (*Crataegus monogyna*), and rose (*Rosa* spp.). IAE and contractors conducted spot-spray herbicide treatments targeting meadow knapweed, bracken fern, blackberry, hawthorn, and rose. IAE also broadcast sprayed 3.5 acres in the SE corner as described in see Section 3.2.

2.3.1 Tall oatgrass

Tall oatgrass was regularly mowed with a string trimmer in May or June from 2013 to 2019; however, mowing was not an effective control method for tall oatgrass at Fir Butte as the population expanded during that time, especially in the northeast corner (Appendix 1). An alternative approach may be to broadcast spray tall oatgrass in the late fall or early winter after green-up when Kincaid's lupine is dormant; this would be most effective after a prescribed burn or mowing to remove thatch. Grass specific herbicides are currently only allowed for research purposes; however, they would be an effective tool to target tall oatgrass without harming Kincaid's lupine if they were allowed to be used more broadly. Pulling of tall oatgrass in the early spring or fall in areas where Kincaid's lupine is not present could also provide some control of this introduced species. Because grass specific herbicide is not currently a management tool at the site, this method could provide some level of control for this introduced species.

Pulling or grubbing could occur in conjunction with seeding of native graminoid or forb species into the disturbed ground created during these efforts.

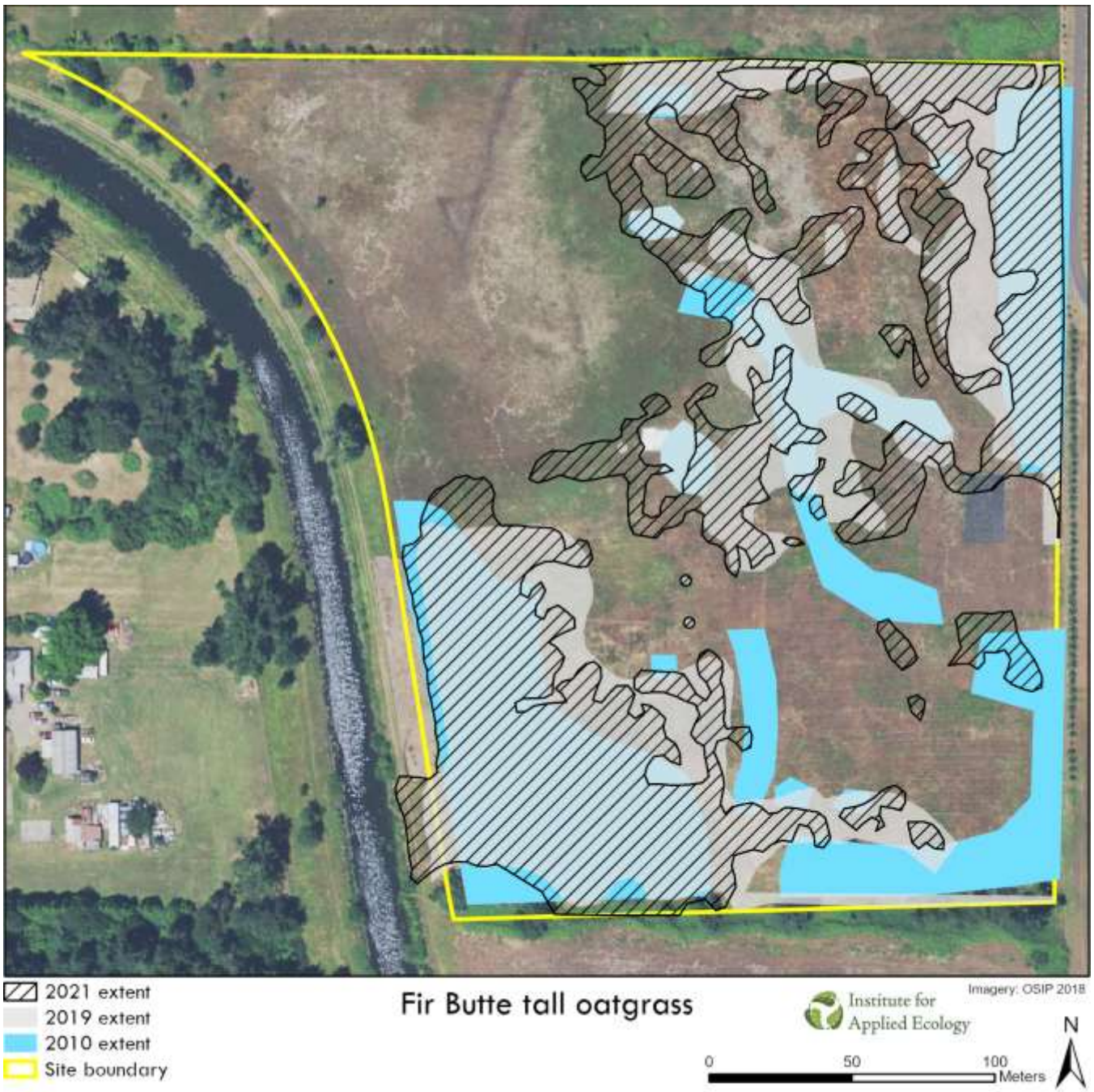

Figure 5. Tall oatgrass (*Arrhenatherum elatius*) distribution at Fir Butte in 2010, 2019, and 2021 showing expansion of the population over time.

2.3.2 Bracken fern

Bracken fern (*Pteridium aquilinum*), although native, is a species of concern at Fir Butte. The population has increased over time and there is concern that it could outcompete Kincaid's lupine and impede access of Fender's blue butterflies to Kincaid's lupine and nectar resources. In previous years, bracken fern was mowed and hand pulled. However, mowing alone was not sufficient to keep pace with bracken fern as new fronds continued to grow through the summer. The West Eugene Wetlands Biological Opinion

prohibits mowing Kincaid's lupine-occupied areas with a tractor during the Kincaid's lupine growing season, which limits the ability to control bracken fern in this manner (USFWS 2014).

Milligan et al. (2016) found that it took six to eight years of repeated treatments to decrease bracken fern cover. The study implemented a single herbicide treatment followed by cutting emerging fronds two to three times per year over an eight-year period. Cutting alone or annual spot spray treatments were as effective as the one-time herbicide treatment followed by cutting. Bracken fern is rhizomatous and management requires a committed effort to deplete carbohydrate resources over multiple years.

In 2021, IAE spot treated bracken fern in August with 1.5 % glyphosate (Figure 6).

Figure 6. Bracken fern at Fir Butte on September 14, 2021, a month after spot spraying with glyphosate in August.

2.3.3 Meadow knapweed

Meadow knapweed is located in patches throughout the prairie and especially on the outer perimeter of the site. Dennehy et al. (2011) recommended manual removal only when herbicides are not available, and emphasized the need to remove all roots. Grubbing can be successful if the entire root system is removed, however this process can also result in substantial ground disturbance. Cutting or mowing stems to remove flowers reduces seed set but does not kill the plant and must be repeated multiple times throughout the growing season. Mowing before plants reach maturity can reduce plant vigor; however, mowed plants will produce flowers lower to the ground. Herbicide is a successful treatment method when applied at the rosette to bud stage in spring.

Prior to herbicide approval, meadow knapweed stems were cut, bagged, and removed multiple times during the growing season to reduce seed set. IAE began spot treating meadow knapweed with 1.5% glyphosate in December 2018 and continued treatments in spring 2019, 2020, and 2021.

In 2021, IAE spot treated meadow knapweed in April and May and hand pulled two small flowering patches in August.

The meadow knapweed population extends outside Fir Butte onto neighboring private properties to the north and east and City of Eugene property to the west. Control of this species will only be achieved by creating partnerships with neighboring landowners to ensure that the entire population is treated.

3. MONITORING AND HABITAT ASSESSMENT

Monitoring Kincaid's lupine was initiated at Fir Butte in 1998 to provide population trend data and test the effects of experimental habitat management treatments implemented from 2003-2006 on Kincaid's lupine cover and Fender's blue butterfly reproductive success. That study has since concluded; however, the existing infrastructure continues to be utilized for monitoring Kincaid's lupine. The Fir Butte plant community was monitored using a variety of methods to assess the presence and quantity of certain weedy species, and the overall habitat quality of the site.

3.1 Monitoring and habitat assessment methods

3.1.1 Kincaid's lupine monitoring methods

3.1.1.1 ORIGINAL PLOT DESIGN

In 1998, a 216m x 288m macroplot was established covering the entire area occupied by Kincaid's lupine at Fir Butte. This macroplot was further divided into 18 subplots, each 24m x 108m with the long axis running west to east (Figure 6). Within each of the 18 subplots were two nested 100m transects (n=36) surrounded by a two-meter wide buffer on each of the long sides and a 4 m wide buffer on each of the narrow sides. Transects were marked on both ends with concrete markers. Corners of the macroplots were marked with t-posts or concrete markers. Each fence post or marker was labeled with a pre-numbered aluminum tag. Additional information regarding initial plot establishment can be found in Thorpe (2011).

While the initial study is complete, the transects continue to be utilized to sample the Kincaid's lupine population and plant community (Thorpe 2011). From 1998-2010, both the north and south sides of each transect were monitored for Kincaid's lupine cover and target weedy species; since 2011, only the north side of the tape was monitored.

3.1.1.2 2021 MONITORING METHODS

In 2021, IAE monitored Kincaid's lupine foliar cover and the number of mature and aborted Kincaid's lupine inflorescences in 100m belt-transects. Foliar cover was determined by measuring the approximate rectangular area occupied by a cluster of plants in centimeters. Population estimates for Kincaid's lupine were made by averaging the data across all monitored transects (n = 36) and multiplying by the total number of possible 100m belt-transects at the site (n=460). Each 100m transect was divided into 5m sections. The foliar cover and count of mature and aborted racemes were recorded for each 5m section.

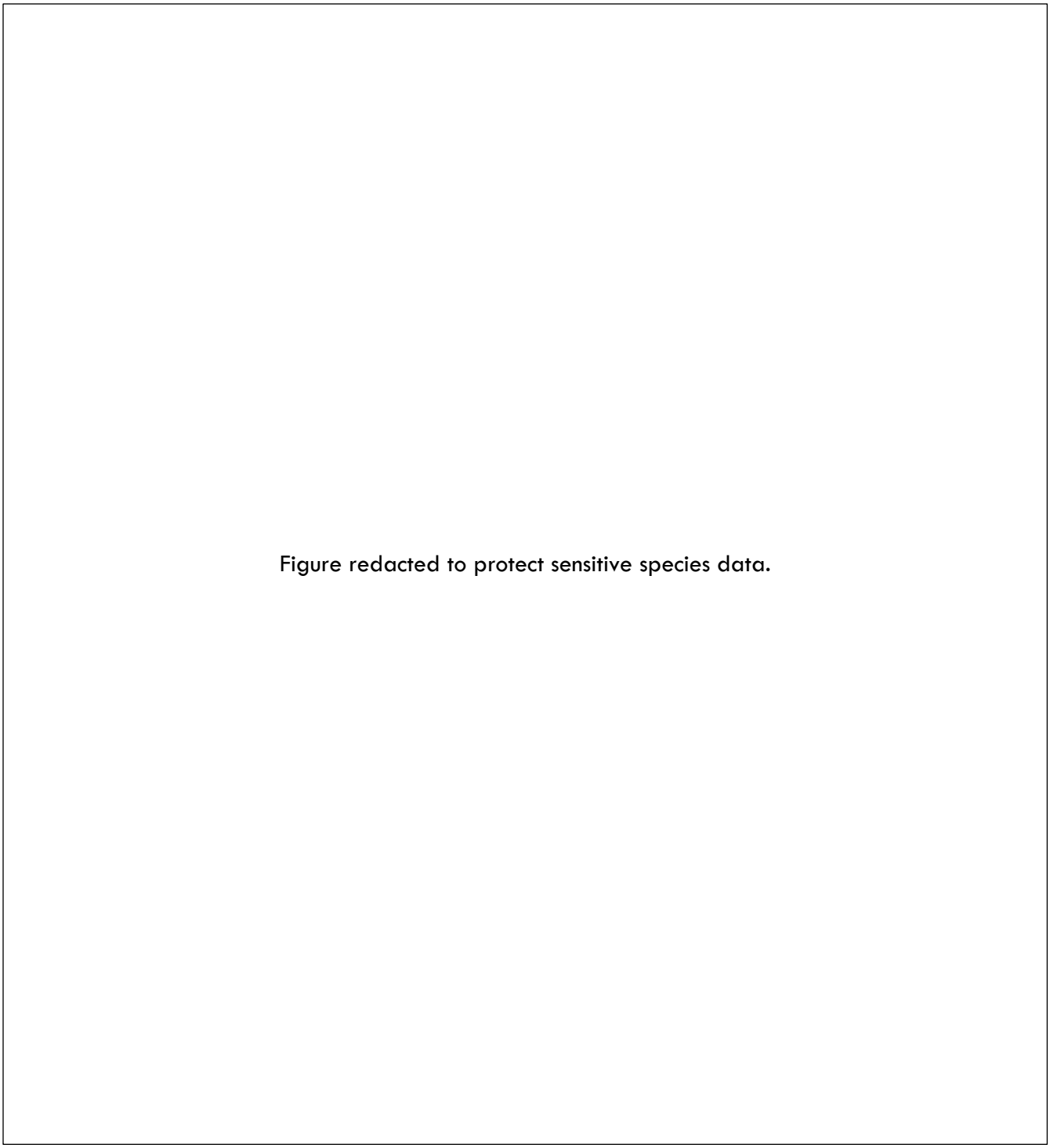

Figure 7. Plot layout for Kincaid's lupine monitoring at Fir Butte. The entire occupied portion of the site was divided in 18 subplots. Two 100m belt-transects were monitored in each subplot in 1m x 5m sections.

3.1.2 Vegetation community monitoring methods

Vegetation community monitoring activities were guided by planned and enacted management actions, the need to address habitat quality standards as described in the Recovery Plan, management thresholds set forth by BLM, and funding availability. In 2021, habitat monitoring focused on assessment of the burned southeast corner and evaluating target weedy species presence and cover along lupine monitoring transects.

3.1.2.1 PERCENT COVER OF TARGET WEEDY SPECIES

In conjunction with Kincaid's lupine monitoring, percent cover of Himalayan blackberry and bracken fern and the presence/absence of meadow knapweed were recorded in the same 5m sections used to monitor Kincaid's lupine. Tall oatgrass cover was measured in each 5m section beginning in 2011. Hedge bindweed (*Calystegia sepium*) cover was quantified in each sub-plot. Confidence intervals for these values were calculated by considering the average cover for each species in each transect. These measurements allow us to quantify changes in weedy species cover and assess management effects in conjunction with changes in Kincaid's lupine cover.

3.1.2.2 PERCENT COVER BY SPECIES

In 2020, 30 randomly placed 1m^2 plots (15 with lupine and 15 without lupine) were monitored within the southeast portion of the site (roughly equivalent to Kincaid's lupine subplots 1-4; Figure 3, Figure 6). IAE assessed the percent cover of all vascular plants and four ground cover types (bare soil, litter, rock, and moss). Percent cover was visually estimated to the nearest 1%; for species occurring at <1% cover we estimated cover to 0.1% or 0.5%. Species names and supplementary information followed the USDA Plants Database (http://plants.usda.gov/java/) and local floras.

3.2 Monitoring and habitat assessment results

3.2.1 Kincaid's lupine

Between 2020 and 2021, Kincaid's lupine cover and racemes decreased (Figure 8, Figure 9, Table 2, and Appendix 5.). The number of mature racemes decreased from an estimated 196,011 racemes (± 61,004) in 2020, the second highest value recorded at the site, to 108,279 (±29,643) in 2021(Appendix 5.). Lupine cover decreased from 2020 to 2021 from an estimated 5,931 m^2 (±1,515m^2) to 4,678 m^2 (±1,214m^2) in 2021. Although lupine cover and racemes decreased from 2020 to 2021, 2020 was the highest lupine cover recorded at the site since monitoring began in 1998; 2021 represents the third highest foliar cover since monitoring began (Figure 8).

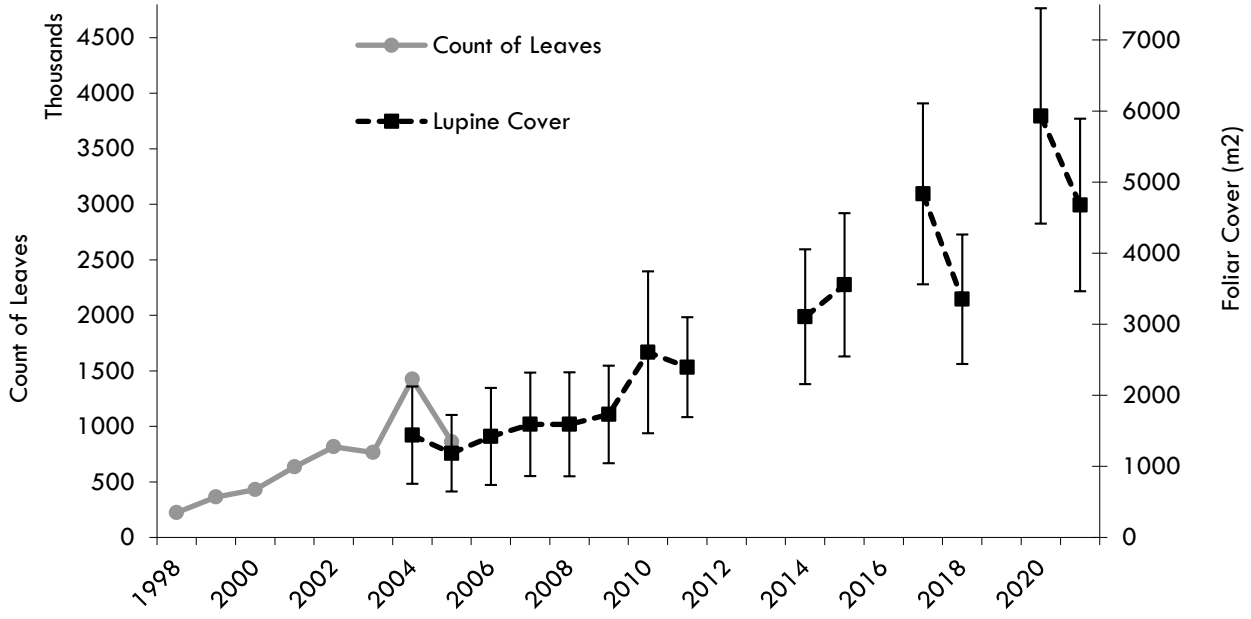

Figure 8. Kincaid's lupine foliar cover and leaf count at Fir Butte from 1998 to present. Error bars represent 95% confidence intervals. Data was not recorded every year.

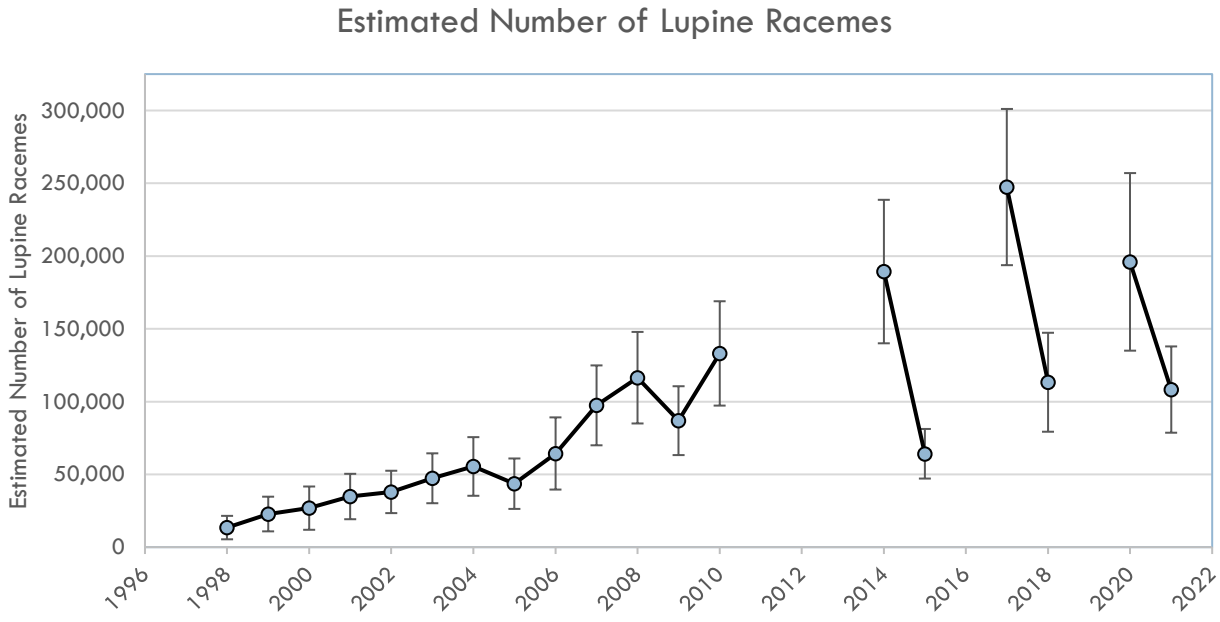

Figure 9. Estimated number of mature lupine racemes at Fir butte from 1998-2021. Data was not recorded in every year. Error bars represent 95% confidence intervals.

3.2.2 Community composition

3.2.2.1 PERCENT COVER OF TARGET WEEDY SPECIES IN KINCAID'S LUPINE TRANSECTS

Average blackberry cover in Kincaid's lupine transects in 2021 was 0.4% (±0.1%). In 2020 cover of blackberry was 4.3% (±1.1%), a decrease from 9.9% (±1.5%) in 2018 (Figure 9; Table 2). In both 2020 and 2021, cover of blackberry was below the threshold for meeting recovery requirements as defined in the Habitat Recovery Plan (USFWS 2010).

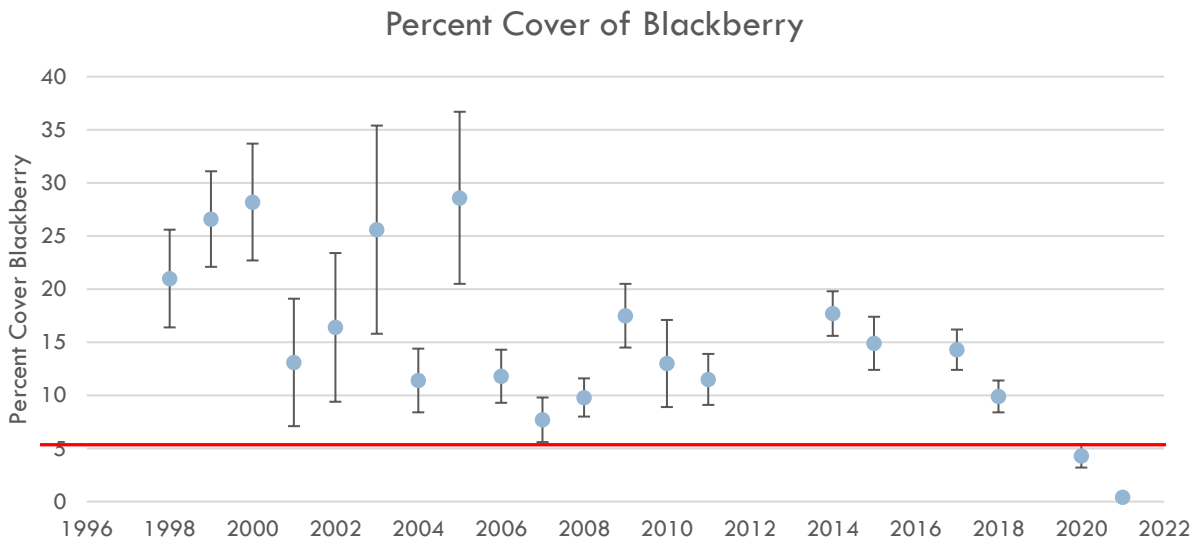

Figure 10. Himalayan blackberry cover at Fir Butte from 1998 to 2020. The red line represents the 5% cover management threshold for blackberry. Data was not collected every year. Error bars represent 95% confidence interval; error bars in 2021 are 0.1% and are not visible at this scale.

Tall oatgrass cover, as measured across all lupine habitat, decreased from 2021 to 2020 from 16% to 12% (Table 2). Bracken fern cover decreased from 3% (±1%) in 2020 to 1% (±1%) in 2021.

Meadow knapweed was observed in a least one transect every year since 2011. In 2021, meadow knapweed was observed in three of the 5m sections along the 100m transects. Due to continued removal efforts, most meadow knapweed at the site is found outside areas occupied by Kincaid's lupine.

Hedge bindweed cover was also measured in the 5m sections along the 100m transects. The average cover across all transects decreased in 2021to 1% (±1%). In 2018, 2020 and 2021, this species was only observed in the western portion of the Kincaid's lupine macroplot, with some 1m x 5m sub-plots having cover as high as 80%.

Table 3. Himalayan blackberry, bracken fern, and tall oatgrass cover at Fir Butte along 100m x 1m transects monitored from 1998 to present. "-" indicates data was not collected that year.

Year	Average % cover								# 5m x 1m plots with meadow knapweed present
	Blackberry		Tall oatgrass*		Bracken fern		Hedge Bindweed		
	Value	*95% CI*	Value	*95% CI*	Value	*95% CI*	Value	*95% CI*	
1998	21.0	*4.6*	-	-	-	-	-	-	-
1999	26.6	*4.5*	-	-	-	-	-	-	-
2000	28.2	*5.5*	-	-	-	-	-	-	-
2001	13.1	*6.0*	-	-	-	-	-	-	-
2002	16.4	*7.0*	-	-	-	-	-	-	-
2003	25.6	*9.8*	-	-	-	-	-	-	-
2004	11.4	*3.0*	-	-	-	-	-	-	-
2005	28.6	*8.1*	-	-	-	-	-	-	-
2006	11.8	*2.5*	-	-	-	-	-	-	-
2007	*7.7*	*2.1*	-	-	-	-	-	-	-
2008	9.8	*1.8*	-	-	-	-	-	-	-
2009	17.5	*3.0*	-	-	-	-	-	-	-
2010	13.0	*4.1*	-	-	-	-	-	-	-
2011	11.5	*2.4*	-	-	*1.7*	*0.7*	-	-	*5*
2012	-	-	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-	-	-
2014	*17.7*	*2.1*	-	-	4.2	*2.1*	-	-	2
2015	14.9	*2.5*	-	-	3.6	*1.5*	-	-	3
2016	-	-	-	-	-	-	-	-	-
2017	14.3	*1.9*	14.6	*4.9*	4.9	2.3	-	-	4
2018**	9.9	*1.5*	9.0	*4.6*	3.4	*1.7*	2.1	*2.0*	2
2019	-	-	-	-	-	-	-	-	-
2020	4.3	*1.1*	16.2	*6.2*	2.6	*1.1*	2.3	*2.1*	3
2021	0.4	*0.1*	12.2	*5.5*	1.1	*0.6*	0.9	*1.0*	3

* Prior to 2017, only presence/absence of tall oatgrass was recorded in the 5m sections for 100m transects.

** In 2018, the site was mowed with a string trimmer prior to monitoring.

3.2.2.2 PERCENT COVER OF SPECIES IN SE CORNER (2018 BURN UNIT)

The following results from 2018, 2020 and 2021are reported in three groups, 1) patches within the southeast corner where Kincaid's lupine is present that have only been treated with herbicide when Kincaid's lupine is dormant (referred to as untreated areas), 2) portions of the southeast corner not occupied by Kincaid's lupine that have been treated with herbicide during the growing season (referred to as treated areas), and 3) an average for both groups combined (Table 3).

From 2018 to 2021 in the southeast corner, colonial bentgrass (*Agrostis capillaris*) decreased from an average cover of 13.1% (±4.7) to 1.5% (±0.8); prior to management treatments, this was the dominant graminoid species in the area. Tall oatgrass cover decreased from 3.4% (±2.9%) in 2020 to 0.1% (±0.1%) in 2021. [In 2018, this species had been weed whacked prior to monitoring and cover of the species was an artificially low 0.5% (±0.4)]. In 2018, introduced graminoid cover was19.8 ±4.8%; in 2021 cover of introduced graminoids was 4.3% (± 1.4%).

Cover of introduced forbs has increased from 9.8% (±3.7%) in 2018 to 22.6% (±5.6%) in 2021; with higher cover of introduced forbs in the 'untreated' lupine areas in 2021 of 27.6% (±6.8%, Table 4). Introduced forb species with increases in cover following treatments include smooth hawksbeard (Crepis capillaris) and wall bedstraw (Galium parisiense).

Blackberry cover initially increased following treatments from 3.7% (±2.4) in 2018 to 9.0% (±8.3%) in 2020, with higher cover in the 'untreated', lupine occupied, portions of the habitat (16% ±15.2, Table 4). In 2021 average cover of this introduced shrub in the treated areas was 1.9% (±1.5%), below the recommended management threshold.

Average cover of bare ground has increased from 1.0% (±1.0) in 2018 to 20% (±9.3) in 2021. Average cover of bare ground in the treated portions in 2021was 37.9% ±13.3%. In the first year of treatment, the cover of litter decreased from 64.7% (±5.7%) in 2018 to 34.2% (±7.3%) in 2020. In 2021, cover of litter remained stable in the treated portion of the area (32.8%± 10.2) and increased in the lupine occupied areas of the unit 75.3 (± 8.7%, Table 4).

Table 4. Average absolute percent cover by functional group in the southeast corner at Fir Butte in 2018, 2020 and 2021

	Pre-treatment 2018		Treated - No lupine 2020		Untreated - Lupine present 2020		Treated - No lupine 2021		Untreated - Lupine present 2021	
	Value	*95% CI*	Value	*95% CI*	Value	*95% CI*	Value	*95% CI*	Value	*95% CI*
Bare Ground	1	*1*	29.1	*12.8*	1.5	*2.6*	37.9	*13.3*	2.1	*2.1*
Litter	64.7	*5.7*	34.7	*10.2*	33.7	*10.8*	32.8	*10.2*	75.3	*8.7*
Native Graminoids	0.0*	*0.0*	0.4	*0.6*	0.3	*0.7*	0	*0*	0	*0*
Introduced Graminoids	28.8	*4.7*	2.4	*1.7*	51.3	*19*	4.9	*1.7*	3.7	*2.1*
Native Forbs	10.1	*5.0*	3.9	*3.5*	20.8	*11.5*	1.7	*0.8*	10.5	*4.7*
Introduced Forbs	13.3	*6.0*	32.3	*12.4*	11.9	*4.8*	17.6	*8.5*	27.6	*6.8*
Trees/Shrubs	9.2	*4.6*	1.5	*2.1*	28	*17.8*	0	*0*	0	*0*

Values with a 0.0 are greater than 0, but do not show here due to rounding.

Table 5. Dominant species recorded in all 1m^2 quadrats in the southeast corner at Fir Butte in 2018, 2020 and 2021. Values in parentheses represent 95% confidence intervals.

	2018 - pretreatment			2020			2021		
Species	**Average**	no lupine	lupine	**Average**	no lupine (treated)	lupine (untreated)	**Average**	no lupine (treated)	lupine (untreated)
Agrostis capillaris	**13.1(4.7)**	11(5.1)	17.6(9.8)	**12.1(8.2)**	2.3(1.7)	21.3(14.4)	**1.5(0.8)**	1.4(1.4)	1.6(0.9)
Festuca arundinacea	**1.2(1.4)**	1.7(2)	0.1(0.2)	**0(0)**	0(0)	0(0)	**0(0)**	0(0)	0(0)
*Arrhenatherum elatius**	**0.5(0.4)**	0.6(0.5)	0.5(0.5)	**3.4(2.9)**	0(0)	6.5(5.1)	**0.1(0.1)**	0(0)	0.2(0.2)
Anthoxanthum odoratum	**0.9(1)**	1.1(1.5)	0.4(0.5)	**1.2(1.2)**	0(0)	2.3(2.1)	**0.3(0.5)**	0(0)	0.7(1.1)
Dactylis glomerata	**0.5(0.5)**	0.5(0.6)	0.6(1.1)	**0.2(0.4)**	0(0)	0.5(0.8)	**0(0)**	0(0)	0(0)
Vulpia sp.	**2.8(2.1)**	2.7(2)	3.1(5.4)	**0.1(0.2)**	0(0)	0.2(0.4)	**0.8(0.6)**	0.6(0.4)	1(1.1)
Lupinus oreganus	**0.7(0.6)**	0(0)	2.2(1.5)	**3.6(3.9)**	0(0)	7(7.2)	**3.2(2.2)**	0(0)	6.3(3.8)
Pteridium aquilinum	**3.1(2.5)**	1.7(1.2)	6.2(7.4)	**2.3(3.1)**	0.1(0.1)	4.3(5.9)	**1.5(1.7)**	0(0)	3.1(3.3)
Rubus bifrons	**3.7(2.4)**	4.4(3.4)	2.1(1.8)	**9(8.3)**	1.5(2.1)	16(15.2)	**1.9(1.5)**	0.2(0.4)	3.6(2.8)
Galium parisiense	**0.4(0.3)**	0.6(0.5)	0.1(0.2)	**1.2(0.7)**	1.5(1)	0.9(1)	**6.7(3.7)**	6.9(6.2)	6.4(4.3)
Daucus carota	**0.4(0.3)**	0.5(0.4)	0.2(0.2)	**2.1(1.6)**	2.5(3.2)	1.7(1.2)	**2.9(2.7)**	2.6(4.5)	3.3(3.2)
Hypochaeris radicata	**1.6(0.7)**	1.7(1)	1.2(0.9)	**0.6(0.5)**	0.8(0.7)	0.4(0.8)	**2(1.8)**	0.8(0.7)	3.2(3.4)
Crepis capillaris	**3.7(2.6)**	4.8(3.7)	1.2(0.6)	**3.6(2.1)**	1.6(1.4)	5.3(3.7)	**8(3.7)**	3.6(2.7)	12.3(6.3)

*In 2018 *Arrhenatherum elatius* had been weedwhacked prior to monitoring.

3.3 Monitoring and habitat assessment discussion

3.3.1 Kincaid's lupine

The cover and count of Kincaid's lupine racemes decreased at the site from 2020 to 2021 though they have generally increased at the site since monitoring began. Ongoing efforts to control introduced species and increase native plant cover and diversity have contributed to expanding and enhancing the Kincaid's lupine population at Fir Butte. Continued management of introduced graminoids and shrubs are recommended to maintain these positive trajectories.

3.3.2 Vegetation community composition

3.3.2.1 SOUTHEAST CORNER (2018 BURN UNIT)

In 2018, introduced grasses and bracken fern were the most abundant species in the southeast corner. In 2021, introduced forbs were the dominant species in the southeast corner with a cover of 22.6% (±5.6%)(Table 4, Table 5). Following management treatments, absolute cover of introduced perennial graminoids in treated areas decreased from 16.3% (±4.9%) in 2018 to 2.0% (±1.1%) in 2021. Bare ground increased from an average of 1.0% (±1.0%) in 2018 to 29.1% (±12.8%) in treated portions of the habitat in 2020 and again in 2021 to 37.9% (±13.3). These increase in bareground in the treated portions of the habitat provide opportunities for increased soil-seed contact for native species.

In the first year post-treatment thatch cover decreased by nearly 50% from 64.7% (±5.7) to 34.2% (±7.3) (Table 4). In the second year post-treatment, litter covered increased particularly in the lupine occupied 'untreated' portions of the habitat (Table 5).

Relative cover of introduced species in both the treated and untreated portions of the southeast corner remain above the recovery goal of <50% relative cover of introduced species; however, the treated area was in chemical fallow and in 2020 nearly 64% of treated areas were bare ground and litter.

Broadcasting native seed in the southeast corner after the chemical fallow period should be a priority to take advantage of bare ground created by management actions. Bare ground and reduced thatch increase seed-soil contact and subsequently contribute to the likelihood of successful germination and establishment of native seeds given appropriate environmental conditions. Continued monitoring will contribute to our understanding of the effects of management treatments on target weed species, Kincaid's lupine, and the overall vascular plant community.

4. 2022 RECOMMENDED ACTIONS

In 2022, IAE recommends the following habitat restoration and assessment activities:

- Identify an area in the northeast corner without Kincaid's lupine to create a new nectar island. Start chemical broadcast treatments in 2022 and keep in fallow for two to three years prior to seeding nectar species.
- Continue targeted herbicide applications of meadow knapweed, bracken fern, blackberry, and other non-native species as necessary throughout the site.
- Work with BLM and the City of Eugene to coordinate treatment of meadow knapweed on neighboring properties.
- Hand pull tansy ragwort as necessary.

- Remove Scotch broom along the southern fence.
- Monitor the SE corner vegetation to evaluate efficacy of ongoing management actions.
- Monitor nectar islands and treatment areas using the Relevé method.
- Monitor Kincaid's lupine and evaluate overall site habitat quality.
- Work with BLM to determine the next suitable area for chemical fallow. Conduct a prescribed burn to clear vegetation, then put into chemical fallow for multiple years before seeding with native species.
- Hold biannual IAE-BLM meetings to coordinate restoration treatments at Fir Butte.
- Write annual report and update the Fir Butte habitat management plan.

5. LITERATURE CITED

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APPENDICES

Appendix 1. Fir Butte management actions (2008-2021)

Year	Date	Activity	Personnel*	Notes
2008	June-July	Weed control	Land steward	Pull tansy ragwort (*Senecio jacobaea*)
2008	June-July	Weed control	Land steward	Clip seed heads on tall oatgrass (*Arrhenatherum elatius*)
2008	June-July	Weed control	Land steward	Shade cloth on meadow knapweed (*Centaurea pratensis*) at N end, S end, and around E small shade cloth patch
2008	June-July	Weed control	Land steward	Pull meadow knapweed in N end, S end, and around E small shade cloth patch
2008	June-July	Weed control	NWYC	Pull scotch broom (*Cytisus scoparius*), tansy ragwort, and tall oatgrass
2008	June-July	Weed control	NWYC	Pull meadow knapweed in N end, S end, and around E small shade cloth patch
2008	April-June	Weed control	Land steward	Cut Himalayan blackberry (*Rubus bifrons*) along fenceline and shade cloth
2008	April-June	Weed control	Land steward	Cut bracken fern (*Pteridium aquilinum*)
2008	June-July	Woody species control	Land steward	Cut Ponderosa pine (*Pinus ponderosa*) in wetland prairie
2008	August-October	Ecological burn	BLM	Wetland and SW third of upland
2008	August-October	Seed nectar mix		Wetland and SW third of upland
2009	June-July	Weed control	Youth crew	Clip seed heads from tall oatgrass
2009		Weed control	Monitoring staff	Pull scotch broom, tansy ragwort, tall oatgrass
2009		Weed control	Monitoring staff	Shade cloth, cut meadow knapweed and Himalayan blackberry
2009	August-October	Ecological burn	BLM	SE third of upland prairie
2009	August-October	Seed nectar species		SE third of upland prairie
2010	June-July	Weed control	Monitoring crew	Pull scotch broom in South end
2010	April-July	Weed control	Monitoring crew	Pull bracken fern
2010	June-July	Weed control	Monitoring crew	Pull purple-anther pepper weed

Year	Date	Activity	Personnel*	Notes
2010		Weed control	Youth crew	Pull scotch broom, tansy ragwort, tall oatgrass
2010		Weed control	Youth crew	Pull scotch broom, tansy ragwort, tall oatgrass
2011	April-June	Shade cloth repair	LGYC	Eastern border
2011	April-June	Weed control	LGYC	Pull bracken fern
2011	June-July	Woody species control	LGYC	Cut woody species
2011	June-July	Weed control	LGYC	Pull tansy ragwort
2011	August-October	Weed control	LGYC	Pull tansy ragwort
2011	April-June	Weed control	NWYC	Pull bracken fern
2011	August-October	Woody species control	BLM contractor	Masticate Himalayan blackberry
2011	August-October	Prescribed burn	BLM	NE third of upland
2011	August-October	Seed nectar mix	BLM	NE third of upland prairie, N and S center shade cloth areas, S border
2012	April-June	Apply shade cloth and solarization	LGYC	E border of site
2012	April-June	Weed control	LGYC	Pull scotch broom, tansy ragwort, tall oatgrass
2012	June-July	Weed control	LGYC	Pull scotch broom, tansy ragwort, tall oatgrass
2012	June-July	Apply shade cloth	IAE/LGYC	5 8m x 10m areas dispersed throughout site
2012	October	Prescribed burn	BLM	6 acres: Wetland and NE third of upland
2012	October	Seed wetland and upland species mix	IAE	Burned area
2012	October	Plant nectar species	IAE/LGYC	Shade cloth and solarization area on E border of site
2013	17-Apr	Marking of weeds site wide	IAE	Systematically marked locations of *Cirsium vulgare*, *Cytisus scoparius, Centaurea pratensis, Lepidium heterophyllum, Hypericum perforatum,* and *Senecio jacobaea.*
2013	23-Apr	Finish marking weeds	IAE	Systematically wandered through rest of site and marked all locations of the species listed from 4/17.
2013	25-Apr	Hand removal of weeds throughout site	IAE	Digging/pulling of all weeds marked on 4/17/13

Year	Date	Activity	Personnel*	Notes
2013	29-Apr	Hand removal of weeds throughout site	IAE	Digging/pulling of all weeds marked on 4/17/13
2013	1-May	Post-treatment data on shade cloth/solarization plots	IAE	Recorded species and cover information in 10 plots per treatment area, 30 plots total. Took photograph of all points.
2013	1-May	Pre-treatment data on new shade cloth areas	IAE	Took pre-treatment data on shade cloth areas to be placed with youth crew the next week
2013	10-May	Weed control	IAE	Weed whacked all new shade cloth plots in preparation for youth crew. Weed whacked 2m wide perimeter around all shade cloth plots. Tilled 3 of the 4 plots that are to receive solarization next week.
2013	14, 15, 22-May	Weed control	IAE/LGYC	Shade cloth/solarization installation.
2013	19-Jun	Weed control	IAE/ NWYC crew of 6	Mow tall oatgrass with string trimmer: Started in NE corner and moved south along east boundary to SE corner. Moved west across southern border to middle. Walked north through middle mowing small patches. Did not mow big patch in SW corner nor small patches in north-middle. Hand weeded solarization plots.
2013	19-Jun	Hand weeding solarization plots	IAE/ NWYC (crew of 6)	Hand weeded starting in SW corner of shade cloth/solarization experiment area. Attempted to be thorough but impractical with this density of *Agrostis capillaris* and *Rumex acetosella* colonization.
2013	10-Jul	Weed control	IAE	Hand weeded in shade cloth/ solarization experiment area. Focused largely on removing seed heads of velvet grass and sheep sorrel. 5 contractor bags full.
2013	16-Sep	Solarization removal	IAE	Upon arrival, found that the plastic on all four solarization plots was shredded and the plots were no longer covered. Perhaps fault of heat or lack of UV stabilizer in plastic. Cleaned up 2 of the 4 plots.
2013	16-Sep	Weed control	IAE	In large shade cloth/solarization experiment plot, dug out all visible Purple anther pepper weed (*Lepidium heterophyllum*) plants that had set seed this year. Small plants in leaf were generally not removed. Lots of dry seed on the plants.
2013	18-Sep	T-post replacement, East edge	IAE	Replaced all T-posts near east edge of property with orange cement markers. The only T-post that had a tag on it was the one in the far SE corner; it was transferred to new marker. T-posts appeared to be regularly spaced in southern 2/3 of property, but were sparse and irregular in northern 1/3.

Year	Date	Activity	Personnel*	Notes
2013	18-Sep	T-post replacement, middle	IAE	Replaced T-posts in middle of property. Started at north end and replaced all green transect T-posts. Put metal scratch tag on concrete markers that says 'transect'. For red plot marker T-posts, replaced #824, 819, and 818 (transferred tags), left #826, 820 in place, and couldn't locate #825, 821-823.
2013	18-Sep	Weed control	IAE	Clipped seed heads on meadow knapweed along north border and east of big shade cloth area.
2013	18-Sep	Wooden post removal	IAE	Removed 2 wooden posts with signs along E edge and placed on nearby shade cloth plots.
2013	18-Sep	Large shade cloth alteration	IAE	Lifted east edge of big shade cloth and folded over so that there will be room to get mower past.
2013	18-Sep	Solarization removal	IAE	Removed shredded plastic at the remaining 2 solarization plots.
2013	30-Sep	Solarization raking, shade cloth removal, weed whacking around plots	IAE	Raked four solarization plots to refill trenches. Weed whacked around all solarization/shade cloth plots because mower will not be able to mow close to plots/stakes. Removed shade cloth on plots 1a and on small lepidium shade cloth plot. Tall oatgrass in areas that were weed whacked on 5/10 flowered more than areas mowed on 6/19.
2013	31-Oct	Flame weeding	IAE	Flame weeded plots 1a-5a.
2013	1-Nov	Plant delivery	IAE	Picked up plants at Eugene NPN and Heritage and delivered to Fir Butte
2013	4-Nov	Planting	IAE/ Lane Metro Youth Corps	Planted in plots 2a, 3a, 4a, and "lepidium".
2013	6-Nov	Seeding	IAE	Seeded over plots 2a, 3a, 4a, "lepidium", and Experiment A-C.
2013	20-Nov	Shade cloth removal	IAE	plot 6a
2013	20-Nov	Flame weeding	IAE	plot 6a
2014	20-Mar	Flame weeding	IAE	Flame weeded plots 1a, 5a, 6
2014	20-May	Flame weeding	IAE	Flame weeded plots 1a, 5a, 6
2014	5, 6-Jun	Weed control	IAE/ 4 people from Walama	Hand mowed tall oatgrass at 6" throughout site. Where growing concurrently with Kincaid's lupine (*Lupinus oreganus*), mowed above top of raceme. At Cheryl Schultz' request did not mow L shape patch in SW corner.
2014	6-Jun	Monitoring	IAE	Monitored shade cloth/solarization experimental plots
2014	17, 18-Jun	Hand weeding	IAE/ 12 from NWYC	Plots 2a, 3a, 4a

Year	Date	Activity	Personnel*	Notes
2014	17, 18-Jun	Hand mow tall oatgrass	IAE/ 12 from NWYC	Finished work started by Walama on 6/5 and 6/6
2014	17, 18-Jun	Hand weeding bracken fern	IAE/ 12 from NWYC	Weeded 200 feet west of plot 2a around Kincaid's lupine
2014	12-Sep	Preparation for new fence construction	IAE	Removed E border T-posts and barbed wire; mowed 15 foot wide blackberries and grass up against fence.
2014	12-Sep	Re-mowed fire line	IAE	N edge of prescribed burn area; preparation for burn
2014	22-Sep	Fence construction	Island Fence	Fence constructed along entire east border of property
2014	29-Oct	Flame weeding	IAE	Flame weeded plots 1a, 5a. Did not reflame plot 6 because excessive weedy grasses had established.
2014	3, 5-Nov	Planting	IAE/ Lane Metro Youth Corps	Planted plugs and bulbs in plots 1a, 5a, 3b
2014	24-Nov	Planting	IAE/ AmeriCorps	Finished planting plugs and bulbs in plots 1a, 3b, 5a
2014	24-Nov	Weeding	IAE	Weeded most velvet grass out of 1a
2015	14-Jan	Seeding	IAE	Overseeded plots 1a, 3b, 5a, and burned area
2015	24-Mar	Orientation visit	IAE	New IAE staff visited site for first time, observed nectar islands and got an overview of the site from Christine
2015	23-Apr	Orientation visit; hand pull & dig weeds	IAE	Removed meadow knapweed rosettes, Lepidium, thistle, tansy ragwort in northern portion of site
2015	6-May	Remove weeds	IAE	Removed meadow knapweed rosettes, Lepidium, thistle, tansy ragwort throughout site
2015	12-May	Monitoring	IAE	Collected data from shade cloth/solarization test plots
2015	13-May	Removed weeds	IAE	Removed Lepidium from plot 6, weeded invasive grasses from nectar islands
2015	26, 27-May	Hand mow tall oatgrass	IAE/ Walama Restoration	Hand mowed tall oatgrass at 6" throughout site. Where growing concurrently with Kincaid's lupine, mowed above top of raceme. Did not mow Cheryl Schultz's research plots in the SW corner.
2015	12-Jun	Nectar island weeding	IAE	Mowed edges of all nectar islands and Experiments A, B, and C. Weeded velvetgrass out of all nectar islands (except 6, which was excessively weedy).
2015	5-Aug	Hand weeding	IAE	Hand weeded and bagged meadow knapweed, mainly in the NW corner

Year	Date	Activity	Personnel*	Notes
2015	7-Aug	Hand weeding	IAE	Removed blackberry from edges of nectar islands, weeded nectar islands
2015	9-Nov	Planting	IAE/ LGYC	Planted plugs and bulbs in plot 4b
2015	10-Nov	Planting	IAE/ LGYC/ AmeriCorps	Planted plugs, bulbs, and runners in plots 4b, 5b and 2b, moved shade cloth to plots 4c, 1c, 2c, and 5c,
2015	13-Nov	Planting	IAE/ 4 volunteers	Planted plugs and bulbs in plots 1b and 2b
2015	19-Nov	Planting	IAE	Planted plugs and bulbs in plots 2b and 5b
2015	3-Dec	Planting, weeding	IAE/ AmeriCorps	Planted strawberry runners in plots 1b, 5b, and 2b weeded *Agrostis* from 1a
2015	8-Dec	Seeding	IAE	Over seeded plots 1a, 1b, 2b, 4b, 5a, and 5b
2016	31-Mar	Herbicide application	IAE	Applied Fusillade herbicide to four experimental plots to test non-target impact of using Fusillade to manage prairie harboring Fender's blue butterfly
2016	19, 20-April	Hand weeding	IAE/LGYC	Hand-weeded meadow knapweed, purpleanther field pepper weed (*Lepidium heterophyllum*), bull thistle (*Cirsium vulgare*), tansy ragwort in northern portion of site; removed hairy cat's ear (*Hypochaeris* spp.), sheep sorrel (*Rumex acetosella*), and bentgrass (*Agrostis* spp.) from nectar islands
2016	6-May	Survey for Fender's blue butterfly	IAE/ BLM	Distance sampling for Fender's blue butterfly
2016	27-May	Hand mow tall oatgrass	IAE	Hand mowed tall oatgrass at 6" throughout site. Where growing concurrently with Kincaid's lupine, mowed above top of raceme. Did not mow Cheryl Schultz's research plots in the SW corner.
2016	2-Jun	Hand mow tall oatgrass	IAE	Hand mowed tall oatgrass at 6" throughout site. Where growing concurrently with Kincaid's lupine, mowed above top of raceme. Did not mow Cheryl Schultz's research plots in the SW corner.
2016	26-Jul	Hand weeding	BLM/ LGYC	Hand weeded meadow knapweed, mainly in the NW corner
2016	17-Aug	Hand weeding	IAE/ BLM	Removed Himalayan blackberry from edges of nectar islands, weeded nectar islands
2016	22-Aug	Burn break prep	IAE/ BLM	Mowed edges of Schultz research plots to prepare for prescribed burn.
2016	22-Aug	Shade cloth	IAE/ BLM	Replaced shade cloth on nectar island 2c.

Year	Date	Activity	Personnel*	Notes
2016	2-Sep	Fire break prep	IAE	Removed tree on the edge of fire break on Schultz research plot.
2016	16-Sep	Prescribed burn	Inter-Agency burn crew	Burned 4 acres in SE corner; burned 8 research plots in SW corner.
2016	19-Oct	Seeding	BLM	Seeded burn unit with native mix
2016	8-Nov	Planting	IAE/ BLM/ LGYC/ AmeriCorps/ volunteer	Planted bulbs and bare root lomatium in plots 1c, 2c, 4c & 5c
2016	21-Nov	Planting	IAE/ BLM/ LGYC/ AmeriCorps/ volunteer	Planted plugs and bulbs in plots 4c, 1c, 2c, and 5c
2016	29-Nov	Seeding	IAE	Over seeded plots 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, 4a, 4b, 4c, 5a,5b, 5c
2017	23-Mar	Herbicide application	Habitat Restoration LLC	Applied Fusillade herbicide to four experimental plots to test non-target impact of using Fusillade to manage prairie harboring Fender's blue butterfly
2017	May-July	Survey for Fender's blue butterfly	BLM	Distance sampling for Fender's blue butterfly
2017	13-Jul	Weed removal	BLM/ LGYC	Removed meadow knapweed inflorescences
2017	6-Jun	Hand mow tall oatgrass	IA/ BLM	Hand mowed tall oatgrass at 6" throughout site. Where growing concurrently with Kincaid's lupine, mowed above top of raceme. Did not mow Cheryl Schultz's research plots in the SW corner
2017	13-Sep	Nectar island prep	IAE/ BLM	Cleared and prepared shade cloth for nectar species planting
2017		Fire break prep	Contractor	Mowed fire brake around burn zone
2017	13-Sep	Fire break prep	IAE/BLM	Delineated burn zone with pin flags
2017	5-Oct	Prescribed burn	Inter-Agency burn crew	Burned 4 acres in north section which contain both upland and wet prairies
2017	19, 26-Oct	Nectar island prep	IAE/ BLM	Burned 1710 holes in shade cloth and seeded with native mix
2017	24-Oct	Seeding	IAE/ BLM	Seeded wet prairie with native mix
2017	26-Oct	Seeding	IAE/ BLM	Seeded upland with native mix
2017	8-Nov	Planting	IAE/ BLM/ LGYC	Planted 400 Kincaid's lupine plugs at Hansen
2017	14-Nov	Planting	BLM/ LGYC	Planted approximately 1200 *Fragaria virginiana* runners
2017	15-Nov	Planting	IAE/ BLM/LGYC	Planted approximately 1600 *Triteleia hyacinthine* bulbs

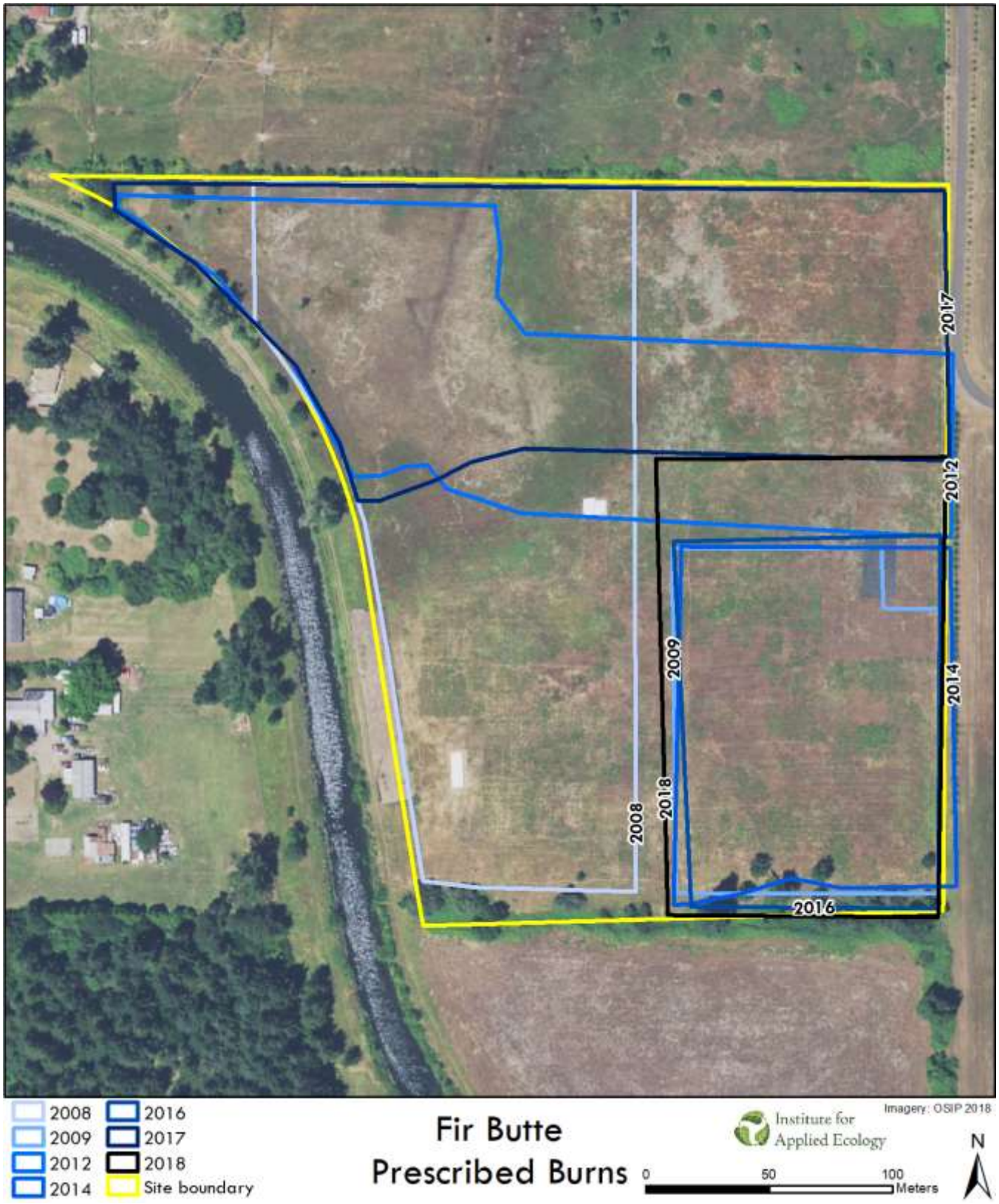
Year	Date	Activity	Personnel*	Notes
2017	20-Nov	Planting	IAE	Planted 50 pots of *Eriophyllum lanatum* and *Sidalcea malviflora*, respectively in the upland area of the burn zone
2017	20-Nov	Nectar island prep	IAE/ BLM	Burned holes in weed barrier
2017	21-Nov	Planting	IAE/ BLM	Planted 200 *Eriophyllum lanatum*, 300 *Sidalcea malviflora* pots, ~300 *Camassia leichtlinii* and ~300 *Allium amplectens* bulbs and a native seed mix in the nectar island
2018	20-Mar	Herbicide application	Habitat Restoration LLC	Applied Fusillade herbicide to four experimental plots to test non-target impacts of using Fusillade to manage prairie harboring Fender's blue butterfly
2018	18-Apr	Weed control	IAE	Flame weeded meadow knapweed in NW corner
2018	18-Apr	Weed control	IAE/ BLM/ LGYC	Picked bracken fern on south east side
2018	8-May	Weed control	LGYC	Picked bracken fern on south east side
2018	17-May	Site preparation	IAE/ BLM	Flame weeded a 9x8m plot for nectar island establishment and covered plot with plastic for solarization treatment
2018	21-May	Weed control	IAE	Mowed bracken fern
2018	29-May	Weed control	IAE/ BLM	Mowed tall oatgrass with string trimmer
2018	30-May	Weed control	IAE	Mowed tall oatgrass with string trimmer
2018	1-Jun	Weed control/site preparation	IAE	Mowed tall oatgrass with string trimmer and put plastic on nectar island
2018	5-Jun	Weed control	IAE	Mowed tall oatgrass with string trimmer
2018	8-Jun	Weed control	IAE	Mowed tall oatgrass with string trimmer
2018	8-Jun	Site preparation	IAE	Established a new 6X20m nectar island by clearing off vegetation with a string trimmer
2018	9-Jun	Site preparation	IAE	Covered mowed nectar island with plastic for solarization treatment
2018	13-Jun	Weed control	IAE	Mowed meadow knapweed in northwest corner
2018	26-Jun	Weed control	IAE	Pulled knapweed
2018	10-Jul	Weed control	IAE	Pulled knapweed
2018	26-Jul	Weed control	IAE	Pulled knapweed
2018	14-Aug	Site preparation	IAE	Flagged nectar islands
2018	27-Aug	Weed control	Contractor	Site wide mowing (except for burn unit and nectar islands)
2018	6-Sep	Site preparation	IAE/ BLM	Removed plastic from solarization treatments

Year	Date	Activity	Personnel*	Notes
2018	2-Oct	Weed control	IAE/ BLM/ LGYC	Removed Scotch broom from SE corner
2018	13-Oct	Prescribed burn	Interagency team	Burned approximately 5-acres in SE corner and all nectar islands
2018	17-Oct	Seeding	IAE	Broadcast nectar island seed mix over nectar islands
2018	7-Dec	Herbicide application	Contractor	Integrated Resource Management broadcast a 1.5% glyphosate solution over the 3-acre burn unit in the SE corner and nectar island 8a.
2018	7-Dec	Herbicide application	IAE	Applied 1.5% glyphosate solution to meadow knapweed across the site using a backpack sprayer.
2019	3/26, 3/29	Site preparation	IAE	Flagged lupine in SE corner (burn area)
2019	4/16	Herbicide application	IAE/ Contractor (IRM)	Broadcast glyphosate over 1.5 acres in SE corner; flagged lupine areas were not sprayed
2019	4/23	Herbicide application	IAE/ Contractor (IRM)	Broadcast glyphosate over additional 1.5 acres in SE corner; flagged lupine areas were not sprayed
2019	5/14, 5/15, 5/22	Weed control	IAE	Mowed tall oatgrass and bracken fern
2019	5/22	Weed control	IAE/ Contractor (IRM)	Spot sprayed bracken fern with 1.5% solution of glyphosate
2019	5/22	Weed control	IAE/ Contractor (IRM)	Applied glyphosate with weed wiper on bracken fern
2019	5/24	Weed control	IAE/ BLM	Mowed tall oatgrass
2019	6/11	Weed control	IAE	Spot sprayed meadow knapweed with 1.5% solution of glyphosate
2019	7/24	Weed control	IAE	Hand pulled and spot sprayed meadow knapweed
2019	7/20	Site preparation	IAE	Removed pin flags from SE corner to prepare for mowing
2019	9/12	Weed control	IAE/ Contractor (NTS)	Spot sprayed blackberry, hawthorn (*Crataegus monogyna)*, and rose (*Rosa* sp.)
2019	11/5	Site preparation	BLM/ LGYC	Removed weed cloth from nectar island 6d
2020	1/30	Weed control	IAE/BLM/Contractor (IRM)	Broadcast spray of Rodeo/Nu-Film-IR with backpacks over 3 acres in SE corner and less than one acre in nectar island 8a. Targeted all vegetation outside lupine patches.
2020	4/28	Weed control	IAE/BLM	Spot spray of meadow knapweed throughout site with Rodeo/NuFilm-IR
2020	5/5	Site visit	IAE	Site visit by Rebecca Currin and Ian Silvernail.
2020	6/23	Weed control	IAE/BLM/Contractor (IRM)	Broadcast spray of Rodeo/Nu-Film-IR with backpacks over 3 acres in SE corner and less than one acre in nectar island 8a. Target was all vegetation outside lupine patches.

Year	Date	Activity	Personnel*	Notes
2020	7/10	Weed control	IAE/BLM	Spot spray with Rodeo/Nu-Film-IR of areas missed during 6/23 spray.
2020	7/22	Site visit	IAE/BLM	Site visit by Sally Villegas-Moore, Julia Fields, Rebecca Currin, and Ian Silvernail.
2020	7/24	Weed control	IAE/BLM	Complete spot spray with Rodeo/Nu-Film-IR of areas missed during 6/23 spray that was initiated on 7/10. Hand pulled tansy ragwort.
2020	8/5	Site visit	IAE/BLM	Site visit to assess conditions.
2020	August	Weed control	BLM/ LGYC	Hand pull meadow knapweed.
2020	9/29	Site visit	IAE/BLM	Site visit, lupine senesced.
2020	10/1	Woody species control	IAE/BLM/Contractor (NTS)	Spot spray blackberry, hawthorn and rose.
2020	11/20	Site preparation	IAE/BLM/Contractor (IRM)	Broadcast glyphosate to 3.5 ac in SE corner and nectar island 8a.
2020	12/22	Site visit	IAE	Site visit to assess herbicide efficacy.
2021	1/14	Weed control	IAE	Spot sprayed SE corner with glyphosate.
2021	3/16	Weed control	IAE	Site visit to assess conditions. Flagged lupine in SE corner.
2021	4/14	Weed control	IAE	Spot sprayed meadow knapweed and SE corner.
2021	5/3	Weed control	IAE	Spot sprayed meadow knapweed, SE corner, and nectar island 8a.
2021	5/13	Site visit	IAE	Site visit to assess herbicide treatment and take photopoints.
2021	5/26	Site visit	IAE	Finished flagging lupine in SE corner.
2021	6/18	Weed control	IAE	Spot sprayed SE corner and nectar island 8a.
2021	7/12	Site visit	IAE/BLM	Site visit to discuss treatment options and seeding.
2021	8/5	Mapping	IAE	Mapped tall oatgrass population.
2021	8/18	Weed control	IAE	Spot sprayed bracken fern and hand pulled meadow knapweed.
2021	9/14	Woody species control	IAE/Contractor (IRM)	Treated woody plants throughout meadow.
2021	9/29	Site visit	IAE/USACE	Site visit to discuss use of seed drill.
2021	10/4	Weed control	IAE	Broadcast glyphosate to SE corner and nectar island 8a.
2021	10/14	Seeding	IAE/BLM	Seeded SE corner and nectar island 8a with dew drop drill borrowed from USACE.

* BLM (Bureau of Land Management), IAE (Institute for Applied Ecology), IRM (Integrated Resource Management), LGYC (Looking Glass Youth Crew), NTS (Nick's Timber Service), NWYC (Northwest Youth Crew)

Appendix 2. Fir Butte prescribed burns from 2008-2018



Appendix 3. Nectar island history

Plot	Size	Year established	Treatment type	Year planted
1a	8m x 10m	2012	Shade cloth	2014 (plants), 2015 (seed), 2016 (seed)
1b	8m x 10m	2014	Shade cloth	2015 (seed), 2016 (seed)
1c	8m x 10m	2015	Shade cloth	2016 (plants and seed)
2a	8m x 10m	2012	Shade cloth	2013 (plants and seed), 2016 (seed)
2b	8m x 10m	2013	Shade cloth	2015 (plants and seed) 2016 (seed)
2c	8m x 10m	2015	Shade cloth	2016 (plants and seed)
3a	8m x 10m	2012	Shade cloth	2013 (plants and seed), 2016 (seed)
3b	8m x 10m	2013	Shade cloth	2014 (plants), 2015 (seed), 2016 (seed)
4a	8m x 10m	2012	Shade cloth	2014 (plants), 2015 (seed), 2016 (seed)
4b	8m x 10m	2013	Shade cloth	2015 (plants and seed), 2016 (seed)
4c	8m x 10m	2015	Shade cloth	2016 (plants and seed)
5a	8m x 10m	2012	Shade cloth	2014 (plants and seed), 2016 (seed)
5b	8m x 10m	2014	Shade cloth	2015 (plants and seed), 2016 (seed)
5c	8m x 10m	2015	Shade cloth	2016 (plants and seed)
6d	15m x 25m	2017	Solarization, shade cloth	2017 (plants and seed)
4e (small)	9m x 8m	2018	Solarization, shade cloth	2018 (seed)
7e	6m x 20m	2018	Solarization, shade cloth	2018 (seed)
4e (big)	20m x 13m	2018	Solarization, shade cloth	2018 (seed)
8a	0.25 acres	2018	Prescribed burn and chemical fallow	2021 (seed)
SE corner	3 acres	2018	Prescribed burn and chemical fallow	2021 (seed)

Appendix 4. Nectar island plant materials

Nectar plots seeded and planted from 2014-2021.

Year	Nectar plot	
	Seeded	Planted
2014	1a, 3b, 5a	1a, 3b, 5a
2015	1b, 2b, 4b, 5b	1b, 2b, 4b, 5b
2016	1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, 4a, 4b, 4c, 5a, 5b, 5c	1c, 2c, 4c, 5c
2017	6d	6d
2018	1a, 1b, 1c, 2a, 2b, 2c, 4a, 4b, 4c, 5a, 5b, 4e (small), 7e	-
2021	8a, SE corner	-

Species planted in nectar plots from 2014-2017.

Scientific name	Common name	Form	Quantity			
			2014	2015	2016	2017
Allium amplectens	narrowleaf onion	bulbs	1,650	700	1,500	-
		plugs	-	-	-	300
Camassia leichtlinii	large camas	bulbs	10 trays	-	-	-
		plugs	-	-	-	300
Eriophyllum lanatum	Oregon sunshine	1'x2' Flats	186	-	-	-
		band pots	-	60	-	-
Eriophyllum lanatum	Oregon sunshine	band pots	-	-	-	250
Festuca roemeri	Roemer's fescue	medium plugs	800	2,448	400	-
Fragaria virginiana	wild strawberry	ramets	-	1,000	-	-
Iris tenax	Oregon iris	4" pots	-	40	-	-
Lomatium nudicaule	barestem biscuitroot	bare root	699	-	2,600	-
Luzula comosa	Pacific woodrush	medium plugs	273	-	800	-
Sidalcea malviflora ssp. *virgata*	dwarf checkermallow	medium plugs	1,080	2,560	1,600	-
		band pots	-	-	-	350
Sisyrinchium idahoense	Idaho blue-eyed grass	4" pots	-	80	-	-
Triteleia hyacinthina	white brodiaea	bulbs	1 tray	-	-	-
Zigadenus venenosus	death camas	bulbs	800	500	-	-

Seed broadcast in nectar plots from 2014-2021.

Scientific name	Common name	Seed (lbs)					
		2014	2015	2016	2017	2018	2021
Achillea millefolium	common yarrow	0.06	0.09	0.20	0.20	0.10	0.17
Allium amplectens	narrowleaf onion	-	-	-	-	1.20	1.39
Camassia leichtlinii var. *suksdorfii*	large camas	1.31	1.61	1.59	1.59	5.01	-
Camassia quamash	Common camas	-	-	-	-	-	4.88
Carex tumulicola	Splitawn sedge	-	-	-	-	-	1.88
Clarkia purpurea ssp. *quadrivulnera*	farewell-to-spring	0.02	0.02	0.06	0.06	-	0.26
Collomia grandiflora	large-flowered collomia	-	-	-	-	-	3.01
Danthonia californica	California oatgrass	-	-	-	-	-	4.36
Epilobium densiflorum	denseflower willowherb	0.05	0.07	0.09	0.09	-	0.43
Eriophyllum lanatum	Oregon sunshine	0.07	0.23	0.17	0.17	0.81	0.42
Festuca roemeri	Roemer's fescue	0.35	0.52	0.84	0.84	-	1.22
Hordeum brachyantherum	meadow barley	-	-	-	-	-	3.25
Iris tenax	toughleaf iris	-	-	-	-	-	7.95
Linanthus bicolor	true babystars	0.02	0.02	0.02	0.02	-	0.15
Lomatium nudicaule	barestem biscuitroot	-	0.22	0.19	0.20	1.21	6.17
Lupinus oreganus	Kincaid's lupine	-	-	-	-	-	6.00
Luzula comosa	Pacific woodrush	0.09	-	-	-	0.12	0.52
Madia elegans	Showy tarweed	-	-	-	-	-	1.14
Microseris laciniata	cutleaf silverpuffs	0.10	0.12	0.17	0.17	0.29	1.54
Nemophila menziesii var. *atomaria*	baby blue eyes	-	0.06	0.05	0.11	-	-
Perideridia oregana	Oregon yampah	-	-	-	-	-	0.77
Plectritis congesta	shortspur seablush	0.07	0.51	0.21	0.21	0.20	0.46
Potentilla gracilis var. *gracilis*	slender cinquefoil	0.03	0.40	0.07	0.07	-	0.26
Prunella vulgaris var. *lanceolata*	self-heal	0.16	0.18	0.31	0.31	0.34	0.91
Ranunculus occidentalis	Western buttercup	-	-	-	-	0.44	1.83
Sidalcea malviflora ssp. *virgata*	dwarf checkermallow	0.49	0.83	0.83	0.83	4.00	4.59
Sisyrinchium idahoense	Idaho blue-eyed grass	-	-	-	-	0.22	2.01
Wyethia angustifolia	narrowleaf mule's ears	0.66	0.75	0.48	0.48	-	3.67
Total		**3.48**	**5.63**	**5.28**	**5.35**	**13.94**	**59.24**

Appendix 5. Kincaid's lupine monitoring results

Foliar cover, number of leaves, number of mature racemes, and racemes/m^2 of Kincaid's lupine at Fir Butte from 1998-2020. Data was not collected every year.

Year	Estimated # of leaves		Estimated foliar cover (m^2)		Estimated # of mature racemes		Estimated # racemes/m^2 lupine cover
	Value	95% CI	Value	95% CI	Value	95% CI	
1998	223,780	±124,773	-	-	13,468	±8,052	-
1999	364,506	±212,576	-	-	22,776	±11,913	-
2000	431,283	±247,315	-	-	26,821	±14,870	-
2001	635,720	±332,041	-	-	34,800	±15,599	-
2002	816,571	±409,937	-	-	37,963	±14,558	-
2003	764,355	±360,055	-	-	47,335	±17,138	-
2004	1,424,524	±678,553	1,440	±685	55,456	±20,147	39
2005	861,633	±448,592	1,185	±539	43,624	±17,324	37
2006	-	-	1,421	±683	64,377	±24,799	45
2007	-	-	1,591	±728	97,437	±27,446	61
2008	-	-	1,592	±732	116,438	±31,446	73
2009	-	-	1,730	±686	86,921	±23,654	50
2010	-	-	2,605	±1,139	133,113	±35,837	51
2011	-	-	2,396	±703	-	-	-
2012	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-
2014	-	-	3,106	±872	189,354	±49,295	61
2015	-	-	3,555	±927	64,183	±17,037	18
2016	-	-	-		-		-
2017	-	-	4,834	±1,170	247,412	±53,661	51
2018	-	-	3,352	±838	113,313	±33,995	34
2019	-	-	-	-	-	-	-
2020			5,931	±1,515	196,011	±61,004	33
2021			4,678	±1,214	108,279	±29,643	23

Appendix 6. Fir Butte photopoints

Photos taken on May 13, 2021.

Photopoint 1

North

East

South

West

Photopoint 2

North

East

Photopoint 2 (continued)

South

West

Photopoint 3

North

East

South

West