Lupinus sulphureus ssp. *kincaidii* (Kincaid's lupine) and *Icaricia icarioides fenderi* (Fender's blue butterfly) in the West Eugene Wetlands: Population monitoring, reintroduction success, and an evaluation of experimental treatments

2010 Report

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PREFACE

This report is the result of a cooperative Challenge Cost Share project between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization dedicated to natural resource conservation, research, and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.

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EXECUTIVE SUMMARY

This report documents research conducted on Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii*), a threatened species in the legume family. Kincaid's lupine serves as an obligate larval host plant for the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*). Both species are endemic to western prairies. The specific objectives of this project are to 1) describe trends of Kincaid's lupine and Fender's blue butterfly eggs at sites managed by the Eugene District Bureau of Land Management in the West Eugene Wetlands (in 2010 Fir Butte and Oxbow West; previous monitoring efforts included Isabelle, Turtle Swale, and Dragonfly Bend), 2) evaluate mowing and burning as management treatments for reducing invasive weeds and enhancing Kincaid's lupine and Fender's blue butterfly populations, and 3) evaluate estimates of lupine foliar cover as an alternative to time-consuming leaf counts.

1. Populations of Kincaid's lupine in the WEW increased in abundance in 2010. Egg counts for Fender's blue butterfly continued to be relatively low at Oxbow West, and increased at Fir Butte from 2009.

    a. Fir Butte was the largest population monitored in this area, with approximately 133,112 inflorescences and a total foliar cover of 2,605 m^2. This remains the highest value for the cover of lupine since monitoring began in 1998, and is a substantial increase from 2009. The number of inflorescences in 2010 was higher than any previous year. The estimated number of Fender's blue butterfly eggs was the highest ever with approximately 17,950.

    b. The lupine population at Oxbow West plateaued in 2008, decreased in 2009 and has slightly rebounded in 2010. The lupine population still covers about 75 m^2. We counted 4,899 inflorescences, the fourth highest number recorded since monitoring began in 1999. We estimated that there were only 35 Fender's blue butterfly eggs, a precipitous decline from previous estimates.

2. From 1998 through 2008, we evaluated the effects of mowing annually, every two years, and prescribed fire. While all management treatments benefited lupine cover and decreased the cover of *Rubus armeniacus*, the greatest benefits were from burning, followed by frequent (at least once per year) mowing. The number of butterfly eggs was unaffected by treatments.

3. Estimating foliar cover is an acceptable alternative to counting leaves of Kincaid's lupine when combined with flower stem counts, especially if the objective is to measure trends in lupine abundance. Lupine leaf density is positively correlated with foliar cover, and this relationship is strongest in habitats with full sun (such as most Willamette Valley sites). Regional differences in this relationship make direct comparisons of lupine cover across sites unreliable in some cases because lupine leaf density varies with the amount of sunlight reaching the habitat.

INTRODUCTION

Species status

This report documents work conducted on Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii*; Figure 1), a rare member of the legume family (Fabaceae) listed by the Oregon Department of Agriculture and the U.S. Fish and Wildlife Service as a threatened species. Kincaid's lupine serves as an obligate host plant for the larvae of the Fender's blue butterfly (*Icaricia icarioides fenderi*), which is listed as an endangered species.

Figure 1. Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii*).

Background information

Kincaid's lupine is found in native prairie remnants in the Willamette Valley, southwestern Washington, and forest openings in Douglas County, Oregon. In the Willamette Valley, Kincaid's lupine serves as a larval host plant for the rare Fender's blue butterfly, making conservation of the lupine a common strategy for the success of both species.

Only 57 sites are known to support Kincaid's lupine and fewer than 20 of these are larger than 1 hectare (Wilson et al. 2003). Additionally, the majority of the sites are on privately held land, which is exempt from protections provided by state and federal listing, increasing the importance of management by state and federal agencies on public land.

Reproduction and population biology

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 appears to spread 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 (Figure 2). After eggs hatch, the larvae emerge and feed on lupine leaves before overwintering in the soil near the base of plants.

Fender's blue butterfly life cycle

The butterflies are mature adults in May and June when they fly, eat nectar, and mate. The females lay their eggs on the underside of lupine leaves. The eggs hatch in a few weeks and the larvae feed on lupine leaves (Figure 2) until late June or early July before crawling under nearby vegetation and plant litter to enter diapause. They remain in that state until February or early March, when they begin feeding again on the newly emerging lupines. Near the end of April they pupate, reemerging as butterflies in May (Schultz and Crone 1998).

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

Objectives

This report summarizes treatment effects and monitoring methods for both natural populations and restoration plantings of Kincaid's lupine in the WEW. The specific objectives of this project are to:

Describe population trends of both natural and introduced populations of Kincaid's lupine as well as to monitor the abundance of Fender's blue butterfly eggs at Fir Butte and Oxbow West in the West Eugene Wetlands owned by the Eugene District BLM. This project previously included introductions and monitoring at Turtle Swale, Isabelle, and Dragonfly Bend. Results and population trends at these sites are reported in Thorpe et al. 2009.

Evaluate mowing and burning as a management treatment for reducing the abundance of blackberry and measure the effects of this treatment on abundance of Kincaid's lupine and Fender's blue butterfly (in terms of both larval survival and egg laying).

METHODS

Fir Butte

Study site

One of the largest known extant populations of Kincaid's lupine occurs at Fir Butte, located northwest of Eugene, Oregon (T17S R5W Sec. 24 NE¼). The site includes both upland and wetland prairie habitats, but these are degraded due to the presence of invasive species that probably established when the site was historically utilized as a pasture and cultivated field. Figure 4 shows a schematic diagram of the plot locations within the Fir Butte site.

Fir Butte is an 18 acre prairie remnant owned by the Eugene District BLM and currently managed primarily for the lupine and Fender's blue butterfly. The overall habitat quality at the site is poor, with heavy infestations of alien plants such as *Rubus armeniacus* (blackberry), *Cytisus scoparius* (Scotch broom), *Centaurea pratensis* (meadow knapweed), and *Arrhenatherum elatius* (tall oatgrass). These non-native plants are the primary threats to the lupine and butterfly, and their control is the main objective for management at this site. Since 1999, BLM crews have made substantial headway in reducing the meadow knapweed, Scotch broom, and blackberry cover.

Monitoring of Kincaid's lupine was initiated at Fir Butte in 1998 to provide data on population trends and test the effects of experimental habitat management treatments, namely mowing and prescribed burning, on Kincaid's lupine cover and Fender's blue butterfly reproductive success. Sampling conducted in 2010 represents the thirteenth year of data collection at Fir Butte.

Plot design

Although plots were established in July 1998, the treatments were not assigned or implemented until 2001; the monitoring design was intended to be flexible enough to accommodate a number of possible management alternatives. A total of 18 plots were established at the site within a 216 x 288 m macroplot. Each plot is 20 x 100 m, surrounded by a 2 m wide buffer on each of the long sides and a 4 m wide buffer on each of the narrow sides (Figure 4). Plots are marked with fence posts in their corners, *outside the buffer*. Thus, the plot size within the posts, inclusive of the buffer, is 24 x 108 m. Each fence post is labeled with a pre-numbered aluminum tag. The long axis of the plots runs due east and west. Within each of these plots, two subplots were selected at random for sampling. Subplots are 2 x 100 m transects that are marked at each end with metal conduit posts. Subplots represent a 15.7% sample of the total macroplot.

Plot sampling

Sampling at Fir Butte was performed by extending a 100 m measuring tape between the posts marking the ends of a subplot. The tape ran down the center of the subplot, which extended 1 m to each side of the tape (north and south). To make sampling more manageable, data were recorded in 5 m segments along each side of the tape. We used 1 m pieces of PVC conduit to determine the north and south limits of the subplots; extra PVC conduit was used to divide up large leaf clusters into smaller counting units. Within each 1 x 5 m segment, we recorded the cover of Kincaid's lupine, the number of mature and aborted Kincaid's lupine inflorescences, the number of Fender's blue butterfly eggs on the leaves, the percent cover of *Rubus armeniacus*, and the presence/absence of *Centaurea pratensis*. *Rubus armeniacus* cover was estimated to the nearest 1% (for values between 1 and 10%), 5% (for values between 10% and 20%), or 10% (20% – 100%). In 2006, it was noted that cover of *Pteridium aquilinum* (bracken fern) appeared to increase dramatically after prescribed fire. Thus, we also estimated the cover of this species along the transects using the same method as for *R. armeniacus*.

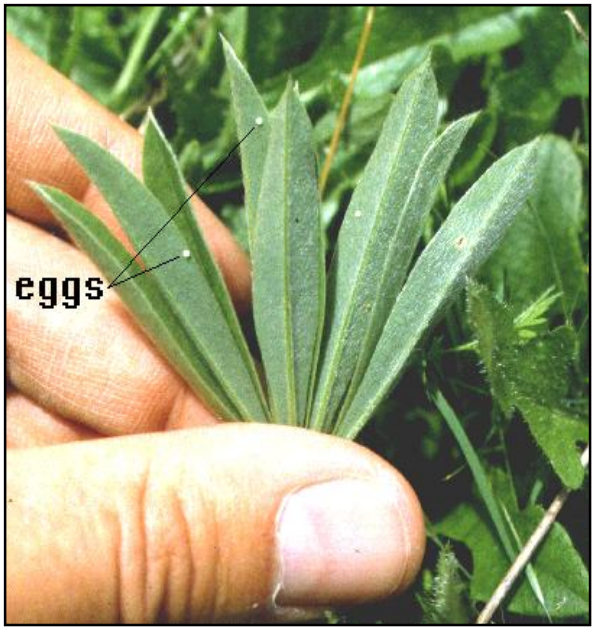


Figure 3. Eggs of Fender's blue butterfly are identifiable as white dots on the undersides of *Lupinus sulphureus* ssp. *kincaidii* leaves.

Percent cover of lupine was determined by measuring the approximate rectangular area occupied by a clump. Cover of lupine is highly correlated with the number of leaves (Kaye and Benfield 2005). Due to this correlation, we eliminated counting leaves from our protocol in 2006. This greatly improved the efficiency of sampling. In 2006, the time required to carry out the set-up and sampling of monitoring plots was approximately 150 person-hours. Monitoring performed by a team of four to six people took up to 250 person-hours in past years, depending on the annual variation in abundance of Kincaid's lupine leaves and Fender's blue butterfly eggs (Gisler and Kaye 2004).

*Eggs of Fender's blue butterfly are identifiable as small (0.5–1.0 mm) white spheres on the underside of lupine leaves (*Figure 3*).* Hatched eggs resemble unhatched eggs except they have burst in the center making them look like little white "donuts." Hatched and unhatched eggs were counted together. When leaf number was counted (1998 - 2005) and the value *exceeded 1,000 per 1 x 5 m* segment, eggs were counted on a random subsample of 25% of the leaves and multiplied by four to obtain an estimate of egg number for the entire segment. When only leaf cover was recorded (2006 to present) and the value was estimated to be at least 25% in any 1 x 5 m segment, eggs were subsampled and estimated as above.

Mowing and burning treatments

In 2001, three mowing treatments were randomly assigned to plots at Fir Butte, every year, every other year, and every third year (Table 1, Figure 4). Mowing was performed during the late summer/early fall (generally September), when Fender's blue butterfly larvae are dormant in the soil litter layer and the lupine have likewise retreated to a dormant stage until the following spring. In fall 2005, all plots were mowed and treatments were reassigned. In 2006, all plots assigned to be mowed every year or every other year were mowed and the plots assigned to be mowed every other year were assigned to be mowed twice a year, in September and February (while the lupine and butterfly were still dormant). This treatment did not occur as scheduled (Sally Villegas, *personal communication*), however, these plots were analyzed separately due to their history of different management relative to other plots. Eugene District BLM attempted to burn plots in October 2004, but due to a green-up of vegetation caused by early fall rains, the grassy fuels at the site would not combust. Only plot #9 was burned, and this was a patchy, incomplete burn that left a large amount of standing fuel and generated very little heat. In October 2006, all burn treatment plots were successfully burned.

2007 was the last year that treatments were applied as assigned to plots, thus data collected in 2008 was the last we could include in our analyses. Currently, Fir Butte is being managed with annual mowing and occasional burns.

Data analysis of treatments

Values for each response variable in each subplot were summed (inflorescences, eggs) or averaged (lupine cover, blackberry cover) to derive a single measure. Values from each of the two subplots were then averaged to derive whole-plot estimates. Subplot data (n = 36) were used for whole-population estimates. Treatment unit averages (n = 6 for each treatment) were used in testing for treatment effects.

As lupine cover, the number of lupine inflorescences, and *R. armeniacus* cover in 2008 were not independent of the 2005 data (prior to the initiation of the treatments), we tested for treatment differences using an Analysis of Covariance with 2005 values for each variable as a covariate. Percent cover of *R. armeniacus* was log transformed to meet assumptions of normality. The number of Fender's blue butterfly eggs in 2008 was dependent on the cover of lupine in 2008, which in turn was dependent on the cover of lupine in 2005. Thus, to test for treatment effects on Fender's blue butterfly, the response variable was the number of butterfly eggs/m^2 lupine cover in 2008 with lupine cover in 2005 as a covariate.

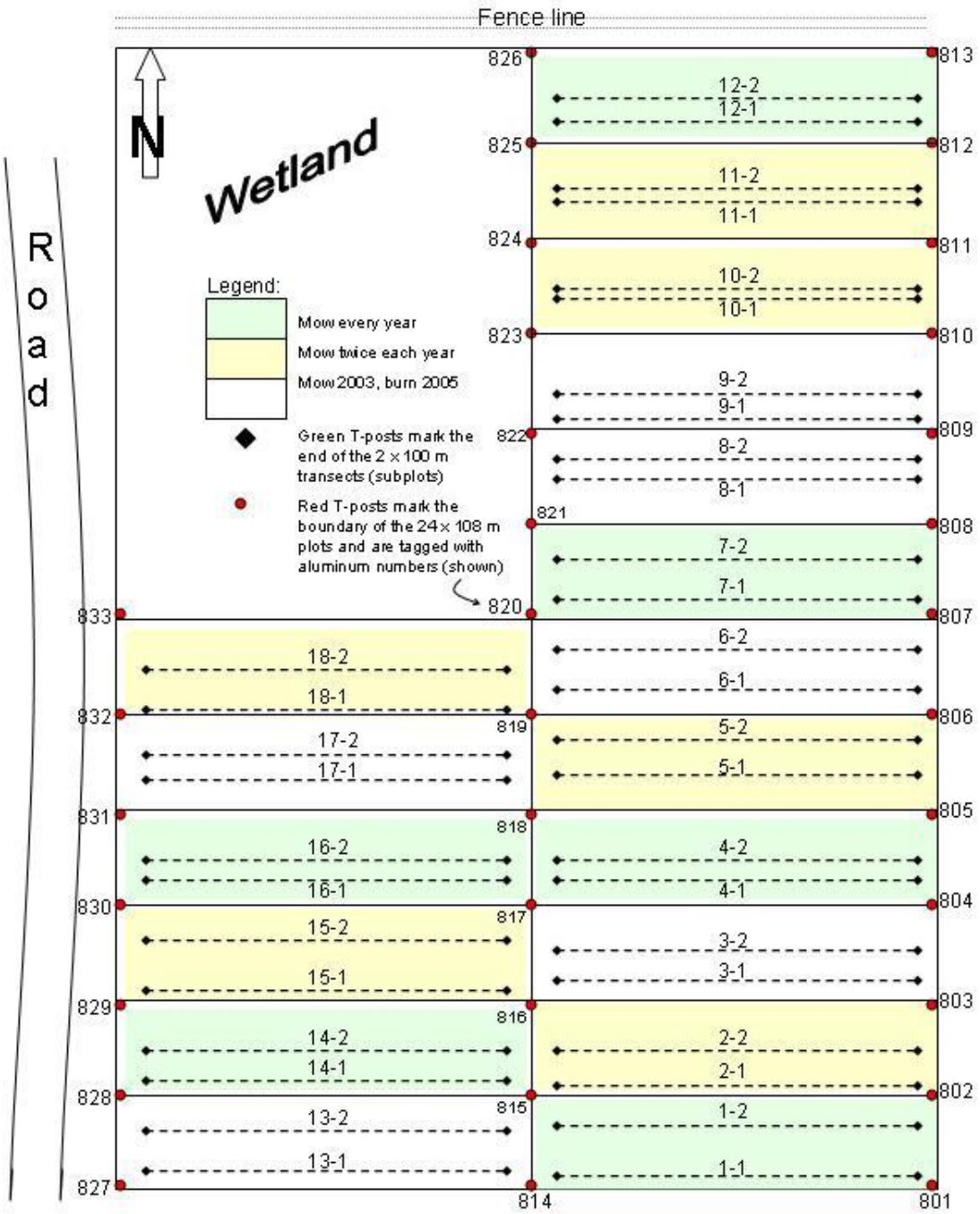


Figure 4. Diagram of plot layout at the Fir Butte Kincaid's lupine site. Assigned treatments were performed from 2001-2007. The macroplot contains 18, 24 x 108 m plots. Each plot is marked in the corner by a tagged metal fence post. Within each plot, two 2 x 100 m subplots are placed at random, with each end of the subplots marked by a metal conduit post. This arrangement leaves a 2 - 4 m buffer around the sampling zone for equipment travel and to reduce edge effects.

Table 1. Treatment assignments for Kincaid's lupine plots at Fir Butte performed from 2001-2007. Every-year and alternate-year mowing treatments both began in 2001, so the latter should take place in all odd numbered years (2001, 2003, 2005, etc.). Plots designated for "burn/mow every three years" were mowed in 2003 and burned in October 2006.

Plot	Treatment
1	mow every year
2	mow twice each year*
3	burn/mow every three years
4	mow every year
5	mow twice each year*
6	burn/mow every three years
7	mow every year
8	burn/mow every three years
9	burn/mow every three years
10	mow twice each year*
11	mow twice each year*
12	mow every year
13	burn/mow every three years
14	mow every year
15	mow twice each year*
16	mow every year
17	burn/mow every three years
18	mow twice each year*

*****Mowing occurred once per year, not twice a year as scheduled. However as these plots had previously been treated with mowing every-other-year, they were analyzed separately from the other treatments.

Oxbow West

Study site

The Kincaid's lupine population at Oxbow West occurs in an opening (~1/4 acre) sparsely edged by woody shrubs and trees such as *Salix* spp. and *Fraxinus latifolia*. The population is located west of the Amazon Canal and north of the Terry Street Bridge (Figure 5). By car, the site is about 0.15 miles north of the bridge and about 15 m west of the paved bike path running along Amazon Canal (T17S R5W Sec. 24 NE¼). The upland prairie habitat occupied by Kincaid's lupine is relatively degraded and harbors numerous weeds, though it is in better overall condition than the plant community at Fir Butte. The area was historically used as pasture and possibly a cultivated field.

Plot layout and sampling

Monitoring of this population incorporates a complete census approach rather than a sampling approach like the one used at Fir Butte. A 30 x 17 m macroplot was established to surround the entire population in 1999, marked by metal posts on all four corners. The long axis of the macroplot runs at a compass bearing of 340^{o}. To perform the census, the macroplot was broken down into 1 m^2 cells. Each cell was identified according to an x-y coordinate system, with the NE corner considered 0, 0 (Figure 5). Variables measured in each 1 m^2 cell included percent cover of lupine, number of mature and aborted lupine inflorescences, number of Fender's blue butterfly eggs, percent cover of blackberry, and the presence/absence of reed canary grass (*Phalaris arundinacea*). Due to the strong correlation between lupine cover and the number of leaves, we used cover as the sole estimate of lupine abundance from 2006 onwards.

By 2004, a few patches of lupine extended beyond the boundaries of the macroplot; an additional row was added onto the south end of the plot, increasing the macroplot size to 31 x 17 m. In 2007, lupine had continued to spread outside the dimensions of the macroplot; the locations of the lupine outside the plot were noted and variables were measured for each patch. In 2008, the plot was again expanded to include an additional meter on either end of the plot, making the plot 33 x 17 m. In 2010 due to time constraints only ¼ of the population, which was randomly selected, was monitored in addition to all plants outside of the plot boundary, We then used these numbers to estimate the lupine cover, raceme estimates and number of butterfly eggs.

Transplanting

Eleven Kincaid's lupine transplants were planted near the existing Oxbow West population in April 2000. These transplants were grown from seed collected from the adjacent population and were planted into a grid with 1 m spacing that was located between the plot edge and the bike path. Plants were marked with a wood stake and watered in, but no fertilizer or nodulating bacteria were added. From 2000 - 2004, data were recorded on maximum and perpendicular width of the transplants, leaf and inflorescence number, and number of butterfly eggs. By 2005, the surviving transplants had grown together in such a way that we were unable to discern individual plants and the measurements for these plants were included in the macroplot totals.

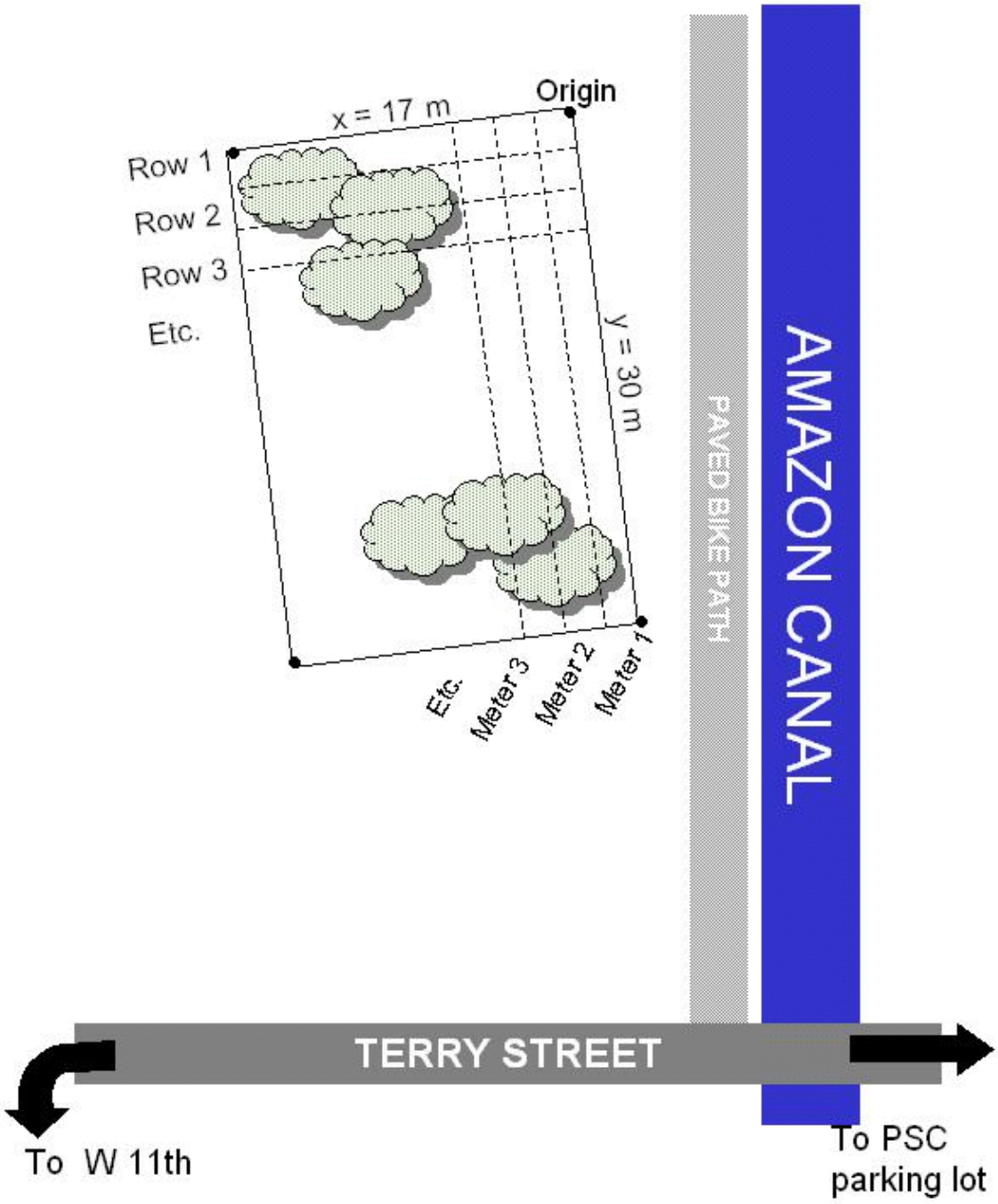


Figure 5. Diagram of the Kincaid's lupine monitoring plot at Oxbow West. Plot layout is a grid-cell structure where each 1 m^2 cell of the plot is censused for lupine and referred to by its x-y coordinates (i.e., row-meter coordinates as shown on diagram). The NE corner is 0, 0 and the y-axis extends 33 meters after additional rows were added in 2004 and 2008. (The y-axis now extends 1m north of the origin and 2 m south of the original plot set-up.)

RESULTS AND DISCUSSION

Fir Butte

Review of plot layout and experimental design

There are currently 18 plots available for habitat manipulation at Fir Butte. From 1998 to 2006, three treatments were randomly assigned to the plots and replicated six times each. The spatial variability in lupine and Fender's blue egg abundance at the site is very high, making site-wide estimates of average leaf or egg number, for example, subject to large error terms (Figure 6, Figure 7, Figure 8, and Table 2). Due to the distribution pattern of lupine patches at the site, this variance would likely be much lower if subplots ran north-south instead of east-west. However, an east-west orientation was selected to facilitate the use of fire as an experimental management treatment because the direction of prevailing winds in late summer and early fall is west to east. Due to the changes in treatments that occurred in 2005 and 2006, treatment differences were not evaluated until 2007. This experiment concluded in 2008 and those analyses are included here.

Trends and current abundance of Kincaid's lupine, butterfly eggs, and blackberry

In 2010, Kincaid's lupine cover (Figure 6) and the number of Fender's blue butterfly eggs (Figure 8) increased from the levels observed in 2009. The number of inflorescences increased in 2010 to 2.9 per square meter of plot area (from 1.9 in 2009), this is the highest since monitoring began at Fir Butte (Figure 7). Although the number of Fender's blue butterfly eggs remained relatively low in 2010 compared to counts in 1998 – 2004, the number of eggs found in 2010 was still more than triple the number counted in 2009 (Figure 8, Table 2). We estimated that there were approximately 17,950 eggs at Fir Butte in 2010, a threefold increase from 2009..

The cover of *Rubus armeniacus* has varied substantially since monitoring began in 1998 (Figure 9), most likely a response to varied mowing intensities and prescribed fire in different years. The cover of *R. armeniacus* increased from 2007 through 2009, when the average cover was 17.5%. In 2010 the cover of *R. armeniacus* decreased slightly from to 13.5%.

Treatment effects

As reported in Kaye and Benfield (2005), mowing at Fir Butte in late summer or early fall had neutral or negative effects on blackberry and positive effects on Kincaid's lupine. The effects of mowing annually were much stronger than the effects of mowing on a two or three year cycle. In 2005, treatments were altered at Fir Butte so that annual mowing became the baseline treatment. Mowing every 2 or 3 years was dropped, and mowing twice per year was scheduled, though not implemented. Plots designated as mow every 3 years/burn were burned in October 2006.

In 2008 we found positive effects of mowing and burning on lupine and negative effects on the cover of *Rubus armeniacus*. All management treatments resulted in an increase in the cover of lupine and the number of inflorescences compared to their 2005 levels. Relative to the plots that were mowed just once per year, there tended to be higher cover in plots that were burned ($P = 0.157$). All treatments led to at least an 800% increase in the number of inflorescences present in the plots. Mowing once per year showed the largest percent change (14,800%) but also had an extremely high standard error (±11,700%). There was little effect of mowing once per year on the cover of *R. armeniacus* compared to 2005.

We did not observe any treatment effects on the number of Fender's blue butterfly eggs in 2008 when compared to the 2005 numbers ($P = 0.32$). These results may stem from the overall low abundance of Fender's blue butterfly in 2008, inferred by using eggs per meter square of lupine cover as a proxy (Figure 8).

These results are consistent with or even more promising than those of previous studies and observations. Mowing annually for three years at Baskett Butte (Baskett Slough National Wildlife Refuge) substantially reduced the cover of woody plants while lupine cover stayed the same or increased slightly and inflorescence production doubled (Wilson et al., 2003). In addition, lupine in mowed plots attracted ovipositing female Fender's blue butterflies, resulting in much greater egg numbers in mowed plots compared to unmanipulated plots (Schultz et al., 2003).

We also observed an increase in butterfly larvae in mowed areas (Kaye and Benfield 2005). Similar results were found by Fitzpatrick (2004), who found that repeated annual mowing increased the number of lupine leaves, egg laying, and larval survivorship, at least at some sites and in some years. Butterfly egg laying may increase in mowed areas because the removal of tall, woody plants like blackberry can improve the ability of female butterflies to reach lupine plants for oviposition. Also, larval survivorship may increase in mowed areas because larvae can do better on plants that have been released from blackberry competition and are hence more nutrient rich. Research with other lupine species (*Lupinus lepidus*) suggests that increased nutrients in lupine foliage improves lepidopteran larval feeding rates in the field and growth in the lab (Fagan et al., 2004).

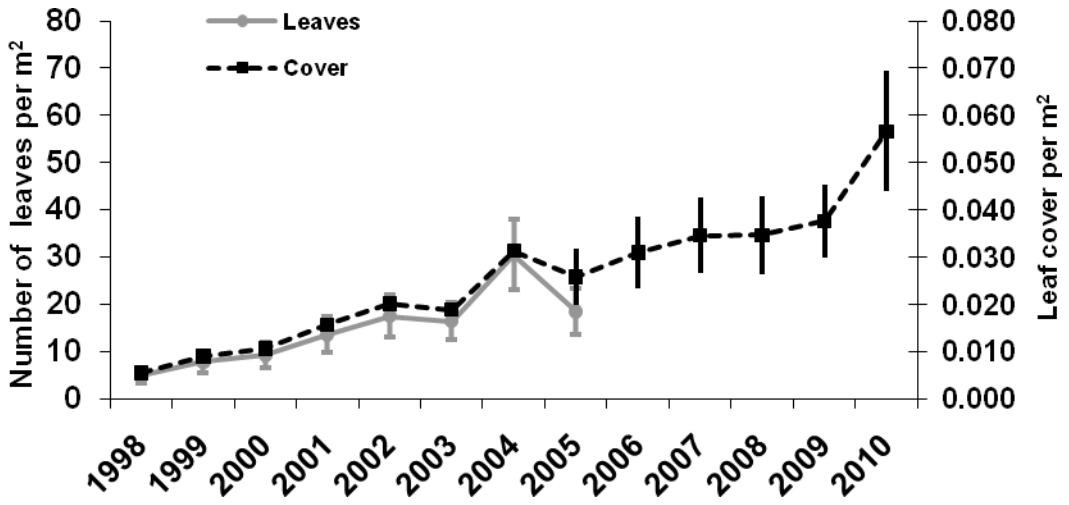


Figure 6. Average number of leaves and leaf cover (m^2) of Kincaid's lupine per total area (m^2) over all experimental plots at Fir Butte. Cover estimates were not made prior to 2004 and leaves were not counted after 2005. There is a strong linear relationship between cover and the number of leaves. The 2004 - 2005 average was 870.2 leaves per m^2 of lupine cover. This ratio is reflected in the scaling of the y-axes. Bars are ±1 S.E.

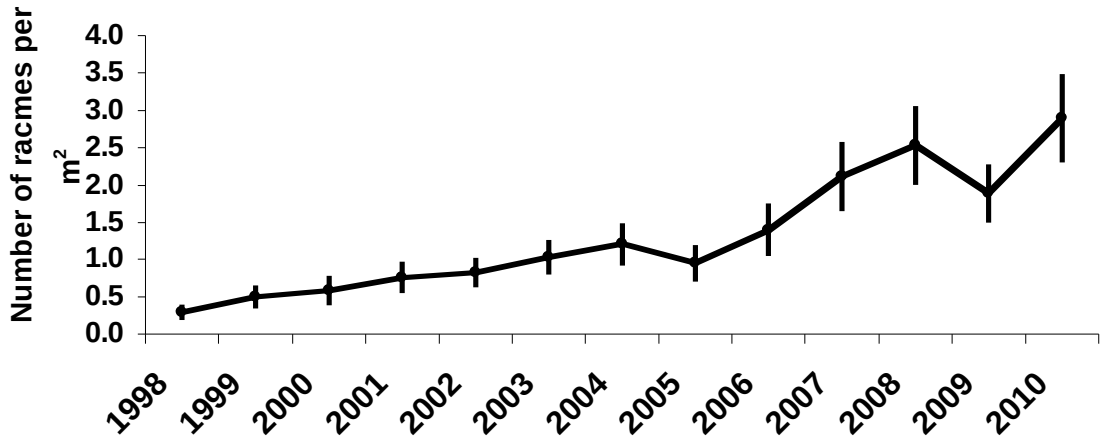


Figure 7. Average number of racemes per m^2 over all experimental plots at Fir Butte. Bars are ±1 S.E.

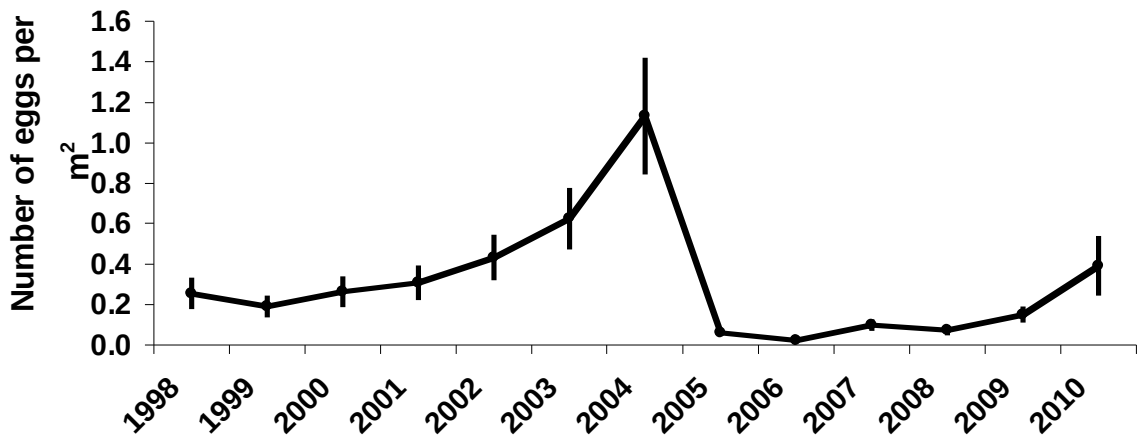


Figure 8. Average number of Fender's blue butterfly eggs per total area (m^2) over all experimental plots at Fir Butte. Bars are ±1 S.E.

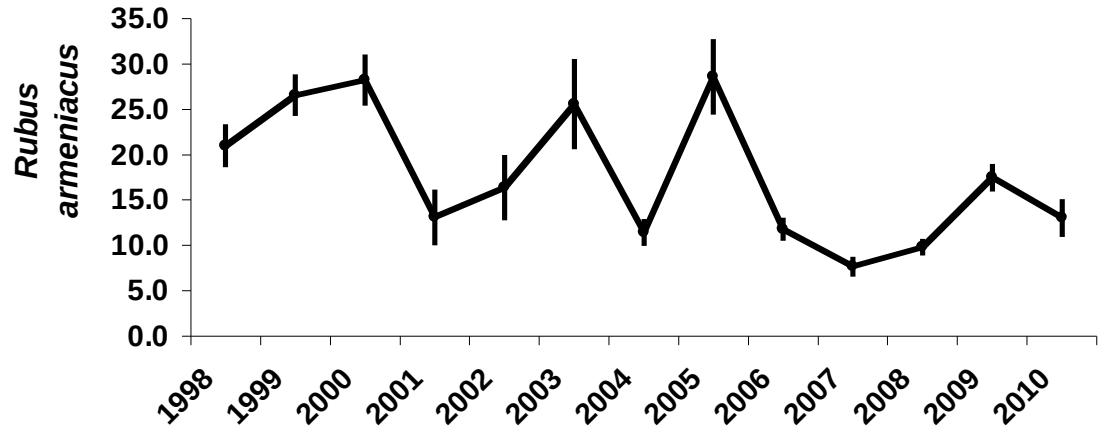


Figure 9. Average cover of *Rubus armeniacus* over all experimental plots at Fir Butte. Bars are ±1 S.E.

Table 2. Estimated totals of Kincaid's lupine inflorescences, leaves, and butterfly eggs at the Fir Butte site, 1998 – 2010. Quantification of lupine cover was initiated in 2004 and in 2006 this became the sole method used to determine the abundance of lupine at the site. A hyphen (-) indicates that no measurements were taken for a variable in that year.

		Lupine cover (m^2)	# Leaves	# Inflorescences	# Butterfly eggs
1998	total at Fir Butte	—	220,634	13,468	11,698
	90% CI		±78,048	±5,683	±4,846
1999	total at Fir Butte	—	359,381	22,776	8,740
	90% CI		±123,540	±8,408	±2,780
2000	total at Fir Butte	—	425,219	26,821	12,056
	90% CI		±149,757	±10,494	±4,195
2001	total at Fir Butte	—	626,782	34,800	14,068
	90% CI		±188,744	±11,009	±4,372
2002	total at Fir Butte	—	805,089	37,963	19,805
	90% CI		±230,423	±10,275	±5,546
2003	total at Fir Butte	—	753,608	47,335	28,731
	90% CI		±209,530	±12,196	±7,811
2004	total at Fir Butte	1,440	1,404,495	55,456	51,897
	90% CI	±373	±377,513	±14,219	±14,056
2005	total at Fir Butte	1,185	849,518	43,623	2,817
	90% CI	±303	±256,989	±12,227	±761
2006	total at Fir Butte	1,421	—	64,377	1,009
	90% CI	±378		±17,503	±404
2007	total at Fir Butte	1,591	—	97,437	4,485
	90% CI	±404		±22,965	±1,357
2008	total at Fir Butte	1,592	—	116,438	3,367
	90% CI	±390		±26,312	±1,197
2009	total at Fir Butte	1,730	—	86,920	6,887
	90% CI	±387		±19,792	±1,958
2010	total at Fir Butte	2,605	—	133,112	17,950
	90% CI	±599		±29,986	±7,346

Oxbow West

Kincaid's lupine exhibited a low-density, patchy distribution within the macroplot at Oxbow West when the plot was first established in 1999. There are currently two main patches of lupine within the macroplot and they are expanding toward one another and the boundaries of the plot. In 2004 and 2009, it was necessary to add three additional rows one to the north end and two to the south end of the monitoring plot.

Cover of lupine at Oxbow West had been steadily increasing from 1999 to 2007 and plateaued in 2008; in 2009 lupine cover decreased approximately 17%, but in 2010, increased to 83m^2, similar to 2006 levels (Figure 10). The number of lupine inflorescences generally increased from 1999-2005, and has fluctuated between approximately 4,800 in 2006 to 7,000 found in 2008. In 2010 the number of inflorescences was approximately, 4,900 (Figure 11). The estimated number of Fender's blue butterfly eggs plummeted to 112 in 2009 and to only 35 in 2010, (Figure 12). In contrast, egg numbers increased substantially at Fir Butte. Fender's blue butterfly has lower ovideposition rates on Kincaid's lupine that is surrounded by dense vegetation (Severns 2008). If egg numbers continue to decrease, treatments to increase edges in the Kincaid's lupine population may need to be considered. Other factors that could be affecting the low numbers of ovideposition could be lack of nectar species for butterflies, or poor weather. However, because egg counts have recently increased at Fir Butte, weather is most likely not an important factor influencing the decrease in eggs at Oxbow West.

The cover of *R. armeniacus* at Oxbow West increased slightly in 2008 and 2009. Blackberry occupied 297 and 317 of the 1 m^2 grid cells in 2008 and 2009 respectively compared to 218 in 2007, still considerably fewer than the number occupied in 2006 (372). The average cover of blackberry at the site was 3.7% in 2009 compared to 1.7% in 2008, 1.3% in 2007 and 8.7% in 2006. In 2010 the cover of *R. armeniacus* decreased to only an estimated 1.0%. However, because the overall cover of blackberry is low and only ¼ of the population was surveyed, the error for this estimate is high, and may not reflect an actual decrease in cover of blackberry.

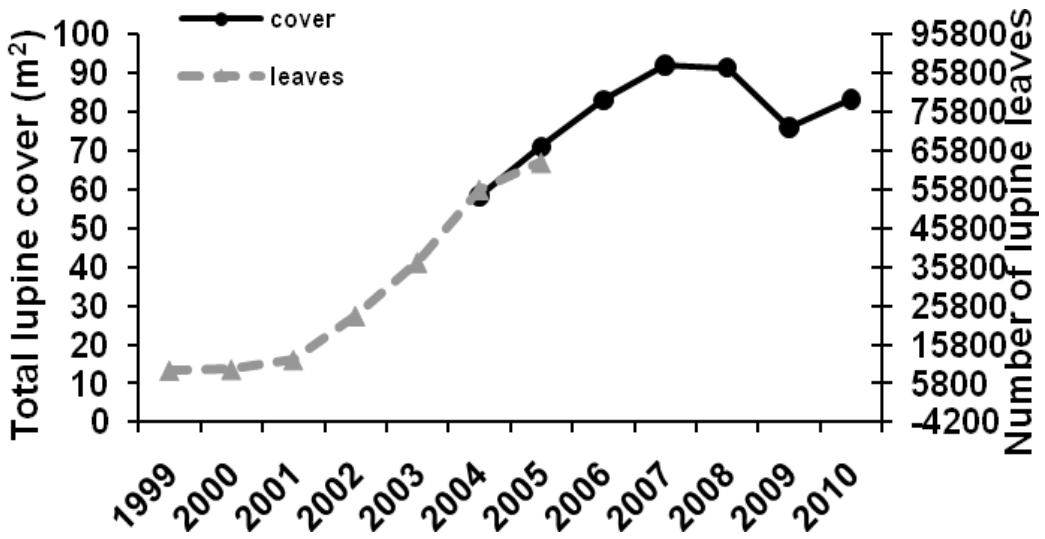


Figure 10. Total number of leaves and cover (m^2) of Kincaid's lupine at Oxbow West. Cover estimates were not made prior to 2004 and leaves were not counted after 2005. There is a strong linear relationship between cover and the number of leaves. This ratio is reflected in the scaling of the y-axes.

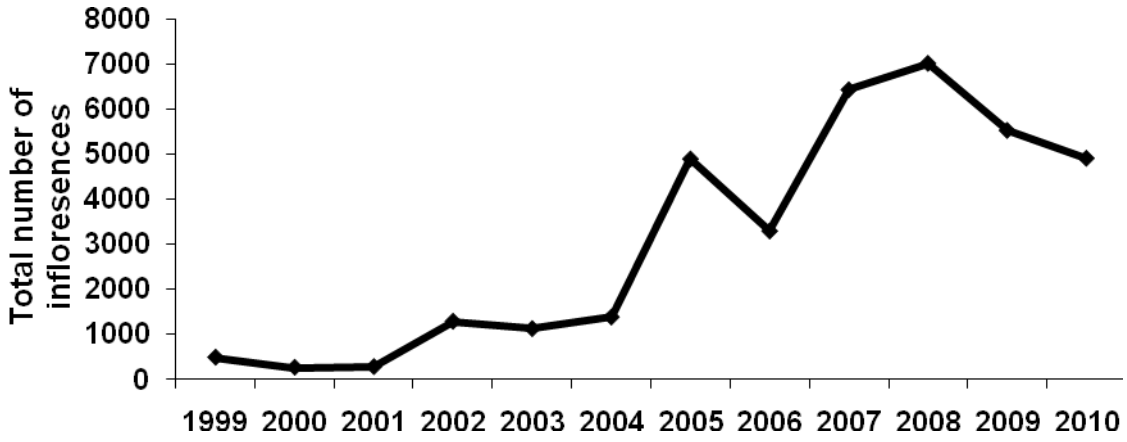


Figure 11. Total number of racemes at Oxbow West.

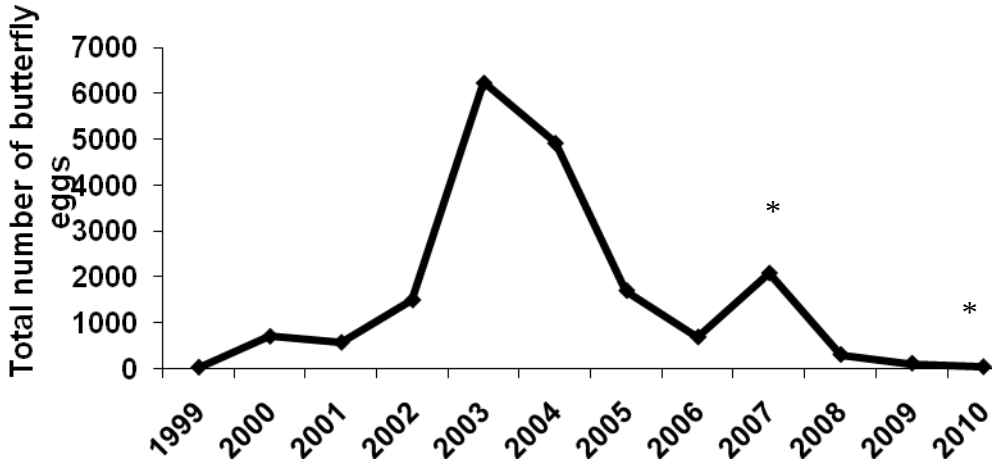


Figure 12. Total number of Fender's blue butterfly eggs at Oxbow West. *In 2007 and 2010, the number of eggs in was estimated using a subsample of the plots.

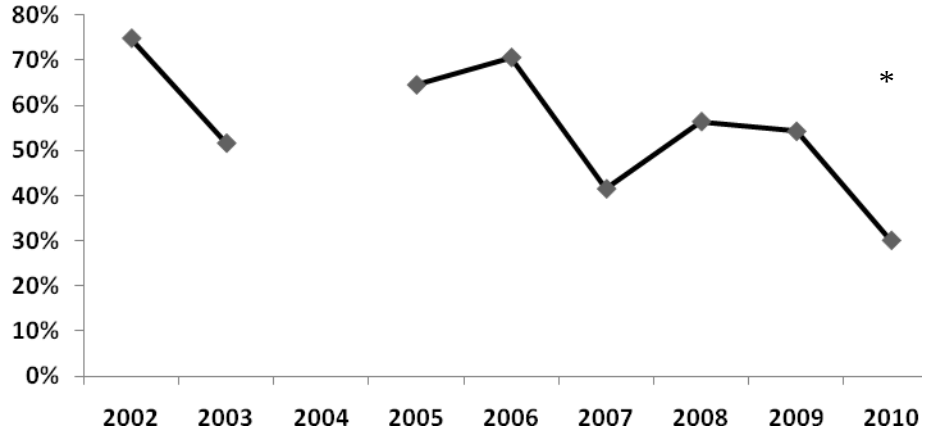


Figure 13. Percentage of 1 m^2 cells containing *R.armeniacus* at Oxbow West. *In 2010 only a subsample of the population was monitored; the cover of blackberry in the remaining cells was estimated based on this subsample.

Lupine cover and leaf counts, a meta-analysis and review

A strong correlation between Fender's blue butterfly egg number and lupine leaf density has previously been reported for Kincaid's lupine populations (Shultz 1998). At Fir Butte, Fender's blue egg numbers have been highly correlated with leaf abundance in every year from 1998 through 2004 (Gisler and Kaye 2004). However, leaf counting is the most time consuming and inefficient part of the monitoring process, so it was our goal in 2005 to assess the use of lupine cover as a substitute for leaf counts. Therefore, we evaluated the relationship between foliar cover of lupine and leaf number (leaves per square meter) using linear regression with data collected from 2004 through 2006. Because we conducted similar monitoring efforts at several other populations of Kincaid's lupine, including Eagles Rest (Kaye and Brandt 2005, Thorpe and Kaye 2006) and six sites in Douglas County (Menke and Kaye 2005, 2006), we can assess this question with data from across the range of the species in Lane and Douglas counties, Oregon, from a wide range of habitats and scale of observations (Table 3).

In Lane County, foliar cover of lupine was consistently and strongly correlated with leaf counts, explaining 87% to 97% of the variation in leaf numbers. Observations from Douglas County suggest that in that region the relationship is somewhat weaker, but still useful (62% to 92% explanation of leaf count variation).

The density of lupine leaves per m^2 differed from site to site, and this may be related to habitat type. Sites in full sun (i.e., without any forest canopy or tree shading) had a substantially higher density of leaves than sites with a mix of full sun and partial shade, or partial shade only (Figure 14). Apparently, where sunlight is plentiful, the plants are capable of producing more leaves per unit area. As sunlight is reduced, the plants respond by producing fewer leaves per area, and those leaves are more spread out. In other words, in shaded environments lupine leaves overlap less and appear to expand more widely.

Lupine foliar cover and leaf density are positively correlated at all sites examined, but the nature of this relationship differs from place to place because leaf density varies with intensity of solar radiation. Within any given site, foliar cover may be an excellent predictor of leaf density. However, due to the variation in the relationship, the most conservative approach would be to use cover as a surrogate for leaf density at a new site only if this correlation has been determined.

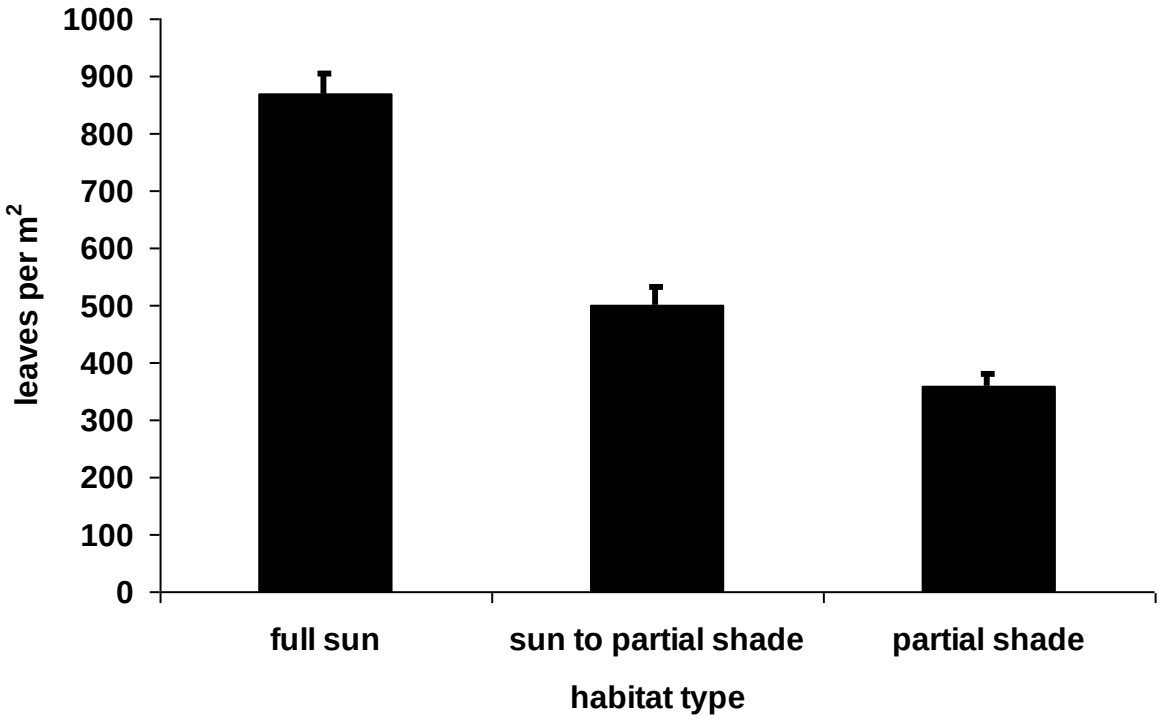


Figure 14. Mean (± 1 SE) density of lupine leaves in habitats receiving full sun (n=6), sun to partial shade (n=8), and partial shade only (n=5).

Table 3. Site, year of observation, habitat type, scale of observation, sample size, regression coefficient (proportion of variance in leaf number explained by foliar cover, R^2), and slope of the relationship between leaf number and cover at eleven sites of Kincaid's lupine from Lane and Douglas Counties.

Site	year	habitat	size of sample unit	n	R^2	slope (leaves/m^2)
Lane County						
Fir Butte	2004	full sun	200 m^2	36	0.97	986
	2005			36	0.91	767
Oxbow	2004	full sun	1 m^2	225	0.93	925
	2005			197	0.87	844
Isabelle	2005	full sun	plant patch (<= 2 m^2)	154	0.88	907
	2007		variable	12	0.87	1812
Turtle Swale	2005	full sun	1 m^2	116	0.87	790
Eagles Rest	2005	sun to partial shade	15 to 75 m^2	20	0.97	606
	2006			17	0.94	404
Oak Basin	2007	sun	variable	18	0.89	659
	2007	partial shade		27	0.64	497
Douglas County						
China Ditch	2005	sun to partial shade	10 to 45 m^2	48	0.623	569
	2006			48	0.74	606
Stout's Creek	2005	sun to partial shade	variable	68	0.623	444
	2006			82	0.81	429
Dickerson Heights	2005	sun to partial shade	10 m^2	28	0.71	424
	2006			34	0.88	521
Loose Laces	2005	partial shade	1 to 40 m^2	76	0.73	415
	2006			37	0.91	357
Letitia Creek	2005	partial shade	100 m^2	22	0.75	380
Callahan Meadows	2005	partial shade	2 m^2	24	0.75	291
	2006			42	0.92	357

LITERATURE CITED

Fagan, W.F., J.G. Bishop, and J.D. Schade. 2004. Spatially structured herbivory and primary succession at Mount St Helens: field surveys and experimental growth studies suggest a role for nutrients. Ecological Entomology 29:398-409.

Fitzpatrick, G. 2004. Status of the Fender's blue butterfly (*Icaricia icarioides fenderi*) in Lane County, Oregon: population estimates and site evaluations, and effects of mowing on the Fender's blue Butterfly (*Icaricia icarioides fenderi*): implications for conservation management. Unpublished report by The Nature Conservancy, Eugene, Oregon to Oregon Natural Heritage Program and U.S. Fish and Wildlife Service.

Gisler, S. and T.N. Kaye. 2004. Population monitoring for Kincaid's lupine at the Fir Butte and Oxbow West sites, West Eugene, 2004 Progress Report. Prepared by Institute for Applied Ecology for Eugene District BLM.

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

Kaye, T.N. and C. Benfield. 2005. Kincaid's lupine and Fender's blue butterfly studies in the West Eugene Wetlands: *Monitoring, mowing, pig effects, and evaluating foliar cover as a measure of abundance*. Prepared by Institute for Applied Ecology for Eugene District BLM.

Kaye, T.N. and A. Brandt. 2003. Monitoring of Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii*) at Fir Butte and Oxbow West, West Eugene. Prepared by Institute for Applied Ecology for Eugene District BLM.

Kaye, T.N. and A. Brandt. 2005. Seeding and transplanting rare Willamette Valley prairie plants for population restoration, Fifth Year (2004) Report. Prepared by Institute for Applied Ecology for Eugene District BLM.

Lane Council of Governments. 2004. Dragonfly bend mitigation improvement plan. Prepared for city of Eugene Parks and Open Space Division, Natural Resources Section. 45pp.

Menke, C.A. and T.N. Kaye. 2005. Population monitoring for *Lupinus sulphureus ssp. kincaidii* on the BLM Roseburg District, 2005 Progress Report. Prepared by Institute for Applied Ecology for Roseburg District BLM.

Menke, C.A. and T.N. Kaye. 2006. Population monitoring for *Lupinus sulphureus ssp. kincaidii* on the BLM Roseburg District, 2006 Progress Report. Prepared by Institute for Applied Ecology for Roseburg District BLM.

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

Schultz, C.B. and K. Dlugosch. 1999. Effects of declining food resources on populations of the Fender's blue butterfly (*Icaricia icarioides fenderi*). Oecologia 119: 231-238.

Schultz, C.B., P.C. Hammond, and M.V. Wilson. 2003. Biology of the Fender's blue butterfly (*Icaricia icarioides fenderi* Macy), and endangered species of Western Oregon Prairies. Natural Areas Journal 23:61-71.

Severns, P. 2008. Exotic grass invasion impacts fitness of an endangered prairie butterfly, *Icaricia icariodes fenderi*. Journal of Insect Conservation 12:651-661.

Thorpe, A.S., R.T. Massatti, and Kaye, T.N. 2008. *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's lupine) and *Icaricia icarioides fenderi* (Fender's blue butterfly) in the West Eugene Wetlands: Population monitoring, reintroduction success, and an evaluation of experimental treatments. 2008 Progress Report. Prepared by Institute for Applied Ecology for Eugene District BLM. 44 pp.

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

APPENDIX A. LUSUKI EUGENE GEAR LIST AND DIRECTIONS

Gear List
copy of gear list and directions
last year's report
last year's datasheets
new datasheets, some rite-in-the-rain
clipboards (4)/pencils
maps/gazetteer
5 tapes: 3-100m, 2 shorter
8 candy canes
rulers- one per person
meter poles- one per person
flagging
~20 pin flags
5 pieces rebar (for replacement)
mallet
compass

Health and Safety Kit (including Tecnu)

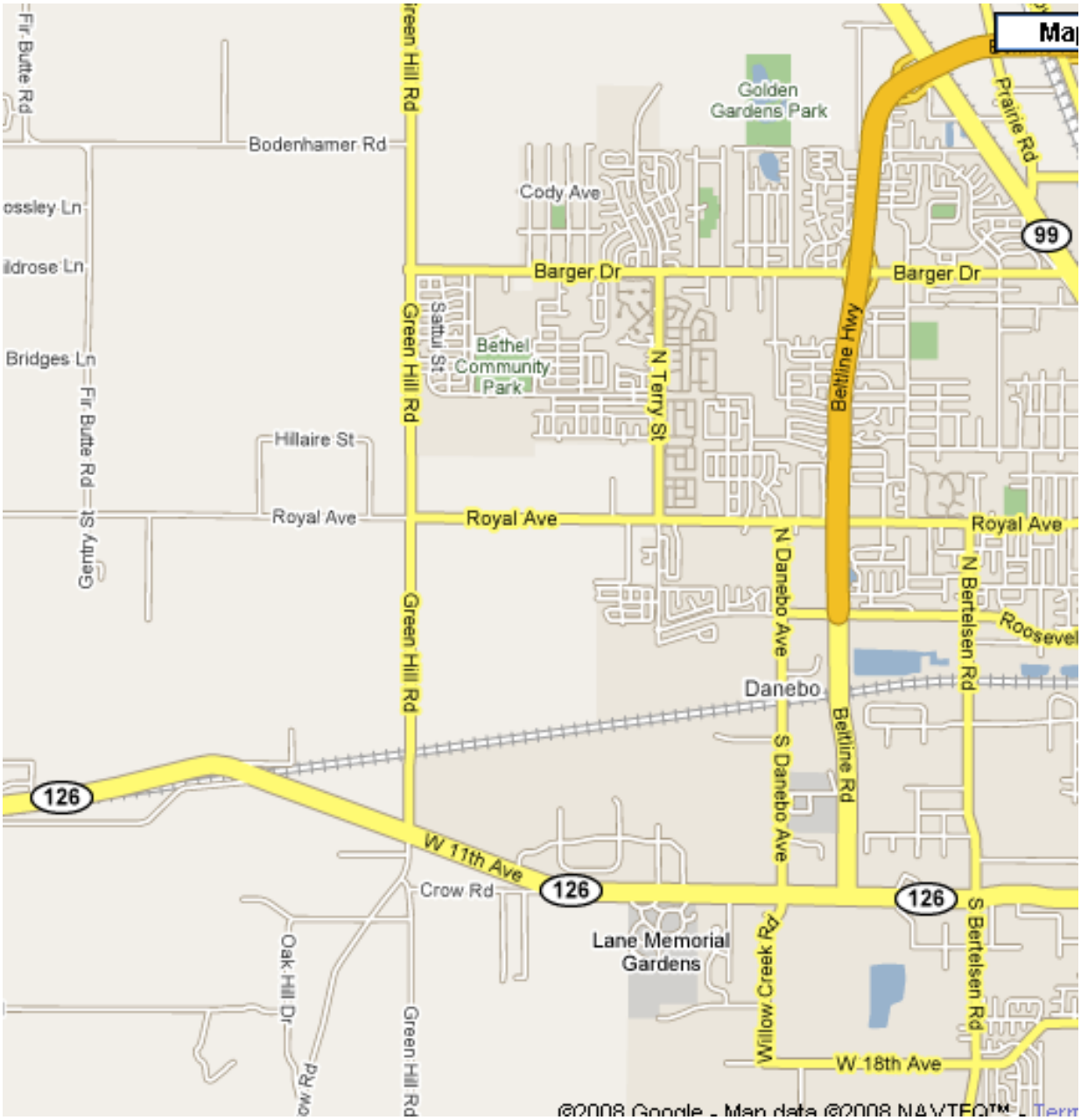
Extra water

Directions

Fir Butte: From Corvallis, drive south on HWY 99. Turn right (west) on Clear Lake Road. Turn left (south) on Green Hill Road. Turn right (west) on Bodenhamer Rd. Turn left (south) on Fir Butte Rd. Park at pullout and walk south along canal, plots will be on your left.

Oxbow West: From Corvallis, drive south on HWY 99. Go west on the Beltline Highway, until it ends at W 11'th St. Turn right on Terry St. and park where the road dead-ends. There have been car thefts here in the past, so make sure to lock the car and put all valuables out-of-site. Go east until you reach the path along the canal. Walk down the path, the plot is on your left just past a small grove of trees.

Dragonfly Bend: From Corvallis, drive south on HWY 99. Go west on the Beltline Highway. Exit at Barger Dr. and go west. Turn onto Terry St. (south), then turn right (west) onto Royal Avenue. Signs indicated site.


Fir Butte Rd
Bodenhamer Rd
ossley Ln
ildrose Ln
Bridges Ln
Fir Butte Rd
Gentry St
Hillaire St
Royal Ave
Green Hill Rd
Satsui St
Bethel Community Park
Cody Ave
Golden Gardens Park
Barger Dr
N Terry St
Beltline Hwy
Prairie Rd
99
N Danebo Ave
N Bertelsen Rd
Danebo
S Danebo Ave
Beltline Rd
126
W 11th Ave
Crow Rd
Lane Memorial Gardens
Willow Creek Rd
S Bertelsen Rd
W 18th Ave
Oak Hill Dr
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APPENDIX B. EXAMPLE DATA SHEET FOR KINCAID'S LUPINE SAMPLING AT FIR BUTTE

Kincaid's lupine population monitoring, Fir Butte site

Name:_____ Date:_____

Plot Number:_____

section		Lupine cover (%)	butterfly eggs	inflorescences (aborted)	*Rubus (%)*	Knapweed (presence)	Bracken fern (%)	notes
0-5	N							
	S							
5-10	N							
	S							
10-15	N							
	S							
15-20	N							
	S							
20-25	N							
	S							
25-30	N							
	S							
30-35	N							
	S							
35-40	N							
	S							
40-45	N							
	S							
45-50	N							
	S							
50-55	N							
	S							
55-60	N							
	S							
60-65	N							
	S							
65-70	N							
	S							
70-75	N							
	S							
75-80	N							
	S							
80-85	N							
	S							
85-90	N							
	S							
90-95	N							
	S							
95-100	N							
	S							

APPENDIX C. EXAMPLE DATA SHEET FOR KINCAID'S LUPINE SAMPLING AT OXBOW WEST

Kincaid's lupine monitoring data, Oxbow West						
Dates of sampling:						
1x1 m grid cell counts						
NE corner is considered 0,0						
x-coord	**y-coord**	**Cover**	**eggs**	**infls**	***Rubus (%)***	***Phalaris***
1	1					
1	2					
1	3					
1	4					
1	5					
1	6					
1	7					
1	8					
1	9					
1	10					
1	11					
1	12					
1	13					
1	14					
1	15					
1	16					
1	17					
2	1					
2	2					
2	3					
2	4					
2	5					
2	6					
2	7					
2	8					
2	9					
2	10					
2	11					
2	12					
2	13					
2	14					
2	15					
2	16					
2	17					
3	1					
3	2					
3	3					
3	4					
3	5					
3	6					
3	7					
3	8					
3	9					
3	10					
3	11					
3	12					
3	13					
3	14					
3	15					