Final Report
Year Two

Control of *Brachypodium sylvaticum* and Restoration of Rare Native Upland Prairie Habitat at Butterfly Meadows, Benton County ODA 1514 GR

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INTRODUCTION

Our project goal is to protect and restore rare Willamette Valley upland prairie habitat at Butterfly Meadows (Benton County) from invasion by the noxious weed *Brachypodium sylvaticum* (false brome).

Native prairies, which once dominated the landscape of the Willamette Valley, are considered among the rarest of Oregon's ecosystems and are in critical need of conservation. One of the largest remaining parcels of native upland prairie, Butterfly Meadows (Benton County), is being invaded by *Brachypodium sylvaticum.* This site is one of the three most important remaining habitats for the Fender's blue butterfly and Kincaid's lupine, listed as Endangered and Threatened respectively.

We propose to develop and implement herbicide treatments that control *Brachypodium sylvaticum* without harming native prairie vegetation. We will also develop and implement measures to reestablish native species from seed after removal of *Brachypodium sylvaticum*. Conifers and mature shrubs that have encroached on the meadow, both on the edge and in the complex, will be removed by mechanical means or girdling with herbicides.

We propose to construct a buffer zone between the boundary of Butterfly Meadows and the neighboring intact forest and recently clear-cut areas, which are continuing sources of seed of *Brachypodium sylvaticum* invading Butterfly Meadows. This buffer zone will extend into both Starker Forest owned portions and OSU owned portions.

To determine the success of control of *Brachypodium sylvaticum* and woody species and restoration of native vegetation, we will monitor changes in abundance of *Brachypodium sylvaticum*, woody species, and native vegetation. We will use monitoring results to adjust future *Brachypodium sylvaticum* control measures and native vegetation restoration measures as needed.

Our specific objectives are

- Objective 1 — Survey and map *Lupinus sulphureus ssp. kincaidii* and assess abundance of *Brachypodium sylvaticum*.
- Objective 2a — Conduct pilot studies on herbicide control of *Brachypodium sylvaticum* and on potential adverse effects on native vegetation.
- 2b — Conduct trial studies on herbicide treatment effects on *Brachypodium sylvaticum* and native vegetation.
- 2c — Implement control measures based on results from herbicide experiments.
- Objective 3a — Conduct experimental studies on reestablishment of native species after removal of *Brachypodium sylvaticum*.
- 3b — Implement measures to restore native vegetation after removal of *Brachypodium sylvaticum.*
- Objective 4 — Remove encroaching woody species.
- Objective 5a — Construct a buffer between Butterfly Meadows and source of *Brachypodium sylvaticum* propagules.
- 5b — Plant native species to replace *Brachypodium sylvaticum* in the buffer.
- Objective 6a — Monitor success of *Brachypodium sylvaticum* control in the buffer zone and adapt herbicide applications based on monitoring results.

6b Monitor success of native species regeneration and adapt restoration strategies based on monitoring results.

6c Monitor success of *Brachypodium sylvaticum* control in the buffer zone and the establishment of native species and adapt management strategies based on monitoring results.

6d Monitor success of removal of woody species and adapt management strategies based on monitoring results.

6e Monitor success of increasing abundance of Fender's blue butterfly adults

OBJECTIVE 1 *Survey and map lupine and assess abundance of Brachypodium sylvaticum*

In summer 2002, a survey of the site was completed, in which we located and mapped the location of all lupines, using a GPS unit. The relative proportion of weeds, particularly *Brachypodium sylvaticum*, was also estimated within each lupine location and the results mapped.

OBJECTIVE 2a *Conduct pilot studies of herbicide control of Brachypodium sylvaticum and the potential adverse effects on native vegetation.*

At the time that we received funding from ODA (fall 2002) we had not yet received the research permit from the USFW allowing us to spray within the boundaries of Butterfly Meadows. We conducted a pilot study outside the meadow boundaries, which is described in *Study A* of this report. As soon as we received the USFW permit, we conducted an additional study within the meadow boundaries, which is described in *Study B.* The results of these pilot studies will be used to design full experimental studies planned for the second phase of this project.

Pilot Study A

Methods

Study area Pilot study A was conducted on October 22, 2002 at nearby meadow dominated by *Brachypodium sylvaticum* just outside the boundaries of Butterfly Meadows (Lat. 44° 36' 55.17″. Long: 123° 21' 7.33″). Although it was late in the fall season when we received funding from ODA, *Brachypodium sylvaticum* still had some green leaves at the base of the clumps, and the decision was made to go ahead with this initial study.

Experimental design

We used a randomized block design with three blocks containing each of the 8 treatments for a total of 24 treatments plots, which were about 3 m × 6 m with 1.5 m buffers between treatments (Figure 1). Wooden posts were placed in the center of the short sides of each plots and labeled with plot numbers. The long axis of the plots was oriented east and west (perpendicular to the slope) so that the herbicide operator could more easily maintain a steady walking speed necessary for proper application rates of the herbicide.

Within each treatment plots, two vegetation measurements plots (1m × 1m) were randomly placed. A meter tape was stretched between the two wooden posts marking the center line of the treatment plots. When one faced uphill, the end-post to the right was designated 0 m, the one to the left was approximately 7 m. A meter buffer was established at each end of the treatment area. The remaining area was divided into ten 1 m quadrats. Quadrats 1-5 are read uphill of the tape, while quadrats 6-10 are downhill of the tape. Two of these 10 quadrats were randomly selected for vegetation measurement.

The herbicide treatments are described in Table 1. As part of the study design, a second Fusilade treatment at a reduced rate (0.05 lb a.i./acre) was applied to the Fusilade only plots on April 9, 2003. All of the treatments were sprayed with a gas operated backpack sprayer and six nozzle spray boom at a rate of ten gallons of total spray mix per acre. Water was used as the carrier in all treatments. The field crew consisted of Matt Blakeley-Smith, Deborah Clark, Bruce Kelpsas, Fred Pfund, and Marc Vomocil.

Data collection
Before herbicide treatments were applied, abundance of *Brachypodium sylvaticum* was measured as percent cover in each measurement plot, along with any visually dominant species. Post-treatment measurements, which included abundance of *Brachypodium sylvaticum* mature plants and seedlings, were conducted on May 2003.

Data analysis
The responses of *Brachypodium sylvaticum* and native species as a group to treatments were examined with analysis of variance for replicated measurements. Rank transformations were applied to conform to statistical assumptions. Where the treatment effect was significant, individual treatments were compared using Tukey's HSD (α = 0.05). Interaction of block and treatment were tested before examining treatment main effects.

Results and Discussion
Brachypodium sylvaticum was the most abundant plant species within plots. At 26% cover, it accounted for over half of the community cover in the post-treatment control plots (Table 2, Table 3). *Brachypodium sylvaticum* cover was also high in some of the post-treatment plots, indicating that some of the herbicide treatments were better at reducing *Brachypodium sylvaticum* cover than others.

The effects of herbicide treatment is seen more directly by looking at the proportional change in *Brachypodium sylvaticum* cover from October 2002, just before herbicide application, to May of 2003. The statistical effect of herbicide treatment was strong (Table 4). *Brachypodium sylvaticum* cover in control plots was essentially unchanged, but *Brachypodium sylvaticum* was reduced >90% in the treatments that contained the foliar herbicide glyphosate found in Accord: Accord, Accord + Plateau, Accord + Pendulum, and Oust + Accord (Table 3). Treatments that were primarily soil active like Plateau (1) and Pendulum (3), although causing reduction in *Brachypodium* cover, were statistically indistinguishable from the control (8).

Other species were too infrequent to test for their individual responses to herbicide application. To examine possible non-target herbicide effects, we grouped native prairie herb species for analysis. Native prairie herbs together averaged 7% cover in control plots (Table 3), and varied strongly across herbicide treatments. Although significant block and block×treatment effects make interpretation difficult (Table 5) the Accord + Plateau and Oust + Accord herbicide treatments seem to significantly reduce native plant herb cover (Table 3), even though the herbicide was applied when most of these plants were dormant. Perhaps the best combination of effective reduction of *Brachypodium sylvaticum* with no significant harm to native prairie herbs was the Fusilade herbicide treatment, which is a grass specific herbicide.

The rates used for these initial pilot studies were very conservative and were on the low end of the allowed label rates. The next steps should focus on investigating the effectiveness of higher rates in controlling mature *Brachypodium sylvaticum* clumps as well as the effective control of all non-native

germinants. The goal is to find the ideal rate that maximizes control of *Brachypodium sylvaticum* while minimizing damage to native plants.

TP24	HT1	TP23	HT7	TP22	HT5				
TP21	HT3	TP20	HT8	TP19	HT2				
		TP18	HT4	TP17	HT6	TP16	HT2	TP15	HT5
				TP14	HT7	TP13	HT4	TP12	HT6
				TP11	HT1	TP10	HT3		
				TP9	HT8	TP8	HT2		
				TP7	HT6	TP6	HT7		
				TP5	HT3				
				TP3	HT4	TP4	HT1		
				TP2	HT5				
				TP1	HT 8				

Figure 1 Plot layout for pilot study A, which includes three replications for each of the eight herbicide treatments. TP = treatment plot number; HT = herbicide treatment number. Herbicide treatments are described in Table 1.

Table 1. Herbicide treatments and rates of applications applied fall 2002 for control of *Brachypodium sylvaticum* at Butterfly Meadows for pilot study A.

Herbicide treatment number	Herbicide treatment	Rate of herbicide application
1	Plateau and surfactant	0.188 lb a.e./acre and Activator 90 (0.5% v/v)
2	Fusilade and surfactant (repeated spring 2003)	fall:0.188lb a.i./acre and MSO (1% v/v) spring: 0.05 lb a.i./acre and MSO (1% v/v)
3	Pendulum	2 lb a.i./acre
4	Accord and surfactant	2 lb a.i./acre and Activator 90 (0.5% v/v)
5	Accord and Plateau and surfactant	2 lb a.i./acre of Accord and 0.188 lb a.e./acre of Plateau and Activator 90 (0.5% v/v)
6	Accord and Pendulum and surfactant	2 lbs a.i./acre of Accord and 2 lb a.i./acre of Pendulum and Activator 90 (0.5% v/v)
7	Oust and Accord and surfactant	2.25 oz a.i./acre of Oust and 2 lbs a.i./acre of Accord and Activator 90 (0.5% v/v)
8	Control (no herbicide application)	

Table 2. Average cover (%) of measured taxa, other than *Brachypodium sylvaticum*, on May 1, 2003, after herbicide treatments applied October 22, 2002. P=native prairie herb; SE = standard error; n = 3 complete blocks.

		Treatments							
		Plateau	**Fusilade**	**Pendulum**	**Accord**	**Accord + Plateau**	**Accord + Pendulum**	**Oust + Accord**	**Control**
Achillea millefolium (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Brodiaea sp.(P)	◎	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0
	SE	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Bromus carinatus (P)	◎	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cardamine sp. (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carex sp. (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cerastium arvense (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chrysanthemum leucanthemum	◎	0.0	0.5	0.9	0.4	0.0	0.6	0.0	0.5
	SE	0.0	0.3	0.6	0.4	0.0	0.5	0.0	0.5
Cirsium arvense	◎	3.8	0.3	1.3	2.5	0.0	3.0	0.0	0.0
	SE	2.4	0.3	0.7	2.3	0.0	3.0	0.0	0.0
Cirsium callilepis (P)	◎	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5
	SE	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5
Corylus cornuta	◎	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Crepis sp.	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cynosurus echinatus	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dactylis glomerata	◎	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8

	SE	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Daucus carota	◎	0.0	0.4	0.4	0.0	0.0	0.2	0.0	0.0
	SE	0.0	0.3	0.3	0.0	0.0	0.2	0.0	0.0
Epilobium paniculatum (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Eriophyllum lanatum (P)	◎	0.2	1.0	1.8	0.2	0.0	0.2	0.0	2.4
	SE	0.2	0.5	1.4	0.2	0.0	0.2	0.0	2.3
Festuca arundinacea	◎	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.8
	SE	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.8
Fragaria virginiana (P)	◎	0.4	1.8	0.8	0.8	0.0	0.7	0.2	1.2
	SE	0.4	0.9	0.4	0.4	0.0	0.3	0.2	1.2
Galium aparine (P)	◎	0.3	0.0	0.2	0.5	0.5	0.9	0.0	0.0
	SE	0.3	0.0	0.2	0.3	0.5	0.8	0.0	0.0
Geranium dissectum	◎	0.0	4.0	0.2	0.0	0.0	0.0	0.0	0.7
	SE	0.0	2.8	0.2	0.0	0.0	0.0	0.0	0.4
Hypericum perforatum	◎	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Juncus sp. (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lathyrus polyphyllus (P)	◎	0.0	0.0	0.0	0.7	0.3	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.7	0.3	0.0	0.0	0.0
Lotus purshiana (P)	◎	0.8	0.0	0.0	0.0	0.0	1.0	0.4	0.2
	SE	0.8	0.0	0.0	0.0	0.0	0.6	0.3	0.2
Madia sp. (P)	◎	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Myosotis discolor	◎	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nemophila parviflora (P)	◎	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0

Plantago major	◎	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.5
	SE	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.5
Potentilla gracillis (P)	◎	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
	SE	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
Prunella vulgaris (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Pseudotsuga menziesii	◎	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0
Pteridium aquilinum	◎	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.2
	SE	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.2
Ranunculus occidentalis (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhamnus purshiana	◎	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
	SE	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Rhus diversiloba	◎	0.0	0.2	0.0	0.0	0.0	0.8	0.0	0.0
	SE	0.0	0.2	0.0	0.0	0.0	0.8	0.0	0.0
Rosa eglanteria	◎	0.0	0.0	0.0	0.0	0.5	1.5	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.5	1.5	0.0	0.0
Rubus ursinus	◎	0.3	0.0	0.3	0.0	1.7	0.0	0.2	0.0
	SE	0.3	0.0	0.3	0.0	1.2	0.0	0.2	0.0
Sanguisorba sp. (P)	◎	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
	SE	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Sanicula crassicaulis (P)	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Sherardia arvensis	◎	0.0	0.0	0.0	0.4	0.0	0.0	0.2	0.4
	SE	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.3
Sidalcea virgata (P)	◎	0.0	0.8	0.7	0.0	0.0	0.0	0.0	0.5
	SE	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.5
Torilis arvensis	◎	0.0	2.3	0.9	0.9	0.7	0.5	0.7	0.2

	SE	0.0	1.3	0.8	0.5	0.7	0.3	0.7	0.2
unknown 1	◎	0.0	0.0	2.5	0.0	0.0	0.0	0.2	2.8
	SE	0.0	0.0	2.5	0.0	0.0	0.0	0.2	2.8
unknown 2	◎	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Veronica sp.	◎	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
	SE	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3
Vicia americana (P)	◎	0.5	0.8	0.2	0.4	0.2	0.3	0.2	0.7
	SE	0.5	0.2	0.2	0.3	0.2	0.2	0.2	0.4
Vulpia bromoides	◎	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SE	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3. Average cover (%) of mature *Brachypodium sylvaticum* plants before herbicide treatments (October 2002), average cover of *Brachypodium sylvaticum* mature plants and seedlings, relative cover, and proportional change after herbicide treatments (May 2003) and change of combined cover of native prairie herbs after herbicide treatments. Treatments sharing a letter are statistically indistinguishable. All data were ranked transformed for statistical analysis. n = 3 complete blocks. SE = standard error

Treatments	*Brachypodium sylvaticum*									Native prairie herbs (combined)	
	October 2002 Cover (%)		May 2003								
			Cover (%)		Relative cover	Proportional change (0-1)		Seedling cover (%)			
	◎	SE	◎	SE		◎	SE	◎	SE	◎	SE
Plateau	82.0	16.0	34.2d	5.8	0.73	-0.50cd	0.20	13.2	5.0	2.6abc	1.0
Fusilade	73.0	11.5	7.8bc	1.2	0.37	-0.88bc	0.04	14.5	3.5	5.1d	0.7
Pendulum	76.3	18.2	30.8d	5.8	0.70	-0.48cd	0.24	16.7	0.8	3.8bcd	1.6
Accord	85.0	8.8	2.7a	0.6	0.25	-0.97a	0.01	39.2	7.3	3.6bcd	1.1
Accord and Plateau	94.2	0.8	3.7ab	0.7	0.47	-0.96ab	0.01	37.2	12.4	1.3ab	0.4
Accord and Pendulum	73.3	10.9	3.2ab	1.2	0.23	-0.96ab	0.01	30.7	7.8	3.3cd	0.5
Oust and Accord	76.7	10.9	2.5a	0.9	0.53	-0.96ab	0.02	16.2	3.9	0.8a	0.3
Control (no herbicide)	50.5	25.5	25.8cd	4.6	0.62	-0.12d	0.46	13.5	3.3	7.1cd	2.9

Table 4. Analysis of variance of the proportional change in *Brachypodium sylvaticum* cover from October, 2002 (before herbicide treatment) to May, 2003. The response variable was rank-transformed before analysis. P is the probability of differences occurring between treatments just by chance.

	df	SS	MS	F	P
Block	2	240.8	120.4	2.38	0.11
Treatment	7	6875.5	982.2	19.38	0.00
Interaction	14	869.7	62.1	1.22	0.32
Residuals	24	1216.5	50.7		

Table 5. Analysis of variance of the combined cover of native prairie herbs. The response variable was rank-transformed before analysis. P is the probability of differences occurring between treatments just by chance.

	df	SS	MS	F	P
Block	2	125.1	62.5	1.11	0.35
Treatment	7	2948.7	421.2	7.44	<0.001
Interaction	14	4751.0	339.4	5.99	<0.001
Residuals	24	1359.3	56.5		

Pilot Study B

Methods

Study area Pilot study B was conducted on November 11, 2002 at the "lower" site of lupine concentration within the boundaries of Butterfly Meadows (Lat. 44° 36' 56.6″. Long: 123° 20' 53.76″).

Experimental design and data collection

Last summer lupine patches on Butterfly Meadows were located, marked, and mapped. Thirty-five of these plots (approximately $1m^2$) were randomly assigned one of 7 herbicide treatments (5 replications/treatment) (Table 6). The plots were marked with color-coded flagging, surveyor flags labeled with plot number, and metal stakes with labeled tags with plot number (Table 6). Applications of herbicides were made using a single flat fan spray tip at a concentration of ten gallons of spray mix per acre. Post-treatment data measuring presence of *Lupinus sulphureus* var. *kincaidii*, cover of *Brachypodium sylvaticum* mature plants and seedlings and Fender's blue butterfly larvae were conducted May, 2003.

Data analysis

The responses of Kincaid's lupine, Fender's blue butterfly larvae, and *Brachypodium sylvaticum* to herbicide treatments were examined with one-way analysis for variance. Transformations were applied to conform to statistical assumptions. Where the treatment effect was significant, individual treatments were compared using Tukey's HSD ($\alpha = 0.05$).

Results and Discussion

Treatments that had a significant effect on *Brachypodium* sylvaticum cover were those that relied primarily on foliar uptake of the herbicide like Accord and Fusilade. Herbicide treatments had a significant effect on *Brachypodium sylvaticum* cover. Accord + Pendulum and Accord + Plateau were most effective, reducing *Brachypodium sylvaticum* to less than one-tenth its cover in control plots (Table 7). Pendulum and Plateau alone were indistinguishable from controls indicating that the Accord tank-mix partner provided most of the control despite the late-season application. The cover of *Brachypodium* seedlings was not significantly affected by the herbicide treatments including Pendulum and Plateau, which should have provided some soil residual effect. Concentrations of these materials may not have been adequate to provide any long lasting control.

Despite the strong mortality of *Brachypodium sylvaticum* in several herbicide treatments, no treatment caused a significant decline in the number of Kincaid's lupine leaves or the number of Fender's blue butterfly larvae (Table 7). In fact, there is some evidence that *Brachypodium sylvaticum* control can stimulate the production of Kincaid's lupine leaves. Perhaps the best balance of *Brachypodium sylvaticum* reduction and favoring lupine leaves and butterfly larvae was the Fusilade treatment. Fusilade reduced *Brachypodium sylvaticum* to 9% cover, in contrast to 31% cover in control plots. There were 70% more lupine leaves compared with the control plots and larva numbers were highest in Fusilade plots.

Table 6. Herbicide treatments and rates of applications applied in fall 2002 for control of *Brachypodium sylvaticum* at Butterfly Meadows (pilot study B).

Treatment	Rate of herbicide application	Flagging	Plot numbers
1. Accord and surfactant	2 lb a.i./acre + Activator 90 (0.5% v/v)	blue/white stripe	7, 26, 33, 22, 18
2. Fusilade and surfactant	0.188 lb a.i./acre and MSO (1% v/v)	red/black stripe	5, 9, 6, 20, 29
3. Pendulum	2 lb a.i./acre	hot pink	34, 21, 30, 14, 24
4. Plateau and surfactant	0.188 lb a.e./acre +Activator 90 (0.5% v/v)	blue	12, 25, 4, 15, 28
5. Accord and Plateau and surfactant	2 lb a.i./acre of Accord and 0.188 lb a.e./acre of Plateau and Activator 90 (0.5% v/v)	yellow stripe	16, 3, 13, 31, 27
6. Accord and Pendulum and surfactant	2 lbs a.i./acre of Accord and 2 lb a.i./acre of Pendulum and Activator 90 (0.5% v/v)	red	1, 2, 11, 35, 23
7. Control (no herbicide)		yellow	8, 19, 32, 10, 17

Table 7. Average responses of Kincaid's lupine, Fender's blue butterfly larvae, and *Brachypodium sylvaticum* to herbicide treatments. n = 5. SE = standard error. P is the probably that differences between treatments occurred just by chance.

Treatment	Lupine leaf number		Larvae		*Brachypodium sylvaticum* adult cover		*Brachypodium sylvaticum* seedling cover	
	◎	SE	◎	SE	◎	SE	◎	SE
Accord + Pendulum	39.4	7.0	1.0	0.3	1.8a	0.9	1.2	1.0
Accord + Plateau	72.8	12.6	1.6	0.2	2.5a	1.0	3.0	1.8
Accord	63.4	19.3	1.8	0.6	7.2ab	3.2	6.8	2.5
Fusilade	80.6	26.9	2.2	0.6	9.0ab	4.6	5.0	2.1
Pendulum	57.4	16.1	1.6	0.6	28.0b	6.6	4.6	1.6
Plateau	54.2	28.9	1.4	0.7	31.6b	9.3	1.4	0.5
control	47.6	9.6	1.6	0.5	31.0b	9.9	1.5	0.3
F	0.82^{r}		0.49		5.99^{s}		1.90^{r}	
P	0.56		0.81		<0.01		0.12	

r: analyzed after rank transformation; s: analyzed after arcsine square-root transformation

OBJECTIVE 2b *Conduct trial studies on herbicide treatment effects on Brachypodium sylvaticum and native vegetation.*

Experimental Study A
Trial studies on herbicide treatment effects on *Lupinus sulphureus* ssp. *kincaidii*

During the spring of 2003, we established 36 $1m^2$ treatment plots which all contained Kincaid's lupine plants (*Lupinus sulphureus* ssp. *kincaidii*). There were eight herbicide treatments and one control, each replicated four times (Table 1). The treatments were conducted in August or October while the lupines were dormant. In May, 2004 we revisited the plots and counted the number of lupine leaves and inflorescences in each plot. There was no significant effect of the herbicide treatments on lupine leaf number ($p = 0.93$) or inflorescence production ($p = 0.24$) in 2004. None of the herbicide treatments differed from each other or the control in terms of leaf number or flowering (Figure 1).

Experimental Study B
Trial studies on herbicide treatment effects on *Brachypodium sylvaticum* and native vegetation.

Experimental plots were established in August 2003 to test the effectiveness of selected herbicides and the timing of application of these herbicides to control *Brachypodium sylvaticum*. We selected the herbicides based on our findings from pilot study A that was conducted in 2002. The criteria that we used to select herbicides for this study were 1) effectiveness in significantly reducing false-brome cover and, 2) retention of native species richness. The treatments are outlined in table 2.

In August and October of 2003 we established 84 plots which contained at least 10% *Brachypodium sylvaticum*. Fourteen treatments, including thirteen herbicide applications and control were replicated six times each and randomly assigned to each plot. Each treatment plot measured 2m x 1.5m, within which was nested a 1m x 0.5m sample plot. We recorded the percentage cover of each individual species in the plots in August or October of 2003 and again, following the treatments, during the week of May 3rd, 2004.

For analytical purposes we examined the proportional change in *Brachypodium* cover as well as the difference in native species richness before and after treatment. We used one-way analysis of variance to test for treatment effects.

The treatment that resulted in the greatest control of *Brachypodium* was a mixture of glyphosate and surflan applied in October, which resulted in a 95.2% reduction in false-brome percent cover (95% C.I. = 80 to 100%). Other treatments which resulted in statistically equivalent control of *Brachypodium* were glyphosate applied in August (95% C.I. = 75 to 100%), mowing in August and glyphosate applied in October (95% C.I. = 71 to 100%), and glyphosate applied alone in October (95% C.I. = 66 to 100%). During this same time period, *Brachypodium* in control plots declined by 2.3 % (95% C.I. = 0 to 39%).

Besides overall reduction in false-brome cover, it is important to consider the effects of these treatments on additional components of the plant community. We calculated the difference in native species richness following the herbicide treatments and found suggestive evidence ($p = 0.063$) that the treatments resulted in differences in native species richness. The treatments with the largest retention in native species richness include mowing in August followed by a glyphosate treatment in October, glyphosate applied in August, fusilade applied in August, and fusilade applied in October. In general, the treatments which included the pre-emergent herbicides pendulum and surflan had lower native species richness. This is most likely attributed to a decline in winter germinating annuals.

Recommendations for controlling *Brachypodium sylvaticum* in upland prairie habitat

In areas where native plant cover is high, we recommend the use of fusilade coupled with a pre-emergent herbicide such as surflan or pendulum, applied in October. In areas where native species retention is of lower importance (such as areas where few natives occur) we recommend using glyphosate with a pre-emergent herbicide. The use of a pre-emergent herbicide is important since in some years high seedling recruitment of *Brachypodium* is possible and we found seedling inhibition is best achieved by using a soil-active herbicide. Although we recommend herbicide treatments be conducted in October, good control of *Brachypodium* can be attained any time between August and October. The results from these herbicide experiments suggest that there are no harmful effects on native forbs, Kincaid's lupine or Fender's blue butterfly when treatments occur while the plants are dormant.

Table 1. Herbicide treatments and date of application for plots ($1m^2$) containing Kincaid's lupine and false brome at Butterfly Meadows. Each treatment was replicated 4 times.

	Treatment	Rate of Application	Date of treatments	
			08/01/03	10/31/03
1	Fusilade DX and surfactant	0.375 lb a.i./acre and MSO (1% v/v)	X	
2	Fusilade DX and surfactant	0.375 lb a.i./acre and MSO (1% v/v)		X
3	Fusilade DX and Pendulum 3.3 EC and surfactant	0.375 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)	X	
4	Fusilade DX (high) and Pendulum 3.3 EC and surfactant	0.375 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)		X
5	Fusilade DX (high) and Surflan AS and surfactant	0.375 lb a.i./acre and 6 lb a.i./acre and MSO (1% v/v)		X
6	Fusilade DX (medium) and Pendulum 3.3 EC and surfactant	0.188 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)	X	
7	Fusilade DX (medium)and Pendulum 3.3 EC and surfactant	0.188 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)		X
8	Accord Concentrate (glyphosate) and surfactant	2 lb a.i./acre + Activator 90 (0.5% v/v		X
9	Control (no herbicide application)			

Table 2. Herbicide treatments and date of application for plots (2m × 1.5 m) containing false brome at Butterfly Meadows. Each treatment was replicated 6 times.

	Treatments	Rate of Application	Date of treatments	
			08/01/03	10/31/03
1	Fusilade DX (high) and surfactant	0.375 lb a.i./acre and MSO (1% v/v)	X	
2	Fusilade DX (high) and surfactant	0.375 lb a.i./acre and MSO (1% v/v)		X
3	Mow (Aug), Accord Concentrate (glyphosate) and surfactant (Sept)	2 lb a.i./acre + Activator 90 (0.5% v/v)	X	X
4	Fusilade DX and Pendulum 3.3 and surfactant	0.094 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)		X
5	Fusilade DX and Pendulum 3.3 EC and surfactant	0.188 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)	X	
6	Fusilade DX and Pendulum 3.3 EC and surfactant	0.188 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)		X
7	Fusilade DX and Pendulum 3.3 EC and surfactant	0.375 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)	X	
8	Fusilade DX and Pendulum 3.3 EC and surfactant	0.375 lb a.i./acre and 3.96 lb a.i./acre and MSO (1% v/v)		X
9	Fusilade DX and Surflan AS and surfactant	0.188 lb a.i./acre and 6 lb a.i./acre and MSO (1% v/v)		X
10	Accord Concentrate (glyphosate) and Pendulum 3.3 and surfactant	2 lb a.i./acre and 3.96 lb a.i./acre and Activator 90 (0.5% v/v)		X
11	Accord Concentrate (glyphosate) and Surflan AS and surfactant	2 lb a.i./acre and 6 lb a.i./acre and Activator 90 (0.5% v/v)		X
12	Accord Concentrate (glyphosate) and surfactant	2 lb a.i./acre and Activator 90 (0.5% v/v)	X	
13	Accord Concentrate (glyphosate) and surfactant	2 lb a.i./acre and Activator 90 (0.5% v/v)		X
14	Control (no herbicide application)			

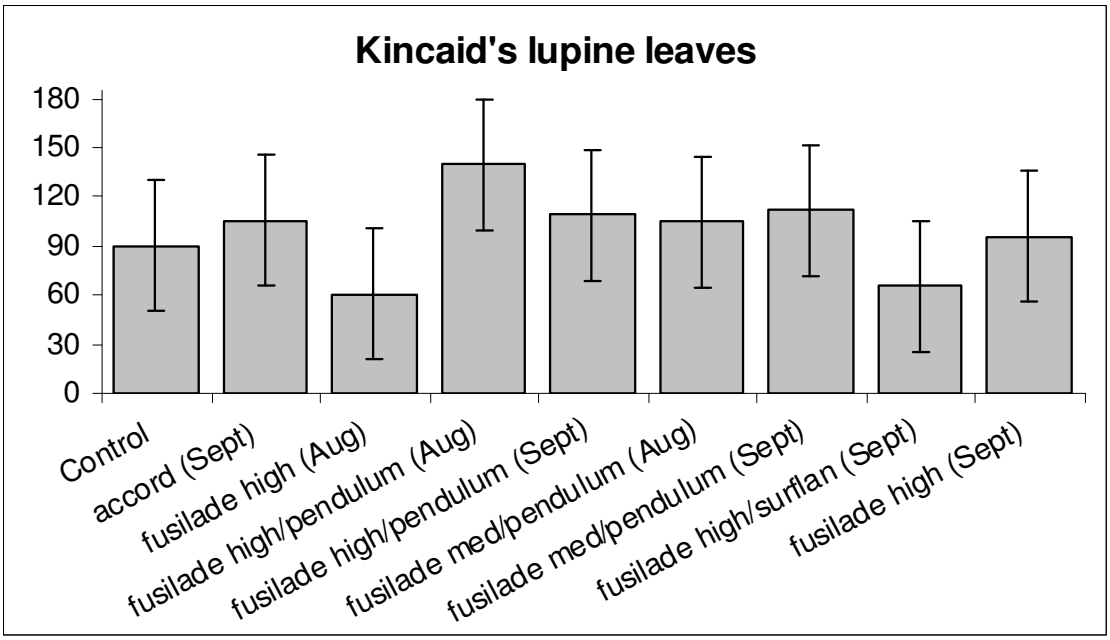

Figure 1. Average number of Kincaid's lupine leaves following herbicide treatments. Error bars correspond to one standard error.

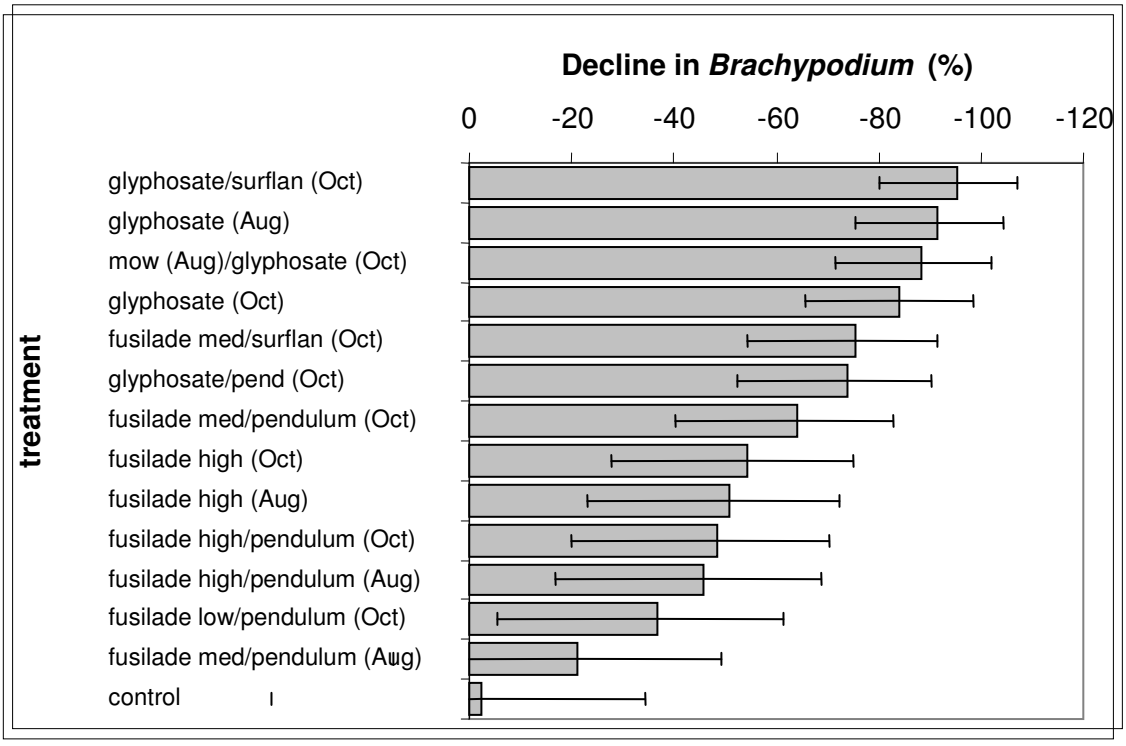

Figure 2. Percent decline in *Brachypodium sylvaticum* nearly one year after 13 combinations of herbicide treatments were applied.

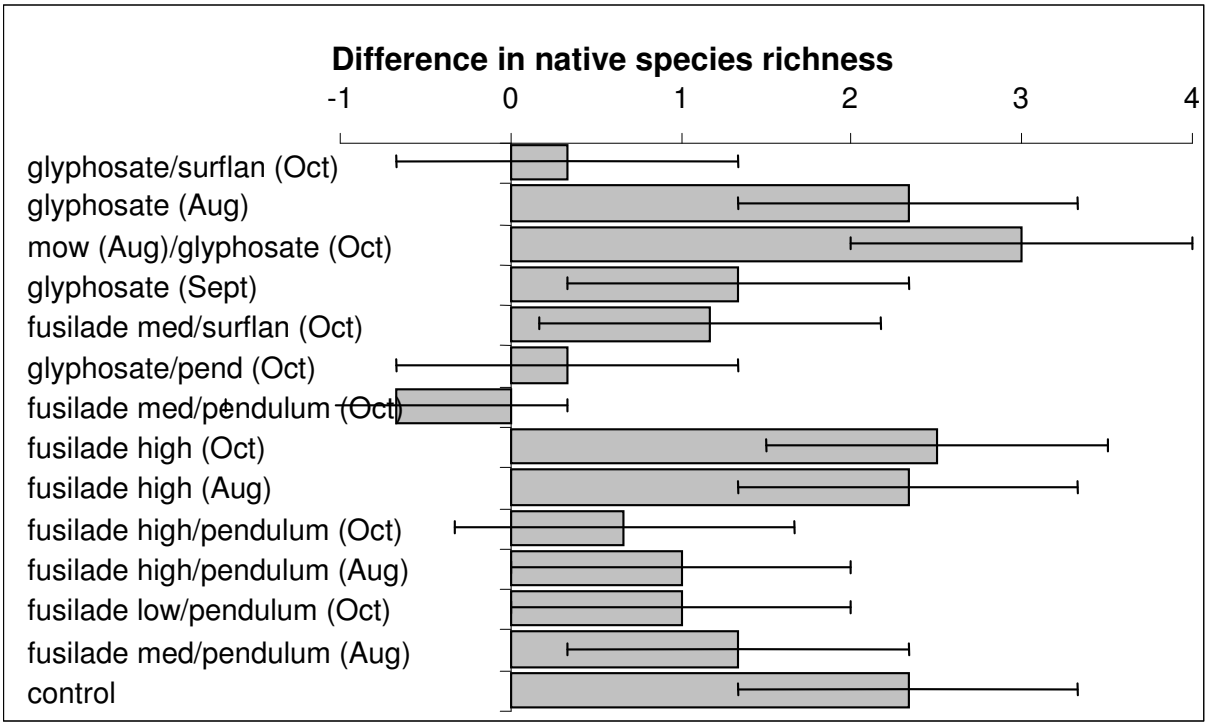

Figure 3. Change in native species richness, nearly one year after 13 combinations of herbicide treatments were applied.

OBJECTIVE 2c *Implement control measures based on results from herbicide experiments.*

Based on the results of the pilot studies and herbicide trials, the next step is to implement different herbicide applications on larger areas to control *Brachypodium sylvaticum*, depending on the density of native plants and Fender's blue butterfly.
a) *Areas with higher native plant cover* (NW sections 1and 2: ¼ acre; SE 1: ½ acre) Spot spray with medium concentrations of fusilade (0.188 lb a.i./acre) coupled with a pre-emergent herbicide such as surflan (3.96 lb a.i./acre and MSO (1% v/v)) or pendulum (3.96 lb a.i./acre and MSO (1% v/v)), applying September 2004.
b) *Areas where few natives occur* (SW section 2: ½ acre) Spray with Accord and surflan (2 lb a.i./acre and 6 lb a.i./acre and Activator 90 (0.5% v/v)), applying in September 2004.

OBJECTIVE 3a *Conduct experimental studies of reestablishment of native species after removal of Brachypodium sylvaticum.*

Study A Seed Sowing

Objectives

- Determine the differential establishment rates of sowed seeds of target native prairie species after removal of *Brachypodium sylvaticum* at Butterfly Meadows.
- Determine the effectiveness of manipulated field conditions in promoting the seedling establishment of target native herbaceous species sowed at Butterfly Meadows after removal of *Brachypodium sylvaticum* at Butterfly Meadows.

Methods

Experimental design

Experimental plots (randomized block design, n = 3) had been previously established at Butterfly Meadows to determine the effectiveness of different herbicide treatments on controlling *Brachypodium sylvaticum* at Butterfly Meadows (see Objective 2a, Study A). The herbicide treatment Fusilade showed the best control of *Brachypodium sylvaticum* without harm to native plant species or to the endangered Fender's blue butterfly and was used for this study. Within each of these three experimental blocks (7m ×3m), four treatments areas (1m × 3m) were randomly placed.

1) unmanipulated
2) litter removed
3) litter removed with sowed seeds treated with fungicide
4) litter removed and slug bait

Litter was removed by gently raking the coarse litter lying loosely on the ground using a hand garden fork. We did not attempt to remove the very fine litter. Seeds were treated with metalaxyl and fludioxonil, following manufacturer's recommendations. Slug bait, pellets containing the active ingredient iron phosphate, was applied at 8 tsp/treatment area ($3m^2$) twice the recommended manufacturer's rate on December 8, 2003, March 22, 2004 and April 23, 2004.

Within each of the treatment areas, four quadrats (each 50 cm ×50 cm) were centered leaving a 25 cm buffer between treatments and a 50cm buffer along the long boundary of the block, next to the untreated areas. Each quadrat contained 25 sowing plots (5cm × 5cm). Within each of the sowing plots, seeds of one of the 22 upland native prairie species were sowed (Table 1) in mid-November 2003. Thus, within each treatment area each species had seeds sowed within each of 4 sowing plots. The number of seedlings of sowed species was counted May 2004, along with background numbers, i.e., seedlings of target occurring in natural vegetation.

Data analysis

To determine the differential establishment rates of the sowed target native prairie specie comparisons of seedling establishment rates made between the species using Analysis of Variance (ANOVA), transforming data as necessary to meet test assumptions. Fisher's

least significant difference (LSD) procedure was used to determine which treatment means were significantly different from each other, $\alpha = 0.05$.

To determine the effectiveness of manipulated field conditions in promoting the seedling establishment of target native species, comparisons of seedling establishment rates were made among the four treatments, using Analysis of Variance (ANOVA), transforming data as necessary to meet test assumptions. Fisher's least significant difference (LSD) procedure was use to determine which treatment means were significantly different from each other, $\alpha = 0.05$.

Results and Discussion

How do target native prairie species differ in their seedling establishment rates after sowing into plots treated with the herbicide Fusilade?

Species differed significantly in their establishment rates in unmanipulated plots that had been previously sprayed with the herbicide Fusilade, ranging from almost 50% establishment to less than 3% (Table 2). The large variability in the data prevented grouping species into distinct groups (Table 2).

Differences in seedling establishment rates between species do not appear to be related to species seed size, whether the species are annuals or perennials, or whether they are dicots or grasses (Tables 1 and 2). At this time we cannot distinguish between poor seed viability and inability to establish under current conditions, particularly for those species with low establishment rates.

Background counts of species were zero or very small. Analysis showed no significant differences in background counts between treatments. Therefore, sowed species seedlings counts were not adjusted for background seedling counts.

Does manipulating the microsite environment improve seedling establishment rates of target native prairie species?

We hypothesized that litter, herbivory from slugs, and soil fungal disease were possible important factors controlling seed and seedling mortality. The results showed support for these factors being influential for only four species (Table 3).

The removal of litter and slug bait treatment increased seedling establishment rates more than twice than that of the other treatments for *Agoseris grandiflora* (Table 3). For the other three species, *Eriophyllum lanatum*, *Lomatium utriculatum*, and *Poa scabrella*, all three treatments that included litter removal increased seedling establishment rates by at least 50% to more than 100% (Table 1). The large variability in establishment rates within a species made it difficult to distinguish these differences statistically.

Study B Transplants

Objectives

- Compare the growth of ten native species grown from seed under greenhouse conditions and transplanted to field plots.
- Compare the growth of ten native species grown from seed under greenhouse conditions and transplanted into field plots that had received different herbicide treatments to control *Brachypodium sylvaticum.*

Methods

Experimental design

Ten native upland prairie species were started from seed in an OSU greenhouse in July 2003 and transplanted December 2003 into experimental plots that had been previously established at Butterfly Meadows to determine the effectiveness of different herbicide treatments to control of *Brachypodium sylvaticum* at Butterfly Meadows (see Objective 2a, Study A). We used the plots (randomized block design, n = 3) that had been left untreated or treated with the herbicides Fusilade or Accord in fall 2002 to control *Brachypodium sylvaticum*. Within each of these three experimental blocks (7m × 3m), 10 quadrats (50cm × 50cm) were placed. Transplants of 10 native species (Table 4), started from seed in July 2003 in OSU greenhouse space donated by Dr. Robin Rose, were planted December 2003 in these quadrats. Two individuals of each of the ten species were planted within a quadrat (50 cm ×50 cm) for a total of 18 plants/species, with the exception of *Aster subspicatus*, in which only one individual was planted in each quadrat.

At the time of planting, species were thinned to one individual or stem per plot, with the exception of *Koeleria macranthus* for which the number of individuals could not be distinguished. However, all pots of *Koeleria macranthus* had similar cover at the time of planting. After planting we replaced any litter that was removed during the planting process. Cover (cm^2) of each species was visually estimated by two observers, using cover templates in May 2004.

Data analysis

To determine the effect of previous herbicide treatments on the cover (cm^2) on the ten transplanted species, comparison of cover were made among the three treatments, using Analysis of Variance (ANOVA), transforming data as necessary to meet test assumptions.

Results and Discussion

How do target native prairie species differ in their growth after being grown from seed under greenhouse conditions and then transplanted to field plots?

Transplanted native prairie species differed significantly in their cover in unmanipulated plots (no herbicide treatments) (Table 4). *Achillea millefolium*, with its extensive system of rhizomes, had significantly greater cover that any of the other species (Table 4).

Species germinated approximately at the same time under greenhouse conditions with the exception of *Lomatium utriculatum.* At the time of planting *Lomatium utriculatum* plants

were still in the first true leaf stage. In contrast, three species were flowering, *Eriophyllum lanatum*, *Aster subspicatus*, and *Sidalcea campestris*. The flowering stalks of these three species were pruned to about half of their height when planted in the field. Although not flowering when planted, three species had massive root masses: *Sidalcea campestris, Bromus sitchensis,* and *Aster subspicatus*.

Even though transplanting took place in winter, mortality was low with all plants surviving with the exception of three individuals of *Sanguisorba occidentalis*. Some herbivory was reported for *Sidalcea campestris*, *Sanguisorba occidentalis*, *Agoseris grandiflora,* and *Lomatium utriculatum.*

Does herbicide treatment to reduce cover of Brachypodium sylvaticum increase the cover of transplanted target native prairie species?

Average cover of the ten transplanted native prairie species showed no differences between treatments (Table 5), i.e., species grew just as well in the non-herbicide treated plots as they did in the herbicide treated plots, where abundance of *Brachypodium sylvaticum* had been significantly reduced the previous season (see Objective 2a, Study A). Cover of *Brachypodium sylvaticum* was not measured in spring 2004, so it is possible that cover in the herbicide treated plots recovered to levels in the unmanipulated plots, but personal observations suggest that there were still significant differences in cover of *Brachypodium sylvaticum plots* between treated and untreated plots a year later. The process of transplanting, however, may have contributed to the lack of differences between treatments as vegetation immediately surrounding the transplants was unavoidable disturbed when digging the holes and placing the transplants.

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Table 1 Target native upland prairie species sowed in experimental plots at Butterfly Meadows, Corvallis, OR. The average mass per 100 seeds includes any chaff leftover from the cleaning process (n=3). Those species marked with an asterisk were also used in the transplant study. *Koeleria macranthus* and *Aster subspicatus* were included only in the transplant studies.

Species	Perennial/Annual	Average mass/100 seeds (mg)	Number of seeds sowed/ plot
Dicots			
Clarkia amoena	Annual	35.0	100
Clarkia purpurea	Annual	66.7	100
Collomia grandiflora	Annual	376.3	50
Madia elegans	Annual	243.6	100
Madia gracilis	Annual	122.7	100
Sanguisorba occidentalis	Annual	288.7	100
Trifolium tridentatum	Annual	162.3	100
Achillea millefolium	Perennial	33.0	100
Agoseris grandiflora	Perennial	53.0	100
Aster subspicatus	Perennial	184.6	NA
Eriophyllum lanatum	Perennial	37.0	100
Lomatium utriculatum	Perennial	285.6	50
Potentilla gracilis	Perennial	13.7	100
Prunella vulgaris	Perennial	142.0	100
Sidalcea campestris	Perennial	487.7	100
Sidalcea virgata	Perennial	459.0	25
Monocots			
Bromus carinatus	Perennial	702.0	100
Bromus sitchensis	Perennial	542.3	50
Danthonia californica	Perennial	367.7	50
Elymus glaucus	Perennial	269.3	50
Elymus trachycaulus	Perennial	360.7	50
Festuca roemeri	Perennial	178.0	100
Koeleria micrantha	Perennial	21.7	NA
Poa scabrella	Perennial	41.7	100

Table 2 Average seedling establishment rates (%) of 22 native upland prairie species in May, 2003, after sowing in field plots in November 2003 at Butterfly Meadows, Benton County, OR. Plots had been previously treated with herbicide Fusilade fall 2002 and spring 2003 to control *Brachypodium sylvaticum*. Transformations were applied as necessary before analysis of variance (ANOVA). All means shown are from untransformed data with standard deviations shown in parentheses. Treatments sharing letters were statistically indistinguishable.
Asterisks indicate annual species.

Species	Seedling establishment rate	
*Madia gracilis**	49.8 (24.2)	a
Bromus sitchensis	45.5 (22.6)	a
*Madia elegans**	40.3 (24.5)	ab
Festuca roemeri	32.7 (14.5)	ab
Prunella vulgaris	27.6 (13.9)	abc
*Clarkia purpurea**	27.0 (16.9)	abc
Eriophyllum lanatum	22.2 (13.4)	abc
Bromus carinatus	25.3 (19.1)	abcd
Lomatium utriculatum	17.5 (11.7)	abcde
*Clarkia amoena**	14.9 (11.2)	abcde
Danthonia californica	14.8 (11.9)	abcde
Sidalcea virgata	11.7 (9.4)	abcde
*Collomia grandiflora**	11.0 (8.4)	abcde
Elymus glaucus	7.8 (5.1)	bcde
Sidalcea campestris	10.0 (7.6)	cde
Achillea millefolium	6.8 (7.5)	cde
Agoseris grandiflora	6.2 (4.9)	cde
Elymus trachycaulus	7.3 (5.2)	cde
Potentilla gracilis	2.9 (4.5)	cde
*Trifolium tridentatum**	3.5 (2.9)	de
Poa scabrella	1.3 (1.6)	de
*Sanguisorba occidentalis**	2.6 (2.4)	e

Table 3 Comparison of average seedling establishment rates (%) for sowed native upland prairie species in May 2004 among four treatments. Seeds were sowed November 2003 into plots at Butterfly Meadows, Benton County, OR that had been treated with herbicide Fusilade in fall 2002 and in spring 2003 to control *Brachypodium sylvaticum*. Transformations were applied as necessary before analysis of variance (ANOVA). All means shown are from untransformed data. *P* is the probability that the differences in treatment means occurred just by chance. Treatments sharing letters were statistically indistinguishable.

Species	**Treatment**				**P**
	No manipula-tion	**Litter removed**	**Litter removed; seed fungicide added**	**Litter removed; slug bait added**	
Madia gracilis	49.8	43.5	51.9	52.3	0.50
Bromus sitchensis	45.5	42.8	31.1	43.0	0.80
Madia elegans	40.3	39.3	30.4	48.2	0.51
Festuca roemeri	32.7	18.4	31.8	23.2	0.12
Prunella vulgaris	27.6	26.7	28.8	34.1	0.17
Clarkia purpurea	27.0	21.5	21.3	36.5	0.70
Bromus carinatus	25.3	15.0	30.3	23.0	0.56
Eriophyllum lanatum	**22.2a**	**42.8ab**	**51.4b**	**45.9b**	**0.02**
Lomatium utriculatum	**17.5a**	**28.7ab**	**33.8ab**	**27.8b**	**0.03**
Clarkia amoena	14.9	18.3	16.2	16.2	0.88
Danthonia californica	14.8	24.0	23.3	26.5	0.34
Collomia grandiflora	11.0	10.7	7.6	15.5	0.60
Achillea millefolium	6.8	15.7	7.6	13.4	0.14
Agoseris grandiflora	**6.2a**	**7.3a**	**8.1ab**	**18.7b**	**0.03**
Sidalcea campestris	10.0	7.8	6.7	6.7	0.29
Elymus glaucus	7.8	3.8	14.3	8.2	0.28
Elymus trachycaulus	7.3	11.3	15.4	24.5	0.36
Trifolium tridentatum	3.5	3.6	3.2	3.8	0.99
Potentilla gracilis	2.9	10.4	9.4	7.8	0.14
Sanguisorba occidentalis	2.6	6.7	5.5	5.8	0.15
Poa scabrella	**1.3**	**5.2**	**6.8**	**5.3**	**0.05**
Sidalcea virgata	3.5	3.6	3.2	3.8	0.99

Table 4 Average cover (cm^2) ten native upland prairie species in May, 2003, started from seed in an OSU greenhouse in July 2003 and transplanted December 2003 into untreated experimental plots at Butterfly Meadows, Benton County, OR. Treatments sharing letters were statistically indistinguishable.

Species	**Cover** (cm^2)	
Achillea millefolium	232.5	a
Eriophyllum lanatum	149.1	b
Prunella vulgaris	134.2	bc
Koeleria macranthus	131.7	bc
Sidalcea campestris	126.7	bc
Bromus sitchensis	118.3	bc
Agoseris grandiflora	95.8	bcd
Aster subspicatus	83.3	cde
Sanguisorba occidentalis	45.8	de
Lomatium utriculatum	34.2	e

Table 5 Comparison of average cover (cm^2) among three treatments for ten native upland prairie species started from seed in an OSU greenhouse in July 2003 and transplanted December 2003 into experimental plots at Butterfly Meadows. Plots had been left untreated or treated with herbicides Fusilade or Accord in fall 2002 to control *Brachypodium sylvaticum*. *P* is the probability that the differences in treatment means occurred just by chance.

Species	**Treatment**			**P**
	No herbicide	**Fusilade**	**Accord**	
Achillea millefolium	232.5	169.2	183.3	0.47
Eriophyllum lanatum	149.1	165.0	150.0	0.93
Prunella vulgaris	134.2	158.7	128.3	0.40
Koeleria macranthus	131.7	130.8	111.7	0.41
Sidalcea campestris	126.7	104.2	111.7	0.69
Bromus sitchensis	118.3	135.0	118.3	0.91
Agoseris grandiflora	95.8	98.7	72.5	0.51
Aster subspicatus	83.3	85.0	75.3	0.90
Sanguisorba occidentalis	45.8	17.5	55.0	0.38
Lomatium utriculatum	34.2	19.5	45.0	0.55

OBJECTIVE 4 *Remove encroaching woody species*.

Removal of encroaching woody species is scheduled for fall 2004 to avoid interference with Fender's blue butterfly larvae and the adult butterflies. Work will be scheduled around any restrictions during fire season.

The management strategy includes

- Spraying poison oak, rose, and other weedy shrubs with 5% glyphosate in SE section 1.
- Spraying poison oak and Douglas-fir with 5% glysophate in NE sections 1 and 2.
- Removing Douglas-fir along boundary buffer by either pruning or by hack-and-squirt using 90% glysophate with 10% water.

OBJECTIVE 5a *Construct buffer between Butterfly Meadows and source of Brachypodium sylvaticum.*

The *Brachypodium sylvaticum* in the buffer area managed by Oregon State University (2.5 acres) was sprayed on May 29, 2003 with a mixture of 1.75% Accord and 5% Velpar mixture over two acres using a backpack sprayer. Great care was taken during the operation and was conducted under favorable wind, temperature and humidity conditions.

Starker Forests marked out the boundary (50 foot buffer) on the land that they managed in early June, 2003. The Starker portion of the Butterfly Meadows buffer (approximately 7.4 acres) was sprayed October 27, 2003 with the following herbicides: Accord (2 quarts/acre) and Oust (30z/acre).

OBJECTIVE 5b *Plant native species to replace Brachypodium sylvaticum in the buffer.*

After reconsidering the effectiveness of herbicides after only one year in controlling *Brachypodium sylvaticum*, the decision was made to postpone the reseeding of the buffer area. The consensus was that it may take more than one year of herbicide spraying to control the *Brachypodium sylvaticum* and rather than risk wasting resources on re-seeding it was suggested to spray multiple years to insure control of *Brachypodium sylvaticum* in the buffer. With permission from Tim Butler (ODA), we redirected the money budgeted for seed to growing out transplants that would be compared to seed sowing in the experimental study on native plant restoration (See Objective 3). Transplants not used in the experiment will be planted on-site as part of our restoration efforts.

OBJECTIVE 6c *Monitor success of Brachypodium sylvaticum control in the buffer zone and the establishment of native species and adapt management strategies based on monitoring results.*

- A plan for monitoring abundance for *Brachypodium sylvaticum* in the buffer zone was developed (see below) and implemented summer 2004. A plan for monitoring native species will be developed after the buffer zone is reseeded with native species.
- First year monitoring results, August, 2004
  Average cover of *Brachypodium sylvaticum* in the southern and western boundary areas in August of 2004 was very low, only 0.1%, with a 95% confidence interval from 0.0% to 0.3%. In contrast, total native cover averaged 1.2% across the 20 quadrats. Those native species that had higher average cover than *Brachypodium sylvaticum* were *Pteridium aquilinum* (0.4%), *Toxicodendron diversilobum* (0.3%), and *Eriophyllum lanatum* (0.2%).

Monitoring Plan for *Brachypodium sylvaticum*
in the Boundary Area of Butterfly Meadows, Benton County, Oregon

Management objective
Limit the cover of *Brachypodium sylvaticum* to 10% cover in the boundary area of Butterfly Meadows, Benton County (T.11S., R.5W.,Sec.18, S1/2 of NW1/4) in any year between 2004 and 2006.

Management response
If the cover of *Brachypodium sylvaticum* is above the threshold of 10%, then the herbicide application will be reapplied (assuming that resources are available to do so) with additional annual monitoring. If the cover of *Brachypodium sylvaticum* is equal or below the threshold of 10%, then no management actions will be taken and the population will be monitored in two years. Note that if any part of the confidence interval has crossed the threshold, then management action will take place.

Management treatment design and implementation
The *Brachypodium sylvaticum* in the buffer area managed by Oregon State University (2.5 acres) was sprayed on May 29, 2003 with a mixture of 1.75% Accord and 5% Velpar mixture over two acres using a backpack sprayer. Great care was taken during the operation and was conducted under favorable wind, temperature and humidity conditions.

Starker Forests marked out the boundary (50 foot buffer) on the land that they managed in early June, 2003. The Starker portion of the Butterfly Meadows buffer (approximately 7.4 acres) was sprayed October 27, 2003 with the following herbicides: Accord (2 quarts/acre) and Oust (30z/acre).

Monitoring design
Sampling objective
Be 95% confident that cover estimates of *Brachypodium sylvaticum* are within 10% of the estimated true value.

Sampling design
Constraints of time and money make it impractical to sample the entire boundary area. So the southern, western and northern areas of the buffer were subjectively selected to be sampled. Although these "key areas" will be representative of the entire boundary area that is being encroached by false brome, we cannot make statistical inferences to the entire boundary area. However, management actions will be taken based on the monitoring results from these key areas.

Twenty quadrats, each 1m², were established along the southern and western portions of the buffer zone, which received herbicide application from Starker Forests. Additional quadrats will be placed at a later time in the northern area, which received herbicide application from Oregon State University. These quadrats were placed approximately in the center of the boundary area, and were systematically located by walking along the

boundary in the middle and then stopping every two minutes and placing the quadrat in that spot. Most of the boundary area is within the forested areas surrounding the meadow. In order to detect whether differences in *Brachypodium sylvaticum* establishment exist between open and closed canopy areas, a disproportionate number of quadrats were placed within the largest open area of the buffer zone. In violation of the two-minute placement system, four quadrats were placed within this large open canopy area.

The square quadrats were oriented perpendicular to the slope. Quadrat locations were marked with 3 pin flags indicating the upper-most corners and lower right corner of the quadrat.

Field measurements

See Attachment B for detailed field procedures and Attachment C for sample data sheet.

Initial measurements of cover along the boundary area of Butterfly Meadows were taken in mid-August, 2004. Within each of 20 1-m² quadrats, cover, measured in percent, was determined for *Brachypodium sylvaticum*, as well as for any other species present in the quadrat.

Monitoring timing

Monitoring will initially be conducted in late summer annually for two years beginning in 2004. If cover values remain below the threshold without continued herbicide treatments, monitoring will done every other year, assuming resources are available.

Data analysis

An estimate of the population abundance of false brome will be determined by calculating the average cover (%) along with a 95% confidence level. The average cover and confidence interval will be compared to the to the management objective to determine if it has been met and if management action is needed.

Monitoring implementation and evaluation of results

1. Collect field data at specified intervals. Ensure that data sheets are completely filled out, duplicated and stored in safe place.
2. Analyze data after each measurement cycle.
3. Complete a summary report that includes recommendations for management responses. Also evaluate field methods, costs, sample size, and relevancy of the monitoring project.
4. After the last monitoring period (2006), prepare a final monitoring report and distribute to all interested parties, including publishing or sharing at a technical forum.

Resources for monitoring

1. See Attachment B for necessary equipment for data collection.

2. Personnel responsible for implementing monitoring for 2004:

Monitoring tasks	**Facilitators**
Set up monitoring plots	Rachael Roberts (OSU) Matt Blakely-Smith (OSU) Debbie Johnson (OSU)
Collect field data	Rachael Roberts (OSU) Matt Blakely-Smith (OSU) Debbie Johnson (OSU)
Analyze field data and evaluate results	Rachael Roberts (OSU) Matt Blakely-Smith (OSU) Debbie Johnson (OSU)
Write and distribute summary report	Deborah Clark (OSU)

The monitoring plan includes three attachments.
1. Attachment A *Monitoring Plot Locations* Includes directions, maps and aerial photographs describing the study location, and the location of permanent sampling units.
2. Attachment B *Field Procedures* Includes field procedures, including necessary equipment and personnel
3. Attachment C *Sample Data sheet*

Attachment A
Monitoring Plot Locations
Monitoring Plan for *Brachypodium sylvaticum*
in the Boundary Area of Butterfly Meadows, Benton County, Oregon

The monitoring plots are located in the boundary just south of the lupine plots used for pilot study B ((Lat. 44° 36' 56.6″. Long: 123° 20' 53.76″). The monitoring plots can be located by driving the Starker's private road up to Butterfly Meadows and then parking at the turnaround just south of the lupine plots. Follow the uphill foot path created by herbicides to where the boundary intersects and then head west.

Attachment B

Field Procedures

Monitoring Plan for *Brachypodium sylvaticum*
in the Boundary Area of Butterfly Meadows, Benton County, Oregon

Field Procedures

Twenty permanent monitoring plots were set up along southern and western portions of the boundary area of Butterfly Meadows. (Additional plots will be set up in the northern boundary area). Sampling locations were determined by walking along the boundary area and stopping every two minutes and placing a 1-m² quadrat in that location. Timing began at a snag (labeled "START" with orange and white striped flagging) located in an open area just west of the main path that leads to the boundary area. Using this as the starting point, one individual (the "timer") with a watch said "start" while the other individual (the "walker") walked ahead along the center of the boundary, in a clockwise direction around the boundary. At exactly two minutes, the timer would yell "stop," at which point the walker would stop. The placement of the tip of the walker's right foot determined the lower right corner of the quadrat. The rest of the quadrat was placed perpendicular to the slope. Pin flags were placed in the two upper corners and in the lower right corner of the quadrat. Each flag was labeled with the plot number. When possible, orange and white striped flagging was tied to a branch above or around the quadrat location to aid in finding these locations in the future.

In order to detect whether establishment of *Brachypodium sylvaticum* differs between open and closed canopy locations of the boundary area, four quadrats were placed within the largest open area in the boundary area. These are plots 6-9. The location of plot 7 was determined by stopping at the 2-minute point. Point 6 was placed just east of plot 7; its placement was determined by an individual throwing a stone over their shoulder. Plot 8 was located 5 seconds from plot 7. Because this was determined to be too short a distance, plot 9 was placed 10 seconds from plot 8. The rest of the plots were placed according to the 2-minute system.

The amount of cover, measured in percent, of *Brachypodium sylvaticum*, and any other species present in the quadrat, was determined using pre-cut templates indicating 1% or 3% of the quadrat. Trace amounts of a species, for example a blade of grass, were measured as "0.1%."

Equipment necessary

Map of Butterfly Meadows with boundary area marked
1-m² quadrat frame
Templates indicating x% of a 1-m² quadrat
Data sheet
Stopwatch or watch with second hand (to help locate plots)
Pin flags (in case needed to replace any that have gotten lost)

Personnel necessary

Two people needed to measure cover in each plot.

Attachment C
Sample Data Sheet
Monitoring Plan for *Brachypodium sylvaticum*
in the Boundary Area of Butterfly Meadows, Benton County, Oregon

BRSY MONITORING AT BUTTERFLY MEADOWS
Southern and Western Boundary
Date:
Data collected by:

Quadrat size 1-m²
Cover %

Species Names								
QUADRAT #	**BRSY**							

NOTES

OBJECTIVE 6e *Monitor success of increasing abundance of Fender's blue butterfly adults.*

- Paul Hammond conducted a survey of Fender's blue butterfly *Icaricia icarioides fenderi* during the flight season, June 3 and 11, 2003 and May 25, 2004.at Butterfly Meadows. He reported that habitat in section SE1 has deteriorated badly for the Fender's blue butterfly due to shading by Douglas-fir trees, which are probably promoting growth of false brome. Butterfly habitat is also deteriorating in NE2 section also due to the heavy encroachment of young Douglas-fir, false brome, and bracken fern.

Table 1 Adult Fender's blue butterfly census at Butterfly Meadows for 2003 and 2004.

Area	2003	2004
SE 1	19	23
NE 1	14	10
NE 2	15	16
NW 1	4	11
NW 2	7	12
SW 1A	18	26
SW 1B	46	56
SW 1C	54	56
SW 2	0	0
SW 3A	0	0
SW 3B	0	2
TOTAL	177	212