Controlling meadow knapweed with manual removal, mulching, and seeding

Final Report
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A Challenge cost Share Project between the
Institute for Applied Ecology, Corvallis, Oregon ***and the***
Eugene District Bureau of Land Management

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 whose mission is conservation of native ecosystems through restoration, 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. Questions regarding this report or IAE should be directed to:

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Cover photographs and all photos within, except where noted: Andrea S. Thorpe, IAE

REFERENCE

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Figure 1. Meadow knapweed.

Meadow knapweed (*Centaurea ×moncktonii* Britt., synonyms include *C. debeauxii* Gren. & Godr. ssp. *thuillieri* Dostál and *C. pratensis* Thuill, nom. illeg., non Salisb.; Asteraceae; Figure 1) is an invasive forb that is a fertile hybrid between two European species that are also invasive in the United States: black knapweed (*C. nigra*) and brown knapweed (*C. jaceae*). Meadow knapweed has been found in 47 counties in Oregon, Washington, Idaho, and Montana and is considered noxious in Oregon, Washington, and Idaho (http://invader.dbs.umt.edu). Particularly in western Oregon, populations of meadow knapweed have been rapidly expanding and new infestations are frequently found. Although meadow knapweed appears to first colonize roadsides, river and stream banks, and disturbed pastures, it is also capable of invading native prairies and meadows.

Meadow knapweed can form near-monocultures in invaded areas (Figure 2). Although meadow knapweed was originally introduced as a forage plant (Roché and Johnson 2003), its palatability and quality decline as the plant matures, and its presence ultimately reduces forage production. There are also concerns that meadow knapweed reduces the cover and richness of native plant species in invaded forests and meadows and adversely affects the growth of tree seedlings.

Meadow knapweed is a perennial that grows from a woody crown. Plants usually grow 20 to 40 inches tall with the main stems branching near the middle. Meadow knapweed leaves can grow up to 6 inches long and 1.25 inches wide and have entire margins to small lobes or teeth. Leaves on the stems are progressively smaller; the uppermost leaves are quite reduced and linear. The rose-purple (occasionally white) flowers are held in round to urn-shaped capitula about the size of a nickel. Flowering peaks in July and August, but can continue into November and December

Figure 2. A field invaded by meadow knapweed near Horton, Oregon. Cover of meadow knapweed in this field was greater than 90%.

west of the Cascade Mountains, particularly on damaged plants. The capitula are surrounded by light to dark brown bracts that have a papery fringed margin (Figure 3). At the time of flowering, these bracts reflect a metallic golden sheen. Cypselae (the type of fruit in Asteraceae) are about 1/8 inch long, ivory-white to light brown, and sometimes bear a row of short hairs (*pappus*) opposite the point of attachment (*hilum*). Seedlings are taprooted; mature plants develop a cluster of somewhat fleshy roots below the woody crown. Meadow knapweed appears to have three life stages: seedling, rosette, and the reproductive bolting stage. Plants appear to be able to reproduce for several years and may flower multiple times during a year, particularly if the plant has been disturbed (e.g. grazed or mowed).

Figure 3. Meadow knapweed capitulum. Note dark brown bracts with a papery, fringed margin. Photo: Wes Messinger/USACE

The Meadow Knapweed Working Group, a multi-agency, multi-disciplinary team, has been formed to address concerns and needs for this species, particularly in the Horton area of Lane County where there is a high level of invasion. Their recommendations include reducing the spread of the species from invaded areas through containment as well as developing new methods for control, especially on roadsides. As meadow knapweed reproduces and spreads by seed, containment of this species must include reducing or eliminating seed production. While herbicides have been relatively effective at controlling meadow knapweed, it is often not possible to use them. Unfortunately, effective and efficient alternatives to herbicides have not yet been identified. Mowing, grubbing, grazing, tilling, and solarization have been anecdotally reported to have some success in controlling meadow knapweed, but these methods have not been compared in a replicated, controlled setting. The purpose of this project was to examine the efficacy of combinations of mechanical removal methods and mulching and seeding to control and suppress meadow knapweed. Specifically, this project addressed the following questions:

- How effective are three non-chemical methods of removing meadow knapweed?
- Does mulching inhibit germination of meadow knapweed seeds after removal of plants?
- Does sowing of native species inhibit reinvasion by meadow knapweed after removal treatments?
- Is one year of treatment sufficient to control meadow knapweed?

We tested three methods commonly used to control invasive weeds: mowing, grubbing, and solarization. Spotted knapweed (*Centaurea stoebe*) and diffuse knapweed (*Centaurea diffusa*) respond to mowing with low stature compensatory growth, resulting in increased seed production that is close to the ground. Local land managers have

reported a similar response by meadow knapweed. However, mowing knapweed repeatedly over a growing season at progressively shorter heights has not yet been tested in a replicated manner. Grubbing has been effective in removing invasive knapweeds in some areas. As it is possible to treat only an individual plant, this method may be particularly useful in prairies where sensitive native species are present. However, in comparison to other control methods, the utility of grubbing may be limited due to the time required to grub sites and the ability of workers to remove meadow knapweed's extensive taproot. Solarization (covering with heavy black plastic) has the potential to not only kill living plants, but may also kill seeds in the seedbank.

Mulch has the potential to inhibit seed germination and seedling growth. In a study on the invasive grass, false-brome (*Brachypodium sylvaticum*), native blue wildrye (*Elymus glaucus*) straw inhibited re-emergence of the grass after mowing. Similar impacts of mulch have been anecdotally reported by The Oregon Department of Transportation. We tested the effectiveness of two different types of straw, blue wildrye straw and wood straw (http://www.woodstraw.com/). While blue wildrye straw is more typical of the litter in the meadow habitats that are frequently invaded by meadow knapweed, it is expensive and may be difficult to obtain. In contrast, wood straw, which is designed to mimic the size and texture of grass straw, is relatively inexpensive and readily available.

Effective control of meadow knapweed will likely require several years of knapweed removal. Seeds of related species have been reported to be viable for up to eight years and mangers have reported that treated sites are frequently reinvaded by meadow knapweed the year following treatment. Thus, we treated our plots for two consecutive years.

METHODS

Two sites were selected for this experiment (Appendix A). Fire Station was located in an unused field at the Lake Creek Fire Station in Horton, Oregon (Figures 4 & 5). This site was chosen because it is characteristic of pastures that are invaded by meadow knapweed and it is easily accessible to the public, making it a good demonstration site. Spur Road was located along the side of BLM road 15-6-19.1. Plots were established and initially monitored in June 2007. Monitoring was repeated in July 2008 and 2009. At Fire Station, we set up a 50 meter transect to serve as the edge of the plots (Figure 5). At the Spur Road site, we set up a 48 meter transect as the edge of the plots and used rebar to mark 0, 20, and 50 meters (Figure 6). Eight inch spikes and/or conduit were used at both sites to permanently mark every 2 meters along the transects. In the center of each 2m x 2m treatment plot we set up a $1m^2$ sampling plot. In each sampling plot we counted the total number of individual meadow knapweed seedlings, rosettes, and bolting plants and measured the heights of ten randomly selected individuals in both the rosette and bolting stages. When plants were in close proximity, individual plants were determined by probing for underground root connections between crowns. In 2009, the number of bolting stems were counted for each plot, but the number of bolting plants was counted in only 9 of the plots at the Spur Road. The average number of stems/plant in those plots was 4.3 ± 0.38 (S.E.). We used this value to estimate the number of plants in all other plots. We also documented the percent cover of all vascular plant species, litter, bare ground/rock, and moss.

Figure 4. General location of meadow knapweed study sites (in and near Horton, Oregon, circled on map).

Figure 5. Fire station study site. Location and orientation of the transect is marked in black.

Table 1. Study design (incomplete factorial) for examining the effects of mechanical removal, mulching and native grass seeding on meadow knapweed and the number of plots established in 2007 at each site. FS = Fire Station, SR = Spur Road.

		Removal			
		Mow twice in season at two different heights	**Grub before seed-set**	**Mow then Solarization**	**No treatment** (full-control)
Mulching and seeding	**No mulch**	yes FS: 3 SR: 4	yes FS: 3 SR: 4	yes FS: 4 SR: 3	yes FS: 4 SR: 5
	Mulching and seeding	yes FS: 3 SR: 4	yes FS: 4 SR: 3	no	yes FS: 3 SR: 2

Treatments were randomly assigned to plots so that there would be at least three replicates of each treatment at each site (Table 1, Appendix B). The number of replicates for each treatment changed over time due to errors in treatment application (Table 2). One mulch/seed control plot was missed at the Spur Road site, resulting in 5 control plots neither mulched nor seeded and 2 control plots that were seeded and mulched. Treatments were applied to plots initially in July 2007. A weed whacker was used to cut all plants in the plots needing mowing to approximately 8 inches above the ground.

Plots assigned to the mow/solar treatment were then covered with black 0.24 inch polyethylene sheeting secured to the ground by large garden staples (Figure 11). Plots assigned to the mow and mow/mulch/seed treatments were mowed again approximately 2 months after the first treatment to approximately 6 inches above the ground (Figure 11). All meadow knapweed plants in the grub and grub/mulch/seed plots were removed to a depth greater than 4 inches using pulaskis. Approximately 3 inches of blue wildrye straw or wood straw was applied to the mulch/seed, mow/mulch/seed, and grub/mulch/seed plots at the Fire Station and Spur Road sites, respectively. At both sites, 85 grams each of blue wildrye and Columbia brome (*Bromus vulgaris*) seed were combined and spread evenly over the appropriate plots.

Treatments were repeated in July 2008 (Appendix B). Mow/solar plots were uncovered and checked for active plant growth; no plants were growing in any plot except one and the plastic was therefore completely removed and the plots were mulched and seeded. The plastic blew up off of half of one mow/solar plot at the Fire Station site, allowing growth of meadow knapweed. This plot was mowed again and resolarized. This plot was not included in our analyses. Plots requiring mowing or grubbing were treated the same as they were in 2007, except that the entire plot, independent of species, were grubbed in each grubbing plot. Additionally, two control plots requiring no treatment were accidently mown at the Spur Road site; these plots were not included in

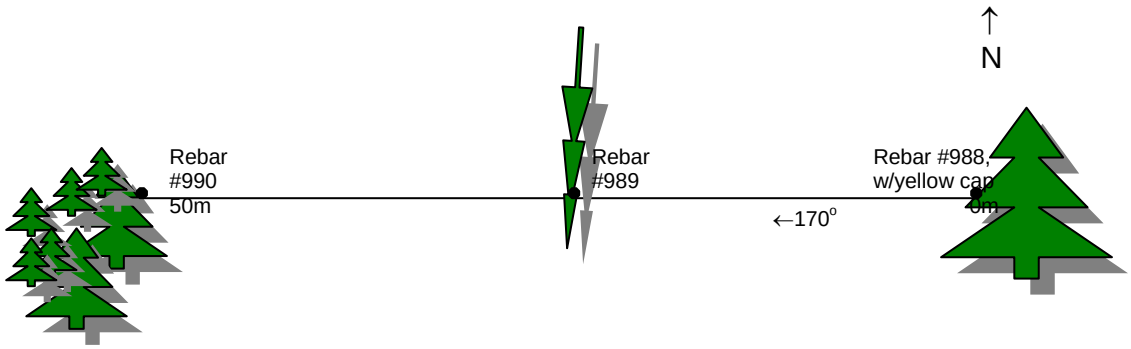

Figure 6. Diagram of the Spur Road study site.

analyses in 2009. Approximately 2 inches of blue wildrye straw or wood straw was applied to all plots requiring mulching at the Fire Station and Spur Road sites, respectively. All plots requiring seeding were seeded with 85 grams of blue wildrye.

The sites were revisited in October 2008. Plots requiring mowing were mowed again to a height of approximately 6 inches with a weed whacker. Approximately 89 grams of a seed mix (Table 2) were evenly spread over each plot requiring seeding. This mix was selected as we had observed low germination of blue wildrye during the July monitoring. We selected several annual forbs as they were expected to germinate quickly in the spring and compete with meadow knapweed seedlings. The perennial forbs were selected to provide high ground cover once established and preclude and/or suppress knapweed growth. The perennial grass species were selected as they have high fidelity to prairie plant communities.

Final monitoring and treatments occurred July 2009. At Fire Station, plots 21, 6, 23, 22, 24, 5, and 4 were mowed prior to sampling during site maintenance. At Spur Road, plots 1 – 3 were accidentally grubbed prior to sampling by a BLM work crew. These plots were not included in our final analyses. All other plots were retreated as in previous years with the exception that only *Elymus glaucus* was used on the mulch/seed plots (185g seed per plot).

To assess the effects of treatments on meadow knapweed cover and number of seedlings, rosettes, and bolting plants, we calculated the relative change as (2009-2007)/2007. For community analyses, nativity and growth form follow http://plants.usda.gov/. In these analyses, the cover of meadow knapweed was considered separately from other introduced species.

Table 2. Components of seed mix added to seeded plots in October 2008.

Form	Scientific Name	grams/plot	% of mix
Annual forb	*Epilobium densiflorum*	9.1	10
Annual forb	*Lotus purshianus*	5.4	6
Perennial forb	*Achillea millefolium*	5.4	6
Perennial forb	*Prunella vulgaris* var. *lanceolata*	5.4	6
Perennial grass	*Bromus sitchensis*	18.2	20
Perennial grass	*Danthonia californica*	9.1	10
Perennial grass	*Elymus glaucus*	36.3	41
	Total:	**89.0**	**100**

RESULTS AND DISCUSSION

Between 2007 and 2009, the cover of meadow knapweed in the control plots increased at both the Fire Station and Spur Road. Most of the treatments showed at least some suppression of meadow knapweed. The most successful treatments were solar/mulch/seed, mow/mulch/seed, and grub/mulch/seed.

Grub

After two years of treatment, the cover of meadow knapweed remained approximately the same as at the initiation of this study. Since meadow knapweed cover increased over 40% in control plots, grubbing appeared to have some effect on controlling knapweed growth. Grubbing led to a reduction in the number of seedlings and bolting plants, but a 2- to 3-fold increase in the number of rosettes. The disturbance created by grubbing may stimulate germination of seedlings in summer/early fall that are subsequently able to develop into rosettes the following spring. Alternatively, grubbing may not be effective at removing seedlings which are then able to develop into rosettes. Finally, if grubbing is not deep enough to remove the root crown, this treatment may stimulate rosette production the following season.

The effect of grubbing on the cover of other species varied between sites. At Fire Station, there was no effect of grubbing alone on cover of either introduced or native species. In contrast, at Spur Road, cover of introduced species in grub plots was approximately 1/3 that in control plots. There was no effect of grubbing on native cover at Spur Road.

Grub/Mulch/Seed

Adding mulch/seed to the grub treatment further suppressed the growth of all three stages of meadow knapweed and grub/mulch/seed was one of the most effective treatments at both sites. The addition of mulch/seed also suppressed other introduced species at the Fire Station to approximately 1/3 that of the control plots, largely due to a decrease in the cover of graminoids. At Spur Road, there was practically no difference between grub/mulch/seed and control on cover of either introduced or native species.

Mow

The effects of mowing varied between sites. At Fire Station, mowing caused a small decrease in cover of meadow knapweed. This change in cover appeared to be largely due to a decrease in the number of larger bolting plants as there was a 100% increase in the number of seedlings. At Spur Road, there was no difference in cover or the number of bolting plants between mow and control plots.

At both sites, there was practically no difference in the cover of introduced and native species between mow and control plots.

It has been observed that when mowed frequently, both spotted and meadow knapweeds will grow more prostrate and produce shorter bolting stems. In this study, there was no treatment effect on the size of rosettes ($P_{\text{Spur Rd}} = 0.134$, $P_{\text{Fire Station}} = 0.686$) or bolting plants ($P_{\text{Spur Rd}} = 0.339$, $P_{\text{Fire Station}} = 0.957$). This may be due to the mowing technique used in this study; first mowing in July at approximately 8 inches in order to

cut the bolting stems, but not significantly impact the remaining aboveground biomass, followed by a second mowing in September that was closer to the ground.

Mow/Mulch/Seed

Mulch/seed improved the performance of mowing at both sites; mow/mulch/seed was the most effective treatment at Fire Station. Mulch/seed also had effects on community composition. At Fire Station, mow/mulch/seed reduced cover of introduced species and had no effect on native species cover. At Spur Road, cover of native species in mow/mulch/seed plots was more than double that in control plots, but there was no effect on introduced species.

Solar/Mulch/Seed

We did not test solarization in the absence of mulch/seed. Solarization removed all living plants from our plots; we are confident that in the absence of mulch/seed, these plots would have quickly been recolonized by seed from the untreated meadow knapweed surrounding our treatment plots.

Solar/Mulch/Seed was the most effective method of reducing cover of meadow knapweed at Spur Road and one of the most effective methods at Fire Station. This treatment also resulted in a decrease in the number of individuals in all life stages of meadow knapweed at both sites.

Solar/mulch/seed also had a strong impact on cover of other species. Cover of introduced species was reduced by more than 60% at both sites. At Fire Station, cover of native species in the solar/mulch/seed plots was more than four times that in the control plots. However, at Spur Road, native species cover was about ½ that of control plots.

Seeded species

In 2007, we seeded *Bromus sitchensis* and *Elymus glaucus* as these native grasses are frequently used for restoration by the BLM. Due to low germination of these grasses observed in 2008 (Thorpe and Massatti 2008), we added four forbs and another grass to the seed mix. In 2009, we assessed the change in cover of all seeded species relative to their cover in 2007. Two seeded species, *Danthonia californica* and *Achillea millefolium* were never observed in our plots.

At Fire Station, *Bromus sitchensis* declined in seeded plots (Table 3). These plots were heavily mulched and it is possible that mulch inhibited germination of this grass. There was an increase in cover of *Elymus glaucus* in all plots; the greatest increases in cover of this species were in grub/mulch/seed (7%) and mow (5%) plots. Cover of *Epilobium densiflorum* increased form 0 to 5.5% in both mow/mulch/seed and solar/much/seed plots; cover was 0 elsewhere. Cover of *Lotus micranthus* increased slightly by 0.1 to 0.2% in all treatments except mulch/seed. Finally, there did not appear to be an effect of seeding on *Prunella vulgaris*; cover decreased in all plots although it had been present in 2007.

At Spur Road, only three of the seeded species, *Elymus glaucus, Lotus micranthus*, and *Prunella vulgaris*, were observed in the three years of monitoring (Table 4). Mow/mulch/seed and mulch/seed resulted in the greatest increases in cover of these species.

CONCLUSION

Several of the treatments that we tested were effective at reducing the cover and abundance of meadow knapweed. The most effective treatments were:

- Solarization with thick black plastic for one year, followed by application of 3 inches of straw and seeding with native species,
- Mowing twice a year, first in July (after bolting but before the majority of flowers have opened) ~8 inches above the ground to remove the undeveloped capitula, second in late August 4-6 inches above the ground to remove the second-wave of bolting stems and reduce aboveground biomass, followed by application of 3 inches of straw and seeding with native species, and
- Grubbing out at least 4 inches of the tap root followed by application of 3 inches of straw and seeding with native species.

Even after two years of treatment, meadow knapweed was not eradicated from these plots. Thus, treatment for longer than two years will be required in order to prevent reinvasion. Finally, there was substantial variation in the effects of the treatments on meadow knapweed, other introduced species, and native species between the two sites, demonstrating the importance of monitoring and adapting treatments as necessary.

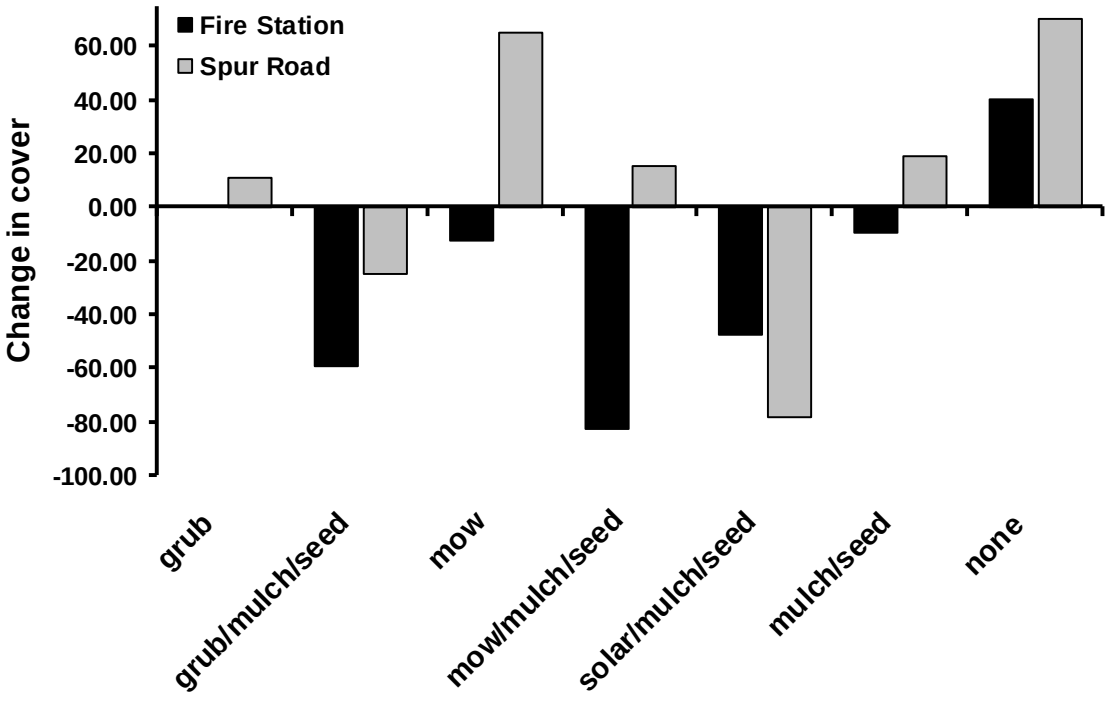

Figure 7. Percent change in meadow knapweed cover from 2007 to 2009 at Fire Station and Spur Road. Treatment types are listed along the x-axis.

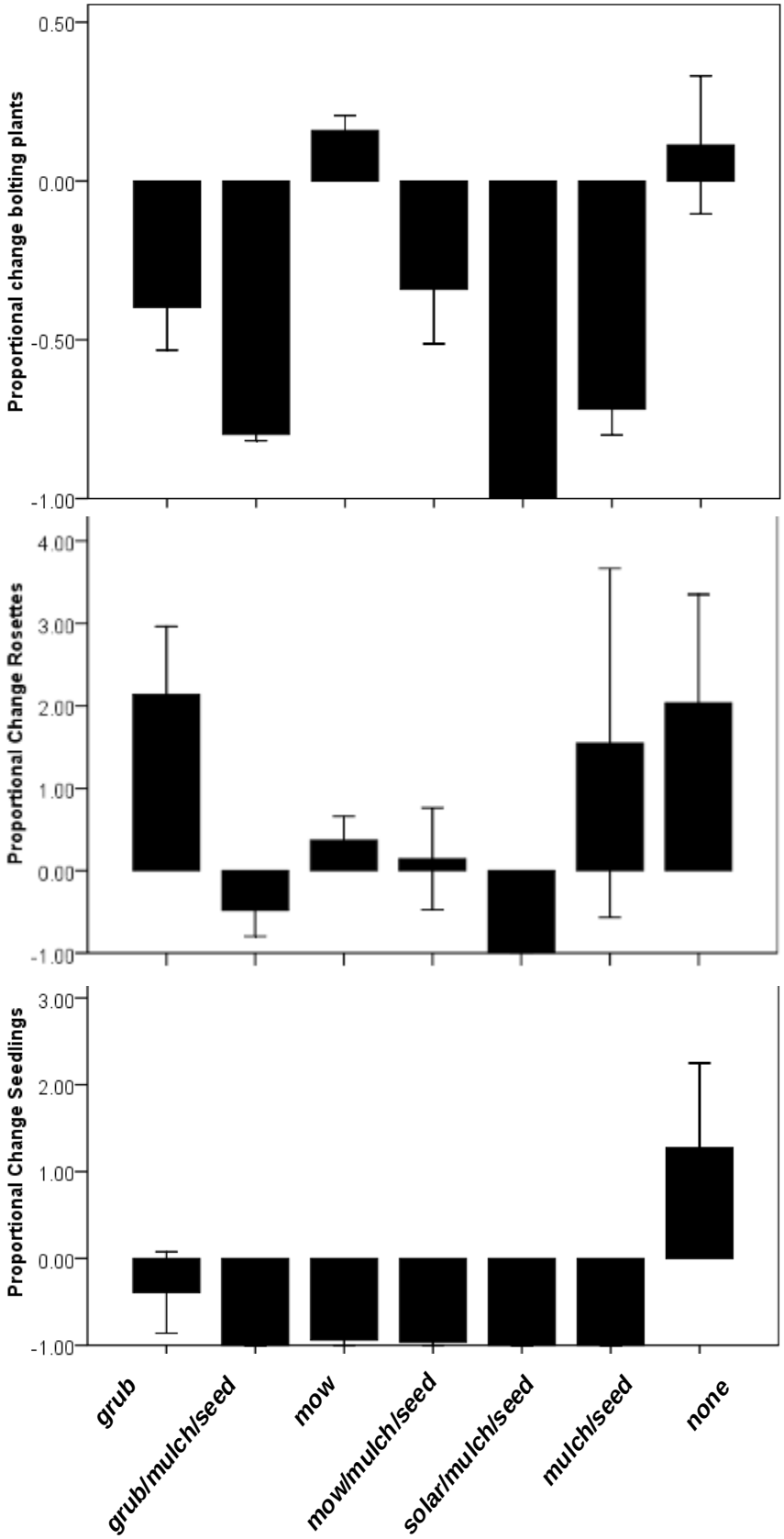

Figure 8. Proportional change in *C. pratensis* seedlings, rosettes, and bolting plants after 2 years of treatment at Spur Road. Bars are means ± 1 S.E.

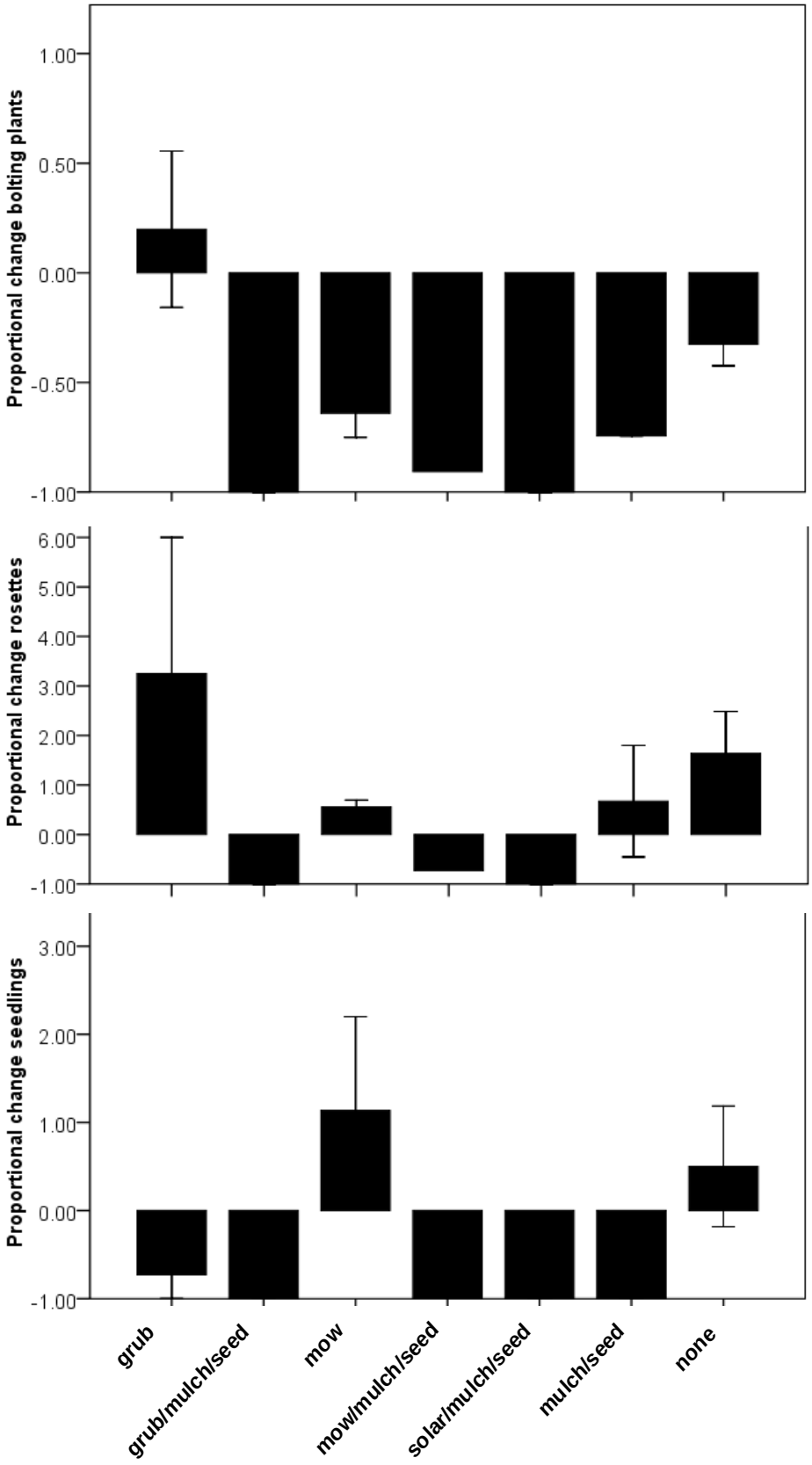

Figure 9. Proportional change in *C. pratensis* seedlings, rosettes, and bolting plants after 2 years of treatment at Fire Station. Bars are means ± 1 S.E.

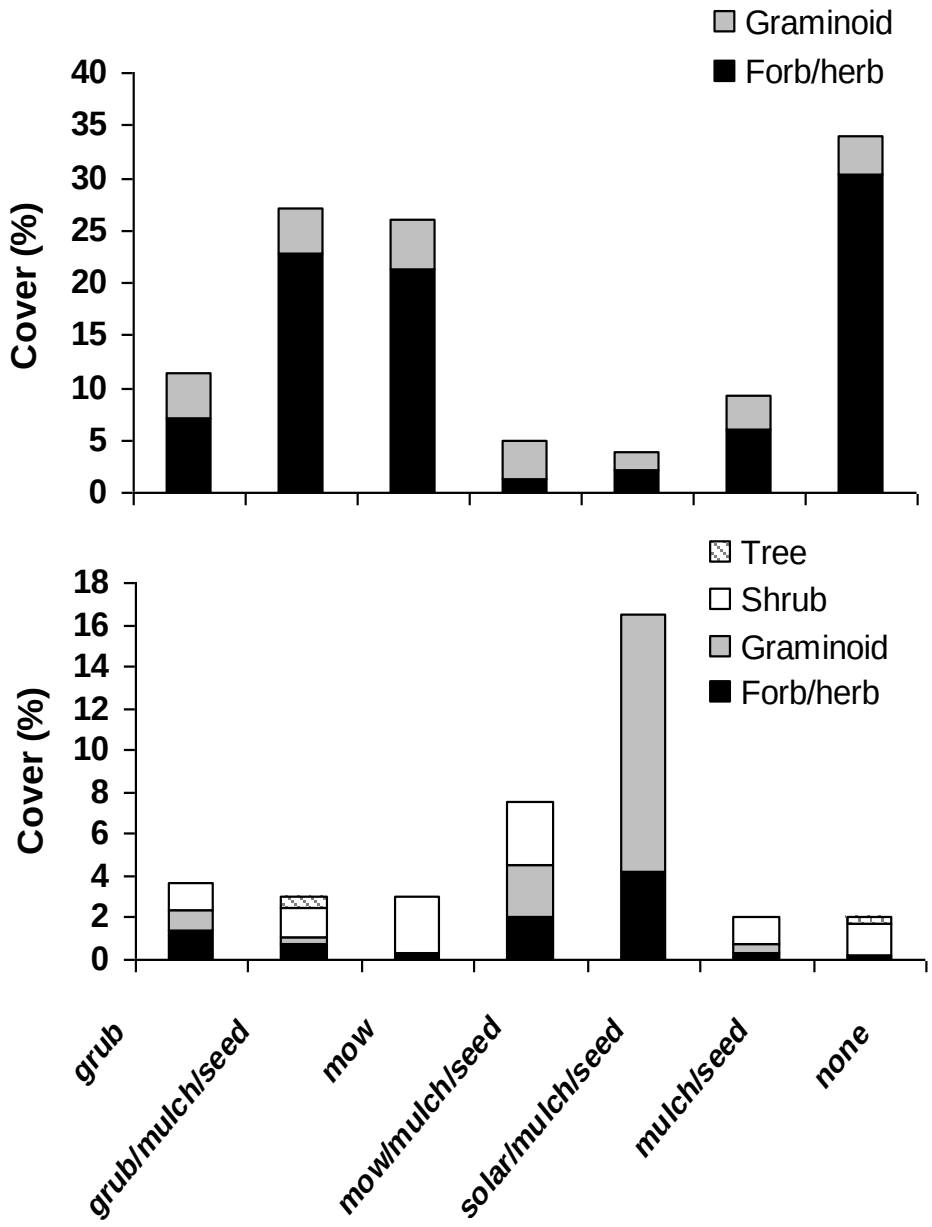

Figure 10. Total cover of introduced (top) and native (bottom) species in each growth form class at the Spur Road. Introduced species does not include meadow knapweed.

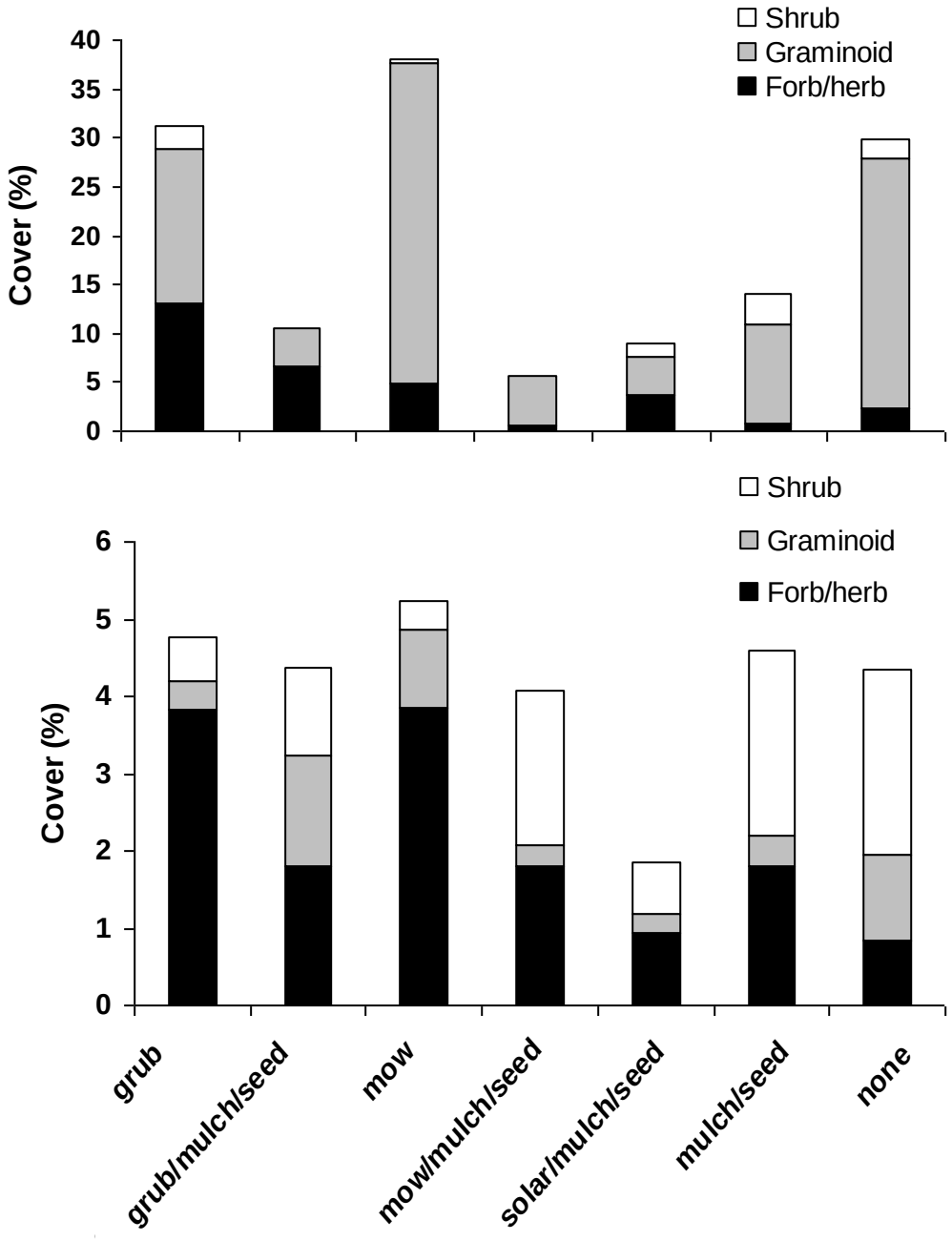

Figure 11. Total cover of introduced (top) and native (bottom) species in each growth form class at the Fire Station. Introduced species does not include meadow knapweed.

Figure 12. Fire Station control plots in 2007 (top) and 2009 (bottom).

Figure 13. Grub (top) and Grub/mulch/seed (bottom) plots at Fire Station, 2009.

Figure 14. Mow (top) and Mow/mulch/seed (bottom) plots at Fire Station in 2009.

Figure 15. Solarized plot at Fire Station, 2009.

Table 3. Change in cover from 2007 to 2009 for seeded species at Fire Station. Although seeded, *Achillea millefolium* and *Danthonia californica* were not observed.

Treatment	*Bromus sitchensis*	*Elymus glaucus*	*Epilobium densiflorum*	*Lotus micranthus*	*Prunella vulgaris*
none	-2.5	1	0	0.1	-2.5
grub	0.5	0	0	0.2	0
mow	2.5	5	0	0.2	-2
grub/mulch/seed	0	7	0	0.1	-4.5
mow/mulch/seed	-2	1	5.5	0.1	-4
solar/mulch/seed	-0.5	1	5.5	0.1	0
mulch/seed	-1	1	0	0	-1

Table 4. Change in cover from 2007 to 2009 for seeded species at Fire Station. Although seeded, *Achillea millefolium, Bromus sitchensis, Danthonia californica,* and *Epilobium densiflora* were not observed.

Treatment	*Elymus glaucus*	*Lotus micranthus*	*Prunella vulgaris*
none	1	0.5	0
grub	7	5.5	3.6
mow	0	1	0.1
grub/mulch/seed	1.1	3.1	1.1
mow/mulch/seed	12.2	4.7	6.5
solar/mulch/seed	58	9	10
mulch/seed	1.1	1.2	0.1

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APPENDIX A. DIRECTIONS AND CONTACTS.

Directions

Take 99S to Monroe, turn right on Territorial Highway.
At intersection, turn right on Highway 36.
Turn right on Horton Road.

To Fire Station plots
Follow Horton Rd. to Y-intersection with High Pass Rd. Plots are located in field at Y next to Fire Station. Park in Fire Station lot.

To Roadside plots
At Fire Station, stay left on Horton Rd. At the market, turn right onto Lake Creek Rd.
At the beginning of the lake, turn right onto Rd. 15-7-26
Right onto 15-6-19.1

Contacts

Horton Fire Station
Erik Goetsch, Assistant Chief, Lake Creek Fire-Rescue
captain2602@yahoo.com
call (all call's) 541-914-3934

BLM Eugene
Theresa Coble, South Valley Resource Area Manager, 541-683-6257
Nancy Sawtelle, Botanist, 541-683-6111

APPENDIX B. TREATMENT ASSIGNMENTS AT FIRE STATION AND SPUR ROAD SITES

Fire Station				
Plots	**Meter**	**2007 Treatment**	**2008 Treatment**	**2009 Treatment**
1	0-2	*solar*/mulch/seed[1]	solar/*mulch/seed*[1]	solar/*mulch/seed*[1]
2	2-4	mow	mow	mow
3	4-6	mulch/seed	mulch/seed	mulch/seed
4	6-8	none	none	mow[2]
5	8-10	mulch/seed	mulch/seed	mow[2]
6	10-12	mow	mow	mow[2]
7	12-14	none	none	none
8	14-16	grub/mulch/seed	grub/mulch/seed	grub/mulch/seed
9	16-18	grub	grub	grub
10	18-20	grub/mulch/seed	grub/mulch/seed	grub/mulch/seed
11	20-22	*solar*/mulch/seed[1]	*solar*/mulch/seed[3]	solar/*mulch/seed*[1,3]
12	22-24	mow	mow	mow
13	24-26	mulch/seed	mulch/seed	mulch/seed
14	26-28	grub/mulch/seed	grub/mulch/seed	grub/mulch/seed
15	28-30	grub/mulch/seed	grub/mulch/seed	grub/mulch/seed
16	30-32	none	none	none
17	32-34	none	none	none
18	34-36	*solar*/mulch/seed[1]	solar/*mulch/seed*[1]	solar/*mulch/seed*[1]
19	36-38	mow/mulch/seed	mow/mulch/seed	mow/mulch/seed
20	38-40	grub	grub	grub
21	40-42	grub	grub	mow[2]
22	42-44	mow/mulch/seed	mow/mulch/seed	mow[2]
23	44-46	mow	mow	mow[2]
24	46-48	mow/mulch/seed	mow/mulch/seed	mow[2]

[1]solar/mulch/seed plots were solarized in 2007 and mulched and seeded in 2008 and 2009

[2]unintended treatment

[3] Half of plastic sheet blew up between August 2007 and July 2008. Meadow knapweed plants continued growing in the uncovered portion and hence the plot was mowed resolarized again in 2008.

Spur Road				
Plots	**Meter**	**2007 Treatment**	**2008 Treatment**	**2009 Treatment**
1	0-2	mow/mulch/seed	mow/mulch/seed	grub[1]
2	2-4	mow	mow	grub[1]
3	4-6	grub/mulch/seed	grub/mulch/seed	grub/mulch/seed
4	6-8	mow	mow	mow
5	8-10	grub	grub	grub
6	10-12	grub	grub	grub
7	12-14	mow	mow	mow
8	14-16	mow/mulch/seed	mow/mulch/seed	mow/mulch/seed
9	16-18	grub/mulch/seed	grub/mulch/seed	grub/mulch/seed
10	18-20	mulch/seed	mulch/seed	mulch/seed
11	20-22	*solar*/mulch/seed [2]	solar/*mulch/seed*[2]	solar/*mulch/seed*[2]
12	22-24	grub	grub	grub
13	24-26	none	none	none
14	26-28	mow	mow	mow
15	28-30	none	none	none
16	30-32	none	none	none
17	32-34	mulch/seed	mulch/seed	mulch/seed
18	34-36	mow/mulch/seed	mow/mulch/seed	mow/mulch/seed
19	36-38	*solar*/mulch/seed [2]	solar/*mulch/seed*[2]	solar/*mulch/seed*[2]
20	38-40	*solar*/mulch/seed [2]	solar/*mulch/seed*[2]	solar/*mulch/seed*[2]
21	40-42	grub	grub	grub
22	42-44	mow/mulch/seed	mow/mulch/seed	mow/mulch/seed
23	44-46	none	mow (1x)[1]	none
24	46-48	grub/mulch/seed	grub/mulch/seed	grub/mulch/seed
25	48-50	none	mow (1x)[1]	none

[1]unintended treatment

[2]solar/mulch/seed plots were solarized in 2007 and mulched and seeded in 2008 and 2009