Demography and Management of Willamette Daisy (*Erigeron decumbens*)

2014

Report to the U. S. Fish and Wildlife Service (Phase 3 Progress Report)

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PREFACE

This report is the result of an agreement 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.

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Cover photograph: *Erigeron decumbens* at Finley National Wildlife Refuge

REFERENCE

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

In 2011 and 2013 Institute for Applied Ecology outplanted at total of eight populations (4 in 2011 and 4 in 2013). In each year, two plots were outplanted in both the Eugene and Corvallis West Recovery Zones. Survivorship was measured for each population and plots then received a variety of management treatments to evaluate the response of both the daisy and the surrounding plant community to management treatments. Measurements of plant vigor, as well as the plant community were taken annually, and are reported here.

Willamette Daisy Response to Treatment:
Results indicate that treatments for plants outplanted in 2011 had no significant effect on survivorship; indicating that well timed (and even aggressive) management treatments may be an effective tool for managing Willamette daisy. There were however, significant effects on plant size, reproduction and recruitment which indicate that Burn + Glyphosate increased both plant size and reproductive effort. Additionally the highest number of recruits were found in the Burn + Glyphosate plots at Field 29, (Finley, Corvallis West Recovery Zone.)

In 2014, 25 of the 75 plants originally outplanted in the Burn + Glyphosate plots at Field 29, had produced recruits, and the number of recruits at this site (289) is as high (or greater) than the number of plants surviving in introductions included as a part of this study. Recruits were also noted in the Glyphosate only plots as well as in the mowed plots at Kirk East.

Plant Community Response to Treatment:
Despite the apparent lack of effect on Willamette daisy survivorship, the effects of management treatments on the plant community varied by site. While the response of plant community varied by site (and starting condition), the most successful treatments for decreasing invasive forb, invasive graminoid and woody/shrubby species cover was the Burn + Glyphosate treatment (followed by mowing, glyphosate only and carbon addition).

Plots that were dominated by invasive forbs (dominantly *Hypochaeris*) responded positively to carbon addition with significant decreases in invasive forb (and less so invasive graminoid) cover following treatment. This response was similar to that observed in the glyphosate only plots, where treatments also decreased cover of invasive forbs.

INTRODUCTION

Figure 1. Flowering Willamette daisy planted at Finley National Wildlife Refuge in April 2011.

Willamette daisy (*Erigeron decumbens;* Figure 1) is listed as an endangered species under the Oregon and federal Endangered Species Acts (ORBIC 2010). Without direct intervention, its prospects for recovery are poor. The majority of populations are small, isolated, and found on unprotected lands. Further, natural recruitment is low due to competition with invasive weeds, altered disturbance regimes, and possible genetic issues (Thorpe and Kaye, *in press*). In the *Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington* (USFWS 2010), both invasive species and improper prairie management were identified as important threats to Willamette daisy. Although management practices such as mowing, grazing, burning, thatch removal, and selective use of herbicides can be useful techniques to maintain prairie habitats and discourage invasive species (Pfeifer-Meister et al. 2007, Boyer 2008; Stanley et al. 2008; Stanley et al. 2010), applying these treatments in the wrong season and/or with the wrong frequency can have detrimental impacts on native prairie species. Unfortunately, we currently have little information on how Willamette daisy responds to various management activities. ***The goal of this project is to combine careful demographic studies with experimental habitat management treatments in order to provide information on effective management of this species.***

Management treatments

Mowing and prescribed fire are the two management techniques most commonly used to maintain habitat occupied by Willamette daisy. However, there is little data on the effects of these treatments on birth and death rates of the species. In a five-year study at Oxbow West, we found that compared to control plots, there tended to be fewer, but larger plants in plots that had been mowed every-other-year or burned (Thorpe and Kaye 2007). There also tended to be fewer capitula per plant in the mowed plots, suggesting that management techniques might not always have positive effects on the species. However, active management is required in most prairies to reduce the cover of invasive and woody plant species (Noss et al. 1995, Floberg et al. 2004). The focus of this study is to ***determine habitat management techniques that will reduce the cover of invasive and woody plant species while maintaining or enhancing the cover of native species, including Willamette daisy.***

We will test the effectiveness of mowing, prescribed fire + glyphosate, glyphosate only (Finley only), sheep grazing, grass-specific herbicide [Fusilade™ (Fluazifop)], and carbon addition

as habitat management techniques in habitat occupied by Willamette daisy. Thatch removal had originally been identified as a potential treatment; however thatch levels at the sites selected for this project were not sufficient to warrant this treatment. Several of these management techniques have previously been found to be effective in enhancing cover of native prairies species in the Willamette Valley/Puget Sound/Georgia Basin ecoregion (Kirkpatrick et al. 2006; Pfeifer-Meister et al. 2007; Boyer 2008; Stanley et al. 2008; Stanley et al. 2010).

Conducting these experiments in natural populations of Willamette daisy provides the best test of how Willamette daisy populations respond to management treatments. However, few populations are large enough to allow for a replicated study and agency regulations limit the scope of treatments that can be applied. For this study, we introduced populations of Willamette daisy in eight macroplots at six sites to test habitat management treatments: two sites at Finely National Wildlife Refuge, each with two macro plots (USFWS), 3 sites at Fern Ridge Natural Area (ACOE), and one site owned and managed by the City of Eugene.

Demographic monitoring

A second objective of this study is to improve our understanding of Willamette daisy population demography. We will use demographic monitoring to determine the effects of habitat treatments on birth and death rates of Willamette daisy. Monitoring will occur in 2011-2015. In the introduced populations, we will record the size (length, width, and height) and reproductive status of each individual. This protocol was followed to monitor the Willamette daisy population at Oxbow West in the West Eugene Wetlands for eight years (Thorpe and Kaye 2007). Each year, we will also survey the area surrounding previously reproductive individuals to evaluate seedling establishment. All individuals will be mapped and assigned unique numbers in order to track yearly changes in individual characteristics and estimate birth and death rates. We will note the presence or absence of grazing for each individual.

In 2011, we also conducted monitoring at several introduced and natural populations throughout the Willamette Valley. The intent of this project is to determine (1) recruitment of new Willamette daisy individuals into introduced populations, and (2) factors impacting recruitment rates. This research was conducted as a MS thesis by Katie Gallagher, at Oregon State University (Gallagher 2012).

METHODS

Plugs for outplanting were produced in fall 2010 – spring 2011 using seed from two Recovery Zones, Corvallis West (Allen and Allen/Muddy Creek), and Eugene West (Balboa and Oxbow West populations). In September of 2010, seeds were placed in germination trays and then placed into 16 weeks of cold stratification at 6°C. Seeds were checked weekly and misted with distilled water to keep them moist. If any mold was present, damaged seeds were removed and a solution of distilled water and hydrogen peroxide was sprayed on the seeds. The seeds were removed from cold stratification and placed in a room with a 25 ^{o}C day / 15 ^{o}C night temperature cycle and 8 h day / 16 h night lighting cycle one week prior to planting into conetainers. Plants were planted into conetainers 3.81cm wide and 13.97cm deep in trays of 98 and kept at the OSU West Greenhouse. Pots were filled with Gardner's Gold potting soil and placed in a greenhouse maintained at 21^{o}C during the day and 13^{o}C at night with 14 hour daily

artificial light provided by Sun System 3 - 400 HPS bulbs. Pots were watered from the bottom 1-4 times per week as necessary. An 8-8-8 fertilizer was sprayed weekly on the plants and then rinsed off to prevent burnt leaves. At approximately eight weeks, the plants were inoculated with nematodes to prevent fungus gnats from attacking the young plants. One week prior to outplanting, all pots were placed outside to harden-off. This procedure was repeated for plants grown for the 2013 outplanting with little variation.

Outplanting

In April 2011, 900 plants were outplanted at Finley National Wildlife Refuge (Finley); 450 each in Field 29 and Field 8 North (Appendix A). Finley is located approximately 16 km south of Corvallis, Oregon, in the Benton West Recovery Zone (USFWS 2010). Historical records indicated that this Refuge once hosted a Willamette daisy population, but the population has not been observed in 20 years. In 2007 and 2008, Willamette daisy was introduced to four sites at Finley, including 174 at Field 29. Plots for this experiment were located approximately 30m from the 2007 and 2008 introductions. Field 29 and Field 8 North were selected because of their relatively low cover of exotic plants, general habitat suitability for Willamette daisy, and ease of access for management. Both sites have been under active restoration and management (including herbicide treatments, mowing, and seeding) by USFWS.

At each site three 14m x 22m blocks were marked with rebar pounded flush with the ground and topped with an orange cap. The three blocks are adjacent, and the NW corner of the 'metablock' was marked with a T-post. Within each block there were six 6m x 6m treatment plots, marked with 8" nails pushed flush with the soil surface and capped with marking whiskers. There is a two meter buffer between each treatment square. Willamette daisy plugs were planted along a 5m x 5m grid in the center of each treatment plot (25 plants per plot).

In April 2011, 716 plants were outplanted at Fern Ridge Natural Area, 360 at Applegate and 356 at Kirk NE (Appendix B). Fern Ridge Natural Area is located approximately 60km south of Corvallis, Oregon in the Eugene West Recovery Zone (USFWS 2010), and is managed by the Army Corps of Engineers (ACOE). Applegate and Kirk East were selected because of habitat suitability for Willamette daisy and ease of access for management. Both sites have been under active restoration and management including mowing and invasive weed removal by the ACOE.

144 plants from the ACOE were used in the outplanting in addition to the plants grown by IAE. Four of these plants and 16 of the plants grown by IAE were planted per plot. Although the plants from the ACOE were smaller, they had robust root structure. At each site, three 14m x 38m blocks were marked with fiberglass poles at each corner. Within each block, there was six 6m x 6m treatment plots, marked with 8" nails topped with marking whiskers. Due to low germination and survival of Eugene West plants in the greenhouse, we had to reduce both the number of individuals planted in each plot and the number of treatments. Thus, one of the seven blocks was randomly excluded from planting. In the remaining treatment plots, Willamette daisy plugs were planted along a 5m x 5m grid in the center of each treatment plot, with the exception that one row or column was skipped so that 20 plants were in each square. Each block also contained a 14m x 14m grazing plot; within this plot, plugs were also planted along a 5m x 5m grid in the center of each treatment plot, with the exception that a one row or column was skipped so that 20 plants were in each square.

In spring 2013, an additional four sites were selected for outplanting: A total of 450 plants were outplanted at each site in 2013. At Finley National Wildlife Refuge, in the Corvallis West Recovery Zone, plots were added adjacent to the existing blocks outplanted in 2011 at Field 8N and Field 29. In the Eugene West Recovery Zone, two additional sites were selected including Big Spires (ACOE) and Atlantic/Pacific, managed by the City of Eugene; 450 plants were outplanted at each site (a total of 900 plants) (Table 1). In 2013, we used the same plot design and outplanting procedures established in 2011.

Table 1. Sites outplanted with Willamette daisy in 2011 and 2013.

Recovery Zone	**Land Manager**	**Site name**		**Year outplanted**	**Number outplanted**
Corvallis West	USFWS	Finley	Field 8 N	2011	450
			Field 8 N	2013	450
			Field 29	2011	450
			Field 29	2013	450
Eugene West	ACOE	Kirk East		2011	356
		Applegate		2011	360
		Big Spires		2013	450
	City of Eugene	Atlantic/Pacific		2013	450

Table 2. Management treatments tested in the course of this study.

Treatment	Treatment Notes/Motivation
Control	-
Burn + Glyphosate	Previous work has shown that in a short window post-burn dormancy non-native species are green, while native species remain dormant, thus a broad spectrum herbicide can be used to target dominantly weedy species.
Glyphosate Only (Corvallis West only)	Glyphosate was applied in a 3% solution in the fall at the same time that the 'burn + glyphosate' treatment occurred.
Grass Specific Herbicide	Fusilade was used in this study and applied at the recommended application rate of 1 oz/acre.
Mowing	Treatment occurred in the fall with mowing to a height of 2-6". Mowing equipment utilized included tractors and weedwhackers.
Carbon Addition	Sucrose addition activates soil microbes which ultimately results in decreased availability of ammonium and nitrate in the soil. Preliminary work by IAE as well as other researchers has shown that these carbon treatments tend to have a greater negative impact on non-native species. Carbon was applied at a rate of 2 kg/m2 in Feb/March of 2012 and 2014.
Grazing (Eugene West only)	Up to 60 sheep were grazed for 12-36 hours in the 14m x 14m grazing blocks.
(Thatch removal)	(Thatch was not an issue at the sites selected, thus this treatment was not implemented.)

Treatments

The habitat management treatments tested include: mowing, prescribed fire + glyphosate, glyphosate only (Finley only), sheep grazing (Fern Ridge only), grass-specific herbicide (Fusilade), and carbon addition. Thatch removal had originally been identified as a potential treatment; however thatch levels at the sites selected for this project were not sufficient to warrant this treatment. Several of these management techniques have previously been found to be effective in enhancing cover of native prairies species in the Willamette Valley/Puget Sound/Georgia Basin ecoregion (Kirkpatrick et al. 2006; Pfeifer-Meister et al. 2007; Boyer 2008; Stanley et al. 2008; Stanley et al. 2010).

Mowing

Mowing was performed in September 2011, 2012, 2013. The sites were evaluated in February 2012, 2013, and 2014 and it was determined that a second mowing treatment was not necessary. At Fern Ridge, mowing was performed by ACOE staff with a tractor. At Finley, and city of Eugene, the plots were mowed with a weedeater. Fall mowing reduces thatch accumulation and cuts back fall-growing grasses. Mowing height was 2-6"; plant material was left on site (Figure 2).

Figure 2. Mow plots at Finley, Field 29 (left) and Fern Ridge, Applegate (right). At both sites mowing occurred in mid-September.

Sheep Grazing (Fern Ridge only)

Sheep grazing occurred in the 14m x 14m treatment plots in October 2011, on plots outplanted in 2011. The treatment was repeated in the fall of 2013. Plots outplanted in 2013 were grazed in the fall of 2013. While most native species are dormant in October, several exotic species are green this time of year, which potentially gives them a competitive advantage the following spring. Approximately 60 sheep were placed in each of the grazing plots until there was no longer suitable forage (12 to 16 hours).

Figure 3. Sheep grazing at Applegate. Sixty sheep were placed in each 14m x 14m grazing plot for 12-36 hours.

Grass-specific Herbicide

A grass-specific herbicide [Fusilade™, (Fluazifop)], was applied in early November (2011-2013) at a rate of 28oz./acre to treatment plots at Fern Ridge, Finley and City of Eugene to reduce abundance of exotic grasses.

Figure 4. Glyphosate application to a burned plot at Finley, Field 8 (left) and grass-specific herbicide at Finley, Field 29 (right).

Burning + Glyphosate

Burning at Finley occurred on September 20th, 2011 (Figure 5) and the spray of glyphosate (Aquamaster™) occurred one month post-burn with a concentration of 3%. The sites were evaluated two weeks post-burn and there had not yet been significant resprout of invasive species. At the time of herbicide treatment, one month post-burn, vegetation was dominated by invasive species. Burning (and subsequent spraying) at Applegate and Kirk east occurred in the Fall of 2012, and in 2013 at Big Spires and Atlantic Pacific. Treatment plots at Finley were also burned and sprayed in the fall of 2013 (both the plots planted in 2011 and 2013). Fall burning reduces biomass and thatch accumulation and post-burn glyphosate (a broad-spectrum herbicide) application reduces abundance of broad-leaf weeds. This last treatment was developed based on observations that non-native species resprout more quickly after fire than do most native species.

Figure 5. Burned plot at Finley Field 8, September 2012.

Glyphosate (Finley only)

A broad-spectrum herbicide treatment was implemented in late fall at the Finley sites in 2011, 2012, and 2013. Because most native plants are dormant at this time this spray is expected to target mostly non-native species. A 3% solution of glyphosate (Aquamaster™) was applied to selected treatment plots.

Carbon Addition

In March 2012 (4 sites) and March 2014 (8 sites), we spread 2 kg of carbon m^{-2} (in the form of sucrose) on selected test plots. Carbon addition limits the amount of soil nutrients available for plant growth (particularly nitrogen and phosphorus) by stimulating microbial activity. Several studies have indicated that native species are more capable of tolerating low nutrient conditions than exotic species (Morgan 1994, Reever Morghan and Seastedt 1999, Alpert and Maron 2000, Blumenthal et al. 2003, Kirkpatrick *et al. unpublished data*).

Survivorship and Vigor Monitoring

Survival and growth of all plants was monitored in June 2011-2014. For each individual, we measured the widest diameter (the outermost part of an individual, including flowers), the diameter perpendicular to the widest diameter, height, and number of capitula (flower heads). The shape of each plant was assumed to be oval, and the maximum diameter and perpendicular diameter were used to calculate the elliptical crown cover of each plant as per equation 1.

Equation 1. Elliptical crown cover = (0.5*widest diameter) * (0.5*perpendicular diameter) * π

Data Analysis

ANOVA procedures, using JMP Statistical software (SAS 2013), were conducted to determine the effect of each treatment on survivorship, flower number, and ellipse size of Willamette daisy. We tested for effects of site on treatment and when significant effects were found, individual ANOVAs were conducted for each site. We used Tukey's HSD multiple comparisons test to evaluate the differences among treatment means. Count data were log (x + 1) transformed to meet ANOVA assumptions prior to analysis. Nontransformed data are presented throughout the report.

RESULTS

Survivorship in 2014 of all plants outplanted in 2011 (independent of treatment or site) was 57% (range 40% at Applegate to 88% at Field 29). The survivorship of plants outplanted in 2011 into control plots are listed in Table 3 and ranged from 39%-94%.

Survivorship of all plants outplanted in 2013 was generally lower than those outplanted in 2011, with an average of 53% of plants surviving into 2014 (with a range by site of 41% - 63%). Field 29 had the highest survivorship (for both 2011 and 2013 outplantings), while Big Spires had lowest survivorship of 2013 outplantings. Survivorship in control plots of plants outplanted in 2013 are listed in Table 3.

The areal cover of plants varied by site, particularly in the first year; plants were larger at the Finley sites than at Fern Ridge (Figure 8). This was not unexpected; in 2011, the Fern Ridge plants were smaller at the time of outplanting. In general plants from Field 29 were significantly larger than those from Finley Field 8N. An undergraduate student, Emily Day, from the OSU Honors College will be investigating potential soil effects with a greenhouse study underway as of spring 2014. [The results from this study will be available in June 2015. Preliminary results suggest that there is a soil component which makes Field 29 more successful than Field 8N, and these differences are not related to any measured soil characteristics (macronutrients, organic material, pH, composition). It is theorized that there may be a biological component that leads to greater reproductive success at Field 29.]

In the Corvallis West Recovery Zone sites, plants at Field 29 had higher survivorship, were consistently larger, and produced more flowers than plants in Field 8N (independent of year outplanted). For plots planted in 2011, survivorship in 2014 at Field 8N was 64% in controls as

compared to 94% in Field 29, three years after outplanting. Plants outplanted in the same sites in 2013 had lower survivorship, however still remained relatively high with 65% and 78% in Field 8N and Field 29 respectively.

Survivorship of outplanted individuals was slightly lower in the Eugene West Recovery Zone (range 39-72%) in both 2011 and 2013 when compared to the Corvallis West Recovery Zone. Control plots from 2011 outplantings in the Eugene West Recovery Zone having 39%-56% survival, and 2013 control plots (53-72%).

Plants from the Corvallis West Recovery Zone were larger and produced more capitula than plants in Eugene West Recovery Zone (Table 3, Figure 10). In the Eugene West Recovery Zone, plants at Kirk East were consistently larger than those at Applegate (Table 3,Figure 11).

Table 3. Table of the number of plants, survivorship and flowering plants at each site (in control plots). Data collected July 2011 (approximately 3 months after outplanting), June 2012, and 2013, 2014.

Year outplanted	**Site Name**	**2011 # surviving**	**2014 # surviving**	**% survivorship in 2014**	**# flowering**	**# of flowers**	**Average flowers /plant**	**Average Ellipse size (cm2)**
	Field 8N	69	44	64%	19	36	1.89	75.5
	Field 29	70	66	94%	44	492	11.18	166.1
	Applegate	57	22	39%	13	115	8.85	120.3
2011	Kirk East	54	30	56%	12	35	2.92	86.5
		2013 # surviving	**2014 # surviving**	**% survivorship in 2014**	**# flowering**	**# of flowers**	**Average flowers /plant**	**Average Ellipse size**
	Field 8N	72	47	65%	3	3	1	40.2
	Field 29	72	56	78%	10	27	2.7	52.1
	Atlantic-Pacific	72	52	72%	13	26	2	47.7
2013	Big Spires	75	40	53%	1	1	1	31.1

Treatment Effects on Willamette Daisy

Survivorship

In plots outplanted in 2011 survivorship varied by site, however there were ***no statistically significant differences among treatments on the survivorship of Willamette daisy.*** In 2013 plots there was less variability in survivorship among sites, and thus treatment effects were statistically significant. Site by treatment interactions were not significant for either outplanting year (2011 P=0.4685 and 2013 P=0.8553), so treatment data were pooled among sites for each year.

Survivorship of individuals outplanted in 2011 and monitored in 2014 ranged from 48-67% in treatment plots in the Eugene West Recovery Zone, and 67%-89% in the Corvallis West Recovery Zone. The apparent lack of treatment effects on survival of Willamette daisy can be interpreted as an indication that though endangered, Willamette daisy can handle aggressive (but well-timed) management treatments without significant detrimental effects. Monitoring in 2015 will track longer term treatment effects on the daisies that may not yet be evident, particularly in the plots more recently outplanted in 2013.

Survivorship of individuals outplanted in 2013 and monitored in 2014 showed significant differences in treatment effects on survival. Survival of plants in the mowing and control plots had higher survival than the grazing, glyphosate, and burn + glyphosate treatments. The single application of Fusilade and carbon addition treatments had intermediate survival of Willamette daisy.

Average size of individuals outplanted in 2013 varied by site and treatment. The burn + glyphosate treatment at Field 29 and Applegate had significantly larger plants as compared to the other treatments. Treatment differences at Field 8 and Big Spires were more variable and likely will begin to show stronger differences in future years. Although not statistically significant at all sites, the carbon treatment resulted in smaller plants across sites.

Average size of individuals outplanted in 2011 varied among sites and treatments. The burn + glyphosate treatment at Field 8N and Field 29 were significantly larger when compared to the other treatments, including the control. The Fusilade treatment at Applegate resulted in significantly larger plants. Plants at Kirk East were not significantly different among treatments (Figure 8, Figure 9).

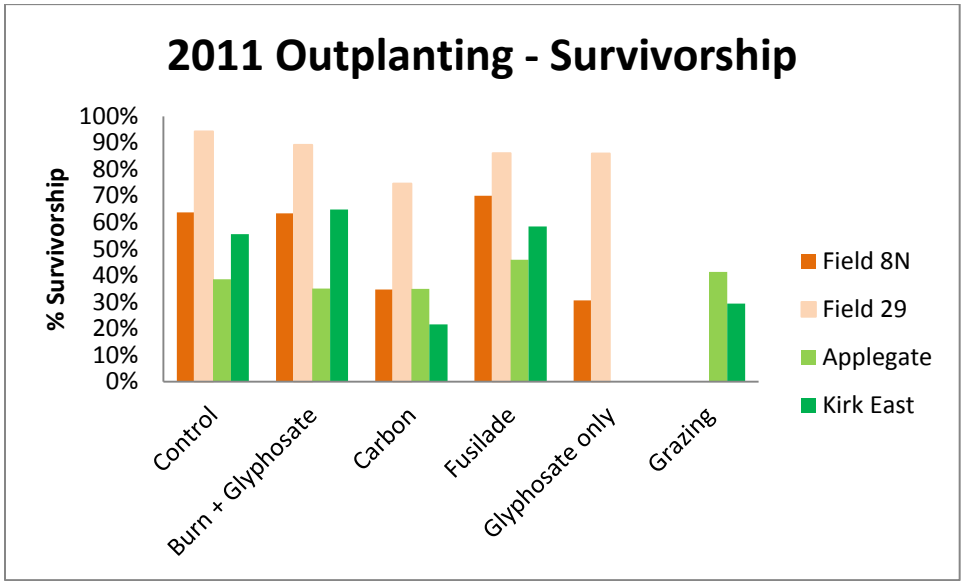


Figure 6. Survivorship of plants outplanted in 2011 by treatment.

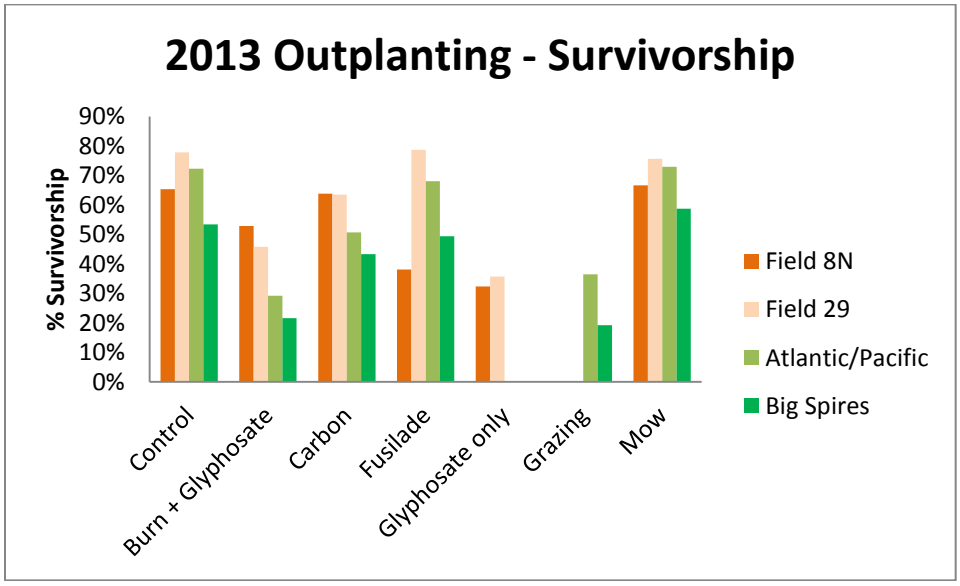


Figure 7. Percent survivorship from 2013-2014 in response to management treatments of plants outplanted in 2013.

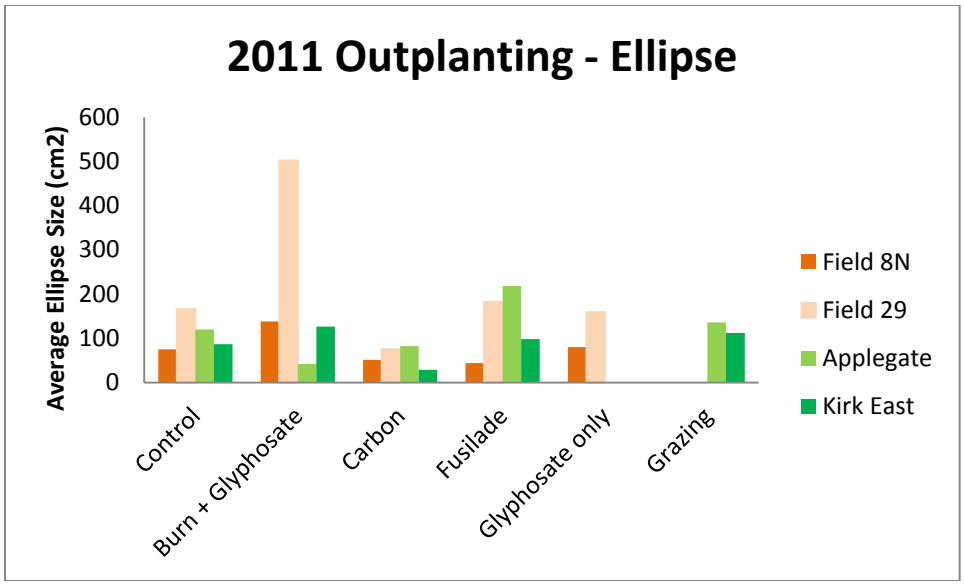


Figure 8. Average ellipse size by treatment for plants outplanted in 2011.

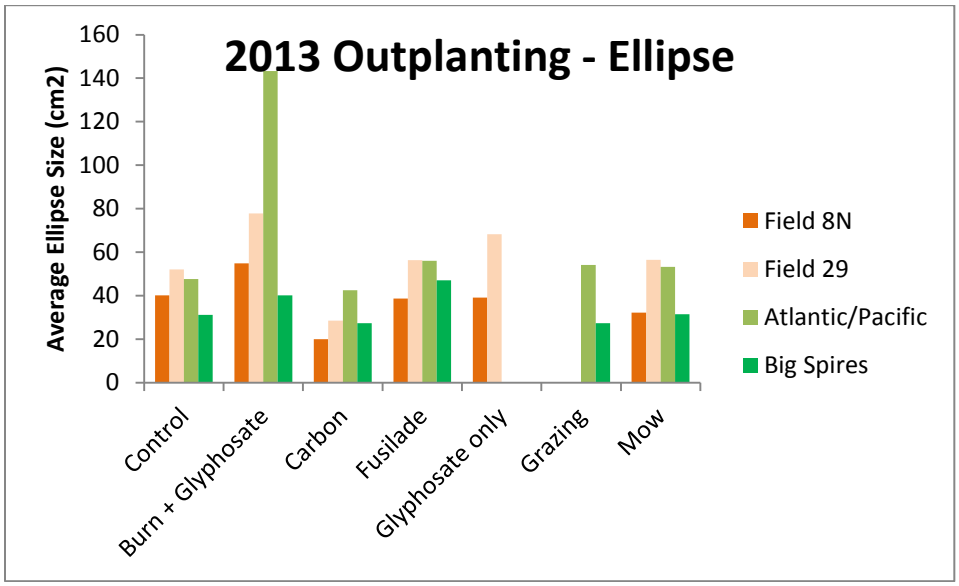


Figure 9. Average ellipse size by treatment of plants outplanted in 2013.

Reproductive Success

Number of Flowers

Monitoring of 2011 outplanted daisies in 2014 indicates that only one treatment at one site had a significant effect on the reproductive success of Willamette daisy; the Burn + Glyphosate treatment at Finley, Field 29 (Corvallis West Recovery Zone) had significantly more flowers than the control (Figure 10, Figure 11).

Monitoring of 2013 outplanted daisies in 2014 indicates that reproductive success was similar among sites and treatments. All sites and treatments had <6 flowers per plant. The lack of difference among treatments is likely due to age of the plants and future monitoring will reveal differences among treatments as they have been elucidated over time in the 2011 plots.

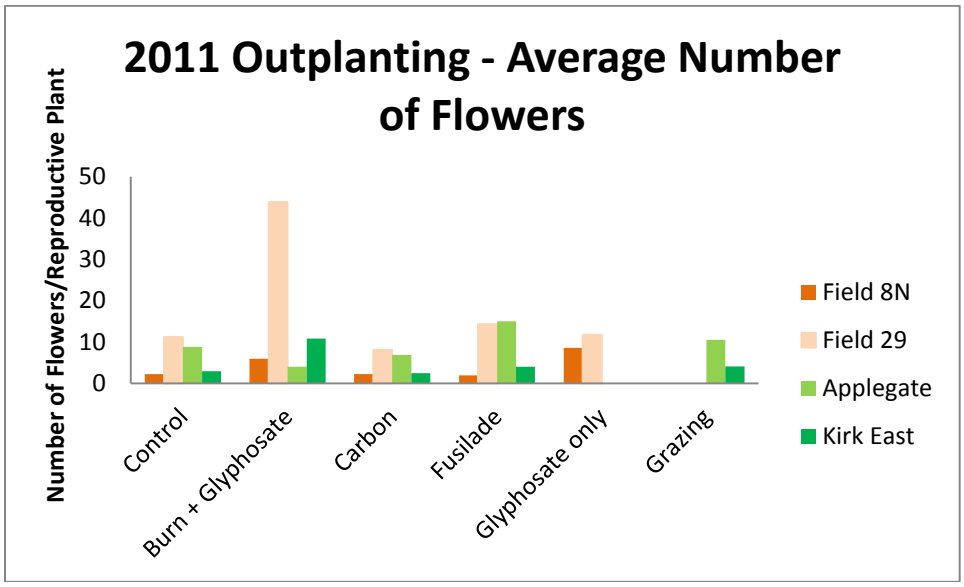


Figure 10. Average number of capitula per reproductive plant for plants outplanted in 2011 by treatment site.

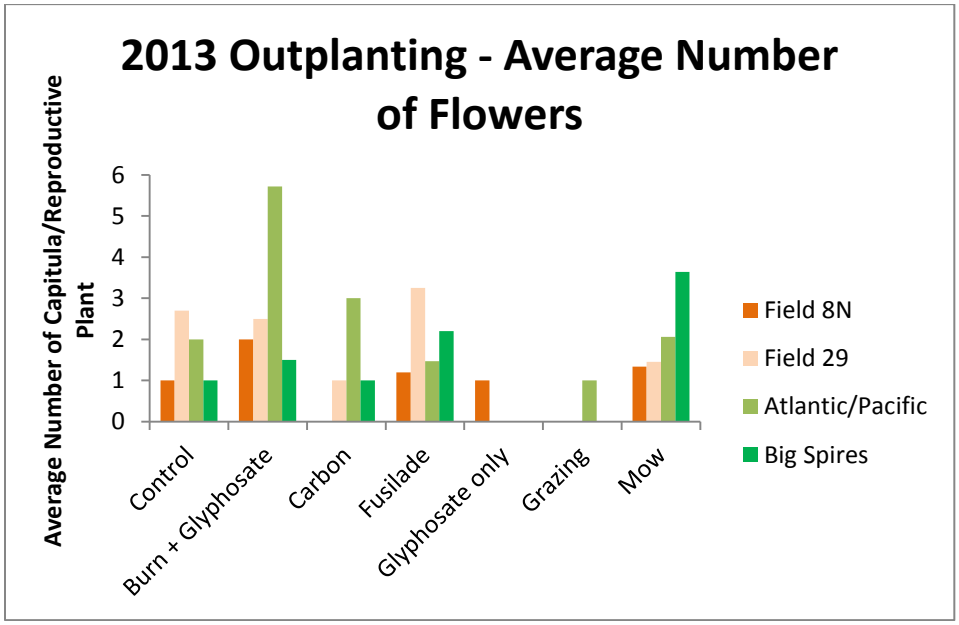


Figure 11. Average number of capitula per reproductive plant for plants outplanted in 2013 by treatment and site.

Recruitment

In 2014, there were 394 new Willamette daisy recruits noted (Table 4). A majority of these plants were from Field 29 (381), where recruits were noted in all treatments except the controls. Burn + Glyphosate had the most recruits at Field 29 (289) followed by the Glyphosate only treatment (82 recruits). In Field 8N, recruits were noted in the Burn + Glyphosate and Glyphosate only treatments.

In the Eugene sites, Kirk East and Applegate, only 5 recruits were counted in mowed plots. No recruitment was noted in plots outplanted in 2013 at any site, however it is expected that more recruitment will be observed in 2015 for these younger plots.

Table 4. Number of recruits and maternal plants observed in 2014. The number of "mother plants" indicates the number of outplanted individuals around which new plants were observed. Number of recruits/mother indicates the average number of recruits that were noted around each maternal plant by treatment.

	Number of "Mother" plants	**Number of recruits/mother**	**Number of recruits observed in each treatment**	**Total number of flowers on recruited plants**
Applegate				
Mow	1	1	**1**	0
Finley#29				
Burn + Glyphosate	25	11.6	**289**	11
Carbon	1	1	**1**	0
Fusilade	1	2	**2**	0
Glyphosate only	10	8.2	**82**	2
Mow	2	3.5	**7**	0
TOTAL Field 29	**39**	**9.7**	**381**	**13**
Finley#8				
Burn + Glyphosate	1	7	**7**	1
Glyphosate only	1	1	**1**	2
Kirk East				
Mow	2	2	**4**	0
Total Number of recruits in 2014	**44**	8.9	**394**	**16**

Treatment Effects on Plant Community

The initial site conditions differ between the Corvallis and Eugene sites. Sites at Finley Wildlife Refuge are dominated by invasive forbs and tend to have more annual invasive grasses whereas two of the sites at Fern Ridge (Applegate and Kirk East) are dominated by invasive perennial grasses, the third (Big Spires) is a near monoculture of native (seeded) *Festuca*. Atlantic-Pacific has a diverse mix of both native and invasive forbs and grasses, and some shrubby species. Below is an average of site conditions in 2012 for plots outplanted in 2011, followed by similar descriptions of plots outplanted in 2013.

The dominant vegetation at Fern Ridge (Applegate and Kirk East, Eugene West Recovery Zone) is invasive grasses with an average cover of 61.6% and invasive forb cover of 10.4%. Dominant invasive grasses at Fern Ridge include the perennial species *Anthoxanthum odoratum* and *Agrostis stolonifera* each with an average of 30% cover, additional invasive species include *Festuca arundinacea* and *Panicum occidentale*. Annual invasive grasses at Fern Ridge have very low cover. In 2012, native grass cover was only 9.2% with 5.4% represented by *Danthonia californica.* Average native forb cover at Fern Ridge is 5.7% and was dominantly attributed to *Fragaria virginiana* and *Aster hallii*. Invasive forb cover has an average of 10.4% cover and is dominated by *Hypochaeris radicata* (4.5%), *Plantago lanceolata* (2%) and *Leucanthemum vulgare* (1%). Tree and shrub cover is relatively high at the Fern Ridge sites with an average cover of 13.3%; dominant species include *Rosa sp.* (8%), *Cytisus scoparius* (2.2%) and *Rubus armeniacus* (2.2%) (Figure 12).

At Finley National Wildlife Refuge (Corvallis West Recovery Zone), the sites are dominated by invasive forb cover with an average of 63.2% and only 30.9% cover of invasive graminoids. Tree and shrub cover is relatively low with only 1.7% cover of mostly *Rubus armeniacus*. The dominant invasive forb species as at Finley is *Hypochaeris radicata*, with an average cover of 52.3%. Native forb cover is 15.8 % and is dominated by *Eriophyllum lanatum* (8.6%)*, Lupinus spp.* (3.9%), and *Potentilla gracilis* (2.0%). These trends are similar for the plots outplanted in 2013 with slightly higher values for *Lupinus* as the seeded species has matured (Figure 13).

At Big Spires the plant community is dominated by graminoids with dominant species being the native *Festuca roemeri (65%)* and the invasive *Agrostis stolonifera (50%)*. Native forb cover is low with only 3% cover (dominantly *Eriophyllum lanatum* and *Prunella vulgaris*), and invasive forbs make up 11% of plant cover (dominantly *Plantago lanceolata* and *Galium aparine*).

At Atlantic/Pacific, the plant community native graminoids make up 25% of the plant community and invasive graminoids 77%. Dominant native graminoid species include (), dominant invasive graminoid species include (). Cover of shrubby and woody species is 6%, and is dominantly *Rubus* and *Rosa spp.*

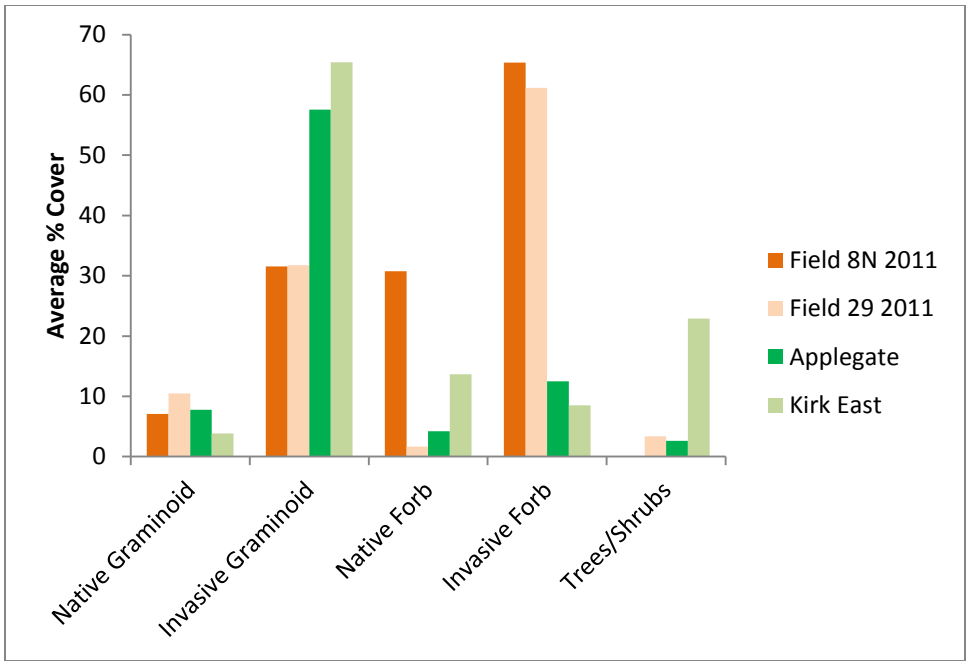


Figure 12. Average plant cover by functional group in 2012 for *Erigeron decumbens* outplanting sites in the Corvallis West (orange) and Eugene West (green) Recovery Zones. Note that the initial site conditions vary in each Recovery Zone.

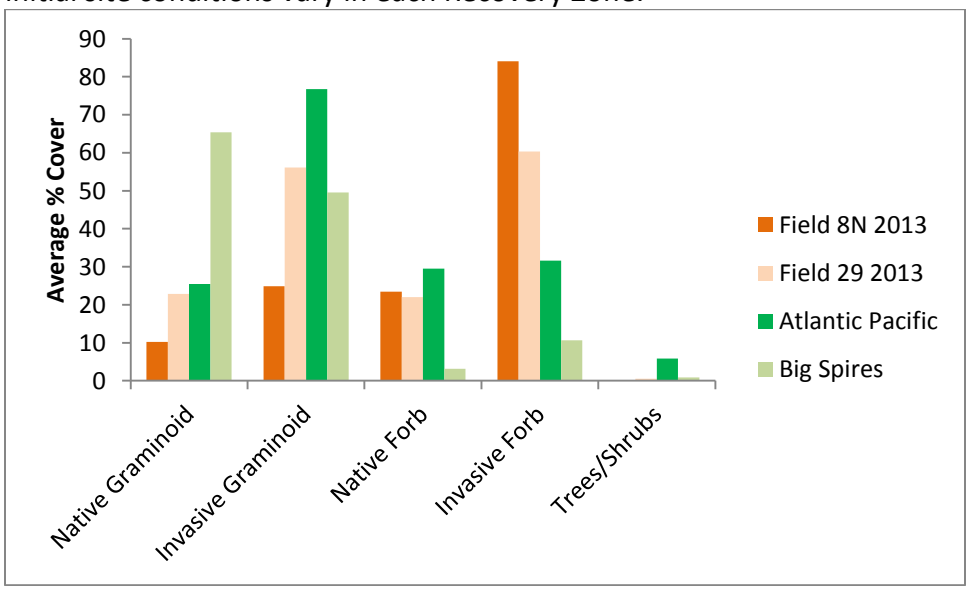
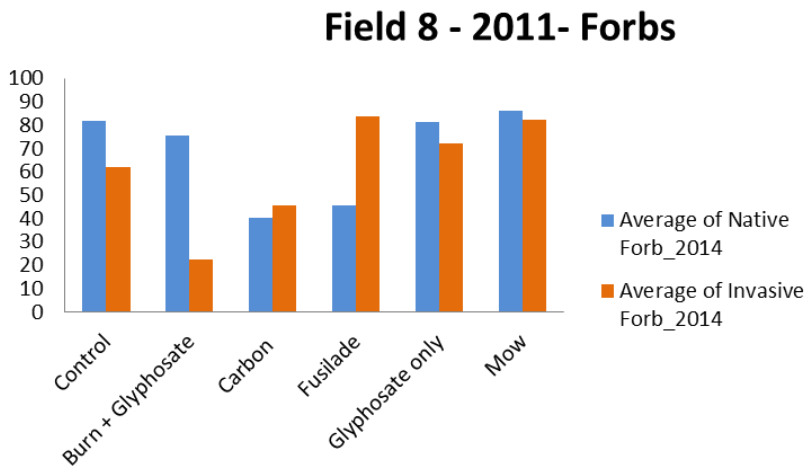
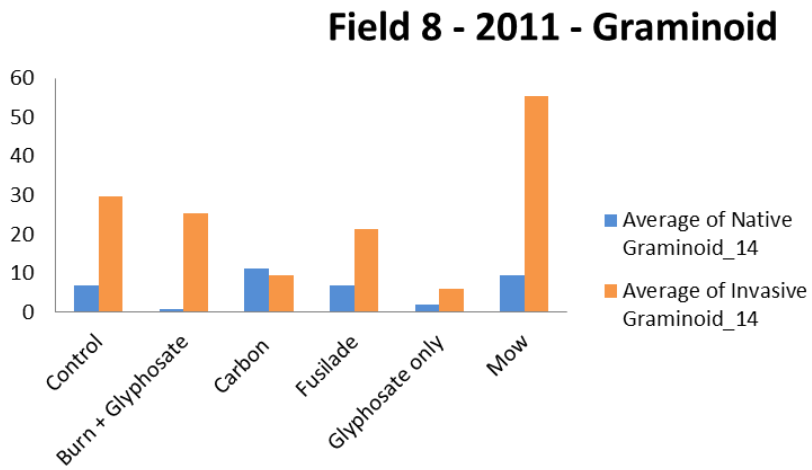
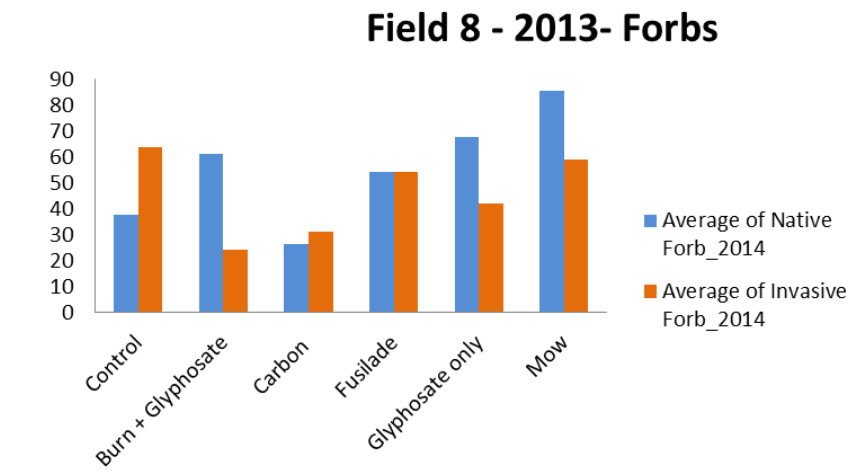


Figure 13. Average plant cover by functional group in 2013 for plots outplanted in 2013. Initial site conditions vary by site.







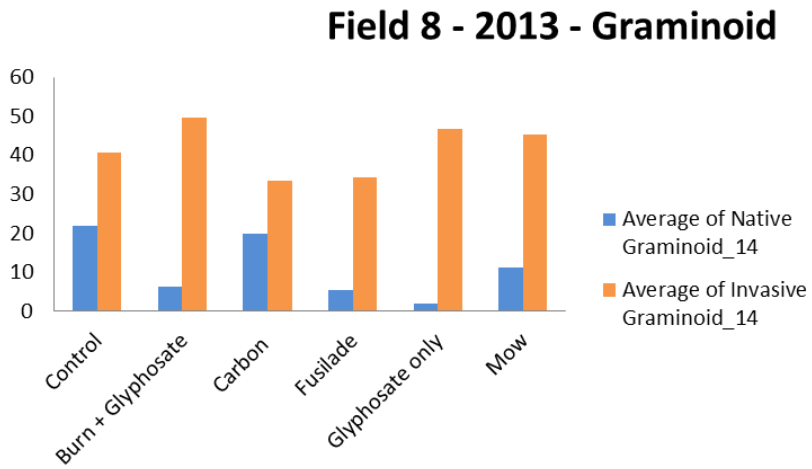
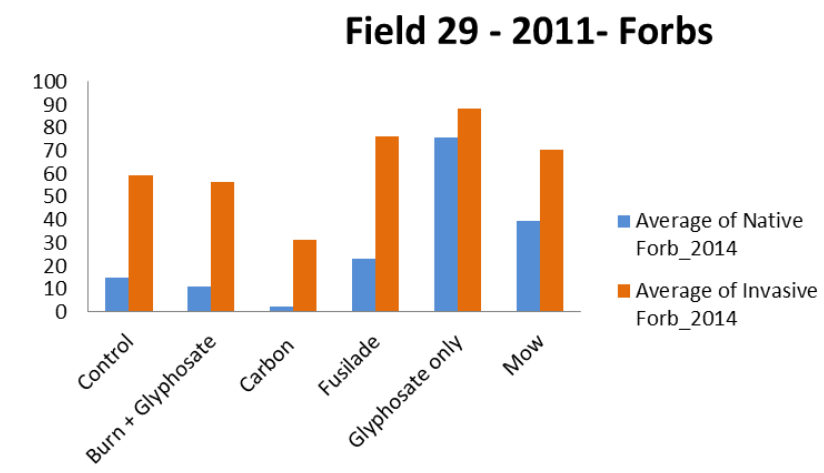
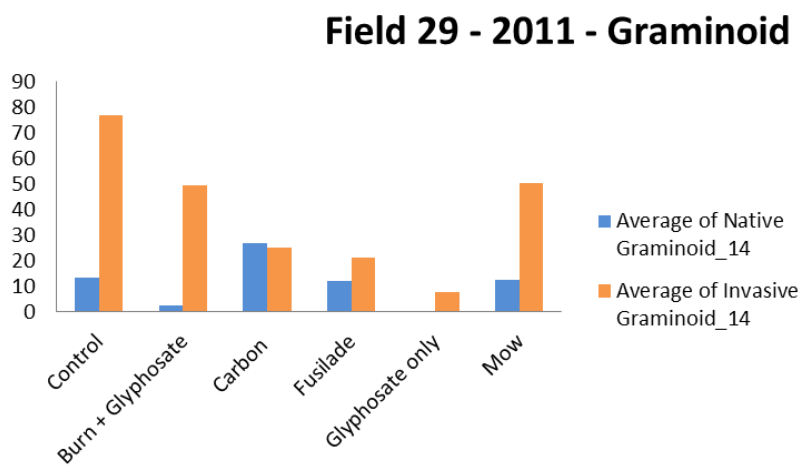
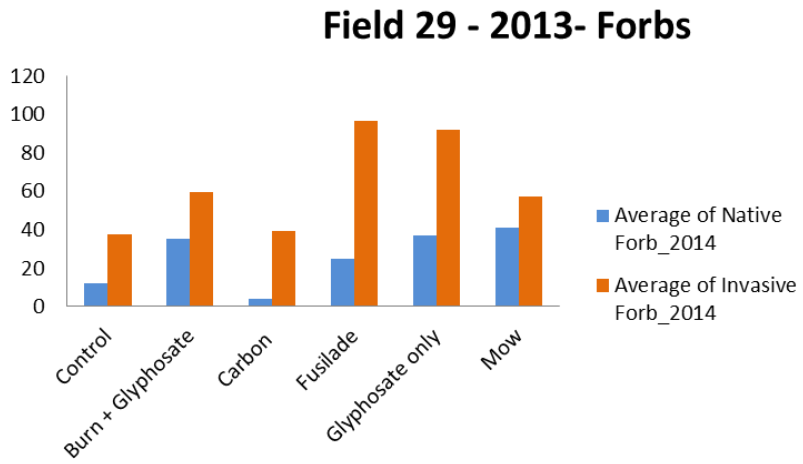


Figure 14. Percent cover of forbs and graminoids at Field 8N and Field 29.







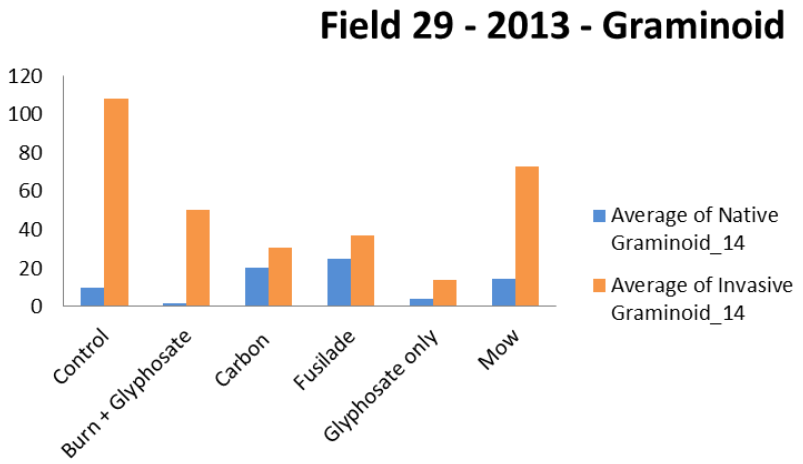


Figure 15. Percent cover of native and invasive graminoid species recorded in 2013 at Finley Field 29.

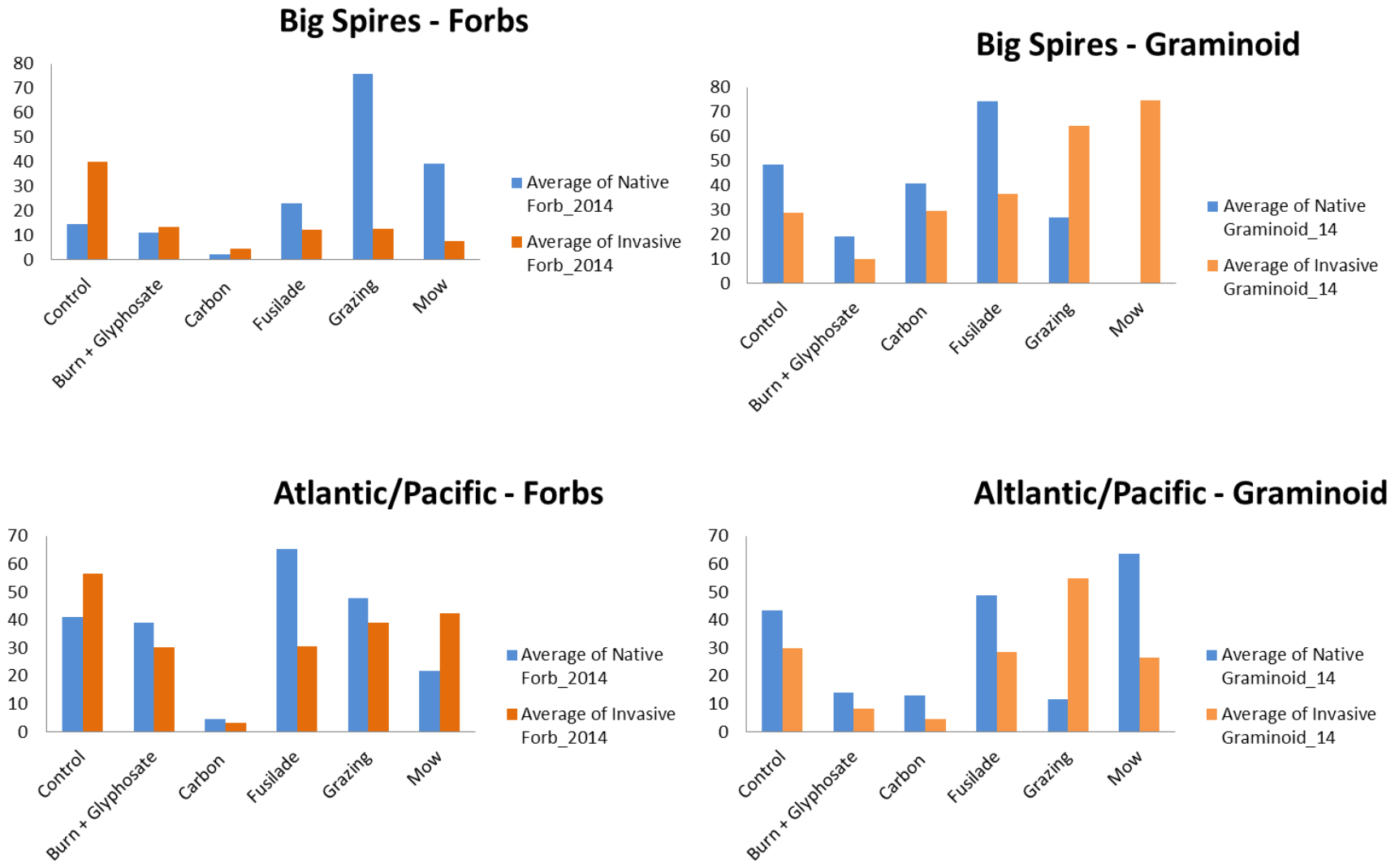


Figure 16. Percent cover of forbs and graminoids for plots outplanted in the Eugene West Recovery Zone in 2013.

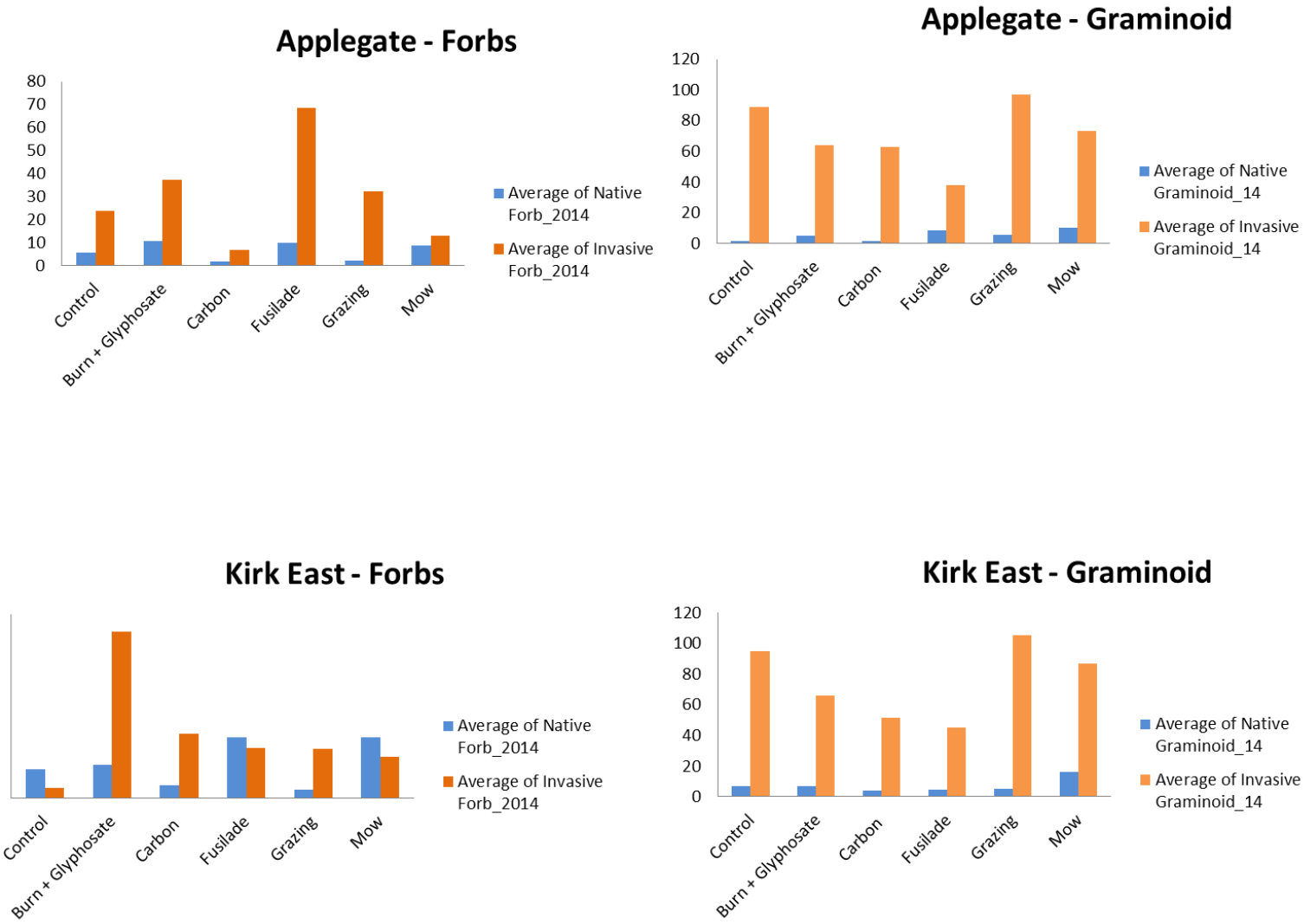


Figure 17. Percent cover of native and invasive forb and graminoid species for plants outplanted in the Eugene West Recovery Zone in 2011.

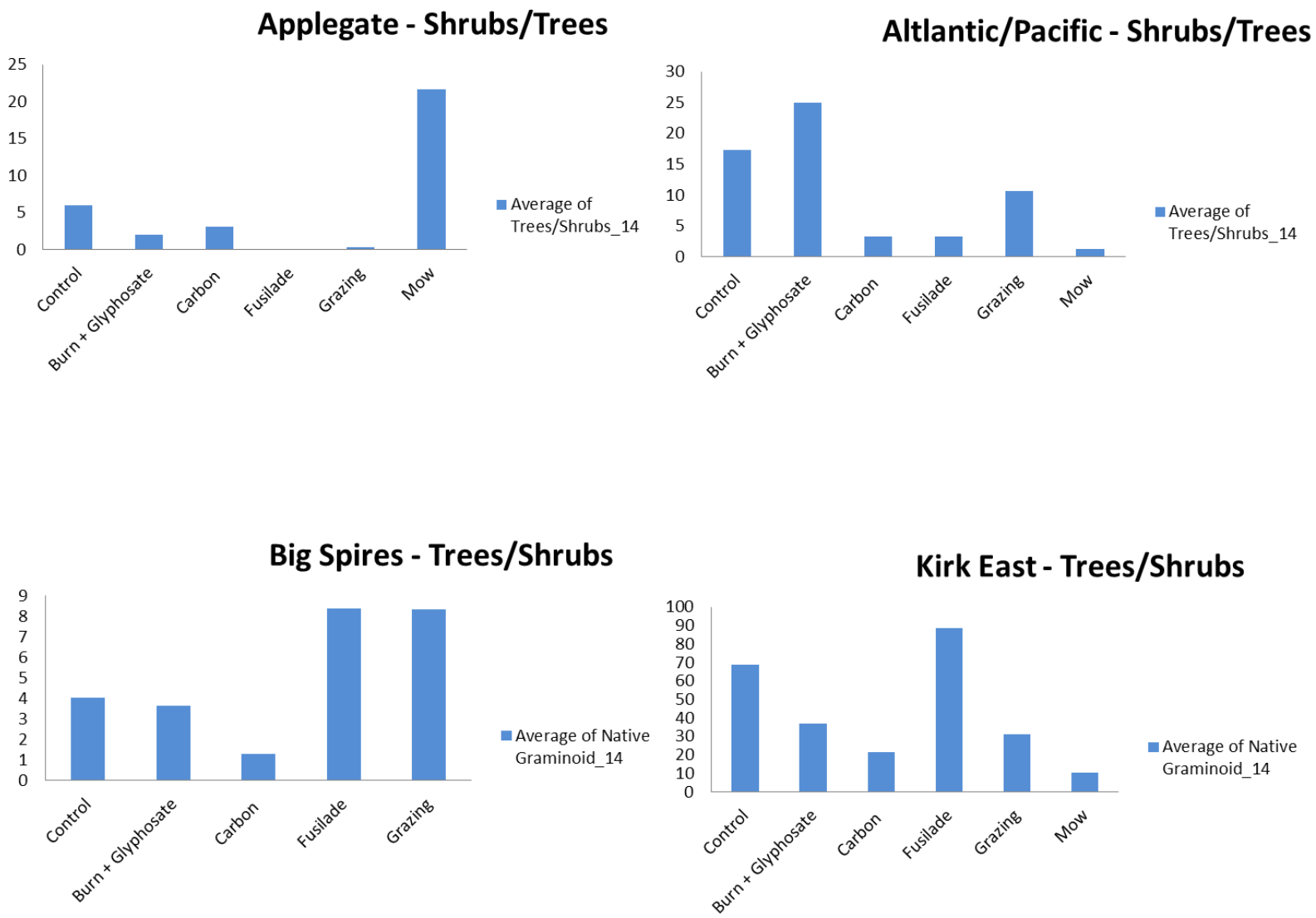


Figure 18. Percent cover of shrubby and woody species at plots in the Eugene West Recovery Zone in 2014.

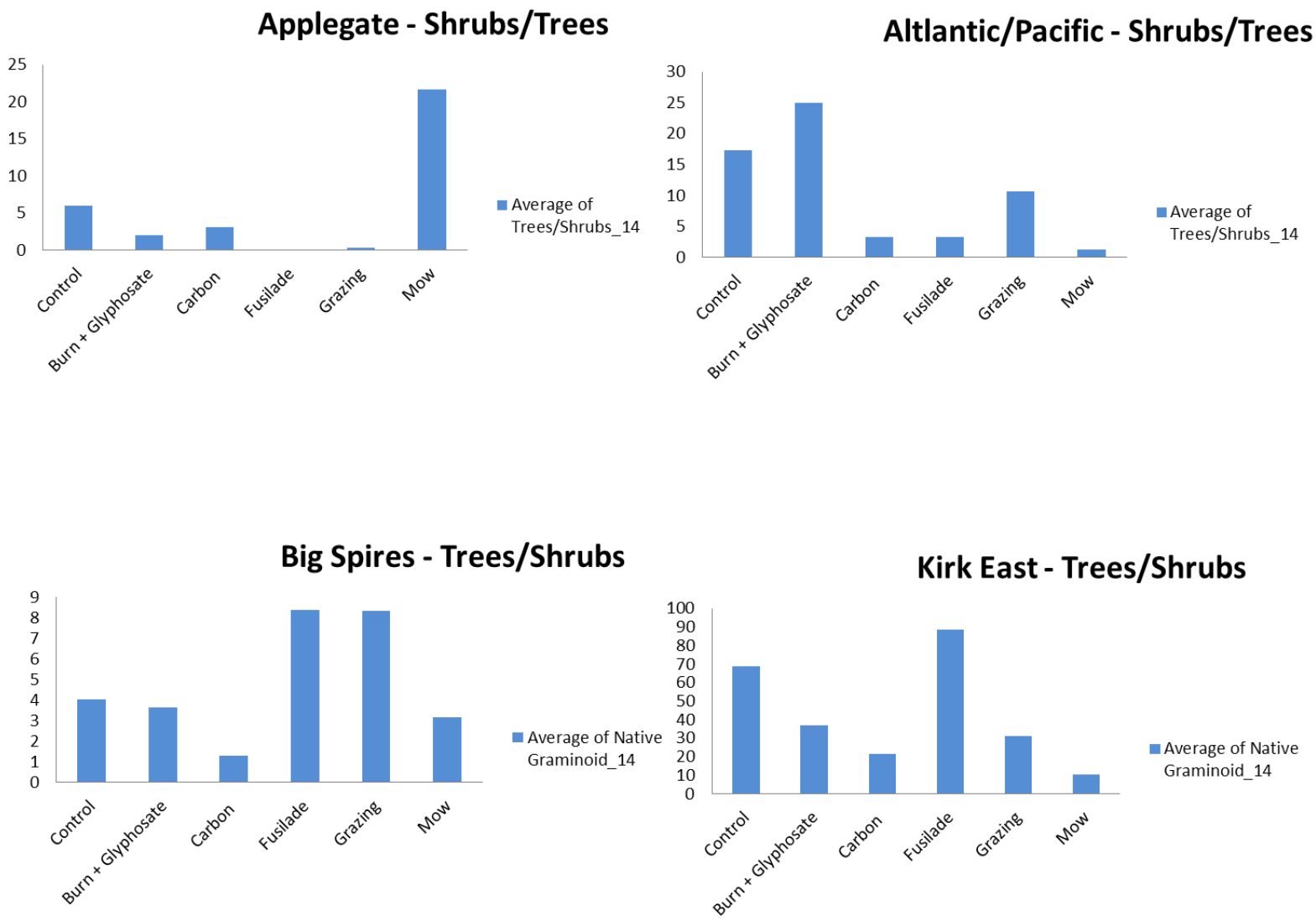


Figure 19. Percent cover of woody and shrubby species at sites in the Corvallis West Recovery Zone in 2014.

Mowing

Mowing did not have a significant effect on graminoid or forb cover (native or invasive) in either Recovery Zone. Shrub cover in the Eugene West Recovery Zone decreased with mowing. At Kirk East, recruitment of daisies was noted only in mowed plots.

Grazing (Fern Ridge only)

Grazing by sheep in the Eugene West Recovery did not have a significant effect on graminoid or forb cover (native or invasive). Shrub cover decreased significantly in plots grazed by sheep (with the exception of Big Spires- which is otherwise dominated by non-native grasses). Mowing also decreased cover of shrubby species in the Eugene West Recovery Zone.

Grass-Specific Herbicide

The application of a grass specific herbicide decreased cover of invasive graminoid species in both Recovery Zones; native graminoid cover was not significantly affected or increased. The application of grass-specific herbicide increased shrub cover in the Eugene West Recovery Zone.

Burning + Glyphosate

The application of a broad-spectrum herbicide after the first flush of green-up post-burn decreased cover of invasive grasses and invasive forbs in the Corvallis West Recovery Zone; native graminoids and forbs were not affected. Burning occurred in the Fall of 2012 at Eugene West sites, and decreased invasive graminoids (but increased invasive forbs). This treatment produced the most recruits as well as the largest, and most reproductive individuals.

Glyphosate (Finley only)

The application of glyphosate in the fall had no significant effect on the cover of native or invasive species, however there were 89 recruits noted in the Glyphosate only plots at Finley field 29.

Carbon Addition

As of 2014, carbon addition significantly reduced the cover of invasive forbs (especially *Hypochaeris radicata*) at Finley Field 8. Observed decreases in invasive forb cover were similar to those observed in the Glyphosate only treatment blocks with invasive forb cover decreasing by ½. In the Corvallis West Recovery Zone, carbon addition did tend to (slightly) decrease cover of native graminoids in the Corvallis West Recovery Zone.

The plant community response may take time to be detected and monitoring in 2015 will elucidate any longer term effects of treatments on both the plant community and the Willamette daisy. It is not uncommon for multiple treatments to be applied before a response can be detected. Repeated treatments as well as continued monitoring will enable us to detect longer term changes in both the plant community and success of Willamette daisy individuals.

FUTURE ACTIVITIES

The activities reported here are part of a 3-phase, 6-year project (Table 5). In Phase 1/2, we have introduced populations of Willamette daisy, implemented 2 years of habitat treatments, and monitored the effects on Willamette daisy and surrounding vegetation. We are currently in the process of completing Phase 3 which will include treatments and monitoring of plots outplanted in 2011 and 2013, as well as analysis of all data collected over the course of the study. This will include management recommendations for the species at each site included in the study. We plan to use the information gained from all phases to inform management at both introduced and natural populations of Willamette daisy.

Table 5. Timeline of activities to determine effects of management on Willamette daisy.

Project Element	Timeframe	Description
Phase 1/2		
Complete site selection and experimental design	Spring '10, ***Complete***	Fern Ridge Natural Area (ACOE) and Finley National Wildlife Refuge (USFWS) selected for introductions and experiments.
Seed collection and cleaning	July – Aug '10, ***Complete*** July – Aug '11, ***Complete***	As needed, we will collect seed from natural populations to augment seed currently in production.
Growout	Oct '10 – April '11, ***Complete*** Oct '12 – April '13[1], Complete	Willamette daisy grow-out will include four months of cold stratification, then propagation of seedlings in our greenhouse located at Oregon State University.
Introduce Willamette daisy	April '11, ***Complete*** April '13[1], ***Complete***	Outplant seedlings.
Demographic, population, and community monitoring	May - June '11, ***Complete*** May - June '12, ***Introductions only***	Monitoring will include demographic and population monitoring of Willamette daisy and cover estimate of all species.
Implement management treatments	Fall '11 – Spring '12 ***Complete*** Fall '12 - Spring '13 ***Complete***	Mowing, thatch removal, grazing, and herbicide treatments will occur during the growing season, but before Willamette daisy is susceptible to damage. Fall burning will be implemented using propane torches. Each treatment will occur twice.
Project and fiscal oversight	ongoing	On-going through-out project.
Status reporting	'13 –'14	Prepare reports and communicate results through the IAE webpage and meetings.
Phase 3		
Adapt and implement methods at new sites	Spring '13, '14, ***Complete***	We will use the information obtained from Phase 1 of this project to guide implementation of management treatments at existing populations and new introduction sites.
Demographic, population, and community monitoring	May - June '13, '14, '15, ***In Progress***	Monitoring will include demographic and population monitoring of Willamette daisy and cover estimate of all species.
Project and fiscal oversight	ongoing	On-going through-out project.
Post-Implementation status reporting	'15 – '16, ***In Progress***	We will prepare reports and communicate results through the IAE webpage, meetings, and conferences.

[1]Dates altered relative to original proposal.

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APPENDIX A PLANTING LOCATIONS AT FINLEY NATIONAL WILDLIFE REFUGE

Field 29:

From Corvallis drive south to Finley National Wildlife Refuge.
Park at the Woodpecker Loop Trailhead
Walk South uphill to series of t-posts and plots. (There are lots of other plots in the area, including CALE and other ERDE plots.) The 2011 plot is marked with a t-post in the NE corner and the remaining plot corners are marked with square concrete markers flush with the ground. Treatment squares are marked with nail/whisker combinations.

ERDE Management plot locations at Field 29, Finley National Wildlife Refuge

ERDE Management plot locations at Field 8N, Finley National Wildlife Refuge

Field 8N

From Corvallis Drive South on Hwy 99.

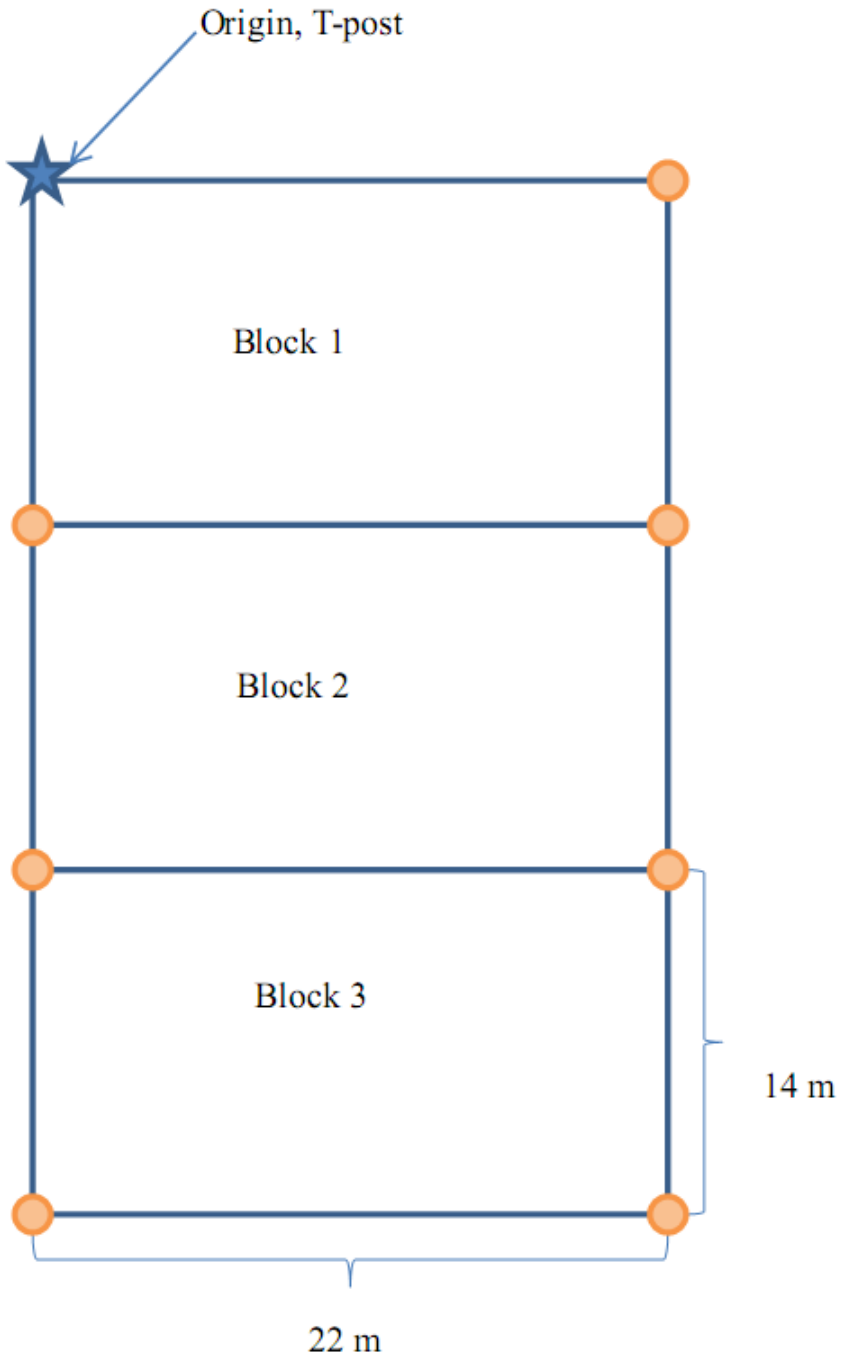
Turn Right (west) onto Bruce Rd.

After ## miles take gated road on right (unmarked)- this is across the street from an overview/lookout.

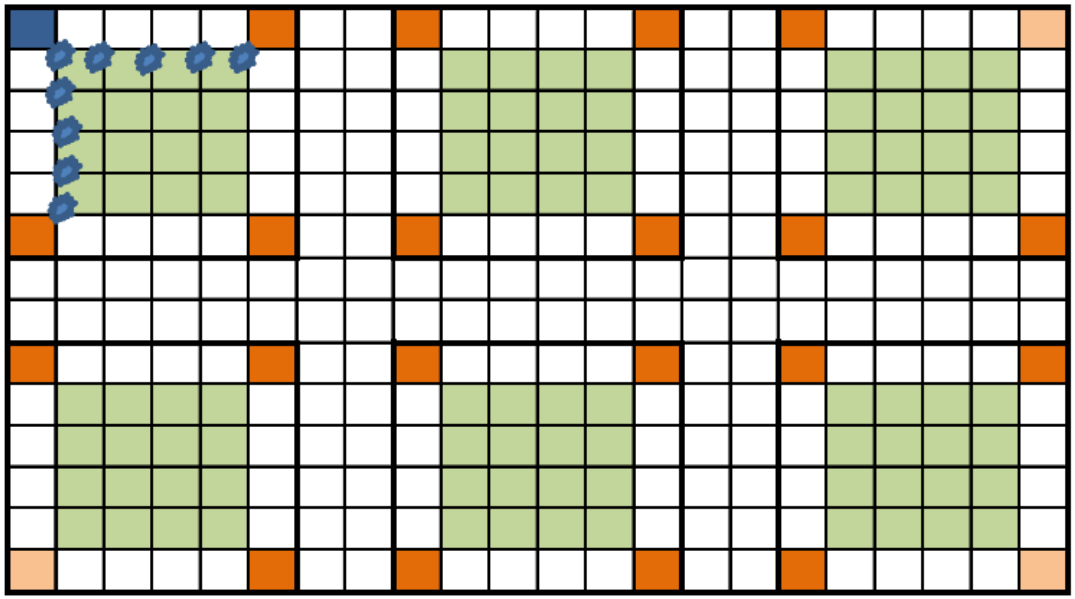
Continue along road 0.3 miles and park on roadside, walk to site.

The NE corner of the 2011 plot is marked with a t-post.

Macroplot design at Finley National Wildlife Refuge.
Blocks at both Field 29 and Field 8 were placed adjacent to each other. The origin is marked with a T-post and the remaining corners are marked with rebar topped with orange caps pounded flush with the ground.



Layout of blocks and treatment plots at Finley National Wildlife Refuge.



= T post and Whisker

= Orange capped rebar

= whisker with spike

= planting area. Start planting at meter 1 to meter 5
Planted block will be 5m x 5m

= 1m x 1m

= ERDE

APPENDIX B PLANTING LOCATIONS AT FERN RIDGE NATURAL AREA

ERDE Management plot locations at Kirk East, Fern Ridge Natural Area

From Corvallis Drive south on HWY 99.

Just north of Beltline turn right (west) onto Clear Lake Road.

After ## miles turn right onto Orchard Rd, and immediately pull into parking lot for Kirk Pond.

Follow path to site.

ERDE Management plot locations at Applegate, Fern Ridge Natural Area

Applegate:
From Corvallis Drive south on Hwy 99.
Turn onto Clear Lake Drive
Turn left onto the Territorial Highway (or take Territorial from Monroe)
5.7 miles after Clear Lake/ Territorial Junction, turn left into ACOE pull-out. This parking lot/pullout is just north of Fir Grove Ln. – If you enter town, you have gone too far.

Atlantic/Pacific:

Atlantic/Pacific:

From 126/West 11th Turn North onto Danebo.

Pass the red house (on the right-WEW office)

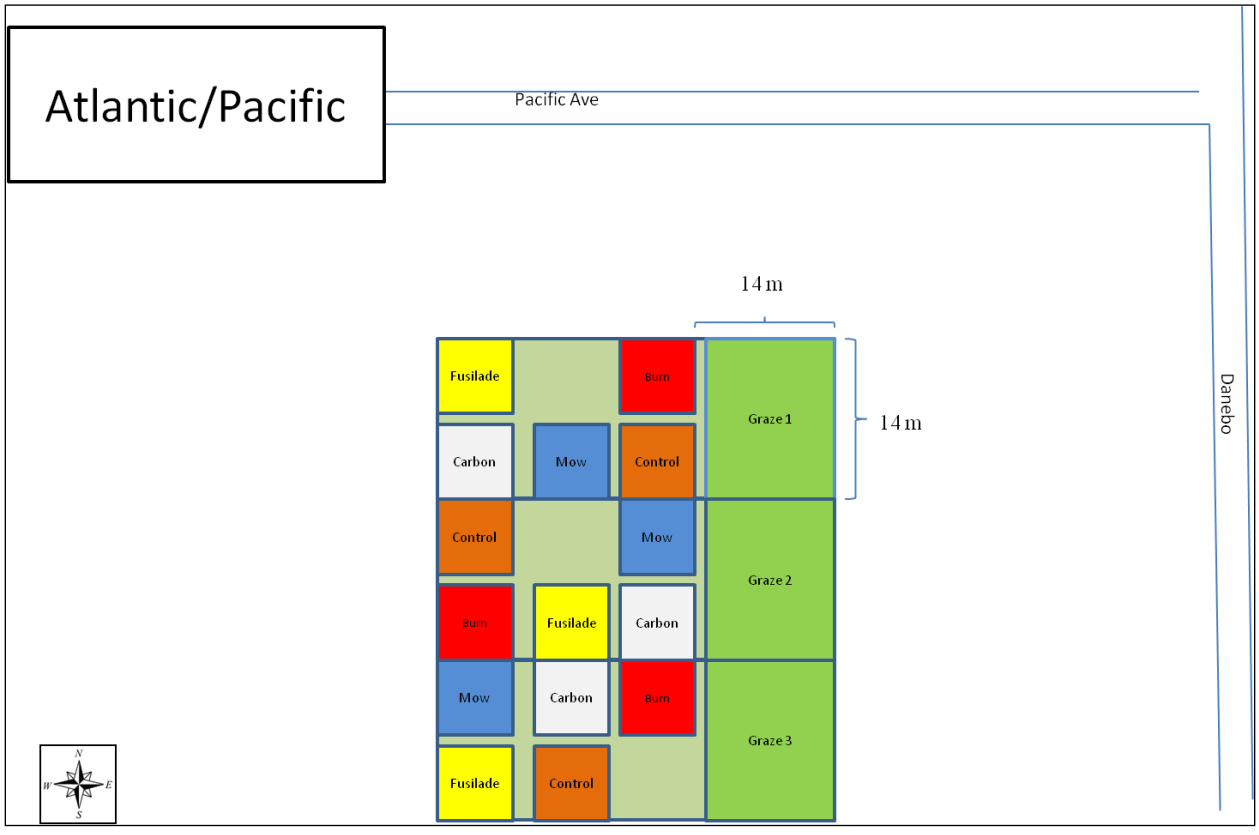
Turn left onto Pacfic Ave.

Park at junction of Atlantic/Pacific and walk to site.

Alternatively, take Beltline (Hwy 569, Randy Pape Beltline) and take the Roosevelt St. Exit.

Left onto Danebo and then Right onto Pacific Ave

(If you see the red house on your left you have gone too far.)



Big Spires:

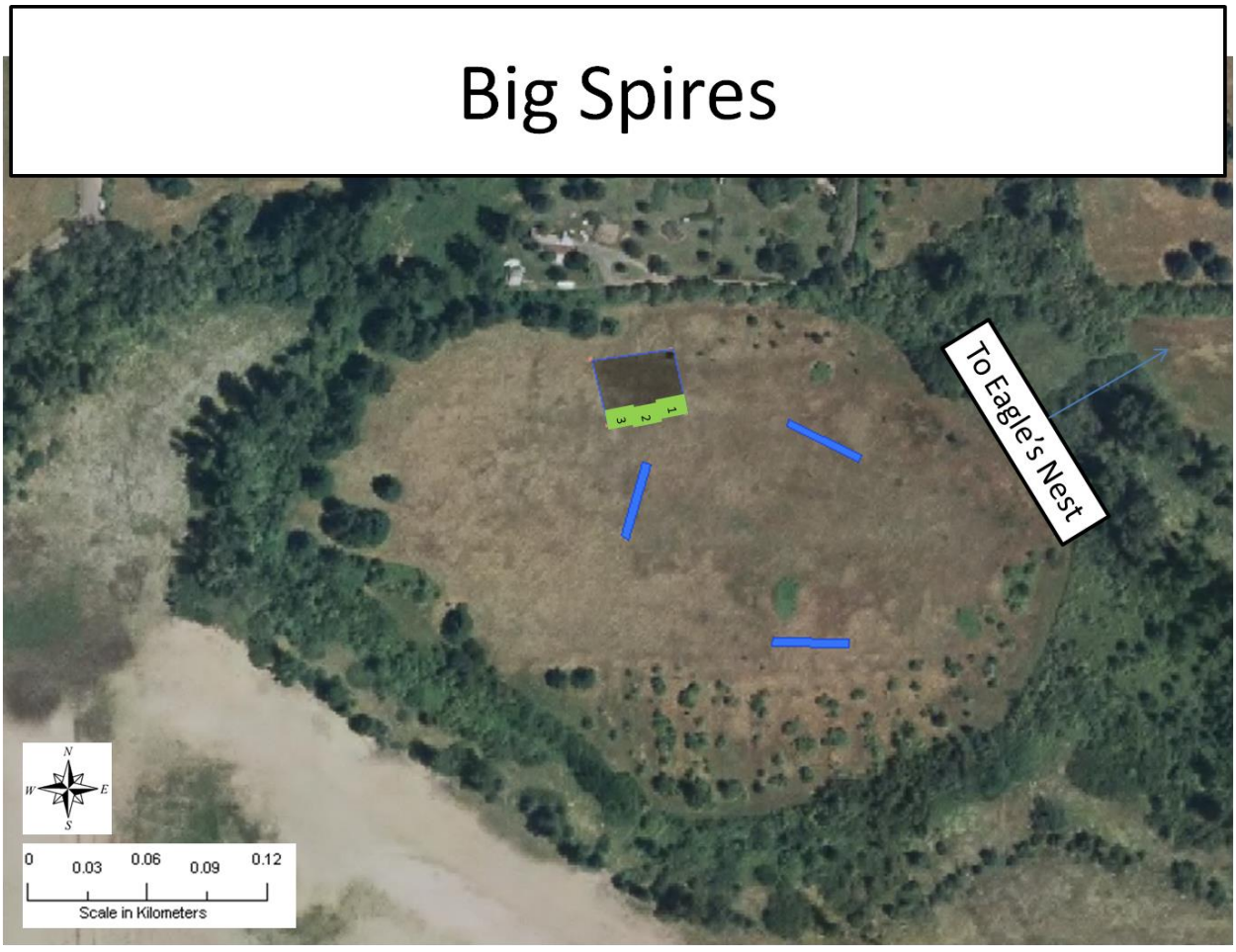
From Corvallis drive south on Hwy 99W

Turn west onto Clear Lake Drive. (Just North of Beltline)

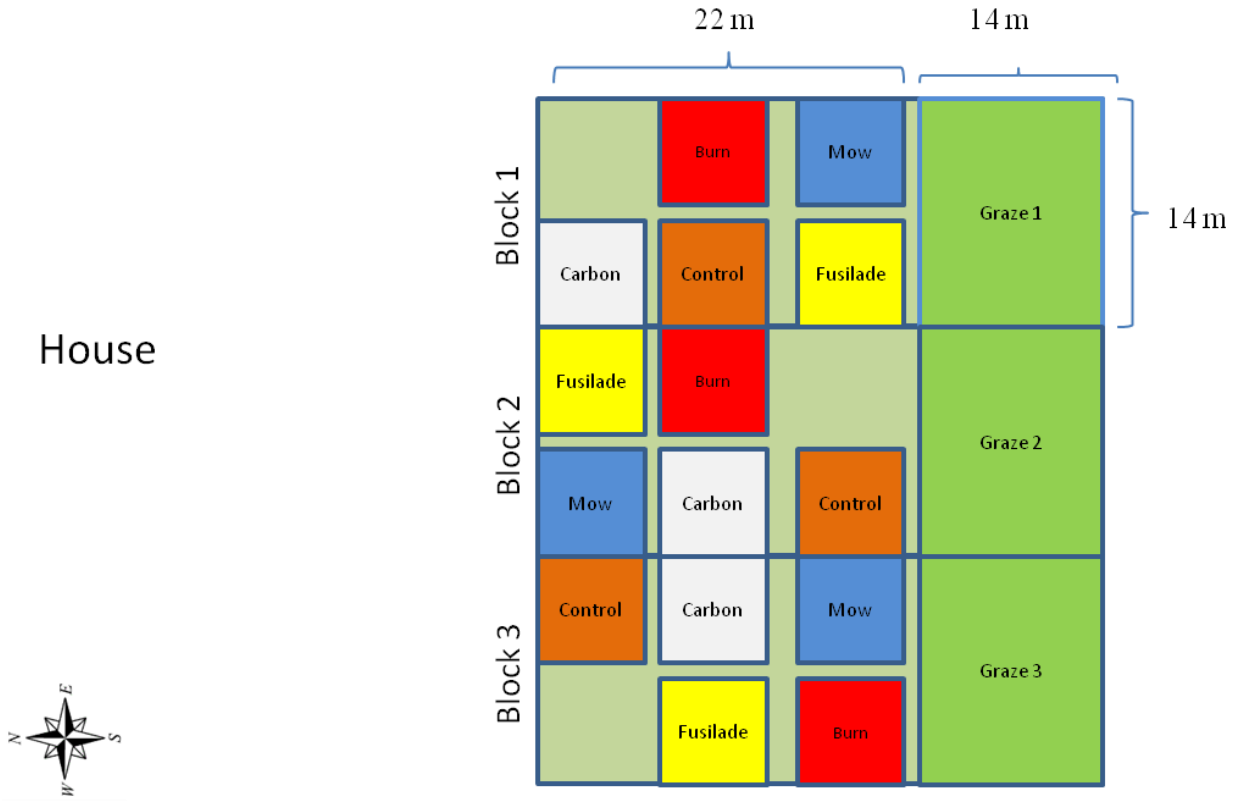
After 4.6 miles turn left onto Spires Lane (along sweeping S-curve)

Park at pull-out near mailboxes at 0.4 miles. (Do not block gate or adjacent roads.)

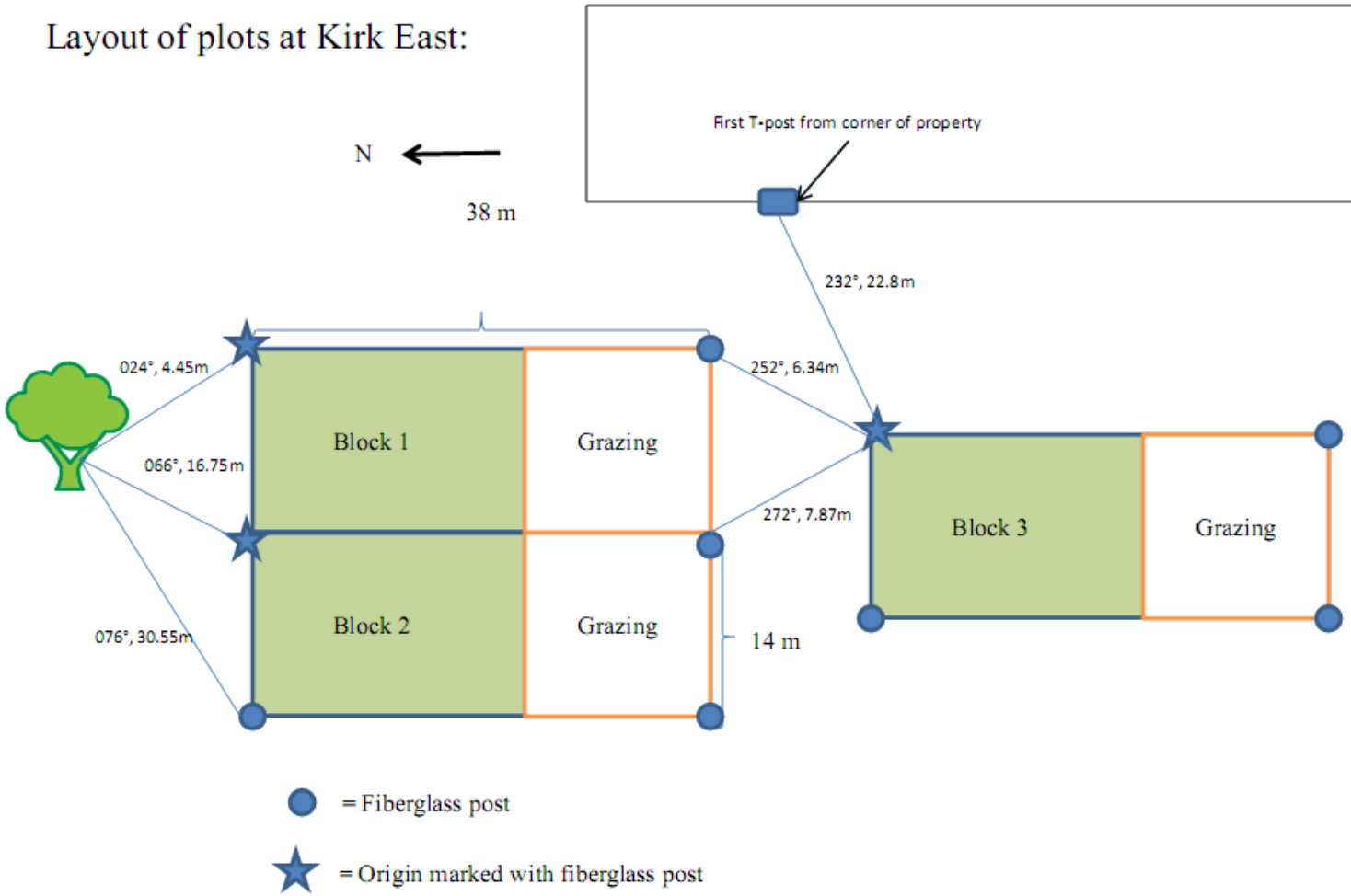
There is a bald eagle nest at the site.



Big Spires Plot Layout:



Layout of plots at Kirk East:

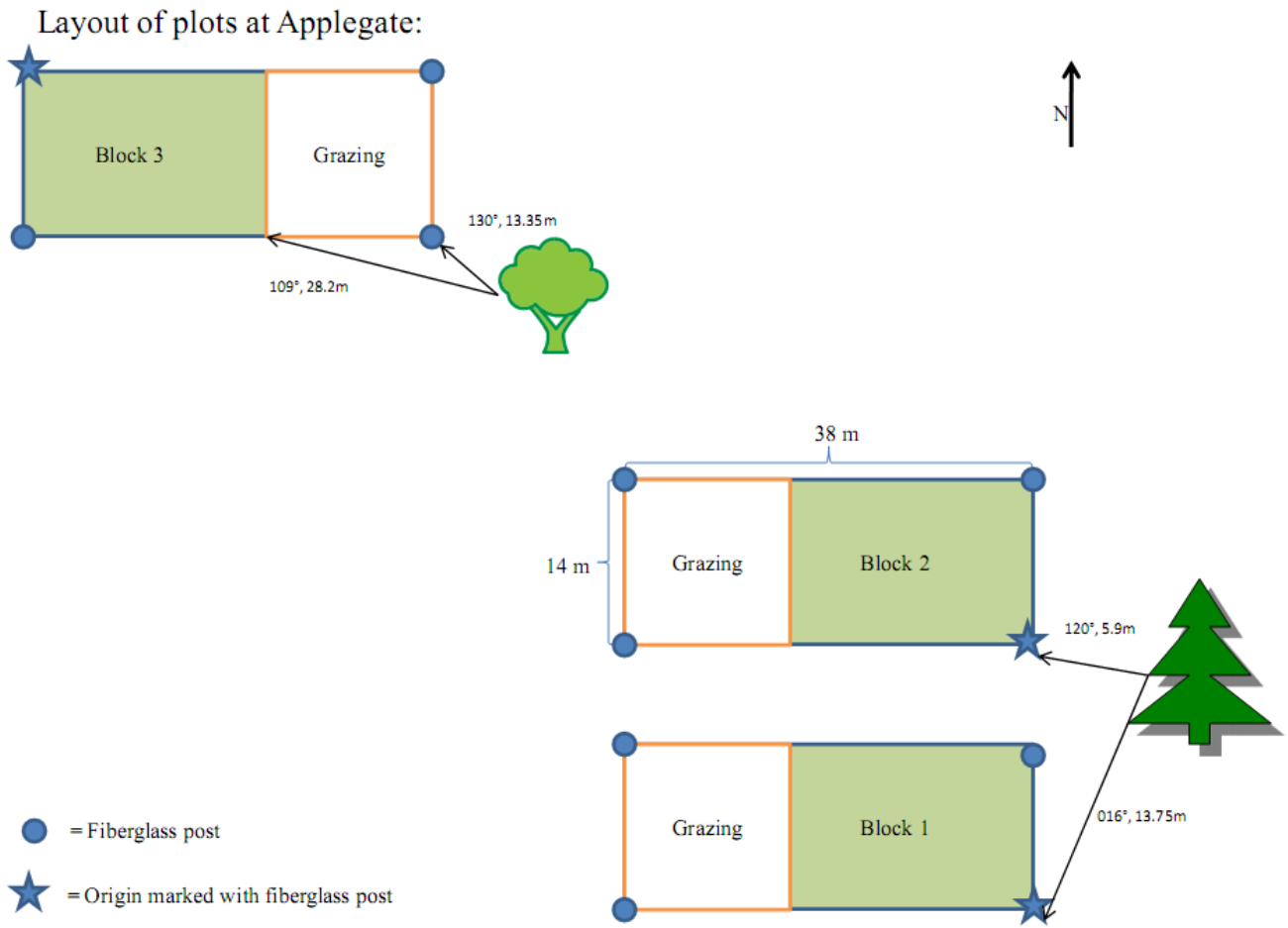


Generalized Plot Layout for Plots at Kirk East, ACOE, Eugene Recovery Zone:

1 Burn	2 empty	3 Fusilade	Grazing
4 Mow	5 Control	6 Sugar	

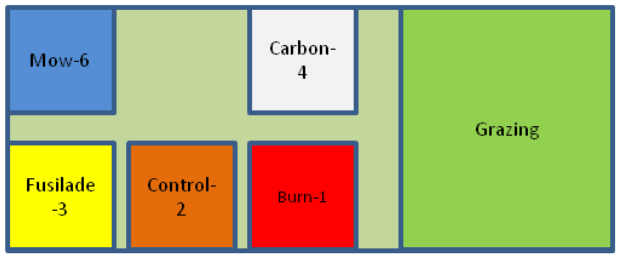
1 Mow	2 Sugar	3 Empty	Grazing
4 Burn	5 Control	6 Fusilade	

1 Fusilade	2 Mow	3 Burn	Grazing
4 Sugar	5 empty	6 Control	



Macroplot design at Applegate, Fern Ridge Natural Area.
During set-up and treatments, the origin of each block is marked with a T-post and the remaining corners are marked with rebar topped with orange caps pounded flush with the ground. In the intervening times, plots are only marked with 8 inch nails and colored whiskers in order to minimize visibility. Map not to scale; there is greater distance between Block 3 and the remaining blocks than indicated on the map.

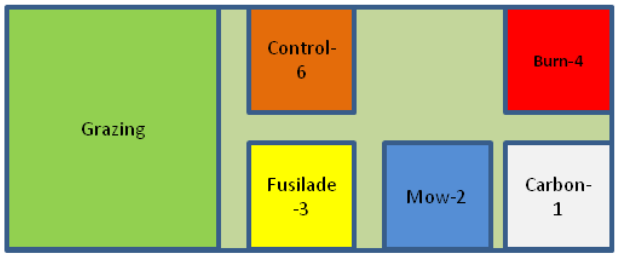
Block 3

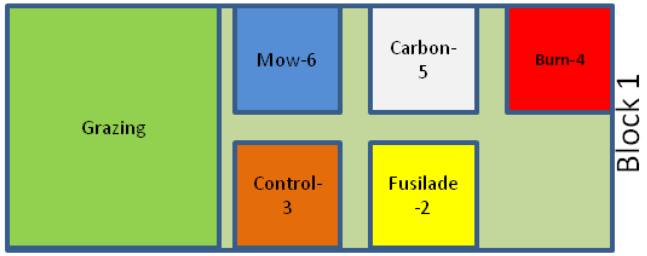


Applegate

N

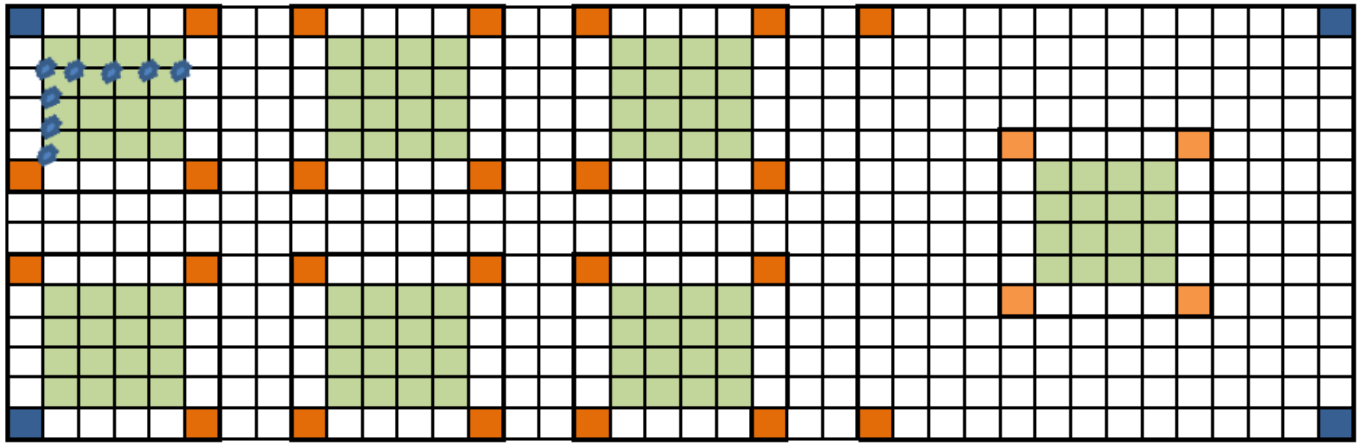
Block 2





Layout of blocks and treatment plots in the Eugene Recovery Zone

One small treatment plot was randomly excluded from planting; in 2011 one planting row or column within each square was skipped due to limitations of plant materials.



= Fiberglass post and Whisker

= whisker with spike

= planting area. Start planting at meter 1 to meter 5
Planted block will be 5m x 5m. One row or column will be skipped in each square

= 1m x 1m

= ERDE