ZUMWALT OLD FIELD REHABILITATION: STATUS, EFFECTIVENESS OF TREATMENTS, AND FUTURE PLANS

PROJECT STATUS REPORT – DECEMBER 2012

Robert V. Taylor[1], Daniel A. Ball[2], and Jeff Fields[3]

1 - Northeast Oregon Regional Ecologist, The Nature Conservancy, Enterprise, OR

2 - Columbia Basin Agricultural Research Station, Oregon State University, Pendleton, OR

3 - Project Director, The Nature Conservancy, Enterprise, OR

INTRODUCTION

Approximately 10% of the Zumwalt Prairie was once cultivated to grow barley, rye, and other grain crops (Bartuszevige et al. 2012). Because the area's climate was not favorable for crop agriculture, cultivation ceased -- mostly in the 1930s-1960s -- and the areas were seeded with exotic pasture grasses. Over time these areas have continued to be dominated by exotic grasses although some re-colonization of native plants has occurred. Old field areas on the Zumwalt Prairie have low plant species richness and thus likely support lower levels of biodiversity than native prairie communities (Taylor and Schmalz 2012). They also appear to be highly vulnerable to invasion by noxious weeds such as sulfur cinquefoil (*Potentilla recta*; Taylor and Jansen 2008). Land managers seeking to improve the ecological condition of these areas currently do not have reliable methods for doing so.

This goal of this project is to take two typical old field areas on the Nature Conservancy's Zumwalt Prairie Preserve (ZPP) and, using non-intensive methods (i.e., plowing was not an option), shift the plant communities towards dominance by native bunchgrasses. Additional objectives are to increase the native plant biodiversity of the sites and to decrease their susceptibility to invasion by noxious weeds. Previous research on the Zumwalt Prairie (Taylor et al. In preparation) suggests that grazing, herbicides, and seeding might be effective at achieving these goals. We describe here the first phase of a pilot project to further test these and other methods (i.e., prescribed fire) to improve the ecological integrity of old fields.

In a previous report (Taylor et al. 2011) we described project goals and presented a summary of pre-treatment conditions of the pilot project areas. Since that time, we have tracked the progress of the project areas, conducting post-treatment monitoring in the summers of 2011 and 2012. We have also executed an additional herbicide treatment (Fall 2012) to address invasion of an exotic annual grass, North Africa grass (*Ventenata dubia*; VEDU[1]). This report expands upon the first, re-iterating project goals and objectives, and describing in detail treatments that have already been implemented and those planned for the near future. We also include an analysis of all monitoring data collected to date and evaluate progress made towards achieving the project's goals. As such, this report largely makes obsolete the first. However, we have not included the pre-treatment vegetation data or detailed photos of the sites before and after the 2010 treatments in this document. For those, please refer to (Taylor et al. 2011).

STUDY AREAS

Two old field areas on the ZPP were chosen (Figure 1): one, Grader was dominated by smooth brome (*Bromus inermi*; BRIN2) and had very few native grasses and forbs. The second area, North was dominated by intermediate wheatgrass (*Thinopyron intermedium*; THIN6) with relatively higher amounts of native grasses and forbs. Other common exotic species include timothy (*Phleum pratense*), exotic bluegrass species (primarily *Poa pratensis* and *P*. *compressa*). The most common native grasses are Idaho fescue (*Festuca idahoensis*; FEID), Sandberg bluegrass (*Poa secunda*; POSE), and prairie junegrass (*Koeleria macrantha*; KOMA).

OBJECTIVES

Based on the pre-treatment abundance and species composition in the project areas, we established the following quantitative, time-specific goals for ecological rehabilitation of the Grader and North old field study areas (Taylor et al. 2011).

Year 1

- Reduce the abundance of exotic grasses via herbicide application, burning, and seeding with native grasses. Specifically, we aim to reduce perennial exotic grasses from their current abundance of ~ 90% frequency in 5m radius plots to <25% by late summer of 2011.

Year 2

- Promote native bunchgrass recruitment via broadleaf weed and annual grass control if necessary. Specifically, we aim to increase the abundance of perennial native bunchgrasses at the study sites from their current abundance of ~ 50% in 1 m radius

[1] See Appendix 1 for an explanation of all species and guild codes.

plots to >90% by late summer of 2011. Furthermore, we seek to increase the abundance of FEID to >90%, bluebunch wheatgrass (*Pseudoroegneria spicata;* PSSP6) to >50% (both in 1 m radius plots). Finally, in Grader Pasture, where we believe there is habitat for basin wildrye (*Leymus cinereus*; LECI4), we seek to increase this species to 10% of 5m radius plots.

Years 3-5

- Increase the species richness of the areas via the planting of locally-collected forb seeds. Because we do not yet know which forbs will be planted and what quantity of seed will be available, we are not establishing precise objectives

TREATMENTS

A combination of grazing, herbicide, and seeding were used to shift the plant community in Grader and North study areas away from exotic and towards native plant dominance. Details on treatments implemented to date are provided below. Additional interventions may be implemented in the future to achieve project goals.

GRAZING

The Grader unit was grazed by 138 cow/calf pairs in late May 23 to May 29, 2010 (6 days) as part of the larger 117 acre Grader pasture. The North Pasture has been grazed most years prior to the start of this project but cattle did not graze there in 2010.

HERBICIDE (PRE-BURN)

Three herbicide treatments were performed in the study areas in the summer and fall of 2010. Two of these herbicide treatments occurred prior to burning.

On 8 July some portions of the project areas were treated with the herbicide glyphosate while other areas were sprayed with clethodim[2] (Figure 1). Glyphosate (Credit Extra) was applied at a rate of 2.5 quarts per acre, along with a non-ionic surfactant (Astound) at 13 oz per acre. Clethodim (Clethodim 2E) was applied at a rate of 16 ounces per acre, along with the adjuvants of concentrated crop oil mixed in at the rate of 1 quart per acre, and ammonium sulfate (Ultra Pro) as a water conditioner at the rate of 2 quarts per acre. For both herbicide mixes the total solution was applied at a volume of 10 gallons per acre.

Approximately a week after the first treatment it became apparent that the contractor had not achieved complete coverage of the study areas. To address this, a second treatment of glyphosate was applied on 30 July by the same contractor, focusing on areas in the glyphosate areas that were missed on the first round. Clethodim was not reapplied because skips were not apparent in the areas where it was used.

---

[2] Applications were performed by contractor Eric Borgerding.

RX FIRE

The study areas were intentionally burned on 24 Sep 2010 (Figure 2). The North unit was burned first, with an ignition time of approximately 1 pm. Fuels across the site (both clethodim and glyphosate treated areas) were nearly 100% consumed. The Grader unit was ignited at approximately 3:30 pm. By this time, wind speeds had dropped, and RH increased somewhat. Fuel consumption within the glyphosate treated areas were good (approximately 85% consumed). Within the clethodim zone, consumption was less (approximately 50%) because of a higher proportion of live grasses in the area.

HERBICIDE (POST-BURN)

20 and 22 Oct 2010 - After the burn, target grasses not killed by earlier herbicide treatments resprouted. By 20th October smooth brome sprouts were approximately 3-4" tall. Glyphosate (Credit Extra formulation) was applied to all burned areas (including glyphosate and clethodim sprayed areas) in Grader and North using a boom sprayer[3] (Figure 2) at a volume of 10 gallons per acre. Credit Extra was applied at a rate of 48 oz per acre, plus 16 oz. per acre of ammonium sulfate, plus R-11 surfactant.

NATIVE GRASS SEEDING

Locally sourced seeds of five native bunchgrass species were applied to the study areas on 21-22 Oct of 2010 using a Truax "Rough Rider" Range Drill[4] (Figure 2). Targeted seeding rates are shown in Table 1. Seed placement was at ¼ to ½ inch depth with reasonably good seed coverage from drill openers. Seeding conditions were excellent with good soil moisture, and minimal dead plant residues due to the effectiveness of the burn. A seeding rate of 15.7 kg/ha was targeted. Calculation of actual seed delivered (170 kg) across the area seeded (14 ha) yields an estimated actual seeding rate of 12.5 kg/ha.

Table 1. Targeted seeding rates used in Grader and North Old Fields.

Common name	Fraction	kg / ha
bluebunch wheatgrass	29%	4.5
Idaho fescue	31%	4.9
basin wildrye	11%	1.8
Sandberg's bluegrass	16%	2.6
prairie junegrass	12%	2.0

[3] October 2010 herbicide Ttreatments applied by contractor Luke Royes (Workhorse, Inc.).
[4] Seeding was performed by Dan Ball and Karl Rhinhart (Oregon State University).

Total	100%	15.7

OUTRIDER HERBICIDE

On 6 November 2012, the herbicide Outrider (Sulfosulfuron) was applied to the majority of areas that were initially treated with glyphosate (Figure 2). This treatment was performed to address high densities of the invasive plant North Africa grass in those areas with the intention of reducing the competition between this invasive and the newly seeded native bunchgrasses thereby improving establishment. Outrider was not applied to the areas originally treated with clethodim as annual grasses were much less abundant in those areas.

NATIVE FORB SEEDING

On 1 December 2012, seeds from 15 species of perennial native forbs and one biennial were broadcast into a portion of the project areas (Table 2). Because a small amount of forb seed was available, we limited this treatment only to glyphosate-treated areas having relatively low native forb abundance. First, we selected 20 survey sites each in Grader and North having the lowest average native forb richness (< 10 species as measured within 5m radius plots; see "Survey Sites" below). Of these 10 sites each were randomly selected for the native forb treatment (Figure 2).

Table 2. Native forb species seeded in the fall of 2012.

Forb species (scientific name	**Quantity (g)**
Lupinus sericeus	1300
Geum macrophyllum	450
Solidago spp. (*S. canadensis and S. missouriensis*)	225
Balsamorhiza spp. (mostly *B. Incana*)	160
Frasera speciosa	110
Eriogonum heracleoides var. angustifolium	90
Arnica sororia	85
Achillea millefolium	39
Potentilla gracilis	16
Potentilla glandulosa	9.3
Agastache urticifolia	5
Geum triflorum	5
Penstemon globosus	5
Penstemon procerus	5
Sidalcea oregano	5
Cirsium brevifolium	2

VEGETATION SAMPLING

SURVEY SITES

Vegetation was sampled within the North and Grader project areas in 2007, prior to anticipated treatments that fall. That year 78 random sites were surveyed in North Pasture and 50 in Grader. Treatments (except for prescribed fire), however, did not occur that year and when the project was resurrected in early 2010, the boundaries of the areas to be treated had changed. Consequently, in 2010 a new set of random survey sites was established within the modified treatment areas (47 in Grader and 59 in North) and additional sampling was done. Because the project areas had been reduced in area, some of the 2007 survey sites now serve as "Controls"(Figure 1). Data from these control sites can be compared to those within the treatment area to better understand the actual treatment effects on vegetation changes.

Vegetation surveys were done in 2011 and 2012 to measure the condition of the areas post-treatment. During these years both the 2010 survey sites within the treatment areas and the 2007 "Control" sites were surveyed. Table 3 shows the number of survey sites for which data were collected the different areas across the four years for which monitoring was performed.

Table 3. Number of survey sites sampled across the study period. The first number in each cell indicates the number of nested frequency plots sampled whereas that within parentheses is the number of density plots.

Pasture	TreatType	2007	2010	2011	2012
Grader	Glyphosate	15 (0)	31 (0)	9 (5)	31 (31)
	Clethodim	3 (0)	16 (0)	0 (0)	16 (16)
	Control	26 (0)	0 (0)	12 (0)	12 (12)
North	Glyphosate	7 (0)	32 (0)	28 (14)	32 (32)
	Clethodim	8 (0)	27 (0)	27 (15)	27 (27)
	Control	49 (0)	0 (0)	16 (0)	17 (17)

VEGETATION SAMPLING PROTOCOL

Field observers navigated to survey sites using a handheld GPS unit. Once the unit indicated that the observer was within 2m of the survey site, the center of a circular nested frequency plot was established. At each survey site presence/absence of a suite of focal grass species and guilds was recorded within each of the three nested plots as follows:

- 1 = species/guild present within 1 m radius plot
- 2 = species/guild present within 3m radius plot (but not in 1m plot)
- 3 = species/guild present within 5m radius plot (but not in 1m or 3m plots)

In 2007 data were collected only on perennial grass species and species groups (Appendix 1) whereas in 2010 we also surveyed for annual grass species. For certain species (i.e., dense silky bent [*Apera interupta;* APIN] and VEDU) presence/absence was recorded only in the 1m and 3m plots. In 2010, in addition to recording presence/absence data for grasses we also recorded data for perennial forbs, sub-shrubs, and shrubs.

Data on the density of seeded perennial bunchgrasses, by species, was collected in a single 20 x 80 cm quadrat (area = 0.16 m^2) at a subset of the plots in 2011 and at all plots in 2012.

ADDITIONAL DATA

Prior to this study, a permanent vegetation plot (UR7) had been established in North pasture (Taylor and Schmalz 2012). Photo-points and data on foliar cover and soil surface characteristics were measured at this site in 2009, 2011, and 2012. This monitoring site is located within an area initially treated with Glyphosate.

A permanent photo-point location was established in Grader prior to the treatments. This site is located within an area initially treated with Clethodim.

RESULTS & DISCUSSION

Results from frequency, density, and line-point intercept monitoring indicate directional changes have occurred in many functional groups and plant species during the course of the study. Below, we summarize these changes, discuss causes of these changes, and evaluate current conditions against the project's *a priori* objectives. Although multiple treatments have been applied over time, the primary differences between areas has been the initial herbicide treatment (Glyphosate, Clethodim) while Control areas have received none of the treatments. Thus for simplicity we make comparisons only between these three area types and refer to them simply as *Glyphosate*, *Clethodim*, and *Control*.

Native grasses

Frequency monitoring (1 m radius plots) indicates the abundance of all native perennial grass species combined (GPN) increased in all treatment areas from pre- post-treatment (Figure 3) suggesting that treatments were having the desired effects. The starkest differences were observed in the North/Glyphosate, North/Clethodim, and Grader/Clethodim areas. For example in North/Glyphosate pre-treatment frequency of GPN was 29% in 2007 and 53% in ’10 but had climbed to 100% in both 2011 and 2012 (see Appendix 2a). Changes in foliar cover of native grass species from upland range plot UR7 corroborates this trend towards increased GPN abundance in the North/Glyphosate area (from 9% pre-treatment to 17% in 2012; Figure 4). GPN was also ubiquitous in Grader/Glyphosate, and North/Clethodim areas post treatment. Similar to the treatment areas, GPN was also observed to increase in Control areas over the period of observation. Pre- to post-treatment frequency increased from 46% to 58% in Grader and from 53% to 82% in North (1m radius plots).

Examination of trends in individual native perennial grass species revealed that GPN increases resulted primarily from increases in four of the species which were included in the seeding treatment: FEID, PSSP6, POSE, and KOMA. Changes in these species across the two project areas and three treatment types, however, were complex (Figure 5; Appendix 2B). All four species increased strongly in the Grader/Glyphosate area with POSE and PSSPS increasing from < 10% frequency (1 m radius plots) pre-treatment to > 80% post-treatment. FEID also increased in this area consistently though more moderately; 40-42% pre-treatment to 89-100% post-treatment (Appendix 2b). In the North/Glyphosate area FEID, KOMA, POSE, and PSSP6 all increased sharply from pre-treatment (0-28%) to post-treatment (64-100%). In this same area data from UR7 also indicates FEID and KOMA increased from pre-to post-treatment, though POSE declined (Figure 6).

Clethodim areas showed less profound changes in native bunchgrass frequency. Only FEID showed substantial increases in Grader/Clethodim (0-13% pre-treatment to 88% post-treatment). In North/Clethodim FEID increased sharply (0-30% pre-treatment to 85-100% post-treatment). Though substantial increases were observed for KOMA, POSE, and PSSP6 from 2010 to 2011, frequency declined sharply for these species from 2011 to 2012 (Figure 5). This pattern of change suggests that initial germination was good but that many of the newly emerged bunchgrasses failed to establish.

Basin wildrye (*Leymus cinereus*; LECI4), the other seeded species, was recorded at very low abundance in most areas in most years (frequencies of 0-3%), however, in 2012 this bunchgrass was found in 35% of 1 m radius plots in the Grader/Glyphosate area. This is consistent with some anecdotal reports that basin wildrye is slow to establish after seeding (RVT pers. obs.).

Bunchgrass density, measured only post-treatment and only for species that were seeded, revealed trends over time and differences between species and treatments (Figure 7). FEID and POSE were far more abundant (16.3 ± 20 SD and 12.6 ± 25 SD plants / m^2, respectively, all areas and years combined) than KOMA (4.1 ± 7.7 SD) or PSSPS (2.1 ± 5.4 SD). The species encountered in lowest abundance was LECI4 (0.1 ± 0.7 SD). Both Glyphosate and Clethodim areas had similar overall bunchgrass densities (7.6 ± 11.7 SD and 7.8 ± 21.5 SD plants / m^2, respectively) whereas non-treated Control areas had approximately half those amounts (3.9 ± 14.7 SD 2012 only) with North having much higher densities (6 ± 18.6 SD) than Grader (0.9 ± 4.3). Both Glyphosate and Clethodim treated areas experienced sharp decreases in seeded bunchgrass species densities from 2011 and 2012 but the decrease was much greater for Clethodim though data were only available for North (Figure 7).

Decreases in native grass densities from 2011 to ’12 were driven mostly by decreases in the two most abundant species, FEID and POSE (Figure 7). For example in Grader/Glyphosate FEID density decreased from 26 ± 23 SD plants / m^2 in 2011 to 12.5 ± 8 SD in 2012 and POSE decreased from 30 ± 19 SD to 6.5 ± 8.0 plants / m^2 (Appendix 2c). Such decreases were somewhat expected since often, a large flush of seedlings emerges the year after seeding only a fraction of which survive due to intense intra-specific competition (Yoda et al. 1963). KOMA densities were relatively stable from 2011 to ’12 whereas PSSP6 tended to increase in Glyphosate areas (from 1 ± 2.3 SD plants / m^2 in 2011 to 3.1 ± 5.1 in 2012, Grader and North combined) while decreasing in Clethodim areas (from 3.3 ± 6.6 SD to 0.5 ± 2.1 SD plants / m^2, Grader and North combined). LECI4 was not encountered in the density plots in 2011 but had increased to 0.2 ± 1.1 SD plants / m2 in the Grader/Glyphosate area in 2012.

Although increases in GPN occurred, as anticipated, in the treatment areas (especially Glyphosate areas), concomitant increases of these species in Control areas suggests that some of the increase we observed may have been due to factors other than the treatments, such as passive colonization of these areas by native species. Other monitoring conducted at old field sites on the Zumwalt Prairie Preserve suggest inconsistent changes in native grass cover over time, with half of the sites increasing in GPN cover while the other half decreased (Taylor and Schmalz 2012).

EXOTIC GRASSES

Taken together, exotic perennial grass species (GPE) were abundant in all areas prior to treatment and tended to remain stable or decrease in the treatment areas over time. GPE frequencies (1 m radius plots) were 93 to 98% prior to treatments (2007, 2010 data combined) and 88-97% post-treatment (Figure 3). The only area showing any appreciable decrease was Grader/Glyphosate in which GPE declined from 93% to 88%. The lack of a decrease in GPE, even in the treatment areas where they were targets of the herbicide treatments, is likely due to the large size (1 m radius or 3.14 m^2) of the sampling plots. That is, plots were considered occupied by GPE if just a single tiller of any GPE species was present in the plot.

More useful is a finer-scale examination of trends in GPE species which suggests that herbicide treatments did reduce their abundance. For example BRIN2, which was the dominant GPE species in Grader, decreased in Grader/Glyphosate from 89% prior to treatment (2007, ‘10 combined) to 78% post-treatment (2011 and ’12 combined; Figure 8) while it remained constant (100%) in Grader/Clethodim and increased in Grader/Control. Exotic wheatgrasses (including *Thinopyron intermedium*; PASM/THIN6/AGCR) also decreased in Grader/Glyphosate (from 60% to 25%) while remaining mostly stable in the Grader/Clethodim and Control areas (Appendix 2b). Exotic bluegrass species (including Poa pratensis; POPR/POCO/POBU) followed a similar trend, though it was seen to decrease in both the Grader/Glyphosate (from 52 to 33%) and Grader/Clethodim areas (from 37% to 13%) while increasing (from 65 to 92%) in Grader/Control. This may indicate that bluegrass species were more susceptible to the grass-specific Clethodim herbicide than were the other exotic perennial species.

In North, where wheatgrasses dominated, PASM/THIN6/AGCR decreased in the Glyphosate area from 90% pre-treatment (2007 and ’10 combined) to 71% in 2011 but then increased to 97% in 2012 (Figure 8; Appendix 2b). This suggests that these grasses rebounded quickly after the herbicide treatment. In North/Clethodim areas PASM/THIN6/AGCR was 97% pre-treatment and 100% post-treatment suggesting that the herbicide had little effect. The bluegrasses decreased slightly in the North/Glyphosate area (from 69% in 2010 to 53% in 2011 and ’12) and somewhat more in the North/Clethodim area (from 81% in 2010 to 26% in 2012), again suggesting sensitivity of these species to Clethodim. A sharp decrease in BRIN2 was observed in the North/Glyphosate and North/Clethodim areas where pre-treatment frequencies of 22 and 33% (respectively) were reduced to < 10% in both post-treatment years.

Decreases in the abundance of GPE in the North/Glyphosate area was evident in data from the monitoring site UR7 where foliar cover decreased from 43% pre-treatment (2003, '09 average) to 10% post treatment (2011, '12 average; Figure 4). Interestingly, GPE cover increased from 2011 to 2012, again, indicating recovery of these grasses from the herbicide treatment. Species level data suggest that the greatest change occurred for PASM/THIN6/AGCR which decreased from 41% (average of 2003 and '09) to 2% in 2011 before rebounding to 13% in 2012. Given these results, we do not know whether the level of control afforded by our treatments will be sufficient to reduce GPE species in the long-term, or whether alternative treatments will be required.

Exotic annual grasses (GAE), considered together, tended to increase in the Grader/Glyphosate (87% to 95% from pre- to post-treatment) and North/Glyphosate (78% to 100%) areas whereas the Clethodim areas were relatively stable and no data was available for Control areas (Figure 3). Considered at the species level, changes were more profound and perhaps more clear (Figure 9). APIN increased sharply in both Grader/Glyphosate (from 26% in 2010 to 78% 2011 and '12 combined) and North/Glyphosate (from 50% in 2010 to 81% in 2012; Appendix 2b). Clethodim-treated areas showed little change in this species. North Africa grass (*Ventenata dubia*; VEDU) also increased sharply in the Glyphosate treated areas from pre- to post-treatment; from 77% to 94% in Grader in 2012 and from 56% to 75% in North. Again, Clethodim treated areas showed much smaller increases though abundance of VEDU was very high in these areas (>90% in Grader and >60% in North) throughout the study. The only other GAE species abundant enough to be important in the area were annual bromes (Bromus spp.; BROMU). Bromus spp. increased in frequency from 6% in 2010 to 19% in 2012 in Grader/Glyphosate and from 0% to 41% in North/Glyphosate. It was stable or decreased in both Clethodim treated areas.

Additional evidence for increases in GAE species in the North/Glyphosate area come from the UR7 monitoring site. There, foliar cover of APIN increased from 0% in 2009 to 8% in 2011 and then doubled to15% in 2012. A very similar pattern was seen for VEDU had 1% cover in 2009, 18% in 2011 and 41% in 2012 (Figure 6; Appendix 2b).

The increases we observed in GAE species we observed, especially within the Glyphosate treated areas suggests that these species were able to increase as a result of decreased competition with other species, especially GPE species following the herbicide and burning treatments. Because annual grasses may compete with GPN species for soil resources, thereby, reducing establishment of these desirable bunchgrassees, further herbicide treatment, specifically targeting GAE species, was done in the Fall of 2012 in Grader/Glyphosate and North/Glyphosate.

NATIVE PERENNIAL AND BIENNIAL FORBS

Native perennial forbs (FPN) were fairly common in the study areas in 2010 prior to treatment (Appendix 2D). In Grader > 50% of 5m radius plots had at least one FPN species in 2010 whereas in North frequency was 96%. Following treatments FPN frequency in Grader increased to 70%; most of this due to sharp increases in the Grader/Clethodim area where FPN increased from 31% in 2010 to 75% in 2012 (no data available for 2011). The Grader/Glyphosate area experienced a decrease in FPN frequency from 2010 to 2011 (65 to 44%) but FPN abundance rebounded in 2012 to 74% (Appendix 2d). The decrease in FPN in the year following treatment in Grader may be attributed to the effects of the herbicide Glyphosate which kills a broad spectrum of plants, including most perennial forbs. Little change was observed in FPN frequencies in North where frequencies remained above 90% throughout the study (even using the smallest plot size of 1 m radius) thus hampering our ability to assess changes in FPN abundance using the nested frequency monitoring method (Elzinga et al. 1998). In 2011 and 2012 Control areas in both Grader and North had similar frequencies of FPN as the treatment areas (67 – 75%, and 100%, respectively). Because FPN species were not sampled in Control areas prior to 2011, no assessment of change in these untreated areas could be made. Observations from the UR7 monitoring plot in the North/Glyphosate area are concordant with those from frequency sampling. There, foliar cover of FPN species decreased from 21% in 2009 to just 8% in 2011 before rebounding to 16% in 2012.

A total of 53 FPN species (some plants were identified only to genus, e.g., *Potentilla* spp.) were encountered over the course of the three years of sampling (Appendix 2e). Grader harbored 23 FPN species whereas North had 33 species. The most abundant species were cinquefoil species (Potentilla spp.; mostly *P. gracilis* or slender cinquefoil), western yarrow (*Achillea millefolium* var. *occidentalis;* ACMIO), western hawkweed (*Hieracium cynoglossoides*), and twin arnica (*Arnica sororia;* ARSO2), goldenrod (*Solidago spp*. SOLID), and old man's whiskers (*Geum triflorum*; GETR).

Species trends over time revealed several interesting patterns relating to both innate differences between the Grader and North sites (e.g., soils, pre-treatment vegetation) as well as contrasts between the three treatment types. Because of the large number of FPN species it was necessary to focus our analysis on those species with the most substantial changes in abundance over time. As such we first created a metric by which we could separate the species whose abundance remained relatively constant throughout the study from those that increased or decreased substantially over time. We considered a species to have “increased” if the average frequency of occurrence of that species within and area/treatment changed by 20% or more (in either the 1m, 3m, or 5m radius plots) from one sampling bout to the next. Likewise for a species to “decrease” it had to do so by at least 20%. A species could have mixed trends as well, for example decreasing from 2010 to 2011 but then increasing from 2011 to 2012.

Despite its lower FPN abundance and diversity, the Grader area had a larger number of species (15) showing substantial trends than did North (13 species) (Appendix 2e). Within Grader there were striking differences between the three treatment types. In the Glyphosate area 12 species decreased in abundance from pre- to post-treatment. These included ACMIO, ARSO2, vetches (Astragalus spp.), whitestem frasera (*Frasera albicaulis*; FRAL2), GETR, HICY, lupines (*Lupinus* spp.; LUPIN), SOLID, and death camas (Zigadenus venenosus). All of these species appeared to quickly rebound, increasing from the 2011 to 2012. Three species increased throughout the study: fleabane (*Erigeron spp.*), death camas ((*Zigadenus venenosus*), and aster (*Symphyotrichum* spp.). The last of these increased strongly, perhaps because these wildflowers tend to bloom relatively late in the season which may have made them less susceptible to the Glyphosate treatment which was done in early July. In the Grader/Clethodim area, we could not assess change from 2010 to 2011 due to lack of data. However, 14 species experienced increases in abundance from 2010 to 2012 likely due to the low toxicity that the Clethodim herbicide has on this guild. In the Grader/Control area no species changed sufficiently to meet our trend criteria suggesting that FPN species were relatively stable there.

The North/Glyphosate area had only a handful of species experiencing substantial trends. Four species – ACMIO, ARSO2, GETR, and POTEN – decreased in abundance from pre- to post-treatment and then increased from 2011 to 2012 (Appendix 2e). The latter three of these species re-attained there pre-treatment abundance whereas ACMIO numbers remained somewhat lower (58 vs. 81%). Our observations of FPN changes in frequency in the North/Glyphosate area are mostly supported by foliar cover data from UR7 where ARSO2, GETR, and POTEN, and ACMIO all declined after treatment but increased the year following (Figure 11). The North/Control area had 9 species with substantial trends; approximately half of these increased from 2011 to 2012 while the other half decreased. As in Grader, no pre-treatment data were available for FPN species in the Control area. In the Clethodim-treated area no species met the trend criteria. Why North/Clethodim did not experience an increase in FPN species similar to the Grader/Clethodim area is not clear as the suite of FPN species present in these areas is similar (all of the species which exhibited trends in Grader were present in North) and the herbicide treatments were done at equal rates and within one day of each other.

Thus Glyphosate areas in both Grader and North experienced a short-term (1 yr) decrease in FPN species after spraying but their abundance increased from the first year post-treatment to the second. This is supports our much other evidence that Glyphosate, a broad-spectrum herbicide, is harmful to FPN species. In contrast, FPN species in Clethodim treated areas remained stable or increased indicating they were not much affected by this grass-specific herbicide. Understanding the capacity for FPN species to rebound quickly after herbicide treatments should help guide future restoration and rehabilitation efforts.

Biennial native forbs (FBN), increased sharply in the Grader/Glyphosate area (from 13% of 1 m radius plots in 2010 to 68% in 2012) and the Grader/Clethodim area (from 19% in 2010 to 69% in 2012; Appendix 2D). North pasture had fewer FBN species pre-treatment than did Grader and experienced negligible changes in the abundance of FBN species. Frequency of FBN increased from 3% to 7% of 5m radius plots in the Glyphosate treated area. In the Clethodim treated frequency was unchanged (4% frequency of FBN before and after treatment in the 5m radius plots). The only common species in this group was the native Palouse thistle (*Cirsium brevifolium;* CIBR) which accounted for over 99% of all FBN observations. Unlike FPN species FBN species did not experience short-term declines in the Glyphosate treated areas indicating that this guild is less susceptible to that broad-spectrum herbicide. It may be that the reproductive capacity of FBN species such as CIBR allows them to take better advantage of bare ground and reduced competition the year following herbicides. Glyphosate is known to kill Canada Thistle (Evans 1984) but its effect on this native thistle species is poorly known.

FPN richness (i.e., the average number of FPN species within a 5m radius plot) varied from 4.4 ± 2.5 SD species to 10.5 ± 9.0 SD in the North/Clethodim and Grader/Glyphosate areas, respectively, prior to treatment (Appendix 2d). Richness tended to increase in treatment areas while in controls FPN richness was stable to very slightly increasing. In Grader, Glyphosate treated areas FPN richness decreased sharply from 10.7 ± 9.0 SD in 2010 to 1.4 ± 4.6 SD in 2011, again indicating that this treatment had strong negative effects on native forbs. But richness rebounded to 13.3 ± 7.4 SD in 2012 suggesting that forbs were able to capitalize on the decreases in GPE that had occurred. In North, similar, though, more subtle changes were observed in FPN richness. In contrast, Clethodim-treated areas showed no decrease in FPN richness from 2010 to 2011, although data were limited to North pasture. FPN richness increased sharply in Grader/Clethodim areas from 2010 to 2012 (from 8.8 ± 10.0 SD to 16.4 ± 5.0 SD) while in North no change in FPN richness was observed.

EXOTIC PERENNIAL AND BIENNIAL FORBS

Exotic perennial forbs (FPE) were scant in both the Grader and North areas prior to initiation of this study with only one species (common dandelion or *Taraxacum officinale*; TAOF) encountered in 2010 prior to treatments. In 2011 four species were encountered (Appendex 2f) and 11 in 2012. The most common FPE species encountered were common dandelion (*Taraxacum officinale*), Canada thistle (*Cirsium arvense*; CIAR4), common St. Johnswort (*Hypericum perforatum;* HYPE), and horehound (*Marrubium vulgare;* MAVU).

We used a similar criteria for assessing trends in FPE and exotic biennial forb species (FBE) as was done for FPN but given the overall low abundance and diversity of these guilds we used 10% as the threshold for substantial change. The Grader/Glyphosate area had the most FPE species with substantial trends in abundance. Four species – CIAR4, HYPE, MAVU, and TAOF – increased over the course of the study. Of these all but MAVU increased the first year post-treatment and was then stable from 2011 to 2012. The increase in MAVU did not occur until the second year post-treatment. No substantial changes were observed in the Grader/Clethodim area; the Grader/Control area saw two species, CIAR4 and TAOF increase from 2011 to 2012. No trends were observed for any FPE species in any of the treatment or control areas of North.

Four species of exotic biennial forbs (FBE) were encountered during the study. No FBE species were recorded in the plots in 2010 and first encounters were made in 2011. The

Grader/Glyphosate area was unique in experiencing substantial change in the abundance of these species. Houndstongue (*Cynoglossum officinale*), teasel (*Dipsacus fullonum* ssp. *Sylvestris*), and Scotch thistle (*Onopordum acanthium*) increased in that area from 2010 to 2011 and then decreased the following year to very low levels (4-8% of 5m radius plots). Bull thistle (*Cirsium vulgare*), however, increased throughout the study, an indication of its invasive character in these ecosystems. No substantial changes were observed in the Clethodim or Control areas of Grader nor in any treatment area of North.

CONCLUSION AND FUTURE WORK

Although the work of rehabilitating the Grader and North old field areas is ongoing, our monitoring to date has provided us with useful information regarding the current status of these areas, progress towards meeting the project's objectives, and the differential effects of the two herbicides employed (Glyphosate and Clethodim) on a variety of plant guilds and species.

PROGRESS TOWARDS MEETING OBJECTIVES

Currently, as we expected, areas treated with Glyphosate, prescribed-fire, and native seeding have reduced amounts of GPE species and higher amounts of GPN species than were present prior to treatment. In areas where the Clethodim herbicide was used, GPE abundance was mostly unchanged though GPN abundance increased. So how well have we met our two objectives related to these guilds?

<u>Objective 1</u>: *Reduce the abundance of perennial exotic grasses from their current abundance of ~ 90% frequency in 5m radius plots to <25%.*

We failed to meet this objective in all areas. Although we documented slight declines in the GPE guild in Glyphosate treated areas in Grader and North from 2010 to 2011 frequencies remained > 85% and in 2012 had rebounded to 100% in all but the Grader/Glyphosate area. Although visually the cover of GPE species appears greatly reduced in the Glyphosate areas and cover data from UR7 show a decline in this guild from 33 to 5%, the 1m frequency data are not sensitive enough to reflect this decline.

<u>Objective 2a</u>: *Increase the abundance of perennial native bunchgrasses at the study sites from their current abundance of ~ 50% in 1 m radius plots to >90%.*

By 2012 we met this objective for all areas including those treated with Glyphosate, Clethodim, and even Control areas. Glyphosate treated areas in Grader and North both had 100% frequencies of GPN by 2011 and maintained those amounts in 2012. Clethodim areas had GPN frequencies of 88-93% while in Control areas frequency was 58-76%

<u>Objective 2b</u>: *Increase the abundance of Idaho fescue (FEID) to >90% and bluebunch wheatgrass (PSSP6) to >50% (both in 1 m radius plots).*

By 2012 FEID frequency in the Glyphosate treated areas was 100% thereby meeting our objective. In Clethodim areas frequencies were 85-88% and thus somewhat lower than desired conditions. For PSSP6 Glyphosate-treated areas exceeded expectations (81% in Grader and 69% in North in 2012) whereas Clethodim-treated areas had < 10% frequency of this bunchgrass in 2012.

Objective 2c: *In Grader Pasture, where we believe there is habitat for basin wildrye, increase this species to 10% of 5m radius plots.*

We met this objective for the Grader/Glyphosate area in 2012 with a measured frequency of 35%.

The third objective outlined in our first report (Taylor et al. 2011) related to increasing species richness via the planting of native forb species. As no specific objectives were given we cannot evaluate progress towards meeting this goal, though we did observe increases in FPN richness in all treatment areas except North/Clethodim. Given our observations to date, we believe it is reasonable to set a goal of 20 FPN species / 5m radius plot. In the future, we will evaluate our progress towards meeting this in areas seeded with FPN species in the fall of 2012 vs. areas not receiving that treatment.

GLYPHOSATE VS CLETHODIM?

Because Glyphosate-treated areas had greater reductions in GPE species and higher abundance of GPN species they came closer to meeting our objectives than did areas treated with Clethodim. Both our data and informal observations of the project areas indicate profound differences between the Glyphosate and Clethodim treated areas. GPE species in Glyphosate-treated areas experienced substantial reductions in abundance while areas sprayed with Clethodim experienced some reductions in 2011 but these mostly rhizomatous grass species were able to re-establish dominance by 2012. Seeding of native bunchgrasses using the range drill succeeded in increasing the abundance of GPN species in both the Glyphosate and Clethodim-treated areas. Because these seedlings face less competition from GPE species in the Glyphosate than in the Clethodim-treated areas we have greater confidence that they will continue to increase in those communities. It is possible, however, that the large increase in annual grass species in these areas may interfere with the ability of GPN species to increase. The application of the herbicide Outrider in the fall of 2012, if effective, should reduce the likelihood of that happening though there is still the possibility that GPE species will continue to increase, thus, inhibiting the recruitment of the native bunchgrasses.

The decision to use Clethodim in some areas was made based on the knowledge that some old fields (e.g., North) have a relatively high amount of FPN species, and we wanted to try a herbicidal treatment that would conserve those species. We found that Clethodim had neutral to positive effects on FPN species whereas Glyphosate-treated areas experienced short-term declines. The quick rebound of FPN species that occurred from the first to second year post-treatment suggests that the short-term advantage conferred by using Clethodim, provided that application is done at a similar time of year and plant phenology, probably does not outweigh its much more limited effectiveness at controlling GPE species.

Based on our results so far, it thus appears that in conjunction with burning and native seeding Glyphosate is a better tool for moving old field areas towards native dominance.

LESSONS LEARNED AND FUTURE PLANS

Nothing goes according to plans thus providing opportunities for learning. What were some of the surprises that we encountered and what might we do differently in the future? Clethodim, it turned out, was not lethal enough to the PGE species that dominated the Grader and North old fields, at least not with timing and rate we used. Barring further studies, we do not recommend it for reducing BRIN or THIN6 but our results do show it was somewhat effective at reducing Poa species (i.e., POPR/POCO/POBU).

Some increase in GAE species VEDU and APIN was not unexpected, but the increase, especially in Glyphosate areas was dramatic. Reducing the abundance of GAE species should benefit GPN recruitment. At present, application of an early postemergence herbicide such as Outrider (Sulfosulfuron) is the only option we are aware of for suppression of GAE species. Future old field rehabilitation projects should plan for this follow-up treatment.

Our monitoring approach of using nested frequency plots of 1m, 3m, and 5m worked well for tracking species level abundance but proved too insensitive for measuring changes in more abundant guilds such as GPN, GPE, and FPN. Data from the UR7 site appeared to capture the changes occurring in the North/Glyphosate area well. We recommend similar monitoring for future studies, supplementing it with belt transects and/or smaller nested frequency sampling for species in lower abundance.

Two years after the initiation of our old field rehabilitation project we are optimistic that we can, with continued monitoring and interventions, meet our goals of improving the ecological condition of the Grader and North old field areas, at least those where the Glyphosate, burning, and seeding treatments were implemented. Continued monitoring of the abundance of important guilds (GPN, GPE, GAE, FPN, FPE) will allow us to gauge our eventual success. Especially interesting will be the future trajectory of basin wildrye in Grader pasture since this species was absent prior to treatment and only in 2012 did we see any recruitment.

We recommend repeat monitoring of this area in 2013, but only in the Glyphosate treated areas that are scheduled for application of the Outrider herbicide. Over the long-term, monitoring of the Clethodim areas may also provide useful information regarding the ability of seeded native bunchgrasses to establish and compete with established exotic grass species.

REFERENCES

Bartuszevige, A. M., P. L. Kennedy, and R. V. Taylor. 2012. Sixty-seven years of landscape change in the last, large, remnant of the Pacific Northwest Bunchgrass prairie. Natural Areas Journal **32**:166-170.

Elzinga, C., D. Salzer, and J. Willoughby. 1998. Measuring and Monitoring Plant Populations. Technical Reference 1730-1, Bureau of Land Management.

Evans, J. 1984. Canada thistle (Cirsium arvense): a literature review of management practices. Natural Areas Journal **4**:11-21.

Taylor, R. V., D. A. Ball, and J. Fields. 2011. Zumwalt Old Field Rehabilitation: Pre-treatment Conditions, Treatment Details, and Project Goals. The Nature Conservancy, Enterprise, OR.

Taylor, R. V. and V. S. Jansen. 2008. Mapping and Monitoring the Abundance of Noxious Weeds on the Prairie Uplands of the Zumwalt Prairie Preserve with Analysis of Short-term Trends. The Nature Conservancy, Enterprise, OR.

Taylor, R. V., M. L. Pokorny, N. Rudd, and J. Mangold. In preparation. Can a combination of grazing, herbicides, and seeding facilitate succession in old fields? Restoration Ecology.

Taylor, R. V. and H. J. Schmalz. 2012. Monitoring of upland prairie vegetation on the Zumwalt Prairie Preserve, 2003-2011. The Nature Conservancy, Enterprise, OR.

Yoda, K., T. Kira, H. Ogawa, and K. Hozumi. 1963. Self thinning in overcrowded pure stands under cultivated and natural conditions. Journal of Biology, Osaka City University **14**:106-129.

APPENDIX 1 - EXPLANATION OF SPECIES AND GUILD CODES

SPECIES

PlantID	Scientific name	Common name	Comments
APIN	*Apera interrupta*	dense silkybent	Exotic, Annual
BRIN2	*Bromus inermis*	smooth brome	Exotic, Perennial
BROMU	*Bromus*	Bromus spp. (annual)	Exotic, Annual
CAREX	*Carex* spp.	Carex spp.	Native, Perennial
FEID	*Festuca idahoensis*	Idaho fescue	Native, Perennial
KOMA	*Koeleria macrantha*	prairie Junegrass	Native, Perennial
LECI4	*Leymus cinereus*	basin wild rye	Native, Perennial
PASM/THIN6	*Pascopyrum smithii/Thinopyron intermedium*	western/intermediate wheatgrass	Exotic, Perennial
POPR/POCO/POBU	*Poa pratensis/P. compressa/P. bulbosa*	Poa species	Exotic, Perennial
POSE	*Poa secunda*	Sandberg bluegrass	Native, Perennial
PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass	Native, Perennial
VEDU	*Ventenata dubia*	North Africa grass	Exotic, Annual

GUILDS

Guild	Description
GPN	Grass, perennial, native
GPE	Grass, perennial, exotic
GAE	Grass, annual, exotic
FPN	Forb, perennial, native
FPE	Forb, perennial, exotic
FBN	Forb, biennial, native
FBE	Forb, biennial, exotic

APPENDIX 2 – DATA TABLES

APPENDIX 2A – FREQUENCY OF GRASSES (NATIVE AND EXOTIC) BY GUILD

Pasture	Treatment Type	Guild[1]	2007	2010	2011	2012
Grader	Glyphosate	GAE	0%	87%	78%	100%
		GPE	80%	100%	89%	87%
		GPN	87%	61%	100%	100%
	Clethodim	GAE	0%	94%	N/A	100%
		GPE	100%	100%	N/A	100%
		GPN	33%	31%	N/A	88%
	Control	GAE	0%	N/A	92%	92%
		GPE	96%	N/A	100%	100%
		GPN	46%	N/A	58%	58%
North	Glyphosate	GAE	0%	78%	100%	100%
		GPE	100%	94%	89%	100%
		GPN	29%	53%	100%	100%
	Clethodim	GAE	0%	93%	100%	96%
		GPE	100%	96%	100%	100%
		GPN	25%	67%	100%	93%
	Control	GAE	0%	N/A	63%	53%
		GPE	98%	N/A	100%	94%
		GPN	53%	N/A	88%	76%

1 – All frequencies based on 1 m radius (3.14 m^2) plots

2 – See Appendix 1 for explanation of species codes.

APPENDIX 2B – FREQUENCY OF GRASSES (NATIVE AND EXOTIC) BY SPECIES

A. Frequency[1] of native perennial grass species and species groups[2] in Grader and North Pasture from 2007-2012 by treatment.

Pasture	Treatment Type	PlantID[3]	2007	2010	2011	2012
Grader	Glyphosate	FEID	40%	42%	89%	100%
		KOMA	73%	29%	78%	87%
		LECI4	0%	0%	0%	35%
		POSE	7%	0%	100%	87%
		PSSP6	0%	0%	100%	81%
	Clethodim	FEID	0%	13%	N/A	88%
		KOMA	33%	31%	N/A	44%
		LECI4	0%	0%	N/A	0%
		POSE	0%	0%	N/A	13%
		PSSP6	0%	0%	N/A	6%
	Control	FEID	27%	N/A	25%	50%
		KOMA	38%	N/A	50%	33%
		LECI4	0%	N/A	0%	0%
		POSE	0%	N/A	8%	17%
		PSSP6	0%	N/A	0%	0%
North	Glyphosate	FEID	14%	25%	100%	100%
		KOMA	0%	3%	82%	75%
		LECI4	0%	0%	0%	3%
		POSE	14%	28%	100%	81%
		PSSP6	0%	0%	64%	69%
	Clethodim	FEID	0%	30%	100%	85%
		KOMA	0%	11%	78%	19%
		LECI4	0%	0%	0%	0%
		POSE	0%	37%	100%	30%
		PSSP6	0%	4%	44%	7%
	Control	FEID	41%	N/A	81%	71%
		KOMA	18%	N/A	63%	41%
		LECI4	0%	N/A	0%	0%
		POSE	10%	N/A	19%	24%
		PSSP6	8%	N/A	44%	35%

1 – All frequencies based on 1 m radius (3.14 m^2) plots
2 – Only species which had an average frequency of 10% or greater across all years or were included in the native bunchgrass seed mix are included here.
3 – See Appendix 1 for explanation of species codes.

B. Frequency[1] of exotic perennial grass species and species groups[2] in Grader and North Pasture from 2007-2012 by treatment.

Pasture	TreatType	PlantID[3]	2007	2010	2011	2012
Grader	Glyphosate	BRIN2	67%	100%	78%	77%
		PASM/THIN6/AGCR	7%	87%	11%	29%
		POPR/POCO/POBU	47%	55%	56%	26%
	Clethodim	BRIN2	100%	100%	N/A	100%
		PASM/THIN6/AGCR	0%	63%	N/A	69%
		POPR/POCO/POBU	67%	31%	N/A	13%
	Control	BRIN2	81%	N/A	100%	100%
		PASM/THIN6/AGCR	31%	N/A	50%	17%
		POPR/POCO/POBU	65%	N/A	100%	83%
North	Glyphosate	BRIN2	0%	22%	4%	3%
		PASM/THIN6/AGCR	100%	88%	71%	97%
		POPR/POCO/POBU	29%	69%	54%	53%
	Clethodim	BRIN2	0%	33%	7%	4%
		PASM/THIN6/AGCR	100%	96%	100%	100%
		POPR/POCO/POBU	50%	81%	63%	26%
	Control	BRIN2	0%	N/A	0%	0%
		PASM/THIN6/AGCR	98%	N/A	94%	94%
		POPR/POCO/POBU	14%	N/A	50%	24%

1 – All frequencies based on 1 m radius (3.14 m^2) plots.

2 – Only species which had an average frequency of 5% or greater across all years are included here.

3 – See Appendix 1 for explanation of species codes.

C. Frequency[1] of annual grass species and species groups[2] (all exotic) in Grader and North Pasture from 2007-2012 by treatment.

Pasture	TreatType	PlantID	2007	2010	2011	2012
Grader	Glyphosate	APIN	0%	26%	67%	81%
		BROMU	0%	6%	0%	19%
		VEDU	0%	77%	78%	94%
	Clethodim	APIN	0%	19%	N/A	19%
		BROMU	0%	6%	N/A	0%
		VEDU	0%	94%	N/A	100%
	Control	APIN	0%	N/A	83%	67%
		BROMU	0%	N/A	0%	17%
		VEDU	0%	N/A	25%	33%
North	Glyphosate	APIN	0%	50%	93%	72%
		BROMU	0%	0%	0%	41%
		VEDU	0%	56%	68%	75%
	Clethodim	APIN	0%	56%	78%	52%
		BROMU	0%	22%	19%	15%
		VEDU	0%	63%	78%	74%
	Control	APIN	0%	N/A	25%	6%
		BROMU	0%	N/A	0%	6%
		VEDU	0%	N/A	50%	47%

1 – All frequencies based on 1 m radius (3.14 m^2) plots.
2 – Only species which had an average frequency of 5% or greater across all years are included here.
3 – See Appendix 1 for explanation of species codes.

APPENDIX 2C – DENSITY OF NATIVE PERENNIAL GRASS SPECIES

			2011		2012	
Pasture	Treatment Type	PlantID[3]	N	Mean (± SD)	N	Mean (± SD)
Grader	Glyphosate	FEID	5	26.3 (± 23.6)	31	12.5 (± 8.7)
		KOMA	5	6.3 (± 6.3)	31	5.4 (± 6.2)
		LECI4	5	0.0 (± 0.0)	31	0.4 (± 1.6)
		POSE	5	30.0 (± 19.0)	31	6.5 (± 8.0)
		PSSP6	5	1.3 (± 2.8)	31	3.2 (± 4.8)
	Clethodim	FEID	0	N/A	16	12.1 (± 16.2)
		KOMA	0	N/A	16	3.9 (± 10.9)
		LECI4	0	N/A	16	0.0 (± 0.0)
		POSE	0	N/A	16	0.4 (± 1.6)
		PSSP6	0	N/A	16	0.8 (± 3.1)
	Control	FEID	0	N/A	12	3.6 (± 8.6)
		KOMA	0	N/A	12	0.0 (± 0.0)
		LECI4	0	N/A	12	0.0 (± 0.0)
		POSE	0	N/A	12	1.0 (± 3.6)
		PSSP6	0	N/A	12	0.0 (± 0.0)
North	Glyphosate	FEID	14	17.4 (± 11.3)	32	13.5 (± 12.1)
		KOMA	14	4.9 (± 5.0)	32	6.4 (± 7.0)
		LECI4	14	0.0 (± 0.0)	32	0.0 (± 0.0)
		POSE	14	30.4 (± 19.3)	32	14.5 (± 16.8)
		PSSP6	14	0.9 (± 2.3)	32	2.9 (± 5.5)
	Clethodim	FEID	15	41.7 (± 31.0)	27	11.1 (± 12.8)
		KOMA	15	3.8 (± 4.6)	27	3.0 (± 12.2)
		LECI4	15	0.0 (± 0.0)	27	0.0 (± 0.0)
		POSE	15	52.5 (± 58.1)	27	3.2 (± 6.1)
		PSSP6	15	3.3 (± 6.6)	27	0.2 (± 1.2)
	Control	FEID	0	N/A	17	24.3 (± 35.1)
		KOMA	0	N/A	17	1.1 (± 3.3)
		LECI4	0	N/A	17	0.0 (± 0.0)
		POSE	0	N/A	17	0.4 (± 1.5)
		PSSP6	0	N/A	17	4.4 (± 11.0)

1 – All densities based on 20 x 80 cm (0.16 m^2) plots.
2 – Only species that were seeded, e.g., FEID, KOMA, LECI4, POSE, and PSSP6) were measured.
3 – See Appendix 1 for explanation of species codes..

APPENDIX 2D – FREQUENCY OF FORBS (NATIVE AND EXOTIC) BY GUILD

Pasture	TreatType	Guild[1]	2007	2010	2011	2012
Grader	Glyphosate	FBE	N/A	0%	33%	61%
		FBN	N/A	13%	22%	68%
		FPE	N/A	10%	44%	61%
		FPN	N/A	65%	44%	74%
	Clethodim	FBE	N/A	0%	N/A	0%
		FBN	N/A	19%	N/A	69%
		FPE	N/A	31%	N/A	44%
		FPN	N/A	31%	N/A	75%
	Control	FBE	N/A	N/A	8%	0%
		FBN	N/A	N/A	75%	42%
		FPE	N/A	13%	21%	25%
		FPN	N/A	N/A	75%	67%
North	Glyphosate	FBE	N/A	0%	4%	3%
		FBN	N/A	3%	7%	3%
		FPE	N/A	0%	4%	3%
		FPN	N/A	100%	96%	100%
	Clethodim	FBE	N/A	0%	0%	0%
		FBN	N/A	4%	4%	4%
		FPE	N/A	11%	15%	15%
		FPN	N/A	93%	100%	100%
	Control	FBE	N/A	N/A	0%	0%
		FBN	N/A	N/A	0%	0%
		FPE	N/A	N/A	13%	18%
		FPN	N/A	N/A	100%	100%

1 – Frequencies of FPN and FBN based on 1 m radius (3.14 m^2) plots; Frequencies of FPE and FBE based on 5 m radius (78.5 m^2) plots;
2 – See Appendix 1 for explanation of guildcodes.

APPENDIX 2E – NATIVE PERENNIAL FORBS BY SPECIES AND TRENDS OVER TIME

A. Abundance of all native perennial forbs occurring in the Grader and North Restoration area. Shown are the frequencies of 5m radius plots averaged across all years and all treatments by species and by area.

PlantID	Grader	North	Common name (SciName)
POTEN	61%	88%	*Potentilla* spp.
ACMIO	40%	88%	western yarrow (*Achillea millefolium* var. *occidentalis*)
HICY	41%	85%	western hawkweed (*Hieracium cynoglossoides*)
ARSO2	49%	76%	twin arnica (*Arnica sororia*)
SOLID	37%	85%	*Solidago* spp.
GETR	49%	69%	old man's whiskers (*Geum triflorum*)
SYMPH4	27%	85%	*Symphyotrichum* spp.
ERIGE2	26%	85%	*Erigeron* spp.
LUPIN	49%	59%	*Lupinus* spp.
CALOCH	23%	85%	*Calochortus* spp.
LOMAT	23%	85%	*Lomatium* spp.
LIGL2	19%	85%	bulbous woodland-star (*Lithophragma glabrum*)
DELPH	18%	85%	*Delphinium* spp.
FRPU2	16%	85%	yellow fritillary (*Fritillaria pudica*)
ANTEN	15%	85%	*Antennaria* spp.
AGOSE	49%	49%	*Agoseris* spp.
CREPI	9%	85%	*Crepis* spp.
SAIN4	8%	85%	wholeleaf saxifrage (*Saxifraga integrifolia*)
PEGA3	7%	85%	Gardner's yampah (*Perideridia gairdneri*)
ZIVE	49%	41%	meadow deathcamas (*Zigadenus venenosus*)
FRAL2	49%	38%	whitestem frasera (*Frasera albicaulis*)
SENEC	49%	37%	*Senecio* spp.
GRIND	0%	85%	*Grindelia* spp.
MINU	49%	35%	nodding microseris (*Microseris nutans*)
ASTRAG	49%	34%	*Astragalus* spp.
SIOR	0%	60%	Oregon checkerbloom (*Sidalcea oregana*)
BERU	0%	42%	red besseya (*Besseya rubra*)
CLHI	0%	39%	hairy clematis (*Clematis hirsutissima*)
PHHE2	0%	36%	varileaf phacelia (*Phacelia heterophylla*)
LIRU4	0%	33%	western stoneseed (*Lithospermum ruderale*)
PENST	0%	27%	*Penstemon* spp.
PHLOX	0%	24%	*Phlox* spp.

CACU7	0%	18%	Cusick's Indian paintbrush (*Castilleja cusickii*)
CASTI2	0%	18%	*Castilleja* spp.
GEVI2	0%	15%	sticky purple geranium (*Geranium viscosissimum*)
ERIOG	0%	12%	Eriogonum spp.
FRSP	0%	12%	elkweed (*Frasera speciosa*)
TRGRG2	0%	12%	largeflower triteleia (*Triteleia grandiflora* var. *grandiflora*)
AMMEI2	0%	9%	common fiddleneck (*Amsinckia menziesii* var. *intermedia*)
BAIN	0%	9%	hoary balsamroot (*Balsamorhiza incana*)
GABO2	0%	9%	northern bedstraw (*Galium boreale*)
ERLA6	0%	6%	common woolly sunflower (*Eriophyllum lanatum*)
PLMA2	0%	6%	common plantain (*Plantago major*)
VIOLA	0%	6%	Viola spp.
AGUR	0%	3%	nettleleaf giant hyssop (*Agastache urticifolia*)
ARHO2	0%	3%	Holboell's rockcress (*Arabis holboellii*)
CEAR4	0%	3%	field chickweed (*Cerastium arvense*)
FRVI	0%	3%	Virginia strawberry (*Fragaria virginiana*)
OLDOI	0%	3%	inflated grasswidow (*Olsynium douglasii* var. *inflatum*)
SCLA	0%	3%	lanceleaf figwort (*Scrophularia lanceolata*)
SEST2	0%	3%	wormleaf stonecrop (*Sedum stenopetalum*)
SISC7	0%	3%	simple campion (*Silene scouleri*)
VAEDE	0%	3%	tobacco root (*Valeriana edulis* var. *edulis*)

B. Native perennial forbs experiencing substantial trends in Grader and North based on frequency monitoring.

Grader

Common name (SciName)	Glyphosate 2010-2011	Glyphosate 2011-2012	Glyphosate 2010-2012	Clethodim 2010-2011	Clethodim 2011-2012	Clethodim 2010-2012
western yarrow (*Achillea millefolium* var. *occidentalis*)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
false dandelion (Agoseris spp.)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
twin arnica (*Arnica sororia*)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
vetch (Astragalus spp.)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
fleabane (Erigeron spp.)	NONE	INCREASE	NONE	NONE	NONE	NONE
whitestem frasera (*Frasera albicaulis*)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
old man's whiskers (*Geum triflorum*)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
western hawkweed (*Hieracium cynoglossoides*)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
lupine (Lupinus spp.)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
nodding microseris (*Microseris nutans*)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
cinquefoil (*Potentilla* spp.)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
groundsel (*Senecio* spp.)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
goldenrod (*Solidago* spp.)	DECREASE	INCREASE	NONE	N/A	N/A	INCREASE
aster (*Symphyotrichum* spp.)	NONE	INCREASE	INCREASE	N/A	N/A	INCREASE
meadow deathcamas (*Zigadenus venenosus*)	NONE	INCREASE	NONE	N/A	N/A	INCREASE

1 – Only species with increasing or decreasing trends across at least two sampling bouts are shown.
2 – A species was considered to have “increased” if the frequency increased by 20% or more from one sampling year to the next. A species was considered to have “decreased” if the frequency decreased by 20% or more from one sampling year to the next.
3 – No changes were observed in the Control area.

North

Common name (SciName)	Glyphosate 2010-2011	Glyphosate 2011-2012	Glyphosate 2010-2012	Control 2010-2011	Control 2011-2012	Control 2010-2012
western yarrow (*Achillea millefolium* var. *occidentalis*)	DECREASE	INCREASE	DECREASE	N/A	NONE	N/A
false dandelion (*Agoseris* spp.)	NONE	NONE	NONE	N/A	INCREASE	N/A
pussytoes (*Antennaria* spp.)	NONE	NONE	NONE	N/A	INCREASE	N/A
twin arnica (*Arnica* sororia)	DECREASE	INCREASE	NONE	N/A	NONE	N/A
vetch (*Astragalus* spp.)	NONE	NONE	NONE	N/A	DECREASE	N/A
fleabane (*Erigeron* spp.)	NONE	NONE	NONE	N/A	DECREASE	N/A
old man's whiskers (*Geum triflorum*)	DECREASE	INCREASE	NONE	N/A	NONE	N/A
gumweed (*Grindelia* spp.)	NONE	NONE	NONE	N/A	INCREASE	N/A
Gardner's yampah (*Perideridia gairdneri*)	NONE	NONE	NONE	N/A	DECREASE	N/A
cinquefoil (*Potentilla* spp.)	DECREASE	INCREASE	NONE	N/A	NONE	N/A
wholeleaf saxifrage (*Saxifraga integrifolia*)	NONE	NONE	NONE	N/A	INCREASE	N/A
goldenrod (*Solidago* spp.)	NONE	NONE	NONE	N/A	DECREASE	N/A
meadow deathcamas (*Zigadenus venenosus*)	NONE	NONE	NONE	N/A	INCREASE	N/A

1 – Only species with increasing or decreasing trends across at least two sampling bouts are shown.
2 – A species was considered to have "increased" if the frequency increased by 20% or more from one sampling year to the next. A species was considered to have "decreased" if the frequency decreased by 20% or more from one sampling year to the next.
3 – No changes were observed in the Clethodim-treated area.

C. Species richness of native perennial forbs over time.

Pasture	Treatment	2010	2011	2012
Grader	Glyphosate	10.7 ± 9.0 SD	1.4 ± 4.6 SD	13.3 ± 7.4 SD
	Clethodim	8.8 ± 10.0 SD	N/A	16.4 ± 5.0 SD
	Control	N/A	1.7 ± 1.2 SD	1.6 ± 1.0 SD
North	Glyphosate	4.7 ± 3.3 SD	3.1 ± 4.0 SD	5.4 ± 3.1 SD
	Clethodim	4.4 ± 2.5 SD	4.6 ± 2.3 SD	4.6 ± 2.0 SD
	Control	N/A	26.5 ± 13.2 SD	29.5 ± 5.6 SD

APPENDIX 2F – EXOTIC PERENNIAL FORBS BY SPECIES AND TRENDS OVER TIME

A. Abundance of all exotic perennial forbs occurring in the Grader and North Restoration area. Shown are the frequencies of 5m radius plots averaged across all years and all treatments by species and by area.

PlantID	Grader	North	Common name (SciName)
TAOF	19%	3%	common dandelion (*Taraxacum officinale*)
CIAR4	18%	1%	Canada thistle (*Cirsium arvense*)
HYPE	7%	0%	common St. Johnswort (*Hypericum perforatum*)
MAVU	5%	0%	horehound (*Marrubium vulgare*)
NECA2	1%	0%	catnip (*Nepeta cataria*)
PORE5	1%	0%	sulphur cinquefoil (*Potentilla recta*)
SAMIM	1%	0%	small burnet (*Sanguisorba minor* ssp. *muricata*)
MELU	1%	0%	black medick (*Medicago lupulina*)
RANUN	1%	0%	*Ranunculus* spp.
TRIFO	1%	0%	*Trifolium* spp.
VIVI	1%	0%	winter vetch (*Vicia villosa*)

B. Exotic perennial forbs experiencing substantial trends in Grader and North based on frequency monitoring.

Grader

	Glyphosate			Control		
Common name (SciName)	**2010-2011**	**2011-2012**	**2010-2012**	**2010-2011**	**2011-2012**	**2010-2012**
Canada thistle (*Cirsium arvense*)	INCREASE	NONE	INCREASE	N/A	INCREASE	N/A
common St. Johnswort (*Hypericum perforatum*)	INCREASE	NONE	INCREASE	NONE	NONE	NONE
horehound (*Marrubium vulgare*)	NONE	INCREASE	INCREASE	NONE	NONE	NONE
common dandelion (*Taraxacum officinale*)	INCREASE	NONE	INCREASE	N/A	INCREASE	N/A

1 – Only species with increasing or decreasing trends across at least two sampling bouts are shown.
2 – A species was considered to have “increased” if the frequency increased by 10% or more from one sampling year to the next. A species was considered to have “decreased” if the frequency decreased by 10% or more from one sampling year to the next.
3 – No changes were observed in the Clethodim-treated area.

North

No trends were observed in the Glyphosate, Clethodim or Control areas of North Pasture.

1 – Only species with increasing or decreasing trends across at least two sampling bouts are shown.
2 – A species was considered to have “increased” if the frequency increased by 10% or more from one sampling year to the next. A species was considered to have “decreased” if the frequency decreased by 10% or more from one sampling year to the next.

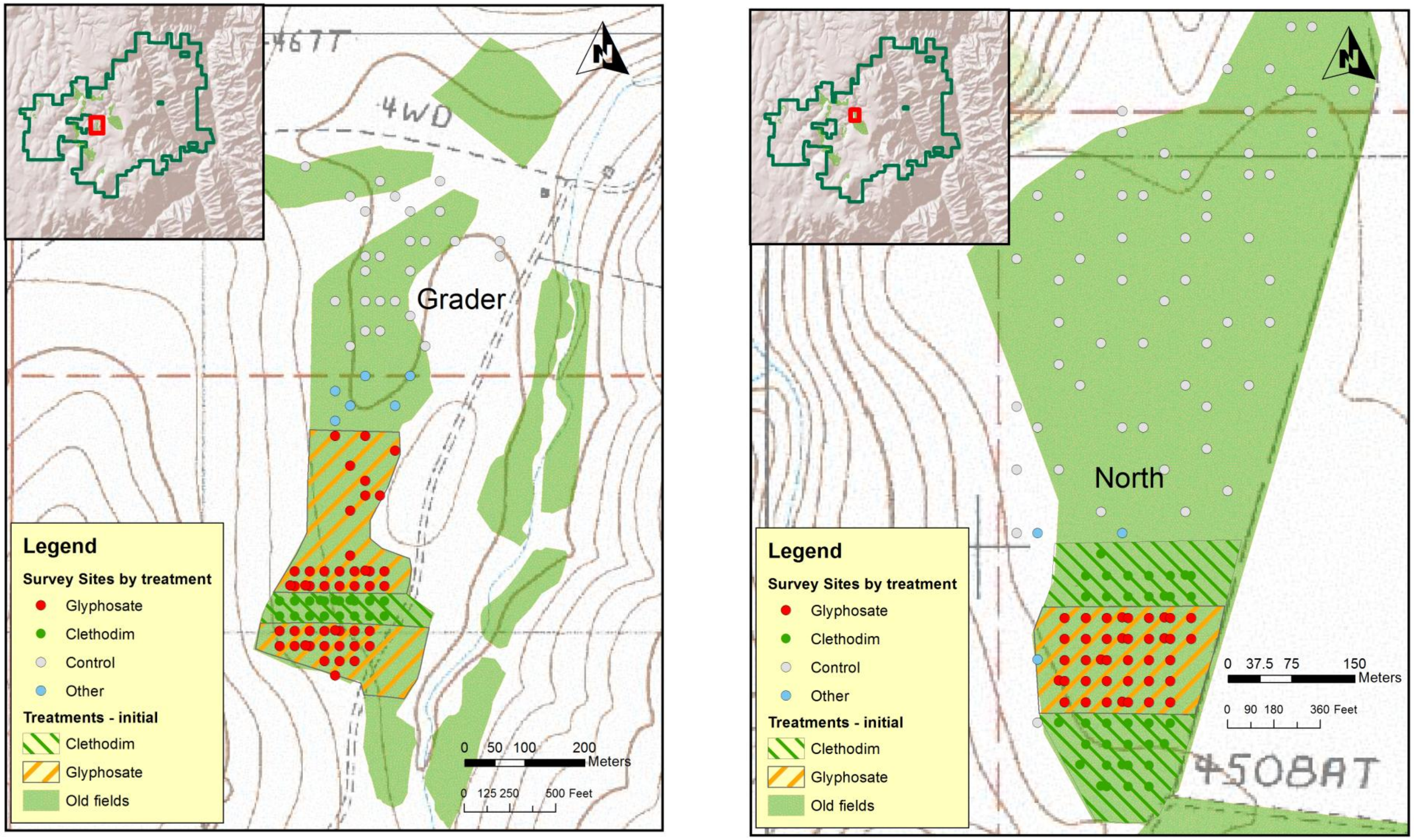

Figure 1. Map of the "Grader" (left) and "North" (right) study areas showing the areas treated with glyphosate and clethodim herbicides in 2010 and the monitoring survey site locations.

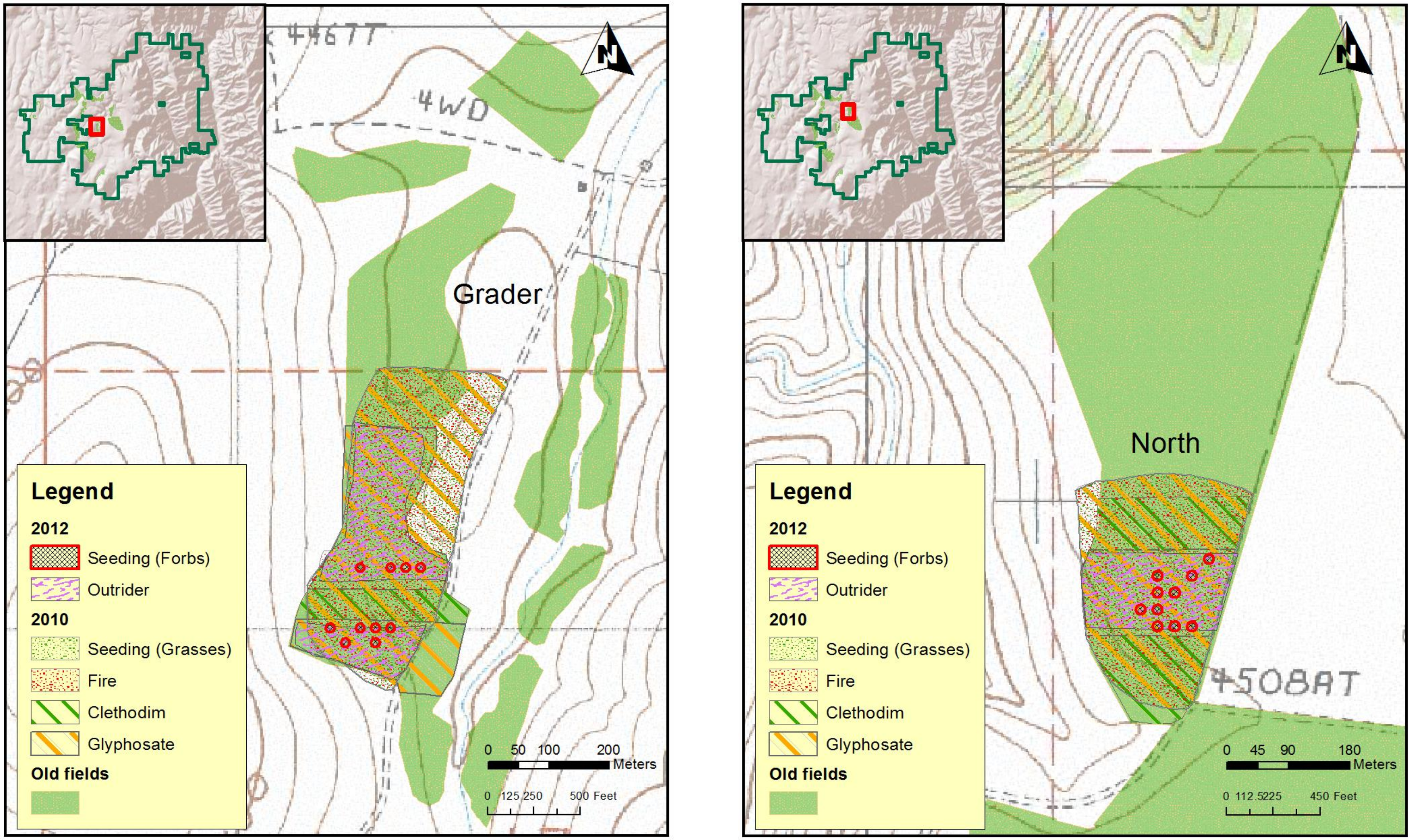

Figure 2. Map of all treatments (herbicides, prescribed fire, and native seeding) applied in the Grader (left) and North (right) study areas from summer of 2010 through fall of 2012.

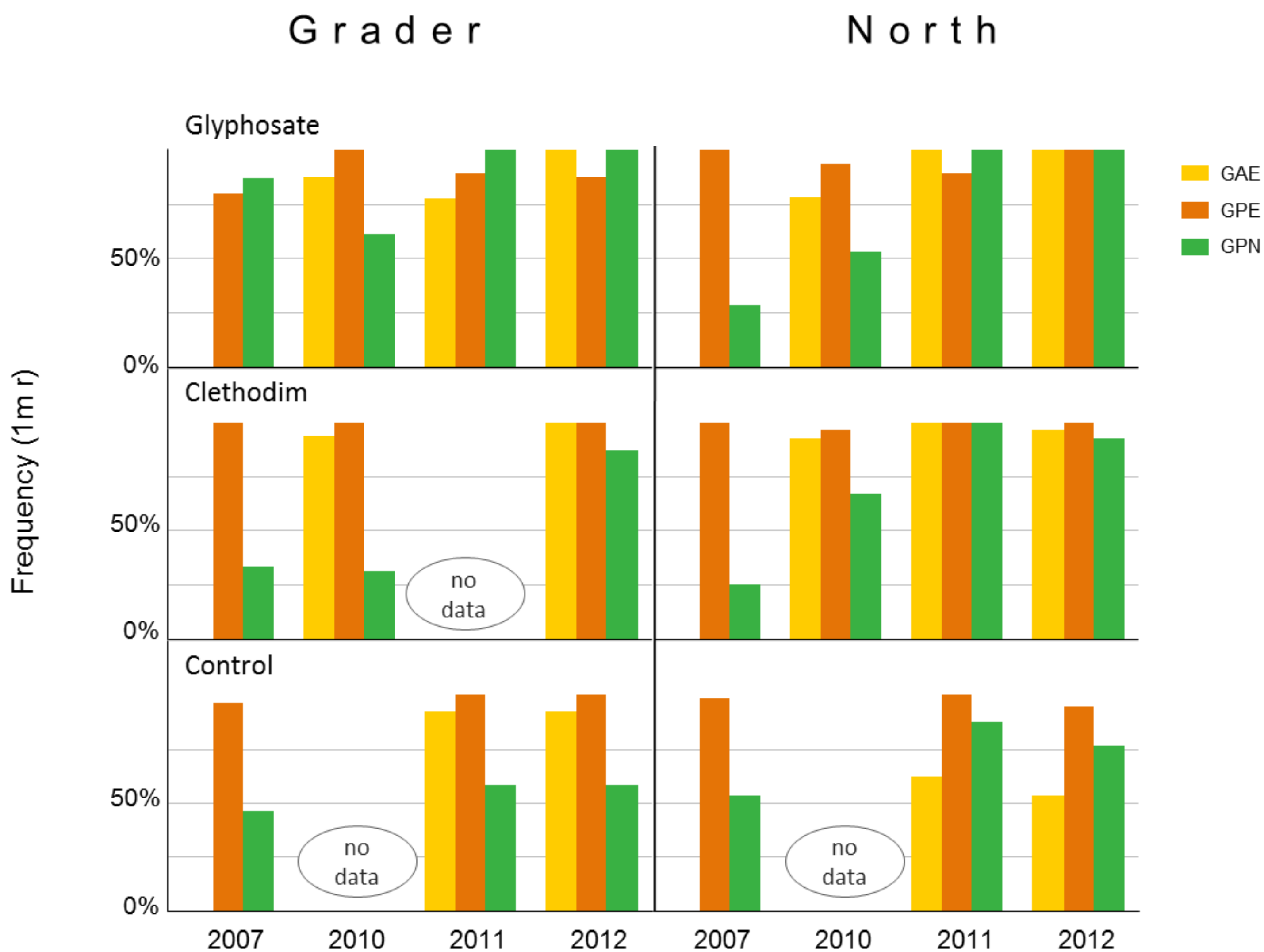

Figure 3. Changes in native perennial (GPN) and exotic annual grass (GAE) and exotic perennial grass (GPE) guilds over time in the treatment and control areas.

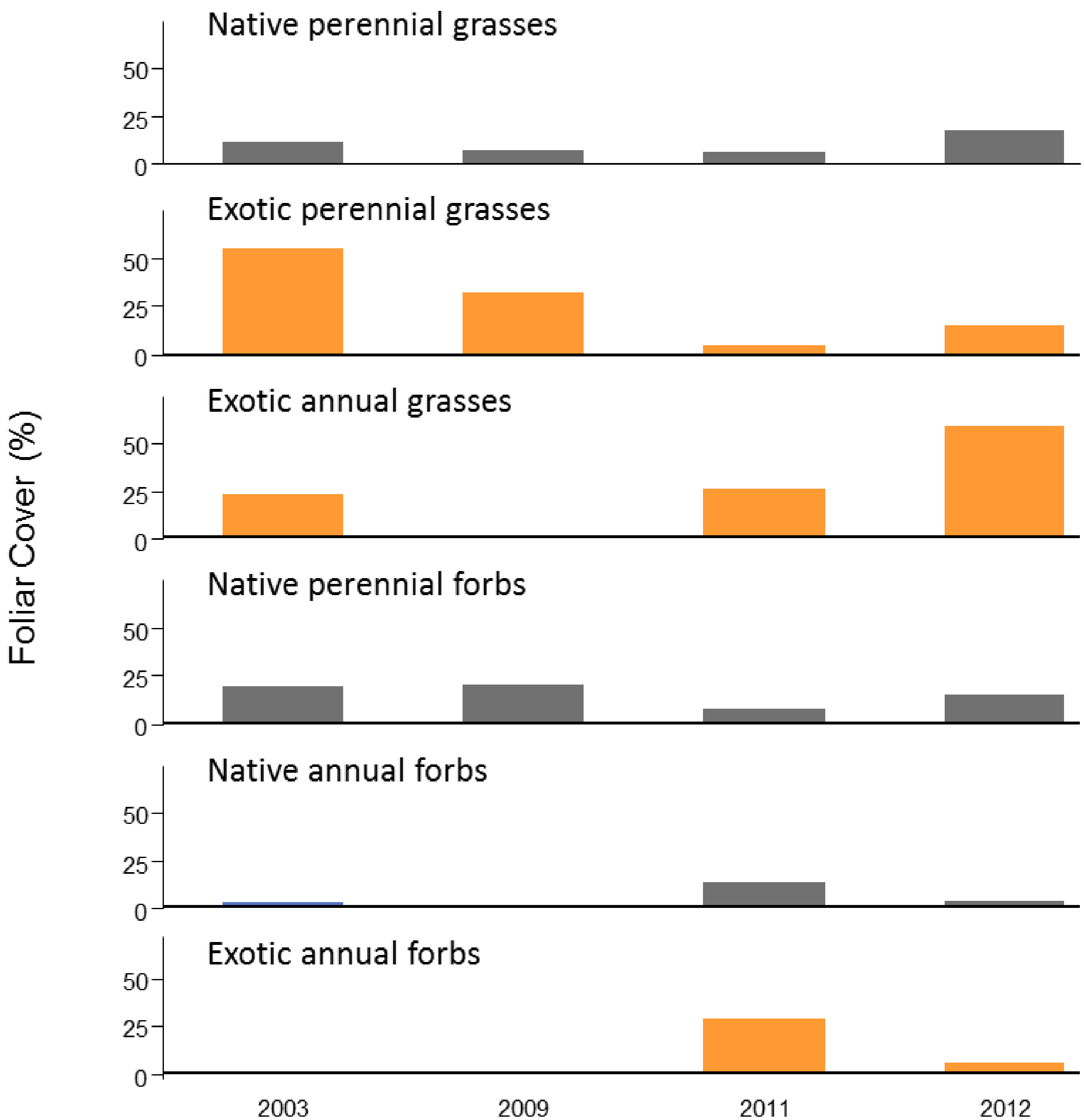

Figure 4. Changes in foliar cover of native and perennial grasses and forbs, by guild, from the upland range monitoring site UR7 in the glyphosate-treated area of North pasture. Exotic species are represented with orange bars while natives are gray.

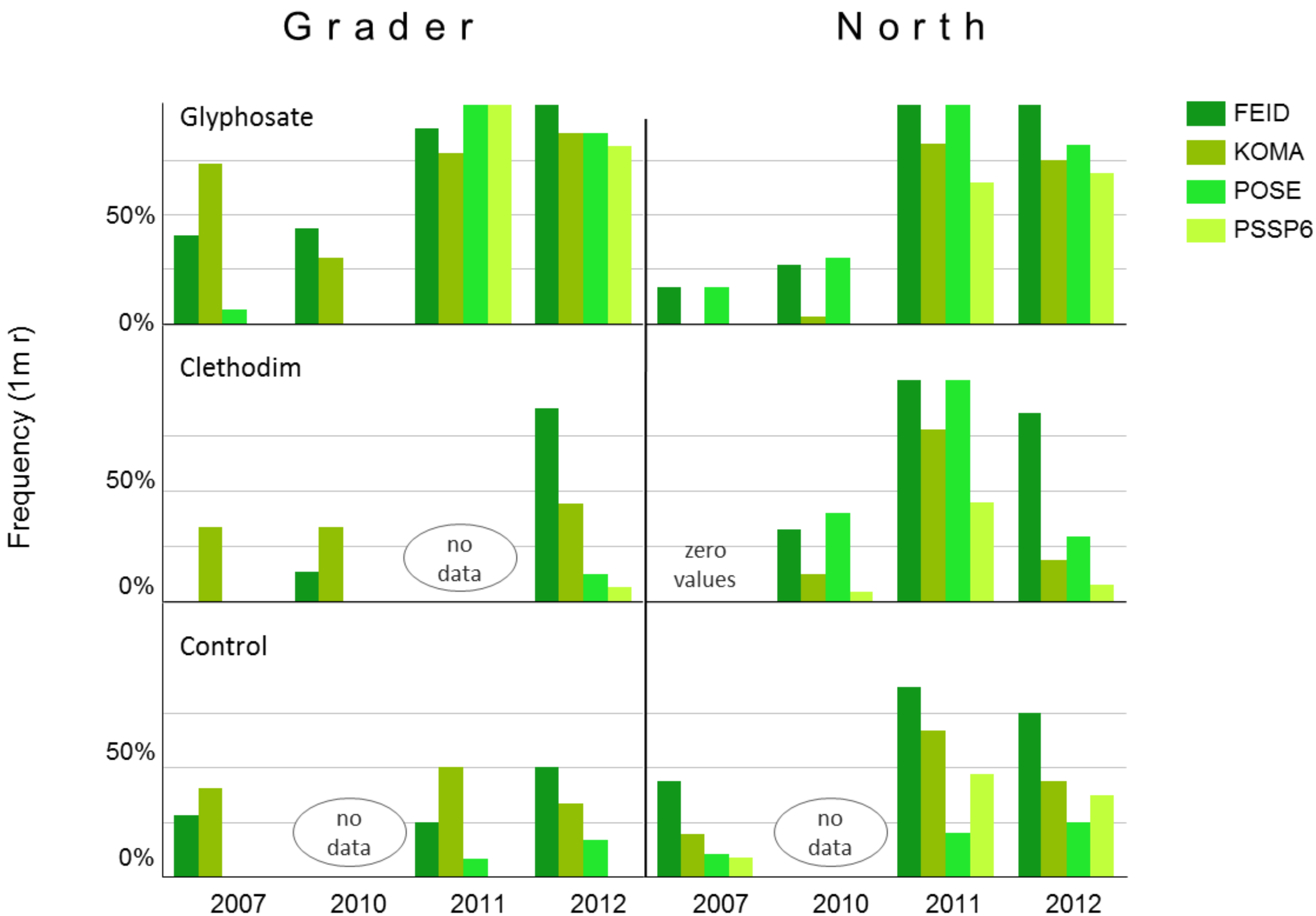

Figure 5. Changes in frequency of native perennial grass species over time within 1 m radius circular plots. Note that only grass species with average frequency values of 10% or greater shown. See Appendix 1 for explanation of species codes.

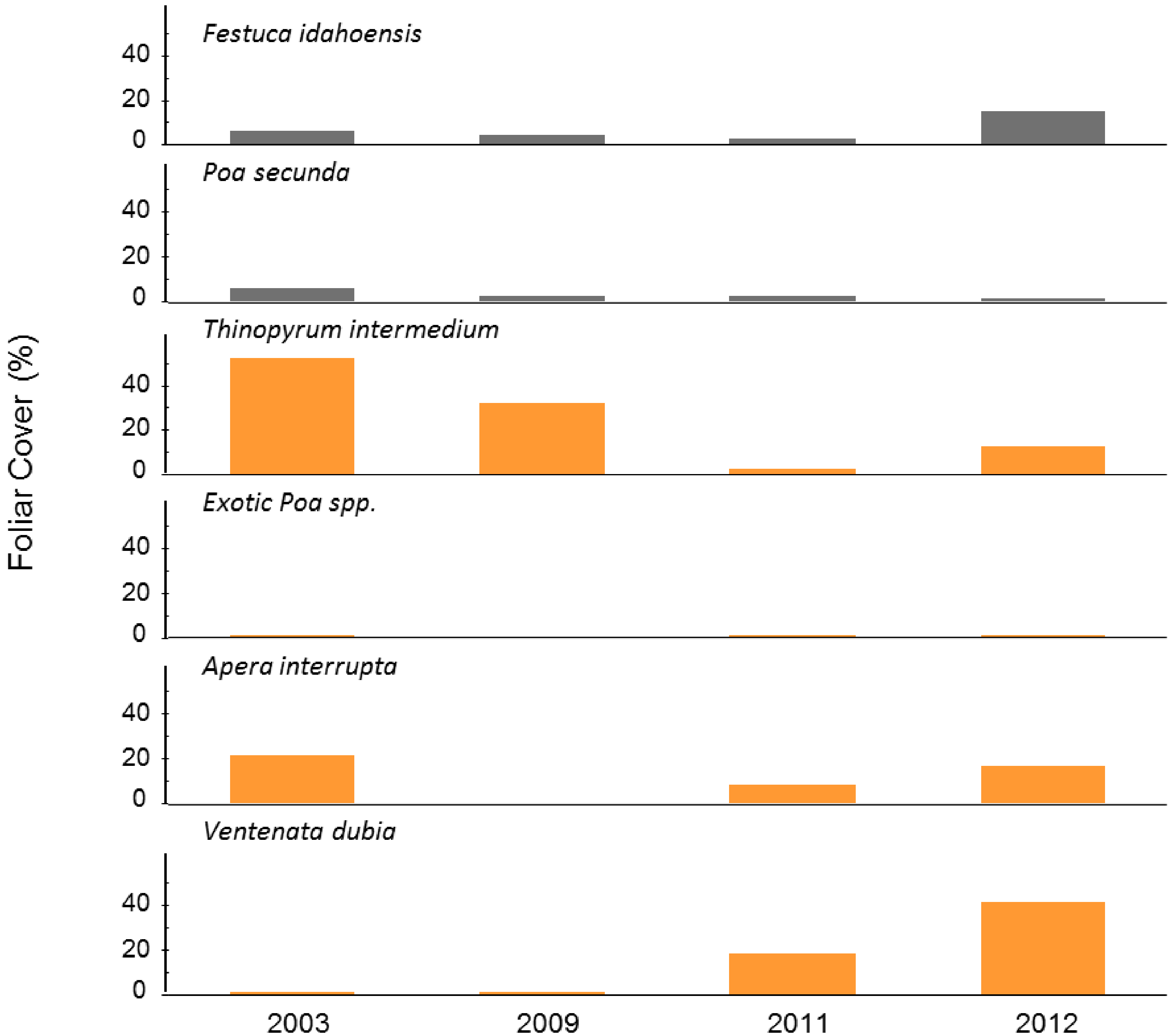

Figure 6. Changes in foliar cover of a select group native and exotic grass species over time from the upland range monitoring site UR7 in the glyphosate-treated area of North pasture. Exotic species are represented with orange bars while natives are shown in gray.

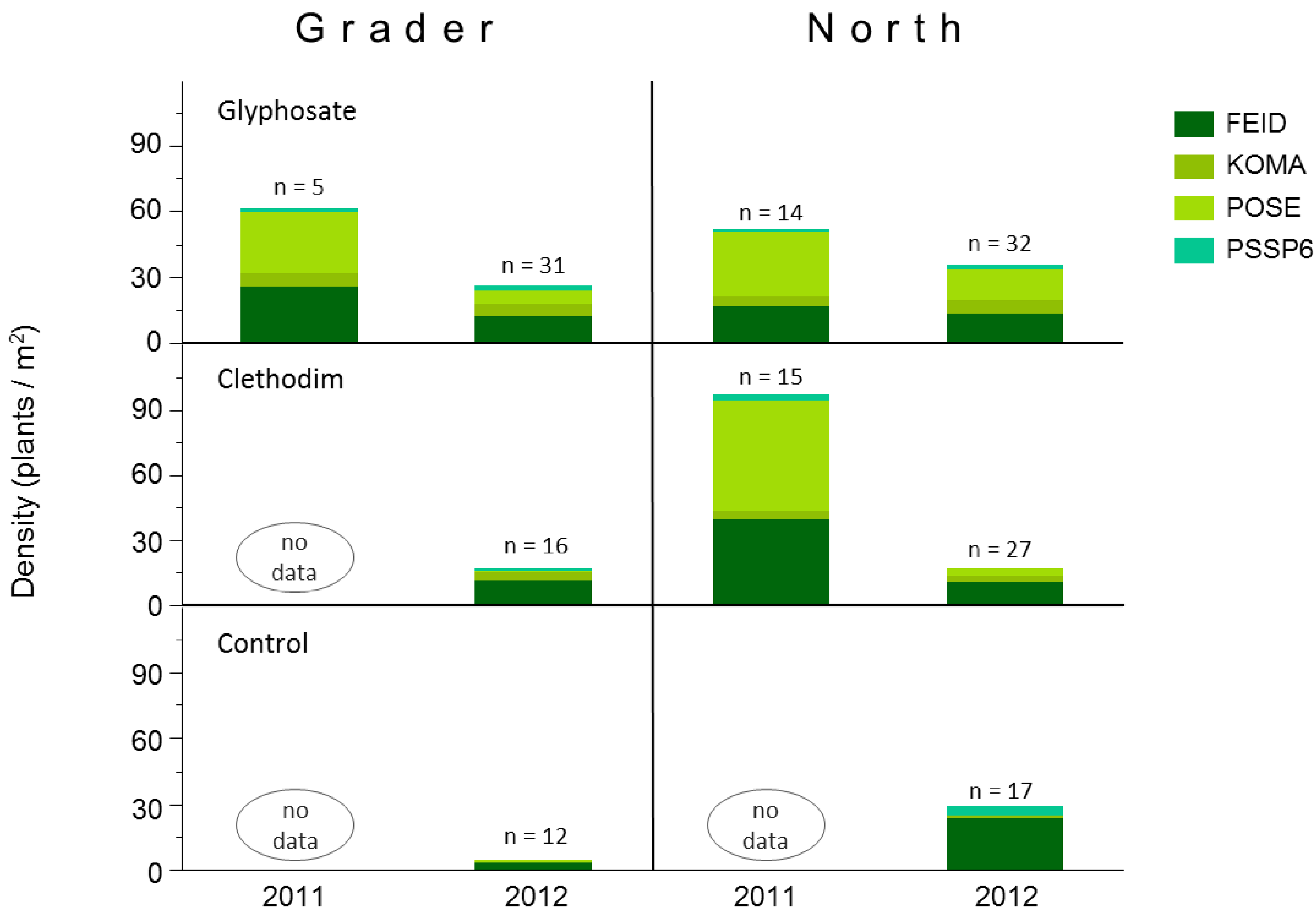

Figure 7. Changes in density of seeded native perennial grass species over time from counts done within 20 x 40 cm quadrats. See Appendix 1 for explanation of species codes.

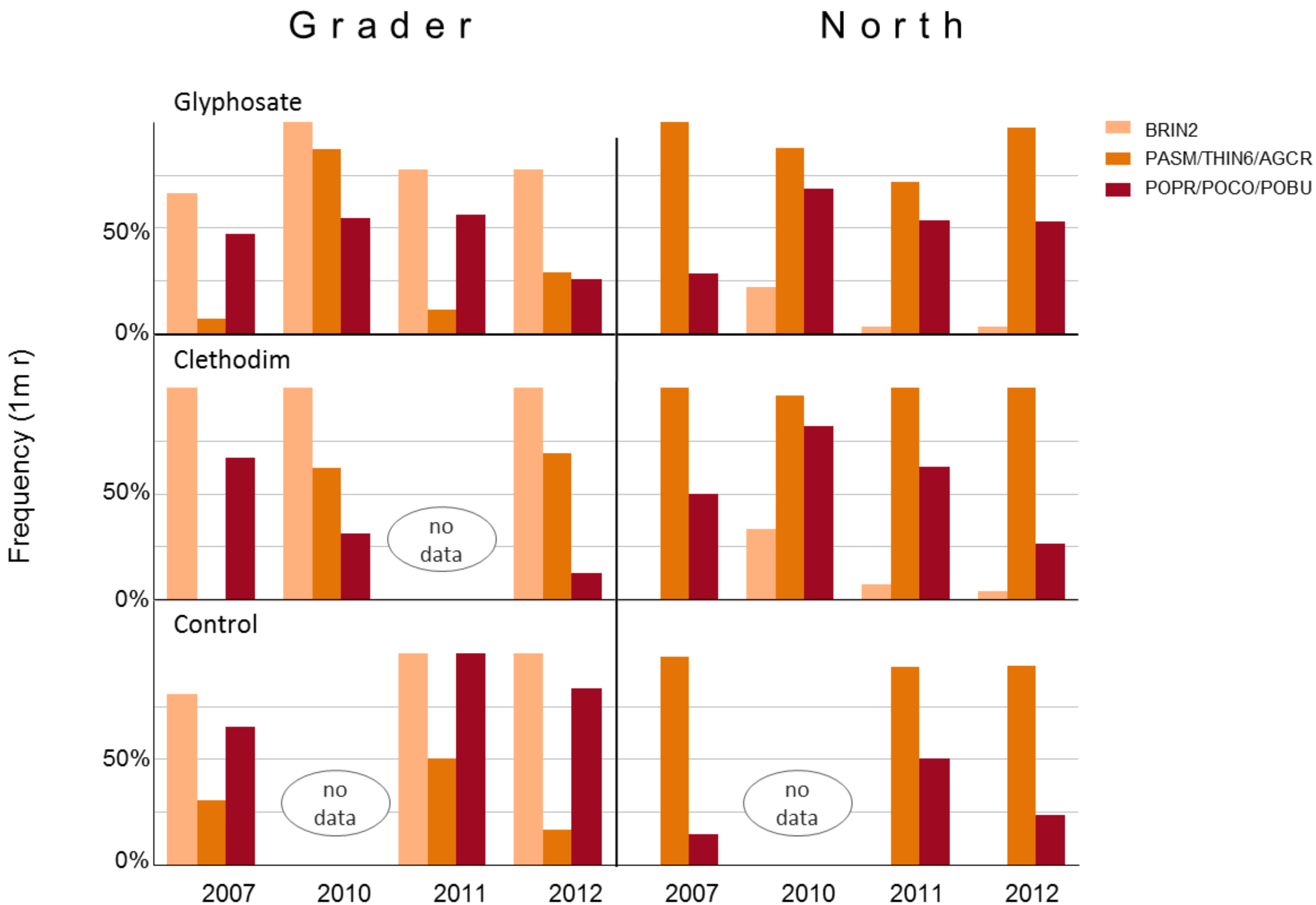

Figure 8. Changes in frequency of exotic perennial grass species over time within 1 m radius circular plots. See Appendix 1 for explanation of species codes.

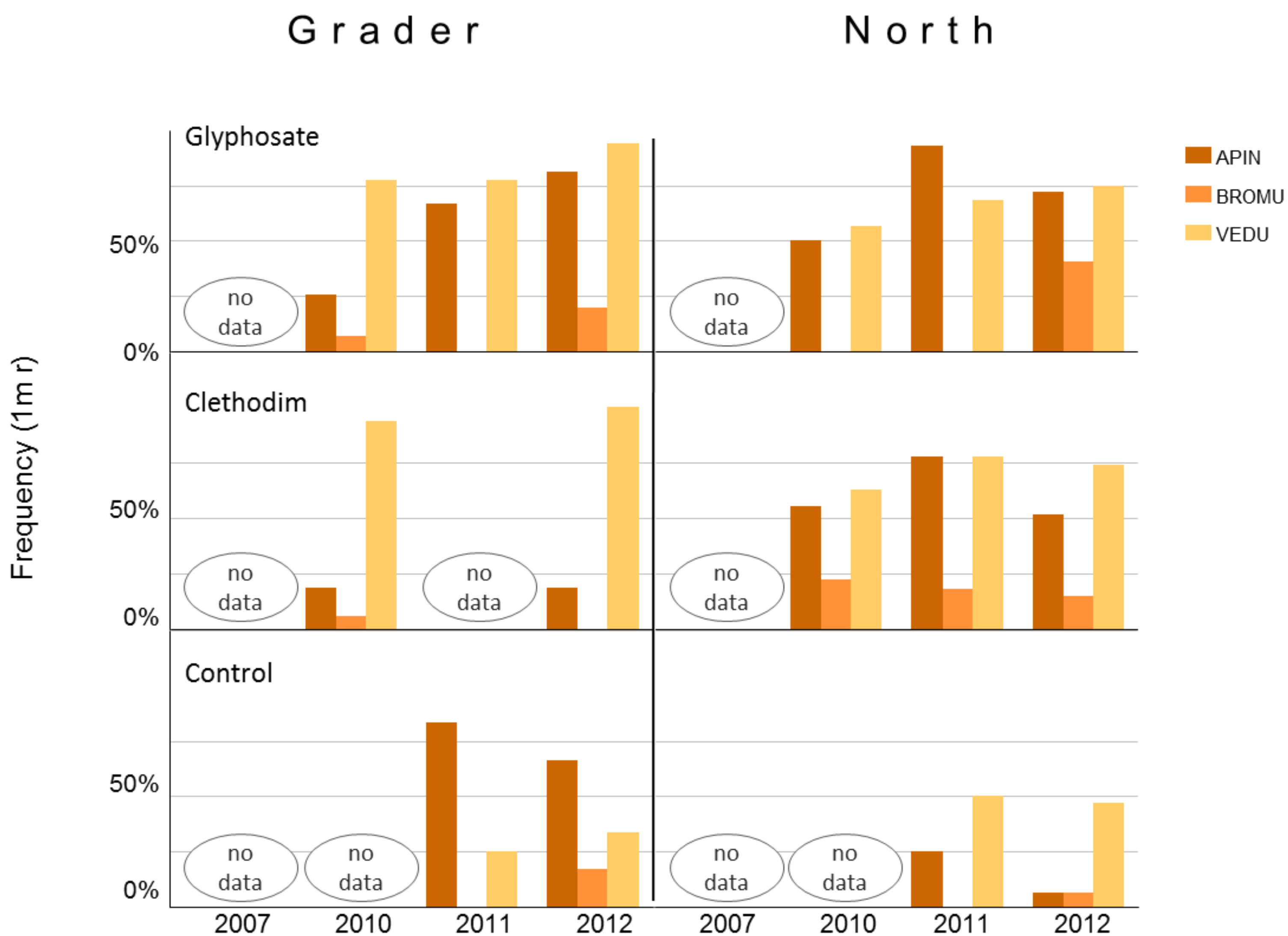

Figure 9. Changes in frequency of exotic annual grass species over time within 1 m radius circular plots. See Appendix 1 for explanation of species codes.

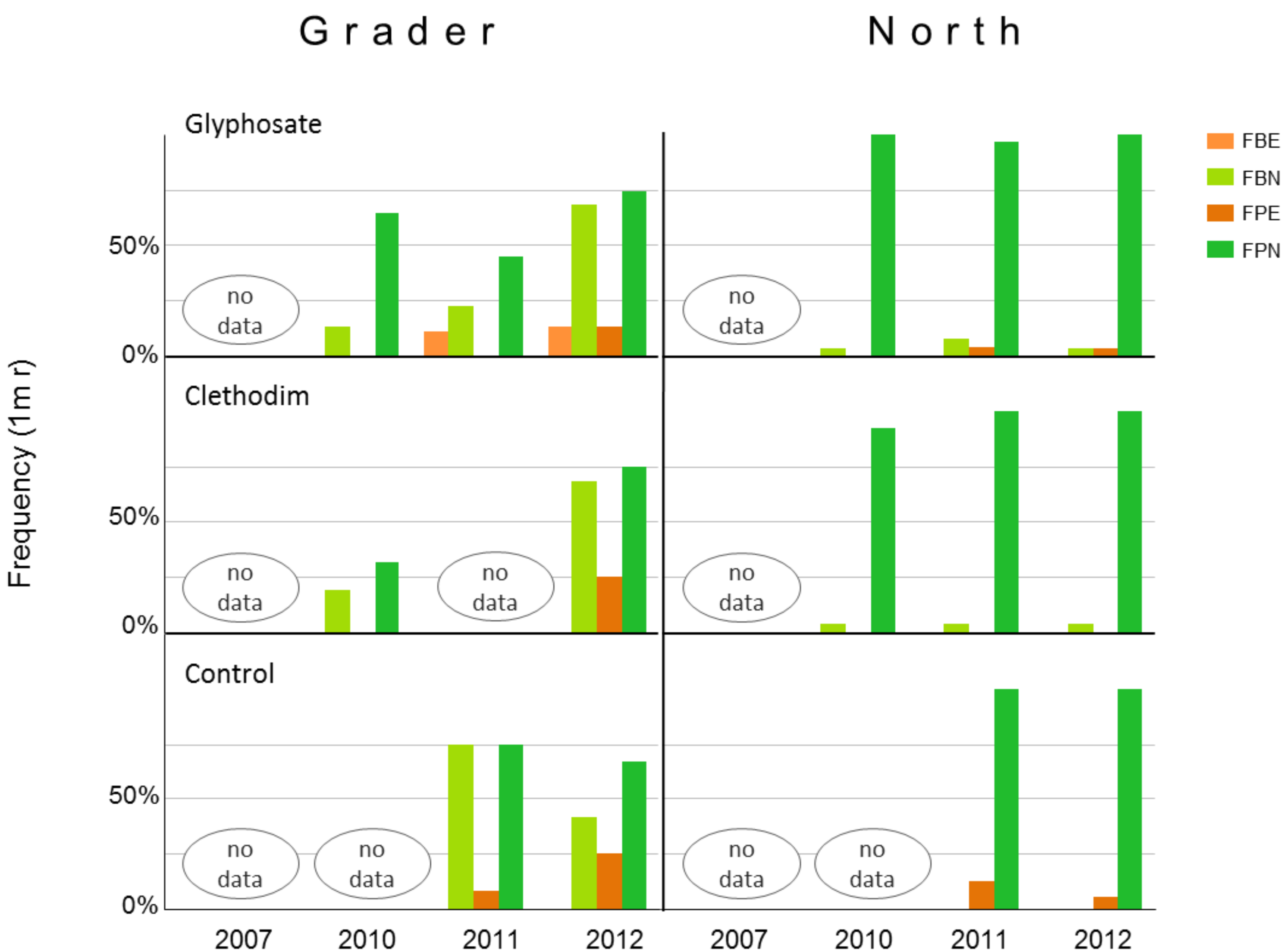

Figure 10. Changes in perennial and biennial native and exotic forbs, by guild over time in within 1 m radius circular plots. See Appendix 1 for explanation of guild codes. Exotic guilds are represented with orange bars while natives are shown in green.

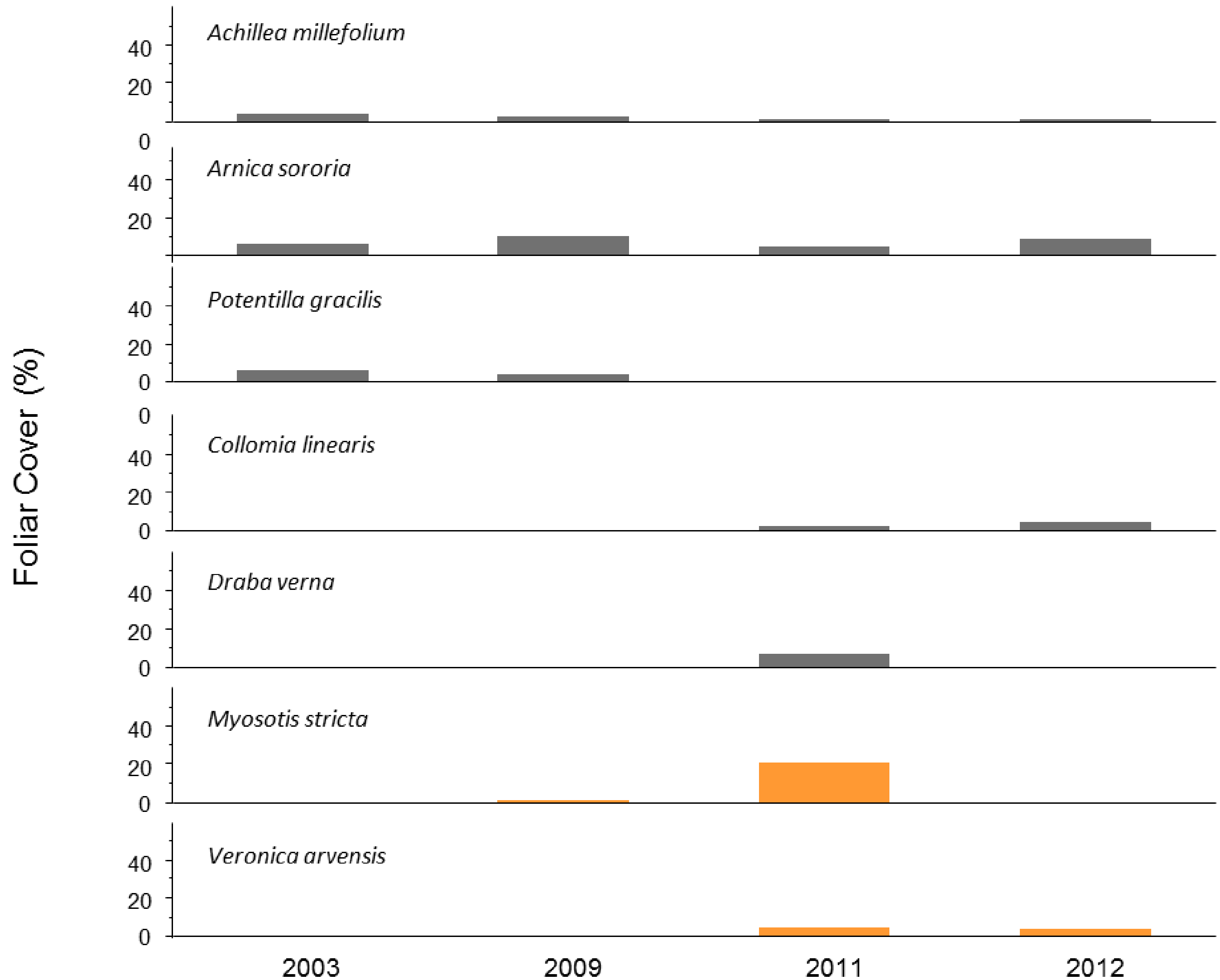

Figure 11. Changes in foliar cover of native and exotic forbs from the upland range monitoring site UR7 in the glyphosate-treated area of North pasture. Exotic species are represented with orange bars while natives are shown in gray.