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Erin K. Espeland
USDA, Agricultural Research Service

Lora B. Perkins
South Dakota State University

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ABSTRACT

Weeds in reclamations interfere with success by: 1) competing with desirable species seeded during revegetation; 2) preventing recolonization of reclamations by native species; and 3) reducing the integrity of landscapes by expanding from reclamations into adjacent, intact areas. In the Bakken oilfield of western North Dakota, dispersed reclamation activity and increased traffic may provide many opportunities for weeds to spread. To determine the potential for disturbance and reclamation to increase resident weed populations and introduce new weed species, we tracked twenty-one weed (non-native/ruderal/invasive) species over a four-year period after the installation of a 1.8 km livestock water pipeline and subsequent land reclamation on a historic ranch in western North Dakota. We included areas of historic (early 20th century homestead) and recent (prairie dog town) landscape disturbances and tracked weed frequency and density in the disturbed pipeline and in the directly adjacent intact prairie. Most of the weeds in the pipeline were non-persistent populations of naturalized species. Our data show that although naturalized weeds may respond positively to disturbance, they can quickly return to pre-disturbance levels. However, disturbance may have resulted in the introduction of one new noxious weed, *Hyoscyamus niger* (black henbane). *Agropyron cristatum* (crested wheatgrass), an invasive, non-native perennial grass that reduces native plant diversity and forage value, was also introduced. This study demonstrates the importance of prevention of weed dispersal during disturbance and reclamation, contamination-free seed sources, and post-reclamation follow up to control any weeds that may have been introduced as a result of pipeline development.

Keywords: *Agropyron cristatum*, homestead, invasion, leafy spurge, prairie dog town

Restoration Recap

- Dispersed reclamation activity and increased traffic as part of energy development may provide substantial opportunities for weeds to spread into intact neighboring prairie.
- Disturbances caused by development and restoration increase the occurrence of weeds in the landscape in the short term.
- Most weeds that established after disturbance decreased in abundance by the end of the four-year study period.
- Disturbance introduced two weeds new to the site, one of which appeared to be persistent.
- Although other vectors cannot be ruled out, it is likely that the introduction of crested wheatgrass to the site was caused by lack of attention to equipment cleaning or by seed contamination.

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The human population density of western North Dakota increased dramatically in recent years due to the development of the Bakken oilfield (Brown 2013, Dobb 2014). Rangeland impacts from increased traffic could include the introduction of new weeds (e.g., non-native, ruderal species and invasive species) to the region or an increase in existing populations (Ellstrand and Schirenbeck 2000). In addition, disturbance related to energy development,

Figure 1. Two years after pipeline installation, common dandelion appears more abundant in the disturbed area. Western North Dakota, USA. *Photo credit: Erin Espeland.*

such as road and pipeline construction, drilling activities, and reclamation, may provide an avenue for weed populations to expand (Tyser and Worley 1992, Spellerberg 1998). Disturbed areas such as recently reclaimed pipeline routes or drilling locations are excellent weed habitat (Johnston 2011) and may allow weed populations to expand into off-road locations. Conversely, because of low plant cover and little standing dead material disturbed areas (Figure 1), weeds may simply be more visible, rather than having increased density as a result of development.

As human population density and associated disturbance increase in western North Dakota, we might expect weeds to rapidly increase (e.g., Trombulak and Frissell 2000). The ability of weeds to establish and proliferate in disturbed areas depends not only on seed inputs, but also on the invasibility of the landscape (e.g., Dietz and Edwards 2006). Historical livestock production, farming, and other forms of seed movement mean large numbers of non-native species were already naturalized in this system (Richardson et al. 2000) prior to oilfield development, therefore the mixed grass prairie of North Dakota may already have achieved a post-disturbance equilibrium of non-native species presence (as in Platt 1975). A recent study of non-native species on 5- and 10-year-old oilfield reclamations and undisturbed control plots in this system found species-specific differences in the three plot types but no overall differences in non-native species cover between reclamations and undisturbed controls (Preston 2015). Ranch water pipelines are trenched to the same depth as oil field pipeline disturbances, however the width of the disturbance is narrower on ranch water pipelines, leading to greater edge to area ratios. Restoration seed mixes and application technologies are the same.

Weeds interfere with reclamation success in several ways: 1) weeds may compete with desirable species seeded as part of revegetation, slowing or preventing their establishment (as in Grant et al. 2003); 2) long-term resident weed populations in reclamation may prevent eventual recolonization of the area by neighboring native plant populations (as in Prach et al. 2013); and 3) the disturbance associated with reclamation bolsters weed populations that then permit weed population expansion into adjacent, intact areas (as in Tyser and Worley 1992). Currently, disturbance associated with restoration activities is dispersed over the mixed grass prairie of south western North Dakota; rural water pipeline installation has been ongoing since 1986 (North Dakota State Water Commission 2015) and oilfield development that has increased from 2007–2013 (NDIC). In the oilfield, wells and pipelines are reclaimed and interim reclamation is required when drilling ends and pumping begins at a well location. In early 2017, over 1500 wells were active in this landscape (NDIC), each representing a 2–6 ha interim reclamation. These developments and reclamations provide opportunities for weeds to interfere with native plant populations at restoration sites and in adjacent grasslands.

Ruderal species population dynamics may differ from those of invasive species. Ruderal, non-native weeds are disturbance-dependent (Grime and Mackey 2002). They can persist without human intervention through other types of disturbance and spread without substantially altering ecosystem processes (Richardson et al. 2000). Invasive species are non-native species that also spread without human assistance and can achieve very high densities and transform ecosystem functions such as primary productivity (i.e., forage production [Dietz and Edwards 2006]) and soil community function (Perkins et al. 2016). Previous research on how disturbance may lead to increases in weed abundance and eventual weed population expansion into adjacent, intact sites has often not distinguished between ruderal and invasive non-native species (e.g., Tyser and Worley 1992, Spellerberg 1998, Trombulak and Frissell 2000, Simmers and Galatowisch 2010, Viall et al. 2014, Preston 2015). An increase in both native and non-native ruderal species is expected after a disturbance event, but ruderal species are expected to decline as the environment becomes more competitive (e.g., Pywell et al. 2003). Invasive species do not necessarily depend on disturbance and can persist and spread in highly competitive environments (Dietz and Edwards 2006, Richardson et al. 2000). The ability of an invasive species to spread depends on its population size, propagule pressure on the surrounding landscape, and the invasibility of the recipient landscape, with biodiverse, equilibrium communities less susceptible to invasion than species depauperate, non-equilibrium communities (Dietz and Edwards 2006).

We tracked 17 non-native ruderal plant species and four invasive plant species (together, weeds) to test the hypothesis that the disturbance would increase weed abundance in the disturbance and, later, in adjacent prairie. First, we examined occurrence, or the presence of weeds in the landscape, to determine if weeds are more often encountered in disturbed areas. Then, we examined weed abundance. We hypothesized that annuals would respond quickly to the disturbance with increased population densities and then move into the prairie, while short-lived perennial species would respond similarly but more slowly. We did not expect ruderal species to persist in the prairie. Our study includes a small number of invasive species whose abundance and persistence we were only able to compare to ruderals in the qualitative sense, however we expect invasive species to persist where ruderals do not. Our four-year study allowed us to observe transient dynamics in weed populations (Dietz and Edwards 2006) and population fluctuations in response to interannual climate variation as is expected for annual and forb species (e.g., Levine and Rees 2004). Because of the relatively short time of this study relative to invasion (Dietz and Edwards 2006), we also examined individual species persistence to make predictions regarding the potential of pipeline disturbance to support weed species for subsequent invasion of the prairie.

Methods

The study area is located near the historic Elkhorn Ranch property formerly owned by President Theodore Roosevelt, west of the Little Missouri River in North Dakota (47°08′44″ N, 103°47′57″ W). Precipitation is generally 280–380 mm per year, with annual temperatures ranging from 6° to 8°C; the freeze-free period averages 140 days (NRCS 2006b). The primary soil series is Patent, occasionally flooded-Badland-Cabbart complex, 6 to 50 percent slopes (NRCS 2014). The study area is located within a large pasture (hundreds of hectares) that is continuously grazed at a low stocking rate. Growing season (April–July) precipitation totals for the study period in nearby Williston, ND were: 324 mm in 2009, 256 mm in 2010, 317 mm in 2011, and 269 mm in 2012 (NOAA).

A 1.8-km water pipeline was trenched (2.13 m depth) in summer of 2008 by the North Dakota State Department of Agriculture on the property and seeded with native perennial grasses and an annual grass cover crop in the summer of 2009 (Espeland and Perkins 2013). The seeding mix and rates in kilograms live seed per hectare (KLS/ha) follows: *Pascopyrum smithii* (western wheatgrass), 9 KLS/ha; *Elymus trachycaulus* (slender wheatgrass), 6 KLS/ha; *Nassella viridula* (green needlegrass), 2 KLS/ha; *Bouteloua curtipendula* (sideoats grama), 2 KLS/ha; and *Avena sativa* (common oat), 22 KLS/ha. *Setaria italica* (foxtail millet) was obviously seeded, however it was not part of the documented mix. The width of the disturbance ranged from 1.5 m to 2.5 m. Our monitoring began in June of 2009 and ended in August of 2012.

We divided the entire pipeline route within the ranch into three, 0.6-km blocks. One block traversed a prairie dog town, another an old homestead, and the third block was relatively free from historic disturbance and was located in between the other two. The study was blocked to account for the different disturbance histories in the landscape: the prairie dog town was of unknown age but was occupied over the course of the study; the homestead was occupied in the first half of the 20th century; and the remaining block appeared to be undisturbed except for the pipeline, containing a *Fraxinus pennsylvanica* (Ash) coulee and a small *Euphorbia esula* (leafy spurge) infestation. By using areas with natural or historic disturbance, we can examine the effects of the disturbance related to the pipeline across a realistic set of other disturbances in the North Dakota landscape. Hereafter, we refer to the pipeline installation and subsequent reclamation as "disturbance". In all, we tracked twenty-one weeds (or focal species) in six life history groups (Table 1). *Poa pratensis* (Kentucky bluegrass) and *Poa compressa* (Canada bluegrass) are not included in this publication because of identification inaccuracies. Most of the focal species are ruderal species that are naturalized over most of the continental United States. We tracked two

Table 1. Maximum percent occurrences for each species by disturbance and year within one observation window (95–103 plots). Each species is identified by life history group. We determined the probable source based on relative occurrences in each plot type in 2009 and 2010. ǂ Life history groups: AG = annual grass, AF = annual forb, ABF = annual or biennial forb, APF = annual or perennial forb, PG = perennial grass, PF = perennial forb, * Leafy spurge was known to have occurred on this property prior to pipeline installation, # Planted.

		Disturbed				Intact				
Species ǂ	Scientific name	2009	2010	2011	2012	2009	2010	2011	2012	Source
Annual brome AG	*Bromus arvensis* & *B. tectorum*	1	4	13	1	9	14	7	1	Prairie
Smooth brome PG	*Bromus inermis*	1	1	0	0	1	3	1	0	Prairie
Black medick APF	*Medicago lupulina*	4	11	14	0	3	3	7	1	Prairie
Sweetclover APF	*Melilotus officinalis*	0	2	26	0	3	4	15	0	Prairie
Pepperweed ABF	*Lepidium densiflorum*	7	6	0	1	17	3	0	0	Prairie
Yellow salsify ABF	*Tragopogon dubius*	5	1	1	1	5	3	3	0	Prairie
Common dandelion PF	*Taraxacum officinale*	45	39	76	54	59	98	100	77	Prairie
Leafy spurge PF	*Euphorbia esula*	1	0	0	0	0	0	0	1	Prairie*
Foxtail millet AG	*Setaria italica*	4	0	1	0	0	0	1	0	Pipeline#
Wild oat AG	*Avena fatua*	65	8	0	0	1	0	0	0	Pipeline#
Black henbane ABF	*Hyoscyamus niger*	1	2	1	0	0	0	0	0	Pipeline
Prickly lettuce ABF	*Lactuca serriola*	4	1	0	0	0	0	0	0	Pipeline
Lambsquarters AF	*Chenopodium album*	1	1	0	0	0	0	0	0	Pipeline
Mat amaranth AF	*Amaranthus blitoides*	1	13	2	0	0	1	0	0	Pipeline
Crested wheatgrass PG	*Agropyron cristatum*	0	4	16	8	0	0	0	0	Pipeline
Crossflower AF	*Chorispora tenella*	11	52	53	17	4	35	2	0	Ubiquitous
Spotted sandmat AF	*Chamaesyce maculata*	0	65	36	2	0	27	20	0	Road
Burningbush AF	*Bassia scoparia*	0	4	0	0	0	0	0	0	Road
Field bindweed PF	*Convolvulus arvensis*	0	7	4	4	0	2	0	0	Road
Russian thistle AF	*Salsola tragus*	0	2	0	0	0	0	0	0	—

invasive perennial grasses (*Agropyron cristatum* [crested wheatgrass] and *Bromus inermis* [smooth brome]) and two invasive forb species (*Hyoscyamus niger* [black henbane] and *E. esula*). *Hyoscyamus niger* and *E. esula* were the only focal species that are noxious weeds in North Dakota. *Agropyron cristatum* and *B. inermis* are non-native, highly competitive cool-season grasses that sometimes exhibit invasive qualities (Perkins et al. 2016, NRCS 2006a). Weeds were identified in the field using regional keys (Bubar et al. 2000, Whitson 2002, Larson and Johnson 2007a, b, Pavek et al. 2012). Individuals of perennial grasses could not be distinguished from one another. Therefore, we measured their cover and predicted that their distribution in the landscape would be comparable to perennial forb density. We confirmed species names, life history group, and distribution using the USDA PLANTS database (2014).

To capture all species, we sampled at two times: late May/early June and late August. At each sampling time, we randomly placed approximately 100 (20 cm × 50 cm inside dimensions) plots in each block of the disturbed pipeline and approximately 100 plots in each section of adjacent prairie (within 3 m of disturbance edge). When any focal species was present in the frame, the frame was logged as "weed present" (or "occurred"). Then the density (or number of individuals in the frame) was logged for each focal species except perennial grasses whose percent cover was recorded. We did not total or average observations across the two sampling times. Within each year, only the sampling time with observed maximum for that year was retained for analysis. For example, when June 2009 held the greatest number of occurrences, data from August 2009 were not analyzed; when August 2010 had the greatest density of perennial forbs but the lowest density of annual grasses, data from June 2010 were used for annual grass density and data from August were used for perennial forb density. Maximum yearly species-specific frequencies (Table 1) were analyzed as well.

Weed occurrence was somewhat low (i.e., there were many zeros in our dataset). Life history groups (Table 1) were combined into three types for analysis: annuals, perennials, and short-lived species that were not strictly annual or perennial. For the binary occurrence data, we ran a logistic regression model (JMP 11.0, SAS Institute, Cary NC) with block, disturbance (pipeline vs. intact prairie), and year as main predictor variables and tested the interaction of disturbance by year. For the density data, we ran a Generalized Linear Model (JMP 11.0, SAS Institute, Cary NC) with a Poisson distribution and log link function with block, disturbance, year, and life history group as main predictor variables, and we tested the interactions of disturbance by year, life history group by year, life history group by disturbance and the three-way interaction. Year and life history group were ordinal variables in the model. Perennial grass weed occurrence was so low in the intact

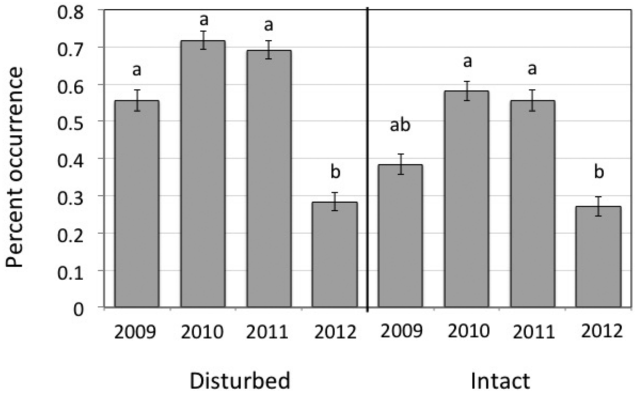

Figure 2. Percent occurrence of weeds in the disturbed and intact prairie plots: the ratio of the number of plots where a focal species was present to the number of plots in the sampling window. Error bars indicate one standard error. Different letters indicate significant differences (parameter estimates, $p < 0.05$).

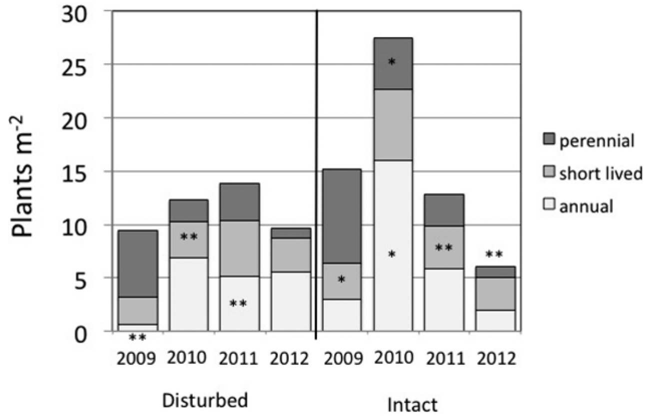

Figure 3. Density (plants m^{-2}) of weeds in disturbed and intact plots over the course of the study by group (annual, short-lived, and perennial). Within groups, a single asterisk indicates a mean greater than all other means; a double asterisk indicates a mean less than all other means (t-test, $p < 0.05$).

prairie (Table 1) that this group could not be analyzed statistically. Differences among means were determined by parameter estimates within the main model for the logistic regression and with t-tests after the GLM. All means are reported ± one standard error in the text. Occurrence is reported as the percentage of plots where a focal species was present.

Table 2. Year effects on weed density (plants m^{-2}). Data reported are means ± standard error. Different letters indicate significant differences (t-test, $p < 0.05$).

Year	Plants m^{-2}
2009	3.3 ± 0.43[a]
2010	7.8 ± 0.78[b]
2011	4.6 ± 0.31[b]
2012	3.3 ± 0.49[a]

Results

Weed occurrence was significantly influenced by the year by disturbance interaction ($\chi^2_{3,3} = 7.84$, $p < 0.05$); component main effects were significant ($p < 0.0001$), as was block ($\chi^2_{2,2} = 41.64$, $p < 0.0001$). Temporal patterns of weed occurrence were very similar across years (Figure 2). Weeds occurred more often in disturbed plots (57% ± 1% versus 45% ± 1% in intact plots), and 2010 and 2011 had similar weed occurrences (65% ± 2% and 63% ± 2% respectively; $\chi^2 = 1.15$, $p = 0.28$) that were different than 2009 (47% ± 2%; $\chi^2 = 43.03$, $p < 0.0001$) and 2012 (28% ± 2%; $\chi^2 = 149.96$, $p < 0.0001$).

For weed density, the three-way interaction between life history, disturbance and year was significant ($\chi^2 = 92.21$, $p < 0.0001$) as were all component two-way interactions ($p < 0.0001$) and main effects ($p < 0.0001$). Block was also significant ($\chi^2 = 373.02$, $p < 0.0001$). Weeds had higher density (Table 2) in the intact prairie (6.4 ± 0.5 plants m^{-2} versus 4.3 ± 0.3 plants m^{-2} in the disturbance). Year effects on density were similar to year effects on occurrence (Figure 2). The highest density within each functional group was found in intact plots (Figure 3).

Eight of the twenty species tracked in this study were locally naturalized in the prairie prior to pipeline installation (Table 1). Invasive *B. inermis* was present at a very low frequency in both the intact prairie and in the disturbance in 2009 but at higher frequency in the intact prairie in 2010 (3%) compared to the disturbed pipeline (1%). Ruderal, annual bromes (*Bromus arvensis* [field brome] and *B. tectorum* [cheatgrass]) were present at 9% of intact prairie plots at the start of the study but present only in 1% of disturbed plots. Ruderal *Taraxacum officinale* (common dandelion) was always more frequent in the prairie compared to the pipeline. The ruderals *Medicago lupulina* (black medick), *Meliotus officinalis* (sweetclover), *Lepidium densiflorum* (pepperweed), and *Tragopogon dubius* (yellow salsify) had similar patterns that led us to believe that they entered the disturbance from the intact prairie. Invasive *H. niger* frequency was low, similar to leafy spurge, and it was found only in the pipeline. *Hyoscyamus niger* may have gained entry through the pipeline, or it may have been present in the intact prairie at very low frequency prior to pipeline installation. Annual grasses *S. italica* and *A. sativa* were purposely introduced into the pipeline as part of the reclamation seed mix and were never found in more than one sample plot in the prairie. Ruderal *Chenopodium album* (lambsquarters) was only found in disturbed plots at very low frequencies. Ruderal *Amaranthus blitoides* (mat amaranth) first occurred in the disturbed plots in 2009, increased its frequency to 13% in 2010 before dropping to 2% in 2011 and 0% in 2012. It was found in 1% of the intact prairie plots in 2010.

Invasive *A. cristatum* was only found in disturbed plots and appeared to be persistent in this plot type. Ruderal *Chorispora tenella* (crossflower) was always more abundant in the disturbance compared to the intact prairie, and was absent from the prairie in 2012 (Table 1). Three ruderal species likely entered the pipeline via the road: *Chamaesyce maculata* (spotted sandmat [= *Euphorbia nutans*]), *Bassia scoparia* (burningbush [= *Kochia scoparia* ssp. *scoparia*]), and *Convolvulus arvensis* (field bindweed) are always present on nearby gravel and paved roads (E. Espeland, personal observation) but were not in the intact or disturbed plots at the start of the experiment. The origin of ruderal *Salsola tragus* (prickly Russian thistle) was difficult to classify because it was only found in 2010, with 2% frequency in disturbed plots.

Discussion

We have every reason to be concerned when weeds appear in the landscape after anthropogenic disturbance: these weeds can interfere restoration establishment and decrease the ecological integrity (e.g., Richardson et al. 2000, Dietz and Edwards 2006) and agricultural value (such as forage quality) of neighboring areas when they spread. We found that weeds are more prevalent in disturbed areas soon after disturbance, however disturbance and intact prairie plots had similar weed occurrence by the second study year. Few ruderal species were more abundant in the disturbance than in the prairie: the disturbance generally did not bolster weed densities as expected. Specifically, only a few species had greater frequency in the disturbance than in the prairie; these differences vanished by the end of the study, except for one invasive species whose appearance we documented. The main result of our study is that ruderal weed response to pipeline installation and subsequent reclamation in this landscape may be ephemeral and not a cause for concern. However, at least one invasive species was introduced via this disturbance and persisted in the pipeline.

We expected shorter-lived species to respond quickly to disturbance, however their densities did not exceed densities of longer-lived plants until the second year of the study. Two-years post-disturbance, the shorter-lived species densities were highest in intact plots. Rather than illustrating a response to disturbance, our data more likely show that annuals respond quickly to interannual variation (as in Levine and Rees 2004). Our results contrast with those from well reclamations in the landscape, where even 10-year-old reclamations appeared to have more occurrences of ruderal species than the intact prairie did, and cover of some ruderal species appeared higher in 5-year-old reclamations compared to controls (Preston 2015). This difference is likely due to the different disturbance intensities between our study and that of Preston: oilfield reclamations are about 2 ha in size and include massive amounts of soil disturbance and potentially, compaction. The ranch water pipeline in this study had only a narrow band of disturbance.

We expect weed response to disturbance to interfere with early restoration via competition, which we were not able to measure in this study because we did not monitor native plant establishment. However, other work in this system has shown that reclamation establishment may be primarily driven by soil parameters (Viall et al. 2014, Espeland et al., this issue) or interannual precipitation (Simmers and Galatowtisch 2010) rather than weed abundance.

As many as six species may have entered the landscape due to the pipeline installation and reclamation; four of these are invasive. The two invasive forb species in this study appeared only in the disturbance and at very low densities. The sometimes invasive *B. inermis* was already present prior to the disturbance (E. Espeland, personal observation) and did not expand over the course of the study. The persistence of the sometimes invasive *A. cristatum* in the disturbance and its absence in the intact prairie means that this species colonized as a result of the disturbance. Seeds may have been a contaminant of the revegetation seed mix or brought in on equipment, livestock, or wildlife. *Agropyron cristatum* is common in broken (or plowed) lands of North Dakota, planted as pasture improvements after farms were abandoned during the dust bowl. No *A. cristatum* occurred at this property prior to the start of this study, although it is common in the surrounding landscape. *Agropyron cristatum* is a long-lived perennial grass species that has been shown to both directly and indirectly outcompete native perennial grasses, reducing native plant species diversity (Evans and Young 1970, Krzic et al. 2000, Henderson and Naeth 2005, Perkins and Nowak 2012, Dong et al. 2014, Perkins and Hatfield 2014). The introduction of *A. cristatum* will likely lead to a decrease in forage production at this property (Christian and Wilson 1999), particularly if populations expand beyond disturbance boundaries. How much *A. cristatum* spreads beyond the pipeline in the future will depend on site management and climatic conditions (e.g., Williamson and Harrison 2002). *Agropyron cristatum* remaining in the pipeline disturbance may eventually compete with planted perennial grasses, limiting the long-term success of reclamation.

Most of the weeds monitored in this study have very low invasive potential, even when species were introduced or populations were bolstered through the disturbance of pipeline installation and reclamation. Ecological site types of this area tend to favor perennials over annuals (NRCS 2006b) and, of the annual species not already present in the local prairie, only *C. tenella* and *C. maculata* had substantial numbers of occurrence over the study period. Although *C. tenella* is a successful colonizer in arid environments (Gómez and Fuentes 2001), the combination of dry conditions and competitive pressure in the intact plots may have driven frequencies below detection limits in intact plots in

2012. However, the disturbed pipeline may provide a habitat from which *C. tenella* can re-invade the intact prairie. *Convolvulus arvensis* appears to be able to establish in the prairie but not persist. Our observations align with the results of others (Henderson and Naeth 2005) who found that *C. arvensis* did not compete well against perennial grasses. Neither of the two noxious weeds in this study, *E. esula* and *H. niger*, exhibited invasive behavior over the four years of the study, with low incidences of occurrence and no indication of population expansion during the short time frame of the experiment.

The strength of this study was our examination of three parameters of weed response to disturbance over the course of four years: occurrence in the landscape, population density by functional group, and species-specific responses. It took four years for the differences between disturbed and intact plots to disappear, but the end result was that the effect of disturbance was largely ephemeral. However, the possible introduction of noxious *H. niger* and definite arrival of invasive *A. cristatum* via the pipeline disturbance highlights the need to prevent invasive species dispersal into construction and restoration. Given the capacity for invasive species to overtake intact landscapes and the over-dispersed nature of restoration in the western part of the state, preventing invasive species introduction in restorations may be vital to preserving forage quality in rangelands of North Dakota.

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Erin K. Espeland (corresponding author), Research Ecologist, USDA ARS NPARL Pest Management Research Unit, Sidney MT 59270, erin.espeland@ars.usda.gov.

Lora B. Perkins Assistant Professor, South Dakota State University Department of Natural Resource Management, Brookings SD 5700.

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