were integral in maintaining the historical structure of the forest. Encouragingly, there is evidence that environmental education efforts by nongovernmental organizations and the Forest Service have been successful in aligning public perceptions and expectations with the objectives of forest restoration (e.g., Ostergren et al. 2008). Engaging stakeholders and educating them on the characteristics of healthy forests and the goals of restoration are the most promising avenues to overcoming generational amnesia presently endemic in the region. Additionally, drawing upon untapped sources of ecological knowledge within the community can also inform management decisions. For instance, an oral history project chronicling Native American institutions may help build cross-generational bridges to traditional practices, such as controlled burning, and shed light on dormant knowledge about regional ecosystems. Aligning public understanding with the reality of fundamentally altered biological conditions is a necessary (though perhaps insufficient) condition for achieving sustainable forest management.

We expect that SBS will become a relevant issue not only for restoration in the American Southwest, but also for many other sites across the world. In nearly all contexts, ecological restoration involves community stakeholders. We recommend survey-based assessments of public understanding of the means, objectives, and context of ecological restoration so that SBS is a key component of the social science research agenda. In scenarios where SBS is a likely problem, rigorous documentation of where social perceptions and ecological realities fundamentally differ, and the reasons and the causes for these discrepancies, can help practitioners gain greater support among community stakeholders.

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Promising Results Restoring Grassland Disturbances with Native Hay (Alberta)

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In Alberta, much of the once dominant rough fescue grassland has been lost to cultivation, overgrazing, and intensive oil and gas activities. Few attempts to restore rough fescue plant communities have been successful (Elsinger 2009, Desserud et al. 2010). Plains rough fescue (*Festuca hallii*) is a perennial bunch grass, slow growing and long lived, requiring 2 to 3 years to become established from seed. Rough fescue is an erratic seed-setter, seldom producing seed (Johnston and MacDonald 1967). The objective of our study was to assess the potential of native hay as a seed source for restoring rough fescue grassland.

The benefits of native hay include no cost for seeds, a natural mix of adapted native species, protective mulch for emerging seedlings, no requirement for special seed processing or seeding, and increased ground cover. However, the relative hardness of prairie grasses requires specialized harvesting equipment, and seed viability is unreliable. The highly variable production of seed set and the resulting dominance of species in seed at time of harvest influence seed viability in native hay (Romo and Lawrence 1990).

We found no previous research involving native hay for rough fescue grassland restoration. Experiments using native hay to restore grasslands were successful in Germany (Kiehl et al. 2006), England (Jones et al. 1995, Edwards et al. 2007), and Idaho (Gates 1962). In Idaho, native hay resulted in successful native grass establishment, while fertilizer and seeding with sawdust and conifer mulches had poor results (Gates 1962). In contrast, no native seedlings emerged from native hay application in mixed-grass prairie restoration in Saskatchewan (Wilson et al. 2004).

The study area is located in Alberta, Canada, in uncultivated rangeland in the Central Parkland natural region. Topography is an undulating complex of small depressions and hills. The soils are Dark Brown Chernozems on loam

Table 1. Mean (± SD) cover (%) for selected plant species on the native hay and seeded pipeline ROWs, showing year of growth, adjacent native grassland control, and initial germination (%) from soil seed bank and native hay. Differing letters indicate significant differences within a ROW at $P < 0.05$. Shading indicates non-native or weedy species.

	Native Hay ROW					Seeded ROW				
	% Cover					% Cover				
	Year 1 (2006)	Year 2 (2007)	Control (2006)	% Germ	*p*	Year 1 (2007)	Year 2 (2008)	Control (2007)	% Germ	*p*
Grasses										
Annual rye	0	0	0	0	n/a	1.5(4.7)	0	0	0	0.076
Bluegrasses	4.5 (6)a	40(13)b	6.3(9)a	4.2(4)a	<0.001	1.6(2)	3.2(5)	0.2(1)	8.3(2)	0.098
June grass	0.5 (2)	0	3.3(6)	0.8(2)	0.073	0.3(1)a	0.1(0)a	15(20)b	0a	0.029
Northern wheatgrass	0	0	0.3(1)	1.8(4)	0.553	0.3(1)	0.5(1)	0	0	<0.001
Plains rough fescue	10 (11)	12(23)	34(26)	24(26)	0.076	0.2(1)a	0a	54(22)b	8.3(2)a	<0.001
Rocky mountain fescue	0	0	0	0	n/a	8.0(7.8)	0	0	0	<0.001
Slender wheatgrass	1.3 (3)a	2.0(6)a	5.5(7)a	37(33)b	<0.001	37(19)a	6.8(10)b	0c	0c	<0.001
Western porcupine grass	5.5 (9)a	0b	6.5(8)a	0.5(1)b	0.003	2.5(6)	0	1.5(5)	0	0.654
Western wheatgrass	14 (9)a	8.1(7)a	7.6(8)a	0.3(1)b	<0.001	0.8(2)	1.8(2)	1.3(3)	0	0.749
Forbs										
Flixweed	1.6 (3)a	0b	0b	0b	0.023	0	0	0	0	n/a
Lamb's quarters	0	0	0	0	n/a	4.3(10)	0	0	0	0.064
Pasture sage	1.9 (5)	0.5(2)	0	0	0.109	2.1(5)	3.8(7)	2.1(6)	17(3)	0.537
Prairie sage	1.8 (5)	3.5(9)	3.6(4)	0	0.119	0.6(2)	1.0(3)	1.2(2)	0	0.924
Yarrow	2.0 (3)	9.7(2)	3.9(4)	4.7(5)	0.073	0	2.0(0)	0.3(1)	0	0.310
Shrubs										
Prairie rose	0	0	0	0	n/a	0.5(1)	1(2)	1.0(2)	0	0.871
Western snowberry	0a	0a	6.0(8)b	0a	<0.001	2.5(6)	1.2(2)	5.1(9)	0	0.581
Total Cover	**47.9a**	**81.4b**	**106.5c**	**76.4b**	**0.002**	**73.3a**	**21.3b**	**104.6c**	**12b**	**<0.001**
Bare ground	0a	10(13)b	0.5(2)a	n/a	<0.001	30(7)a	18(14)b	4(10)c	n/a	<0.001
Litter	0a	42(24)b	27(18)c	n/a	<0.001	0a	55(21)b	25(14)c	n/a	<0.001

textured glacial till. Rough fescue grassland occurs on uplands and upper slopes.

We studied 2 natural gas pipeline rights of way (ROWs) between 2006 and 2008. One was located on public land, where regulations require vegetative cover of at least 65% of predisturbance species, with no non-native species (native hay ROW). The other pipeline, 15 km to the southeast, was located on private land, and therefore was not subject to the above regulations (seeded ROW).

In August 2005, an energy company removed topsoil from the native hay ROW (15 × 150 m) before pipeline installation, which they spread back within 1 month after construction, and left the ROW unseeded. They cut hay in adjacent grassland on July 16, 2006, after plains rough fescue peak flowering in central Alberta in June and before midsummer seed shattering. A modified combine, with more durable and sharper than traditional crop blades, was used to cut about 67 m^3 of hay in grassland approximately 50 to 200 m from the pipeline and immediately spray it on the ROW to a depth of 2 to 3 cm.

In July 2007, a different energy company removed topsoil from the seeded ROW (3 × 150 m) before pipeline installation and spread it back after construction. In August 2007, they seeded the ROW (approximately 15 kg/ha) with annual rye (*Elymus* sp.), slender wheatgrass (*Elymus trachycaulus*), and Rocky Mountain fescue (*Festuca saximontana*).

We collected monthly precipitation data at a well site (Byemoor) about 30 km east of each pipeline between April 2007 and August 2009, which we averaged with Environment Canada data from weather stations 35 km south (Craigmyle), 25 km northwest (Big Valley), and 30 km west (Trochu) of the pipelines, forming a circle around the pipeline areas.

To evaluate native hay seed content, we randomly collected 10 hay samples and spread each approximately 1 cm thick over 3 cm of potting soil (1:4 vermiculite and peat) in trays (10 × 15 × 5 cm). To assess seed bank potential of the seeded ROW, we collected 10 soil samples (15 × 15 × 6 cm) from the newly reclaimed ROW, which we spread approximately 2 cm thick over potting soil in trays (10 × 15 × 5 cm). When the surface began to dry, we watered all trays with tap water, approximately every 2 days. We enumerated emerging seedlings and removed them once identified for a 3-month period.

We sampled the native hay ROW in 2007 and 2008, and the seeded ROW in 2008 and 2009, in July, when

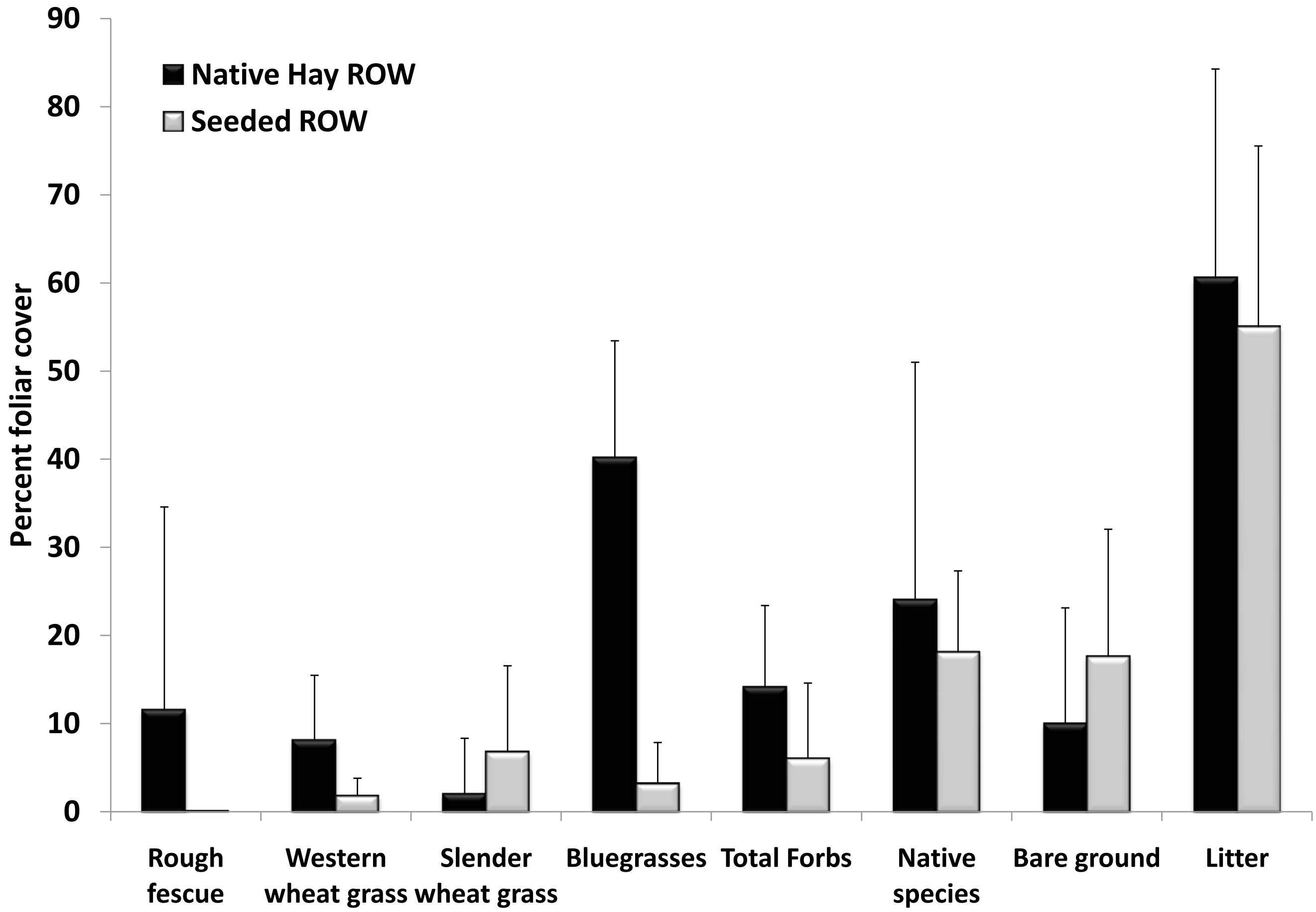

Figure 1. Second year growth in 2 pipeline rights of way (ROW) that either received native hay (2006) or seed mix (2007). Error bars are standard deviation.

the majority of grass species were mature. With 2 50-m transects, randomly located and each containing 5 subplots (20 × 50 cm) spaced 10 m apart, along the native hay and seeded ROWs, we assessed foliar cover of all species, litter, and bare ground. During the first year for each ROW, we sampled vegetation, litter, and bare ground in adjacent native grassland, 15 m from the ROW, to serve as an undisturbed control.

We subjected data to one-way ANOVA with Tukey's post hoc test and independent sample *t*-tests for pairwise comparisons at 1% level of significance ($p < 0.05$) using PASW (vers. 18.0, SPSS, Chicago IL) and Excel (vers. 2007, Microsoft, Redmond WA). We used nonparametric multiple response permutation procedure (MRPP), operating on Sorenson (Bray-Curtis) distance measures, to evaluate significant differences between seeded plots and controls using PC-ORD (vers. 5.31, MjM Software, Gleneden Beach OR). The MRPP generates a chance-corrected within-group agreement value (A), which evaluates the difference between species composition of grouped plots. The lower the A value, the more similar are the groups (McCune and Grace 2002).

The adjacent native grassland at both sites was dominated by plains rough fescue, shortbristle needle and thread (*Hesperostipa curtiseta*), prairie Junegrass (*Koeleria macrantha*), western wheatgrass (*Pascopyrum smithii*), slender wheatgrass, bluegrasses (*Poa* spp.), sedges (*Carex* spp.), and an abundance of forbs, such as northern bedstraw (*Galium boreale*) and yarrow (*Achillea millefolium*). The dominant grass species in the native hay were slender wheatgrass, plains rough fescue, bluegrasses, and western wheatgrass. The seed bank from the seeded ROW included plains rough fescue and bluegrasses (Table 1).

In the first year, western wheatgrass had the greatest cover on the native hay ROW, followed by plains rough fescue, shortbristle needle and thread, and bluegrasses (Table 1). Rough fescue plants were seedlings approximately 3 cm in height. First year's growth on the seeded ROW was dominated by seeded slender wheatgrass and several weeds (Table 1). Bare ground averaged 10% on the native hay ROW and 30% on the seeded ROW, and neither had litter.

Cover of slender wheatgrass ($p = 0.207$), total forbs ($p = 0.833$), native species ($p = 0.198$), and litter ($p = 0.283$) was similar in both ROWs the second year. The native hay ROW had greater cover of western wheatgrass ($p = 0.018$) and bluegrasses ($p < 0.001$). Less bare ground occurred on the native hay ROW, although the difference was not significant ($p = 0.234$). The seeded ROW had no rough fescue, while the native hay ROW had 12% cover (Figure 1).

Comparing the native hay ROW second year growth to the adjacent grassland showed similarities in rough fescue ($p = 0.011$), slender wheatgrass ($p = 0.032$), western wheatgrass ($p = 0.043$), and bluegrass ($p = 0.047$) cover. The native hay ROW had fewer forbs ($p < 0.001$) and native species ($p < 0.001$), and more litter ($p = 0.001$). Total vegetation cover was 68% of the control. In contrast, the seeded ROW had less rough fescue cover ($p < 0.001$), more slender wheatgrass ($p = 0.040$), and greater bare ground ($p = 0.024$), as well as fewer native species ($p < 0.001$) and more litter ($p = 0.002$) than the adjacent grassland in the second year. No differences were found in bluegrass ($p = 0.056$), western wheatgrass ($p = 0.668$), and total forb ($p = 0.423$) cover. Total vegetative cover was 20% of the control. The MRPP analyses showed the native hay ROW was more similar to controls ($A = 0.198$, $p < 0.001$) than the seeded ROW ($A = 0.383$, $p < 0.001$).

Monthly precipitation varied over the years of the study. In 2006, the year that the native hay treatment occurred, the accumulated precipitation before treatment (April–June) was 250 mm, followed by 27 mm in July during the haying and first-year sampling, and 45 mm in August. In 2007, the accumulated precipitation from April to June was 148 mm, followed by 37 mm in July (when the second year growth in the native hay ROW was sampled) and 46 mm in August (when the seed treatment occurred). In 2008, the accumulated precipitation was 30 mm, followed by 53 mm in July (when the second year growth of the seeded ROW was sampled). While 2006 was a wetter season than 2007, both native hay and seeded ROWs experienced similar precipitation levels in August immediately following treatment.

This experiment supports the hypothesis that native hay cut from rough fescue grassland is a viable seed source for restoring disturbances. All species that emerged on the native hay ROW were found in undisturbed grassland. Our results were consistent with those from European (Jones et al. 1995, Kiehl et al. 2006, Edwards et al. 2007) and American (Gates 1962) grassland restoration experiments.

Of particular note in our experiment was the emergence of rough fescue seedlings in the first year, and their continued growth over the following year. This is a promising result given the failure of rough fescue establishment, even when seeded, on other oil and gas disturbances in the area (Elsinger 2009, Desserud et al. 2010). As expected, the seeded ROW was dominated by seeded species in the first and second year. Despite the occurrence of rough fescue in the seed bank of the seeded ROW, only a small amount of rough fescue appeared in the first year, possibly remnant plants from the initial topsoil stripping, and none appeared in the second year. Cover on the native hay ROW met provincial reclamation regulatory requirements, unusual after only 2 years of growth. It included cover exceeding 65% of control, similar species, and no non-native species. The seeded ROW, while admittedly affected by a dry growing season, did not meet criteria, having low total cover and few species similar to the control.

Applied hay would have increased ground cover, which likely accounted for the reduction of weedy species on the ROW, similar to what occurred in the experiment by Jones and others (1995). The limited amount of bare ground, commencing in the first year, is in direct contrast to the seeded ROW and what Elsinger (2009) and Desserud and colleagues (2010) found on seeded ROW even 30 years after recovery. While precipitation before seeding was greater at the native hay site than the seeded site, precipitation during and after the seeding month was similar, suggesting first year germination may have been comparable. The second-year growing season of the seeded ROW was very dry, probably accounting for lower vegetation cover; nevertheless, species composition of perennial grasses should not have been affected (Holmes and Rice 1996).

Seasonal timing of hay cutting is important in determining which seeds will be available and viable. Since our experiment targeted rough fescue, the hay was cut when its seeds were mature. To obtain a full suite of native grassland species, Edwards and others (2007) recommended cutting hay several times, such as in early, middle, and late summer. Kiehl and colleagues (2006) had success baling hay from a donor site and transporting it; however, further research into the longevity of native hay bales is needed. Being able to store native hay for future use would be important for well-site restoration, which may take place several years after construction, or for retaining species, such as rough fescue, that do not produce seeds every year.

This experiment showed that native hay has potential to provide early species establishment and a diverse plant cover similar to predisturbance grassland conditions. Since only 1 native hay site was available for study, extrapolation of the results to other sites is not strong. Nevertheless results are promising and warrant further study to evaluate timing of hay harvesting, how native hay responds to storage, and optimal coverage.

Acknowledgments

We thank Mark Hendricks of Penn West for his suggestion to use native hay, PennWest Energy Trust for allowing us to use their site and for funding the native hay application, and Paramount Resources Ltd. for their funding and access to their ROW. We acknowledge funding from NSERC, the University of Alberta, and the government of Alberta: Sustainable Resources Development.

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Farming for Restoration: Building Bridges for Native Seeds

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In both Europe and the United States, a shortage of native plant material frequently precludes successful restoration. Native plant materials are needed to restore ecosystem functioning and services, provide for in situ conservation of biodiversity (e.g., Hobbs and Cramer 2008), maintain genetic diversity (Bischoff et al. 2010), and afford resistance to invasive species. Long-term stewardship goals are to create diverse, resilient systems with the genetic diversity and structure to facilitate adaptation to climate change and other environmental perturbations (e.g., Johnson et al. 2010). Commercial seed mixtures of non-native species and genetically uniform varieties threaten local diversity. Consequently, efforts to develop native seed sources are receiving considerable attention.

During the 7th Society for Ecological Restoration European Conference in Avignon, a special session focused on the successes and challenges of producing and using native plant material on a regional scale. European and American participants highlighted common issues encountered in developing native seed supplies (Figure 1), creating new market niches, and adapting seed certification procedures for use with native materials with the goal of sharing effective solutions and devising new approaches. Here we share the key findings and next steps outlined in this special session.

Several biological and technical challenges hinder the development of native plant programs at local or regional scales, such as: 1) identifying species-specific seed zones derived from ecological studies and provisional seed zones based on climatic and environmental variables (Johnson et al. 2010); 2) developing genetically diverse, ecologically adapted materials (Johnson et al. 2010); 3) formulating strategies to track plant materials from wildland harvest through agricultural production as well as to manage stock seed or other types of plant materials (Figure 2); 4) developing seed technology for diverse woody and herbaceous species; 5) understanding pollinator requirements and potentially managing wild pollinators in seed fields; 6) identifying cultural practices, including pest and disease control, for maximizing seed production; and 7) developing effective strategies and equipment for reestablishing native plant communities (USDI BLM 2009). Major political and economic obstacles include sustaining funding for research and development, creating new market niches for seed growers, and creating and maintaining collaboration among researchers, seed regulatory agencies, the private seed industry, and private and public end users.

One of the main topics in the session was the limited European production of native plant material owing to high costs and lack of propagation experience. Native seed production is often organized by local nongovernmental organizations (NGOs) or very small companies, and seed quantities and range of species are limited. Moreover, the lack of administrative support for native plant material leads to widespread use of low-cost commercial seed mixtures containing horticultural and agricultural cultivars and wildflower seeds of unknown or nonlocal origin. Use of easily propagated and widespread cultivars ensures the continuous availability and affordability of these mixtures but ignores the importance of local genotypes. Conrad (2007) and Tischew and others (2010) evaluated grassland restorations to counteract impacts of infrastructural projects on natural systems in Germany. Approximately