Dynamics of exotic species and their establishment in the Pawnee National Grasslands

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Abstract

We investigated the distribution of plant species in the shortgrass steppe to determine if the roadsides were acting as corridors, increasing the susceptibility of the open steppe to exotic species establishment. We surveyed 45 paired roadside and open steppe sites and found few exotic species in the the open steppe (.36/m^2), whereas the roadsides contained significantly more (5.42/m^2).

We examined the soil seed bank along a transect from roadsides to 25 meters into the open steppe to investigate the range of seed dispersal and abundance of roadside exotic seeds. We found that a significantly greater number of exotic seeds in the roadsides (873 seeds per m^2) versus the open steppe (109 seeds per m^2).

To investigate the dynamics of exotic species establishment we planted two exotic species, downy brome (*Bromus tectorum*) and Dalmation toadflax (*Linaria dalmatica*), into the open steppe. A matrix of 5 treatments was applied and after one field season *Bromus tectorum* germinated and established in many plots. The nitrogen and nitrogen plus water treatments were the most successful in promoting the growth of *Bromus*. *Linaria dalmatica* did not establish in any of the research plots.

The open steppe has few exotic species and we found that few exotic seeds exist in the seed bank. Furthermore, our work indicates that even if exotic species seeds were numerous, they may have difficulty germinating and establishing in the native communities.

Introduction

Exotic plant species invasions have profoundly affected plant communities in many types of grassland (Mack and Thompson 1982, Stohlgren et al. 1999). The shortgrass steppe is one of the types that has not been drastically affected. Previous analyses have suggested that most of the exotic species in shortgrass areas are found along roadsides. One of our objectives was to discover whether roadsides were acting as corridors allowing exotic plants to invade the open steppe and by which mechanisms this may occur.

To establish the relationship between roadsides and open steppe, we conducted a survey of the Western Section of the Pawnee National Grasslands in Weld County, Colorado. The results of the survey suggested that, while there were many exotic plant species along the roadsides, few were found in the open steppe. This led us to ask two questions about mechanisms. The first question was – Are seeds from the roadside plants being dispersed into the steppe? To answer this question we designed a seed bank study. The second question was – Is the establishment of exotic plants in the open steppe limited by competition from existing plants or by resource availability? To answer this question we designed a seed addition experiment in which we manipulated neighbor plants, water and nitrogen availability.

Objectives

1. Survey the Western Section, Pawnee National Grasslands to determine the distribution of exotic species in the roadsides and open steppe.
2. Examine the seed bank along transects from roadsides to the open steppe to determine the range of dispersal and abundance of exotic plant seeds.
3. Plant exotic species and determine which factors: grazing, water, nitrogen or disturbance, influence exotic species establishment.

Objective 1: Survey of Roadsides and Open Steppe

Methods - During the summer of 1998, 45 paired roadside and open steppe sites were surveyed to estimate the species richness, number of individuals and percent canopy cover in 3 x 1 meter plots. Grazed and ungrazed roadsides were sampled.

Results -

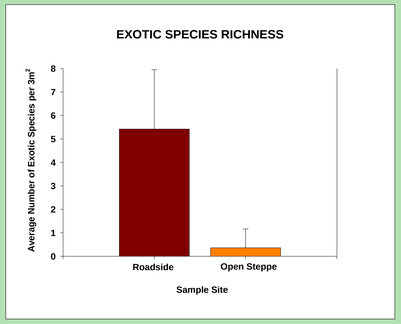


Fig. 1. Comparison of exotic species richness in roadsides and open steppe (P<.0001).

Significantly fewer exotic species, number of individuals and percent canopy cover were found in the open steppe than the roadsides (Fig. 1).

After surveying 45 different open steppe sites, only 8 exotic species were found. Thirty-five of the 45 sites contained no exotic species. None were known species of concern.

Exotic species established in the roadsides, do not appear to be encroaching onto the open steppe.

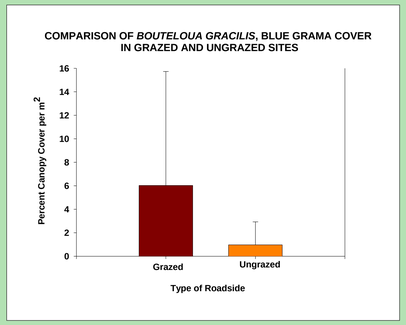


Fig. 2. Comparison of percent canopy cover of *Bouteloua gracilis* in 13 grazed and 13 ungrazed roadsides with standard deviation error bars (P<.03).

Grazed roadsides contained significantly more total native species than ungrazed roadsides.

In addition, there was a significantly greater percent canopy cover of the dominant shortgrass steppe native grass, *Bouteloua gracilis* in the grazed roadsides than the ungrazed roadsides (Fig 2).

There was no significant difference of exotic species richness, density or canopy cover between the grazed and ungrazed roadsides.

Objective 2 : Seed Bank Study

Methods - Seven grazed and seven ungrazed sites were chosen to extract 5 cm diameter soil cores, 10 cm deep from a transect starting at the roadside:

0 - 2.5m - Fence - 4.5m - 6.5m - 25m

The samples were shallowly spread in trays and placed in a greenhouse from June until October. Species and number of individuals emerging were recorded.

Results -

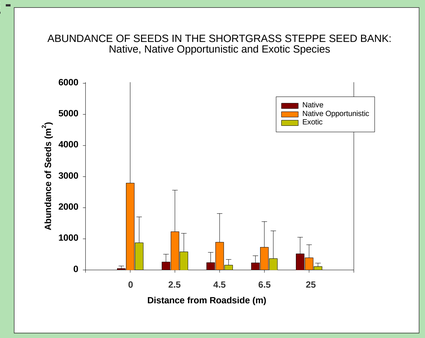


Fig. 3. Comparison of the abundance of native, native opportunistic and exotic seeds at various sampling distances, beginning with the roadsides and ending with 25 meters into the open steppe.

More seeds of exotic species were found at the roadside than 25 meters away into the open steppe (Fig. 3).

Furthermore, there was a greater number of seeds in the roadsides than the open steppe.

Few exotic species were found in the open steppe.

These results indicate that seeds of exotics species dominate the seed bank in the roadsides but their abundance declines with increasing distance from the roadside.

Table 1. Density of seeds of exotic species (# of individuals/ m^2) at each sampling point. All data was tabulated from 14 sites, however only 9 sites contained a fence.

Species	Plant Type	Sample Location					
		Roadside	2.5 m	Fence	4.5 m	6.5 m	25 m
Amaranthus blitoides	exotic	81.81	227.25	169.68	36.36	18.18	9.09
Cenchrus longispinus	exotic	63.63	18.18	14.14	0	0	0
Convulvulus arvensis	exotic	9.09	0	0	0	0	0
Eragrostis cilianensis	exotic	145.44	0	14.14	0	0	0
Kochia scoparia	exotic	218.16	63.63	56.56	18.18	0	0
Lactuca serriola	exotic	18.18	54.54	0	0	0	0
Melilotus officianalis	exotic	36.36	0	28.28	9.09	18.18	0
Panicum capillare	exotic	9.09	0	0	0	0	0
Portulaca oleracea	exotic	9.09	9.09	42.42	0	9.09	9.09
Salsola tragus	exotic	0	0	28.28	0	0	0
Salvia reflexa	exotic	9.09	0	0	0	0	0
Setaria pumila/viridis	exotic	36.36	0	0	0	0	0
Thlaspi arvense	exotic	0	9.09	0	0	0	0
Verbascum thapus	exotic	0	0	28.28	0	0	18.18
Verbena brachaeta	exotic	236.34	199.98	127.26	81.81	318.15	72.72

Objective 3 : Field Manipulative Experiment in the Open Steppe

Methods - Dalmation toadflax (*Linaria dalmatica*) and downy brome (*Bromus tectorum*), 2 exotic species, were each planted at the end of April in 30 plots (3 replicates). Each plot had 32 seeds planted in a 25 x 25 cm area, so 960 seeds were planted of each species.

Five treatments were applied: 1) water addition, 2) nitrogen application, 3) removal of existing plants, 4) light cattle grazing, and 5) water plus nitrogen addition. The water was applied every week in an amount similar to the wettest year on record, 1967. Twelve grams of nitrogen per m^2 were applied in the first week of May and 6 grams were later added in mid-July.

Results -

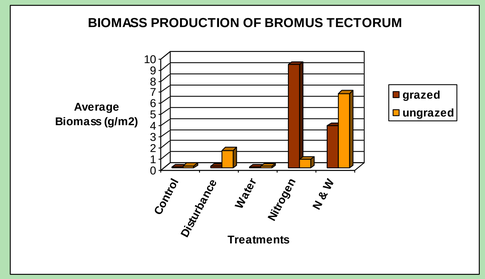


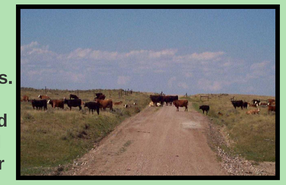
Fig. 4. Comparison of *Bromus tectorum* productivity across 5 treatments: control, disturbance or plant removal, water addition, nitrogen addition and water and nitrogen addition during one field season.

Disturbance, which we thought would be similar to the water and nitrogen application, actually affected the seeds much differently. Seedlings in the disturbance plots only grew to 15 mm in height before turning brown and dying.

Water applications alone did not seem to significantly benefit the establishment of downy brome, however it appears nitrogen and water or nitrogen alone can significantly effect the growth.

Linaria dalmatica did not establish in any of the plots. In fact, only one had germinated but days later it was chewed off.

Conclusions



The open steppe of the Western Section of the Pawnee National Grasslands has few exotic species. This is most likely a result of a paucity of exotic seeds in the seed bank and a native community and climate which makes it difficult for exotic species to establish.

Our vegetation survey suggested that very few exotic species have established in the open steppe. The seed bank study revealed that currently few exotic species seeds exist in the open steppe, which supports our vegetation survey.

The field experiment revealed that even if exotic seeds are planted, establishment is difficult in the open steppe. With the addition of nitrogen or nitrogen and water, however exotic species may have an increased chance of establishment.

A lack of establishment of *Linaria* during the experiment may have been due to a low germination rate (20% in the lab). Despite the fact that *Linaria dalmatica* did not establish, it exists in the open steppe (though not recorded in our vegetation survey) and has become more abundant over the past 15 years. A longer study is needed to capture the long term dynamics of *Linaria*, a species of concern in this semiarid region.

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Stohlgren, T. J., Binkley, D., Chong, G. W., Kalkhan, M. A., Schell, L. D., Bull, K. A., Otsuki, Y., Newman, G., Bashkin, M., and Y. Son. 1999. Exotic plant species invade hot spots of native plant diversity. Ecol. Mono. 69(1):25-46.