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Abundances of Coplanted Native Bunchgrasses and Crested Wheatgrass after 13 Years☆,☆☆

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ABSTRACT

Crested wheatgrass (*Agropyron cristatum* [L] Gaertm) has been seeded on more than 5 million hectares in western North America because it establishes more readily than native bunchgrasses. Currently, there is substantial interest in reestablishing native species in sagebrush steppe, but efforts to reintroduce native grasses into crested wheatgrass stands have been largely unsuccessful, and little is known about the long-term dynamics of crested wheatgrass/native species mixes. We examined the abundance of crested wheatgrass and seven native sagebrush steppe bunchgrasses planted concurrently at equal low densities in nongrazed and unburned plots. Thirteen years post establishment, crested wheatgrass was the dominant bunchgrass, with a 10-fold increase in density. Idaho fescue (*Festuca idahoensis* Elmer), Thurber's needlegrass (*Achnatherum thurberianum* (Piper) Barkworth), basin wildrye (*Leymus cinereus* [Scribn. & Merr.] A. Löve), and Sandberg bluegrass (*Poa secunda* J. Presl) maintained their low planting density, whereas bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve), needle-and-thread (*Hesperostipa comata* [Trin. & Rupr.] Barkworth), and squirreltail (*Elymus elymoides* [Raf.] Swezey) densities declined. Our results suggest that densities of native bunchgrasses planted with crested wheatgrass are unlikely to increase and that some species may only persist at low levels. The high recruitment of crested wheatgrass suggests that coplanting of some native bunchgrasses may be a viable way of avoiding crested wheatgrass monocultures when this species is necessary for rehabilitation or restoration.

Introduction

Crested wheatgrasses (*Agropyron cristatum* [L] Gaertm. and *Agropyron desertorum* [Fisch.] Schult.) have been seeded on more than 5 million hectares across semiarid and arid western North American rangelands (Maryland et al., 1992). In the Intermountain West, crested wheatgrass is often seeded in mixes with native species (Pellant and Lysne, 2005). It is relatively cost effective, establishes readily, and, as it is highly competitive with undesirable weedy species (Arredondo et al., 1998; Eiswerth et al., 2009), may facilitate establishment of more desirable native vegetation (Cox and Anderson, 2004). However, the competitive nature of crested wheatgrass can result in monoculture stand formation and seed bank domination (Pyke, 1990), which can both hinder establishment of native species (Gunnell et al., 2010; Marlette and Anderson, 1986) and induce native species displacement and low biological diversity (Christian and Wilson, 1999; Krzic et al., 2000; Vaness and Wilson, 2008). When crested wheatgrass is included in seed mixtures with native species, crested wheatgrass frequently becomes dominant (Heinrichs and Bolton, 1950; Knutson et al., 2014; Schuman et al., 1982); however, it remains relatively unclear as to whether crested wheatgrass excludes natives or if natives just fail to establish. Efforts to remove crested wheatgrass and reseed natives rarely increases native vegetation establishment (Fansler and Mangold, 2011; Hulet et al., 2010). Native herbaceous vegetation has successfully reestablished in some crested wheatgrass communities (Williams, 2009); however, because most studies are shorter than 5 years, little is known about the ability of established native bunchgrasses to coexist with crested wheatgrass more than a decade after planting.

Successfully established native vegetation produces seed, potentially increasing the availability of seed on a site. Edwards and Crawley (1999) suggest that seed rain is likely critical for maintaining

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a species. If established native vegetation species coexist with crested wheatgrass, they may provide a seed source that allows for continued recruitment, persistence, and even increases of native vegetation in crested wheatgrass communities. Alternatively, because crested wheatgrass frequently dominates the seedbank and is more competitive than many native species at the seedling stage, it may thereby exclude or a least limit the recruitment of native vegetation (Gunnell et al., 2010). Therefore more information is needed about the potential likelihood of native bunchgrass species to maintain their presence the community after co-establishment with crested wheatgrass.

To evaluate the long-term response of native perennial bunchgrasses when coplanted with crested wheatgrass, we looked at bunchgrass species abundance 13 years after simultaneous planting. We hypothesized that the density of each native bunchgrass species would decrease over time and that crested wheatgrass would become the dominant bunchgrass.

Methods

Study Area

The study site is located on the Northern Great Basin Experimental Range (lat 43 28′48.3′′N, long −119 42′32.2′′W, elev 1/403 m) 56 km west of Burns, Oregon. Average annual precipitation at the site is 286 mm, typically arriving as snow or rain from October to March (data file, Eastern Oregon Agricultural Research Center, Burns, OR). Soils at the site are a complex of loam and loamy fine sands (Milican coarse-loamy, mixed, frigid Orthidic Durixerolls and Holte coarse-loamy, mixed, frigid Orthidic Haploxerolls, respectively (Lentz and Simonson, 1986; Ganskopp et al., 2007). Depth to bedrock or hardpan ranged from 90–150 cm (Ganskopp et al., 2007).

Vegetation in neighboring pastures is characterized by Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis* Beetle) overstory with a diverse understory that contained all of the native bunchgrasses evaluated in this study.

Experimental Design

In 1989 nine 313-m^2 plots were established in a site cleared of vegetation for a paddock study using methods outlined in Cruz and Ganskopp (1998) and Ganskopp et al. (2007). Seven native bunchgrass species, bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve), basin wildrye (*Leymus cinereus* [Scribn. & Merr.] A. Löve), Idaho fescue (*Festuca idahoensis* Elmer), bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey), needle-and-thread (*Hesperostipa comata* [Trin. & Rupr.] Barkworth), Sandberg bluegrass (*Poa secunda* J. Presl), and Thurber's needlegrass (*Achnatherum thurberianum* [Piper] Barkworth) and one introduced bunchgrass species, "Nordan" crested wheatgrass, were transplanted into each plot as mature plants harvested from nearby plant communities. The bunchgrass species were planted so that each plot contained 2.6 total plants or 0.33 plants per species $\cdot$ m^{-2} randomly assigned to an evenly spaced grid of 29 rows and 29 columns (resulting in 841 cells) with plants positioned at the center of each cell such that there were 0.61 m between plant centers. This resulted in a total of 800 (100 per species) planted cells and 41 randomly distributed empty cells in each plot. In 1998 the site was weeded and restocked with transplants from nearby communities when necessary to achieve original plant densities (Ganskopp et al., 2007). Except for the 1998 experiment (Ganskopp et al., 2007), domestic livestock grazing was excluded since 1989. Since the last treatment in 1998, the communities were left to the natural processes of recruitment and mortality.

Vegetation Measurement and Statistical Analyses

In 2011, we recreated the original grid described earlier and counted, by species, the bunchgrasses in each plot. To determine whether there was a change in species abundance over time, we used repeated measures multivariate analysis of variance (MANOVA) with density in 1998 and density in 2011 as response variables and species as an independent variable in JMP 10.0.2. To determine which species were different, we used a pairwise comparison with the Tukey HSD adjustment obtained using an analysis of variance (ANOVA) on the change in abundance grouped by species in R (version 3.0.2). This change in abundance was the 1998 abundance subtracted from the 2011 abundance. In order to determine the effect of time on individual species, we used a one sample two-tailed t-test to compare the 2011 abundance of each species to the null starting (1998) abundance using R (version 3.0.2; R Core Team, 2013). Results were reported as density $\cdot$ m^{-2}. Abundance data were normally distributed, and a transformation was not used. Means were reported with standard error of means (SE). For the t-tests, significance was set at a conservative $P < 0.006$ (0.05/8) to reduce the chance of type I error. All P values refer to t-test results unless otherwise indicated.

Results

The MANOVA revealed a significant effect for the interaction of species and time ($F\,[7, 64] = 29.5$, $P < .001$). Given the significance of the overall test, an ANOVA was used to examine the change in species abundance, which showed there was an increase in total bunchgrass density from 2.64 plants $\cdot$ m^{-2} (8 species at 0.33 plants $\cdot$ m^{-2} each) in 1998 to 5.23 $\pm$ 0.02 plants $\cdot$ m^{-2} in 2011 ($P < 0.001$, F [7, 64] = 260.0). The Tukey pairwise comparison revealed that crested wheatgrass had the greatest increase in density in the community: a 10-fold increase in density over the 13-year period (3.37 $\pm$ 0.35 plants $\cdot$ m^{-2}; $P < 0.001$; Fig. 1). Crested wheatgrass comprised 64% of the total bunchgrass abundance. The native bunchgrasses each contributed between 3% and 8% of the remaining bunchgrass abundance. Idaho fescue was the only native grass that slightly increased in density, by about 0.1 plants . m^2 to 0.43 $\pm$ 0.13 plants $\cdot$ m^{-2}. However, its response was highly variable (Fig. 1) and was not strongly statistically significant ($P = 0.07$). Thurber's needlegrass, Basin wildrye, and Sandberg bluegrass maintained a similar density over time (0.28 $\pm$ 0.08, 0.26 $\pm$ 0.04, and 0.32 $\pm$ 0.20, respectively; $P > 0.01$; Fig. 1). In contrast, squirreltail, needle-and-thread, and bluebunch wheatgrass decreased over the 13-year study interval (0.17 $\pm$ 0.07, 0.20 $\pm$ 0.03, and 0.19 $\pm$ 0.06 plants $\cdot$ m^{-2}, respectively; $P \leq 0.001$; Fig. 1), with squirreltail experiencing the greatest decline (ca. 50%).

Discussion

As we hypothesized, crested wheatgrass became dominant in the community after 13 years. Similar to other, more short-term studies (see Grant-Hoffman et al., 2012; Heidinga and Wilson, 2002), we found that crested wheatgrass rapidly became the most abundant bunchgrass in the mixed-grass community, and increases in crested wheatgrass were often, though not always, associated with declines in native grasses. The presence of established native species may reduce the extent of crested wheatgrass dominance (Bakker and Wilson, 2004), potentially slowing the recruitment of crested wheatgrass into the community. The relatively stable density of Idaho fescue, Thurber's needlegrass, Basin wildrye, and Sandberg bluegrass over our 13-year study suggests that these species may persist in sagebrush steppe when coplanted with crested wheatgrass, especially at our elevation and sparse planting densities. Other studies have

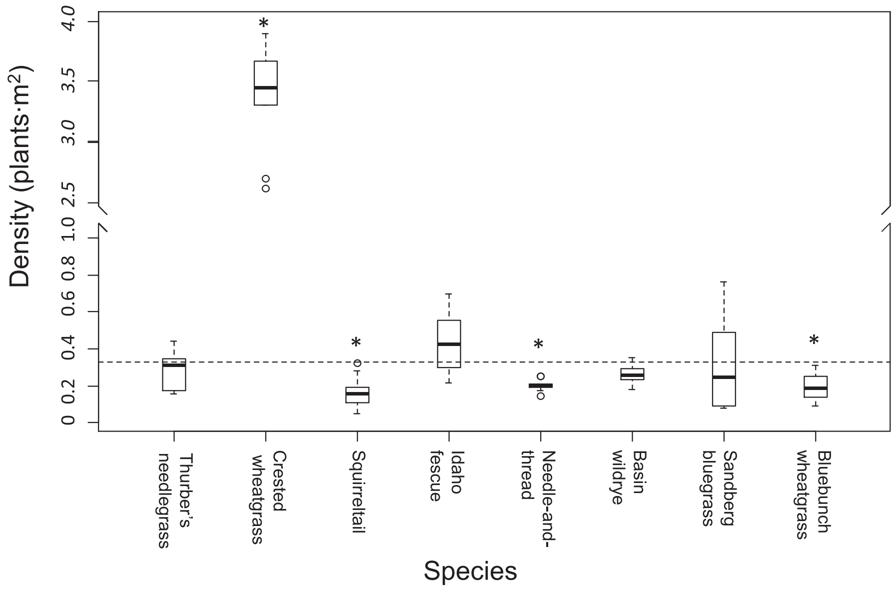

Fig. 1. Average density of perennial bunchgrasses in 2011. Starting density was 0.33 plants m^{-2} in 1998 (dashed line). Asterix indicates a statistically significant ($P < 0.05$) difference in density between 1998 and 2011. Note scale change on y axis. below solid reference line.

found that Sandberg bluegrass is less negatively impacted by the presence of crested wheatgrass than other species (e.g., bluebunch and needle-and-thread grass) and can coexist with crested wheatgrass (Broersma et al., 2000; Heidinga and Wilson, 2002; Henderson and Naeth, 2005), possibly because it grows and senesces earlier than other bunchgrasses (James et al., 2008), which may allow it to avoid competition for scarce moisture resources.

It is difficult to determine whether those species that showed declines in density (squirreltail, needle-and-thread, bluebunch wheatgrass) will simply have a decreased presence in the community or whether declines will lead to their eventual extirpation. Similar to our results, Henderson and Naeth (2005) found that bluebunch wheatgrass decreased when it coexisted in communities with crested wheatgrass. Squirreltail also tends to be negatively correlated with crested wheatgrass abundance (Davies, 2010; Grant-Hoffman et al., 2012) despite its greater ability to effectively compete with crested wheatgrass at the seedling stage than other native bunchgrasses (Gunnell et al., 2010).

We found that crested wheatgrass appears to be filling available open spaces while the density of native bunchgrasses remained static or decreased slightly. Perennial bunchgrasses in our study sites were spaced at even distances from one another and at relatively low densities. This is a stark contrast to the clumping of bunchgrasses in drill rows with drill seeding, which may alter plant community dynamics. The ability of crested wheatgrass to recruit high numbers of individuals relative to native bunchgrasses in coplanted communities means that even if native bunchgrasses are established into existing stands of crested wheatgrass, their presence is unlikely to increase in the community. The dominance of crested wheatgrass suggests that efforts to diversify crested wheatgrass stands with native bunchgrasses may not be successful without significant and lasting control of crested wheatgrass. Knutson et al. (2014) found evidence suggesting that planting native bunchgrasses is most successful when crested wheatgrass is not included in the seed mixture. When native species do successfully establish with crested wheatgrass, they often decrease within 3 years (Davies, 2010; Fansler and Mangold, 2011; Hulet et al., 2010). However, despite decreases in some species, migration of the coplanted native bunchgrasses into neighboring cells suggests that they were recruiting into the plant community; even if at low levels, and so may maintain a presence in the community. Presence of larger native species may be underestimated in our study because cover or plant size was not measured and species like Basin wildrye have a stronger presence than density can indicate. The high recruitment of crested wheatgrass helps explain why its presence can limit exotic annual grasses, especially in wetter, cooler environments such as our study site (Knutson et al., 2014), and why, in some situations, crested wheatgrass may be selected for seeding when the goal is to reduce the risk of exotic annual grass invasion and dominance, particularly following a wildfire event (Davies, 2010).

Although our experiment is replicated at one site only, it is a valuable contribution to our understanding of the relationship between crested wheatgrass and native perennial bunchgrasses as there are few studies with a similar combination of duration and experimental control. Our study provides a unique opportunity to examine long-term changes in abundance of native bunchgrasses established alongside crested wheatgrass in the sagebrush steppe. Longer-term monitoring will be necessary to determine whether the community maintains its diversity or eventually converts to a near monoculture stand of crested wheatgrass. Further evaluations at sites with varying site and climatic characteristics may help identify the species that are more likely to effectively coexist with crested wheatgrass across its seeded range.

Management Implications

The 10-fold increase in crested wheatgrass density and decrease in half of the native bunchgrass species raise the question of how effective simultaneous seedings of crested wheatgrass and native bunchgrasses will be if the management objective is for native vegetation to establish and increase. Some native bunchgrass species, in our case, Sandberg bluegrass, Thurber's needlegrass, and Idaho fescue, may be more likely to maintain a presence in the community, though the most suitable species will likely also differ depending on site characteristics. We had an evenly dispersed, low-density planting, which may reduce competitive interactions compared with a more typical seeding where plants tend to emerge at higher densities. If crested wheatgrass is necessary to reclaim a site or reduce exotic annual grass invasion, it may be an ineffective use of resources to seed those native bunchgrass species that are less likely persist over long time periods. Our results suggest that if native bunchgrasses are likely to establish and meet management objectives, it may be undesirable to include crested wheatgrass because it will likely increase at greater rates than native bunchgrasses.

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