Exotic Species and Overgrazing Can Drive Declines in Grassland Biodiversity and Productivity

Forest Isbell, PhD candidate
Brian Wilsey, associate professor
Department of Ecology, Evolution, and Organismal Biology

Introduction

Plant species diversity has declined rapidly in grasslands, and it is poorly known how to establish and maintain diverse mixtures containing grasses, forbs, and legumes. Each of these groups can be important. For example, grasses and forbs can produce forage and increase resistance to weeds, and legumes can produce forage and maintain high fertility by fixing nitrogen. There is some evidence that exotic (introduced) plant species and changes in land use are contributing to declines in diversity. Exotic species could be causing declines in diversity in situations where they differ from native plant species in growth rates and other plant traits. However, previous studies were based on correlative data, and we have a poor understanding of whether exotic species themselves are causing direct declines in diversity, or if associated land use changes are causing the declines in diversity.

Grazing may interact with the plant species present to affect diversity. Managed grazing is the most extensive type of land-use worldwide and is often an order of magnitude more intense than grazing in natural systems. Experimental studies have shown that, although moderate grazing can greatly increase diversity, high intensity grazing can reduce diversity. Exotic grassland species often have been selected and introduced for specific uses such as forage and erosion control that may allow them to have very different growth responses compared with native species. These differences might be enhanced under intense grazing. Thus, the potential trade-offs between managing for high forage production and managing for biodiversity and sustainability needs to be better understood.

Materials and Methods

We established a long-term experiment in 2007 to determine whether high intensity grazing and plant species origin (native vs. exotic) affect grassland diversity and productivity. Plots were planted as single species monocultures or four-species mixtures. Mixtures had either all native species or all exotic perennial grassland species. Native and exotic species were chosen to be comparable in other aspects besides origin such as phylogeny and growth form. Seedlings from eight native and eight exotic grassland plant species were grown in a greenhouse, and were transplanted into 1-m^2 field plots May 8–11, 2007.

Monocultures and mixtures were established during the first growing season, and the grazing treatment was applied during the second growing season. The aboveground peak biomass was estimated by a nondestructive point-intercept method during years one and two. During the second growing season, half of the plots were intensely grazed by twenty 450 kg steers from June 10-11, 2008, while the other plots were protected by exclosures. Point-intercept sampling was conducted before and after the grazing event to quantify consumption and the change in biodiversity during grazing (i.e., change = before grazing – after grazing). All aboveground biomass in all plots was clipped 3 cm above the soil surface after the point-intercept sampling at peak biomass in year two. Peak biomass was sorted to species, dried, and weighed to estimate aboveground net primary productivity (ANPP = peak + consumption), and to quantify Simpson's diversity index (1/D, where $D = \sum p_i^2$ and p_i is the relative biomass of species *i*), and its richness (S, number of species) and evenness (E = [1/D]/S, the equity of biomass among species) components.

Results and Discussion

We found that exotic species drove declines in species evenness (i.e., the equity of biomass among species, $P < 0.001$), but not richness (i.e., the number of species, $P > 0.10$) during year one (Table 1).

Overgrazing drove declines in species richness ($P < 0.05$), but increased species evenness ($P < 0.001$) in native communities (Table 2).

Exotic species reduced productivity during both years, and overgrazing reduced productivity during year two (Tables 1 and 2).

In conclusion, there is some evidence that exotic species and overgrazing reduce both biodiversity and productivity by changing species interactions. However, further study is needed to identify the specific processes explaining these patterns.

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Table 1. Mean change in diversity (ΔD), evenness (ΔE), and richness (ΔS); and mean aboveground net primary productivity (ANPP, g/m^2) during establishment in native and exotic communities.

	ΔD	ΔE	ΔS	ANPP
Native	−0.34	−0.08	−0.03	332.1
Exotic	−0.95	−0.23	−0.13	245.3

Table 2. Mean change in diversity (ΔD), evenness (ΔE), and richness (ΔS); and mean aboveground net primary productivity (ANPP, g/m^2) during establishment in native and exotic communities that were either overgrazed or ungrazed.

	ΔD	ΔE	ΔS	ANPP
Native, ungrazed	0.03	0.01	−0.06	732.6
Native, overgrazed	−0.08	0.15	−0.88	495.1
Exotic, ungrazed	0.00	0.01	−0.13	268.8
Exotic, overgrazed	−0.14	0.00	−0.25	232.0