Biological Conservation 159 (2013) 292–302

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Ecological tradeoffs in non-native plant management

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ARTICLE INFO

Article history:
Received 10 July 2012
Received in revised form 13 October 2012
Accepted 22 October 2012
Available online 23 January 2013

Keywords:
Invasive plants
Plant community impacts
Removal experiment
Management effects
Native plant conservation
Natural areas

ABSTRACT

Controlling non-native plants in natural areas should, ideally, not only reduce target species' abundance, but also benefit broader management objectives such as conserving native species, improving wildlife habitat, and maintaining ecosystem function. In this context, the effectiveness and non-target impacts of control strategies, such as broadleaf herbicides, must be weighed against the impacts of non-native plants themselves. We undertook this relative assessment for *Centaurea stoebe*, one of the most widespread and heavily managed non-native plant species in the Intermountain West, USA. While effectiveness and plant community impacts of herbicide treatment for *C. stoebe* have been assessed, field-based experiments quantifying community-level impacts of *C. stoebe* are rare. In a three-year experiment in sagebrush–grassland communities of southwest Montana, USA, we found that the broadleaf herbicide, picloram, was highly effective at reducing *C. stoebe*, but also caused a significant loss of native forb cover and a significant increase in non-native grass cover, primarily *Bromus tectorum*. There was a significant increase in native forb cover in response to manual removal of *C. stoebe*, which would seem to indicate *C. stoebe* had been suppressing native forbs. However, there was an equivalent increase in native forb cover with no treatment. In some communities, *C. stoebe* appears to have a negligible effect on native forb and grass cover and richness. Depending on management objectives, the loss of native forb cover and potential secondary invasion may outweigh the benefits of reduced target non-native plant abundance; thus, highlighting an ecological tradeoff of non-native plant management in natural areas.

1. Introduction

Non-native plants pose a significant threat to biodiversity and ecosystem structure and function (Vitousek et al., 1997; Mack et al., 2000; Simberloff, 2011; Vilà et al., 2011), motivating aggressive and sustained control programs throughout the world. The invasion of non-native plants into natural areas and protected lands is particularly troublesome given the importance of these areas for conserving biological diversity and providing ecosystem services. Consequently, controlling non-native plants is either strongly advised or mandated for most natural areas and public lands. However, controlling non-native plants is only one of many land management objectives in natural areas, and whether common non-native plant control strategies are congruent with these other objectives is unclear.

The Intermountain West of North America ('the west' hereafter)—a region of both high conservation and human use value—exemplifies many of the challenges of managing natural areas for multiple natural resource objectives. Numerous non-native plants species have established and spread throughout the region, and one of the species of greatest concern is *Centaurea stoebe* L. (spotted knapweed; formerly known as *Centaurea maculosa* Lam.). *C. stoebe* is a short-lived perennial native to Europe and northern and central Asia that was accidentally introduced to North America in contaminated alfalfa (*Medicago sativa* L.) seed in the 1890s (Roché and Talbott, 1986). *C. stoebe* is now one of the most widespread non-native plants and is a designated "noxious weed" in the 11 contiguous western states (NRCS, 2012), meaning state and federal land management agencies are mandated to control *C. stoebe* and minimize the economic, ecological, and human health impacts that it causes (Executive Order 13112 of 1999).

The major impacts associated with *C. stoebe* in natural areas of the west (i.e. grasslands, shrublands, sagebrush steppe) include displaced native plant species, reduced forage quality and quantity, and negatively altered wildlife habitat (Hirsch and Leitch, 1996; DiTomaso, 2000; Duncan, 2005). A number of traits have been indentified that make *C. stoebe* highly competitive against native North American plant species, including extensive mycorrhizal colonization (Marler et al., 1999; Callaway et al., 2004a; Harner et al., 2010), production of allelopathic compounds (Ridenour and Callaway, 2001; Bais et al., 2003; Thorpe et al., 2009), greater nutrient-use efficiency relative to native species (Blicker et al., 2002;

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0006-3207/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2012.10.017

Zabinski et al., 2002; Thorpe et al., 2006), greater compensatory growth after herbivory relative to native species (Walling and Zabinski, 2006), and cultivation of soil biota in the invaded range that increase *C. steobe*'s growth (Callaway et al., 2004b). When seeded into experimental monocultures, *C. stoebe* significantly reduced the biomass of several native western USA forb and grass species (Maron and Marler, 2008b). It is generally assumed that *C. stoebe* displaces native plant species in natural plant communities because the presence and abundance of *C. stoebe* is often negatively correlated with native plant species cover, richness and diversity (Tyser and Key, 1988; Kedzie-Webb et al., 2001; Ortega and Pearson, 2005; May and Baldwin, 2011). The only experimental (manipulative) study of *C. stoebe* impacts under natural conditions that we are aware of is Lesica and Shelly (1996). They found that removing *C. stoebe* in two western Montana bunchgrass communities led to significantly higher seedling recruitment of a rare native Brassicaceae, Mt. Sapphire rockcress (*Arabis fecunda* Rollins); thus, demonstrating a species-specific competitive effect of *C. stoebe*. Collectively, these studies and others have greatly advanced our understanding of the biology, ecology, and potential impacts of *C. stoebe*. Nevertheless, quantitative field-based evidence linking *C. stoebe* to plant community-level impacts remains scarce.

C. stoebe is the most heavily managed non-native plant on public lands in the west (based on quantity of herbicide used, number of hectares treated, and hours of labor (USFS et al., 2010)). Management objectives in natural areas typically include maintaining native plant diversity and wildlife habitat, increasing forage production, sustaining ecosystem services, and conserving species of concern. It is generally assumed that reducing non-native plants in natural areas will benefit these objectives (Pearson and Ortega, 2009). However, the legal mandate to control noxious weeds may compel action before there is sufficient knowledge of how other land management objectives will be affected. Assessing the impacts of non-native plant species, as well as the impacts of the strategies used to control them, are crucial steps in managing natural areas for multiple conservation objectives (Buckley, 2008; Pearson and Ortega, 2009; Downey et al., 2010).

While there have been numerous studies of the effectiveness (i.e. reduction of *C. stoebe* abundance) and plant community impacts of herbicide treatments for *C. stoebe* (e.g. Rice and Toney, 1998; Sheley et al., 2000; Crone et al., 2009; Ortega and Pearson, 2010), there have not been similar experimental studies of the community-level impacts of *C. stoebe*. Thus, it is unclear how the benefits of *C. stoebe* management compare with the impacts of *C. stoebe* itself.

We conducted replicated removal experiments to quantify the relative impacts of *C. stoebe* and herbicide treatment of *C. stoebe* on sagebrush–grassland plant communities in southwest Montana. Removal experiments, along with experimental additions, provide the strongest evidence for assessing non-native plant impacts and avoid the confounding effects of environmental variation that arise in multi-site comparison studies (Adair and Groves, 1998). The objective of removal experiments is to approximate how a plant community would be structured in the absence of the non-native plant species. Non-native plants are removed with as little disturbance as possible and, after a recovery period, impacts are quantified as the change in plant community metrics from before removal.

The objectives of this study were to: (1) quantify impacts of *C. stoebe* on sagebrush–grassland plant communities in southwestern Montana; (2) compare the impacts of *C. stoebe* with those of herbicide control of *C. stoebe*, small-scale disturbance, and no treatment; and (3) determine whether invaded plant communities differed from nearby uninvaded plant communities and, if so, whether plant communities treated for *C. stoebe* became more similar to nearby uninvaded plant communities 3 years after treatment. The response variables measured for all three objectives were the percent cover and species richness and composition of native and non-native forbs and grasses, as well as the aboveground biomass of two native forage grasses. We focused on growth form (forbs and grasses) and origin groups (native and non-native) because these are common land management metrics and may be better indicators of a range of ecosystem processes, such as nutrient cycling, decomposition, and water retention, than individual species identity alone (Diaz and Cabido, 2001; Cadotte et al., 2011).

2. Methods

2.1. Study area

The study was conducted in the sagebrush–grassland habitat type of southwest Montana. These communities occupy the transition zone between valley bottoms and Douglas fir-dominated forest (*Pseudotsuga menziesii* (Mirb.) Franco). Perennial grasses feature prominently, ranging between 40% and 60% canopy cover (Mueggler and Stewart, 1980). The dominant species are bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve), western wheatgrass (*Pascopyrum smithii* (Rydb.) Á. Löve), and Idaho fescue (*Festuca idahoensis* Elmer), and frequent species include green needlegrass (*Nassella viridula* (Trin.) Barkworth), slender wheatgrass (*Elymus trachycaulus* (Link) Gould ex Shinners), prairie junegrass (*Koeleria macrantha* (Ledeb.) Schult.), squirreltail (*Elymus elymoides* (Raf.) Swezey), and Sandberg bluegrass (*Poa secunda* J. Presl). Forb canopy cover ranges from 20% to 30% and typically includes: arrowleaf balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.), buckwheat (*Eriogonum* species), rosy pussytoes (*Antennaria rosea* Greene), hairy false goldenaster (*Heterotheca villosa* (Pursh) Shinners var. *villosa*), prairie sagewort (*Artemisia frigida* Willd.), silvery lupine (*Lupinus argenteus* Pursh), Indian paintbrush (*Castilleja* species), fleabane (*Erigeron* species), phlox (*Phlox* species), scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.), and milkvetch (*Astragalus* L. species). Shrub canopy cover averages 5–10%, comprised mainly of big sagebrush (*Artemisia tridentata* Nutt.) and mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle). Average litter cover in these communities is 40–60% and bare ground 5–10%. Average temperatures in the study area are 19 °C in the summer and −4 °C in the winter. The average annual precipitation is 480 mm, with most falling in April, May, and June.

High forage production and diverse plant communities make sagebrush–grasslands in this region important habitat for numerous large mammals (e.g. elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*) and black bear (*Ursus americanus*)); small mammals (e.g. deer mouse (*Peromyscus maniculatus*), Uinta ground squirrel (*Urocitellus armatus*), bushy-tailed woodrat (*Neotoma cinerea*)); songbirds (e.g. Brewer's sparrow (*Spizella breweri*), Vesper sparrow (*Pooecetes gramineus*), western meadowlark (*Sturnella neglecta*)); upland game birds (e.g. greater sage-grouse (*Centrocercus urophasianus*), sharp-tailed grouse (*Tympanuchus phasianellus*)); and raptors (e.g. golden eagle (*Aquila chrysaetos*), ferruginous hawk (*Buteo regalis*)). Many taxa that are at-risk due to declining population trends and habitat loss ("species of concern") inhabit sagebrush–grasslands in this region for at least part of the year (MNHP, 2011).

There is a long history of human activity in the region, including mining, logging, farming, and ranching. In addition, due to moderate topography, open landscapes and proximity to wildlands, the last quarter century has seen rapid growth in recreational use and exurban development in lowland habitats such as sagebrush–grasslands (Gude et al., 2006). All of these activities and