Rangeland Ecology & Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: http://www.elsevier.com/locate/rama

Impacts of Feral Horse Use on Herbaceous Riparian Vegetation Within a Sagebrush Steppe Ecosystem

C.S. Boyd [a,*], K.W. Davies [a], G.H. Collins [b]

[a] Rangeland Scientists, US Department of Agriculture–Agricultural Research Service, Eastern Oregon Agricultural Research Center, Burns, OR 97720, USA
[b] Supervisory Wildlife Biologist, US Department of the Interior–Fish and Wildlife Service, Sheldon-Hart Mountain National Wildlife Refuge Complex, Lakeview, OR 97630, USA

ARTICLE INFO

Article history:
Received 19 April 2016
Received in revised form 26 January 2017
Accepted 9 February 2017
Available online xxxx

Key Words:
bare ground
herbivory
springs
wild horses
wildlife habitat

ABSTRACT

Feral horses inhabit rangeland ecosystems around the world, and their impacts on riparian ecosystems are poorly understood. We characterized impacts of a free-ranging horse population on the structure and composition of riparian plant communities in the sagebrush steppe ecosystem in the western United States. We used a randomized block design with single 25 × 50 m exclosures and grazed plots on four study sites within Sheldon National Wildlife Refuge in northwestern Nevada. Exclosures were constructed in 2008. Herbaceous plant utilization was measured from 2009 to 2013 by clipping within excluded and grazed plots. Herbaceous production and vertical structure were measured in 2013, and plant functional group and ground cover components were estimated in 2012–2013. Herbaceous utilization ranged from 27% to 84%, and herbaceous production did not differ by grazing treatment ($P = 0.472$). Grazed plots had seven-fold higher bare ground cover ($P < 0.001$), 60% less litter cover ($P < 0.001$), and the basal cover index was 65% higher. Grazing increased rush density by 50% ($P = 0.041$) but did not affect sedge density ($P = 0.514$). Grazing decreased herbaceous stubble height up to 80% and visual obstruction by about 70% ($P < 0.05$). Deep-rooted hydrophytic plant species did not increase with grazing exclusion, but greater vertical structure in excluded plots could improve hiding and nesting habitat for some riparian-associated wildlife species. Additionally, decreased bare ground with grazing exclusion could reduce erosion potential and susceptibility to invasive plant species.

Published by Elsevier Inc. on behalf of The Society for Range Management.

Introduction

During the Pleistocene, the range of a variety of species of wild horses (*Equus* sp.) covered much of Europe, Asia, North America, and perhaps North Africa (Kavar and Dove, 2008). Wild horse populations underwent a significant range contraction at the end of the Pleistocene and became extinct in North America by approximately 10,500 years before present (Guthrie, 2003, 2006). Free-ranging domestic horses (*E. caballus)* were introduced to North America by Spanish explorers during the 16th and 17th centuries (Haines, 1938) and by inadvertent and purposeful releases associated with the ranching industry and perhaps the military during the late 19th and early 20th centuries (Young and Sparks, 2002). Similar introductions of domestic horse stock have occurred globally, and current feral horse (horses whose ancestors are of domesticated lineage; Ostermann-Kelm et al., 2009) populations are stable or increasing in both the United States and Australia (Nimmo and Miller, 2007; Garrott and Oli, 2013).

Feral horses are currently a management issue on rangelands throughout much of the world. In the western United States, horses lack effective predators to control populations and periodic gathering of horses on federal lands has been necessary to control horse numbers and their associated impact on plant and soil resources (Garrott and Oli, 2013). Gauging the ecological impact of feral horses can be difficult because grazing by these animals often coincides in space and time with utilization by other large herbivores, particularly domestic livestock. In the western United States, most public lands are grazed by cattle and cattle diets overlap substantially with those of horses (Krysl et al., 1984; Scasta et al., 2016). Unlike domestic livestock, feral horse grazing is difficult to manage on a rotational or deferred basis due to difficulties associated with moving horses, resulting in continuous or near continuous use of rangeland plant communities. Previous work suggests that feral horse grazing can alter upland vegetation and soil resources within rangeland ecosystems at local (Fahnestock and Detling, 1999a; Ostermann-Kelm et al., 2009) and landscape scales (Beever et al., 2008; Zeigenfuss et al., 2014). Horse grazing has also been linked to community scale changes in composition and demographics of insect (Beever and Herrick, 2006), small mammal (Beever and Brussard, 2004), avian (Zalba and Conzzani, 2004), and estuarine fauna populations (Levin et al., 2002), as well as competition for water resources with a variety of native wildlife species (Hall et al., 2016).

Impacts of grazing animals on plant and soil resources can be particularly acute in and around riparian areas that serve as an attractant to herbivores due to forage and water availability (Kauffman and Krueger, 1984; Turner, 2015). Riparian areas are critical for maintaining a broad

* Correspondence: Chad S. Boyd, 67826-A Hwy 205, Oregon State University, Burns, OR 97720, USA.
E-mail address: chad.boyd@oregonstate.edu (C.S. Boyd).

http://dx.doi.org/10.1016/j.rama.2017.02.001
1550-7424/Published by Elsevier Inc. on behalf of The Society for Range Management.

suite of plant and animal species, contain biotic and abiotic habitats that differ from the surrounding landscape, and may serve as important travel corridors for a variety of wildlife species (Gregory et al., 1991; Naiman et al., 1993; Chambers and Miller, 2011). In the sagebrush steppe of the US Great Basin these habitats harbor the majority of regional biodiversity (Sada, 2008). Research suggests preference of feral horses for riparian areas during summer months with the potential for reduction in plant species richness, height, and cover and for alteration of plant community composition (Ganskopp and Vavra, 1986; Crane et al., 1997; Beever and Brussard, 2000). In desert environments typical of the US Great Basin, upland vegetation surrounding riparian areas may also be impacted by feral horse grazing; for example, Davies et al. (2014) reported reduced sagebrush density in riparian-adjoining upland areas exposed to feral horse grazing relative to grazing exclosures.

Sheldon National Wildlife Refuge in northern Nevada offers a unique opportunity to examine the impacts of feral horses on riparian plant communities that are not currently grazed by domestic livestock. Our objective was to determine habitat structure and composition of plant communities in riparian areas exposed to and excluded from feral horse grazing. We hypothesized that plant basal cover would increase in response to horse grazing exclusion, and that grazing exclusion would shift plant community composition away from grazing-tolerant rush (*Juncus* sp.) species. We further hypothesized that vertical structure of habitat would increase with grazing exclusion in association with increased shrub density, herbaceous stubble height, and visual obstruction.

Methods

Study Area

Our study took place within the Sheldon National Wildlife Refuge (SNWR) in northwestern Nevada. Since the 1880s cattle, sheep, and horses (>20,000 animals) grazed on the SNWR, but cattle and sheep were removed between 1990 and 1994 (U.S. Fish and Wildlife Service, 2013). SNWR covers an area of 230,000 ha of largely sagebrush steppe rangeland, and our study sites were located within an unfenced and contiguous 80,000-ha management unit. Feral horse density within the management unit varied from 0.5 to 0.8 horses.km^{-2} between 2007 and 2013 (USFWS, unpublished data). Free-ranging burros occurred within SNWR, but not within our study area. Elevations within SNWR average approximately 1900 m, and climate is characterized by warm, dry summers and cold, wet winters with most precipitation occurring during the winter and spring periods. Average water year precipitation (1 October to 30 September) for the study area is approximately 300 mm, and during the study period it was 67%, 88%, 148%, 110%, 70%, and 69% of normal for 2008, 2009, 2010, 2011, 2012, and 2013, respectively. Climate information for the study period was collected from remote weather stations located within 50 km of study sites (RAWS USA Climate Archive).

Dominant plant species across study sites included the sedges *Carex nebrascensis* (Dewey) and *Carex microptera* (Mack.), the grasses *Agrostis* sp. and *Poa sp*., and the rush *Juncus balticus* (Willd. Var.). Common forb species included *Veronica americana* (Schwein.), *Polygonum bistortoides* (Pursh.), and *Achillea millefolium* (L). The only shrub species encountered within the riparian zone of the study plots was *Rosa woodsii* (Lindl.). Non-native plant species were almost nonexistent within study plots.

Experimental Design

We used a randomized block design consisting of four blocks (sites) and two treatments. We established 25 × 100 m sites near the origin of perennial springs in 2008. Study sites were chosen by random selection from the population of approximately 40 springs within the 80,000-ha management unit. The long axis of each site was bisected by the dominant riparian channel. Sites were then divided into two 25 × 50 m plots, and plots were randomly assigned to be either excluded from ("excluded") or exposed to ("grazed") feral horse use. Excluded plots were fenced with 1-m high fencing consisting of evenly spaced metal pipe rails. This fence did not completely restrict access of native large mammals (mule deer and pronghorn), but field observations (i.e., lack of fecal matter and lack of utilization in excluded areas) suggest minimal utilization of excluded and grazed plots by these species. Sites varied in elevation from 1 850 m to 1 900 m and consisted of obligate or facultative wetland vegetation (Lichvar et al., 2014) communities associated with outflow from perennial springs. The end of season (October) wetted width (flowing or standing water) of riparian zones varied across both study sites and years and ranged from 0 m to 3.9 m in a dry year (2013) and from 1.4 m to 6.1 m in a wet year (2011; Table 1). Three sites had a flat aspect, and one was located on a northerly aspect. Extreme distance between sites was < 15 km. Most sites were characterized by multiple channels with a single dominant channel. Although springs were perennial, above-ground channel flow through sites was generally ephemeral and associated with the seasonal period of snow melt. However, water availability was sufficient to allow persistence of hydrophytic vegetation species within a defined riparian zone (Winward, 2000) at all sites.

Data Collection

Within each plot, vegetation measurements occurred along two 30-m long sampling transects placed within the riparian zone on both sides of and running parallel to the dominant channel (i.e., two transects total per plot). In grazed plots, utilization of herbaceous biomass by herbivores was estimated by clipping herbaceous materials to ground level in five randomly located 40 × 50 cm quadrats located within the riparian zone on each sampling transect in October of 2009–2013 and expressing remaining biomass as a percentage of ungrazed biomass. Ungrazed biomass was estimated by clipping three 40 × 50 cm quadrats within a 1-m diameter circular wire cage that was randomly located within each grazed plot and moved annually to a new location. Utilization was subjectively characterized as indicative of grazing that is suitable for providing a relatively high level of herbaceous vegetation structure ("light" grazing, < 30%), will allow for limited vertical structure development ("moderate" grazing, 30–60%), or will not allow for significant vertical structure ("heavy" grazing, > 60%, Table 2). Annual herbaceous production was estimated within exclosures in 2013 by separating dead from live plant material in five randomly located 40 × 50 cm quadrats along each sampling transect and weighing clipped materials. Herbaceous production in grazed areas was estimated by randomly locating a total of five (for each plot) 50 × 50 cm wire exclosures along sampling transects in April of 2013 and clipping and weighing live herbaceous plant material in October of 2013. All clipped material was oven-dried to constant weight before weighing.

Ground cover of bare ground and litter was estimated (ocular) in June or July 2012–2013 within thirty 20 × 50 cm quadrats spaced at 1-m intervals along each sampling transect; obstruction of the ground surface when viewed from above due to canopy vegetation was not considered when making these estimates (i.e., we looked under the

Table 1
Wetted width during an above (2011) and below (2013) average precipitation year for riparian study sites in northern Nevada. Values represent site averages of plots that were excluded from or accessible to horse grazing

	2011		2013	
Site	Mean (cm)	SE (cm)	Mean (cm)	SE (cm)
Tenmile	138.3	26.1	0.0	0.0
Buckaroo	607.2	177.8	389.8	92.0
Corral	167.7	45.6	0.0	0.0
Smith	227.8	31.3	302.0	39.4