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Original Research

Targeted Grazing Impacts on Invasive and Native Plant Abundance Change with Grazing Duration and Stocking Density☆

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ABSTRACT

The science underpinning targeted grazing has been advancing for decades, supporting a major paradigm shift concerning the role of grazing in addressing critical natural resource management challenges across the globe. A next step for expanding adoption is to understand how conservation benefits derived from this practice may change depending on how the components of a targeted grazing strategy change. Using two studies on California annual rangeland, one with heifers and one with ewes, we evaluated how two stocking attributes that underpin a targeted grazing plan, animal density and grazing duration, influence the ability of livestock to reduce the abundance of the invasive annual grass medusahead (*Taeniatherum caput-medusae* [L.] Nevski) and increase the abundance of native plants. Across studies, conservation benefits tended to be higher (lower invasive plant abundance and greater native plant abundance) under higher stocking density and shorter stocking duration, but we also found evidence that stocking density could be relaxed in some situations, allowing some conservation benefits to be achieved by grazing fewer animals over a longer duration. For California annual rangelands where most vegetation growth occurs over a period of a few short weeks, the potential to achieve similar conservation benefits by extending grazing duration and using fewer animals represents a major opportunity to apply targeted grazing over larger areas in one season with a set number of grazing animals. These initial findings provide justification for more extensive research in how changes in targeted grazing strategies may alter conservation benefits from grazing. Such insight is essential for understanding the range of cost-benefit trade-offs that may occur with this practice.

Introduction

Targeted grazing, which involves using specific kinds of livestock to defoliate vegetation at key time periods for a specific duration and a designated intensity to achieve defined management goals, is one of most important tools for maintaining ecosystem services on rangelands across the globe (Launchbaugh and Walker, 2006). Valuable work has been published on the theory, application, and benefits of using livestock to drive desired changes in rangeland plant community composition and the associated services these ecosystems provide (e.g., Launchbaugh and Walker, 2006; Diamond et al., 2009; Goodman et al., 2014). An important next step is centered on understanding trade-offs that occur with targeted grazing when trying to balance vegetation management goals with the logistics of animal production and management (Kott et al., 2006; Launchbaugh and Walker, 2006; Macon, 2014).

One key trade-off that occurs in balancing vegetation and animal management goals is between stocking rate and area grazed during the time period in which grazing needs to occur. Namely, if $S = AU \times time^{-1}\ ha^{-1}$ where S is the target stocking rate and a producer is constrained by the number of animal units (AU) available, the main avenue for increasing the area grazed by livestock (ha) while maintaining S is to increase grazing duration $(time)$. The animal density-grazing duration trade-off is key in management of invasive plants, which usually requires intense grazing for a short period when invasive plants are palatable and susceptible to defoliation while desired plant species are less susceptible to defoliation (e.g., Goehring et al., 2010). Number of animals available to implement targeted grazing is partially constrained by the annual forage supply. Therefore, it is often difficult to graze a

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large proportion of the landscape at the time and with the intensity required to change vegetation composition in a targeted manner (Macon, 2014). In some situations, short grazing windows and the high stocking densities required to effectively control weeds limits ranchers to treating only 2 − 5% of their land each year (DiTomaso et al., 2008). While contract grazing is cited as one solution to this challenge, a complementary approach is to determine the degree to which longer duration of grazing can be substituted for a higher stocking density while maintaining a stocking rate that yields desirable changes in vegetation composition.

The broad goal of this research was to evaluate how two key stocking attributes of a targeted grazing strategy, animal density and grazing duration, influence the ability of livestock to reduce the abundance of the invasive annual grass medusahead (*Taeniatherum caput-medusae* [L.] Nevski) and increase the abundance of native plants on annual rangelands. Medusahead is a widely distributed invasive plant dominating over 1 million ha of rangeland across 17 western states. On California rangeland, this invasive annual grass establishes and spreads within communities of other annual plant species, including native grasses and forbs, as well as a suite of other desirable non-natives that provide valuable forage. Because these invasive, native, and non-native annual plants have similar life histories, selective control of a particular species is challenging. Previous work has shown that grazing medusahead in midspring can be effective, but the time period in which medusahead has adequate palatability and nutrition for livestock but is also susceptible to defoliation may be as short as 2 − 3 wk (DiTomaso et al., 2008; Brownsey et al., 2016).

Methods

Two grazing trials were conducted to evaluate how different combinations of stocking density and grazing duration influence the abundance of medusahead, native plants, and non-native but palatable forage species. One trial was conducted in Glenn County, California, and used heifers. The other trial was conducted in Yolo County about 120 km south of the Glenn County site and used dry ewes. Both trials were grazed in spring 2008 when medusahead was susceptible to grazing (DiTomaso et al., 2008). At the Glenn sites, all grazing treatments were initiated on 21 April 2008. At the Yolo site, the low-density/long-duration treatment started in mid-April 2008 (see Table S1 for exact dates, pasture 8 had a delayed start date) while the high-density/short-duration treatment started at the end of April 2008. These two treatments were started at different times so that the approximately 15-d and 30-d grazing interval for the two treatments corresponded to the time period in which medusahead was most susceptible to grazing. The phenological stage of medusahead when grazing was applied was similar at the Yolo and Glenn sites. A sample of 518 tillers taken on 8 April 2008 in the Glenn County site had 62% of medusahead in the vegetative stage, 21% in internode elongation to boot stage, 12% with partially emerged spikes, and 3% of medusahead with fully emerged spikes. No grazing occurred in theses pastures the following year (2009).

Grazing Ewes

The trial using ewes occurred on a relatively level valley grassland site in the Sacramento Valley with an average annual precipitation of about 490 mm. In this trial, we assigned each of eight, approximately 0.30-ha pastures to be grazed by dry ewes either at a low density/long duration (4.1 AU ha^{-1} for 30 d) or a high density/short duration (8.1 AU ha^{-1} for 16 d) for a common stocking rate of about 4.1 animal unit months (AUMs) per ha (4 pastures per grazing treatment). This stocking rate is similar to that applied by DiTomaso et al. (2008), but stocking densities we used were 10 − 20 times lower and thus, our grazing durations were 10 − 20 times longer. Exact size and stocking for each pasture are provided as a supplementary table (Table S1). Two 1.5 × 1.5 m grazing exclosures were established at random locations in each pasture at the start of the trial to evaluate forage production, as well as vegetation composition in the absence of grazing.

Grazing Heifers

The trial using heifers occurred on a gently sloped (<5%) foothill site on the west side of the Sacramento Valley with an average annual precipitation of about 456 mm. In this trial, we assigned each of 12 approximately 1.1-ha pastures to be grazed by yearling heifers at either a low density/long duration (2.6 AU ha^{-1} for 21 d) or a high density/short duration (4.5 AU ha^{-1} for 14 d) and a common stocking rate of about 1.9 AUM ha^{-1} (6 pastures per grazing treatment). These stocking rates were selected because they were considered feasible in working ranches (DiTomaso et al., 2008). Exact size and stocking for each pasture are provided as a supplementary table (Table S1). There were two to three 1.5 × 1.5 m grazing exclosures established at random locations within each pasture at the start of the trial to evaluate forage production, as well as vegetation composition in the absence of grazing.

Vegetation Sampling and Statistical Analysis

Vegetation at both sites was sampled just before grazing in 2008 and 1 yr after grazing treatments were applied (spring 2009). Pastures were sampled by clipping vegetation in 6 − 11, randomly placed 30 × 30 cm quadrats (depending on pasture sizes) at the soil surface. Composition of this sample was then quantified by spreading the sample out evenly on a laboratory bench and using the point intercept method (50 − 100 points per quadrat), identifying plants to species to determine the proportion of three key functional groups—medusahead, native plants, and desired forage plants—in each sample (Heady and Torell, 1959). Two researchers (E. A. Laca and P. Brownsey) independently scored species as desirable or undesirable on the basis of published data related to toxicity, palatability, and species productivity. Medusahead made up the majority of undesirable vegetation in all pastures (Table S2). Nongrazed vegetation in each exclosure was sampled in a similar manner by clipping one randomly placed 30 × 30 cm quadrat. We quantified the effects of the different targeted grazing treatments on the proportion of each functional group using the natural log response ratio (ln *RR*) where $\ln RR = \ln(X^E/X^c)$ and X^E and X^C are the proportion of a particular functional group in the grazed pasture and grazing exclosures within the pasture, respectively (Hedges et al., 1999). We present point estimates and confidence intervals to describe the likely distribution of effect size generated by the various grazing treatments and then used paired *t*-tests and the distribution of confidence intervals around treatment means to compare grazing treatments within a functional group within a site (Rinella and James, 2010). All statistical tests were performed using R v3.2.2 (R Core Team, Vienna, Austria).

Results

Grazing Heifers

Functional group composition at the start of the heifer study (2008, treatment year) consisted of 39% ± 4% (mean ± SE) medusahead, 4% ± 1% native species, and 43% ± 3% desirable forage species. In 2009, in ungrazed control plots this composition remained relatively stable at 42% ± 5% medusahead, 5% ± 1% native species, and 49% ± 5% desirable forage species. The response ratios (means and 95% confidence interval) for native plant abundance were confined to positive values, indicating both grazing treatments increased the abundance of native plants compared with the ungrazed control plots (Fig. 1; increase in native plant

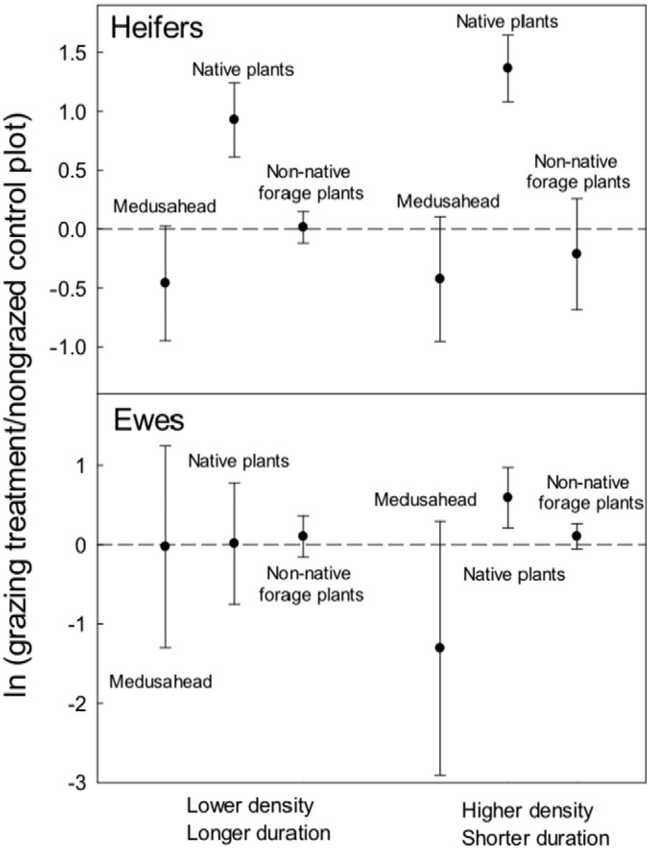

Figure 1. Effects of different targeted grazing strategies on the proportion of medusahead, native plants, and desired forage plants in pastures grazed at one site by heifers and another site by ewes. The two grazing treatments applied differed in animal density and grazing duration but had comparable stocking rates within a site. Grazing effects were quantified using the natural log response ration ln RR where ln RR = ln (proportion of a particular functional group in the grazed pasture) − (proportion of a particular functional group in the grazing exclosures within a pasture). *Solid circles* are means, and *vertical bars* are 95% confidence intervals. Values < 0 indicate grazing reduced the functional group relative to the ungrazed control, while values > 0 indicate grazing increased the functional group relative to the ungrazed control.

abundance was primarily driven by an increase in the native annual forb *Hemizonia* sp., not perennial forbs or grasses; see Table S2). There was also evidence that the higher-density/shorter-duration grazing treatment increased native plant abundance more than the lower-density/longer-duration grazing treatment ($t = -2.648$, $P = 0.025$). Response ratios for medusahead in the heifer study were almost entirely contained to negative values, suggesting both grazing treatments were effective at reducing medusahead abundance. We saw no evidence, however, that the two grazing treatments used in the heifer study differed in the degree to which they reduced medusahead abundance ($t = -0.125$, $P = 0.903$). Response ratios for non-native forage plants had confidence intervals that included both positive and negative values, providing little evidence that either grazing treatment significantly impacted desirable forage species. Total forage utilization varied between 29% and 62% and was higher for the low-density/long-duration treatment compared with the high-density/short-duration treatment (Table 1).

Grazing Ewes

Functional group composition in pastures at the start of the ewe study (2008) consisted of 38% ± 7% (mean ± SE) medusahead, 6% ± 2% native species, and 35% ± 3% desirable forage species. In 2009, in ungrazed control plots this composition shifted to 16% ± 4% medusahead, 14% ± 3% native species, and 62% ± 4% desirable forage species. The response ratios for native plants and medusahead were distributed differently between the grazing treatments with the higher-density/shorter-duration grazing treatment reducing medusahead abundance and increasing native plant abundance more than the lower-density/longer-duration grazing treatment (see Fig. 1, $t = -1.991$, $P = 0.096$, and $t = 2.148$, $P = 0.091$, respectively). All confidence intervals for the lower-density/longer-duration grazing treatments with ewes were centered close to zero and contained both positive and negative values, suggesting this treatment was largely ineffective in shifting composition in any of the three functional groups. Total forage utilization varied between 48% and 58% and was higher for the low-density/long-duration treatment compared with the high-density/short-duration treatment (see Table 1).

Discussion

Most importantly, this work shows that targeted grazing with stocking densities and durations that are feasible under production conditions reduced abundance of medusahead and increased abundance of native species. This result was obtained with both cattle and sheep. Previous work on targeted grazing of medusahead used stocking densities of 100 − 200 AU ha^{-1} and grazing durations of 1 − 2 d, which are practically unfeasible at production scale. While the roles of grazing timing and animal class in reducing abundance of invasive species are well described in this literature (DiTomaso et al., 2008; Goehring et al., 2010; Henderson et al., 2012), we know little about how variation in the components that determine stocking rate, grazing duration, and animal density per unit area influences conservation benefits achieved by targeted grazing programs. This study provides a first step toward filling this gap. Overall, across the two studies we found that conservation benefits of targeted grazing, in terms of reducing the abundance of the invasive plant medusahead and increasing the abundance of native species, changed depending on how stocking rate was achieved. Across studies, conservation benefits tended to be higher (lower invasive plant abundance and greater native plant abundance) under higher stocking density and shorter stocking duration even though pasture utilization was lower compared with the low-density/long-duration treatment. These patterns are largely in line with the principles of targeted grazing and suggest timing of grazing was a relatively larger driver of vegetation change than overall degree of vegetation utilization (Launchbaugh and Walker, 2006). Grazing intensities achieved by the targeted grazing treatments were moderate, and in most cases more residual dry matter (standing forage left at the end of the grazing season) was left than would be typically recommended for these sites. Future work examining how grazing intensity and timing impact conservation benefits

Table 1
Forage biomass in vegetation exclosures, standing forage biomass in pastures post grazing, and average utilization by livestock during spring 2008 for the two grazing treatments applied at the two study sites. Forage biomass values are means ± SE

Sites	Treatment	Exclosure biomass (kg ha^{-1})	Postgrazing pasture biomass (kg ha^{-1})	Average utilization (%)
Glenn	High density/short duration	2465 ± 148	1749 ± 300	29
	Low density/long duration	2857 ± 261	1074 ± 226	62
Yolo	High density/short duration	3893 ± 669	2024 ± 184	48
	Low density/long duration	4450 ± 318	1873 ± 210	58

would be useful as it may be that greater utilization under the high density/short duration could yield additional conservation benefits. Assessing these trade-offs would be important as achieving greater utilization targets would require grazing smaller portions of the landscape, assuming number of available animals was fixed.

Despite an overall trend of greater conservation benefits with higher density and shorter grazing duration, however, we also found evidence that in some situations comparable conservation benefits could be achieved when stocking density is relaxed and grazing duration is increased to achieve a similar stocking rate. Namely, for the heifer study, we observed that in both targeted grazing treatments, medusahead abundance declined significantly while native plant abundance increased significantly. While the higher-density/shorter-duration treatment resulted in a greater increase in native plant abundance than the lower density/shorter duration treatment, the overall patterns of changes in conservation benefit were in the same direction. On an absolute basis, the difference in grazing duration between these treatments was small (*c.* 7 d) and occurred over a time period where medusahead was susceptible to grazing but also palatable to livestock (DiTomaso et al., 2008). Most of the forage production in this system occurs over a narrow time period of about 8 wk. Thus, the potential to extend grazing over an additional week and achieve similar conservation benefits is significant and represents a major opportunity to apply targeted grazing over more acreage in a season given a set amount of animals.

The degree to which stocking density and grazing duration could be substituted for a given stocking rate and achieve comparable conservation benefits, however, was not equal across studies. Specifically, in the ewe study, the lower density/longer duration grazing treatment did not yield any significant increase in conservation benefits while the higher density/shorter duration grazing treatment did. Thus, contrary to the heifer study, the ewe study provided no evidence that producers may be able to graze fewer animals over a longer duration and achieve similar conservation benefits as a grazing program that utilized more animals over a shorter duration. Unfortunately, given the constraints of the study design, we do not know if these observed differences between the heifer and ewe study were due to kind of animal, site, or other uncontrolled or unmeasured factors, but this evidence makes a strong case for a line of research to continue to explore how a suite of conservation benefits may vary as components of an overall targeted grazing program change.

Implications

The science underpinning targeted grazing has been advancing for decades and has supported a major paradigm shift concerning the role of grazing in addressing critical natural resource management challenges across the globe (Launchbaugh and Walker, 2006). Because animal production and other logistics may place constraints on how targeted grazing can be applied, to increase adoption it is important to understand how conservation benefits derived from this practice change depending on the components of a targeted grazing strategy. The results presented here suggest minor changes in how stocking rate is applied can alter the conservation benefits achieved from a targeted grazing program. For medusahead management on annual rangeland, our results suggest, for both cattle and sheep, as little as a 7- to 15-d difference in grazing duration may alter conservation benefits achieved by targeted grazing. More broadly, these findings provide a strong justification for additional and more extensive research in how small but strategic changes in the parameters that define a targeted grazing scheme can alter conservation benefits from grazing. From this point of view, grazing science has barely started to exploit the vast opportunities for achieving targeted grazing goals through simultaneous manipulation of the components of stocking rate (density, duration, and timing) in relation to plant phenology. Such insight will be essential to understand the range of cost-benefit trade-offs that may occur with this practice.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.rama.2017.01.006.

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