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Research Note

Livestock Riparian Guidelines May Not Promote Woody Species Recovery Where Wild Ungulate Populations Are High☆

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ABSTRACT

Stubble height, streambank alteration, and woody species use are indicators used to monitor livestock impacts on riparian areas in the western United States. Effects of wild ungulates on riparian conditions are often not monitored and assumed to be represented by indicators developed for livestock. We tested this assumption by evaluating effects of elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) on grazing indicators along Meadow Creek, a salmonid-bearing stream in northeastern Oregon. Wild ungulates reduced stubble height by 20% to 30%. Mean streambank alteration was 1.1% (ranged from 0.3–8%). Woody species use was negatively related to stubble height and positively related to streambank alteration ($P < 0.05$). Despite maintenance of stubble height and streambank alteration within regulatory guidelines, wild ungulate use of preferred woody species was moderate to high (>50%). Adherence to guidelines developed for livestock may not result in desired riparian conditions where wild ungulate populations are high.

Introduction

Active monitoring is necessary to prevent negative impacts of ungulates on riparian areas. Because domestic (Kauffman and Krueger, 1984) and wild ungulates (Danell et al., 2006) can have profound impacts on riparian vegetation composition and structure, monitoring indicators must reflect the effects of all ungulates—domestic and wild—on riparian systems. However, wild ungulate effects are often not monitored, ignored, or assumed to be represented by indicators developed for livestock.

Stubble height, streambank alteration (alteration), and woody species use are the most common indicators used to manage livestock grazing in riparian areas. The simplicity and repeatability of these measurements has prompted their use as catchall guidelines to indicate grazing effects and overall riparian health for some land management and regulatory agencies (Roper, 2016; University of Idaho Stubble Height Review Team, 2004). Stubble height can be a good indicator of livestock effects on woody species, sediment trapping, and short-term recovery potential of grass/grass-like species in some situations (Clary and Leininger, 2000; Skinner, 1998). At landscape scales, stubble height and alteration can be useful indicators of cattle effects in riparian areas and correlate with stream conditions important for salmonids (e.g., bank angle, percent pools, pool depth; Goss and Roper, 2018). However, stubble height and alteration relationships with wild ungulate impacts on riparian vegetation have not been studied. Because woody shrubs compose a larger percentage of elk and deer diets compared with cattle (Hofmann, 1989), reliance on indicator guidelines developed for cattle (e.g., minimum stubble height) may not protect woody species from overbrowsing by wild ungulates. Our objectives were to evaluate the effects of elk and deer herbivory on riparian stubble height, and to examine the relationship between both stubble height and alteration with woody species use by elk and deer along a cold-water, salmonid stream.

Methods

Study Area

This study took place along Meadow Creek within the Starkey Experimental Forest and Range (SEFR) in northeastern Oregon (45°12′ N, 118° 3′ W). SEFR elevations range between 1 120 and 1 500 m, annual average temperatures range from –4°C (winter) to 18°C (summer), and average annual precipitation is 510 mm (Rowland et al., 1997). SEFR vegetation includes shallow-soil bunchgrass communities and *Pinus ponderosa* or *Pseudotsuga menziesii* and *Abies grandis* or *Pseudotsuga menziesii* forests.

☆ Bryan Endress, Michael Wisdom, and Joshua Averett conceived and designed the research. Joshua Averett, Michael Wisdom, and Bryan Endress performed the experiment, analyzed the data, and wrote the manuscript.

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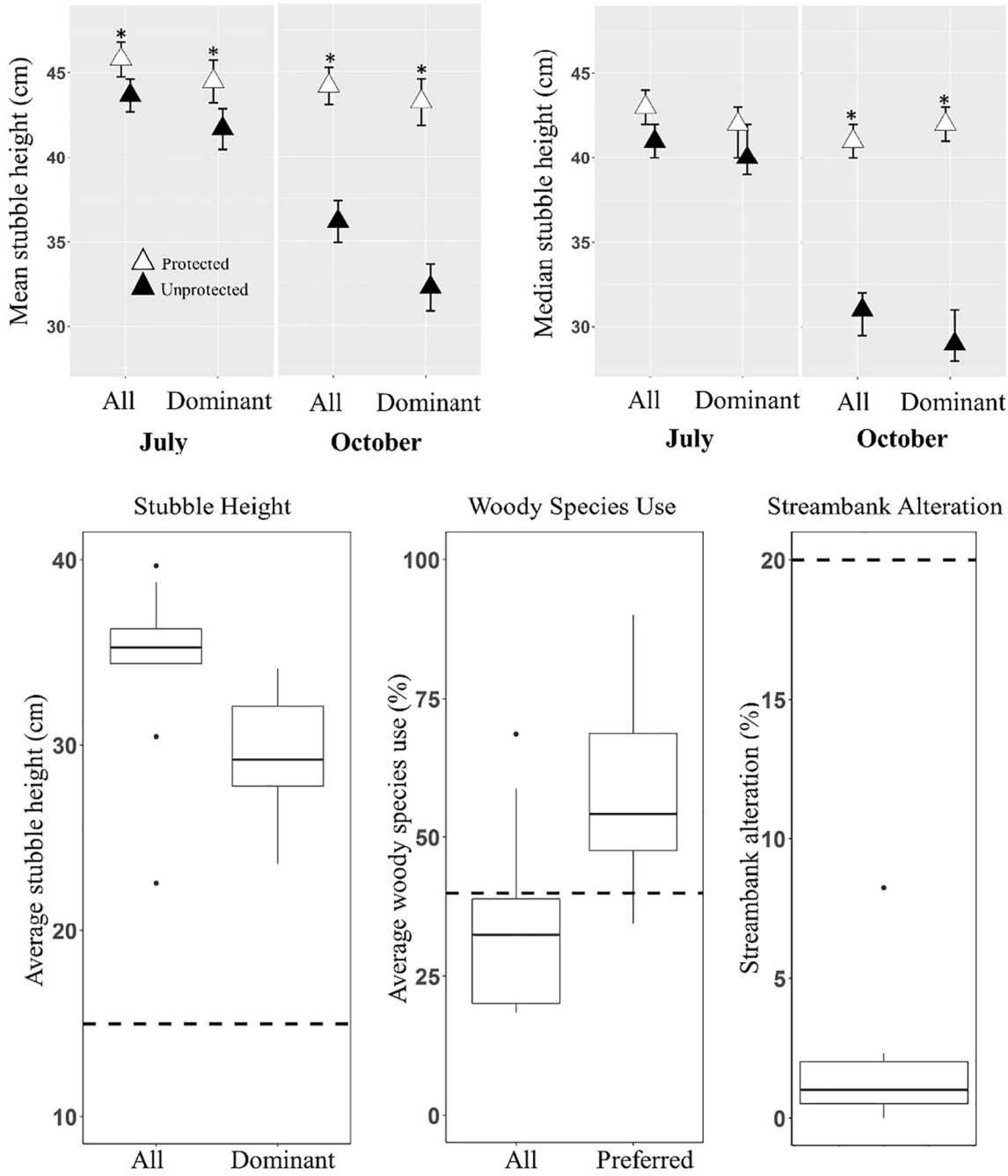

Figure 1. (Top panel) Stubble heights (protected or unprotected from wild ungulates) for all and dominant graminoid species. Error bars show 95% confidence intervals. Asterisks indicate significance ($P \leq 0.05$). (Bottom panel) End of growing season stubble height, woody species use (all and preferred species), and streambank alteration for unprotected DMAs. Boxes show 1st and 3rd quartiles. Whiskers extend 1.5 times the interquartile range; points show data beyond the whiskers. Dashed lines: (left panel) minimum stubble height guideline, 15 cm; (middle panel) woody species use guideline, ≤40%; (right panel) maximum alteration guideline, 20%.

Dominant herbaceous species along Meadow Creek included *Agrostis stolonifera*, *Scirpus microcarpus*, *Carex pellita*, and the most abundant woody species were *Alnus incana* and *Crataegus douglasii*.

The Meadow Creek study area served as spring-fall range for elk (density = 5.6–6.8 per km^2) and mule deer (2.8–3.6 per km^2; Ager et al., 2003). Population estimates equate to approximately one elk per 36 to 44 acres and one deer per 68 to 88 acres. In addition, elk use of the Meadow Creek riparian area—around the time of this study—was estimated to be ~11 times greater than that of mule deer (Averett et al., 2017). Wild ungulate use along Meadow Creek was sparse in winter because most animals migrated in late fall-early winter to the SEFR winter area (Rowland et al., 1997). Livestock grazing did not occur during the period of our study.

Sampling

We sampled vegetation along the "greenline" within 16 designated monitoring areas (DMAs; each ~150 m in length) using the Multiple Indicator Monitoring Protocol (Burton et al., 2011). Twelve DMAs were located within three different stream reaches that coincided with herbivory treatments—six excluded from wild ungulates using 2.4 m tall fencing, and six exposed to wild ungulates. Four additional DMAs (exposed to wild ungulates) were established to increase coverage along the entire 11 km reach. Stubble heights of graminoids (grasses, sedges, and rushes), alteration, and woody species use were measured simultaneously within quadrats composed of two adjoining plots (50 × 20 cm) placed at 2.5-m increments

Table 1
Stubble height summary statistics for all, dominant, and the 10 most abundant graminoid species, ordered top to bottom by rank abundance.

Species	Mean (cm)				Sample size		STDEV (cm)	
	Protected	Unprotected	Change (cm)	% Change	Protected	Unprotected	Protected	Unprotected
All	44.2	36.2	−8.0	−18.1	1 612	1 178	22.2	21.8
Dominant	43.2	32.3	−10.9	−25.2	909	765	20.9	19.4
Agrostis stolonifera	30.0	22.9	−7.1	−23.7	336	366	17	14.3
Scirpus microcarpus	47.2	36.5	−10.7	−22.7	217	149	14.9	14.8
Carex pellita	48.9	40.8	−8.1	−16.6	184	108	12.8	15.8
Elocharis palustris	31.7	30.6	−1.1	−3.5	173	84	9.8	10.1
Carex lenticularis	40.7	33.9	−6.8	−16.7	84	82	13.5	15.3
Juncus ensifolius	29.6	28.0	−1.6	−5.4	105	47	9.8	11.3
Alopecurus pratensis	74.5	60.9	−13.6	−18.3	88	60	24.1	26.5
Glyceria striata	61.2	55.8	−5.4	−8.8	61	61	23.5	29.1
Phleum pretense	56.7	52.6	−4.1	−7.2	65	55	26.4	27.7
Juncus arcticus	60.0	57.5	−2.5	−4.2	64	30	14.1	15.0

along the greenline on both sides of the stream (n ~ 120 plots per DMA).

Stubble height was measured for each species nearest the frame handle to minimize bias using the method in Burton et al. (2011). Alteration was measured using a 5-line intercept method described by Burton et al. (2011) and calculated as the percentage of plot lines that intercepted depressions and hoof prints or trails. Woody species use was measured as percentage of current year's leaders browsed (Burton et al., 2011) for species rooted within 1 m of the greenline, classified into the following categories: one (0–20%); two (21–40%); three (41–60%); four (61–80%); and five (81–100%), and limited to plants available for browsing (>50% of photosynthetic area below 2.5 m; Burton et al., 2011). Sampling occurred in midsummer (late July 2015) to coincide with peak production when species were easiest to identify and then repeated in late October 2015 at the end of the growing season.

Data Analysis

We compared mean and median stubble heights (July and October separately) across herbivory treatments using randomization tests. A randomization test calculates the proportion of test statistics (difference in mean and medians between groups), determined from a large number of random permutations (10,000), into groups of the same size as observed that are greater than or equal to the observed test statistic (Manly, 1991). We limited comparisons to treatment areas (n = 12; six protected and six unprotected) because the other four DMAs were spatially distant from the protected DMAs and may not be comparable. Comparisons were made for all graminoids and then again for dominant species (five most abundant species based on plot frequency). Median stubble height was evaluated because it is less sensitive than the mean to a few extreme values. To compare herbivory effects by species, percent change (unprotected–protected) in stubble height was calculated for the 10 most abundant graminoids.

Mean deciduous woody species use (arithmetic midpoint of use class) was calculated for all species combined and then separately for species preferred by elk and deer (i.e. *Cornus sericea* [dogwood], *Populus balsamifera* [cottonwood], and *Salix* [willow] species). Chronic herbivory can result in species composition shifts where sensitive or preferred woody species decline and tolerant or less preferred species become dominant (Rooney and Waller, 2003). Therefore, use of less preferred species (e.g., *Alnus* spp. and *Crataegus douglasii*) may underestimate herbivore impacts (Rooney and Waller, 2003). Use of preferred species was of special interest because cottonwoods and willows are functionally important to western riparian areas (Patten, 1998), making them key restoration species along salmonid streams. One DMA did not contain preferred species, resulting in a DMA sample size of 15 for preferred species. Boxplots of woody species use, stubble height, and alteration were interpreted in relation to common regulatory guidelines for grazing in the region (National Marine Fisheries Service, 2017; USDA Forest Service, 2016). Linear regression was used to explore relationships between woody species use and stubble height and alteration. Models were fit for all and preferred species separately. The alteration data had one extreme outlier (8.26%; 3.5 standard deviations above the mean of 1.1%) that was excluded from this analysis.

Results and Discussion

Mean stubble height was greater ($P < 0.001$) in protected sites compared with unprotected sites (Fig. 1). The treatment effect (mean protected stubble height minus the mean unprotected stubble height) was small in July (all species = 2.1 cm, 95% CI = 0.8–3.6 cm; dominant species = 2.8 cm, 95% CI = 1.2–4.5 cm) but increased substantially by October (all = 8.0 cm, 95% CI = 6.3–9.8 cm; dominant species = 10.9 cm, 95% CI = 8.8–13.1 cm; Fig. 1). Median stubble height did not differ between treatments in July but was higher ($P < 0.001$) for protected sites in October (all = 9.6 cm, 95% CI = 8–11 cm; dominant species = 12.9 cm, 95% CI = 11–15 cm; Fig. 1). Wild ungulates reduced end of growing season greenline stubble heights by ~8 to 10 cm (~3–4 inches) for all species and by ~11 to 13 cm (~4–5 inches) for dominant species, corresponding to height reductions of 20% to 30% (Fig. 1). October stubble heights in DMAs unprotected from wild ungulates varied from 22–40 cm (Fig. 1). Variation was likely due to site factors, plant species composition, and wild ungulate disturbance. Wild ungulate effects on stubble height may have different implications for livestock management depending on site conditions. For example, in stream sections with inherently shorter stubble heights, wild ungulate disturbance may pose challenges for compliance with grazing guidelines (National Marine Fisheries Service, 2017). Research is needed to determine if the introduction of livestock into our riparian system will add to wild ungulate effects, or if wild ungulates will shift distributions in response to livestock presence (Coe et al., 2001).

Wild ungulates reduced the height of the 10 most abundant graminoids (Table 1). Percent height change ranged from −23.7% (*Agrostis stolonifera*) to −3.5% (*Eleocharis palustris*; Table 1). Variation by species was likely due to a combination of herbivore preference, species composition, and differential regrowth (following herbivory) among species. Monitoring protocols often focus on measuring stubble height for "key species" (e.g., important forage, or species sensitive to grazing) (Burton et al., 2011). We found that stubble heights were highly variable along Meadow Creek, depending on the species selected for monitoring, reinforcing the concern that monitoring just a few key species may not represent overall vegetation trends (Roper, 2016).

Woody species use in unprotected DMAs ranged from 19% to 69% for all species (mean = 34.6%; SD = 17.3%), and from 34% to 90% for preferred species (mean = 57.8%; SD = 16.6%; Figs. 1 and 2). Use was moderate to heavy (>40% of leaders browsed) in 3 out of 10 (30%) DMAs for

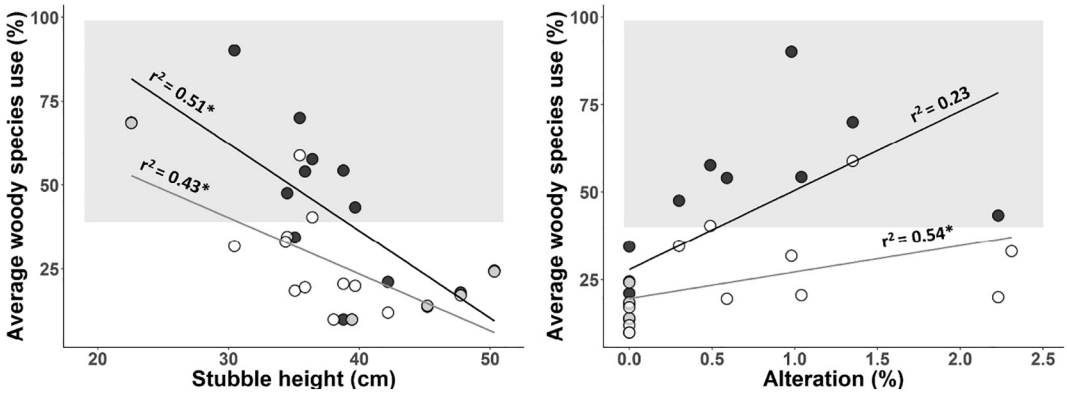

Figure 2. Average woody species use against stubble height and streambank alteration (black indicates preferred species; white, all species). Linear regression lines (black indicates preferred species; grey, all species; shaded area, use above regulatory guideline [>40%]). Asterisks indicate significance ($P < 0.05$).

all species, and in 8 out of 9 (89%; Fig. 2) for preferred species despite maintenance of the following: 1) streambank alteration well below (mean = 1.1%; SD = 2.0%) the regulatory guideline (<20%; Fig. 1); and 2) stubble heights that were above the minimum 15-cm guideline (USDA Forest Service, 2016; National Marine Fisheries Service, 2017; Fig 1). Previous research at Meadow Creek provides evidence that the current browsing pressure by wild ungulates is suppressing the establishment of woody species, particularly preferred species (e.g., willow and cottonwood) (Averett et al., 2017; Case and Kauffman, 1997). This is of particular concern because cottonwoods and willows are among the few riparian species able to attain heights tall enough to provide substantial stream shading. Consequently, cottonwood and willow species are important for moderating high late-summer stream temperatures, a major limiting factor for salmonid populations in systems like Meadow Creek (McCullough, 1999). Other studies have also demonstrated suppression or alteration of riparian woody communities by wild ungulates in the absence of livestock (Danell et al., 2006; Kay, 1994). Our results suggest that even if riparian monitoring takes place, compliance with grazing guidelines may not protect preferred woody species from high browsing pressure by wild ungulates.

Woody species use was negatively related ($P < 0.01$) to stubble height and positively associated ($P < 0.01$) with alteration (Fig. 2); there was slightly less evidence ($P = 0.07$) for a relationship between preferred woody species use and alteration. Results suggest that estimates of stubble height and alteration may provide a coarse indication of woody species use. Our ability to detect relationships between use and stubble height or streambank alteration was limited by a small sample size (n = 16 DMAs). Future analyses with a greater sample size, an increased spatial scale, and consideration for wild ungulate distributions and woody species composition will increase our understanding of these relationships. Nonetheless, our results indicate that maintenance of stubble heights above 35 to 40 cm (~14–16 inches) and streambank alteration below even 5% may not protect preferred woody species from moderate to heavy browsing (>40% leaders browsed) by wild ungulates in this system.

Implications

Wild ungulates contributed measurable reductions to greenline stubble height. Managers should consider monitoring wild ungulate impacts on herbaceous species in riparian areas to inform decisions related to grazing implementation and/or duration. As our results demonstrate, adherence to regulatory guidelines designed for managing livestock in riparian areas may not protect functionally important woody species (i.e., willows, cottonwoods) from overbrowsing in similar systems with high populations of wild ungulates.

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