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Alterations of Shrub Communities in Relation to Herbivory in Northern Idaho

Abstract

Characteristics of shrubs were compared inside and outside of 3 wildlife exclosures constructed between 1981 and 1985 in northern Idaho. Eighteen shrub species were identified, 16 of which occurred inside the exclosures and 14 outside. Stems per m^2 were greater inside the exclosures than outside for most species. Twigs per m^2, twig length, twig biomass, and average height of species were greater inside exclosures for all but two species. Overall biomass production was $\geq$26.55 g/m^2 inside exclosures compared to $\leq$16.67 g/m^2 outside. These marked differences in woody vegetation were attributed to ungulate herbivory outside the exclosures.

Introduction

The North Fork of the Clearwater River and Dworshak Reservoir are surrounded by public and private forest lands that have undergone timber harvest since the early 1900s. Removal of overstory canopy resulted in increased understory vegetation and initial increases in ungulate populations, which are currently declining. However, large populations of ungulates can affect the successional development of regenerating areas (Irwin et al. 1994, Peek 2000), and affect net primary production of utilized species (Hobbs 1996).

The four ungulates in the area, elk (*Cervus elaphus*), moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*Odocoileus hemionus*) are browsers. Elk are generalist herbivores (Geist 1982) and may forage on graminoids, herbs, and shrubs. Studies indicate that elk shift from a diet of graminoids and herbs in summer, to browse species during the fall and winter months in northern Idaho (Irwin and Peek 1983, Alldredge 1999). Moose are often considered concentrate selectors that use primarily browse species (Renecker and Schwartz1997), although Peek (1997) referred to moose as selective generalists, recognizing their capabilities of altering food habits to maximize benefits within a given environmental situation. White-tailed deer and mule deer are also typically lumped into the concentrate selector category but they also exhibit a high degree of dietary flexibility (Kufeld et al. 1973, Urness 1981).

The potential effect of herbivory on winter range is greater than on summer range as ungulates are forced into restricted areas by snow and browse is a major component of diets. This study was designed to examine the shrub vegetation layer of 3 wildlife exclosures that were constructed between 1981 and 1985 on recently clearcut sites and located in historical winter range. The exclosures were constructed on similar aspects within 5 kilometers of each other, so variation relative to location would be minimal. The objective was to examine differences in stems per m^2, twigs per m^2, shrub height, and annual shrub biomass production between the inside and outside of exclosures.

Study Area

The three exclosures were constructed in 1981, 1982, and 1985 along the upper portion of the Dworshak Reservoir near Grandad Bridge, in northern Idaho. The locations of the 3 exclosures were west of the Grandad Bridge, Boehl's Butte, and east of the Grandad Bridge. All exclosures were located on southwest-facing slopes and were constructed of welded wire fencing 2 meters high.

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The west Grandad exclosure was 15 meters by 15 meters, while the other 2 measured 15 meters by 30 meters. Dworshak Reservoir extends to the northeast of Orofino, Idaho for 86.3 km (53.6 miles) (Hansen et al. 1989). About 30% of historical elk winter range along the North Fork of the Clearwater River was flooded by the creation of Dworshak Reservoir (U.S. Fish and Wildlife Service 1960, Meske 1977). Western Red Cedar-Pachistima (*Thuja plicata-Pachistima myrsinites*) habitat type dominates the area (Daubenmire and Daubenmire 1968). Domestic livestock grazing occurs in adjacent areas but there is no record of any domestic livestock in the vicinity of the exclosures (Meske 1977).

Methods

The shrub vegetation layer within and immediately adjacent to exclosures was sampled during 1998, 13 to 17 years after construction. All sampling was conducted in the latter part of August, after shrub growth had ceased for the year.

Vegetation was sampled using 4-m^2 circular plots both inside and outside the exclosure (Shafer 1963). A distance of 4 meters between plots was maintained to insure independence of vegetation structure between adjacent plots. A total of 20 4-m^2 circular plots were sampled outside of each exclosure. Fifteen plots were sampled in Boehl's Butte and east Grandad exclosures and 9 plots were sampled in the west Grandad exclosure. Within each plot all shrub species were identified and number of rooted stems, number of twigs, and height were recorded by species. Twigs were defined as current year's growth and measured to determine annual shrub biomass production. Plots were treated as cylinders and all twigs within these vertical cylinders were counted regardless of whether they originated from stems rooted inside the plots or not. However, the heights of the cylinders were restricted to 2.4 m (8 ft) due to the difficulty of accurately counting twigs above this height, and the observation that ungulate herbivory would be minimal above this height.

Biomass production of current-year twig growth for all species was also determined inside and outside the exclosures. A regression of twig dry weight as a function of length was used for all species to convert measured twigs into biomass estimates. Twenty twigs from each species were collected from both inside and outside each exclosure. These twigs were measured to the nearest 0.5-cm, oven dried at 40°C for 48 hours, and weighed. This sampling scheme yielded between 20 and 60 randomly selected twigs for each species representing the range of possible lengths inside and outside the exclosures. Lengths of 50 unbrowsed twigs from each species inside and outside the exclosures were measured to within 0.5 cm. Using the length-to-weight regression and average twig length a mean weight per twig was obtained for each species inside and outside the exclosure. Annual biomass production by species was then estimated as the product of the mean weight per twig times the average number of twigs per m^2. Composite biomass productivity was then determined by summing the annual biomass per m^2 across all species for the site.

The design of this study, with only 3 experimental units, is primarily descriptive and valid statistical comparisons are limited. In such situations, comparison of means and ranges may be the most meaningful (Hurlbert 1984). Paired t tests (Zar 1996) were used to determine if any of the shrub characteristics were different between the inside and outside of each exclosure for commonly occurring species. Commonly occurring species were those that occurred in all 3 exclosures. Statistical analysis for other species was not done as sample size would have been less than 3. Finally, a paired t test was used to compare productivity inside and outside an exclosure by pairing the productivity estimates of each species inside and outside. If a species did not occur in both places it was omitted from the analysis. A log transformation was used to normalize these estimates.

Results

Vegetation Characteristics

The differences in shrub characteristics inside and outside all 3 exclosures were obvious (Figure 1). There were 16 species of shrubs identified inside 1 or more of the exclosures and 14 species identified outside 1 or more exclosures, 12 of which were found both inside and out. Rocky mountain maple (*Acer glabrum*), thinleaf alder (*Alnus incana*), bittercherry (*Prunus emarginata*) and sticky currant (*Ribes viscosissimum*) were only observed inside exclosures, whereas Oregon grape (*Berberis repens*) and red-osier dogwood (*Cornus stolonifera*) were only found outside exclosures.

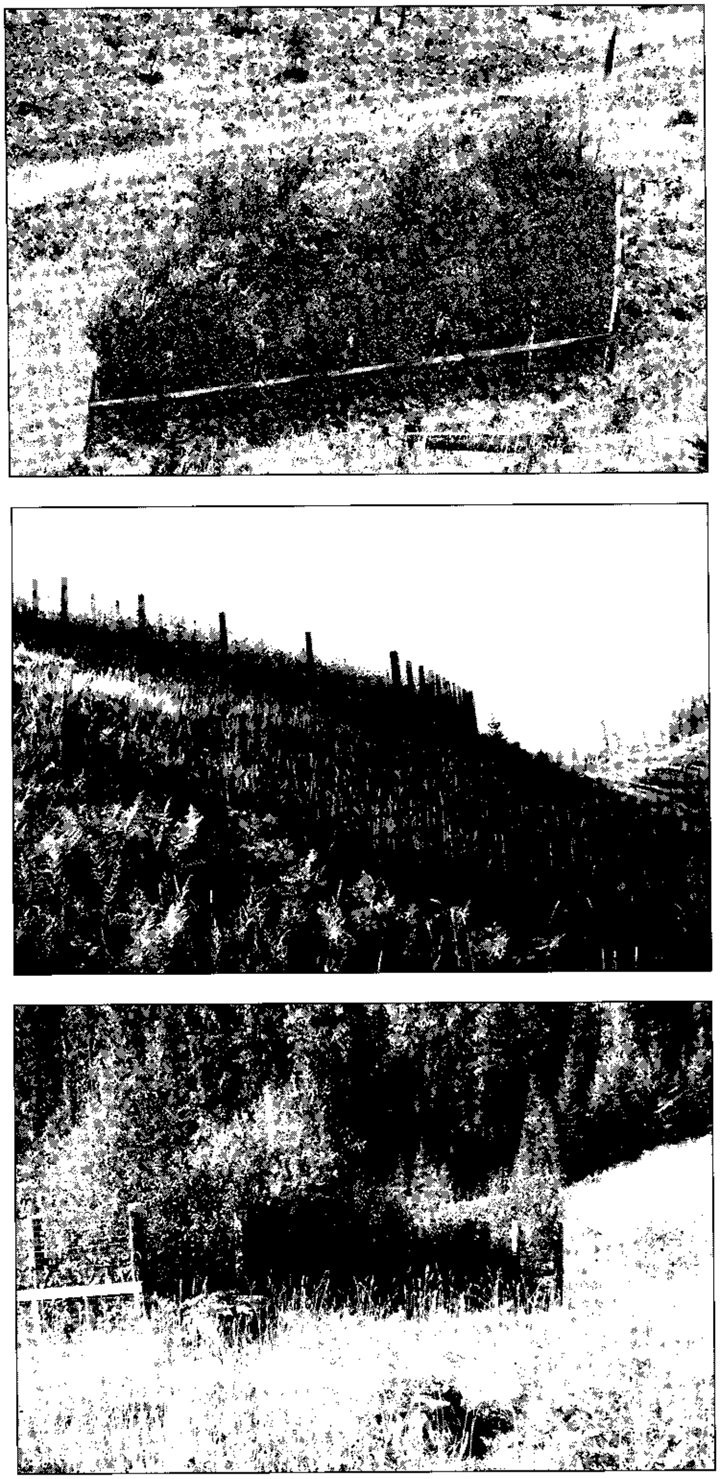

Figure 1. Photographs, top to bottom, of west Grandad, east Grandad, and Boehl's Butte big game exclosures taken in 1998.

Mean stems per m^2 inside exclosures was greater than outside for serviceberry (*Amelanchier alnifolia*), redstem ceanothus (*Ceanothus sanguineus*), ocean-spray (*Holodiscus discolor*), western thimbleberry (*Rubus parviflorus*), blue elderberry (*Sambucus cerulea*), scouler willow (*Salix scouleriana*), and common snowberry (*Symphoricarpos albus*), but greater outside for Utah honeysuckle (*Lonicera utahensis*), baldhip rose (*Rosa gymnocarpa*), and creeping snowberry (*Symphoricarpos mollis*). Mean stems per m^2 for pachistima and ninebark (*Physocarpus malvaceus*) were the same inside and outside of exclosures. Mean twigs per m^2 were greater inside exclosures for all species that occurred in both locations except for baldhip rose and creeping snowberry. Mean heights were greater inside exclosures for all species except Utah honeysuckle, which was equivalent, and pachistima and ninebark, which were taller outside the exclosures, although not significantly different (Table 1).

Redstem ceanothus and creeping snowberry were the only species to occur both inside and outside of all 3 exclosures. No difference between the inside and outside of exclosures was detected in stems/m^2 for redstem ceanothus ($P = 0.37$). However, redstem ceanothus was significantly taller ($P \leq 0.0001$) and had significantly more twigs/m^2 ($P \leq 0.0001$) inside exclosures. No significant differences were detected in stems/m^2 ($P = 0.59$), height ($P = 0.63$), or twigs/m^2 ($P = 0.27$) for creeping snowberry. Baldhip rose occurred outside all 3 exclosures and once inside and western thimbleberry occurred inside all 3 exclosures and once outside. A similar analysis was run for these species but zeros were used when the species was absent. No comparison was done for height because it was felt that the zeros would drive the results of the analysis. No significant differences were detected between the inside and outside of exclosures for twigs/m^2 or stems/m^2 for either species ($P > 0.2$).

Annual Productivity

Regression coefficients of the twig length-to-weight relationship were not significantly different inside and outside exclosures for twigs of any species. Thus, a single regression of twig weight by length was developed for each species. All regressions were significant ($P < 0.02$) and had coefficients of determination above 0.85. Twig production was much greater inside the exclosures than outside (Table 2). Productivity inside the exclosures was 8.6, 5.3, and 1.6 times greater than outside the exclosures for Boehl's Butte, east Grandad, and west Grandad exclosures respectively.

TABLE 1. Mean values of stems per m^2, height, twigs per m^2, and twig length across all exclosures comparing differences between the inside and outside by species. Parenthesis indicate number of sites where species occurred inside and outside exclosures, respectively. [ ] indicate the largest deviation from the mean.

Species	Stems/m^2 Inside	Stems/m^2 Outside	Height (m) Inside	Height (m) Outside	Twigs/m^2 Inside	Twigs/m^2 Outside
Rocky Mountain Maple (1,0)	0.02		4.6		0.68	
Thinleaf Alder (1,0)	0.02		3.7		0.45	
Serviceberry (2,2)	0.04 [0.01]	0.02 [0.01]	4.1 [1.2]	0.3 [0.02]	0.90 [0.11]	0.72 [0.22]
Oregon Grape (0,2)		0.05 [0.04]		0.1 [0.02]		0.19 [0.17]
Redstem Ceanothus (3,3)	0.57 [0.27]	0.26 [0.21]	4.3 [2.1]	0.3 [0.16]	16.55 [6.9]	1.40 [1.56]
Red-osier Dogwood (0,1)		0.01		0.3		0.38
Ocean-spray (1,2)	0.02	0.01 [0.0]	3.7	0.6 [0.27]	1.17	0.78 [0.14]
Utah Honeysuckle (1,1)	0.03	0.08	0.1	0.1	4.35	0.21
Pachistima (1,1)	0.01	0.01	0.1	0.2	1.04	0.46
Ninebark (1,1)	0.01	0.01	0.2	0.3	3.81	1.28
Bittercherry (2,0)	0.24 [0.09]		5.6 [2.3]		3.22 [0.88]	
Sticky Currant (2,0)	0.07 [0.02]		0.6 [0.15]		1.78 [0.34]	
Baldhip Rose (1,3)	0.01	0.08 [0.07]	0.8	0.3 [0.14]	0.50	0.61 [0.58]
Western Thimbleberry (3,1)	0.67 [0.83]	0.05	0.9 [0.15]	0.2	0.90 [1.10]	0.11
Blue Elderberry (1,1)	0.10	0.01	1.4	0.3	0.28	0.01
Scouler Willow (2,1)	0.09 [0.06]	0.03	4.6 [2.2]	0.8	6.66 [5.13]	0.40
Common Snowberry (2,2)	0.23 [0.12]	0.17 [0.9]	0.8 [0.13]	0.4 [0.09]	6.00 [2.77]	3.65 [2.24]
Creeping Snowberry (3,3)	0.93 [0.27]	1.08 [0.28]	0.4 [0.04]	0.2 [0.1]	30.8 [10.4]	79.8 [47.2]

TABLE 2. Annual twig biomass by species for all 3 exclosures, in g/m^2.

Species	Boehl's Butte Inside	Boehl's Butte Outside	East Grandad Inside	East Grandad Outside	West Grandad Inside	West Grandad Outside
Rocky Mountain Maple	0.79					
Thinleaf Alder	0.23					
Serviceberry	0.37			0.15	0.11	0.02
Oregon Grape		0.01		0.27		
Redstem Ceanothus	22.46	0.14	22.99	1.51	14.73	0.08
Red-osier Dogwood						0.38
Ocean-spray	0.52	0.50				0.28
Utah Honeysuckle					1.62	0.01
Pachistima			0.12	0.05		
Ninebark			1.07	0.32		
Bittercherry	0.35				3.15	
Sticky Currant			0.07		2.17	
Baldhip Rose		0.49	0.07	0.03		0.02
Western Thimbleberry	0.15		3.07	0.16	0.13	
Blue Elderberry					0.67	0.02
Scouler Willow	5.32	0.18			0.86	
Common Snowberry	3.20	0.11			1.36	0.75
Creeping Snowberry	4.66	3.00	2.46	3.14	1.75	15.12
Total Productivity	38.05	4.43	29.86	5.62	26.55	16.67

The smaller difference in productivity inside and outside the west Grandad exclosure was attributable to creeping snowberry, which accounted for 56 to 91 percent of the total productivity outside the exclosures but only 7 to 12 percent inside. Comparing the mean value of productivity for each species between the inside and outside of the exclosures demonstrates the increased productivity of most shrub species (Table 2). A paired t test on productivity of a species occurring both inside and outside the exclosures revealed that the mean productivity across all species was greater inside the exclosure than outside ($P = 0.008$).

Discussion

The effects of grazing or browsing on vegetation varies between vegetation communities and levels of herbivory (Hobbs 1996). Bitterbrush (*Purshia tridentata*) productivity was maintained by browsing levels falling within the maximum allowable annual utilization levels, but became decadent in the absence of herbivory within an exclosure (Peek et al. 1978). However, heights of bitterbrush were similar with and without browsing. Other studies have shown increased shrub height and cover in the absence of herbivory inside exclosures (Krueger and Winward 1974, Edgerton 1987, Pastor et al. 1988). Evidence from exclosure studies suggests that alterations in the shrub vegetation layer will be manifested in some characteristics but not in others. Thus, it is important to consider multiple characteristics of the vegetation to determine the effects of herbivory.

Redstem ceanothus and creeping snowberry were the only 2 species that occurred inside and outside of all 3 exclosures. Additionally, rooted stems per m^2 suggest that these 2 species were more abundant than any other species both inside and outside exclosures. This likely was a factor of site preparation. All 3 sites were broadcast burned following cutting, and both redstem ceanothus and creeping snowberry exhibit vigorous growth following fire. In fact, sprouts of redstem ceanothus were more abundant following hot burns than cooler burns, and was the dominant browse species on sites following a broadcast burn (Meske 1977).

Highly palatable browse species were more abundant inside exclosures than outside. Rocky mountain maple, thinleaf alder, bittercherry, and sticky currant were absent from all locations outside exclosures, possibly due to selective herbivory on preferred forages. Other studies have also shown that herbivory by large ungulates can alter the composition of shrub communities by diminishing natural regeneration of preferred shrubs (Allison 1990, Irwin et al. 1994).

Additional evidence for alterations of the shrub community was apparent in differences in stem densities, which were higher inside exclosures for all species but Utah honeysuckle, baldhip rose, and creeping snowberry. No evidence of creeping snowberry use was found in the food-habits reviews for elk (Kufeld 1973, Cook in press) moose (Renecker and Schwartz 1997) or deer (Kufeld et al. 1973). The other 2 species are browsed, but the difference is probably random change associated with small sample size. Large stem and twig densities of creeping snowberry outside exclosures is probably due to a lack of competition between other species. Whereas, overtopping by other species inside the exclosures may reduce vigor of creeping snowberry.

Redstem ceanothus, a highly palatable species, had the highest stem densities, with the exception of creeping snowberry, of all the species found outside the exclosures. Meske (1977) reported that from 1973 to 1976, 39 to almost 100 percent of all available redstem ceanothus twigs were browsed. Based on this heavy use it might be expected that redstem ceanothus would be less common outside exclosures. In fact, it was less common at the west Grandad and Boehl's Butte exclosures. The high stem density of redstem ceanothus was largely attributable to occurrence at the east Grandad exclosure. Reasons for this are that redstem ceanothus is the most abundant browse species to regenerate after broadcast burning in this area (Meske 1977), and thus may persist longer on a site than other less dominant browse species. Redstem ceanothus also has the ability to re-sprout from the basal stem under heavy browsing. Meske (1977) reported that as browsing on redstem ceanothus intensified decadence of the plant increased from 33 percent to 82 percent.

Most species were taller inside the exclosures than outside, suggesting herbivory reduced shrub heights. Pastor et al. (1988) and Tiedemann and Berndt (1972) reported similar increases in shrub height in the absence of herbivory. While herbivory suppressed shrub height, in the absence of herbivory shrubs can quickly grow out of reach of herbivores.

Twig densities were also greater inside exclosures than outside, except for creeping snowberry, which resulted in increased biomass inside exclosures. Creeping snowberry contributed the majority of all annual biomass production for locations outside exclosures, possibly attributable to lack of use by herbivores. Redstem ceanothus consistently contributed the largest portion of the biomass inside exclosures, partially attributable to its post-burn dominance. However, other tall shrubs would have contributed more if our sampling height limit had been higher. Including upper shrub canopy productivity would have significantly increased the reported differences between the inside and outside of exclosures. Other studies have suggested similar decreases in shrub productivity in relation to herbivore pressure (Irwin et al. 1994).

The implications of this study are limited due to the small inferential space provided by only 3 big-game exclosures. However, if large herbivore populations impose heavy browsing pressure within an area they may actually decrease their own carrying capacity. Analysis of forage quality for this area has shown that elk and possibly other ungulates must carefully select forage items to obtain sufficient amounts of digestible energy (Alldredge 1999). This problem would be exacerbated by decreases in annual biomass of palatable plant parts as intake rates decrease, which in turn would increase foraging time, movements and culminate in an overall increase in daily requirements of digestible energy. Grazing trials with conditioned elk in the Blue Mountains have shown concentrated browsing on preferred shrubs inside exclosures, but less concentrated browsing outside exclosures with lower intake rates and increased movements (Irwin et al. 1994). These researchers suggested that alterations in the structure and composition of plant communities might lead to depressed reproduction and recruitment of elk populations.

To maintain large quantities of palatable browse species it is tempting to implement repeated burning of seral shrub-fields, especially considering the predominance of redstem ceanothus, a preferred forage, following burning. Fire improves soil nitrogen and hence the nutritional quality of forage (Hobbs and Spowart 1984). However, other studies suggest that repeated burning could ultimately decrease soil nutrients through volatilization and runoff and thus, eventually reduce ecological carrying capacity of the area (Irwin et al. 1994).

Several studies in the past have examined the use of clearcuts by elk and guidelines have been developed for the optimal size of a cut area to maximize elk use (Leege 1984). Irwin et al. (1994) suggest increasing the size of individual timber harvests. However, intensive timber harvest in localized areas might reduce long-term forage values as synchronous succession results in mid-successional stands with little forage production (Alldredge 1999). The value of early successional stands to ungulates for forage production and the alterations in shrub communities from herbivory indicates that forest management should be directed at creating a diversity of cover types across the landscape. This should disperse elk across the landscape and maintain early successional areas within typical silviculture rotations. The need to manage populations at levels that do not adversely affect plant species composition is implicit.

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