Northwest Science Notes

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Pattern of Herbivory, Nitrogen Content, and Biomass of Bluebunch Wheatgrass on a Mountain Sheep Habitat in Central Idaho

Abstract

Bluebunch wheatgrass (*Pseudoregneria spicata* [Pursh] A. Love) is a major forage species for mountain sheep (*Ovis canadensis*) in central Idaho. Observed condition of this forage species is high, prompting an investigation of herbivory levels and subsequently nutrient content and biomass of this species. Mean amounts of tissue removed from wheatgrass plants on a slope frequently used by mountain sheep ranged from 5.3% to 26.8% from 1992-1996. Nitrogen levels ranged from 0.7-1.4% from 1998-2007 in plants collected in late June after seed-set. Higher levels of N occurred in growth following wildfire burns. Above-ground growth of bluebunch wheatgrass ranged from 11.3 to 102.1 gm/m^2 and was highly correlated with spring precipitation. While herbivory on this major forage species was low to moderate, nitrogen levels may vary enough to affect mountain sheep population trends without appreciably affecting productivity of their major forage species.

Introduction

Observations over a 20-year period that suggested the herbaceous components of mountain sheep (*Ovis canadensis*) habitats in the Salmon River Mountains of central Idaho were in excellent condition (Figure 1) prompted a five-year investigation of bluebunch wheatgrass utilization by mountain sheep. Results of this work prompted further investigations of nitrogen content and biomass of this forage species. I hypothesized that utilization intensity and frequency were not high enough to affect condition of bluebunch wheatgrass. After evaluating this hypothesis, I tested the hypothesis that nitrogen levels in bluebunch wheatgrass changed significantly between years. If this hypothesis was accepted then changing nutritional levels in forage could affect mountain sheep nutritional status in this area.

Bluebunch wheatgrass is the most common dominant grass species in shrub-steppe communities of the Salmon River Mountains (Peek et al. 2005). Preliminary observations indicated that plants were robust and exhibited no evidence, such as an abundance of hollow-centered plants or soil pedestals suggesting soil loss, that this species was heavily grazed. Forbs were abundant and associated shrubs, regardless of their palatability, did not show evidence of heavy browsing.

Figure 1. Mountain sheep on study slope, showing the prominence of bluebunch wheatgrass, their major forage species.

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Bluebunch wheatgrass is highly palatable to mountain sheep (Blood 1967, Oldemeyer et al. 1971, Kasworm et al. 1984, Wikeem and Pitt 1992). In the Salmon River Mountains, bluebunch wheatgrass is the most important species in the yearlong diet of the indigenous mountain sheep population (Wagner and Peek 2006).

Methods

The study area was a 145.4 ha south-facing slope located in the Big Creek drainage approximately 12 km west of its confluence with the Middle Fork of the Salmon River. This area is within the Frank Church River-Of-No-Return Wilderness. The slope is representative mountain sheep habitat, dominated by bluebunch wheatgrass, and at higher elevations, Idaho fescue (*Festuca idahoensis* Elmer). Douglas fir (*Pseudotsuga menziessi* (Mirbel) Franco) and ponderosa pine (*Pinus ponderosa* C. Lawson) occur as sparse forest cover. Stands of curlleaf mountain mahogany (*Cercocarpus ledifolius* Nutt.) occur on rocky outcrops. Sheep beds, pawed from rocky sites were abundant, and sheep were frequently observed on this slope. Mean rainfall at Taylor Ranch, < one km from the study sites was 35.5 cm over the 1987-2007 period (National Climate Data Center). Elevations range from 1170 m ASL at Big Creek, to over 1870 m on ridge tops that circumscribe this habitat. Nonforested vegetation was described by Peek et al. (2005) and coniferous vegetation by Steele et al. (1981). The area was burned by wildfires in August 2000 and August 2005.

Population estimates of mountain sheep for the Big Creek drainage ranged from 131 to 165 during the 1992-1996 period (Idaho Department of Fish and Game 2004). Mountain sheep, native to the area, were not appreciably affected by humans for at least the preceding 75 years. Hunting was restricted to a small portion of the adult ram population. Native predators, cougar (*Puma concolor*), coyote (*Canis latrans*), and golden eagle (*Aquila chreatos)*, were present through this period, but have not exerted significant mortality on mountain sheep (Hornocker 1970, Akenson and Akenson 1992). No wolves (*Canis lupus*) were present during the 1992-1996 period. Elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) frequented the area but individuals and their sign were infrequent on study sites during the five-year study period. Domestic sheep *(Ovis aries*) were removed from the drainage and adjacent areas in 1970 (Jones 1989), but the mountain sheep population was part of a larger metapopulation that occasionally occurred in proximity to domestic sheep allotments.

Herbivory of bluebunch wheatgrass was examined from January 1992 to July 1996. Six 50 x 50 m macroplots were randomly established on the slope. Macroplots were not replicated since they occurred on the same slope. Elevations of macroplots ranged from 1232 m ASL to 1610 m ASL. All macroplots were established in communities dominated by bluebunch wheatgrass. Five 50 m transects were established in each macroplot at randomly selected intervals. Six 20 x 50 cm quadrats were located at 3 m intervals from a randomly selected starting point along each transect for 30 quadrats per site. The lower right corner of each quadrat was marked with a spike to positively identify its location.

Height/weight relationships were developed to estimate biomass produced and removed from individual wheatgrass plants ('tMannetje 1978, Bonham 1989). Heights of grazed and ungrazed plants occurring in the quadrats were measured to the nearest cm. Mean height of ungrazed plants in plots was used to estimate total plant biomass and as the basis for determining the proportion of plant material removed by grazing for each plant.

The distribution of weight along individual bluebunch wheatgrass plants was estimated by clipping 10 plants of varying heights at 2 cm above ground level in the vicinity of each macroplot (Lommasson and Jensen 1938). Height of each plant was measured, then plants were oven-dried at 40 °C for 24 hours and weighed. Each plant was then cut into 10 cm segments and each segment was weighed. Height-weight regressions were explored for each site using Proc REGR and Proc GLM (SAS Institute 2002).

Total heights and weights of 69 plants were used to develop a regression to estimate biomass from height. Comparisons of height-weight regressions between study sites showed no significant differences, so an equation using data from all sites was used. The regression ln(weight, g) = 0.504 (height, cm), ($F = 44.03$, $P > F = .0001$, adjusted $R^2 = 0.919$), was developed from the range of heights found on macroplots over the study period (Figure 2).

Cumulative weight-proportion of height curves were used to estimate proportion of weight removed

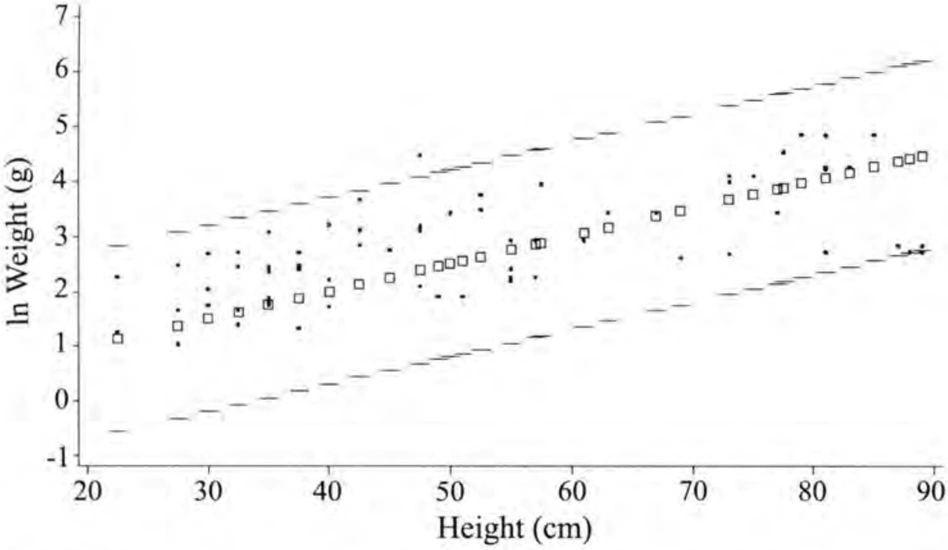

Figure 2. The relationship of the log of weight (g) on height (cm) of bluebunch wheatgrass with measured values (filled circles) and predicted values (open squares).

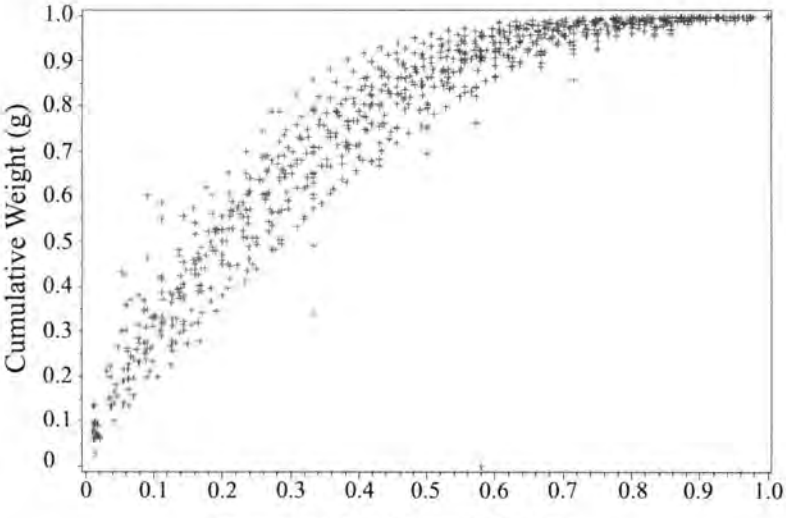

Figure 3. Estimations of cumulative weight of bluebunch wheatgrass as plant height increases using the proportion of total height (PHGT) of the plant, using data obtained from all sites.

for each plant (Figure 3). Approximately 90% of the weight of the plant was realized at approximately 50% of its height. A polynomial equation with adjusted $R^2 = 0.952$ estimated cumulative weight:

$$CUWGT = 0.0788 + 2.367(PHGT) - 1.489\ (PHGT^2)$$

Where, CUWGT = the weight of the plant remaining after it was grazed and PHGT = the proportion of height remaining after a plant was grazed. Height of grazed and ungrazed plants and their estimated weights were tabulated and means obtained for each quadrat using the above equations.

Nitrogen content of above-ground plants was determined from two sites within the study area from 1998 to 2007. Plants located in 20, 20 x 50 cm quadrats randomly distributed across each site were clipped at 2 cm above-ground in late June after seed set when plants had reached maximum growth for the year. Composited samples were oven-dried at 40 °C for 24 hours, and content determined using furnace combustion at the Analytical Sciences Laboratory at the University of Idaho. The purpose of this collection was to determine whether changes in nitrogen content of plants at maturity could be detected between years. A randomized complete block ANOVA with sites as blocks and years as treatments was used to determine differences in N content.

In addition 10 plants were clipped in July 1997 on the study area, separated into 20 cm segments from top to 2 cm above ground, and analyzed for N content.

Estimations of above-ground biomass of bluebunch wheatgrass were determined by clipping 20, 20 x 50 cm quadrats adjacent to the macroplots in July after seedhead development was complete. Plants were clipped to 2 cm above ground level, oven-dried at 40 °C for 24 hours and weighed to the nearest 0.01 gm. Mueggler (1976) and Van Dyne et al (1963) reported high variation in biomass estimates of bluebunch wheatgrass and other species, regardless of sample size but Tsutsumi et al. (2007) concluded that small samples could be used for less heterogeneous grasslands such as occurred in this study area. The data reflected above-ground biomass at time of measurement for the study sites but were not used for estimations of biomass removed by sheep.

Results

Macroplots were examined 10 times over the 1992-1996 period. A total of 133 bluebunch wheatgrass plants were located in the quadrats. Mean amounts of tissue removed from bluebunch wheatgrass plants ranged from 5.3% to 26.8% over the 5-year period (Figure 4), with significant differences between times (ANOVA, $F = 3.91$, $P > F = 0.001$) but not sites ($F = 1.52$, $P > F = 0.202$). Ranges of tissue removed per individual plant varied from 0 to 59% between examinations. Mid-elevation and one of the highest plots revealed higher foliage removal than other sites, probably because snow cover reduced access by sheep to other sites during parts of each winter, or to preference for habitat at these sites.

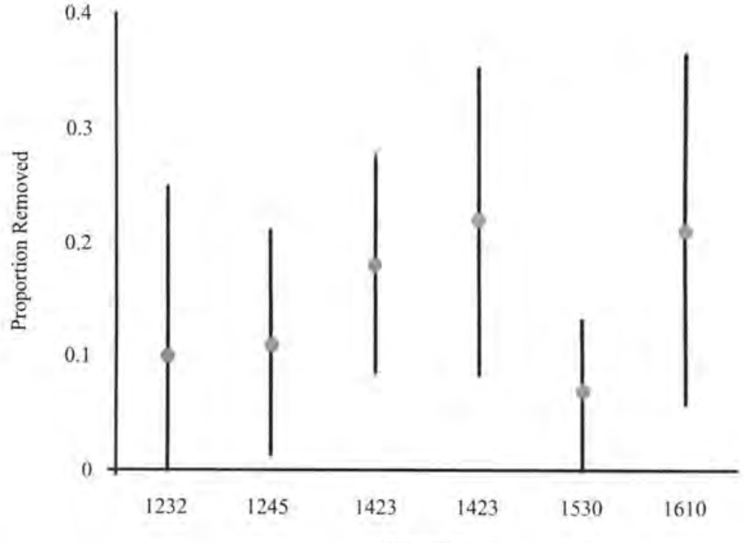

Figure 4. Mean proportion of herbage removed from 6 sites over the 1992-1996 period. The middle number is the mean and upper and lower numbers represent 90% confidence intervals.

TABLE 1. Frequency of grazing on bluebunch wheatgrass plants at 10 examinations, 1992-1996. Elevation at river below sites is 1171 m.

Macro-plot elev. (m)	No. plants examined	No. plants grazed	Times plants grazed (range)	Number of plants grazed consecutively[1]
1232	14	13	1-3	2
1245	17	10	1-2	0
1423	29	21	1-3	10
1423	30	21	1-4	4
1506	21	12	1-4	6
1530	22	14	1-5	6
Totals	133	91		28

[1]This is the number of times a plant was grazed at two or more consecutive observations.

Of 91 plants that were grazed, 28 were grazed on consecutive observations (Table 1). There were 10 instances of individual plants being grazed on consecutive observations at one mid-elevation site. These instances involved two or three consecutive times. One individual plant was grazed at five consecutive observations on one of the highest elevation (1610 m) quadrats. No plants were grazed during consecutive examinations on one of the lowest macroplots and only two plants were grazed during consecutive times at the other low elevation macroplot. More plants were grazed at mid-elevation macroplots (1423 m) than at lower or higher elevations. Highest levels of grazing occurred in February and April 1993, coinciding with the lowest precipitation level for February and the highest level for April. Next highest levels occurred in January and August 1995 and March 1996. Again, high levels of precipitation in January and March were recorded, but a relatively low level in August 1995. Winter snow depth and summer drought likely promote mountain sheep occupation of the macroplots that in turn reflects utilization levels at different elevations and between years.

Above-ground biomass at plant maturity was highly correlated with April-May-June precipitation in this area (Peek et al. 2005). Annual biomass at plant maturity varied considerably between macroplots and years (Table 2). Above-ground growth of bluebunch wheatgrass ranged from 41.8 to 162.2 gm/m^2 on the two lowest macroplots and from 63.1 to 158.2 gm/m^2 on the mid-elevation macroplots. Precipitation for this three-month period from 1992-1996 averaged 6.52 cm (range 5.52 cm-9.04 cm) compared with the 1987-2006 average of 5.61 cm. Precipitation in 1992 was the only year with lower precipitation than the longer-term average.

TABLE 2. Biomass of bluebunch wheatgrass at 1244 m elevation. Data were taken last week of June of each year after seed set. The estimate of above-ground biomass = -17.1897+5.2168 (PRECIP). AIC= 132.845, ΔAICc=2.62, AIC weight = 0.788).

Year	Biomass April-June gms/m^2	Precip (cm)
1992	43.6	10.78
1993	98.4	22.6
1994	62.0	13.7
1995	78.3	19.7
1996	98.2	14.68
1997	67.2	15.1
1998	102.1	22.48
1999	38.4	9.65
2000	45.3	8.48
2001	16.8	10.25
2002	36.4	9.98
2003	11.3	7.7
2004	51.5	16.68
2005	56.5	15.88
2006	19.0	7.15
2007	15.9	9.1

TABLE 3. Nitrogen content of bluebunch wheatgrass at two sites adjacent to other study sites. Data were taken last week of June of each year after seed set. Elevation at river below sites is 1171m.

Year	Elevation (m) 1244	1332
	Percent Nitrogen	
1998	0.87	0.87
1999	0.70	0.80
2000	0.88	1.00
2001	1.30	1.40
2002	1.20	1.00
2003	0.86	1.30
2004	1.10	1.30
2005	0.85	0.81
2006	1.30	1.10
2007	1.30	1.40

N levels ranged from 0.7-1.4% over the 1998-2007 period (Table 3). The ANOVA revealed a significant difference between years but not macroplots (F = 5.00, $P>F$ = 0.0118 for year, F = 1.96, $P>F$ = 0.12 for macroplot, R^2 = 0.85). The highest levels of N occurred for three years following a fire in 2000 and for two years following a fire in 2006. Plants clipped into the 20 cm sections from top to 60 cm from top also showed major differences in nitrogen levels. The top 20 cm had 1.5% N, next 20 cm had 0.85% N and the third 20 cm had 0.54% N.

Discussion

Height-weight relationships of grasses vary annually (Heady 1950), seasonally (Bonham 1989, Merrill et al. 1994), and by soil type (Hurd 1959). The equations used here may under-estimate production for more robust plants with more stems and over-estimate it for less robust plants, for earlier in growing season, and for years with higher precipitation.

Few investigations into changes in N in native plants between years at similar phenological stages were located to compare with these results, although extensive work on changes through a growing season is available. Blaisdell et al. (1952) reported similar levels of N in bluebunch wheatgrass with similar changes over a four-year period as observed here. Stannard and Kelley (1993) found similar levels for a cultivar of bluebunch wheatgrass for a one-year period. Protein levels in bluebunch wheatgrass in the fresh mature stage were similar to our results (National Academy of Sciences 1971). Similarly, Goldberg et al (1980) found small amounts of variation in N content of beach grass (*Ammophila breviligulata*) over a three-year period. Moss (1969) reported similar range of changes in N content but at higher levels in heather (*Calluna vulgaris*) in Scotland over a three-year period. Regrowing vegetation following wildfire typically has increased nutrient content (Singer and Harter 1996).

The estimates of N content in mid-summer do not necessarily coincide with the timing of biomass removal, the latter of which could occur any time following the mid-winter observations. The timing of collections for N analysis coincided with declining levels of N to lowest levels for the year (Wagner and Peek 2006), but at a time when this species was the most-used of all plants grazed, constituting approximately 15% of the observed diet. Wagner (2000) estimated that mountain sheep ewes expended over 4800 kcal/day while acquiring approximately 5500 kcal/day in summer. Protein intake from bluebunch wheatgrass plants on the study sites would be low at this time of year, with crude protein levels at between 6 and 7%, but digestible energy would remain at reasonably high levels, although lower than in spring (Wagner and Peek 2006). Mountain sheep would be very selective of forage at this time, taking only those parts of wheatgrass plants that were highest in nutrients in order to maintain a high energy balance. Resistance of herbage to fracture and mastication, height of herbage and its density, size of feeding group and bonds within that group all affect selection and intake by domestic sheep (Dumont et al. 2006). Domestic sheep have relatively high rumino-reticular volume to body weight ratios (0.25, Hanley 1982), indicating their adaptation for diets high in graminoids, as with mountain sheep.

Mountain sheep adjust their diet to maintain nutrient intake by changing species composition and habitat use (Festa-Bianchet 1988). They are classified as intermediate feeders (Hofmann 1989), having a mixed diet of grasses, forbs, and shrubs. The mixed diet appears necessary if sheep are to acquire sufficient nutrients to offset the amount of low-quality bluebunch wheatgrass in the diet. The most rapidly growing plant parts are known to have the highest nutrient levels (National Academy of Sciences 1971). Mountain sheep that grazed a mature wheatgrass plant down to approximately two thirds of its original height would be receiving approximately 80% of the nitrogen than if they were only grazing the highest third of that plant. Thus, the distribution of nutrients within the plant acts with the nutrient demands of the sheep to reduce the likelihood of damage by herbivory (Strauss and Agrawal 1999).

Bluebunch wheatgrass is sensitive to grazing. Mueggler (1972, 1975) found reduction in herbage production of bluebunch wheatgrass of 90% or more from a single year of severe clipping during flowering stage. Branson (1985), Ellison (1960), Jameson (1963), and Milchunas et al. (1988) concluded that bunchgrasses characteristic of the Rocky Mountains may not have evolved with the intensive herbivory from native ungulates that the rhizomatous grasses of the Great Plains evolved with.

However, individual bunchgrass plants may respond to intensive herbivory by increasing photosynthetic capacity of regrowing tillers and continuing root growth (Caldwell et al. 1981), increasing gross mineralization (Frank and Groffman 1998), redirecting biomass flow (Coughenour 1991), and by decreasing the ratio of photosynthesis to transpiration to increase efficiency of water-use (Caldwell et al. 1983).

Whether responses in plant physiology and growth (Maschinski and Whitham 1989, Mysterud 2006) were occurring on these sites at the observed grazing intensity were not determined. Caldwell et al. (1981) employed removals of >80% of photosynthetic tissue to obtain responses. Levels of herbivory were much higher in investigations suggesting compensatory growth (Caldwell et al. 1981, Frank and McNaughton 1993, Merrill et al. 1994) than observed here. However, Sheley and Svejcar (2009) reported reductions in biomass of bluebunch wheatgrass clipped twice at 20% at the 3 to 3.5 leaf stage and at 50% at peak standing crop. With 21% of plants observed being grazed two or more consecutive times, even at the low to moderate levels of grazing intensity recorded, the foliage removal could suppress growth of some plants.

There is a need to investigate whether bunchgrasses in the robust condition observed here that are exposed to low levels of herbivory demonstrate compensatory responses and changes in physiology. If plants in these circumstances show changes, this would further suggest that they did evolve defenses to herbivory. Regardless, the high condition of bluebunch wheatgrass plants on these habitats used by mountain sheep is attributable to the low levels of herbivory and variation in nitrogen content and biomass.

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