Characterizing Bighorn Sheep Foraging Sites Using the Modified Robel Pole in the Southern Black Hills, South Dakota

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Abstract

Evaluating foraging behavior of bighorn sheep (*Ovis canadensis*) and filling information gaps for their habitat requirements is important for population level management in the southern Black Hills of South Dakota. Our objectives were to: (1) evaluate the overall summer foraging area post lambing use during July and August for standing herbage with the modified Robel pole (1.27 cm bands) with visual obstruction readings (VOR) related to clipped herbage at ground level; (2) calibrate the Robel pole visual obstruction (bands) with clipped vegetation; and (3) develop guidelines for monitoring the landscape of the bighorn sheep foraging areas. The study area is located in a ponderosa pine (*Pinus ponderosa*) savanna with few shrubs and dominated with native grasses. Each transect had 10 visual obstruction (bands) stations spaced 10 meters apart with 4 visual obstruction readings at each station. At 4 stations, total vegetation was clipped at ground level within a 0.25-m^2 circular hoop. Clipped standing herbage ranged from 418 kg/ha to 3731 kg/ha with a mean of 1519 kg/ha. VOR measurements ranged from 0.2 cm to 14.9 cm with a 3.9 cm mean. Calibration of the modified Roble pole (visual obstruction of bands) with transect means using linear regression reliability predicted average clipped standing herbage (dry weights) within the bighorn sheep foraging area. The relationship was significant ($R^2 = 0.65$; $F_{1,\ 27} = 50.75$, $P < 0.01$). Cluster analysis (ISODATA) applied to the pole readings (VOR) and herbage resulted in 3 categories: short, intermediate and tall. We recommend 14 Robel pole transects (100 m in length) for VOR measurements within key foraging areas for future monitoring of herbaceous biomass for bighorn sheep. Foraging sites were in areas with little overstory tree canopy, close to rocky escape terrain, and where abundant grasses and forbs had little woody debris. The modified Robel pole provides a simple, reliable and cost effective alternative to clipping vegetation and obtaining dry weights.

Key words: Black Hills, *Ovis canadensis*, bighorn sheep, herbaceous biomass, foraging, Robel pole, vegetation

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Introduction

Bighorn sheep (*Ovis canadensis*) populations have experienced significant declines across their range from the late 1800s through the mid 1900s as a result of diseases introduced from domestic livestock, unregulated hunting, habitat loss, and competition for foraging resources from domestic livestock (Beecham et al. 2007). Bighorn sheep need resources that contain adequate amounts of forage, escape terrain, lambing and loafing areas, water, and movement corridors (Brewer et al. 2013). Vegetation change due to overgrazing or shrub invasion can make previously occupied range unsuitable from the standpoint of forage quality and quantity (Risenhoover and Bailey 1985, Etchberger et al. 1989). Forage production and quality are factors that can regulate bighorn populations (Stelfox 1976). Ensuring adequate bighorn sheep habitat can be a significant challenge for managers, particularly in the Black Hills where ponderosa pine (*Pinus ponderosa*) can regenerate quickly leading to increased tree density and loss of open areas (Shepperd and Battaglia 2002, Battaglia et al. 2008). Specific habitat resources important to bighorn sheep typically include slopes >50% slope, less distance to escape terrain (<320 m), and less overstory canopy cover or lack of dense tree vegetation (Geist 1971, Tilton and Willard 1982, McCarty and Bailey 1994, Sweanor et al. 1996, Johnson and Swift 2000). Escape terrain has been described as any habitat such as cliffs and steep hillsides (Geist 1971). Grazing by domestic or feral animals on bighorn sheep ranges can degrade and dramatically reduce availability of preferred forage and contribute to the spread of invasive or noxious plant species (Brewer et al. 2013). Bighorn sheep primarily forage on grasses and forbs, and determining the amount of herbaceous biomass at foraging sites is needed for subsequent monitoring (Chapman and Feldhamer 1982).

Monitoring herbaceous biomass use on rangelands by direct clipping measurements is time consuming, expensive, limited to sample size and slow to finalize estimates of herbage for management decisions. To meet the increasing demand for intensive monitoring of vegetation for livestock grazing and wildlife habitat on public rangelands, the modified Robel pole is widely used and cost-effective method for monitoring (Robel et al. 1970, Benkobi et al. 2000; Uresk and Benzon 2007; Uresk et al. 2009). Once the relationship between visual obstruction readings and standing herbage has been calibrated, the modified Robel pole provides a quick, yet effective tool to estimate standing herbage (Robel et al. 1970; Benkobi et al. 2000). The primary advantage of using techniques that have been calibrated to actual measurements (i.e. clipping vegetation) is that they are more accurate than ocular estimates (Kershaw 1973).

The Western Association of Fish and Wildlife Agencies Wild Sheep Working Group has identified several key management goals for wild sheep. A primary focus is to optimize quality and quantity of bighorn sheep habitat throughout the range of this iconic species. Further, management direction for conservation efforts of bighorn sheep in Region 2 of the U.S. Forest Service includes managing bighorn habitat to restore, enhance, or maintain vegetative openness adjacent to bighorn escape cover and along movement corridors (Beecham et al. 2007). Our objectives were to: (1) evaluate the overall summer foraging area post lambing use during July and August for standing herbage with the modified Robel pole (1.27 cm bands) with visual obstruction readings (VOR) related to clipped herbage at ground level; (2) calibrate the Robel pole visual obstruction (bands) with clipped vegetation; and (3) develop guidelines for monitoring the landscape of the bighorn sheep foraging areas. Further, we provide fine scale resource characteristics such as distance to escape cover, overstory and understory canopy cover, woody debris, and slope at foraging sites.

Study Area

Our study was located in the southern Black Hills of South Dakota on public land administered by the USDA Forest Service in Custer County, located in the southern Black Hills physiographic region (Flint 1955). Our study area was adjacent to Jewel Cave National Park and was 26 km^2 in size using a minimum convex polygon of all foraging site locations sampled during the study. Elevations varied from 1488 m to 1908 m. The Black Hills National Forest is dominated by ponderosa pine, but a wildfire in 2000 created open-canopied areas composed of primarily grasslands and shrublands. Western snowberry (*Symphoricarpos occidentalis*), chokecherry (*Prunus virginiana*), and common juniper (*Juniperus communis*) are common shrubs (Hoffman and Alexander 1987). Common native grasses include needle and thread (*Stipa comata*), green needlegrass (*Stipa viridula*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), and little bluestem (*Schizachyrium scoparium*); Larson and Johnson 1999). Non-native plants such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) were also common.

Average annual precipitation was 49.91 cm. Precipitation from April through August was 31.95 cm and 49.58 cm for 2014, and 2015 respectively (National Climatic Data Center 1981-2015). Average annual temperature was 7º C for the study area (National Climatic Data Center 1981-2015).

Methods

Capture and Radio-telemetry

Bighorn sheep were captured during January 2014 utilizing netguns from helicopters in northeastern Montana. Following capture, sheep were blindfolded and equipped with a very high frequency (VHF) transmitter (Telonics Inc., Mesa, AZ.). Sheep were aged as adults (> 20 months) or yearlings (18-20 months of age) by evaluating lower incisors (Dimmick and Pelton 1994). Following capture, sheep were loaded into enclosed trailers and were transferred via vehicle and trailer from Montana to Hells Canyon in the southern Black Hills of South Dakota. Sheep were released on 7 January 2014.

Radio-marked sheep were systematically located and observed throughout the summer period, i.e., 15 July - 31 August, during 2014 - 2015. Visual locations were marked with a Global Positing System (GPS) where sheep were foraging and not disturbed. Within 3-5 days following the observation foraging site measurements were collected at those sites.

Foraging Site Measurements

We measured fine scale vegetative characteristics along a 100-m transect centered at each foraging observation oriented along a contour (0.04 ha plot). Overstory canopy cover was recorded at 1-m intervals along these transects (n = 100) using a GRS densitometer (Stumpf 1993). We estimated percent canopy cover of total herbaceous cover, grass, forbs, and shrubs in a 0.1 m^2 quadrat (Daubenmire 1959) at 3-m intervals along transects (n = 33). Aspect was recorded using a compass as the prevailing downhill direction from the site; percent slope was estimated along this same gradient with a clinometer. Distance (m) to nearest escape terrain, or granite rock outcropping, was measured using a range finder. Downed woody debris (metric tons/ha) was interpolated using a pictorial guide (Simmons 1982).

We determined understory herbaceous biomass at GPS locations where we observed bighorn sheep foraging sites using the following protocol. We used a modified Robel pole marked with alternating colors at 1.27-cm increments (Robel et al. 1970, Uresk and Benzon 2007) to characterize visual obstruction readings (VOR) from vegetation at sites. VOR measurements were centered at the foraging site and then taken at 10-m intervals (n = 10) along transects. With the pole positioned on the transect VOR's were made from a distance of 4 m with the reader's eye at a height of 1 m. We recorded 4 VOR's (one in each cardinal direction) where the lowest visible band was recorded at each for the 4 readings and averaged for the pole station (Robel et al. 1970). We clipped standing herbage to ground level within a 0.25 m^2 circular plot located and centered at each Robel pole station at 20, 40, 60, and 80 m. Vegetation was oven dried at 60˚ C for 48 hours and weighed to nearest 0.1 g. Robel pole measurements were correlated with dried herbaceous biomass to estimate standing herbage expressed as kg/ha (Uresk and Benzon 2007).

Statistical Analyses

All VORs and clipped herbage were averaged by transect for analyses. Relationships between VOR and herbaceous biomass were analyzed using linear regression with 90% prediction intervals. Regression models alone are not satisfactory to provide guidelines for resource management. Probability plots were examined graphically for normality of residuals. We implemented linear regression with the "glm( )" function in R version 3.1.0 (R Development Core Team 2014) (R Version 3.1.0, 2014, www.R-project.org/, accessed 1 Apr 2014). Significance was set at $\alpha = 0.05$.

Non-hierarchical cluster analysis (ISODATA) was used (transect means, VOR and clipped herbage) to develop standing herbage resource categories for guidelines to evaluate grazing for allotments and pastures as it pertains to bighorn sheep management (Ball and Hall 1967; del Morel 1975). Resource categories of standing herbage included short, intermediate, and tall. Minimum and maximum thresholds for each category were computed using 95% confidence intervals (CI). The difference between lower and upper CI bounds across categories was divided by 2 and added to the lower bound and subtracted from the upper bound to define the ranges of each standing herbage category.

Visual obstruction readings and kg/ha were standardized to give equal weight for analyses (individual data subtracted from the sample mean/standard deviation). Estimated number of transects to achieve estimates to be within 20% of the mean with an 80% confidence level were evaluated on the regression variance (Cochran 1977). Future landscape level monitoring of standing herbage (number of transects) for bighorn sheep habitat, or in our case study 35% of the area from the minimum convex polygon was defined as a foraging area (Figure 5 in Benkobi et al. 2000; Uresk and Mergen 2012).

Results

A total of 18 bighorn sheep ($n = 16$ adult ewes, $n = 2$ male lambs or yearlings during second year) were included in our analyses, resulting in 36 summer foraging sites measured during 2014-2015. Relationship between VOR and herbaceous biomass was significant but not very predictive ($R^2 = 0.29$; $F_{1, 34} = 13.83$, $P < 0.01$). Removal of transects with >30% shrub cover, based on understory cover estimates resulted in 29 foraging sites, but improved the regression fit ($R^2 = 0.65$; $F_{1, 27} = 50.75$, $P < 0.01$; Figure 1). Herbage ranged from 1014 kg/ha to 3263

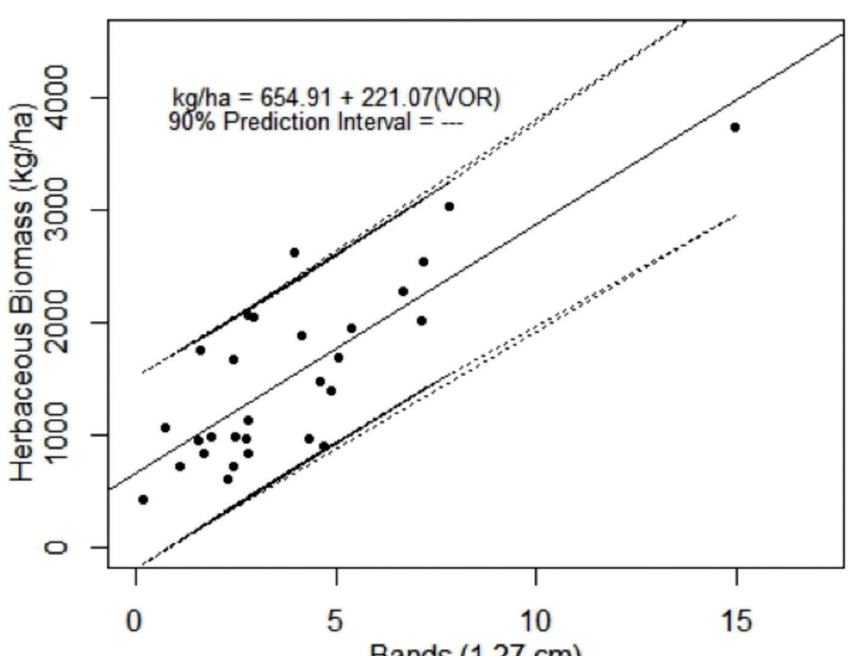

Figure 1. Model and scatter plot of dry weight herbaceous biomass (kg/ha) in relation to Robel pole visual obstruction bands that were in 1.27 cm intervals with 90% prediction intervals from the southern Black Hills, South Dakota, 2014-15.

kg/ha across short, intermediate, and tall categories using cluster analysis and 95% CI at foraging sites (Table 1). Cluster analyses (ISODATA) based on transect means for VOR's and clipped herbage resulted in 3 distinct minimum-variance VOR categories. These VOR categories were short (1.62–2.96), intermediate (2.97–5.12) and tall (5.13–11.80) (Table 1). Foraging sites were typically in areas with little overstory tree canopy, close to rocky escape terrain, and where abundant grasses and forbs had little woody debris (Table 2). Monitoring of the total area occupied by bighorn sheep would require 14 Robel pole transects located at random. Results from the 14 transects would be 80% confident to be within 20% of the mean.

Discussion

Providing baseline data at foraging sites for bighorn sheep will fill needed information gaps for bighorn sheep habitat management (Brewer et al. 2013). Depending upon the geographic location, summer range for bighorn sheep is often open-canopied areas with grasses, sedges (*Carex* spp.), and a diversity of forbs used as forage (Valdez and Krausman 1999). Grasses, followed by forbs and shrubs, were

Table 1. Visual obstruction categories resulting from cluster analysis for short, intermediate, and tall bands (1.27 cm, 0.5 inch) on a modified Robel pole with corresponding standing herbage (kg•ha^{-1}). Band represents visual obstruction reading (VOR).

Category		Minimum	Mean	Maximum
Short (*n*=14)[a]	Band	1.62	2.27	2.96
	kg/ha[b]	1014	1157	1309
Intermediate (*n* =10)	Band	2.97	3.78	5.12
	kg/ha	1310	1491	1787
Tall (*n*=5)	Band	5.13	8.75	11.80
	kg/ha	1788	2589	3263

[a] Number of transects

[b] Kg/ha based on band-weight regression equation

Table 2. Characteristics of summer foraging sites for bighorn sheep in the southern Black Hills, South Dakota, 2014–2015. Metrics in table were from 29 sites where understory shrub cover was ≤30%.

Variable	Mean	SE
Tree canopy cover (%)	4.48	2.06
Total understory cover (%)	64.30	2.70
Understory grass cover (%)	43.98	3.57
Understory forb cover (%)	23.78	2.74
Understory shrub cover (%)	15.73	1.90
Distance to escape cover (m)	36.59	5.29
Slope (%)	28.14	3.08
Woody debris (metric tons/ha)	8.56	0.63
Herbaceous biomass (kg/ha)	1519.18	148.00
Visual obstruction readings (1.27 cm bands)	3.91	0.54

the primary forage available to sheep in our study. Forage quality is an important factor for ungulate ecology but there can be several limiting factors such as temperature regulation (Belovsky 1981, Millspaugh et al. 1998), requirement of minerals (Schwantje 1988), risk of predation (Berger 1978, Bowyer et al. 1998, Bleich et al. 1997), and forage availability (Rominger 1983, Vivas and Saether 1987). Diets of bighorn sheep are typically comprised of grasses, forbs, and shrubs but can vary markedly depending upon gender and geographic location (Valdez and Krausman 1999, Schroeder et al. 2010). Most bighorn sheep migrate seasonally over an altitudinal gradient (Geist 1971) which can influence their diet seasonally and geographically. Our study population does not exhibit spatial or altitudinal migrating behavior and foraging availability of grasses and forbs was greater than for shrubs. Shrub availability was greater for some bighorn populations that exhibit altitudinal migrations (Risenhoover and Bailey 1985, Greene et al. 2012).

In addition to selecting for forage availability, sheep selected for areas close to escape terrain and for open areas providing good visibility (Risenhoover and Bailey 1985, McCarty and Bailey 1994, Sweanor et al. 1996, Johnson and Swift 2000). A large wildfire had burned much of the area used by our study population; sheep are attracted to ranges that have been burned because such areas have been cleared of trees and woody debris that can reduce visibility while also providing adequate forage (Peek et al. 1979, Riggs and Peek 1980).

The modified Robel pole was adequate at predicting herbaceous biomass once we removed sites with greater than 30% shrub cover. Our study was not as predictive as previous studies using the modified Robel pole in meadow habitats where $R^2 \geq 0.80$ (Uresk and Benzon 2007, Uresk et al. 2009). The greater percentage of shrubs in the understory (mean of roughly 16%) may have lowered predictions, particularly given the weights of biomass were slightly heavier than biomass measured in meadow habitats with similar VOR bands (Uresk and Benzon 2007, Uresk et al. 2009). When we included sites with greater shrub density (>30%) we had difficulty predicting herbaceous biomass as shrubs were heavier than grasses and forbs with comparable visual obstruction readings.

We recommend a range of 1310 – 1787 kg/ha herbaceous biomass be made available for wild sheep at summer foraging areas, a range identified as the intermediate grouping in our cluster analysis. This range is similar but more restrictive to what was found on summer range in the Pusch Ridge Wilderness in Arizona (seasonal range 851–1,985 kg/ha; Mazaika et al. 1992). The three resource categories defined by cluster analyses provide useful guidelines for management of bighorn sheep. The short category is the minimum herbage required to maintain the sheep through winter or drought periods. Monitoring of the available sheep habitat for this short category is required to maintain the herd with adequate forage, and if forage falls below this critical value emergency supplemental feeding may be required during drought and harsh winters. Intermediate category will sustain the current needs for forage. However, the tall category is surplus feed that is available for summer grazing and harsh winter months. Bighorn sheep from our study population had high annual ewe survival (≥87%) and lamb production through winter (≥ 45 lambs:100 ewes) (SDGFP, unpublished data).

Monitoring at the landscape level and sampling efficiency is related to the area of land occupied by the bighorn sheep (see Figure 5, Benkobi et al. 2000; Uresk and Mergen 2012). The area currently occupied by bighorn sheep is 26 km^2 and equals 10 sections of land (259 ha/section or 640 acres/section), which results in 40 quarter sections. Therefore, 35% of the quarter sections to be sampled would equal 14 transects for monitoring the total area. We recommend stratifying the area into 3 strata as a minimum to randomly distribute the 14 transects among the 3 strata. Once the random locations are located (14), one transect is required to be sampled at each of the locations. If the area of concern increases, sampling adjustments can be determined. The level of confidence of this monitoring is established to be within 20% of the mean at an 80% confidence level.

Management Implications

We recommend range managers monitoring forage availability for bighorn sheep use the modified Robel pole as a tool in the southern Black Hills. The relationship of visual obstruction (VOR) to herbage weight was developed as a tool to monitor available herbage for bighorn sheep. Resource categories developed provide useful guidelines for management of standing herbage to meet objectives and we recommend the intermediate category (1310 – 1787 kg/ha herbaceous biomass) as an objective. Wildlife managers can relate to short, intermediate and tall VOR categories to maintain current management direction or develop new objectives to achieve desired needs for bighorn sheep. It gives wildlife managers a fast, easy to use, accurate and cost effective technique for monitoring foraging resources within the habitat of bighorn sheep and making resource management decisions.

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