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ABSTRACT—A modified Robel pole with white and gray alternating bands (2.54 cm) was used to measure vegetation on sands and choppy sands ecological types in the Sandhills of Nebraska. Objectives were to determine the relationship between visual obstruction readings (VOR) and clipped standing herbage, develop guidelines for monitoring standing herbage, and provide sample size estimates. Visual obstruction measurements of standing herbage were linear, and regression coefficients were significant ($P < 0.001$) for 125 transects ($R^2 = 0.60$, SE = 496 kg/ha). Clipped standing herbage ranged from 293 to 4389 kg/ha with a mean of 1,559 kg/ha. A minimum of four transects (20 stations/transect with four readings/station) is required for monitoring key areas or small areas up to 259 ha in size. Cluster analyses (ISODATA) applied to VOR and standing herbage resulted in four resource categories: short, short intermediate, intermediate, and tall. Band 3 corresponded to approximately 40% utilization of herbage. The protocol and guidelines developed provide managers with a tool that is cost effective, accurate, and reliable for management and monitoring standing herbage.

Key Words: grassland structure, livestock, management, Robel pole, wildlife

INTRODUCTION

Standing herbage or standing crop and vegetation structure are important variables for managing multiple uses such as livestock grazing, wildlife habitat, plant and animal diversity, and protection from soil erosion (Bement 1969; Hooper and Heady 1970; Heady and Child 1994; Reece et al. 2001). Standing herbage has been conventionally estimated by clipping, drying, and weighing the vegetation from plots or transects. This procedure is limited in practice because of time, cost, and sample size constraints (Benkobi et al. 2000). A modified Robel pole with 2.54 cm bands as specified by Benkobi et al. (2000) provides greater precision and accuracy for the same effort. Monitoring vegetation for an ecological vegetation type with the Robel pole can be accomplished at the local or landscape level.

Monitoring rangelands often involves indirect methods of assessing forage utilization or estimates of standing herbage. Ocular methods are widely used for monitoring, but they suffer from inaccuracies and observer biases (Schultz et al. 1961; Kershaw 1973; Irving et al. 1985; Block et al. 1987). The Robel pole marked for visual obstruction readings overcomes the drawbacks of indirect methods based on subjective observations.

Several studies involving the Robel pole, direct clipping of vegetation, estimating standing herbage, and relating these to wildlife habitat have been performed in the Sandhills of Nebraska (Frolik and Keim 1933; Gilbert et al. 1979; Potvin and Harrison 1984; Stubbendieck and Reece 1992; Volesky et al. 1999; Reece et al. 2001; Volesky et al. 2005; Volesky et al. 2007). An overall review of the ecology of plants and animals, soils, livestock grazing, climate, geology, hydrology, and streams and lakes in the Sandhills is presented by Bleed and Flowerday (1990). Stubbendieck et al. (1989) provide an additional review of the literature. However, no research has been conducted with the Robel pole to monitor standing herbage or to establish guidelines based on VOR and standing herbage on the sands and choppy sands ecological type.

The objectives of this study were (1) to quantify the relationship between standing herbage and visual obstruction readings, (2) to develop sample size estimates for the number of transects required to achieve adequate precision for monitoring, and (3) to develop guidelines for monitoring and management.

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STUDY AREA

This study was conducted on the Samuel R. McKelvie National Forest located southwest of Valentine and on the Bessey Ranger District at Halsey (Nebraska National Forest), a combined area of approximately 82,463 ha (203,770 acres). The Sandhills in Nebraska include sand dune hills to sandy basins and valleys. This study focused on vegetation in the sands and choppy sands ecological types (USDA-NRCS 2000, 2001). Dominant plants include sand bluestem (*Andropogon hallii* Hack.), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), prairie sandreed (*Calamovilfa longifolia* [Hook.] Scribn.), needle-and-thread grass (*Stipa comata* Trin. & Rupr.), hairy grama (*Bouteloua hirsuta* Lag.), blue grama (*Bouteloua gracilis* [H.B.K.] Lag.), and sedge (*Carex* spp.). Common forbs are green sagewort (*Artemisia* spp.), lemon scurfpea (*Psoralea lanceolata* [Pursh] Rydb.), and western ragweed (*Ambrosia psilostachya* DC.). Plant nomenclature follows the Great Plains Flora Association (1986). Elevations range from 1,219 to 1,310 m above sea level. Average annual precipitation at Halsey (87–year average) is 541 mm, most of it occurring as rain from April through August (High Plains Regional Climate Center 2011). Average maximum temperature is 16.9°C and average minimum temperature is 1.4°C. The frost-free period is 150 days.

METHODS

Visual obstruction readings (VOR) and clipped vegetation data were collected in the fall of 1997 after a killing frost. All procedures and methods follow Benkobi et al. (2000). The modified Robel pole has alternating white and gray bands (2.54 cm bands) with the bottom band labeled 1. VOR were recorded at a distance of 4 m, from the four cardinal directions, with the reader's eye at a height of 1 m. The lowest visible band was the recorded VOR. If the first band, placed at the soil surface, was visible, the reading was 0; however, if the first band was totally obscured, the reading was 1. Transects were 200 m long with Robel pole stations spaced 10 m apart. At stations 50, 100, 150, and 200 m along the transect, vegetation was clipped to ground level. All clipped vegetation was oven-dried at 60°C for 48 hours and weighed to the nearest 0.1 g. Weights were expressed as kilograms/hectare.

A stratified sampling design based on vegetation height (short, intermediate, and tall) was used to collect transect data (Cochran 1977; Thompson et al. 1998; Levy and Lemeshow 1999). A total of 125 transects were located randomly within the three strata and on sands and choppy sands ecological vegetation types (USDA-NRCS 2000, 2001). Sampling vegetation was conducted in the fall after frost over a broad range of pasture conditions from no grazing through heavy grazing. Data were used over this broad range of sampling to define guidelines for resource management.

All data for VOR and clipped standing herbage were averaged by transect for statistical analyses. Linear regression (SPSS 2003) was used to quantify the relationship between VOR and standing herbage, and ISODATA was used for cluster analyses (Ball and Hall 1967; del Morel 1975) to establish resource groupings and management guidelines. All VOR and standing herbage (kg/ha) were standardized (individual data subtracted from the sample mean/standard deviation) to give equal weight for cluster analyses. Probability plots were examined for normality of residuals. Significance is at $P = 0.05$ unless actual P-values are presented. The number of transects required for monitoring standing herbage, one section (259 ha) at a precision of 20% of the mean at 80% confidence, was based on the grouping variance within the resource categories.

RESULTS

VOR values ranged from 0.5 to 7.1 bands with an overall mean of 2.5. Oven-dried, clipped herbage had a mean of 1,559 kg/ha and ranged from 293 to 4,389 kg/ha. The relationship between standing herbage and VOR was linear, with a correlation of determination of $R^2 = 0.60$ (Fig. 1). Both slope and intercept of the regression model were significant ($P < 0.001$). Examination of normal probability plots showed residuals were normally distributed. The slope was 349.5 kg/ha per band with an intercept of 669.0 kg/ha.

Cluster analyses resulted in four distinct categories (Table 1): short (0.5–1.7 bands), short intermediate (1.8–3.5 bands), tall intermediate (3.6–5.4 bands), and tall (5.5–7.0+ bands). Standing herbage (kg/ha) by categories included short (844–1,263), short intermediate (1,298–1,892), tall intermediate (1,927–2,556), and tall (2,591–3,116). These categories represent heavy, moderate, light, and no grazing. Herbivory at 40% utilization based on the mean of the tall category (2,836 kg/ha) is 1,702 kg/ha residual herbage remaining on the rangeland. This equates to approximately band 3. The number of transects needed to estimate standing herbage based on the variance from the four groupings at a precision of 20% of the mean with 80% confidence was four transects per section (259 ha).

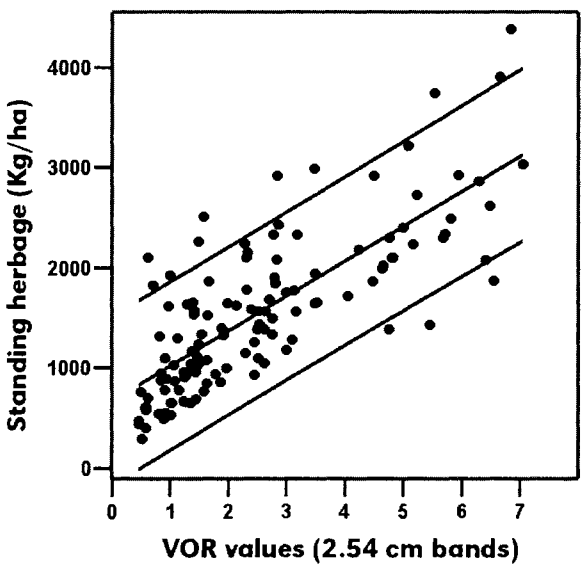

Figure 1. Relationship between VOR values (pole bands) and standing herbage. Prediction intervals are 90% for individual transects. SE is the standard error of the estimate. Standing herbage (kg/ha) = 660.0 to 669.0 x bands. $R^2 = 0.60$. SE = 496.

TABLE 1
CATEGORIES OF STANDING HERBAGE IN SANDS AND CHOPPY SANDS ECOLOGICAL TYPES DEFINED BY CLUSTER ANALYSIS

Category		Minimum	Mean	Maximum
Short	Band:	0.5	1.1	1.7
(n = 47)[a]	Kg/ha:[b]	844	1,053	1,263
Short intermediate	Band:	1.8	2.3	3.5
(n = 48)	Kg/ha:	1,298	1,473	1,892
Tall intermediate	Band:	3.6	4.8	5.4
(n = 22)	Kg/ha:	1,927	2,347	2,556
Tall	Band:	5.5	6.2	7.0+
(n = 8)	Kg/ha:	2,591	2,836	3,116

Note: Bands (2.54 cm) represent visual obstruction readings (VOR).
[a]Number of transects.
[b]Standing herbage (kg/ha) is based on VOR band-weight equation.

DISCUSSION

Comparisons of several Robel studies show differences among various vegetation types in the Sandhills or in other sandy areas. In the current study, standing herbage per VOR centimeter, 275.2 kg/ha, was 12.1% lower than on sandy soils (Benkobi et al. 2000). Our standing herbage study per VOR centimeter was 44% lower than reported by Vermeire and Gillen (2000) in a tallgrass prairie in Oklahoma with similar vegetation. Clearly, the weight per centimeter is less in the current study on sands and choppy sands.

USDA-NRCS (2000, 2001) reported maximum standing herbage of 3,026 kg/ha for choppy sands soils and 3,250 kg/ha for sands soils. Standing herbage for the tall category in our study is in close agreement with USDA-NRCS standing herbage values. Therefore, it seems reasonable to use the mean of the tall category as a measure of the potential of the sands and choppy sands vegetation for development of resource guidelines.

Grazing a pasture to band 3 (leaving 1,702 kg/ha standing herbage) is commensurate to 40% utilization, a common guideline for range use, and is the recommended guideline for maintaining residual vegetation. At this level of use, it should be possible to maintain or even improve the vegetation (Hooper and Heady 1970; Holechek et al. 1989; Heady and Child 1994). I do not advocate changing the guideline yearly to adjust bands to 40% utilization of the current year's standing herbage. With VOR-based monitoring, a fixed amount of residual standing herbage is maintained through wet and dry years. Maintaining the proper amount of residual vegetation results in cooler soil for a longer period during the growing season, and increased plant growth and production. It also greatly reduces wind speed at the soil surface, reducing wind erosion and soil evaporation (Beetle et al. 1961; Lal 1994; Molinar et al. 2001). The guideline may be altered based on the results of trend monitoring.

Monitoring standing herbage for livestock use on rangelands is generally based on utilization measurements (NAS-NRC 1962; Holechek et al. 1989; Heady and Child 1994). The fixed amount of forage utilization by livestock is estimated from the current year's peak standing herbage. The peak standing herbage varies from year to year, so the residual amount remaining is highly variable between and among years, assuming 50% utilization. During wet years, more residual herbage is left. In dry years there is less. Several consecutive years in which minimal residual herbage remains will negatively impact the subsequent year's growth (Stubbendieck and Reese 1992). Monitoring with VOR, a fixed amount of residual standing herbage (band 3) is maintained regardless of yearly variation in peak standing herbage. In dry years, the impact on resources will be minimal or avoided, and in wet years, additional time or numbers of livestock may be allocated.

Four resource categories were defined from clusters analyses (Table 1) for management of livestock and wildlife. These categories correspond to none, light, moderate, and heavy grazing and may be useful with the various grazing management systems presented by Stubbendieck and Reece (1992). Wildlife habitat requirements for residual standing herbage will vary by animal species. Sharp-tailed grouse is a key species whose nesting habitat it is prudent to manage at approximately VOR band 4 (>3.4 inches) (Prose et al. 2002). Sharp-tailed grouse select nesting sites up to approximately band 5 (4.7 inches) in the Sandhills (Reece et al. 2001). Maintaining a range of residual standing herbage wherein 10%–15% of the vegetation is in the short and tall categories and the remainder in the intermediate categories is recommended to maintain diversity (Mueller-Dombois and Ellenberg 1974; Rumble and Gobille 1998; Fritcher et al. 2004; Benkobi et al. 2007).

Future sampling with an unknown variance will require four transects to be within 20% of the mean with 80% confidence for estimating standing herbage. This has long been the standard for management of federal lands (USDA Forest Service 1996). Monitoring with four transects applies for a section of land (259 ha) or key areas. When the objective is to manage for a specific VOR, a one-sided t-test using the variance of the four transects is appropriate (Steel and Torrie 1980; Uresk and Juntti 2008; Uresk et al. 2010). Monitoring with four transects (Robel pole bands = 1.27 cm) in the Bighorn National Forest showed differences from an established band at 0.64 cm (0.25 inches) 95% of the time (Uresk and Juntti 2008, Tongue District, Bighorn National Forest, Sheridan, WY, 2011). When considering a higher level of precision with the current study, a sample size estimated to be within 10% of the mean with 95% confidence for monitoring standing herbage would be 23 transects to monitor 259 ha. At this level, science-based resource management and monitoring for residual standing herbage would essentially be cost prohibitive. Benkobi et al. (2000) explains the methodology for landscape monitoring. Uresk (2012) found that validation data collected in July for a fall cool-season grass model on the Fort Pierre National Grassland could be used to monitor from near-peak standing herbage to fall.

As with any field technique, monitoring with the Robel has several constraints. Monitoring requires staying within the ecological vegetation types described for sands and choppy sands. Sampling outside these types will produce spurious results when estimating standing herbage. The model was developed with standing herbage and has constraints when the vegetation is subjected to heavy rains, winds, and heavy snow after melts. The vegetation may bend over, resulting in errors for estimating standing herbage.

CONCLUSIONS

Monitoring rangeland resources for standing herbage and visual obstruction readings on sands and choppy sands with the Robel pole is simple and precise. I developed four resource management guidelines corresponding to the intensity of grazing. Managing for a mosaic of short, short intermediate, tall intermediate, and tall vegetation structures provides diversity in residual vegetation required for key wildlife species. A guideline of three bands of standing herbage for removal of livestock (1,702 kg/ha) should maintain or improve the range resource. The calibrated Robel pole is a tool that provides data and information for resource managers to determine compliance of management plans for vegetation conditions and to implement guidelines.

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