Daalkhaijav Damiran, **Timothy DelCurto**[1], **Enkhjargal Darambazar**, **Abe A. Clark**, and **Patricia L. Kennedy**, Eastern Oregon Agricultural Research Center, Union, Oregon 97883

Robert V. Taylor, The Nature Conservancy, Enterprise, OR 97828.

Visual Obstruction: Weight Technique for Estimating Production on Northwestern Bunchgrass Prairie Rangelands

Running footer: Estimating standing crop in bunchgrass prairie

2 figures.

[1]Correspondence: Timothy DelCurto, Eastern Oregon Agricultural Research Center, P.O. Box E, Union, Oregon 97883.

Suggested Citation for Paper:

Damiran, D**.,** T. DelCurto, E. Darambazar, A. A. Clark, P. L. Kennedy, and R. V. Taylor. 2007. Visual obstruction: weight technique for estimating production on northwestern bunchgrass prairie rangelands. *In:* Proceedings of Western Section, American Society of Animal Sciences 58:225-228.

Abstract

The estimation of standing crop is important in the management of rangeland resources. Direct measurements by clipping, drying, and weighing of herbaceous vegetation are time-consuming and labor-intensive. Therefore, non-destructive methods for efficiently and accurately estimating standing crop are needed in rangeland forage management. We assessed a visual obstruction (VO) technique to estimate standing crop (SC) of northwest native bunchgrass communities at The Nature Conservancy's Zumwalt Prairie Preserve in northeastern Oregon. This method involves obtaining a height-density index by measuring the height of a pole that is obscured by vegetation when viewed from the side. Five hundred seventy six plots (0.5 m^2) were subjected to VO measurement; and subsequently, all vegetation within a plot was clipped to ground level. Only current year's crop was taken. Regression analysis was used to evaluate the relationships of VO to standing crop, with standing crop as the dependent variable. Total standing crop was 1261 ± 51 $kg \cdot ha^{-1}$ and mean of VO measurement was 12.8 ± 0.4 cm for vegetation in the study site. By growth habit of plants, standing crops were 688 ± 26, 13 ± 26, 416 ± 26, and 144 ± 26 $kg \cdot ha^{-1}$ for grasses, grasslikes, forbs, and shrubs, respectively, and all growth habits differed from each other ($P < 0.01$). A positive ($P < 0.01$) linear relationship occurred between VO and SC measurements, however, correlation was low with only 46% of the variation in standing crop being attributable to VO (y, $kg \cdot ha^{-1} = 270.58 + 77.66x$, cm; $r^2 = 0.46$, $n = 576$). In heterogeneous mid-height bunchgrass communities like the Zumwalt Prairie Preserve, the VO technique will not accurately predict standing crop although many wildlife investigators will still find it useful for describing vegetative structure in these communities. Consequently, we recommend that, if considering VO as a surrogate for SC, investigators should calibrate VO technique against clip plots to evaluate applicability to their situation.

Key Words: Biomass, Non-destructive Technique, Rangelands, Robel Pole, Visual Obstruction

Introduction

The measurement of rangeland herbage standing crop is important in the management of multiple uses such as livestock production, wildlife food and cover, and soil protection against erosion. For decades, a common technique to obtain standing crop dry weight estimates has been the standard clip and weigh technique (Cook and Stubbendieck 1986), which consists of clipping herbage of known area, and then the clipped herbage is oven dried and weighed. This technique is destructive, labor-intensive, and requires considerable time. In an attempt to overcome these problems, several non-destructive techniques, such as the biometer (Pearson and Miller 1972), the Massey grass meter (Holmes 1974), the Ellinbank pasture meter (Earle and McGowan 1979), and the rising plate meter (Michell and Large 1983, Gabriels and Van Den Berg 1993) have provided estimates of standing crop with high degrees of accuracy. However, they were not designed to measure vegetation visual obstruction (VO), a height-density measurement that relates to habitat suitability for grassland wildlife (Fontaine et al. 2004, Winter et al. 2005, Lueders et al. 2006). If the VO technique could be used to simultaneously estimate forage availability for livestock grazing management and status of habitat conditions for various grassland wildlife species, both researchers and managers would have a useful tool that could be used with inter-disciplinary collaboration.

Robel et al. (1970) and Vermeire and Gillen (2001) concluded that in tallgrass prairie, standing crop dry weight estimates can be indirectly obtained using measured VO in regression models. Visual obstruction technique also has been used to predict standing crop (r^2 = 0.88) for the sandy lowland sites on Nebraska sandhills (Benkobi et al. 2000). Likewise, Harmoney et al.

(1997) and Ganguli et al. (2000) found that VO measurement were accurate predictors of standing crop in Iowa pastures (r^2 = 0.63) and in the shortgrass prairie (r^2 = 0.85) of Texas, respectively. However, in other ecosystems, such as marshes in Upper Texas, VO was only able to explain 35% of the variance in clip plot standing crop (Whitbeck and Grace 2006). In another study, Volesky et al. (1999) reported that VO measurement would probably not be useful in a double-sampling technique for prediction of total standing crop on upland range sites in the Nebraska Sandhills.

The accuracy and precision of the VO technique for predicting standing crop thus appears to vary from ecosystem to ecosystem. The performance of the VO as a predictor of aboveground productivity in bunchgrass community ecosystem is limited. Our objective therefore was to determine the potential of a VO technique in assessing standing crop on bunchgrass prairie in northeastern Oregon.

Materials and Methods

Study Site

The study was conducted from late June to late July 2006 on the Zumwalt Prairie which is the last large remnant of the northwest bunchgrass ecosystem type (Tisdale 1982) community. Our study area within the prairie was The Nature Conservancy's (TNC) Zumwalt Prairie Preserve (lat 45°34′N, long 122°57′W) which is located near Enterprise, Ore., in northeastern Oregon. Elevations of the study area ranged from 1340 to 1460 m and topography was relatively flat with rolling hills (7% slopes on average). The area receives around 330 mm of precipitation annually (30-yr average) with a distinct dry period in July and August. Precipitation is bimodal; falls in spring as localized thunderstorms and in winter as snow. Long-term average annual temperature (30-yr average) is 6.4°C, and ranged from -2.8°C (December) to 17.1°C (July).

Precipitation and temperature data (NOAA 1957-1987) were from the Enterprise, Ore. weather station at 1163 m elevation located northwest (<30 km) of the study site. Soils are mostly shallow to moderate deep silt loams with localized areas of shallow and very shallow rocky soils (USDA NRCS, TNC unpublished data). Idaho fescue (*Festuca idahoensis* Elmer), prairie Junegrass (*Koeleria macrantha* [Ledeb.] J.A. Schultes), bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve), and Kentucky bluegrass (*Poa pratensis* L.) are the dominant grasses, while western yarrow (*Achillea millefolium* L. var. *occidentalis* DC.), tall annual willowherb (*Epilobium brachycarpum* K. Presl), twin arnica (*Arnica sororia* Greene), corn speedwell (*Veronica arvensis* L.), and old man's whiskers (*Geum triflorum* Pursh) are the dominant forbs. Silky lupine (*Lupinus sericeus* Pursh) and slender cinquefoil (*Potentilla gracilis* Dougl. ex Hook.) were the primary subshrub/shrub species, while dwarf rose (*Rosa gymnocarpa* Nutt.), Nootka rose (*Rosa nutkana* K. Presl.), and common snowberry (*Symphoricarpos albus* [L.] Blake) were occurring occasionally. Further descriptions of vegetation characteristics of the study site can be found in Darambazar et al. (2007). The study site has grazed for over 100 yr and in the past >50 yr as spring/summer pasture for cattle (P. Shephard, personal communication). Native ungulates (*Odocoileus hemionus*, *Cervus elaphus*) and Belding's ground squirrels (*Spermophilus beldingi*) are also common.

Experimental Design

This study was conducted as part of a larger, multi-disciplinary study examining the effects of livestock stocking rates on this grassland food web. The experimental design for the larger study is a randomized complete block design with one factor (livestock grazing) and four grazing treatment levels (livestock densities). In 2006, fences were erected around four blocks (Block A, B, C, and D) of land 160 ha in size, and within each block, four contiguous paddocks were partitioned, each 40 ha in size. The data summarized here are based on the pre-treatment sampling of vegetation that was conducted in these paddocks during 2006 (treatments will not occur until 2007). Within each paddock, we established a set of 36 sampling points which were uniformly distributed along a grid of 6 north (N)-south (S) transects (columns) and 6 east (E) - west (W) transects (rows) that traversed each paddock. Transects were approximately 90 m apart. Sampling points were then located 1.5 m from the intersection of each N-S and E-W transects. This resulted in 144 sampling points for each block, for a total of 576 sampling points available for direct comparisons between the 2 techniques.

Visual Obstruction

Visual obstruction and clipped standing crop data were collected from each sampling point in late June to late July 2006. Two 2-person teams carried out field work of this study. The approach described by Robel et al. (1970) was used to measure VO and a 0.5 m^2 (0.5 × 1 m) rectangular frame or plot was used to clip and harvest standing crop. Equipment used for VO measurement was similar in design to that used by Robel et al. (1970). Our equipment consisted of 2 poles (60 and 100 cm, reading and sighting pole, respectively) that were connected by a 4-m nylon cord attached to the top of each pole. The reading pole was painted in white and marked at each decimeter, with 0.5-dm increments in red. The bands were numbered in ascending order beginning with 1 at the bottom. One person positioned the reading pole vertically in the center of a 0.5 m^2 (0.5 × 1 m) rectangular frame. A second person, the observer, would place the sighting pole at a distance of 4 m from the center of the frame. Looking from a height of 1 m, the observer would read the number of the lowest band not obstructed by vegetation. At each sampling point, 4 VO measurements were recorded, 1 for each cardinal direction. The four VO measurements were averaged for each sampling point and multiplied by 10 to convert to centimeters (Volesky et al. 1999). Every 3 days of fieldwork, observers rotated between their duties to minimize potential individual observer's biases.

Standing Crop

After VO measurement, all vegetation within the rectangular frame was clipped at ground level. All clipped samples were separated by live and dead materials, the latter of which was discarded. Live material (standing crop) further separated by botanical species, was oven dried at 60°C for 48 h and weighed. Total standing crop of each sampling point was determined by summing the aboveground biomass of all species removed from each plot and expressed in $kg \cdot ha^{-1}$. Plant nomenclature and separating plants by growth habit throughout this paper follows the recommendations of the USDA Natural Resources Conservation Service (USDA, NRCS, 2007).

Data Analysis

Regression analysis was used to evaluate the relationships of VO to standing crop, with standing crop as the dependent variable using REG procedures of SAS (SAS 2002). Individual sampling points were considered as observations. Prediction accuracy of the developed regression model was checked at the 0.05 level ($P < 0.05$). A variety of transformations (LOG, LOG10) were compared to attain maximum variance explanation. Residuals were also examined to evaluate assumptions of normality and homogeneity of variance. Statistical analysis was conducted with non-transformed values. Least squares means of standing crop, as well as standing crop summed by growth habit, and visual obstruction measurements data were generated and separated using MIXED procedure of SAS and were considered different at the 0.05 level ($P < 0.05$).

Results and Discussion

The total standing crop of the experimental site was 1261 ± 51 kg·ha^{-1} during 2006. By plant growth habit, standing crops were 688 ± 26, 13 ± 26, 416 ± 26, and 144 ± 26 kg·ha^{-1} for grass, grasslike, forb, and shrub plants, respectively (Figure 1). Biomass of plant growth habits differed from each other ($P < 0.05$).

Mean VO was 12.8 ± 0.4 cm. Neither VO measurement nor SC differed ($P > 0.05$) by blocks. The results of the ANOVA tests associated with the regression analysis indicate that the relationship between standing crop and VO is significant ($P < 0.001$, $F = 490.54$, n = 576). However, when data were pooled from all sampling points, VO was only able to explain 46% of the variance in standing crop (Figure 2). Relations of VO and SC were slightly different with experimental blocks. In particular, VO was able to explain 54%, 52%, 35%, and 43% of the variance in standing crop, for block A (y, kg·ha^{-1} = 40.09 + 100.84x, cm; $r^2 = 0.54$, $F = 165.24$, $n = 144$), block B (y, kg·ha^{-1} = 248.19 + 79.12x, cm; $r^2 = 0.52$, $F = 153.80$, $n = 144$), block C (y, kg·ha^{-1} = 314.09 + 71.30x, cm; $r^2 = 0.35$, $F = 76.30$, $n = 144$), and block D (y, kg·ha^{-1} = 479.58 + 59.06x, cm; $r^2 = 0.44$, $F = 109.24$, $n = 144$), respectively.

Given the wide range of micro-environmental conditions across our study site, the spatial, and vegetation structural heterogeneity present in bunchgrass prairie ecosystems, and the inherent differences in the VO and SC techniques, r^2 values 0.46 between the 2 techniques are probably quite reasonable and acceptable. There are several possible different aspects (or a combination of several reasons) why VO was not a good predictor of current year's standing crop in bunchgrass communities on Zumwalt Prairie Preserve.

Vermeire and Gillen (2002) believe that plant stature and morphology are the primary factor controlling the volume measured by visual obstruction. In a companion study, Darambazar et al.

(2007) found that the vegetations throughout the study sites were relatively heterogenic and a diverse mixture of plants. In particular, abundance of mid-height or taller plants like silky lupine and slender cinquefoil were high. In lesser but still significant extent contributed dwarf rose, Nootka rose, and common snowberry. For plants, three-dimensional distribution on the plant is often highly varied. For instance, these plants usually have medium-height, relatively tiny stem, but large, widely-spreading leaves on the top. And their contribution to total standing crop expected to be greater than that of their contribution to VO measurement. Therefore, stratification of data in different vegetation groups before regression determination may also be expected to result in different relations.

As mentioned previously, when we clip sampling plots, we discarded dead material and hence it did not contribute to total standing crop. Whereas, in VO measured before vegetation clipping, plant dead material can contribute to VO measurement (Vermeire and Gillen 2001, Whitbeck and Grace 2006). Also, Whitbeck and Grace (2006) documented that inclusion of the percent dead variable in the VO regression raised the percentage of explained variance in standing crop from 35% to 55%. They further discussed that results indicate that magnitude of dead material presence did compromise the ability of the VO technique to predict standing crop efficiently. While during the current study, there was significant amount of standing dead material at our study site.

Additional potential confounding influence is likely that, surface microtopographic variance (e.g., zoogenic micro-hills, micro-terraces and hummock) might also make even more difficult to accurately predict SC through VO. Finally, we conclude that a complex and interacting set of management and environmental factors must be considered when measuring, predicting, or managing rangelands through visual obstruction technique.

Conclusions

Results obtained from the current study show that the VO technique is not accurate in predicting the current year's standing crop across the diverse plant communities of northwestern bunchgrass prairie areas such as those found on the Zumwalt Prairie Preserve. Visual obstruction is a valuable technique for evaluating the amount of plant cover as it relates to wildlife species and may have use to managers as a rough estimate of standing crop, especially when used to compare grassland communities of similar structure across space or the same communities across time. However, we recommend that in all cases, investigators should calibrate VO technique against clip plots to evaluate its accuracy in specific situations.

Acknowledgments

The project was supported by the National Research Initiative of the USDA Cooperative State Research, Education and Extension Service, grant number 2006-35101-16572, The Nature Conservancy and Oregon State University's Eastern Oregon Agricultural Research Center. We thank Uranbileg Daalkhaijav, Samuel Wyffels, and Amartuvshin Daalkhaijav for their assistance with the field work. Our gratitude extends to Phil Shephard and Angie Freeman who assisted us with many logistical details while on the study area.

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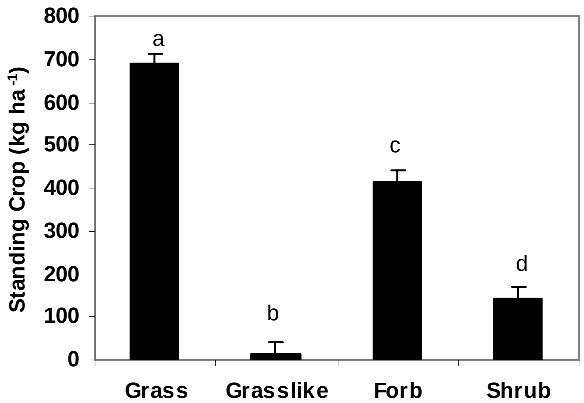

Figure 1. Standing crop by growth habit of bunchgrass communities on the Zumwalt Prairie Preserve in northeastern Oregon. Data are presented as the mean ± SEM. Bars with different letters are different at $P < 0.05$.

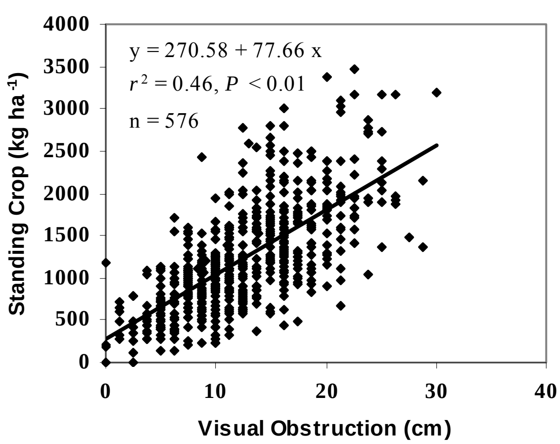

Figure 2. Relationship between standing crop (y) and visual obstruction measurements (x) of northwestern bunchgrass communities on the Zumwalt Prairie Preserve in northeastern Oregon.