Technical Note

Digital Photography: Reduced Investigator Variation in Visual Obstruction Measurements for Southern Tallgrass Prairie

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Abstract

Landscapes with structural heterogeneity or patchiness can support diverse and stable wildlife populations. Visual obstruction methods (i.e., Robel pole and Nudd's coverboard) are common and useful techniques for quantifying vegetation structure; however, both rely on ocular estimations, which can be highly variable between observers. Our objectives were to 1) compare measurement and observer variation for visual obstruction among the two standard methods and the digital image method we developed using a digital camera; and 2) compare the performance of the Robel pole and digital image to estimate standing crop. The mean variation across the five observers using the digital image method (6.8%) was significantly lower ($P < 0.05$) than both the Nudds' coverboard (32.1%) and the Robel pole (52.2). There were no significant differences among locations for the digital image method; however, there were for both the Robel pole and Nudds' cover board ($P < 0.05$). The digital image method provided a better estimate of standing crop ($r^2 = 0.89$) compared to the Robel pole ($r^2 = 0.68$), accounting for 21% more of the observed variation in biomass. Long-term research programs that utilize seasonal field technicians to quantify habitat structure with a visual obstruction method could benefit from implementing use of the digital image method we developed. The low measurement error observed with this technique relative to the more traditional methods compared in this study might limit year-to-year and within-year variability of habitat structure data collected by numerous technicians with a high annual turnover.

Resumen

Los paisajes con una hetrogeneidad estructural o con muchos parches pueden sostener poblaciones diversas y estables de fauna silvestre. Los métodos de obstrucción visual (por ejemplo, el poste de Robel y la tabla de cobertura de Nudd) son técnicas comunes y útiles para cuantificar la estructura de la vegetación; sin embargo, ambas dependen de estimaciones oculares, las cuales pueden ser altamente variables entre observadores. Nuestros objetivos fueron: 1) comparar las mediciones y la variación de los observadores en la obstrucción visual entre los dos métodos estándar y el método de imagen digital que desarrollamos usando una cámara digital; y 2) comparar el comportamiento de los métodos el poste de Robe y de imagen digital para estimar la biomasa aérea. La variación media entre los cinco observadores usando el método de imagen digital (6.8%) fue significativamente menor ($P < 0.05$) que los métodos de la tabla de cobertura de Nudd (32.1%) y el poste de Robel (52.2%). No hubo diferencias significativas entre localidades para el método digital; sin embargo, si la hubo para los métodos de la tabla de cobertura de Nudd y el poste de Robel ($P < 0.05$). El método de imagen digital proveyó una mejor estimación de la biomasa ($r^2 = 0.89$), comparado con el método del poste de Robel ($r^2 = 0.68$), explicando 21% más de la variación observada en la biomasa. Los programas de investigación a largo plazo que utilizan técnicos de campo en forma estacional para cuantificar la estructura del hábitat con un método de obstrucción visual pudieran beneficiarse de la implementación del uso del método de imagen digital que desarrollamos. El bajo error de las mediciones observado con esta técnica en relación con los métodos más tradicionales comparados en este estudio pudiera reducir la variabilidad entre años y dentro del año de los datos de la estructura del hábitat colectados por numerosos técnicos con una alta tasas de rotación.

Key Words: biomass, sampling variation, techniques, wildlife habitat

INTRODUCTION

Landscapes with structural heterogeneity, i.e., patchy vegetation, as found in tallgrass prairie, support diverse and stable wildlife populations (Roth 1976; McGarigal and McComb 1995). A variety of measurements of the two-dimensional vegetation structure from a vertical and horizontal perspective are used to assess wildlife habitat (Higgins et al. 2005) and are essential to many other ecological disciplines, including rangeland management. Visual obstruction methods from a vertical and horizontal perspective are common and useful techniques for quantifying vegetation structure (Robel et al. 1970; Nudds 1977; Higgins et al. 2005). Rapid and accurate description of vegetation structure is crucial to assessing wildlife habitat, and vegetation structure is especially important for avian habitat assessment (Roth 1976; Haensly et al. 1987; McGarigal and McComb 1995; Sutter and Brigham 1998).

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Manuscript received 1 October 2006; manuscript accepted 17 May 2007.

Estimates of standing crop in tallgrass prairie (e.g., by clipping herbaceous vegetation) also provide essential information used in developing proper land management strategies. However, clipping herbaceous vegetation is labor intensive, and therefore clipping often is replaced with visual obstruction estimates such as the Robel pole or Nudds' coverboard (Vermeire and Gillen 2001; Higgins et al. 2005).

Because most of the common horizontal and vertical visual obstruction methods depend on ocular estimations of both vegetation height and density of the plant material, visual obstruction methods carry inherent potential to introduce excessive measurement error together with investigator variation (Schultz et al. 1961; Gotfryd and Hansell 1985; Block et al. 1987; Collins and Becker 2001; Higgins et al. 2005). For example, Hall and Max (1999) noted that observer variation represented 20% of the variation among visual estimates of shrub twig length. That is not to say that when a visual obstruction technique is mastered and a limited number of technicians collect the data, accurate and reliable results are not possible (Volesky et al. 1999; Ganguli et al. 2000; Collins and Becker 2001; Vermeire and Gillen 2001). However, accuracy using ocular sampling methods can be compromised by high technician turnover and inexperienced labor.

Increasing the sample size is often the approach used to overcome large measurement error together with observer variation, but increased sample size translates into increased sampling time and costs. Other techniques for measuring habitat structure, such as the cone of vulnerability (Kopp et al. 1998), can reduce measurement error and observer variation (Harrell and Fuhlendorf 2002), but they are limited to a few habitat types, and they are labor intensive. Photography (aerial and satellite images), along with radar and LIDAR (Light Detection and Ranging), have been used to map and monitor vegetation change through time (Mullerova 2004; Boyd and Svejcar 2005; Higgins et al. 2005), but remote sensing has not yet been used to measure horizontal visual obstruction in tallgrass prairie. Hence, our objectives were to 1) compare measurement variation (precision) for horizontal visual obstruction among the two standard methods (Robel et al. 1970; Nudds 1977) and the digital image method we developed using a digital camera at a typical tallgrass prairie site in Oklahoma; and 2) compare the performance of the Robel pole and digital image to estimate standing crop at the same site. Ideally, the digital image technique would have the following attributes: 1) low measurement variance (high precision), 2) ease of use, and 3) low cost. We discuss these attributes as they relate to sampling vegetation structure and mass with a digital camera on rangelands.

METHODS

Development of the protocol for the digital horizontal visual obstruction method involved capturing a series of digital images of vegetation using a tripod mounted Canon PowerShot® A520 camera (4 megapixels) and standard factory lens placed at a distance of 4 m from the sampling point and at a camera lens height of 1 m, similar to that described for the Robel pole (Robel et al. 1970). Tallgrass prairie vegetation was photographed, on calm days, using white plastic sheeting

Figure 1. Example of a digital image **(A)** imported to Adobe Photoshop®. The color image was converted to black and white **(B)**.

fastened to a 1 × 1 m frame positioned as a backdrop to the sampled vegetation point (Fig. 1A). Height reference points spaced at 0.1 m were marked on each vertical side of the board using a 2.5-cm black dash. Vegetation and backdrop occupying the camera viewfinder were maximized. Digital images were imported into CS2 (Adobe Systems Inc, San Jose, CA) and cropped such that only the 1 × 1 m backdrop and vegetation remained in the field of view. We used the Adobe Photoshop® software threshold function in the image menu to convert the color images to binary black and white images. The threshold value determined the amount of luminance (amount of light reflected from an object) necessary to convert an individual pixel to either black or white, with all values higher than the threshold value converted to white, and the lower values converted to black. Those pixels above the threshold values corresponded to the white background, whereas lower values were vegetation and shadow. We selected one threshold setting for all images (128), which was often the default setting, to reduce unnecessary variation. Threshold values below 128 did not convert all of the color pixels to black based on the original color photograph, and values over 128 often converted white pixels to black. After conversion to a binary image (Fig. 1B) the histogram feature was used to provide the percentage of black and white pixels in each image. We defined visual obstruction as the percent black pixels in each image tallied by the software.

To assess measurement variation (precision) among the three horizontal visual obstruction methods (i.e., Robel pole, Nudd's coverboard, digital image method) and to compare the performance of the Robel pole relative to the digital image to estimate standing crop, we conducted a study in a 3-ha tallgrass prairie remnant in Payne County, Oklahoma (lat 36°10′N, long 97°5′W). Ten vegetation sampling locations were systematically selected to maximize structural heterogeneity along the continuum found within the study area. Horizontal visual obstruction measurements using standard techniques for the Robel pole and Nudds' coverboard (Robel et al. 1970; Nudds 1977) and the digital image method were recorded independently by five technicians, four times in rapid sequential order (20 observations per method) at the same point within each of the ten sampling locations. The digital image backdrop and camera were removed after each individual image, and were recentered at the same location in an effort to sample the same vegetation structure. The height and line of site among observers for all methods were done at 1 m in height and 4 m from the sampling point. The technicians were inexperienced with visual obstruction; however, they did receive instruction on proper use of the three visual obstruction methods in the classroom and in field demonstrations.

The variability (precision) of multiple measurements from the same observer was estimated using coefficient of variation (CV). A CV was calculated for each observer using the four different readings at each location for all method–location combinations. The measurement variability among the three methods and the ten locations was tested using repeated measures analysis of variance. In the repeated measures analysis the five observers (experimental units) were treated as replications with the ten locations and the three methods treated as fixed variables. Locations were treated as fixed rather than random variables because locations were selected to represent different cover levels rather than being a random selection of the locations, and we wanted to infer whether measurement variability within each method is different at the selected locations (Schabenberger and Pierce 2002). Repeated measures analysis was used because measurements over the ten locations from the same five observers could be correlated. The SAS/STAT® software procedure PROC MIXED (SAS Institute 2004) was used for the analysis because the variance and covariance structures present can be modeled. The Akaike information criterion (AIC) was used to guide the selection of the variance-covariance model used in the analysis (Burnham and Anderson 1998). The unstructured covariance model had the lowest AIC value among various other covariance models tried and was selected for the final analysis. The probability levels for the multiple comparisons tests were adjusted using the Tukey procedure.

To estimate the number of samples required to adequately measure the horizontal visual obstruction of the study location, sample adequacy for each method was estimated at 95% confidence and within 10% of the true mean using the equation $n = (t_\alpha SD)^2/(a\bar{x})^2$ where a = accuracy and α = precision (Zar 1984). Specific sampling protocols vary with different vegetation types; however, our objective was to provide an estimate of sample adequacy, not to estimate the visual obstruction for our study site.

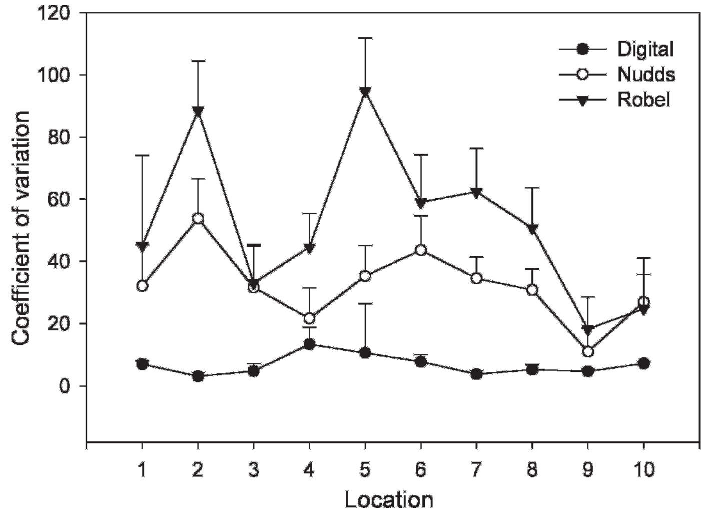

Figure 2. Mean coefficient of variation from the five observers for each method by location. Only positive standard deviation bars are shown to reduce clutter in the graph.

To compare the Robel pole and digital image processing methods of estimating herbage mass, we measured horizontal visual obstruction at 50 locations. We then determined herbage mass at these locations using a 0.25 × 0.5 m frame centered directly in front of the Robel pole and digital image backdrop. All Robel pole measurements were taken by a single observer to minimize observer variation. Clipped herbage was bagged and dried at 50°C until mass stabilized (8–9 days). The data on herbage mass as a function of visual obstruction was fitted with polynomials using regression (SPSS 2005) with the AIC used for model selection.

RESULTS

Measurement variation (precision) varied greatly among the three methods for this tallgrass prairie site. The CV values averaged over the 10 locations were significantly lower for the digital image method (6.8%) compared to both the Nudds' coverboard (32.1%) and the Robel pole (52.2%; $P < 0.05$; Fig. 2). The CV among the locations was significantly different along with the interaction between the location and method ($P < 0.05$). Comparisons of the mean CV values between each location within a method found that there were no significant differences between locations for the digital method ($P > 0.05$; Fig. 2). There were significant differences between some locations for both the Nudds and Robel method ($P < 0.05$). Significant differences between the various locations within the Nudds and Robel method are most likely the reason for the interaction of location and method. Based on the data recorded and assuming that the sites selected for measurement were representative of the tallgrass prairie site, 20 samples would have been needed for the digital image technique to adequately sample the horizontal visual obstruction at our study location (95% confidence) compared to 158 and 233 for the Robel pole and Nudds' coverboard, respectively.

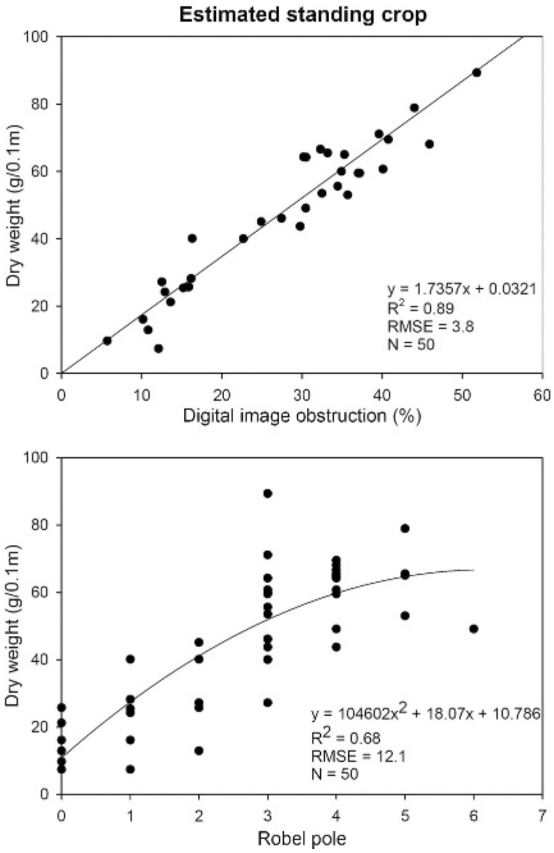

Figure 3. Lines fit by linear and polynomial regression estimating herbage standing crop (dry weight) with two methods of visual obstruction (digital image, top, and Robel pole, bottom). The digital image method utilizes the number of black and white pixels to determine percent cover.

The regression model with the best fit between the digital image obstruction and herbage mass was the linear model (root mean square error [RMSE] = 3.8). The best fit model between the Robel pole obstruction and herbage mass was the quadratic model (RMSE = 12.1; Fig. 3). Values of zero excluded the logarithmic model from the analysis of the Robel pole. The digital image method provided a better estimate of herbage mass, as determined by horizontal visual obstruction ($r^2 = 0.89$, $P < 0.001$), compared to the Robel pole ($r^2 = 0.68$, $P < 0.001$), accounting for 21% more of the observed variation in biomass (Fig. 3). Others (Robel et al. 1970; Ganguli et al. 2000; Vermeire and Gillen 2001) reported similar r^2 values for the Robel pole. The digital image method estimates herbaceous biomass more reliably than the Robel pole for tallgrass prairie. Residuals for the digital image method are more evenly distributed at all standing crop values than the Robel pole. This suggests that it is a more robust method, and not biased toward low, medium, or high standing crop values.

DISCUSSION

Long-term research programs that utilize seasonal field technicians to quantify habitat structure with a horizontal visual obstruction method could benefit from implementing the digital image method we developed. The low measurement variation with this technique relative to the traditional horizontal visual obstruction methods has the ability to limit year-to-year and within-year measurement variability for tallgrass prairie. The digital method is probably not prone to the affects of high annual technician turnover because the method is not dependent on trained technicians asked to visually estimate obstruction.

The digital image technique used to estimate horizontal visual obstruction was relatively rapid and produced low measurement variation (high precision) in comparison to the two standard visual methods for tallgrass prairie. The time required to measure visual obstruction at a given sampling point is comparable among the three methods tested (15 seconds per sample); however, additional lab analysis is required for the digital image method to convert the digital image. Once imported, each image required an average of 30 seconds to complete the analysis process. However, the additional lab analysis time required is relatively small compared to the additional field time required (8× and 12×, respectively) by the Robel pole and Nudds' coverboard. Overall, landscape level sampling with the digital image method requires less time due to the reduced sample size required to accurately estimate horizontal visual obstruction.

The strong relationship between clipped herbaceous biomass and the digital method points to how this method might be better related to the actual horizontal vegetation structure than the other methods. Both the Nudds and Robel method have been criticized for being estimates and not accurately reflecting the actual vegetative structure (Higgins et al. 2005). A standard method of measuring actual cover is debated with no accepted way of accessing accuracy (Booth et al. 2006; Laliberte et al. 2007). In fact, Booth et al. (2006) used a digital image as a known standard for a 2-dimensional study of different cover estimation methods.

Horizontal visual obstruction produced by the digital image is relative to the size of the backdrop, which must be noted when reporting the measurements, similar to reporting the size quadrat used for estimating plant species density or biomass. Backdrops other than 1 m × 1 m might be better suited in other ecosystems (e.g., shortgrass prairie or sagebrush steppe), thus sampling protocol is site-specific and will need to be developed accordingly to account for unique vegetation and landscape conditions. Other investigators have used digital image techniques with colored backdrops and color recognition software to estimate vegetation measurements (Boyd and Svejcar 2005); however, we found the white backdrop and converted black vegetation in the foreground to be a simple and reliable combination for digital horizontal visual obstruction estimates. However, with white backdrops, shadows cast by the surrounding vegetation and crew members relative to the sun are major drawbacks to the digital image method, so careful backdrop placement is necessary, along with timing sampling efforts with the position of the sun.

The total cost of field equipment for this technique was \$600. Digital cameras, similar to the camera used in this experiment, range in price between \$100 and \$300 (US currency). The image processing software is readily available through most software suppliers or can be purchased directly from the manufacturer for \$300. The backdrop, frame, and camera tripod totaled \$35, and can be used for multiple years.

This relatively low cost would easily fit into most sampling budgets, especially when considering the labor savings over several sampling seasons.

MANAGEMENT IMPLICATIONS

Relatively large sample sizes for sampling adequacy are common with traditional visual obstruction methods (Higgins et al. 2005). Given that the digital method studied here had low measurement variability (high precision) compared to the other popular methods, it is the more desirable visual obstruction method. The decreased sample size for accurate measurements enables land managers to monitor additional sites with little or no increased cost and effort, which promotes greater habitat quality.

LITERATURE CITED

Block, W. M., K. A. With, and M. L. Morrison. 1987. On measuring bird habitat: influence of observer variability and sample size. *The Condor* 89:241–251.

Booth, D. T., S. E. Cox, T. W. Meikle, and C. Fitzgerald. 2006. The accuracy of ground-cover measurements. *Rangeland Ecology and Management* 59:179–188.

Boyd, C. S., and T. J. Svejcar. 2005. A visual obstruction technique for photo monitoring of willow clumps. *Rangeland Ecology and Management* 58:434–438.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information—theoretic approach. New York, NY: Springer-Verlag. 353 p.

Collins, W. B., and E. F. Becker. 2001. Estimation of horizontal cover. *Journal of Range Management* 54:67–70.

Ganguli, A. C., L. T. Vermeire, R. B. Mitchell, and M. C. Wallace. 2000. Comparison of four nondestructive techniques for estimating standing crop in shortgrass plains. *Agronomy Journal* 92:1211–1215.

Gotfryd, A., and R. Hansell. 1985. The impact of observer bias on multivariate analyses of vegetation structure. *Oikos* 45:223–234.

Haensly, T. F., J. A. Crawford, and S. M. Meyers. 1987. Relationships of habitat structure to nest success of ring-necked pheasants. *Journal of Wildlife Management* 51:421–425.

Hall, F. C., and T. Max. 1999. Test of observer variability in measuring riparian shrub twig length. *Journal of Range Management* 52:633–636.

Harrell, W. C., and S. D. Fuhlendorf. 2002. Evaluation of habitat structural measures in a shrubland community. *Journal of Range Management* 55:488–493.

Higgins, K. F., K. J. Jenkins, G. K. Clambey, D. W. Uresk, D. E. Naugle, J. E. Norland, and W. T. Barker. 2005. Vegetation sampling and measurement. *In*: C. E. Braun [ed.]. Techniques for wildlife investigations and management. 6th ed. Bethesda, MD: The Wildlife Society. p. 524–553.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. *Journal of Wildlife Management* 62:884–895.

Laliberte, A. S., A. Rango, J. E. Herrick, E. L. Fredrickson, and L. Burkett. 2007. An object-based image analysis approach for determining fractional cover of senescent and green vegetation with digital plot photography. *Journal of Arid Environments* 69:1–14.

McGarigal, K., and W. C. McComb. 1995. Relationships between landscape structure and breeding birds in the Oregon coast range. *Ecological Monographs* 65:235–260.

Mullerova, J. 2004. Use of digital aerial photography for sub-alpine vegetation mapping: a case study from the Krkonose Mountains, Czech Republic. *Plant Ecology* 175:259–272.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. *Wildlife Society Bulletin* 5:113–117.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. *Journal of Range Management* 23:295–297.

Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. *Ecology* 57:773–782.

Schabenberger, O., and F. J. Pierce. 2002. Contemporary statistical models for the plant and soil sciences. Boca Raton, FL: CRC Press. 738 p.

Schultz, A. M., R. P. Gibbens, and L. Debano. 1961. Artificial populations for teaching and testing range techniques. *Journal of Range Management* 14:236–242.

SAS Institute, Inc. 2004. SAS OnlineDoc 9.1.3. Cary, NC: SAS Institute, Inc. 1906 p.

[SPSS] Statistical Procedures for Social Science. 2005. SPSS Guide to data analysis, release 14.0. Old Tappan, NJ: SPSS. 652 p.

Sutter, G. C., and R. M. Brigham. 1998. Avifaunal and habitat changes resulting from conversion of native prairie to crested wheat grass: patterns at songbird community and species levels. *Canadian Journal of Zoology* 76:869–875.

Vermeire, L. T., and R. L. Gillen. 2001. Estimating herbage standing crop with visual obstruction in tallgrass prairie. *Journal of Range Management* 54:57–60.

Volesky, J. D., W. H. Schacht, and P. E. Reece. 1999. Leaf area, visual obstruction, and standing crop relationships on Sandhills rangeland. *Journal of Range Management* 52:494–499.

Zar, J. H. 1984. Biostastial analysis. Engelwood Cliffs, NJ: Prentice Hall. 718 p.