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The Use of Stereoscopic Photography to Estimate Browse Use by Large Ungulates

Abstract

We developed a stereophotographic technique to estimate browse use by moose. We collected 30 whole plant specimens representing 4 different browse species and placed them in an outdoor compound on the campus of The University of Northern BC. We physically counted all branches on each plant and categorized them as recently browsed, browsed prior to the preceding winter, or unbrowsed. Then, we stereophotographed the plants against a white backdrop in ambient outdoor light. We viewed stereopair prints under a stereoviewer and classified them using the same method as was used in manual counting. We found that this stereophotographic technique tended to underestimate total browse removal, but allowed us to determine browse availability (the number of unbrowsed shoots) and percentage of plant shoots removed by browsing for all species examined. Of the 4 species we examined, we were able to most accurately determine the number of total browsed shoots through stereoscopy on *Cornus stolonifera*, *Acer douglasii* and *Salix scouleriana* while the percentage of newly browsed shoots was best determined on *Betula papyrifera*, *A. douglasii* and *C. stolonifera*. Our findings suggested that estimating browse supply with stereophotography is possible, whereas estimating browse use is more appropriate for some species, but not for others. With adjustments, the method may be useful in reducing field time and costs involved with spring browse surveys.

Introduction

Rangeland ecologists and wildlife biologists often undertake browse-use surveys in the spring to quantify winter browse-use by ungulates. Methods have included shoot counts (Dumont et al. 2000, Tremblay et al. 2005), counts of bite marks (Ball and Dahlgren 2002), calculations of percent browse removal (percentage of shoots cropped/unbrowsed shoots) (Bowyer and Bowyer 1997), and estimates of biomass removal (Bobek and Bergstrom 1978, Foroughbakhch et al. 2005, Persson et al. 2005). Although these methods have proven useful, all require considerable effort in the field to complete the surveys. Consequently, researchers have begun to experiment with innovative ways to reduce the time and costs associated with browse surveys.

Stereophotography has been used by archaeologists (Warner 1995, Andries et al. 2005, Tack et al. 2005), geomorphologists and civil engineers (Warner 1995), aquatic and marine biologists (van Rooij and Videler 1996, Evans and Norris 1997, Schierup et al. 2002), botanists (Wang and Li 2005), and medical researchers for a variety of analytical purposes (Hood 1986, Morton 1989). Although 2-dimensional photographic monitoring has been used as a means to reduce field effort when measuring changes in plant biomass (Boyd and Svejcar 2005), stereophotography does not appear to have been used previously for estimating browse-use.

Because stereophotography provides a 3-dimensional perspective, better resolution of plant attributes is possible with 3-dimensional relative to 2-dimensional photography (Bullimore and Hiscock 2001). We explored the utility of using a stereophotography technique to reduce the amount of field time required for assessing browse-use of woody deciduous shrubs and trees by large ungulates. Specifically, we sought to determine if a stereophotographic technique could help us quickly and accurately record: a) the number of current annual shoots of a plant; b) the total number of shoots that were browsed relative to those that were unbrowsed; and c) the number

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of recently (during the previous winter) browsed shoots relative to those that had been browsed in the more distant past.

Study Area

Our study was conducted on an approximately 20 ha area located adjacent to the University of Northern British Columbia endowment lands near Prince George, B.C., Canada (53° 53′ N, 122º 48′ W). The topography in our study area is rolling and the site elevation is 780 m. The climate is continental and characterized by seasonal extremes with cold winters and warm, moist summers. Mean annual precipitation is approximately 46 cm; snow fall averages approximately 200 cm and mean annual temperatures range from 1.7 to 5.0 °C (Atmospheric Environment Service 1993). The study area was clear cut logged approximately 15 years prior to the study. Trembling aspen (*Populus tremuloides* Michx.) is the dominant species on the site, with pioneering species such as willow (*Salix* spp.), paper birch (*Betula papyrifera* Marsh.) and alder (*Alnus* spp.) also present. Moose and deer (*Odocoileus* spp.) are both native to the area and use browse within the study site. Our observations, however, indicate that most of the browsing in our study area is done by moose (~1.35 individuals km^{-2}; Walker et al. 2006).

Methods

In the spring of 2004, we collected 30 specimens of *Cornus stolonifera* Michx., *B. papyrifera* Marsh., *Acer glabrum* Doug., and *Salix scouleriana* Barratt ex Hook. for analysis from the study area. All specimens were important browse species in the area and showed signs of several seasons of having been browsed by ungulates. In an effort to test the robustness of our technique and sample a broad cross-section of available morphometries, we selected specimens of each species in a systematic way, such that plants varied in size (~40 – 220 cm), architecture (tree-like vs. hedged), and degree of previous browsing.

We collected plants by cutting them at the stump (approximately 10 cm above the ground) before spring leaf flush and transported them to the Enhanced Forestry Lab at the University of Northern BC. In the lab's outdoor compound, we manually counted the shoots of each plant and categorized them as being unbrowsed, browsed during the previous winter, or browsed prior to the previous winter season. We were able to distinguish between recent browsing and older browsing by determining the presence of subapical shoot release below the bite mark and the amount of weathering at the bite mark. Recently browsed shoots were free from discoloration and wound healing attributes that appear on shoots that had been healed over during the previous growing season(s). We gave all plants a distinct identifier and stored whole plants at the lab until photographed in the days following collection.

After completing manual counts, we positioned plants, one at a time, against a white backdrop and photographed them from 2 slightly different angles (approximately 15 cm apart) to obtain a stereo image of the plant. We photographed plants outside in natural light using a Canon AE-1 single lens reflex camera with a 50 mm lens using the camera's automatic exposure system on Fuji 200 ISO color print film. We positioned the camera to take advantage of natural light. Film was processed at a professional photo lab and printed in a glossy 5 x 7 inch format. We then placed image pairs of each plant under a stereoviewer (Geoscope stereoaid RD70.485) in a well-lit lab and collected the same data as in the manual counts. When using the stereophotograhic technique, shoots were not classified or tallied if we could not positively determine if they had been or had not been browsed.

Statistical Analyses

We examined the data to determine how closely counts for unbrowsed, recently browsed and previously browsed shoots from stereophoto analysis compared with manual counts. We ploted residuals and examined them for evidence of linearity, homoscedasticity, and outliers. We removed outliers (defined as a standard residual > 2 times SD) from the dataset using standard statistical leveraging procedures. We tested the data for normality (Shapiro-Wilks) and homogeneity of variance (Levene's test; Sokal and Rohlf 1995). These tests showed that the assumptions for a valid F-statistic were violated. Further, we were unable to obtain normalized data via transformation. Accordingly, we used a rank sum test (Gould and Gould 2002) to test if the 2 techniques (manual and stereophotography) yielded the same results. All analyses were conducted in Stastica (Statsoft 2002).

Results

Our results showed that the stereophotographic technique tended to underestimate the manual browse counts (Figure 1), albeit underestimation was only significant when comparing techniques used on *B. papyrifera* (Figure 1a) and *S. scouleriana* (Figure 1c). The stereophotographic technique performed best when used for analyzing: 1) The total percentage of browse removal (Figure 1d) and the total number of unbrowsed shoots (Figure 1b) on all species we examined (estimates made with the two techniques were not significantly different, regardless of species); 2) *A. glabrum*, *C. stolonifera* and *S. scouleriana* for determination of the total number of browsed shoots (Figure 1a) and; 3) *B. papyrifera*, *A. glabrum* and *C. stolonifera* for the total number of newly browsed shoots (Figure 1c).

Discussion

With few exceptions, our stereophotographic technique performed well for estimating the total number of browsed and unbrowsed shoots per plant for all 4 species studied. In 14 of 16 tests we found no significant difference between shoot counts made manually and those obtained with stereophotography. Where significant differences existed, such differences were attributable to the stereophotographic technique underestimating the total number of browsed shoots of *B. papyrifera* as well as the number of shoots recently browsed on *S. scouleriana*.

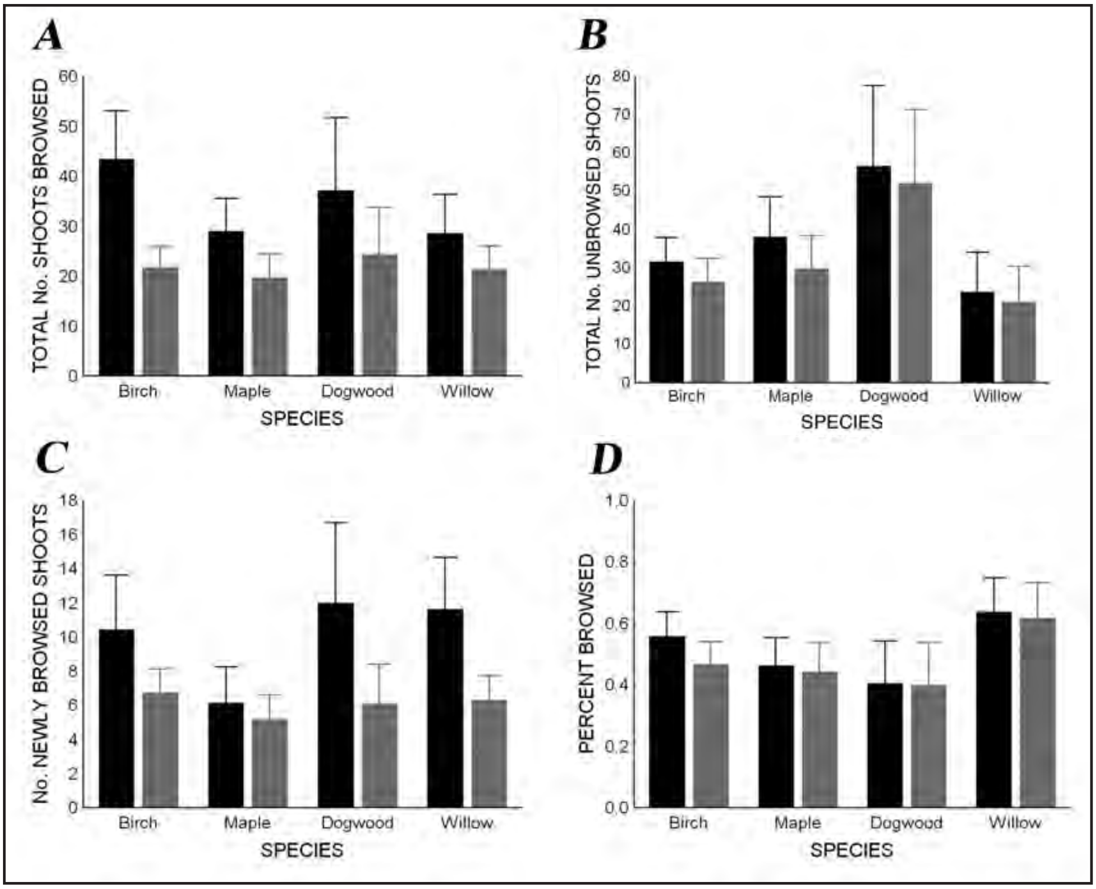

Figure 1. Comparing the stereophotographic technique (black bars) to the manual count (grey bars) for the (A) average (± 95% CI) number of shoots browsed (recently or during previous years) per plant, (B) average (± 95% CI) the number of unbrowsed shoots per plant, (C) average (± 95% CI) number of shoots browsed during the previous year per plant, and (D) the average (± 95% CI) percent of browsed shoots per plant. A significant difference between the techniques (α = 0.05) was only detected for Total Browsed Birch (A) and Newly Browsed Willow (C).

Despite our inability to always accurately determine the number of browsed *S. scouleriana* and *B. papyrifera* shoots per plant with the stereophotographic technique, the accuracy of our predictions were reasonable between the techniques for measurements such as percent shoots browsed per plant. Our results suggested that while we were not always capable of accounting for all shoots on plants through the use of the stereophotographic technique, we essentially missed counting unbrowsed shoots as often as browsed shoots, resulting in our assessments of percent use being reflective of herbivory on individual plants.

Although our ability to determine the total number of browsed shoots and the total number of newly browsed shoots per plant was unequal between species, the use of stereophotography appeared to work consistently well for plants such as *A. glabrum* and *C. stolonifera*. Why the technique performed less well for *S. scouleriana* and *B. papyrifera* is unknown, but appeared to be related to plant height and architecture. In our study area, both *S. scouleriana* and *B. papyrifera* tend to be tall growing species that eventually grow into trees whereas *A. glabrum* and *C. stolonifera* remain as shrubs (especially when used heavily by moose). Because some of the willow and birch we analyzed were in the transition from sapling to tree size, many of the shoots of their crowns were above our tripod/camera set up (≥ 1.5 m). Thus, the angle required to photograph the plant made it difficult to photograph the shoot tips of the plant crown and subsequently made it complicated for us to conclusively determine if shoots were or were not browsed when analyzing stereo pairs. Furthermore, the shoots at the top of taller plants were farther from the camera lens and were sometimes found to be out of focus relative to those shoots lower down on the plant and closer to the camera. This was especially true for the smaller bite marks common on birch, which moose browse at smaller diameters in our area (an average of 2.6 mm, R.V. Rea, unpublished data) than the diameters at which they browse other species such as maple, dogwood, and willow (an average of 4.0 mm; Carson et al. 2007).

In contrast to the difficulties we encountered in determining whether or not shoots had been browsed, our results suggest that it was much easier and more accurate for us to positively identify and classify unbrowsed shoots using stereophotography. Assessing the total number of unbrowsed shoots with the technique was the most accurate of the four tests we performed and worked well for all four species examined. This result indicates the potential strengths of the technique for assessing browse supply or abundance per plant regardless of whether or not plants have been previously browsed.

The performance of our stereophotographic technique in estimating browse-use is reflected in determinations of browse levels or amount browse removed from the various species and speaks to the utility of the technique for performing browse surveys. Our main objective was to assess whether stereophotography would be useful for quicker field assessments of browse-use than traditional techniques (Joyal 1976, Bowyer and Bowyer 1997). Although the technique performed well for determining the number of shoots in general and identifying the proportion of browse shoots removed by herbivores for shrubbier species, it performed less well when assessing taller plants. Our inability to distinguish newly versus total (earlier and newly) browsed shoots precludes the type of robust analysis of current year browse use that we were hoping the technique would provide. Even so, depending on the species in question, the technique is still likely to outperform ocular estimates (Litvaitis et al. 1996) or bring higher resolution to browse use assessments than the implementation of categorical groupings of browse use (Hörnberg 2001).

Evaluating the Technique

Several factors appeared to limit our ability to make accurate determinations of which shoots have been recently, versus previously, browsed. These appear to be attributable to biotic and technical factors.

As previously discussed, plant heights above the angle at which the camera could capture shoot tips and the inability to be able to resolve small bite diameters in our stereo pairs seemed to limit the effectiveness of the stereophotographic technique for species such as birch. Additionally, although unquantified, the contrast between the color of the plant bark and woody cortex also influenced our ability to clearly distinguish bite marks in our photos. Exposed and lighter-colored stem cortex materials in *C. stolonifera* and *A. douglasii* stems were much easier to distinguish against a burgundy-colored bark than we found possible for plants such as willow, where bark and cortex colors were more similar.

Resolving the technical problems associated with plant architecture may be difficult, but we believe that improving image quality/resolution might facilitate distinguishing bite marks where bark and cortex colors are similar. Shallow depth of field in some stereophoto pairs prevented us from accurately assessing which shoots were browsed and which were unbrowsed. In photos where depth of field was greater, shoot attributes were more discernable. Yet, plant characteristics such as shrub versus tree form and color contrast between bark and cortex may always limit a broader application of the stereophotographic technique for use in assessing all browse species.

Photographic quality could be improved by maximizing depth of field and using optimal lighting (Langford 1998). Although it could be argued that our experiment was conducted in a highly simplified and unnatural environment, we photographed plants in a setting that allowed us to specifically control for the photographically complex environment found in the field. We recommend professional level color print or transparency film with a maximum ISO of 100 or professional level digital images (minimum 2400 x 3000 pixels or print size of 8 x 10 inches at 300 dpi). We suggest the use of a stereo camera, stereo attachment, or sliding bracket (inter-ocular distance adjuster) to record images (Langford 1998), which could help reduce errors stemming from repositioning the tripod between photographing specimens.

Because distinguishing plants from one another in the field is difficult, we have experimented with a white plastic curtain or cloth as a backdrop to enhance the contrast between individual shoots and between study plants and their surroundings. Both our lab experiments and subsequent field testing suggested that photos should be taken at higher angles to ensure that no branches are excluded from counting. Eliminating shadows from other parts of the plant through the use of artificial light might allow for a clearer assessment of whether or not shoots were browsed.

Conclusions

Our findings suggest that stereophotography may be able to be used to estimate browse supply or abundance on four different species of browse plants, although further improvements on the stereophotographic technique are necessary. If refinement to the technique produces better estimates of browse removal by large ungulates, the technique can likely improve browse surveys in general and should outperform surveys that determine degree of browsing with the use of categorical measurements (e.g., slight: <1/3, moderate: 1/3-2/3, and severe >2/3; Hörnberg 2001).

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