COMBINING PHOTOGRAPHY AND A GEOGRAPHIC INFORMATION SYSTEM TO MEASURE WINTER BROWSE USE

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ABSTRACT: Browse use surveys such as the twig-length method typically used to assess browsing by ungulates are time-consuming and costly. Here, we describe a modification of the twig-length method that utilizes digital photography and a Geographic Information System (GIS) technique to quantify browse shoot removal. Linear regression analysis indicated that the cumulative shoot length (cm) and biomass removal (g) estimated with our indirect method was similar to direct measurements on Scouler's willows (*Salix scouleriana*). Our results suggest that this indirect browse assessment procedure could reduce field time, presumably increase sample size and efficiency, and create a photographic record of each plant for long-term assessment of moose (*Alces alces*) browsing.

Measuring winter browse utilization of trees and shrubs by ungulates is performed by ecologists to understand ungulate diet choice and feeding requirements, and to provide important information for sound range and ungulate management programs (Jensen and Urness 1981). Quantifying browse removal by herbivores is also fundamental to understanding the ecology of shrub and tree communities that are consumed (Bilyeu et al. 2007). Methods for determining browse use include detailed twig counts before and after ungulate browsing and percent shoot removal calculations (Stickney 1966, Dumont et al. 2000, Ball and Dahlgren 2002), as well as various techniques to estimate the amount of biomass removal (Bobek and Bergström 1978, Rutherford 1979, Persson et al. 2005) including broad browsed/form classification systems (Schmutz 1983, Luttmerding et al. 1990). Many of these procedures, however, are time-consuming and expensive, with certain techniques requiring both fall and spring field visits in addition to marking and tracking use of individual twigs (Jensen and Urness 1981).

The twig-length method assesses utilization of shrubs and trees by measuring the amount of plant material removed by browsing livestock and/or wildlife (Smith and Urness 1962). Utilization is determined by measuring current annual growth on browse plants both before and after use by browsers, typically during fall and spring in temperate zones. It is an accurate and unbiased method, but has been criticized as labour intensive and requiring lengthy field time (Jensen and Scotter 1977) - criticisms commonly directed at most techniques that provide robust and accurate estimates of forage/browse use (Hyder et al. 2003, Rea et al. 2010).

Digital photography has been used to simplify field counts and to provide estimates of leaf area index (Macfarlane et al. 2007),

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canopy closure (Guevara-Escobar et al. 2005), and fruit yields (Zaman et al. 2008). Recently, photographic methods have been tested for their accuracy and objectivity in estimating forage use (Hyder et al. 2003) and simulated browse removal (Rea et al. 2010). In this study, we combined the use of digital photography and Geographic Information System (GIS) technology (a digital measurement technique) to quantify winter browse use by moose (*Alces alces*). Specifically, in the laboratory we combined these two approaches as an indirect method to estimate the length and biomass of willow twigs removed by simulated (clipping) moose browsing. We hypothesized that the combination of high resolution photography and digital measurements would provide accurate estimates of shoot removal and a more efficient field method to estimate browse use while maintaining the accuracy of the twig-length method.

METHODS

During the fall months of 2010, we removed at the stump, 50 whole saplings (~1.5 – 2.0 m tall) of Scouler's willow (*Salix scouleriana* Barratt) from the forested lands surrounding the University of Northern British Columbia, Prince George, British Columbia, Canada (53.895033 °N, −122.816162 °W). The above-ground biomass of each willow sapling was weighed and photographed in the lab in front of a 10 cm lined grid (Fig. 1) using a tri-pod mounted Canon 5-D digital camera positioned at 130 cm above the ground (just above the mid-point height of our average sapling) and placed 4 m in front of the grid (Fig. 2). The camera was equipped with a wide angle lens (EF 24-105mm Canon Zoom) set at a 50 mm focal length, high resolution, and on automatic focus and exposure. Images were framed around the midpoint of the grid so that neither the camera position nor its focal length were adjusted between photographs.

After photographing each plant, stems were hand-clipped at an approximate diameter of 4 mm (average bite diameter of local moose; Carson et al. 2007) at different intensities. The stem mass removed varied between 3 and 86 g, and cumulative shoot
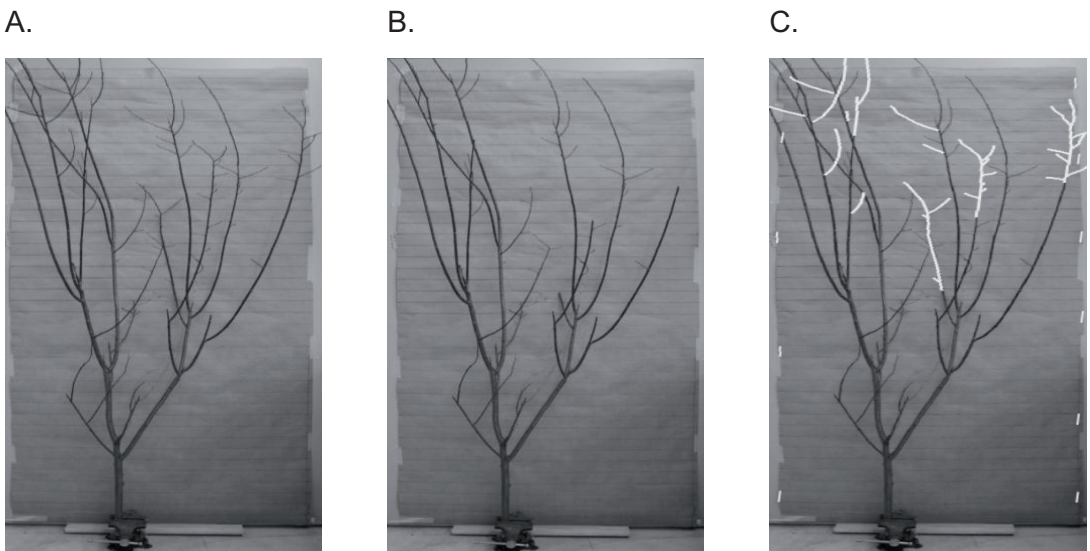
A.

B.

C.

Fig. 1. Photographs of a ~2.0 m tall willow plant before (A) and after (B) simulated browsing. Digitized shoots in (C) are marked in highlighter showing those removed by clipping.
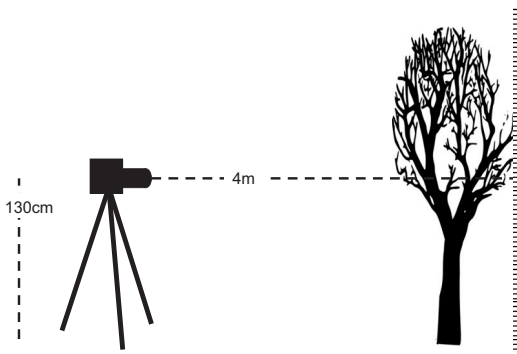
Fig. 2. A photo-geometric representation of the protocol used to photograph willow saplings in front of our lined grid.

length between 90 and 1180 cm per plant. Plants were re-weighed and photographed a second time in front of the grid as described above. For later comparison, the total length (cm) of stems removed from each plant was measured directly with a hand ruler (nearest mm).

Photographic Analysis

Pre-browse and post-browse photographs were imported into ArcGIS (Version 9.3.1, ESRI 2010, Redlands, California, USA) and assessed side-by-side to identify which shoots were removed by clipping. Following calibration of each photograph with the cells on the measurement grid, we used ArcView's measurement tool to overlay (see Fig. 1C) and measure the length (cm) of each shoot removed by clipping. The cumulative shoot length removed ('browsed') was then calculated for each willow sapling.

Data analysis

We used linear regression analysis to determine 1) the relationship between the cumulative shoot removal measured with the simulated browsing photographic/GIS technique (indirect) and the direct measurements, and 2) the relationship of biomass removal to cumulative shoot length removal associated with the indirect and direct measurement

techniques. All analyses were conducted in Statistica 9.0 (Statsoft 2009).

RESULTS

There was a strong and significant relationship (indirect shoot length (cm) = 0.991 [direct shoot length] + 2.1455; Fig. 3) between shoot length estimated with the photographic/GIS (indirect) technique and the direct measurements ($F_{1,48}$ = 3853.9, P < 0.0001; r^2 = 0.988). The relationship between biomass removal and cumulative shoot length was strong and significant for both the indirect estimates ($F_{1,48}$ = 521.327, P < 0.0001; r^2 = 0.916) and direct measurements ($F_{1,48}$ = 510.495, P < 0.0001; r^2 = 0.914). The predictive relationships were similar producing nearly identical regression lines (Fig. 4): indirect shoot length = 14.247 (biomass removed) + 86.811 and direct shoot length = 14.280 (biomass removed) + 87.661.

DISCUSSION

Our indirect photographic/GIS browse assessment technique described here performed extremely well for estimating winter
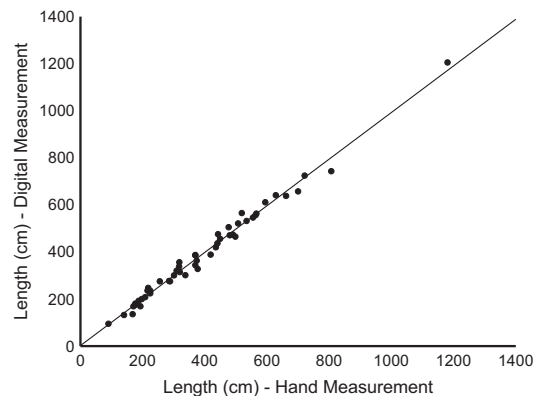

Fig. 3. The relationship (indirect shoot length (cm) = 0.991[direct shoot length] + 2.1455; r^2 = 0.988) between the hand-measured (direct) and the photographic/GIS (indirect) measurements of cumulative shoot length removal from Scouler's willows (n = 50).
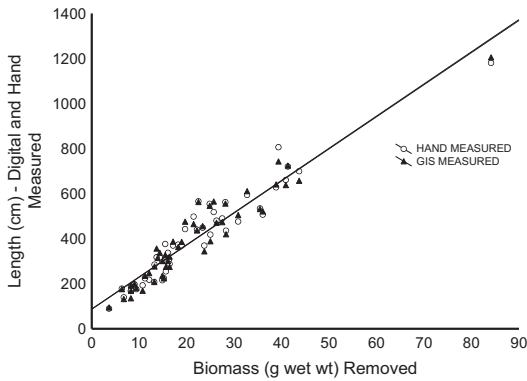
Fig. 4. With respect to simulated browsing, similar relationships between shoot biomass (g wet weight) removed from willow saplings (n = 50) and the cumulative shoot length (cm) as measured with the direct and indirect techniques are shown. The direct relationship was: direct shoot length = 14.280 (biomass removed) + 87.661; r^2 = 0.914. The indirect relationship was: indirect shoot length = 14.247 (biomass removed) + 86.811; r^2 = 0.916. Note: regression lines are superimposed on one another.

shoot length and biomass removal from willow saplings. We expect digital photography coupled with GIS technology to be equally useful for estimating browse shoot removals from other deciduous species, although certain differences may occur due to variable plant architecture (Rea et al. 2010). The method was subsequently found equally useful in estimating the amount and position of winter twigs removed from both Scouler's willow and paper birch (*Betula papyrifera* Marsh.) by moose in cafeteria style feeding trials (Rea et al. 2015). Although tested here in a laboratory setting, the design of an easily transportable simple plastic or cloth sheet (see Schmutz 1983) with a superimposed grid as a backdrop would provide for the photographic component to be performed in the field for pre- and post-browse utilization assessments on *in situ* plants (Rea et al. 2010). To test field applicability, a much longer-term study could be designed and executed where plants are photographed at the end of summer and the following spring before leaf flush. The challenge would be to mark plants such that both photographs are taken from the same perspective to ensure an accurate estimate of browse removal.

The length of shoot removal is closely correlated with biomass removal (Jensen and Scotter 1977), and our results were also strongly correlated. The indirect estimates of cumulative shoot length removal so closely approximated the direct measurements that we accurately estimated biomass removal using photography/GIS. We did not measure diameter where shoots were clipped (bite diameters), as is often done in browse surveys (Portinga and Moen 2015). The diameter at the browsed tip, however, is often predicted with regression equations developed from shoot biomass or length or *vice versa*, with biomass removal more typically predicted from bite diameter (Ruyle et al. 1983). Instead, we used the length measured with GIS to predict browse biomass which, we believe, circumvented the need to consider or calculate diameter at point of clipping/biting.

Browse assessments in the field that employ more traditional and direct measurement techniques can be costly and time consuming (Jensen and Scotter 1977). The use of this indirect, digital technique described here could reduce the field time spent at each *in situ* plant by replacing direct measurements with photography. As such, there is the potential to increase the number of plants assessed in the field within a given time frame, thereby increasing sample size and presumably improving analytical accuracy. Digital photographs taken at the time of assessment would additionally provide a permanent record of each plant that would allow for multiple assessments and reduce observer bias. Databases containing such information could better describe activity, health, and population status of local moose, as well as ecological impacts on vegetative communities.

Although our technique required time spent working with the GIS to outline/digitize the twigs removed by clipping (Fig. 1C), computer algorithms and intelligent vision systems (McCarthy et al. 2010) designed to interpret the differences in plant morphology (e.g., between pre- and post-browsed plants) could reduce the time required to calculate cumulative shoot length and biomass removal. The creation of an artificial Cartesian coordinate grid in the GIS for registering each photograph to that grid would provide a more systematic measurement protocol. Ensuring the angle and perspective at which the pre- and post-browsed photographs are taken is critical for proper interpretation of the data. Standardized lighting, ISO, quality, and depth of field settings on the camera also need to be harmonized between pre- and post-browse photos.

Like any browse assessment procedure, results will vary by species relative to plant form and twig growth characteristics. How the method performs with plants of complex architecture remains untested; however, accommodation for different plant forms could be approached with some resourcefulness. For example, browsed plants taller or wider than the grid could be imaged by subsections that are later summed for whole plant assessments. Plant and browsing height will likely define the practical limits of this technique. Nevertheless, when considering allocated field time, working within seasonal windows (e.g., assessing plants after snow melt, but before leaf flush), or attempting to increase plant numbers and data sample sizes – our technique offers an efficient and quick field method for collecting snapshots of browse use on specific plants that can be examined more closely within a controlled laboratory setting regardless of time and weather constraints.

ACKNOWLEDEMENTS

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