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Technical Note

A Visual Obstruction Technique for Photo Monitoring of Willow Clumps

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Abstract

Quantifying woody plant biomass has often proven difficult in the field for reasons that include irregular plant morphology, between-observer variability, and lack of standardized techniques. One potential solution to these challenges is the use of ground-based photographic technology. Our objective was to develop a photo-based technique that could be used to monitor changes in willow (*Salix* spp.) biomass over time and estimate changes in biomass associated with herbivory. We focused on young willows ($\leq$ 2 m in height) because this size class represents a critical life history stage for establishment of willow clumps. In August 2000 and 2001, we harvested 25 willow (*Salix boothii* Dorn.) clumps and clamped them in front of a fluorescent orange photoboard (150 $\times$ 200 cm). Clumps were defoliated of leaves and tips of current annual stem growth (referred to as "biomass") by hand in 4 to 7 increments and photographed before and after each removal. Images were scanned to digital format and the degree of photoboard obstruction was determined with Adobe® Photoshop® 4.0 software. Regression analysis indicated that visual obstruction of the photoboard was a good predictor of total clump biomass ($r^2 = 0.89, P < 0.01$) as well as biomass remaining following sequential defoliations ($r^2 = 0.92, P < 0.01$). These results suggest our technique provides a reliable index of both willow biomass and utilization within the size class of willow tested. Results might differ with larger willows and increased woody biomass. The technique minimizes observer bias and provides a permanent photo record that can be reanalyzed at a later date if necessary.

Resumen

La cuantificación en campo de la biomasa de plantas leñosas frecuentemente es difícil por razones que incluyen una morfología irregular de las plantas, variabilidad entre observadores y la falta de técnicas estandarizadas. Una solución potencial a estos retos es el uso de tecnología fotográfica a nivel del suelo. Nuestro objetivo fue desarrollar una técnica basada en fotografía que pudiera ser utilizada para monitorear cambios en la biomasa de "Willow" (*Salix* spp.) a través del tiempo y estimación de cambios en biomasa asociados con herbivoría. Nos enfocamos en plantas jóvenes de "Willow" jóvenes ($\leq$ 2 m de altura) debido a que esta clase de tamaño, dentro de la historia de vida, representa un estado crítico para el establecimiento de cepas de "Willow". En agosto del 2000 y 2001 se corto un grupo de 25 varetas de "Willow" (*Salix boothii* Dorn.), se juntaron y expusieron en una mesa fotográfica de 150 $\times$ 200-cm a fluorescencia naranja. Las varetas fueron manualmente defoliadas y se eliminaron los brotes del crecimiento del ultimo año (citado como biomasa) en incrementos de 4 a 7 y fotografiados antes y después de cada corte. Las imágenes fueron registradas en un formato digital y el grado obstrucción de la tabla de fotografía fue determinado usando el programa Adobe® Photoshop® 4.0. El análisis de regresión indicó que la obstrucción visual de la tabla de fotografía fue un buen estimador de la biomasa total del grupo de varetas ($r^2 = 0.89$, $P < 0.01$) así como de la biomasa remanente posterior a defoliaciones secuenciales ($r^2 = 0.92, P < 0.01$). Los resultados sugieren que nuestra técnica provee un índice confiable tanto de la biomasa como de la utilización del "Willow" de dentro de clase de tamaño evaluada. Los resultados pueden diferir en "Willow" grandes y mayor biomasa leñosa. La técnica minimiza sesgos del observador y provee un registro fotográfico permanente que puede ser re-analizado en fechas posteriores de ser necesario.

Key Words: browsing, image analysis, revegetation, utilization

INTRODUCTION

Willow (*Salix* spp.) and associated riparian shrubs fill a variety of important niches in many riparian ecosystems (Winward 2000). With this importance comes the managerial need to document changes in willow biomass over time. This is particularly true in areas where willow populations are establishing (e.g., restoration projects) or where herbivory might negatively affect willow resources. However, quantifying biomass and changes in biomass of woody plants has often proven difficult for a variety of reasons, including irregular plant morphology (Bryant and Kothmann 1979), intensive labor inputs (Bobek and Bergstrom 1978), variability in measurement among observers (Hall and Max 1999), and difficulties in developing standardized techniques (Harniss and Murray 1976). One potential solution to these monitoring

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Figure 1. Willow clumps were cut and placed in a holding device located directly in front of the photoboard. These images show a willow clump during (left) and after defoliation (right). Clumps were defoliated in 4 to 7 increments, and photographs were taken before and after each defoliation.

challenges is the use of ground-based photographic technology to estimate willow biomass. Photo monitoring can reduce observer bias and provide a permanent record of vegetation status such that samples (photographs) can be reanalyzed at a later date if new technologies become available. However, most methodologies for photo monitoring either do not produce quantitative estimates of biomass or are associated with very large scale phenomena (e.g., aerial imagery). Our objective was to evaluate the use of a photo-based visual obstruction approach for monitoring point-in-time biomass of willow clumps and changes in biomass associated with defoliation by herbivores. We further stipulated that the technique should employ easily obtainable equipment and require minimal training and equipment cost. We focused on young willows ($\leq$ 2 m in height) because this size class represents a critical life history stage in the development of willow clumps and can be easily affected by browsing (Keigley and Frisina 1998).

METHODS

Our study site was located in the Big Creek drainage in Grant County, Oregon (11T0370683 UTM4890874). Big Creek is a C-class stream (Rosgen 1994) flowing through a wet/mesic meadow system that has intermittent populations of willow (*Salix* spp.). Sampling took place during peak biomass (August) of 2000 and 2001. Our technique focused on the relationship between visual obstruction of a photoboard and the biomass of obstructing willows (*Salix boothii* Dorn.). Rather than move the photoboard to a willow clump, we cut clumps, or portions of clumps, moved them to the photoboard location, and clamped them in a holding device located immediately in front of the photoboard (Fig. 1). This approach helped to minimize variability from camera and photoboard setup and more accurately evaluated the relationship between visual obstruction and willow biomass. Our selection of willow clumps was subjective in that 1) clumps were < 2 m in height and 2) within this size category we purposefully selected a wide range of clump sizes to maximize variation in our sample population. The photoboard was constructed from 0.6-cm-thick plywood painted fluorescent orange to increase color variation between the board and willow clumps when determining visual obstruction. Board dimensions were 150 $\times$ 200 cm (horizontal $\times$ vertical axes). Support legs were used to elevate the lower horizontal axis to 40 cm and avoid obstruction of the board by herbaceous plants. Twenty-five willow clumps were sampled in each year of the study.

The clamped willows were photographed at a distance of 3.5 m with a tripod-mounted 35-mm camera (Cannon EOS Elan II) elevated to a height (140 cm) equal to the midpoint of the photoboard. We used a 50-mm lens and allowed the program function of the camera to select the appropriate shutter speed and aperture for exposing the color 200 ASA slide film. Clumps were then defoliated by hand in 4 to 7 increments, and photographs were taken before and after each removal (Fig. 1). Defoliations were meant to simulate the effects of biomass removal via herbivory. Defoliation removed the leaves and the distal portion of current annual stem growth, which we assumed to be similar to the fraction removed by large herbivores. Harvested biomass was dried at 50°C and weighed. For defoliated clumps, biomass present in each photograph was determined by subtracting the total weight of defoliations before that photograph from the total weight of all defoliations for that clump. Images were scanned to digital format (472 pixels $\cdot$ cm^{-1}) with a Nikon LS-2000 slide scanner, and the number of visible photoboard pixels was estimated with Adobe® Photoshop® 4.0 computer software (Adobe Systems Inc, San Jose, CA). This software package had a color recognition feature (Color Range module under the Select pull-down menu) that allowed us to select only those pixels that were the color of the photoboard. We then used the Histogram feature to sum the number of pixels selected. Visual obstruction was defined as the number of visible photoboard pixels in a photograph subtracted from the number of pixels visible on an uncovered "blank" board (photographed by the same technique) and the difference divided by the blank board value. The relationship between percent visual obstruction of the photoboard and the weight of willow clump biomass (n = 50) was evaluated by regressing percent visual obstruction of the photoboard against biomass (SAS 1999). We generated a second equation that regressed biomass remaining following each defoliation against visual obstruction (n = 231). This model was used to evaluate the utility of the technique for estimating the extent of biomass decrease associated with simulated browsing.

We evaluated model accuracy with values for root mean square error; the ability of visual obstruction to explain willow biomass was evaluated with the coefficient of determination. Model precision was assessed by constructing 95% confidence intervals and noting the smallest, largest, and mean difference between predicted values and confidence limit boundaries (Vermeire and Gillen 2002). We also examined the influence of sample size on slope and intercept parameters for the relationship between total clump biomass and visual obstruction. This was accomplished by randomly selecting sample sizes of 5, 10, … 50 from the data set and generating regression equations. This process was repeated 50 times, and mean and standard error estimates for regression parameters were then generated for each sample size class.

We developed a portable version of the visual obstruction board to evaluate the potential year to year variability

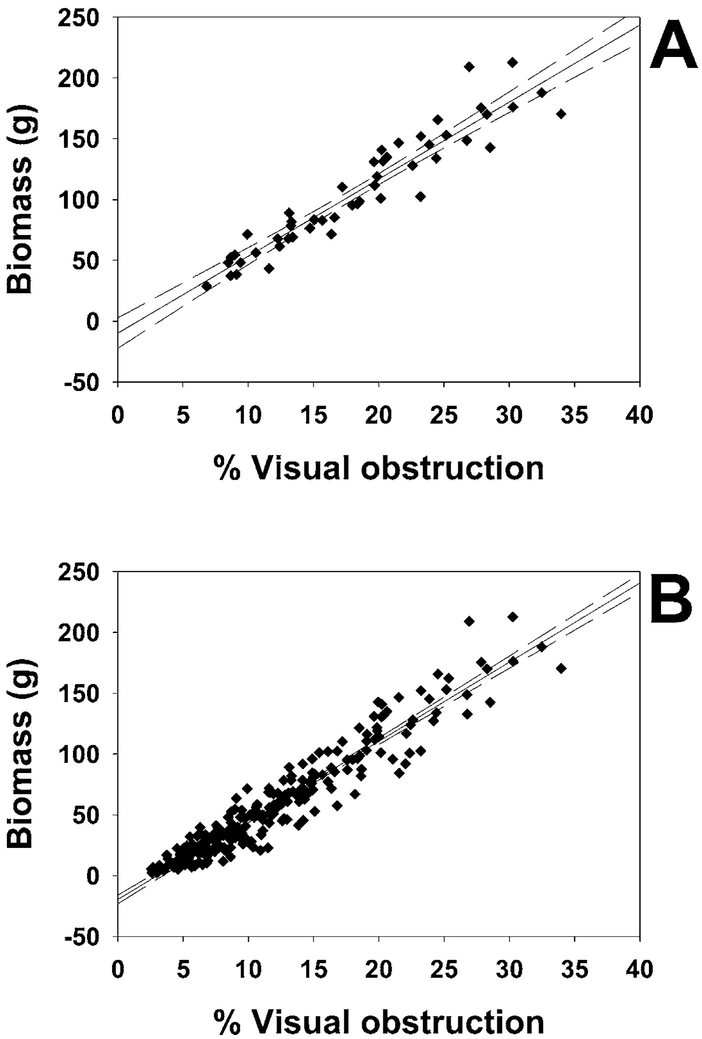

Figure 2. The relationship between percent visual obstruction of a photoboard (2 × 1.5 m) and **(A)** total biomass (weight of leaves and tips of current annual stem growth) of willow clumps without defoliation and **(B)** remaining biomass for harvested willow clumps following sequential defoliation in 4 to 7 increments. Data are shown with 95% confidence intervals.

associated with board placement and camera assembly during field monitoring. The portable board (150 × 200 cm) was built on an aluminum frame fitted with 2-mm-thick white plastic sheeting elevated 40 cm from the ground surface. Stabilizing legs allowed the board to be freestanding. We photographed 5 rooted willow clumps of varying size 5 times each, and the board and camera were disassembled and reassembled between photographs. Board and camera locations were marked with pin flags. Field monitoring procedures used the same camera distance, camera height, and lens as described previously. Where terrain was uneven, we determined proper camera height by placing an inclinometer set to zero slope on top of the camera tripod, and raised the tripod until the instrument sighted on a small red dot at the center of the photoboard. Photographs were scanned and analyzed, and visual obstruction was determined as described above. We calculated an index of sampling error by dividing the root mean square error for each shrub by its respective mean value.

Table 1. Regression statistics and coefficients for the relationship between percent visual obstruction of a photoboard (2 × 1.5 m) and biomass for harvested willow (*Salix boothii* Dorn.) clumps.

	Biomass total[1]	Biomass remaining[2]
Model *P* value	< 0.01	< 0.01
n	50	231
Slope (SE)	6.33 (0.32)	6.50 (0.13)
Slope *P* value	< 0.01	< 0.01
Intercept (SE)	−9.78 (6.29)	−19.59 (1.83)
Intercept *P* value	0.13	< 0.01
Root mean square error (g)	15.83	13.37
Coefficient of determination	0.89	0.92
Maximum estimate error (g)[3]		
Smallest	4.50	1.73
Largest	10.79	6.00
Mean	6.18	2.35

[1]Model depicts relationship between percent visual obstruction and total biomass of harvested willow clumps.
[2]Model depicts relationship between percent visual obstruction and remaining biomass for harvested willow clumps that were defoliated in 4 to 7 increments.
[3]Values calculated as deviations of data points from 95% confidence interval.

RESULTS AND DISCUSSION

Total clump biomass ranged from 28.8 to 212.7 g and was associated positively with visual obstruction. Visual obstruction explained 89% of the variation in clump biomass ($P < 0.01$; Fig. 2a; Table 1). Total clump visual obstruction values ranged from 6.9% to 34.0%. For defoliated clumps, biomass weight ranged from 2.2 to 212.7 g and visual obstruction values from 1.9% to 34.0%. Visual obstruction was related positively to weight of biomass for defoliated clumps and explained 92% of the variation in biomass ($P < 0.01$; Fig. 2b; Table 1). Confidence intervals indicated that within the range of visual obstruction values measured in this study, the true value of biomass influencing the photoboard would be within 10.79 and 6.0 g for the total clump and defoliation models, respectively (Table 1). The accuracy of these models suggests that the technique would be suitable for monitoring of either total clump biomass or biomass disappearance associated with browsing.

We subjectively selected our sample population; therefore, it could be misleading to use these data to estimate the sample size required to achieve a given level of statistical confidence. However, our results do indicate that within the sample population, variability in regression parameters for total clump biomass decreased with increasing sample size and that most of the decrease in variability had occurred by the time sample size reached approximately 25–30 samples (e.g., the magnitude of the standard error for intercept values decreased by 78% as sample size increased from 5 to 30; Fig. 3). This suggests that the regression parameters for our sample population could adequately have been estimated by fewer clumps than the 50 used. Field time averaged 41 minutes to collect data for an individual clump and ranged from 12 to 48 minutes depending on clump size and the number of defoliations. This included harvesting the clump, placing it in front of the photoboard, defoliating the clump, and photographing the defoliation. Field time decreased to 11.4 minutes per clump if only initial photographs are counted (i.e., no defoliations).

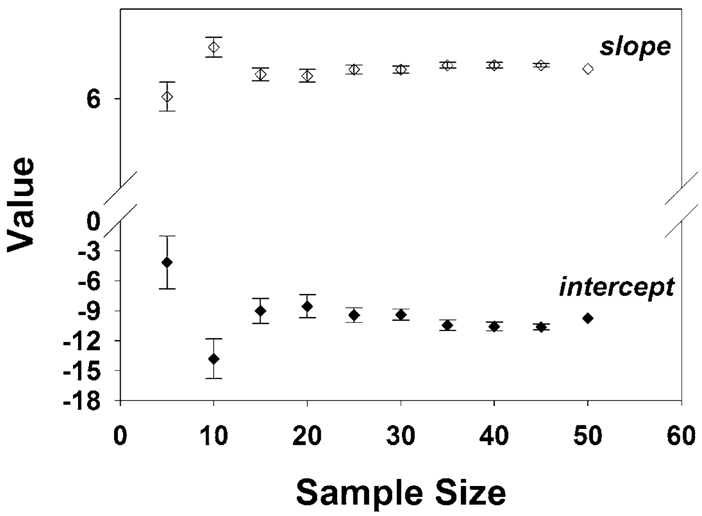

Figure 3. Changes in slope and intercept parameters with increasing sample size for the relationship between weight of current annual growth (leaves and tips of current annual stem growth) and visual obstruction. Values were generated by randomly selecting X_{i-j} data points from the overall data set and generating a regression equation. This process was repeated 50 times for each sample size category; mean values with standard errors are expressed in the graph.

Training for our image analysis technique requires only that the operator have a rudimentary knowledge of operating procedures in the Adobe Photoshop environment. The time needed to determine visual obstruction from scanned images varied depending on the degree of color separation between the willow clump and the photoboard, but averaged about 2.5 minutes per image. Color separation can be affected by a number of factors, including lighting (e.g., sun angle, overcast sky), photoboard color, leaf senescence, and potentially interspecies differences. With a fluorescent orange board we found best color separation under sunny conditions with the sun directly overhead (i.e., not backlit). In cases in which color separation makes it difficult to distinguish photoboard pixels from those of the willow clump, the user could adjust the Fuzziness value within the Color Range module of Adobe Photoshop. Decreasing the Fuzziness value decreases the tolerance range of color values selected under the Color Range module and allows for easier selection of photoboard pixels when color contrast is limited.

Visual obstruction has been used previously as a predictor of herbaceous biomass and standing crop (e.g., Robel et al. 1970; Vermeire and Gillen 2002) and as an index to cover characteristics in wildlife habitat (e.g., Nudds 1977). However, its use in predicting woody plant biomass has been limited. Ansley et al. (1988) photographed honey mesquite (*Prosopis glandulosa* Torr.) on a contrasting background and used a digital imaging process to estimate leaf area of whole trees. Reynolds (1999) used a similar technique to model both leaf area and simulated utilization (on the basis of changes in leaf area with defoliation) for black cottonwood (*Populus trichocarpa* T. & G.) and Douglas hawthorn (*Crataegus douglasii* Lindl.). Both of these efforts relied on spatially corrected images, computer recognition of pixels containing plant material, and digital outlines of the plant material being photographed. This digital outline was then used to generate estimates of leaf area. In this study, our technique differs from these previous efforts in that we are predicting biomass on the basis of the visible area of a photoboard. Our approach might present some advantages from an analysis standpoint in that 1) spatial correction of images is not needed as long as pictures are taken with proper technique (e.g., correct distance from photoboard, camera height, and lens focal length) and 2) variation in photoboard color is less than that of the plant material, making it easier to isolate the predictive element in the image.

Table 2. Mean values, ranges, and sampling errors for percent visual obstruction for 5 different willow (*Salix boothii* Dorn.) shrubs. Each shrub was photographed 5 times, and the board and camera were disassembled and reassembled between photographs. Percent sampling error was calculated by dividing root mean square error for each shrub by its mean value.

	% Visual obstruction			
Shrub	Mean	High value	Low value	% Sampling error
1	10.3	11.0	9.9	0.58
2	21.3	21.8	20.2	3.11
3	30.3	31.0	29.4	1.77
4	47.7	48.6	46.9	1.55
5	76.3	77.0	75.7	0.60

It will not be possible to estimate total clump biomass for clumps wider than the photoboard. However, with accurate repeat board placement, it will be possible to estimate changes in the amount of willow biomass influencing the photoboard over time. These data can be used as both a quantitative (i.e., index to weight of total clump biomass) and qualitative (i.e., determination of whether visual obstruction, and thus biomass weight, is either increasing, decreasing, or staying the same over time) monitoring tool. Alternatively, users could construct and develop predictive equations for a photoboard large enough to be used for all plants in the population of interest. Although our regression equations provide a good fit for our dataset, we strongly recommend that users develop site-specific regression equations because of potential variability associated with differences in willow species, clump size, and ratio of woody to foliar willow biomass. It is important that regression equations used to estimate rate of disappearance with herbivory be based on absolute changes in biomass with defoliation, not percent utilization, because a given change in biomass will represent a different level of utilization for clumps of different sizes. Additionally, errors in estimates of biomass could result if leaf morphology in monitoring photographs differed from leaf morphology at the time predictive equations were developed. Similarly, differences in leaf morphology could also be problematic if a sufficient time interval elapsed between successive photographs used to monitor willow biomass disappearance associated with herbivory.

For field monitoring purposes, the data suggest that our technique would have minimal year-to-year variability. Sampling error across shrubs ranged from 0.58% to 3.11% and averaged 1.5% (Table 2). The field monitoring board was constructed in 2 pieces so that the more portable half frame could be used for small willow clumps. Visual obstruction values for the half board can be expressed as a percentage of either the half or whole board. Alternatively, for qualitative monitoring, the number of visible pixels can be measured. This approach would not require comparison to a "blank" board or predictive equations. If monitoring incorporates the use of visible pixels (vs. visual obstruction), care must be taken to ensure that the electronic images are saved at the same pixel density between successive photographs. To minimize variation in between-year photographs, camera and photoboard locations should be referenced with permanent markers. We used 2 plastic stakes to mark the board location, and these stakes corresponded to permanent marks on the back of the photoboard, which were lined up directly with the stakes.

Our results suggest that this technique can be used to predict both qualitative (i.e., increasing or decreasing amount) and quantitative (i.e., amount of increase or decrease) changes in willow biomass within the size class of clumps and with the species of willow used in our work. The technique accurately predicted total clump biomass, and the strong relationship between disappearance of biomass and change in visual obstruction suggests this technique could be useful for monitoring changes in willow biomass associated with browsing. However, users should keep in mind that the relationships we report might differ by species of willow, leaf morphology, and the ratio of woody to leaf plant material. For these reasons, we recommend that predictive equations be developed on a site-specific basis.

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