Twig Diameter-Length-Weight Relations Of Bitterbrush

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Highlight

Relations between bitterbrush twig diameters and their lengths and weights are sufficiently consistent to enable wildlife technicians to estimate browse utilization solely from postbrowsing measurements of the diameters and lengths or weights of the remaining portion of twigs.

Wildlife technicians often determine browse utilization by measuring length of selected current year’s twigs before and after browsing. The difference in lengths represents utilization, usually expressed in percent. Knowledge of the relations between twig diameters and their lengths and weights may provide a means of estimating utilization solely from postbrowsing measurements, and may also permit expressing utilization in terms of either length or weight of twigs.

Two hypotheses were proposed for testing: (1) both lengths and weights are highly correlated with twig diameters; and (2) a single regression equation may yield reliable estimates of twig lengths or weights for a given species. If these hypotheses are valid, measurement of twig diameter after browsing provides an index of twig length and weight before browsing; then, from a measurement of either length or weight of the remaining portion of the twig, percent utilization can be computed.

We chose bitterbrush (Purshia tridentata (Pursh) D.C.) as the species to use in testing these hypotheses because this shrub is relished by most species of big game and livestock, it is widespread in occurrence, and it is important in the winter diet of deer in our area. Bitterbrush utilization is the criterion most often used by game managers in southern Idaho to indicate whether deer populations are in balance with their forage supplies.

Our sampling was confined to two contiguous sites in a stand of mature bitterbrush 18 miles east of Boise, Idaho. Site 1 faced generally northeast on a slope of approximately 40%. Site 2 was on a southeast-facing alluvial fan of about 5 to 20% slope. Soils on both sites have been derived from granitic rocks. Precipitation averages 15 inches per year. Elevation is approximately 3,100 feet.

Methods

During plant dormancy we sampled current-year twigs from 20 mature shrubs on each site. Sampling was confined to unbranched, un-browsed terminal and lateral twigs at least 1 inch long.

Each shrub was sampled by quarters—upper north, lower north, upper south, and lower south. Twelve twigs were selected from each quarter by visually dividing the quarter into three equal portions and choosing four twigs from each portion. Twig selection was subjective in that a wide range of twig sizes was sought in each portion of the shrub.

Twigs were removed from the shrubs, tagged, and taken to the laboratory for measurement. Lengths were measured to the nearest 0.1 inch, including the terminal buds. Diameters were measured with a dial gage (Fig. 1) to the nearest 0.001 inch at a point 0.5 inch from the twig base. If a bud occurred at this point, it was removed to facilitate measurement; if node swelling occurred, the twig diameter was measured immediately above or below the swelling, whichever was nearer the 0.5 inch mark. Cross sections of most twigs were somewhat elliptical; hence, an average of the minimum

Fig. 1. Dial gage used to measure diameter of bitterbrush twigs.
and maximum diameters was used for all computations. Twigs were oven-dried at 70°C for 24 hours and then individually weighed to the nearest 0.01 g.

Twig measurements from all shrubs were appropriately grouped to yield one regression equation for each quarter for each site and for both sites combined. Coefficients were computed for the regressions of: length on diameter, weight on diameter, weight on length, and weight on diameter + length.

Results

Results obtained in this study are unusual in that most differences in regression coefficients were statistically significant but were too small to have practical importance. This high precision reflects the intensive sampling; 12 twigs from each quarter of 20 shrubs provided a sample of 960 twigs for each site.

Regression coefficients were similar for the two upper quarters of the shrubs and also for the two lower quarters. Because of these similarities, data for quarters were combined to compare twigs on the upper versus lower halves and the north versus south halves.

From a practical viewpoint the coefficients for the north and south halves were similar, two “significant” differences notwithstanding (Table 1). However, some differences between vertical segments of shrubs were great enough to be important; twigs on the lower halves were longer and more slender than those on the upper halves. Although such differences might dictate stratification of sampling, they do not rule out the possibility of a single prediction equation. From this viewpoint, the differences between sites appear to be more critical, especially for length and diameter (Table 1). This is discussed later.

The above considerations led to analyses combining data from all shrub segments to obtain a more generalized prediction formula and to evaluate the influence of site on twig conformation (Table 2).

Length-Diameter and Weight-Diameter Relations.—Regressions on diameter accounted for approximately 50% and 80% of the variation in length and weight respectively. Fiducial limits (P.05) for estimating length and weight from the diameter of a randomly selected individual twig were within approximately 50% and 55% of their respective means. However, fiducial limits for a stratified random sample of 30 twigs (Fig. 2 and 3) indicate that the mean length and mean weight probably can be estimated within approximately 10% of their respective actual means. The variation in twig weight (0.04 to 1.14 g) was about twice the variation in twig length (1.0 to 12.8 inches); coefficients of variation were 39 and 62% respectively. Although weight varied more than length it was more closely related to diameter, with the net effect that the residual errors around the regression lines were about equal for weight and length. Therefore, mean twig weight and mean twig length can be estimated with approximately the same precision with equal sized samples.

Differences between length-di-

| Relation          | Site | Upper vs. Lower | North vs. South | Shrub Segments |
|-------------------|------|-----------------|-----------------|----------------|----------------|
| Length-diameter   | 1    | 95.65 **        | 126.59 **       | 104.08 **      | 103.90 **      |
|                   | 2    | 78.06 **        | 104.88 **       | 80.82 **       | 79.86 **       |
| Weight-diameter   | 1    | 6.85 **         | 7.54 **         | 7.05 **        | 6.92 **        |
|                   | 2    | 7.83 **         | 7.46 **         | 7.67 **        | 7.83 **        |
| Weight-length     | 1    | 0.08 **         | 0.05 **         | 0.05 **        | 0.06 **        |
|                   | 2    | 0.07 **         | 0.05 **         | 0.07 **        | 0.07 **        |

* Differences between shrub segments or between sites significant at the 5% probability level.
** Differences between shrub segments or between sites significant at the 1% probability level.

n.s. Differences not significant at the 5% probability level.
ameter relations for north and south halves of shrubs were not significant (P.05) on either site, but differences between upper and lower halves were highly significant (P.01) on both sites (Table 1). Twigs of a given diameter usually were slightly longer on the lower halves of shrubs. The relation of length to diameter also differed between sites. Regression coefficients for each canopy segment and for entire shrubs on site 1 differed significantly (P.01) from their counterparts on site 2.

Unlike length-diameter relations, weight-diameter relations sometimes differed with either the radial or the vertical positions of twigs on the shrubs (Table 1). Whereas the vertical position affected the weight-diameter relation on site 1, the radial position affected it on site 2. Twigs of a given diameter were slightly heavier on the lower than on the upper portions on site 1, and slightly heavier on the north than on the south portions on site 2.

Regression coefficients for entire shrubs differed significantly (P.05) between sites (Table 2). Thus the relations between weight and diameter differed between sites as well as between twig positions. However, these between-site and within-site differences, though statistically significant, have no practical significance because the regression lines and coefficients are extremely close (Fig. 4 and Table 1). The use of a stratified sample and of the prediction equation for entire shrubs would practically cancel these small differences.

**Weight-Length Relations.**—Approximately three-fourths of the variation in twig weights were accounted for by regression with length. The regression equation for weight-length relations for both sites combined was Weight = -0.063 + 0.057 Length, and the correlation, r = .86. Mean weight may be estimated within approximately 11% of the actual mean with samples of 30 twigs. For this size of sample, fiducial limits (P.05) were ± 0.019 gram (rounded to 3 places) both at the mean length and at a 3.0-inch departure from mean length. Fiducial limits for a weight estimate from the length of an individual twig were ± 0.10, or about ± 62% of the mean.

Weight-length relations were also affected by twig position (Table 1). On both sites, twigs of a given length were heavier on the upper part of the shrub than twigs of the same length on the lower half. The regression coefficient for the north halves of shrubs was not significantly different from that for the south halves on site 1, but a difference (P.05) did occur on site 2, where twigs were heavier on the north than on the south side.

Highly significant differences (P.01) between sites also occurred among regression coefficients of the entire shrub canopies. Thus weight-length relations differed between sites as well as with positions of twigs within sites. However, as with weight-diameter relations, these statistically significant differences have little practical importance except perhaps at the very extremes of twig diameters.

**Weight-Diameter-Length Relations.**—The multiple regression
of weight on diameter plus length of bitterbrush twigs accounts for 90% of the variation in twig weight. The regression formula for both sites combined was Weight = -0.22 + 4.56 Diameter + .0301 Length. This relation is primarily of academic interest because length of twigs cannot be measured in postbrowsing samples if the twigs are grazed. Hence the relationship cannot be used to estimate twig utilization. However, it can be used to estimate twig production from measurements of twig diameter and length on areas where clipping is undesirable.

On both sites, tests between the multiple regression equations for the four portions of the shrub revealed significant differences due to twig position. Between-site differences were highly significant (P<0.01). Although the differences were statistically significant they were not great enough to have practical importance. Prediction values of weight obtained from the regression equations are extremely close for twigs within the range of diameters and lengths encountered in the study. A sample of 100 twigs should give reliable estimates of twig weight.

**Discussion**

The relations of weight to length and to diameter + length provide a basis for developing a method for estimating twig production on areas where clipping is undesirable. However, a concomitant estimate of twig numbers per shrub or per unit area would be needed before these relations would have much practical value.

The length-diameter and weight-diameter relations offer a promising method for estimating bitterbrush use on both a length and weight basis solely from postbrowsing measurements. A measurement of twig diameter after browsing provides an estimate of total length and of total weight before browsing. The length of the portion of twig remaining after browsing can be measured and the percentage utilization can be computed as follows:

\[
P = 100 \left( \frac{T - R}{T} \right)
\]

where \(P\) is the percentage utilization by length, \(T\) the total length of twig computed by regression, and \(R\) the length of the remaining portion.

To estimate utilization by weight, the portion of twig remaining after browsing can be clipped and weighed and utilization computed by substituting weight for length in the above formula.

Important within-site and between-site differences in regression of either length or weight with diameter would not handicap estimates of utilization. Where these differences are due to twig position on the shrub, sampling each canopy segment at equal intensity would permit use of the prediction equation for entire shrubs. This procedure eliminates the need for tallying data by canopy segments and for use of more than one prediction equation.

Similarly, significant between-site differences need not be as forbidding as they may seem. Estimates of utilization are usually confined to the same few key areas year after year. Unless length-diameter and weight-diameter relations differ significantly from year to year—a variable not tested—a prediction equation need be computed only once for a given key area.

Future savings should more than compensate for the cost of determining the equation. Estimating utilization solely from postbrowsing measurements eliminates the costs of transportation and manpower required for making prebrowsing measurements, the need for tagging twigs for subsequent identification, and the possibility of missing data resulting from lost tags and from lost or undecipherable prebrowsing records.

The proposed method has not been field-tested. However, the accuracy with which means may be estimated from small samples (30 twigs) lends considerable confidence that the method is practical. The same concepts embodied in this method should be applicable to other browse species and to other areas.

**Summary**

We measured 12 twigs from each quarter segment of 20 bitterbrush shrubs on each of 2 sites. Coefficients were computed for regressions of length on diameter, weight on diameter, weight on length, and weight on diameter + length. Data were grouped to evaluate differences in regression attributable to site and to position of twigs on the shrubs.

Twig weight was highly correlated with length \((r=.86)\) and with diameter + length \((r=.95)\). Both of these relations were affected by twig position on the shrub and by sites, but the differences were too small to have practical importance. Both relations provide a basis for developing a method for estimating twig production on areas where clipping is undesirable.

The length-diameter and weight-diameter relations offer considerable promise for estimating utilization on both a length and weight basis solely from postbrowsing measurements. A diameter measurement after browsing provides an index of total twig length and weight before browsing. The remaining portion of the twig can be clipped and weighed and its length measured and the percentage of utilization can be easily computed.

The highly precise sampling rendered small differences between shrub segments statis-
Pot Test of Nutritive Status of Two High Elevation Soils in Wyoming

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Highlight
Pot tests of two high altitude soils showed them to be deficient in available phosphorus. Protection from grazing for 20 years did not increase their productive capability as measured in this study.

The soils at timberline and above in the Rocky Mountains are a complex mosaic which have received little attention from the soil scientist. Superimposed on the soil mantle is an equally complex vegetation which varies greatly in its floristic composition and productivity. This variation in vegetation is difficult to interpret without more knowledge of the nutritive status of the soil, and how this status is affected by grazing.

The purpose of the study reported here was to investigate (1) the effects of grazing on the growth potential of two high altitude soils and (2) the nutrient status of these two soils.

Methods
Two long-established exclosures were available for study areas on the Medicine Bow Range of south-central Wyoming. Both were located on soils developed on glacial till. The Headquarters Park exclosure, established in 1940, was located on sheep range at an elevation of 10,200 feet. The Libby Flat exclosure, also located on sheep range, was established in 1939. It is at an elevation of 10,600 feet.

At each exclosure, adjacent and comparable sites subject to grazing were selected for study. A sample of about 40 lb of soil was removed from the upper 10 inches of the soil mantle at three randomly located points, both inside and outside each enclosure. Each of the twelve soil samples was thoroughly mixed, and passed through a ¥ inch mesh to remove the larger stones. These samples were then used in the studies.

Cultivated oats (Avena sativa L.) was used as a test species. The tests were made in 6-inch pots containing 1,600 g of air-dry soil. All pots were lined with plastic bags to prevent contamination. Soils were irrigated with distilled water when necessary to prevent wilting of the plants being grown. Water in excess of field capacity was collected in plastic containers and returned to the pot from which it was drained.

The first trial compared growth of the test species on the soil samples without the addition of any nutrients. Three subsamples of each of the original soil samples were placed in a random pattern on the greenhouse bench. In the analysis of variance, a mixed model was assumed in which sites within study areas was a fixed effect.

In the second trial the 6 samples at each study area were composited. Then each soil was treated as follows: check, nitrogen, phosphorus, potassium, and micronutrients.

Nitrogen was supplied in the form of ammonium nitrate at the rate of 200 lb N/acre; phosphorus as monobasic calcium phosphate at 200 lb P2O5/acre; and potassium as potassium sulfate at 200 lb K2O/acre. These pure salts were mixed with the soil prior to planting the test species. In establishing these rates, it was assumed that an acre of soil to a depth of 6 inches weighed 2 million lb.

Micronutrients were supplied by adding 1 ml of a stock solution to each liter of distilled water used to irrigate the relevant treatments. This stock solution, described by Bonner and Galston (1952), was prepared by adding the following materials to 1 liter of distilled water:

<table>
<thead>
<tr>
<th>Material</th>
<th>Grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2BO3</td>
<td>0.60</td>
</tr>
<tr>
<td>MnCl2 · 4H2O</td>
<td>0.40</td>
</tr>
<tr>
<td>ZnSO4 · 7H2O</td>
<td>0.05</td>
</tr>
<tr>
<td>CuSO4 · 5H2O</td>
<td>0.05</td>
</tr>
<tr>
<td>H2MoO4 · 4H2O</td>
<td>0.02</td>
</tr>
<tr>
<td>MgSO4</td>
<td>0.50</td>
</tr>
<tr>
<td>FeSO4 · 7H2O</td>
<td>0.01</td>
</tr>
<tr>
<td>CaSO4 · 2H2O</td>
<td>0.20</td>
</tr>
</tbody>
</table>

The ten treatments were arranged in a randomized complete block with 5 replications. In the analysis of variance a fixed model was assumed.

1 Central headquarters maintained at Fort Collins in cooperation with Colorado State University; research reported here was conducted at Laramie in cooperation with the University of Wyoming.