Accuracy and Efficiency of Methods to Sample Logs for Wildlife Research and Management[1]

Lisa J. Bate,[2] Torolf R. Torgersen,[3] Edward O. Garton,[4] and Michael J. Wisdom[5]

Abstract

We evaluated performance (accuracy and efficiency) of the line-intersect and strip-plot methods for estimating the density, length, percent cover, and weight of logs important to wildlife. To conduct the evaluation, we sampled 17 coniferous stands in northeastern Oregon and northwestern Montana. These stands contained a gradient of log conditions based on seral stage, physiography, disturbance regime, and history of timber management. A complete count (census) of logs in these stands was used to evaluate the precision, bias, and efficiency of each sampling method. Preliminary results indicated that both methods were relatively unbiased and precise. The strip-plot method, however, was more efficient in estimating density, but neither the strip-plot method nor line-intersect method was clearly more efficient in estimating length, percent cover, or weight. Consequently, which method is better depends on a variety of factors, particularly the stand conditions to be sampled and the log characteristics of most interest. Our results also demonstrated the strong difference in methods needed to sample logs for wildlife research and management versus conventional methods that have been used for fire management.

Introduction

Fallen trees, often referred to as logs or coarse woody debris, are a critical resource for a myriad of wildlife (Maser and others 1979). Logs act as a foraging substrate and a food base for a variety of birds and mammals (Carey and Johnson 1995, Tallmon and Mills 1994, Torgersen and Bull 1995). Logs also function as thermal and hiding cover for many reptiles, amphibians, and mammals (Maser and others 1979, Parks and others 1997). Moreover, large hollow logs serve as den, hibernation, and shelter sites for black bear *(Ursus americana),* American marten *(Martes americana),* and a variety of small mammals (Parks and others 1997).

Despite the importance of logs to survival of wildlife, little work has been done to develop and test methods to sample logs from the perspective of meeting wildlife

needs. Brown (1974) adapted the line-intersect method (LIM) to estimate the volume and weight of logs for managing fuels and predicting fire behavior. Brown's sampling method was based on the line-intersect technique developed by Van Wagner (1968), who evaluated the technique using matchsticks of equal length and diameter. Hazard and Pickford (1986) further evaluated Van Wagner's line-intersect method using computer-simulated log populations; simulations were drawn from a population of logs that were tapered and variable in length, based on data collected from stands that were clearcut. Hazard and Pickford (1986) found that the sampling effort needed to achieve the same precision as that in Van Wagner's (1968) study increased sixfold when logs of variable length and shape were used. Hazard and Pickford (1986), however, verified that the LIM produced unbiased estimates of coarse woody debris when sampled using random location and orientation of line transects.

Because the LIM was developed to estimate log characteristics important for fuel management, namely volume and weight, not all structural characteristics important to log-dependent wildlife are measured with conventional application of this method. For example, percent cover of logs, which is not measured for purposes of fuel management, was correlated positively with the abundance of small vertebrates and their forage base in recent studies (Carey and Johnson 1995, Tallmon and Mills 1994). Log density, large-end diameter, and length, none of which are outputs of Brown's line-intersect method, were documented as important variables in defining foraging habitat for the pileated woodpecker *(Dryocopus pileatus)* (Bull and Holthausen 1993, Torgersen and Bull 1995).

In this paper, we describe procedures and preliminary results for testing the performance of two sampling methods to estimate the density, length, percent cover, and weight of logs considered valuable to wildlife. Specifically, we compare two approaches: the line-intersect (Brown 1974, DeVries 1973) and strip-plot methods. We compare each method in terms of precision, bias, and efficiency under a variety of field conditions.

Study Area

Seventeen coniferous stands in the Blue Mountains of Oregon and the Salish and Mission Mountains of Montana were selected for sampling. Our main objective in selecting stands was to sample a gradient of log densities, lengths, percent cover, and weights representing a range of conditions found within the Columbia River basin east of the Cascade Mountains. These variable conditions were a function of seral stage, shrub abundance, slope, disturbance regime, and history of timber management.

Nine of the 17 stands were unharvested, which we defined as stands composed primarily ($\geq$90 percent) of logs whose lengths had not been altered by timber harvest or gathering of fuelwood. Unharvested stands typically had closed canopies and were in mid- or late-seral stages of development. The other eight stands, referred to as harvested, had a history of more intensive timber management; clearcutting and seed-tree cutting occurred in these stands within the last 10 years.

Stand size averaged 3.3 ha and ranged from 1.2 to 7.4 ha. Slopes ranged from 0 to 85 percent. Grand fir *(Abies grandis),* western larch *(Larix occindentalis),* lodgepole pine *(Pinus contorta),* Douglas-Fir *(Pseudotsuga menziesii),* and

ponderosa pine *(Pinus ponderosa)* dominated one or more stands in Oregon. Stands in Montana were dominated by two or more of the following: western larch, Douglas-Fir, grand fir, lodgepole pine, Engelmann Spruce *(Picea engelmannii),* subalpine fir *(Abies lasiocarpa),* and white pine *(Pinus monticola).*

Methods
Field Procedures

To evaluate our sampling methods against known parameters, within each stand we first conducted a complete count (census) of all logs that had a large-end diameter of 15 cm or greater and a length of at least 1 meter. Trees that had fallen and broken were tallied as two pieces if the pieces were not touching; otherwise, each fallen tree was considered one piece. Only logs whose central axis lay above the ground were tallied (Brown 1974). If a log was suspended, only that portion of a log that was within 1.8 meters of the ground was tallied. A log was considered downed if it lay within 45 degrees of the ground. In the remainder of this paper, we refer to logs of these dimensions and characteristics as "qualifying" logs.

Each log was painted at both its large and small ends where the diameter measurements were taken using 1 m-long calipers. Diameters were measured to the nearest millimeter. Lengths of logs were measured to the nearest decimeter between the painted diameter marks. For large logs with their root systems still attached, the large-end diameter was measured just above the butt swell, whereas the length was measured along the entire bole from the root wad out to the 2-cm small-end diameter.

After finishing the complete count of logs, we then sampled along randomly established transects. We established six transects in most stands. Because of size constraints, however, a few stands only contained five transects. All transects were randomly located and oriented to minimize overlap. The typical transect was 100 m long and was delineated into 12.5 m subsegments; some stands, however, contained shorter transects owing to limitations on stand size. At the midpoint of each transect we established a cluster unit. This was a three-legged sampling unit, with each leg 25 m long and oriented at 120 degrees from other legs. Design of the three-legged sampling unit followed the example given by Hazard and Pickford (1986).

We then sampled along each 12.5 m subsegment using both the line-intersect method (LIM) and the strip-plot method (SPM). For the SPM, we conducted a complete count of all logs, or portions of qualifying logs, that fell within 2 m of either side of the transect line. We used the 1-m long calipers, which by design functioned as a square, to determine the outer boundaries of the strip plots. By contrast, only logs that were intersected by the transect line were tallied using the LIM. For the SPM, we recorded the length, the small- and large-end diameters, and the condition (sound or rotten) of each section of a qualifying log that fell within the boundaries of the strip plot. In addition, we recorded whether or not the mid-point of a log fell within the boundaries of the plot. For the LIM, we recorded the same information as with the SPM. In addition, we recorded the diameter of the log at the point of intersection.

Statistical Analysis

We used ordinary least squares regression to examine the relation between the true values of log density, total length, percent cover, and weight in each stand compared to our estimates of these parameters obtained from the SPM and the LIM. Specifically, we regressed the true value of log density, total length, percent cover, and weight on the estimated values generated by LIM and SPM. This resulted in four regression equations for each method, with one equation corresponding to each of the four log characteristics of interest. For the preliminary analysis conducted here, we used data from all stands to compute each equation, with each stand designated as a statistical unit of observation (n=17).

To evaluate bias of each method, we forced each regression line through zero by removing the y-intersect constant. This allowed us to determine whether a method over- or underestimated each parameter. Specifically, a regression slope (b) = 1.0 indicated no bias. By contrast, $b > 1.0$ indicated that the sampling method underestimated the true parameter, whereas $b < 1.0$ indicated that the sampling method overestimated the parameter.

To evaluate precision of each method, we used the coefficient of determination (r^2 values) obtained from the regression analysis. Coefficients of determination at or near 1.00 (100 percent) indicated high precision, whereas coefficients at or near 0.00 (0 percent) indicated extremely low precision.

To evaluate efficiency, we used two approaches. Under the first approach, we calculated the length of transect line required for each method to obtain an estimate of each log characteristic that was within 20 percent of the true mean, 90 percent of the time. Sample sizes given were based on the average length of transect required per stand. We standardized these calculations by using only straight-line transects that were 100 m long (n=75). We then incorporated the true value for each parameter obtained from our complete counts, rather than the sample value, into the sample size equation. This controlled for any strong influences created by using the sample mean statistic.

Under the second approach, we ranked the amount of field time (sampling effort) that was required by each method to measure each of the four log characteristics. Ranks were assigned on a relative scale that ranged from 1 to 3, as follows: rank 1, least effort; rank 2, moderate effort; and rank 3, most effort.

Results

Accuracy

Both the LIM and SPM produced relatively unbiased estimates of density, length, percent cover, and weight of logs. Values of b ranged from 0.99 to 1.04 for the LIM and from 0.97 to 1.02 for the SPM. Precisions of these estimates, however, were more divergent between the two methods. Coefficients of determination ranged from 0.58 to 0.93 for the LIM and from 0.75 to 0.94 for the SPM. In particular, the LIM was relatively imprecise in estimating density of logs, accounting for only 58 percent (0.58) of the variation in the true density. By contrast, the SPM accounted for 75 percent of the variation in the true density of logs. Finally, precision of both methods in estimating length, percent cover, and weight was relatively high, with coefficients of determination ≥ 0.82.

Efficiency

The LIM required more transect length per stand than the SPM to achieve the same level of precision for estimating density, length, percent cover, and weight of logs under all stand conditions. Transect length required of the LIM ranged from 1.0 to 3.8 km, while transect length required of the SPM ranged from 0.7 to 1.8 km. Differences were most pronounced for estimates of weight in harvested stands, where the LIM required an average of 138 percent more transect line per stand (3.8 km) compared to the SPM (1.6 km) to obtain the same level of precision.

Field effort required of LIM also was greater (ranking of 3) than SPM (ranking of 1) for estimating density of logs. The LIM required less field effort, however, than the SPM to estimate length and weight (LIM rankings of 1 versus SPM rankings of 2). Finally, either less field effort or the same amount of effort was required using LIM versus SPM to estimate percent cover, depending on how log diameters were measured with LIM. When large- and small-end diameters of logs were measured as part of the estimation of percent cover under LIM, field effort was ranked as moderate, the same as that estimated for SPM. Alternatively, when log diameters were measured at the point of line intersection under LIM, field effort for estimating percent cover with LIM was ranked as low.

Discussion

Our results indicate that both the LIM and SPM are relatively unbiased and precise estimators of most log characteristics under the conditions tested. The SPM appeared to be more precise, however than LIM in estimating density of logs. SPM also was more efficient than LIM in estimating density. By contrast, neither SPM nor LIM was clearly more efficient in estimating length, percent cover, or weight of logs. Consequently, which method is better depends on a variety of factors, particularly the stand conditions to be sampled and the log characteristics of most interest. For example, if the primary interest is to obtain accurate, efficient estimates of log density, then SPM appears to be the better choice. If other log characteristics are of primary interest, the choice of method is less clear. Finally, if all four log characteristics are of equal interest, SPM is the likely choice owing to its superior performance in estimating log density. We are currently exploring questions about each method's performance in relation to a variety of field conditions, using additional data collected during our study. Further analysis of our data should help clarify the merits of each method under a variety of conditions.

Our results also demonstrated the strong need for different methods to sample logs for wildlife research and management versus conventional methods that have been used for fire management. Conventional applications of LIM for fire management estimate log volume and weight, but ignore density, percent cover, and length. Because wildlife respond to a rich set of log characteristics, it behooves wildlife managers and researchers to apply methods like those described here to obtain accurate estimates of log characteristics most important to wildlife.

Acknowledgments

References

Brown, James K. 1974. **Handbook for inventorying downed woody material**. Gen. Tech. Rep. INT-16. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 24 p.

Bull, Evelyn L.; Holthausen, Richard S. 1993. **Habitat use and management of pileated woodpeckers in northeastern Oregon.** Journal of Wildlife Management. 57(2): 335-345.

Carey, Andrew B.; Johnson, Murray L. 1995. **Small mammals in managed, unharvested young, and old-growth forests**. Ecological Applications 5(2): 336-352.

De Vries, P. G. 1973. **A general theory on line intersect sampling with application to logging residue inventory.** Wageningen, The Netherlands: Mededelingen Landbouwhogeschool 73-11; 23 p.

Hazard, John W.; Pickford, Stewart G. 1986. **Simulation studies on line intersect sampling of forest residue, Part II**. Forest Science 32(2): 447-470.

Maser, Chris; Anderson, Ralph G.; Cromack, Kermit, Jr.; Williams, Jerry; Martin, Robert. 1979. **Dead and down woody material.** In: Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture; 78-95.

Parks, Catherine G.; Bull, Evelyn L.; Torgersen, Torolf R. 1997. **Field guide for the identification of snags and logs in the interior Columbia River basin**. Gen. Tech. Rep. PNW-GTR-390. Portland, OR: Pacific Northwest Research Station, Forest Service, U.S. Department Agriculture; 40 p.

Tallmon, David; Mills, Scott. 1994. **Use of logs within home ranges of California red-backed voles on a remnant of forest**. Journal of Mammalogy 75(1): 97-101.

Torgersen, Torolf R.; Bull, Evelyn L. 1995. **Down logs as habitat for forest-dwelling ants—the primary prey of pileated woodpeckers in northeastern Oregon**. Northwest Science 69: 294-303.

Van Wagner, C. E. 1968. **The line intersect method in forest fuel sampling.** Forest Science. 14(1): 20-26.