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Sampling Large Woody Debris Loading in Streams: A Comparison of the Line-Intersect and Census Methods

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SUMMARY

The two methods most commonly used to measure the loading of large woody debris (LWD) in streams are the line-intersect method and the census method. The line-intersect method uses a sub-sample of LWD to predict the total loading, while the census method involves measuring every piece of LWD in a reach. To date there has been limited validation of the line-intersect method for LWD measurement in streams. Both the line-intersect and census methods were undertaken on 7 stream reaches: 4 reaches in the Edward River in south central New South Wales, and 3 reaches in the Acheron River, central Victoria. Comparison of the two methods shows that the line-intersect method produces a very consistent and repeatable result (R^2 = 0.95). However the line-intersect method consistently overestimated the LWD volume loading by 100%. A third, rapid LWD sampling method was also used on the same stream reaches. The rapid method requires that the number of LWD stems over a minimum diameter of 0.3m be counted for a known reach of stream. When undertaken in conjunction with the census method for a number of reaches, the rapid method is calibrated and can be applied to a wider number of reaches. This rapid method has a lower sampling time than the line-intersect method with comparable results.

THE MAIN POINTS OF THIS PAPER

- The line-intersect method for LWD measurement should not be used without calibrating the method using a census of all LWD in a reach.
- A rapid assessment method can be used in conjunction with the census method to provide a wide coverage of LWD loading information.

1. INTRODUCTION

Knowledge of LWD loading is important for stream management and rehabilitation and is becoming part of the routine sampling of habitat features in our streams. Where the intended measurement is of LWD volume, or of surface area per unit of channel bed, to date there have principally been two methods of LWD sampling, line-intersect and full census methods. The line-intersect method is rapid technique that is used to estimate the total volume (or surface area) of LWD measured by a full census. The purpose of this paper is to provide a comparison of results using the two currently used methods (line-intersect and full census), and to suggest an alternative 'rapid' method. The procedures for the line-intersect and census methods are summarised below.

1.1 Census method

The full census method entails the recording of the diameter and length of each piece of LWD above a predetermined threshold size within a quadrat or known stream area (Harmon et al. 1986). The threshold size depends on the intention of the study. A lower limit of 0.1m diameter and a minimum length of 1m are commonly adopted (Gippel et al. 1996; Hogan 1987). There are several exceptions though, a minimum diameter of 0.15m was used by Cherry and Beschta (1989), while Robison (1988) and Robison and Beschta (1990) used a minimum diameter of 0.2m. A minimum length of 1.5m was specified by Lienkaemper and Swanson (1987), while Cherry and Beschta (1989) used a minimum length of 3m.

Various plot sizes have been used for the quadrat or known stream area (Harmon, et al. 1986). Warren and Olsen (1964) cited in Harmon et al. (1986), found long rectangles more efficient than circular plots. Based on these results and the elongated nature of streams, the quadrat area usually encompasses a reach or known length of stream with side boundaries governed by the channel banks (water surface width, or bankfull width) (Robison 1988).

The census method is a time consuming but very accurate and repeatable method of measuring the absolute loading of LWD in a reach of known length. The measurements can easily be presented as a volume loading, usually presented as m^3 of LWD per m^2 of channel bed, or as a surface area loading, m^2 LWD surface area per m^2 channel bed.

1.2 Line-intersect method

The line-intersect method was introduced for stream LWD measurement by Wallace and Benke (1984). The method was initially developed for forestry managment, to enable the volume of fallen timber and logging waste to be rapidly estimated (see Van Wagner (1968) and De Vries (1974)).

$$\hat{X}_v = \left(\pi^2 / 8L\right) \sum_{i=1}^{n} d_i^2 \qquad (1)$$

Where

$\hat{X}_v$ = estimated volume of LWD ($m^3$of LWD/m^2 of bed area)
L = length of the transect
d_i = diameter of the *i*th piece of LWD

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Equation 1 shows that the volume of woody debris is proportional to the sum of the square of the diameters of all the pieces of LWD intersected by the transect. Note there is no need to record the length of the pieces. Similarly the line intersect method can be used for estimating the surface area of LWD per unit bed area (equation 2).

$$\hat{X}_{sa} = \left(\pi^2/2L\right)\sum_{i=1}^{n} d_i \qquad (2)$$

$\hat{X}_{sa}$ = estimated surface area of LWD per unit of channel bed surface area (m^2 LWD / m^2 bed area)

Both formulae depend on three assumptions as presented by Van Wagner (1968):

1. "The Pieces are cylindrical. However, the presence of taper probably introduces no error.
2. All pieces are horizontal. However, the vertical angle can be quite large before the error is serious.
3. The pieces are randomly oriented. Bias in orientation can be corrected by special factors determined in field trials, or by running sample lines in two or more directions"

The critical assumption is that of random orientation. There is usually a higher proportion of LWD oriented in the direction of flow than other directions (O'Connor 1992; Gippel et al. 1996). Hence to reduce error in the line-intersect technique due to the non-random orientation of LWD, transects need to be either:

1. based on the known orientation distribution of debris (Warren and Olsen 1964), or
2. conducted in more than one direction (where the combination of transects is orthogonal) and averaging the results (Van Wagner 1968).

Using option 1 to determine a suitable transect angle to minimise error due to orientation bias requires pre-survey knowledge of the LWD orientation (Van Wagner 1968). Undertaking a pre-survey of the orientation of LWD in a reach prior to sampling, removes the advantage of the line-intersect method over the census method (speed) hence the second option is preferred (Gippel et al. 1996).

Van Wagner (1968) presented theoretical results using different transects in more than one direction for the extreme case where all sample pieces were oriented in the same direction. The three trials conducted were firstly, one single straight transect, secondly, two segments perpendicular to each other, and thirdly, three segments each at 60^0 to the previous. The first, single straight transect had a maximum possible error of –100 to +57% depending on the chosen angle of the transect with respect to the angle of the aligned sample pieces. The second transect (two segments at 90^0) had an error of –21 to +11% depending on the chosen angle of the initial transect, the transect with segments at an angle of 60^0 had the least error (-9 to +5%). Conclusions from Warren and Olsen (1964), recommend that for populations with a biased orientation, half of the transect should be oriented at right angles to the other half.

Another key characteristic when using the line-intersect method is to have a transect of suitable length to ensure that LWD loading is estimated with an acceptable degree of reliability (alternatively transects should be replicated to achieve the desired reliability). Van Wagner (1968) investigates this problem, with the conclusion that a length of transect that ensures at least 20 crossings provides a suitably reliable result.

2. METHODS

2.1 Census Method

The census method described above was followed, using 0.1 m diameter and 1m as the minimum size threshold for LWD. Eight reaches were surveyed, including 5 on the Edward River in south central new south Wales, and 3 on the Acheron in Central Victoria (Table 1).

2.2 Line-intersect method

Transect surveys proceeded with the following adaptations to minimise the potential error due to biased LWD orientation and ensure a simple and repeatable methodology.

The initial transect commenced on one bank at the bankfull height at one end of the reach in question. A string line was drawn across the channel at an angle of 45 degrees to the starting bank. The first leg of the transect stopped where the bankfull height was intersected on the opposite bank (Figure 1). From the second point the transect was conducted at 45 degrees to the second bank. In a straight channel this method results in an angle of incidence of 90 degrees between subsequent legs of the transect. However as the stream goes through a bend the angle of incidence will vary.

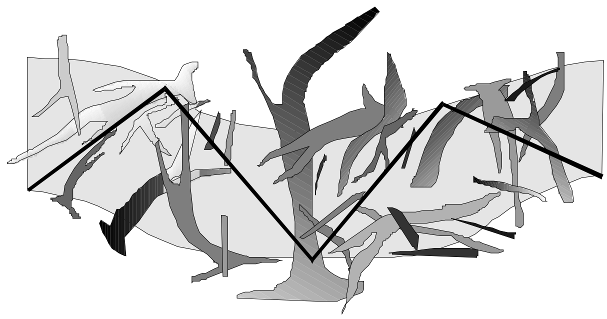

Figure 1: Line-intersect method:- Transect lines were surveyed at 45 degree to the bank for the length of the reach.

From the study by Van Wagner (1968), using two perpendicular transect lines could produce an underestimation of true loading by 21% if all LWD pieces are parallel and oriented in the direction of one of the transect lines. The maximum overestimation using this technique is 11% when all LWD pieces are parallel and are aligned parallel to the stream bank

The transect for the line-intersect sampling was continued to the end of the same reach surveyed using the census method. The line-intersect method was not undertaken on reach 2 of the Edward River (Table 1). This reach was characterised by deep pools and longitudinal bars made up of fine silt that extended the length of the reach. The fine silt bars were unable to be crossed in a straight line as is required by the line intersect technique, without significant risk to the surveyor.

2.3 Rapid survey method

An additional rapid method for estimating the LWD volume was also used on all 8 reaches. This involved counting the number of pieces of debris greater than 0.3m diameter, over the reach length. The result was recorded for each reach as the number of LWD pieces greater than 0.3m per 100m of stream.

The rapid survey method was developed to extend the application of census data. Census data is accurate but time consuming to collect, so only a limited number of reaches can usually be surveyed. To apply the rapid survey method, firstly the rapid assessment derived LWD loading values are correlated with the census survey results for corresponding reaches. If the correlation coefficient is acceptable for the project, and the assumption that the LWD size distribution is similar on all other reaches to be surveyed is acceptable, then the rapid survey method may be conducted on all remaining reaches. Once the census data has been collected, the rapid survey method can provide a relative loading value to allow the estimation of LWD loading on additional reaches. The equation to the line of best fit for the rapid survey method loading and census values can be used to estimate the LWD data for those reaches where only the rapid assessment technique has been used.

Table 1: Summary of stream reaches studied

River	Reach	Channel bankfull width (m)	Channel bed slope %	Dominant Riparian vegetation
Edward River	1	24.1	0.035*	Redgum
	2	47	0.003*	Redgum
	3	40.7	0.027*	Redgum
	4	32.9	0.024*	Redgum
	5	40	0.044	Redgum
Acheron River	1	6.1	0.026	Myrtle Beech
	2	9.4	0.010	Myrtle Beech
	3	13.4	0.005	Myrtle Beech – Redgum

*water surface slope from channel long-section surveyed during bankfull discharge

3. RESULTS

3.1 Sampling time

The sampling time for both the line-intersect and census methods varied according to the accessibility of the channel, the depth of water, size of the channel and density of LWD. However, for 100m reach lengths, a full LWD census required between 3 and 6 hours sampling time. The line-intersect method was completed in 0.5 to 1 hrs and the rapid survey method took approximately 10 minutes to complete. However, as we discuss below, the line-intersect and rapid survey methods both work best in combination with the more time consuming census method.

3.2 Debris loading

A comparison of the results of the line-intersect and census methods are presented for volume loading in Figure 2. The high R^2 (0.95) indicates that for the seven reaches where both methods were conducted, the line-intersect method produced a *consistent* approximation of the actual LWD loading as given by the census method. If the line-intersect method is to provide an *accurate* estimation of the total LWD loading, the slope of the line of best fit in Figure 2 should approach one. The slope shown on Figure 2 is approximately 2, hence for the reaches surveyed, the line-intersect method appears to *consistently* predict the LWD loading (volume) to be double that of the true loading provided by the census method.

A similar but slightly less well correlated result is found when comparing the line-intersect and census methods to predict LWD surface area (Figure 3). Again the line-intersect method is consistent with the census results (R^2 = 0.72). The magnitude of LWD surface area estimated using the line-intersect method was again much higher than that measured by the census method as shown by the slope of the line of best fit (slope = 1.7). These results imply that the line-intersect method must be calibrated with a more accurate measure of LWD loading.

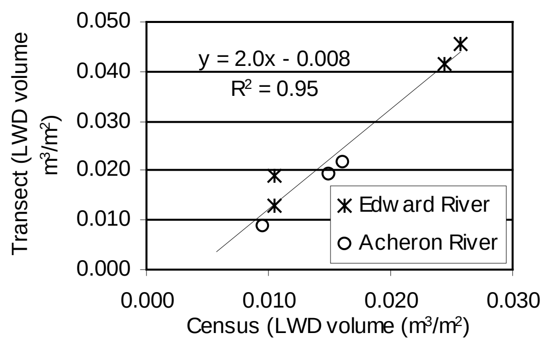

Figure 2: LWD volume prediction: comparison of the line-intersect and census methods.

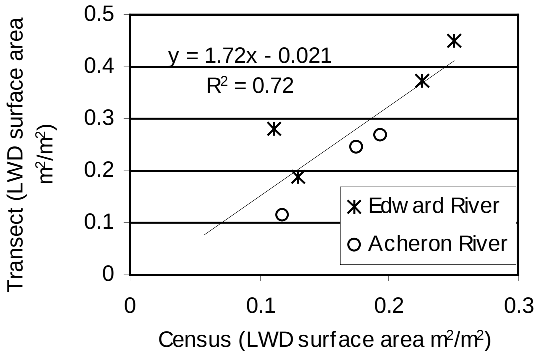

Figure 3: LWD surface area prediction: comparison of the line-intersect and census methods.

The rapid method was also well correlated with the census measure of debris load. Figure 4 shows a comparison of the number of LWD pieces (>0.3m) per 100m of channel length compared to the census values for each reach (LWD volume loading). The rapid assessment values correlate to the census values in a comparable way to the line-intersect values (R^2 = 0.80). Using the line of best fit through these data points provides some basic calibration of the rapid assessment data and allows for the estimation of LWD loading from other reaches where the rapid assessment method has been used.

The basic assumption of this approach is that the size distribution of LWD is comparable for all reaches investigated. The main influence on the size distribution of LWD is the riparian zone vegetation (ie. size of source material). All the reaches of the Edward River presented here had similar open River Red Gum forest on both banks. The riparian zone of the first two reaches of the Acheron River where characterised by Myrtle Beech forest, and the third reach was a transition between Myrtle Beech and River Red Gum dominated riparian forest. The correlation (Figure 4) between the census and rapid methods appears to be insensitive to the three different riparian zones covered in this project.

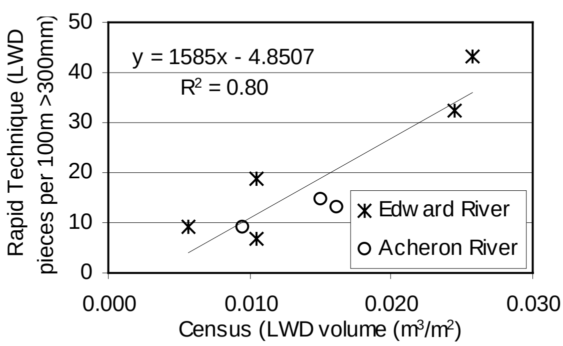

Figure 4: LWD volume using the census method compared to the rapid method for eight reaches on the Edward and Acheron Rivers.

4. CONCLUSIONS

From the limited data presented, the line-intersect method appears to be consistent and repeatable in its approximation of both LWD volume and surface area loading. However in both cases the line-intersect method dramatically overestimates the actual loading (by 100% for LWD volume and 72% for LWD surface area). The potential error due to bias in orientation accounts for only a small portion of this error (up to 11%). At this stage the authors have no theoretical basis for the apparently consistent difference between the two techniques.

A single reach comparison of line-intersect and census data in another lowland Australian stream showed that the line-intersect method overestimated the LWD volume by a factor of 5 (although transects were conducted perpendicular to the channel) (Gippel et al. 1996). This result does not match the trend of line-intersect estimated volume being approximately 2 times the volume measured using the census method presented above. The much reduced sampling time of the line intersect method makes it a preferable field method, however the results presented here provide evidence that line-intersect derived values should be validated with at least limited LWD census data.

We recommend the following approach to rapid sampling of LWD loading. The rapid method provided a correlation with the census method comparable to the line-intersect method. This method is useful where data is required over many reaches. Rather than attempt the time consuming census approach on all reaches it may be appropriate to undertake the census and rapid methods on a proportion of reaches. If the correlation between the two methods is acceptable, then only the rapid method is required for the remaining reaches. The regression line between census and rapid method data may be used to estimate the loading in these additional reaches where only the rapid method has been used. The line-intersect method may be used in the same manner as the rapid method, but with a greater time expenditure.

5. ACKNOWLEDGEMENTS

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