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Characterizing the variability of wood in streams: simulation modelling compared with multiple-reach surveys

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Abstract

Wood abundance in streams is an indicator of its likely geomorphological and ecological importance. However, wood volume estimates can be highly variable, due in part to natural variability and the methodology used to characterize it. We measured wood volume in streams of similar sizes and riparian forest conditions using extended field surveys and simulation modelling. We surveyed a total of 3·1 km along four tributary streams of New Zealand's Waihaha River to obtain an estimate of wood volume in streams with similar basin positions (second order), forest types (podocarp/hardwood forest), disturbance histories (post volcanic eruption of Taupo ca. 180 AD) and stream sizes (2–3 m bankfull width). A 'sliding window' analysis was conducted whereby the wood volume was calculated for a 'window' (i.e., reach survey of fixed length) that was progressively moved upstream in 10 m increments. The resulting frequency distributions of wood volume were bimodal and represented the range and relative proportion of reach volumes possible from the wood surveys. The wood volume based on all streams surveyed (23 m^3/100 m) was equivalent to the 64th percentile of the sliding window distribution, suggesting that a randomly placed study reach would be likely to underestimate wood volume. The bimodal distribution was attributed to the inclusion/exclusion of relatively large (≥10 m^3), but rare (0·3 logs/100 m) logs. We also examined the variability of reach-level wood volume estimates (200 m and 400 m) for the Waihaha tributaries using the model OSU StreamWood. The volume frequency distributions from the simulations were similar to those from the empirical approach, except that they were unimodal. We attribute the unimodal distribution to the greater number of reach-scale estimates used in the simulations ($n = 2000$). The two independent approaches characterized the variation of wood volumes possible for this forest type and stream width. Copyright © 2007 John Wiley & Sons, Ltd.

Keywords: New Zealand; wood in streams; OSU StreamWood; wood survey; LINKNZ; forest-gap model

Introduction

Wood affects biological, chemical and geomorphic processes in many streams throughout the world (see Gregory *et al.*, 2003a, for a recent review). One of the most fundamental variables describing wood in streams is its abundance (frequency and volume), which reflects the potential importance that wood may have in a given stream.

Estimates of wood abundance can vary considerably for streams in the same region (see, e.g., Berg *et al.*, 1998; Hering *et al.*, 2000). For example, estimates of wood volume in old-growth *Pseudotsuga menziesii* forest streams in the Cascade Mountains, Oregon, ranged from 45 to 1400 m^3 ha^{-1} (Harmon *et al.*, 1986, Table 6). Many variables contribute to the variability in wood abundance estimates such as stream width and forest type and age, as well as differences in numerous input and output processes and in the field methods (e.g. minimum size, sample length) (Bilby and Bisson, 1998). However, the range of volume in this example was from surveys (a Blue River tributary and Quartz Creek tributary 1) that were of the same forest type and age, stream width and methods. At least a portion of this wide range in wood volume can be attributed to the inherent variability in these systems caused by the magnitude and timing of input and output events.

In addition, the wide range in wood volume estimates for streams of similar forest and stream conditions may also be influenced by the methods used. A survey method used in many wood studies involves measuring all logs greater than an arbitrary minimum size within a fixed reach length (see, e.g., Harmon *et al.*, 1986; Hering *et al.*, 2000, but see Elosegi *et al.*, 1999, for a different approach). Since the longitudinal distribution of logs within a stream may not be uniform (Bilby and Bisson, 1998), the starting position and survey reach length can influence the wood volume estimate for a stream reach. For example, in a study of wood in old-growth forest streams in New Zealand, two 200 m survey reaches along the a Blue Grey River tributary differed in total wood volume by a factor of three (Meleason *et al.*, 2005). The difference in volume was influenced by the inclusion of large logs in one of the surveys. Since the large logs were not distributed uniformly within the stream, their inclusion or exclusion in the two surveys was directly related to the initial starting positions and survey length.

Wood surveys are temporal and spatial 'snap-shots' of a dynamic system. Resurveys of a study reach (e.g. tagging study) over years to decades provide information on wood dynamics and fluctuations in wood abundance (see, e.g., Lienkaemper and Swanson, 1987; Young, 1994; McHenry *et al.*, 1998). Longer time frames, which take into account changes in the riparian forest, have been examined using simulation models (see Gregory *et al.*, 2003b, for a review). Several wood models are stochastic, which enables them to predict the variability in wood abundance at a given time step (Malanson and Kupfer, 1993; Bragg, 2000; Meleason, 2001). This is similar to multiple reach surveys, which are designed to estimate the mean and variance of wood in streams with the same forest type and stream width (see, e.g., Berg *et al.*, 1998). As with the stochastic wood models, the multiple reach surveys produce a collection of wood abundance estimates for reaches of fixed length. In addition to providing an estimate of the overall mean (and variance) of wood, what additional information is contained in these data on the distribution and abundance of wood in streams of similar size and forest type?

In this study, we characterize the wood standing stock for a given forest type and stream size using frequency–volume distributions constructed from wood volume estimates. We present two independent but complementary methods to develop frequency–volume distributions for wood in 200 m and 400 m reaches on tributaries of the Waihaha River, New Zealand. The first method uses a 'sliding window' analysis of extensive wood survey data, and the second method uses numerical models based on the Monte Carlo technique. The volume frequency distributions produced by the two methods are compared and their value in describing wood abundance in streams is discussed as well as the implications for management of wood in streams.

Methods

Site description

Our study sites were on New Zealand's North Island in the Waihaha Basin (Figure 1) within Pureora Forest Park. The Waihaha River drains a volcanic zone, with peak stream flows moderated by the relatively high infiltration rates through the volcanic pumice that covers the area (McKerchar and Pearson, 1990). The last major eruption of Taupo, around 180 AD, covered c. 30 000 km^2 with pumiceous tephra, destroying all forests within range. The extent can be judged from the tephra fall, which damaged forests up to 170 km east of the vent. Based on pollen and charcoal analyses of sediments overlaying tephra deposits, seral vegetation flourished immediately after the eruption, regeneration was completed within 200 years and the restored forest composition was similar to the pre-eruption vegetation (Wilmshurst and McGlone, 1996). The forest below 600 m elevation is a podocarp/hardwood forest (McEwen, 1987) with a scattering of emergent podocarp species (height to 40 m) such as *Dacrydium cupressinum* and *Prumnopitys taxifolia*, with occasional *Podocarpus totara* and rare *Dacrycarpus dacrydioides*, over mostly mixed hardwood canopy trees such as *Beilschmiedia tawa*, *Weinmannia racemosa* and *Elaeocarpus dentatus*, with typical maximum heights of 20–25 m (Hinds and Reid, 1957). The Waihaha Basin is located within the Pureora Forest Park, in which small areas were subject to selective harvest from 1975 until 1981, when all logging in the park ceased (Smale *et al.*, 1987). We found no evidence of logging in the stream sections that we surveyed.

Streams in the Waihaha Basin tend to have three distinct sections: a relatively flat valley section on the floodplain of the Waihaha River, a middle section that is very steep on the basin side slopes and an upper terrace section. We surveyed the valley sections of four streams that were below 600 m in elevation (thus containing the same forest type) and were 2–3 m bankfull width. The four streams selected are unnamed, and identified in this study as streams A–D (Figure 1). Each reach survey started near the confluence with the Waihaha River and ended at an upstream junction, which was below 600 m elevation (Figure 1).

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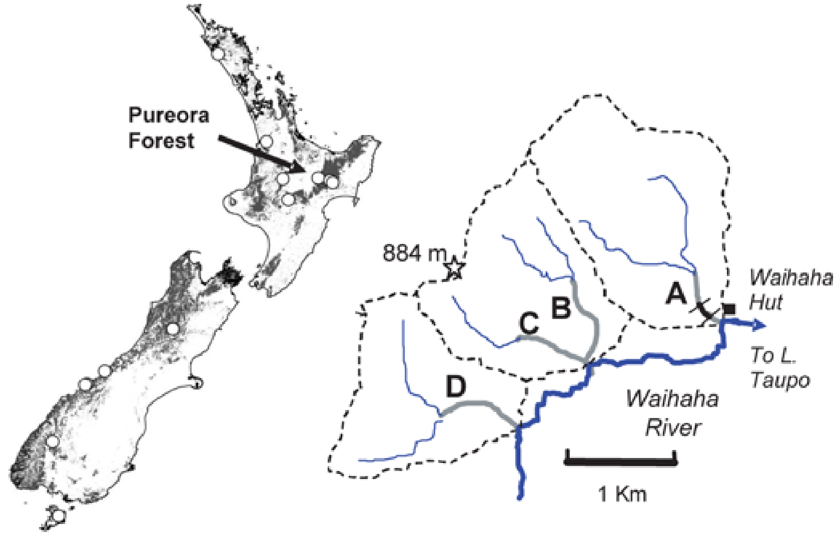

Figure 1. Location map of the study area in Pureora Forest, North Island, New Zealand. The outline map of New Zealand indicates forests (shading) and shows 12 locations (circles) where stream wood surveys reported earlier (Meleason *et al*., 2005) were conducted. Study reaches along four un-named tributary streams (denoted A–D) in the Waihaha Basin of Pureora Forest are shown, including the 200 m reach originally surveyed on Tributary A by Meleason *et al.* (2005). This figure is available in colour online at www.interscience.wiley.com/journal/espl

Field survey

We used a rapid assessment procedure that focused on the larger pieces that contribute disproportionately to total wood volume. For logs >4 m in length, we recorded total log length and the diameter at each end. Log volume (including the portion of the log outside of the stream) was then calculated using the volume formula for a truncated cone. For logs 1–4 m long, we tallied the logs within 1 m length size classes, and used results from previous detailed surveys (Meleason *et al.*, 2005) to estimate the mean volume for each length class. In our previous survey, logs 1–4 m long accounted for 66% of the frequency and 3·5% of the volume. Thus, we feel the error in estimating total wood volume for a study reach using the tally method was negligible. The mean volumes for the length classes (with sample size in parentheses) were as follows: length class 1–2 m, 0·02 m^3 ($n = 25$); length class 2–3 m, 0·09 m^3 ($n = 16$); length class 3–4 m, 0·2 m^3 ($n = 10$).

Field survey analysis

We used a 'sliding-window' technique to examine the variability of wood volume along each study reach. In this technique, a 'window' (survey reach) of given length is moved incrementally and the wood within the window recorded. A 200 m and 400 m reach length (sliding window) was used and a 10 m incremental distance. The reach lengths were selected to represent typical survey lengths (see, e.g., Harmon *et al.*, 1986, Table 6). The incremental distance was arbitrarily selected to provide a sufficient sample size for the analysis. Frequency distributions of wood volumes were constructed for each of the two sliding window analyses for the four study reaches.

Simulation modeling

Wood volumes were simulated with the OSU StreamWood model (Meleason, 2001) with the wood input from the forest provided by LINKNZ (Hall and Hollinger, 2000). Further details of these models and their linkage can be found in the work of Meleason and Hall (2005) and so are only described in outline here.

Both models are individual-based, stochastic (i.e., using the Monte Carlo method) programs that operate on an annual time step. LINKNZ belongs to a long-established family of forest-gap models (Botkin *et al.*, 1972) that reproduce the long-term dynamics of a forest by simulating recruitment, growth, and death of individual trees on fixed size sample plots. LINKNZ was developed to simulate successional sequences in the native forests of New Zealand and, like its predecessor LINKAGES (Pastor and Post, 1986), it includes a soil moisture balance and tracks litter return and decomposition. As the forest develops, the model monitors litter quality, the decomposition of foliar litter, twigs and coarse wood and the variation in soil organic matter and available soil-nitrogen pools.

OSU StreamWood was modified to import a dead tree file from LINKNZ and populate the riparian zone of a user-specified area. Each tree is assigned a location (*x* and *y* coordinates) and fall angle from a uniform random distribution. An effective tree height (tree height to10 cm top diameter) is also calculated for each tree. Trees are subjected to a breakage function when they fall, and all resulting logs that are at least partially within the channel are tracked in the simulation. Each log is subjected to the following in-channel wood dynamics on an annual time step: breakage, movement and decay. Breakage is a function of stream residence time and log diameter. If the location of the break along the log is outside the stream, then the portion of the log completely on the bank is no longer considered. The chance of movement is a function of the log length to bankfull width ratio, the proportion of the log outside of the channel, annual peak flow (randomly selected from a log-normal distribution for each year) and the number of key pieces per reach (log length ≥1 bankfull width). If a log is a 'mover', then the distance it moves is calculated using an exponential function with average travel distance equal to the reciprocal of the exponential constant (set to 10 channel widths for these simulations). Logs are decayed using a negative exponential function of time and species-specific decay rates for both the terrestrial and stream environments. The decay rate for logs partly in the channel is an intermediate value between the terrestrial and aquatic rates based on the proportion of log outside the channel.

LINKNZ Simulation

A forest simulation was conducted by LINKNZ for a sample site (448 m elevation, latitude 38°44, longitude 175°44) located close to the Waihaha River in the central North Island. The area is covered in lowland, podocarp/mixed hardwood forest. Mean monthly temperature (annual average = 12·37°) and total monthly precipitation (average = 1440 mm/yr) for the site were estimated from climate parameter surfaces fitted to a network of meteorological stations (Busby, 1991; Leathwick *et al.*, 2003). Soil parameters for field capacity at 15·4 cm, soil wilting point at 3·3 cm, initial soil organic matter at 81 Mg/ha and initial soil N at 1·43 Mg/ha were set from sample data and characteristics of the predominant soil class (New Zealand Soil Bureau, 1954). Forest growth was simulated over an 1800 yr period (representing the period since the Taupo eruption) with 100 iterations (1/12th ha sample plots) to reproduce the forest dynamics around the site. No major catastrophic disturbance effects were modeled during the period. Propagules from 75 ecologically significant tree species were assumed to be constantly available at the site throughout the simulation period. Each forest simulation was begun with the assumption that initially the site was clear. LINKNZ generated a tree mortality file that identified the species, stem diameter at breast height, total tree height, year of death and plot iteration.

OSU StreamWood Simulations

Two simulations were conducted, one using a 200 m reach length and the second using a 400 m reach length for comparability with the sliding window analysis of field data from the four study reaches. The hypothetical stream in each simulation consisted of four reaches arranged linearly with bankfull widths of 3 m wide. From previous work, a 50 m wide riparian area was sufficient to capture the full recruitment potential of this old-growth forest type (Meleason and Hall, 2005). Therefore, the dimension of each riparian forest was 50 m wide by the length of the reach (200 m or 400 m). Each riparian forest was populated with forest plots randomly selected from the 100 plots from LINKNZ forest model output – 12 plots for the 200 m simulation and 24 for the 400 m simulation. The simulations were for 2000 iterations of 1800 years (time since the Taupo volcanic cataclysm) and the total volume predicted for the most downstream reach (inputs include logs from upstream reaches) at year 1800 was used for comparison with outputs from the sliding window analyses. Thus, the simulation data sets consisted of $n = 2000$ estimates of total wood volume for this reach width and forest type at a forest age of 1800 years.

Results

Wood Volume and Longitudinal Distribution

We surveyed a total of 3·1 km along four separate streams, which had a mean bankfull width of 2·7 m (range 1·7–3·2 m) (Table I). A total of 845 logs were sized with an overall average abundance of 27·4/100 m and an overall average volume of 23·9 m^3/100 m (Table I). Out of all logs measured, 50% were in the smallest volume class (<0·1 m^3), accounting for 3·5% of total volume, and 1·2% (10 individual pieces) were in the largest volume class

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Table I. Reach survey results

Reach survey	Bankfull width (sd) (m)	Survey length (m)	Log number (/100 m)	Wood volume (m^3/100 m)
A	3·2 (0·8)	807·8	37·5	37·1
B	3·1 (0·9)	893·0	21·1	15·4
C	1·7 (0·4)	497·0	20·5	11·4
D	2·9 (1·0)	890·3	28·3	27·3
A–D[1]	2·8 (0·8)	30 881	27·4	23·9

[1] Value based on all reach surveys combined except for survey length, which is the sum of the four reach survey lengths.

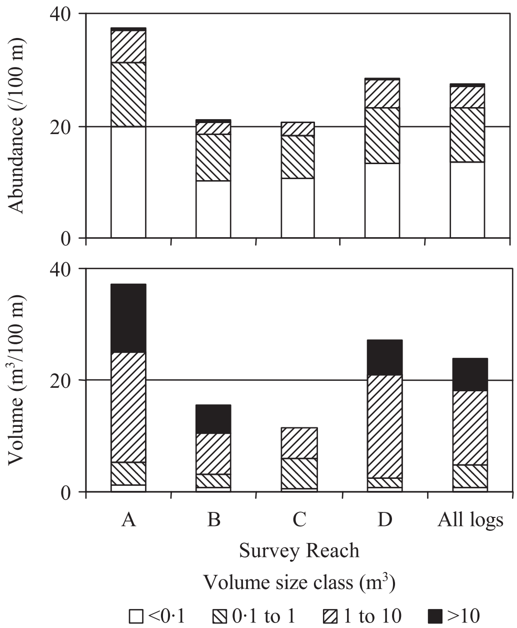

Figure 2. Contribution to log abundance and wood volume of four volume size classes. Data are presented separately for each survey reach (A–D) and for all logs combined.

(≥10 m^3), accounting for 24·6% of total volume (Figure 2). Total volume by survey reach varied threefold (Table I, Figure 2), which was attributed in part to the contribution of these rare, large logs. For example, four logs were in the largest size class in Reach A, accounting for 33% of the total volume, and the largest individual log measured (38·2 m^3) accounted for 13% of the volume (Figure 2). The largest log in Reach D (25·9 m^3) accounted for 15% of the total log volume in the reach. In contrast, Reach C had no logs in the largest size class and had the least wood volume of all the reaches (Figure 2).

The longitudinal distribution of logs in the largest size class was not uniform (Figure 3). The average dispersion distance (stream length per log) for the largest size class was 290 m for all reaches, and 202 m, 223 m and 445 m for Reaches A, B and D respectively (Reach C lacked large logs). The locations of these large logs can be identified in Figure 3 as sharp increments on the cumulative volume curves. Because these average dispersion distances are comparable with the empirical reach lengths, we might expect bimodality of volume frequency distributions depending on whether one or more large logs are encountered.

Large logs tended to occur along the reaches in clusters reflecting species composition and forest dynamics. For Reach A, logs in the largest size class were absent in the first 58% of the survey (473 m), but three logs in the largest size class occurred within the next 100 m section, and the last large log 226 m further upstream (Figure 3). For Reach B, the first two logs in the largest size class were 30 m apart starting at 336 m and the remaining two large logs were found at 588 and 824 m (Figure 3). The largest log along Reach C was 7·6 m^3. However, 44% of the log volume in Reach C occurred within a 20 m section at 240 m (Figure 3). In Reach D, the two logs in the largest size class

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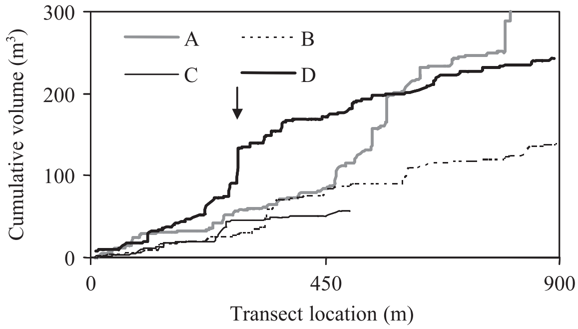

Figure 3. Longitudinal profile of cumulative wood volume for the four study reaches. Large logs are indicated by 'jumps' in the distributions – an example log is indicated for stream reach D.

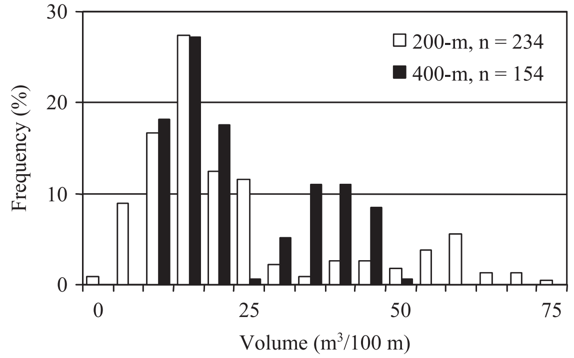

Figure 4. Frequency distributions of wood volume in 200-m (open bars) and 400-m (solid) survey reaches. Data are from a 200-m and 400-m sliding window analysis applied to the four study reaches.

occurred within 16 m of each other, starting at 267 m (Figure 3). Overall, three logs ≥30 m^3 were observed: 36 m^3 (reach D, 283 m), 38 m^3 (reach A, 796 m) and 30 m^3 (reach A, 570 m).

Sliding Window Analysis

The mean volume from the 200 m sliding window analysis was 25·3 m^3/100 m with a range of 2·9–75·3 m^3/100 m (Figure 4). The mean volume for the 400 m window analysis was similar (26·0 m^3/100 m), but the range was appreciably smaller (11·6–54·0 m^3/100 m) (Figure 4). Both frequency distributions were bimodal, with the most frequent volume between 15–20 m^3/100 m (Figure 4). The second peak was not as distinct as the first, and occurred at 60–65 m^3/100 m for the 200 m window and 35–45 m^3/100 m for the 400 m window.

Simulation of Wood Volume

An 1800-year time series of wood volume was simulated for streams in the Waihaha forest for both 200 m (Figure 5) and 400 m reach lengths. Wood volumes from the 200 m reach were predicted to increase steadily to a mean 30·0 m^3/100 m by year 500, corresponding to the growth of mean forest biomass to ~400 Mg/ha. The distinct spike in mean volumes to 40·0 m^3/100 m at year 900 was caused by the mortality over a 50 year period of several podocarp trees, mainly *Dacrydium cupressinum*. These large senescent trees were the last survivors from the initial cohort. A smaller pulse in wood volumes from the mortality of podocarp species was predicted after year 1400. The simulated spikes showed the impact that clusters of large logs could make on wood volumes and reflected the variation found in the survey data.

The mean volume from the 200 m reach simulation at 1800 yr was 19·7 m^3/100 m with a range of 2·8 to 67·3 m^3/100 m (Figures 5 and 6). The mean from the 400 m reach simulations at year 1800 was very similar (20·0 m^3/100 m), but the range was less (3·6–56·6 m^3/100 m) (Figure 6). The mean abundance of logs was also similar; with 25·2 and 25·0/100 m for the 200 and 400 m reach simulations respectively. The frequency–volume distributions for both simulations were positively skewed like the empirical distributions, but were unimodal rather than bimodal (Figure 6).

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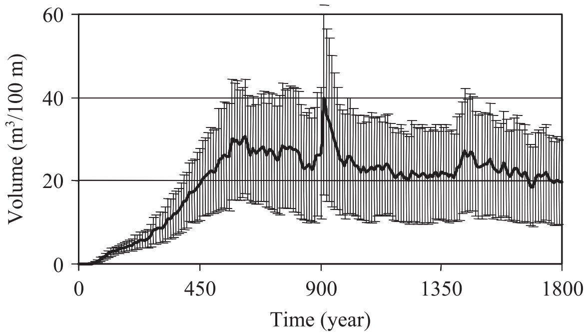

Figure 5. Simulated time series of wood volume for a 200 m reach. Error bars are ±1 standard deviation.

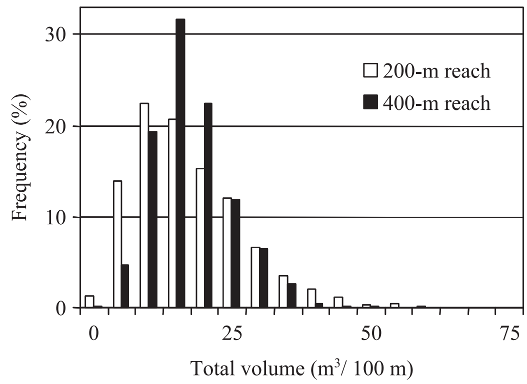

Figure 6. Simulated distributions of wood volume in 200 m (open bars) and 400 m (solid) survey reaches. Data are for the 200 and 400 m reach simulations at 1800 yr. Note that for both simulations $n = 2000$.

Observed Versus Simulated Reach Volumes

When the empirical and simulated volume cumulative frequency distributions (200 m reach length) were compared (Figure 7), both were positively skewed and broadly similar in shape, despite the fact that the empirical distribution was bimodal, in contrast to the simulated unimodal distribution. The frequencies of logs by volume class for the observed and simulated 200 m reach estimates were also very similar (Figure 8), and a Kolmogorov–Smirnov test found no evidence that the two samples were drawn from different populations (p-value = 1·0, $n = 4$).

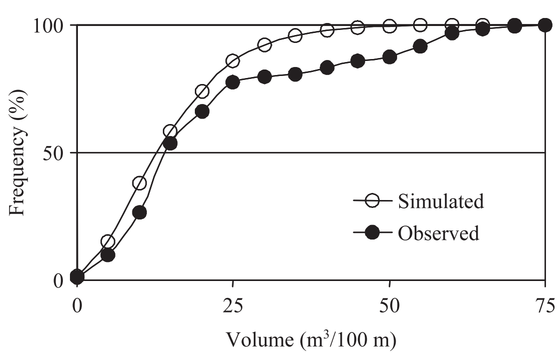

Figure 7. Comparison of the empirical (sliding-window analysis) and simulated cumulative frequency distributions of wood volume in 200 m reaches.

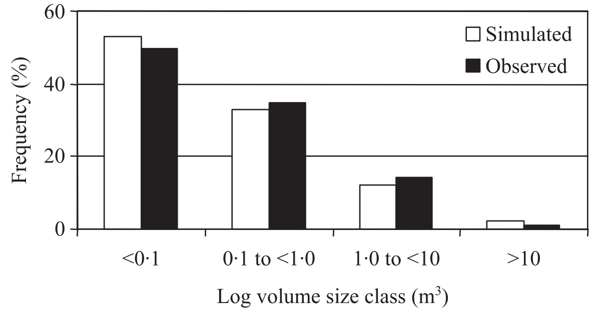

Figure 8. Comparison of the empirical (sliding-window analysis) and simulated frequency distributions of logs partitioned into four different size classes.

Discussion

Wood Volume in Waihaha River Tributaries

The streams selected for this study had several key attributes in common, including size, forest type, disturbance history and basin position. Based on all field surveys (3·1 km surveyed over four streams), the wood volume associated with an old-growth podocarp/hardwood forest type in the Waihaha Basin was 23·9 m^3/100 m. There was appreciable variation in wood volume between the four study reaches (Figure 2), which was driven largely by the presence/absence of large logs. This influence of large but rare logs on reach wood volume estimates has been highlighted in previous research (Meleason *et al.*, 2005). For example, a single redwood log accounted for 60% of the wood volume reported for a study section in the Redwood Creek Basin (Keller *et al.*, 1995). In a review of wood surveys in Central Europe, one study reach was heavily loaded with wood (206·2 m^3/100 m owing to several large beech (*Fagus sylvatica*)), whereas at other sites wood volume was <27 m^3/100 m (Hering *et al.*, 2000). Local environmental conditions may favour the establishment of particular species and contribute to the variation in wood volumes for each stream, and contribute to the variability at the landscape scale. For example, the dominant forest species *Dacrydium cupressinum* tends to favour elevated sites in a forest stand and so is less likely to establish than other shorter species near low stream banks below steep terrain. In contrast, the tall podocarp species *Dacrycarpus dacrydioides*, which is rare in the study area, is more tolerant and often found in flood-prone fluvial areas (Hinds and Reid, 1957; Duncan, 1991).

Sliding-window Analysis

Each 'window' in the analysis represented a potential wood volume estimate that could have been observed in the field with random placement of a study reach. The variability of wood volume in the sliding-window analysis reflected the longitudinal distribution of the logs, especially the larger (>10 m^3) pieces, and gave rise to bimodal wood volume frequency distributions (Figure 4). The 400 m window had a narrower range of volumes than the 200 m window because it was more likely to include a large wood piece. In essence, the shorter window provided more information on the relative volume per fixed reach length. This compares with the concept of selecting a 'representative' reach length, in which a longer reach would be most likely to capture the 'true' mean volume but provide limited information on the variability in wood loading.

Because the volume frequency distribution was sensitive to window size, setting the window size to 200 m, a reach length adopted in previous surveys, permitted comparisons to be drawn. For example, a previous survey at a Waihaha tributary estimated a volume of 49 m^3/100 m (Meleason *et al.*, 2005), equal to the 86th percentile of the frequency distribution of volumes (Figure 7). Moreover, the average wood volume based on the surveys of streams A–D (23·9 m^3/100 m) was equivalent to the 63rd percentile of the 200 m window distribution, suggesting that a randomly placed study reach would be likely to underestimate the overall wood volume.

Simulation Scenarios

The simulations predict the mean and variance of wood volume through time as the riparian stands mature and species replacement sequences occur on the site due to competitive pressures (Figure 5). The mean wood volume at 1800 yr

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is similar for the two simulations (19·7 and 20·0 m^3/100 m) and was slightly less than the observed wood volume. Besides measurement error, allometric differences and modelling error, there are at least three other reasons for the models' slight (17%) underestimations of mean wood volume. First the current stream/forest conditions were assumed to correspond to recovery following the post-Taupo eruption 1800 yr ago. This may have been an overestimate of how rapidly the forest regenerated, despite the pollen and charcoal evidence suggesting seral vegetation quickly established and the restored forest composition was similar to the pre-eruption vegetation within 200 years (Wilmshurst and McGlone, 1996). The simulation year in the 200 m run that was closest to the observed mean volume was 1580 yr. Second, tree fall direction, which can influence the volume estimate by a factor of three (Van Sickle and Gregory, 1990), was assumed to be random, when it is likely that the topography would induce a directional bias, favouring more wood reaching the stream. Third, the empirical mean wood volume might be a (slight) overestimate, which would decrease with additional stream surveys.

Another interesting property of the analyses presented is that the empirical volume frequency distributions were bimodal whereas the simulated distributions were unimodal. The sliding-window analysis reflects the actual spatial variability of a fixed set of logs (number, size, volume, longitudinal location). In contrast, each of the 2000 volume estimates at 1800 yr was from a *unique* set of logs. The 'real-world' equivalent would be to have 2000 × 200 m reaches (400 km!) of surveys in the Waihaha basin. This suggests that if the total length of stream survey were extended indefinitely, the frequency–volume distribution of the observed data set would approach unimodality.

Implications for Management

The mean wood volume associated with a given forest type and stream size is useful in comparing wood standing stock across regions. However, the volume distributions provide additional information on how common a given reach survey's wood volume would be for that system. Similarly, the frequency–volume distribution would provide a context for previous wood surveys.

The volume frequency distributions presented here characterized the potential range of wood volumes possible at the reach scale for an old-growth system. Reducing the riparian width or employing other riparian management regimes such as selective thinning would affect the range in wood volumes possible through time. Through simulation modelling, this approach could also be used to evaluate the likelihood of obtaining a targeted amount of wood within the channel for a given riparian management prescription.

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