The Influence of LWD and Tributary Confluences on the Local Grain Size Distributions of the H.J. Andrews Stream Network

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Abstract

The influence of Large Woody Debris (LWD) and tributary confluences on the grain size distributions of a mountainous stream network in the Western Cascades was analyzed. Longitudinal Trends in grain sizes were determined to be increasing with downstream distance. The influences that LWD and tributary confluences have on these trends were investigated using spatial and bivariate correlations. The median and fine fraction grain sizes were found to generally not be spatially correlated. Inconclusive correlations were determined between LWD abundance and local grain sizes, as well as for the local influences of tributaries. Considerations for future work include additional grain size sampling and log-jam type classification.

Introduction

The longitudinal trend of decreasing grain size with increasing downstream distance within a stream network is thought to be largely attributed to the physical phenomena of abrasion and sorting of grains during transport. There have been several predictions of the functional relationship that best describes these trends. An exponentially decreasing trend has been observed for the mean grain size of sandstone and shale (Knighton, 1980), while power functions have been observed to better describe longitudinal reduction in the grain size of coarse alluvial gravels in which the reduction mechanism was thought to be primarily sorting (Brierley and Hickin, 1985). Sorting coefficients, determined using the *Folk and Ward's 1957* method, have also been observed to decrease as downstream distance increases and hypothetically follow a sinusoidal pattern (Knighton, 1980). The irregularities in longitudinal trends have been hypothesized to be partly due to tributary confluences (Knighton, 1980). Such irregularities in the form of downstream coarsening and upstream fining have been observed to occur at tributary confluences with the main stem (Benda et al., 2004). However few studies have been performed to investigate the influences of tributaries and Large Woody Debris (LWD) on the grain size distribution throughout a stream network. Understanding the effect that LWD and tributaries have on the local grain size distribution within a stream network has great importance in regards to ecological conservation and land management.

The objective of this investigation is to evaluate the longitudinal trends of, and the extent to which LWD and tributary confluences influence, the grain size distribution within a mountainous stream network in the Western Cascades.

Methods

Study site

The H.J. Andrews experimental forest was first established in 1948, and in 1980 became a member of the National Science Foundation's Long-Term Ecological Research program. It is located within the Western Cascades of Oregon. Within the forest lies the Lookout Creek watershed, and accompanying stream network

(Figure 1). The watershed drainage area is approximately 15,800 acres, and consists of diverse landscapes due to geologic variation and land disturbance history.

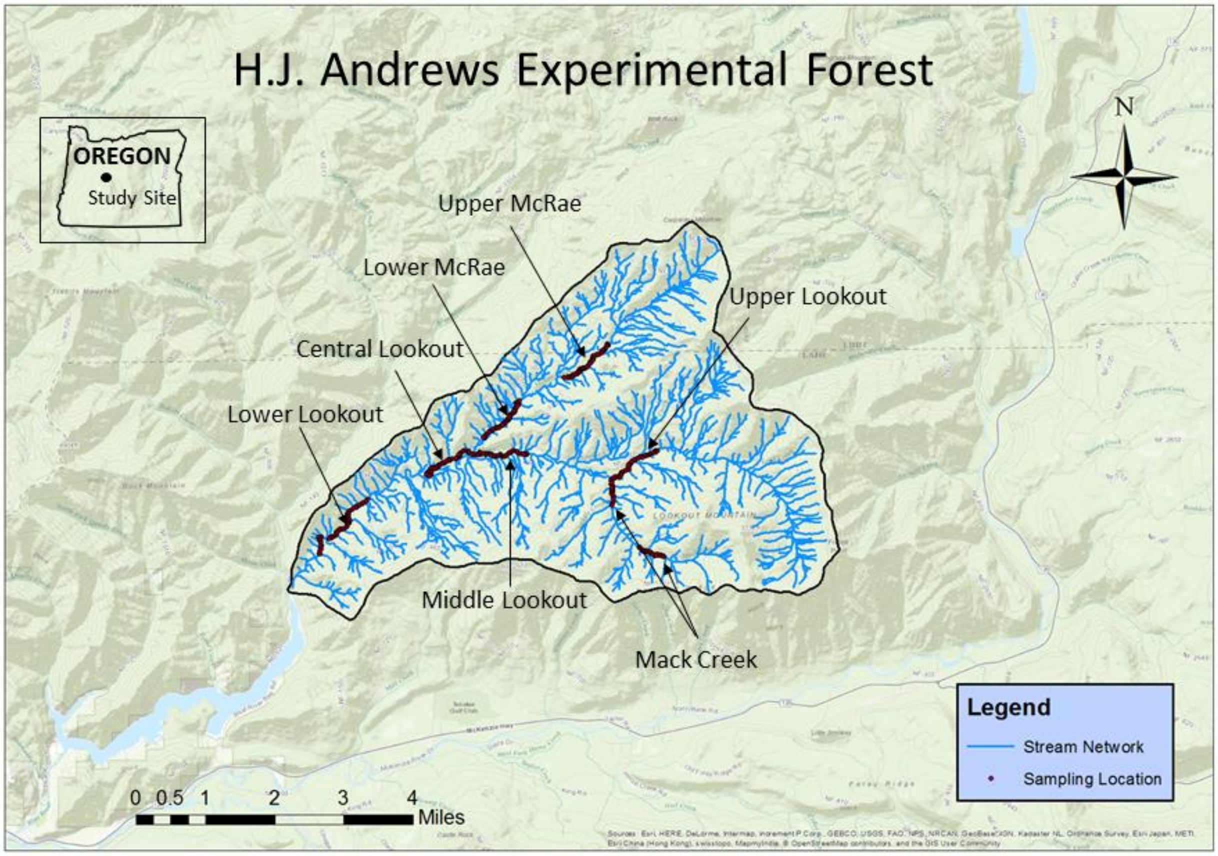

Figure 1: HJ Andrews stream network with designated study segments.

Data Collection

Longitudinal surveys of channel cross sections were conducted every 50 meters for approximately 11 kilometers of streams in the H.J. Andrews Experimental Forest. Data was collected from a total of seven segments throughout the network (Figure 1). The data collected included cross section location, grain size distributions, channel width and gradient, and an inventory of LWD. Locations were georeferenced using Avenza maps software. Grain size was recorded into geometric size classes with use of gravelometers and Wolman particle counts (sample size of 100 per cross section). Channel width was measured with a measuring tape and included mid-channel bars if side channels were thought to be part of the active channel. Channel gradient was measured every 50 meters with use of a clinometer and stadia rod. LWD was counted via estimates of size based on the classification developed by Czarnomski et al (2002). Differentiations were made between single pieces of LWD and pieces that formed log-jam accumulations. LWD was categorized as a log-jam if there were at least three pieces of LWD and two points of contact between the pieces. The location of prominent features such as tributary confluences, log-jams, debris flow runout tracks, road crossings and transitions from old growth forest to new growth were noted.

Grain Size Distributions

Using the data collected, grain size distributions were determined for each individual cross section using a log base two interpolation between grain size categories (Equation 1, DSWC 2004). Important grain sizes (mean,

d_{16}, d_{50}, and d_{84}) were compared against downstream distance for individual segments, and the entire network, to determine present trends.

$$S = 2^{\log_2(S^-)+[P-P^-]*\frac{[\log_2(S^+)-\log_2(S^-)]}{[P^+-P^-]}} \tag{1}$$

Where:

S = grain size (mm)
S^+ = grain size at the top of range (mm)
S^- = grain size at the bottom of range (mm)
P = grain size percentile of inquiry
P^+ = percent of particles smaller than S^+
P^- = percent of particles smaller than S^-

Spatial Autocorrelation

Correlation techniques were performed on individual segments to determine if correlation was present. Correlations in the local grain size distributions between cross sections were analyzed spatially with autocorrelation and with wood volume in a bivariate analysis. .

Spatial autocorrelation determines whether a particular sample of interest is correlated spatially, and the lag at which the particular variable can be estimated based on the sample taken. The autocorrelation function (ACF) (Equation 2) was used in the R programming language with a 95% confidence interval to determine if there was spatial correlation for the median and sixteen-percentile grain size (d_{16}) of each segment.

$$ACF_k = \frac{\sum_{i=1}^{N-k}(Y_i - \overline{Y})\,(Y_{i+k} - \overline{Y})}{\sum_{i=1}^{N}\left(Y_i - \overline{Y}\right)^2} \tag{2}$$

Where:

$r = autocorrelation\ coefficient$
$N = number\ of\ sample\ sites$
$i = index\ number$
$Y = observation\ value$
$\overline{Y} = mean\ observation\ value$
$k = lag\ index$

Pearson Correlation

Pearson's correlation coefficient (Equation 3) was used to determine if there was a linear relationship between the volume of wood in the stream and the grain size. The total volume of wood in one particular 50-meter section was compared to multiple grain size percentiles (d_{16}, d_{50}, and d_{84}) for each of the seven segments.

$$r = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2}\,\sqrt{\sum_{i=1}^{n}(y_i - \overline{y})^2}} \tag{3}$$

Where:

$r = Pearson\ correlation\ coefficient$
$y = second\ sample\ dataset$

$$x = first\ sample\ dataset$$

Results

Longitudinal plots for Lookout Creek were generated for multiple grain size percentiles ((d_{16}, d_{50}, and d_{84}) (Figure 2).

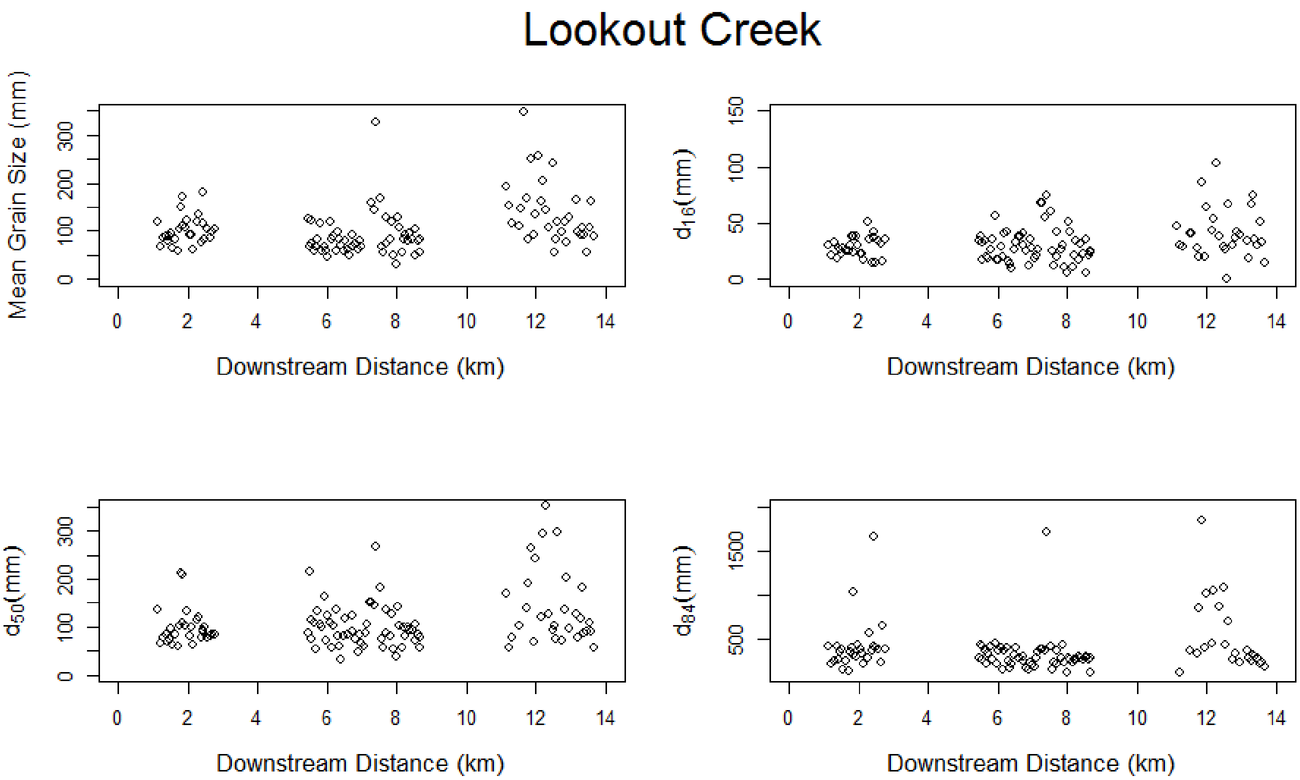

Figure 2: Longitudinal grain size (mean, d16, d50, and d84) plots for Lookout Creek.

Contrary to what is found in the literature, the longitudinal trends for each grain size increased with increasing downstream distance. Linear, exponential and power functions were fit to the Lookout Creek grain size versus downstream distance data but resulted in insignificant coefficients of determination (<0.06 for all cases). Additionally, the graphical inclusion of tributary confluences and log-jams showed no visually apparent trend (Figure 3).

Throughout the network the median grain size was generally not correlated spatially. The autocorrelation analysis established that the median grain size was autocorrelated for only two out of seven segments within a 95% confidence interval. For those two autocorrelated segments, the ACF was within confidence intervals for only one 50-meter lag and did not appear to be correlated with the presence of tributaries or log-jams. (Figures 4 & 5).

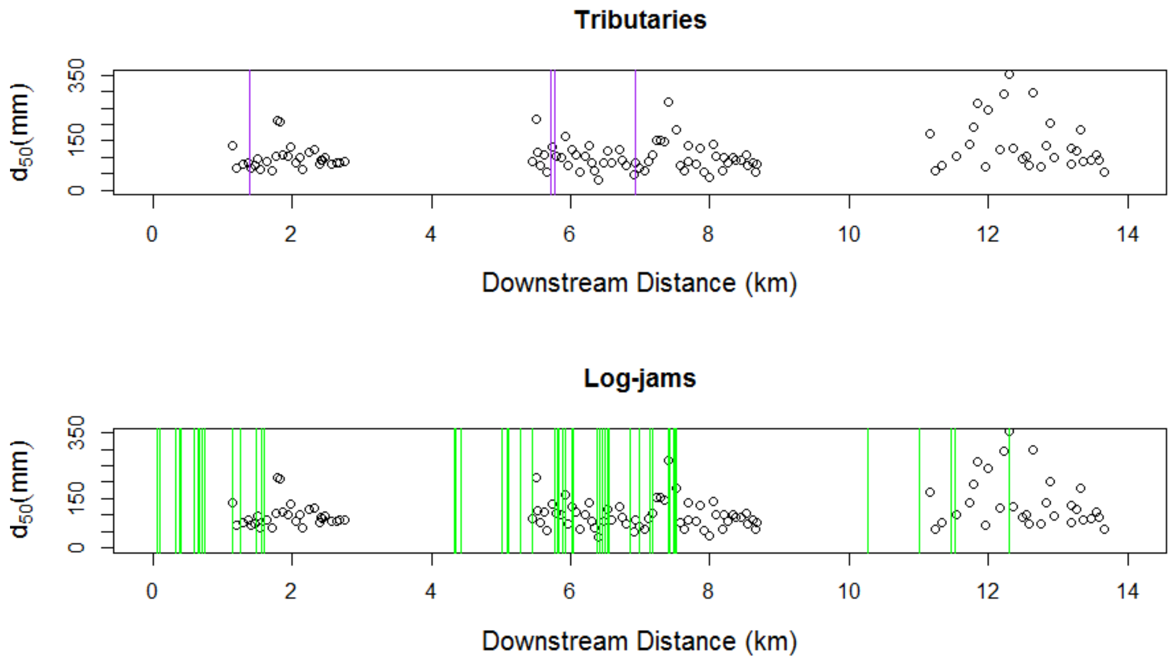

Figure 3: Median grain size versus downstream distance plots for Lookout Creek with intersecting lines for tributaries (top) and log-jams (right).

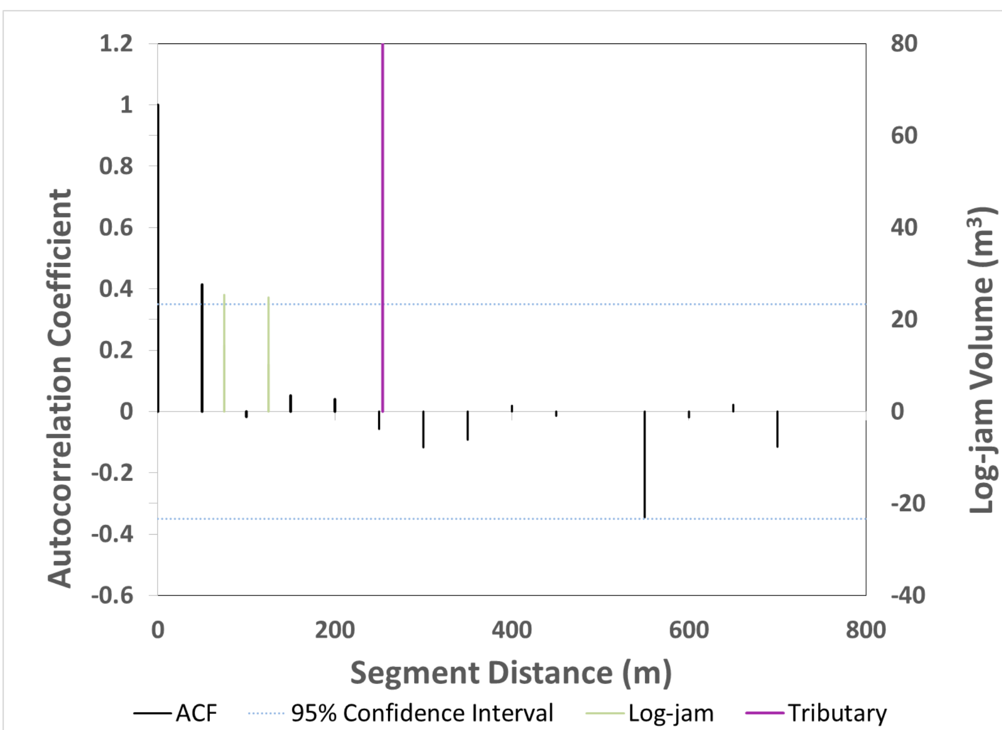

Figure 4: Autocorrelation function (ACF) versus downstream segment distance for Upper Lookout with log-jams and their respective volumes (secondary axis).

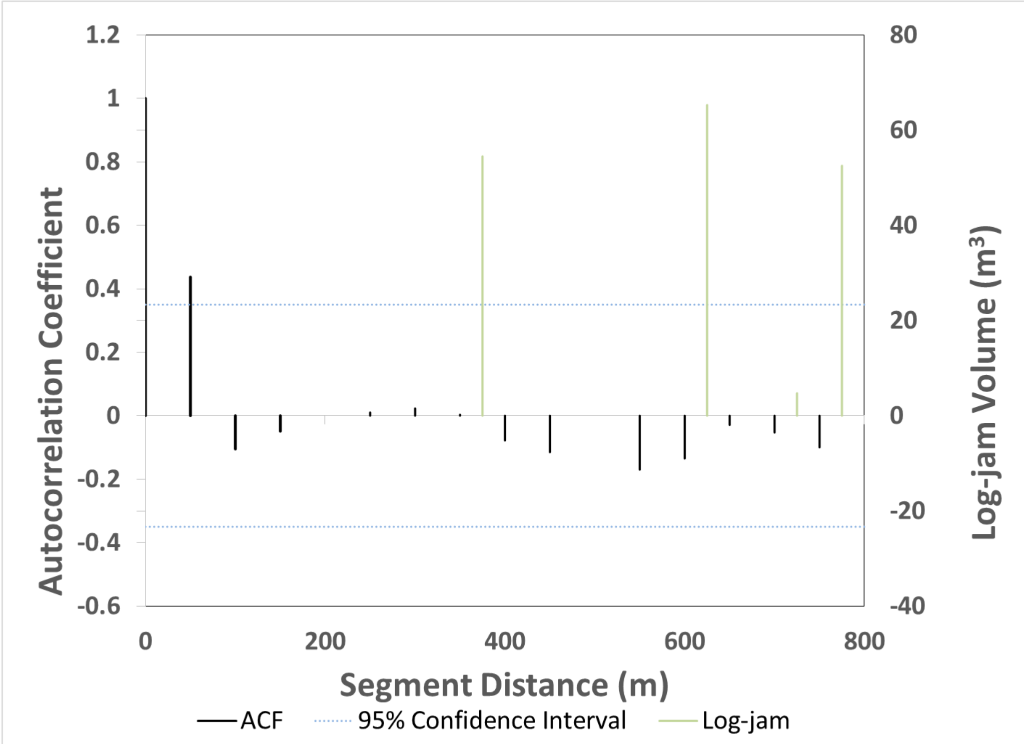

Figure 5: Autocorrelation function (ACF) versus downstream segment distance for Upper McRae Creek with log-jams and their respective volumes (secondary axis).

Bivariate analyses suggested that there was a weak correlation between the grain size and the volume of wood within close proximity. Pearson's correlation coefficient was computed to analyze correlation between different grain size percentiles and the nearby (within 50 meters) accumulated wood both downstream and upstream (Figures 6 & 7 respectively). Positive weak (r = 0.20 – 0.39) correlations were found for fine grain sizes (d_{10} & d_{16}) when related to the downstream LWD for two of the moderately wooded segments, and a negative weak correlation was found for various grain sizes in three of the relatively large LWD abundant segments. Correlations between grain sizes and upstream LWD resulted in negative weak correlations for several LWD abundant segments. The most abundant segment however had a positive weak correlation with upstream LWD.

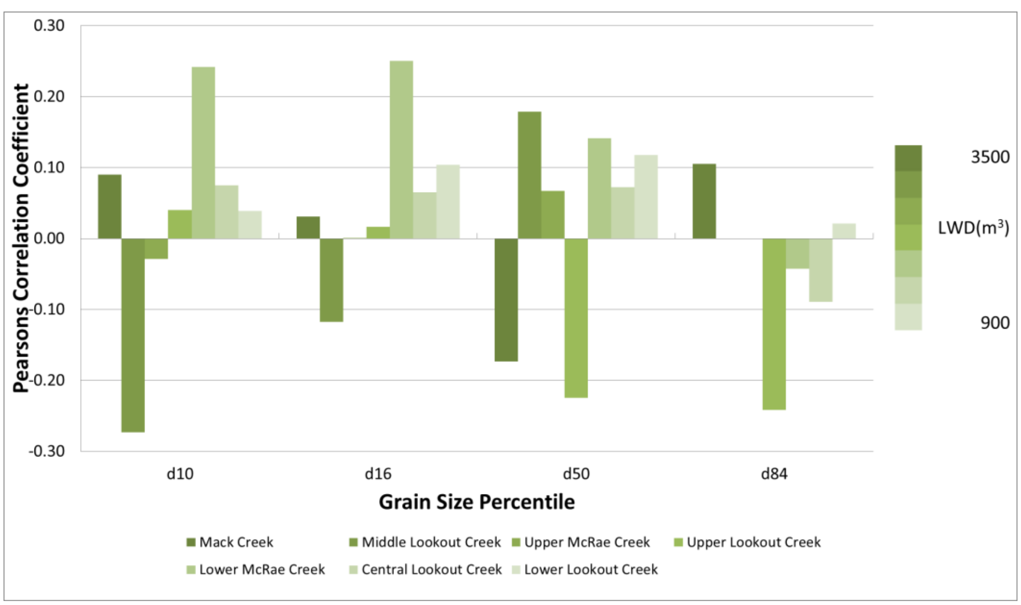

Figure 6: Pearson correlation coefficients for grain size percentiles versus accumulated volume of wood in 50 meter proximity downstream of grain size location for all seven segments.

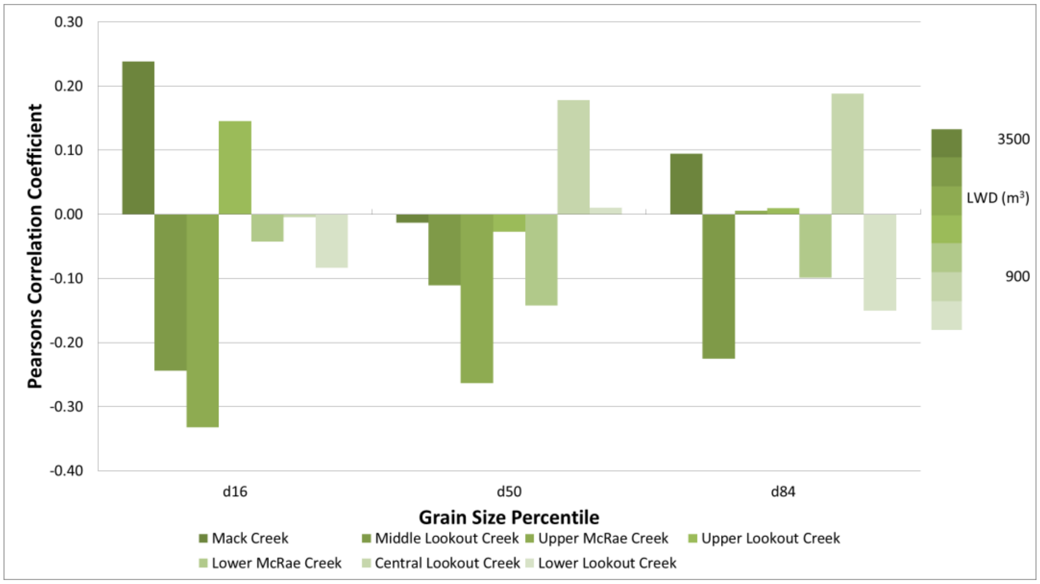

Figure 7: Pearson correlation coefficients for grain size percentiles versus accumulated volume of wood in 50 meter proximity upstream of grain size location for all seven segments.

Longitudinal trends were also analyzed on individual segments in which tributaries were present (Appendix A). Local grain sizes increased downstream and decreased upstream of Lookout Junction (the junction between McRae Creek and Lookout Creek). Middle Lookout Creek showed immediate (within 50 meters) upstream decrease in grain size and downstream increase in grain size for the median and eighty-forth percentile grain sizes. Mack Creek had immediate upstream decrease and downstream decrease in the eighty-forth percentile grain size only. Conversely Mack Creek also showed an upstream increase and downstream decrease in median and fine fraction grain sizes.

Discussion

Longitudinal trends for the grain size distribution were assessed for Lookout Creek. Although no significant functional correlation was found, the overall longitudinal trend for increasing downstream distance was increasing for all grain size percentiles. Discrepancies with what is found in the literature (decreasing grain size with increasing downstream distance) may be attributed to the influences that LWD and tributaries have within the HJ Andrews stream network.

The autocorrelation analysis for the median and fine fraction grain sizes suggests that there is minimal correlation for the grain size distribution spatially. Bivariate analyses suggested that coarsening of grain size occurs for fine fractions in relatively moderately wooded segments. Downstream fining of larger grain sizes was suggested for Upper Lookout Creek, and for the tenth percentile grain size of Middle Lookout Creek (two of the most LWD abundant segments). Additionally an upstream fining was observed for the LWD abundant segments except for Mack Creek (the most LWD abundant segment). Inconsistent trends in LWD abundance and change in grain size suggests that additionally influences may be present.

The influence of tributaries differed depending on the segment analyzed. Mack Creek experienced upstream coarsening and downstream fining for the median and fine fractions (contradictive to Benda et al., findings) at tributary junctions. In the lower gradient, and less LWD abundant, junction of McRae Creek and Lookout

Creek, upstream fining and downstream coarsening occurred for the median and eighty-forth percentile grain sizes (similar to Benda et al., findings).

The type of log-jams present in each segment is likely to effect the upstream and downstream effects on the grain size distribution. The log-jams within Mack Creek were predominantly channel spanning log-jams (i.e. bench and step jams) (Figure 8). Channel spanning log-jams may act as a blockage to large sediment. The less porous a channel spanning logjam becomes, the greater the obstruction is to larger sediment. This could explain why Mack Creek experienced upstream coarsening. Less steep segments, such as those in Lookout Creek, had logjams that were predominantly bank residing log-jams that did not span the entire channel (i.e. meander jams) (Figure 8). These log-jams redirect flow causing local scour, but may be less of a blockage for the passage of large sediment.

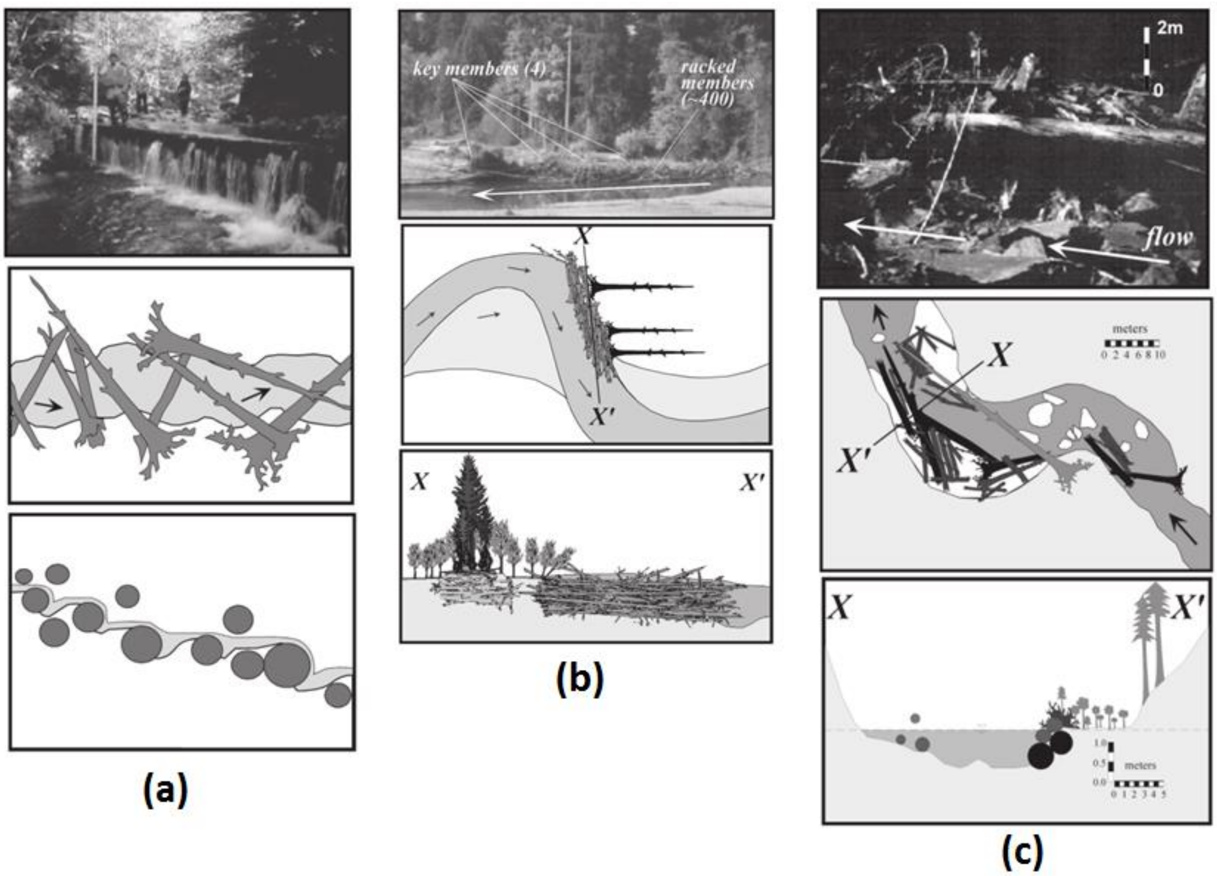

Figure 8: Different types of log-jams(a) step jams, b) meander jams, and c) bench jams) commonly found in alluvial rivers, with a corresponding photograph, plan view, and side view (from top to bottom) (Abbe et al., 2003).

Conclusion

The grain size distribution of a mountain stream network within the Western Cascades was analyzed to determine the longitudinal trends and the influence of LWD and tributary confluences. Contrary to what is commonly found in the literature, the longitudinal grain size trend for Lookout Creek was increasing within increasing downstream distance. The median and fine fraction grain sizes were found to have minimal spatial correlation, and are thought to be influenced by the presence of LWD and tributary confluences. Pearson's correlation coefficient found weak correlations for several segments, and opposite correlations for two of the most LWD abundant segments (Mack Creek and Middle Lookout). The type of log-jams present (either channel spanning or not) is likely to influence the way in which the grain size is effected by the LWD and the passage of sediment. On the segment scale local grain size trends were analyzed where tributaries were present, which resulted in opposite trends for two segments. The oppositional trends at tributary confluences may be due to cumulative flow and stream power at junctions.

Future considerations include additional finer sampling at tributary junctions and log-jams. Close proximity spatially incremented pebbles counts (both upstream and downstream) of tributaries and log-jams may give a better idea of the influence LWD has on various grain sizes. Additionally classifications of each log-jam (either channel spanning or not) will give insight into whether or not a log-jam is obstructing the passage of sediment.

Literature Cited

Benda, L., Poff, N. L., Miller, D., Dunne, T., Reeves, G., Pess, G., and Pollock, M. (2004). "The Network Dynamics Hypothesis: How Channel Networks Structure Riverine Habitats." BioScience, 54(5), 413.

Brierley, G. J., and Hickin, E. J. (1985). "The downstream gradation of particle sizes in the Squamish river, British Columbia." Earth Surface Processes and Landforms, 10(6), 597–606.

D. S. W. C. (2004). "Calculating D50." Ohio Department of Natural Resources. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwi6ocbH_PDVAhWJjFQKHfhrB5IQFggoMAA&url=https%3A%2F%2Fwater.ohiodnr.gov%2Fportals%2Fsoilwater%2Fdata%2Fdoc%2FCalculating_D50.doc&usg=AFQjCNGDkQxXLpjlTlXQLWqDYuKWhHltzg

Knighton, A. D. "Longitudinal changes in the size and shape of stream bed material: evidence of variable transport conditions." Catena 9.1-2 (1982): 25-34.

Acknowledgements

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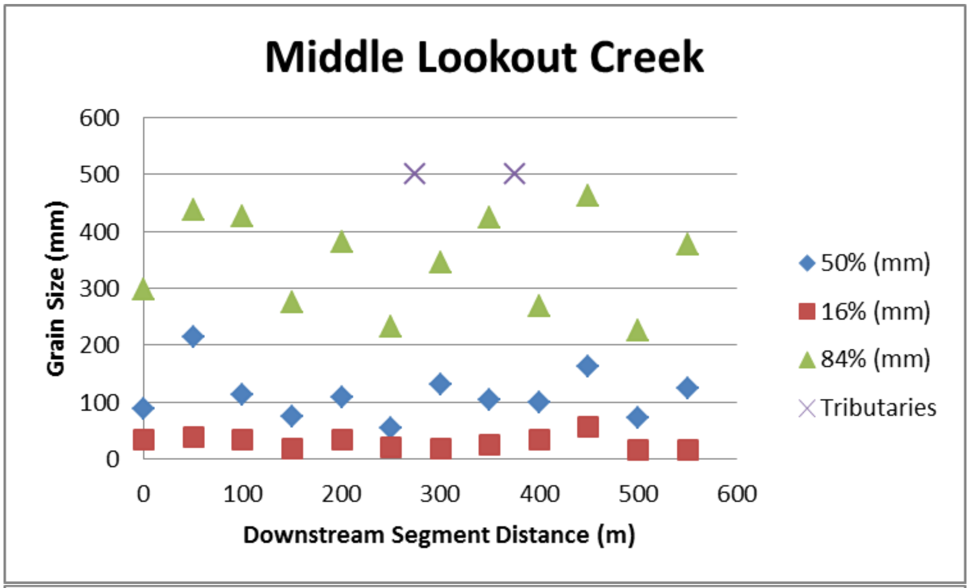
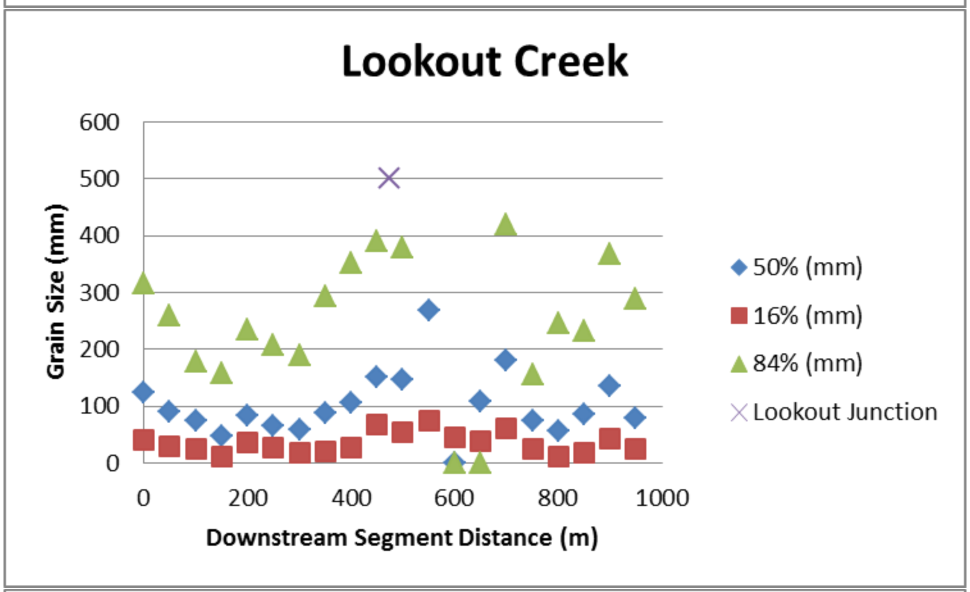
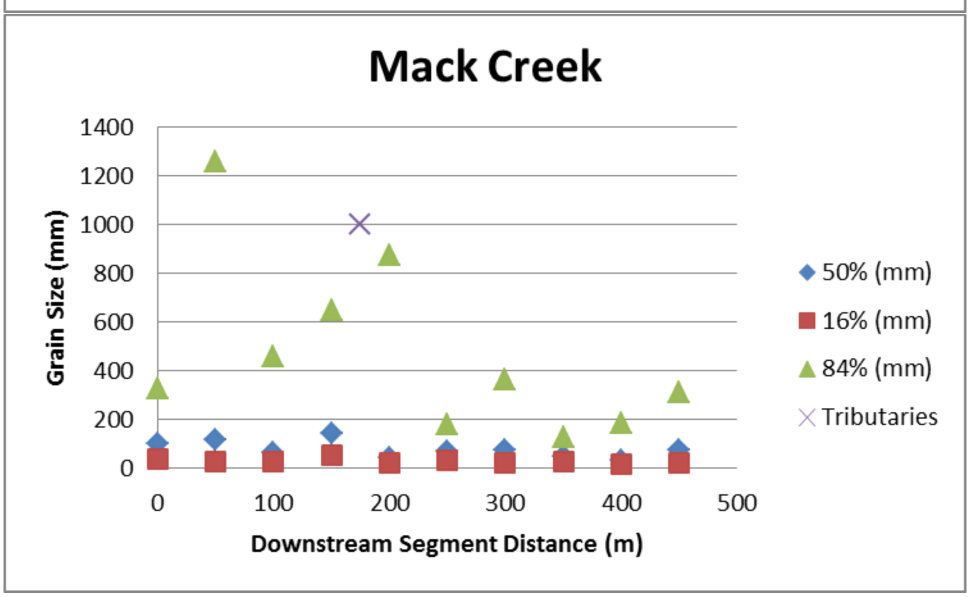
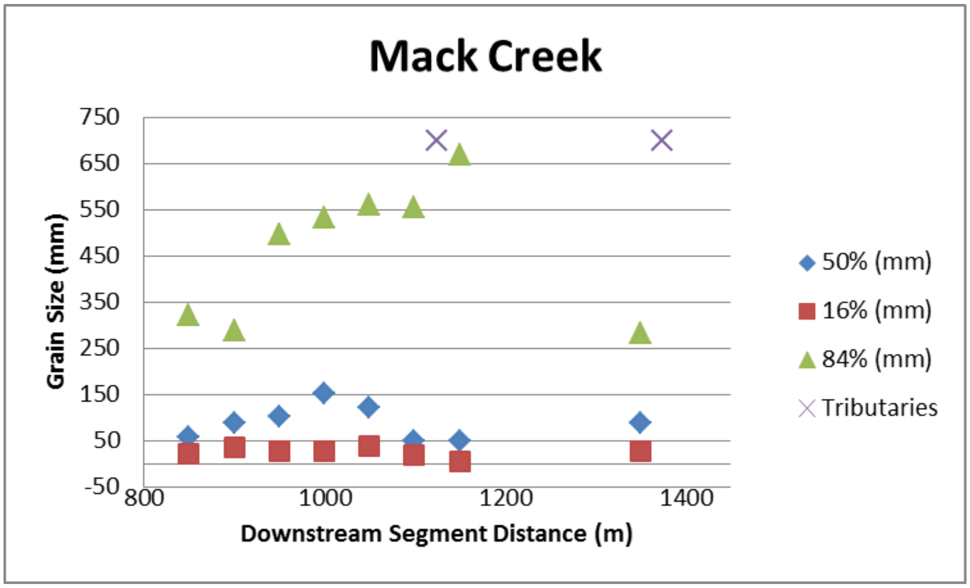
Appendix

Tributary containing segment plots of grain size versus downstream distance.


Middle Lookout Creek
Grain Size (mm)
600
500
400
300
200
100
0
0
100
200
300
400
500
600
Downstream Segment Distance (m)
50% (mm)
16% (mm)
84% (mm)
Tributaries


Lookout Creek
Grain Size (mm)
600
500
400
300
200
100
0
0
200
400
600
800
1000
Downstream Segment Distance (m)
50% (mm)
16% (mm)
84% (mm)
Lookout Junction


Mack Creek
Grain Size (mm)
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
Downstream Segment Distance (m)
50% (mm)
16% (mm)
84% (mm)
Tributaries


Mack Creek
Grain Size (mm)
750
650
550
450
350
250
150
50
-50
800
1000
1200
1400
Downstream Segment Distance (m)
50% (mm)
16% (mm)
84% (mm)
Tributaries