

*Woody debris in fjord sediments  
influenced by localized logging in  
Barkley Sound, British Columbia*

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## Non-technical summary

Logging activity on Vancouver Island has many potential impacts on proximal rivers and streams, including the destabilization of stream banks, increased erosion, and rafting of sediment downstream that eventually deposited at the river mouth. However, the effects of logging on the transport of woody debris (such as twigs, wood chips, and pieces) have not been well documented. The focus of this study was to examine the impacts of logging activity on the concentration of particulate woody debris deposited in three rivers (Sarita, Franklin, and Effingham) that feed into Barkley Sound. The focus areas include a 500-meter buffer bounding the rivers, and the entire span of their drainage basins. Logging activity was calculated by classifying satellite images into three land cover classes: freshly logged forest/bare soil, recovering logged areas, and fully-grown forest (either previously logged or undisturbed). Results of this analysis show that older logging plots (previously logged and now in the process of recovering) within a 500-meter buffer of these rivers are significantly more influential in wood transport than recently logged patches within that same buffer. Analyses of all three river basins show that there is no correlation between logging activity and woody debris deposition at the mouth of the drainage basin. Additionally, there is a positive correlation between the amount of fully grown forest (within both the 500-meter buffer and over the entire basin) and the amount of woody debris deposited at the mouths of each river. The Sarita, Franklin, and Effingham basins all have very similar amounts of logging activity (both current and recovering plots), yet do not exhibit similar amounts of woody debris deposited at the river mouth.

## Acknowledgements

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## Abstract

Logging activity on Vancouver Island has many potential impacts on proximal rivers and streams, including the destabilization of stream banks, increased erosion, and rafting of sediment downstream that is eventually deposited at the river mouth. However, the effects of logging on transport of woody debris (such as twigs, wood chips, and pieces) have not been well documented. The focus of this study is to examine the impacts of logging activity on the concentration of particulate woody debris deposited in three rivers (Sarita, Franklin, and Effingham) that feed into Barkley Sound. Woody debris was measured as a percent by weight in sample marine sediments, typically located at the mouth of the drainage river. Particulate woody material was separated manually and fine material by density fractionation methods with 1.2 g/ml sodium polytungstate as a medium. The focus areas include a 500-meter buffer bounding the rivers, and the entire span of their drainage basins. Logging activity was calculated by classifying satellite images in ArcGIS into three land cover classes: freshly logged forest/bare soil, recovering logged areas, and fully-grown forest (either previously logged or undisturbed). Drainage basins were determined by creating triangulated irregular networks (TIN) in ArcGIS and tracing along topographical high points. Results of this analysis show that older logging plots (previously logged and now in the process of recovering) within a 500-meter buffer of these rivers are significantly more influential in wood transport than recently logged patches within that same buffer. Analyses of all three river basins show that there is no correlation between logging activity and woody debris deposition at the mouth of the drainage basin. Additionally, there is a positive correlation between the amount of fully grown forest (within both the 500-meter buffer and over the entire basin) and the amount of woody debris deposited at the mouths of each river. The Sarita, Franklin, and Effingham basins all have very similar amounts of logging activity (both current and recovering plots), yet do not exhibit similar amounts of woody debris deposited at the river mouth.

## Introduction

Vancouver Island, located on the western margin of British Columbia, is a bountiful source of natural resources, particularly timber. Historically, more than half of British Columbia's total exports have been timber, and nearly a quarter of the workers in logging and other primary industries are located in the Vancouver Island/Coast region of British Columbia ([http://www.guidetobceconomy.org/major\\_industries/forestry.htm#1](http://www.guidetobceconomy.org/major_industries/forestry.htm#1)). Exploitation of timber for paper products has stressed the natural environment, by compromising the integrity of forest substrate and through the construction of roads to transport material.

Hartman et al. (1996) categorized long-term impacts of deforestation on Carnation Creek, also located in Barkley Sound. Over the course of the study, 41% of the basin was clear-cut between 1976 and 1981 and another 42% between 1987 and 1994. To date, ~61% of the length of headwater streams has been logged, requiring 38.5 km of road and 21 crossings of hillslope slides (Hartman 1996). After logging a 21 ha sub-basin, summer flow levels increased 78% and runoff peaks increased by ~20%, but only for early autumn storms. Alterations of natural hydrological pathways, such as loss of water interception by the canopy, compaction of soils along skid trail road and ditch channels probably caused the increased yield and runoff. This resulted in an estimated 25,480 m<sup>3</sup> of sediment deposition, principally from landslides into the creek. The largest impacts, as determined by this study, were the destabilization of large woody debris, erosion of stream banks, entrainment of sediment, widening of the channel, and deposition of sediment in the lower reaches (Hartman 1996).

In addition to the study at Carnation Creek, Beschta (1978) examined the Needle Branch and Deer Creek (Figure 1). They also concluded that logging activity resulted in increased sediment deposition as a result of stream erosion. Approximately 82% of Needle Branch was clear-cut and 25% of Deer Creek was patch-cut, of which 5% and 4% was for roads and landings, respectively. There was no effort to leave riparian buffer zones for the clear-cutting of Needle Branch. Deer Creek however, contained a 15-30 meter buffer zone on the two lower patch-cut units to prevent changes in stream temperature and to slow erosion. However, there were distinct increases in sediment loading in both streams shortly after logging, even though Deer Creek had a riparian zone in place (Figure 1).

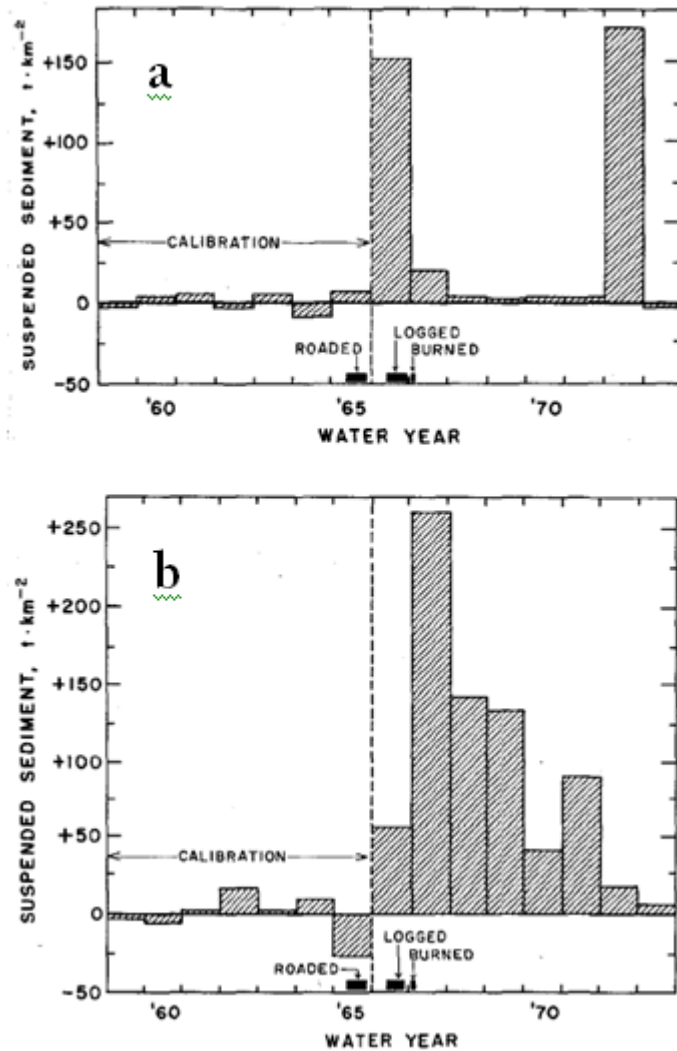


Figure 1. Increases in annual sediment yield after road building and: 25% patch cut logging on Deer Creek watershed (a), 82% clear-cut logging on Needle Branch watershed (b). Figures from Beschta (1978).

Based on these studies, it is evident that clear-cutting results in a variety of impacts within nearby streams. However, an analysis of the loading of small woody debris into nearby streams as a direct result of logging has not been investigated as thoroughly. Woody debris transport is becoming a larger focus when evaluating the effects that logging has on nearby streams. There is increasing interest in protecting the sources of in-stream wood in managed forest because of the important role wood plays in the geomorphology and ecology of streams and rivers (Bilby 1981). A large source of this woody debris originates in the riparian zones that border each river. The province of British Columbia currently mandates a minimum Riparian Management Area (RMA) of 40 meters, and it can range up to 70 meters, dependent on the classification of the river or stream (Young 2000).

The goal of this study was to delineate the localized impacts of terrestrial logging on the woody debris deposition (processes or quantification of debris sedimentation) in nearby marine sediments. The focus was to contrast the degree of logging activity within a 500-meter buffer and over the entire drainage basins of the Effingham, Sarita, and Franklin Rivers to the amount of woody debris that is found in the marine sediments at the mouths of those rivers. These rivers were chosen due to their differing levels of logging activity in close proximity to the river.

## Materials and Methods

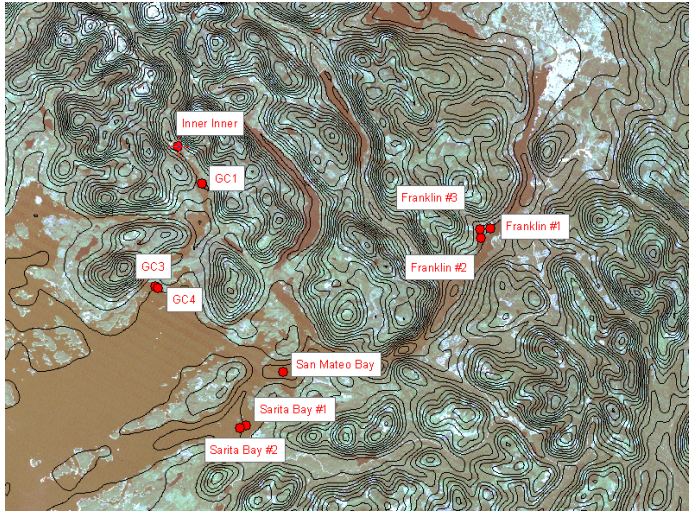


Figure 2. Barkley Sound sample locations. Franklin 3 was taken directly at the mouth of the Franklin River, with Franklin 2 nearer the mouth and Franklin 1 further up the inlet. Inner Inner, GC1, GC3, and GC4 were all taken within Effingham Inlet, San Mateo Bay near a large coastal logging area, and Sarita Bay 1&2 were taken at the mouth of the Sarita River.

on Barkley Sound, Vancouver Island. All samples were of surface marine sediment (top 2-3 in) and intended to show relatively recent deposition trends. Methods of collection included use of a van-veen grab, 3" diameter gravity core, and 2" gravity core. Van-veen grabs were used at areas of rocky substrate. All samples were stored in sediment bags shortly after collection and refrigerated until analysis.

### *Processing*

All laboratory analyses were completed at the University of Washington, Seattle, Washington. The lab is operated by Dr. Richard Keil, a professor at the University in the School of Oceanography.

Density fractionation methods outlined by Arnarson et al (2005) were used to distinguish woody organic material from the rest of the sample and to calculate percentage by weight. Firstly, samples were rinsed through a 250 micrometer sieve with de-ionized water to separate clay and silt particles from sand and debris. Material that was too large to pass through

### *Field sampling*

The primary sampling locations for this study were at the mouths of the Sarita, Franklin, and Effingham rivers. These rivers were chosen due to their varying levels of logging activity in close proximity to the river as well as over the entire drainage basin.

Ten sampling locations were examined in this study (Figure 2). Sediment samples at these locations were collected aboard either the R/V Barkley Star or R/V Alta in March, 2010. Both vessels were used in coordination with Bamfield Marine Science Center, located

the sieve was dried, and then separated into organic and non-organic material. Sediment able to pass through the sieve was allowed to settle in either a 2-liter or 1-liter container, depending on the volume, over a period of a few days until particulates concentrated at the bottom.

Once settled, the overlaying water in the settling chambers was decanted off, leaving a stratified column of sediment. The sediment was homogenized manually, and a subsample of ~20 grams transferred to a 50 ml centrifuge tube with equivalent mass of 1.2 g/ml sodium polytungstate. This mixture was then centrifuged at 4000 rpm for 11 minutes to allow separation of different density particles. The material that remained suspended in the sodium polytungstate mixture was classified as “woody” particulate by its density. Resultant supernatant was removed by pipette, filtered, dried and weighed. The remaining sediment that had not been centrifuged was then dried, in order to yield a mass to volume ratio of the sample.

This allowed calculation of the percent organic material in the sample on a dry weight basis. The organic woody debris was a sum of both debris that did not pass through the 250 micrometer filter and the material filtered from the centrifuge supernatant. Dry weight of the entire sample is a sum of the material that passed through the 250 micrometer sieve, woody debris, non woody debris, and subsamples that were centrifuged (centrifuge dry weight was calculated based on the mass to volume ratio).

### *Analysis in ArcGIS*

To relate the information obtained from sampled marine sediments to land use processes, calculations of logging activity were achieved using ArcGIS. Firstly, a 6-band satellite image was obtained from the United States Geological Survey covering the extent of Barkley Sound and classified into five categories: water (including ocean, lake, and river), newly logged forest and bare soil, recovering logged areas,



Figure 3. Classification of Barkley Sound into different types of land cover. This figure is a result of classifying a 2005 satellite image from the United States Geological Survey into 15 classes, then combining similar land types.

fully grown forest (either previously logged or undisturbed), and in some rare cases, snow. The satellite image was first classified into 15 classes, which were then processed individually and combined into one of the aforementioned categories (Figure 3). This was done by comparing the classified image to a satellite image in order to identify different classes as land features (ie: lake, river, logged land, bare soil, etc.). There were no images available from the USGS with a smaller raster size (resolution) than 30 m<sup>2</sup>, which presented difficulty in defining classes. In some cases, bare soil or natural grasslands were not distinguishable from logged patches.

Logging extent was measured on two different spatial scales; within buffer zones of rivers that empty near sample locations and for entire drainage basins. There were three major rivers of focus for this study; the Franklin River, Sarita River, and Effingham River. Buffer zones of 500 meters to either side of each river were calculated in ArcGIS, and the area within the buffer classified into different levels of logging activity; the drainage basins for these rivers were also determined and classified. A buffer of 500 meters was chosen because this range encompassed both riparian zones and much of the logging activity in close proximity to the river. The classifications within both of these areas were then compared to woody debris concentrations in marine sediments collected at the mouth of the river.

A digital elevation model (DEM) was used to define the drainage basins of the three rivers investigated (Franklin, Sarita, and Effingham). This model was also obtained from the United States Geological Survey online database and had a resolution of 30 m<sup>2</sup>. To define the drainage basins, triangulated irregular network (TIN) was created from this model and the basin was hand-traced based on topographical high points. This TIN model was also used to

a

|                 | Water | Older Forest | Recovering Forest | New Logged/ Bare Soil |
|-----------------|-------|--------------|-------------------|-----------------------|
| Sarita River    | 5.6%  | 14.4%        | 61.1%             | 19.0%                 |
| Franklin River  | 3.6%  | 33.5%        | 52.9%             | 10.0%                 |
| Effingham River | 2.2%  | 17.9%        | 54.5%             | 25.3%                 |

b

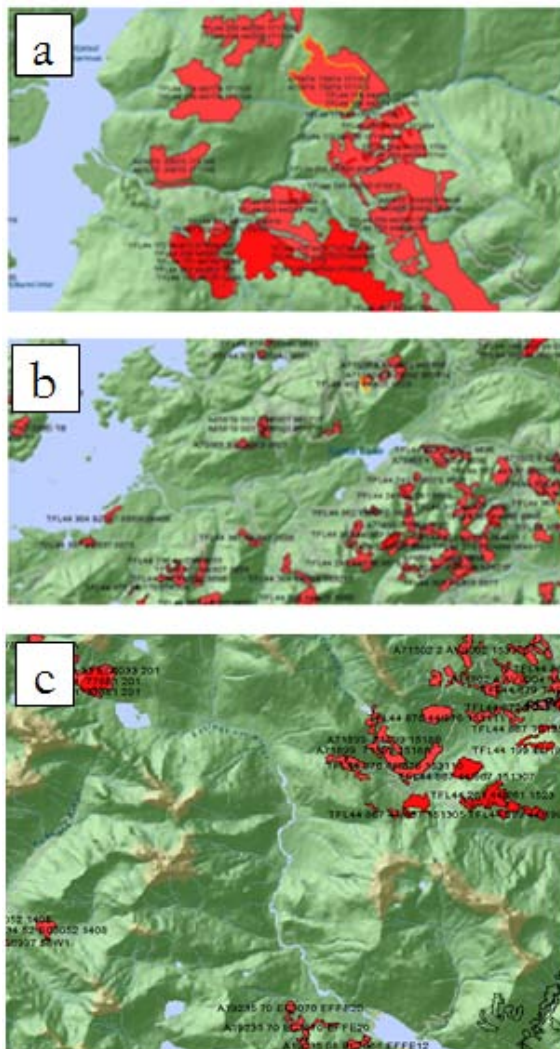
|                       | Water | Older Forest | Recovering Forest | New Logged/ Bare Soil | Area (km <sup>2</sup> ) |
|-----------------------|-------|--------------|-------------------|-----------------------|-------------------------|
| Sarita River Basin    | 1.4%  | 19.9%        | 64.1%             | 14.6%                 | 955.77                  |
| Franklin River Basin  | 0.6%  | 24.9%        | 62.8%             | 11.7%                 | 1089.33                 |
| Effingham River Basin | 0.9%  | 31.4%        | 52.4%             | 15.4%                 | 510.69                  |

Table 1. Classification of a 500 meter buffer zone for each of the rivers investigated (a) as well as each river basin (b).

create elevation profiles of the three rivers. To do so, a polyline of the rivers were overlaid on the DEM and interpolated. The resultant graphic allowed for estimations of the river steepness, in units of meters elevation loss per kilometer of river length.

## Results

The primary focus of this study was to compare the Sarita, Franklin, and Effingham rivers due to their differing levels of logging activity in close proximity to their respective river. It originally appeared that the Franklin River had been exposed to high levels of recent logging while the Sarita River has had much less exposure and the Effingham River very little. This was illustrated by logging permits obtained from the Land Management Bureau of British Columbia (Figure 4). My assumption was that patches of forest were logged during the same year of which a logging permit was obtained.



My land classification of a 500 meter buffer around each river does not agree with this qualitative data. This buffer distance was chosen because it incorporates both riparian zones that are left along the edges of the river as well as logging that begins just beyond the riparian zones. Within the buffer, newly logged area or bare soil constituted 19.0%, 10.0%, and 25.3% of the Sarita River, Franklin River, and Effingham River, respectively. Recovering logged areas within these three buffers were 61.1%, 52.9%, and 54.5%,

Figure 4. Logging permits within the Franklin River basin (a), Sarita River basin (b), and Effingham River basin (c). Many of the cut blocks within the Franklin basin are in close proximity to the drainage river, while those in the Sarita basin are much further away. The Effingham River has not had high exposure to logging in close proximity to the river. Images taken from the Integrated Land Management Bureau of British Columbia (<http://www.lrdw.ca/>).

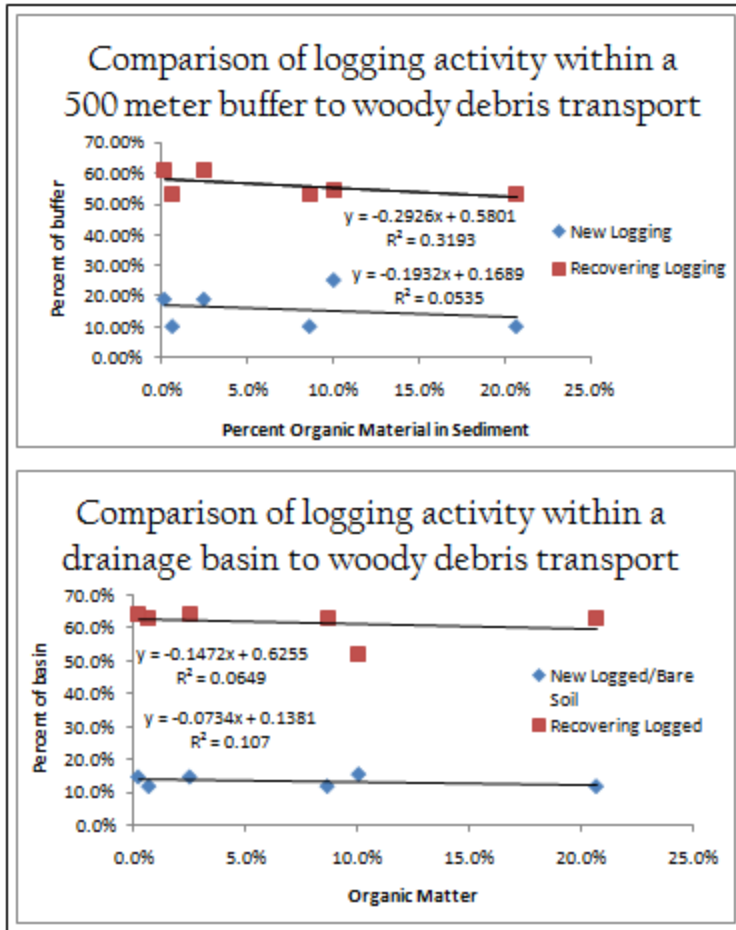


Figure 5. Organic woody debris in marine sediments at the mouths of Effingham, Franklin, and Sarita Rivers in comparison to the amount of logged area in each within a 500 meter buffer of the river (a) and within the entire drainage basin (b). The river buffer extends roughly 10 km up each river.

debris by dry weight were compared to the percent logged area within a 500 meter buffer zone of each river, and to the entire drainage basin (Figure 5). When aggregating data from all three river basins, there is a much stronger relationship between levels of previous logged area and woody debris transport ( $R^2 = 0.32$ ) than current logging activity or bare soil ( $R^2 = 0.05$ ), within a 500 meter buffer of each logged river (Figure 5). Alternatively, there is clearly no correlation between the amount of logging activity on a basin-wide scale and the amount of woody debris that is deposited at the mouth of river that drains that basin (Figure 5). This trend holds true for

respectively (Table 1).

Although land classification varied between each river within a 500 meter buffer, all three basins were comparable when evaluated on a basin-wide scale. Current logging patches or bare soil within the Sarita, Franklin, and Effingham River basins were 14.6%, 11.7%, and 15.4% of the total basin surface area, respectively (Table 1). Additionally, the percentage of land that is either currently logged or recovering from logging activity is relatively consistent between basins, composing 78.7%, 74.5%, and 67.8% of the total land coverage, respectively (Table 1). This comparison proved

valuable in evaluating each basin as a whole, because although each has very similar levels of logging activity, the distribution of logging patches is vastly different.

Calculations of percent woody

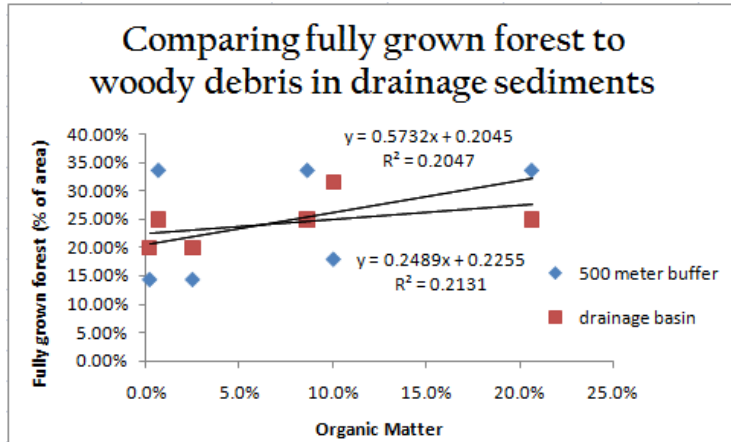


Figure 6. Organic woody debris in marine sediments at the mouths of Effingham, Franklin, and Sarita Rivers in comparison to the amount of fully grown forest with either a 500-meter buffer of each river or over the extent of the drainage basin.

correlation is a positive one, that is, in both spatial scales, a greater percent of large, fully grown forest is indicative of greater woody debris in surface marine sediments.

Sediment samples in Effingham Basin expose woody debris attenuation away from the mouth of the Effingham River. The marine surface sediment sample at the “Inner Inner” sample location, near the mouth of the Effingham River, yielded an organic woody debris composition of 10.05% on a dry weight basis. Organic debris composition in marine sediments reduces with further distance away from the source; GC1 (middle of Effingham Basin) contained 4.60%

both recently logged areas as well as recovering patches. The Sarita, Franklin, and Effingham river basins are all comparable with respect to the level of logging activity.

Alternatively, my data indicate a slight correlation between the amount of fully grown forest and woody debris in marine surface sediments at the mouth of each river. This trend holds true within a 500-meter buffer as well as over the entire drainage basin (Figure 6). The

| Sample ID                   | Latitude   | Longitude   | Total sample wt. (dried, g) | Organic Material (g) | % Organic Material |
|-----------------------------|------------|-------------|-----------------------------|----------------------|--------------------|
| GC1                         | 49 04 32 N | 125 09 37 W | 9.76                        | 0.449                | 4.60%              |
| GC3                         | 48 58 78 N | 125 09 94 W | 62.24                       | 0.278                | 0.45%              |
| GC4                         | 48 58 75 N | 125 09 81 W | 40.79                       | 0.666                | 1.63%              |
| Inner Inner                 | 49 05 52 N | 125 11 60 W | 43.95                       | 4.417                | 10.05%             |
| Franklin 1                  | 49 06 35 N | 124 49 32 W | 447.04                      | 3.009                | 0.67%              |
| Franklin 2                  | 49 06 01 N | 124 49 61 W | 76.39                       | 15.789               | 20.67%             |
| Franklin 3                  | 49 05 85 N | 124 49 73 W | 145.84                      | 12.615               | 8.65%              |
| San Mateo Bay               | 48 56 77 N | 124 59 77 W | 270.62                      | 0.049                | 0.02%              |
| Sarita bay 1 (SB1)          | 48 54 22 N | 125 01 38 W | 255.89                      | 0.523                | 0.20%              |
| Sarita bay (Sarita River 2) | 48 54 11 N | 125 02 00 W | 116.02                      | 2.906                | 2.50%              |
| BS1                         | 49 04 24 N | 125 09 41 W | 147.16                      | 1.75                 | 1.17%              |
| BS2                         | 49 02 53 N | 125 09 18 W | 44.87                       | 1.001                | 2.23%              |

Table 2. Each sample location and the respective percent by dry mass that organic, woody debris was present in the surface marine sediment sample.

organic material by weight, GC3 and GC4 ( at the mouth of Effingham Basin) were 0.45% and 1.63%, respectively (Table 1).

Sample locations in Alberni Inlet reveal a similar trend. The locations do not cover the length of the fjord, but instead differ spatially in relation to the Franklin River. Franklin #1 is located further away from the fjord mouth than the Franklin River, Franklin #3 is located directly in front of the River, and Franklin #2 is located closer to the mouth of the fjord. The Franklin River is the largest river in this area, and it is assumed to be the largest input of terrestrial woody debris. There is a clear trend of attenuating debris with further distance away from the mouth of the fjord (Franklin #1 – 0.67%, Franklin #3 – 8.65%, Franklin #2 – 20.67%).

## Discussion

Results of this study indicate that logging patterns within a 500 meter buffer of a river are much more influential in the amount of woody debris that is deposited at the mouth of that river, in comparison to land use patterns over the entire basin. Contrasting the land cover classifications of the Sarita, Franklin, and Effingham river basins make this correlation more apparent. All three basins had similar amounts of current logging activity, composing 14.6%, 11.7%, and 15.4% of the total basin surface area, respectively (Table 1), yet had widely varying amounts of woody debris in marine sediments at the mouth of each river.

These results are hard to compare to the documented increases in sediment deposition observed by Beschta (1978) and Hartman (1996). My data show that there is a negative correlation between the percentage of previously logged areas within a 500-meter buffer of these rivers and woody debris deposition. That is, a greater percentage of previously logged area within the buffer is representative of less woody debris in the proximal fjord sediments. I would expect, based on the studies by Beschta (1978) and Hartman (1996), that greater logging activity within a 500-meter buffer would result in more sediment deposition. It is possible then, that woody debris deposition into nearby streams may be influenced differently than sediment deposition.

The percentage of land that is either currently logged or recovering from logging activity is relatively consistent between basins, composing 78.7%, 74.5%, and 67.8% of the total land coverage (Table 1). The amount of woody material in marine sediments where these rivers drain is vastly different (Table 2). A non-correlation between these variables suggests that, at least on

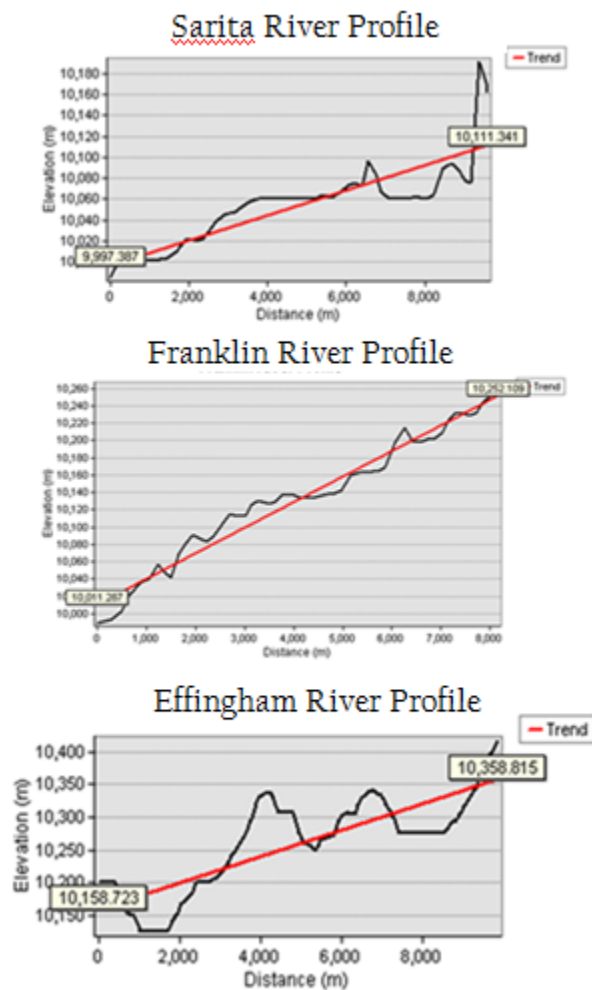


Figure 7. Elevation profile of the Sarita, Franklin, and Effingham Rivers. Sea level is represented by a relative elevation of -10,050 m. This value, however, is an estimate due to the large pixel size in the digital elevation model of which the profile came. Elevation decrease rates for the Sarita, Franklin, and Effingham Rivers were around 11.4 m/km, 29.2 m/km, and 20 m/km.

falls into the rivers. If erosion rates were different between rivers, sediment transport may be different and, if any of the sediment eroded away contained woody debris, this may change the results.

The elevation profile of the three rivers may influence the amount of material that is able to flow downstream. Two rivers of comparable size but of differing elevation gradients may have the possibility of transporting different quantities of material (including woody debris) and

a basin-wide scale, ecosystem function and natural wood transport are not influenced to any great extent by logging that is not in close proximity to the drainage river.

Within both a 500-meter river buffer and over entire drainage basins, my data indicate a positive correlation between the amount of fully grown forest and woody debris found in marine sediments at the mouths of the Effingham, Sarita, and Franklin Rivers (Figure 6). This finding is particularly interesting, considering there was an opposite trend between both recently logged/bare soil as well as recovering logged patches when compared to the same variable (Figure 5). This suggests that older forest is possibly a larger input of woody debris into proximal streams than wood as a result of logging activity.

Although a correlation was found between logging patterns within said buffers and woody debris in our samples, natural processes may also influence woody debris distribution patterns. Further analysis of the three rivers in this study could reveal new information about their structure and dynamics. For example, factors such as tree proximity to the river could influence the amount of organic material that

depositing that material at the mouth of the river. Intuition would suggest that steeper rivers have more potential energy and thus, may be able to transport more material. The Effingham, Franklin, and Sarita Rivers all differ in steepness; the elevation subsidence rates were 20 m/km, 29.2 m/km, and 11.4 m/km, respectively (Figure 7). This may have influence on the quantity of woody debris that was deposited at the mouth of each river. The Sarita River was the least steep and had the least woody debris while the Franklin River was the steepest and had the greatest concentration of woody debris (averaged from all three stations).

Trends in woody debris deposition may provide insight into the circulation patterns of Alberni Inlet and Effingham Inlet. In the cases of both Alberni and Effingham Inlets, my data supports water transport toward the mouth of the inlet. In Effingham Inlet, there is a reduction in woody debris within surface sediments from the highest values at the head of the Inlet (Inner Inner), moderate values in the middle (GC1), and lowest values at the mouth (GC3, and GC4). The only major river input into Effingham Inlet is located at the end of the basin (Inner Inner sample site) and is assumed to be the only major woody debris input location. The coastline along the inlet is relatively natural and thus not likely to input different amounts of woody debris dependent on location within the inlet. Similarly, data from Alberni Inlet also supports a circulation pattern that allows debris to flow toward the mouth of the inlet. Although data is not present on as large of a spatial scale as Effingham, proximity of the three Franklin River stations provide insight to general patterns. Franklin #3 is located directly at the mouth of the Franklin River, while Franklin #1 is nearer the end of the inlet and Franklin #2 closer to the mouth. Within these stations, there is a trend of decreasing woody debris from the end of the inlet to the mouth, cascading from 0.67% at Franklin #1 to 8.65% at Franklin #3 to 20.67% at Franklin #2. This information reveals that the Franklin River is a major source of woody debris and it is traveling toward the mouth of the inlet once leaving the river, as opposed to dispersing evenly.

An analysis of logging road effects was not included in this study. Roads that cross rivers or are located near the banks could result in additional wood deposition. In particular, the Franklin River has a large stretch of area that runs alongside a logging road, at times separated by less than 50 meters. The Sarita River also has a road that runs alongside it, but it does not appear to be a logging road, rather, one that provides access to the town of Sarita, located on Barkley Sound. The influences that logging roads have on erosion and woody debris transport could be substantial; many authors have observed that road construction is a more important

factor than deforestation in accelerating erosion (Dyrness 1967, Fredriksen 1970). Roads increase potential slope instability through all of the factors imposed by deforestation. However, they also create several additional critical problems: 1) interruption of surface drainage associated with road surfaces, ditches, and culverts; 2) alteration of subsurface water movement due to redistribution of soil and rock material, especially where road cuts intersect a water table; and 3) change in distribution of mass on a slope surface by cut-and-fill construction (Swanson 1975).

This observation raises the reasonable question of whether observed woody debris concentrations are influenced to a greater extent by the logging roads rather than the logged patches of land. To fully understand the impacts that logging roads have on woody debris transport, subsequent studies are needed.

## Conclusions

Although this study draws correlations between woody debris concentrations in marine sediments at the mouths of various rivers and terrestrial logging activity, drainage basin systems are complex and some possibly influences were not evaluated. Due to limited resources and time within the scope of this project, further studies need to be completed to get a more comprehensive illustration on woody debris transport in these rivers and the processes that cause influence.

Several things were determined from this project, however. My results indicate that logging locally (in this case, within 500 meters) of a drainage river has a greater influence on woody debris transport than logging on a basin-wide scale. This finding was accentuated by the finding that all three drainage basins investigated had very similar levels of logging activity. My data also show that there may be a correlation between the amount of fully grown forest and woody debris in marine sediments. Furthermore, within the 500 meter buffer, the highest correlations were with previously logged patches of land, not areas that have been recently clear-cut. The spatial distribution of my sample sites allowed general circulation patterns of Effingham and Alberni Inlets to be inferred. It appears that in both basins, woody debris is traveling toward the mouth of the inlet in relation to the source of material. This could be a result of generalized outward flowing freshwater from river sources.

Further studies on these rivers are needed to determine the largest influences on woody debris transport. The information from my study may provide a foundation for further

investigations related to logging activity and resultant woody debris transport. Follow-on studies could include the examination of:

- Logging road proximity to rivers
- Logging road river crossings
- Differences in erosional processes between rivers
- River slope influences on erosion and woody debris transport
- Stream bank differences between rivers and how that may influence woody debris deposition.
- Contrasting effectiveness of different width riparian zones as regulated by local governance.

In concert, compilation of results from these suggested research activities could result in a more comprehensive analysis that may help provide valuable guides to forest regulation.

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