# An exploration of the relationship between historical logging practices, large woody debris, and fish community structure in the streams of the Ottawa National Forest, Upper Peninsula of Michigan

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*Abstract:* By studying aquatic ecosystems in terms of LWD and its influence on geomorphology, valuable insight can be gained regarding the fish communities of a particular stream. With this in mind, my project explores the relationship between logging practices, the presence of large woody debris in streams, stream geomorphology, and the structure of the fish communities within the streams of the University of Notre Dame Environmental Research Center and the Ottawa National Forest.

Although analysis of variance failed to produce a statistically significant p values, several trends could be derived from the data. Regarding LWD, recently logged streams showed the smallest volume of LWD per 100 m reach, with the more mature stands containing a larger volume. Recently logged systems had the highest number of species, with the mature forests (>100) showing the fewest. Analysis of Shannon H' values indicated that the longer a stream has to recover from logging, the healthier and more diverse its fish community will become. An analysis of the relationship between H' and the volume of large woody debris per 100 m streamlength indicated a positive relationship, while comparing H' and the number of habitat units per 100 m reach showed a slightly negative relationship.

The data we gathered from this study allowed us to compare streams and watersheds to one another, assess the environmental impact of historical logging practices, contribute to regional, national, and international resource inventories and databases, and potentially develop new resource management strategies.

**Submitted to:**
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# INTRODUCTION:

Exploring the geomorphological and biological processes of aquatic ecosystems is a critical step in developing a more complete understanding of their functional and structural characteristics (*10*). The broad spectrum of physical and biological factors that lead to differences in geomorphology between streams create a high degree of habitat variability in these ecosystems (5). The presence of Large Woody Debris (LWD) in streams is one such biological factor. By studying aquatic habitats in terms of LWD and its influence on geomorphology, valuable insight can be gained regarding the fish communities of a particular stream. With this in mind, my project is aimed at exploring the relationship between logging practices, the presence of large woody debris in streams, stream geomorphology, and the structure of the fish communities within the streams of the University of Notre Dame Environmental Research Center and the Ottawa National Forest.

Large woody debris consists of fallen logs, snags, wood pieces, beaver dams, branches, and exposed root masses (10). The volume and type of LWD in the stream is primarily dependent upon the composition of the surrounding riparian zone, but logging, fire, wind, insect damage, bank cutting, and flooding are also significant factors in this equation. (10). The riparian zones surrounding the streams of the Ottawa National Forest are composed of coniferous species including red pine, white pine, hemlock, balsam fir, and deciduous species including speckled alder, sugar maple, and aspen, and these species therefore compose the majority of the naturally occurring LWD.

The presence of large woody debris in streams has been shown to significantly effect many aspects of stream ecosystem structure and function. The habitat templet concept states that the characteristics of habitat variability have a significant influence on the stability of communities of organisms. Since large woody debris is a source of habitat variability in streams, it effects the structure and function of the ecosystem as a whole (15). LWD has to potential to dam water, form plunge and scour pools, form steps, deflect flow, armor the bank, store sediments, cause the accumulation of debris jams, increase channel width, and form and stabilize gravel bars thus strongly shaping the geomorphology of the stream (3). According to Bilby and Likens, LWD also influences abiotic stream components such as sediment transport and storage, energy flow, nutrient cycling, and channel stability and morphology (4).

Large woody debris also greatly affects the biology of lotic ecosystems. LWD provides habitat and food for aquatic organisms, increasing fish and invertebrate abundance (3, 10). Ehrman and Lamberti found that LWD also increases retention of water and organic matter, allowing for increased uptake of nutrients by autotrophic and heterotrophic organisms and potentially causing increased productivity among higher trophic levels within these ecosystems (6). In terms of geomorphology, by increasing pool abundance and depth, forming backwaters, eddies, and side channels, large woody debris also provides crucial habitat that fish utilize for refuge, spawning, and rearing (3).

Previous studies have illustrated that geomorphology does influence fish at the community level. In certain Northwestern streams, for example, Dolly Varden char and bull trout occupied different areas of the stream because their foraging strategies, spawning behaviors, and metabolic requirements were dependent on the structure of their habitat (9). Other studies indicated that nutritional requirements based on geomorphology had the potential to shape fish communities. Depositional environments, such as pools, had communities based upon the consumption of coarse organic matter, while communities in erosional environments (riffles) relied on fine organic matter as the primary food source (12). In American trout streams, it been indicated that brook trout favor riffle areas with a silt-free substrate of gravel or cobble (*2*), while other species of suckers and chubs are more suited to the slower water of deep pools. Clearly, by influencing the amount of LWD present in the streams, logging in riparian areas has the potential to effect stream geomorphology, and therefore the dynamics of fish communities within these ecosystems.

In the Ottawa National Forest, natural resource managers are concerned with maintaining a balance between utilizing the timber resources of the vast forests and preserving optimal habitat for fish such as native brook trout and non-native brown trout in order to enhance sportfishing opportunities. Forestry is an important industry for the Midwest fishery resources are crucial components of these forests and support an important recreational industry. Within the Ottawa National Forest, fishing and hunting constitute a significant portion of the total recreation activity, and this amount is expected to increase in years to come. Since stream geomorphology is influenced by logging and has been shown to affect trout habitat quality, this issue would be relevant to their interests (8). The Ottawa National Forest is planning stream habitat enhancement projects for trout streams in the national forest in the near future, and any information regarding how these species relate to the geomorphic features of the streams could make their efforts more successful.

## Materials:

In order to complete the specified tasks, we utilized the following equipment:

- drysuit
- 100m measuring tape
- 25m measuring tape
- meter stick
- waders
- thermometer
- electroshocking unit
- calipers for LWD analysis
- diving mask and snorkel

## Methods:

My study was conducted during the months of June and July during the summer of 2002. To accomplish this study, I collaborated with graduate students Jean Miesbauer and Asako Yamamuro. I examined a total of six streams within the Ottawa National Forest in the Upper Peninsula of Michigan. To assess the effect of historical logging, I sampled two rivers from each of three logging treatments. These three treatments included streams with no recent logging history (>100 years ago), streams that were recently logged (<20 years ago), and systems with an intermediate logging history (50-70 years). Candidate streams and site locations from the Ontonagon, Black-Presque Isle, and Sturgeon watersheds were surveyed and selected at the beginning of the summer session, and the logging history of each stream was determined with the help of GIS maps and the Forest Service.

The chosen streams for this study were wadeable, comparable in discharge rate, had a bankfull width of approximately 5-10 meters, and included both warm-water woodland streams as well as cool-water trout streams. Our chosen streams were McGinty Creek, the Perch River, Montowibo Creek, the East Branch of the Presque Isle River, and two sections of Two-Mile Creek (Fig. 1).

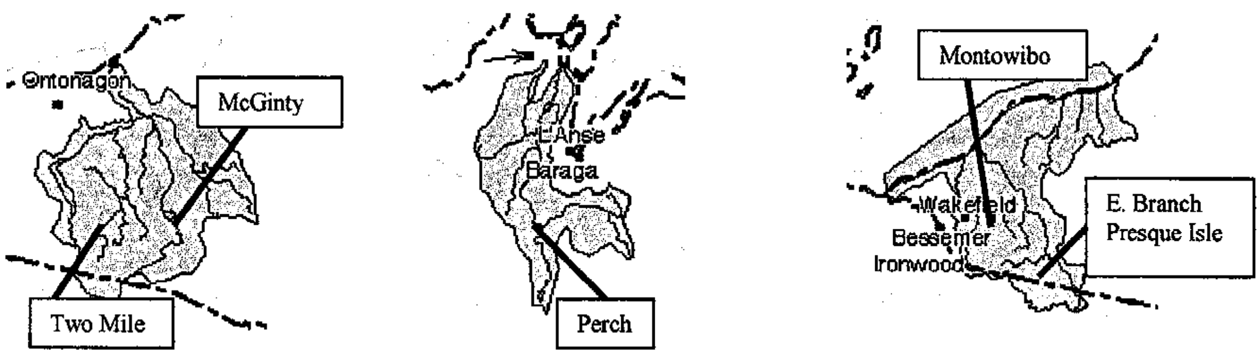



Figure 1. The three watersheds where our stream sites were located within the Ottawa National Forest, Upper Peninsula, Michigan. Left: The Ontonagon Watershed (Two-Mile and McGinty Creeks) Center: The Sturgeon Watershed (Perch River) Right: The Black-Presque Isle Watershed (East Branch Presque Isle River, Montowibo Creek)

For this project, I surveyed 100 meter reaches on each of the six selected streams. At each site, a longitudinal profile was established and a habitat assessment was conducted. The selected reach was divided into habitat units (pool, riffle, or glide) based on changes in geomorphology and flow patterns. At each habitat unit, three cross-sectional profiles were established. The cross-section surveys involved establishing endpoints at the bankfull level on the opposing banks, stretching a tape, and measuring the depth of the water at half-meter increments across the channel. In order to determine bankfull levels, we relied on indicators such as the tops of bars, changes in riparian vegetation, changes in bank slope, deviations in bank substrate material, undercuts, and stain lines (11).

Backpack and barge electroshocking was conducted on each site with the help of the Forest Service in order to assess the number and distribution of fish species present within each aquatic community. The 100 meter reach was blocked on each end with netting, and three passes were made with the electroshocker per reach. Collected specimens were identified, weighed, and measured lengthwise before being released outside the contained study reach. An assessment of the volume of large woody debris (LWD) in the 100 m reach was also conducted. Any piece of wood greater than one meter in length and 10 cm in average diameter was included in our assessment. The average diameter of each wood piece was measured with the calipers, and the length was assessed with a tape measure. When water clarity or depth prevented us from locating submerged wood, a mask and snorkel were utilized.

Table 1. Stream Classification Data

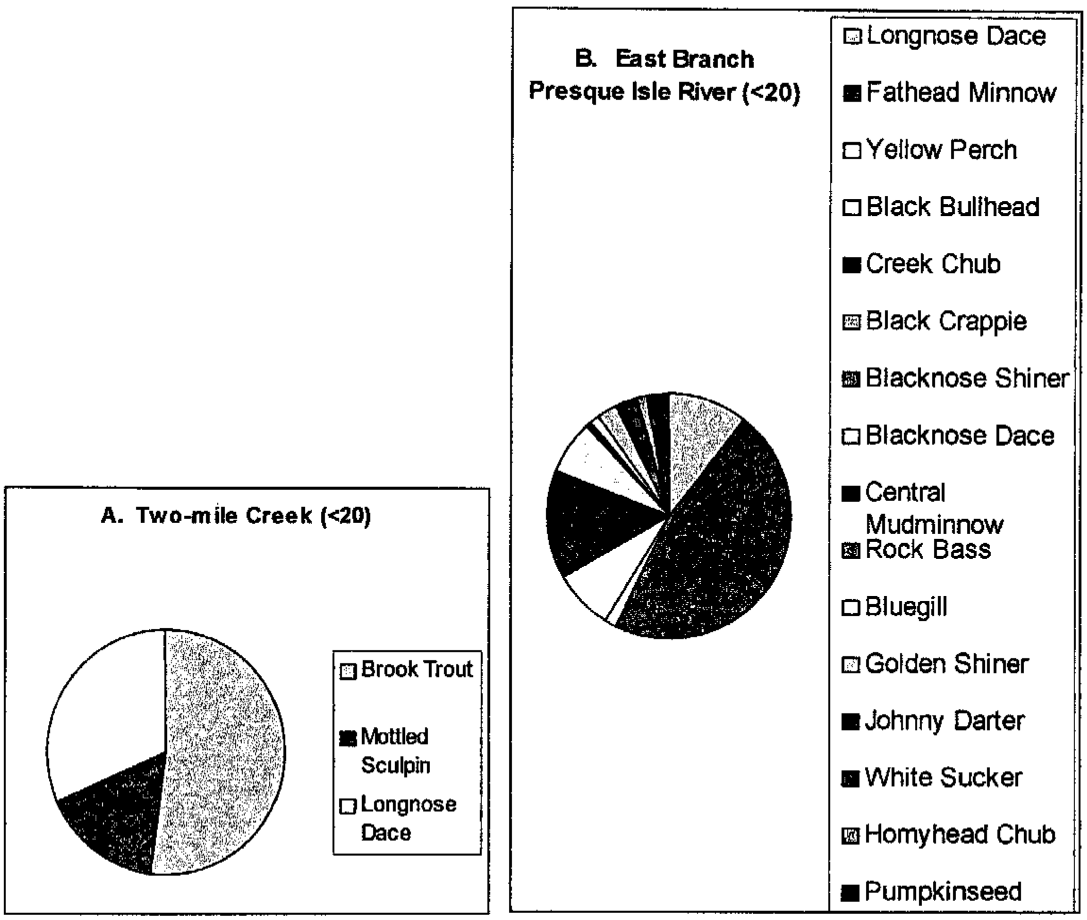
| Stream Name | Watershed | Logging Treatment | Bankfull Width (m) | # Habitat Units | Shannon Index H' Value | Volume Large Woody Debris |
|---|---|---|---|---|---|---|
| McGinty Creek | Ontonagon | 50-70 | 5.2 | 6 | 2.47 | 7.52 |
| Two-Mile Creek | Ontonogan | < 20 | 11.9 | 3 | 1.44 | 6.85 |
| Two-Mile Creek | Ontonogan | 50-70 | 9.6 | 5 | 2.95 | 16.74 |
| E. Branch Presque Isle | Black-Presque Isle | < 20 | 9.9 | 5 | 2.62 | 2.45 |
| Montowibo Creek | Black-Presque Isle | > 100 | 4.6 | 10 | 1.39 | 13.09 |
| Perch River | Sturgeon | > 100 | 10.25 | 3 | 2.68 | 10.48 |

## Results:

### Fish community profiles:

The data we gathered from the stream assessments allowed us to compare reaches, streams, watersheds, and logging treatments to one another. The streams we studied were typically low gradient with slow-flowing pools situated between fast-flowing riffles. Brook trout are the primary sport fish in the streams of the Ottawa National Forest; we found them in Montowibo Creek, Two-mile Creek, McGinty Creek, and the Perch River (Figure 2). Brook trout composed a more significant portion of the aquatic communities in Two-mile Creek (<20), Montowibo Creek (>100), and the Perch River (>100), largely due to the lower water temperatures and relatively low species richness in these sites. Other prevalent species in the same habitats included blacknose dace, longnose dace, mottled sculpin, common shiners, creek chubs, hornyhead chubs, and white suckers

(Figure 2). Several warm-water species including black crappie, black bullhead, pumpkinseed, bluegill, rock bass, and yellow perch were observed in the East Branch of the Presque Isle River due to its proximity to a source lake and elevated temperatures. While the elevated temperature was not suitable for brook trout, this site had the greatest richness value, with 18 species (Figure 2B).



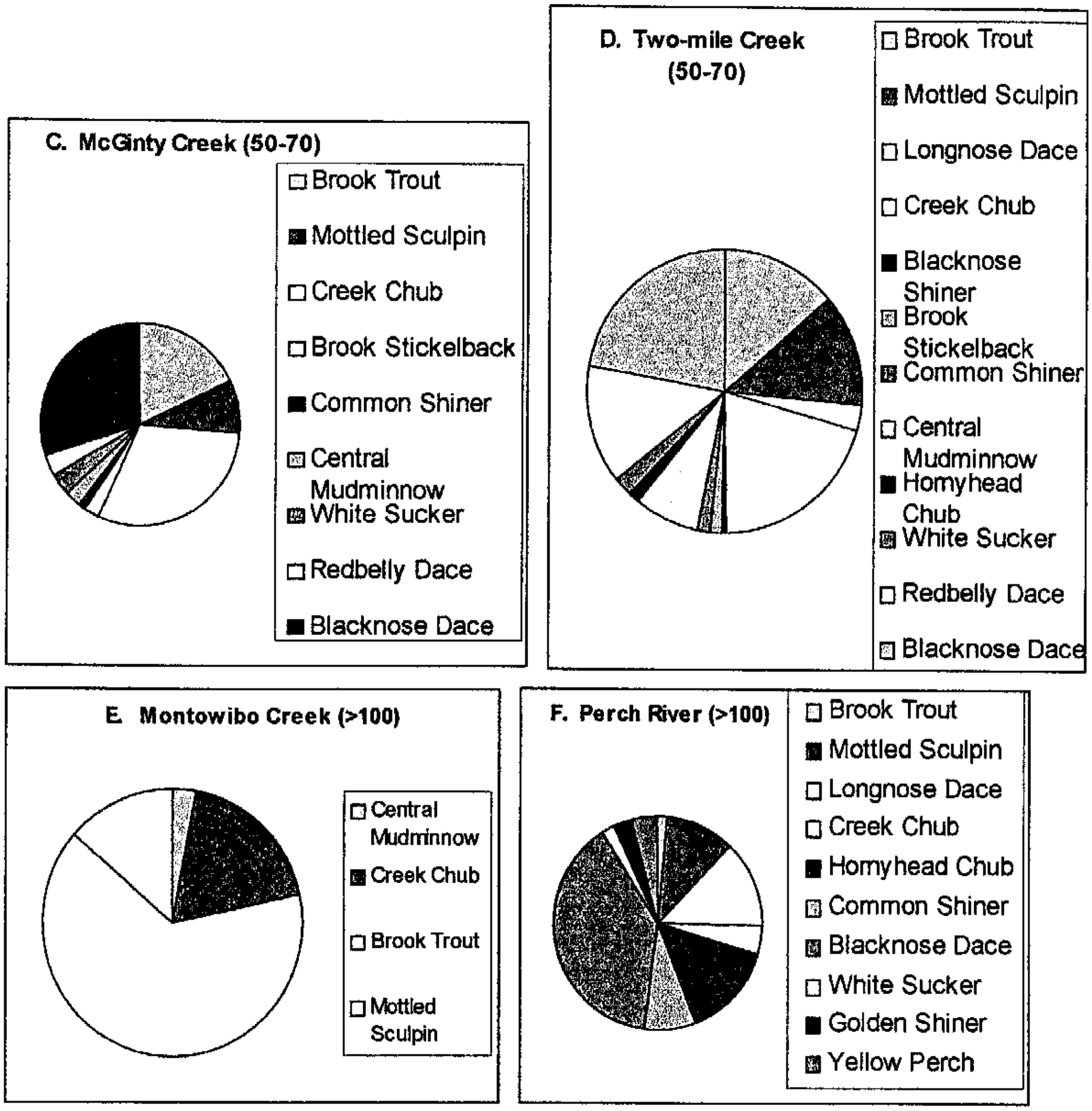
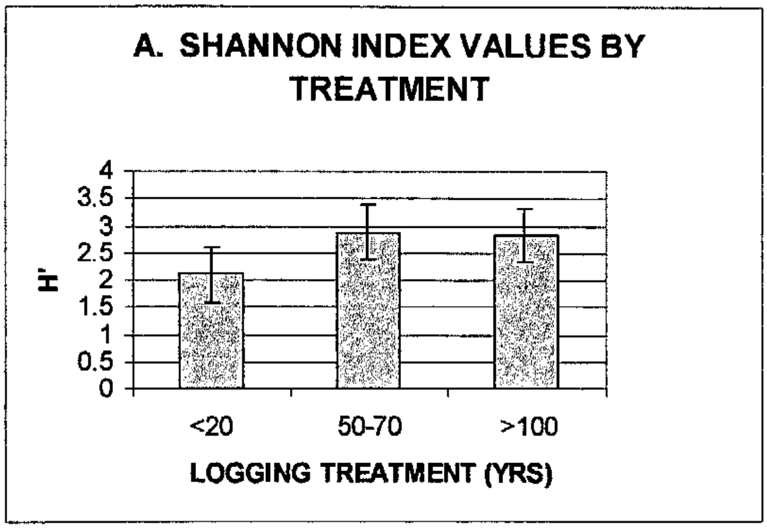


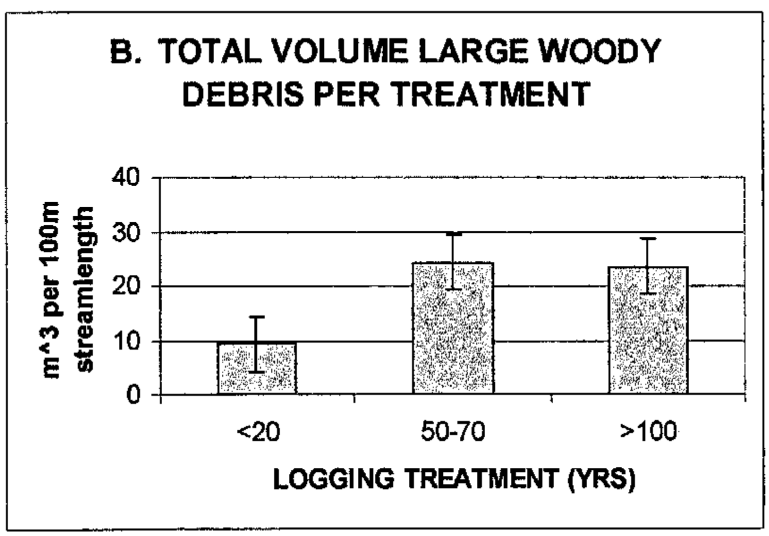

Figure 2: Fish Community profiles for: (A,D)Two Mile Creek, (C)McGinty Creek, (F)Perch River, (E)Montowibo Creek, and (B)East Branch Presque Isle River.

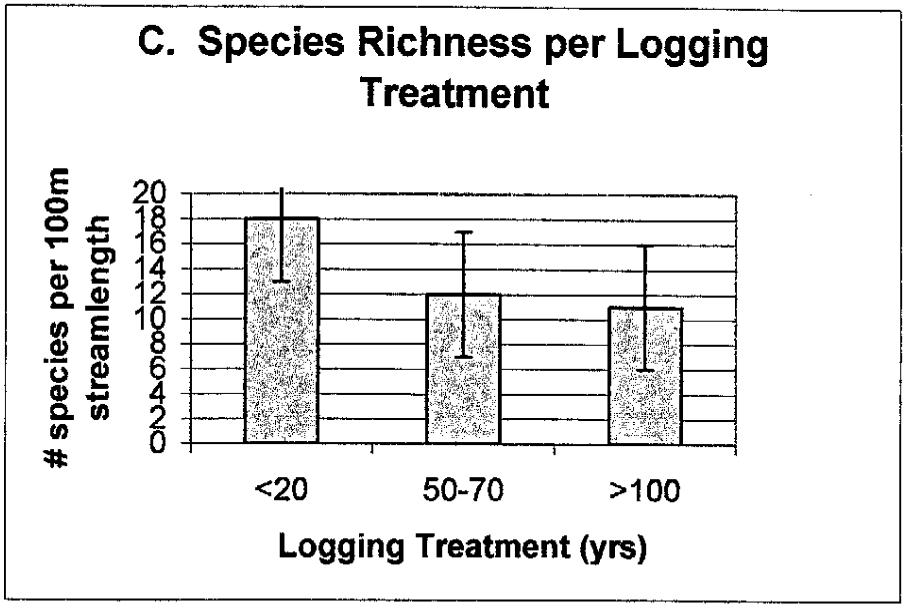
<u>Effect of logging on species richness, biodiversity, and LWD:</u>

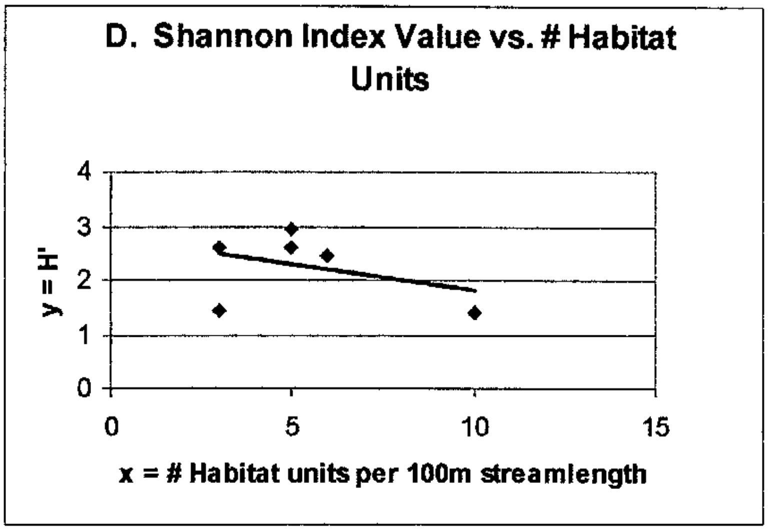
Past logging of riparian zones has greatly shaped the face of the stream ecosystems of the Ottawa National Forest. Previous studies have indicated that areas of mature forest yielded large pieces and a larger total volume of wood debris to the stream, while recently logged or managed forests contributed comparatively diminutive amounts of smaller wood debris to streams (14). Although analysis of variance (ANOVA) failed to produce statistically significant results, my data supported this trend. The recently logged streams showed the lowest volume of LWD, with the intermediate treatment containing the largest amount. At and after this 50-70 year interval, the riparian areas have become more mature, thus contributing a greater volume of LWD. The volume of large woody debris per 100 m streamlength ranged from 2.45 m^3 at East Branch Presque Isle to 16.74 m^3 at the 50-70 yr reach on Two-mile Creek. A single large debris jam contributed 11.2 m^3 of LWD at this site (Table 1), perhaps giving a misleading spin on the data and explaining our lack of statistically significant results (Table 2). Another potential source of the variation in our data is the range of average bankfull widths among the streams. The average bankfull width of the streams ranged from 4.6m (Montowibo) to 11.9m (Two-Mile), and this variability in channel width probably affected the volume of large woody debris contained in these streams (Table 1).

With the electroshocking data, I was able to compare species richness among the three treatments. Although ANOVA failed to produce a statistically significant p value, the recently logged systems had the highest number of species, with the mature forests (>100) showing the fewest. By removing the shading timber in riparian zones and raising the water temperature, the logging activities may have effectively shifted the balance of the fish communities in the favor of new warm-water species. The large number of warm-water species found at East Branch Presque Isle River seems to give credence to this hypothesis (Figure 3C). I was also able to calculate Shannon H' index values in order to estimate the diversity of the fish communities. The mean H' value for recently logged streams was lower than both the 50-70 yr and >100 year systems, with he 50-70 streams showing the highest diversity. Although the ANOVA did not produce a statistically significant p value, this may suggest that the longer a stream has to recover from logging, the healthier and more diverse its fish community will become.




C. Species Richness per Logging Treatment
# species per 100m streamlength
20
18
16
14
12
10
8
6
4
2
0
<20
50-70
>100
Logging Treatment (yrs)


D. Shannon Index Value vs. # Habitat Units
y = H'
4
3
2
1
0
0
5
10
15
x = # Habitat units per 100m streamlength

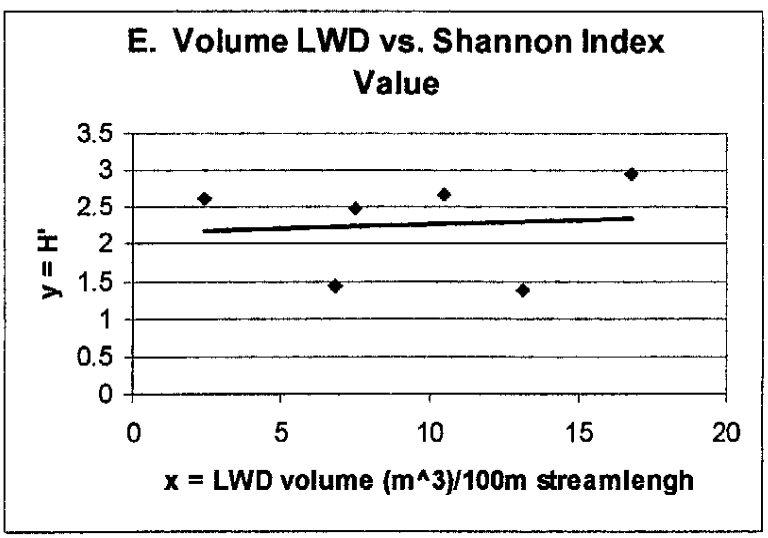

E. Volume LWD vs. Shannon Index Value
y = H'
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
x = LWD volume (m^3)/100m streamlengh

Figure 3: Graphical Analysis: (A) Shannon H' values, (B) Volume LWD per 100 m streamlength, and (C) species richness per 100 m electroshocked reach compared among the logging treatments <20 years, 50-70 years, and >100 years. The relationship between (D) the number of habitat units per 100 m streamlength and H' values and (E) the volume of LWD per 100m streamlength and the H' values was also assessed.

Effect of # habitat units and LWD on H':

With my data, I was able to evaluate the extent to which the volume of large woody debris in the stream affected the Shannon H' value. Pools created below large woody debris provide refuge for fish from predators and high flows, thus generally increasing the number of species and overall abundance in these regions (7). Also, the increased retention of sediments behind debris dams helps provide optimal spawning habitat, thus potentially contributing to the increased number of species observed (3). In accordance with these predictions, an analysis of the relationship between H' and the volume of large woody debris (Figure 3E) produced a regression line with a slightly positive slope, yet the p value of 0.867 was not significant (Table 2). My study of the relationship between the number of habitat units per 100m reach and the H' value for that reach (Figure 3D) also failed to produce statistically significant results (p value of 0.451). Although I would have predicted to find a positive relationship between the number of habitat units and H', the general trend indicated by analysis of the regression line is for lower H' values as the number of habitat units increases. For both of these relationships, extending this project and increasing the number of replicate streams may generate statistically significant results and provide a more accurate and complete picture of how channel geomorphology and large woody debris influence the biodiversity of fish communities.

Table 2: Results of Statistical Analysis

| Treatment/variables | Test Type | F-ratio | P value |
|---|---|---|---|
| Treatment: logging levels (3) Dependent Var: H' | One way ANOVA | 0.559 | 0.662 |
| Treatment: logging levels (3) Dependent var: vol. LWD per 100 m stream (m^3) | One way ANOVA | 1.924 | 0.290 |
| Treatment: logging levels (3) Dependent Var: Richness | One way ANOVA | 0.182 | 0.842 |
| Dependent Var: H' Factor: # Hab. units per 100 m stream (m^3) | Regression | 0.695 | 0.451 |
| Dependent Var: H' Factor: vol LWD per 100 m stream (m^3) | Regression | 0.032 | 0.867 |

Implications:

As part of their management strategy, the Forest Service has attempted to artificially alter the geomorphology of streams to enhance populations of rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*) within the Ottawa National Forest (ONF). Dams and structures of large woody debris such as half logs, skybooms, and K-dams are constructed and placed in streams in an effort to enhance habitat structures for these organisms. By attaining a better understanding of the role large woody debris plays in determining the structure of fish communities, resource managers will hopefully become more effective in the allocation of their limited resources toward this end. My study indicated that the presence of large woody debris in streams does have a positive influence on H' values, and considering the fact that recently logged streams have the lowest volumes of large woody debris, it may be a more efficient management strategy to focus their wood introduction efforts on these streams. Hopefully, the collaboration of UNDERC researchers and the Forest Service will yield a more comprehensive database of ecological data for the region, help assess the environmental impact of historical logging practices, provide a more complete understanding of aquatic ecosystem structure and function in UNDERC and the Ottawa National Forest, and ultimately produce better management of natural fish habitat.

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