The Effects of Logging Practices on Predominant Native Fish Species in the Great Lakes Region

Brent Burish

Dr. Lamberti, Advisor

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Abstract

The effects of logging practices along stream riparian zones on three of the most predominant native fish in streams of the Great Lakes region (brook trout, mottled sculpin, and longnose dace) were studied in the summer of 2002. Forestry is a predominant industry in the Upper Peninsula of Michigan, and 84% of this region has already been forested. Fish populations from six streams were analyzed: two streams with riparian zones recently logged within the past 20 years, two streams with riparian zones logged 50 to 70 years ago, and two streams whose riparian zones either have never been logged or have not been logged in the past century. All three fish species had healthiest condition factor values at sites most recently logged, most likely due to a nutrient increase from runoff from weakened riparian zones. However, recently logged streams also showed the most total fish diversity, particularly competitors of adult brook trout. Furthermore, mottled sculpin and longnose dace both showed a decrease in average length and, for the latter, average mass, in streams with riparian zones logged 50-70 years ago, suggesting stream ecosystems can remain altered from this human practice 70 years after the fact.

Introduction

Riparian zones, the interface of terrestrial and aquatic domains, have major impacts in lotic ecosystems. In streams and rivers, riparian zones contribute to overall cover, nutrients, organic matter, and physical structure. In smaller streams, developed riparian zones have also been shown to protect the ecosystem from large temperature fluctuations, thus indirectly providing more stable levels of dissolved oxygen and turbidity (Keim and Schoenholtz 1999).

Human alteration of riparian zones has been well documented under several circumstances, including logging practices. By decreasing the area of the riparian zone, logging practices have been shown to alter set physical characteristics of streams, including elevating water temperature due to decreased canopy shade and causing an increase in silt and sediments (Waters 1995). Increases in stream temperature lead to lower dissolved oxygen (DO) affinity in streams (Saroglia et al. 2000). Increases in silt can lead to higher turbidity levels within a stream ecosystem (Townsend et al. 1992). Both a decrease in DO and an increase in turbidity can have a negative impact on fish populations, possibly decreasing the total biomass of fish communities or altering species diversity (Ross et al. 2001).

Forestry is a predominant industry in the Upper Peninsula of Michigan, and 84% of this region has already been forested (Yamamuro 2002). Effects of such heavy forestry have been studied in the Pacific Northwest, but such information is lacking in the Midwest especially in the Great Lakes region. This study examines six sites in three watersheds in the Ottawa National Forest (ONF) and University of Notre Dame Environmental Research Center (UNDERC), located in the Upper Peninsula of Michigan, to determine the effect of logging on the total biomass and growth rates of three fish native to this region: brook trout (*Salvelinus fontinalis*), mottled sculpin (*Cottus bairdi*), and longnose dace (*Rhinichthys cataractae*).

Brook trout are the only stream-dwelling trout native to the Great Lakes area, and generally only live in cool water conditions of 22°C or less. Furthermore, they are much more abundant in clean, pure, and well-oxygenated water (Lewis 1966). Thus, a decrease in the riparian zone could negatively affect the ideal DO and temperature at which brook trout comfortably inhabit. While brook trout also spawn on a greater variety of substrates than most of their Salmonidae counterparts, they may still be negatively impacted by increased sediments and turbidity due to logging (Sirois 1995). High amounts of sediment have been hypothesized to cover recently lain eggs of trout, creating a barrier preventing these eggs from hatching and thus decreasing the number of young of year fish in the region. Furthermore, high sediments have been shown to reduce feeding and the subsequent growth rate of several species of fish, including trout (Waters 1995). These factors may place added stress on brook trout for survival as local habitats decrease with an increase in logging practices and riparian zone destruction.

Mottled sculpin, like brook trout, prefer cooler, clear streams with moderate flow (Coombs 1999). Unlike brook trout, though, mottled sculpin actually thrive on gravel and rocky bottoms made up of course sediment. However, mottled sculpin cannot survive when silt is present in high amounts (Grossman et al. 2002). When suspended particles are present in the water column at elevated rates, high turbidity has been shown to increase stress on fish due to gills clogging with fine sediment (Cline et al. 1994).

This increase in silt, which could be caused by riparian zone destruction and deforestation, presents an equal risk to longnose dace. Longnose dace are one of several species of Cyprinidae in this region and prefer to inhabit riffles, where flow is fastest and DO levels are highest (Novinger and Coon 2000). If DO levels are lowered, increased competition occurs between similar fish species for nesting grounds (Ingendahl 2001), which would limit potential habitat for longnose dace. In addition, while an increase in course sediments adds to potential spawning gravel and cover from predators, fine sediment increase may negatively impact the overall growth rate of this benthic fish.

In studying the anthropogenic impact of logging factors on stream biota at the ONF and UNDERC, three subwatershed treatments were analyzed: streams whose riparian zones were recently logged within the previous 20 years, past logged 50-70 years ago, or never-been logged within the previous century. The latter treatment serves as a control, as small stream ecosystems are assumed to naturally be restored within a 100 year period. Because the physical landscape of UNDERC and the ONF was formed during the last period of glaciation that formed similar ecosystems throughout the Midwest (Miesbauer 2002), this study provides a model for the entire upper Midwest region of the United States and Southern Canada.

Methods and Materials

Field studies were conducted throughout the summer of 2002 in three watersheds (6 total sites, 2 of each logging treatment) in the Upper Peninsula of Michigan. A total reach of 15x the average bankful width was studied at each site. Table 1 summarizes the sites and their respective locations.

Stream reaches were first sub-classified into riffle, glide, and pool habitat. Data were collected in accordance with USDA Forest Service guidelines (Harrelson, Rawlins, and Potyondy 1994). Site maps were created, and one to five cross-section surveys were done per habitat unit to gain an accurate depiction of total wetted and bankfull volume. Wetted and bankfull depth was measured a minimum of 6 times with a survey staff for each cross-section. Water surface slope was recorded using a clinometer by standing

20m upstream or downstream of a landmark to determine a possible change in elevation. A suitable 100m reach for fish collection was then determined, making sure to encompass at least one pool and one riffle.

Table 1. Summaries of streams in the Ottawa National Forested studied May-July 2002. The Shannon-Weaver index reflects the relative health of each stream considering each stream's total fish diversity. Values closest to 1.00 are healthiest.

Stream	Previous Period of Logging	Average Bankful width (m)	Watershed	Shannon-Weaver HI Value
McGinty	<20 yrs	5.2	Ontonagon	2.47
Two-Mile, Site 1	<20 yrs	11.9	Ontonagon	1.44
Two-Mile, Site 2	50-70 yrs	9.6	Ontonagon	2.95
East Branch Presque Isle	50-70 yrs	9.8	Black-Presque Isle	2.62
Montowibo	>100 yrs	4.6	Black-Presque Isle	1.39
Perch River	>100 yrs	10.23	Sturgeon	2.68

A multi-probe sonde measured water quality, including temperature, pH, DO, and conductivity. Data was analyzed to assure that no drastic abiotic factors distinguished one stream from another before fish collecting occurred. To assure that each stream reflected as similar conditions as possible outside of logging treatments, all fish collecting was done in the morning and occasionally early afternoon and only during sunny or partially sunny conditions.

Fish were collected using a series of electroshocking tools and the guidelines outlined in Lamberti and Hauer, 1996. After a 100m reach at each site was determined, the upstream and downstream margins of the reach were obstructed using block seines so that no fish would get in or out of the desired reach. Electroshocking backpacks were then used and shocking conducted by the U.S. Forest Service. For streams with pools more than .75m deep, an electroshocking barge was used to help prevent fish from escaping capture. Fish were kept in a water-enclosed case until they could be analyzed. Three consecutive passes were made at each stream to ensure adequate accuracy. After each pass all fish were identified, weighed, and measured before being immediately released back into the water outside of the sampling area. The length was measured from the snout tip to the base of the caudal fin, where the vertebral column ends.

The Cole Condition Factor was then used to determine the relative growth rates of each fish, specifically brook trout, mottled sculpin, and longnose dace, given the length and mass of each individual. The Cole Condition Factor states that $K = M * 10^5$ (mass in grams)/L^3 (length in mm), where 1.00 is considered a maximum value for fish health (Bruns and Minshall 1983). A basic condition factor (M/L) was also extrapolated from the data. Due to a clear distinction in brook trout young of year fishes, only adult brook trout were analyzed in these manners.

Results

Brook trout, mottled sculpin, and longnose dace, all natives, together represent over 50% of the total biomass for all fish collected at all six sites combined. Figs. 1-3 represent the total biomass and all species found for each of the logging treatments (<20 years ago, 50-70 years ago, and >100 years ago or never-been logged). These figures represent two sites for each treatment, and show the diversity of both fish species and families in these streams. Brook trout make up less total fish biomass in streams with riparian zones recently logged (<20 years) than in past logged (50-70 years) or never-been logged sites. Mottled sculpin and longnose dace (Fig. 3) each constitute more of the overall fish biomass in never-been logged streams then in those with recently or past logged riparian zones.

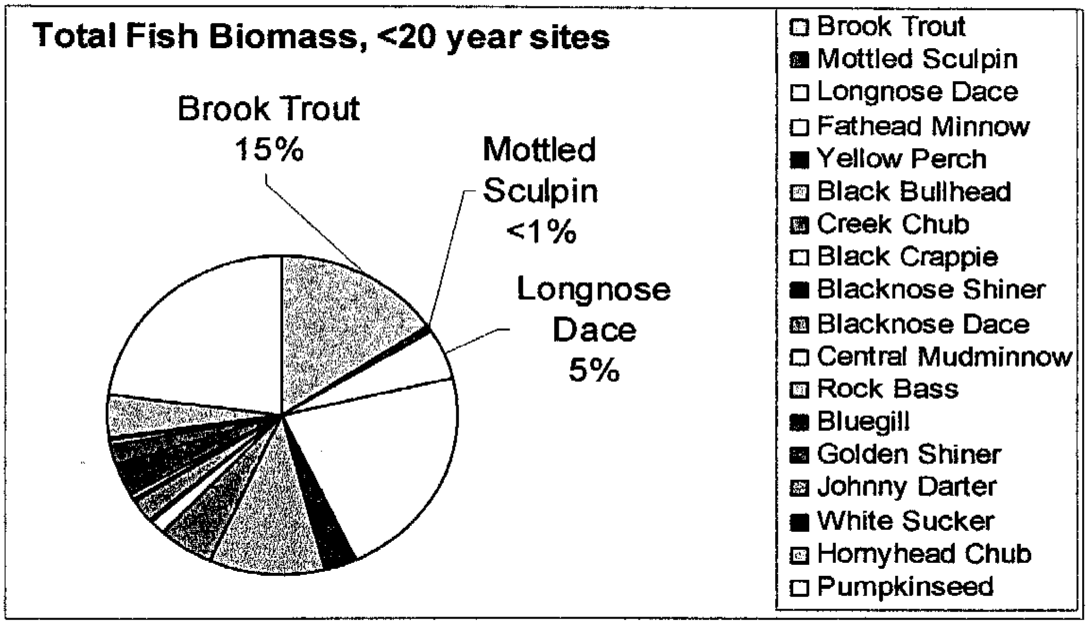

Fig. 1. Complete species list and corresponding proportion of biomass of all fish found in two streams with riparian zones logged within the past twenty years.

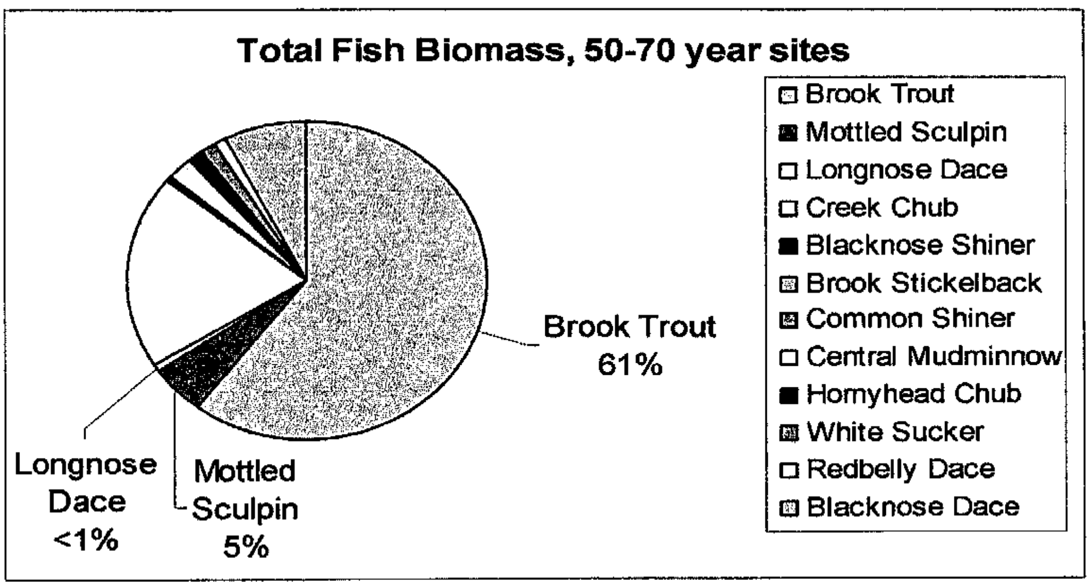

Fig. 2. Complete species list and corresponding proportion of biomass of all fish found in two streams with riparian zones logged fifty to seventy years ago.

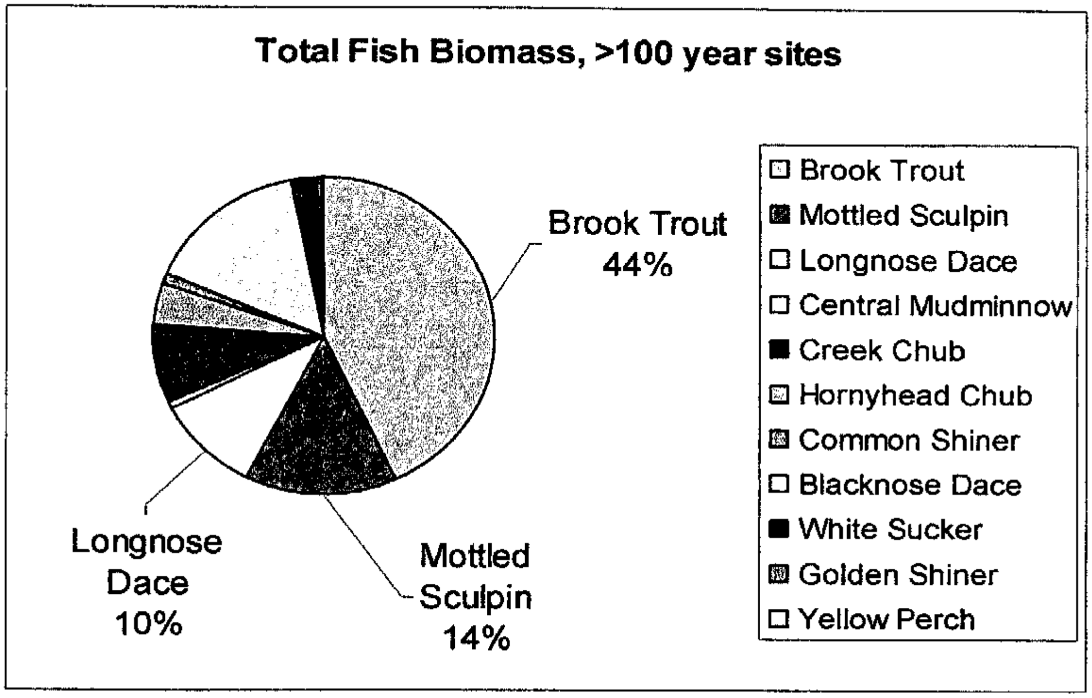

Fig. 3. Complete species list and corresponding proportion of biomass of all fish found in two streams with riparian zones that have never-been logged in their history or in the last 100 years.

Brook trout, mottled sculpin, and longnose dace also contribute over 66% of total fish biomass for all streams except those which have been recently logged. These recently logged streams (<20 years) contain more brook trout competitors such as rock bass and bluegills, then all other streams analyzed. In addition, adult brook trout (2999.8g) contribute approximately 10x as much total biomass when compared to mottled sculpin or longnose dace, which had similar total biomasses (318.9g and 306.3g respectively).

For total species biomass, brook trout and mottled sculpin display similar trends. Over 50% of total brook trout and mottled sculpin biomass are located within streams logged 50-70 years ago, while recently logged streams (<20 years) account for less than 20% biomass (Table 2). Longnose dace display opposite trends; over 60% of total longnose dace biomass are gathered in recently logged streams, whereas past logged streams make up the smallest percentage (Table 2).

Table 2: Percentage of total species biomass of brook trout, mottled sculpin, and longnose dace per logging treatment

Logging Treatment	Brook Trout	Mottled Sculpin	Longnose Dace
<20 yrs ago	18.59%	5.64%	62.23%
50-70 yrs ago	67.48%	51.87%	5.65%
>100 yrs ago	13.92%	42.49%	32.12%

Total species biomass tends to follow the frequency of adult brook trout, mottled sculpin, and longnose dace per treatment site. On average, the greater the percentage of biomass per treatment site, the greater the number of individuals present. Figures 4-6 display the frequency of adult brook trout, mottled sculpin, and longnose dace per site, and reveal growth trends for each species, respectively. All three species display larger growth curves and greater frequency at streams that contained the most total biomass per population.

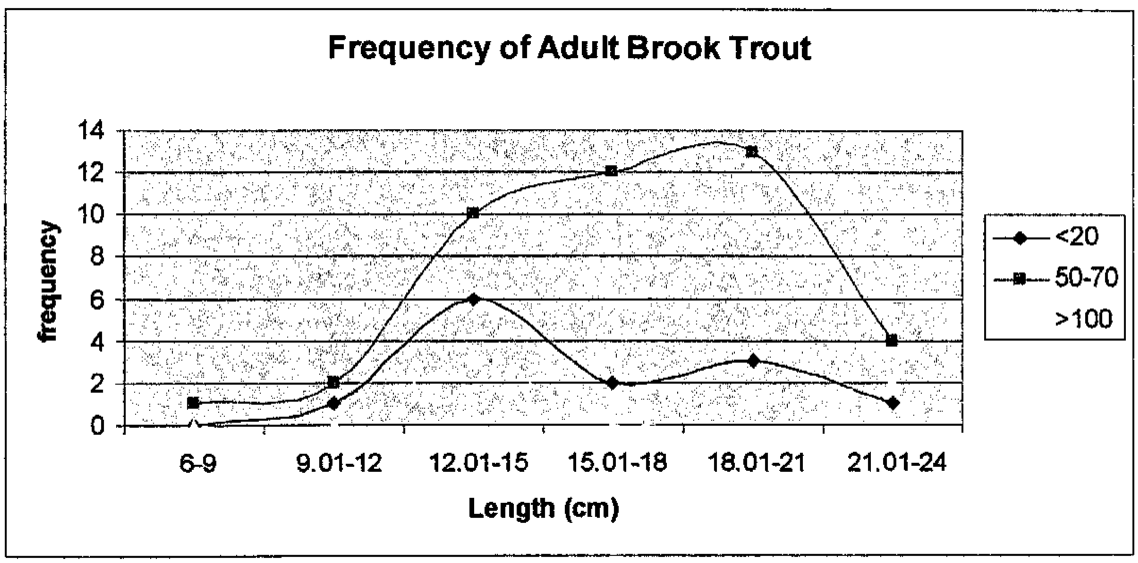

Fig. 4. Frequency and relative growth curve, measured in terms of body length, of adult brook trout per logging treatment.

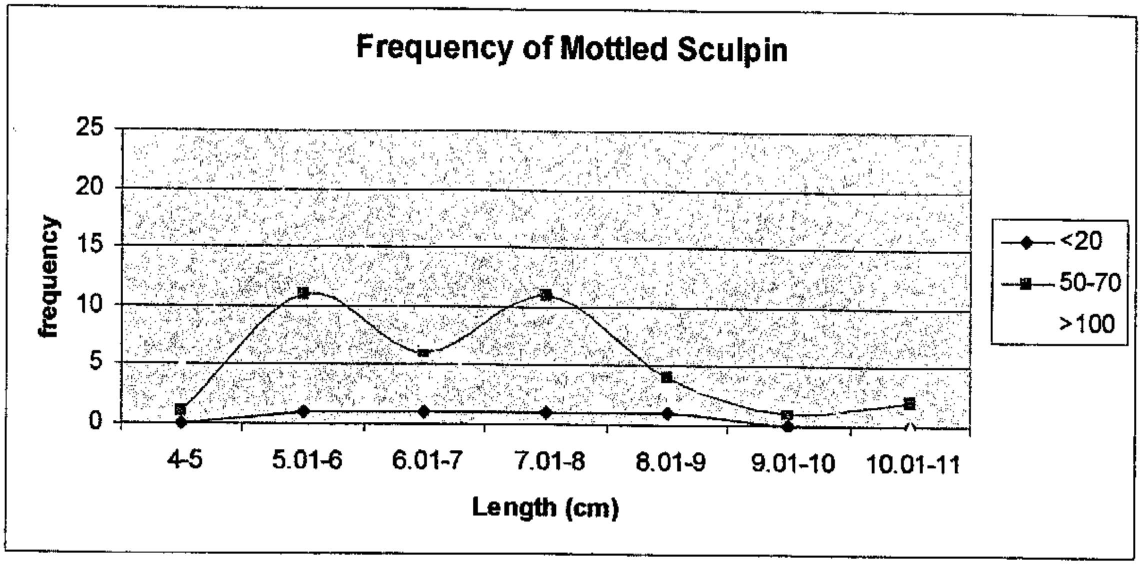

Fig. 5. Frequency and relative growth curve, measured in terms of body length, of mottled sculpin per logging treatment.

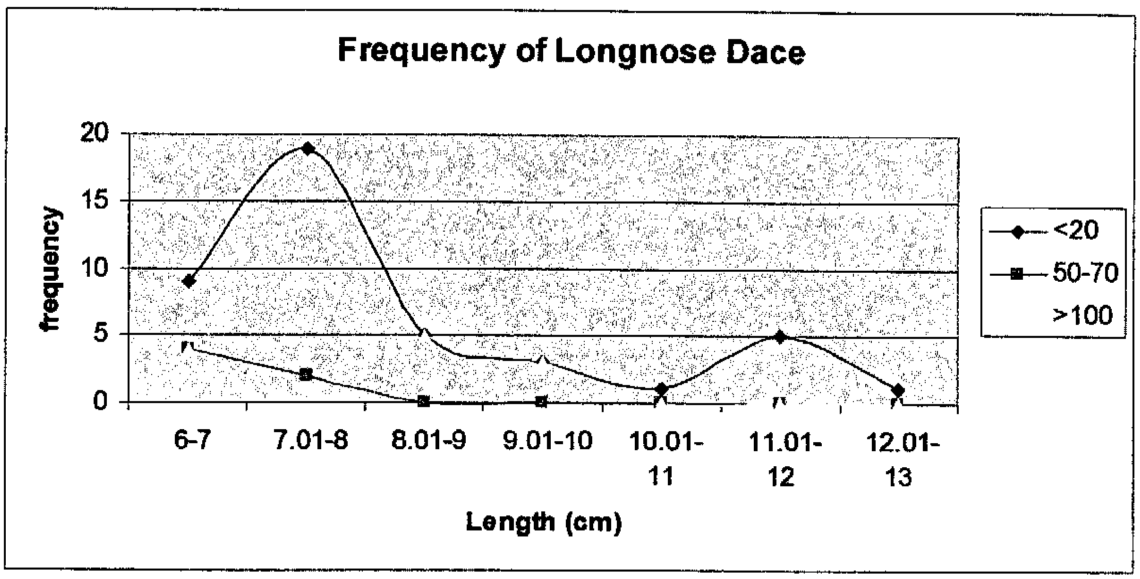

Fig. 6. Frequency and relative growth curve, measured in terms of body length, of longnose dace per logging treatment.

Adult brook trout follow identical trends for average length (Fig. 7) and average mass (Fig. 8). While there are no significant differences for average length ($p = .53$) or average mass ($p = .67$), similar trends appear, whereby the more recently logged the riparian zones of a stream is, the smaller the average length and mass of brook trout found. Thus, the recently logged streams (<20 years) have the smallest brook trout in length and mass, while the unlogged streams (>100 years) have, on average, the largest.

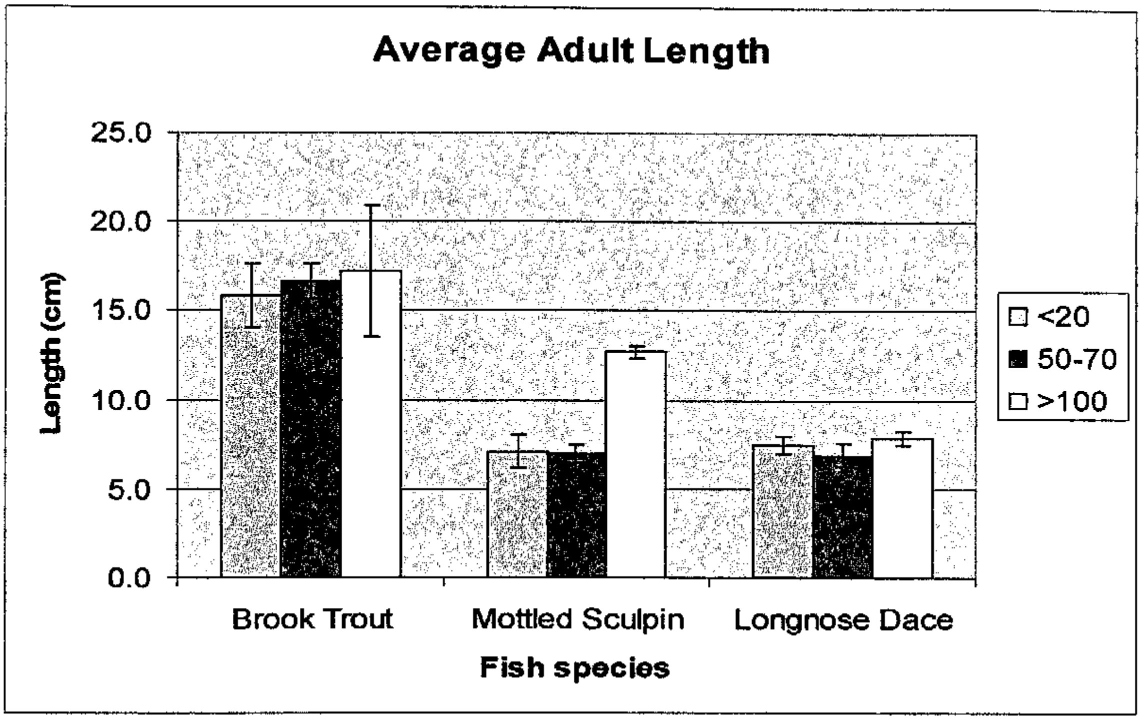

Fig. 7. Average adult length of brook trout, mottled sculpin, and longnose dace per logging treatment, with respective 95% Confidence Interval (CI).

Longnose dace also show identical trends in average length (Fig. 7) and mass (Fig. 9). While there are no significant trends for average length ($p = .72$) or average mass ($p = .80$), clear trends arise. A decrease in both average length and mass of longnose dace individuals can be found in past logged (50-70 years) streams, while recently logged and never-been logged streams have near identical values.

Mottled sculpin show disparity when average length (Fig. 7) and mass are compared (Fig. 10). Although mottled sculpin show a significant increase in length in unlogged streams ($p < .05$), there are no significant trends in average mass between logging treatments ($p = .45$). Furthermore, on average, the mass of mottled sculpin is least in unlogged streams (>100 years), whereas the length is greatest. The opposite holds true as well, as mottled sculpin show the shortest average length for the logging treatment (50-70 years) for which they have the greatest average mass.

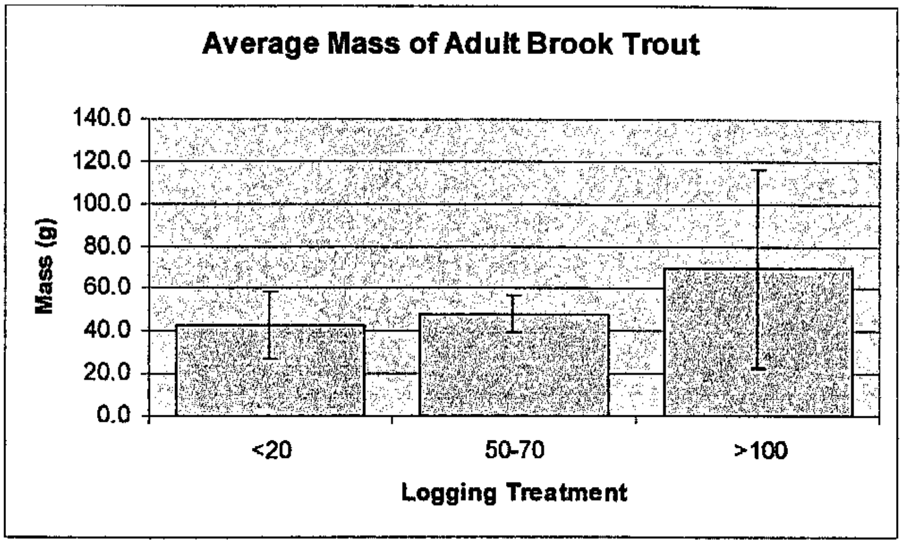

Fig. 8. Average mass of adult brook trout individuals per logging treatment (95% CI).

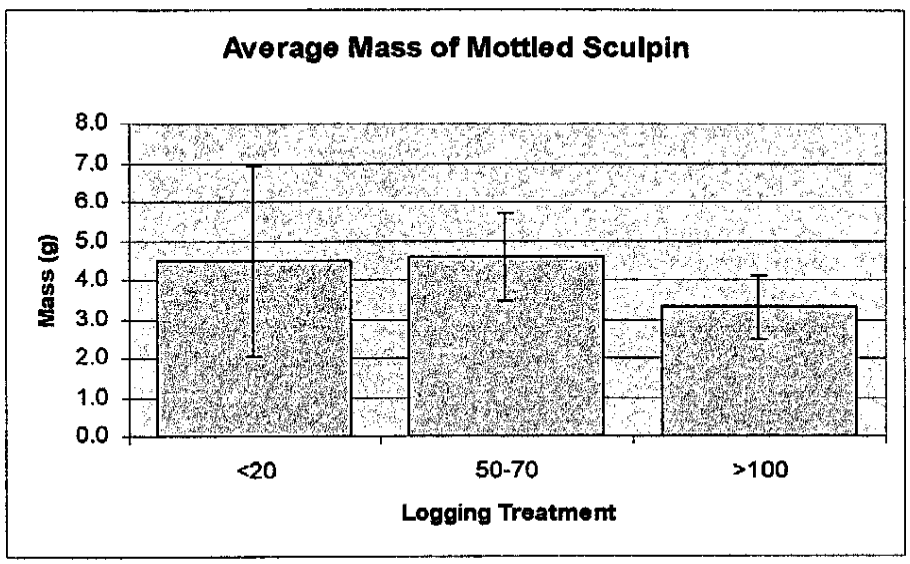

Fig. 9. Average mass of mottled sculpin individuals per logging treatment (95% CI).

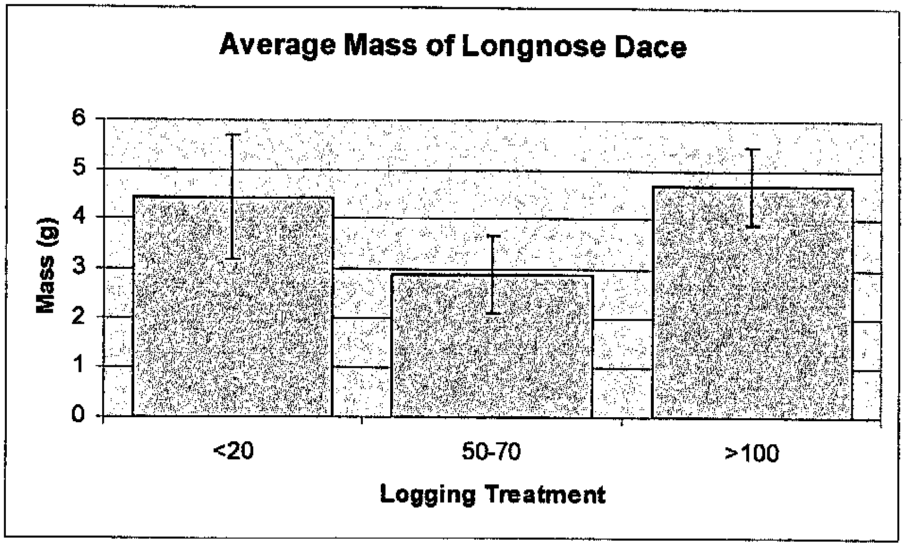

Fig. 10. Average mass of longnose dace individuals per logging treatment (95% CI).

To test the relationship between average length and average mass for these three species, Cole Condition Factor (Table 3) and basic condition factors (figs. 11-13) were performed. The Cole Condition Factor is a basic indicator of fish health, with a value of 1.00 being ideal. The further the deviation from 1.00, the more diminished the health of a fish, and ideally the less chance for survival.

Table 3 shows that all three native species deviate from their ideal condition factors. Recently logged sites (<20 years) have healthier individuals within a population adult brook trout, mottled sculpin, and longnose dace when compared to past logged sites (50-70 years). Streams with past logged riparian zones, in turn, have healthier average populations for all three species when compared to streams with never-been logged riparian zones (>100 years). However there is no direct correlation between the health of a population and its frequency. While longnose dace show the greatest overall frequency (Fig. 6), relative growth rate (Fig. 13), and net total biomass (Table 2) at the same logging treatment (<20 years) in which they have the healthiest individuals, the same does not hold true for brook trout or mottled sculpin.

Adult brook trout have the greatest total number of individuals (Fig. 4) and total biomass (Table 2) in past logged streams, while on average the healthiest brook trout are found in recently logged streams. However, basic condition factors, a more simple and direct comparison between mass and length for an entire population, reveal that the growth trends of adult brook trout parallel their frequency and total biomass directly (Fig. 11).

Mottled sculpin populations show the healthiest condition values in recently logged streams, even though recently logged streams make up only a fraction of total biomass (Table 2) and the least frequency of individuals (Fig. 5). Mottled sculpin, however, show near identical growth curves at streams under all three logging treatments (Fig. 12).

Table 3. Average Cole Condition Values for adult brook trout, mottled sculpin, and longnose dace per logging treatment. Values closest to 1.0 are healthiest.

Logging Treatment	Brook Trout	Mottled Sculpin	Longnose Dace
<20	9.52	11.51	7.38
50-70	9.85	11.57	8.66
>100	10.69	12.33	9.15

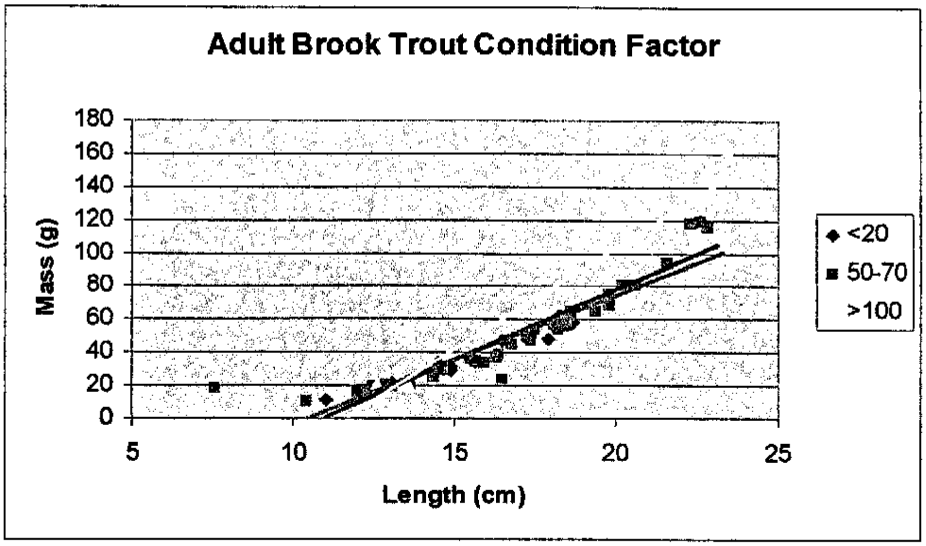

Fig. 11. Basic condition factor, a direct comparison of mass and length for all individuals in a population, for adult brook trout.

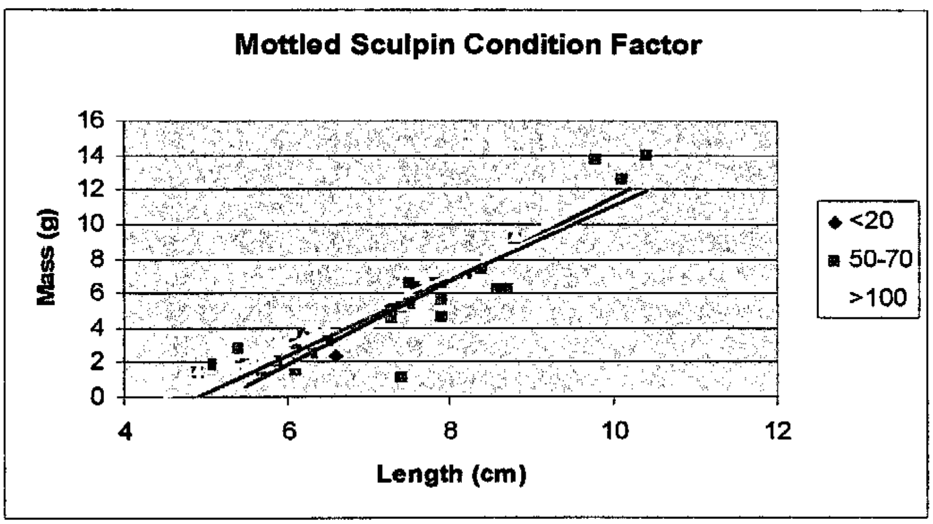

Fig. 12. Basic condition factor, a direct comparison of mass and length for all individuals in a population, for mottled sculpin.

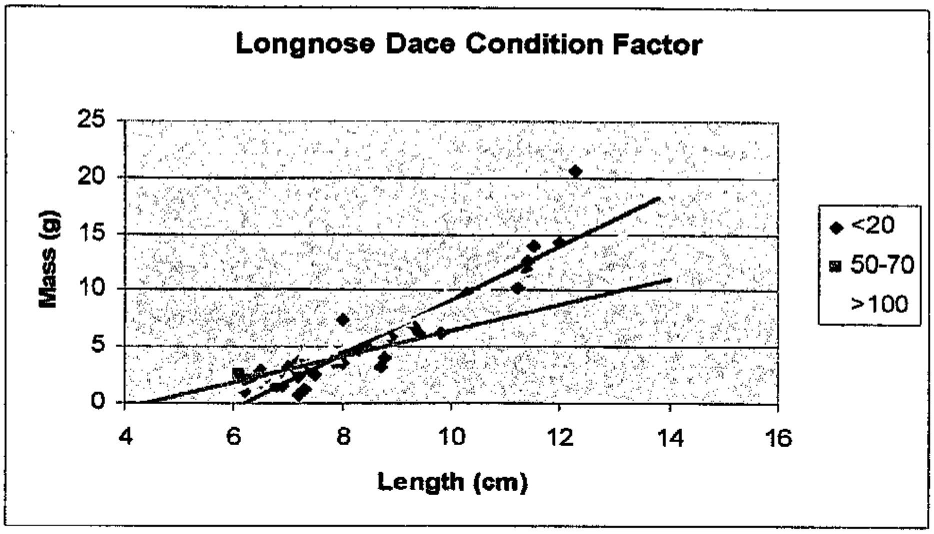

Fig. 13. Basic condition factor, a direct comparison of mass and length for all individuals in a population, for longnose dace.

Discussion

Human logging patterns, especially on stream edges, have definitive effects in altering the riparian zone, removing cover, and changing stream ecosystems (Stott et al. 2001). These alterations appear to extend to native fish populations as well. Brook trout, mottled sculpin, and longnose dace are among the three most abundant native fish in streams in the Great Lakes region of the Upper Peninsula of Michigan. These three species collectively contribute over 68% to the total fish biomass of unlogged streams, which have not had riparian zones altered by humans within the past century (Fig. 3), while they contribute to only 21% of total fish biomass in recently logged streams (Fig. 1). Furthermore, longnose dace (Fig. 10) and adult brook trout (Fig. 7) reveal greatest average mass in unlogged streams when compared to recently logged and past logged (50-70 years ago) streams, while mottled sculpin show a significantly larger average size in unlogged streams compared to those that have been logged (Fig. 6). Such alterations in mass and length suggest that logging treatments may negatively affect native fish almost immediately.

This decrease in total biomass of these three native fish in recently logged streams is in part due to an increase in competition. Only recently logged streams have trout competitors such as rock bass, bluegills, and pumpkinseed (Fig. 1) that likely contribute to the limited frequency and lower growth rates (Fig. 4) of adult brook trout in streams at this logging treatment. Thus increased competition would inevitably make resources scarce and enable only the fittest trout to survive. This is supported by the fact that adult brook trout have the highest health factor (Table 3) in recently logged streams despite a decrease in number and size.

As seen by the average length of mottled sculpin (Fig. 7) and the average length and mass of longnose dace (Figs. 7,10), streams with riparian zones logged over a half-century ago still can limit the size of some fish aw well, suggesting that human influence remains at least for 70 years in stream ecosystems after logging. In streams with riparian zones logged 50-70 years ago, the relative growth rate and condition factor is lowest for all three native species studied, considerably lower in the case of longnose dace (Table 3). One possible cause for this decrease in frequency is that as fish size decreases within a population, susceptibility to parasitic infection increases (Poulin 2000). Alternatively, nutrient depletion from logging practices may take up to 70 years to impact negatively a stream community. Increase runoff from lack of riparian structural support may cause all nutrients to be washed off initially. This explains why all three native fish have the healthiest Cole Condition Value for recently logged streams when compared to those past logged and never-been logged. After 50-70 years, though, all necessary nutrients would be moved further downstream, and a relative deficiency of essential minerals may be found in the stream directly near riparian zones weakened by logging, negatively impacting primary production and ultimately native fish communities as well.

Logging practices also often soften the ground on riparian zones, and may allow new springs, whose flow normally would not have been great enough to penetrate through the riparian zone, to enter the stream bed. Such pure springs bring fountains of cold water, and may provide ideal refuge for brook trout and mottled sculpin near stream banks. For this reason, it is not surprising that brook trout and mottled sculpin show the greatest net frequency in past logged sites (Figs. 4,5), which have had enough time for springs to penetrate weakened stream banks. Indeed, while electroshocking, brook trout especially seemed isolated only within occasional 1m x 1m sites next to the bank at both recently and past logged. These sites were densely populated, and usually reflected a noticeable input of spring water (i.e. McGinty Creek). Mottled sculpin especially, though, displayed decreased frequency in recently logged streams (Fig. 5), which over the past 20 years most likely had significantly higher average water temperature due to decreased canopy cover (Larson and Larson 2001) because of large trees being removed for logging purposes. Nevertheless mottled sculpin have similar basic condition factors under all treatments (Fig. 12), suggesting that unlike brook trout (Fig. 11) or longnose dace (Fig. 13), mottled sculpin can retain their relative health despite change in environment due to logging.

The lack of significance ($p>.05$) found in the average lengths of mottled sculpin, brook trout, and longnose dace (Fig. 8,9,10), and in average mass of the latter two (Fig. 7), suggest more replicates are needed to determine definitively the effect of logging on these native fish populations. Additional streams of set logging conditions would inevitably include more watersheds and streams of increasingly varying quality. Clearly, however, the general findings from this study suggest that logging practices negatively impact three vastly different native fish in the Great Lakes region which make up a major portion of stream fish populations. While adverse effects from recently logged streams are most notable in the larger brook trout (Fig. 8), bottom-dwelling mottled sculpin and benthic longnose dace also showed a decreased frequency (Fig. 5,6) and net size (Figs. 9,10) 50-70 years after a stream has been logged. An input of large woody debris, which would provide additional habitat for many native fish including brook trout (White 1996, Meisbauer 2002), may be a temporary solution to aiding these native fish after logging. However, a lack of nutrients from a washed out riparian zone and decrease in canopy cover likely invites increased intraspecies competition in streams with recently logged riparian zones. These issues must be addressed in future studies and managerial practices.

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