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FISH ASSEMBLAGES IN MANISTEE RIVER TRIBUTARIES: LONGITUDINAL DISTRIBUTION ANALYSIS, SEASONAL VARIATION, AND RIPARIAN IMPROVEMENT EVALUATION

A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Science

By

Nicholas J. Gressick

To

Biology Department
Grand Valley State University
Allendale, Michigan
June 2009

Signature page has been removed.

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Nicholas John Gressick

2009

This is dedicated to Misty Gressick, my wife, whom I had met while working on this project in Manistee, Michigan

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I wish to thank Dr. Eric Snyder, Dr. Mark Luttenton, Dr. Carl Ruetz, and Marty Holtgren for their support and guidance. I would also like to thank Grand Valley State University for this great opportunity. Also, the Little River Band of Ottawa Indians for assistance in the field and use of equipment. I would like to thank Kevin Donner, April Wright, Stephanie Ogren, and Bob Sanders for assistance with sampling. I would also like to thank the Environmental Protection Agency for providing funds available for this project. Also, I thank the Little River Band of Ottawa Indians and Grand Valley State University for equipment and guidance with the project.

Abstract

Sedimentation and culvert issues can affect both stream physical and biological integrity and can negatively impact the fish assemblage by impeding fish passage, degrading food resource availability, and masking requisite spawning gravel and cobble. The purpose of this study included (1) an attempt to quantify impacts of poorly constructed road stream crossings and eroding banks on fish assemblages and subsequently assess these sites as sediment sources and connectivity breaks on entire fish assemblages and individual fish species, (2) give a detailed description of the fish assemblage structure from headwaters to mouth on the three study streams and assess the differences between streams regarding fish assemblage structure, and (3) designate the potential differences between whole fish assemblages and individual species between three tributaries of the lower Manistee River, Michigan, using a headwater to mouth approach. Electrofishing was conducted during spring and fall 2004 and 2005 on three tributary streams (Sickle Creek, 1st order, Pine Creek, 2nd order, Bear Creek, 4th order) within the lower Manistee River watershed. A total of 29 electrofishing reaches were sampled and included 5 road-stream and streambank restoration sites. Sickle Creek had reduced diversity and increased dominance above a substantially perched culvert. Fish assemblage response above and below impact sites was mixed, and largely determined by either an up vs. downstream impact. In the longitudinal analysis, unique fish assemblages were observed between Sickle, Pine, and Bear Creeks. Whole fish assemblage measurements revealed no significant differences between seasons for Pine, Sickle, or Bear Creeks with respect to fish density, dominance, diversity, and richness. It appears that different order streams and patterns in fish community abundance and diversity seemed to reflect the environmental habitat template, even when this template deviated from the predicted longitudinal conditions.

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CHAPTER 1

PREFACE

In 2003, the Little River Band of Ottawa Indians received a U.S. Environmental Protection Agency Targeted Watershed Initiative grant to aggressively improve water quality in the Big Manistee River watershed. Restoration efforts focused on the Bear Creek and Pine Creek sub-watersheds. Projects included 1) replacing undersized culverts with the appropriate open bottom culvert or bridge and 2) replacing undersized bridges with modern bridges designed to direct stormwater (and sediment run-off) away from the stream. Additionally, these designs improved fish passage and restored the natural flow patterns to help remove accumulated fine sediment (silt and sand). The main objectives were to: 1) determine site locations for road-stream crossings, streambanks and access-site improvements through review of pre-existing inventories or site assessments, 2) implement restoration activities of constructing new road-stream crossings, stabilizing streambanks and creating access-sites, and 3) to critically evaluate the effectiveness of each habitat restoration practice through the use and development of biological metrics. The focus of this thesis project revolved around the third objective and specifically involved an assessment of the fish assemblages while two other GVSU graduate students, Nichol De Mol and April Wright, focused on aquatic insect communities and sediment composition change, respectively.

Excessive sedimentation can be considered a major abiotic disturbance affecting stream biotic community structure and function (Lake 2000). In fact, sediment has been found to adversely affect most fish species, especially salmonids by smothering redds, masking spawning gravel and reducing habitat complexity (Barton 1977, Scott et al. 1986, Alexander and Hansen 1988, Curry and MacNeil 2004, and many others).

Most of the studies previously mentioned used a BACI design, however, only used simple comparisons in relation to sedimentation problems. In this study we used an upstream versus downstream comparison, with multiple sampling points at both upstream and downstream sites. Fausch et al. (2002) suggested that the importance of different physical and ecological processes will be revealed at different spatiotemporal scales, and processes will interact among scales. Furthermore, Allan (2004) suggested that further research is needed that examines responses to land-use under different management strategies and that employs response variables that have greater diagnostic value than many of the current measures. The results of our study, in conjunction with the considerations in the previous two studies, contribute to our understanding of what occurs further upstream and downstream of a potential sediment source, although results of this research constitute the pre-restoration monitoring—additional GVSU MS theses document the post-restoration phase (De Mol 2007, DeBoer 2008).

In addition to a larger spatial assessment of sedimentation, we have utilized a headwaters to mouth approach within the Great Lakes Region to examine stream fish distribution impaired by high rates of sedimentation and barriers to fish migration. Many studies have examined fish longitudinal distribution and its relationship to biotic and abiotic factors (Schlosser 1991, Grenouillet et al. 2004, Schaefer and Kerfoot 2004, Helms et al. 2008 and many others). Schlosser (1991) stated that, as a whole, land-use activities can decrease spatial heterogeneity and connectivity of physical habitats. Torgersen et al. (2006) compared gradients in fish assemblage structure among rivers and at multiple spatial scales and found spatial structuring of fish assemblages exhibited a generalized pattern of cold- and coolwater fish assemblage zones, but was variable between thermal zones, particularly in the warmest stream. Helms et al. (2008) evaluated the impact of land cover on fish assemblages in a western Georgia stream and found that fish assemblages were largely explained by physiochemical and hydrological rather than habitat variables. Similar to our study area, Zorn et al. (1998) examined the distribution and abundance patterns of fish assemblages at numerous locations in lower Michigan streams using low-flow yield and catchment area as variables. While providing a framework for stream fish distribution in the lower peninsula, they also determined that stream fishes respond in an individualistic manner to stream conditions, and that focus on individual species is needed to describe fish assemblage structure in streams. While each of these studies attempted to explain fish distribution in each stream using various abiotic measurements with few in sand-dominated, upper Midwest streams, we examined the relationship with Michigan coldwater stream fish longitudinal distribution and various water quality parameters, substrate composition, up vs. downstream impacts of localized sediment sources, and stream passage constrictions created by road stream crossings and eroding stream banks.

The purpose of this study was to: 1) examine the response of fish assemblage structure to historic sand inputs, constricted and perched culverts, and consequences for restoration, 2) study longitudinal fish distribution from up to downstream, and 3) focus on fish assemblage spring/summer longitudinal patterns in three tributaries of the lower Manistee River, Michigan.

This thesis is divided into three chapters that focus on sediment and restoration, longitudinal fish assemblage, and seasonal (spring and summer) fish assemblage. Finally, all three chapters are summarized.

CHAPTER 2

RESPONSE OF FISH ASSEMBLAGE STRUCTURE TO HISTORIC SAND INPUTS, CONSTRICTED AND PERCHED CULVERTS, AND CONSEQUENCES FOR RESTORATION

ABSTRACT

Sedimentation affects both stream physical and biological integrity. Improperly designed stream passage accompanied with sedimentation and altered hydrology can impede fish passage and reduce fish assemblage integrity. The purpose of this study was to: 1) quantify impacts of poorly constructed road stream crossings and eroding banks on fish assemblages, and 2) assess these sites as sediment sources and connectivity breaks on entire fish assemblages and individual fish species. Electrofishing was conducted during spring and fall 2004 and 2005. A total of 29 electrofishing reaches were sampled which included 5 road-stream and streambank restoration sites. Sickle Creek (1^{st} order) had reduced diversity and increased dominance above a substantially perched culvert (Shannon's diversity = 0.180 vs. 0.552; Simpson's dominance = 0.688 and 0.412 above vs. below, respectively). Pine Creek (2^{nd} order) had 12 reaches sampled, while Bear Creek (4^{th} order) had 7 reaches sampled. In both river systems, fish assemblage response above and below impact sites was mixed, and largely determined by either an up vs. downstream impact. For example, undersized road-stream culverts reduced upstream habitat quality while eroding banks reduced downstream habitat quality. Improvements to road-stream crossings should be done to maximize natural river structure and function.

Introduction:

Stream disturbance plays a major role in determining the structure and function of stream communities (Lake 2000). Disturbance determines both patchiness and diversity in streams (Lake 2000). Sedimentation represents a disturbance that can negatively impact fish assemblages by altering physical, chemical, and biological characteristics of streams (Lake 2000).

Although many studies have examined the effects of natural and anthropogenic disturbance on streams, there are fewer studies involving fish assemblages and sedimentation effects from road stream crossings, especially in a longitudinal gradient perspective. Whole watershed disturbances include water fluctuations, forestry practice, livestock grazing, and urbanization, all of which can contribute to sedimentation (Larimore et al. 1959, Junk et al. 1989, Jones et al. 1999). Local or proximate disturbances such as sedimentation can affect fish assemblages directly by changing water quality, habitat, and spawning areas (Bjornn 1971, Berg and Northcote 1985, Lisle 1989, Lisle and Hilton 1991, Servizi and Martens 1992, Waters 1995).

Peters (1967) found that brown trout in a Montana stream decreased with increased sedimentation from agricultural sources, similar to results obtained by Saunders and Smith (1965) who studied the effect of heavy siltation in a Prince Edward Island brook trout stream. They reported 70% declines in trout populations, (both age-0 and older fish) due to loss of cover by sediment deposits. More recently, Alexander and Hansen (1988) showed an experimental addition of sand in Hunt Creek, Michigan, reduced the brook trout population by 50%. Drastic declines in a Minnesota brook trout population after catastrophic spring floods were observed from stream bottom sediments covered by shifting sand, leading to scouring of eggs and reducing fry abundance (Elwood and Waters 1969). Curry and Macneill (2004) studied sediment deposition effects on brook trout embryos and young of the year. They found that mortality occurred at late encapsulated stages before hatching; the result of depleted oxygen from fine sediment deposition. Groundwater inputs in some areas reduced sedimentation in redds and increased survival (Curry and Macneill 2004)

Sedimentation can occur when road-stream crossings are constructed. For example, Beschta (1978) showed that road construction causes soil movement or landslides. Chisholm and Downs (1978) reported that construction of a four-lane highway along Turtle Creek, West Virginia generated large amounts of sediment, burying the streambed under 10 inch deposits and eliminating the stream benthos. Road construction along Joe Wright Creek, a mountain stream in Colorado, reduced macroinvertebrates where sediment deposits occurred (Cline et al. 1983). Loomis (1989) showed detrimental impacts of road building on recreational and commercial fisheries. Barton (1977) observed a decline in total fish standing stock from 24 to 10 kg/ha owing to sedimentation downstream from a bridge construction on an Ontario brook trout stream. Comparative analysis of a pristine creek and a road-stream crossing impacted by urban development, suggested restructuring of the fish community in Kelsey Creek, Washington (Scott et al. 1986). Specifically, results showed environmental disturbance, including habitat alteration (sedimentation), increased nutrient loading, and degradation of the intragravel environment had a large negative effect on coho salmon, while not affecting cutthroat trout (*Oncorhynchus clarki*). Kelsey Creek became dominated with cutthroat trout, whereas the control stream had a diverse composition of salmonids.

In summary, research shows that species-specific responses to road-stream crossings are variable and urban development does not necessarily displace all salmonids. However, these studies did not account for overall stream ecosystem integrity when road-stream crossing construction occurred. Alternatively, if construction is conducted in an ecologically appropriate manner, then impacts can be potentially minimized. Improvement of existing road-stream crossings that historically contributed significant amounts of sediment could substantially improve the fish assemblage by reducing sediment impacts.

The purpose of this study was to: 1) quantify impacts of existing road-stream crossings and eroding banks on fish assemblages, and 2) assess these sites as sources of sediment and connectivity breaks on entire fish assemblages and individual fish species.

Materials and Methods:

Study Area: The Manistee River flows westward into Lake Michigan through northern lower Michigan (Figure 1) through the Manistee National Forest and drains a largely forested watershed in northwestern lower Michigan characterized by a stable baseflow. Currently, land use is mainly forested (75%) with occasional agricultural practice (25%). Sickle, Pine, and Bear creek tributaries of the lower Manistee River (Figure 1) were chosen based on their unique fish assemblages and accessibility.

Study Stream characteristics: Sickle Creek is a small 1st order stream that flows southward into the Big Manistee River. Discharge in this stream can fluctuate rapidly and average wetted stream width is 2 m. Riparian vegetation consists mainly of white cedar (*Thuja occidentalis*), American basswood (*Tilia americana*), silver maple (*Acer saccharinum*), red maple (*Acer rubrum*), and musclewood (*Carpinus caroliniana*). Canopy cover is approximately 80% with associated large woody debris and sediment composition consists of the largest component of sand, with occasional silt, pebble and gravel pockets. The fish community includes brook trout, brown trout, and rainbow trout, along with juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon as well as burbot and associated resident fish species including mottled sculpin (*Cottus bairdi*). In each stream, dissolved oxygen (mg/L), pH, specific conductivity (umhos/m), and temperature (^{0}C) were measured using portable water quality multimeters (either a

Hydrolab and/or YSI 600). Discharge was measured using a Marsh-McBirney flow meter (Table 1).

Pine Creek is a moderately-sized, 2nd order stream that originates at Pine Lake and flows northwest to the Manistee River. Discharge fluctuates seasonally with stream widths averaging 5m. Riparian vegetation at lower regions includes white cedar, maples, eastern hemlock (*Tsuga canadensis*) and American basswood with upper regions primarily consisting of speckled alder (*Alnus rugosa*), white pine (*Pinus strobus*), white cedar, red osier dogwood (*Cornus stolonifera*) and silky dogwood (*Cornus amomum*). Canopy cover is approximately 50%, and large woody debris is abundant. Sediment composition consists largely of sand, with additional silt, pebble, and gravel. Pine Creek has a self-sustaining brown trout population and resident fish species including mottled sculpin, rainbow trout, and western blacknose dace.

Bear Creek is a large, 4th order stream that flows southward to the Manistee River. Discharge fluctuates seasonally with a 10 m average wetted stream width. Riparian vegetation at lower regions include maples, American basswood, willow (*Salix spp*.), and sassafras (*Sassafras albidum*). Stream riparian vegetation includes white cedar, speckled alder, and American basswood. Canopy cover is higher (75%) at the lower regions than at upper regions (50%). Large woody debris is moderate in lower and upper regions and stream sediments composition consists of mainly sand, along with some silt, while upper regions consist of sand, silt, pebble, gravel, and cobble. Bear Creek has self-sustaining brown trout and brook trout populations, and resident fish species include longnose dace and mottled sculpin.

Experimental design: Study reaches were delineated within each stream; 5 in Sickle, 7 in Bear, and 12 in Pine creeks. The number of reaches was determined based on stream size, length, and accessibility. The basic sampling design for Sickle Creek (Figure 2) is also representative of Pine and Bear creeks. Each reach within each stream represented a replicate, and each of the replicates were used in the statistical analyses with 2 replicates for each reach for each respective season, with a total of 4 per reach for the two years of the study, excluding the Bear Creek reaches that lacked a spring 2004 sampling period due to high water and equipment problems leaving one replicate for spring and 2 for fall.

Electrofishing reach length was determined using a value of 40 times stream width, which is the standard used by the EPA (Barbour et al. 1999). Fish assemblages were assessed using pulsed DC electrofishing equipment (Carline 2001). A Smith-Root backpack electrofisher (Model 15-D 300 Watt generator-powered) was used to sample Sickle and Pine Creeks, while Bear Creek was sampled with a tote barge (Model 15-D 300 Watt generator-powered). Sickle Creek, the smallest system, was sampled using a multiple-pass depletion technique with blocker nets, while the two larger systems, Pine Creek (2nd order) and Bear Creek (4th order), were sampled using single-pass techniques with no blocker nets. Allen at al. (2003) showed that the single-pass technique was as effective as the multiple-pass technique to sample fish assemblages.

Whole Fish Assemblages and Individual Species: Fish assemblages were estimated for each respective stream during spring and summer 2004 and 2005 with the exception of Bear Creek in spring 2004 due to a combination of equipment problems and high water levels. Data were quantified using catch per unit effort (CPUE, i.e. fish/minute), which divides catch by effort, removing the effect of variable effort in the abundance measurements (Hubert and Kohler 1999). However, it is important to note that CPUE may be proportional to abundance, but can be influenced by catchability of a species. Catchability may be influenced by gear selectivity, size and age of fish, horizontal and vertical distribution of fish, and electrofishing method (Maunder at al. 2006).

Total fish density, dominance, diversity, and richness were evaluated using repeated measures ANOVA (SAS 9.1) for whole fish assemblages using upstream vs. downstream fish assemblage data. Individual fish species were assessed using density, CPUE, and relative abundance. Significance was determined at $p \leq 0.05$. Density was calculated as the total number of the entire fish assemblage and individual species divided by the reach area although population estimates were not quantified. Dominance values were calculated using Simpson's Dominance Index, while diversity was calculated using Shannon's Diversity Index (Lake 2000). Richness was calculated as the sum of all species present at each reach.

Non-metric multidimensional Scaling (NMDS) was used to determine if there was any separation between fish communities at the four road-stream crossings (PCORD software package) (Mather 1976, Kruskal 1964). NMDS is an ordination method well suited to data that are nonnormal or on arbitrary, discontinuous, or otherwise questionable scales (McCune and Grace 2008). NMDS allows the user to avoid the assumption of linear relationships among variables, uses ranked distances to linearize the relationship between distances measured in species space and distances in environmental space, and allows the use of any distance measure. Historically, NMDS tended to fail to find the best solution because of intervening local minima, however, this problem is easily avoided by requesting more random starts, more iterations, and a more stable solution. Scree plots were generated to determine the appropriate number of dimensions that should be used with each analysis and the main matrix used in NMDS was relative abundance.

Results and Discussion:

Whole Fish Assemblages: Pine Creek at Pine Lake Road showed significantly higher dominance values for downstream sites than upstream sites (Table 3). Differences were also seen in general fish assemblage structure between upstream and downstream reaches (Figure 3 and 7). These differences were based primarily on brook stickleback (*Culaea inconstans*), rainbow trout, and white sucker (*Catostomus commersoni*). Brook stickleback appeared to have higher abundance upstream with more suitable habitat. White sucker also had higher abundance upstream likely the result of upstream migration of juveniles. Rainbow trout were higher downstream where there was a larger abundance woody debris (personal observation) and larger sized substrate (DeMol 2007).

Possible reasons for the differences above and below the culvert based on qualitative observations include different habitat types, less fishing pressure up- vs. down-stream, and more LWD downstream. In addition, substrate was quantitatively measured and was significantly coarser downstream (A. Wright, personal communication, DeMol 2007). No significant differences were seen with total fish density or richness at this site.

Pine Creek at Steinberg Road showed no significant differences with respect to total fish density, dominance, diversity, and richness (CPUE, Table 3, Figures 4-7). However, study reaches were distinct with respect to the overall fish community (Figure

8). These differences were seen mainly with brown trout, mottled sculpin, and rainbow trout with higher abundance and CPUE downstream (Table 2). Qualitative differences suggested that there was more overhanging cover, while quantitative differences indicated significantly larger substrate downstream (A. Wright, personal communication, DeMol 2007). Grenouillet et al. (2004) showed that only stream width and gradient influenced local species richness and also that the relative importance of local habitat and biotic processes may depend on the position along the longitudinal gradient.

Other qualitative observations suggest that passage to upstream reaches at this location consisted of a constricted area with flow through non-even culverts. Depth of water within culverts was less than that directly downstream and upstream of the road crossing with considerable sediment buildup directly upstream with water backed up into a drainage ditch. Other differences could result from individual species requirements of substrate, habitat, water quality, food availability, and discharge. Directly downstream, larger substrate was evident, indicating passage of sediment further downstream from the road crossing. This indicates that poor quality substrate is not always evident below poorly constructed road stream crossings and increased water velocities are a likely cause of scouring directly downstream of the culverts.

The Sickle Creek site showed significantly greater density, diversity, and richness (CPUE) with downstream sites compared to upstream sites. Dominance was greater at the upstream locations, due to a higher relative abundance of mottled sculpin. Differences in general fish assemblage structure were also seen (Figure 9). Here, the two upstream reaches showed different fish assemblage structure compared to that of the downstream reaches. These differences were mostly attributed to increased abundance of burbot, Chinook and coho salmon (CPUE) downstream (Table 2). Burbot are not capable of swimming against high velocities, which would have been the only method for breaching the severely perched culvert at this location (Wootton 1998). The Chinook and coho salmon were primarily young individuals and were likely not capable of swimming against the highest velocities that were present in spring. Additionally, during base flow, the culvert was perched by a large enough gap (approximately 3-4 inches) that these species could likely not pass upstream. Sickle Creek also empties directly into the Big Manistee River, providing adequate passage for species migrating in and out for refuge purposes, while other species are continuously in the creek.

Bear Creek at Milks Road showed no differences up- vs. down-stream for density, dominance, diversity, richness (CPUE). Results of the NMDS analysis suggested that the upstream Milks Road reach and the two downstream reaches were different from the first downstream reach (MILKSDS, Figure 10). These differences could be attributed to specific taxa including brown trout, mottled sculpin, and rainbow trout abundance which were higher downstream (Table 2). This road crossing also was undersized, but not to the same extent as the other road crossings and in addition there was a significant eroding bank just upstream of the culvert that was stabilized in the summer of 2007. Consequently, these species were able to move upstream to reach potentially more suitable habitat and better water quality. Further downstream from the Milks Road site, streambank stabilization measures were occurring on two sites, SWAINDS1 and SWAINDS2, which may have influenced fish assemblage structure further upstream at the Milks Road stream crossing.

Fish assemblage measurements in response to poorly constructed road crossings can be affected by fine sediment deposition as many species are affected by this size of sediment. Lisle and Hilton (1991) showed that filling of fines affects pool habitat by reducing volume, particularly during drought conditions, and covers substrate. Stream velocity can be linked to bed mobility and sediment transport and thereby to spawning habitat through scour of spawning substrate. Furthermore, fine sediment in pools is transported first as flow increases and could infiltrate spawning habitat constructed immediately downstream and adjacent riffles.

My results indicate that 3 of the 4 restoration sites included in this analysis experienced significant sediment impacts upstream—likely a result of undersized and poorly aligned culverts. These included the two sites on Pine Creek (Pine Lake Road and Steinberg) and the site on Sickle Creek. In contrast, the site on Bear Creek (Milks Road) did not show dramatic differences above vs. below an undersized bridge. Ongoing analyses beyond the scope of this thesis project have documented the rapid redistribution of fine sediment downstream once the culverts were replaced. Given enough time, the return of a more natural flow regime should see an improvement both up and downstream of these culverts as the system continues to establish a new dynamic equilibrium between flow and sediment transport.

Taxa-specific Patterns:

Individual Species at Pine Lake Road, Pine Creek: Western blacknose dace, mottled sculpin, and rainbow trout had significantly higher density, CPUE, and relative proportions at the downstream sites than the upstream sites (Table 3, 4). Higher proportions of large woody debris, coarse substrate, more suitable water quality parameters, velocity, and food availability are likely the cause. Lisle and Hilton (1991) found that fine sediment deposition reduced fish pool habitat and obliterated substrate cover of certain fish species.

Brook stickleback, central mudminnow (*Umbra limi*), and white sucker were significantly higher in the upstream sites than the downstream sites in all measurements. Some possible factors include less competition for food, better species-specific water quality needs, lower velocities suitable for these species, and finer substrate. Creek Chub (*Semotilus atromaculatus*) relative proportions were significantly higher in the upstream sites but density and CPUE were not significant. Lower proportions of other species are possible contributing factors. Brook trout, brown trout, coho salmon, johnny darter (*Etheostoma nigrum*), longnose dace, and northern redbelly dace (*Phoxinus eos*) were not different in any of the measurements. Burbot, Chinook salmon, and northern brook lamprey (*Ichthyomyzon fossor*) were absent from this site possibly as a result of substrate, discharge, water quality, access to site, competition, and food availability.

Individual Species at Steinberg Road, Pine Creek: Western blacknose dace had significantly higher relative proportions upstream than downstream, although no significant differences were seen regarding density and CPUE (Table 3, 4). Western blacknose dace contributed a higher proportion of the upstream fish assemblage. Brown trout and rainbow trout density and relative proportion were significantly higher downstream, but CPUE was not. These species were better adapted for faster velocities and resided in conditions with larger amounts of substrate, woody debris, undercut banks, and possibly optimal food availability. McRae and Diana (2005) indicated that percent gravel substrate and percent emergent vegetation accounted for 62% of the variance in age-0 brown trout density in the Au Sable River, Michigan. Waters (1992) indicated that stream salmonid production is influenced by water quality. But controversially, Mann and Penczak (1986) suggested that the potential level of salmonid production predicted is not by a stream's water quality, ultimately showing that more salmonids inhabit streams of lower water quality.

Substrate is very important to survival of some species. Bjornn (1971) showed that reductions in salmonid fry were linearly related to the degree of cobble embeddedness. The greatest effect of excess sediment occurred in pools, where decreases in area and depth caused decreases in summer rearing capacity for juvenile salmonids. Slower velocities at the Steinberg Road site influenced sediment-holding capacity in pools above the culverts.

Brook stickleback, brook trout, burbot, central mudminnow, Chinook salmon, coho salmon, creek chub, johnny darter, mottled sculpin, northern redbelly dace, and white sucker had no significant differences among all measurements. Even though differences in brook trout were not significant in any of the measurements, other studies suggest that mean minimum water temperatures and mean daily water temperature fluctuation account for variances in density of age-0 brook trout (McRae and Diana 2005). Longnose dace and northern brook lamprey were absent at this site possibly as a result of discharge, habitat, substrate, physiological components, water quality, and food availability.

Individual Species at USFS 5575, Sickle Creek: Brook trout relative proportions were significantly higher at the upstream sites versus the downstream but density and CPUE were not (Table 3, 4). The latter two were not significant because brook trout were relatively scarce in this stream but relative proportions were high given very few other fish species at the upstream sites. Brown trout density was significantly higher in the downstream sections but CPUE and relative proportions were not. This species was more prevalent in the downstream sections most likely a result of not being able to move upstream during low water conditions and from patterned stocking by state agencies into the mainstream Manistee River. Waters (1999) showed that brook trout declined after sedimentation and then continued to decline while brown trout increased. Brown trout abundances at this location were relatively low, indicating low impacts to resident brook trout populations. Also, Fausch and White (1981) showed that brook trout tend to be more abundant in headwaters and brown trout more abundant downstream as a result of competition, consumption of smaller brook trout by larger brown trout, easy catchability of brook trout by angling, and physical stream changes.

Burbot and Chinook salmon density, CPUE, and relative proportions were all significantly higher in the downstream sections. Burbot were not able to move upstream above the perched culvert. They were located generally in undercut banks in the downstream reaches. Chinook salmon juveniles were not able to move upstream past the perched culvert, at least during base flow conditions. Coho salmon and johnny darter density and CPUE were significantly higher in the downstream sections while relative proportions of each were not. These species both could not move upstream past the perched culvert but could readily move in from the mainstream Big Manistee River possibly for refuge, food, and cooler water as Sickle Creek was always cooler than the mainstream. Beschta and Taylor (1988) suggested that stream temperature in many regions has increased as a result of land use practices, providing increased sunlight and warmer temperatures on coldwater species. Sickle Creek, however, has large quantities of surrounding riparian vegetation with full cover near the confluence. This refuge from warmer temperatures likely provides a thermal refuge for some fish.

Mottled sculpin relative proportions were significantly higher in the upstream sections but density and CPUE were not. It is unknown how long the culvert has been perched. Also the only time fish can pass the perched culvert in the upstream direction would be during high discharge intervals when water velocity would be quite high. Western blacknose dace, brook stickleback, central mudminnow, northern redbelly dace, and rainbow trout did not have any significant differences at this site. Most of these species were present in very small numbers. Longnose dace and white sucker were absent from this site, although periodic usage is possible from migrating fish from the mainstream river.

Individual Species at Milks Road, Bear Creek: Brook trout density was the only measurement at this site that was significantly higher in the upstream sections (Tables 3, 4). Brook trout predominantly reside in headwater areas of streams in the Midwest including this one (Wootton 1998). Optimal water quality, substrate, discharge, less competition with other species, and food availability help to explain this pattern. In similar fashion, Alexander and Hansen (1988) suggested that brook trout populations would increase after declining from an experimental addition of sand in Hunt Creek, Michigan. The results showed initially that the brook trout population declined to half of the pre-sand abundance. Age-0 brook trout had reached their apparent maximum productivity ten years after sand abatement measures were implemented (namely sediment traps), indicating other possible influences. Adult brook trout have nearly completely recovered. In contrast, Curry and MacNeil (2004) showed that groundwater inputs may alleviate sedimentation in spawning areas and increase survival and durability of salmonids. Zones where groundwater inputs are large may allow quite speciose food webs to exist (Stanford and Ward 1993).

Western blacknose dace, brook stickleback, brown trout, burbot, central mudminnow, Chinook salmon, coho salmon, creek chub, johnny darter, longnose dace, mottled sculpin, northern brook lamprey, northern redbelly dace, rainbow trout, and white sucker did not have significant differences. Culverts at this location were larger and fish passage was never a problem. Human disturbance is also greatest at this site in contrast to the other sites.

NMDS: Results from the multivariate analysis suggested that in some cases the fish assemblages separated differently above vs. below a restoration site, but in others there was no apparent separation. Both the USFS 5575 (Sickle Creek) and Pine Lake Road (Pine Creek, Figure 7) sites showed separation among the fish assemblages between upstream and downstream sites, while the Steinberg Road (Pine Creek, Figure 8) and Milks Road (Bear Creek) sites did not show the same separation between fish assemblages (Table 5). At the USFS 5575 (Figure 9) site, two major gradients captured most of the variance in the fish communities, the first two dimensions containing 35.2% and 37.0%, respectively, of the information in the analytical data set. Similarly, at the Pine Lake Road site, two major gradients captured most of the variance in the fish communities, 47.5% and 46.2%, respectively. At the Milks Road (Figure 10) site, the first two dimensions only captured 20.6% and 20.5%, respectively, while at the Steinberg Road had less than 1.0% of the variance captured by the first two dimensions. In each NMDS output, each higher dimension improved the model very little and, at most, a two-dimensional solution was recommended.

Perched culverts at both the USFS 5575 and Pine Lake Road sites were the likely explanation as to why the upstream and downstream fish assemblages separated differently on the NMDS plots. At the Steinberg Road and Milks Road sites, the culverts were not similarly perched, thus not changing the upstream to downstream fish assemblages at each site. However it is important to note that the degree to which the culverts were perched was much greater in Sickle Creek. At Pine Lake Road, dual culverts were not perched, but did experience significantly higher velocity vs. the natural stream channel.

Conclusion:

The restoration that has since occurred at these sites will likely have a dramatic effect on the fish assemblage given that we have documented some differences above and below the road stream crossings prior to restoration. Indeed, ongoing monitoring conducted by GVSU graduate students Kristofor Nault (personal communication) and Jason DeBoer (DeBoer 2008) has documented significant post-restoration effects.

Discontinuity caused by a perched culvert led to higher downstream species diversity, density and CPUE in a small tributary stream. Impacts of road-stream crossings in larger streams had multiple negative effects both up and downstream. Higher brown and rainbow trout downstream at Pine Lake and Steinberg Road (Pine Creek) indicated that negative impacts are not always felt downstream of sediment sources. Larger substrate, larger woody debris, deeper pools, water quality, food preference, and discharge may be involved. We believe that improperly designed culverts that are too small may lead to poor conveyance of floodwaters and decrease upstream habitat quality. As was done in this project, improvements to road-stream crossings and bank stabilization should be done in such a way as to maximize and restore natural stream structure and function mainly through a return to a more natural flow regime that accommodates floods and sediment transport.

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Tables:

Table 1. Mean water quality variables (+1 SD) for each respective reach sampled. Each reach was sampled twice each year, May/June and late July/August 2004 and 2005, except for Bear Creek, which had one sample period in 2004, and two in 2005. N.A. = not available.

River	Abbrev.	GPS Coordinates		Mean Temperature (0ºC)	Mean pH	Mean Dissolved Oxygen (mg/L)	Mean Specific Conductivity (mS/cm^2)	Mean Discharge (m^3/s)
		Start	End					
Pine	HUFF	N 44º 14' 43.4" W086º 03' 41.2"	Bridge	14.6 (0.53)	8.42 (0.02)	14.8 (4.19)	0.28 (0.01)	52.3 (23.0)
	STDS3	N 44º 13' 45.7" W086º 01' 49.9"	N 44º 13' 41.9" W086º 01' 43.7"	13.8 (0.40)	8.05 (0.29)	10.1 (1.31)	0.41 (0.15)	28.0 (4.68)
	STDS2	N 44º 13' 40.2" W086º 01' 40.3"	N 44º 13' 36.6" W086º 01' 40.3"	13.8 (0.40)	8.05 (0.29)	10.1 (1.31)	0.41 (0.15)	28.0 (4.68)
	STDS1	N 44º 13' 34.9" W086º 01' 36.1"	Bridge	13.8 (0.40)	8.05 (0.29)	10.1 (1.31)	0.41 (0.15)	28.0 (4.68)
	STUS1	Bridge	N 44º 13' 26.3" W086º 01' 23.0"	13.9 (1.26)	8.14 (0.16)	10.4 (0.47)	0.42 (0.16)	26.3 (15.2)
	STUS2	N 44º 13' 24.4" W086º 01' 20.3"	N 44º 13' 19.3" W086º 01' 23.5"	13.9 (1.26)	8.14 (0.16)	10.4 (0.47)	0.42 (0.16)	26.3 (15.2)
	USFS 8430	N.A.	N.A.	14.1 (0.84)	8.23 (0.22)	10.4 (0.50)	0.42 (0.16)	26.1 (15.1)
	PLDS3	N 44º 12' 34.5" W085º 59' 11.1"	N 44º 12' 36.1" W085º 59' 03.5"	14.5 (0.71)	8.13 (0.22)	11.2 (0.85)	0.42 (0.14)	23.0 (10.2)
	PLDS2	N 44º 12' 37.9" W085º 58' 00.8"	N 44º 12' 38.5" W085º 58' 53.3"	14.5 (0.71)	8.13 (0.22)	11.2 (0.85)	0.42 (0.14)	23.0 (10.2)
	PLDS1	N 44º 12' 37.6" W085º 58' 49.0"	Bridge	14.5 (0.71)	8.13 (0.22)	11.2 (0.85)	0.42 (0.14)	23.0 (10.2)
	PLUS1	Bridge	N 44º 12' 34.0" W085º 58' 35.9"	14.4 (0.73)	8.17 (0.19)	11.3 (0.63)	0.42 (0.14)	20.2 (11.0)
	PLUS2	N 44º 12' 34.9" W085º 58' 32.2"	N 44º 12' 33.8" W085º 58' 24.8"	14.4 (0.73)	8.17 (0.19)	11.3 (0.63)	0.42 (0.14)	20.2 (11.0)
Sickle	SIDS3	N 44º 17. 632' W086º 08.929'	N 44º 17. 678' W086º 08.957'	13.9 (0.51)	8.57 (0.09)	11.1 (0.39)	0.41 (0.16)	2.88 (0.72)
	SIDS2	N 44º 17' 41.7" W086º 09' 06.6"	N 44º 12' 38.5" W085º 58' 53.3"	13.9 (0.51)	8.57 (0.09)	11.1 (0.39)	0.41 (0.16)	2.88 (0.72)
	SIDS1	N 44º 17' 42.0" W086º 09' 13.5"	Bridge	13.9 (0.51)	8.57 (0.09)	11.1 (0.39)	0.41 (0.16)	2.88 (0.72)
	SIUS1	Bridge	N 44º 17' 47.6" W086º 09' 14.2"	13.7 (0.13)	8.60 (0.12)	11.2 (0.53)	0.42 (0.14)	2.07 (0.94)
	SIUS2	N 44º 17' 49.8" W086º 09' 16.9"	N 44º 17' 50.4" W086º 09' 20.0"	13.7 (0.13)	8.60 (0.12)	11.2 (0.39)	0.42 (0.14)	2.07 (0.94)
Bear	LOWER BEAR	N 44º 17' 22.4" W086º 03' 46.6"	N 44º 17' 27.6" W086º 04' 01.9"	16.2 (1.05)	8.56 (0.34)	11.3 (2.55)	0.29 (0.04)	144 (80.6)
	SPIRIT OF WOODS	N 44º 18' 42.0" W086º 02' 56.9"	Bridge	15.4 (0.59)	8.45 (0.13)	14.2 (6.58)	0.29 (0.04)	279 (203)
	JOHNSON	N.A.	N.A.	16.5 (1.09)	8.53 (0.17)	13.9 (6.90)	0.28 (0.02)	236 (146)
	SWAINDS2	N 44º 20' 56.6" W086º 03' 09.9"	N 44º 21' 03.0" W086º 03' 06.7"	18.5 (2.16)	8.68 (0.30)	15.6 (7.11)	0.31 (0.03)	271 (125)
	SWAINDS1	N 44º 21' 02.4" W086º 03' 09.8"	N 44º 21' 09.6" W086º 03' 06.0"	18.5 (2.16)	8.68 (0.30)	15.6 (7.11)	0.31 (0.03)	271 (125)
	MILKSDS	N.A.	N.A.	17.7 (1.60)	8.64 (0.25)	11.3 (1.44)	0.33 (0.02)	217 (63.0)
	MILKSUS	N.A.	N.A.	17.7 (1.60)	8.64 (0.25)	11.3 (1.44)	0.33 (0.02)	217 (63.0)

Table 2. Average abundance data for most influential species affecting site differences in NMDS. The three most influential species were selected and their average abundance per reach in each respective reach has been given.

		Reach and Average Number/Reach				
Site	Species	US2	US1	DS1	DS2	DS3
Pine Lake Road (Pine Creek)	Brook stickleback	4	7	0	0	0
	Rainbow trout	0	1	5	7	5
	White sucker	5	5	3	0	0

Steinberg Road (Pine Creek)	Brown trout	3	2	5	5	13
	Mottled sculpin	8	12	7	12	41
	Rainbow trout	3	4	5	8	11
USFS 5575 (Sickle Creek)	Burbot	0	0	15	12	8
	Chinook salmon	0	0	3	3	2
	Coho salmon	0	0	4	4	6
		US	DS	SWAINUS	SWAINDS	
Milks Road (Bear Creek)	Brown trout	11	8	7	6	
	Mottled sculpin	29	19	13	9	
	Rainbow trout	71	52	47	44	

Table 3. Mean density, CPUE, and relative abundance data for significant differences between upstream and downstream locations at respective sites. Standard deviations are in parentheses. Abbreviations are as follows: WBND = western blacknose dace, BRS = brook stickleback, BRT = brook trout, BNT = brown trout, BUT = burbot, CEM = central mudminnow, CHS = Chinook salmon, COH = coho salmon, CRC = creek chub, JOD = Johnny darter, MOS = mottled sculpin, RBT = rainbow trout, WHS = white sucker.

	Mean Relative Density (ha)			Mean CPUE			Mean Relative Abundance		
Species and Location	Upstream	Downstream	p-value	Upstream	Downstream	p-value	Upstream	Downstream	p-value
WBND (Pine Lake Rd.)	430 (60)	920 (200)	0.002	2.8 (0.64)	5.11 (0.73)	0.002	24.8 (2.0)	46.6 (3.18)	0.001
WBND (Steinberg Rd.)							60.0 (4.0)	48.5 (4.1)	0.05
BRS (Pine Lake Rd.)	55 (2.0)	3.0 (1.0)	0.001	0.38 (0.15)	0.013 (0.008)	0.001	3.17 (1.1)	0.09 (0.05)	0.001
BRT (Milks Rd.)	6.0 (4.0)	1.0 (0.05)	0.031						
BRT (USFS 5575)							3.19 (1.5)	0.18 (0.18)	0.035
BNT (USFS 5575)	5.0 (7.0)	37 (2.0)	0.046						
BNT (Steinberg Rd.)	30 (7.0)	80 (7.0)	0.049				3.56 (0.76)	7.45 (1.6)	0.05
BUT (USFS 5575)	0	45 (20)	0.01	0	0.84 (0.41)	0.01	0	13.6 (3.4)	0.002
CEM (Pine Lake Rd.)	260 (60)	62 (3.0)	0.001	1.58 (0.38)	0.37 (0.17)	0.001	13.8 (1.6)	3.06 (0.78)	0.001
CHS (USFS 5575)	0	103 (50)	0.013	0	0.19 (0.09)	0.001	0	4.15 (1.1)	0.004
COH (USFS 5575)	0	18.3 (10)	0.04	0	0.31 (0.06)	0.036			
CRC (Pine Lake Rd.)							16.9 (1.5)	12.2 (1.5)	0.033
JOD (USFS 5575)	0	70 (4.0)	0.02	0	0.153 (0.10)	0.049			
MOS (Pine Lake Rd.)	13 (1.0)	31 (10)	0.008	0.009 (0.01)	0.20 (0.10)	0.017	0.066 (0.06)	1.89 (0.68)	0.023
MOS (USFS 5575)							85.6 (4.0)	54.8 (5.7)	0.001
RBT (Pine Lake Rd.)	50 (4.0)	5.4 (2.0)	0.001	0.04 (0.03)	0.34 (0.12)	0.002	0.294 (0.16)	3.43 (1.1)	0.016
RBT (Steinberg Rd.)	38 (1.0)	80 (2.0)	0.031				4.91 (0.74)	7.66 (0.89)	0.028
WHS (Pine Lake Rd.)	50 (20)	10 (6.0)	0.001	0.31 (0.11)	0.060 (0.04)	0.002	2.65 (0.60)	0.429 (0.29)	0.001

Table 4. Summary of various taxa-specific and community level responses above and below restoration sites.

	Undersized culverts			Bridge/bank erosion
Observed response	Pine Lake Road (Pine Creek)	Steinberg Road (Pine Creek)	USFS 5575 (Pine Creek)	Milks Road (Bear Creek)
Higher upstream	Brook stickleback Central mudminnow White sucker	Western blacknose dace	Brook trout Mottled sculpin	Brook trout
Higher downstream	Western blacknose dace Mottled sculpin Rainbow trout	Rainbow trout Brook trout	Brown trout Burbot Chinook salmon Coho salmon Johnny darter	
Absent	Burbot Chinook salmon Northern brook lamprey	Longnose dace Northern brook lamprey		

Table 5. Set-up and results of NMDS analysis for each restoration site.

	Pine Lake Road (Pine Creek)	Steinberg Road (Pine Creek)	USFS 5575 (Sickle Creek)	Milks Road (Bear Creek)
Distance measure	Sorenson	Sorenson	Sorenson	Sorenson
Software used	PCORD	PCORD	PCORD	PCORD
Starting coordinates	Random	Random	Random	Random
Reduction in dimensionality	1	1	1	1
Step length	0.2	0.2	0.2	0.2
Random number of seeds	Use time	Use time	Use time	Use time
Run with real data	40	40	40	40
Runs with randomized data	50	50	50	50
Autopilot	Yes	Yes	Yes	Yes
Dimensionality	Scree plot	Scree plot	Scree plot	Scree plot
Number of axes	1	Not found	1	Not found
Maximum iterations	400	400	400	400
Final stress	0.15276	Not found	0.00001	Not found
Final iterations for best solution	49	Not found	31	Not found
Stability criterion	0.00001	0.00001	0.00001	0.00001
R-squared	0.937	0.001	0.722	0.416
Monte Carlo Test (p)				
Number of axes				
1	0.0196	0.549	0.0392	0.3922
2	0.3922	0.7451	0.4118	0.9804
3	0.8235	0.9412	0.9412	1
4	0.9608	0.9608	1	1
5	0.9608	0.9608	1	1
6	0.9804	0.9608	1	1

Figures:

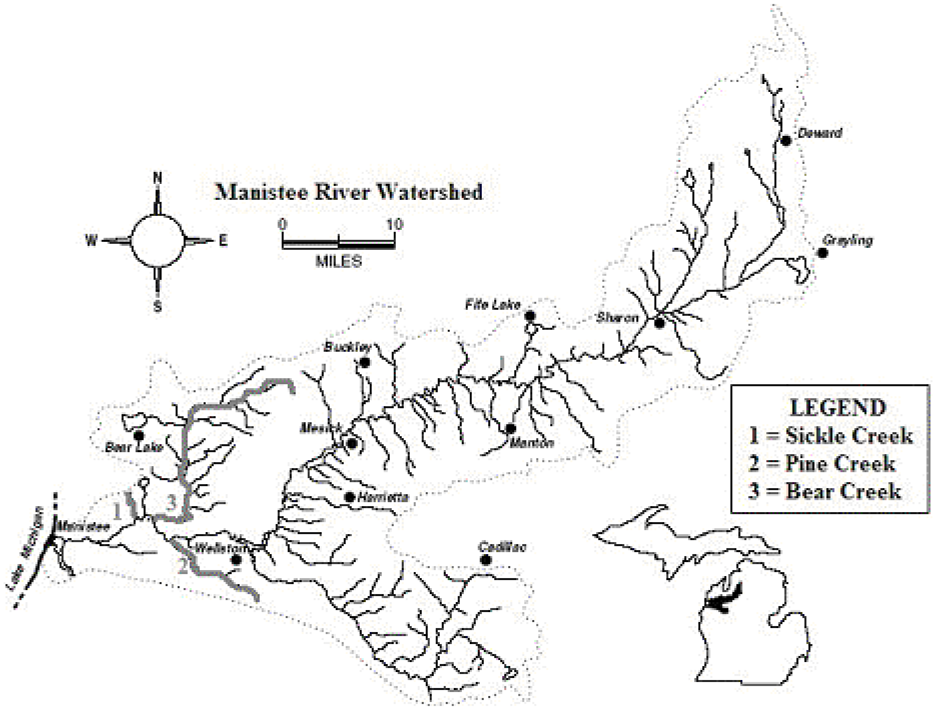

Figure 1. Sickle, Pine, and Bear Creeks within the Manistee River Watershed.

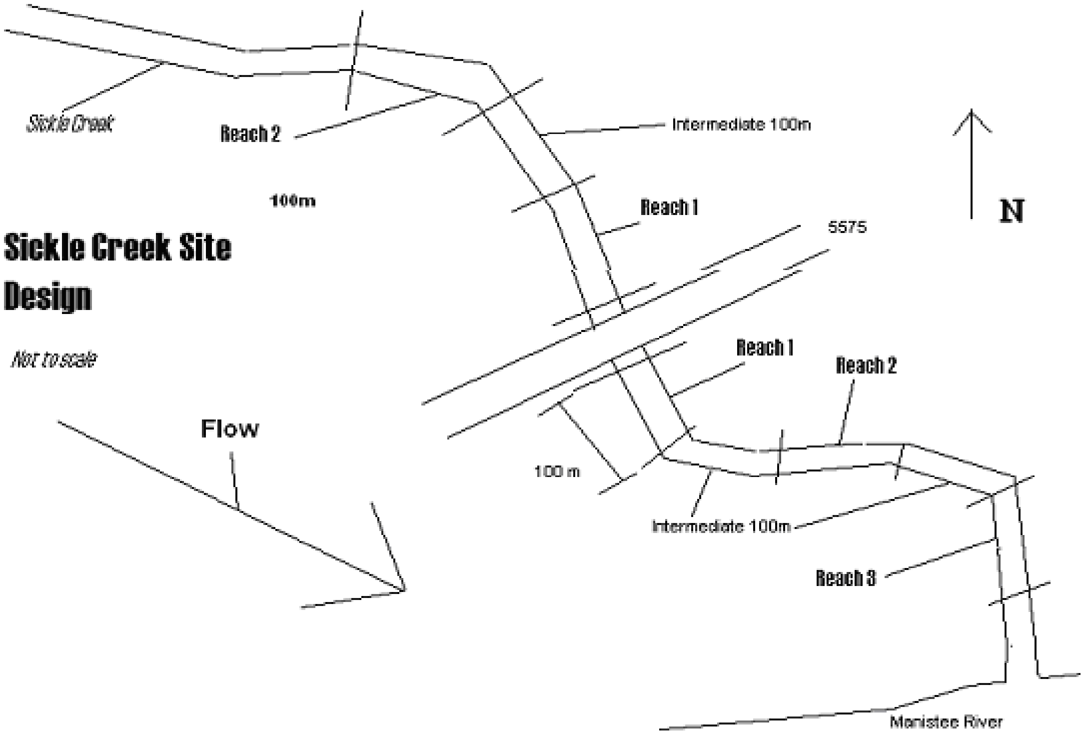

Figure 2. Sickle Creek site design.

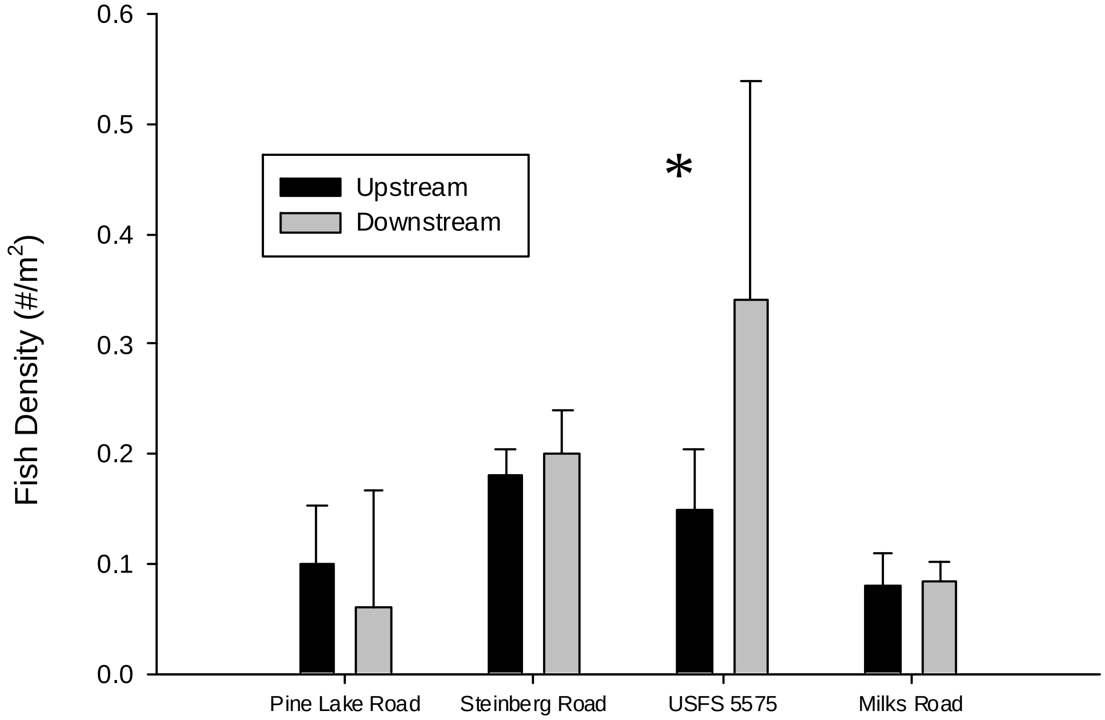

Figure 3. Total fish density above and below road stream crossings. Pine Lake and Steinberg Road = Pine Creek, USFS 5575 = Sickle Creek, Milks Road = Bear Creek. Standard error bars are also present. Sites are listed on the x-axis. Reach, season and year are pooled; Pine Lake = 8 & 12 (up/dn), Steinberg = 8 & 12 (up/dn), USFS = 8 & 12 (up/dn), & Milks = 3 & 9 (up/dn).

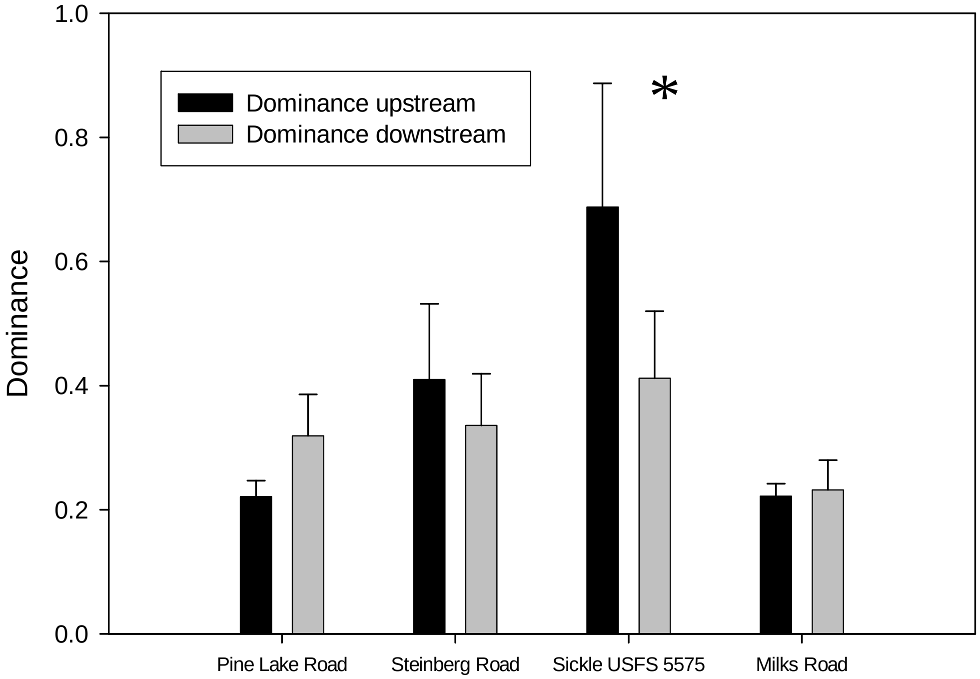

Figure 4. Fish species dominance (Simpson's Index) above and below road stream crossings. Standard error bars are also present. Sites are listed on the x-axis. Data pooled and sample size as in Fig. 3.

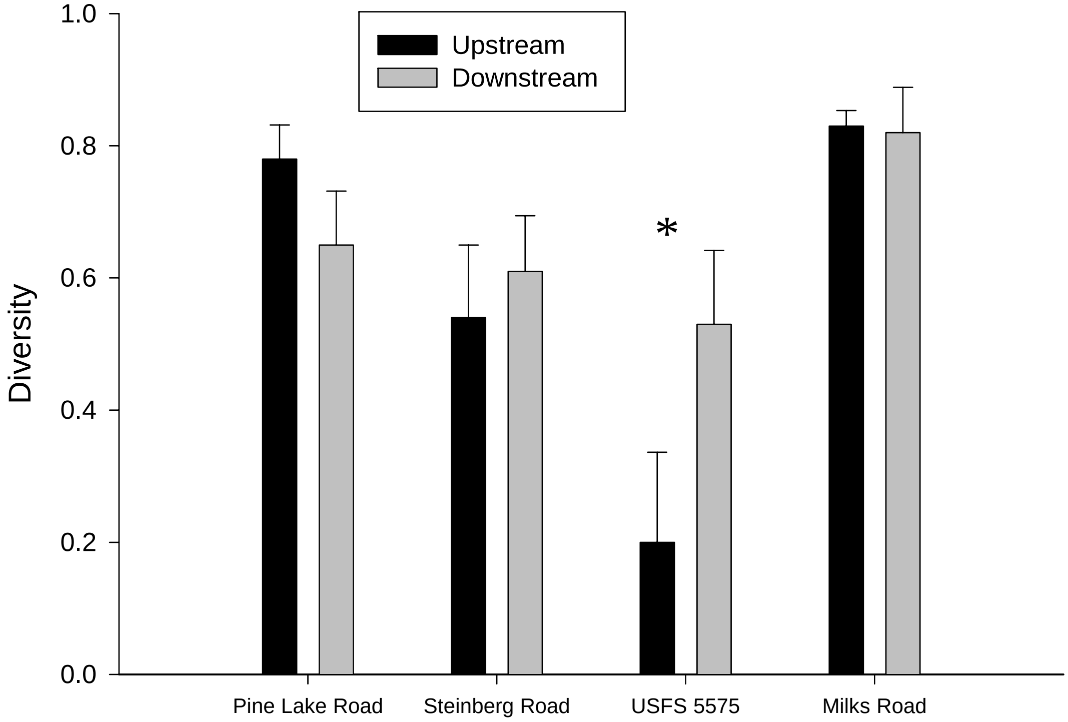

Figure 5. Species diversity (Shannon's Diversity) above and below road stream crossings. Standard error bars are also present. Sites are listed on the x-axis. Data pooled and sample size as in Fig. 3.

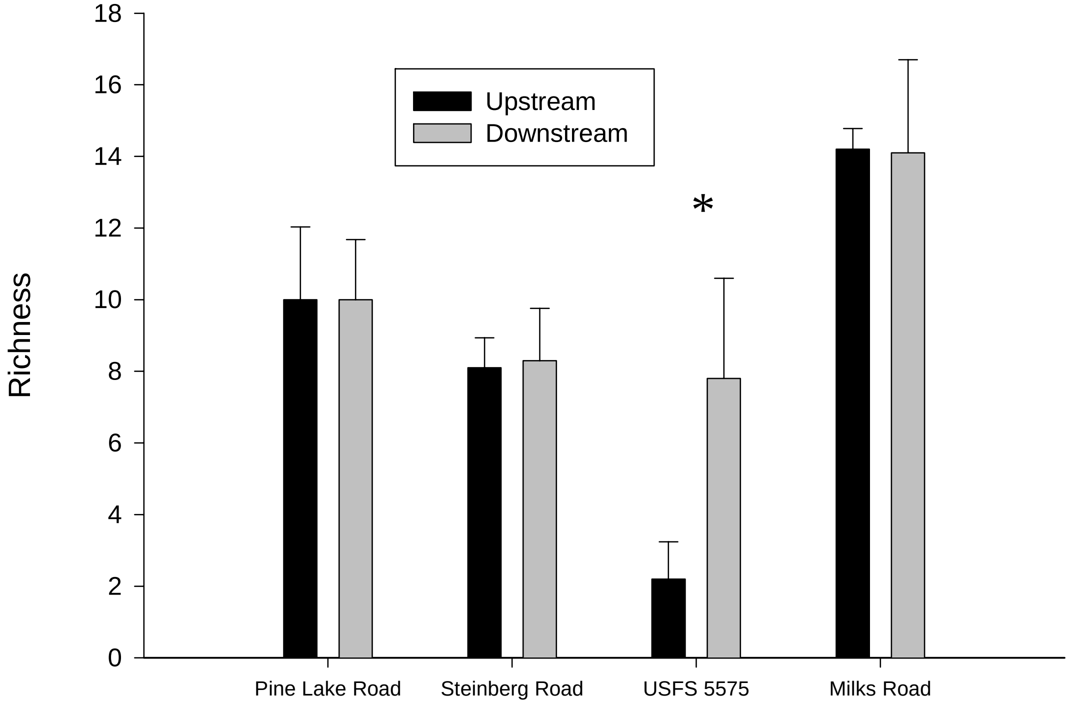

Figure 6. Species richness above and below road stream crossings. Standard error bars are also present. Sites are listed on the x-axis. Data pooled and sample size as in Fig. 3.

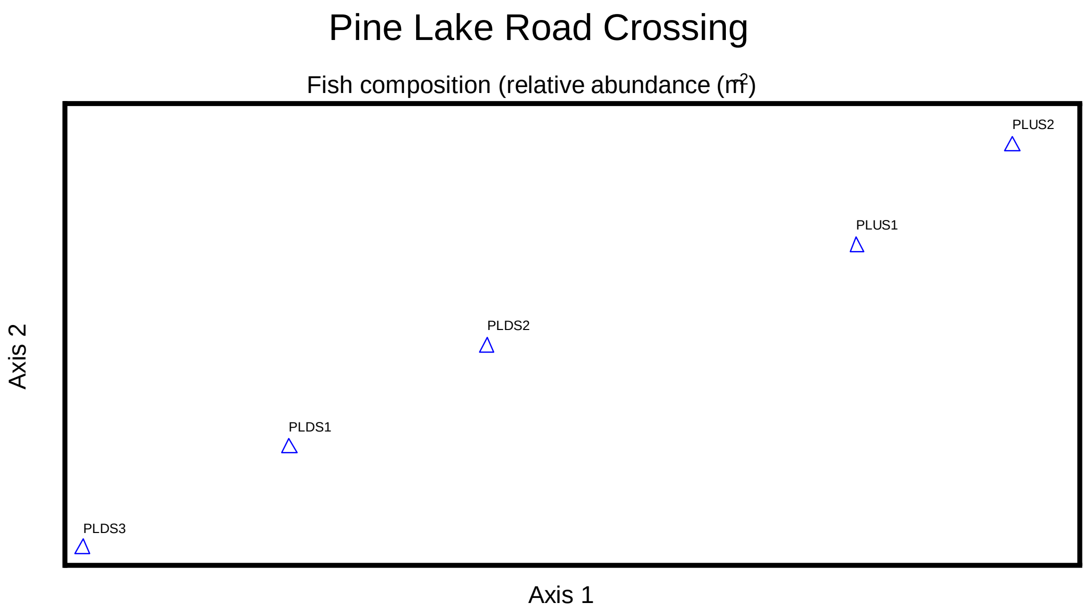

Figure 7. Fish assemblage differences among Pine Lake Road reaches, Pine Creek, based on NMDS analysis. Site abbreviations as in Table 1 and set-up and results in Table 5.

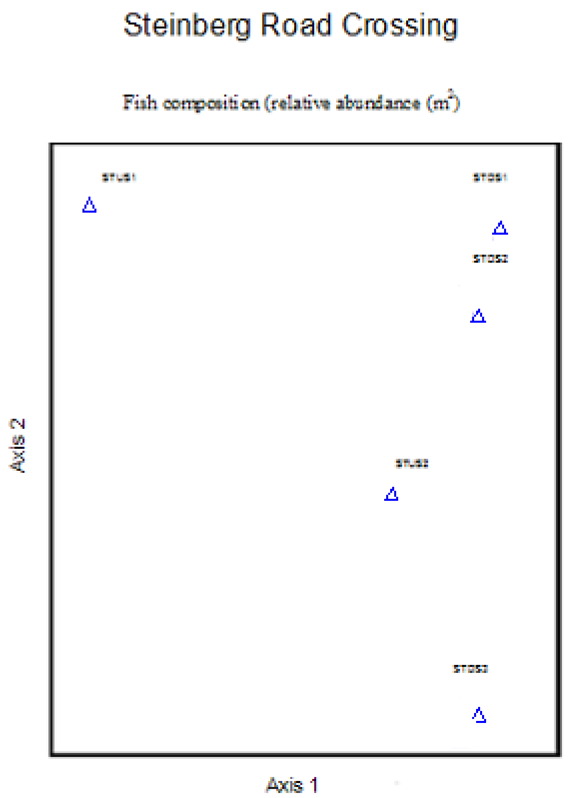

Figure 8. Fish assemblage differences among Steinberg Road reaches, Pine Creek. Site abbreviations as in Table 1 and set-up and results in Table 5.

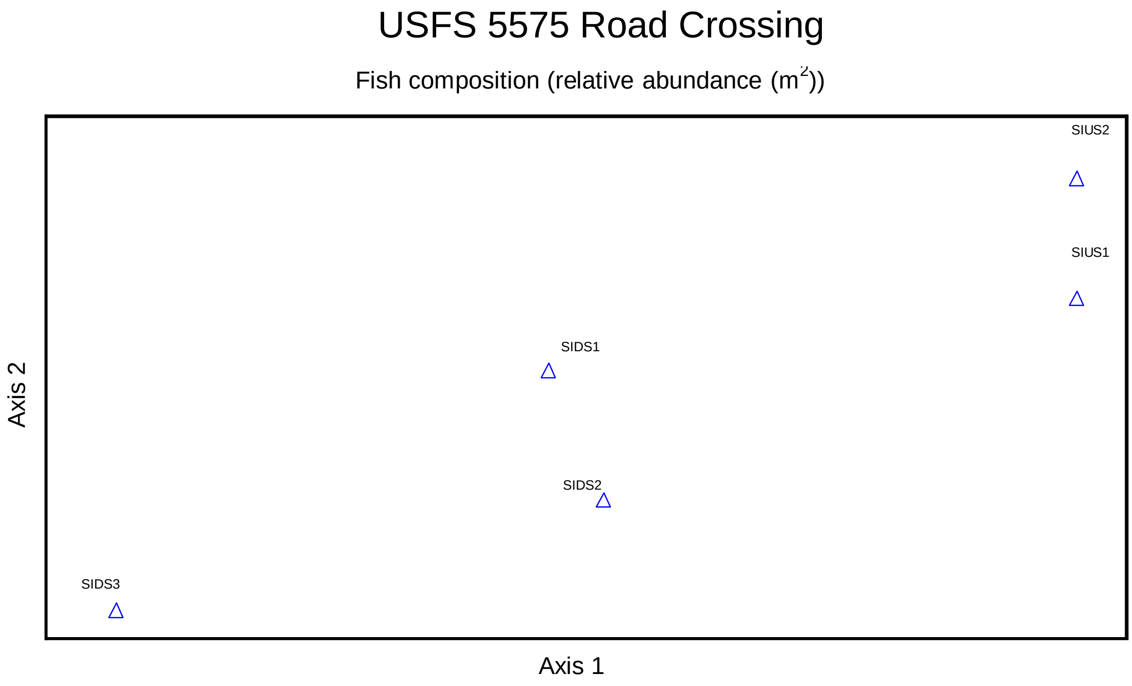

Figure 9. Fish assemblage differences at Sickle Creek (USFS road 5575). Site abbreviations as in Table 1 and set-up and results in Table 5.

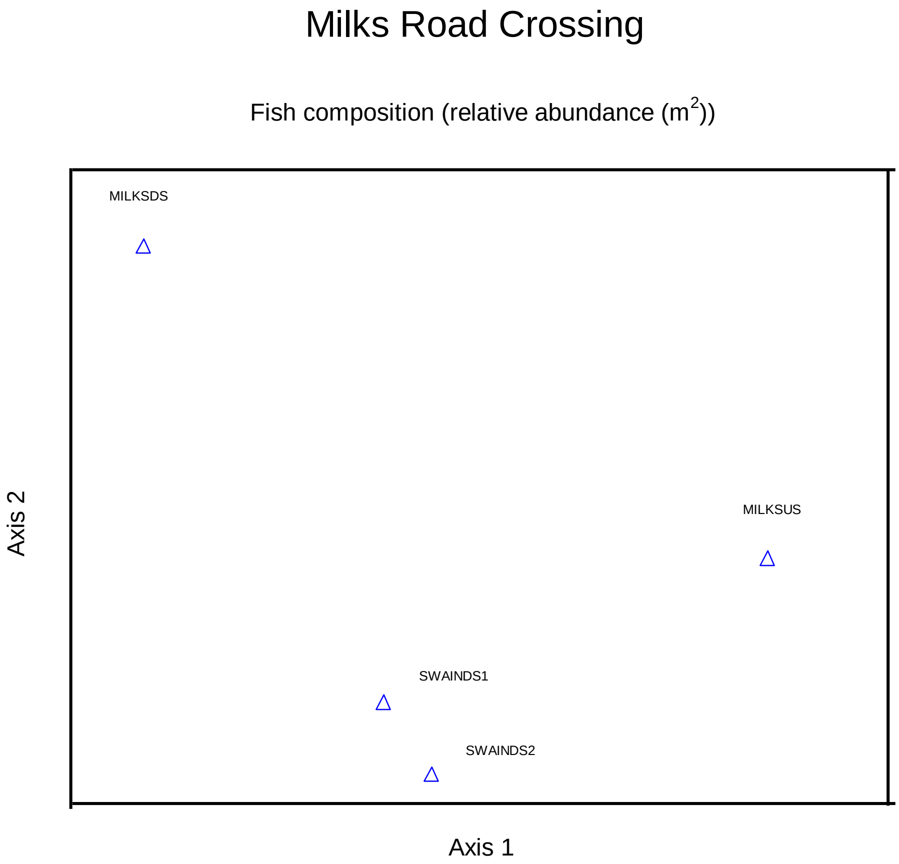

Figure 10. Fish assemblage differences among Milks Road reaches, Bear Creek. Site abbreviations as in Table 1 and set-up and results in Table 5.

CHAPTER 3

LONGITUDINAL FISH DISTRIBUTION IN THREE WEST MICHIGAN STREAMS OF DIFFERENT ORDERS

ABSTRACT

Few studies have examined fish longitudinal distribution in river systems impaired by high rates of sedimentation, or, for that matter, in the Great Lakes Region. The purpose of this study was to 1) provide a detailed description of the fish assemblage structure from headwaters to mouth on the three study streams, and 2) assess the differences between streams regarding fish assemblage structure. The study included three tributary streams (Sickle Creek, 1st order, Pine Creek, 2nd order, Bear Creek, 4th order) within the lower Manistee River watershed. A total of 24 electrofishing reaches comprised the longitudinal gradient analysis. Longitudinal analysis and non-metric multidimensional scaling showed unique assemblages between Sickle, Pine, and Bear Creeks. Sickle Creek was most uniquely different with occurrence of brook trout in headwater reaches and burbot in downstream reaches; a pattern attributed to the presence of a largely impassable perched culvert that separated up from downstream reaches. Pine Creek had northern redbelly dace throughout, whereas neither of the other two streams had this species present. This is likely due to the colder thermal regime of Pine Creek, an environmental attribute preferred by northern redbelly dace. Pine Creek was also characterized by an abundance of brown and rainbow trout in the most downstream location (Huff Road) again due to cold thermal regime and abundance of large woody debris. Bear Creek was characterized by burbot only in downstream sections, as well as longnose and western blacknose dace, and an increase in brook trout upstream. As such, Bear Creek conformed to the more expected patterns in longitudinal distribution. In conclusion, different order streams and patterns seemed to reflect the environmental habitat template, even when this template deviated from expected conditions.

Introduction:

Fish longitudinal distribution has been shown to be affected by biotic and abiotic factors. For example, Grenouillet et al. (2004) studied within basin distribution of local species richness in the Upper Saone River, France, and found that stream width and gradient significantly influenced local species richness (LSR). Schaefer and Kerfoot (2004) working in Illinois showed a correlation between distance from the mouth of the stream and assemblage variability over time, as well as a negative correlation between distance from the mouth of the stream and mean diversity over time. They hypothesized that the observed patterns in community variability and the distribution of some species within the drainage are best explained by the interactions between the fauna of big and small rivers. In their study, Grenouillet et al. (2004) showed that spatial factors also influenced the within-basin distribution of LSR and resulted in spatial autocorrelation, highlighting biotic processes in structuring stream fish assemblages. However, the study did not confirm other published predictions that headwater streams entering large rivers directly should have greater species richness. The spatial autocorrelation was only significant in larger rivers (from 4th- to 7th-order streams), suggesting that the relative importance of local habitat and biotic processes may depend on the position along the longitudinal gradient.

Some studies have examined correlations between stream order and fish assemblage measurements within the United States. Paller (1994) examined relationships between fish assemblage structure and stream order in South Carolina coastal plain streams. Average species richness adjusted to a constant stream surface area were 12.7, 17.5, 21.4, and 22.0 species in first- through fourth-order streams, respectively. Species addition and replacement led to large changes in species composition among stream orders. Relatively small fishes numerically dominated headwater streams. Relatively large fishes were most common in fourth-order streams. Headwater species richness was lower and longitudinal species replacement was greater than often observed in other geographic regions of the United States. A comparative assessment of long-term temperature and precipitation records suggested that high species richness at headwater sites was related to mild climate and lack of steep elevation gradients. The presence of numerous small headwater species created the potential for multiple species replacements as downstream increases in habitat volume permitted the establishment of larger fish with predatory and competitive advantages. Smith and Kraft (2005) showed that the proportion of fine substrate, canopy cover, in-stream vegetation, and water temperature were the four local habitat factors related to the abundance of fish species in the Beaverkill- Willowemoc watershed in New York. Confluence link and stream order were the stream network position measures with the greatest influence on fish assemblages. The results showed that stream fish assemblages in the study watershed were influenced by a combination of small-scale habitat variables and stream position within a watershed network.

Only a handful of studies have examined fish longitudinal distribution in river systems impaired by high rates of sedimentation, or, for that matter, in the Great Lakes Region (Seelbach and Wiley 1997, Zorn et al. 1998, Fausch et al. 2002). For example, Thomas (2002) examined fish and invertebrate communities and habitat of the fifth-order mainstem, two second-order adventitious tributaries to the mainstem, and three second-order headwater streams of the Pine River (Alcona County, Michigan) from May to August 2000. Fish species richness generally increased with increasing stream order and was higher in the adventitious streams than in the headwater streams. Little published research is evident in the Great Lakes regarding entire fish assemblages, their structure, their differences between stream order, and also the influence of barriers to fish migration. The purpose of this study was to: (1) provide a detailed description of the fish assemblage structure from headwaters to mouth on the two larger study streams, (2) to assess fish assemblage structure above and below a perched culvert, and (3) assess the differences in fish assemblage structure between streams.

Materials and Methods:

Fish Longitudinal Distribution: Fish assemblage relative abundance data were used to construct stacked area plots with respective sites in order from upstream to downstream in each season. Basic descriptive data trends were inferred using patterns visible from stacked area plots. Species catch/minute data were compared along the gradient using ANOVA ($\alpha < 0.5$).

Fish Assemblage and Longitudinal Analyses: Fish assemblage data were collected during spring and fall of 2004 and 2005 to determine fish longitudinal distribution between seasons and streams. Bear Creek data for spring 2004 was not collected because of high water and equipment problems. Fish assemblages were monitored along longitudinal gradients for all streams using temperature, pH, dissolved oxygen, specific conductivity, and discharge as indicators for the longitudinal fish distribution patterns. The statistical program, PCORD, and NMDS were used to evaluate the effects of these abiotic factors on fish distribution patterns, most importantly to depict which factors were affecting the fish assemblages the most with respect to the longitudinal distribution of sites in each respective stream (McCune and Grace 2002).

The first data matrix in NMDS was the fish assemblage data as relative abundance and the second data matrix included the water quality parameters (pH, dissolved oxygen (mg/L), specific conductivity (umhos/cm), temperature (^{0}C), and discharge (ft^3/s). Multiple regression analysis was used to determine significance of water quality variables to fish assemblages. Only whole fish community assemblage measurements were used: density, richness, dominance, and diversity.

Results and Discussion:

Longitudinal predictions:

Because of the predictable dynamic and shifting nature of lotic ecosystems from headwaters to mouth (Vannote et al. 1980), we can make some predictions of the expected fish community composition along this continuum. Many studies have documented the longitudinal shift in salmonids from headwaters to mouth and have explained these patterns based largely on temperature (Smith and Kraft 2005), wetted stream area (Grenouillet et al. 2004; Paller 2004), proximity to a larger receiving river (Grenouillet et al. 2004; Schaefer and Kerfoot 2004; Thomas 2002), and measures of discharge (Grenouillet et al. 2004). Based on this physical and chemical template, we predicted that the upper reaches of both Pine and Bear Creek would consist of more brook trout, while lower reaches would see a decline in brook trout and a relative increase in brown and rainbow trout. Similarly, we expected that the entire fish community diversity would be maximized in the mid-reaches of both Pine and Bear Creeks due to the overlap of taxa from up and down-stream fish communities, respectively.

<u>Sickle Creek</u>*:* Longitudinal sampling and subsequent analysis of Sickle Creek was very limited and constrained to essentially one reach. Ideally, a further reach upstream from the furthest upstream reach at this site would allow comparison along the continuum from

headwaters to mouth. However, the experimental design does allow for comparisons above and below an undersized, perched culvert.

Brook trout were only seen in upstream reaches (Figure 11). Reasons for this might include competition from other species, colder water temperatures, and the presence of a perched culvert that reduced brown trout introductions. Still only about 5% of the fish assemblage at this location consisted of brook trout. Brook trout are normally located within clear, cool, well-oxygenated creeks and small to medium rivers (Page and Burr 1991). Species found only in the downstream reaches included blacknose dace, bluntnose minnows (*Pimephales notatus*), burbot, and brown trout. Western blacknose dace are normally located within rocky runs and pools of headwater streams (Page and Burr 1991) while bluntnose minnows are normally located within clear, rocky streams. Many of these species may migrate in and out of this stream on a short time scale. Species that were fairly uniform throughout this stream were mottled sculpin, rainbow trout, and Chinook salmon. Mottled sculpin are normally found within the headwater reaches of streams (Page and Burr 1991). These species appeared to have good food resources and habitat. Mottled sculpin were most abundant throughout the stream. The patterns seen were very similar between seasons and years. However, Chinook and coho salmon were both located in the upstream reaches in 2004 but constrained to the downstream reaches in 2005. In 2004, increased discharge rates may have allowed for increased fish passage upstream. Species contributing most to differences above vs. below the perched culverts included brook trout, burbot, northern redbelly dace, western blacknose dace, longnose dace, and rainbow trout (Table 9).

Catch Per Unit Effort: No significant differences with fish catch per minute were seen in Sickle Creek longitudinally in any reaches measured (Table 6, Figure 14). Mottled sculpin were the most dominant species in all reaches sampled and did not change significantly from headwaters to mouth.

Pine Creek: Western blacknose dace steadily increased in relative abundance from upstream to downstream reaches and then decreased steadily from U.S Forest Service Road 8430 to Huff Road, thus peak densities occurred in the mid reaches of the stream (Figure 12). This species prefers upstream sections within streams (Wootton 1998). Other reasons for this distribution may include habitat, competition, and greater abundance of predatory fish (trout) in downstream reaches. Brook trout were low in relative abundance at all reaches, a fact that may be correlated with increased sedimentation and competition with brown trout. Northern redbelly dace were more abundant in upstream reaches versus lower reaches. These species prefer colder water and usually inhabit headwater reaches of streams (Page and Burr 1991). Brown trout were more abundant at lower reaches with a large portion of the fish community at Huff Road consisting of this species. Reasons include recent stocking, proximity to the mainstream Manistee River. Furthermore, brown trout can withstand a wider range of temperatures and can inhabit a wide range of habitats (Page and Burr 1991). Rainbow trout mimicked brown trout in this respect and also increased from lower abundance in headwater reaches to a quarter of the fish community at Huff Road. These patterns were fairly consistent between seasons and are consistent with other studies examining longitudinal distribution of trout and salmonid taxa (Page and Burr 1991; Thomas 2002; Smith and Kraft 2005). Species contributing most to differences along the river continuum included western blacknose dace, brown trout, northern redbelly dace, and rainbow trout (Table 9). Based on the higher relative abundance and CPUE of rainbow and brown trout at Huff Road we expected that the macroinvertebrate forage base would be higher at this site as well. However, De Mol (2007) found the inverse. Total macroinvertebrate abundance (m^2) was significantly lower at Huff Road vs. the two upstream sites at Steinberg and Forest Service road 8430, averaging approximately 220. Unpublished gut content data suggests that terrestrial insects and smaller forage fish contribute significantly to the energy budget of the larger rainbow and brown trout (Kevin Donner and Eric Snyder, personal communication).

Catch Per Unit Effort: Western blacknose dace showed significantly higher CPUE in upstream reaches versus downstream reaches, especially the Huff Road reach where they were absent (Table 7, Figure 15). Brown trout CPUE was very high at the Huff Road reach and thus predation may explain why western blacknose dace were absent at this site. Creek chub and central mudminnow were significantly higher in upstream reaches versus downstream reaches. Northern redbelly dace were significantly more common in the upstream reaches versus downstream reaches, especially Huff Road, where they were absent. Rainbow trout were significantly higher at the Huff Road reach versus all other reaches. High rainbow and brown trout at the Huff Road reach may have negatively affected creek chub, northern redbelly dace, and central mudminnow CPUE in the same manner. Future studies should be implemented to try and explain the increased abundance of brook and rainbow trout with an apparent lack of a forage base.

Our predictions of the longitudinal distribution of the fish community in Pine Creek were generally met: higher rainbow and brown trout populations in lower Pine Creek (Huff Road) vs. upstream sites, higher abundance of northern red belly dace and western blacknose dace upstream. Interestingly, we did not observe an increase in brook trout in the upstream reaches—a fact that may simply be related to the size of the stream (2^{nd} order), although this deserves future consideration and study.

Bear Creek: Brook trout were most abundant in upstream sections (Figure 13). Reasons could include colder water temperatures, and less competition from other species. Brook trout tend to inhabit headwater reaches of streams (Page and Burr 1991). Burbot were minimal at upstream sections and increased in lower Bear Creek, where they appeared to be located near undercut banks and sandy substrate. Most burbot were small in size, likely the result of recent spawning activity by adults. Adults spawn in clear, cool streams, while the adults reside in deep lakes (Page and Burr 1991). Most rainbow trout were present in upstream reaches versus downstream reaches, likely the result of colder stream temperatures. Western blacknose dace were more abundant in upstream sections, increasing steadily from mouth to headwaters. These species also require cooler water temperatures, but were also likely affected by predation. Species contributing most to differences along the river continuum include western blacknose dace, burbot, and longnose dace (Table 9). Fish assemblage composition was very similar between seasons.

Catch Per Unit Effort: Western blacknose dace were significantly higher in the Swain downstream reach versus the Lower Bear reach (Table 8, Figure 16). Western blacknose dace require larger substrate and cooler water temperatures, both of which are prevalent at the Swain reach versus the downstream sites. Burbot were significantly higher in downstream reaches, mainly the lower Bear Creek reach, compared to upper reaches and may be a result of more abundant undercut banks that would be preferred by this species and proximity to the Big Manistee River. All other species were not determined to be significantly different between reaches.

Our predictions of the longitudinal distribution of the fish community in Bear Creek were similarly met: higher rainbow and brook trout populations in upper reaches vs. downstream reaches, higher abundance of western blacknose dace increasing from Lower Bear upstream, as well as higher burbot populations at Lower Bear. Interestingly, even higher populations of brook trout were found further upstream at Leffew Road (Snyder et al. 2007), thus supporting our predictions of brook trout occupying headwater reaches of streams.

Fish assemblages and water chemistry:

<u>Sickle Creek</u>*:* Discharge was positively correlated to and significantly explained 22.3 and 25.6% of the variation in diversity and richness, respectively, in Sickle Creek (multiple regression analyses, Figures 17 & 20). Thirty-one percent of the variation in total fish density was explained by pH. Species dominance was not significantly correlated to any water quality variable. Discharge and pH were the only significant water quality variables related to total fish density, species diversity, and species richness in Sickle Creek and showed a positive correlation. Discharge can be a good predictor of what species are in a reach, selecting for and against good versus poor swimmers, respectively (Wootton

1998), and also affecting stream wetted channel area and therefore available habitat. Total fish density in Sickle Creek was explained to some extent by pH, which is generally not thought to be a good predictor of species presence/absence, at least at the circumneutral pH values recorded in this study. This correlation is likely ecologically meaningless. Species dominance was not found to be predicted by any water quality variable.

Pine Creek: In Pine Creek, discharge explained 11% of the variation in species diversity and15.7% of richness and may be affected similarly as mentioned for Sickle Creek (Figures 18 & 21). Species dominance and total fish density were not explained by any water quality variable measured and are likely the result of variability between sampling reaches, seasons, and interaction with biotic factors versus abiotic.

Bear Creek: In Bear Creek, temperature accounted for 23.5% of the variation in species diversity and 10.9% of dominance (Figures 19 & 22). Temperature is usually a good predictor as many species have thresholds and optimal temperatures. Brazner et al. (2005) showed that although a variety of regional, fragmentation, and storage-related factors had significant influences on the fish assemblages; water temperature appeared to be the single most important environmental factor in western Lake Superior 2nd and 3rd order tributaries. Total fish density was most strongly correlated to dissolved oxygen (24.6%) with higher dissolved oxygen levels indicative of better water quality in middle and upstream reaches, allowing for the presence of a wider range of fish species within a reach.

Bear Creek species richness was not explained by any of the water quality variables measured. Bear Creek had the highest species richness of the three sample streams and the distribution was not necessarily uniform from headwaters to mouth. Some reaches, specifically the Johnson Road reach, had the highest species richness, despite the middle position of this reach in the longitudinal continuum. Bear Creek was the largest of the streams measured had the highest species richness, and was considered to have the most stable discharge. Similarly, Taylor et al. (2006) showed the most stable assemblages were the most species-rich and occurred in relatively large, stable environments.

Conclusion:

Longitudinal analysis showed unique assemblages between Sickle, Pine, and Bear Creeks and through NMDS, Sickle Creek was most uniquely different with placement of brook trout and burbot, while Pine Creek had northern redbelly dace throughout. Pine Creek was also unique in the high abundance of brown and rainbow trout in the most downstream location (Huff Road), while Bear Creek was characterized by burbot only in downstream sections. Bear Creek also had longnose and western blacknose dace as unique contributors. In conclusion, the site-specific habitat template of each stream strongly dictated the fish species composition. For example, lower Bear Creek had much high concentrations of fine sediment and lower gradient – these two variables coupled with proximity to the Big Manistee River may have accounted for the high abundance of burbot found at this site. The habitat of lower Pine Creek consisted of relatively higher gradient and cooler water temperatures on account of the stream traversing a lateral glacial moraine. These two factors coupled with the large abundance of large woody debris likely explain the high density of brown and rainbow trout. Further studies are underway to identify this relationship. Similarly, upstream Pine Creek was located at the outflow from a large and extensive marsh and therefore fine sediments were dominant and water temperatures were relatively warm.

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Tables:

Table 6. Analysis of variance results for various species CPUE for longitudinal distribution in Sickle Creek. Statistical analysis included repeated measures ANOVA. See table 1 for full names of location abbreviations.

Species	Locations compared and mean CPUE	p-value
Coho salmon	SIUS2 (0), SIDS3 (0.575)	0.078
	SIUS1 (0), SIDS3 (0.575)	0.078

Table 7. Analysis of variance results for various species CPUE for longitudinal distribution in Pine Creek. Statistical analysis included repeated measures ANOVA. See Table 1 for full names of location abbreviations.

Species	Locations and mean CPUE	p-value	Species	Locations and mean CPUE	p-value
W. blacknose dace	PLUS1 (2.67), PLDS1 (6.09)	0.070	Creek chub	PLDS3 (1.57), STDS3 (0.16)	0.011
	PLDS1 (6.09), Huff Road (0)	0.000		PLDS3 (1.57), Huff Road (0.01)	0.003
	PLDS2 (3.87), Huff Road (0)	0.023	Central mudminnow	PLUS2 (1.42), PLDS3 (0.32)	0.008
	PLDS3 (5.38), Huff Road (0)	0.000		PLUS2 (1.42), USFS 8430 (0.03)	0.033
	USFS 8430 (4.46), Huff Road (0)	0.005		PLUS2 (1.42), STDS1 (0.32)	0.002
	STUS1 (3.38), Huff Road (0)	0.075		PLUS2 (1.42), STDS3 (0.04)	0.033
	STDS1 (3.49), Huff Road (0)	0.058		PLUS2 (1.42), Huff Road (0.03)	0.003
Brown trout	PLUS2 (0.05), Huff Road (3.11)	0.000		PLUS1 (1.72), PLDS1 (0.63)	0.002
	PLUS1 (0). Huff Road (3.11)	0.000		PLUS1 (1.72), PLDS2 (0.16)	0.038
	PLDS1 (0.03), Huff Road (3.11)	0.000		PLUS1 (1.72), PLDS3 (0.32)	0.000
	PLDS2 (0.01), Huff Road (3.11)	0.000		PLUS1 (1.72), USFS 8430 (0.03)	0.002
	PLDS3 (0.02), Huff Road (3.11)	0.000		PLUS1 (1.72), STUS2 (0.46)	0.000
	USFS 8430 (0.42), Huff Road (3.11)	0.000		PLUS1 (1.72), STUS1 (0.40)	0.005
	STUS2 (0.21), Huff Road (3.11)	0.000		PLUS1 (1.72), STDS1 (0.32)	0.002
	STUS1 (0.16), Huff Road (3.11)	0.000		PLUS 1 (1.72), STDS2 (0.39)	0.004
	STDS1 (0.34), Huff Road (3.11)	0.000		PLUS1 (1.72), STDS3 (0.04)	0.000
	STDS2 (0.35), Huff Road (3.11)	0.000		PLUS1 (1.72), Huff Road (0.03)	0.000
	STDS3 (0.73), Huff Road (3.11)	0.000	N. redbelly dace	PLUS2 (3.78), STUS2 (0)	0.042
Creek chub	PLUS2 (2.03), PLDS2 (1.01)	0.008		PLUS2 (3.78), STDS2 (0)	0.042
	PLUS2 (2.03), PLDS3 (1.56)	0.033		PLUS2 (3.78), STDS3 (0.02)	0.043
	PLUS2 (2.03), USFS 8430 (0.43)	0.002		PLUS2 (3.78), Huff Road (0)	0.042
	PLUS2 (2.03), STDS1 (0.22)	0.033		PLDS1 (5.90), PLDS3 (1.71)	0.016
	PLUS2 (2.03), STDS3 (0.16)	0.003		PLDS1 (5.90), USFS 8430 (0.27)	0.000
	PLUS2 (2.03), Huff Road (0.01)	0.002		PLDS1 (5.90), STUS2 (0)	0.000
	PLUS1 (1.52), STUS2 (0.21)	0.023		PLDS1 (5.90), STUS1 (0.13)	0.000
	PLUS1 (1.52), STUS1 (0.07)	0.008		PLDS1 (5.90), STDS1 (0.10)	0.000
	PLUS1 (1.52), STDS1 (0.22)	0.024		PLDS1 (5.90), STDS2 (0)	0.000
	PLUS1 (1.52), STDS2 (0.20)	0.022		PLDS1 (5.90), STDS3 (0.02)	0.000
	PLUS1 (1.52), STDS3 (0.16)	0.016		PLDS1 (5.90), Huff Road (0)	0.000
	PLUS1 (1.52), Huff Road (0.01)	0.005	Rainbow trout	PLUS2 (0), Huff Road (1.87)	0.000
	PLDS1 (1.68), USFS 8430 (0.43)	0.033		PLUS1 (0.07), Huff Road (1.87)	0.000
	PLDS1 (1.68), STUS2 (0.21)	0.006		PLDS1 (0.30), Huff Road (1.87)	0.002
	PLDS1 (1.68), STUS1 (0.07)	0.002		PLDS2 (0.43), Huff Road (1.87)	0.005
	PLDS1 (1.68), STDS1 (0.22)	0.006		PLDS3 (0.29), Huff Road (1.87)	0.002
	PLDS1 (1.68), STDS2 (0.20)	0.006		USFS 8430 (0.45), Huff Road (1.87)	0.006
	PLDS1 (1.68), STDS3 (0.16)	0.004		STUS2 (0.24), Huff Road (1.87)	0.001
	PLDS1 (1.68), Huff Road (0.01)	0.004		STUS1 (0.31), Huff Road (1.87)	0.002
	PLDS3 (1.57), STUS2 (0.21)	0.016		STDS1 (0.40), Huff Road (1.87)	0.004
	PLDS3 (1.57), STUS1 (0.07)	0.005		STDS2 (0.63), Huff Road (1.87)	0.027
	PLDS3 (1.57), STDS1 (0.22)	0.017		STDS3 (0.67), Huff Road (1.87)	0.036
	PLDS3 (1.57), STDS2 (0.20)	0.015			
	PLDS3 (1.57), STDS3 (0.16)	0.011			

Table 8. Analysis of variance results for various species CPUE for longitudinal distribution in Bear Creek. Statistical analysis included repeated measures ANOVA.

Species	Locations and mean CPUE	p-value
W. blacknose dace	SWAINDS (2.58), LOWER BEAR (0.08)	0.084
Burbot	MILKSUS (0.11), LOWER BEAR (1.83)	0.002
	MILKSDS (0.12), LOWER BEAR (1.83)	0.002
	SWAINDS (0.13), LOWER BEAR (1.83)	0.002
	SWAINDS2 (0.04), LOWER BEAR (1.83)	0.001
	JOHNSON (0.02), LOWER BEAR (1.83)	0.001
	SPIRITOFWOODS (0.29), LOWER BEAR (1.83)	0.006

Table 9. Fish species that differed significantly (ANOVA) between upper, mid, and lower reaches for Sickle, Pine, and Bear Creeks. Common species are also listed that indicate species that are fairly consistent along the longitudinal continuum.

	Sickle Creek (1st)	Pine Creek (2nd)	Bear Creek (4th)	Common Species
Upper	Brook trout	Northern redbelly dace Western blacknose dace	Western blacknose dace	Mottled sculpin Central mudminnow Chinook salmon Coho salmon
Middle		Northern redbelly dace Western blacknose dace	Longnose dace Western blacknose dace	Mottled sculpin Central mudminnow Chinook salmon Coho salmon
Lower	Burbot	Brown trout Rainbow trout	Burbot	Mottled sculpin Central mudminnow Chinook salmon Coho salmon

Figures:

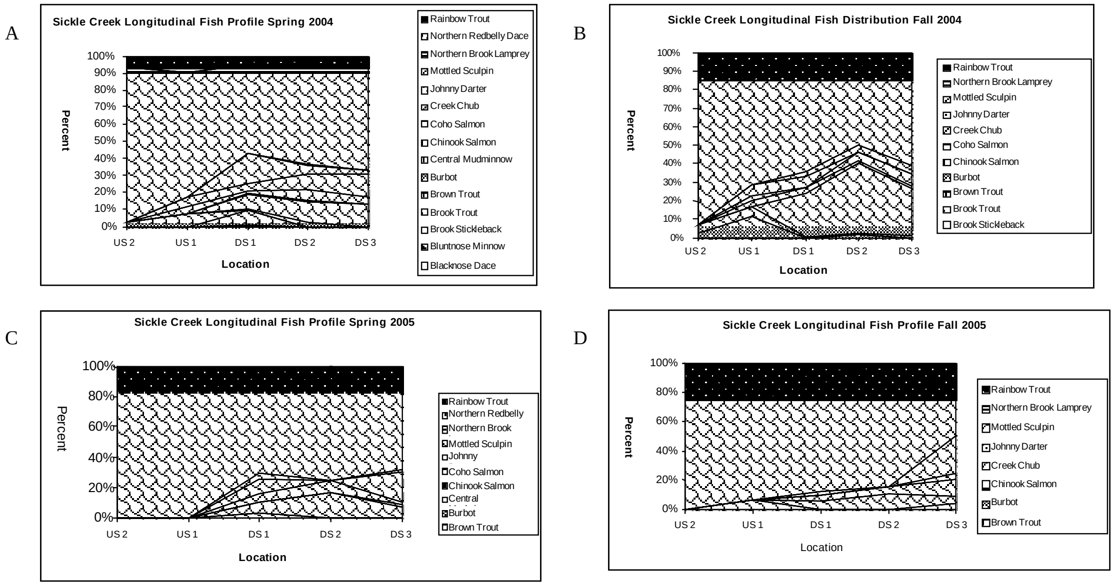


Figure 11. Sickle Creek longitudinal profile for Spring 2004 (A), Fall 2004 (B), Spring 2005 (C), and Fall 2005 (D). In Spring 2004, burbot and coho salmon increase from zero abundance above vs. below the perched culverts. Mottled sculpin were fairly consistent throughout and were the most dominant species in the entire stream. In Fall 2004, the same trends are seen with burbot increasing from up to down stream with brook trout only in upper reaches. In Spring 2005, mottled sculpin were the most dominant species throughout. Also, rainbow trout were highest above the culverts, while burbot, chinook salmon, and coho salmon were only found in downstream reaches. In Fall 2005, Mottled sculpin were the most dominant species throughout, while burbot and chinook salmon were only found in lower reaches. US = upstream, DS = downstream, culvert was located between US 1 and DS 1. The order of the legends matches the sequence of fish from top to bottom in the figure.

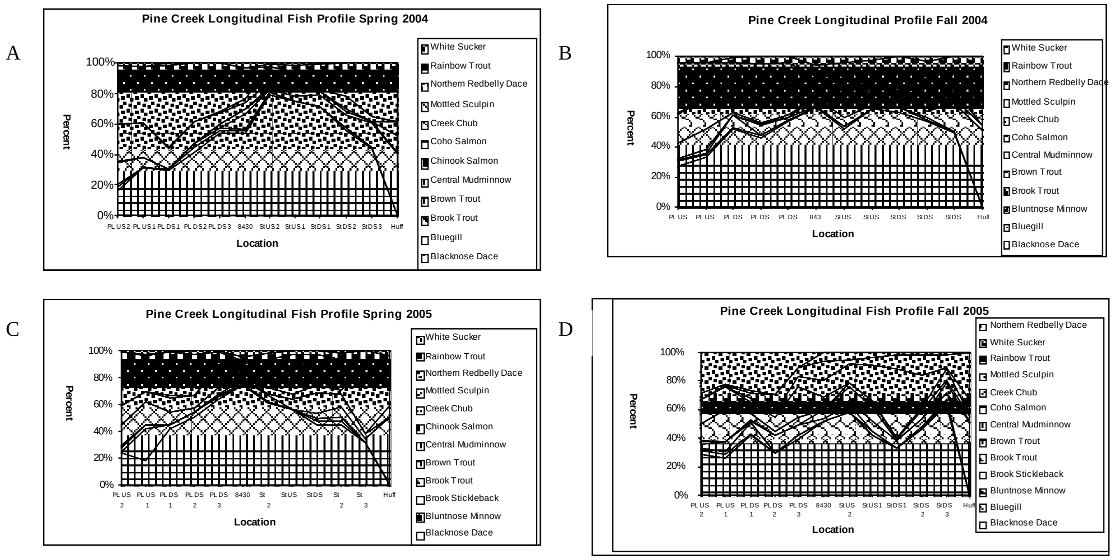


Figure 12. Pine Creek longitudinal profile for Spring 2004 (A), Fall 2004 (B), Spring 2005 (C), and Fall 2005 (D). In Spring 2004, brown and rainbow trout decreased in upper reaches but were dominant at Huff Road, the furthest reach downstream. Also, western blacknose dace were most dominant in mid-reaches and decreased in either direction, while northern redbelly dace were most abundant in headwater reaches. In Fall 2004, brown and rainbow trout increased from headwater reaches to downstream reaches. Western blacknose dace were most dominant at mid-reaches, while northern redbelly dace were most dominant in headwater reaches. In Spring 2005, chinook salmon abundance was higher in headwater reaches while creek chub were in low abundance in the lower reaches. Brown and rainbow trout were the most dominant at the Huff Road reach. In Fall 2005, northern redbelly dace were only located in the headwater reaches, while most brown and rainbow trout were located in downstream reaches. Western blacknose dace were dominant in most reaches, except for Huff Road.

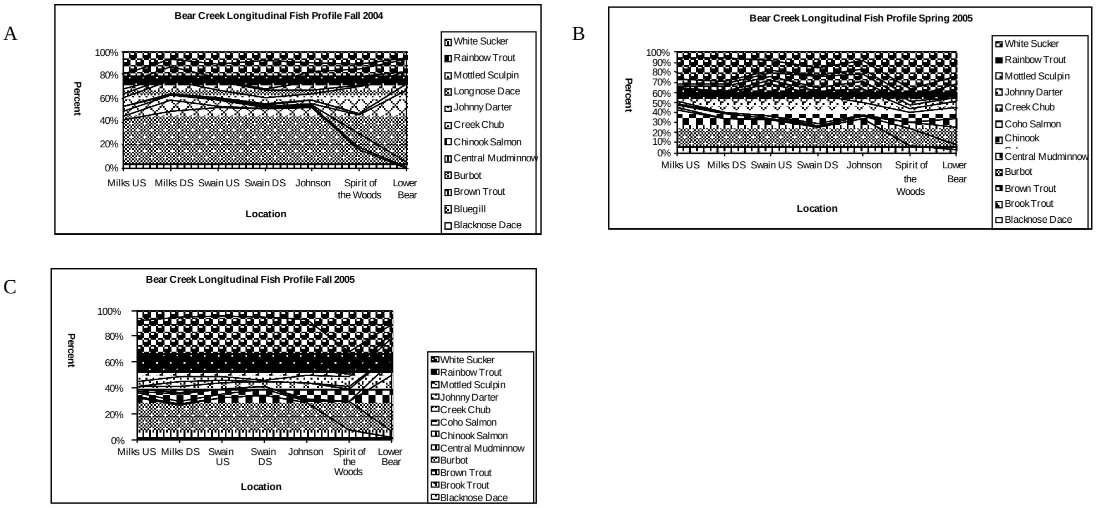


Figure 13. Bear Creek longitudinal profile for Fall 2004 (A), Spring 2005 (B), and Fall 2005 (C). In Fall 2004, western blacknose dace increased in abundance from lower to upper reaches, while burbot were mainly located in lower reaches. Most other species were fairly consistent throughout the stream. In Spring 2005, western blacknose dace were in highest abundance in headwater reaches, while burbot were located only in downstream reaches. White sucker were in highest abundance in lower reaches. In Fall 2005, western blacknose dace and mottled sculpin were highest in upper reaches, while burbot and white sucker were highest at lower reaches.

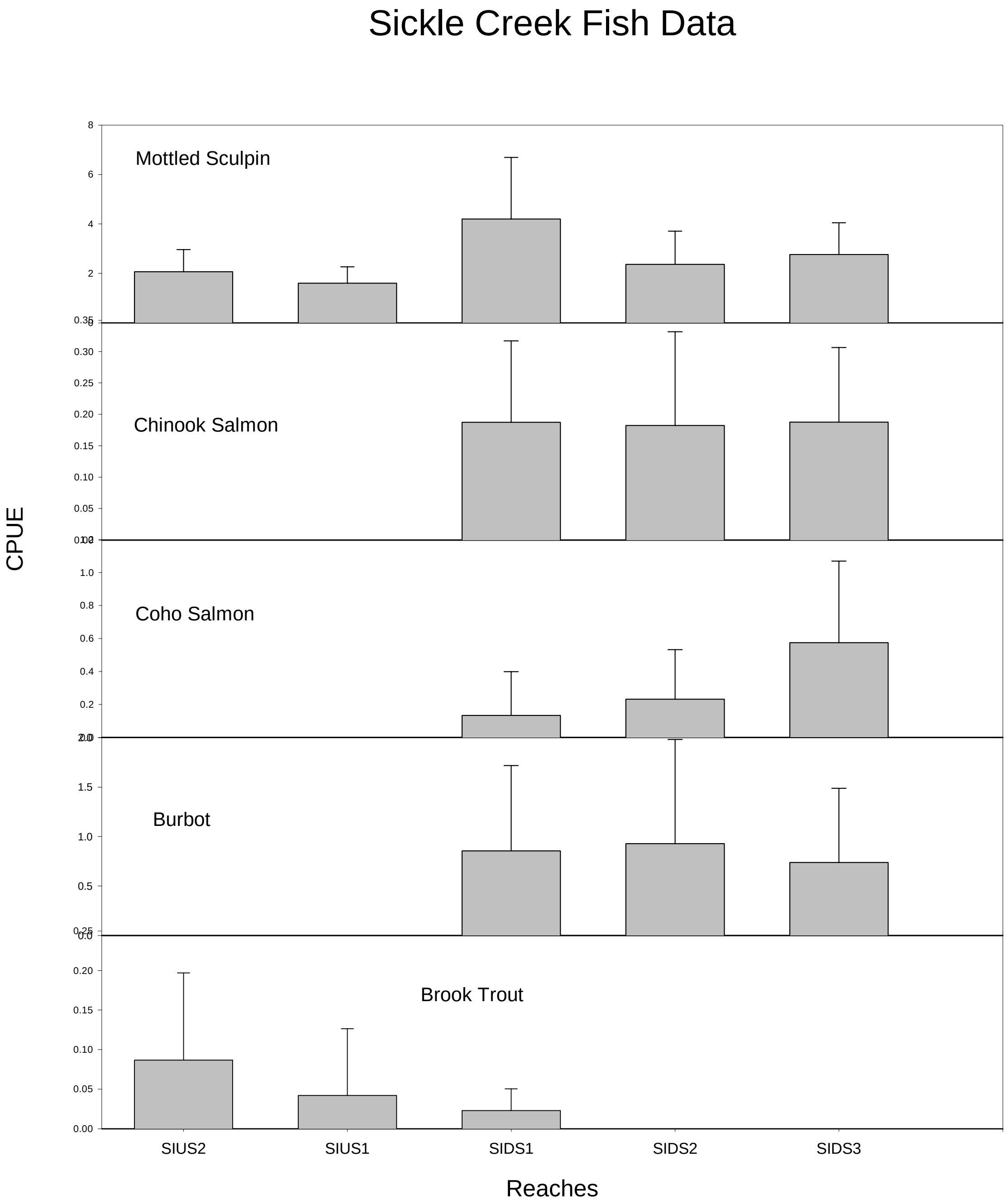


Figure 14. CPUE (fish/minute) data for various fish species in Sickle Creek. Reach abbreviations as in Table 1.

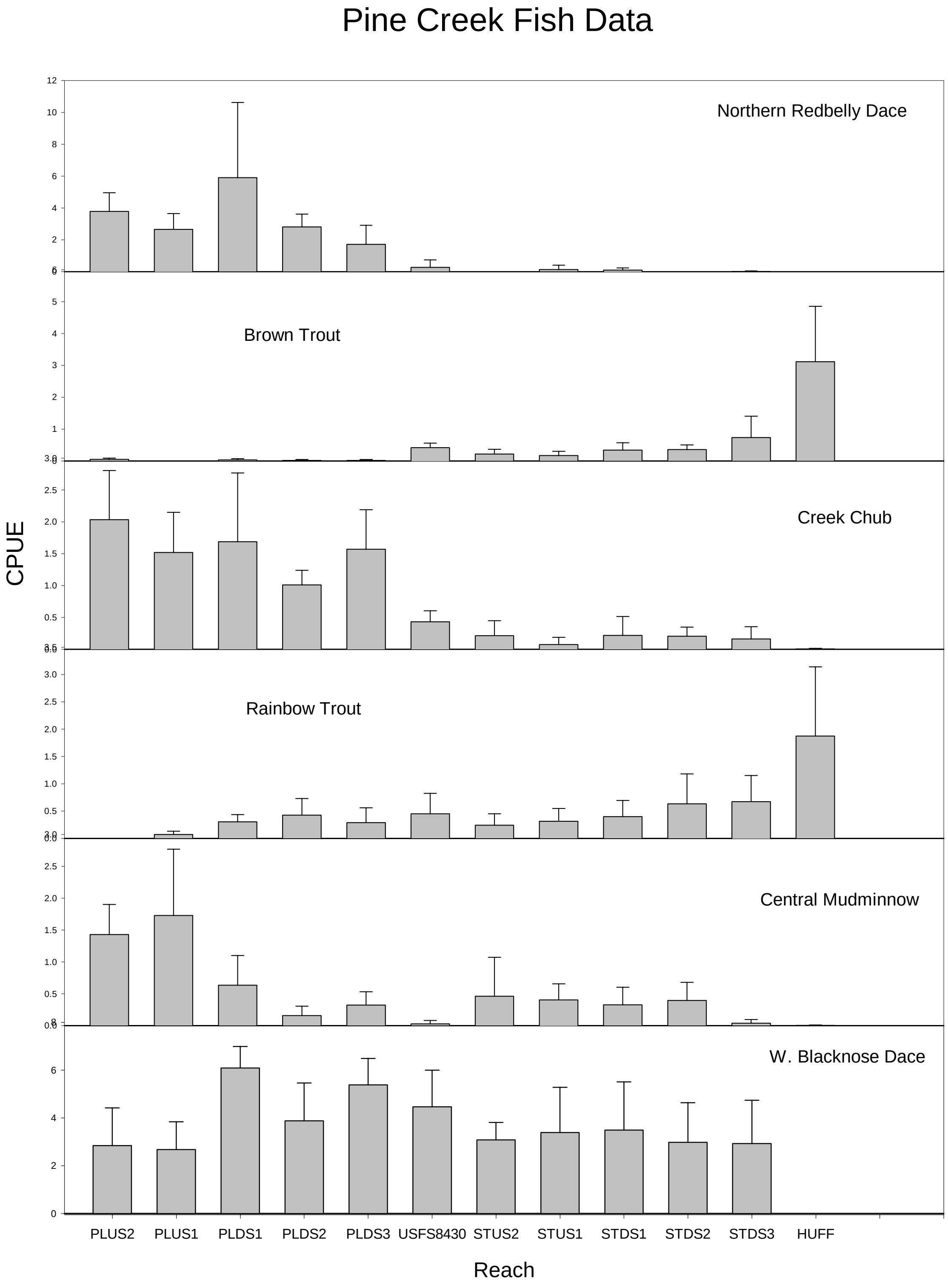


Figure 15. CPUE (fish/minute) data for various species in Pine Creek. Reach labels as in Table 1.

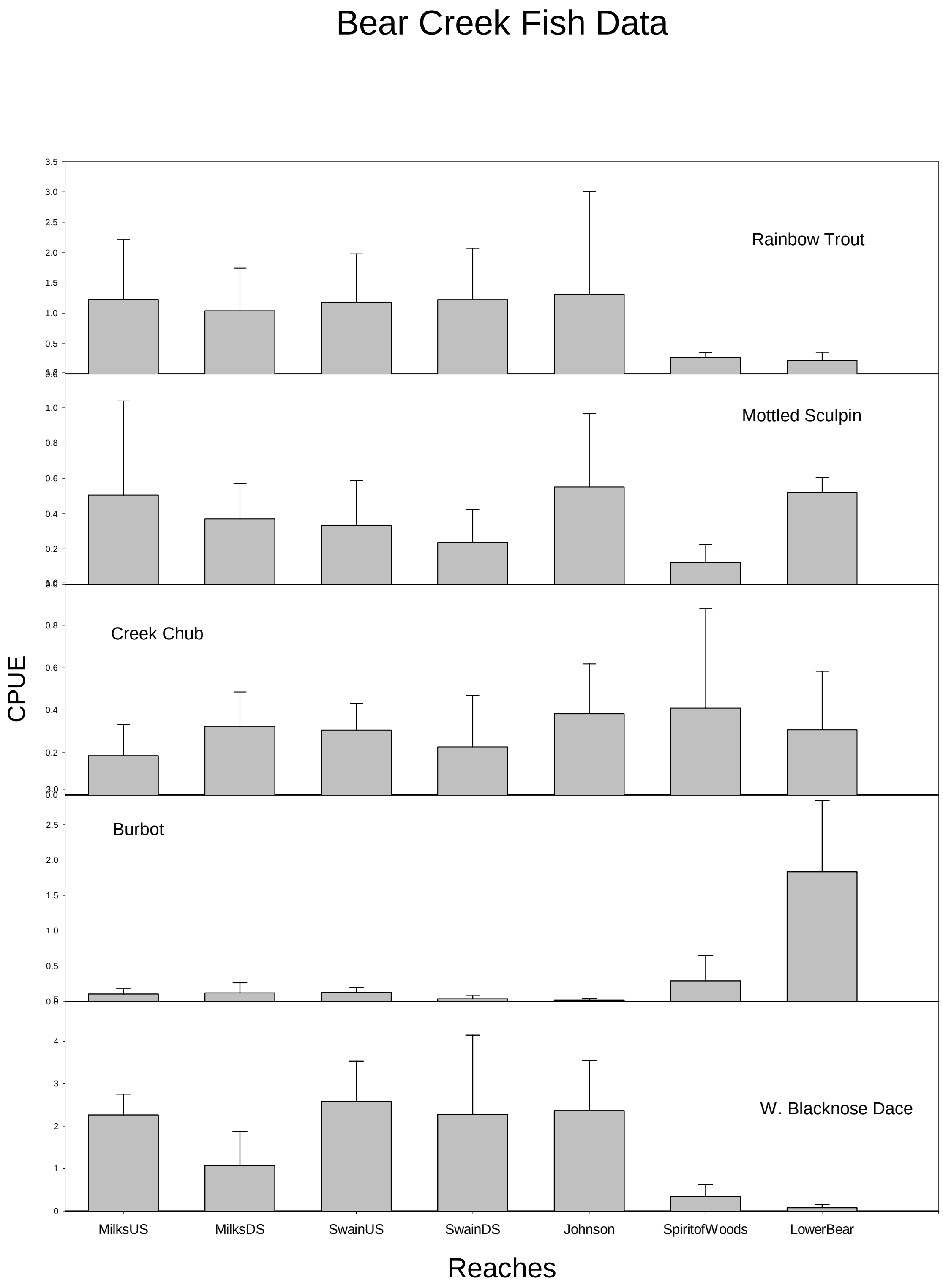


Figure 16. CPUE (fish/minute) data for various fish species in Bear Creek. Reach labels as in Table 1.

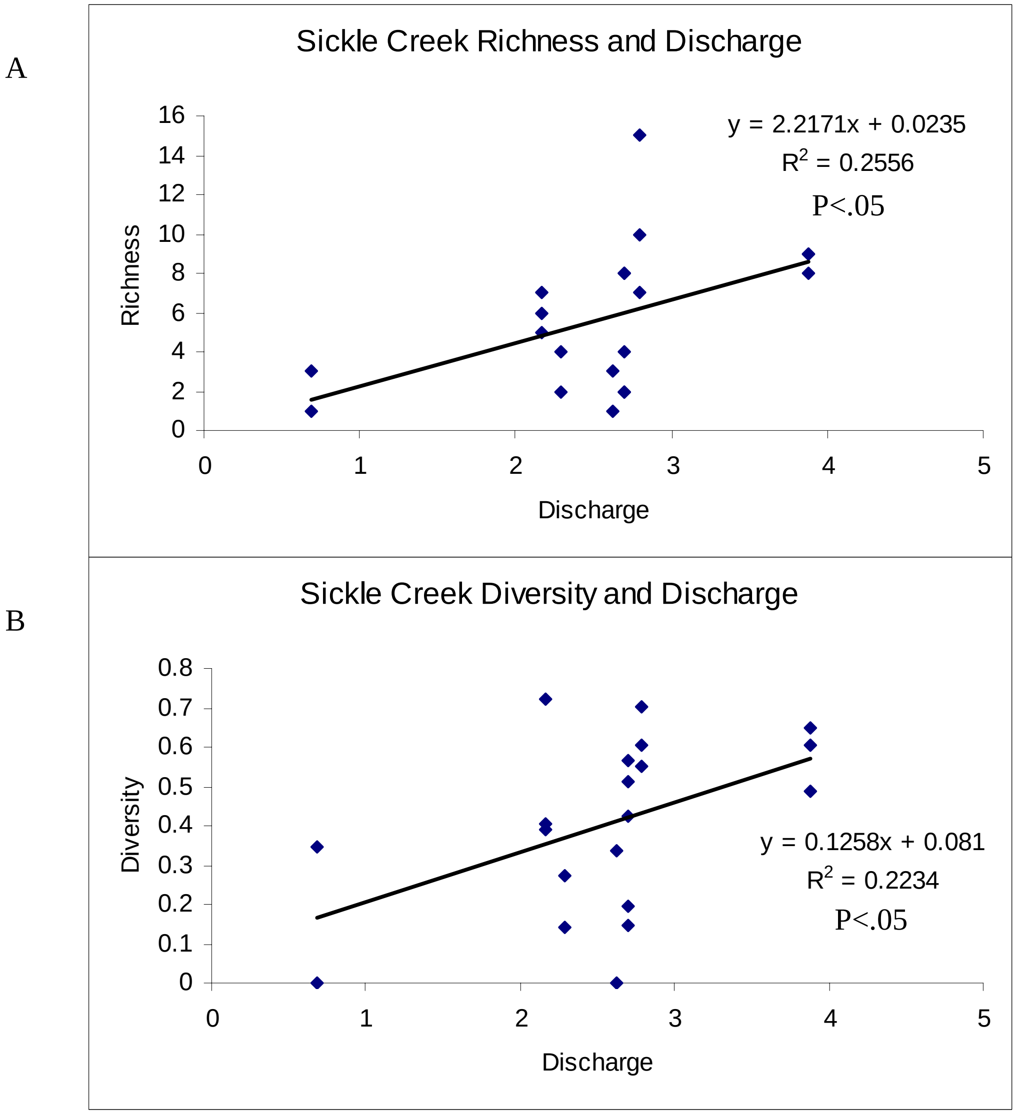


Figure 17. Discharge was positively correlated and explained 25.5% and 22.3% of the variation in species richness (A) and fish diversity (B) in Sickle Creek. pH was negatively correlated to fish density, but this was largely driven by a single data point and likely has limited ecological significance.

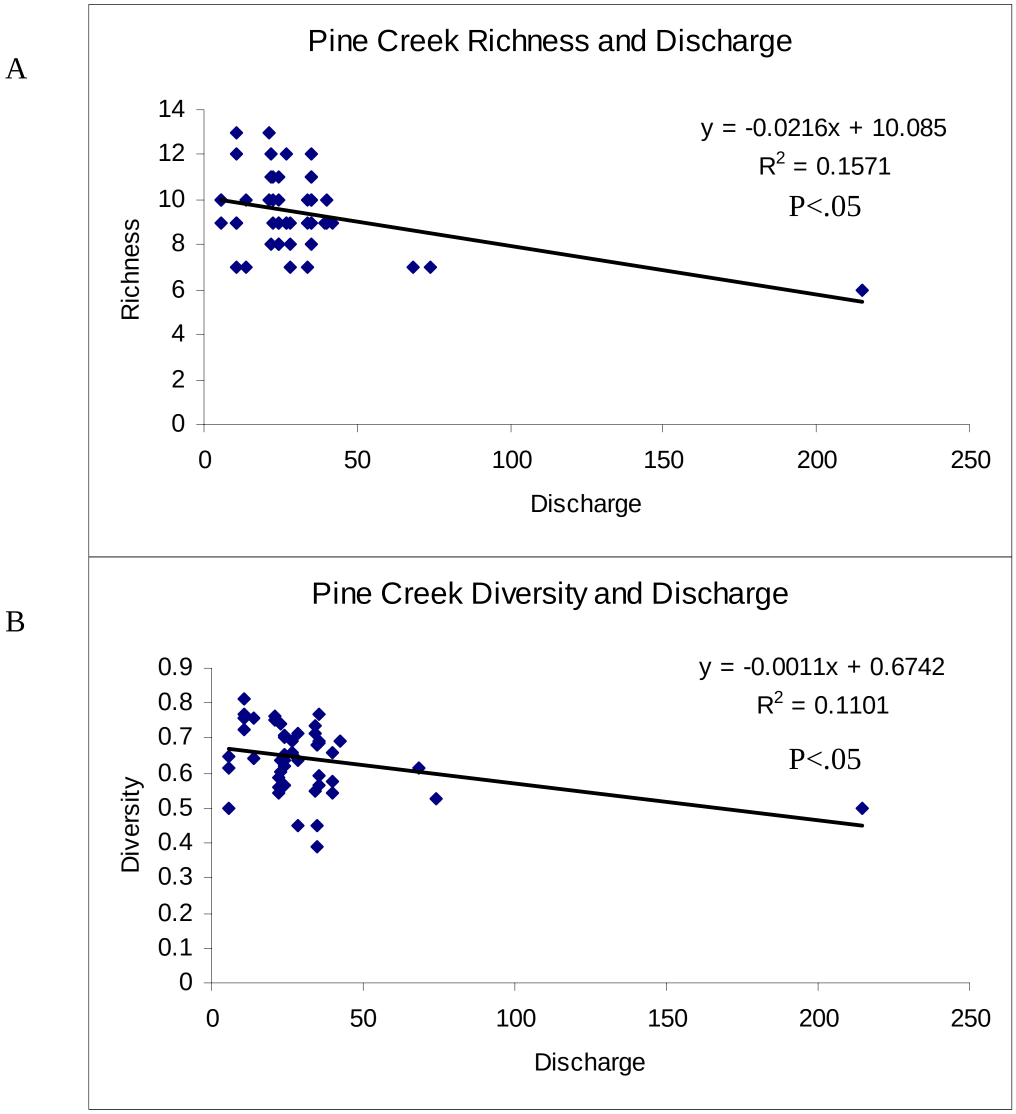
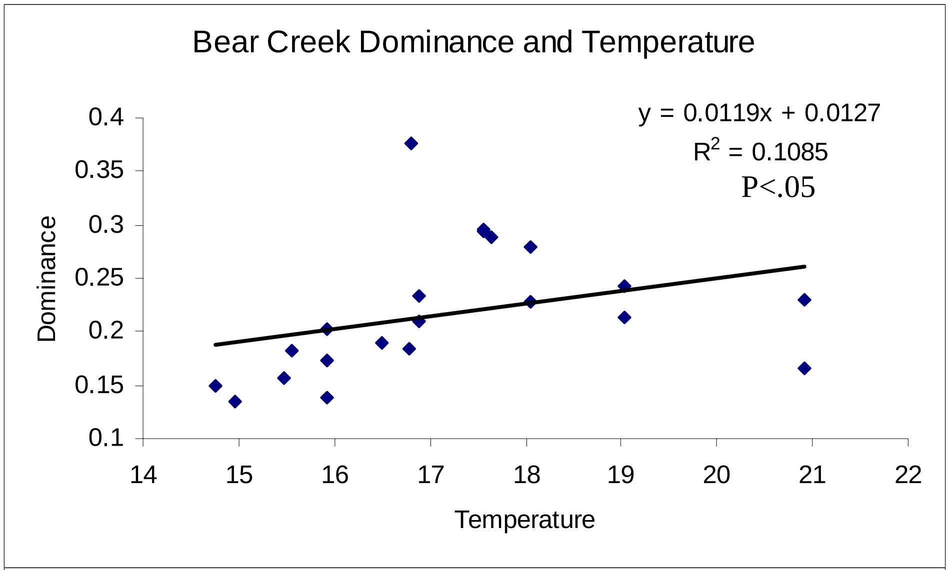
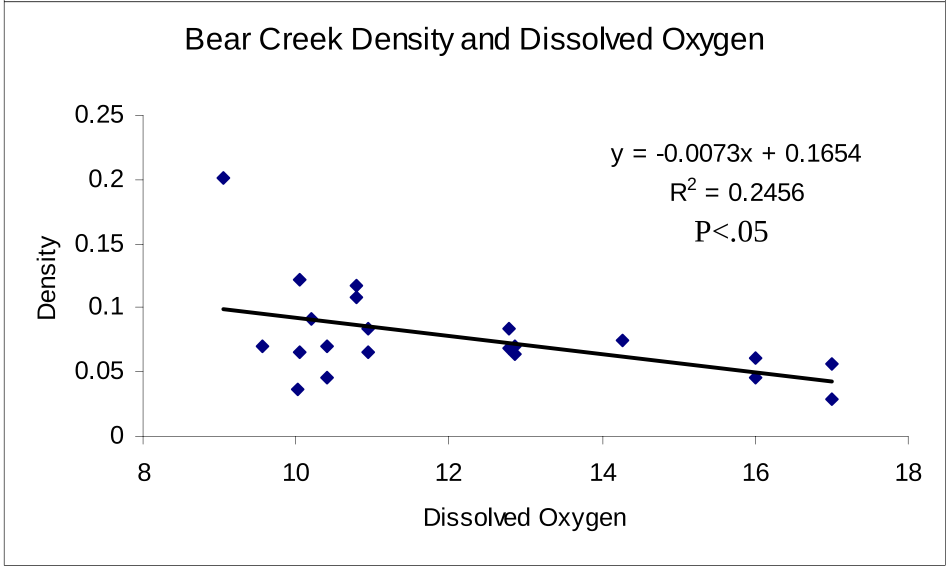


Figure 18. Discharge was negatively correlated with species richness (A) and species diversity (B) in Pine Creek.

A


Bear Creek Dominance and Temperature

B


Bear Creek Density and Dissolved Oxygen

C

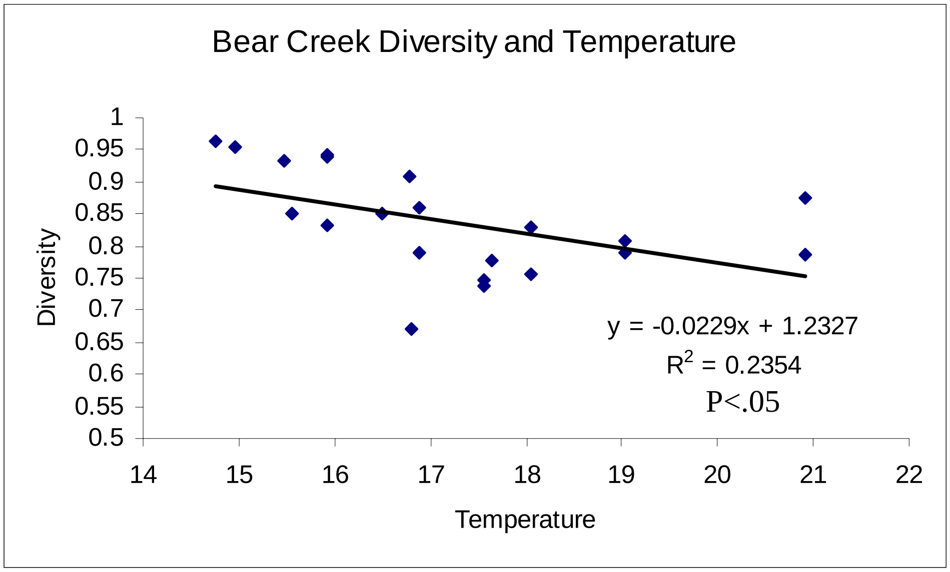


Figure 19. Temperature was positively correlated with species dominance (A) while dissolved oxygen was negatively correlated with species diversity (B) in Bear Creek. Species diversity (C) was also negatively correlated with temperature in Bear Creek.

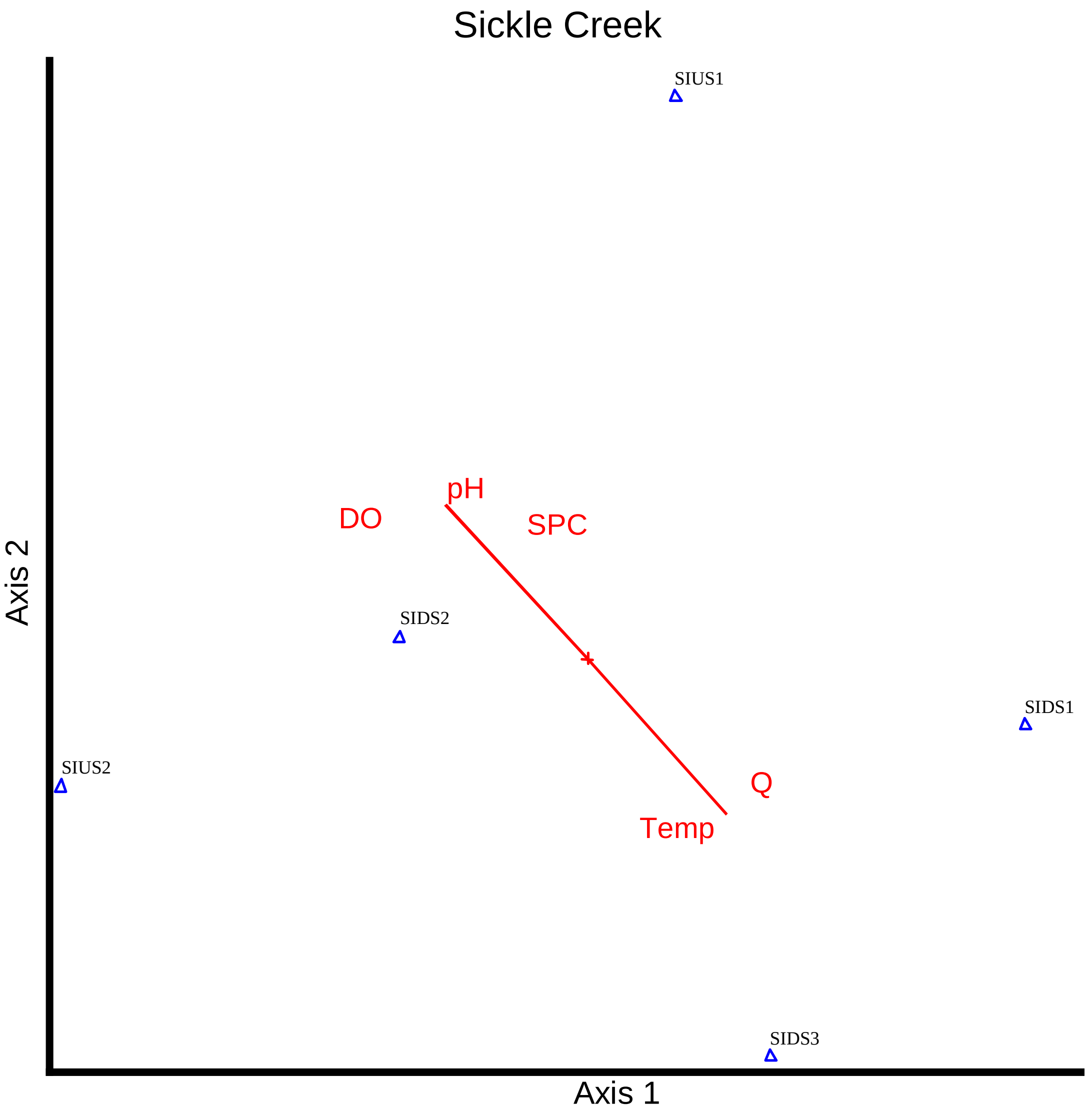


Figure 20. NMDS plot showing dispersal of fish assemblages at reaches and their relationship to water quality measurements in Sickle Creek. The blue triangles are the reaches with their respective name (as indicated in Table 1), and the red lines are the vectors for the joint bi-plot. The length of each vector is an indication of the strength of the relationship between that chemical parameter and the closest reach-level fish community. For example, both temperature and discharge are strongly associated with the fish communities at both SIDS1 and 2. Temp = temperature, DO = dissolved oxygen, pH = pH, SPC = specific conductivity, and Q = discharge.

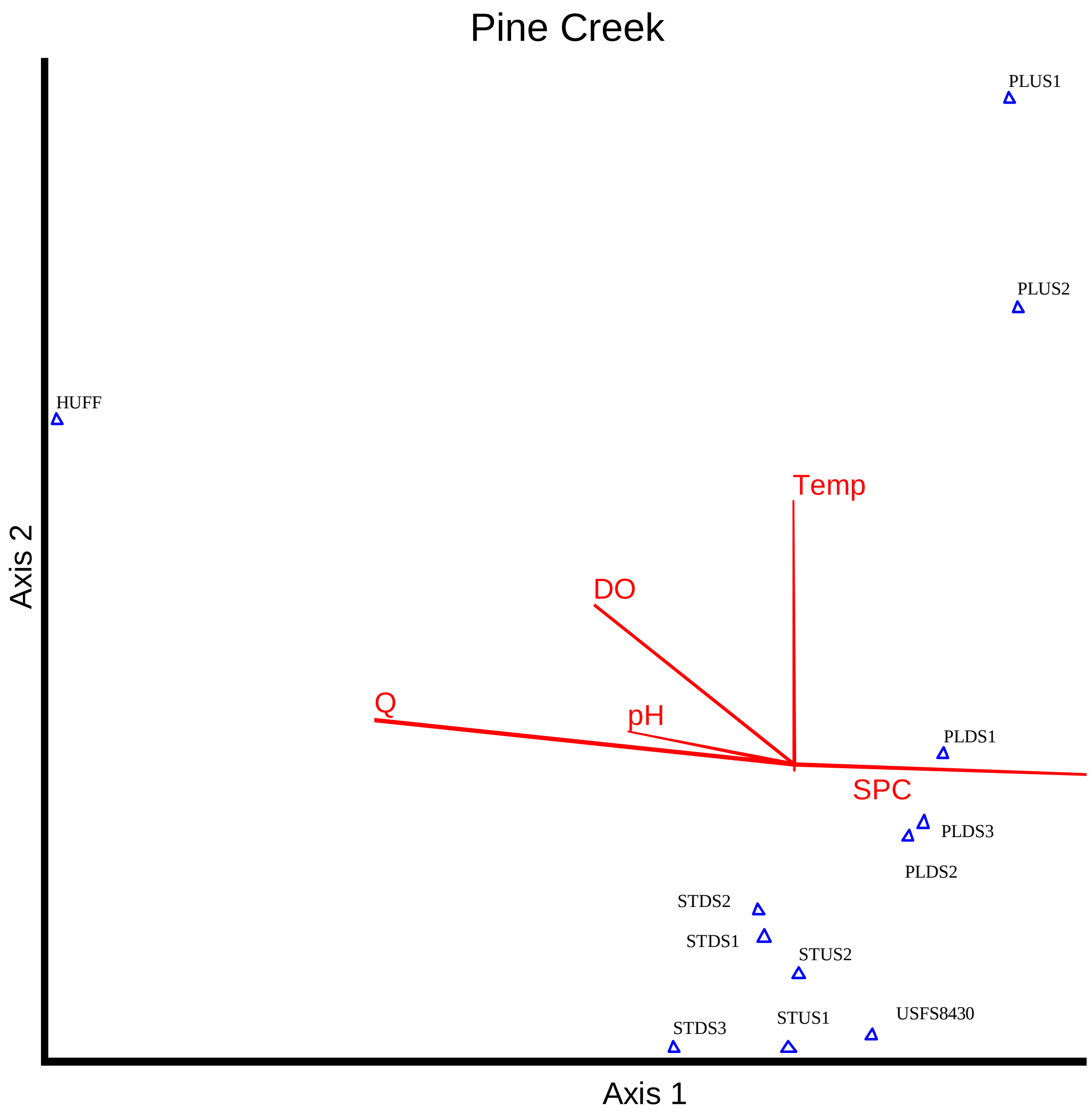


Figure 21. NMDS plot showing dispersal of fish assemblages at reaches and their relationship towards water quality measurements in Pine Creek. The blue triangles are the reaches with their respective name (as indicated in Table 1), and the red lines are the vectors for the joint bi-plot. Temp = temperature, DO = dissolved oxygen, pH = pH, SPC = specific conductivity, and Q = discharge.

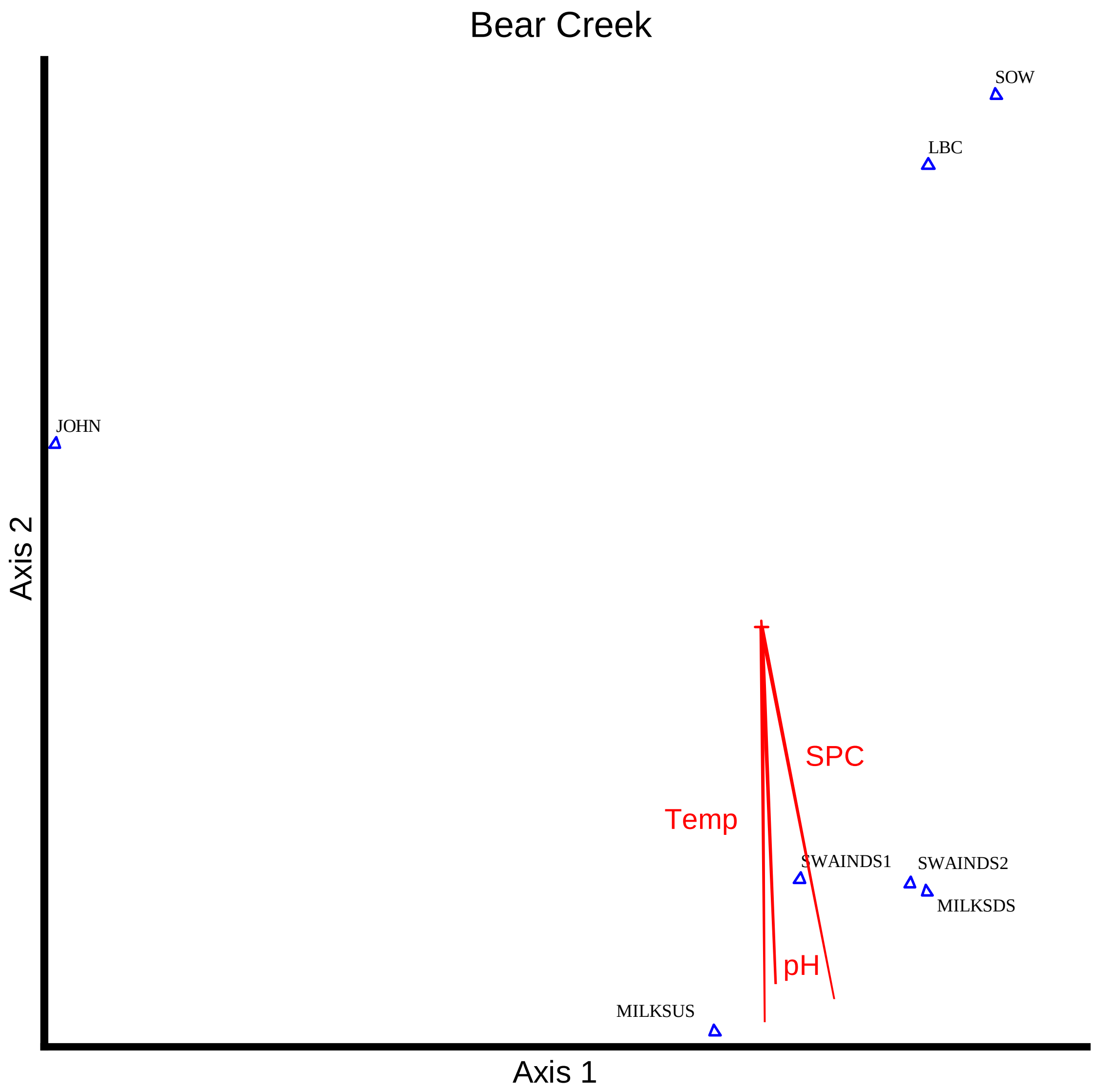


Figure 22. NMDS plot showing dispersal of fish assemblages at reaches and their relationship towards water quality measurements in Bear Creek. The blue triangles are the reaches with their respective name (as indicated in Table 1), and the red lines are the vectors for the joint bi-plot. The length of each vector shows how intense the relationship with the reaches are. Temp = temperature, pH = pH, and SPC = specific conductivity.

CHAPTER 4

FISH ASSEMBLAGE SPRING/SUMMER LONGITUDINAL PATTERNS IN THREE TRIBUTARIES OF THE LOWER MANISTEE RIVER, MICHIGAN

ABSTRACT

Fish migrate to various areas within and between coldwater watersheds, but few studies have examined the effects of seasonal differences with regard to entire stream, coldwater fish assemblages. The purpose of this study was to designate differences between whole fish assemblages and individual species among three tributaries of the lower Manistee River, Michigan, during spring and summer using a headwater to mouth approach in the two larger streams and a single location at the smallest stream. A total of 24 electrofishing reaches comprised the longitudinal gradient analysis. Whole fish assemblage measurements revealed no significant differences between seasons for Pine, Sickle, or Bear Creeks with respect to fish density, dominance, diversity, and richness. Sickle Creek (1st order) had no significant seasonal differences among any fish species present. In Pine Creek (2nd order), brook trout and coho salmon catch per unit effort were significantly higher in fall than spring. Bear Creek (4th order) had higher relative proportions of brook trout in spring versus fall samples. Most species from the streams appeared to remain in similar areas during these two seasons.

Introduction:

Fish migrate to various areas between and within coldwater watersheds and do so primarily to reach spawning areas, cooler water, and food resources. Diana et al**.** (2004) conducted telemetry evaluations of brown trout movements in the mainstream Au Sable River, Michigan and showed that brown trout remained near resting sites diurnally and moved various distances nocturnally. The brown trout returned to the same home resting sites as the previous year. Similarly, Curry et al. (2002) studied riverine brook trout populations with radio telemetry in the Kennebecasis River, New Brunswick, Canada and found that while summer and winter movements were minimal, spring and fall movements were substantial—potentially for finding summer holding areas and spawning grounds. Trout species have been examined extensively because of their importance to the recreational fishing industry, but are only a small portion of the entire fish assemblage within a coldwater stream. Other fish species migrations are not as well known and documented.

Some studies have examined somewhat larger portions of stream fish assemblages. For instance, Magalhaes (1993) examined food resource use by seven cyprinids from an Iberian stream and found that differences in food resource use were found both between species and within species between seasons. In another study, Grossman et al. (1987), studied some members of a Mediterranean riverine fish assemblage in relation to microhabitat use. Most seasonal differences in microhabitat use were attributable to seasonal changes in microhabitat availability, although all species selectively occupied deeper microhabitats during spring and early summer.

Few studies have examined the effects of seasonal differences with regard to entire stream, coldwater fish assemblages. Meador and Matthews (1992) studied spatial and temporal patterns in fish assemblage structure of an intermittent Texas stream and found that despite drastic seasonal fluctuations in discharge, abundance of individual species varied more spatially among sites than temporally at individual sites. Jonsson (1991) showed that water flow, water temperature, and light are environmental variables that influence when fish migrate and the intensity of the migration itself and that these variables apply to both upstream and downstream migration, but their effects may vary among rivers and species.

While many studies have examined the effects of seasonality on movements of fish species, few have studied the entire fish assemblage at numerous locations, headwaters to mouth, and between three different order streams. The tributaries of the lower Manistee River offered an excellent opportunity to study the unique species associated with three different order streams and also to describe the seasonal differences seen with respect to not only individual species, but also the entire assemblages using various indices. The purpose of this study was to 1) designate differences between whole fish assemblages and individual species between spring and summer in three different order streams, and 2) hypothesize why seasonal changes in these different order streams may be variously impacted by sedimentation and serial disconnection.

Materials and Methods:

Seasonal Fish Assemblage Change Experimental design: Fish assemblages were monitored during spring and summer of 2004 and 2005 to determine change between seasons. Data were pooled for each season and was assessed along a longitudinal gradient and both entire fish assemblages and individual species were analyzed. Data were quantified using CPUE as in the previous chapters.

Total fish relative density, dominance, diversity, and richness were evaluated using repeated measures ANOVA for whole fish assemblages using seasonal fish assemblage data. Individual species relative density, catch per unit effort, and relative proportions were also evaluated using repeated measures ANOVA. Sickle Creek had 2 replicates for each season and 5 reaches with a total of 10 replicates per season. Pine Creek had 2 replicates with 12 reaches with a total of 24 reaches used per season. Bear

Creek had 1 replicate for spring sampling with 2 replicates for fall with a total of 7 and 14 for spring and fall, respectively. Each sample was considered a representative sample from each reach during each sampling period.

Results and Discussion:

Whole Fish Community Seasonal Differences: There were no significant differences found between seasons for Sickle, Pine, or Bear Creeks for density, dominance, diversity, and richness (Table 10, Figures 23-26). One possible reason why density, dominance, diversity, and richness between seasons for each stream was not significant was that if one species moved out, another species was there to replace it and if one species decreased in density, another species filled the space of the former. Many migratory species inhabit these streams at certain times of the year including rainbow trout, Chinook salmon, and coho salmon. These species may be migrating out and other more abundant species such as brown trout may displace those species when the other species do not seasonally inhabit the area. It appears that the potadromous species may not be significantly influencing the fish community in terms of relative density, dominance, diversity, and richness. More sampling in late fall and winter would yield more valuable insight into what is occurring in these streams.

Taxa-specific seasonal differences:

Pine Creek: Brook trout and coho salmon CPUE were found to be higher in summer than spring (Table 10 & 11, Figures 27-29). Coho salmon have been known to move out of rivers after the first year, although a few remain and could be considered residents. This correlates with Welsh et al. (2001) who showed juvenile coho salmon reside in streams until smolting occurs, usually within two years at most. Seasonal migration may be a reason for higher CPUE for brook trout in summer versus spring, however, higher CPUE for coho salmon in summer may be the result of the smaller size of the fry earlier in the year. This species may have been freshly hatched and fairly untouched by electrofishing. Also, it may be that more individuals may have emigrated to the reaches electrofished in this study.

Higher CPUE for brook trout in summer could be a consequence of movements far upstream from other areas such as Lake Michigan, which is located roughly 20 miles downstream from Pine Creek, or the mainstream Big Manistee River, into which Pine Creek empties. It may be possible that lake brook trout may enter the smaller streams to spawn. Other reasons why brook trout had higher CPUE in summer include movement to spawn in headwaters, movement for water quality preferences, and fishing pressure. Petty et al. (2005) found that the spatial distribution of brook trout within a central Appalachian watershed was significantly correlated with spawning intensity and habitat features such as instream cover, stream depth and width, and riparian canopy cover; all variables that would change significantly from spring to summer, especially in response to the seasonal flow regime. Another study found that brook trout from the Sainte-Marguerite River, Quebec, Canada, first migrated downstream over a month in spring and adults then undertook upstream migration to spawning areas from July to September with larger individuals migrating earlier (Lenormand et al. 2004). Other reasons for higher brook trout CPUE in summer include movement to unsampled reaches in spring and inability to sample certain sections of reaches effectively due to higher water levels and resulting habitat.

Longnose dace density and CPUE were higher in spring versus summer. In fact, no longnose dace were found in this stream in summer. One reason could be the influence of larger predatory salmonid movement into the area. Another reason could be movement to reaches unsampled, but also the effect of many macroinvertebrates emerging as adults and dispersing out of the area. Though speculative, this compares to the findings of Thompson et al. (2001), which showed there was a significant, positive correlation between the biomass of benthic macroinvertebrates and longnose dace density in all seasons in a southern Appalachian stream. Perhaps various invertebrate taxa were not available in high abundances in summer versus spring.

Rainbow trout density and CPUE were higher in summer versus spring. Rainbow trout grow rapidly from hatching to the fall of the first year. Some rainbow trout in spring may have been overlooked from electrofishing size-selectivity, but also these species tend to move upstream to locate cooler water temperatures, food availability, and better-suited current velocities. Rainbow trout then migrate downstream usually after the second year, supporting the findings of very few larger rainbow trout within the streams. This compares with the findings of Daugherty et al. (2003) who showed rainbow trout had residence times of usually no more than two years in streams of the eastern Upper Peninsula of Michigan.

Other species present in Pine Creek had no significant seasonal differences. We hypothesized that brown trout would have large seasonal movements, but did not observe this pattern. Bettinger and Bettoli (2004) showed that the range of movement for brown trout in the Clinch River, Tennessee, was significantly larger in fall than in any other season. Brown trout that were monitored for more than 1 year exhibited a limited range of movement during the winter, spring, and summer, but they made extensive movements during the fall season, presumably to spawn. In the current study, if seasonal movements of these individuals occurred, they may have happened later or earlier than when sampling was conducted.

As expected, another species not seasonally different was the Johnny darter; an observation supported by Mundahl and Ingersoll (1983) who found that only a small percentage of Johnny darters moved between seasons in an Ohio stream.

Sickle Creek: Sickle Creek had no seasonal differences among any fish species present, which was not surprising for species like the mottled sculpin. Downhower and Brown (1979) showed that even during spawning periods, mottled sculpin moved only small distances to find mates and that they are generally considered residents of the streams in which they reside.

Bear Creek: Brook trout had higher spring relative abundance than summer (Table 10 & 11). This could be a consequence of water quality preferences, fishing pressure, and the seasonal shift in abundances of other species. The change in migratory fish abundance may ultimately affect brook trout by displacing them to other areas of the stream, although both Chinook and coho salmon had higher spring density, CPUE, and relative proportions. Ultimately, it may be that in Pine Creek, that the increased summer coho salmon CPUE was the result of more individuals of this species remaining within the stream reaches and that less individuals were within the stream reaches in spring. The same may be true for brook trout in both Pine and Bear Creeks.

The pattern in brook trout was originally hypothesized to be adversely affected by Chinook and coho salmon abundance. However, it appears that the potential effect of these two salmonids on brook trout may not be as adverse as previously thought. Brook trout had higher spring relative abundances in Bear Creek, along with both Chinook and coho salmon showing a similar trend. However, it may be that most brook trout were located in more upstream reaches, while Chinook and coho salmon were found in a more widespread distribution, although they decreased toward the furthest downstream reach. The brook trout in Bear Creek may have had a higher relative abundance in spring because they had moved to even further upstream reaches during the summer. Those reaches were not sampled as part of this study, although ongoing research has documented an evenly dominated community of brook and rainbow trout approximately 50 river kilometers upstream of the Milks Road site at the Leffew road stream crossing (Snyder et al. 2007). Alternatively, it may be that this pattern observed is not ecologically meaningful, and is simply due to chance.

Creek chub and mottled sculpin had higher summer CPUE values versus spring. Our data contradicts that of Pezold et al. (1997), who showed that in the Little Missouri River System in the Ouachita Mountains of Arkansas, creek chub appeared to be year-around residents with few seasonal movements. Downhower and Brown (1979), found that mottled sculpin are generally considered residents of the streams they reside in with little seasonal movement. We observed significant seasonal changes in sculpin CPUE in Bear Creek. In this system, temperature changes the most among the three streams studied with values reaching 20^0C in mid-summer. The increased creek chub and mottled sculpin CPUE in summer are likely to be from new arrivals of these species, either from emigration from the main channel or, more likely from emigration from unsampled adjacent reaches.

Sickle, Pine, and Bear Creeks each have visible problems associated with sedimentation and serial disconnection from improperly designed bridge and culvert placement. Little movement upstream of a perched culvert in Sickle Creek may have prohibited seasonal migration of some species. However, when flow was high enough to eliminate the plunge pool below the perched culvert, some species including trout that have physical attributes for swimming against high flow speeds, would potentially have been able to move upstream. Anthropogenic disturbances can affect migration patterns and management of tributaries of relatively large river systems is necessary to promote necessary seasonal movement patterns of the associated species.

Conclusion:

There were no significant differences found between seasons for Pine, Sickle, or Bear creeks for fish relative density, dominance, diversity, and richness. Seasonal fluctuations with individual species were mainly as expected. In Pine Creek, brook trout and coho salmon CPUE, and Rainbow trout density and CPUE were significantly higher in summer than spring. Sickle Creek had no significant seasonal differences among any fish species present. In Bear Creek, brook trout had significantly higher spring relative proportions than summer samples and both Chinook and coho salmon had significantly higher spring density, CPUE, and relative proportions. However, creek chub and mottled sculpin had significantly higher summer CPUE values than spring. Differences are likely from physiological changes of habitat, physical, and biotic parameters needed for species fitness and survival. Most species from the streams appeared to remain in similar areas from season to season. However, these results suggest that regular sampling is necessary to establish long-term patterns and trends. Also, we recommend incorporation of more seasons into fish sampling to truly understand seasonal patterns. We also believe that management of tributary rivers is essential to the watershed scale maintenance of healthy and dynamic fish communities and that the results of studies such as this one can be used as an effective tool to better manage and conserve the fishery.

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Tables:

Table 10. Mean density, CPUE, and relative abundance data for significant differences between seasons. Standard deviations are in parenthesis.

	Mean density (ha)			Mean CPUE			Mean relative abundance	
Species and location	spring	fall	p-value	spring	fall	p-value	spring	fall
Brook trout (Bear Creek)							0.30 (0.20)	0.09 (0.03)
Brook trout (Pine Creek)				0.05 (0.02)	0.16 (0.07)	0.026		
Chinook salmon (Bear Creek)	48 (2)	3 (2)	0.025	0.40 (0.19)	0.21 (0.12)	0.011	8.5 (0.77)	3.1 (0.44)
Coho salmon (Bear Creek)	12 (6)	6 (2)	0.021	0.09 (0.04)	0.05 (0.02)	0.017	2.01 (0.78)	0.86 (0.35)
Coho salmon (Pine Creek)				0.040 (0.02)	0.12 (0.05)	0.013		
Creek chub (Bear Creek)				0.07 (0.03)	0.39 (0.08)	0.021		
Longnose dace (Pine Creek)	25 (2.0)	0	0.038	0.10 (0.07)	0	0.034		
Mottled sculpin (Bear Creek)				0.10 (0.05)	0.46 (0.09)	0.049		
Rainbow trout (Pine Creek)	38 (31)	10. (4.0)	0.011	0.20 (0.08)	0.74 (0.25)	0.002		

Table 11. Summary of spring/summer fish community responses in Sickle, Pine, and Bear creeks. RA = relative abundance, n.s. = not significant at p >.05.

	Fish community metrics	Species-specific Responses					
Stream	Density, Richness, Diversity, Dominance	Chinook salmon	Coho salmon	Rainbow trout	Brook trout	Creek chub	Mottled sculpin
Sickle	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Pine Creek	n.s.	n.s.	CPUE (summer)	Density, CPUE (summer)	CPUE (summer)	n.s.	n.s.
Bear Creek	n.s.	RA, CPUE, Density (spring)	RA, CPUE, Density (spring)	n.s.	RA (spring)	CPUE (summer)	CPUE (summer)
🟨	spring						
🟥	summer						

Figures:

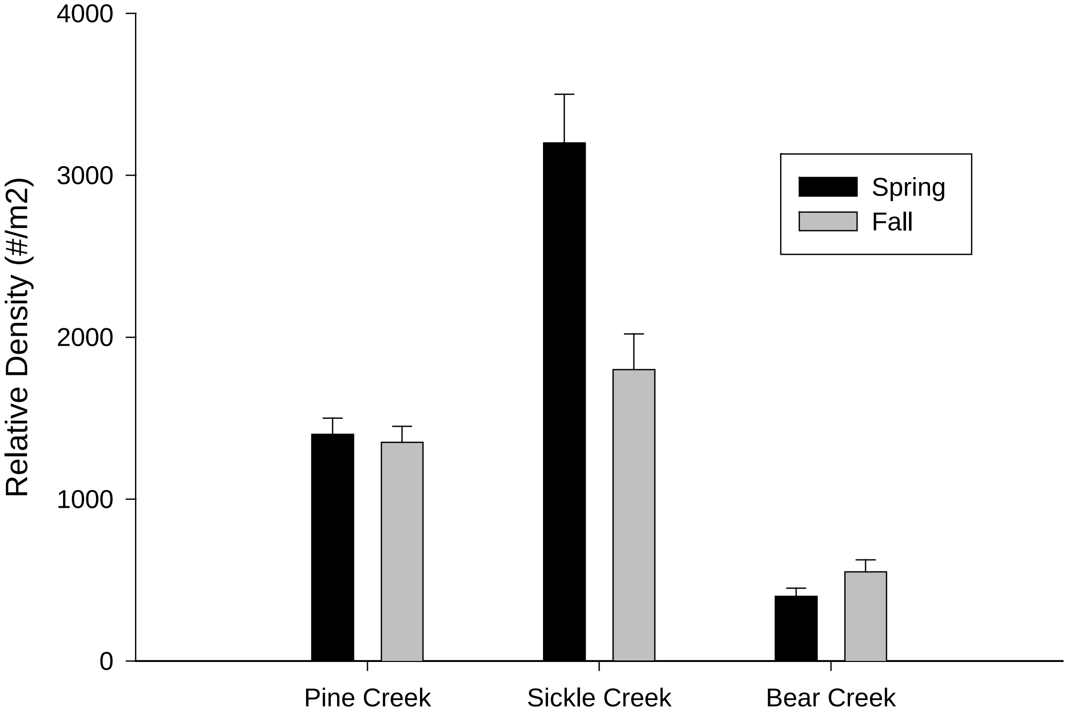

Figure 23. Relative seasonal fish density of Pine, Sickle, and Bear Creeks, Manistee County, Michigan. Each stream spring and fall from data are placed adjacent to each other respective of the stream and date. Pine, Sickle, and Bear Creek seasonal fish density are shown. Standard error bars are also given.

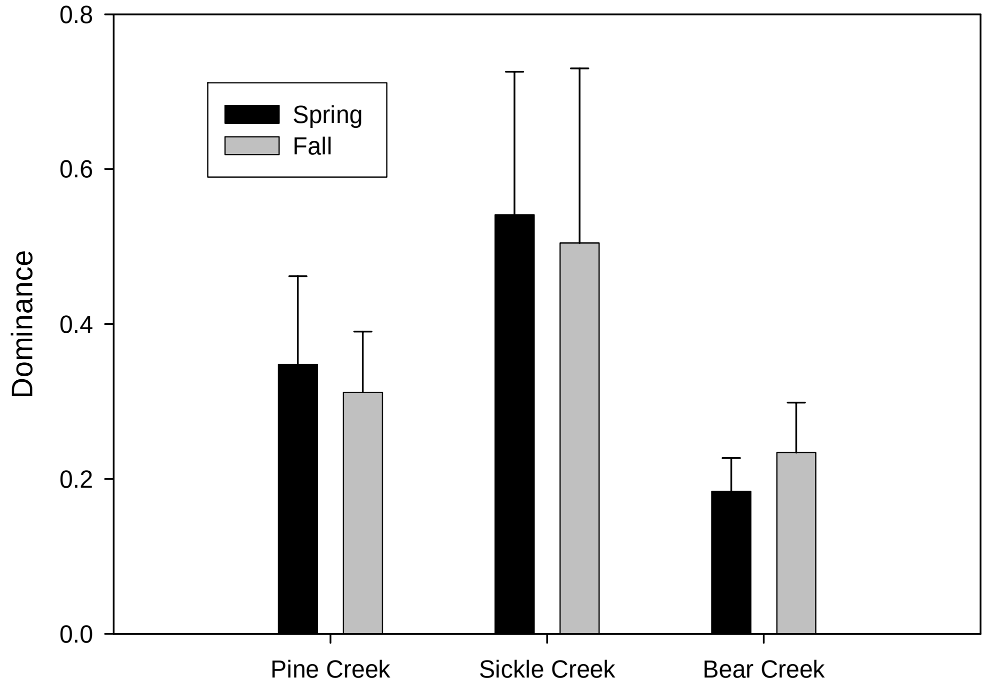

Figure 24. Seasonal fish dominance for Pine, Sickle, and Bear Creeks, Manistee County, Michigan. Dominance values closer to a value of 1 indicate that some species were much more abundant in those areas. These data values are the spring and fall values.

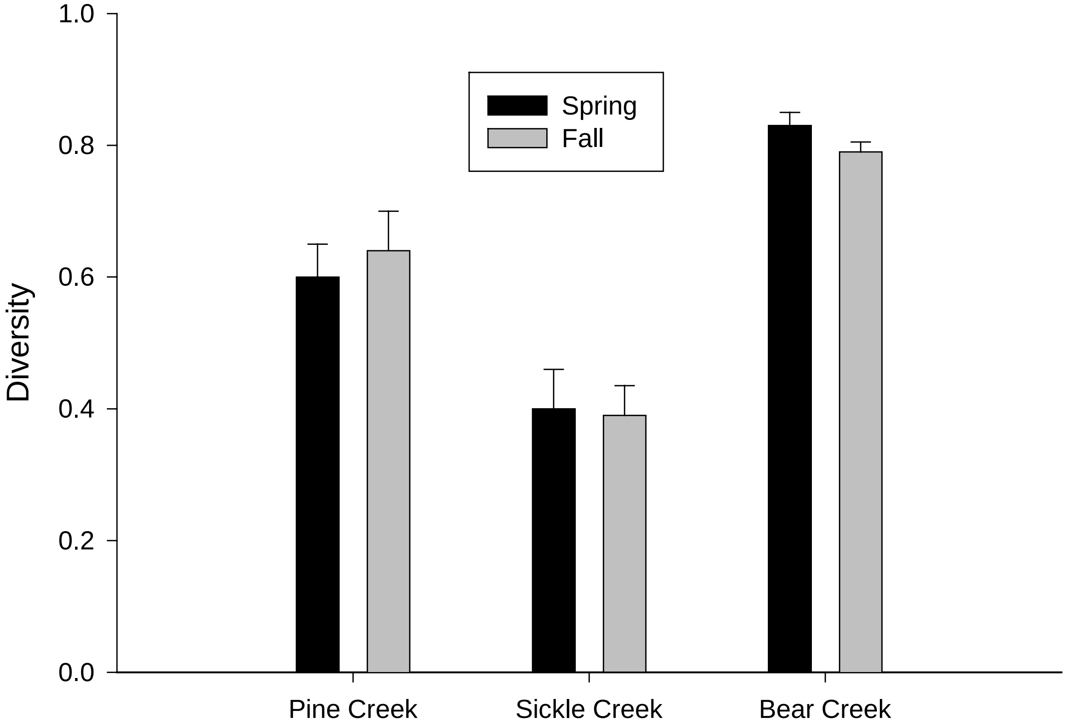

Figure 25. Seasonal species diversity of Pine, Sickle, and Bear Creeks, Manistee County, Michigan. Spring and fall data are shown in the figure. Standard error bars are also shown. The higher the value towards one, the more diverse the area. As the value reaches 0, the less diverse. Bear Creek has the highest diversity.

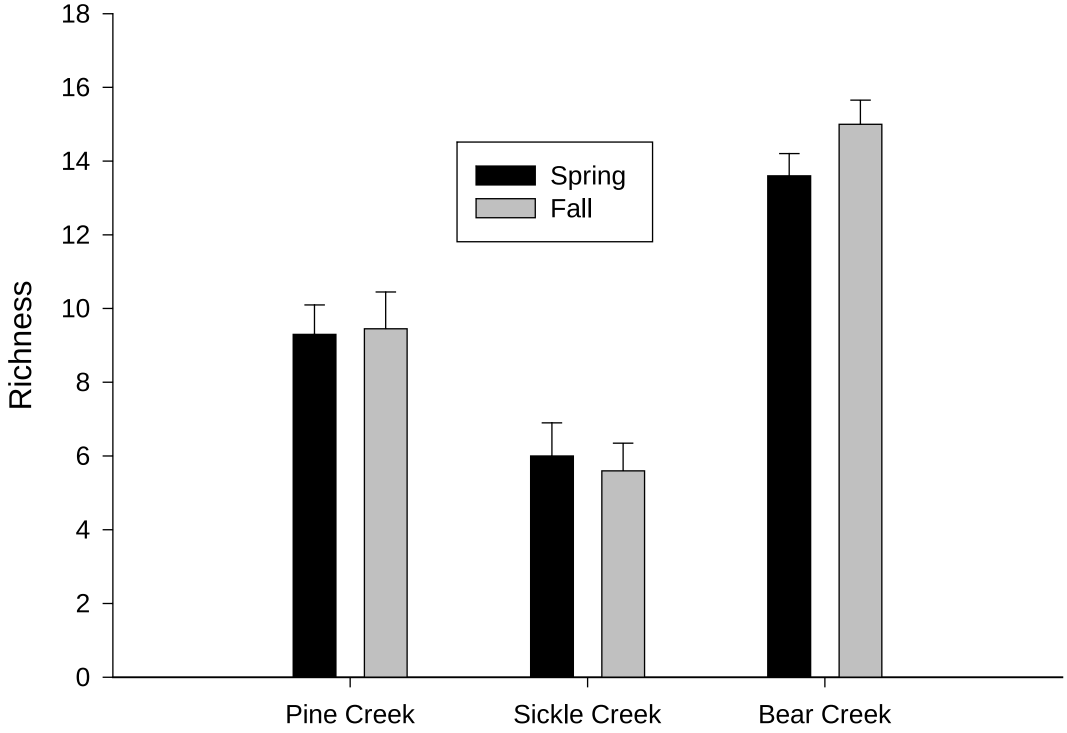

Figure 26. Seasonal fish species richness of Pine, Sickle, and Bear Creeks, Manistee County, Michigan. The number of species is what the species richness represents. Bear Creek has the highest species richness, with Sickle Creek having the lowest richness.

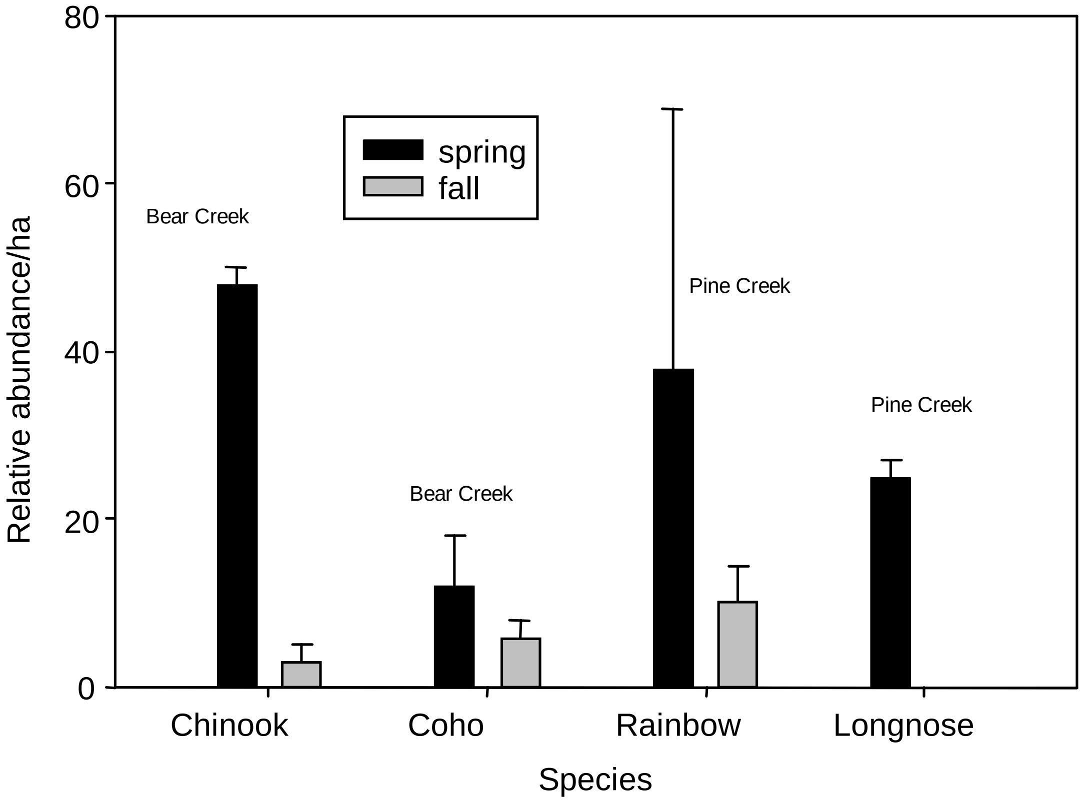

Figure 27. Relative fish density per hectare of all significant fish differences for each respective stream. The streams where the differences occur are shown above the respective species. All differences shown are p<.05.

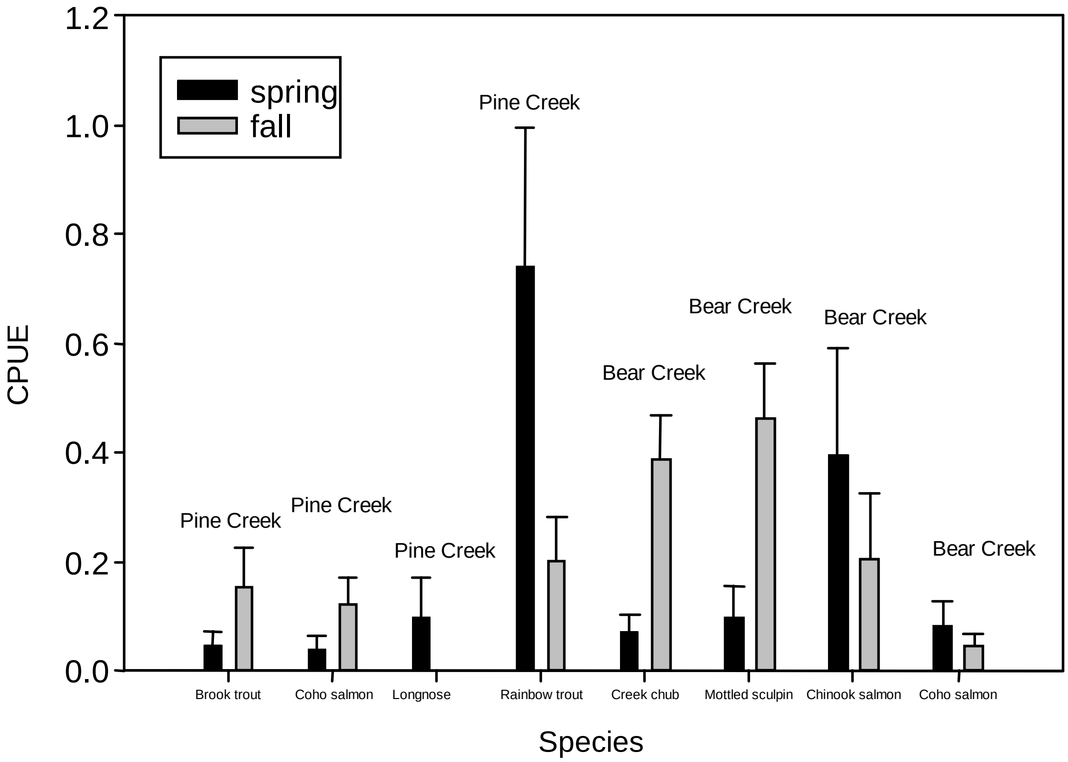

Figure 28. Fish catch per minute of all significant fish differences for each respective stream. The streams where the differences occur are shown above the respective species. All differences shown are p<.05.

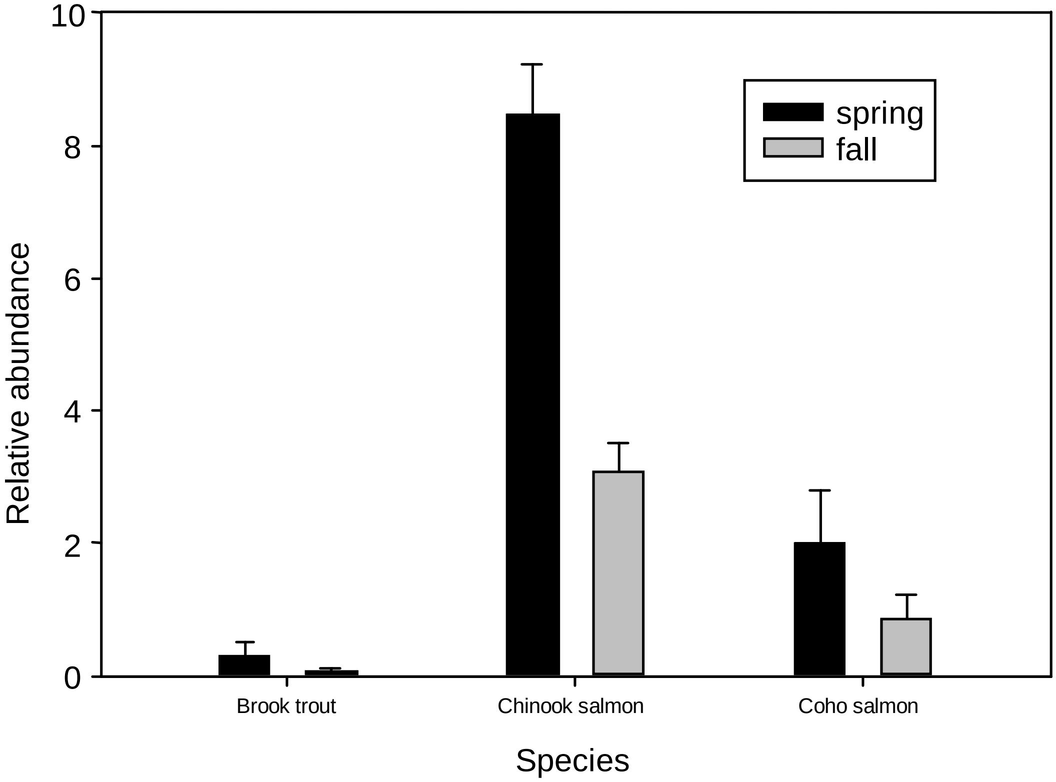

Figure 29. Fish relative abundance of all significant fish differences for Bear Creek. The streams where the differences occur are shown above the respective species. All differences shown are p<.05.

CHAPTER 5

OVERALL DISCUSSION

Effect of undersized road-stream crossings:

Sickle Creek had reduced diversity and increased dominance above a substantially perched culvert. In Pine and Bear creeks, fish assemblage response above and below impact sites was mixed. For example, undersized road-stream culverts reduced upstream habitat quality while eroding banks tended to reduce downstream habitat quality. Consequently, fish assemblage measurements were correlated with sediment composition at most sites, although this was not tested empirically in this thesis but is based on statistically significant differences in sediment composition above and below sediment sources (Holtgren and Ogren 2007). Most reaches above road-stream crossings had finer sediment buildup above culverts and larger substrate in downstream reaches, thus supporting our hypothesis that large amounts of finer substrate upstream would influence whole fish community metrics such as diversity and dominance. Moreover, downstream reaches generally had more diverse whole fish community values than those located above the road-stream crossing. Such trends suggest that undersized road-stream crossings that have been in place for long periods of time tend to accumulate sediment upstream--the amount which depends on the degree of constriction. Our results also suggest that when each road-stream crossing is restored, larger substrate and more diverse fish communities would exist above the road-stream crossing more similar to those below the crossing. Improvements to road-stream crossings should be done in such a way to maximize natural river structure and function.

Longitudinal fish distribution:

Few studies have employed a headwaters to mouth approach to Great Lakes Region stream fish distribution, impaired by high rates of sedimentation and barriers to fish migration (but see Seelbach and Wiley 1997, and Zorn et al. 1998). Results of our study showed that each stream had a distinctive fish community, usually attributed to a few select species as well as their longitudinal distribution. Sickle Creek had more brook trout upstream and more burbot in downstream reaches. Pine Creek had a large concentration of brown and rainbow trout downstream and more western blacknose and northern redbelly dace upstream. Bear Creek had more burbot downstream with more western blacknose and longnose dace upstream.

Most other studies have focused on fish longitudinal distribution and its relationship to biotic and abiotic factors (Zorn et al. 1998, Wang et al. 2003, Grenouillet et al. 2004, Schaefer and Kerfoot 2004, Torgersen et al. 2006, and many additional studies). In the Great Lakes region, specifically Michigan, few studies have been done. Zorn et al. (1998) examined fish distribution and abundance patterns within the lower peninsula and used low-flow yield and catchment area as independent variables. They determined that stream fishes responded in an individualistic manner to stream conditions, but also mentioned the need for additional species-specific studies. In the western United States, Torgersen et al. (2006) had compared gradients in fish assemblage structure among rivers and at multiple spatial scales and found spatial structuring of fish assemblages exhibited a generalized pattern of cold- and coolwater fish assemblage zones, but varied with temperature, especially in the warmest stream. Our study results were similar with respect to cold- versus coolwater fish assemblages. Also, including sediment and a constricted/perched culvert factor, fish distribution patterns continued to follow similar patterns. Such results suggest that even though differences may be seen at smaller spatial scales (road-stream crossings, up- versus downstream comparisons), those differences do not affect the headwater to mouth continuum and may be considered a relatively small-scale problem unless the road-stream crossing is perched. That being said, there is a significant body of evidence that cumulative impacts will negatively affect stream ecosystems (Frissell et al. 1986, Bohn and Kershner 2002, Bond and Lake 2003), although less work has been done specifically on the cumulative effects of road-stream crossings per se (Harper and Quigley 2000, Wheeler et al. 2005). Once restoration activities commence, the smaller spatial scales differences can be alleviated and restore fish passage above and below these sites. Road-stream crossing and eroding banks seem to have a localized versus a watershed-scale impact and furthermore, funds for repairing the road-crossings were well spent and should have a beneficial affect on each stream.

In addition to this study, additional focus on whole fish communities and individual species, combined with a longitudinal approach, sedimentation, and fish passage between up- and downstream reaches, should support our findings. For instance, one smaller-scale study could focus on tracking individual species distribution within each stream. Larger-scale studies should focus on overall stream impacts from restoration activities from both road-stream crossing improvements and stream bank stabilizations. Time is an important consideration in these types of studies, as many of the species sampled may take years to establish a new dynamic equilibrium. Moreover, the study would be strengthened by additional years of post-restoration sampling

Stream restoration is very important tool for maintaining and improving stream ecosystem integrity and should be implemented at a much higher rate then it is today. Many studies have stressed the importance of stream restoration as a tool for dealing with problems of land use and for improving and enhancing fish migration, reproduction, forage, and successful completion of all life-history stages (Schlosser 1991, Allan and Flecker 1993, Harding et al. 1998, Ward et al. 2001, Jungwirth et al. 2002, Allan 2004, Bernhardt et al. 2005, Jansson et al. 2005, Palmer et al. 2005, Meyer et al. 2007, Jacobson and Galat 2008). In conclusion, Allan and Flecker (1993) note that the potential for recovery of damaged river ecosystems is considerable, and promoting restoration in these affected areas will prove to be beneficial for all organisms—including humans—that rely on lotic systems for goods and service, asthetics, and life in general.

Appendix A - Electrofishing Data

Sickle Creek Electrofishing Data

Sickle Upstream #2

Spring 2004 7/7/2004

Species	Number	Proportion	Catch/Minute
Mottled Sculpin	51	91.071	3.844
Brook Trout	1	1.786	0.075
Rainbow Trout	4	7.143	0.302

Summer 2004 8/10/2004

Species	Number	Proportion	Catch/Minute
Brook Trout	1	2.326	0.095
Brown Trout	2	4.651	0.190
Mottled Sculpin	35	81.395	3.333
Northern Brook Lamprey	2	4.651	0.190
Rainbow Trout	3	6.977	0.286

Spring 2005 6/17/2005

Species	Number	Proportion	Catch/Minute
Mottled Sculpin	26	89.655	2.500
Rainbow Trout	3	10.345	0.288

Summer 2005 7/27/2005

Species	Number	Proportion	Catch/Minute
Mottled Sculpin	24	100	2.88

Sickle Upstream #1

Spring 2004 7/7/2004

Species	Number	Proportion	Catch/Minute
Brook Trout	3	7.317	0.234
Chinook Salmon	2	4.878	0.156
Coho Salmon	2	4.878	0.156
Mottled Sculpin	30	73.171	2.338
Northern Brook Lamprey	1	2.439	0.078
Rainbow Trout	3	7.317	0.234

Summer 2004 8/10/2004

Species	Number	Proportion	Catch/Minute
Brook Trout	4	11.429	0.501
Brown Trout	2	5.714	0.251
Chinook Salmon	1	2.857	0.125
Coho Salmon	1	2.857	0.125
Creek Chub	2	5.714	0.251
Mottled Sculpin	20	57.143	2.505
Rainbow Trout	5	14.286	0.626

Spring 2005 6/17/2005

Species	Number	Proportion	Catch/Minute
Mottled Sculpin	15	83.333	1.500
Rainbow Trout	3	16.667	0.300

Summer 2005 7/27/2005

Species	Number	Proportion	Catch/Minute
Brown Trout	1	6.250	0.131
Mottled Sculpin	11	68.750	1.438
Rainbow Trout	4	25.000	0.523

Sickle Downstream #1

Spring 2004 6/30/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	2	0.604	0.071
Bluntnose Minnow	1	0.302	0.036
Brook Stickleback	28	8.459	0.994
Brook Trout	1	0.302	0.036
Brown Trout	2	0.604	0.071
Burbot	28	8.459	0.994
Central Mudminnow	1	0.302	0.036
Chinook Salmon	6	1.813	0.213
Coho Salmon	15	4.532	0.533
Creek Chub	56	16.918	1.988
Johnny Darter	2	0.604	0.071
Mottled Sculpin	171	51.662	6.071
Northern Brook Lamprey	3	0.906	0.107
Northern Redbelly Dace	12	3.625	0.426
Rainbow Trout	3	0.906	0.107

Summer 2004 8/9/2004

Species	Number	Proportion	Catch/Minute
Brown Trout	1	0.847	0.074
Burbot	27	22.881	2.010
Chinook Salmon	4	3.390	0.298
Creek Chub	7	5.932	0.521
Johnny Darter	3	2.542	0.223
Mottled Sculpin	74	62.712	5.509
Northern Brook Lamprey	1	0.847	0.074
Rainbow Trout	1	0.847	0.074

Spring 2005 6/24/2005

Species	Number	Proportion	Catch/Minute
Brown Trout	1	3.226	0.101
Burbot	2	6.452	0.201
Chinook Salmon	2	6.452	0.201
Coho Salmon	3	9.677	0.302
Johnny Darter	1	3.226	0.101
Mottled Sculpin	20	64.516	2.013
Northern Redbelly Dace	1	3.226	0.101
Rainbow Trout	1	3.226	0.101

Summer 2005 7/27/2005

Species	Number	Proportion	Catch/Minute
Burbot	3	5.769	0.357
Chinook Salmon	2	3.846	0.238
Johnny Darter	1	1.923	0.119
Mottled Sculpin	39	75.000	4.643
Northern Brook Lamprey	5	9.615	0.595
Rainbow Trout	2	3.846	0.238

Sickle Downstream #2

Spring 2004	6/23/2004		
Species	Number	Proportion	Catch/Minute
Brown Trout	3	2.055	0.135
Burbot	18	12.329	0.811
Central Mudminnow	1	0.685	0.045
Chinook Salmon	9	6.164	0.406
Coho Salmon	14	9.589	0.631
Creek Chub	7	4.795	0.316
Johnny Darter	1	0.685	0.045
Mottled Sculpin	88	60.274	3.967
Northern Brook Lamprey	3	2.055	0.135
Rainbow Trout	2	1.370	0.090

Summer 2004	8/9/2004		
Species	Number	Proportion	Catch/Minute
Brook Stickleback	1	1.493	0.098
Brown Trout	1	1.493	0.098
Burbot	25	37.313	2.451
Chinook Salmon	1	1.493	0.098
Coho Salmon	3	4.478	0.294
Johnny Darter	3	4.478	0.294
Mottled Sculpin	29	43.284	2.843
Northern Brook Lamprey	3	4.478	0.294
Rainbow Trout	1	1.493	0.098

Spring 2005	6/24/2005		
Species	Number	Proportion	Catch/Minute
Burbot	2	16.667	0.212
Chinook Salmon	1	8.333	0.106
Lamprey	1	8.333	0.106
Mottled Sculpin	8	66.667	0.847

Summer 2005	7/27/2005		
Species	Number	Proportion	Catch/Minute
Burbot	2	10.000	0.240
Chinook Salmon	1	5.000	0.120
Mottled Sculpin	15	75.000	1.804
Rainbow Trout	1	5.000	0.120
White Sucker	1	5.000	0.120

Sickle Downstream #3

Spring 2004	6/22/2004		
Species	Number	Proportion	Catch/Minute
Burbot	6	13.043	0.615
Chinook Salmon	2	4.348	0.205
Coho Salmon	6	13.043	0.615
Creek Chub	1	2.174	0.103
Mottled Sculpin	28	60.870	2.872
Northern Brook Lamprey	1	2.174	0.103
Rainbow Trout	2	4.348	0.205

Summer 2004	8/9/2004		
Species	Number	Proportion	Catch/Minute
Brown Trout	1	1.299	0.096
Burbot	19	24.675	1.818
Central Mudminnow	1	1.299	0.096
Chinook Salmon	1	1.299	0.096
Coho Salmon	5	6.494	0.478
Grass Pickerel	1	1.299	0.096
Johnny Darter	3	3.896	0.287
Mottled Sculpin	36	46.753	3.445
Rainbow Trout	10	12.987	0.957

Spring 2005	6/23/2005		
Species	Number	Proportion	Catch/Minute
Burbot	4	6.667	0.401
Central Mudminnow	1	1.667	0.100
Chinook Salmon	1	1.667	0.100
Coho Salmon	12	20.000	1.204
Johnny Darter	1	1.667	0.100
Lamprey	1	1.667	0.100
Mottled Sculpin	38	63.333	3.813
Rainbow Trout	2	3.333	0.201

Summer 2005	7/27/2005		
Species	Number	Proportion	Catch/Minute
Brown Trout	1	4.167	0.116
Burbot	1	4.167	0.116
Chinook Salmon	3	12.500	0.349
Creek Chub	1	4.167	0.116
Johnny Darter	6	25.000	0.698
Mottled Sculpin	8	33.333	0.930
Rainbow Trout	4	16.667	0.465

Pine Creek Electrofishing Data

Pine Lake Road Upstream #2

Spring 2004 7/16/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	30	14.706	0.915
Bluegill	5	2.451	0.153
Brook Trout	2	0.980	0.061
Central Mudminnow	27	13.235	0.824
Coho Salmon	1	0.490	0.031
Creek Chub	46	22.549	1.403
Longnose Dace	18	8.824	0.549
Northern Redbelly Dace	69	33.824	2.105
Pumpkinseed	2	0.980	0.061
White Sucker	4	1.961	0.122

Summer 2004 8/11/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	50	26.60	3.61
Bluegill	6	3.19	0.43
Bluntnose Minnow	1	0.53	0.07
Brook Stickleback	3	1.60	0.22
Brook Trout	1	0.53	0.07
Brown Trout	1	0.53	0.07
Central Mudminnow	20	10.64	1.45
Creek Chub	35	18.62	2.53
Johnny Darter	1	0.53	0.07
Largemouth Bass	1	0.53	0.07
Mottled Sculpin	1	0.53	0.07
Northern Redbelly Dace	61	32.45	4.41
White Sucker	7	3.72	0.51

Spring 2005 7/11/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	38	23.899	2.327
Bluntnose Minnow	1	0.629	0.061
Brook Stickleback	4	2.516	0.245
Brook Trout	2	1.258	0.122
Brown Trout	1	0.629	0.061
Central Mudminnow	24	15.094	1.469
Common Shiner	2	1.258	0.122
Creek Chub	22	13.836	1.347
Northern Redbelly Dace	63	39.623	3.857
White Sucker	2	1.258	0.122

Summer 2005 8/16/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	62	27.193	4.537
Bluegill	6	2.632	0.439
Bluntnose Minnow	4	1.754	0.293
Brook Stickleback	8	3.509	0.585
Brook Trout	2	0.877	0.146
Brown Trout	1	0.439	0.073
Central Mudminnow	27	11.842	1.976
Creek Chub	39	17.105	2.854
Johnny Darter	2	0.877	0.146
Largemouth Bass	3	1.316	0.220
Northern Redbelly Dace	65	28.509	4.756
Redear Sunfish	1	0.439	0.073
White Sucker	8	3.509	0.585

Pine Lake Road Upstream #1

Spring 2004 7/14/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	28	30.435	1.246
Brook Stickleback	2	2.174	0.089
Central Mudminnow	6	6.522	0.267
Creek Chub	20	21.739	0.890
Longnose Dace	1	1.087	0.045
Northern Redbelly Dace	32	34.783	1.424
White Sucker	3	3.261	0.134

Summer 2004 8/11/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	53	31.93	4.08
Bluegill	2	1.20	0.15
Bluntnose Minnow	1	0.60	0.08
Brook Stickleback	10	6.02	0.77
Brook Trout	4	2.41	0.31
Central Mudminnow	22	13.25	1.69
Creek Chub	30	18.07	2.31
Northern Redbelly Dace	38	22.89	2.92
Rainbow Trout	1	0.60	0.08
White Sucker	5	3.01	0.38

Spring 2005 7/11/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	46	17.490	2.532
Bluntnose Minnow	63	23.954	3.468
Brook Stickleback	7	2.662	0.385
Central Mudminnow	45	17.110	2.477
Common Shiner	1	0.380	0.055
Creek Chub	21	7.985	1.156
Northern Redbelly Dace	69	26.236	3.798
Rainbow Trout	1	0.380	0.055
White Sucker	10	3.802	0.550

Summer 2005 8/16/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	38	26.027	2.850
Bluegill	4	2.740	0.300
Bluntnose Minnow	2	1.370	0.150
Brook Stickleback	10	6.849	0.750
Central Mudminnow	33	22.603	2.475
Creek Chub	23	15.753	1.725
Northern Redbelly Dace	33	22.603	2.475
Rainbow Trout	2	1.370	0.150
White Sucker	1	0.685	0.075

Pine Lake Road Downstream #1

Spring 2004	7/8/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	141	28.088	6.957
Bluegill	5	0.996	0.247
Brook Stickleback	2	0.398	0.099
Brook Trout	1	0.199	0.049
Brown Trout	1	0.199	0.049
Central Mudminnow	8	1.594	0.395
Creek Chub	65	12.948	3.207
Longnose Dace	8	1.594	0.395
Mottled Sculpin	2	0.398	0.099
Northern Redbelly Dace	260	51.793	12.829
Rainbow Trout	6	1.195	0.296
White Sucker	3	0.598	0.148

Summer 2004	8/11/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	101	51.01	5.94
Bluegill	2	1.01	0.12
Bluntnose Minnow	16	8.08	0.94
Central Mudminnow	4	2.02	0.24
Creek Chub	17	8.59	1.00
Largemouth Bass	1	0.51	0.06
Mottled Sculpin	1	0.51	0.06
Northern Redbelly Dace	46	23.23	2.71
Rainbow Trout	7	3.54	0.41
White Sucker	1	0.51	0.06
Yellow Bullhead	2	1.01	0.12

Spring 2005	7/7/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	112	40.580	6.575
Bluegill	1	0.362	0.059
Bluntnose Minnow	10	3.623	0.587
Central Mudminnow	22	7.971	1.292
Coho Salmon	3	1.087	0.176
Creek Chub	29	10.507	1.703
Green Sunfish	3	1.087	0.176
Mottled Sculpin	7	2.536	0.411
Northern Redbelly Dace	84	30.435	4.932
Rainbow Trout	2	0.725	0.117
White Sucker	3	1.087	0.176

Summer 2005	8/16/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	64	41.026	4.898
Bluegill	2	1.282	0.153
Bluntnose Minnow	12	7.692	0.918
Brook Trout	2	1.282	0.153
Brown Trout	1	0.641	0.077
Central Mudminnow	8	5.128	0.612
Creek Chub	11	7.051	0.842
Johnny Darter	2	1.282	0.153
Mottled Sculpin	5	3.205	0.383
Northern Redbelly Dace	41	26.282	3.138
Rainbow Trout	5	3.205	0.383
White Sucker	3	1.923	0.230

Pine Lake Road Downstream #2

Spring 2004	7/8/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	77	40.104	3.717
Bluegill	6	3.125	0.290
Brook Trout	6	3.125	0.290
Common Shiner	1	0.521	0.048
Creek Chub	26	13.542	1.255
Longnose Dace	2	1.042	0.097
Northern Redbelly Dace	72	37.500	3.475
Rainbow Trout	1	0.521	0.048
Rainbow Trout	1	0.521	0.048

Summer 2004	8/12/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	71	45.513	4.004
Bluegill	4	2.564	0.226
Brook Trout	10	6.410	0.564
Brown Trout	1	0.641	0.056
Central Mudminnow	2	1.282	0.113
Creek Chub	19	12.179	1.071
Mottled Sculpin	1	0.641	0.056
Northern Redbelly Dace	40	25.641	2.256
Rainbow Trout	8	5.128	0.451

Spring 2005	7/7/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	98	49.495	5.833
Bluntnose Minnow	7	3.535	0.417
Brook Trout	1	0.505	0.060
Central Mudminnow	6	3.030	0.357
Coho Salmon	1	0.505	0.060
Creek Chub	17	8.586	1.012
Green Sunfish	1	0.505	0.060
Mottled Sculpin	1	0.505	0.060
Northern Redbelly Dace	59	29.798	3.512
Rainbow Trout	7	3.535	0.417

Summer 2005	8/16/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	25	29.762	1.969
Brook Trout	10	11.905	0.787
Central Mudminnow	2	2.381	0.157
Creek Chub	9	10.714	0.709
Mottled Sculpin	3	3.571	0.236
Northern Redbelly Dace	25	29.762	1.969
Rainbow Trout	10	11.905	0.787

Pine Lake Road Downstream #3

Spring 2004 7/13/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	145	52.920	5.894
Bluegill	4	1.460	0.163
Bluntnose Minnow	1	0.365	0.041
Brook Trout	4	1.460	0.163
Central Mudminnow	7	2.555	0.285
Common Shiner	1	0.365	0.041
Creek Chub	21	7.664	0.854
Longnose Dace	4	1.460	0.163
Mottled Sculpin	1	0.365	0.041
Northern Redbelly Dace	85	31.022	3.455
White Sucker	1	0.365	0.041

Summer 2004 8/12/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	126	57.014	6.290
Bluegill	2	0.905	0.100
Brook Trout	4	1.810	0.200
Central Mudminnow	1	0.452	0.050
Coho Salmon	2	0.905	0.100
Creek Chub	42	19.005	2.097
Mottled Sculpin	4	1.810	0.200
Northern Redbelly Dace	30	13.575	1.498
Rainbow Trout	10	4.525	0.499

Spring 2005 7/7/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	94	63.514	5.562
Bluntnose Minnow	2	1.351	0.118
Brook Stickleback	1	0.676	0.059
Brook Trout	1	0.676	0.059
Brown Trout	1	0.676	0.059
Central Mudminnow	7	4.730	0.414
Coho Salmon	1	0.676	0.059
Creek Chub	21	14.189	1.243
Mottled Sculpin	3	2.027	0.178
Northern Redbelly Dace	14	9.459	0.828
Rainbow Trout	2	1.351	0.118
White Sucker	1	0.676	0.059

Summer 2005 8/16/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	49	38.889	3.774
Bluegill	4	3.175	0.308
Brook Trout	8	6.349	0.616
Central Mudminnow	7	5.556	0.539
Creek Chub	27	21.429	2.080
Mottled Sculpin	9	7.143	0.693
Northern Redbelly Dace	14	11.111	1.078
Rainbow Trout	7	5.556	0.539
Yellow Bullhead	1	0.794	0.077

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Spring 2004 7/14/2004

Species	Number	Proportion	Catch/Minute
Bluegill	1	0.935	0.048
Blacknose Dace	56	52.336	2.710
Brown Trout	10	9.346	0.484
Brook Trout	1	0.935	0.048
Creek Chub	4	3.738	0.194
Johnny Darter	1	0.935	0.048
Longnose Dace	3	2.804	0.145
Mottled Sculpin	3	2.804	0.145
Central Mudminnow	4	3.738	0.194
Northern Redbelly Dace	20	18.692	0.968
White Sucker	4	3.738	0.194

Summer 2004 8/11/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	114	65.517	5.556
Brook Trout	1	0.575	0.049
Brown Trout	11	6.322	0.536
Creek Chub	9	5.172	0.439
Johnny Darter	1	0.575	0.049
Largemouth Bass	1	0.575	0.049
Mottled Sculpin	14	8.046	0.682
Rainbow Trout	13	7.471	0.634
White Sucker	10	5.747	0.487

Spring 2005 7/6/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	111	72.549	5.925
Brown Trout	4	2.614	0.214
Brook Trout	2	1.307	0.107
Central Mudminnow	2	1.307	0.107
Creek Chub	9	5.882	0.480
Johnny Darter	2	1.307	0.107
Mottled Sculpin	8	5.229	0.427
Northern Redbelly Dace	2	1.307	0.107
Rainbow Trout	6	3.922	0.320
White Sucker	7	4.575	0.374

Summer 2005 8/10/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	60	50.420	3.659
Brook Trout	2	1.681	0.122
Brown Trout	7	5.882	0.427
Creek Chub	10	8.403	0.610
Johnny Darter	2	1.681	0.122
Largemouth Bass	1	0.840	0.061
Mottled Sculpin	14	11.765	0.854
Rainbow Trout	14	11.765	0.854
Rock Bass	1	0.840	0.061
White Sucker	8	6.723	0.488

Steinberg Road Upstream #2

Spring 2004 7/15/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	72	78.261	3.303
Bluegill	1	1.087	0.046
Brook Trout	1	1.087	0.046
Brown Trout	2	2.174	0.092
Coho Salmon	1	1.087	0.046
Creek Chub	3	3.261	0.138
Mottled Sculpin	9	9.783	0.413
Rainbow Trout	2	2.174	0.092
White Sucker	1	1.087	0.046

Summer 2004 8/13/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	36	52.174	3.956
Bluegill	1	1.449	0.110
Brown Trout	4	5.797	0.440
Central Mudminnow	12	17.391	1.319
Coho Salmon	1	1.449	0.110
Creek Chub	5	7.246	0.549
Mottled Sculpin	2	2.899	0.220
Rainbow Trout	5	7.246	0.549
White Sucker	3	4.348	0.330

Spring 2005 7/6/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	41	57.746	2.228
Brook Trout	1	1.408	0.054
Brown Trout	3	4.225	0.163
Central Mudminnow	1	1.408	0.054
Creek Chub	3	4.225	0.163
Johnny Darter	2	2.817	0.109
Mottled Sculpin	14	19.718	0.761
Rainbow Trout	3	4.225	0.163
Red ear Sunfish	1	1.408	0.054
White Sucker	2	2.817	0.109

Summer 2005 8/10/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	36	58.065	2.842
Brook Trout	3	4.839	0.237
Brown Trout	2	3.226	0.158
Central Mudminnow	6	9.677	0.474
Coho Salmon	2	3.226	0.158
Mottled Sculpin	8	12.903	0.632
Rainbow Trout	2	3.226	0.158
White Sucker	3	4.839	0.237

Steinberg Road Upstream #1

Spring 2004 7/14/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	44	73.333	2.505
Brown Trout	2	3.333	0.114
Central Mudminnow	2	3.333	0.114
Creek Chub	1	1.667	0.057
Johnny Darter	1	1.667	0.057
Mottled Sculpin	6	10.000	0.342
Rainbow Trout	3	5.000	0.171
White Sucker	1	1.667	0.057

Summer 2004 8/13/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	84	65.116	6.139
Brown Trout	3	2.326	0.219
Central Mudminnow	10	7.752	0.731
Chinook Salmon	1	0.775	0.073
Coho Salmon	2	1.550	0.146
Creek Chub	4	3.101	0.292
Mottled Sculpin	12	9.302	0.877
Northern Redbelly Dace	4	3.101	0.292
Rainbow Trout	7	5.426	0.512
White Sucker	2	1.550	0.146

Spring 2005 7/6/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	51	53.125	3.048
Brook Stickleback	1	1.042	0.060
Central Mudminnow	6	6.250	0.359
Coho Salmon	2	2.083	0.120
Creek Chub	4	4.167	0.239
Johnny Darter	2	2.083	0.120
Mottled Sculpin	18	18.750	1.076
Northern Redbelly Dace	9	9.375	0.538
Rainbow Trout	3	3.125	0.179

Summer 2005 8/10/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	23	42.593	1.865
Brook Stickleback	1	1.852	0.081
Brown Trout	4	7.407	0.324
Central Mudminnow	5	9.259	0.405
Coho Salmon	3	5.556	0.243
Mottled Sculpin	13	24.074	1.054
Rainbow Trout	3	5.556	0.243
White Sucker	2	3.704	0.162

Steinberg Road Downstream #1

Spring 2004 7/15/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	45	71.429	2.290
Brown Trout	5	7.937	0.254
Central Mudminnow	1	1.587	0.051
Creek Chub	1	1.587	0.051
Mottled Sculpin	6	9.524	0.305
Rainbow Trout	4	6.349	0.204
White Sucker	1	1.587	0.051

Summer 2004 8/16/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	64	62.136	4.689
Bluegill	3	2.913	0.220
Brown Trout	9	8.738	0.659
Central Mudminnow	2	1.942	0.147
Coho Salmon	2	1.942	0.147
Johnny Darter	2	1.942	0.147
Mottled Sculpin	12	11.650	0.879
Rainbow Trout	9	8.738	0.659

Spring 2005 7/5/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	24	43.636	1.341
Brook Stickleback	1	1.818	0.056
Brook Trout	1	1.818	0.056
Brown Trout	2	3.636	0.112
Burbot	1	1.818	0.056
Central Mudminnow	8	14.545	0.447
Creek Chub	3	5.455	0.168
Mottled Sculpin	10	18.182	0.559
Northern Redbelly Dace	2	3.636	0.112
Rainbow Trout	2	3.636	0.112

Summer 2005 8/9/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	52	61.905	5.652
Brook Stickleback	2	2.381	0.217
Brook Trout	1	1.190	0.109
Brown Trout	3	3.571	0.326
Central Mudminnow	6	7.143	0.652
Coho Salmon	2	2.381	0.217
Creek Chub	6	7.143	0.652
Johnny Darter	2	2.381	0.217
Mottled Sculpin	1	1.190	0.109
Rainbow Trout	7	8.333	0.761
White Sucker	2	2.381	0.217

Steinberg Road Downstream #2

Spring 2004 7/16/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	50	44.643	2.101
Bluegill	1	0.893	0.042
Brown Trout	8	7.143	0.336
Central Mudminnow	2	1.786	0.084
Coho Salmon	2	1.786	0.084
Creek Chub	7	6.250	0.294
Longnose Dace	22	19.643	0.924
Mottled Sculpin	14	12.500	0.588
Rainbow Trout	6	5.357	0.252

Summer 2004 8/16/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	63	56.250	4.484
Bluegill	1	0.893	0.071
Brook Trout	1	0.893	0.071
Brown Trout	5	4.464	0.356
Central Mudminnow	10	8.929	0.712
Chinook Salmon	1	0.893	0.071
Coho Salmon	3	2.679	0.214
Creek Chub	5	4.464	0.356
Mottled Sculpin	7	6.250	0.498
Pumpkinseed	1	0.893	0.071
Rainbow Trout	12	10.714	0.854
White Sucker	3	2.679	0.214

Spring 2005 7/5/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	18	45.000	1.071
Brook Stickleback	1	2.500	0.060
Brook Trout	1	2.500	0.060
Brown Trout	3	7.500	0.179
Central Mudminnow	4	10.000	0.238
Creek Chub	1	2.500	0.060
Mottled Sculpin	9	22.500	0.536
Rainbow Trout	2	5.000	0.119
White Sucker	1	2.500	0.060

Summer 2005 8/9/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	39	42.857	4.239
Brook Trout	2	2.198	0.217
Brown Trout	5	5.495	0.543
Central Mudminnow	5	5.495	0.543
Chinook Salmon	1	1.099	0.109
Coho Salmon	5	5.495	0.543
Creek Chub	1	1.099	0.109
Mottled Sculpin	19	20.879	2.065
Rainbow Trout	12	13.187	1.304
White Sucker	2	2.198	0.217

Steinberg Road Downstream #3

Spring 2004 7/16/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	50	43.103	1.609
Bluegill	1	0.862	0.032
Brown Trout	18	15.517	0.579
Central Mudminnow	1	0.862	0.032
Creek Chub	4	3.448	0.129
Longnose Dace	2	1.724	0.064
Mottled Sculpin	31	26.724	0.998
Rainbow Trout	9	7.759	0.290

Summer 2004 8/16/2004

Species	Number	Proportion	Catch/Minute
Blacknose Dace	61	48.8	4.480
Bluegill	1	0.8	0.073
Brook Trout	1	0.8	0.073
Brown Trout	23	18.4	1.689
Chinook Salmon	1	0.8	0.073
Coho Salmon	4	3.2	0.294
Creek Chub	6	4.8	0.441
Mottled Sculpin	17	13.6	1.248
Rainbow Trout	11	8.8	0.808

Spring 2005 7/5/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	19	30.645	1.132
Brown Trout	2	3.226	0.119
Central Mudminnow	2	3.226	0.119
Coho Salmon	1	1.613	0.060
Mottled Sculpin	32	51.613	1.907
Northern Redbelly Dace	1	1.613	0.060
Rainbow Trout	5	8.065	0.298

Summer 2005 8/9/2005

Species	Number	Proportion	Catch/Minute
Blacknose Dace	59	32.240	4.487
Brown Trout	7	3.825	0.532
Chinook Salmon	5	2.732	0.380
Coho Salmon	3	1.639	0.228
Creek Chub	1	0.546	0.076
Johnny Darter	2	1.093	0.152
Mottled Sculpin	85	46.448	6.464
Rainbow Trout	17	9.290	1.293
White Sucker	4	2.186	0.304

Huff Road

Spring 2004 5/19/2004

Species	Number	Proportion	Catch/Minute
Bluegill	2	0.844	0.024
Brown Trout	93	39.241	1.130
Central Mudminnow	1	0.422	0.012
Chinook Salmon	25	10.549	0.304
Coho Salmon	23	9.705	0.280
Common Shiner	2	0.844	0.024
Mottled Sculpin	46	19.409	0.559
Rainbow Trout	44	18.565	0.535
Yellow Bullhead	1	0.422	0.012

Summer 2004 8/17/2004

Species	Number	Proportion	Catch/Minute
Bluegill	3	0.513	0.041
Brown Trout	292	49.915	4.031
Chinook Salmon	6	1.026	0.083
Coho Salmon	19	3.248	0.262
Mottled Sculpin	68	11.624	0.939
Rainbow Trout	197	33.675	2.720

Spring 2005 6/10/2005

Species	Number	Proportion	Catch/Minute
Brook Trout	3	1.075	0.051
Brown Trout	135	48.387	2.274
Chinook Salmon	21	7.527	0.354
Coho Salmon	5	1.792	0.084
Mottled Sculpin	40	14.337	0.674
Rainbow Trout	64	22.939	1.078
White Sucker	11	3.943	0.185

Summer 2005 8/8/2005

Species	Number	Proportion	Catch/Minute
Brown Trout	244	50.206	5.014
Burbot	3	0.617	0.062
Chinook Salmon	14	2.881	0.288
Coho Salmon	16	3.292	0.329
Creek Chub	1	0.206	0.021
Mottled Sculpin	54	11.111	1.110
Rainbow Trout	154	31.687	3.164

Bear Creek Electrofishing Data

Milks Road Upstream

Summer 2004	8/8/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	105	41.339	1.881
Bluegill	7	2.756	0.125
Brook Stickleback	1	0.394	0.018
Brown Trout	11	4.331	0.197
Burbot	11	4.331	0.197
Central Mudminnow	1	0.394	0.018
Chinook Salmon	1	0.394	0.018
Creek Chub	16	6.299	0.287
Johnny Darter	10	3.937	0.179
Longnose Dace	10	3.937	0.179
Mottled Sculpin	12	4.724	0.215
Northern Pike	1	0.394	0.018
Rainbow Trout	19	7.480	0.340
White Sucker	49	19.291	0.878

Spring 2005	6/22/2005		
Species	Number	Proportion	Catch/Minu
Blacknose Dace	139	41.742	2.089
Bluegill	1	0.300	0.015
Brook Trout	7	2.102	0.105
Brown Trout	8	2.402	0.120
Burbot	3	0.901	0.045
Central Mudminnow	9	2.703	0.135
Chinook Salmon	44	13.213	0.661
Coho Salmon	4	1.201	0.060
Creek Chub	1	0.300	0.015
Golden Redhorse	1	0.300	0.015
Johnny Darter	13	3.904	0.195
Lamprey	2	0.601	0.030
Mottled Sculpin	12	3.604	0.180
Rainbow Trout	69	20.721	1.037
White Sucker	20	6.006	0.301

Summer 2005	8/3/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	156	32.099	2.818
Brook Trout	4	0.823	0.072
Brown Trout	14	2.881	0.253
Burbot	4	0.823	0.072
Central Mudminnow	7	1.440	0.126
Chinook Salmon	9	1.852	0.163
Coho Salmon	3	0.617	0.054
Creek Chub	14	2.881	0.253
Green Sunfish	1	0.206	0.018
Johnny Darter	37	7.613	0.668
Mottled Sculpin	62	12.757	1.120
Northern Brook Lamprey	7	1.440	0.126
Rainbow Trout	127	26.132	2.294
White Sucker	40	8.230	0.723
Yellow Perch	1	0.206	0.018

Milks Road Downstream

Summer 2004	8/8/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	137	49.104	2.394
Bluegill	27	9.677	0.472
Brown Trout	8	2.867	0.140
Burbot	2	0.717	0.035
Central Mudminnow	2	0.717	0.035
Chinook Salmon	2	0.717	0.035
Creek Chub	29	10.394	0.507
Green Sunfish	2	0.717	0.035
Johnny Darter	12	4.301	0.210
Mottled Sculpin	25	8.961	0.437
Rainbow Trout	17	6.093	0.297
White Sucker	16	5.735	0.280

Spring 2005	6/22/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	88	33.208	1.597
Brook Trout	1	0.377	0.018
Brown Bullhead	1	0.377	0.018
Brown Trout	11	4.151	0.200
Burbot	2	0.755	0.036
Central Mudminnow	2	0.755	0.036
Chinook Salmon	53	20.000	0.962
Coho Salmon	2	0.755	0.036
Creek Chub	11	4.151	0.200
Golden Redhorse	1	0.377	0.018
Johnny Darter	6	2.264	0.109
Lamprey	3	1.132	0.054
Mottled Sculpin	8	3.019	0.145
Rainbow Trout	62	23.396	1.125
White Sucker	14	5.283	0.254

Summer 2005	8/3/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	67	25.475	1.475
Bluntnose Minnow	2	0.760	0.044
Brook Trout	1	0.380	0.022
Brown Trout	6	2.281	0.132
Burbot	13	4.943	0.286
Central Mudminnow	3	1.141	0.066
Chinook Salmon	11	4.183	0.242
Coho Salmon	9	3.422	0.198
Creek Chub	12	4.563	0.264
Green Sunfish	2	0.760	0.044
Johnny Darter	12	4.563	0.264
Largemouth Bass	1	0.380	0.022
Longnose Dace	2	0.760	0.044
Mottled Sculpin	24	9.125	0.528
Northern Brook Lamprey	5	1.901	0.110
Pumpkinseed	1	0.380	0.022
Rainbow Trout	77	29.278	1.695
White Sucker	14	5.323	0.308
Yellow Perch	1	0.380	0.022

Swain Property Upstream

Summer 2004	8/6/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	139	50.91575	3.682119205
Bluegill	6	2.197802	0.158940397
Brown Trout	13	4.761905	0.344370861
Burbot	2	0.732601	0.052980132
Central Mudminnow	1	0.3663	0.026490066
Chinook Salmon	2	0.732601	0.052980132
Creek Chub	17	6.227106	0.450331126
Golden Redhorse Sucker	1	0.3663	0.026490066
Johnny Darter	19	6.959707	0.503311258
Longnose Dace	3	1.098901	0.079470199
Mottled Sculpin	7	2.564103	0.185430464
Rainbow Trout	32	11.72161	0.847682119
Shorthead Redhorse Sucker	3	1.098901	0.079470199
White Sucker	28	10.25641	0.741721854

Spring 2005	6/7/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	73	32.444	2.022
Bluegill	1	0.444	0.028
Brook Trout	2	0.889	0.055
Brown Trout	1	0.444	0.028
Burbot	5	2.222	0.139
Chinook Salmon	72	32.000	1.994
Coho Salmon	6	2.667	0.166
Creek Chub	9	4.000	0.249
Golden Redhorse	1	0.444	0.028
Johnny Darter	8	3.556	0.222
Mottled Sculpin	7	3.111	0.194
Rainbow Trout	22	9.778	0.609
White Sucker	18	8.000	0.499

Summer 2005	8/2/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	85	30.576	2.044
Bluegill	1	0.360	0.024
Bluntnose Minnow	1	0.360	0.024
Brown Trout	9	3.237	0.216
Burbot	8	2.878	0.192
Chinook Salmon	13	4.676	0.313
Coho Salmon	6	2.158	0.144
Creek Chub	9	3.237	0.216
Golden Redhorse Sucker	2	0.719	0.048
Johnny Darter	10	3.597	0.240
Largemouth Bass	1	0.360	0.024
Longnose Dace	1	0.360	0.024
Mottled Sculpin	26	9.353	0.625
Northern Brook Lamprey	4	1.439	0.096
Northern Redbelly Dace	4	1.439	0.096
Rainbow Trout	87	31.295	2.092
White Sucker	11	3.957	0.265

Swain Property Downstream

Summer 2004	8/6/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	165	49.107	4.371
Bluegill	1	0.298	0.026
Brook Stickleback	1	0.298	0.026
Brown Trout	5	1.488	0.132
Burbot	1	0.298	0.026
Central Mudminnow	5	1.488	0.132
Chinook Salmon	2	0.595	0.053
Coho Salmon	5	1.488	0.132
Common Shiner	3	0.893	0.079
Creek Chub	19	5.655	0.503
Golden Redhorse Sucker	1	0.298	0.026
Johnny Darter	22	6.548	0.583
Longnose Dace	1	0.298	0.026
Mottled Sculpin	15	4.464	0.397
Rainbow Trout	65	19.345	1.722
Shorthead Redhorse Sucker	1	0.298	0.026
White Sucker	24	7.143	0.636

Spring 2005	6/7/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	26	22.609	0.783
Brook Trout	1	0.870	0.030
Brown Trout	1	0.870	0.030
Central Mudminnow	2	1.739	0.060
Chinook Salmon	30	26.087	0.904
Coho Salmon	3	2.609	0.090
Creek Chub	4	3.478	0.120
Golden Redhorse	12	10.435	0.361
Johnny Darter	11	9.565	0.331
Mottled Sculpin	1	0.870	0.030
Rainbow Trout	8	6.957	0.241
White Sucker	16	13.913	0.482

Summer 2005	8/2/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	59	32.597	1.674
Brown Trout	9	4.972	0.255
Burbot	3	1.657	0.085
Chinook Salmon	7	3.867	0.199
Creek Chub	2	1.105	0.057
Golden Redhorse Sucker	3	1.657	0.085
Johnny Darter	14	7.735	0.397
Largemouth Bass	3	1.657	0.085
Mottled Sculpin	10	5.525	0.284
Northern Brook Lamprey	2	1.105	0.057
Rainbow Trout	60	33.149	1.702
White Sucker	9	4.972	0.255

Johnson Road

Summer 2004	7/30/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	237	50.641	2.841
Bluegill	7	1.496	0.084
Brook Stickleback	5	1.068	0.060
Brown Trout	6	1.282	0.072
Burbot	1	0.214	0.012
Central Mudminnow	18	3.846	0.216
Coho Salmon	5	1.068	0.060
Common Shiner	1	0.214	0.012
Creek Chub	25	5.342	0.300
Greater Redhorse Sucker	1	0.214	0.012
Johnny Darter	15	3.205	0.180
Longnose Dace	29	6.197	0.348
Mottled Sculpin	41	8.761	0.491
Raibow Trout	37	7.906	0.443
White Sucker	40	8.547	0.479

Spring 2005	6/3/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	66	27.049	1.018
Bluegill	2	0.820	0.031
Brown Trout	5	2.049	0.077
Central Mudminnow	1	0.410	0.015
Chinook Salmon	22	9.016	0.339
Coho Salmon	27	11.066	0.417
Common Shiner	3	1.230	0.046
Creek Chub	13	5.328	0.201
Golden Redhorse	5	2.049	0.077
Johnny Darter	15	6.148	0.231
Longnose Dace	1	0.410	0.015
Mottled Sculpin	11	4.508	0.170
Northern Redbelly Dace	4	1.639	0.062
Rainbow Trout	15	6.148	0.231
White Sucker	54	22.131	0.833

Summer 2005	8/5/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	225	27.881	3.238
Bluegill	1	0.124	0.014
Brown Trout	9	1.115	0.130
Burbot	3	0.372	0.043
Central Mudminnow	9	1.115	0.130
Chinook Salmon	95	11.772	1.367
Common Shiner	4	0.496	0.058
Creek Chub	45	5.576	0.648
Golden Redhorse Sucker	1	0.124	0.014
Johnny Darter	39	4.833	0.561
Largemouth Bass	3	0.372	0.043
Longnose Dace	13	1.611	0.187
Mottled Sculpin	69	8.550	0.993
Northern Redbelly Dace	5	0.620	0.072
Rainbow Trout	227	28.129	3.267
Redear Sunfish	1	0.124	0.014
White Sucker	58	7.187	0.835

Spirit of the Woods

Summer 2004	7/28/2004		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	70	16.166	0.671
Bluegill	8	1.848	0.077
Brown Trout	48	11.085	0.460
Burbot	72	16.628	0.690
Central Mudminnow	3	0.693	0.029
Coho Salmon	4	0.924	0.038
Common Shiner	1	0.231	0.010
Creek Chub	99	22.864	0.949
Greater Redhorse Sucker	2	0.462	0.019
Johnny Darter	7	1.617	0.067
Longnose Dace	27	6.236	0.259
Mottled Sculpin	25	5.774	0.240
Rainbow Trout	21	4.850	0.201
White Sucker	45	10.393	0.431
Yellow Perch	1	0.231	0.010

Spring 2005	6/2/2005		
Species	Number	Proportion	Catch/Minu
Blacknose Dace	10	5.405	0.165
Brown Trout	26	14.054	0.430
Burbot	11	5.946	0.182
Chinook Salmon	15	8.108	0.248
Coho Salmon	5	2.703	0.083
Creek Chub	6	3.243	0.099
Golden Redhorse	5	2.703	0.083
Johnny Darter	6	3.243	0.099
Longnose Dace	1	0.541	0.017
Mottled Sculpin	5	2.703	0.083
Pumpkinseed	1	0.541	0.017
Rainbow Trout	14	7.568	0.231
Shorthead Redhorse	23	12.432	0.380
White Sucker	56	30.270	0.925
Yellow Perch	1	0.541	0.017

Summer 2005	8/4/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	11	7.534	0.181
Brown Trout	30	20.548	0.493
Chinook Salmon	14	9.589	0.230
Coho Salmon	3	2.055	0.049
Common Shiner	2	1.370	0.033
Creek Chub	11	7.534	0.181
Golden Redhorse Sucker	2	1.370	0.033
Johnny Darter	2	1.370	0.033
Mottled Sculpin	3	2.055	0.049
Rainbow Trout	22	15.068	0.362
Redear Sunfish	1	0.685	0.016
White Sucker	45	30.822	0.740

Lower Bear Creek

Summer 2004	7/27/2004		
Species	Number	Proportion	Catch/Minute
Alewife	2	0.548	0.025
Blacknose Dace	1	0.274	0.013
Bluegill	1	0.274	0.013
Brown Trout	16	4.384	0.202
Burbot	217	59.452	2.738
Central Mudminnow	21	5.753	0.265
Chinook Salmon	2	0.548	0.025
Coho Salmon	1	0.274	0.013
Creek Chub	12	3.288	0.151
Grass Pickerel	1	0.274	0.013
Johnny Darter	25	6.849	0.315
Mottled Sculpin	37	10.137	0.467
Northern Pike	1	0.274	0.013
Rainbow Trout	5	1.370	0.063
Rock Bass	7	1.918	0.088
White Sucker	16	4.384	0.202

Spring 2005	6/1/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	10	3.378	0.159
Brown Trout	14	4.730	0.223
Burbot	47	15.878	0.748
Central Mudminnow	29	9.797	0.462
Chinook Salmon	30	10.135	0.477
Coho Salmon	21	7.095	0.334
Common Shiner	2	0.676	0.032
Creek Chub	9	3.041	0.143
Johnny Darter	3	1.014	0.048
Mottled Sculpin	39	13.176	0.621
Rainbow Trout	20	6.757	0.318
Shorthead Redhorse	1	0.338	0.016
White Sucker	71	23.986	1.130

Summer 2005	8/1/2005		
Species	Number	Proportion	Catch/Minute
Blacknose Dace	3	1.079	0.059
Blacksided Dace	2	0.719	0.039
Brown Trout	13	4.676	0.254
Burbot	103	37.050	2.014
Central Mudminnow	27	9.712	0.528
Chinook Salmon	12	4.317	0.235
Common Shiner	1	0.360	0.020
Creek Chub	32	11.511	0.626
Johnny Darter	10	3.597	0.196
Largemouth Bass	1	0.360	0.020
Mottled Sculpin	24	8.633	0.469
Northern Brook Lamprey	1	0.360	0.020
Northern Pike	2	0.719	0.039
Rainbow Trout	14	5.036	0.274
Rock Bass	6	2.158	0.117
White Sucker	27	9.712	0.528