Michigan DNR

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

Number 2059
June 2001

Dam Removal Effects on Fisheries Resources, Habitat, and Summer Diet of Trout in The Pine River Manistee County, Michigan

Jessica L. Mistak

www.dnr.state.mi.us

FISHERIES DIVISION
RESEARCH REPORT

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Research Report 2059
June 2001

Dam removal effects on fisheries resources, habitat, and summer diet of trout in the Pine River Manistee County, Michigan

Jessica L. Mistak

Printed under authority of Michigan Department of Natural Resources
Total number of copies printed 200 — Total cost $1,770.20 — Cost per copy $8.85

DAM REMOVAL EFFECTS ON FISHERIES RESOURCES, HABITAT, AND SUMMER DIET OF TROUT IN THE PINE RIVER MANISTEE COUNTY, MICHIGAN

By

Jessica L. Mistak

A THESIS
Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

2000

ABSTRACT

DAM REMOVAL EFFECTS ON FISHERIES RESOURCES, HABITAT, AND SUMMER DIET OF TROUT IN THE PINE RIVER, MANISTEE COUNTY, MICHIGAN

By

Jessica L. Mistak

Stronach Dam was built in 1912 as a hydroelectric facility. The Pine River carries a high bedload of sand, which contributed to the filling of the reservoir and the 1953 decommissioning of the dam. The staged removal of Stronach Dam began in 1996 and is expected to be complete in 2003. Baseline habitat conditions were assessed in 1995 to delineate distinct zones: the Downstream Zone, the Impacted Zone, and the Non-Impacted Zone. Survey data has shown streambed elevation changes in the areas near the dam. Electrofishing results indicated that trout were most abundant upstream of the dam and were fast growing compared to state averages, but had a low overall biomass compared to similar rivers. White suckers were most abundant downstream of the dam and were slow growing. Annual monitoring of the habitat and fish population will continue throughout the removal process. A summer trout diet study showed that stomach fullness was generally high but declined over the summer. Trout fed similarly throughout the river within a single month. The most abundant prey items found in the diet were underused in comparison to their availability in the drift. Based on their growth and diet, trout biomass did not appear to be controlled by a low number of drifting macroinvertebrates. Further research needs to be conducted to determine the exact cause of limiting trout numbers.

To all the little brook trout.

ACKNOWLEDGEMENTS

Recognition is given to the Michigan Department of Natural Resources for their support in the form of funding and assistance in the field. Additional thanks are given to the U.S. Forest Service, Consumers Power, and Trout Unlimited for various forms of support throughout the project. Specific individuals from these agencies who provided assistance include Tom Rozich, Mark Tonello, Troy Zorn, Bob Stuber, Tom Moris, and Dave Battige.

I would like to thank my advisor, Dan Hayes, for keeping me entertained while directing my development as a fisheries scientist. My gratitude is also extended to my committee members Rich Merritt and Mary Bremigan for their guidance. My lab mates were a continuous source of ideas and reprieve. I need to especially thank my comrade in arms, JoAnna Lessard, for motivation and encouragement.

I would never have accomplished my research without the help of my field and lab technicians: Jeff Leighton, Nolan Banish, Ed McCoy, and Dean Burdett, These fellow trout lovers deserve recognition for all of their hard work in the field and lab.

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Effects of Stronach Dam Removal on Fisheries Resources and Habitat

INTRODUCTION

The building of dams on North American streams began in the 1800's (Petts 1980), with the largest effort towards dam construction occurring in the 1930's (Benke 1990). Dams provide society with drinking water, routes of travel and transport, irrigation, waste removal, and renewable energy (Allan and Flecker 1993). The Nationwide Rivers Inventory, completed in 1982 by the National Park Service, estimated a total 5,200,000-km of rivers in the lower 48 states. Of this, less than 200 km of the 42 river systems surveyed were determined to be high quality and free flowing (Benke 1990). Today, all large rivers in the United States have been impounded in at least some reaches with the exception of the Yellowstone and Salmon rivers (Kohler and Hubert 1993). The number of dams greater than six feet tall is estimated between 68,000 and 75,000, while millions of dams smaller than six feet in height exist nationwide (Shuman 1995). Of all dams, private entities or municipalities own 90%, while state and federal government agencies own 7% (Shuman 1995).

The effects of dams have been well documented (Hammad 1972, Ligon et al. 1995, Shuman 1995, Petts 1980, Cushman 1985, Doppelt 1993, Benke 1990, Bain et al. 1988, and Ward and Stanford 1989). The damming of a river or stream has been called a cataclysmic event in the life of a riverine ecosystem (Gup 1994). Dams interrupt and alter most of a river's ecological processes by changing the flow of water, sediment, nutrients, energy and biota (Ligon et al. 1995). Some of the main ecological issues regarding effects of dams include temperature change, prevention of fish migration, and altered flow regimes. In many streams, discharge is artificially regulated by dams. Dams transform long river reaches into impoundments and change downstream reaches, resulting in streambed degradation (Kohler and Hubert 1993).

Dam removal has become an increasingly visible topic in the past few years because it not only removes barriers to migrating fish, but also serves as a river restoration tool. Recent dam removal projects and proposals that have received national attention include the 1999 removal of Edwards Dam in Maine and the proposed removal of the four lower Snake River dams in Washington. Across the nation, many smaller projects are currently being pursued. Wisconsin in particular has actively engaged in the removal of small dams (Born et al. 1998) with approximately 30 dams removed in the last 20 to 30 years.

Many of the more than 68,000 large dams in the United States are privately owned, built 50 to 150 years ago (Haberman 1995). The Federal Energy Regulatory Commission (FERC) is the agency responsible for the licensing of private hydroelectric projects and issues operational permits which are valid for 30 to 50 years (Bowers and Bowman 1995). In addition, new license applications are subject to an amendment of the Federal Power Act which requires the FERC to equally consider the "adequate protection, mitigation, and enhancement of fish and wildlife (including spawning grounds and habitat)" when licensing hydropower operations (Scurlock et al. 1993). With hundreds of dams coming up for relicensing, managers are looking for ways of dealing with aging dams that are deteriorated, pose safety hazards, or are no longer economical to operate. For these dams, the cost of rehabilitation is often very high, positioning removal as an increasingly viable alternative for river restoration (Shuman 1995). Yet with all of this interest, there is a relatively small amount of scientific information relating to dam removal, including pre- and post-dam removal studies, to determine the responses of habitat and fish populations within the river. Hence, more information is needed to assess the benefits of dam removal projects.

Stronach Dam was built in 1912 on the Pine River, Manistee County, Michigan. Original construction of the 12-foot concrete dam created a 26-hectare reservoir. The Pine River is a coldwater stream with valued resident populations of brook trout (*Salvelinus fontinalus*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*). As the Pine River flows downstream, it joins with the Manistee River to create Tippy Reservoir above Tippy Dam.

Logging operations during the late 1800's created unstable banks along the Pine River. As a result, the river carries a high sand bedload. Problems with the operation of the dam's turbines transpired immediately as a result of this sediment load. Although attempts were made in the 1930's and 1940's to remove the sediment that built up in the reservoir, these efforts were only marginally successful. Over time the original reservoir, acting as a sediment trap, filled up with sand and other fine sediment. Subsequently, the dam was decommissioned by Consumers Power Company as a power-generating plant in 1953.

In the early 1990's, it was decided that removal of Stronach Dam was an appropriate action after considering other alternatives that would have involved costly improvements to maintain the safety of the already deteriorating structure. This removal was proposed as part of a FERC agreement in the relicensing of the Tippy Dam hydroelectric project on the Manistee River. The staged removal of Stronach Dam commenced in fall of 1996 with completion expected in 2003. The removal process involves the removal of a six-inch stoplog every three months over a course of six years. Removing the dam in this manner allows the river to gradually restore its channel in the areas closest to the dam with the least amount of environmental impact, at the lowest cost, and without impacting the operation of Tippy Dam (Battige et al. 1997).

With the removal of the dam, it was predicted that downcutting of the streambed upstream of the dam would expose a gravel/cobble substrate (Resource Management Group 1994). One of the goals of the dam removal is to restore the 3.8-kilometer Impacted Zone, where the old reservoir used to be, to near pre-dam conditions. Because the existing sand substrate in the Impacted Zone provides poor habitat for invertebrate food organisms (Pennak and VanGerpen 1947, Hynes 1970, Merritt and Cummins 1996), the existing habitat is considered to be sub-optimal for fish. Additionally, the sand substrate buries spawning gravel and destroys cover, ultimately reducing survival of early life stage trout (Alexander and Hansen 1983). Uncovering of a coarser substrate not only creates more diverse hydraulic and channel conditions favorable for efficient resting and feeding behavior of fish, it also results in increased habitat for aquatic invertebrates. Ultimately, it is predicted that the growth rate and abundance of trout in the Impacted Zone will increase.

To better understand the response of sediment to dam removal, usually one of the greatest concerns, other studies were consulted. As an example, after the 1969 dam removal on the Muskegon River in Michigan, it was estimated that nearly 40% of the sediment from the impoundment flushed downstream immediately (Shuman 1995). The remaining sand was expected to take 50 to 80 years to fully flush through the Muskegon River system (Simons and Simons 1991). Likewise, after the removal of the Woolen Mills

Dam in Wisconsin, sediment from the impoundment was scoured out within six months, leaving behind a gravel and rubble substrate (Kanehl et al. 1997). Ultimately, the response of sediment corresponds to dynamic changes within the river system, which may not reach full equilibrium for many years.

Being a barrier to fish migration, removal of the dam will allow fish populations that currently reside only below the dam access upstream. Although river connectivity is generally perceived as favorable, one of the primary concerns of anglers and other enthusiasts focuses on the potential migration of fish from Tippy Reservoir into the upper reaches of the Pine River. The reservoir supports coolwater fish species such as yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), and white suckers (*Catostomus commersoni*). While some of these species are currently found upstream of the dam, there is concern that migration may occur in sufficient numbers to negatively impact the trout fishery above the dam. Overall fish production is expected to increase as fish, specifically trout, have more access to favorable habitats on a seasonal basis. Although this is desirable from an ecological perspective, from a fishery perspective there is some concern that increases in total fish production may occur at the expense of desirable game species.

The long-term goal of this project is to determine how the dam removal and potential for fish migration from Tippy Reservoir affect the salmonid populations in the Pine River. The research presented here continues the evaluation of fish and habitat response to the removal of Stronach Dam that began in 1995. My continued monitoring of the Pine River will be added to previously collected baseline data. As a result, changes in the biotic community will be documented throughout the entire dam removal process. A planned staged removal provides the opportunity to document subsequent changes in the fish community and habitat as the dam is removed in a controlled fashion. The results from this study will provide insight for fisheries managers faced with future dam removals.

The four major objectives to my study were to: (1) document changes in streambed elevation, substrate, and gradient along a six-mile stretch of the Pine River; (2) estimate the abundance of selected species (rainbow trout, brown trout, brook trout, and white suckers) within the six mile study stretch; (3) determine if growth rates of these selected species differ between the Downstream Zone, Impacted Zone, and Non-Impacted Zone, and if growth rates are changing over time; and (4) compare the diet of rainbow trout, brown trout, and brook trout within and among the Downstream Zone, Impacted Zone, and Non-Impacted Zone (results for this objective will be presented in Chapter 2).

STUDY AREA

The Pine River, a tributary of the Manistee, is located in the northwest portion of Michigan's lower peninsula (Figure 1.1). Rozich (1998) provides a comprehensive assessment of the Manistee River watershed, including the Pine River. Stronach Dam lies approximately 5 kilometers upstream of the Manistee and Pine River confluence, while Tippy Dam lies 1.7 kilometers downstream of this confluence. No dams exist upstream of Stronach Dam. The river measures 48 miles from the mouth in the East Branch of the Pine to the backwaters of Tippy Reservoir (Rozich 1998). Substrates in the watershed are dominated by sandy glacial outwash plains, recessional moraines, and areas of consolidated clay. The Pine River is deeply entrenched in these soils and is characterized by steep, sandy banks reaching up to 30 meters above the water surface (Hansen 1971). Because of the steep banks and logging operations that took place in the late 1800's, the Pine River carries a high bedload of sand.

The Pine River has the highest gradient of any stream in northwest lower Michigan at 15 feet per mile (Rozich 1998), causing the river to have a high flow velocity. Stronach Dam lies at the foot of a rapid, where the river descends from the headwaters to its confluence with the Manistee. The Pine River is estimated to drain an area of about 686 square-kilometers (265 square miles) (Hansen 1971). At the USGS gauging station number 04125510, located 13 kilometers upstream of Stronach Dam, the Pine River had an average discharge of 8.18 m^3/s (289 cfs) (Blumer et al. 1998), with the minimum discharge recorded being 161 cfs, and the flood peak discharge equaling 2240 cfs (Rozich 1998). The Pine River is less stable when compared to other rivers in the

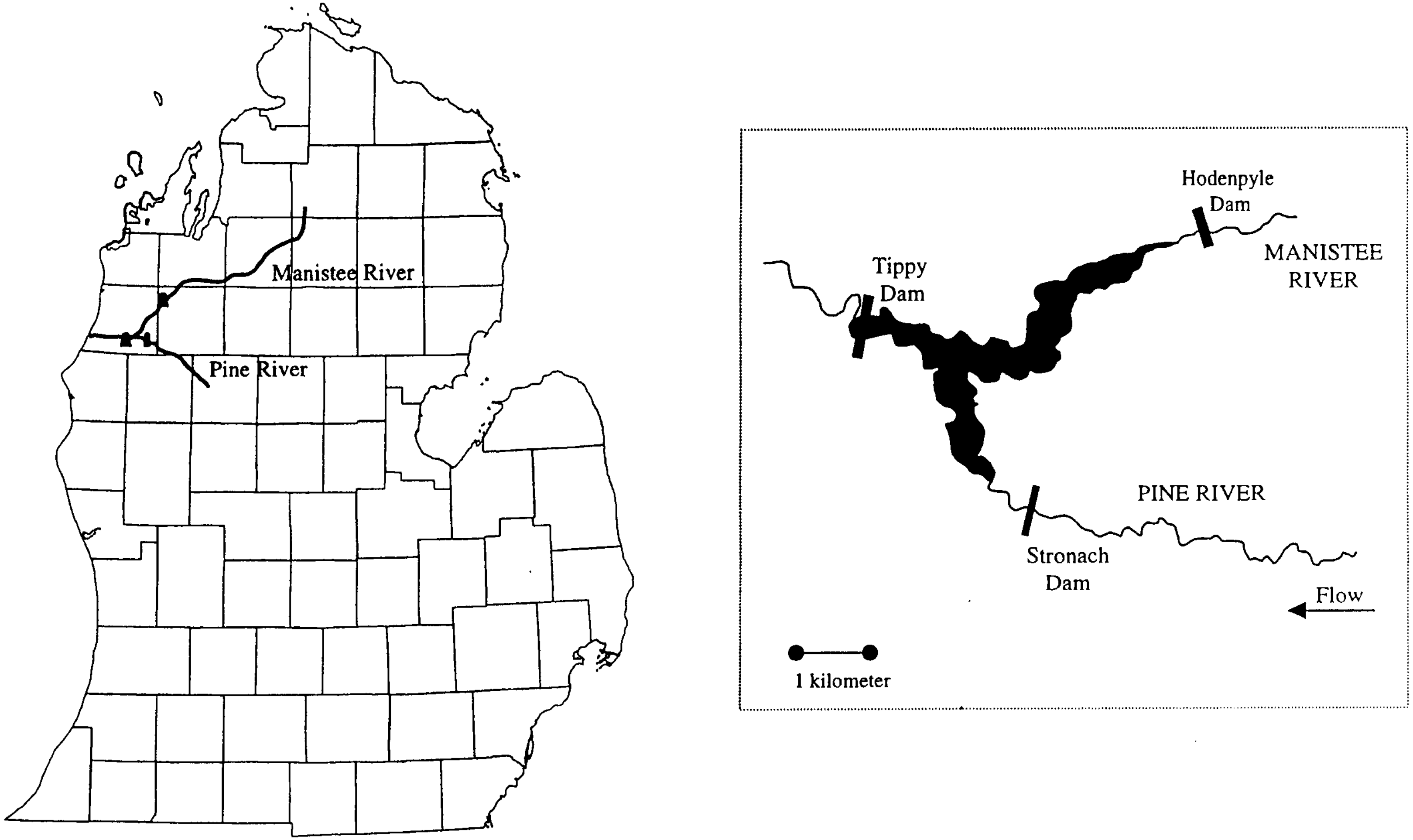


Figure 1.1. Location of Stronach Dam on the Pine River in relation to the state of Michigan and Tippy Dam.

Manistee River watershed. During periods of heavy rain or snowmelt, the river may rise one to four feet above its average level (Rozich 1998).

As noted in Rozich (1998) the Pine River is classified as a "Blue-Ribbon" trout stream with self-sustaining populations of rainbow trout, brook trout, and brown trout, eliminating the need for fish stocking. Of note is the presence of Michigan's largest non-migratory population of rainbow trout (Rozich 1998). Although the river is home to an impressive fishery, the biomass of trout is one-third that of other northern Michigan streams (Alexander and Gowing 1980, Stuber 1996) because of its high sand bedload.

Based on habitat mapping completed in 1995, a 9.2-kilometer stretch of the river was selected for this study. This study site is located in a relatively remote area of the Huron-Manistee National Forest and includes a section of the 40 kilometers (25 miles) of the Pine River designated as a National Wild and Scenic River under the Federal Michigan Scenic Rivers Act of 1991. The 1995 habitat assessment allowed the river to be divided into three distinct reaches: the Downstream Zone between Low Bridge and Stronach Dam (1.1 kilometers); the Impacted Zone above the dam (3.8 kilometers); and the Non-Impacted Zone (4.3 kilometers) above the Impacted Zone (Figure 1.2).

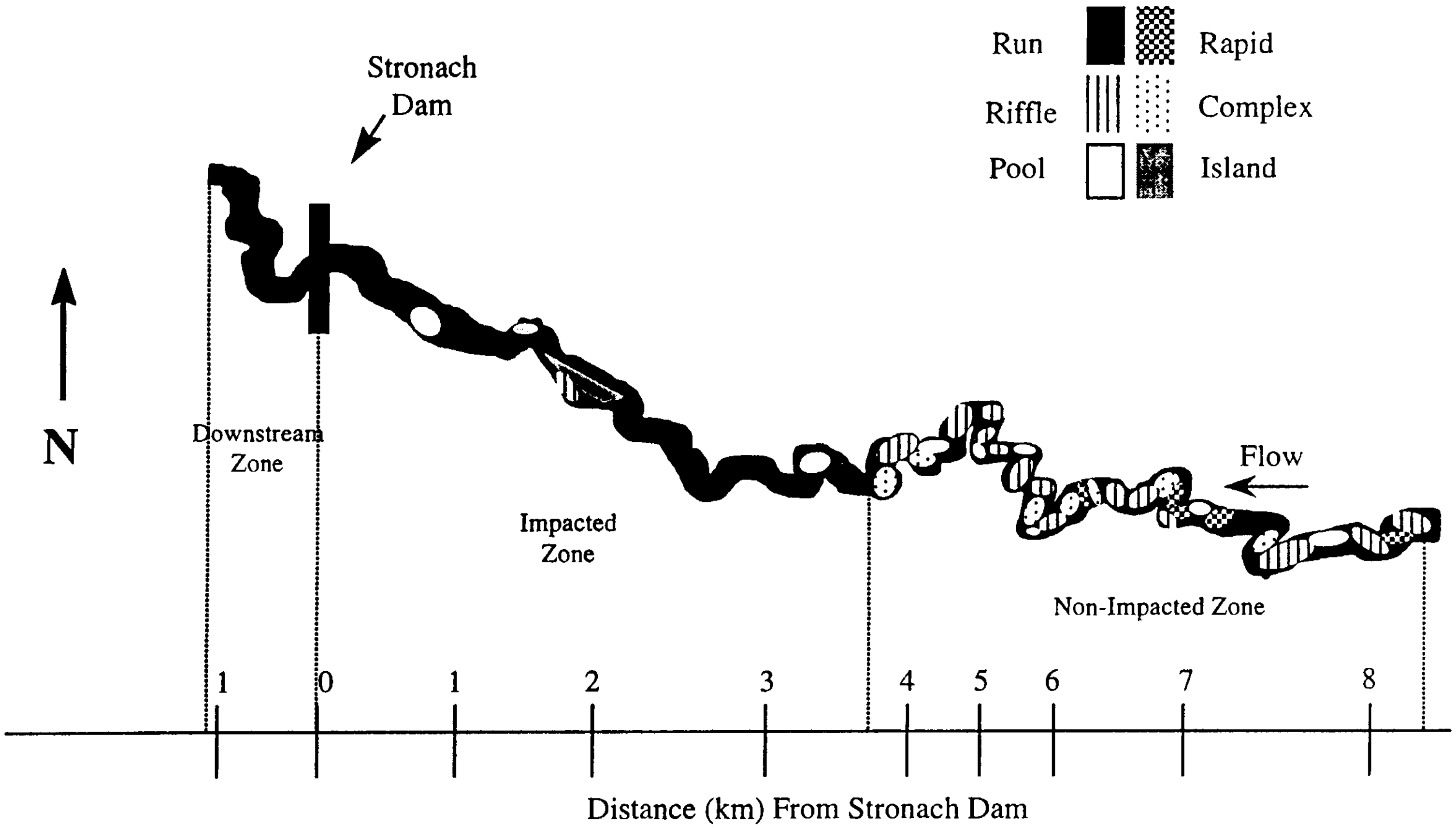


Figure 1.2. Pine River study region delineated into zones by distribution of habitat types.

METHODS

Habitat

Habitat conditions were documented prior to dam removal in 1995 (Klomp 1998). At that time, six miles of stream from Low Bridge (near M-55) to a point approximately five miles upstream from Stronach Dam were assessed. The assessment provided a detailed description of physical characteristics and categorization of the stream into habitat units of runs, riffles, pools, rapids, or complex (a designation where more than one category applied). Classification of these habitat units was determined following criteria developed by Hicks and Watson (1985). The effects of the dam on habitat in the Pine River were apparent in substrate composition and habitat conditions assessed in 1995. These effects could be seen by the streambed consisting primarily of sand for approximately 2.4 miles upstream. Downstream of the dam, wide runs with sandy substrate are the dominant habitat.

Because it has been shown that permanent transects are useful in evaluating management activities on channel form and trout habitat (Stuber 1985, Kondolf and Micheli 1995), thirty-one permanent cross-sectional transects were established in 1996. Twenty-nine transects are located above the dam and two are located below. These transects, established with the aid of a Michigan Department of Natural Resources survey crew, allow for the detection of changes in the channel morphology as the dam is removed (Figure 1.3). In cases where actual elevation was not known, or USGS datum was not available, assumed elevations were used. These sites were measured annually to detect changes in streambed elevation attributable to the dam removal, and will continue to be monitored annually. Photo documentation of each transect, taken in 1999, is

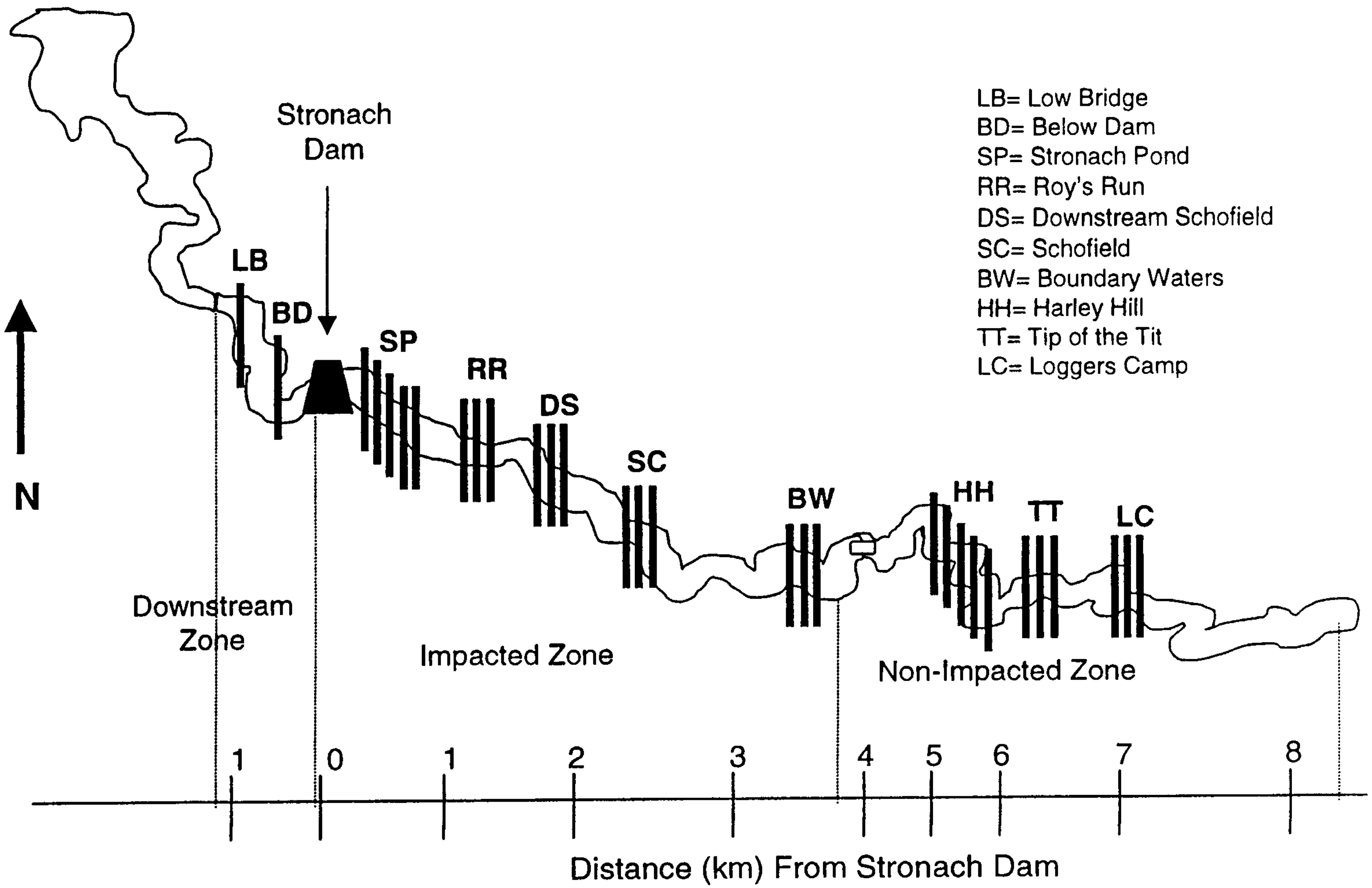


Figure 1.3. Cross-sectional survey sites located on the Pine River.

archived in the Michigan State University Department of Fisheries and Wildlife Fisheries Laboratory. Water surface elevation measurement was included in the surveying of each transect. These data were also used to calculate gradient, or water surface elevation change in meters per river kilometer.

Flow velocity was measured at 10 of the survey transects using a Marsh-McBirney Model 201 portable current meter. Data collection began in 1996 and will continue to be collected throughout the study. Beginning at each bank, flow readings were taken in two-foot increments to include the entire river. From these data, discharge was calculated using the equation

$$Q=w*d*v$$

where Q equals discharge, w, d, and v are the river width, depth, and mean flow velocity at each measurement, respectively.

Surface bed material size distributions, or particle composition, was determined through pebble counts at the survey sites (Wolman 1954, Kondolf and Li 1992). This method involved randomly selecting 100 streambed particles along a transect and measuring their intermediate axis before assigning a size class from a modified Wentworth scale (Table 1.1). These data have been collected on an annual basis since 1996.

Fish Abundance

Fish were collected during the summer of 1996 using a backpack electrofishing unit, during the spring of 1997 using fyke nets, and during the summers of 1997, 1998, and 1999 using an electofishing boat. The backpack unit was set to deliver pulsed DC

Table 1.1. Size classes and codes used to denote particle composition.

Size Code	Size Class	Particle
1		Organic
2	0.00024-0.004mm	Clay
3	0.04-0.062	Silt
4	0.062-2mm	Sand
5	2-4mm	Very Fine Gravel
6	4-8mm	Fine Gravel
7	8-16mm	Medium Gravel
8	16-32mm	Coarse Gravel
9	32-64mm	Very Coarse Gravel
10	64-128mm	Small Cobble
11	128-256mm	Large Cobble
12	256-512mm	Small Boulder
13	>512mm	Medium Boulder

(10% cycle duty) at 250-450 V. The electrofishing boat consisted of a Smith Root-17 CataRaft delivering pulsed DC (40% cycle duty) at 50-500 V or 4-5 amps.

We sampled fish abundance at 10 sites along the river (Figure 1.4). These sites ranged individually from 80 to 428 meters in length and a total of 208 meters downstream from the dam and 2,001 meters above the dam were sampled. A multi-pass removal method using block nets to enclose sampling sites was used (VanDeventer and Platts 1985). At each site, at least three passes were made within the block nets until a clear depletion pattern was detected. Fish abundance was sampled in 1997, 1998, and 1999, and will continue until the dam is removed. MicroFish (Van Deventer and Platts 1985), a software program using the Burnham maximum-likelihood estimator (Van Deventer and Platts 1983), was used to estimate abundance. The abundance estimates were then converted to density estimates (fish/hectare) using river width and site length information.

Fish Growth

Trout and white suckers from the three zones were sampled to determine growth rates and age distribution. Scales from brook trout, brown trout, and rainbow trout were collected from the region on the diagonal between the posterior of the dorsal fin and the anterior of the anal fin, two rows above the lateral line (Minard and Dye 1998). Pectoral fin rays were collected from white suckers, cutting at least the first three fin rays. The use of pectoral fin rays has proven to be a more reliable method of aging white suckers than the scale method (Beamish and Harvey 1969, Scidmore and Glass 1953). While in the field, total length of the selected species was measured to the nearest millimeter.

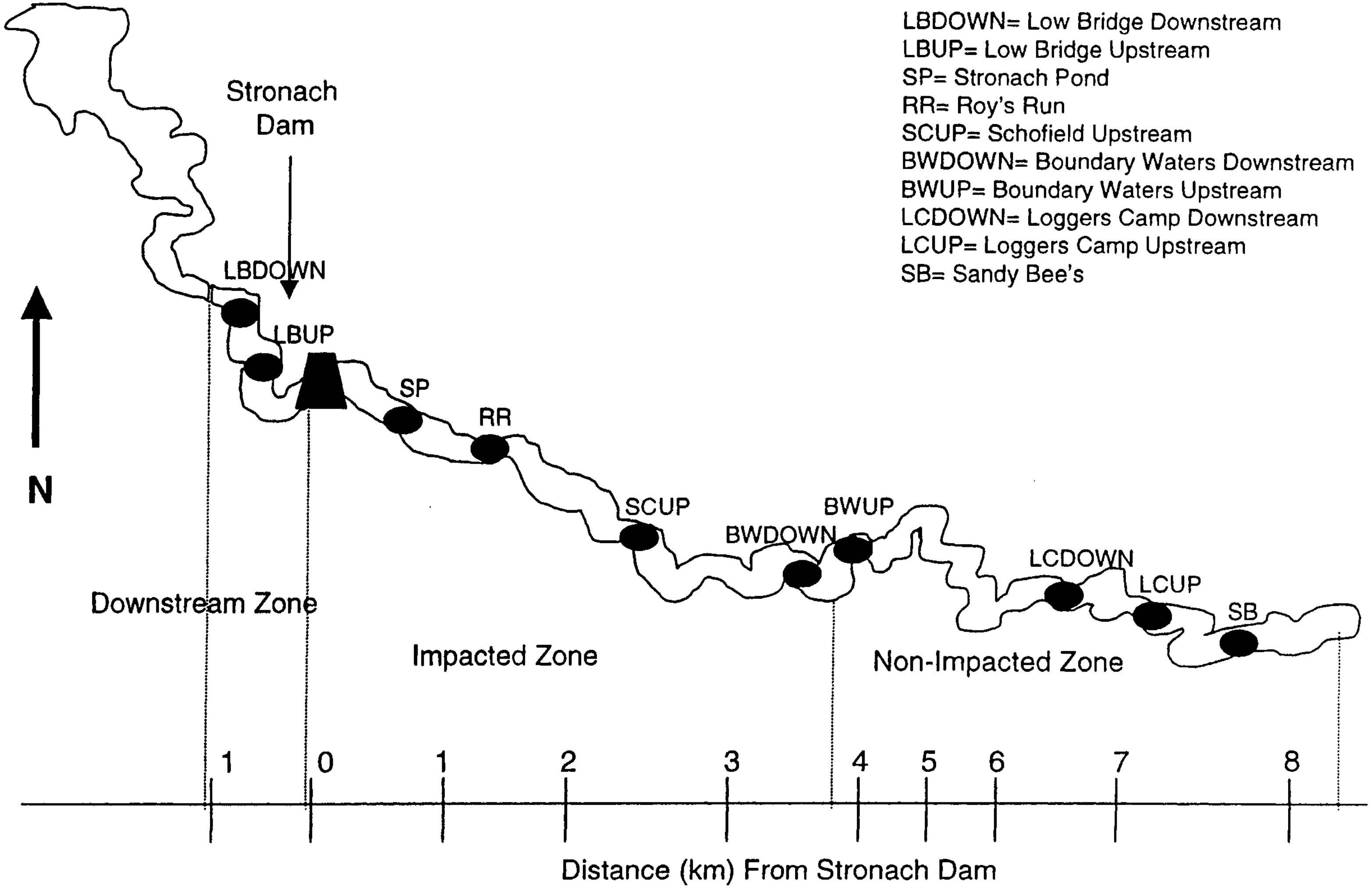


Figure 1.4. Fish abundance sampling sites located on the Pine River.

In the laboratory, trout scales were mounted between glass slides for analysis. The fin rays of white suckers were embedded in epoxy, sectioned using a diamond blade saw, and mounted between glass slides. An Optimus imaging system was used to age and measure annuli of scales and fin rays. After aging, length at capture by age was determined for the target species and compared to average growth in Michigan streams (Laarman et al. 1981).

Back-calculated lengths at age were determined from trout lengths and scale radii sampled between 1996 and 1999 using a linear regression. The same method was also applied to white sucker lengths and pectoral fin ray cross sections collected between 1997 and 1999. Brook trout length at age was only calculated for 1998 and 1999, as brook trout scales from 1996 and 1997 have not been analyzed. The Hile formula, a modified version of the Fraser-Lee method, was used to back-calculate length at age, using the formula

$$B_{age} = ((TL-_{Rscale})*(R_{age}/TR))+R_{scale}$$

where B_{age} was the backcalculated length at age, TL was the total length of the fish, R_{scale} was the length of the fish at first scale formation, R_{age} was the radius (mm) of the scale at the annuli correspondidng to the age of interest, and TR was the total scale radius (mm) (Francis 1990).

To determine if length at previous age was a factor affecting fish growth, a general linear regression was performed. Growth over the previous year was modeled using an incremental growth model so that growth would not be biased with month of capture (Manceina 1992, Weisberg 1993).

$$L = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_{12}x_1x_2$$

In this model, L was the incremental change in length, x_1 was the beginning length, and x_2 was the indicator zone variable being fit to a generalized linear model. The difference in back-calculated length between the previous year and the beginning of the current year was estimated to be the change in length. An analysis of covariance (ANCOVA) was used to determine differences in annual incremental growth between the three zones with incremental growth as the response variable, zone as the main effect, and length at previous age as the covariate. Analyses were performed on untransformed data using the GLM procedure of SAS (SAS Institute 1988). These analyses tested significance at an alpha of 0.05.

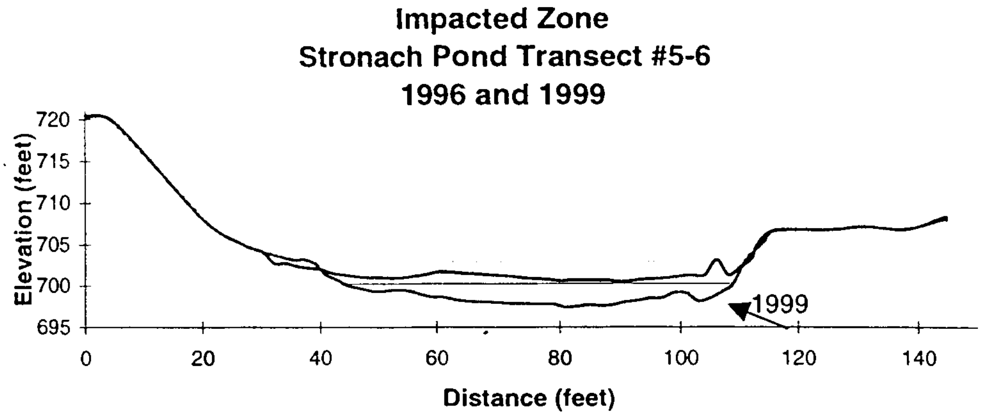
RESULTS

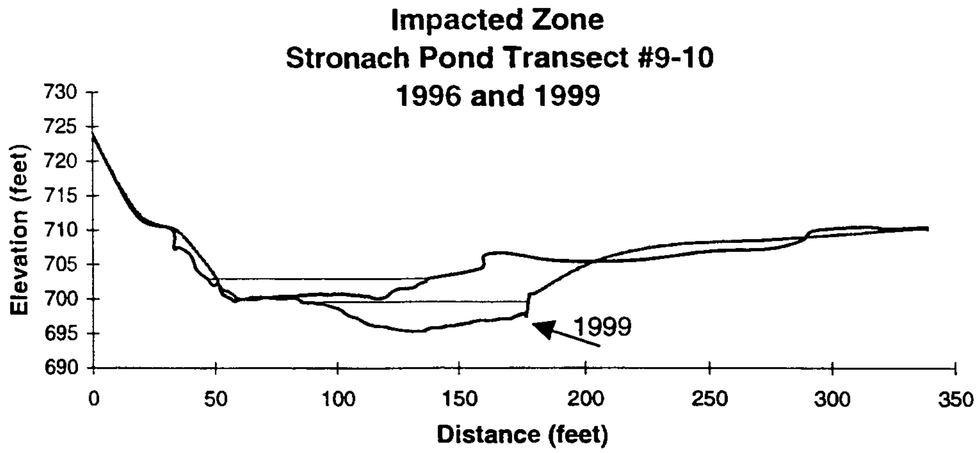
Habitat

Channel morphology was documented between 1996 and 1999. At the time of surveying in 1999, the dam had been lowered approximately six feet. Since 1996, the river has changed dramatically near the dam, by both narrowing and deepening. Both above and below the dam, the river is shifting to the right or the area where the stoplogs are being removed and scouring was seen on the right side as a result of the dam removal and the rerouting of the river (Figure 1.5). Below the dam, an aggradation of particles can be seen on the left side where the dam spillway lies. An overall raising of the streambed below the dam has resulted from sediment being flushed downstream. Since 1996 there has been a water level drop of approximately five feet in the area immediately upstream of the dam. In fact, the 1999 water levels near the dam lie below the 1996 stream bottom. Although some changes were a result of organic debris being moved along the streambed, those closest to the dam were likely associated with the dam removal. As predicted, few changes have occurred in the Non-Impacted Zone, and these changes were attributable to normal stream events (Figure 1.6).

As the stoplogs have been removed, the longitudinal progression of streambed changes was seen through differences in water elevation at each transect (Figure 1.7). Setting the 1996 water levels equal to zero, the progressive changes in the water level due to dam removal were apparent.

Gradient is reported for the eight upstream stations from 1996 through 1999 (Figure 1.8). These numbers were determined using the change in water surface elevation from the most upstream to the most downstream transect in a series. The overall gradient





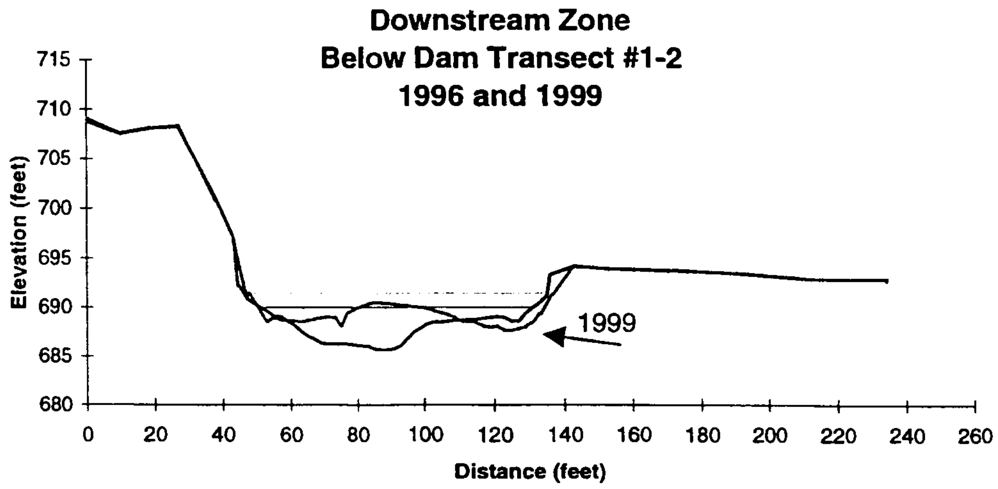
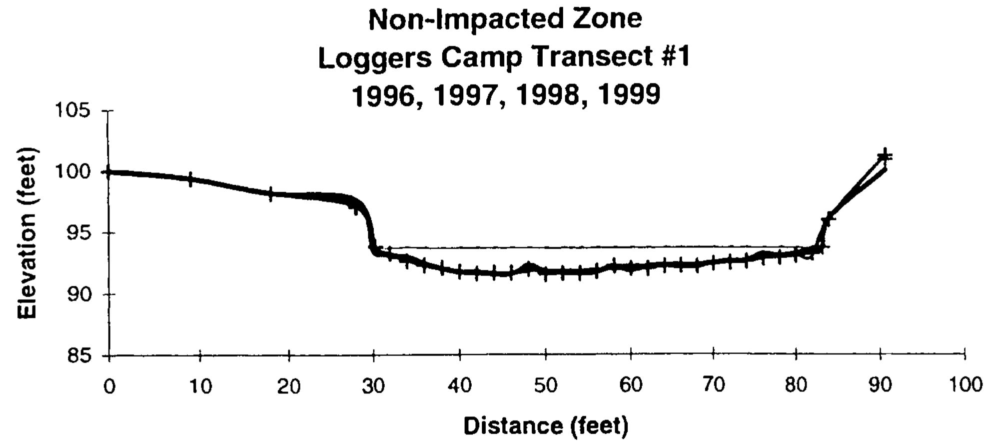
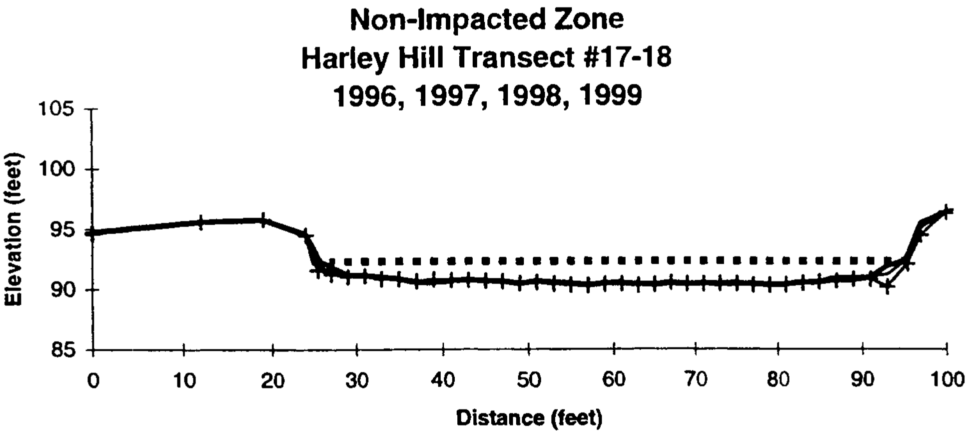


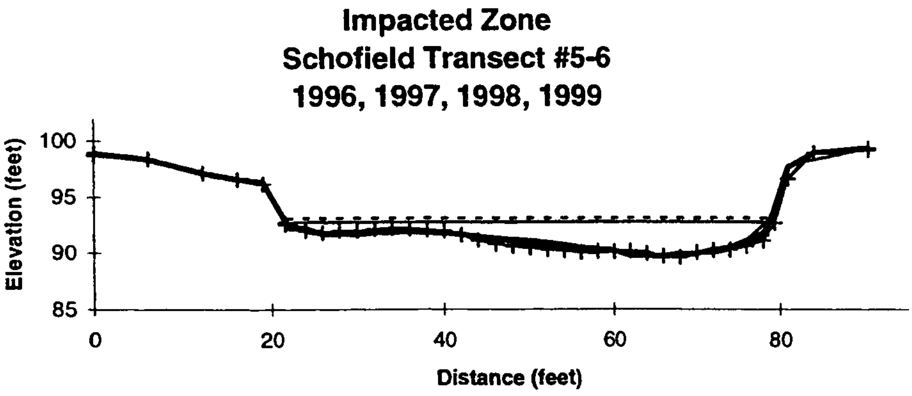
Figure 1.5. Pine River cross-sections illustrating examples where changes in streambed elevation have been detected between 1996 and 1999.



Non-Impacted Zone
Loggers Camp Transect #1
1996, 1997, 1998, 1999



Non-Impacted Zone
Harley Hill Transect #17-18
1996, 1997, 1998, 1999



Impacted Zone
Schofield Transect #5-6
1996, 1997, 1998, 1999

Figure 1.6. Pine River cross-sections illustrating examples where no changes in streambed elevation have been detected between 1996 and 1999.

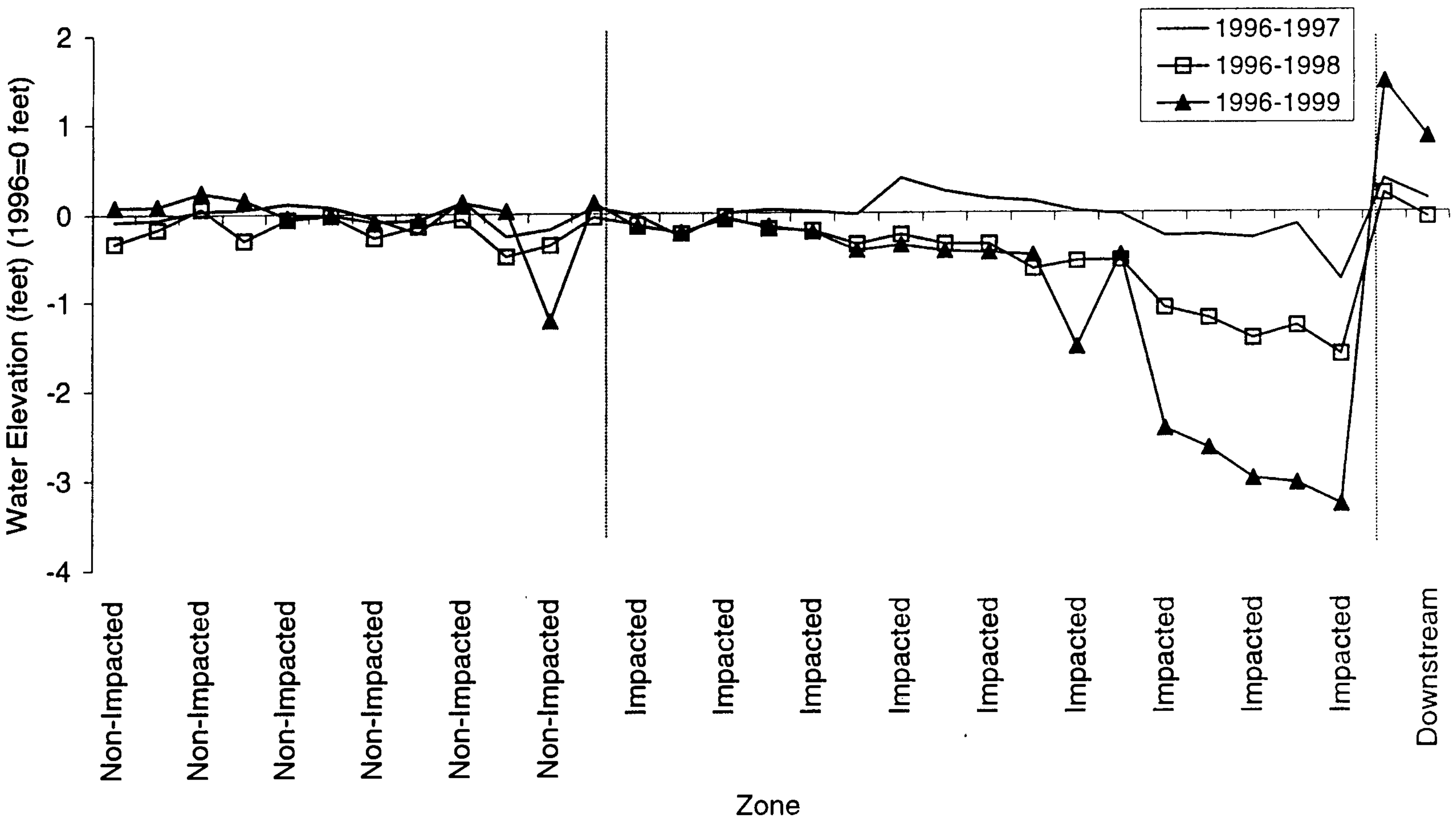


Figure 1.7. Pine River changes in water surface elevation (feet) as deviated from 1996.

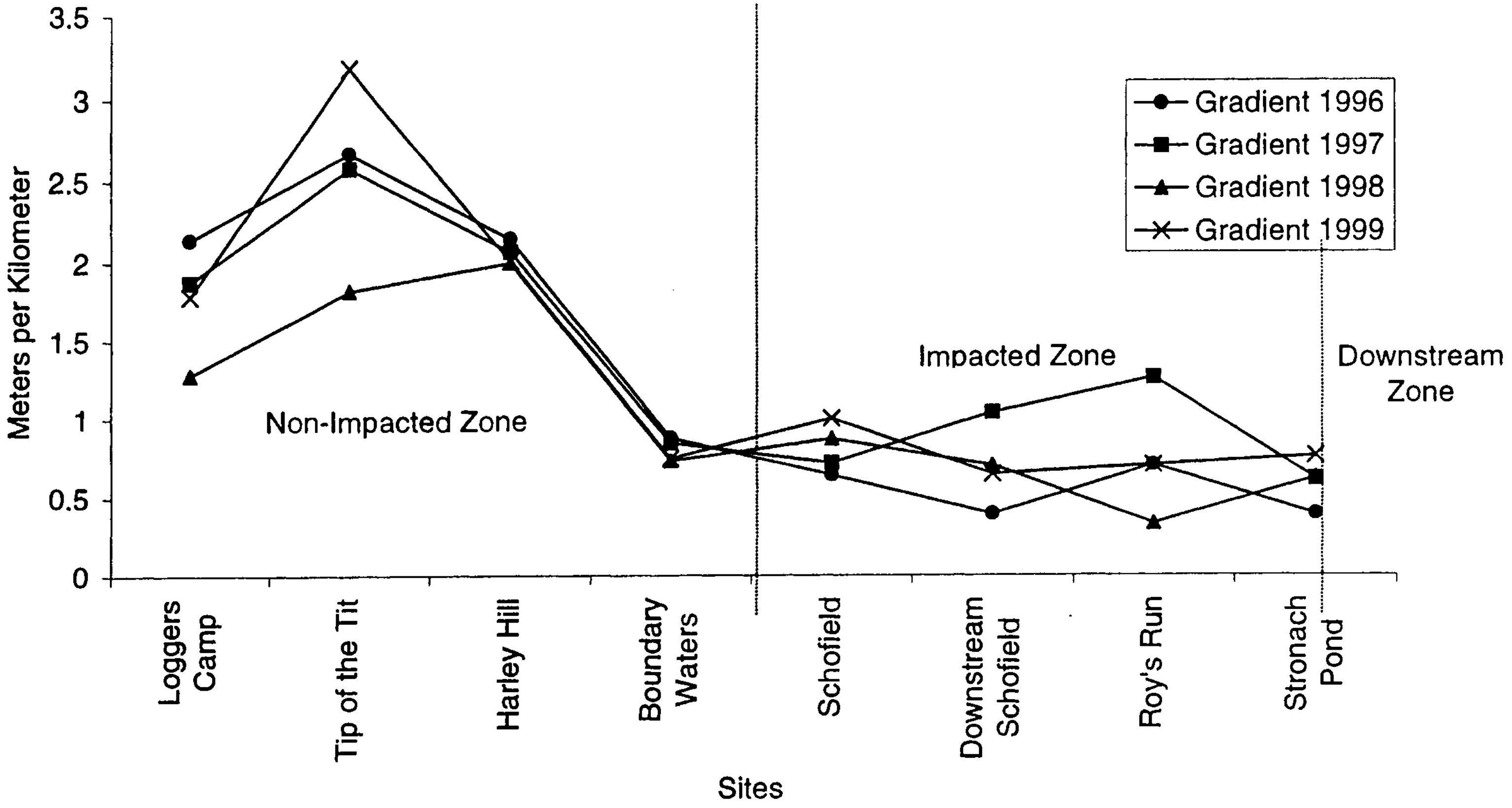


Figure 1.8. Gradient, or water surface elevation change (meters per kilometer), measured on the Pine River between 1996 and 1999.

decreases moving downstream, with the highest gradients (>2m/km) found in the Non-Impacted Zone, and lower gradients (<1m/km) found in the Impacted Zone. Because the Downstream Zone has only two transects, each in a separate series, gradient could not be determined. Year to year variability shows no clear patterns, and may be attributed to seasonal or daily fluctuations in water level.

The average discharge for the years 1997-1999 showed a pattern of increase in a downstream direction (Figure 1.9). Over time, discharge has ranged from approximately six to nine cubic meters per second. Mean velocity (cm/s) in the study section tended to decline in a downstream direction, in contrast to discharge (Figure 1.10). Over time, mean velocity in the Impacted Zone has become progressively higher with the steeping of gradient above the dam. Few changes were seen below the dam in the Downstream Zone.

After dividing the annual velocity measurements into percent frequency by zone, the differences in the study stretch were shown (Figure 1.11). Raw flow data from 1997 were unavailable, although 1997 means were taken from Klomp (1998). In 1996, 1998, and 1999 the Downstream Zone had the highest frequency of low velocities (0 to 0.5 m/s), while the Impacted Zone had the highest frequency of mid-range velocities (0.5 to 1 m/s). The Non-Impacted Zone had both the largest range of velocities and the highest frequency of high velocity measurements (0.5 to 1.5 m/s).

Generally, substrate in the Non-Impacted Zone was dominated by medium to very coarse gravel, and has shown no directional change over time (Figure 1.12). In the Impacted Zone, the substrate was comprised mostly of very fine gravel to medium gravel. In 1999, the mean particle size in the Impacted Zone appeared to be increasing through a coarsening of the bedload. Substrate in the Downstream Zone substrate consisted

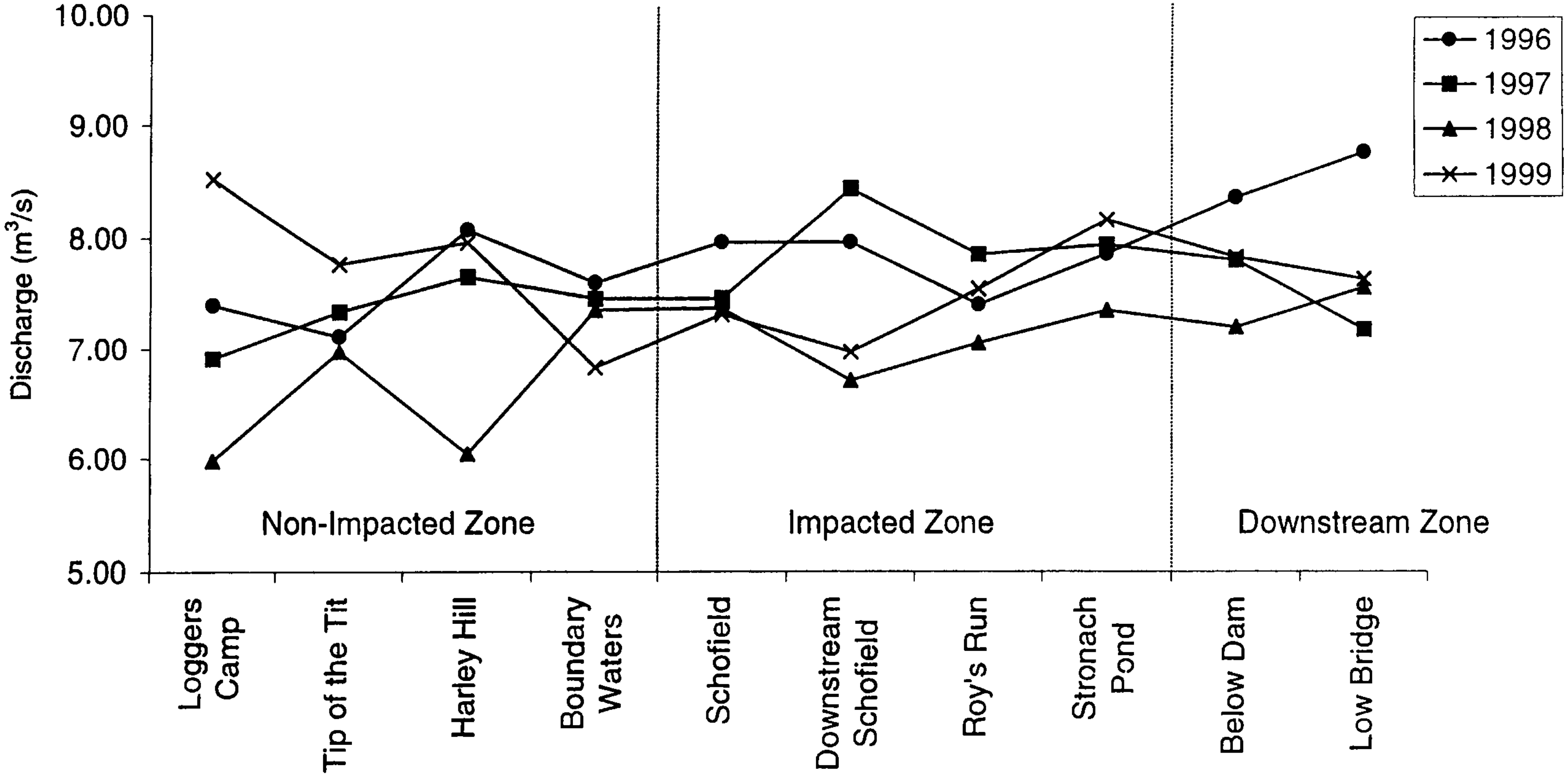


Figure 1.9. Pine River overall mean discharge at each site sampled between 1996 and 1999.

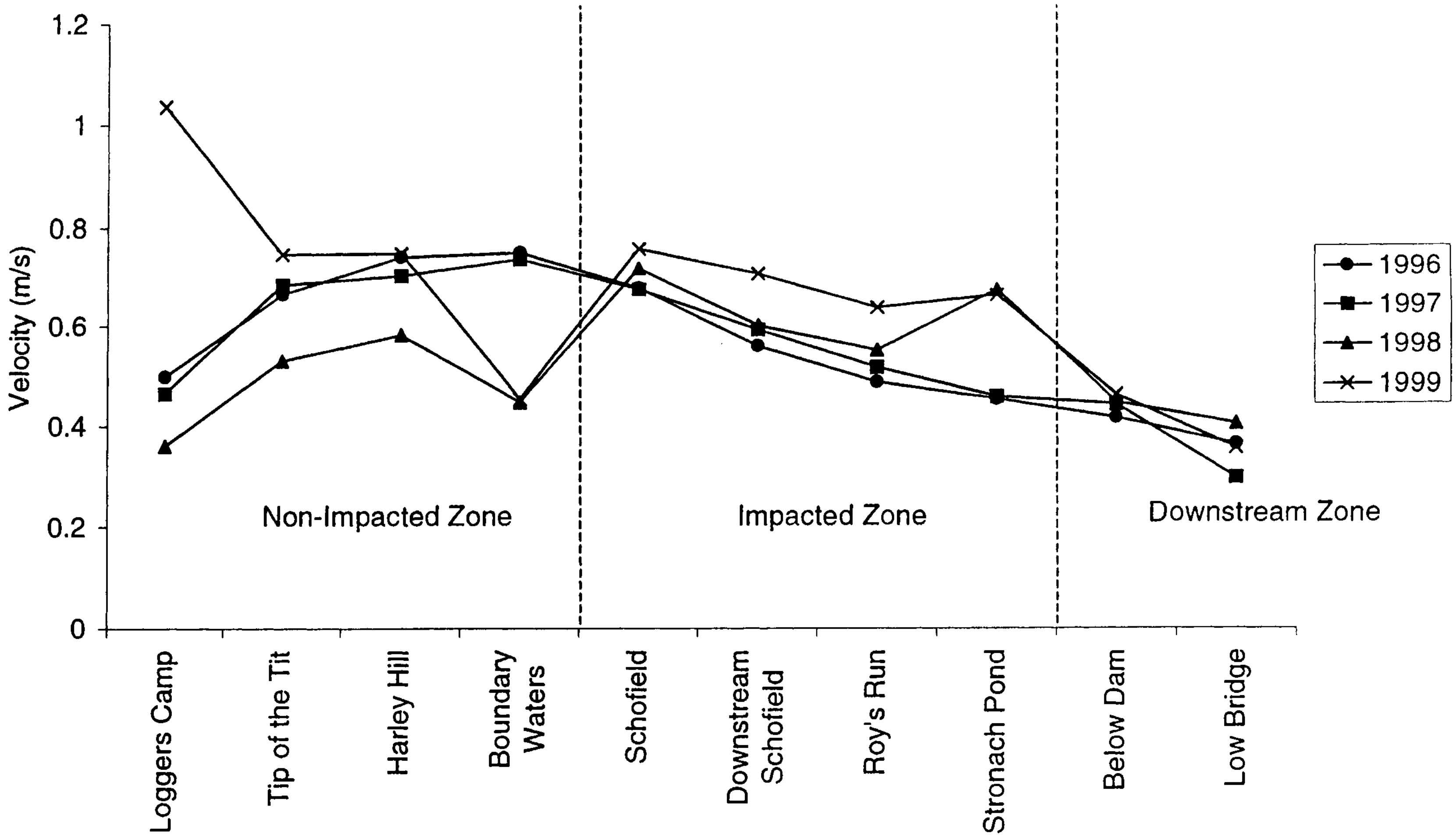
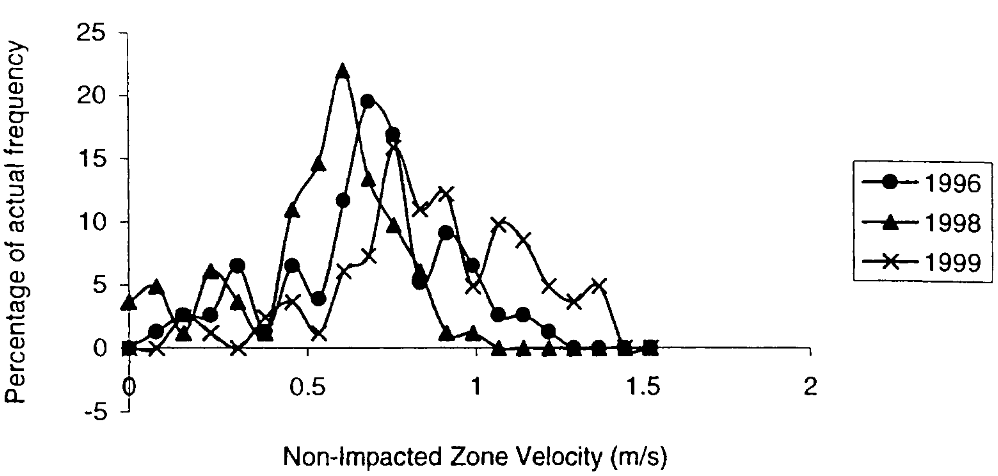
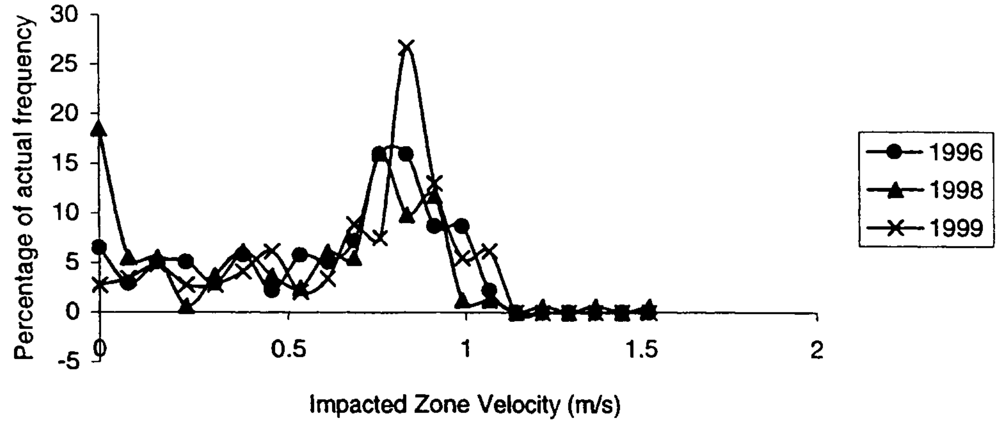


Figure 1.10. Pine River mean velocity (meters per second) for each site measured between 1996 and 1999.





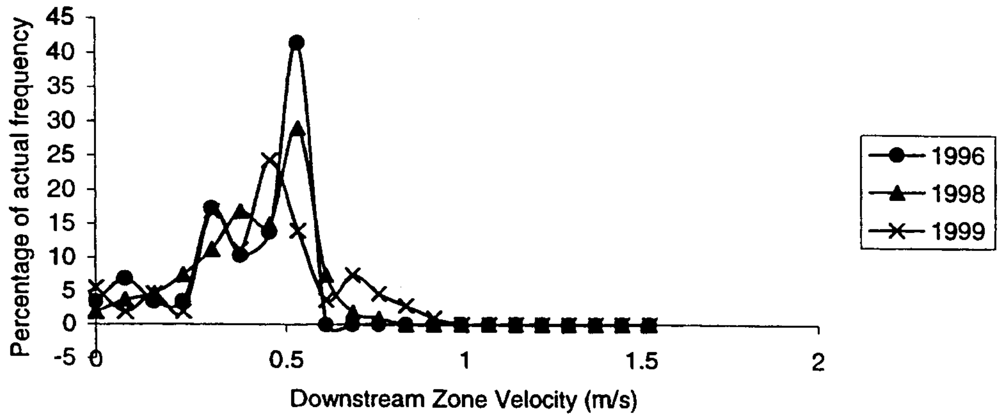


Figure 1.11. Pine River velocity percentage frequency by zone in 1996, 1998, and 1999. Data from 1997 were unavailable.

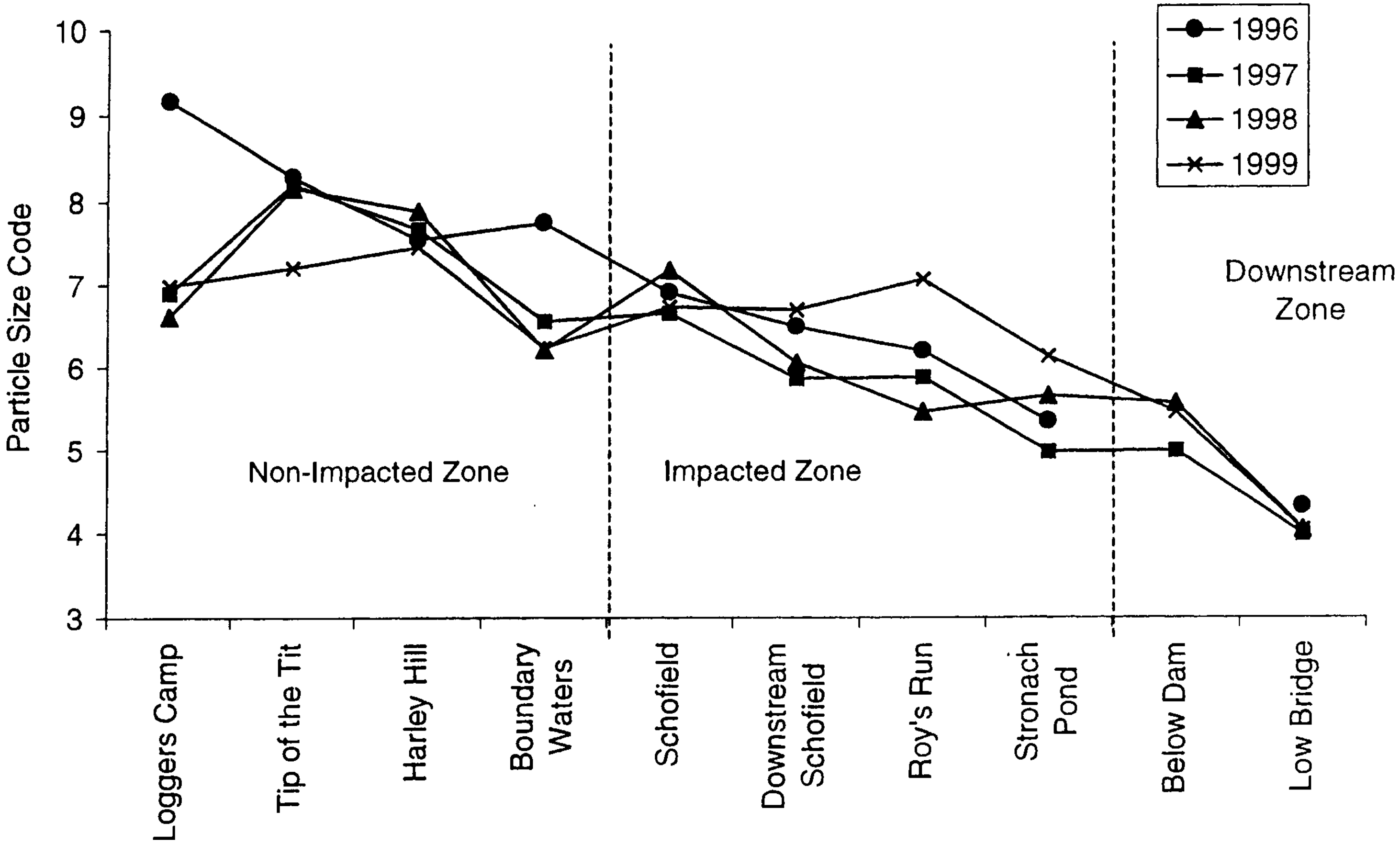


Figure 1.12. Pine River pebble count means by site for 1996 through 1999.

primarily of sand and very fine gravel. Substrate size below the dam did not appear to be shifting.

Fish Abundance

A total of 34 fish species have been encountered on the Pine River since 1996 (Table 1.2). In 1999, redear sunfish (questionable identification) and banded killifish were added to the list. Of the 34 species sampled, three species were encountered only upstream from the dam and represent mostly headwater species. Seventeen species were found only downstream of the dam and represent mostly coolwater species. Some of the species only found below the dam include walleye, yellow perch, northern pike, and redhorse suckers (*Moxostoma macrolepidotum* and *M. anisurum*). Fourteen species were found both upstream and downstream of the dam.

Density of key species was established over time to compare annual patterns within different stretches of the river. The population density (number/hectare) for brook trout, brown trout, rainbow trout, and white suckers was determined for the years 1997 through 1999 at each of the ten sampling sites (Table 1.3). Although there does not appear to be significant trends over time, patterns have begun to emerge when comparing the zones (Table 1.4). For example, the overall pattern of density showed that trout population numbers increased moving in an upstream direction.

Over time, not much change in brook trout abundance was apparent within a zone, indicating that the relative abundance among zones was stable. In 1999, there was a sizeable increase in brown trout, both in the Non-Impacted and Downstream Zone. Rainbow trout density has remained stable, excepting for an increase in the Non-Impacted

Table 1.2. Fish species sampled on the Pine River between 1996 and 1999. An * indicates questionable identification.

Taxon Scientific Name	Downstream from Stronach Dam Common Name	Upstream from Stronach Dam Common Name
Esox americanus	Grass pickerel	------------------------------
Percopsis omiscomaycus	Trout-perch	------------------------------
Ambloplites rupestris	Rock bass	------------------------------
Lepomis gibbosus	Pumpkinseed	------------------------------
Notropis atherinoides	Emerald shiner	------------------------------
Percina maculata	Blackside darter	------------------------------
Percina caprodes	Logperch	------------------------------
Ichthyomyzon castaneus	Chestnut lamprey	------------------------------
Perca flavescens	Yellow perch	------------------------------
Stizostedion vitreum	Walleye	------------------------------
Esox lucius	Northem pike	------------------------------
Umbra limi	Central mudminnow	------------------------------
Moxostoma anisiurum	Silver redhorse sucker	------------------------------
Moxostoma macrolepidotum	Shorthead redhorse sucker	------------------------------
Notemigonus crysoleucas	Golden shiner	------------------------------
Etheostoma nigrum	Johnny darter	------------------------------
Lepomis microlophus	*Redear sunfish	------------------------------
Luxilus comutus	Common shiner	Common shiner
Lampetra appendix	American brook lamprey (ammocetes)	American brook lamprey (ammocetes)
Rhinichthys cataractae	Longnose dace	Longnose dace
Semotilus atromaculatus	Creek chub	Creek chub
Lepomis macrochirus	Bluegill	Bluegill
Cottus bairdi	Mottled sculpin	Mottled sculpin
Cottus cognatus	Slimy sculpin	Slimy sculpin
Catostomus commersoni	White sucker	White sucker
Salmo trutta	Brown trout	Brown trout
oncorhynchus mykiss	Rainbow trout	Rainbow trout
Ameiurus melas	Black bullhead	Black bullhead
Salvelinus fontinalis	Brook trout	Brook trout
Notropis hudsonius	Spottail shiner	Spottail shiner
Micropterus dolomieu	Smallmouth bass	Smallmouth bass
Culaea inconstans	------------------------------	Brook stickleback
Rhinichthys atratulus	------------------------------	Blacknose dace
Fundulus diaphanus	------------------------------	Banded killifish

Table 1.3. Pine River fish population density (number per hectare) for each site sampled between 1997 and 1999.

Site	Distance from Dam (kilometers)	Site Length (meters)	Brook Trout (fish/hectare)				Brown Trout (fish/hectare)			
			1997	1998	1999	Mean	1997	1998	1999	Mean
Sandy Bee's	8.1	80	89	44	18	50	40	17	9	22
Loggers Camp Up	7.4	181	25	30	51	35	20	44	89	51
Loggers Camp Down	6.5	75	7	0	40	16	17	25	32	25
Boundary Waters Up	4.4	383	27	104	13	48	54	22	92	56
Boundary Waters Down	3.9	428	12	17	6	12	22	42	48	38
Schofield Up	2.5	290	12	12	13	12	37	37	63	46
Roy's Run	1.5	222	2	20	13	12	62	7	3	24
Stronach Pond	0.7	342	7	0	6	4	20	17	21	20
Low Bridge Up	0.5	105	0	0	0	0	20	5	15	13
Low Bridge Down	0.9	103	0	0	0	0	5	27	78	37

Table 1.3 (cont'd).

Site	Distance from Dam (kilometers)	Site Length (meters)	Rainbow Trout (fish/hectare)				White Sucker (fish/hectare)			
			1997	1998	1999	Mean	1997	1998	1999	Mean
Sandy Bee's	8.1	80	62	40	35	46	0	0	0	0
Loggers Camp Up	7.4	181	7	86	67	53	22	79	149	83
Loggers Camp Down	6.5	75	0	15	40	18	17	0	0	6
Boundary Waters Up	4.4	383	15	49	38	34	2	10	13	8
Boundary Waters Down	3.9	428	20	42	44	35	44	12	4	20
Schofield Up	2.5	290	27	10	21	19	49	37	6	31
Roy's Run	1.5	222	7	12	5	8	37	27	21	29
Stronach Pond	0.7	342	25	7	10	14	119	59	1	60
Low Bridge Up	0.5	105	0	0	0	0	153	82	378	204
Low Bridge Down	0.9	103	7	5	0	4	161	432	113	235

Table 1.4. Pine River fish population density (number per hectare) for each zone sampled between 1997 and 1999.

Brook Trout	**Non-Impacted**	**Impacted**	**Downstream**
1997	37	9	0
1998	44	12	0
1999	30	9	0
Brown Trout	**Non-Impacted**	**Impacted**	**Downstream**
1997	33	35	12
1998	27	26	16
1999	55	34	46
Rainbow Trout	**Non-Impacted**	**Impacted**	**Downstream**
1997	21	20	4
1998	48	18	2
1999	45	20	0
White Sucker	**Non-Impacted**	**Impacted**	**Downstream**
1997	11	62	157
1998	22	34	257
1999	40	8	245

Zone in 1998 and 1999. Looking at white suckers, numbers in the Non-Impacted Zone have shown a relatively dramatic increase, along with a subsequent decrease in the Impacted Zone in 1999.

The spatial distribution of trout and white suckers was established to distinguish patterns of density within the zones. In general, densities of brook trout, brown trout, and rainbow trout were highest in the Non-Impacted Zone (Figure 1.13). Brown trout, however, showed a different spatial distribution in having a substantial number in the Downstream Zone. Specifically, brook trout were most abundant in the Non-Impacted Zone, less abundant in the Impacted Zone, and none were captured during our abundance sampling in the Downstream Zone. A few brook trout were seen in the Downstream Zone during other sampling efforts, however. Brown trout were nearly equally distributed between the Non-Impacted and Downstream Zone, and were overall less abundant in the Impacted Zone. The distribution of rainbow trout was similar to brook trout. They were found most abundantly in the Non-Impacted Zone, less abundantly in the Impacted Zone, and rarely in the Downstream Zone. White suckers showed a very different spatial distribution than trout (Figure 1.14). White suckers were much more abundant in the Downstream Zone with comparatively few residing above the dam. The overall abundance of white suckers in the Impacted and Non-Impacted Zone has shifted over the course of the study, with a higher population number now in the most upstream sampling sites.

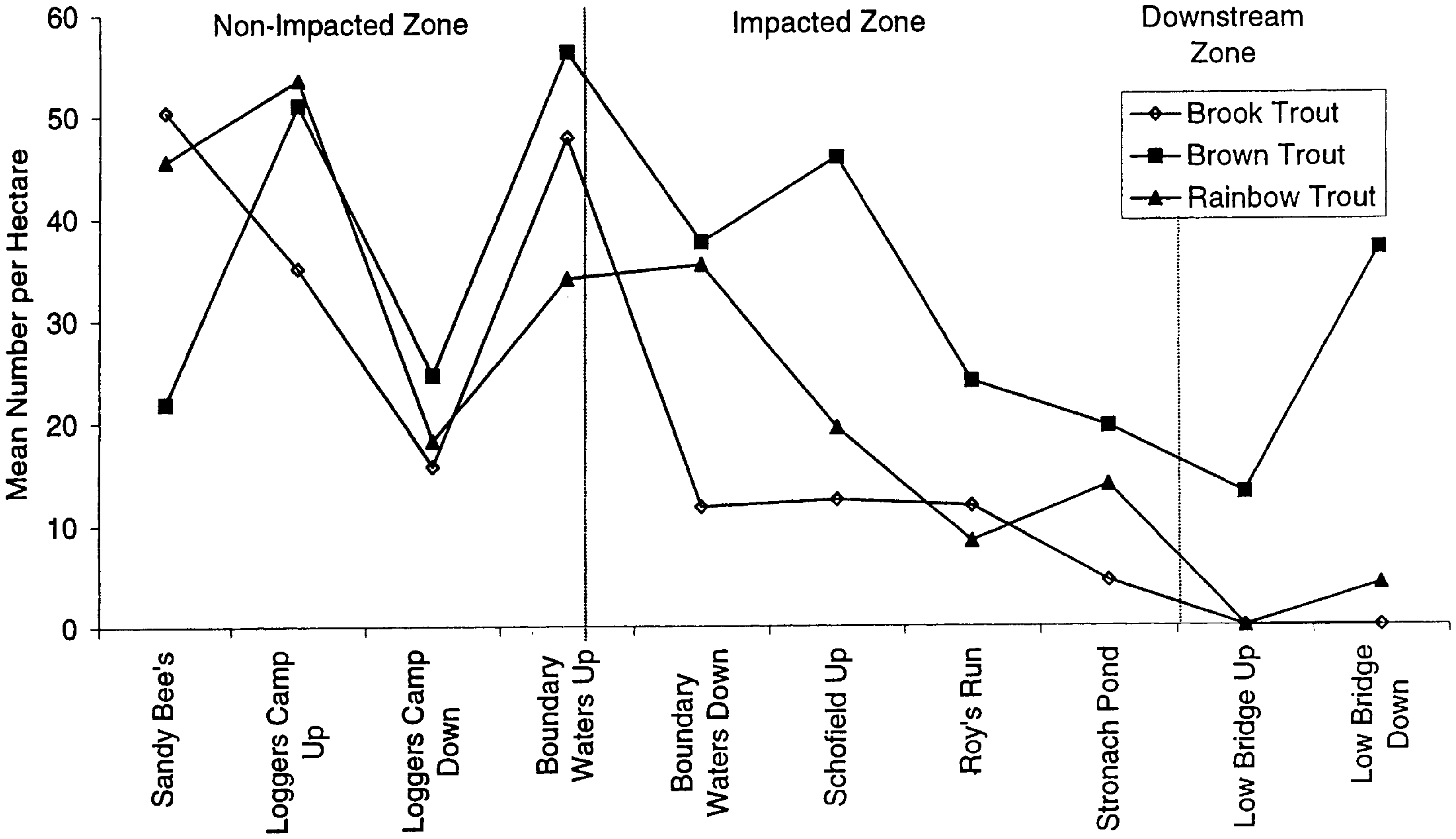


Figure 1.13. Mean brook trout, brown trout, and rainbow trout density (number per hectare) for all sites sampled on the Pine River between 1997 and 1999.

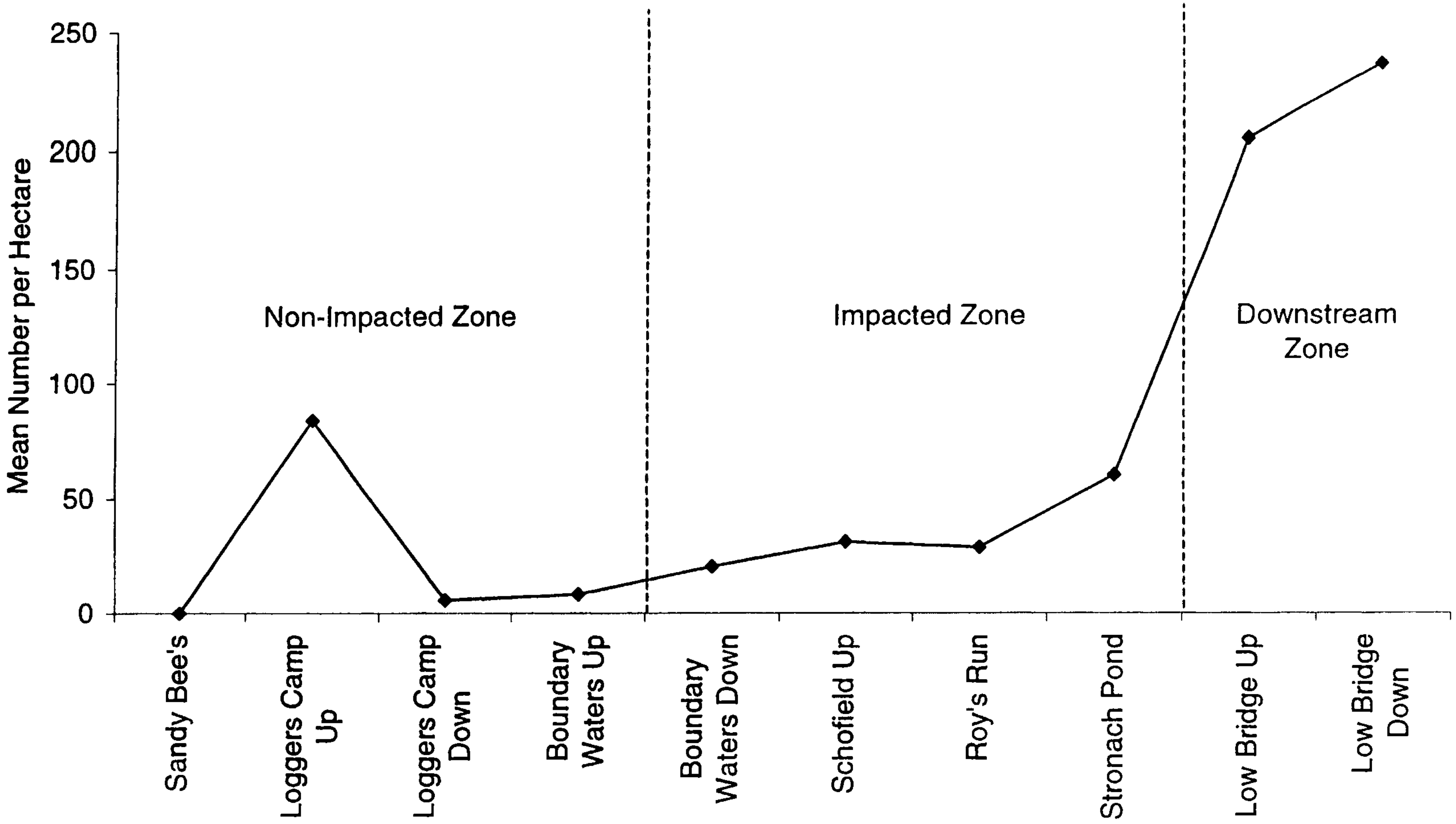


Figure 1.14. Mean white sucker density (number per hectare) for all sites sampled on the Pine River between 1997 and 1999.

Age Distribution

Most of the brook trout caught in 1998 and 1999 were age zero and one, while the remaining were age two and three (Figure 1.15). The age distribution of brook trout varied among years, but was similar between the Non-Impacted and Impacted Zones.

Most of the brown trout captured between 1996 and 1999 were ages one and two (Figure 1.16). Upstream of the dam, brown trout were dominated by age zero and one fish, which comprised over half of the population sampled. Additionally, the majority of age zero brown trout were found above the dam, while only a small percentage of brown trout ages three and older were sampled above the dam. Below the dam, the majority of fish were age two, followed by a relatively high number of ages one, three, and four fish. Between 1996 and 1999, few age zero rainbow trout were caught, and the majority of the rainbow trout were age one and two (Figure 1.17). Similar to brown trout, upstream of the dam rainbow trout were dominated by age one fish, followed by age two. Below the dam the majority of rainbow trout were age two, followed by a relatively high number of age one and three fish.

Overall, the age structure of white suckers was dominated by age zero through three, comprising almost all of those sampled (Figure 1.18). Some differences were apparent in the age structure among zones, however. The Non-Impacted Zone was dominated by age zero, while the Impacted Zone was predominately age two and three fish. Similar to the Non-Impacted Zone, most of the suckers in the Downstream Zone were age zero, followed closely by ages one, two, and three.

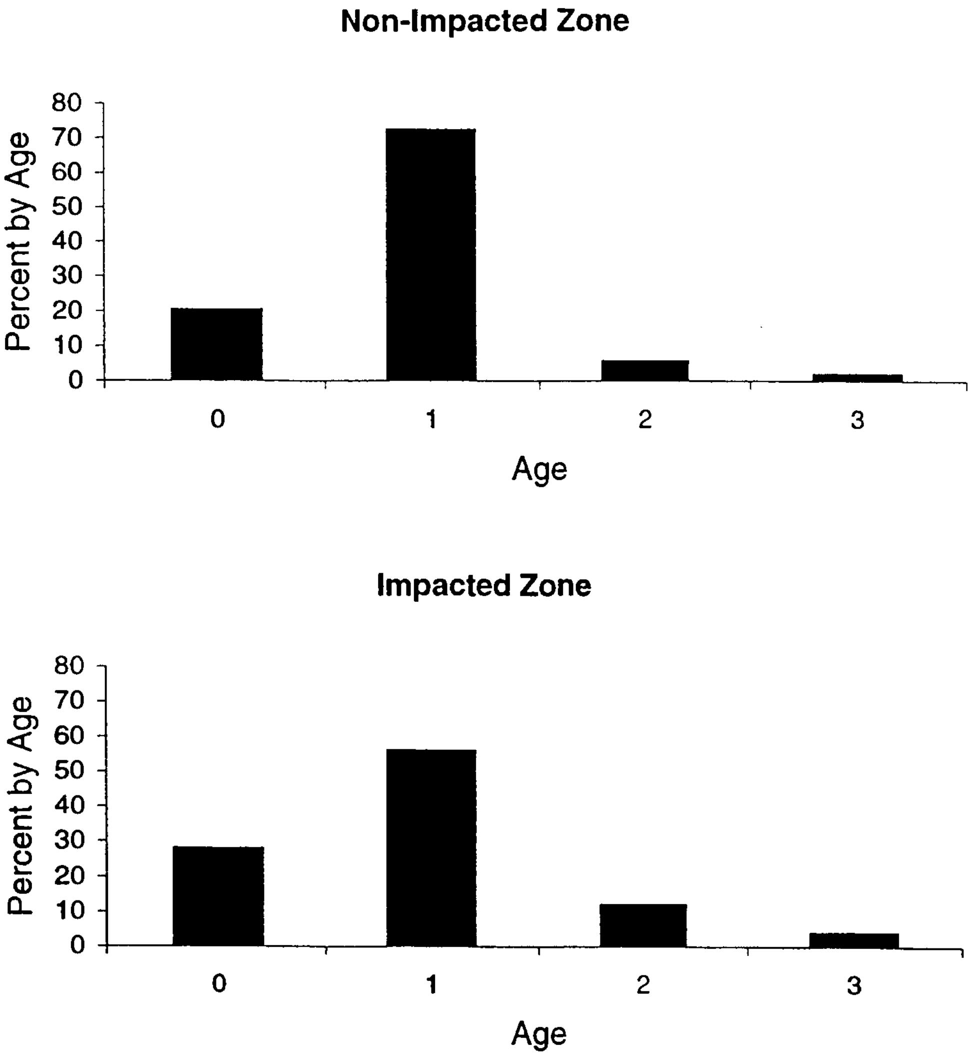


Figure 1.15. Brook trout age structure within each zone on the Pine River for 1998 and 1999.

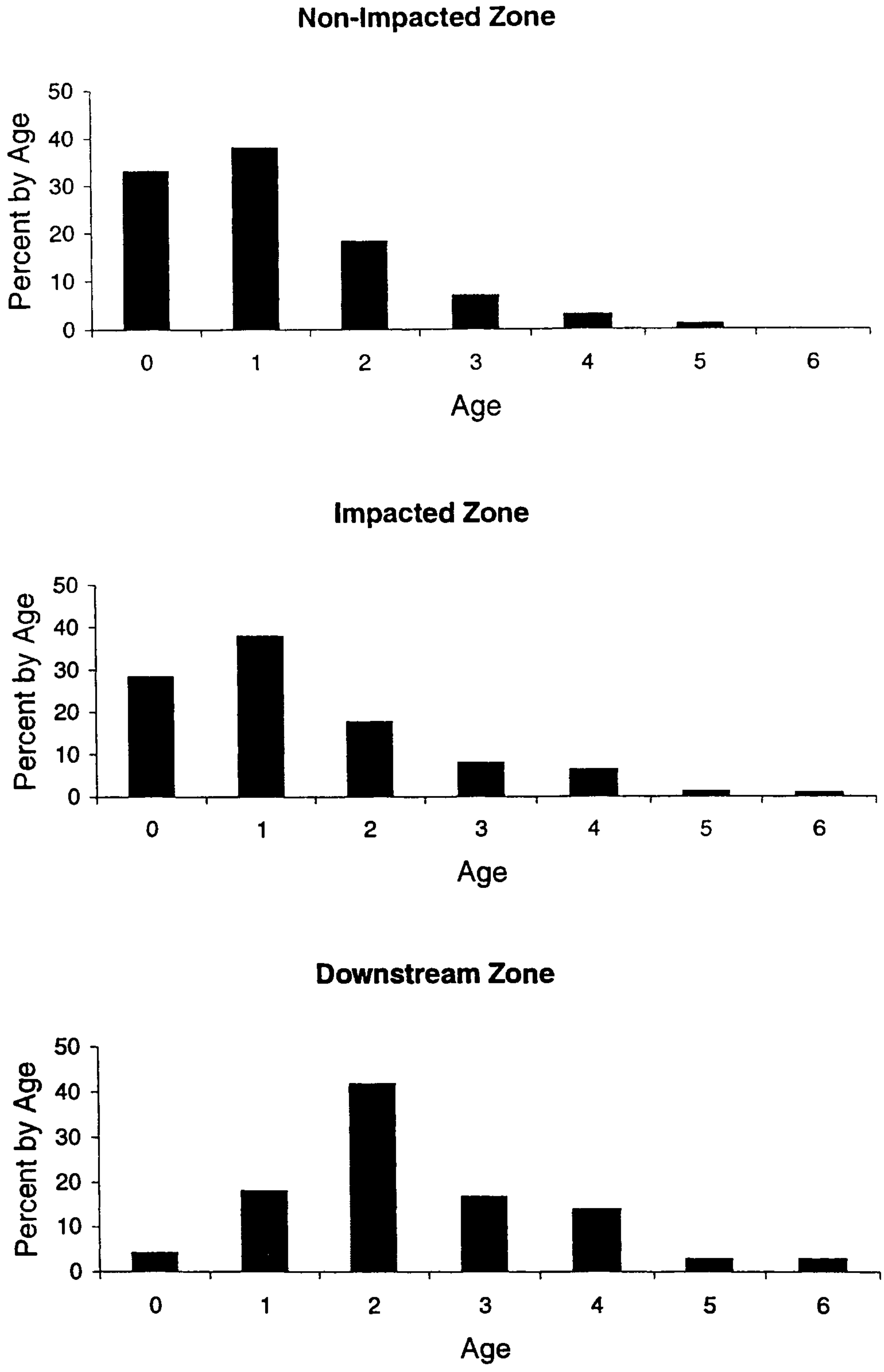


Figure 1.16. Brown trout age structure within each zone on the Pine River between 1996 and 1999.

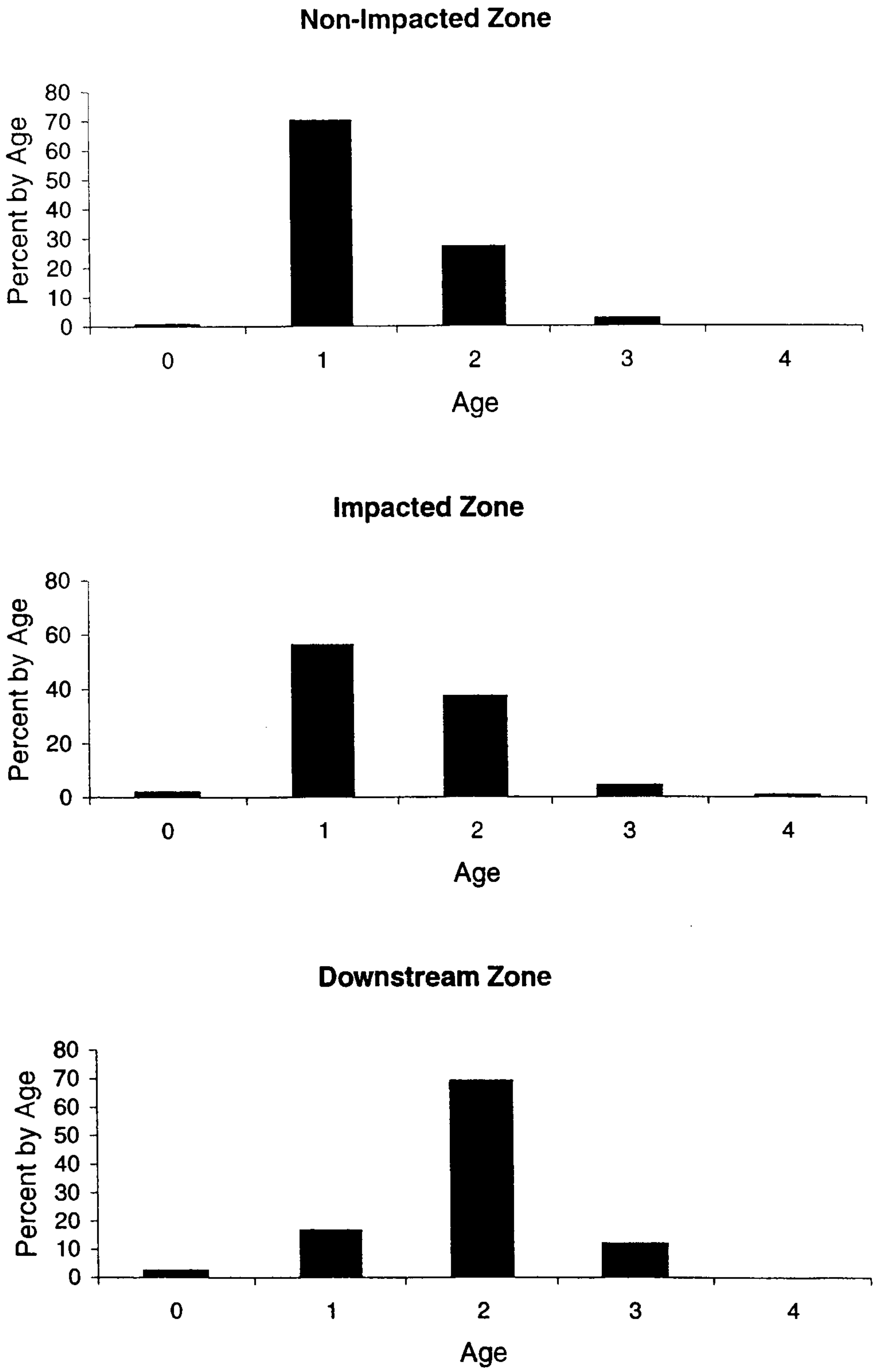


Figure 1.17. Rainbow trout age structure within each zone on the Pine River between 1996 and 1999.

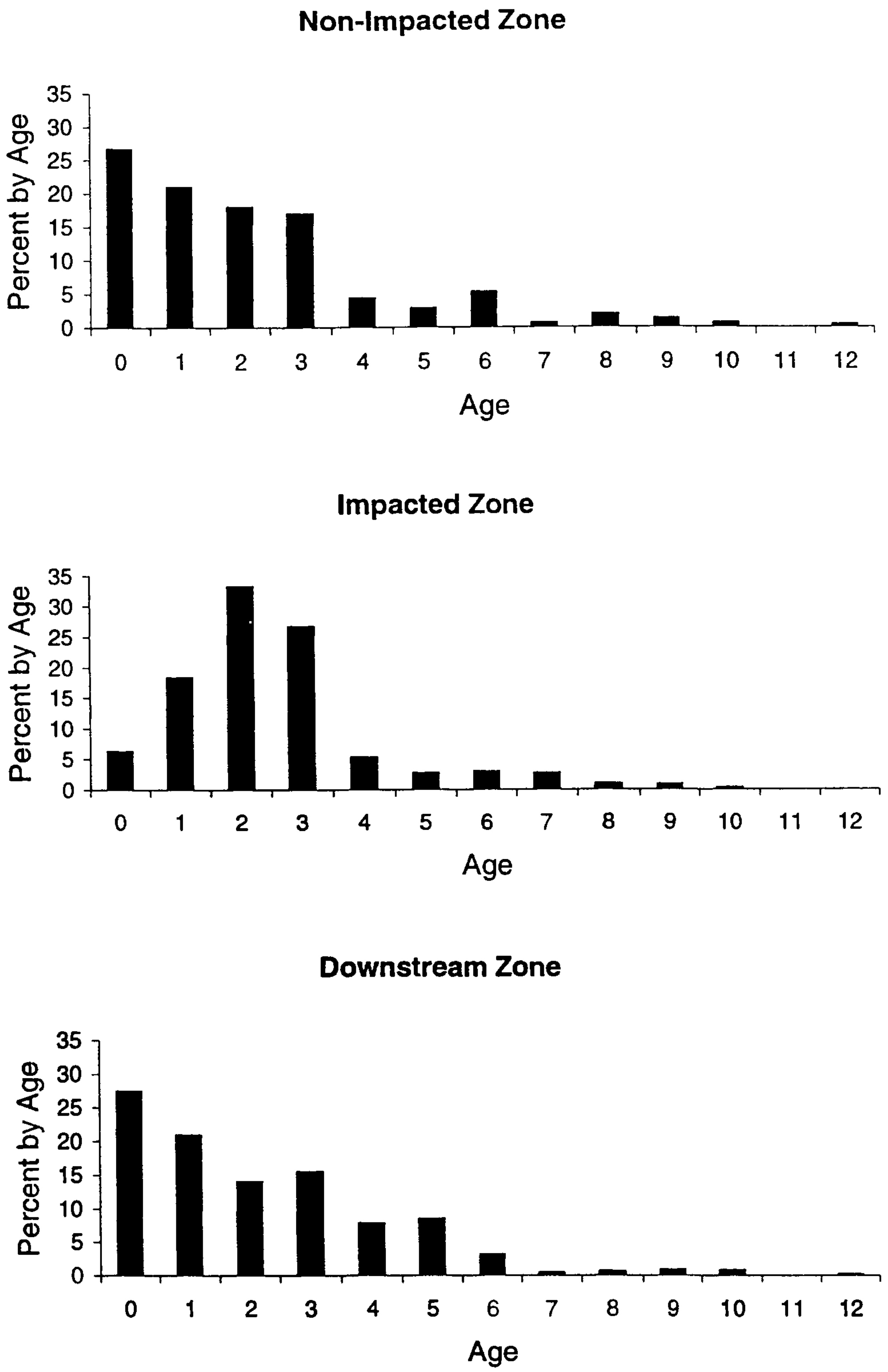


Figure 1.18. White sucker age structure within each zone on the Pine River between 1997 and 1999.

Fish Growth

The mean length at capture was calculated for trout sampled between 1996 and 1999 (Table 1.5). Compared to the length at capture for Michigan stream averages, it appears that the Pine River trout are fast growing and white suckers are slow growing.

To back calculate length at age for trout, a linear regression of fish length to total scale radius was used to determine the length at which scale formation began. Overall, the regression fit for these equations was quite good (Table 1.6). Although some sizes at scale formation were calculated to be negative, negative numbers were nonsensical and a result of non-linear regressions, and in those cases zero was used to back-calculate the length at annulus formation for previous years.

For brook trout, the pooled regression for 1998 and 1999 had an estimate of length at scale formation of –13 mm. It appeared that this was a result of the lack-of-fit for the smallest group of fish in the regression, suggesting a non-linear regression for age-0 fish. Instead of the negative estimate, the size at scale formation was fixed to 0 mm. The regression of brown trout length to scale radius, pooled from 1996, 1997, 1998, and 1999 also showed negative size at scale (-20 mm), and as with brook trout zero was instead used. The estimated size at scale formation from the regression of rainbow trout length to scale radius from 1996, 1997, 1998, and 1999 equaled 10 mm. Previous length at age was back calculated for white sucker similarly to trout using a regression of white sucker length to fin ray radius. The size at fin ray formation for white sucker length regressed on fin ray radius for 1997, 1998, and 1999 was 51 mm.

Incremental growth was regressed on length at previous age for all trout and white suckers aged between 1996 and 1999 to determine if growth differed among zones and

Table 1.5. Mean length at capture in mm for Pine River trout and white suckers, compared to Michigan stream averages (Laarman et al. 1981). All fish were captured during the growing season. Data from 1996 and 1997 was taken from Klomp (1998).

Brook Trout	0	1+	2+	3+						
1998	96	189	255	285						
1999	82	170	197	230						
Pine River Average	89	180	226	258						
Michigan Average	69	145	208	264						
Brown Trout	0	1+	2+	3+	4+	5+	6+			
1996 and 1997	72	218	341	434	542	.	.			
1998	102	225	286	385	483	.	645			
1999	84	207	279	359	411	470	508			
Pine River Average	86	217	302	392	479	470	577			
Michigan Average	76	163	229	292	384	.	.			
Rainbow Trout	0	1+	2+	3+	4+					
1996 and 1997	61	201	279	323	363					
1998	.	198	234	384	.					
1999	.	185	245	304	.					
Pine River Average	61	195	252	337	363					
Michigan Average	56	160	213	262	.					
White Sucker	0	1+	2+	3+	4+	5+	6+	7+	8+	9+
1996 and 1997	107	191	244	312	394	419	439	493	.	.
1998	86	162	234	284	376	334	456	.	.	.
1999	93	147	220	283	310	329	361	459	465	418
Pine River Average	96	167	233	293	360	361	419	317	465	418
Michigan Average	89	218	305	363	414	429	460	460	.	.

Table 1.6. Equations and R^2 values for body-scale and incremental growth regressions for trout and white suckers sampled on the Pine River.

	Body-Scale Regression	R^2
Brook Trout	y = 0.0019x + 0.0247	0.8135
Brown Trout	y = 0.0041x + 0.0828	0.9359
Rainbow Trout	y = 0.005x - 0.0522	0.819
White Sucker	y = 0.003x - 0.1534	0.8439

	Incremental Growth Regression					
	Non-Impacted Zone	R^2	Impacted Zone	R^2	Downstream Zone	R^2
Brook Trout	y = -0.2204x + 98.97	0.2128	y = -0.5933x + 114.74	0.5986		
Brown Trout	y = -0.1383x + 122.63	0.1705	y = -0.1316x + 118.87	0.2614	y = -0.1149x +126.83	0.2243
Rainbow Trout	y = 0.0304x + 89.855	0.004	y = 0.0497x + 92.491	0.0099	y = 0.0028x + 109.48	0.00004
White Sucker	y = -0.1924x + 105.54	0.4089	y = -0.186x + 100.58	0.5071	y = -0.2105x + 109.61	0.4471

years (Figures 1.19-1.22). ANCOVA results indicated no significant difference over time for any of the species analyzed ($p > 0.05$). However, variability was high and there appeared to be differences in rainbow trout and brook trout growth. When all years were analyzed together using the Impacted Zone as the arbitrary standard position, or the basis for comparison, significant differences were found in growth (Table 1.7). For brook trout, annual growth was significantly less by 11.8 mm per year in the Non-Impacted Zone ($p = 0.0079$). As no brook trout were caught in the Downstream Zone, growth rates were not determined in this area. Brown trout showed no significant differences in growth throughout the river, even though estimated growth was slightly better in the Non-Impacted Zone by 2.6 mm ($p = 0.4380$) and in the Downstream Zone by and 9.1 mm ($p = 0.0519$). Rainbow trout showed slightly slower growth in the Non-Impacted Zone by 2.6 mm ($p = 0.3247$), and significantly better growth in the Downstream Zone by an average of 9.5 mm per year ($p = 0.0285$). Like brown trout, white suckers displayed no significant difference in growth rate among zones. In the Non-Impacted Zone, white sucker growth was 5.2 mm higher ($p = 0.3785$), as well as in the Downstream Zone where growth was slightly higher by 0.2 mm ($p = 0.9720$). Overall, trout seem to be growing better in the Downstream Zone. Brook and rainbow trout grew slowest in the Non-Impacted Zone, while brown trout and white suckers exhibited their worst growth in the Impacted Zone.

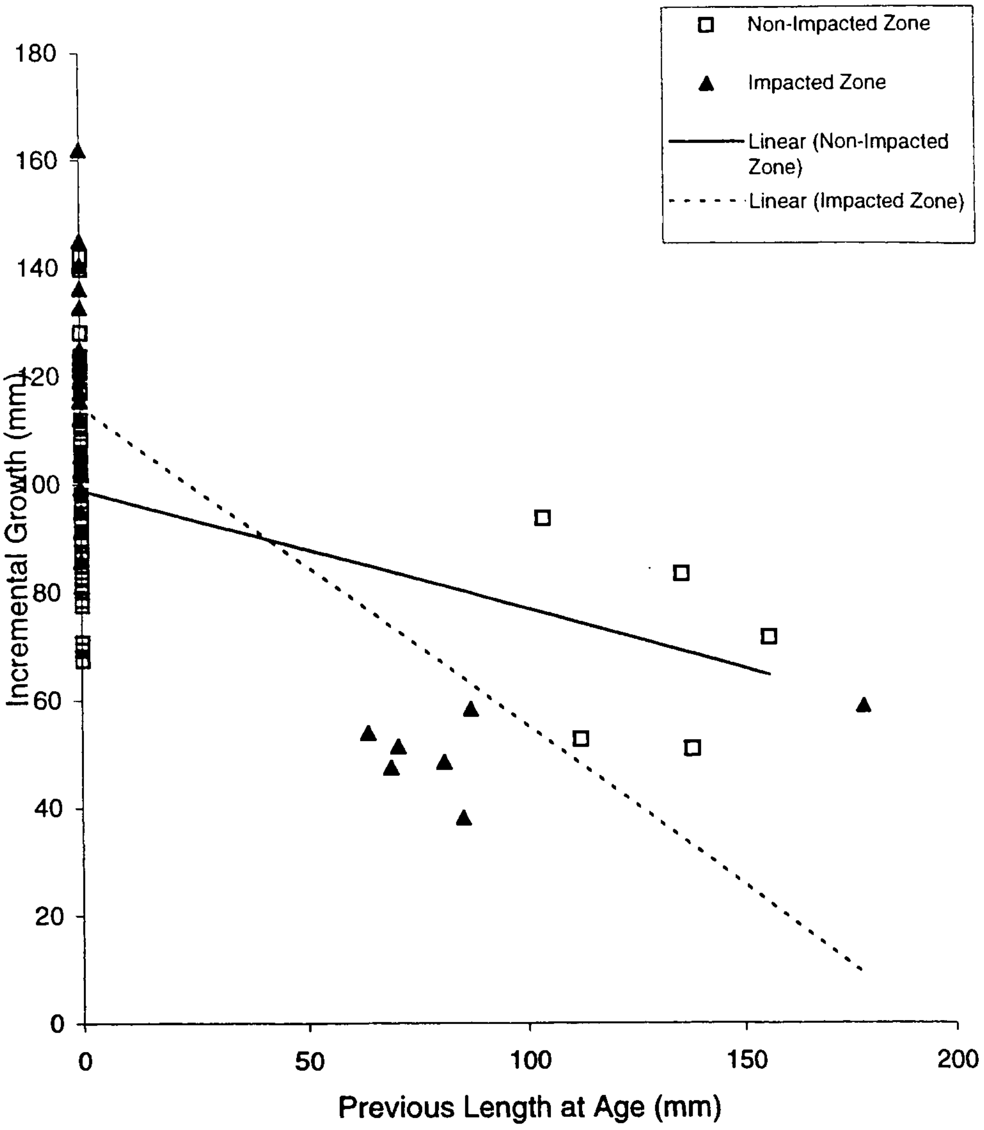


Figure 1.19. Incremental growth regressed on length at previous age by zone for brook trout sampled on the Pine River between 1998 and 1999.

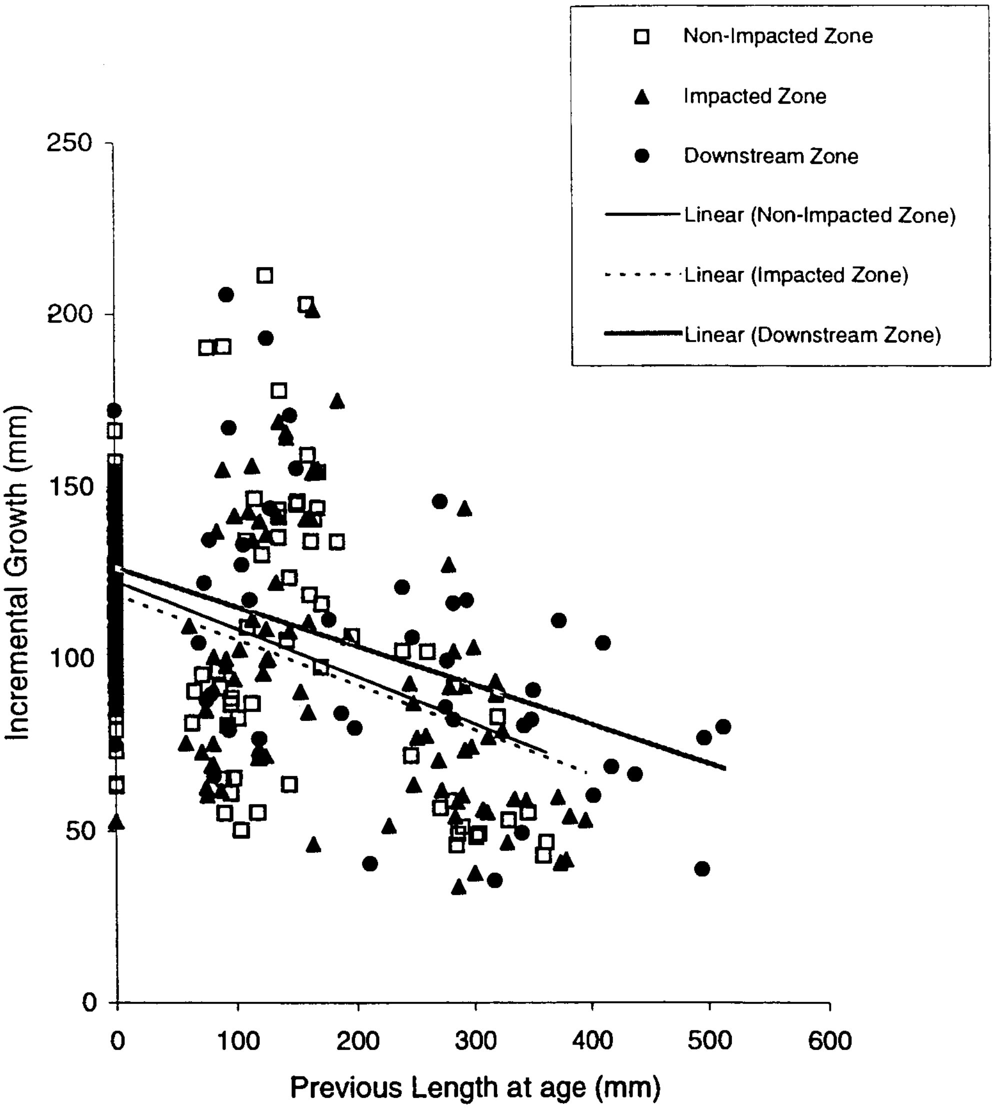


Figure 1.20. Incremental growth regressed on length at previous age by zone for brown trout sampled on the Pine River between 1996 and 1999.

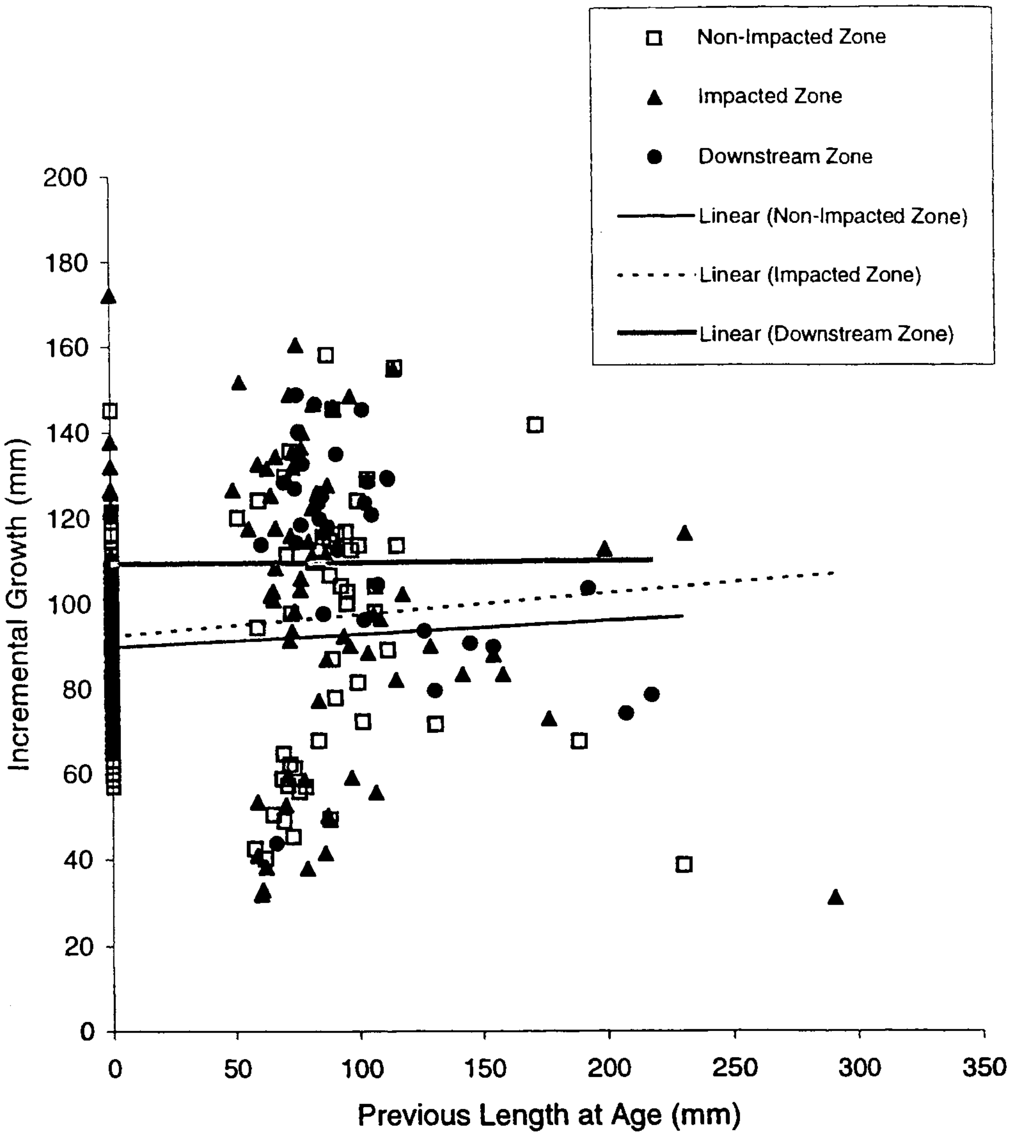


Figure 1.21. Incremental growth regressed on length at previous age by zone for rainbow trout sampled on the Pine River between 1996 and 1999.

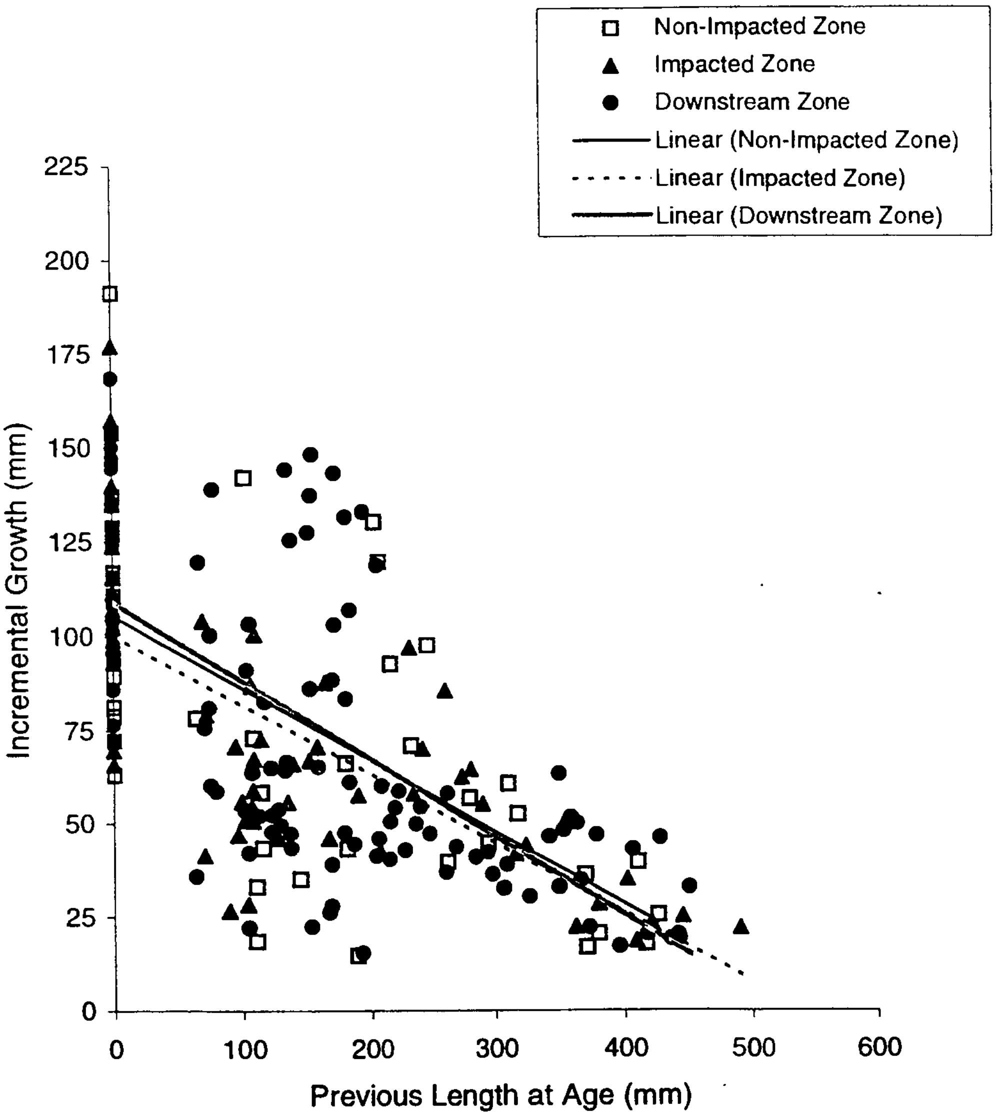


Figure 1.22. Incremental growth regressed on length at previous age by zone for white suckers sampled on the Pine River between 1997 and 1999.

Table 1.7. Pine River growth differences (mm) documented in trout and white suckers sampled from different zones between 1996 and 1999 .

	Non-Impacted	Impacted	Downstream
Brook Trout	Significant (-11.8 mm)	Standard	None Sampled
Brown Trout	Not Significant (2.6 mm)	Standard	Not Significant (9.1 mm)
Rainbow Trout	Not Significant (-2.6 mm)	Standard	Significant (9.5 mm)
White Sucker	Not Significant (0.2 mm)	Standard	Not Significant (5.2 mm)

DISCUSSION

Habitat

Sediment transport is undoubtedly one of the major concerns during and following a dam removal. Although the Pine River does not have toxic sediments, it does carry a high bedload of sand that could potentially degrade water quality and habitat below the dam. The staged dam removal was agreed upon in an effort to allow for revegetation of exposed floodplains. As a result, this protected the downstream area from an increased amount of erosion, or sediment transport. To monitor changes in the stream channel, baseline streambed and water elevations were established in 1996 through a series of transects. At the time of annual surveying in 1999, approximately 6 ½ feet of the dam had been removed.

The initial habitat measurements taken in 1995 (Klomp 1998) delineated the river into distinct habitat zones: the Non-Impacted, Impacted, and Downstream Zones. The initial findings were used as a basis for comparison to establish the extent of change in the river correlating to the dam removal. Hammad (1972) stated that a riverbed upstream of a dam will continue to erode following a dam removal until the natural armoring layer of coarse sand or gravel was exposed. Because the river is both characterized by a gravel substrate and is not hydrologically controlled by Stronach dam in the Non-Impacted Zone, changes in the streambed are not expected in this area as the dam is removed. As predicted, virtually no changes have been documented in the upstream stretches. Naturally occurring river dynamics including movement of large rocks or the introduction of coarse woody debris were attributed to those sites that have exhibited changes.

Alternately, changes caused by the dam removal were evident in the Impacted Zone. The preliminary findings by Klomp (1998) agreed with the results of a sediment study done by Hansen (1971) on the Pine River, where it was found that Stronach Dam increased the sediment in the stream channel as far as 2.8 miles, or 4.5 km upstream of the dam. Thus, changes may be documented up to this point. Currently, in the Stronach Pond transect series, scouring has degraded the river bottom to the point where several sites had a 1999 water level elevation below the original 1996 stream bottom. Above and below the dam, the river has narrowed by shifting to the area where the stoplogs were being removed. Additionally, the Downstream Zone showed an overall raising of the stream bottom as a result of sediment being flushed downstream.

Since changes in the streambed parallel water surface elevation changes, the graph showing water surface changes from 1996 gave a good indication of the sequence of sediment changes. Compared to baseline data from 1996, the river has changed dramatically both above and below the dam. Of note were the progressive changes documented in the Impacted Zone. Here, the process of head-cutting or scouring has occurred up through an area approximately 2 kilometers above the dam, with most of the changes documented within the first 1.5 kilometers. Above this, the river is characterized by a coarser substrate and subsequently more resistant to erosion. Below the dam, the streambed has risen owing to the aggradation of particles scoured from above the dam. Because Tippy Dam controls the water up to Stronach Dam, changes below Stronach Dam will not be detected past Tippy Dam. The hydrological operations at Tippy Dam can be used as a tool in changing the Downstream Zone streambed. For example, by drawing down the water levels at Tippy Dam, the mass of sand below Stronach Dam may be flushed downstream into Tippy Reservoir. Most importantly, the influence of Tippy Dam reduces the amount of certainty we have in attributing changes detected in the Downstream Zone to the dam removal.

The overall pattern of river gradient, or water surface elevation change in meters per river kilometer, decreased moving downstream. The highest gradient was recorded in the Non-Impacted Zone, while the dam caused the gradient to be reduced in the Impacted Zone. Because the dam was originally built to provide hydroelectric power to the city of Manistee, it was constructed over the area of river that contained the highest gradient water (Battige et al. 1997). As the removal of the dam allows sediment that aggraded in the upstream areas to erode, water gradient is expected to increase. Changes could not be documented in the Downstream Zone as each of the transects belonged to a separate series. Additionally, over the years gradient has not shown any definitive patterns of change, and those fluctuations seen may be attributed to seasonal or daily water fluctuations.

As expected, discharge increased as the Pine River flowed downstream. This was in accordance with the findings of Hansen (1971). Because there are no major tributaries on the Pine River, this increase was attributed to groundwater inflow. Yet, this increase displayed no annual pattern and fluctuated between approximately six and nine cubic meters per second. The variability in point measures of discharge was credited to seasonal or daily water fluctuations caused by precipitation or groundwater inflow. Velocity showed a trend of increasing from upstream to downstream. Because the streambed was being scoured away in the areas above the dam, a resultant increase in velocity has been occurring in the Impacted Zone since the dam removal began. As mentioned previously, fluctuations in velocity apparent in the Non-Impacted Zone were most likely a result of precipitation fluctuations. In the Downstream Zone, water velocities have remained relatively stable since the dam removal began in 1996.

The frequency distribution of velocity within each zone showed the diverse range of hydraulics within the river. These measurements have utility in showing the range of velocities that may be used to fulfill the habitat requirements of the various fish species. Within the Non-Impacted Zone, the velocity not only encompassed the widest range, but also the highest percentage of high velocities. The most upstream area was most suitable for trout, although the lesser occurrence of slower water did provide some habitat for white suckers. As expected, the Impacted Zone had the highest percentage of mid-range velocities. The increasing water velocity in the Impacted Zone should benefit the trout population by providing more suitable habitat. A study by Ford (1984) found a simultaneous increase in brown trout and decrease in white suckers as water velocity increased in response to habitat restoration. The Downstream Zone contained the lowest velocities of water sampled on the Pine River, suitable for coolwater reservoir species such as white suckers, northern pike, yellow perch, and walleye. White suckers specifically prefer to inhabit slower velocity waters (less than 40 cm/s) such as those found in the downstream area (Twomey et al. 1984). Because the area upstream of the dam does not possess a great deal of slower velocity water, habitat requirements make it unlikely that those species now found below the dam and in the reservoir will migrate upstream.

The analysis of pebble count data showed the overall trend of decreasing substrate size moving downstream, which corresponded to gradient and velocity measurements.

The particle composition also related to changes in streambed elevation. In the areas of greatest streambed change, there was a gradual coarsening of material. However, head-cutting will transport sand through areas with high erosion. Thus, although coarser gravel may be uncovered upstream of the dam, it will not be characterized as the dominant substrate until equilibrium is reached and sand is no longer being eroded from upstream. Hansen's (1971) study defended these results by showing a relationship between major sediment classes and slope of the water surface. As mentioned previously, the Non-Impacted Zone was dominated by medium to coarse gravel, thus making it more resistant to change than the fine gravel substrate dominating the Impacted Zone. Although the river was characterized by the prevalence of sand bedload, as emphasized by Hansen (1971) who found that sand comprised 70% of the total sediment load, the Downstream Zone was the only zone in which sand dominated the mean substrate classification. Because substrate composed of smaller material is more easily transported by higher velocity water, more changes are expected to occur in the Impacted Zone.

As time passes, further changes in channel morphology and substrate are expected, especially in areas where the river was inundated by sediment, as in the Impacted and Downstream Zones. The river will continue to downcut and the channel will shift as a result of the drawdown. With these changes, the scouring of sediment will uncover coarser underlying substrate in addition to creating an aggradation of sediment below the dam. A stable physical equilibrium may take years to reach, and until then, the extent of change seen in the fish and macroinvertebrate populations will not be fully expressed (Petts 1980).

Fish Abundance

Overall trout population density increased moving in an upstream direction, especially for brook trout and rainbow trout. This corresponded to the increased diversity in habitat as revealed through diversity in substrate and flow velocities. Alternately, the number of white suckers increased moving in a downstream direction. Although it is predicted that the carrying capacity of trout will increase as sand is scoured from the Impacted Zone, data from 1997, 1998, and 1999 indicated that the number of trout above the dam was fairly stable, showing little year-to-year variation. On the other hand, white sucker numbers were increasing in the Non-Impacted Zone while decreasing in the Impacted Zone. This shift may be attributed to the unsuitability of the substrate in the areas above the dam. Because white suckers are characterized as benthic foragers (Magnan 1988), the changing composition of the Impacted Zone may be causing them to seek more stable substrate refuge in the upstream reaches.

The pattern of abundance for trout found in the Pine River was similar to patterns seen in other rivers. For instance, in rivers with coexisting populations of brook trout, brown trout, and rainbow trout, upstream areas were typically characterized by brook trout, while rainbow and brown trout were found more often downstream (Vincent and Miller 1969, Gard and Seegrist 1972, Magoulick and Wilzbach 1997). Most of the reasons for this pattern were thought to stem from differences in competitive abilities (Rose 1986, Lohr and West 1992), or the adaptation to and selection of different environmental conditions (Cunjak and Green 1983).

While trout were present throughout the river, their comparatively low biomass suggested that habitat was limiting. Alexander and Gowing (1980) found that the standing stock (biomass/area) of the Pine River was about one-third that of other northern Michigan streams. The main underlying reason for low trout numbers appeared to be controlled by the high sand bedload of the Pine River. Reasons for the low number of trout in the Pine River might include a limiting production of macroinvertebrates, embeddedness of spawning gravels by sand, a reduction of diverse habitat, and a relative lack of coarse woody debris when compared to historical records (Stuber 1996).

Other studies have elaborated on the effects of sand on fish populations (Hansen 1971, Waters 1995, Alexander and Hansen 1983, Alexander and Hansen 1986). As an example, Ellwood and Waters (1969) found a distinct decrease in the population of brook trout after flooding inundated pools with sand and caused a decrease in habitat complexity. Brook trout were least abundant in the Impacted Zone and Downstream Zone of the Pine River where sand was most abundant and habitat was the least complex. Additionally, another study by Alexander and Hansen (1986) found that, although trout growth did not change after an addition of sand to the bedload, it resulted in the presence of less available food which could only support half of the original trout population. These results were similar to the Pine River in that it contains trout that are fast growing trout, but low in density. Most commonly in the literature, the predominance of sand has been linked to an overall reduction in the number or recruitment of trout. This is primarily accomplished through low survival rates of early life stages in trout, including the production of the egg to the health of the fry (Alexander and Hansen 1983, Alexander and Hansen 1986). Ultimately, this suggested that the combination of limited forage, less diverse habitat and decreased survival of early life stages reduced the number of trout in a river.

Improved habitat, whether through the addition of coarse substrate or the removal of sand, has been shown to be correlated with an increase in trout numbers. As an example, Alexander and Hansen (1983) were able to show that trout respond positively to decreased sand bedload through increased numbers in a Michigan stream. It is expected that the carrying capacity of trout will increase as habitat in the Pine River changes and sand is flushed downstream. Additionally, coarse substrate provides cover for trout fry by offering shelter from high water velocities (Heggenes 1988). Thus, the number of trout should be higher in the most upstream reaches, as well as in the improving Impacted Zone of the Pine River, where the overall amount of sand is less and coarser substrate can provide shelter for early life stages of trout.

Other studies have found that dam removal had contributed to both improved habitat and increased target fish populations. Kanehl et al. (1997) found that in five years after the Woolen Mills Dam removal in Wisconsin, habitat was improved, smallmouth bass (target species) abundance was higher, and the abundance of non-desirable carp was lower. Similarly, the removal of Dead Lake Dam in Florida resulted in improved habitat, increased overall fish abundance, and the resurgence of anadromous striped bass (*Morone saxatilis*) (Hill et al. 1994).

A reduction in population levels has been shown to control competition between trout species (Larkin 1956, Hayes 1987). However, competitive dominance appeared to exist in the Pine River as shown by the varying population abundance. For example, few brook trout were sampled below the dam. Initial hypothesis might point towards limiting food resources as defined by habitat. However, a few rainbow trout and substantial numbers of brown trout were sampled in this area. Because rainbow trout and brown trout feed similarly to brook trout (Carlander 1969), these species would not be present if food was the limiting factor controlling population size. Instead, brook trout and rainbow trout may be outcompeted by species better suited for certain habitats.

Where optimal habitat has been reduced, as in the Impacted and Downstream Zones, brown trout have been shown to exclude brook trout from preferred resting positions (Fausch and White 1981). Moreover, brook trout are more sensitive to angling and predation than brown trout (Fausch and White 1981). Differences that exist between brook trout and rainbow trout numbers may be explained by rainbow trout dominance over brook trout. Yet this dominance was not likely a result of the ability to compete better for food and space (Fausch 1988). Rather, reduced brook trout fecundity and year class failures seemed to give rainbow trout a competitive advantage (Clark and Rose 1997). Also, brook trout have been noted for their inability to compete successfully with non-trout species, especially yellow perch and white suckers (Flick and Webster 1992, Eschmyer 1938). In the presence of white suckers, brook trout shift their spatial distribution and feeding habits, especially when food resources are limiting (Schoener 1982). Although the fast growth rates of trout indicate that food resources were non-limiting, the high numbers of white suckers and other coolwater species in the Downstream Zone likely contribute to the lack of brook trout in this area. Consequently, trout in the Pine River seemed to be driven by changes in the physical environment rather than competition.

Based on the substrate composition, I feel that spawning success was limited by available substrate in the Impacted and Downstream Zones. Raleigh (1982) found that brook trout prefer spawning gravel between 30 and 80 mm in size. This size gravel was typically only found in the Non-Impacted Zone, with the streambed downstream of this area containing 16 mm to 0.062 mm (sand) sized particles. In comparison, it has been shown that brown trout and rainbow trout prefer spawning gravel composed of smaller particle sizes than brook trout. For example, Raleigh and Zuckerman (1996) found that brown trout prefer particles sized 10 mm to 70 mm, but will use particles between 3 mm and 100 mm in size. Likewise, Heggenes (1988) found 50 mm to 70 mm to be the preferred substrate size for brown trout. Rainbow trout less than 500 mm prefer substrate between 15 mm and 60 mm for spawning gravel (Raleigh and Hickman 1984). Again, these sizes of substrate were found most commonly in the Non-Impacted Zone, while some was also found in the Impacted Zone. Together with this, it looked as if brown trout and rainbow trout were able to utilize both the Non-Impacted and upper stretches of the Impacted Zone for spawning, while brook trout spawning was likely to be limited to the Non-Impacted Zone.

White suckers have been shown to prefer a gravel substrate with a current velocity between 30 and 59 cm/s for spawning (Twomey et al. 1984). Although velocities in the Pine River that fit into this range occurred most frequently in the Downstream Zone, the Non-Impacted Zone also had a high amount of velocity measurements that fit within this range. This may lead to the explanation underlying the higher number of white suckers inhabiting the Non-Impacted Zone as opposed to the Impacted Zone. White suckers were generally lacking above the dam and the density of the Non-Impacted Zone was highly influenced by one of the four Non-Impacted Zone sampling sites. As with any river, velocity may change by season, allowing periods of suitability. Most importantly, however, velocities that exceed the optimal spawning range for white sucker dominated the river above the dam.

Age Distribution

Most trout sampled in the Pine River were between ages zero and two. As for brook trout, the majority sampled was age one, with none older than age three or aged from below the dam. This indicated that some mechanism was limiting the existence of older brook trout.

Brown trout were predominately age zero and one above the dam and ages one through four below. Although these differences may be linked to habitat, I hypothesized that food resources most likely drive the age distribution of brown trout. Based on electrofishing data, trout below the dam have access to a larger fish forage base than exists upstream, which may allow them to select this habitat and, in turn, live longer. The food base below the dam was comprised of fish including large numbers of trout-perch (*Percopsis omiscomaycus*) and slimy sculpin (*Cottus cognatus*). These trout residing below the dam also have access to Tippy Reservoir, which may be used as a thermal refuge in the winter. As for the lack of younger brown trout below the dam, they may be consumed by species that now exist solely below the dam or below the dam in substantial numbers. These predatory species which have access to Tippy Reservoir include brown trout, northern pike, yellow perch, and walleye.

The rainbow trout sampled were mostly ages one and two. Below the dam, age two fish were more common than age one, while the opposite held true for above the dam. Because rainbow trout fry do not hatch until spring (Scott and Crossman 1985), few young of year rainbow trout were captured owing to their small size and lack of susceptibility to electrofishing equipment during the summer.

Comparing trout aged in the Pine River to similar streams in Michigan, a study by Fausch and White (1981) found that in a moderately fished river, the East Branch of the Au Sable, few brook trout lived to age three and brown trout lived up to age five. Similarly, Gowing and Alexander (1980) stated that brown trout lived longer than brook trout, with browns commonly surviving to age seven while brook trout rarely lived to age four. On the other hand, a study of an unfished population found that brook trout lived to be ages five or six (Cooper 1967). As stated previously, predation and fishing have been shown to be more limiting to brook trout when compared to brown trout (Fausch and White 1981).

White sucker age distribution indicated that most were ages zero through three. Those older than age three were most often sampled from below the dam. Because suckers are characterized as benthivores, they do not take advantage of the abundance of forage fish. Instead, white suckers may also be utilizing Tippy Reservoir, a more preferred environment based on their habitat requirements, as a winter refuge. This would allow suckers in the Downstream Zone an increased area of suitable habitat compared to their upstream counterparts.

Fish Growth

In the Pine River, trout appeared to be growing faster than the Michigan stream average while white suckers were growing slower than averages recorded for Michigan (Laarman et al. 1981). Yearly difference in annual length at capture may be attributed to whether or not the fish was captured earlier or later in the growing season. For example, fish sampling was conducted approximately one month earlier in 1999, leading to slightly smaller lengths when compared to other years.

The upstream sections have the least amount of sand, the most suitable substrate for benthic macroinvertebrates, and the highest amount of overhanging cover. Therefore, the numbers of drifting and terrestrial macroinvertebrates would be expected to peak in the Non-Impacted Zone. As a result, my initial hypothesis assumed that trout growth would be highest in the most upstream or unaltered stretches of the river. Thus far, the analysis has shown the opposite to be true. Trout do not appear to be affected by the sub-optimal habitat below the dam, as evidenced by better growth in rainbow trout and brown trout in the Downstream Zone when compared to the Impacted Zone. Likewise, when compared to the Impacted Zone, brook trout and rainbow trout exhibited significantly worse growth in the Non-Impacted Zone. This corresponds to the previously mentioned findings of Alexander and Hansen (1986), who found that trout growth was not compromised by an increased sand bedload. Most likely, these differences in growth were related to the density of trout in each of these zones. Benthic macroinvertebrate production levels should have been the highest in the Non-Impacted Zone based on suitable substrate. However, the highest density of trout was documented in the Non-Impacted Zone. Conversely, the lower numbers of trout inhabiting the Impacted Zone and Downstream Zone may have offset the low macroinvertebrate production expected to occur because of the unsuitable substrate documented in these areas.

White suckers showed a similar pattern to trout in that they showed evidence of higher growth in the Downstream Zone, followed by the Non-Impacted Zone. This indicates that either forage or environment may limit white sucker growth above the dam. As mentioned before, white suckers are primarily benthic feeders, and the shifting nature of the Impacted Zone seemed to have driven them further upstream to find better habitat. As expected, growth was best in the Downstream Zone, which characterized the preferred habitat for white suckers.

Studies have demonstrated the important role water temperature plays in the regulation of trout growth (Baldwin 1956, Jenson 1987). In addition to an evaluation done by Lawler et al. (1992), temperature in the Pine River is monitored continuously by the Michigan Department of Natural Resources. However, the data have shown that water temperature does not differ among the zones as Stronach Dam does not retain water and fluctuations were limited by groundwater input (Kruger 1999).

Management Implications

Although dams and impoundments create benefits for society, advances in our ecological understanding have demonstrated the negative consequences caused by the extensive alteration of river systems by dams. In the past, dam removal was usually only considered when dams either came up for FERC relicensing, threatened public safety, or provided a lack of economic revenue. The process of dam removal was often initiated when it was found that the cost of restoration exceeded the cost of removal. Oftentimes, however, a dam removal has been shown to be less expensive than a restoration project. As an example, in Wisconsin, a case study found that the overall cost of repair generally exceeded the cost of removal by three times (Born et al. 1998). Based on this information, economics and legislature will most likely drive future dam removal initiatives.

Although the above-mentioned reasons still exist and often bring the option of dam removal to light, a current trend is emerging where dams are being removed as a river restoration tool. Consequently, the increased interest in dam removal has resulted in attention being given to environmental as well as socioeconomic dimensions of dam removal effects (Kanehl et al. 1997, Hill 1994, Shuman 1995, Born et al. 1998). This is of monumental importance because it has been stated that ecological impacts caused by dams on entire river systems, which are the hardest for the public to recognize, have the greatest detrimental impacts (Born et al. 1998).

While little research has been done on the ecological effects of dam removal, even less has focused on social or economic aspects. One example is the study by Born et al. (1998) which documented the social, economic, and institutional concerns of dam removal in Wisconsin, a national leader in the removal of small dams. An example of social problems in the form of local controversy occurred with the removal of Michigan's Salling Dam (Shuman 1995). In this case, concerns involved lowered property values, lost recreational opportunities, downstream sediment transport, and increased flood potential. Because dam removal can be controversial, issues such as liability costs, property values, and stakeholder/community interests need to be addressed.

Controversial problems have largely been avoided in the case of Stronach Dam removal. Financial liability was undertaken by Consumers Energy in their agreement to pay for the removal as part of the FERC relicensing of Tippy Dam. Before the dam removal process began, Consumer Energy had the foresight to have studies conducted on the existing habitat including sediment, wetlands, and fish populations of the Pine River. Additionally, a large portion of the river lies within the Manistee National Forest National Wild and Scenic River designation and is therefore devoid of riparian property owners, and the removal is not expected to impact privately owned property which lies further upstream. Community and stakeholder participants include anglers, fishing guides, canoe liveries, upstream property owners, Michigan Department of Natural Resources, and the United States Forest Service. Concerns of these individuals and organizations were assessed prior to removal and continue as the dam is removed in the form of presentations, annual reports, and open communication.

A fundamental goal of fisheries science is the synthesis of information regarding the aquatic environment in order to predict how the structure and function of biotic communities may respond to change. This study is valuable in that it demonstrates a comparison of zones that will change as the dam is removed, as well as an upstream zone that is unlikely to change. The monitoring of dam pre and post removal effects is instrumental to future management actions. Unfortunately, there is a lack of rigorous stream restoration project evaluations (Kondolf and Micheli 1995). Observations on the extent of change during and after the Stronach Dam removal will provide valuable information for management decisions considering other dam removal projects. Although the dam removal process will be complete in 2003, evidence of further changes in the river system may occur for several years before equilibrium is reached.

SUMMARY AND CONCLUSIONS

Habitat and fisheries resource conditions have been monitored on the Pine River since 1996, or the same time that Stronach Dam removal began. Since that time, approximately half of the dam's stoplog structures have been removed. For the most part, the response of the river to the removal has been limited to habitat changes within the proximity of the dam. Changes in fish populations have not been documented, but are expected to develop as further changes occur within the river.

Changes in sediment have been recognized in both the Impacted and Downstream Zone. Scouring has taken place up through 2 kilometers upstream of the dam. Similarly, this scoured sediment has been deposited below the dam, causing an aggradation of the streambed. Although gradient is expected to increase as the dam is removed, no annual variation has been detected to date. Corresponding to the scouring seen in the Impacted Zone streambed, water velocity and substrate sizes have increased in this area above the dam. These changes are predicted to provide an increasing amount of suitable habitat for trout.

The population abundance of trout on the Pine River is approximately one-third that of similar northern Michigan streams. This relatively low biomass is most likely related to the high bedload of sand within the river. Sand not only provides limited spawning habitat through embededdness of spawning gravels, but also ultimately results in high mortality of trout early life stages. Within the river, trout are most abundant in the upstream stretches while white suckers are most abundant downstream of the dam. It is expected that fish populations, especially trout, will increase in abundance as the dam is removed and habitat becomes more favorable for resting and spawning. Thus far, fish populations have not amplified in accordance with the improved habitat. Instead, it appeared as though the shifting nature of the Impacted Zone did not provide a suitable habitat for fish species. The proposed increase in trout numbers may not occur until the dam is further removed and river changes are compounded or until the river reaches some stage of equilibrium.

The age distribution of trout found that the majority were ages one and two, with few fish older than age four. Brook trout had the shortest life span, with up to three years, while brown trout were aged up to six years. Trout sampled from below the dam tended to be older, with few ages zero or one sampled. These fish may live longer as a result of access to a food resource not available to upstream trout. On the other hand, the absence of younger fish indicated that either trout were recruited at an older age, or younger trout succumbed to predation. White sucker age distribution indicated that most were ages zero through three, with older fish residing below the dam. A possible explanation for this is that white suckers below the dam may be using Tippy Reservoir as a thermal refuge, allowing them access to increased suitable habitat which may result in fish surviving to older ages.

It has been documented that trout in the Pine River are fast growing while white suckers are slow growing. Contrary to previous findings, a difference in fish growth was detected when comparing fish from different habitats. All trout species and white suckers exhibited slower growth in the most upstream areas, with fastest growth documented in the Downstream Zone. This phenomenon may be further explained through food availability and fish density comparisons.

Chapter 2

Trout Diet Variability over a Summer Season in the Pine River

INTRODUCTION

Although many studies have examined trout feeding habits (e.g. Allan 1981, Cada et al. 1987, Hubert and Rhodes 1989, Angradi and Griffith 1990, Lacasse and Magnan 1992, Bozek et al. 1994) few have looked at variation within a population occupying different habitats. Bridcut and Giller (1995) found that most research on salmonid diets compares populations, seasons, or rivers. Additionally, Rader (1997) determined that studies of trout diet over large spatial scales, or multiple sites, and a complete growth season are rare. Rader also reported that most diet analyses are based on small sample sizes (i.e. 20-25 stomach samples). Quantifying the feeding habits of a large sample of trout over a full growing season would allow for a greater understanding of possible ecological processes such as diet selectivity or predatory-prey interactions.

In the Pine River, Manistee County, Michigan, naturally reproducing stocks of brook trout (*Salvelinus fontinalus*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*) coexist (Figure 2.1). Stronach Dam, built in 1912, has altered the habitat of this river. When the dam was built, it created a 26-hectare reservoir extending approximately 3.8 kilometers upstream. The reservoir, acting as a sediment trap, had filled in by 1953. As a result of this and operational problems, the dam was decommissioned in 1953 by Consumers Power Company. The dam created three distinct habitat zones delineated by Klomp (1998): the Downstream Zone extending for 1.1 kilometers below the dam, consisting entirely of runs; the Impacted Zone 3.8 kilometers upstream of the dam, consisting mostly of runs, with some riffles and pools; and the Non-

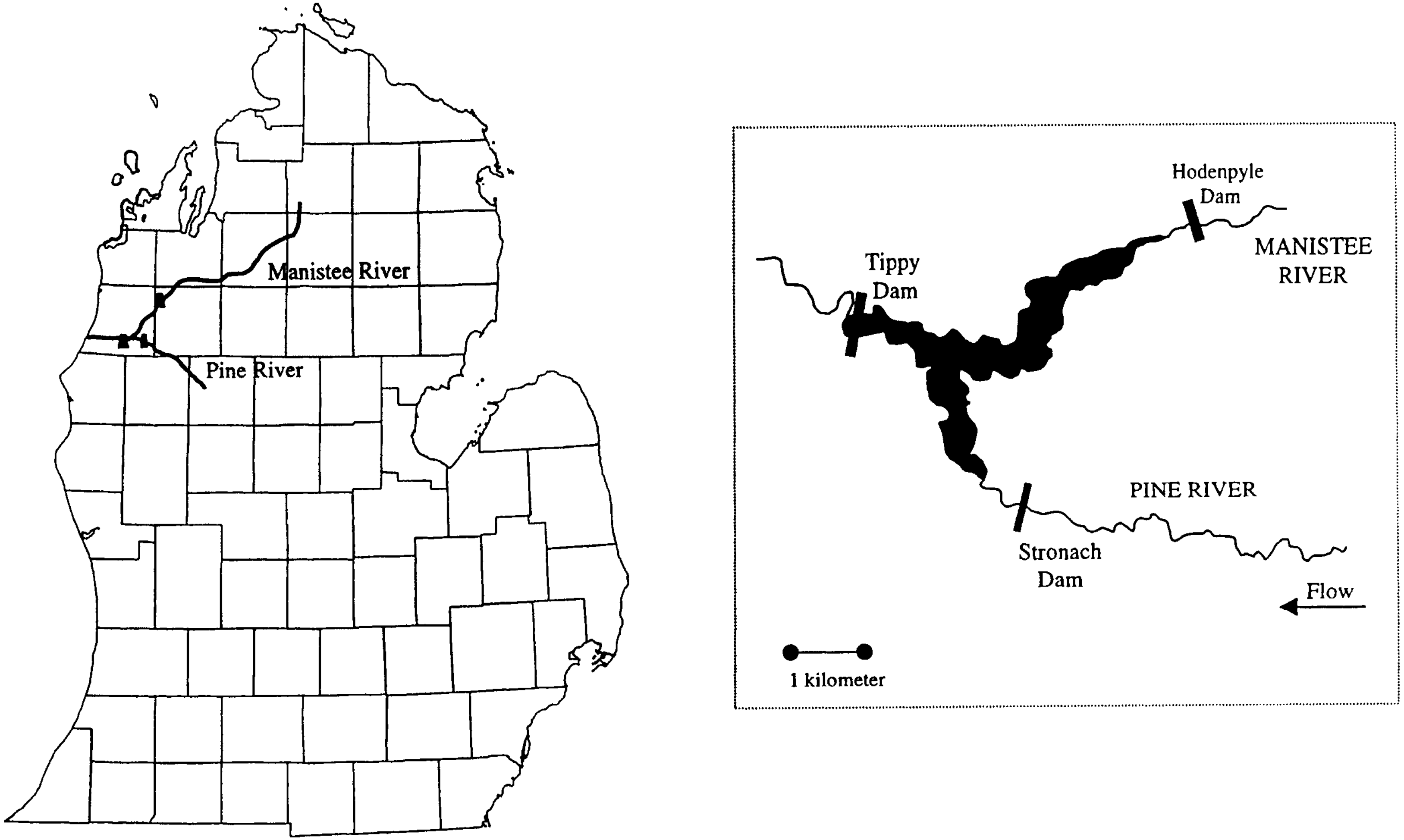


Figure 2.1. Location of Stronach Dam on the Pine River in relation to the state of Michigan and Tippy Dam.

Impacted Zone comprising 4.3 kilometers above the Impacted Zone, consisting of a complex run, riffle, pool, rapid system (Figure 2.2).

This now defunct dam is being removed in a staged process as part of a Federal Energy Regulatory Commission (FERC) agreement in the relicensing of the Tippy Dam hydroelectric project on the Manistee River. The staged removal of Stronach Dam commenced in fall of 1996 and is expected to be complete in 2003. Concurrent studies are being conducted to further understand habitat and fish population responses to the dam removal.

The overall, long term goal of the project is to determine how the dam removal and potential for fish migration from Tippy Reservoir impact the salmonid population in the Pine River. Currently, a number of species are found only below the dam. These species include redhorse suckers (*Moxostoma macrolepidotum* and *M. anisurum*), walleye (*Stizostedion vitreum*), yellow perch (*Perca flavescens*), and northern pike (*Esox lucius*). As the dam is removed, species that now only reside below the dam, or are very abundant below the dam, have the potential to migrate upstream and compete with trout. The analysis of trout diets presented here will give an indication of their feeding habits at the present level of population abundance, prey availability, and fish community composition. As the dam is removed, a change in trout feeding may indicate competition or predation resulting from the influx of species from below the dam. Although white suckers are found throughout the river, they are one of the most abundant fish species below the dam. From the collection and analysis of trout diets presently coexisting with varying populations of white suckers, we can draw inferences into how white suckers impact trout feeding. We can also develop insight into the potential impact an increased

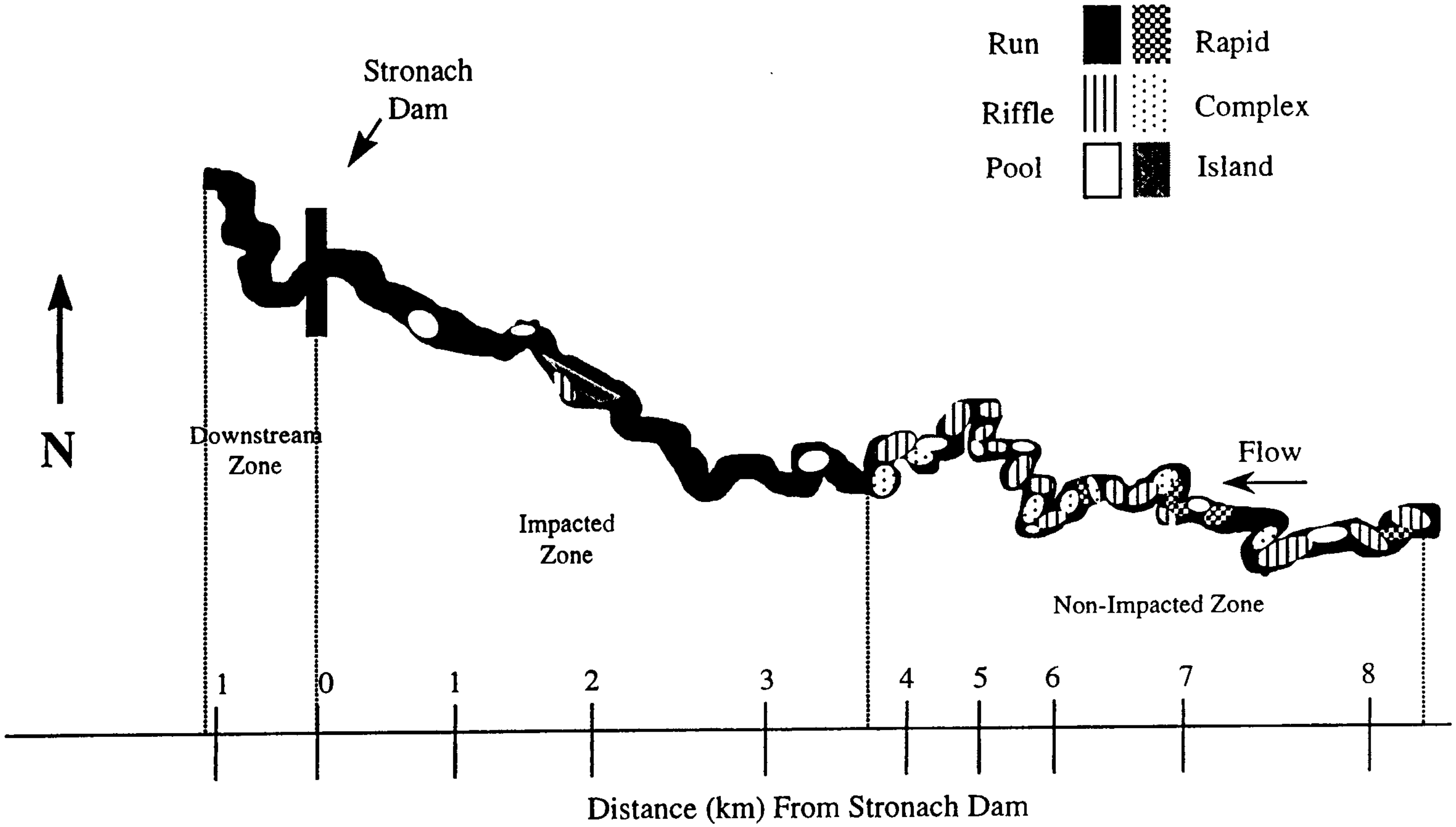


Figure 2.2. Pine River study region delineated into zones by distribution of habitat types.

white sucker population will have on trout if white suckers migrate upstream en masse once the dam is removed.

The goal of the research reported here is to describe the feeding habits of coexisting brook trout, brown trout, and rainbow trout in different habitats over a summer season and compare them to food availability in the drift. This analysis will develop insight into the diet overlap and selectivity for available food resources. By doing this, knowledge of feeding patterns for coexisting trout over a summer season (May through August) will be established. Additionally, this will provide a basis for later comparison in order to detect possible competition from other upstream migrating fish species.

The major objectives to my study were to: (1) determine the total wet weight of the stomach contents for rainbow trout, brown trout, and brook trout by month, habitat, and length class (2) describe the daytime feeding habits of rainbow trout, brown trout, and brook trout during the summer (3) compare similarity of diet by month, habitat, and trout species (4) assess the variability of macroinvertebrate drift across summer months and habitat and (5) determine patterns in electivity of trout across summer months and habitat.

STUDY AREA

(Refer to Chapter 1)

METHODS

Diet

A total of 189 trout were collected from May through August 1999 to determine the taxonomic composition and total wet weight of stomach contents. Fish with a minimum length of 100 mm were collected with a 17-foot electrofishing boat designed by Smith-Root. Because studies have shown that summer salmonid feeding occurs mainly during the day (Swift 1962, Chaston 1969, Tippets and Moyle 1978, Allan 1981, Campbell and Neuner 1985, Sagar and Glova 1988, Forrester et al. 1994, Young et al. 1997), trout of each species were collected during daylight within each zone. The stomach samples would then characterize the prey eaten in the previous 12-24 hours within the spatial scale defined by individual fish movement (Rader 1997). Sampling was conducted at ten sites along the 9.2-km study stretch. Individual sites ranged from 80 to 428 meters in length and totaled 208 meters downstream from the dam and 2,001 meters upstream from the dam.

Gastric lavage (Foster 1977, Light et al. 1983) was used to sample fish stomach contents. Using a battery operated pump, a continuous supply of water was flushed via a tube (4 mm outside diameter) into the stomach of each trout. An initial sub-sample of approximately five trout from each of the zones was used to determine if the flushing technique removed all items. Large items lodged in the mouth were removed using forceps. The stomach contents were flushed into a 250 um sieve before being preserved in 80% ethanol and placed in a sealable plastic bag. After gastric lavage was performed, each trout was given a unique site fin clip in order to distinguish these fish on later sampling dates. Survival was noted by activity of trout immediately after stomach flushing and the subsequent recapture of fin clipped trout in the following months.

In the laboratory, items in the diet were counted and identified to the lowest taxonomic level, usually family, and life stage was recorded when possible. Identification was based on Arnett (1985), Pennak (1989), and Merritt and Cummins (1996). Fragments of organisms without a head attached were neither counted nor identified, as it was assumed that the source organism had already been represented in the count of heads or head capsules.

Drift

Because other studies have shown that trout feed primarily on drift (Hunt 1966, Elliott 1970, Elliott 1973, Metz 1974, Allan 1981, Angradi and Griffith 1990), drift was sampled once a month in each zone, concurrent with fish sampling efforts. Studies have shown that a peak in invertebrate drift occurs after sunset (Waters 1972). Because of this, every month a series of three nets was placed in each zone to record the drift between 6pm and 12am. The drift nets, measuring 35 x 15 cm with a 350um mesh, were placed in a transect to encompass as much of the stream width as possible while allowing part of the net mouth to be above the water surface. The contents of the nets were emptied after every two-hour period and preserved in 80% ethanol for later analysis. The water depth and current velocity (ft/s) were measured at the mouth of each net.

In the laboratory, rose bengal (a biological dye) was added to each sample to facilitate sorting of organisms. To sub-sample the drift, two of the three nets were randomly chosen to represent each series. Samples were passed through a series of nested sieves to separate the organisms into 500 um and 1000 um size classes. Because many of the samples contained a large number of organisms, a Folsom plankton splitter was used to further sub-sample the material collected. The plankton splitter has a rotating drum fashioned with a divider to separate a sample into two subdivisions of equal volume. In order to identify a target of 100 organisms per sample, sorting ranged from an entire sample to as little as 1/16 of a sample. Because studies have shown that prey smaller than 1-mm are rarely consumed by trout (Hubert and Rhodes 1992, Bozek et al. 1994), only organisms retained in the 1000 um sieve were analyzed from the drift. The 1000 um size drift was counted and identified to the lowest taxonomic level, usually family, and life stage was recorded when possible. After adjusting for sub-sample size, drift density was estimated using the following equation provided by Allan and Russek (1985): Drift density = 100 x ((Number of organisms per net hour)/(m^3 filtered per net hour)).

Wet Stomach Content Weight

Because Glenn and Ward (1968) found that wet weight was highly significantly correlated with dry weight, and wet weight was a more convenient measure of stomach contents, total wet stomach content weight was recorded to the nearest 0.01 g in the laboratory. To reduce the amount of error, attempts were made to blot excess water before weighing. While preservation in ethanol tends to increase the overall weight (Parker 1963), consistency of the procedure allowed for useful comparisons to be made.

In order to detect differences between species and habitat, mean stomach content weight was evaluated by zone, month, and species using the SAS general linear model function (GLM). The procedure performed a generalized analysis of variance appropriate for unbalanced data (SAS Institute 1988). To see how the amount eaten changed as trout size increased, mean stomach weight was compared graphically by 50-mm length classes.

Differences in stomach weight, evaluated as a percentage of body weight, were expressed using mean percent stomach content weight. The results were compared for varying lengths of each trout species using the SAS GLM function. Mean percent stomach weight was compared for brook trout, brown trout, and rainbow trout using 50-mm length classes. The final analysis reported only those trout that measured between 175 mm and 325 mm in length in order to avoid outlying data points. Because different prey organisms have different individual weights, the mean number of organisms per trout stomach was compared across length groups of trout.

Diet Percent Composition and Mean Number Eaten by Taxa

After all items in the diet were counted, the mean number of individuals per stomach in each prey category, along with standard error, was calculated by trout species for each month and zone. These numbers were then used to determine the individual importance, or percent composition, of each prey item when looking at all components of the diet for each species by month and zone. From these data, items accounting for 5% or greater of the total diet for each month or zone were compared by fish species. Likewise, the total contribution of terrestrial items to the diet of each species was calculated for each month and zone. Terrestrial items comprised both terrestrial insects and adult stages of aquatic insects (e. g. Ephemeroptera adults). To establish which size trout were most piscivorous, the mean number of fish in the diet was compared using 50-mm size classes of trout.

Diet Similarity

Similarity was examined using Morista's index (Morista 1959) to compare the relative abundance of items in the diet by adjacent months, all zones, trout species, and to compare trout diet to the drift.

Morista's index (C_λ) is calculated as:

$$C_\lambda = \frac{2 \Sigma n_{i1} n_{i2}}{(\lambda_1 + \lambda_2) N_1 N_2} \qquad \text{where} \qquad \lambda_j = \frac{\Sigma n_{ji} (n_{ji} - 1)}{N_j (N_j - 1)}$$

and where n_{i1} and n_{i2} equal the number of individuals of species i in samples 1 and 2 respectively and N_j represents the total number of individuals in sample j. The index values range from 0 (no overlap) to 1 (complete overlap). The index gives a ratio of the probability that an individual selected from sample 1 and one from sample 2 will belong to the same species versus the probability that two individuals drawn from either sample 1 or 2 will belong to the same species (Krebs 1989).

Drift Density and Taxonomic Composition

After drift density was calculated, the mean number of each taxon, along with standard error, was calculated using nets set in each month and zone. These numbers were then used to determine the percent composition of the drift by month and zone. Items accounting for 5% or greater of the total drift for each month and zone were compared. Additionally, the percent terrestrial contribution to the drift was calculated for each month and zone.

Electivity

To compare diet composition with drift composition, electivity was calculated using Vanderploeg and Scavia's electivity index (Vanderploeg and Scavia 1979):

$$E_i^* = \frac{[W_i - (1/n)]}{[W_i + (1/n)]} \quad \text{where} \quad W_i = \frac{r_i/p_i}{\Sigma_i\, r_i/p_i}$$

where r_i equals the proportion of taxon i in the diet, p_i equals the proportion of taxon i in the environment, and n equals the number of kinds of food items. The index ranges from +1 to −1. If a taxon constitutes a larger proportion of the diet than in the drift, it is considered to be preferred, as indicated by a positive number. Likewise, a negative number designates taxa that were eaten less proportionately in the diet. Taxa that are eaten in an equal proportion to that which is found in the environment are indicated by a zero value. Lechowicz (1982) recommends this index owing to its ability to measure the preference of prey as a function of the abundance of that prey and the abundance of additional food types. The electivity of individual prey taxa by brook trout, brown trout, and rainbow trout was calculated from abundance in the drift and compared with the abundance of prey taxa in diets sampled each month between May and August 1999. Non-drifting benthic macroinvertebrates were not sampled because trout have been classified as primarily drift feeders.

RESULTS

Diet and Drift

A total of 47 brook trout, 79 brown trout, and 63 rainbow trout stomach samples were analyzed. Initial sub-sampling methods indicated the technique of gastric lavage was 100% effective. Short-term survival of trout after sampling also appeared to be 100%, as many of the fish sampled were fish that had been previously marked. In noting behavior immediately after gastric lavage was performed, larger trout (>300 mm) took the longest to recover, with up to five minutes after stomach flushing, while it did not appear to affect smaller fish. Of the 189 trout stomachs, seven were empty: one brook trout sampled in August, two brown trout sampled in June and July each, and one rainbow trout in May and June.

While the majority of trout sampled were between 150 and 250 mm in length, a wide range of lengths was encompassed. Brook trout length ranged between 101 mm and 490 mm, with an average of 193 mm. The minimum length of brown trout measured 100 mm, with a maximum length of 605 mm and an overall mean of 313 mm. Rainbow trout were sampled at a minimum length of 127 mm and a maximum length of 445 mm; the average length of rainbow trout included in diet analysis was 237 mm. On average, brook trout were smaller than rainbow trout and rainbow trout were smaller than brown trout.

Wet Stomach Content Weight

Mean wet stomach content weight was measured to quantify how the amount eaten varied with species over time and habitat. Overall, rainbow trout had the highest mean stomach weights, followed by brown trout and brook trout. Brook trout tended to have the highest stomach weight when expressed as a function of body weight, while brown trout were lower. Looking at the differences among months, an overall pattern of seasonal decline was observed for both stomach weight and percent weight (Table 2.1). For example, brook trout and brown trout had the highest stomach weight in May, with a pattern of decline over the rest of the season. Percent weight showed a summer decline for all trout species. Dissimilar to the overall stomach weight pattern, rainbow trout had the highest mean stomach weight in July, followed by May, June, and August.

Within a zone, few patterns were apparent, although the highest mean stomach weights generally occurred in the Downstream Zone and the highest percent stomach weight was documented in the Non-Impacted Zone (Table 2.2). Comparisons of stomach content weight and percent weight of each species were similar across zones and yielded no clear patterns. Brook trout had the highest stomach weight in the Downstream Zone and the highest percent weight in the Non-Impacted Zone. Brown trout had the highest stomach weight and percent weight in the Downstream Zone. For rainbow trout, the pattern was different with highest mean stomach content weigh and percent weight in the Non-Impacted Zone.

General linear models indicated that the zone, month, and species effects on stomach weight varied in significance. The factors of month and species were significant ($p < 0.0025$ across all terms), while zone was not significant ($p = 0.24$). The interaction terms of zone and month, along with month and species were both significant ($p = 0.02$ and 0.03). Furthermore, the analysis of mean stomach weight by length class showed the

Table 2.1. Mean stomach weight (g) and percent weight (g/g) with standard errors for trout sampled each month from the Pine River in 1999.

	May			June		
	Weight ± SE	Percent Weight ± SE	Number	Weight ± SE	Percent Weight ± SE	Number
Brook Trout	3.09 ± 0.39	7.54 ± 1.75	8	1.55 ± 1.63	3.13 ± 0.63	11
Brown Trout	5.91 ± 1.11	2.42 ± 0.50	22	2.97 ± 0.88	1.39 ± 0.41	19
Rainbow Trout	4.48 ± 0.97	4.43 ± 0.69	15	2.39 ± 0.33	2.56 ± 0.56	16
Average	4.49 ± 0.82	4.80 ± 0.98		2.30 ± 0.95	2.36 ± 0.53	

	July			August		
	Weight ± SE	Percent Weight ± SE	Number	Weight ± SE	Percent Weight ± SE	Number
Brook Trout	1.24 ± 0.17	2.16 ± 0.33	17	0.92 ± 0.31	1.58 ± 0.58	11
Brown Trout	2.36 ± 0.39	1.30 ± 0.30	16	1.73 ± 0.30	2.83 ± 1.04	22
Rainbow Trout	5.63 ± 1.70	2.38 ± 0.30	16	1.69 ± 0.39	1.40 ± 0.02	16
Average	3.08 ± 0.75	1.95 ± 0.31		1.45 ± 0.33	1.94 ± 0.55	

Table 2.2. Mean stomach weight (g) and percent weight (g/g) with standard errors for trout sampled in each zone from the Pine River in 1999.

	Downstream Zone			Impacted Zone			Non-Impacted Zone		
	Weight ± SE	Percent Weight ± SE	Number	Weight ± SE	Percent Weight ± SE	Number	Weight ± SE	Percent Weight ± SE	Number
Brook Trout	1.89 ± 0.93	3.06 ± 0.76	11	1.48 ± 0.25	2.24 ± 0.45	17	1.47 ± 0.24	4.06 ± 0.98	19
Brown Trout	4.71 ± 1.32	2.20 ± 0.55	20	2.55 ± 0.53	2.08 ± 0.73	26	3.08 ± 0.46	1.96 ± 0.50	33
Rainbow Trout	3.02 ± 1.04	2.79 ± 0.54	21	2.90 ± 0.44	2.30 ± 0.38	20	4.60 ± 1.09	2.87 ± 0.46	22
Average	3.21 ± 0.93	2.68 ± 0.62		2.31 ± 0.41	2.21 ± 0.52		3.05 ± 0.60	2.96 ± 0.65	

expected trend of an increasing amount of food in the stomach as length increased, with fish between 300 and 350 mm showing a peak in stomach weight (Figure 2.3).

Analysis of stomach weight as a percentage of body weight using general linear models indicated that length class and month were both significant variables ($p = 0.0001$), while species was not significant ($p = 0.1682$) when comparing brook trout, brown trout, and rainbow trout.. Because most trout sampled fell within the 175 mm and 325 mm length range, fish outside this range were excluded from analysis. Trout feeding across length classes was shown to be very similar when stomach weight was expressed as a function of body weight (Figure 2.4). Using all length classes, brook trout stomach weight averaged 3.9% of their body weight, while brown trout stomachs equaled 2.6% and rainbow trout stomach weight comprised 2.7% of their body weight.

Also, the mean number of organisms per trout stomach varied widely among trout lengths (Figure 2.5). Taking into account the amount of variability, a similar number of organisms were consumed over all trout lengths.

Diet Percent Composition and Mean Number Eaten by Taxa

At the level of taxonomic classification used, a total of 72 different items were found in the diet. Overall, taxonomic richness varied little among trout species. For example, brook trout had a total of 54 different items in their stomach, while brown trout possessed 60 and rainbow trout diets included 59 different organisms. These items included varying stages of aquatic and terrestrial insects, as well as organic material, fish, gastropods, mammals, Hirudinea, and Oligochaeta (Appendix A).

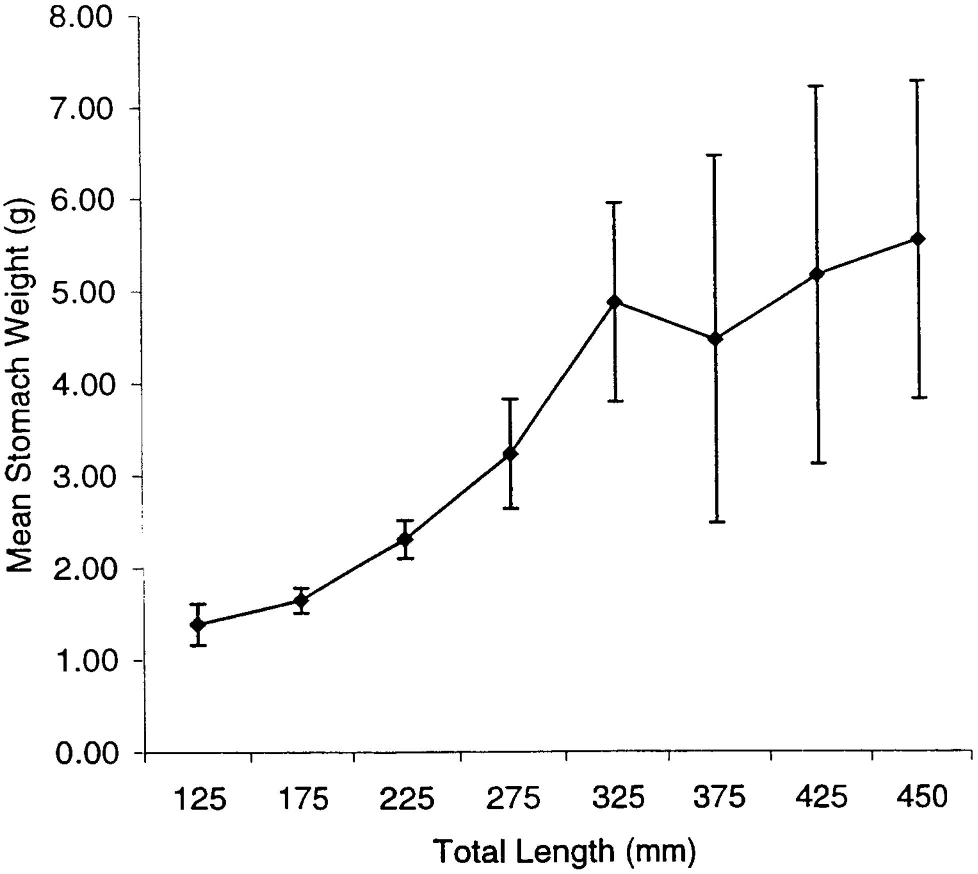


Figure 2.3. Mean stomach weights (g) and standard errors per Pine River trout length class (mm) in 1999.

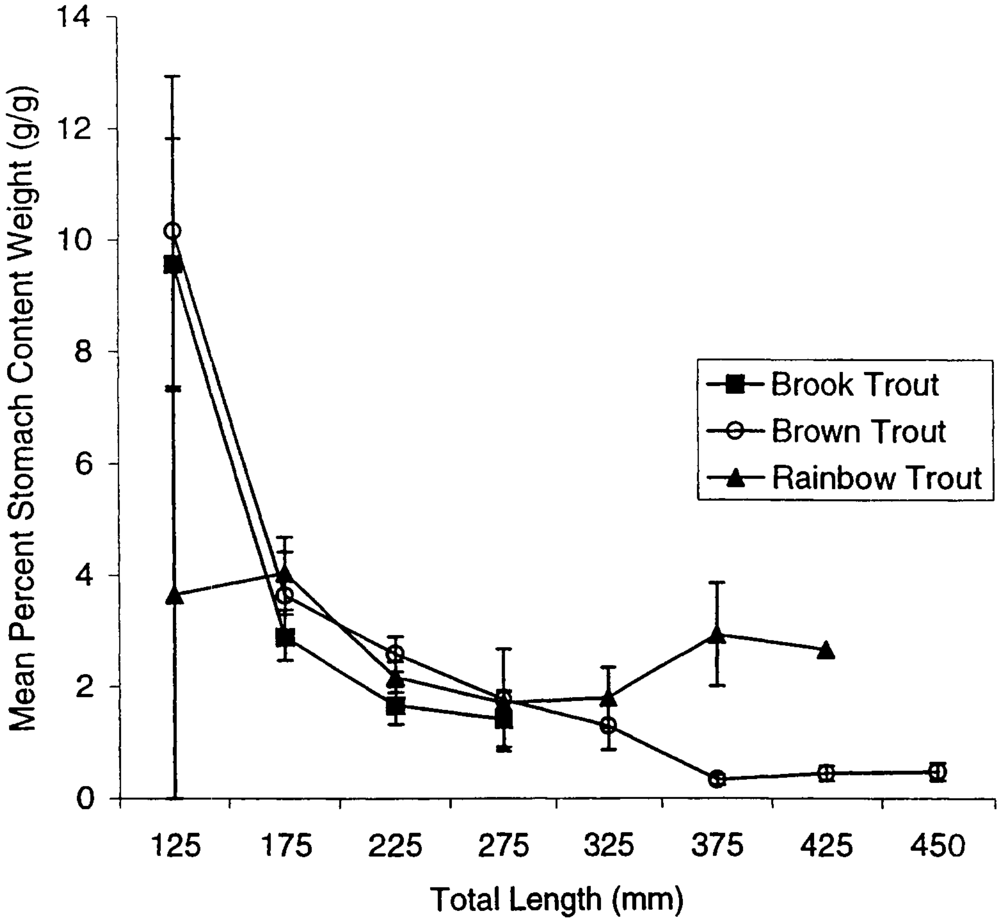


Figure 2.4. Mean percent stomach content weight (g/g), + or - 1 standard error, for all lengths (mm) of brook trout, brown trout, and rainbow trout sampled on the Pine River in 1999.

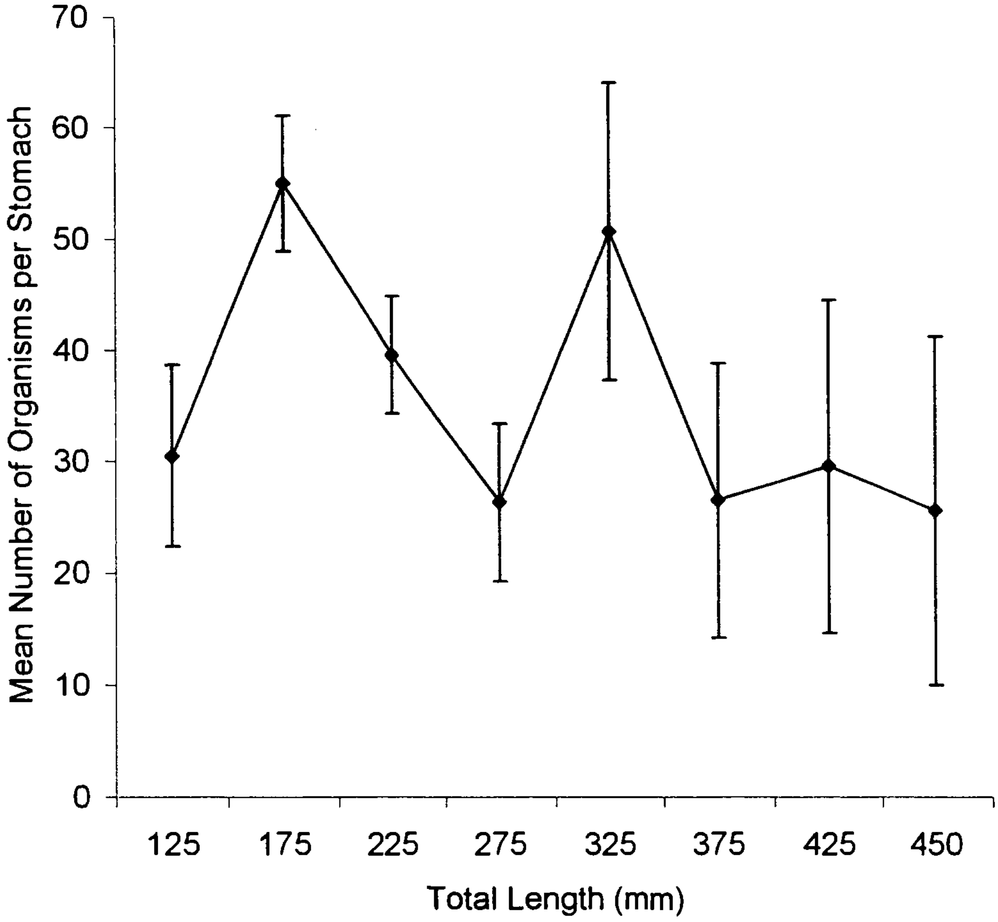


Figure 2.5. Mean number of organisms per stomach, + or - 1 standard error, for all lengths (mm) of trout sampled on the Pine River in 1999.

The percentage and mean total was calculated for each prey item found in the diet (Appendix B). The overall trend for all trout showed a decline in the mean number of prey per stomach as the summer proceeded (Figure 2.6), with trout having the highest mean number of prey items in their stomachs in May. Temporal differences varied for each trout species, but showed an overall trend of rainbow trout having notably more items in their stomach compared to brook trout and brown trout.

The mean number of items in the stomachs of trout showed an overall trend of increasing as you move in an upstream direction (Figure 2.7). Individually, spatial differences in the mean number of prey items per stomach were observed for each trout species. Brown trout and rainbow trout both displayed increasing numbers of items in the stomach moving upstream. Brook trout, however, had similar numbers across all zones, with approximately 40 items per stomach. Brown trout also contained considerably fewer prey items in their stomachs in the Downstream and Impacted Zones when compared to brook trout and rainbow trout.

In addition to general patterns of temporal distribution, monthly variations in trout diet were apparent. For example, brook trout diets were characterized by an abundance of chironomid, ephemerellid, and baetid larvae (Table 2.3). Although ephemerellid larvae was an important part of the diet, it was only identified in substantial numbers during the months of May and June. Chironomid larvae contribution to the diet was highest in July and August, but also formed a substantial portion of the diet in May. Baetid larvae were most numerous in the diet in July, but made up a relatively large portion of the diet in May and June. Other taxa that were seasonally important included athericid larvae in May, tipulid larvae and brachycentrid larvae in June, and corixid larvae and hydroptilid

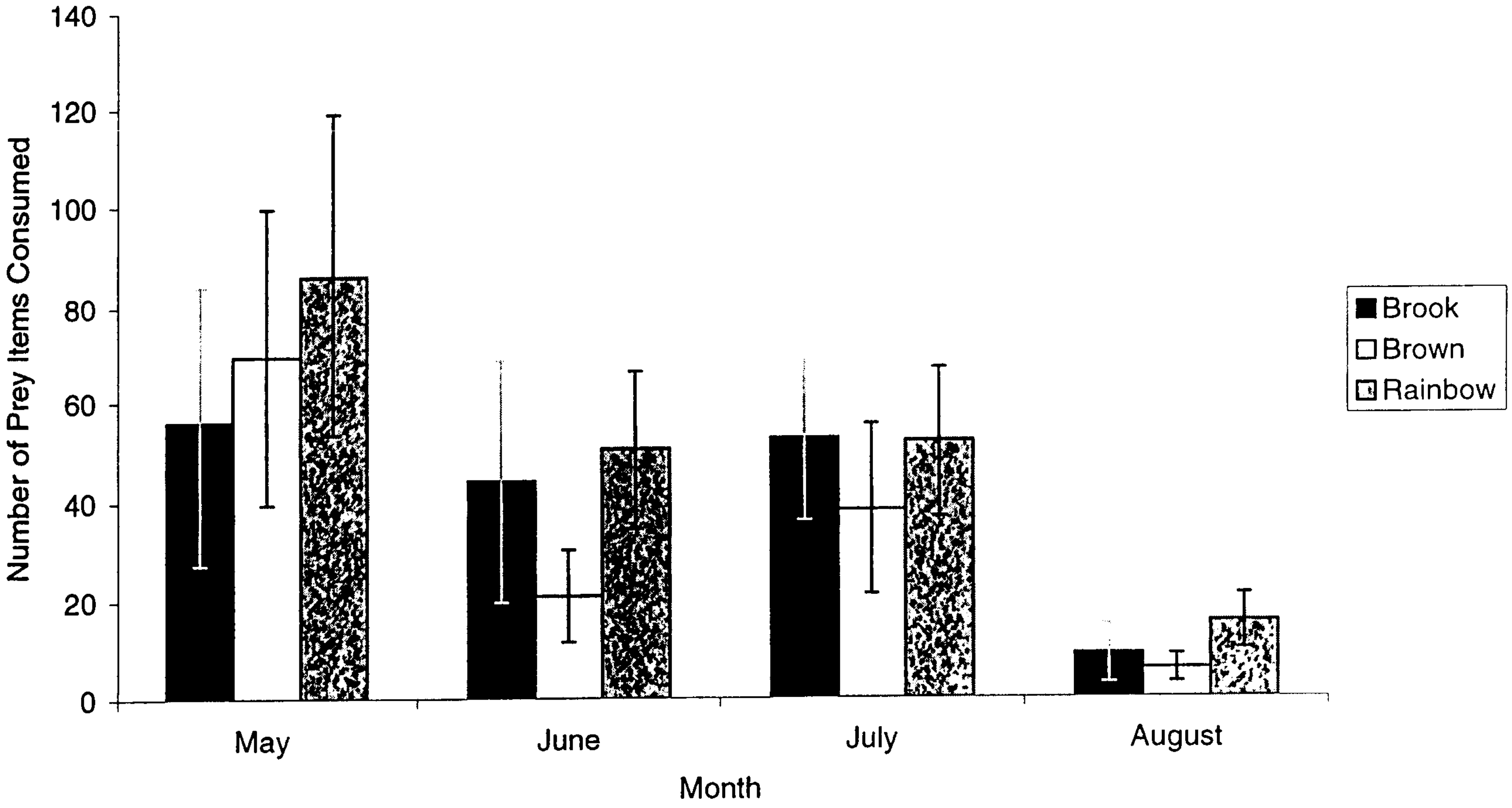


Figure 2.6. Mean number of items consumed on the Pine River during the summer of 1999 by brook trout, brown trout, and rainbow trout.

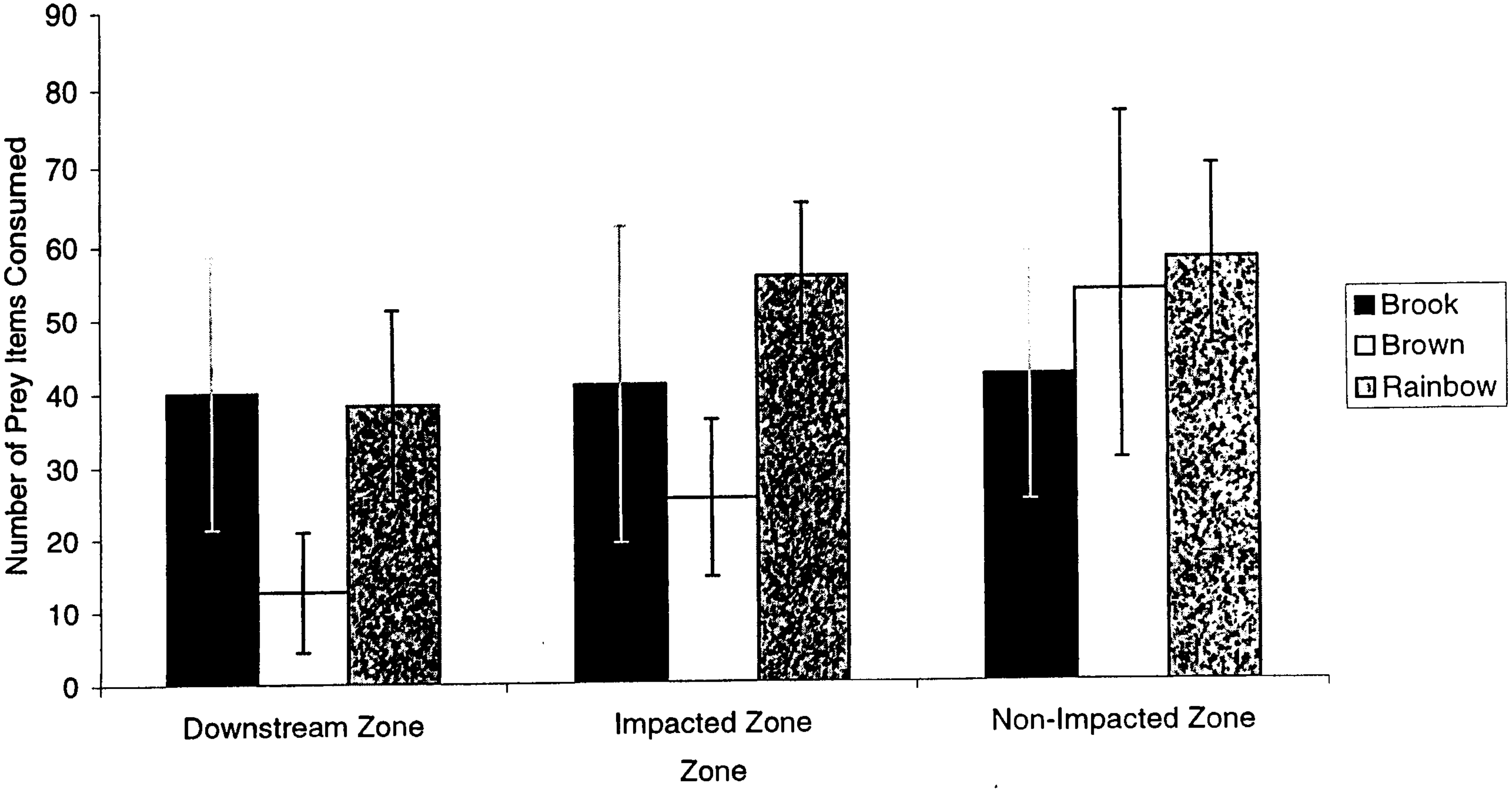


Figure 2.7. Mean number of items consumed in each zone of the Pine River in 1999 by brook trout, brown trout, and rainbow trout.

Table 2.3. Monthly mean number, standard error, and percent of most common taxa identified per brook trout sampled on the Pine River in 1999.

Taxon			May			June		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Diptera	Athericidae	Larva	14.88	10.55	26.62	1.09	0.41	2.47
Diptera	Chironomidae	Larva	5.25	4.29	9.40	0.36	0.24	0.82
Diptera	Tipulidae	Larva	3.13	1.47	5.59	11.55	10.46	26.13
Ephemeroptera	Baetidae	Larva	4.38	1.93	7.83	3.45	1.82	7.82
Ephemeroptera	Baetidae	Adult	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera	Ephemerellidae	Larva	16.63	3.65	29.75	14.73	5.00	33.33
Ephemeroptera	Unidentified	Adult	0.25	0.25	0.45	1.27	1.09	2.88
Hemiptera	Corixidae	Adult	0	0.00	0.00	0.27	0.19	0.62
Trichoptera	Brachycentridae	Larva	4.63	3.64	8.28	5.91	3.20	13.37
Trichoptera	Hydropsychidae	Larva	2.88	1.56	5.15	2.36	0.91	5.35
Trichoptera	Hydroptilidae	Larva	0.00	0.00	0.00	0.00	0.00	0.00
Other	Other	Other	3.88	1.11	6.94	3.18	1.17	7.2
Total of all items			55.88	28.45		44.17	24.49	

Table 2.3 (cont'd).

Taxon			July			August		
Order	Family		Mean	Standard Error	Percent	Mean	Standard Error	Percent
Diptera	Athericidae	Larva	0.24	0.14	0.45	0.27	0.20	3.03
Diptera	Chironomidae	Larva	17.29	3.80	32.92	1.45	0.67	16.16
Diptera	Tipulidae	Larva	2.82	0.96	5.38	0.18	0.12	2.02
Ephemeroptera	Baetidae	Larva	12.06	3.20	22.96	0.18	0.12	2.02
Ephemeroptera	Baetidae	Adult	2.76	2.00	5.26	0.09	0.09	1.01
Ephemeroptera	Ephemerellidae	Larva	2.18	0.46	4.14	0.00	0.00	0.00
Ephemeroptera	Unidentified	Adult	3.29	2.83	6.27	0.00	0.00	0.00
Hemiptera	Corixidae	Adult	0.47	0.19	0.90	3.45	2.98	38.38
Trichoptera	Brachycentridae	Larva	2.12	0.78	4.03	0.09	0.09	1.01
Trichoptera	Hydropsychidae	Larva	2.71	0.71	5.15	0.27	0.14	3.03
Trichoptera	Hydroptilidae	Larva	0.00	0.00	0.00	1.18	1.09	13.13
Other	Other	Other	6.59	1.17	12.54	1.82	0.52	20.21
Total of all items			52.54	16.24		8.98	6.02	

larvae in August. The percentage of taxa contributing to the "other" category generally increased from May to August.

Like monthly patterns of feeding, brook trout diet varied by zone (Table 2.4). Chironomid larvae, baetid larvae, and ephemerellid larvae were most prevalent in the Downstream Zone. Although chironomid larvae were important in the Impacted Zone, there were also high numbers of tipulid larvae. In the Non-Impacted Zone, ephemerellid larva, baetid larva, and athericid larva were most abundant in brook trout stomachs. The percentage of taxa in the "other" category was highest in the Downstream Zone, or the area where habitat was the least complex.

Brachycentrid larvae comprised the overall highest percentage of brown trout diet, but the percentage decreased from May through August (Table 2.5). Similar to brook trout, baetid larvae were most abundant in brown trout stomachs in July, but were also relatively important in May and June. Other items that made up a large part of the diet include athericid larvae in May, Gastropoda in August, ephemerellid larvae in June, and corixid larvae in August. The percentage of taxa in the "other" category increased from May through July.

In the Downstream Zone and Impacted Zone, baetid and brachycentrid larvae made up the bulk of brown trout diet (Table 2.6). Athericid larvae, followed by brachycentrid larvae dominated the Non-Impacted Zone. Like the brook trout, the percentage of organisms in the "other" category was highest in the Downstream Zone.

The analysis for rainbow trout identified brachycentrid, chironomid, and ephemerellid larvae as constituting the highest monthly percentage of macroinvertebrates in the diet (Table 2.7). The percentage of brachycentrid and ephemerellid larvae declined

Table 2.4. Mean number, standard error, and percent of most common taxa identified per brook trout sampled in each zone of the Pine River in 1999.

Taxon			Downstream Zone			Impacted Zone			Non-Impacted Zone		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Diptera	Athericidae	Larva	1.91	1.25	1.77	0.06	0.06	0.14	6.11	4.56	14.63
Diptera	Chironomidae	Larva	13.27	4.66	33.18	8.71	3.79	21.39	3.26	1.35	7.82
Diptera	Tipulidae	Larva	1.82	1.03	4.55	8.24	6.78	20.23	2.21	0.77	5.30
Ephemeroptera	Baetidae	Larva	6.73	3.77	16.82	4.35	1.52	10.69	6.95	2.53	16.65
Ephemeroptera	Baetidae	Adult	0.00	0.00	0.00	0.00	0.00	0.00	2.53	1.79	6.05
Ephemeroptera	Ephemerellidae	Larva	5.27	2.34	13.18	2.18	0.69	5.35	12.47	3.49	29.89
Ephemeroptera	Unidentified	Adult	0.00	0.00	0.00	4.12	2.86	10.12	0.11	0.11	0.25
Hemiptera	Corixidae	Adult	0.09	0.09	0.23	2.76	1.91	6.79	0.05	0.05	0.13
Trichoptera	Brachycentridae	Larva	3.73	2.65	9.32	4.24	2.13	10.40	1.37	0.69	3.28
Trichoptera	Hydropsychidae	Larva	2.18	1.16	5.45	2.12	0.80	5.20	1.90	0.53	4.79
Other	Other	Other	5	1.71	15.50	3.94	0.96	9.69	4.68	1.04	11.22
Total of all items			40.00	18.66		40.71	21.50		41.64	16.91	

Table 2.5. Monthly mean number, standard error, and percent of most common taxa identified per brown trout sampled on the Pine River in 1999.

Taxon			May			June		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Gastropoda	Gastropoda	Snail	7.14	4.96	10.27	0.79	0.36	3.80
Scorpaeniformes	Cottidae	Fish	0.14	0.10	2.00	0.42	0.27	2.03
Diptera	Athericidae	Larva	29.18	14.25	42.02	0.79	0.34	3.80
Diptera	Chironomidae	Larva	0.36	0.15	0.52	0.11	0.07	0.51
Diptera	Simuliidae	Larva	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera	Baetidae	Larva	4.41	2.27	6.35	1.37	0.47	6.60
Ephemeroptera	Ephemerellidae	Larva	2.36	0.75	3.40	5.79	2.89	27.92
Ephemeroptera	Unidentified	Adult	0.14	0.14	2.00	0.05	0.05	0.25
Hemiptera	Corixidae	Adult	0.32	0.18	0.46	1.16	1.05	5.58
Trichoptera	Brachycentridae	Larva	19.27	5.36	27.75	4.00	1.41	19.29
Trichoptera	Hydropsychidae	Larva	0.72	0.28	1.05	3.68	1.85	17.77
Other	Other	Other	5.41	1.47	4.18	2.58	0.61	12.45
Total of all items			69.45	29.91		20.74	9.37	

Table 2.5 (cont'd).

Taxon			July			August		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Gastropoda	Gastropoda	Snail	1.13	0.81	2.94	1.64	0.92	27.48
Scorpaeniformes	Cottidae	Fish	0.25	0.14	0.65	1.05	0.42	17.56
Diptera	Athericidae	Larva	0.19	0.14	0.49	0.00	0.00	0.00
Diptera	Chironomidae	Larva	1.60	0.63	4.25	0.73	0.38	12.21
Diptera	Simuliidae	Larva	2.31	1.99	6.05	0.00	0.00	0.00
Ephemeroptera	Baetidae	Larva	15.38	6.47	40.20	0.14	0.07	2.29
Ephemeroptera	Ephemerellidae	Larva	1.56	0.48	4.09	0.00	0.00	0.00
Ephemeroptera	Unidentified	Adult	3.00	1.79	7.84	0.00	0.00	0.00
Hemiptera	Corixidae	Adult	0.5	0.38	1.31	1.27	0.74	21.37
Trichoptera	Brachycentridae	Larva	4.13	1.47	10.78	0.09	0.06	1.53
Trichoptera	Hydropsychidae	Larva	0.31	0.15	0.82	0.18	0.11	3.05
Other	Other	Other	7.88	2.55	20.58	0.86	0.18	14.5
Total of all items			38.23	17.00		5.95	2.88	

Table 2.6. Mean number, standard error, and percent of most common taxa identified per brown trout in each zone of the Pine River in 1999.

Taxon			Downstream Zone			Impacted Zone			Non-Impacted Zone		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Gastropoda	Gastropoda	Snail	0.00	0.00	0.00	1.46	0.77	5.80	5.70	3.32	10.67
Percopsiformes	Percopsidae	Fish	0.65	0.31	5.24	0	0	0	0.00	0.00	0
Diptera	Athericidae	Larva	0.45	0.35	3.63	1.08	0.70	4.27	18.88	9.76	35.36
Diptera	Simuliidae	Larva	0.05	0.05	0.40	1.35	1.23	5.34	0.03	0.03	0.06
Ephemeroptera	Baetidae	Larva	4.75	4.34	38.31	3.92	1.94	15.57	5.30	2.25	9.93
Ephemeroptera	Ephemerellidae	Larva	0.50	0.25	4.03	1.65	0.63	6.56	4.06	1.70	7.61
Trichoptera	Brachycentridae	Larva	2.15	1.47	17.34	7.85	2.78	31.15	9.73	3.45	18.22
Trichoptera	Hydropsychidae	Larva	0.55	0.23	4.44	2.35	1.36	9.31	0.70	0.31	1.30
Other	Other	Other	3.3	1.26	26.61	5.53	1.36	21.99	9.00	2.15	16.86
Total of all items			12.40	8.26		25.19	10.77		53.40	22.97	

Table 2.7. Monthly mean number, standard error, and percent of most common taxa identified per rainbow trout sampled on the Pine River in 1999.

Taxon			May			June		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Diptera	Athericidae	Larva	11.47	3.78	13.32	2.75	1.11	5.45
Diptera	Chironomidae	Larva	7.20	6.99	8.37	0.31	0.12	0.62
Diptera	Tipulidae	Larva	1.80	0.64	2.09	2.56	1.21	5.08
Ephemeroptera	Baetidae	Larva	5.73	3.15	6.66	3.00	1.47	5.95
Ephemeroptera	Ephemerellidae	Larva	16.13	3.40	18.75	14.31	3.50	28.38
Hemiptera	Corixidae	Adult	0.27	0.12	0.31	0.19	0.14	0.37
Trichoptera	Brachycentridae	Larva	35.80	12.57	41.60	20.19	6.04	40.02
Trichoptera	Hydropsychidae	Larva	2.93	1.06	3.41	2.06	0.77	4.09
Other	Other	Other	4.73	1.10	5.50	5.06	1.49	10.04
Total of all items			86.06	32.81		50.43	15.85	

Table 2.7 (cont'd).

Taxon			July			August		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Diptera	Athericidae	Larva	0.31	0.25	0.60	1.06	0.51	6.83
Diptera	Chironomidae	Larva	8.81	2.60	17.05	6.06	2.28	38.96
Diptera	Tipulidae	Larva	3.44	1.37	6.65	0.31	0.15	2.01
Ephemeroptera	Baetidae	Larva	13.44	4.01	26.00	0.19	0.10	1.20
Ephemeroptera	Ephemerellidae	Larva	5.63	1.27	10.88	0.00	0.00	0.00
Hemiptera	Corixidae	Adult	0.13	0.09	0.24	1.75	0.73	11.25
Trichoptera	Brachycentridae	Larva	8.63	3.28	16.69	1.13	0.93	7.23
Trichoptera	Hydropsychidae	Larva	3.88	1.18	7.50	0.88	0.33	5.62
Other	Other	Other	7.43	0.99	14.40	4.19	0.57	26.91
Total of all items			51.68	15.04		15.57	5.60	

as the summer progressed, while chironomid increased. Baetid larvae were the largest part of the diet in July and athericid larvae were relatively important in May. Similar to brook trout, the percentage of taxa in the "other" category increased from May to August.

In the Downstream Zone, chironomid larvae comprised the largest percentage of rainbow trout diet, followed by baetid and ephemerellid larvae (Table 2.8). Rainbow trout captured in the Impacted Zone clearly had mostly brachycentrid larvae in their stomach, whereas rainbow trout in the Non-Impacted Zone had primarily brachycentrid and ephemerellid larvae. The percentage of taxa making up the "other" category was highest in the Impacted Zone.

Terrestrial contribution to the diet varied both temporally and spatially. Averaged across trout species, the highest percentage of terrestrial taxa occurred in July and August, with 12% and 6% of the trout diets (Table 2.9). Brook trout and brown trout stomachs had the highest number of terrestrial items in July, while rainbow trout possessed the highest number in August. Items commonly identified included various Ephemeroptera, simuliid, formicid, and acridid adults, along with Lepidoptera larvae. Contribution by zone was highest in the Impacted Zone and Non-Impacted Zone, with 8% and 6% of the diet (Table 2.10). In the Downstream Zone, terrestrial taxa did not contribute substantially to the diets of trout. Within the Impacted Zone and Non-Impacted Zone, brook trout and brown trout contained the highest percentage of terrestrial taxa.

The overall amount of piscivory was low and no cannibalism was documented. Generally, brown trout were the only species that ate a substantial proportion of fish. Except for brook trout in August, fish contributed less than 1% to brook trout and rainbow trout diets during the summer. Across months, fish appeared in the diet most

Table 2.8. Mean number, standard error, and percent of most common taxa identified per rainbow trout in each zone of the Pine River in 1999.

Taxon			Downstream Zone			Impacted Zone			Non-Impacted Zone		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Diptera	Athericidae	Larva	1.24	0.47	0.00	2.60	1.17	0.00	7.27	2.77	12.64
Diptera	Chironomidae	Larva	11.05	5.15	28.96	3.80	1.86	6.87	1.95	0.89	3.40
Diptera	Tipulidae	Larva	1.52	0.97	4.00	1.25	0.43	2.26	3.23	1.00	5.61
Ephemeroptera	Baetidae	Larva	4.24	2.67	11.11	5.75	2.47	10.39	6.73	2.39	11.69
Ephemeroptera	Ephemerellidae	Larva	5.95	2.00	15.61	6.15	1.62	11.11	14.23	3.23	24.72
Trichoptera	Hydropsychidae	Larva	2.76	0.87	7.24	2.60	0.93	4.70	1.95	0.59	3.40
Other	Other	Other	4.43	0.83	14.85	6.70	0.96	16.80	6.72	1.09	11.68
Total of all items			31.19	12.96		28.85	9.44		42.07	11.96	

Table 2.9. Monthly mean number, standard errors, and percent contribution of terrestrial taxa to diets of trout sampled in the Pine River in 1999.

	May			June		
	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Brook Trout	0.75	0.31	1.34	2.64	2.06	6.38
Brown Trout	0.86	0.44	1.24	0.58	0.23	2.79
Rainbow Trout	0.40	0.09	0.46	1.69	1.05	3.35
Average	0.67	0.28	1.02	1.64	1.11	4.17

	July			August		
	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Brook Trout	7.94	3.60	15.01	0.91	0.28	8.08
Brown Trout	6.62	2.67	17.32	0.09	0.06	1.53
Rainbow Trout	2.06	0.45	3.99	1.50	0.30	9.64
Average	5.54	2.24	12.11	0.83	0.21	6.42

Table 2.10. Mean number, standard errors, and percent contribution of terrestrial taxa to diets of trout sampled in each zone of the Pine River in 1999.

	Downstream Zone			Impacted Zone			Non-Impacted Zone		
	Mean	Standard Error	Percent	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Brook Trout	1.09	0.38	2.95	5.71	3.35	14.60	3.42	1.93	8.32
Brown Trout	0.60	0.33	4.44	1.42	0.88	5.65	2.72	1.27	5.11
Rainbow Trout	0.76	0.21	2.00	1.45	0.32	2.62	2.00	0.79	3.55
Average	0.82	0.31	3.13	2.86	1.52	7.62	2.71	1.33	5.66

strongly in August, when it accounted for nearly 7% of all trout diets, with brown trout contributing substantially of that total (Table 2.11). Most of the piscivory took place in the Downstream and Impacted Zones, where fish contributed to 3%and 1% of the diet on average (Table 2.12).

The overall amount of piscivory was low, with trout 250 mm and greater consumed the greatest number of fish (Figure 2.8). Piscivory was rare in trout smaller than 250 mm, with a peak in piscivory occurring when trout reached 250 mm. It is important to note that the amount of variability for piscivorous feeding probably indicated that feeding was similar for all trout lengths.

Diet Similarity

The amount of diet overlap varied substantially between species, drift, months, and zones. Similarity index values ranged from 0.07, indicating almost no overlap, to 0.95, indicating almost complete overlap. The comparison of trout species to other coexisting trout species found that their diets were highly similar. For example across all temporal and spatial variables, brown trout and rainbow trout diets were the most similar (0.84), followed by brook trout and rainbow trout (0.73), then brook trout and brown trout (0.59). The similarity between diets and drift varied among the trout species. For the most part, trout diets were not highly similar to the drift. Brook trout showed the highest similarity (0.70), while brown trout and rainbow trout exhibited low similarity values (0.30 and 0.43).

Monthly similarity of trout diets was variable, with adjacent months displayed higher similarity to each other when compared to non-adjacent months (Table 2.13).

Table 2.11. Monthly mean number, standard errors, and percent contribution of fish to trout diets sampled on the Pine River in 1999.

	May			June		
	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Brook Trout	0.38	0.26	0.67	0.09	0.09	0.21
Brown Trout	0.77	0.29	1.11	0.53	0.27	2.54
Rainbow Trout	0.00	0.00	0.00	0.06	0.06	0.12
Average	0.38	0.18	0.59	0.23	0.14	0.96

	July			August		
	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Brook Trout	0.06	0.06	0.11	0.09	0.09	1.01
Brown Trout	0.25	0.14	0.65	1.09	0.42	18.32
Rainbow Trout	0.06	0.06	0.12	0.06	0.06	0.40
Average	0.12	0.09	0.30	0.41	0.19	6.58

Table 2.12. Mean number, standard error, and percent contribution of fish to trout diets sampled in each zone of the Pine River in 1999.

	Downstream Zone			Impacted Zone			Non-Impacted Zone		
	Mean	Standard Error	Percent	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Brook Trout	0.36	0.20	0.91	0.12	0.08	0.29	0.00	0.00	0.00
Brown Trout	1.05	0.37	8.47	0.81	0.35	3.21	0.39	0.13	0.74
Rainbow Trout	0.05	0.05	0.12	0.05	0.05	0.09	0.05	0.05	0.08
Average	0.49	0.21	3.17	0.33	0.16	1.20	0.15	0.06	0.27

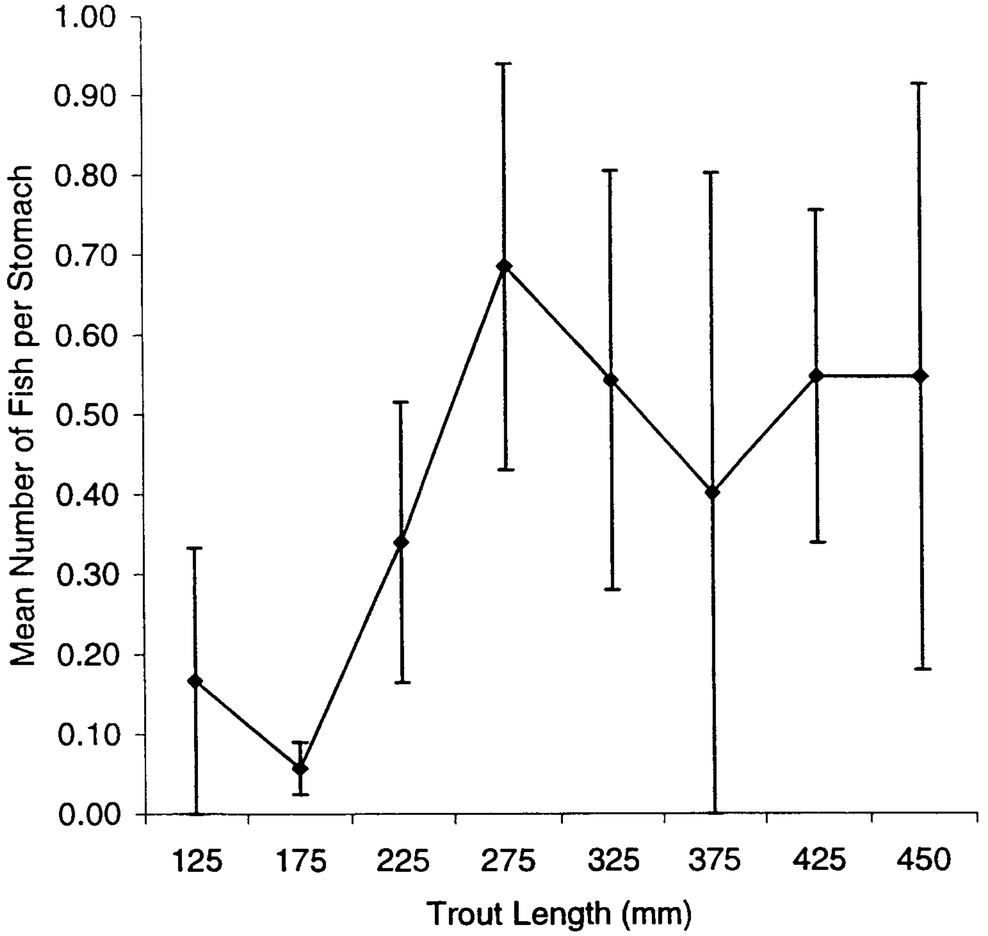


Figure 2.8. The mean number, + or -1 standard error, of fish per stomach by varying length classes of trout sampled on the Pine River in 1999.

Table 2.13. Morista similarity index values for month to month comparisons of trout diets sampled on the Pine River in 1999.

	May-June	May-July	May-August
Brook Trout	0.72	0.40	0.15
Brown Trout	0.42	0.27	0.17
Rainbow Trout	0.95	0.66	0.36
Average	0.70	0.44	0.23

	June-July	June-August	July-August
Brook Trout	0.31	0.07	0.36
Brown Trout	0.37	0.23	0.17
Rainbow Trout	0.61	0.19	0.55
Average	0.43	0.16	0.36

Similarity also seemed to decline as summer progressed. Zone comparisons indicated that organisms comprising trout diets were generally similar across the study reaches (Table 2.14). Again, adjacent zones exhibited higher similarity than the comparison of non-adjacent zones.

Patterns were evident when comparing each trout species individually. For example, brook trout diet showed the highest similarity between May and June (0.72), and the least overlap found between June and August (0.07). Comparing zones, brook trout diet similarity was highest between the Downstream and Impacted Zones with an index value of 0.78, and lowest between the Impacted and Non-Impacted Zones with 0.48.

Brown trout diets showed greater seasonal variation than brook trout, with all monthly overlap values being less than 0.50. Like brook trout, the highest degree of overlap was between May and June (0.42). The least amount of overlap was found between July and August with an index value of 0.17. Also similar to brook trout, the highest similarity among zones was found between the Downstream and Impacted Zones (0.75). The Downstream and Non-Impacted Zones were found to have the least amount of overlap (0.47).

Rainbow trout followed a similar monthly pattern of overlap as brook trout and brown trout with the highest index value were found between May and June (0.95). Also, parallel to brook trout, the lowest amount of overlap was observed between June and August (0.19). Overall, diet similarity comparing zones was high, with the Impacted and Non-Impacted Zone having the highest value of 0.83 and the Downstream and Impacted Zone having the lowest index value of 0.67.

Table 2.14. Morista similarity index values for zone to zone comparisons of trout diets sampled on the Pine River in 1999.

	Downstream Zone-Impacted Zone	Downstream Zone-Non-Impacted Zone	Impacted Zone-Non-Impacted Zone
Brook Trout	0.79	0.67	0.48
Brown Trout	0.75	0.47	0.61
Rainbow Trout	0.67	0.72	0.83
Average	0.74	0.62	0.64

Drift Density and Taxonomic Composition

Sixty-three different items were identified in the drift (Appendix A). Items which accounted for five percent or greater of the total drift for each month (Table 2.15) and zone (Table 2.16) were evaluated (see Appendix C for details on all taxa). Comparing months, the total number of organisms in the drift was highest in July with a total of 784 ± 329 items per 100 m^3 of water. The other months had lower numbers and averaged between 112 ± 29 items per 100 m^3 in August and 181 ± 107 items per 100 m^3 in May. Across zones, the largest number of drifting organisms was observed below the dam in the Downstream Zone (475 ± 228 items per 100 m^3), with similar drift density occurring in the Impacted and Non-Impacted Zones (207 ± 97 items per 100 m^3 and 244 ± items per 100 m^3). Although chironomid and baetid larvae dominated overall drift, temporal and spatial differences existed in drifting macroinvertebrates, as shown by the variability in the monthly and zonal percent composition.

In May, chironomid larvae, curculionid adults, and brachycentrid larvae dominated the drift. This shifted to chironomid larvae and pupa, as well as baetid larvae in June. Similar to June, July had a high number of drifting chironomid and baetid larvae, but also included a large percentage of chironomid adults. August showed a greater percentage of simuliid larvae in addition to patterns observed in prior months. Other items comprised 5% to 20% of the drift over the season.

Chironomidae in all stages, as well as baetid larvae dominated the drift in all zones. The Downstream Zone had the highest percentage of chironomid, baetid, and curculionid adults. Excluding the adult organisms, the Impacted and Non-Impacted Zones showed similar patterns of drifting organisms when compared to the Downstream

Table 2.15. Monthly mean number, standard error, and percent of most common taxa identified in drift ($100m^3$) sampled on the Pine River in 1999.

Taxon			May			June		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Coleoptera	Curculionidae	Adult	34.21	34.00	18.95	1.18	1.00	0.75
Coleoptera	Elmidae	Larva	0.42	0.00	0.23	1.00	1.00	0.64
Diptera	Chironomidae	Larva	67.24	40.00	37.25	67.66	42.00	42.96
Diptera	Chironomidae	Pupa	4.51	2.00	2.50	21.97	18.00	13.95
Diptera	Chironomidae	Adult	2.29	1.00	1.27	4.24	1.00	2.69
Diptera	Simuliidae	Larva	1.61	1.00	0.89	8.57	4.00	5.44
Ephemeroptera	Baetidae	Larva	13.79	4.00	7.64	38.51	13.00	24.45
Ephemeroptera	Baetidae	Adult	0.00	0.00	0.00	0.12	0.00	0.07
Ephemeroptera	Ephemerellidae	Larva	11.54	6.00	6.40	2.44	1.00	1.55
Trichoptera	Brachycentridae	Larva	19.19	7.00	10.63	3.74	3.00	2.38
Trichoptera	Hydropsychidae	Larva	1.64	1.00	0.91	0.08	0.00	0.05
Other	Other	Other	24.06	11.00	13.33	7.98	3.00	5.07
Total of all items			180.51	107.00		157.48	87.00	

Table 2.15 (cont'd).

Taxon			July			August		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Coleoptera	Curculionidae	Adult	0.37	0.00	0.05	0.08	0.00	0.07
Coleoptera	Elmidae	Larva	4.93	2.00	0.63	6.82	2.00	6.08
Diptera	Chironomidae	Larva	204.71	54.00	26.11	27.51	6.00	24.55
Diptera	Chironomidae	Pupa	76.52	26.00	9.76	3.42	1.00	3.06
Diptera	Chironomidae	Adult	115.65	79.00	14.75	3.50	1.00	3.12
Diptera	Simuliidae	Larva	50.30	22.00	6.41	19.02	4.00	16.97
Ephemeroptera	Baetidae	Larva	202.65	72.00	25.84	19.55	5.00	17.45
Ephemeroptera	Baetidae	Adult	43.52	37.00	5.55	1.30	1.00	1.16
Ephemeroptera	Ephemerellidae	Larva	11.35	10.00	1.45	0.75	0.00	0.67
Trichoptera	Brachycentridae	Larva	4.90	4.00	0.62	2.58	1.00	2.30
Trichoptera	Hydropsychidae	Larva	2.78	2.00	0.35	5.07	1.00	4.53
Other	Other	Other	66.50	21.00	8.48	22.46	7.00	20.04
Total of all items			784.16	329.00		112.05	29.00	

Table 2.16. Mean number, standard error, and percent of most common taxa identified in drift (100m^3) sampled in each zone of the Pine River in 1999.

Taxon			Downstream Zone			Impacted Zone			Non-Impacted Zone		
Order	Family	Stage	Mean	Standard Error	Percent	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Coleoptera	Curculionidae	Adult	26.11	26.00	5.50	0.56	0.00	0.27	0.20	0.00	0.08
Diptera	Chironomidae	Larva	146.47	47.00	30.84	80.20	36.00	38.76	48.67	25.00	19.96
Diptera	Chironomidae	Pupa	38.19	19.00	8.04	25.88	14.00	12.51	15.75	12.00	6.46
Diptera	Chironomidae	Adult	67.62	54.00	14.24	4.23	3.00	2.04	22.41	20.00	9.19
Diptera	Simuliidae	Larva	22.24	8.00	4.68	11.56	4.00	5.59	25.83	16.00	10.60
Ephemeroptera	Baetidae	Larva	77.64	27.00	16.35	50.32	29.00	24.32	77.92	47.00	31.96
Ephemeroptera	Baetidae	Adult	33.37	28.00	7.03	0.06	0.00	0.03	0.28	0.00	0.11
Other	Other	Other	63.31	19.00	18.83	34.10	11.00	16.48	52.74	22.00	21.63
Total of all items			474.94	228.00		206.35	97.00		243.59	142.00	

Zone. Diversity seemed to increase in an upstream direction. For example, the Non-Impacted Zone was unique in showing a higher number of baetid and simliid larvae in addition to taxa existing further downstream. The percentage of "other" taxa found in the drift increased in an upstream pattern.

The terrestrial component of drift increased over the summer and was highest below the dam. Over time, the contribution of terrestrial taxa to drift increased over May and June, peaked in July with 23% of the total drift, and declined in August (Table 2.17). Individual items responsible for the terrestrial contribution to the July diet include chironomid and baetid adults. By zone, the Downstream Zone contributed the highest percentage of terrestrial items with 24% followed by the Non-Impacted and Impacted Zone with 12% and 4% of the drift (Table 2.18). Chironomid and baetid adults were again responsible for the majority of terrestrial taxa identified in the Downstream Zone.

Electivity

Overall, those taxa making up the largest percentage of the diet were generally not selected for, as indicated by the majority of negative electivity indices. For all trout species, the Ei, or electivity index included the full range from –1 to 1, with the majority of values being less than 0. Although electivity indices were calculated to quantify the preferences for all prey taxa between May and August 1999 (Appendix D), the following figures report electivity only for those taxa which were found to contribute five percent or greater to the diet of each trout species.

Brook trout had an overall negative electivity index for ephemerelllid, chironomid, and baetid larvae, the taxa comprising the highest percentage of their diet

Table 2.17. Monthly mean number and percentage of terrestrial taxa identified in drift (100m^3) sampled on the Pine River in 1999.

		May			June	
	Mean	Standard Error	Percentage	Mean	Standard Error	Percentage
Drift	4.27	1.87	2.36	7.88	2.88	5.01

		July			August	
	Mean	Standard Error	Percentage	Mean	Standard Error	Percentage
Drift	179.48	120.72	22.89	9.84	3.37	8.78

Table 2.18. Mean number and percentage of terrestrial taxa identified in drift ($100m^3$) sampled in each zone of the Pine River in 1999.

	Downstream Zone			Impacted Zone			Non-Impacted Zone		
	Mean	Standard Error	Percent	Mean	Standard Error	Percent	Mean	Standard Error	Percent
Drift	112.83	90.56	23.76	7.88	3.10	3.81	30.37	22.62	12.46

(Figure 2.9). Of the additional items observed most abundantly in the diet, only tipulid, athericid, and hydropsychid larvae were, on average, positively selected for in relation to the drift. Monthly electivity patterns were variable and included positive selection of tipulid, athericid, brachycentrid, and hydropsychid larvae, as well as corixid adults, and unidentified Ephemeroptera adults.

Brown trout also negatively selected for the taxa comprising the highest percentage of items in the diet, including brachcentrid, baetid, and athericid larvae (Figure 2.10). Positive selection was seen for Gastropoda, corixid adults, and Cottidae (sculpin). Drift nets were not efficient in sampling fish species, thus all fish observed in the diet would show positive selection relative to drift samples. Likewise, Gastropoda were not effectively sampled in the drift nets, and their electivity was most likely not well represented. Like brook trout, brown trout electivity showed a highly variable pattern among months. Peaks in electivity were seen in Cottidae, hydropsychid larvae, Gastropoda, Corixidae, unidentified Ephemeroptera adults, and athericid larvae.

Rainbow trout were different in that they showed positive selection for the most frequent item found in their diet, brachycentrid larvae (Figure 2.11). The next most common items in the diet, chironomid, ephemerellid and baetid larvae were negatively selected for as seen in the other trout species. Like brook trout, rainbow trout also positively selected for tipulid, athericid, and hydropsychid larvae. Looking at rainbow trout electivity for each month, few patterns were shown, however, a higher number of items were positively selected for, including tipulid, hydropsychid, athericid, brachycentrid, and ephemerellid larvae, as well as corixid adults.

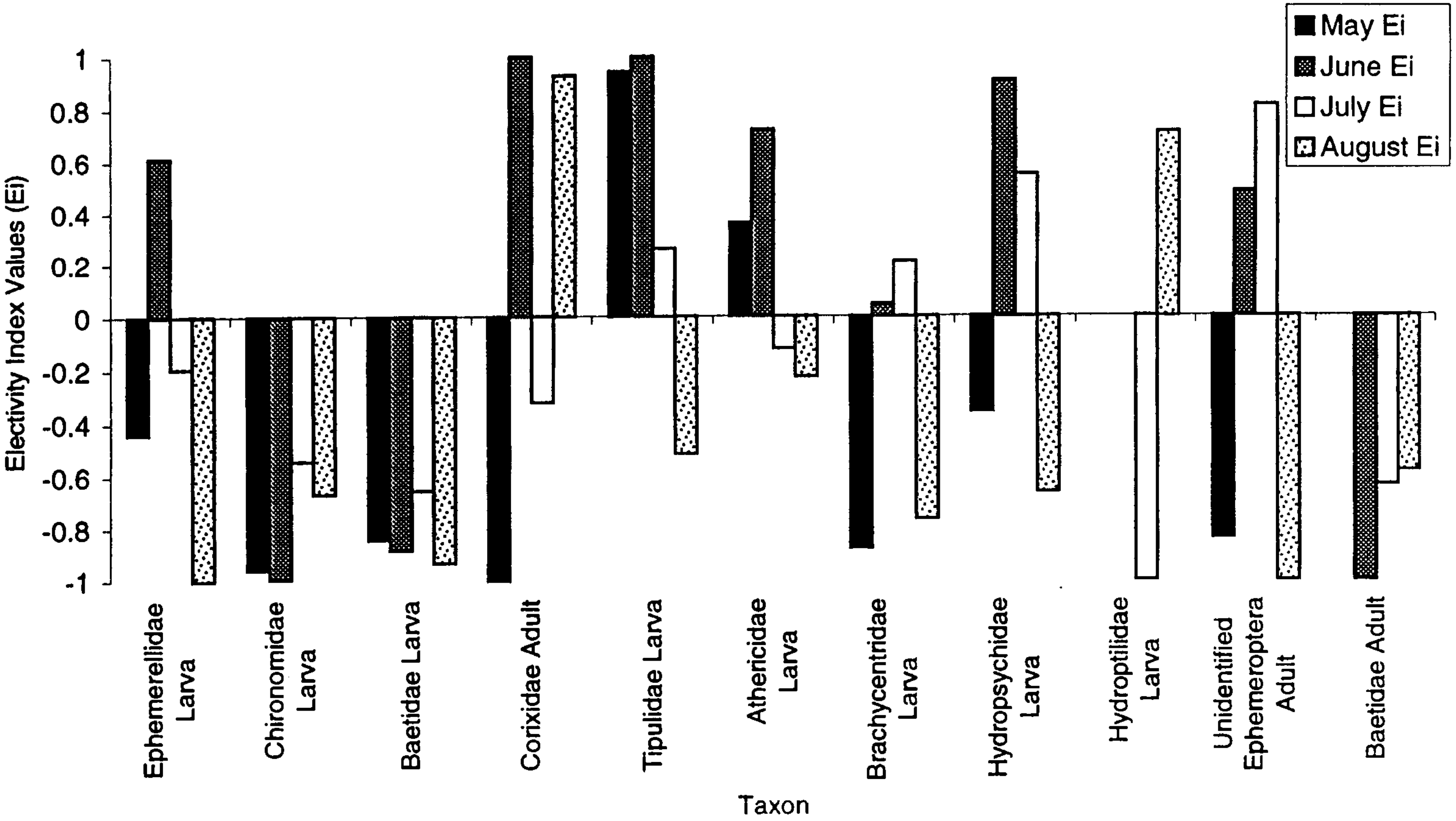


Figure 2.9. Mean Ei values sorted from left to right by taxa most frequently consumed by brook trout on the Pine River in 1999.

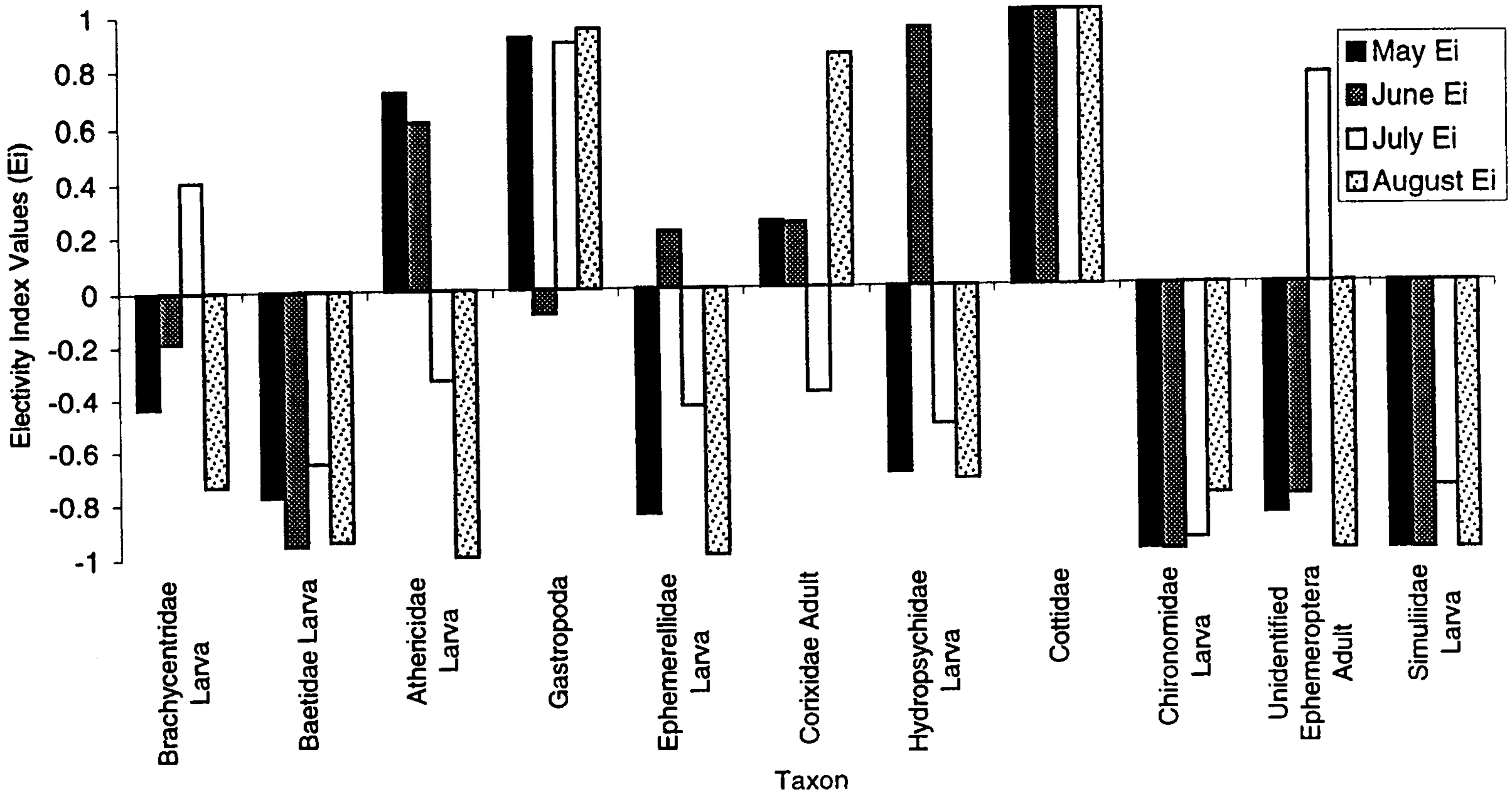


Figure 2.10. Mean Ei values sorted from left to right by taxa most frequently consumed by brown trout on the Pine River in 1999.

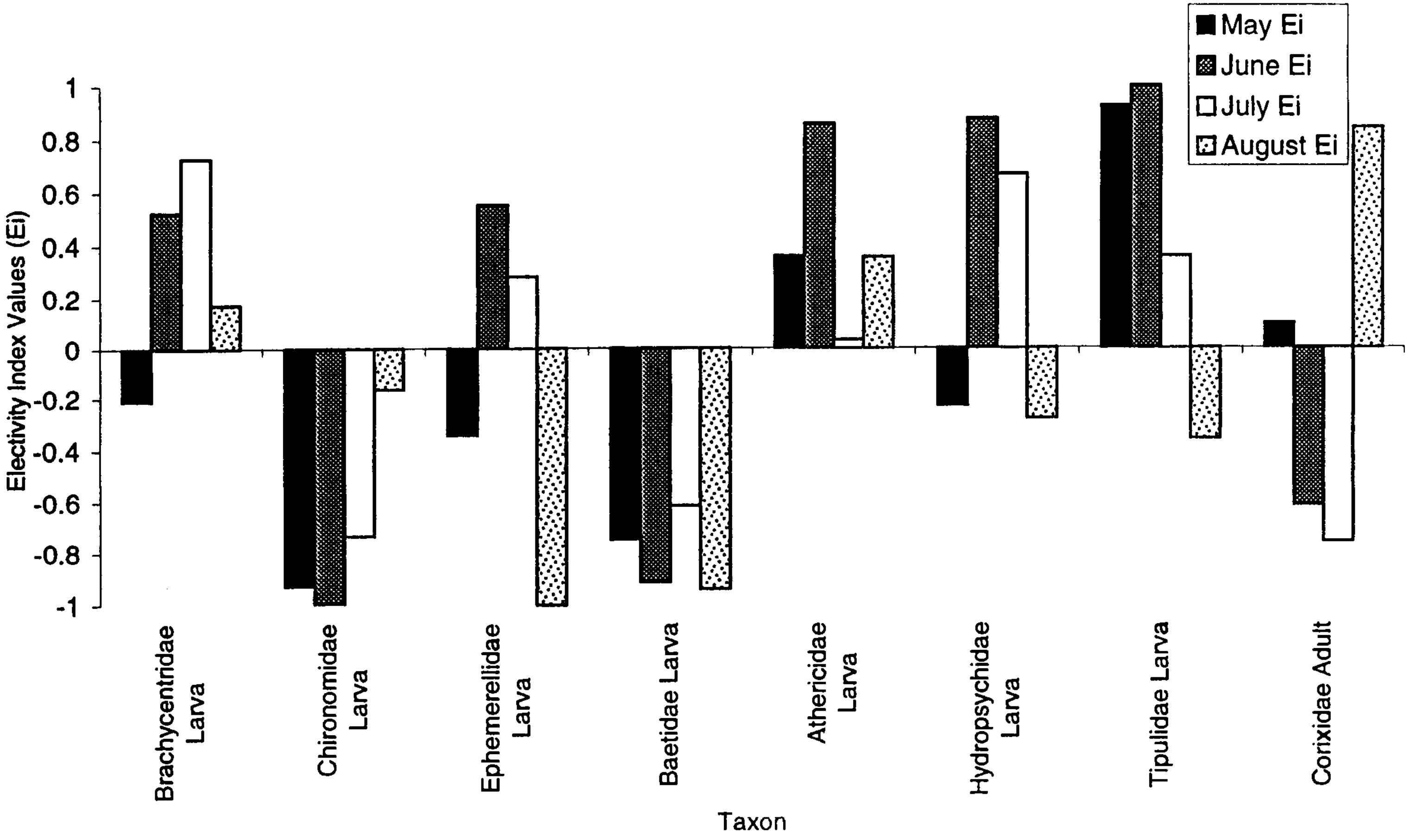


Figure 2.11. Mean Ei values sorted from left to right by taxa most frequently consumed by rainbow trout on the Pine River in 1999.

DISCUSSION

Because a main concern of ecology is to not only describe patterns of distribution and abundance, but also to determine which factors are responsible for these patterns, a diet study was conducted to further understand trout population dynamics and interactions on the Pine River. Trout have been documented as size selective, visual, opportunistic generalists, feeding primarily on drift (Hunt 1966, Elliott 1970, Elliott 1973, Allan 1978, Allan 1981, Newman 1987, Bachman 1984, Angradi and Griffith 1990, Allan 1995, Rader 1997, Young et al. 1997), with little feeding done on benthos. When quantifying daytime foraging behavior, Bachman (1984) calculated that brown trout consumed approximately 87% of their diet from the drift and less than 15% from the substrate. Because of this, invertebrates that occur in the drift as immature and adult stages generally provide the most important food resource for trout. Additionally, trout feeding has been documented as being variable. The main reasons for variation include availability of prey, which is controlled by factors such as an increase in terrestrial taxa availability during the day, light intensity, an evening peak in invertebrate drift, river habitat, age and size of the predator, and social behavior of the trout (Elliott 1967, Jenkins 1969, Elliott 1973, Allan 1981, Fausch 1984).

Wet Stomach Content Weight

In this study, efficiency of gastric lavage and survival of trout afterwards was nearly 100%. This correlated to a study by Light et al. (1983) which found gastric technique to be effective for 98% of brook trout sampled, with a 100% survival rate.

Also, Meehan and Miller (1978) reported a similar method of stomach flushing to be effective in removing stomach contents from salmonids.

Mean wet weight of stomach contents provided an indication of how trout feeding changed over the months and zones. Among the trout species, rainbow trout had a higher mean stomach content weight compared to brook trout and brown trout. For all these species, the amount of food, as measured by weight and percent weight, declined as the summer progressed. This decline may be a result of macroinvertebrate life cycles and emergence schedules. Differences among zones were not significant, but the spatial pattern of stomach content weight varied among the three species. Trout appeared to have more food in their stomach in the Downstream and Non-Impacted Zones. It was also recognized that as trout length increased, the weight of food in the stomach showed a parallel increase. Stomach weight expressed as a function of body weight showed similar spatial and temporal patterns to stomach weight. However, brook trout had higher percent weights and brown trout had lower percent weights when fish length was taken into consideration.

Analysis of stomach weight as a percentage of body weight using general linear models established that length class and month were both significant variables, while species was not significant. These results denoted that trout feeding across length classes was similar when stomach weight was expressed as a function of body weight. Wet stomach weight averaged between 2.6 and 3.9% for the present study. This was slightly higher than values determined by Angradi and Griffith (1990) who found that the relative wet weight of trout from the Snake River in Idaho averaged between 1.8 and 2.1% of the total body weight. Also, the mean number of organisms per trout stomach showed a pattern of decline in the number of organisms consumed as trout length increased. Because previous results indicated that mean stomach weight increased as trout grew, it was determined that larger trout consumed fewer but bigger organisms. This was comparable to the literature which has shown that size selection of prey increased with trout size, although smaller prey continued to be an important part of the diet (Ringler 1979, Allan 1981).

The mean wet weight of trout stomach contents in the Pine River, compared to other Michigan streams, was much higher. For these comparisons, 1 ml was assumed to be equal to 1 g (Alexander and Gowing 1976). The average wet stomach content weight for trout in the Pine River was 2.83 g. On the other hand, Alexander and Gowing (1976) determined that the mean stomach volume for northern Michigan stream trout was 1.2 ml.

An abundance of empty stomachs could indicate that food was limiting. Looking at trout from the Pine River, less than 4% of the stomachs were empty, suggesting that there was an abundant supply of food on which most trout were feeding. In a study of brown trout and rainbow trout from unproductive southern Appalachian streams, 28% of the brown trout stomachs and 22% of the rainbow trout stomachs were empty (Cada et al. 1987). Comparatively, it appeared as though Pine River trout were feeding well.

By month, trout stomach weight in the Pine River declined as the summer progressed. For example, the highest mean stomach weight was noted in May with 5.9 g, while the lowest average stomach weight of 0.92 g was recorded in August. Stauffer (1977) found that the mean stomach volume for brown trout sampled in the Au Sable River between May and September averaged approximately 0.8 ml, while brook trout in the upper Au Sable River averaged between 0.282 ml and 1.033 ml and brown trout in the upper Manistee River were between 0.1325 ml and 0.720 ml (Strogen 1979). Although trout in the Pine River had higher average stomach content weights than trout in other Michigan streams, the patterns were similar in that seasonal changes within these studies illustrated that the total stomach volume was highest earlier in the summer and declined through August.

Diet Percent Composition and Mean Number Eaten by Taxa

Trout coexisting in the Pine River can be characterized as opportunistic feeders, as exemplified by the consumption of 72 different organisms in the diet. Corresponding to the overall decline of mean wet stomach content weight, the number of items per stomach declined as summer progressed. A seasonal decline in the number of organisms eaten has been documented in other studies (Allan 1981, Wilhelm et al. 1999). Brown trout and rainbow trout were documented as having more food items in their stomachs moving upstream, while brook trout possessed similar numbers of items across all zones.

Chironomid, ephemerellid, brachycentrid, athericid, and baetid larvae all proved to be numerically important in the diets of brook trout, brown trout, and rainbow trout. These families of taxa appear to consistently play an important role in the diets of trout given their prevalence in this study as well as previous research (Elliott 1973, Metz 1974, Stauffer 1977, Tippets and Moyle 1978, Strogen 1979, Cada et al. 1987, Angradi and Griffith 1990). Additionally, most of these studies found that the number and types of prey eaten by trout varied in different months and habitats. This phenomenon was observed in this study with an increasing number of taxa contributing to the "other" category between May and August and in the Downstream Zone and Impacted Zone.

This indicated that a greater number of food items added to the diet of trout as summer continued and in the areas of less complex habitat.

Terrestrial organisms, mostly comprised of adult forms of aquatic insects, were an important part of trout food, contributing an overall 12% of the diet in July and followed by 6% of the diet in August. Most of the terrestrial taxa were eaten in the Non-Impacted Zone and Impacted Zones, where the most diverse cover was located. Rainbow trout contained the highest number of terrestrial items in their stomach during August in the Non-Impacted Zone, while brook trout and brown trout had the highest number during July in the areas upstream of the dam. Other results have shown terrestrial organisms to be more important in the diets of trout later in the summer (Hunt 1975). For example, Allan (1981) found that trout ate more terrestrial items as aquatic organisms became more rare in the latter part of summer. Cada et al. (1987) also determined that trout consumed more terrestrial organisms later in the summer, comprising up to 36% of their total diet. Reasons for this high number included the low autochthonous productivity of the Appalachian stream, which forced trout to seek alternative food sources (Cada et al. 1987).

The amount of fish eaten, or piscivory, in the diet was low. For instance, brown trout were the most piscivorous trout species with approximately 7% of their August diet being fish. As expected, most incidences of piscivory took place in the Downstream Zone and Impacted Zone, where forage fishes were comparatively more abundant. Trout greater than 250 mm had the greatest amount of fish in their stomach. Although no cases of cannibalism were confirmed during the study, other studies have contradicted these results by showing cannibalism by trout to be more prevalent (Griffith 1974, Wilhelm et al.

1999). The rarity of cannibalism indicated that the abundance of food resources in the form of drift and forage fishes was plentiful enough for the relatively low abundance of trout.

Diet Similarity

As mentioned previously, Angradi and Griffith (1990) suggested that index values greater than 0.6 were viewed as indicating significant overlap. This guideline showed that trout diets in the present study were all highly similar to each other. Brown trout and rainbow trout had the most overlap, while brook trout and brown trout had the least amount of dietary overlap. When comparing the diets of trout to the drift, the amount of overlap was low for both brown trout and rainbow trout. Brook trout, however, demonstrated a high level of overlap with drift. Various levels of overlap have been calculated between drift composition and trout diets in a multitude of research (Elliott 1967, Cada et al. 1987, Hubert and Rhodes 1989, Angradi and Griffith 1990, Forrester et al. 1994, Young et al. 1997), with some of the studies contending that trout diets overlapped significantly with drift (Elliott 1970, Elliott 1973, Allan 1978, Allan 1981). However, comparisons are difficult because selectivity or overlap indices function as a property of sampling frequency, resolution of taxonomic identification, and the method of comparison rather than behavior of individual fish (Hunt 1975).

Monthly diet similarity declined as the summer progressed, with adjacent months showing lower similarity than overlap between diets of different trout species (0.70 to 0.36). In contrast, Elliott (1973) found that brown trout and rainbow trout had very similar diets from June to August. Wilhelm et al. (1999) documented the dietary overlap of bull trout between July and September to be greater than 0.60. Time or month seemed to control the type of organisms available for trout predation. Consequently, similarity was high for trout diets from all zones, with the Downstream Zone and Impacted Zone having the highest level of similarity.

Drift Density and Taxonomic Composition

Trout have been characterized as primarily drift feeders. Therefore, it is important to understand the mechanisms that drive drift. Invertebrates may intentionally or behaviorally drift to avoid predation (Allan 1978, McIntosh and Peckarsky 1996) or become accidentally dislodged (Peckarsky 1980, Kohler 1985, Forrester et al. 1994). Studies have shown that most invertebrates drift after sunset to avoid detection by fish predators (Elliott 1973, Walton 1980, Cibrowski 1983, Kohler 1985). Above all, macroinvertebrate drift in trout streams can exhibit high spatial and temporal variability (Needham and Usinger 1956, Wiley et al. 1997).

A total of 63 different organisms were identified in the drift. Various stages of chironomids, as well as baetid and simuliid larvae, were among the most abundant organisms recognized. Items contributing to the "other" category were responsible for approximately 5 to 20% of the total drift. Terrestrial items were most abundant in July, with 23% of the monthly drift. July was noted for its high amount of terrestrial macroinvertebrates, particularly an abundance of grasshoppers and adult forms of aquatic insects. The Downstream Zone contained the highest amount of drifting terrestrial taxa with 24% of the total amount analyzed. The Non-Impacted Zone had the highest amount of overhanging cover and higher numbers of terrestrial organisms were expected in this zone. The habitat near the dam was less complex than the upstream areas and fewer organisms were expected to contribute to the drift in this area. One plausible explanation for the abundance of terrestrial organisms downstream may be attributed to the lack of sand banks when compared to the upstream section. The downstream riparian habitat consisted of banks with vegetative cover in addition to fauna typically found in wetland regions. Furthermore, many of the terrestrial taxa identified were adult forms of aquatic macroinvertebrates such as chironomid and baetid adults.

Initial hypotheses expected that the number of invertebrate food organisms in the Pine River would be lower as a result of the sand substrate, which has been documented as the poorest substrate for macroinvertebrates (Pennak and Van Gerpen 1947, Hynes 1970, Merritt and Cummins 1996). Peaks of drift density occurred in July, when emerging insects and terrestrial organisms were most abundant. Excluding this peak in July, drift abundance appeared to decline as the summer progressed. These results were similar to a study of Idaho streams by Griffith (1974) which also found that the number of drifting organisms declined over the summer. Spatially, peak drift for the river was documented in the Downstream Zone. The high number of drifting organisms in the Downstream Zone was partially may be explained by the placement of the drift nets in the shifting area of water below the dam. Uniform high water levels limited drift net placement to an area approximately 100 meters below the dam. Consequently, the flow of water over the stoplog structure in the dam may have caused an increasing number of macroinvertebrates to be disturbed from the benthos, or have introduced a higher number of organisms carried from upstream.

A correlation between drift and diet in the Pine River existed for stomach weight, but not number of items. Rainbow trout took advantage of the peak drift in July, as evidenced by their high stomach weight. Also, brook trout and brown trout had the highest stomach weights in the Downstream Zone, where drift tended to be higher. As for the number of organisms, there was no correlation between diet and drift.

The average drift density estimates in the Pine River ranged from 112 to 784 organisms per 100 m^3 of water. These estimates were comparable to high drift density estimates from other rivers. For example, Sagar and Glova (1988) found that drift density not to be limiting in the Rakaia River, New Zealand with between 200 and 900 organisms sampled per 100 m^3 of water. Likewise, Bowles and Short (1988) found that non-limiting peak drift densities in a Texas stream ranged between 500 and 600 organisms per 100 m^3 of water in May and August. In contrast, several Southern Appalachian streams had drift densities as low as 0.24 to 27.77 organisms per 100 m^3 of water, resulting in food limitation for salmonids (Cada et al. 1987). Based on the high number of drifting macroinvertebrates and the fast growth of trout, food did not appear to be limiting in the Pine River.

Electivity

Although trout are opportunistic feeders, it is known that they are selective for certain taxa (Bryan and Larkin 1972, Bisson 1978, Forrester et al. 1994). This selectivity may be seasonal, as demonstrated by the importance of terrestrial taxa in trout diets (Hunt 1975, Aho 1977, Cada et al. 1987, Young et al. 1997).

Diet collection was conducted during the day while drift was sampled in the evening. In the extent of literature on the diets of trout, there has been much emphasis placed on the timing and rate of trout feeding. The peak in summer salmonid feeding has been said to occur during the day (Swift 1962, Chaston 1969, Tippets and Moyle 1978, Allan 1981, Campbell and Neuner 1985, Sagar and Glova 1988, Forrester et al. 1994, Young et al. 1997), at dusk (Elliott 1970, Jenkins et al. 1970, Ware 1972, Elliott 1973, Bisson 1978, Bachman 1984, Angradi and Griffith 1990), and at night (Ringler 1979, Clapp et al. 1990). Some of these studies have shown that trout feeding is for the most part continuous, with feeding showing little overall effect for time of day (Jenkins 1969, Bachman 1984, Dedual and Collier 1995). Overall, studies have determined that individual trout vary considerably as to when they feed by showing a lack of synchrony with the peak evening drift (Griffith 1974, Tippets and Moyle 1978, Bisson 1978, Allan 1981). Because of sampling constraints, trout feeding was estimated during the day on the Pine River. Drift was sampled in the evening to take advantage of peak densities in order to include the highest number and widest range of organisms. Electivity index values were not absolute representations of trout preferences for certain taxa because of the different sampling times and the exclusion of benthic macroinvertebrates that did not drift. All selection indices are limited in that they cannot explain the underlying mechanisms of observed selectivity patterns generated by preference, prior experience, prey detection, or prey availability.

In the Pine River, the majority of electivity values (Ei) were less than 0. This indicated that organisms comprising the largest percentage of the diet were not highly selected. Compared to the availability of organisms in the drift, negative values did not indicate that these organisms were avoided by trout, but instead underused. Alexander and Gowing (1976) came to a similar conclusion when determining that trout in northern Michigan waters were randomly selective and consumed any available organism.

Items that were positively selected for in the Pine River included tipulid, athericid, hydropsychid, and corixid larvae, as well as Ephemeroptera adults and Gastropoda. A comparison of trout feeding habits in Idaho also documented a preference for adult Ephemeroptera (Angradi and Griffith 1990). Rainbow trout displayed a different pattern in that they positively selected for the most abundant item in their diet, brachycentrid larvae. Positive selection was seen for all fish found in the diet, as shown by Cottidae (sculpin). Because drift nets do not effectively sample fish, any fish identified within trout stomachs would have been assigned a positive electivity.

Management Implications

The Pine River presents special circumstances and opportunities in that it contains naturally reproducing populations of brook trout, brown trout, and rainbow trout. It has been documented that these trout are fast growing when compared to other stream systems in Michigan (Klomp 1998, Chapter 1). The goal of the research reported here was to describe the feeding habits of these coexisting trout in different habitats over a summer season and compare them to food availability in the drift. By doing this, I hoped to develop insight into trout diet overlap and selectivity for available food resources as well as establishing feeding patterns over a summer season (May through August). These data will also provide a basis for later comparison in efforts to detect possible competition from other upstream migrating fish species.

Alexander and Gowing (1976) found that quantity, not quality, of food was the most important factor influencing growth of trout in Michigan. It is also known that the abundance, or number, of food in the stomach is generally related to the overall growth of trout (Cooper 1953, Ensign et al. 1990, Nicieza and Metcalfe 1997). I showed that brook trout had an average total of 54 different organisms in their stomach, while brown trout contained 80 and rainbow trout had 59 various items. A study by Cada et al. (1987) which documented trout feeding in a low productivity southern Appalachian stream described brown trout as having an average of 9 items per stomach, while rainbow trout averaged 6.5 items per stomach. Comparatively, the majority of trout in the Pine River was eating a high number of organisms and should not be food limited.

Growth was generally better in the Downstream Zone, with the lowest growth rates documented in the Non-Impacted Zone. Therefore, feeding did not seem to be influenced by high populations of white suckers found below the dam. Although the number of items in trout diets was lowest for the Downstream Zone, trout had the highest mean stomach weight in this area, as well as the most available drift. Since brown trout and rainbow trout contained the lowest number of items in their stomach in the Downstream Zone, some mechanism other than number must be driving growth. As a result, better growth may be explained by the weight of food, as mean wet stomach content weights tended to be higher in the Downstream Zone. Also, trout in the Downstream Zone had a tendency to consume more fish when compared to trout residing above the dam. The mean wet stomach weight of trout that had fish in their stomach was substantially higher when compared to trout that ate only macroinvertebrates. It has been shown in the literature that piscivorous salmonids experience higher growth rates compared to trout feeding on drifting benthic macroinvertebrates (Garman and Nielsen 1982). Consequently, the comparatively high number of organisms found in trout stomachs was likely responsible for better growth and best growth was achieved through the selection of fewer, but larger, food items such as fish.

Chapter 1 also explained that the density of trout in the Pine River was approximately one-third that of other northern Michigan streams (Alexander and Gowing 1980, Stuber 1996). Initial hypotheses pertaining to the mechanism suppressing trout numbers have involved the high sand bedload of the Pine River. The sand-dominated substrate was thought to not only reduce the number of benthic macroinvertebrates, but also result in greater embeddedness of spawning gravels and reduced habitat for trout.

The results of the trout diet, growth, and drift analysis indicated that the numbers of food organisms in the Pine River were not likely to be limiting. Because food was abundant, competition between trout species was not evident. Therefore, sand was not limiting benthic macroinvertebrates in a manner that would cause a reduction in trout population numbers. Presumably, the low standing stock of trout in the Pine River is either linked to early life stage survival as mentioned above, predation, or angling.

Although sand may be the driving force controlling the low biomass of trout on the Pine River, other explanations are plausible. Predation by fish-eating birds has been shown to be a substantial factor in stocked trout mortality, especially in lakes frequented by common loons (*Gava immer*) and great blue herons (*Ardea herodias*) (Matkowski 1989). A review by Draulans (1988), however, concluded that piscivorous birds did not considerably decrease the abundance of fish in freshwater habitats. Although not quantified, trout predation by birds on the Pine River was assumed to be low. Most stretches of the river are too swift for wading birds such as great blue herons. Although a few diving ducks such as common mergansers (*Mergus merganser*) and hooded mergansers (*Lophodytes cucullatus*) were seen on the river, they did not appear in sufficient numbers to inflict trout population-level changes. It has also been suggested that cannibalism or predation by piscivorous fish may negatively affect fish populations (He and Kitchell 1990, Magnuson 1991). Although predation may be occurring with other fish species, such as those present below the dam, no cases of cannibalism were noted while examining trout stomach contents on the Pine River in the summer of 1999.

Seasonal fishing restrictions coupled with restricted outfitter and individual access, limits angling pressure on the Pine River. For example, only two outfitter services guide on the Pine River and catch and release fishing is highly promoted. Individual angler entry is limited by the topography of the Manistee National Forest, which often includes steep banks and a protected ¼ mile corridor.

Although I hypothesize that reduced survival of early life stages is controlling trout biomass on the Pine River, future research is needed to determine the exact causes.

SUMMARY AND CONCLUSIONS

Removal of Stronach Dam has the ability to allow fish species that reside only below the dam, or are abundant below the dam, to migrate up and potentially compete with the resident trout population. The Pine River is noted for its naturally reproducing population of brook trout, brown trout, and rainbow trout, and it is of utmost importance to preserve the integrity of these species. To this effect, a trout diet study was conducted to document feeding in comparison to macroinvertebrate drift availability at present levels of population abundance and community level competition. Thus, if species from below the dam ultimately have negative effects on the trout population, these effects will be recognized through slower growth and a change of feeding habits or food availability. This study also attempted to characterize how trout feeding differed with a varying population abundance of white suckers, which are one of the most abundant species occurring below the dam. I attempted to use this information to develop insight into the diet overlap and selectivity for food resources over a summer season.

The wet stomach content weight of trout in the present study was much higher than the average for similar northern Michigan streams. Seasonally, comparable to other studies, stomach content weight declined as the summer progressed. Trout appeared to eat more in weight as they grew longer, but had fewer organisms in their stomach. Overall wet stomach content weight was highest in the Downstream Zone, where trout had access to a high number of forage fishes.

Macroinvertebrate families that included Chironomidae, Ephemerellidae, Brachycentridae, Athericidae, and Baetidae larvae dominated trout stomach contents. The number of organisms identified in each stomach declined between May and August, likely owing to the increasing number of emerging insects. This was confounded by an increase of taxa contributing to the “other” category and to the Downstream and Impacted Zone, or areas of less complex habitat. Terrestrial taxa were an important part of trout diets later in the summer and in the upstream areas. Overall piscivory was low, occurring mostly in fish greater than 250 mm that resided downstream.

Trout stomach contents were highly similar to each other, with only brook trout showing a high degree of similarity to the drift. Although month to month similarity was variable, similarity between zones was high. This indicated that trout tended to eat the same things because similar prey organisms were available to all trout within each month.

Macroinvertebrate drift was dominated by various life stages of chironomidae, as well as Baetidae and Simuliidae larvae. Drift appeared to decline over the summer, except for a peak in July attributed to the increasing amount of terrestrial organisms. Because the Pine River is characterized by its high sand bedload, which is the poorest substrate for macroinvertebrate suitability, it was anticipated that the number of macroinvertebrate food organisms would be low. However, the drift density estimates from this study were comparable to non-limiting drift densities recorded in other river systems. This, combined with the knowledge that trout in the Pine River are fast growing, indicates that drift was not limiting.

The majority of organisms identified in the stomach contents of trout were not highly selected. Instead, these items were most likely underused when compared to their availability in the drift. Positive selection was documented for larger prey items such as Athericidae and Tipulidae larvae, fish, and adult forms of aquatic insects.

Feeding did not appear to be influenced by the number of white suckers. In the Downstream Zone, where white suckers are most abundant, trout growth was generally better as a result of higher wet stomach content weight and increased availability of drifting organisms.

It can be deduced that the low biomass of trout in the Pine River is not caused by a limiting production of benthic macroinvertebrates. Instead, the abundance of sand most likely results in low survival of trout early life stages through the burying of spawning gravel. Other possible causes, although improbable, leading to low numbers of trout include predation and angling pressure. Further research needs to be conducted to determine the exact reason for low trout biomass.

APPENDICES

APPENDIX A. Taxon code list including class, order, family, habitat, and life stage for prey items collected in the Pine River in 1999.

Taxon Code	Class	Order	Family	Terrestrial/Aquatic	Life Stage
1	Organic/Vegetation	.	.	.	.
2	Organic/Wood	.	.	.	.
3	Organic/Rock	.	.	.	.
4	Organic/Fish Egg	.	.	.	.
5	Arachnida	Acarina	.	Terrestrial	Adult
6	Arachnida	Hydracarina	.	Aquatic	Adult
7	Osteichthyes	Scorpaeniformes	Cottidae	Aquatic	Adult
8	Osteichthyes	Percopsiformes	Percopsidae	Aquatic	Adult
9	Osteichthyes	Unknown Fish	Unknown Fish	Aquatic	Adult
10	Mammalia	Rodentia	Cricertidae	Terrestrial	Adult
11	Gastropoda	Mesogastropoda	Hydrobiidae	Aquatic	Adult
12	Hirudinea	Arynchobdellae	.	Aquatic	Adult
13	Malacostraca	Decapoda	.	Aquatic	Adult
14	Malacostraca	Isopoda	.	Aquatic	Adult
15	Malacostraca	Amphipoda	.	Aquatic	Adult
16	Oligochaeta	.	.	Aquatic	Adult
17	Diplopoda	.	.	Terrestrial	Adult
74	Empty Gut	Empty	Empty	Empty	Empty
79	Gastropoda	Neritacea	.	Aquatic	Adult
81	Chilopoda	.	.	Terrestrial	Adult
82	Agnatha	Petromyzontiformes	Petromyzontidae	Aquatic	Larva
18	Insecta	Hymenoptera	Formicidae	Terrestrial	Adult
19	Insecta	Hymenoptera	Vespidae	Terrestrial	Adult
20	Insecta	Ephemeroptera	Unidentified	Aquatic	Larva
21	Insecta	Ephemeroptera	Unidentified	Terrestrial	Adult

APPENDIX A (cont'd).

Taxon Code	Class	Order	Family	Terrestrial/Aquatic	Life Stage
22	Insecta	Ephemeroptera	Baetidae	Aquatic	Larva
23	Insecta	Ephemeroptera	Baetidae	Terrestrial	Adult
24	Insecta	Ephemeroptera	Baetiscidae	Aquatic	Larva
25	Insecta	Ephemeroptera	Heptageniidae	Aquatic	Larva
26	Insecta	Ephemeroptera	Ephemerellidae	Aquatic	Larva
27	Insecta	Ephemeroptera	Tricorythidae	Aquatic	Larva
28	Insecta	Ephemeroptera	Siphlonouridae	Aquatic	Larva
29	Insecta	Plecoptera	Unidentified	Aquatic	Larva
30	Insecta	Plecoptera	Pteronarcyidae	Aquatic	Larva
31	Insecta	Plecoptera	Perlodidae	Aquatic	Larva
32	Insecta	Hemiptera	Corixidae	Aquatic	Adult
33	Insecta	Lepidoptera	Pyralidae	Aquatic	Larva
34	Insecta	Lepidoptera	Unidentified	Terrestrial	Larva
35	Insecta	Trichoptera	Unidentified	Aquatic	Larva
36	Insecta	Trichoptera	Unidentified	Aquatic	Pupa
37	Insecta	Trichoptera	Unidentified	Terrestrial	Adult
38	Insecta	Trichoptera	Brachycentridae	Aquatic	Larva
39	Insecta	Trichoptera	Hydropsychidae	Aquatic	Larva
40	Insecta	Trichoptera	Leptoceridae	Aquatic	Larva
41	Insecta	Trichoptera	Mollanidae	Aquatic	Larva
42	Insecta	Trichoptera	Limnephilidae	Aquatic	Larva
43	Insecta	Trichoptera	Glossosomatidae	Aquatic	Larva
44	Insecta	Coleoptera	Unidentified	Terrestrial	Adult
45	Insecta	Coleoptera	Elmidae	Aquatic	Larva
46	Insecta	Coleoptera	Elmidae	Aquatic	Adult

APPENDIX A (cont'd).

Taxon Code	Class	Order	Family	Terrestrial/Aquatic	Life Stage
47	Insecta	Coleoptera	Chrysomelidae	Aquatic	Adult
48	Insecta	Coleoptera	Chrysomelidae	Terrestrial	Larva
49	Insecta	Coleoptera	Hydrophilidae	Aquatic	Larva
50	Insecta	Coleoptera	Curculionidae	Aquatic	Adult
51	Insecta	Coleoptera	Curculionidae	Terrestrial	Adult
52	Insecta	Coleoptera	Dytiscidae	Aquatic	Larva
53	Insecta	Coleoptera	Gyrnidae	Aquatic	Adult
54	Insecta	Diptera	Tipulidae	Aquatic	Larva
55	Insecta	Diptera	Tipulidae	Aquatic	Pupa
56	Insecta	Diptera	Tipulidae	Terrestrial	Adult
57	Insecta	Diptera	Chironomidae	Aquatic	Larva
58	Insecta	Diptera	Chironomidae	Terrestrial	Adult
59	Insecta	Diptera	Ceratopogonidae	Aquatic	Larva
60	Insecta	Diptera	Simuliidae	Aquatic	Larva
61	Insecta	Diptera	Simuliidae	Aquatic	Pupa
62	Insecta	Diptera	Simuliidae	Terrestrial	Adult
63	Insecta	Diptera	Tabanidae	Aquatic	Larva
64	Insecta	Diptera	Athericidae	Aquatic	Larva
65	Insecta	Diptera	Empididae	Aquatic	Larva
66	Insecta	Diptera	Empididae	Terrestrial	Adult
67	Insecta	Diptera	Stratiomyidae	Aquatic	Larva
68	Insecta	Orthoptera	Acrididae	Terrestrial	Adult
69	Insecta	Homoptera	Cicadellidae	Terrestrial	Adult
70	Insecta	Orthoptera	Acrididae	Semi-Aquatic	Adult
71	Insecta	Odonata	Aeshnidae	Aquatic	Larva

APPENDIX A (cont'd).

Taxon Code	Class	Order	Family	Terrestrial/Aquatic	Life Stage
72	Insecta	Homoptera	Unidentified	Terrestrial	Adult
73	Insecta	Collembola	Unidentified	Aquatic	Adult
75	Insecta	Odonata	Gomphidae	Aquatic	Larva
76	Insecta	Plecoptera	Unidentified	Terrestrial	Adult
77	Insecta	Hemiptera	Unidentified	Terrestrial	Adult
78	Insecta	Homoptera	Aphidae	Terrestrial	Adult
80	Insecta	Trichoptera	Hydroptilidae	Aquatic	Larva
83	Insecta	Ephemeroptera	Ephemeridae	Terrestrial	Adult
84	Insecta	Diptera	Chironomidae	Aquatic	Pupa
85	Insecta	Coleoptera	Haliplidae	Aquatic	Adult
86	Insecta	Ephemeroptera	Caenidae	Aquatic	Larva
87	Insecta	Coleoptera	Hydrophilidae	Aquatic	Adult
88	Insecta	Plecoptera	Nemouridae	Aquatic	Larva

APPENDIX B. Mean number per stomach and percent for each taxon eaten by brook trout in each month and zone on the Pine River in 1999.

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Acarina	0.13	0.22	0.27	0.62	0.12	0.22	0.09	1.01
Acrididae Adult (Semi-Aquatic)	0.00	0.00	0.00	0.00	0.12	0.22	0.18	2.02
Acrididae Adult (Terrestrial)	0.00	0.00	0.18	0.41	0.06	0.11	0.00	0.00
Amphipoda	0.13	0.22	0.00	0.00	0.06	0.11	0.00	0.00
Athericidae Larva	14.88	26.62	1.09	2.47	0.24	0.45	0.27	3.03
Baetidae Adult	0.00	0.00	0.00	0.00	2.76	5.26	0.09	1.01
Baetidae Larva	4.38	7.83	3.45	7.82	12.06	22.96	0.18	2.02
Brachycentridae Larva	4.63	8.28	5.91	13.37	2.12	4.03	0.09	1.01
Ceratopogonidae Larva	0.25	0.45	0.00	0.00	0.06	0.11	0.00	0.00
Chironomidae Larva	5.25	9.40	0.36	0.82	17.29	32.92	1.45	16.16
Chironomidae Pupa	0.00	0.00	0.00	0.00	0.29	0.56	0.00	0.00
Chrysomelidae Adult	0.13	0.22	0.45	1.03	0.00	0.00	0.00	0.00
Cicadellidae Adult	0.00	0.00	0.18	0.41	0.00	0.00	0.00	0.00
Coleoptera Adult	0.13	0.22	0.18	0.41	0.18	0.34	0.00	0.00
Corixidae Adult	0.00	0.00	0.27	0.62	0.47	0.90	3.45	38.38
Cottidae	0.00	0.00	0.00	0.00	0.06	0.11	0.09	1.01
Curculionidae Adult (Terrestrial)	0.00	0.00	0.00	0.00	0.12	0.22	0.00	0.00
Curculionidae Adult (Aquatic)	0.00	0.00	0.00	0.00	0.06	0.11	0.00	0.00
Diplopoda	0.00	0.00	0.09	0.21	0.18	0.34	0.18	2.02
Empididae Adult	0.13	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Empididae Larva	0.00	0.00	0.00	0.00	0.12	0.22	0.09	1.01
Ephemerellidae Larva	16.63	29.75	14.73	33.33	2.18	4.14	0.00	0.00
Ephemeroptera Adult	0.25	0.45	1.27	2.88	3.29	6.27	0.00	0.00
Fish Egg	0.13	0.22	0.00	0.00	0.00	0.00	0.09	1.01
Formicidae	0.00	0.00	0.18	0.41	0.53	1.01	0.09	1.01

APPENDIX B (cont'd).

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Gastropoda	0.00	0.00	0.00	0.00	0.12	0.22	0.00	2.02
Gomphidae Larva	0.00	0.00	0.09	0.21	0.00	0.00	0.00	0.00
Heptageniidae Larva	0.63	1.12	0.00	0.00	0.06	0.11	0.18	2.02
Hydracarina	0.13	0.22	0.00	0.00	0.35	0.67	0.00	0.00
Hydrophilidae Larva	0.00	0.00	0.00	0.00	0.06	0.11	0.00	0.00
Hydropsychidae Larva	2.88	5.15	2.36	5.35	2.71	5.15	0.27	3.03
Hydroptilidae Larva	0.00	0.00	0.00	0.00	0.00	0.00	1.18	13.13
Isopoda	0.13	0.22	0.00	0.00	0.06	0.11	0.00	0.00
Lepidoptera Larva	0.00	0.00	0.09	0.21	0.29	0.56	0.18	2.02
Limnephilidae Larva	0.00	0.00	0.09	0.21	0.00	0.00	0.00	0.00
Mollanidae Larva	0.00	0.00	0.18	0.41	0.00	0.00	0.00	0.00
Oligochaeta	0.25	0.45	0.09	0.21	0.06	0.11	0.09	1.01
Percopsidae	0.25	0.45	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae Larva	0.38	0.67	0.00	0.00	0.00	0.00	0.00	0.00
Pteronarcyidae Larva	0.00	0.00	0.00	0.00	0.00	0.00	0.09	1.01
Pyralidae Larva	0.13	0.22	0.09	0.21	0.00	0.00	0.00	0.00
Simuliidae Adult	0.13	0.22	0.36	0.82	0.35	0.67	0.00	0.00
Simuliidae Larva	0.13	0.22	0.00	0.00	1.41	2.69	0.09	1.01
Simuliidae Pupa	0.63	1.12	0.00	0.00	0.35	0.67	0.00	0.00
Tabanidae Larva	0.00	0.00	0.27	0.62	0.18	0.34	0.00	0.00
Tipulidae Larva	3.13	5.59	11.55	26.13	2.82	5.38	0.18	2.02
Tipulidae Pupa	0.00	0.00	0.00	0.00	1.24	2.35	0.09	1.01
Trichoptera Larva	0.00	0.00	0.18	0.41	0.00	0.00	0.00	0.00
Trichoptera Pupa	0.00	0.00	0.09	0.21	0.06	0.11	0.00	0.00
Unknown Fish	0.13	0.22	0.09	0.21	0.00	0.00	0.00	0.00
Vespidae	0.00	0.00	0.00	0.00	0.00	0.00	0.09	1.01

APPENDIX B (cont'd).

	Downstream Zone		Impacted Zone		Non-Impacted Zone	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent
Acarina	0.09	0.23	0.24	0.58	0.11	0.25
Acrididae Adult (Semi-Aquatic)	0.09	0.23	0.00	0.29	0.05	0.13
Acrididae Adult (Terrestrial)	0.09	0.23	0.06	0.14	0.05	0.13
Amphipoda	0.09	0.23	0.00	0.00	0.05	0.13
Athericidae Larva	1.91	4.77	0.06	0.14	6.11	14.63
Baetidae Adult	0.00	0.00	0.00	0.00	2.53	6.05
Baetidae Larva	6.73	16.82	4.35	10.69	6.95	16.65
Brachycentridae Larva	3.73	9.32	4.24	10.40	1.37	3.28
Ceratopogonidae Larva	0.18	0.45	0.00	0.00	0.05	0.13
Chironomidae Larva	13.27	33.18	8.71	21.39	3.26	7.82
Chironomidae Pupa	0.45	1.14	0.00	0.00	0.00	0.00
Chrysomelidae Adult	0.09	0.23	0.29	0.72	0.00	0.00
Cicadellidae Adult	0.00	0.00	0.12	0.29	0.00	0.00
Coleoptera Adult	0.18	0.45	0.18	0.43	0.05	0.13
Corixidae Adult	0.09	0.23	2.76	6.79	0.05	0.13
Cottidae	0.09	0.23	0.06	0.14	0.00	0.00
Curculionidae Adult (Terrestrial)	0.00	0.00	0.00	0.29	0.00	0.00
Curculionidae Adult (Aquatic)	0.09	0.23	0.12	0.00	0.00	0.00
Diplopoda	0.09	0.23	0.06	0.14	0.21	0.50
Empididae Adult	0.09	0.23	0.00	0.00	0.00	0.00
Empididae Larva	0.00	0.00	0.00	0.00	0.16	0.38
Ephemerellidae Larva	5.27	13.18	2.18	5.35	12.47	29.89
Ephemeroptera Adult	0.00	0.00	4.12	10.12	0.11	0.25
Fish Egg	0.09	0.23	0.00	0.00	0.05	0.13
Formicidae	0.45	1.14	0.18	0.43	0.21	0.50

APPENDIX B (cont'd).

Taxon Name	Downstream Zone Mean	Downstream Zone Percent	Impacted Zone Mean	Impacted Zone Percent	Non-Impacted Zone Mean	Non-Impacted Zone Percent
Gastropoda	0.00	0.00	0.06	0.14	0.11	0.38
Gomphidae Larva	0.00	0.00	0.06	0.14	0.00	0.00
Heptageniidae Larva	0.18	0.45	0.12	0.29	0.21	0.50
Hydracarina	0.18	0.45	0.00	0.00	0.26	0.63
Hydrophilidae Larva	0.00	0.00	0.00	0.00	0.05	0.13
Hydropsychidae Larva	2.18	5.45	2.12	5.20	2.00	4.79
Hydroptilidae Larva	0.00	0.00	0.06	0.14	0.63	1.51
Isopoda	0.09	0.23	0.06	0.14	0.00	0.00
Lepidoptera Larva	0.09	0.23	0.29	0.72	0.11	0.25
Limnephilidae Larva	0.00	0.00	0.00	0.00	0.05	0.13
Mollanidae Larva	0.00	0.00	0.12	0.29	0.00	0.00
Oligochaeta	0.18	0.45	0.00	0.00	0.16	0.38
Percopsidae	0.18	0.45	0.00	0.00	0.00	0.00
Perlodidae Larva	0.27	0.68	0.00	0.00	0.00	0.00
Pteronarcyidae Larva	0.00	0.00	0.00	0.00	0.05	0.13
Pyralidae Larva	0.00	0.00	0.00	0.00	0.11	0.25
Simuliidae Adult	0.09	0.23	0.53	1.30	0.05	0.13
Simuliidae Larva	0.45	1.14	0.94	2.31	0.26	0.63
Simuliidae Pupa	0.00	0.00	0.00	0.00	0.58	1.39
Tabanidae Larva	0.09	0.23	0.06	0.14	0.21	0.50
Tipulidae Larva	1.82	4.55	8.24	20.23	2.21	5.30
Tipulidae Pupa	0.91	2.27	0.00	0.00	0.63	1.51
Trichoptera Larva	0.00	0.00	0.12	0.29	0.00	0.00
Trichoptera Pupa	0.00	0.00	0.06	0.14	0.05	0.13
Unknown Fish	0.09	0.23	0.06	0.14	0.00	0.00
Vespidae	0.00	0.00	0.00	0.00	0.05	0.13

APPENDIX C. Mean number per stomach and percent for each taxon eaten by brown trout in each month and zone on the Pine River in 1999.

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Acarina	0.00	0.00	0.00	0.00	0.06	0.16	0.00	0.00
Acrididae Adult (Terrestrial)	0.00	0.00	0.00	0.00	0.19	0.49	0.00	0.00
Acrididae Adult (Semi-Aquatic)	0.00	0.00	0.05	0.25	0.56	1.47	0.05	0.76
Amphipoda	0.00	0.00	0.11	0.51	0.00	0.00	0.00	0.00
Athericidae Larva	29.18	42.02	0.79	3.81	0.19	0.49	0.00	0.00
Baetidae Adult	0.00	0.00	0.16	0.76	0.00	0.00	0.00	0.00
Baetidae Larva	4.41	6.35	1.37	6.60	15.38	40.20	0.14	2.29
Baetiscidae Larva	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Brachycentridae Larva	19.27	27.75	4.00	19.29	4.13	10.78	0.09	1.53
Chironomidae Larva	0.36	0.52	0.11	0.51	1.63	4.25	0.73	12.21
Chironomidae Pupa	0.00	0.00	0.00	0.00	0.25	0.65	0.00	0.00
Chrysomelidae Adult	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Cicadellidae Adult	0.00	0.00	0.00	0.00	0.44	1.14	0.00	0.00
Coleoptera Adult	0.09	0.13	0.11	0.51	0.13	0.33	0.00	0.00
Corixidae Adult	0.32	0.46	1.16	5.58	0.50	1.31	1.27	21.37
Cottidae	0.14	0.20	0.42	2.03	0.25	0.65	1.05	17.56
Decapoda	0.00	0.00	0.00	0.00	0.06	0.16	0.00	0.00
Diplopoda	0.00	0.00	0.11	0.51	0.00	0.00	0.00	0.00
Elmidae Adult	0.18	0.26	0.00	0.00	0.06	0.16	0.00	0.00
Ephemerellidae Larva	2.36	3.40	5.79	27.92	1.56	4.09	0.00	0.00
Ephemeroptera Adult	0.14	0.20	0.05	0.25	3.00	7.84	0.00	0.00
Ephemeroptera Larva	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Fish Egg	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.76
Formicidae	0.18	0.26	0.05	0.25	0.38	0.98	0.00	0.00
Gastropoda	7.14	10.27	0.79	3.81	1.13	2.94	1.64	27.48
Gomphidae Larva	0.00	0.00	0.05	0.25	0.00	0.00	0.05	0.76

APPENDIX C (cont'd).

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Hemiptera Adult	0.00	0.00	0.00	0.00	0.25	0.65	0.00	0.00
Heptageniidae Larva	1.41	2.03	0.05	0.25	0.00	0.00	0.00	0.00
Hirudinea	0.00	0.00	0.16	0.76	0.00	0.00	0.00	0.00
Hydracarina	0.14	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Hydrophilidae Larva	0.00	0.00	0.00	0.00	0.06	0.16	0.05	0.76
Hydropsychidae Larva	0.73	1.05	3.68	17.77	0.31	0.82	0.18	3.05
Isopoda	0.00	0.00	0.00	0.00	0.06	0.16	0.09	1.53
Lepidoptera Larva	0.00	0.00	0.05	0.25	0.19	0.49	0.00	0.00
Limnephilidae Larva	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.76
Mollanidae Larva	0.00	0.00	0.00	0.00	0.19	0.49	0.00	0.00
Oligochaeta	0.09	0.13	0.05	0.25	0.00	0.00	0.05	0.76
Percopsidae	0.59	0.85	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae Larva	1.00	1.44	0.05	0.25	0.00	0.00	0.00	0.00
Petromyzontidae Larva	0.00	0.00	0.05	0.25	0.00	0.00	0.05	0.76
Plecoptera Larva	0.14	0.20	0.11	0.51	0.00	0.00	0.00	0.00
Pteronarcyidae Larva	0.14	0.20	0.16	0.76	0.06	0.16	0.05	0.76
Pyralidae Larva	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Rodentia	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Simuliidae Adult	0.41	0.59	0.00	0.00	1.19	3.10	0.05	0.76
Simuliidae Larva	0.00	0.00	0.00	0.00	2.31	6.05	0.00	0.00
Simuliidae Pupa	0.05	0.07	0.11	0.51	1.88	4.90	0.05	0.76
Siphlonouridae Larva	0.09	0.13	0.26	1.27	0.00	0.00	0.00	0.00
Tabanidae Larva	0.05	0.07	0.05	0.25	0.13	0.33	0.14	2.29
Tipulidae Larva	0.59	0.85	0.63	3.05	0.50	1.31	0.09	1.53
Tipulidae Pupa	0.00	0.00	0.00	0.00	0.75	1.96	0.05	0.76
Trichoptera Adult	0.00	0.00	0.00	0.00	0.19	0.49	0.00	0.00

APPENDIX C (cont'd).

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Trichoptera Larva	0.00	0.00	0.11	0.51	0.00	0.00	0.00	0.00
Trichoptera Pupa	0.00	0.00	0.00	0.00	0.06	0.16	0.00	0.00
Unknown Fish	0.05	0.07	0.11	0.51	0.00	0.00	0.05	0.76
Vespidae	0.00	0.00	0.00	0.00	0.25	0.65	0.00	0.00

APPENDIX C (cont'd).

Taxon Name	Downstream Zone Mean	Downstream Zone Percent	Impacted Zone Mean	Impacted Zone Percent	Non-Impacted Zone Mean	Non-Impacted Zone Percent
Acarina	0.05	0.40	0.00	0.00	0.00	0.00
Acrididae Adult (Terrestrial)	0.10	0.40	0.00	0.00	0.30	0.57
Acrididae Adult (Semi-Aquatic)	0.00	1.21	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00	0.00	0.06	0.11
Athericidae Larva	0.45	3.63	1.08	4.27	18.88	35.36
Baetidae Adult	0.00	0.00	0.00	0.00	0.09	0.17
Baetidae Larva	4.75	38.31	3.92	15.57	5.30	9.93
Baetiscidae Larva	0.05	0.40	0.00	0.00	0.00	0.00
Brachycentridae Larva	2.15	17.34	7.85	31.15	9.73	18.22
Chironomidae Larva	0.30	2.42	0.81	3.21	0.76	1.42
Chironomidae Pupa	0.20	1.61	0.00	0.00	0.00	0.00
Chrysomelidae Adult	0.00	0.00	0.04	0.15	0.00	0.00
Cicadellidae Adult	0.00	0.00	0.00	0.00	0.21	0.40
Coleoptera Adult	0.00	0.00	0.12	0.46	0.09	0.17
Corixidae Adult	0.00	0.00	0.42	1.68	1.64	3.06
Cottidae	0.35	2.82	0.73	2.90	0.36	0.68
Decapoda	0.00	0.00	0.04	0.15	0.00	0.00
Diplopoda	0.00	0.00	0.00	0.00	0.06	0.11
Elmidae Adult	0.00	0.00	0.15	0.61	0.03	0.06
Ephemerellidae Larva	0.50	4.03	1.65	6.56	4.06	7.61
Ephemeroptera Adult	0.00	0.00	1.00	3.97	0.79	1.48
Ephemeroptera Larva	0.00	0.00	0.00	0.00	0.03	0.06
Fish Egg	0.05	0.40	0.00	0.00	0.00	0.00
Formicidae	0.05	0.40	0.15	0.61	0.18	0.34
Gastropoda	0.00	0.00	1.46	5.80	5.70	10.67
Gomphidae Larva	0.05	0.40	0.00	0.00	0.03	0.06

APPENDIX C (cont'd).

Taxon Name	Downstream Zone Mean	Downstream Zone Percent	Impacted Zone Mean	Impacted Zone Percent	Non-Impacted Zone Mean	Non-Impacted Zone Percent
Hemiptera Adult	0.00	0.00	0.00	0.00	0.12	0.23
Heptageniidae Larva	0.25	2.02	0.77	3.05	0.21	0.40
Hirudinea	0.00	0.00	0.12	0.46	0.00	0.00
Hydracarina	0.00	0.00	0.12	0.46	0.00	0.00
Hydrophilidae Larva	0.05	0.40	0.04	0.15	0.00	0.00
Hydropsychidae Larva	0.55	4.44	2.35	9.31	0.70	1.31
Isopoda	0.05	0.40	0.08	0.31	0.00	0.00
Lepidoptera Larva	0.15	1.21	0.00	0.00	0.03	0.06
Limnephilidae Larva	0.05	0.40	0.00	0.00	0.00	0.00
Mollanidae Larva	0.00	0.00	0.00	0.00	0.09	0.17
Oligochaeta	0.10	0.81	0.08	0.31	0.00	0.00
Percopsidae	0.65	5.24	0.00	0.00	0.00	0.00
Perlodidae Larva	0.10	0.81	0.00	0.00	0.64	1.19
Petromyzontidae Larva	0.10	0.81	0.00	0.00	0.00	0.00
Plecoptera Larva	0.00	0.00	0.04	0.15	0.12	0.23
Pteronarcyidae Larva	0.05	0.40	0.08	0.31	0.15	0.28
Pyralidae Larva	0.00	0.00	0.04	0.15	0.00	0.00
Rodentia	0.00	0.00	0.04	0.15	0.00	0.00
Simuliidae Adult	0.15	1.21	0.04	0.15	0.76	1.42
Simuliidae Larva	0.05	0.40	1.35	5.34	0.03	0.06
Simuliidae Pupa	0.15	1.21	0.08	0.31	0.88	1.65
Siphlonouridae Larva	0.00	0.00	0.19	0.76	0.06	0.11
Tabanidae Larva	0.10	0.81	0.04	0.15	0.12	0.23
Tipulidae Larva	0.05	0.40	0.15	0.61	0.91	1.70
Tipulidae Pupa	0.35	2.82	0.04	0.15	0.15	0.28
Trichoptera Adult	0.05	0.40	0.00	0.00	0.06	0.11

APPENDIX C (cont'd).

	Downstream Zone		Impacted Zone		Non-Impacted Zone	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent
Trichoptera Larva	0.10	0.81	0.00	0.00	0.00	0.00
Trichoptera Pupa	0.05	0.40	0.00	0.00	0.00	0.00
Unknown Fish	0.05	0.40	0.08	0.31	0.03	0.06
Vespidae	0.05	0.40	0.08	0.31	0.03	0.06

APPENDIX D. Mean number per stomach and percent for each taxon eaten by rainbow trout in each month and zone on the Pine River in 1999.

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Acarina	0.00	0.00	0.06	0.12	0.13	0.24	0.06	0.40
Acrididae Adult (Terrestrial)	0.00	0.00	0.00	0.00	0.56	1.09	0.25	1.61
Amphipoda	0.00	0.00	0.00	0.00	0.13	0.24	0.00	0.00
Aphidae Adult	0.00	0.00	0.00	0.00	0.13	0.24	0.06	0.40
Athericidae Larva	11.47	13.32	2.75	5.45	0.31	0.60	1.06	6.83
Baetidae Adult	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00
Baetidae Larva	5.73	6.66	3.00	5.95	13.44	26.00	0.19	1.20
Baetiscidae Larva	0.00	0.00	0.06	0.12	0.00	0.00	0.00	0.00
Brachycentridae Larva	35.80	41.60	20.19	40.02	8.63	16.69	1.13	7.23
Ceratopogonidae Larva	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00
Chilopoda	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.40
Chironomidae Larva	7.20	8.37	0.31	0.62	8.81	17.05	6.06	38.96
Chrysomelidae Adult	0.00	0.00	1.00	1.98	0.06	0.12	0.00	0.00
Cicadellidae Adult	0.00	0.00	0.00	0.00	0.13	0.24	0.00	0.00
Coleoptera Adult	0.00	0.00	0.25	0.50	0.13	0.24	0.00	0.00
Corixidae Adult	0.27	0.31	0.19	0.37	0.13	0.24	1.75	11.25
Cottidae	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.40
Curculionidae Adult (Terrestrial)	0.00	0.00	0.00	0.00	0.06	0.12	0.13	0.80
Curculionidae Adult (Aquatic)	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00
Diplopoda	0.07	0.08	0.13	0.25	0.00	0.00	0.19	1.20
Dytiscidae Larva	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00
Elmidae Adult	0.00	0.00	1.06	2.11	0.06	0.12	0.00	0.00
Elmidae Larva	0.00	0.00	0.00	0.00	0.13	0.24	0.00	0.00
Empididae Adult	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Empididae Larva	0.20	0.23	0.00	0.00	0.00	0.00	0.06	0.40
Ephemerellidae Larva	16.13	18.75	14.31	28.38	5.63	10.88	0.00	0.00

APPENDIX D (cont'd).

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Ephemeroptera Adult	0.00	0.00	1.06	2.11	0.13	0.24	0.00	0.00
Fish Egg	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Formicidae	0.20	0.23	0.13	0.25	0.38	0.73	0.25	1.61
Gastropoda	0.00	0.00	0.06	0.12	0.19	0.36	0.13	0.80
Heptageniidae Larva	1.60	1.86	0.19	0.37	0.25	0.48	0.13	0.80
Hirudinea	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Hydracarina	0.13	0.15	0.00	0.00	0.31	0.60	0.00	0.00
Hydrophilidae Larva	0.00	0.00	0.13	0.25	0.00	0.00	0.06	0.40
Hydropsychidae Larva	2.93	3.41	2.06	4.09	3.88	7.50	0.88	5.62
Isopoda	0.00	0.00	0.19	0.37	0.38	0.73	0.13	0.80
Lepidoptera Larva	0.00	0.00	0.00	0.00	0.19	0.36	0.44	2.81
Mollanidae Larva	0.00	0.00	0.00	0.00	0.19	0.36	0.00	0.00
Perlodidae Larva	0.27	0.31	0.06	0.12	0.00	0.00	0.00	0.00
Plecoptera Larva	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Pteronarcyidae Larva	0.67	0.77	0.25	0.50	0.31	0.60	0.56	3.61
Pyralidae Larva	0.13	0.15	0.06	0.12	0.00	0.00	0.00	0.00
Simuliidae Adult	0.07	0.08	0.06	0.12	0.00	0.00	0.06	0.40
Simuliidae Larva	0.20	0.23	0.06	0.12	1.00	1.93	0.19	1.20
Simuliidae Pupa	0.13	0.15	0.00	0.00	1.19	2.30	0.44	2.81
Siphlonouridae Larva	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Stratiomyidae Larva	0.00	0.00	0.00	0.00	0.13	0.24	0.00	0.00
Tabanidae Larva	0.27	0.31	0.19	0.37	0.31	0.60	0.44	2.81
Tipulidae Adult	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00
Tipulidae Larva	1.80	2.09	2.56	5.08	3.44	6.65	0.31	2.01
Tipulidae Pupa	0.00	0.00	0.00	0.00	0.38	0.73	0.13	0.80
Trichoptera Adult	0.00	0.00	0.00	0.00	0.13	0.24	0.06	0.40

APPENDIX D (cont'd).

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Trichoptera Larva	0.47	0.54	0.00	0.00	0.06	0.12	0.00	0.00
Trichoptera Pupa	0.00	0.00	0.00	0.00	0.06	0.12	0.25	1.61
Unknown Fish	0.00	0.00	0.06	0.12	0.06	0.12	0.00	0.00
Vespidae	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.40

APPENDIX D (cont'd).

Taxon Name	Downstream Zone Mean	Percent	Impacted Zone Mean	Percent	Non-Impacted Zone Mean	Percent
Acarina	0.05	0.12	0.00	0.00	0.14	0.24
Acrididae Adult	0.10	0.25	0.30	0.54	0.23	0.39
Amphipoda	0.05	0.12	0.05	0.09	0.00	0.00
Aphidae Adult	0.00	0.00	0.00	0.00	0.14	0.24
Athericidae Larva	1.24	3.25	2.60	4.70	7.27	12.64
Baetidae Adult	0.00	0.00	0.00	0.00	0.05	0.08
Baetidae Larva	4.24	11.11	5.75	10.39	6.73	11.69
Baetiscidae Larva	0.00	0.00	0.05	0.09	0.00	0.00
Brachycentridae Larva	6.95	18.23	26.50	47.88	15.45	26.86
Ceratopogonidae Larva	0.05	0.12	0.00	0.00	0.00	0.00
Chilopoda	0.00	0.00	0.00	0.00	0.05	0.08
Chironomidae Larva	11.05	28.96	3.80	6.87	1.95	3.40
Chrysomelidae Adult	0.05	0.12	0.30	0.54	0.45	0.79
Cicadellidae Adult	0.00	0.00	0.10	0.18	0.00	0.00
Coleoptera Adult	0.14	0.37	0.05	0.09	0.09	0.16
Corixidae Adult	0.24	0.62	0.55	0.99	0.95	1.66
Cottidae	0.00	0.00	0.00	0.00	0.05	0.08
Curculionidae Adult (Terresti	0.10	0.25	0.05	0.09	0.05	0.00
Curculionidae Adult (Aquatic	0.00	0.00	0.00	0.00	0.00	0.08
Diplopoda	0.00	0.00	0.15	0.27	0.14	0.24
Dytiscidae Larva	0.05	0.12	0.00	0.00	0.00	0.00
Elmidae Adult	0.05	0.12	0.75	1.36	0.09	0.16
Elmidae Larva	0.05	0.12	0.05	0.09	0.00	0.00
Empididae Adult	0.05	0.12	0.00	0.00	0.00	0.00
Empididae Larva	0.05	0.12	0.15	0.27	0.00	0.00
Ephemerellidae Larva	5.95	15.61	6.15	11.11	14.23	24.72

APPENDIX D (cont'd).

Taxon Name	Downstream Zone Mean	Downstream Zone Percent	Impacted Zone Mean	Impacted Zone Percent	Non-Impacted Zone Mean	Non-Impacted Zone Percent
Ephemeroptera Adult	0.00	0.00	0.10	0.18	0.77	1.34
Fish Egg	0.05	0.12	0.00	0.00	0.00	0.00
Formicidae	0.14	0.37	0.50	0.90	0.09	0.16
Gastropoda	0.00	0.00	0.05	0.09	0.23	0.39
Heptageniidae Larva	0.24	0.62	1.10	1.99	0.27	0.47
Hirudinea	0.00	0.00	0.00	0.00	0.05	0.08
Hydracarina	0.24	0.62	0.00	0.00	0.09	0.16
Hydrophilidae Larva	0.00	0.00	0.10	0.18	0.05	0.08
Hydropsychidae Larva	2.76	7.24	2.60	4.70	1.95	3.40
Isopoda	0.33	0.87	0.10	0.18	0.09	0.16
Lepidoptera Larva	0.19	0.50	0.20	0.36	0.09	0.16
Mollanidae Larva	0.00	0.00	0.00	0.00	0.14	0.24
Perlodidae Larva	0.10	0.25	0.00	0.00	0.14	0.24
Plecoptera Larva	0.00	0.00	0.05	0.09	0.00	0.00
Pteronarcyidae Larva	0.14	0.37	0.80	1.45	0.41	0.71
Pyralidae Larva	0.00	0.00	0.10	0.18	0.05	0.08
Simuliidae Adult	0.05	0.12	0.00	0.00	0.09	0.16
Simuliidae Larva	0.10	0.25	0.50	0.90	0.50	0.87
Simuliidae Pupa	0.57	1.50	0.05	0.09	0.68	1.18
Siphlonouridae Larva	0.05	0.12	0.00	0.00	0.00	0.00
Stratiomyidae Larva	0.05	0.12	0.05	0.09	0.00	0.00
Tabanidae Larva	0.57	1.50	0.30	0.54	0.05	0.08
Tipulidae Adult	0.00	0.00	0.00	0.00	0.05	0.08
Tipulidae Larva	1.52	4.00	1.25	2.26	3.23	5.61
Tipulidae Pupa	0.00	0.00	0.00	0.00	0.36	0.63
Trichoptera Adult	0.05	0.12	0.00	0.00	0.09	0.16

APPENDIX D (cont'd).

Taxon Name	Downstream Zone Mean	Downstream Zone Percent	Impacted Zone Mean	Impacted Zone Percent	Non-Impacted Zone Mean	Non-Impacted Zone Percent
Trichoptera Larva	0.38	1.00	0.00	0.00	0.00	0.00
Trichoptera Pupa	0.14	0.37	0.05	0.09	0.05	0.08
Unknown Fish	0.05	0.12	0.05	0.09	0.00	0.00
Vespidae	0.00	0.00	0.05	0.09	0.00	0.00

APPENDIX E. Pine River 1999 mean drift density (number per 100m^3)and percent for each month and zone.

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Acarina	0.06	0.03	0.00	0.00	0.10	0.01	0.50	0.45
Acrididae Adult	0.06	0.03	0.00	0.00	0.49	0.06	0.19	0.17
Aeshnidae Larva	0.00	0.00	0.00	0.00	0.15	0.02	0.00	0.00
Amphipoda	0.30	0.16	0.00	0.00	0.00	0.00	0.27	0.24
Aphidae Adult	0.20	0.11	0.00	0.00	0.60	0.08	0.15	0.13
Athericidae Larva	1.89	1.05	0.12	0.08	1.05	0.13	1.64	1.46
Baetidae Adult	0.00	0.00	0.12	0.07	43.52	5.55	1.30	1.16
Baetidae Larva	13.79	7.64	38.51	24.45	202.65	25.84	19.55	17.45
Baetiscidae Larva	0.23	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Brachycentridae Larva	19.19	10.63	3.74	2.38	4.90	0.62	2.58	2.30
Caenidae Larva	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.13
Ceratopogonidae Larva	0.00	0.00	0.04	0.02	0.15	0.02	0.60	0.54
Chironomidae Adult	2.29	1.27	4.24	2.69	115.65	14.75	3.50	3.12
Chironomidae Larva	67.24	37.25	67.66	42.96	204.71	26.11	27.51	24.55
Chironomidae Pupa	4.51	2.50	21.97	13.95	76.52	9.76	3.42	3.06
Cicadellidae Adult	0.00	0.00	0.00	0.00	1.20	0.15	0.08	0.07
Coleoptera Adult	0.00	0.00	0.04	0.02	0.10	0.01	0.00	0.00
Collembola Adult	0.00	0.00	0.15	0.10	0.06	0.01	0.68	0.60
Corixidae Adult	0.08	0.04	0.46	0.29	3.22	0.41	0.48	0.43
Curculionidae Adult	34.21	18.95	1.18	0.75	0.37	0.05	0.08	0.07
Elmidae Adult	0.68	0.38	0.31	0.20	5.80	0.74	0.90	0.81
Elmidae Larva	0.42	0.23	1.00	0.64	4.93	0.63	6.82	6.08
Empididae Adult	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.07
Empididae Larva	0.88	0.49	0.04	0.02	0.10	0.01	0.24	0.21
Ephemerellidae Larva	11.54	6.40	2.44	1.55	11.35	1.45	0.75	0.67
Ephemeridae Adult	0.00	0.00	0.00	0.00	0.30	0.04	0.00	0.00

APPENDIX E (cont'd).

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Ephemeroptera Adult	0.77	0.43	0.31	0.20	1.18	0.15	0.21	0.19
Ephemeroptera Larva	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.00
Formicidae	0.21	0.12	0.38	0.24	3.95	0.50	1.59	1.42
Gastropoda	0.13	0.07	0.61	0.38	0.18	0.02	0.21	0.19
Glossosomatidae Larva	0.24	0.13	0.00	0.00	0.00	0.00	0.12	0.11
Gyrnidae Adult	0.00	0.00	0.00	0.00	0.15	0.02	0.00	0.00
Haliplidae Adult	0.00	0.00	0.00	0.00	0.72	0.09	0.00	0.00
Hemiptera Adult	0.02	0.01	0.22	0.14	0.13	0.02	0.08	0.07
Heptageniidae Larva	0.59	0.33	0.08	0.05	0.78	0.10	0.33	0.29
Hydracarina	5.56	3.08	0.49	0.31	9.62	1.23	2.67	2.39
Hydrophilidae Adult	0.00	0.00	0.00	0.00	0.10	0.01	0.23	0.20
Hydrophilidae Larva	0.00	0.00	0.46	0.29	0.09	0.01	0.24	0.21
Hydropsychidae Larva	1.64	0.91	0.08	0.05	2.78	0.35	5.07	4.53
Hydroptilidae Larva	0.00	0.00	0.00	0.00	0.18	0.02	0.75	0.67
Limnephilidae Larva	2.65	1.47	0.05	0.03	0.00	0.00	0.12	0.11
Mollanidae Larva	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.00
Nemouridae Larva	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.07
Oligochaeta	0.85	0.47	0.10	0.06	2.73	0.35	0.89	0.80
Perlodidae Larva	1.65	0.91	0.44	0.28	1.20	0.15	0.33	0.30
Plecoptera Larva	0.40	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Pteronarcyidae Larva	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Simuliidae Adult	0.45	0.25	0.89	0.57	7.59	0.97	1.66	1.48
Simuliidae Larva	1.61	0.89	8.57	5.44	50.30	6.41	19.02	16.97
Simuliidae Pupa	0.02	0.01	0.11	0.07	3.58	0.46	2.19	1.96
Siphlonouridae Larva	0.05	0.03	0.03	0.02	0.00	0.00	0.00	0.00
Stratiomyidae Larva	0.00	0.00	0.00	0.00	0.06	0.01	0.08	0.07

APPENDIX E (cont'd).

	May		June		July		August	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Tabanidae Larva	0.00	0.00	0.00	0.00	0.13	0.02	0.23	0.21
Tipulidae Adult	0.00	0.00	0.04	0.02	1.20	0.15	0.15	0.13
Tipulidae Larva	0.02	0.01	0.00	0.00	5.85	0.75	2.15	1.92
Tipulidae Pupa	5.59	3.10	0.16	0.10	0.53	0.07	0.46	0.41
Trichoptera Adult	0.20	0.11	1.64	1.04	3.19	0.41	0.36	0.32
Trichoptera Larva	0.00	0.00	0.00	0.00	0.18	0.02	0.00	0.00
Trichoptera Pupa	0.00	0.00	0.15	0.09	2.11	0.27	0.21	0.19
Tricorythidae Larva	0.05	0.03	0.55	0.35	7.45	0.95	1.17	1.05
Unknown Fish	0.20	0.11	0.07	0.05	0.00	0.00	0.00	0.00
Vespidae	0.00	0.00	0.00	0.00	0.30	0.04	0.00	0.00

APPENDIX E (cont'd).

Taxon Name	Downstream Zone Mean	Percent	Impacted Zone Mean	Percent	Non-Impacted Zone Mean	Percent
Acarina	0.00	0.00	0.26	0.13	0.24	0.10
Acrididae Adult	0.00	0.00	0.36	0.18	0.16	0.07
Aeshnidae Larva	0.11	0.02	0.00	0.00	0.00	0.00
Amphipoda	0.31	0.07	0.00	0.00	0.11	0.05
Aphidae Adult	0.60	0.13	0.00	0.00	0.11	0.05
Athericidae Larva	0.09	0.02	0.18	0.09	3.26	1.34
Baetidae Adult	33.37	7.03	0.06	0.03	0.28	0.11
Baetidae Larva	77.64	16.35	50.32	24.32	77.92	31.96
Baetiscidae Larva	0.17	0.04	0.00	0.00	0.00	0.00
Brachycentridae Larva	8.67	1.82	7.26	3.51	6.88	2.82
Caenidae Larva	0.00	0.00	0.00	0.00	0.11	0.05
Ceratopogonidae Larva	0.14	0.03	0.00	0.00	0.45	0.19
Chironomidae Adult	67.62	14.24	4.23	2.04	22.41	9.19
Chironomidae Larva	146.47	30.84	80.20	38.76	48.67	19.96
Chironomidae Pupa	38.19	8.04	25.88	12.51	15.75	6.46
Cicadellidae Adult	0.90	0.19	0.00	0.00	0.06	0.02
Coleoptera Adult	0.03	0.01	0.08	0.04	0.00	0.00
Collembola Adult	0.16	0.03	0.00	0.00	0.51	0.21
Corixidae Adult	1.45	0.30	0.88	0.42	0.86	0.35
Curculionidae Adult	26.11	5.50	0.56	0.27	0.20	0.08
Elmidae Adult	1.81	0.38	2.17	1.05	1.79	0.73
Elmidae Larva	1.57	0.33	3.58	1.73	4.72	1.94
Empididae Adult	0.00	0.00	0.06	0.03	0.00	0.00
Empididae Larva	0.61	0.13	0.20	0.10	0.13	0.05

APPENDIX E (cont'd).

Taxon Name	Downstream Zone Mean	Downstream Zone Percent	Impacted Zone Mean	Impacted Zone Percent	Non-Impacted Zone Mean	Non-Impacted Zone Percent
Ephemerellidae Larva	8.87	1.87	1.20	0.58	9.49	3.89
Ephemeridae Adult	0.22	0.05	0.00	0.00	0.00	0.00
Ephemeroptera Adult	0.67	0.14	0.26	0.13	0.92	0.38
Ephemeroptera Larva	0.00	0.00	0.02	0.01	0.00	0.00
Formicidae	2.66	0.56	0.91	0.44	1.04	0.43
Gastropoda	0.23	0.05	0.46	0.22	0.16	0.06
Glossosomatidae Larva	0.09	0.02	0.04	0.02	0.14	0.06
Gyrnidae Adult	0.11	0.02	0.00	0.00	0.00	0.00
Haliplidae Adult	0.00	0.00	0.54	0.26	0.00	0.00
Hemiptera Adult	0.00	0.00	0.19	0.09	0.16	0.06
Heptageniidae Larva	0.73	0.15	0.54	0.26	0.06	0.02
Hydracarina	6.69	1.41	4.26	2.06	2.81	1.15
Hydrophilidae Adult	0.00	0.00	0.08	0.04	0.17	0.07
Hydrophilidae Larva	0.23	0.05	0.23	0.11	0.12	0.05
Hydropsychidae Larva	4.13	0.87	0.96	0.46	2.09	0.86
Hydroptilidae Larva	0.00	0.00	0.14	0.07	0.56	0.23
Limnephilidae Larva	2.08	0.44	0.04	0.02	0.00	0.00
Mollanidae Larva	0.00	0.00	0.02	0.01	0.00	0.00
Nemouridae Larva	0.00	0.00	0.06	0.03	0.00	0.00
Oligochaeta	1.17	0.25	1.59	0.77	0.67	0.27
Perlodidae Larva	1.89	0.40	0.04	0.02	0.79	0.32
Plecoptera Larva	0.30	0.06	0.00	0.00	0.00	0.00
Pteronarcyidae Larva	0.00	0.00	0.02	0.01	0.00	0.00
Simuliidae Adult	2.18	0.46	1.23	0.60	4.53	1.86

APPENDIX E (cont'd).

	Downstream Zone		Impacted Zone		Non-Impacted Zone	
Taxon Name	Mean	Percent	Mean	Percent	Mean	Percent
Simuliidae Larva	22.24	4.68	11.56	5.59	25.83	10.60
Simuliidae Pupa	1.20	0.25	1.87	0.90	1.37	0.56
Siphlonouridae Larva	0.00	0.00	0.06	0.03	0.00	0.00
Stratiomyidae Larva	0.04	0.01	0.00	0.00	0.06	0.02
Tabanidae Larva	0.00	0.00	0.06	0.03	0.21	0.09
Tipulidae Adult	0.92	0.19	0.00	0.00	0.11	0.05
Tipulidae Larva	1.19	0.25	1.46	0.71	3.38	1.39
Tipulidae Pupa	4.15	0.87	0.21	0.10	0.69	0.28
Trichoptera Adult	3.43	0.72	0.25	0.12	0.35	0.14
Trichoptera Larva	0.00	0.00	0.14	0.07	0.00	0.00
Trichoptera Pupa	0.10	0.02	0.11	0.05	1.64	0.67
Tricorythidae Larva	3.04	0.64	2.04	0.99	1.84	0.75
Unknown Fish	0.15	0.03	0.06	0.03	0.00	0.00
Vespidae	0.22	0.05	0.00	0.00	0.00	0.00

APPENDIX F. Electivity index values (Ei) reported by month for brook trout, brown trout, and rainbow trout sampled in 1999 from the Pine River.

	Brook Trout				Brown Trout				Rainbow Trout			
Name	May	June	July	August	May	June	July	August	May	June	July	August
Acarina	-0.30	1.00	0.61	-0.18	-1.00	.	0.26	-1.00	-1.00	1.00	0.63	-0.42
Acrididae Adult (Semi-Aquatic)	.	.	1.00	0.80	.	1.00	1.00	0.45	.	.	1.00	0.83
Acrididae Adult (Terrestrial)	-1.00	1.00	-0.40	-1.00	-1.00	.	0.04	-1.00	-1.00	.	-1.00	-1.00
Aeshnidae Larva	.	.	-1.00	.	.	.	-1.00	.	.	.	-1.00	.
Amphipoda	-0.80	.	1.00	-1.00	-1.00	1.00	.	-1.00	-1.00	.	1.00	-1.00
Aphidae Adult	-1.00	.	-1.00	-1.00	-1.00	.	-1.00	-1.00	-1.00	.	-0.14	0.15
Athericidae Larva	0.36	0.72	-0.12	-0.23	0.72	0.61	-0.34	-1.00	0.36	0.86	0.03	0.36
Baetidae Adult	.	-1.00	-0.63	-0.58	.	-0.07	-1.00	-1.00	.	-1.00	-0.99	-1.00
Baetidae Larva	-0.84	-0.88	-0.65	-0.93	-0.78	-0.96	-0.65	-0.94	-0.75	-0.91	-0.61	-0.94
Baetiscidae Larva	-1.00	.	.	.	-0.85	.	.	.	-1.00	1.00	.	.
Brachycentridae Larva	-0.88	0.04	0.21	-0.76	-0.44	-0.19	0.40	-0.73	-0.21	0.52	0.73	0.17
Caenidae Larva	.	.	.	-1.00	.	.	.	-1.00	.	.	.	-1.00
Ceratopogonidae Larva	1.00	-1.00	0.16	-1.00	.	-1.00	-1.00	-1.00	.	-1.00	0.20	-1.00
Chilopoda	.	.	.	.	.	.	.	.	.	.	.	1.00
Chironomidae Adult	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Chironomidae Larva	-0.96	-0.99	-0.54	-0.67	-1.00	-1.00	-0.96	-0.79	-0.93	-0.99	-0.73	-0.17
Chironomidae Pupa	-1.00	-1.00	-0.97	-1.00	-1.00	-1.00	-0.98	-1.00	-1.00	-1.00	-1.00	-1.00
Chrysomelidae Adult	1.00	1.00	.	.	1.00	.	.	.	.	1.00	1.00	.
Cicadellidae Adult	.	1.00	-1.00	-1.00	.	.	0.01	-1.00	.	.	-0.45	-1.00
Coleoptera Adult	1.00	0.54	0.72	.	1.00	0.28	0.55	.	.	0.59	0.63	.
Collembola Adult	.	-1.00	-1.00	-1.00	.	-1.00	-1.00	-1.00	.	-1.00	-1.00	-1.00
Corixidae Adult	-1.00	-0.42	-0.32	0.93	0.24	0.23	-0.40	0.84	0.10	-0.61	-0.75	0.84
Cottidae	.	.	1.00	1.00	1.00	1.00	1.00	1.00	.	.	.	1.00
Curculionidae Adult (Terrestrial)	-1.00	-1.00	-0.27	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-0.24	0.69
Curculionidae Adult (Aquatic)	.	.	1.00	.	.	.	.	.	.	.	1.00	.
Decapoda	.	.	.	.	.	.	1.00	.	.	.	.	.
Diplopoda	.	1.00	1.00	1.00	.	1.00	.	.	1.00	1.00	.	1.00
Dytiscidae Larva	.	.	.	.	.	.	.	.	.	.	1.00	.
Elmidae Adult	-1.00	-1.00	-1.00	-1.00	-0.81	-1.00	-0.94	-1.00	-1.00	0.34	-0.93	-1.00

APPENDIX F (cont'd).

Name	Brook Trout May	June	July	August	Brown Trout May	June	July	August	Rainbow Trout May	June	July	August
Elmidae Larva	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-0.83	-1.00
Empididae Adult	1.00	.	.	-1.00	.	.	.	-1.00	1.00	.	.	-1.00
Empididae Larva	-1.00	-1.00	0.61	0.18	-1.00	-1.00	-1.00	-1.00	-0.85	-1.00	-1.00	-0.08
Ephemerellidae Larva	-0.44	0.61	-0.19	-1.00	-0.85	0.21	-0.44	-1.00	-0.34	0.55	0.28	-1.00
Ephemeridae Adult	.	.	-1.00	.	.	.	-1.00	.	.	.	-1.00	.
Ephemeroptera Adult	-0.84	0.48	0.82	-1.00	-0.87	-0.80	0.75	-1.00	-1.00	0.34	-0.45	-1.00
Ephemeroptera Larva	.	-1.00	.	.	1.00	-1.00	.	.	.	-1.00	.	.
Fish Egg	1.00	.	.	1.00	.	.	.	1.00	1.00	.	.	.
Formicidae	-1.00	-0.50	-0.36	-0.64	-0.50	-0.84	-0.58	-1.00	-0.51	-0.68	-0.49	-0.32
Gastropoda	-1.00	-1.00	0.39	0.53	0.91	-0.09	0.89	0.94	-1.00	-0.89	0.58	0.32
Glossosomatidae Larva	-1.00	.	.	-1.00	-1.00	.	.	-1.00	-1.00	.	.	-1.00
Gomphidae Larva	.	1.00	.	.	.	1.00	.	1.00	.	.	.	.
Gymidae Adult	.	.	-1.00	.	.	.	-1.00	.	.	.	-1.00	.
Haliplidae Adult	.	.	-1.00	.	.	.	-1.00	.	.	.	-1.00	.
Hemiptera Adult	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	0.68	-1.00	-1.00	-1.00	-1.00	-1.00
Heptageniidae Larva	-0.56	-1.00	-0.58	0.36	-0.04	-0.38	-1.00	-1.00	-0.03	0.19	0.07	0.11
Hirudinea	.	.	.	.	.	1.00	.	.	1.00	.	.	.
Hydracarina	-0.99	-1.00	-0.77	-1.00	-0.98	-1.00	-1.00	-1.00	-0.98	-1.00	-0.79	-1.00
Hydrophilidae Adult	.	.	-1.00	-1.00	.	.	-1.00	-1.00	.	.	-1.00	-1.00
Hydrophilidae Larva	.	-1.00	0.41	-1.00	.	-1.00	0.33	-0.09	.	-0.72	-1.00	-0.08
Hydropsychidae Larva	-0.36	0.91	0.55	-0.66	-0.70	0.94	-0.52	-0.73	-0.23	0.88	0.67	-0.28
Hydroptilidae Larva	.	.	-1.00	0.71	.	.	-1.00	-1.00	.	.	-1.00	-1.00
Isopoda	1.00	.	1.00	.	.	.	1.00	1.00	.	1.00	1.00	1.00
Lepidoptera Larva	.	1.00	1.00	1.00	.	1.00	1.00	.	.	.	1.00	1.00
Limnephilidae Larva	-1.00	0.11	.	-1.00	-1.00	-1.00	.	0.25	-1.00	-1.00	.	-1.00
Mollanidae Larva	.	0.66	.	.	.	-1.00	1.00	.	.	-1.00	1.00	.
Nemouridae Larva	.	.	.	-1.00	.	.	.	-1.00	.	.	.	-1.00
Oligochaeta	-0.85	-0.23	-0.86	-0.44	-0.92	-0.50	-1.00	-0.64	-1.00	-1.00	-1.00	-1.00
Percopsidae	1.00	.	.	.	1.00	.	.	.	.	.	.	.

APPENDIX F (cont'd).

Name	Brook Trout May	 June	 July	 August	Brown Trout May	 June	 July	 August	Rainbow Trout May	 June	 July	 August
Perlodidae Larva	-0.88	-1.00	-1.00	-1.00	-0.62	-0.86	-1.00	-1.00	-0.89	-0.85	-1.00	-1.00
Petromyzontidae Larva	.	.	.	.	.	1.00	.	1.00	.	.	.	.
Plecoptera Larva	-1.00	.	.	.	-0.76	1.00	.	.	-0.89	.	.	.
Pteronarcyidae Larva	-1.00	.	.	1.00	0.37	1.00	1.00	1.00	0.81	1.00	1.00	1.00
Pyralidae Larva	1.00	1.00	.	.	1.00	.	.	.	1.00	1.00	.	.
Rodentia	.	.	.	.	1.00	.	.	.	.	.	.	.
Simuliidae Adult	-0.86	-0.56	-0.72	-1.00	-0.48	-1.00	-0.39	-0.79	-0.90	-0.92	-1.00	-0.78
Simuliidae Larva	-0.96	-1.00	-0.82	-0.96	-1.00	-1.00	-0.77	-1.00	-0.92	-0.99	-0.87	-0.94
Simuliidae Pupa	0.75	-1.00	-0.48	-1.00	-0.15	-0.25	0.19	-0.84	0.32	-1.00	0.09	-0.21
Siphlonouridae Larva	-1.00	-1.00	.	.	-0.15	0.74	.	.	-0.35	-1.00	.	.
Stratiomyidae Larva	.	.	-1.00	-1.00	.	.	-1.00	-1.00	.	.	0.77	-1.00
Tabanidae Larva	.	1.00	0.65	-1.00	1.00	1.00	0.45	0.44	1.00	1.00	0.79	0.72
Tipulidae Adult	.	-1.00	-1.00	-1.00	.	-1.00	-1.00	-1.00	.	-1.00	-0.68	-1.00
Tipulidae Larva	0.94	1.00	0.26	-0.51	0.81	1.00	-0.61	-0.69	0.93	1.00	0.36	-0.36
Tipulidae Pupa	-1.00	-1.00	0.78	-0.14	-1.00	-1.00	0.59	-0.40	-1.00	-1.00	0.43	-0.06
Trichoptera Adult	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-0.72	-1.00	-1.00	-1.00	-0.75	-0.27
Trichoptera Larva	.	1.00	-1.00	.	.	1.00	-1.00	.	1.00	.	0.11	.
Trichoptera Pupa	.	-0.41	-0.82	-1.00	.	-1.00	-0.85	-1.00	.	-1.00	-0.81	0.59
Tricorythidae Larva	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Unknown Fish	-0.71	-0.09	.	.	-0.83	-0.05	.	1.00	-1.00	-0.34	1.00	.
Vespidae	.	.	-1.00	1.00	.	.	0.40	.	.	.	-1.00	1.00

LITERATURE CITED

LITERATURE CITED

Aho, R. S. 1977. A population study of the cutthroat trout in an unshaded and shaded ssection of stream. Master's thesis. Oregon State University, Corvallis.

Alexander, G. R., and H. Gowing. 1976. Relationships between diet and growth in rainbow trout (*Salmo gairdneri*), brook trout (*Salvelinus fontinalus*), and brown trout (*Salmo trutta*). Michigan Department of Natural Resources Fisheries Division Special Report 1841, Lansing, Michigan.

Alexander, G. R,. and H. Gowing. 1980. Population dynamics of trout in some streams of the Northern Lower Peninsula. Michigan Department of Natural Resources, Fisheries Report 1877, Lansing, Michigan

Alexander, G. R., and E. A. Hansen. 1983. Sand Sediment in a Michigan trout stream Part II. Effects of reducing sand bedload on a trout population. North American Journal of Fisheries Management 3:365-372.

Alexander, G. R., and E. A. Hansen. 1986. Sand bed load in a brook trout stream. North American Journal of Fisheries Management 6:9-23.

Allan, J. D. 1978. Trout predation and the size composition of stream drift. Limnology and Oceanography 23(6):1231-1237.

Allan, J. D. 1981. Determinants of diet of brook trout (*Salvelinus fontinalis*) in a mountain stream. Canadian Journal of Fisheries and Aquatic Sciences 38:184-192.

Allan, J. D. 1995. Stream ecology: structure and function of running waters. Chapman and Hall, Inc., New York.

Allan, J. D., and A. S. Flecker. 1993. Biodiversity conservation in running waters. BioScience 43(1):32-43.

Allan, J. D., and E. Russek. 1985. The quantification of stream drift. Canadian Journal of Fisheries and Aquatic Sciences 42:210-215.

Angradi, T. R., and J. S. Griffith. 1990. Diel feeding chronology and the diet selection of rainbow trout (*Oncorhynchus mykiss*) in the Henry's Fork of the Snake River, Idaho. Canadian Journal of Fisheries and Aquatic Sciences 47:199-209.

Arnett, R. H., Jr. 1985. American insects: A handbook of the insects of America north of Mexico. Van Nostrand Reinhold, New York.

Bachman, R. A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout. Transactions of the American Fisheries Society 113(1):1-32.

Bain, M. B., J. T. Finn, and H. E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69(2):382-392.

Baldwin, N. S. 1956. Food consumption and growth of brook trout at different temperatures. Transactions of the American Fisheries Society 86:323-328.

Battige, D. S., B. L. Fields, and D. L. Sowers. 1997. Removal of Stronach Dam. Proceedings of the International Conference on Hydropower (WaterPower '97) 2:1341-1350.

Beamish, R. J., and H. H. Harvey. 1969. Age determination in the white sucker. Journal Fisheries Research Board of Canada 26(3):633-638.

Benke, A. C. 1990. A perspective on America's vanishing streams. Journal of the North American Benthological Society 9(1):77-88.

Blumer, S. P., T. E. Behrendt, J. M. Ellis, R. J. Minnerick, R. L. LeuBoy, and C. R. Whited. 1998. Water Resources Data – Michigan, Water Year 1997. U. S. Geological Survey Water Data Report MI-97-1.

Bisson, P. A. 1978. Diel food selection by two sizes of rainbow trout (*Salmo gairdneri*) in an experimental stream. Journal of the Fisheries Research Board of Canada 35:971-975.

Born, S. M., K. D. Genskow, T. L. Filbert, N. Hernandez-Mora, M. L. Keefer, and K. A. White. 1998. Socioeconomic and institutional dimensions of dam removals: The Wisconsin experience. Environmental Management 22(3):359-370.

Bowers, R., and M. Bowman. 1995. Hydroelectric relicensing: how relicensing can affect dam removals. River Voices 5(4):7-10.

Bowles, D. E., and R. A. Short. 1988. Size composition of invertebrate drift and fish predation in a Texas stream. The Southwestern Naturalist 33(2):177-184.

Bozek, M. A., L. D DeBrey, and J. A. Lockwood. 1994. Diet overlap among size classes of Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) in a high-elevation mountain stream. Hydrobiologia 273:9-17.

Bridcut. E. E., and P. S. Giller. 1995. Diet variability and foraging strategies in brown trout (*Salmo trutta*) : an analysis from subpopulations to individuals. Canadian Journal of Fisheries and Aquatic Sciences 52:2543-2552.

Bryan, J. E., and P. A. Larkin. 1972. Food specialization by individual trout. Journal of the Fisheries Research Board of Canada 29:1615-1624.

Cada, G. F., J. M. Loar, and D. K. Cox. 1987. Food and feeding preferences of rainbow and brown trout in southern Appalachian stream. The American Midland Naturalist 117(2):374-385.

Campbell, R. F., and J. H. Neuner. 1985. Seasonal and diurnal shifts in habitat utilized by resident rainbow trout in western Washington Cascade Mountain streams. Pages 39-48 *in* F. W. Olsen, R. G. White, and R. H. Jamre, editors. Symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section, Bethesda, Maryland.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, volume 1. Iowa State University Press, Ames.

Chaston, I. 1969. Seasonal activity and feeding pattern of brown trout, *Salmo trutta*, in a Dartmoor stream in relation to availability of food. Journal Fisheries Research Board of Canada 26(8):2165-2171.

Cibrowski, J. J. H. 1983. Influence of current velocity, density, and detritus on drift of two mayfly species (Ephemeroptera). Canadian Journal of Zoology 61:119-125.

Clapp, D. F., R. D. Clark, Jr., and J. S. Diana. 1990. Range, activity, and habitat of large, free-ranging brown trout in a Michigan stream. Transactions of the American Fisheries Society 119:1022-1034.

Clark, M. E., and K. A. Rose. 1997. Factors affecting competitive dominance of rainbow trout over brook trout in southern Appalachian streams: Implications of an individual-based model. Transactions of the American Fisheries Society 126(11):1-20.

Cooper, E. L. 1953. Periodicity of growth and change in condition of brook trout (*Salvelinus fontinalis*) in three Michigan trout streams. Copeia 2:107-114.

Cooper E. L. 1967. Growth and longevity of brook trout (*Salvelinus fontinalus*) in populations subjected to light exploitation. Transactions of the American Fisheries Society 96:383-386.

Cunjak, R. A., and J. M. Green. 1983. Habitat utilization by brook char (*Salvelinus fontinalus*) and rainbow trout (*Salmo gairdneri*) in Newfoundland streams. Canadian Journal of Zoology 61:1214-1219.

Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5:330-339.

Dedual, M., and K. J. Collier. 1995. Aspects of juvenile rainbow trout (*Oncorhynchus mykiss*) diet in relation to food supply during summer in the lower Tongariro River, New Zealand. New Zealand Journal of Marine and Freshwater Research 29:381-391.

Doppelt. B. 1993. Entering the watershed: a new approach to save America's river ecosystems. Island Press, Washington D. C.

Draulans, D. 1988. Effects of fish-eating birds on freshwater fish stocks: an evaluation. Biological Conservation 44:251-263.

Elliott, J. M. 1967. The food of trout (*Salmo trutta*) in a Dartmoor stream. Journal of Applied Ecology 4:59-71.

Elliott, J. M. 1970. Diel changes in invertebrate drift and the food of trout, *Salmo trutta L.* Journal of Fish Biology 2:161-165.

Elliott, J. M. 1973. The food of brown and rainbow trout (*Salmo trutta* and *S. gairdneri*) in relation to the abundance of drifting invertebrates in a mountain stream. Oecologia 12:161-165.

Ellwood, J. W., and T. F. Waters. 1969. Effects of floods on food consumption and production rates of a stream brook trout population. Transactions of the American Fisheries Society 2:253-262.

Ensign, W. E., R. J. Strange, and S. E. Moore. 1990. Summer food limitation reduces brook and rainbow trout biomass in a southern Appalachian stream. Transactions of the American Fisheries Society 119:894-901.

Eschmeyer, P. S. 1938. Management of a group of small Michigan lakes. Transactions of the American Fisheries Society 67:120-129.

Fausch, K. D. 1984. Profitable stream positions for salmonids: relating specific growth rate to net energy gain. Canadian Journal of Zoology 62:441-451.

Fausch, K. D. 1988. Tests of competition between native and introduced salmonids in streams: what have we learned? Canadian Journal of Fisheries and Aquatic Sciences 45:2238-2246.

Fausch, K. D., and R. J. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. Canadian Journal of Fisheries and Aquatic Sciences 38:1220-1227.

Flick, W. A., and D. A. Webster. 1992. Standing crops of brook trout in Adirondack waters before and after removal of non-trout species. North American Journal of Fisheries Management 12:783-796.

Ford, R. 1984. Suckers to trout- effect of habitat restoration on fish populations in Rapid City, South Dakota. Pages 133-136 *in* F. Richardson and R. H. Hamre, editors. Proceedings of the Symposium Wild Trout III. Federaton of Fly Fishers and others.

Forrester, G. E., J. G. Chace, and W. McCarthy. 1994. Diel and density-related changes in food consumption and prey selection by brook charr in a New Hampshire stream. Environmental Biology of Fishes 39:301-311.

Foster, J. R. 1977. Pulsed gastric lavage: An efficient method of removing the stomach contents of live fish. The Progressive Fish Culturist 39(4):166-169.

Francis, R. I. C. C. 1990. Back-calculation of fish length: a critical review. Journal of Fish Biology 36:883-902.

Gard, R., and D. W. Seegrist. 1972. Abundance and harvest of trout in Sagehen Creek, California. Transactions of the American Fisheries Society 101:463-477.

Garman, G. C., and L. A. Nielsen. 1982. Piscivory by stocked brown trout (*Salmo trutta*) and its impact on the nongame fish community of Bottom Creek, Virginia. Canadian Journal of Fisheries and Aquatic Sciences 39:862-869.

Glenn, C. L., and E. J. Ward. 1968. 'Wet weight' as a method of measuring stomach contents of walleyes, *Stizostedion vitreum vitreum*. Journal of the Fisheries Research Board of Canada 25:1505-1507.

Gowing, H., and G. R. Alexander. 1980. Population dynamics of trout in some streams of the northern lower peninsula of Michigan. Michigan Department of Natural Resources Fisheries Division Special Report 1877, Lansing, Michigan.

Griffith, J. S., Jr. 1974. Utilization of invertebrate drift by brook trout (*Salvelinus fontinalus*) and cutthroat trout (*Salmo clarki*) in small streams in Idaho. Transactions of the American Fisheries Society (103):440-447.

Gup, T. 1994. Dammed from here to eternity: dams and biological integrity. Trout 35:14-20.

Haberman, R. 1995. Dam fights of the 1990's: Removals. River Voices 5(4):1-6.

Hammad, H. Y. 1972. River bed degradation after closure of dams. American Society of Civil Engineers, Journal of the Hydraulics Division 98:591-607.

Hansen, E. A. 1971. Sediment in a Michigan trout stream, its source, movement, & some effects on fish habitat. U. S. Forest Service Research Paper NC-59.

Hayes, J. W. 1987. Competition for spawning space between brown (*Salmo trutta*) and rainbow trout (*S. gairdneri*) in a lake inlet tributary, New Zealand. Canadian Journal of Fisheries and Aquatic Sciences 44:40-47.

He, X., and J. F. Kitchell. 1990. Direct and indirect effects of predation on a fish community: a whole-lake experiment. Transactions of the American Fisheries Society 119:825-835.

Heggenes, J. 1988. Substrate preference of brown trout fry (*Salmo trutta*) in artificial stream channels. Canadian Journal of Fisheries and Aquatic Sciences 45:1801-1806.

Hicks, B. J., and N. R. N. Watson. 1985. Seasonal changes in abundance of brown trout (*Salmo trutta*) and rainbow trout (*S. gairdnerii*) assessed by drift diving in the Rangitikei River, New Zealand. New Zealand Journal of Marine and Freshwater Research 19:1-10.

Hill, M. J., E. A. Long, and S. Hardin. 1994. Effects of dam removal on Dead Lake, Chipola River, Florida. Proceedings of the Annual Conference SEAFWA: 512-523.

Hubert, W. A. and H. A. Rhodes. 1989. Food selection by brook trout in a subalpine stream. Hydrobiologia 178:225-231.

Hubert, W. A., and H. A. Rhodes. 1992. Sizes of prey consumed by age-0 brown trout In Douglas Creek, Wyoming. Journal of Freshwater Ecology 7:277-282.

Hunt, R. L. 1966. Production and angler harvest of wild brook trout in Lawrence Creek, Wisconsin. Wisconsin Conservation Department Technical Bulletin 35.

Hunt, R. L. 1975. Food relation and behavior of salmonid fishes. 6.1. Use of terrestrial invertebrates as food by salmonids. Pages 137-151 *in* A. D. Hasler, editor. Coupling of land and water systems. Springer-Verlag, New York.

Hynes, H. B. N. 1970. Ecology of running waters. University of Toronto Press, Toronto, Canada.

Jenkins, T. M. Jr. 1969. Night feeding of brown and rainbow trout in an experimental stream channel. Journal of the Fisheries Research Board of Canada 26:3275-3278.

Jenkins, T. M. Jr., C. R. Feldmeth, and G. V. Elliott. 1970. Feeding of rainbow trout (*Salmo gairdneri*) in relation to abundance of drifting invertebrates in a mountain stream. Journal of the Fisheries Research Board of Canada 27:2356-2361.

Jenson, A. J. 1987. Hydropower development of salmon rivers: Effect of changes in water temperature on growth of brown trout (*Salmo trutta*) presmolts. Pages 207-218 *in* J. F. Craig and J. B. Kemper, editors. Regulated streams: Advances in ecology. Plenum Press, New York.

Kanehl, P., D. J. Lyons, and J. E. Nelson. 1997. Changes in the habitat and fish community of the Milwaukee River, Wisconsin, following removal of the Woolen Mills Dam. North American Journal of Fisheries Management 17:387-400.

Klomp, K. 1998. An initial evaluation of the habitat and fisheries resources associated with a dam removal in a Michigan coldwater stream. Master's thesis. Michigan State University, East Lansing, Michigan.

Kohler, S. L. 1985. Identification of stream drift mechanisms: an experimental and observational approach. Ecology 66:1749-1761.

Kohler, C. C., and W. Hubert, editors. 1993. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Kondolf, G. M., and E. R. Micheli. 1995. Evaluating stream restoration projects. Environmental Management 19(1):1-15.

Kondolf, G. M., and S. Li. 1992. The pebble count technique for quantifying surface bed material size in instream flow studies. Rivers 3(2):80-87.

Krebs, C. R. 1989. Ecological methodology. Harper Collins, New York.

Krueger, K. 1999. Personal communication. Michigan Department of Natural Resources. Mio, Michigan.

Laarman, P. W., J. C. Schneider, and H. Gowing. 1981. Methods in age and growth analyses of fish. Appendix A-4 *in* J. W. Merna, G. R. Alexander, W. D. Alward, and R. L. Eshenroder, editors. Manual of Fisheries Survey Methods. Michigan Department of Natural Resources Fisheries Management Report No. 9, Lansing, Michigan.

Lacasse, S., and P. Magnan. 1992. Biotic and abiotic determinants of the diet of the brook trout *Salvelinus fontinalus*, in lakes of the Laurential Shield. Canadian Journal of Fisheries and Aquatic Sciences 49:1001-1009.

Larkin, P. A. 1956. Interspecific competition and population control in freshwater fish. Journal of the Fisheries Research Board of Canada 13:327-342.

Lawler, Matusky, and Skelly Engineers. 1992. Evaluation of Pine River temperature. Unpublished report for Consumers Power Company, Cadillac, Michigan.

Lechowicz, M. J. 1982. The sampling characteristics of electivity indices. Oecologia 52:22-30.

Light, R. W., P. H. Adler, and D. E. Arnold. 1983. Evaluation of gastric lavage for stomach analyses. North American Journal of Fisheries Management 3:81-85.

Ligon, F. K., W. E. Dietrich, and W. J. Trush. 1995. Downstream ecological effects of dams. BioScience 45(3):183-192.

Lohr, S. C. and J. L. West. 1992. Microhabitat selection by brook and rainbow trout in a southern appalachian stream. Transactions of the American Fisheries Society 121: (6) 729-736.

McIntosh, A. R., and Peckarsky. B. L. 1996. Differential behavioural response of mayflies from streams with and without fish to trout odour. Freshwater Biology 35:141-148.

Magnuson, J. J. 1991. Fish and fisheries ecology. Ecological Applications 1:13-26.

Magoulick, D. D., and M. A. Wilzbach. 1997. Microhabitat selection by native brook trout and introduced rainbow trout in a small Pennsylvania stream. Journal of Freshwater Ecology 12(4):607-614.

Magnan, P. 1988. Interactions between brook charr, *Salvelinus fontinalis*, and nonsalmonid species: ecological shift, morphological shift, and their impact on zooplankton communities. Canadian Journal of Fisheries and Aquatic Sciences 45:999-1009.

Manceina, M. J. 1992. A simple regression model to assess environmental effects on fish growth. Journal of Fish Biology 41:557-565.

Matkowski, S. M. D. 1989. Differential susceptibility of three species of stocked trout to bird predation. North American Journal of Fisheries Management 9:184-187.

Meehan, W. R., and R. A. Miller. 1978. Stomach flushing: effectiveness and influence on survival and condition of juvenile salmonids. Journal Fisheries Research Board of Canada 35:1359-1363.

Merritt, R. W., and K. W. Cummins, editors. 1996. An introduction to the aquatic insects of North America, 3rd edition. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Metz, J. P. 1974. Die invertebratendrift an der Oberflache eines Voralpenflusses und ihre selektive Ausnutzung durch die Regenbogenforellen (*Salmo gairdneri*). Oecologia (Berlin) 14:247-267.

Minard, R. E., and J. E. Dye. 1998. Rainbow trout sampling and aging protocol. Alaska Department of Fish and Game Special Publication 98-2, Juneau.

Morista, M. 1959. Measuring of interspecific association and similarity between communities. Memoirs of the Faculty Science Kyushu University, Series E Biology 3:65-80.

Needham, P. R., and R. L. Usinger. 1956. Variability in the microfauna of a single riffle in Prosser Creek, California, as indicated by the Surber sampler. Hilgardia 24:383-409.

Newman, R. M. 1987. Comparison of encounter model predictions with observed size-selectivity by stream trout. Journal of the North American Benthological Society 6(1):56-64.

Nicieza, A. G., and N. B. Metcalfe. 1997. Growth compensation in juvenile Atlantic salmon: responses to depressed temperature and food availability. Ecology 78:2385-2400.

Parker, R. R. 1963. Effects of formalin on length and weight of fishes. Journal of the Fisheries Research Board of Canada. 20:144-155.

Peckarsky, B. L. 1980. Predator-prey interactions between stoneflies and mayflies: behavioral observations. Ecology 61:932-943.

Pennak, R. W. 1989. Freshwater invertebrates of the United States, Protozoa to Mollusca, 3rd edition. John Wiley & Sons, New York.

Pennak, R. W., and E. D. Van Gerpen. 1947. Bottom fauna production and physical nature of the substrate in a northern Colorado trout stream. Ecology 28:42-48.

Petts, G. E. 1980. Long-term consequences of upstream impoundment. Environmental Conservation 7(4):325-332.

Rader, R. B. 1997. A functional classification of the drift: traits that influence invertebrate availability to salmonids. Canadian Journal of Fisheries and Aquatic Sciences 54:1211-1234.

Raleigh, R. F. 1982. Habitat suitability index models: Brook trout. U. S. Fish and Wildlife Service FWS/OBS-82/10.24, Washington, D. C.

Raleigh, R. F., and T. Hickman. 1984. Habitat suitability information: Rainbow trout. U. S. Fish and Wildlife Service FWS/OBS-82/10.60, Washington, D. C.

Raleigh, R. F., and Zuckerman L. D. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout. U. S. Fish and Wildlife Service 82(10.124), Washington, D. C.

Resource Management Group, Inc. 1994. Assessment of potential wetland impacts associated with the removal of Stronach Dam on the Pine River in Manistee County, Michigan. Unpublished manuscript for Consumers Power Company, Cadillac, Michigan.

Ringler, N. H. 1979. Selective predation by drift-feeding brown trout. Journal Fisheries Research Board of Canada 36:392-403.

Rose, G. A. 1986. Growth decline in subyearling brook trout (*Salvelinus fontinalus*) after emergence of rainbow trout (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences 43:187-193.

Rozich, T. J. 1998. Manistee River Assessment. Michigan Department of Natural Resources Fisheries Division Special Report Number 21, Lansing, Michigan.

Sagar, P. M., and G. J. Glova. 1988. Diel feeding periodicity, daily ration and prey selection of a riverine population of juvenile chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Biology 33:643-653.

SAS Institute. 1988. SAS user's guide, version 6.03. SAS Institute, Cary, North Carolina.

Schoener, T. W. 1982. The controversy over interspecific competition. American Scientist 70:586-595.

Scidmore, W. J., and A. W. Glass. 1953. Use of pectoral fin rays to determine age of the white sucker. Progressive Fish Culturist 15:114-115.

Scott, W. B., and E. J. Crossman. 1985. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Scurlock, M., D. Gilcrest, and B. Doppelt. 1993. The failure of existing riverine protection and restoration policies and programs. Pages 135-368 *in* B. Doppelt, M. Scurlock, C. Frissell, and J. Karr editors. Entering the watershed: A new approach to save America's river ecosystems. Inland Press, Washington, D.C.

Shuman, J. R. 1995. Environmental considerations for assessing dam removal alternatives for river restoration. Regulated Rivers: Research & Management 11:249-261.

Simons, R. K., and D. B. Simons. 1991. Sediment problems associated with dam removal- Muskegon River, Michigan. Hydraulic Engineering. Proceedings of the 1991 National Conference of the American Society of Civil Engineers.New York: ASCE.

Stauffer, T. E. 1977. A comparison of the diet and growth of brown trout (*Salmo trutta*) from the South Branch and the Main Stream, AuSable River, Michigan. Michigan Department of Natural Resources Fisheries Division Special Report 1845, Lansing, Michigan.

Strogen, J. W., Jr. 1979. A comparison of the diet and growth of the trout from the upper Au Sable and upper Manistee Rivers, Michigan. Michigan Department of Natural Resources Fisheries Division Special Report 1867, Lansing, Michigan.

Stuber, R. 1996. Pine River monitoring report 1995: fish habitat and population information. Unpublished report for the U. S. Forest Service Huron-Manistee National Forests

Stuber, R. J. 1985. Trout habitat, abundance, and fishing opportunities in fenced vs. unfenced riparian habitat along Sheep Creek, Colorado. U. S. Forest Service General Technical Report RM-120:310-314.

Swift, D. R. 1962. Activity cycles in the brown trout (*Salmo trutta Lin*). Hydrobiologia 20:241-247.

Tippets, W. E., and P. B. Moyle. 1978. Epibenthic feeding by rainbow trout (*Salmo gairdneri*) in the McCloud River. California Journal of Animal Ecology 47:549-559.

Twomey, K. A., K. L. Williamson, and P. C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: White sucker. U. S. Fish and Wildlife Service FWS/OBS-82/10.64, Washington, D. C.

Vanderploeg, ,H. A., and D. Scavia. 1979. Two electivity indices for feeding with special reference to zooplankton grazing. Journal of the Fisheries Research Board of Canada 36:363-365.

Van Deventer, J. S., and W. S. Platts. 1983. Sampling and estimating fish populations from streams. Transactions of the North American Wildlife and Natural Resources Conference 48:349-354.

Van Deventer, J. S., and W. S. Platts. 1985. A computer software system for entering, managing, and analyzing fish capture data from streams. USDA Forest Service Research Note INT-352. Intermountain Research Station, Ogden, Utah.

Vincent, R. E., and W. H. Miller. 1969. Altitudinal distribution of brown trout and other fishes in a headwater tributary of the South Platte River, Colorado. Ecology 50:464-466.

Walton, O. E. 1980. Active entry of stream benthic macroinvertebrates into the water column. Hydrobiologia 74:129-139.

Ward, J. V., and J. A. Stanford. 1989. Riverine ecosystems: the influence of man on catchment dynamics and fish ecology. Pages 56-64 in D. P. Dodge editor. Proceedings of the International Large River Sumposium. Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Ware, D. M. 1972. Predation by rainbow trout (*Salmo gairdneri*) influence of hunger, prey density and prey size. Journal of the Fisheries Research Board of Canada 29:1193-1201.

Waters, T. F. 1972. The drift of aquatic insects. Annual Review of Entomology 17:253-272.

Waters, T. F. 1995. Sediment in streams: sources, biological effects and control. American Fisheries Society, Monograph 7, Bethesda, Maryland.

Weisburg, S. 1993. Using hard-part increment data to estimate age and environmental effects. Canadian Journal of Fisheries and Aquatic Sciences 50:1229-37.

Wiley, M. J., S. L. Kohler, and P. W. Seelbach. 1997. Reconciling landscape and local views of aquatic communities: lessons from Michigan trout streams. Freshwater Biology 37:133-148.

Wilhelm, F. M., B. R. Parker, D. W. Schindler, and D. B. Donald. 1999. Seasonal food habits of bull trout from a small alpine lake in the Canadian Rocky Mountains. Transactions of the American Fisheries Society 128:1176-1192.

Wolman, M. G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35(6):951-956.

Young, M. K., R. B. Rader, and T. A. Belish. 1997. Influence of macroinvertebrate drift and light on the activity and movement of Colorado River cutthroat trout. Transactions of the American Fisheries Society 126:428-437.