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Competition Between White Sucker (*Catostomus commersoni*) and Yellow Perch (*Perca flavescens*): Results of a Whole-Lake Manipulation

Daniel B. Hayes

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COMPETITION BETWEEN WHITE SUCKER (*CATOSTOMUS COMMERSONI*) AND YELLOW PERCH (*PERCA FLAVESCENS*): RESULTS OF A WHOLE-LAKE MANIPULATION[1]

Daniel B. Hayes

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COMPETITION BETWEEN WHITE SUCKER (*CATOSTOMUS COMMERSONI*) AND YELLOW PERCH (*PERCA FLAVESCENS*): RESULTS OF A WHOLE-LAKE MANIPULATION

By

Daniel Brian Hayes

A DISSERTATION

Submitted to

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DOCTOR OF PHILOSOPHY

Department of Fisheries and Wildlife

1990

To Teresa and Kendra

The two most important people in my life

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ABSTRACT

COMPETITION BETWEEN WHITE SUCKER (CATOSTOMUS COMMERSONI) AND YELLOW PERCH (PERCA FLAVESCENS): RESULTS OF A WHOLE-LAKE MANIPULATION

By

Daniel Brian Hayes

The effects of competition with white sucker (*Catostomus commersoni*) on yellow perch (*Perca flavescens*) population dynamics and the mechanisms involved were determined experimentally by removing adult white suckers from Douglas Lake, Michigan during 1987 with trap nets. Yellow perch abundance, growth, diet, feeding rate, fecundity and survival and prey abundance were examined two years prior to sucker removal and three years following treatment. A nearby lake, Little Bear Lake, served as a reference lake to account for trends in perch population characteristics due to weather or other factors which would affect lakes in this region. In these lakes, the axis of competition was determined to be benthic invertebrates. The predominant prey item of adult suckers were chironomid larvae and *Caenis*. Following sucker removal, a 13 to 19 fold increase in the abundance in these taxa were observed. In Little Bear Lake over the same time period, *Caenis* showed a 33% decline in numbers and chironomid larvae showed a 2.2 fold increase, suggesting that increases in benthic invertebrate abundance in Douglas Lake were due to sucker removal. Coincident with increasing abundance of chironomid

larvae and *Caenis* was an increase in the utilization of benthic invertebrates and a decline in the utilization of zooplankton by adult yellow perch in Douglas Lake. Further, this shift resulted in increased stomach fullness, feeding rate and growth of adult yellow perch in Douglas Lake. These changes did not occur immediately following sucker removal, but required one to two years to develop. In Little Bear Lake, no trend in diet composition was observed, and variations in stomach fullness, feeding rate and growth were small compared to changes in these parameters observed in Douglas Lake, again suggesting that the results obtained in Douglas Lake were due to sucker removal. Although higher growth rates were observed in Douglas Lake, the size structure of the yellow perch population showed only a small increase in the proportion of fish greater than 150 mm. As such, other management techniques should be considered in addition to sucker removal for improving the growth rate of yellow perch populations.

INTRODUCTION

Competition is one of the of the fundamental ecological interactions occurring between species (Hairston et al. 1960, Roughgarden 1983). As such, competition forms one of the paradigms of community ecology. Competition, however, is difficult to demonstrate outside of the laboratory in field experiments (Hairston 1981). Because of this, some ecologists have expressed doubt concerning the importance of competition in community dynamics (e.g. Connell 1983, Conner and Simberloff 1983, Strong 1984). Other ecologists, however, have countered that there is considerably more evidence showing cases of competition (e.g. Schoener 1983, 1985, Persson 1983, Hanson and Leggett 1985). In part, some of the differences of opinion result from differing or ambiguous definitions of competition and the resulting differences in interpretation of experimental results (Ferson et al. 1986).

Numerous definitions of competition have been proposed, but many are similar to that given by Pielou (1981): "Competition takes place when the growth of a biological population, or any part of it, is slowed because at least one necessary factor is in short supply." Competition between individuals of the same species is termed intra-specific, and competition between individuals of different species is termed inter-specific competition.

In a pragmatic sense, arguments concerning the role of competition in community dynamics are important since they affect how ecologists view the structure and function of ecosystems, and how managers of these systems approach their management. For example, many fishery management practices are predicated on the assumption that intra-specific or inter-specific competition play an important role in fish community and fish species dynamics (Swingle 1950, Redmond 1986).

Control of fish density with predators to improve growth rates is an example of a management practice based on the assumption that individual fish growth rates are strongly influenced by intra-specific competition (Redmond 1986). Cases where reductions in inter-specific competition have been used to improve fish growth include removal of bullheads (Ictalurus sp.) to improve yellow perch, Perca flavescens, (Schneider 1981) and panfish growth (Olson and Koopman 1976). Another group of fish that has often been targeted for removal as a competitor with game fishes are the suckers (Catostomus sp.). Suckers have been removed to improve growth of several species of game fishes including trout (Rawson and Elsey 1948) and yellow perch (Johnson 1977, Schneider and Crowe 1980).

Although numerous fishery management actions have been performed based on the assumption that inter-specific competition plays a significant role in determining fish growth (i.e. Schneider 1981), there have been relatively few investigations that have identified the resources that are being co-utilized. This information is needed, however, in order to provide a mechanistic basis for understanding the results of management actions undertaken.

The primary goal of this study is to determine if white suckers (Catostomus commersoni) compete for food resources with yellow perch and to determine the processes underlying competitive interactions (if any) between these species. These species were chosen because yellow perch is an important sport fish in the upper midwest, and because it shows a propensity to grow slowly (stunt) in many lakes in this region (Scott et al. 1985). White suckers have previously been removed in a number of lakes in this region to improve the growth of coexisting populations of yellow perch (Johnson 1977, Schneider and Crowe 1980, Schneider 1981). However, the results of sucker removal have been variable (Holey et al 1979) and the mechanisms responsible for any changes have not been elucidated except in two cases (Johnson 1977, Schneider and Crowe 1981).

As indicated earlier, competition has been defined in a number of ways. It is difficult to form objective criteria for the detection of competition from many of these definitions. I propose the following as an operational definition of competition:

Competition is the process whereby the age-specific fecundity or survival of an individual (A) is decreased by the presence of another individual (B) through the direct or indirect impacts of (B) on the ability of (A) to obtain some limiting resource(s).

In this definition, based on DeBenedictis (1974), competition is designated in terms of its effects on fecundity and survival rather than fitness, as has sometimes been done (Pielou 1981). The reason for the choice of these variables, rather than fitness, is that fecundity and survival are measurable attributes of an individual or population whereas fitness is not. Fecundity and survival rate are important components of fitness and as such form a bridge between traditional definitions of competition and the one I have chosen (Hayes and Taylor 1990).

In the above definition, competition is specified in terms of the effects (decreased fecundity or survival) on individuals in each population and the mechanism (i.e. decreased resource availability or utilization) causing these effects. Accordingly, for an interaction between two species to be identified as competition, one must first observe changes in the fecundity or survival rates of the population in question, and secondly one must be able to relate these changes to the mechanism of resource availability and utilization. Thus, the specific objectives of this study are to determine if yellow perch fecundity or survival change in response to sucker removal. Additionally, the mechanisms responsible for changes observed (if any) will be investigated by examining trends in prey abundance and utilization by yellow perch, and associated changes in their feeding rate and growth rate.

STUDY SITES

Two lakes were chosen as study sites. One lake, Douglas Lake (Figure 1), was subjected to manual sucker removal while the other lake, Little Bear Lake (Figure 2), acted as a reference lake. Both lakes are located in Otsego County, Michigan, and are located less than 10 miles apart. Because of the close proximity of these lakes and their similarity in size and depth, many of the limnological parameters of the lakes are similar (Table 1). Furthermore, preliminary netting conducted in 1984 indicated that the status of the yellow perch population (growth rates and abundance) and fish community composition were similar in each lake.

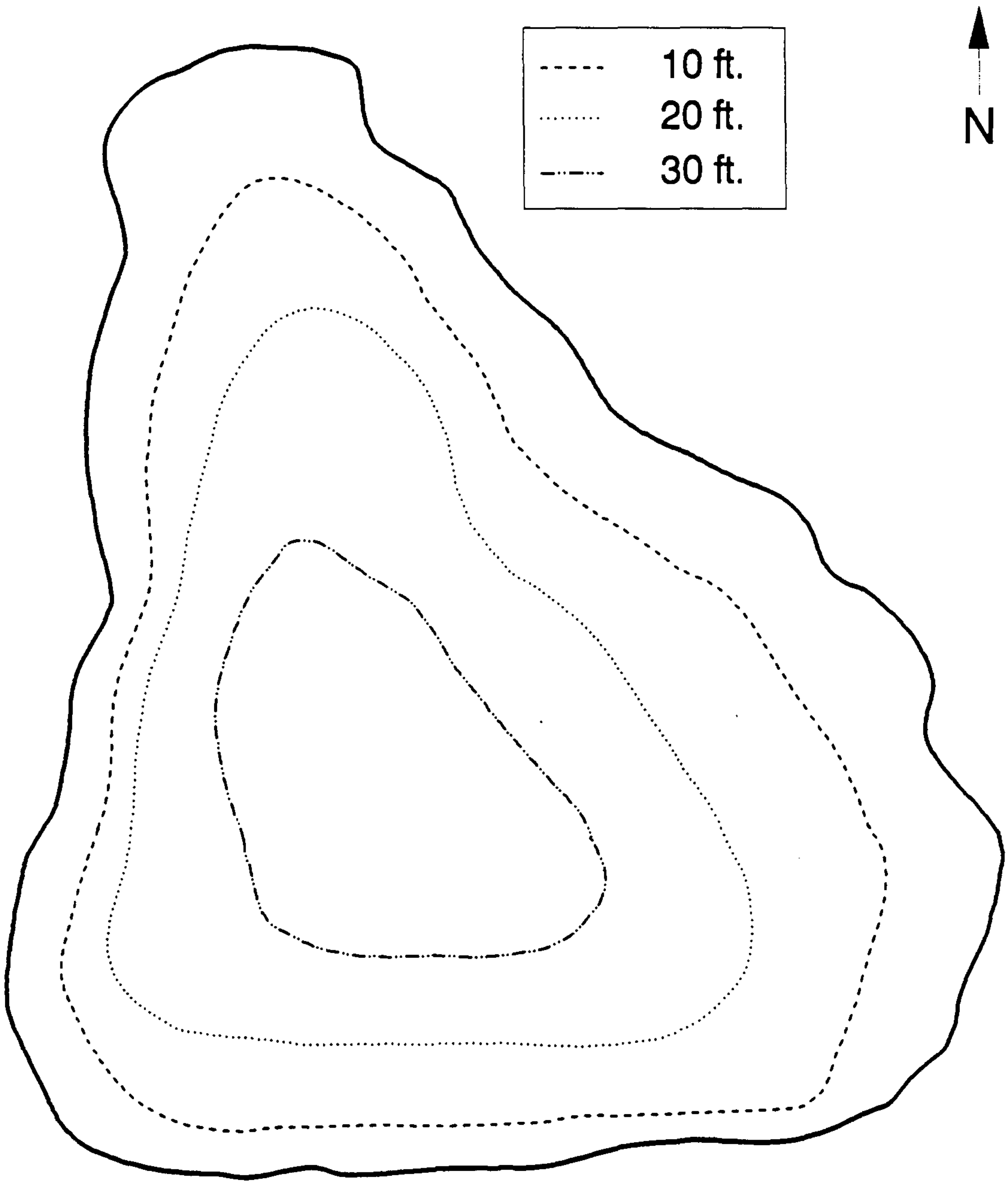

Figure 1. Contour map of Douglas Lake. Contour interval is 10 feet.

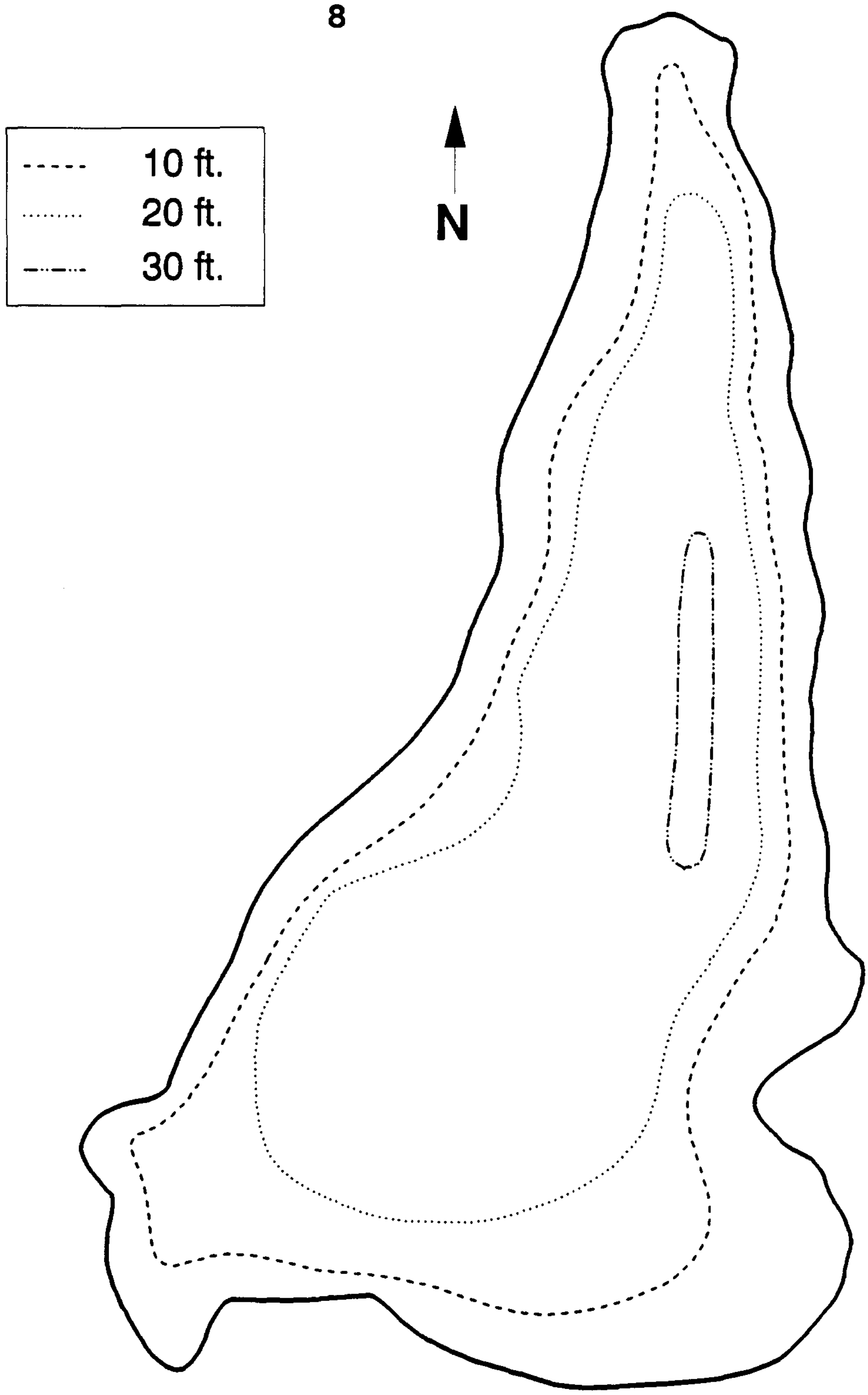

Figure 2. Contour map of Little Bear Lake. Contour interval is 10 feet.

Table 1. Limnological characteristics of Little Bear and Douglas Lakes, Otsego County, Michigan, 1985-89.

Parameter	Little Bear	Douglas
Area	51.8 ha	38.1 ha
Volume	2.3×10^6 m^3	1.8×10^6 m^3
Mean Depth	4.5 m	4.7 m
Maximum Depth	10 m	11 m
Approximate Date of ice break-up	April 20	April 20
Maximum Summer Temperature (1985-1989)	21.8-25.8°C	23.7-26.0°C
Alkalinity (April 1985)	117 mg $CaCO_3 \cdot l^{-1}$	93 mg $CaCO_3 \cdot l^{-1}$
pH (April 1985)	8.26	7.98
Spring Phosphorus Concentration (May 1988)	14.0 ppb	14.2 ppb
Mean Secchi Disk (1985-1989)	4.4 m	4.9 m
Percent of Lake Area:		
0-3 meters	28.5%	30.6%
3-6 meters	21.1%	18.6%
>6 meters	50.3%	50.8%
Percent of Lake Volume:		
0-3 meters	6.1%	7.2%
3-6 meters	15.5%	14.8%
>6 meters	78.4%	78.0%

MATERIALS AND METHODS

Age-0 fish abundance

Abundance of age-0 fishes was measured in May during the peak hatching period of larval yellow perch and white suckers, and during late July and August after most of early life mortality had taken place. Thus, an index of initial production was estimated for each year-class as well as an index of the eventual strength of the year class.

Peak density after hatching was estimated with a surface ichthyoplankton trawl towed after dark. Nighttime surface trawls was used because perch and sucker larvae concentrate near the lake surface after dark (Clady 1976, Corbett and Powles 1983). The ichthyoplankton net used was 0.5 meters in diameter and had 760-micron mesh. Sampling was initiated in early to mid-May and continued on a weekly basis through mid-June each year except during 1989 when sampling was conducted only during a two week period corresponding to peak hatching time as determined by results from previous years. Each night, a total of 9 trawl samples were taken on each lake. Sampling was stratified by depth, with 3 tows being taken on each of the 2, 4, and 8-meter contours. Fixed sampling sites were utilized since the total length of the trawls on each contour covered the majority of the lake's circumference. At each site, the net was towed for 5 minutes at approximately 1 meter·sec^{-1}. A flowmeter was installed at the mouth of the net to allow for determination of the volume of water sampled.

Estimates of year class strength in late July and August were made using seine hauls at 9 fixed sites in Douglas Lake and 7 sites in Little Bear Lake. Fixed sites were used because some areas of the shoreline could not be readily seined due to obstructions such as boat docks and fallen trees. The additional sites in Douglas Lake were added because preliminary seining results indicated that more sites were necessary to provide an adequate sample size of age-0 yellow perch for growth determinations. At each site, 15.2 meters of shoreline were seined, with the width of the area swept dependent on the site's depth. Catch was then standardized to number per 139.4 m^2 (1500 feet^2). The seine used was 7.6 meters in length, 1.2 meters in depth and had 0.48-cm bar mesh.

<u>Adult fish abundance</u>

The term "adult fish" is used here to refer to all fish older than age-0 regardless of their state of sexual maturity. Most age I+ yellow perch were observed to have maturing gonads during the summer and were in spawning condition when they reached age II (Hayes, unpublished data). Too few age I white suckers were caught to determine their state of sexual maturity. In other lakes of this region, white suckers typically mature at age III or IV (Scott and Crossman 1973).

Adult fish abundance was indexed by gill net catch per effort. Gill net samples were taken four times each year, from mid-May to early September except during 1985 when sampling was initiated in mid-June. Netting sites were stratified by depth, with two sites positioned on each of the 2, 4, and 8-meter contours. At the 2-meter sampling sites, a single horizontal gill net was set. Horizontal gill nets were 1.8 meters in depth and were 15 meters in length. Each net contained five meshes, graded in size from 2.54 cm (stretch mesh) to 7.62 cm in 1.27 cm increments. Each panel of mesh was 3 meters in length. At each 4-meter site, two horizontal gill nets were set. One net was set on the bottom and the other net had additional floats and was set at the surface. This allowed for complete coverage of the water column. At each 8-meter sampling site, five vertical gill nets were set, one in each of the above mesh sizes. Each vertical gill net was 1.8 meters in width and 8 meters in length.

On each sampling date, gill nets were checked every three hours for 24 hours. This interval was chosen to provide samples intended for diet and feeding rate analysis which will be described later. All fish captured were removed from the net, identified and counted. The distance from the bottom was determined to the nearest meter for fish captured in the vertical gill nets. Since nets on the 2 and 4-meter contours were set in close proximity, catches in these nets were grouped for each time period. Nets on the 2 and 4-meter contours were set near one another to enhance our ability to check the nets quickly. An index of abundance for adult fish was computed by a weighted mean of the catch rate on the 8-meter contour and the 2 and 4-meter contour's combined. The weighting factor used for the 2 and 4-meter catch was the percent of lake area contained between 0 and 6 meters, and the weight for the 8-meter catch was the percent of lake area greater than 6 meters in depth (Table 2). The variance of the weighted mean was computed using the formula for stratified random samples in Cochran (1977).

Annual differences in catch per effort were tested using a one-way ANOVA using a RT-1 transformation (Conover and Iman 1981). In this transformation, each observation in the data set (in this case the value of the catch index) is assigned a rank according to its value relative to all other observations. Use of this type of transformation with standard one-way ANOVA provides an analog to the non-parametric Kruskal-Wallis test that is as robust as the Kruskal-Wallis test, but is simpler to compute and can be extended to more complex experimental designs (Iman and Davenport 1976). Differences between pre-treatment (1985 and 1986) and post-treatment (1987-1989) time periods were tested through a linear contrast applied to annual means and results from the preceding ANOVA (Day and Quinn 1989). The use of such contrasts allows for tests of hypotheses regarding groups of treatments (in this case years) while testing for overall differences.

Adult fish diet and feeding rate

All adult suckers collected during the 24-hour gill netting sampling dates were preserved in 10% formalin to be used for diet analysis. Because of the relatively small sample size of adult suckers obtained on each date (generally <20) the feeding rate of adult suckers could not be estimated. The diet of adult suckers was determined by removing the contents of the entire gastro-intestinal tract into a flask, creating a suspension of this material in a known quantity of water, and subsampling with a Hensen-Stemple pipette. Prey items were then enumerated, and a subsample of these items were measured for total length (for cladocerans) or for head capsule width (for insects). Dry weight of prey items were then estimated using regressions of length (head capsule width) and dry weight from Smock (1980) for insects and Culver et al. (1985) for cladocerans using methods outlined by Bowen (1983).

A subsample of adult yellow perch collected during the 24-hour gill netting sampling dates was preserved in 10% formalin to be used for diet analysis. Target subsamples for adult yellow perch were 20 fish from each 3-hr period with 6-7 fish from each of the 2, 4 and 8-meters contours.

When less than 6 fish were caught on a given contour, more fish were retained from the other contours to obtain a total of 20 fish per time period. When less than 20 fish were caught within a time period, all fish captured were kept. The diet of adult yellow perch was determined from the contents of the stomach only since material in the intestinal tract often was too digested to identify. The contents of the stomach were removed from the fish and weighed as an aggregate. All items in the stomach were then identified to family or genus and enumerated. The contribution of each taxon to stomach content weight was estimated by a multiple regression of counts of prey against total stomach content weight (Hayes and Taylor, in review).

To estimate feeding rate, the contents of the intestine were also removed and weighed, and this weight was added to the stomach content weight. Gut fullness was then represented as the weight of the gastro-intestinal tract contents as a proportion of the fish weight. Mean gut fullness was then computed for each 3-hour period, and daily mean fullness was then computed by the unweighted mean of the means of each 3-hour period. This computational method was used to allow for unequal sample sizes between the sampling periods within each day. Feeding rate was then estimated with the formula from Eggers (1977):

$F=24*S*R$

where,

F=feeding rate

S=mean stomach fullness for the entire day

R=instantaneous evacuation rate (hour^{-1})

Instantaneous evacuation rate could not be estimated directly from field data due to low or zero sample sizes available from some sampling periods from some dates. As evacuation rate is strongly related to water temperature, I used the following relationship from Boisclair and Leggett (1988) to estimate evacuation rate:

$\ln R= 0.150*\text{Temperature} - 5.79$

Fish growth

Growth in length of age-0 yellow perch has been shown to be approximately linear from the time of hatch through the first growing season (Ney and Smith 1975, Hayes 1988). Thus, growth rate was estimated from a linear regression of mean length against time. This additionally provided a convenient means of testing differences between years and time periods using ANCOVA.

The growth rate of adult yellow perch was determined through age determination and back-calculations of length from scale reading. Ages and annuli measurements were taken from an image of the scale projected on a digitizing pad. Back-calculated lengths were estimated following the procedures outlined in Smale and Taylor (1987).

Prey resources

Benthos samples were collected using a 15.24 x 15.24 centimeter Ekman dredge, sieved through a 250-micron benthos bucket, and fixed in the field in a 10% formalin solution. In the laboratory, invertebrates were sorted by hand from sediments using sugar floatation. All invertebrates were generally identified to family, and the head capsule width of all insects was measured. Samples were generally collected on or within one week of the day 24-hour gill net samples were collected. During 1985 and 1986, three random samples were taken on each of the 2, 4, and 8-meter contours each sampling date, for a total of 36 samples each year from each lake. From 1987 to 1989, six samples on each contour (72 samples per year) were taken to increase precision of our estimates. Preliminary data analysis using MANOVA indicated significant changes in the benthic invertebrate community between years in both lakes. As these analyses did not indicate which taxa changed, further statistical analysis of benthic invertebrate abundance was performed for each taxon separately using a randomized block design ANOVA on log(x+1) data (Elliott 1977) with years as the main treatment and months as a blocking variable. Differences between the pre-treatment and post-treatment period were tested using linear contrasts between years (Quinn and Day 1989).

Zooplankton samples were also collected on or within one week of 24-hour sampling dates. A 20-centimeter diameter, 80-micron mesh Wisconsin net was towed vertically from 0.5 meter of the bottom to the surface. All tows were taken between 0900 hr and 1600 hr. Two random samples were taken on each of the 2, 4, and 8-meter contours for a total of 6 samples for each sampling date. Zooplankton samples were preserved in the field in a sucrose-formalin solution (Haney and Hall 1973). In the laboratory, each sample was subsampled with a Hensen-Stemple pipette to provide at least 100 cladocerans. All individuals w*18^I^\ ^Se subsample were identified to genus and counted. Statistical analysis of zooplankton abundance was performed using the same procedure as benthos.

<u>Sucker removal</u>

Adult white suckers were removed from Douglas Lake during 1987 using trap nets with 2.54 and 5.08-centimeter stretch mesh set in shallow water. A total of 19 nets were set continuously from May 1 to May 11. Because of low catch rates in 2.54 centimeter mesh nets, these nets were removed. The remaining 11 nets were fished continuously from May 11 to August 8, 1987. All fish other than suckers were returned to the lake immediately after capture. In 1988, eleven 2.54 centimeter mesh nets were set from April 18 to May 16 to determine the degree of success of the prior year's removal efforts and to determine if high numbers of age-0 suckers were produced the previous year.

RESULTS

Douglas Lake

Sucker abundance

Larval white suckers were caught in very low numbers in ichthyoplankton nets in Douglas Lake throughout this study (Table 2). For example, only 7 larval suckers were caught during 1986 which had the highest peak density of all years. No significant difference in catch rates from the pre-treatment period to the post-treatment period ($p>0.05$) were observed in peak density (corresponding to time of hatching) during the larval phase of life.

Catch of age-0 white suckers in seine hauls during August was also very low in Douglas Lake. In fact, no age-0 suckers were caught at all from 1985 to 1987 in August during the catch index period (Table 2). Although catch of age-0 white suckers was significantly greater during the post-treatment period ($p<0.01$, linear contrast test), catch rates remained low, averaging less than 1 fish per seine haul.

During 1985, catch rate of adult white sucker averaged 0.39 fish per 3-hr gill net set. Mean catch rates declined 80% over the course of the study, reaching a minimum of 0.08 in 1989 (Table 2). The decline in catch rates from the

Table 2. Catch per effort of white sucker in Douglas Lake, 1985-1989. The number of ichthyoplankton trawls per date, and the number of seine hauls or gill net sets is denoted by n, standard error by S.E.

Peak larval density (number·m^{-3})

	1985	1986	1987	1988	1989
mean	0.011	0.064	0.051	0.010	0.000
n	9	9	9	9	9
S.E.	0.010	0.030	0.022	0.004	0.000

Number of age-0 fish per standard seine haul in August

	1985	1986	1987	1988	1989
mean	0.00	0.00	0.00	0.75	0.11
n	40	41	18	27	27
S.E.	0.00	0.00	0.00	0.41	0.06

Number of adult fish per 3-hr gill net set

	1985	1986	1987	1988	1989
mean	0.39	0.20	0.11	0.16	0.08
n	64	64	64	64	64
S.E.	0.11	0.06	0.05	0.06	0.04

pre-treatment period to the post-treatment period was significant ($p<0.01$, linear contrast test).

Reductions in white sucker abundance occurred through both natural mortality and sucker removal. From April 30 to August 8, 1987, a total of 1497 adult suckers weighing 536 kg were removed from Douglas Lake using trap nets. On an areal basis, this represents a removal rate of 14 kg/ha. Suckers removed ranged from 300 mm to 449 mm (mean=354 mm, S.E.= 1.9, n=150) in total length and from 198 g to 630 g (mean=358 g, S.E.=5.8, n=150) in weight. In 1988, small-mesh trap nets were set April 18 to index catch rates of adult suckers, and to determine if high levels of recruitment occurred in the year following sucker removal. Catch rates were low compared to 1987, with only 42 suckers, being captured by May 16. All white suckers captured during 1988 were age II and older judged by their size. From the low capture rate observed and lack of age I fish (indicating low year class strength in 1987), the sucker removal was considered to have successfully depleted the sucker population and further trap netting was terminated.

Based on the size frequency of white suckers captured in gill nets (Figure 3), no age I+ or II+ fish were captured in Douglas Lake from 1985 to 1988. In 1989, recruitment of age I+ suckers was evident in the capture of fish 100 to 150 mm in length (Figure 3). Since no recruitment was detected from 1985 to 1988, the annual survival rate of adult suckers

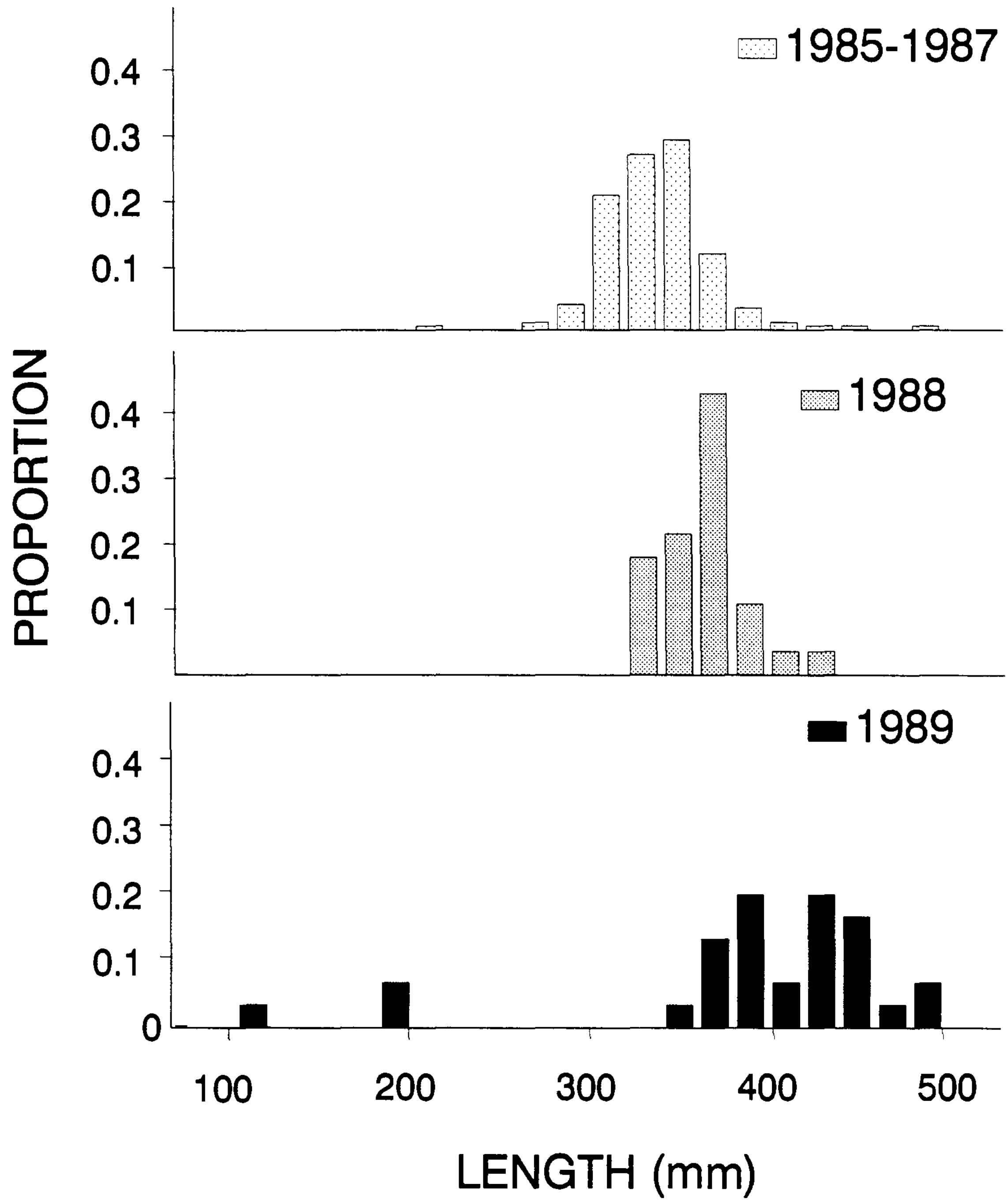

Figure 3. Length frequency distribution of adult white suckers in Douglas Lake.

was estimated from the rate of decline observed. Total annual survival rates calculated from these data were: 54% in 1985-86; 58% in 1986-87 and approximately 100% in 1987-88. In 1989, 2 of the 15 adult suckers captured were new recruits (age 1+ fish). Discounting these individuals from the analysis, total annual survival from 1988-89 was 53%.

From the annual survival rates derived above, an estimate of the minimum population size prior to netting was made. If all mortality from the summer of 1986 to the summer of 1987 was due to the removal project, then the population of adult suckers during 1986 would have been 2994 fish. Based on this, the biomass of adult suckers during 1986 would have been 20.7 kilograms/hectare. Using a survival rate of 54% from 1985 to 1986, the initial population of white suckers during 1985 would have been 5091 fish with a biomass of 35.2 kilograms/hectare. Since some natural mortality probably occurred in addition to that imposed by our netting, these estimates should be treated as a minimum level.

<u>White sucker diet</u>

Since age-0 white suckers were caught in such low numbers, diet data were grouped for both Little Bear and Douglas Lake for all years. Qualitatively, the diet of age-0 suckers in both lakes consisted primarily of benthic crustaceans such as chydorid cladocerans and harpacticoid copepods.

The numbers of food items in the diet of age-0 white suckers varied significantly between size classes ($p<0.01$, ANOVA). Hence, their diet is presented by size classes. In only the 15 mm size class did planktonic crustaceans (i. e. Bosmina, Daphnia) contribute substantially to the diet by numbers. In all size classes larger than 15 mm, age-0 white suckers primarily ate benthic organisms (Figure 4). Benthic crustaceans (including chydorid cladocerans, harpacticoid copepods, ostracods and amphipods) were the predominant benthic items consumed. Numbers of benthic crustaceans consumed increased from the 15 mm size class to the 35 mm size class, after which numbers in the gut were approximately the same. Benthic insects were also consumed by age-0 white suckers with a trend of increasing consumption in larger size classes (Figure 4, also Appendix A).

During the pre-treatment period, chironomid larvae, chydorid cladocerans and Caenis were numerically the most common items in the diet of adult white suckers in Douglas Lake (Table 3). During this time period, chironomid larvae and Caenis contributed over 90% of the diet by weight, with chydorid cladocerans comprising nearly all the remainder (Table 4). During the post-treatment period, the diet of adult white suckers shifted towards increased utilization of Caenis and chironomid pupae. Significantly fewer ($p<0.01$) chydorid cladocerans and other microcrustaceans

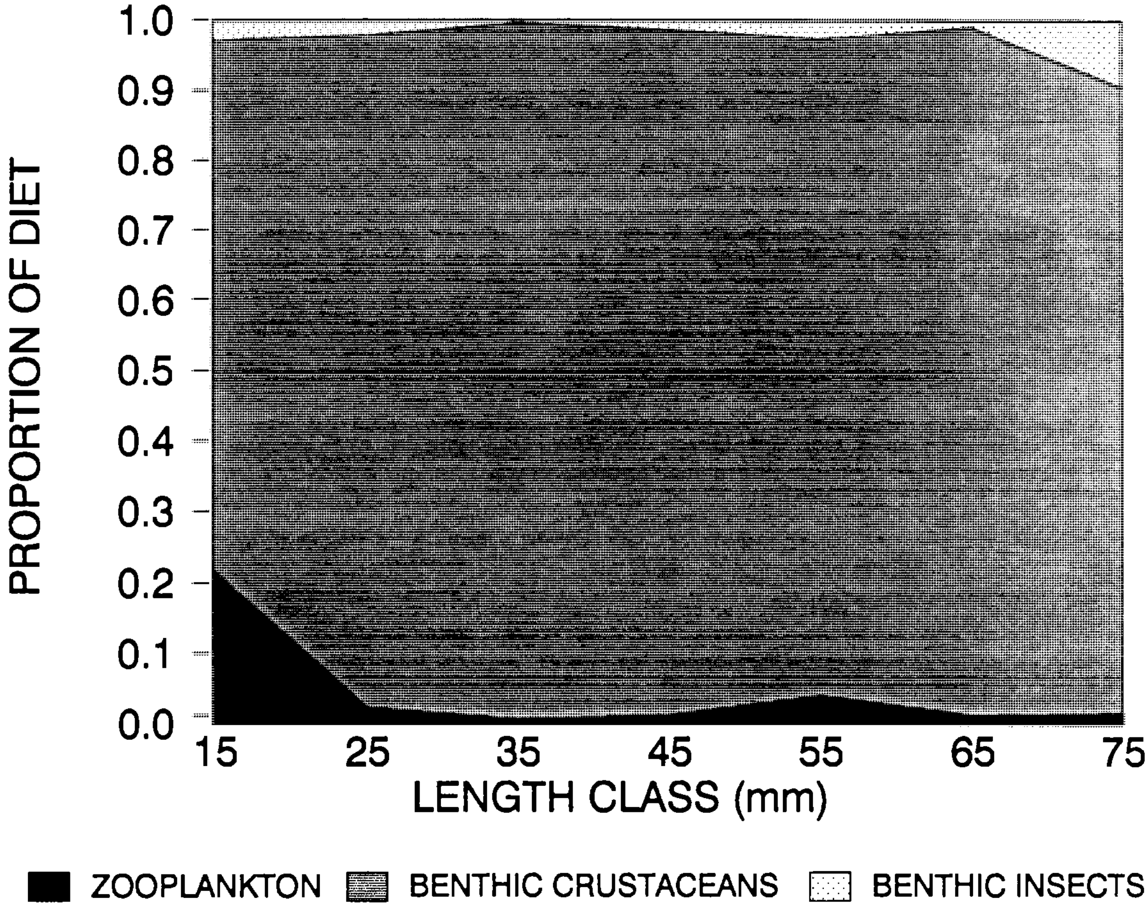

Figure 4. Diet composition (by numbers) of age-0 white sucker in Douglas Lake and Little Bear Lake, 1985-1989.

Table 3. Mean number of prey taxa in the gut of adult white sucker in Douglas Lake. The mean number of each prey taxon is indicated on the first line and the standard error on the second line. The significance of differences between pre-treatment and post-treatment periods and between years are indicated in the columns marked Treat and Year.

Taxon	Treat	Year	1985	1986	1987	1988	1989
Chironomid larvae	o	o	620	780	1523	1913	725
			68	101	634	454	176
Chironomid pupae	xx	xx	10	3	28	35	262
			4	2	24	16	79
Caenis	x	x	82	57	216	479	101
			17	19	110	239	61
Trichoptera	o	xx	0	23	47	6	0
			0	15	25	3	0
Sididae	xx	xx	125	55	0	0	0
			48	22	0	0	0
Bosmina	xx	xx	56	877	0	32	0
			55	733	0	30	0
Macrothricidae	xx	xx	27	3	88	0	0
			8	3	82	0	0
Chydoridae	xx	xx	6241	625	403	120	16
			1952	127	196	59	15
Harpacticoidae	o	o	0	1	0	8	0
			0	1	0	7	0
Cyclopoidae	xx	xx	61	39	13	8	0
			14	11	12	7	0
Ostracoda	o	xx	9	59	13	7	3
			8	40	12	6	3
Gastropoda	xx	xx	33	29	13	0	4
			10	8	9	0	4
Others	o	x	29	36	24	34	7
			8	9	12	13	3
Sample size			111	52	18	28	30

o= $p>0.05$
x= $p<0.05$
xx= $p<0.01$

Table 4. Weight contribution of prey items to the diet of suckers in Douglas Lake. The estimated mean dry weight (grams) per gut for each item is indicated on the first line and the percent of the total is indicated on the second line. tr indicates less than 0.001 g dry weight contribution for that taxon.

Taxon	Year 1985	1986	1987	1988	1989	Grand mean
Chironomid larvae	0.267	0.179	0.398	0.521	0.331	0.339
	56.3	72.5	55.5	45.3	48.5	52.0
Chironomid pupae	0.006	0.003	0.023	0.026	0.250	0.060
	1.3	1.2	3.2	2.3	36.6	9.2
Caenis	0.159	0.057	0.288	0.601	0.102	0.241
	33.5	23.1	40.2	52.3	14.9	37.0
Sididae	0.001	tr	tr	tr	tr	tr
	0.2	0.0	0.0	0.0	0.0	0.0
Bosmina	tr	0.001	tr	tr	tr	tr
	0.0	0.4	0.0	0.0	0.0	0.0
Macrothricidae	tr	tr	tr	tr	tr	tr
	0.0	0.0	0.0	0.0	0.0	0.0
Chydoridae	0.026	0.007	0.008	0.002	tr	0.009
(large genera)	5.5	2.8	1.1	0.2	0.0	1.4
Chydoridae	0.015	tr	tr	tr	tr	0.003
(small genera)	3.2	0.0	0.0	0.0	0.0	0.5
Harpacticoidae	tr	tr	tr	tr	tr	tr
	0.0	0.0	0.0	0.0	0.0	0.0
Cyclopoidae	tr	tr	tr	tr	tr	tr
	0.0	0.0	0.0	0.0	0.0	0.0

(i.e. Bosmina) were consumed during the post-treatment period (Table 3). As such, Caenis, chironomid larvae and chironomid pupae comprised virtually all the diet by weight during the post-treatment period (Table 4).

Relative Consumption Rates and predation pressure

The decrease in abundance of adult white sucker in Douglas Lake was accompanied by an increase in the consumption rate of some taxa (i.e. Caenis and chironomid pupae) per individual fish. Thus, the predation pressure exerted by the sucker population over time is not proportional to their abundance. Accordingly, I estimated the relative consumption rate of the sucker population for each taxon by the product of the mean annual gill net catch per effort and the mean number of that taxon in the gut. Since chironomid larvae and pupae, Caenis and chydorid cladocerans form the bulk of sucker diet in both lakes, I restricted my analysis to these taxa. Where the mean number consumed per fish did not differ significantly between years (Table 5), the mean number for all years combined was used. For each taxon, these results were then standardized relative to the first year of the study (1985) to allow for a clearer indication of trends in predation pressure.

In Douglas Lake, the relative consumption rate of chydorid cladocerans declined over the entire study period, reaching a minimum of 1% or less of initial consumption rates in 1989 (Table 5). Adult sucker predation pressure on chironomid pupae and Caenis declined from 1985 to 1987 but

Table 5. Relative consumption rate of adult white suckers in Douglas Lake for predominant prey items.

Prey item		Year				
		1985	1986	1987	1988	1989
Chironomid larvae	Adult Sucker CPE	0.39	0.20	0.11	0.16	0.08
	Mean number per gut	887	887	887	887	887
	Product	346	177	98	142	71
	Proportion of 1985	1	0.51	0.28	0.41	0.21
Chironomid pupae	Adult Sucker CPE	0.39	0.20	0.11	0.16	0.08
	Mean number per gut	10	3	28	35	262
	Product	3.9	0.6	3.1	5.6	21.0
	Proportion of 1985	1	0.15	0.79	1.44	5.37
Caenis	Adult Sucker CPE	0.39	0.20	0.11	0.16	0.08
	Mean number per gut	82	57	216	479	101
	Product	31.98	11.4	23.76	76.64	8.08
	Proportion of 1985	1	0.36	0.74	2.40	0.25
Chydoridae	Adult Sucker Cpe	0.39	0.20	0.11	0.16	0.08
	Mean number per gut	6241	625	403	120	16
	Product	2434	125	44	19	1
	Proportion of 1985	1	0.05	0.02	0.01	0.00

increased in 1988. This increase was due to increases in per capita consumption. Relative consumption dropped far below initial level during 1989 for Caenis, but increased to over 5 times the 1985 population consumption rate for chironomid pupae (Table 5). Since no significant differences were observed between years in mean numbers of chironomid larvae in adult sucker guts, the mean from all fish (877 chironomids per fish) was used. Predation pressure on chironomid larvae dropped dramatically from 1985 to 1986 and remained at or below 51% of 1985 levels throughout the remainder of the study. Relative consumption rates of chironomid larvae reached a minimum during 1989 when they were only 21% of 1985 levels.

Yellow perch abundance

Larval yellow perch were much more abundant in Douglas Lake than larval white suckers throughout the study (Table 6). There was no significant difference ($p>0.05$) in the abundance of larval yellow perch from the pre-treatment period to the post-treatment period. During 1989, however, the peak density of larval yellow perch was substantially higher than in all previous years, suggesting there may be a time-lagged increase in yellow perch reproductive output following sucker removal.

Catch rates of age-0 yellow perch in seine hauls during August were relatively low, averaging less than 3 fish per standard haul in all years except 1989 when catch rates

Table 6. Catch per effort of yellow perch in Douglas Lake, 1985-1989. The number of ichthyoplankton trawls per date, and the number of seine hauls or gill net sets is denoted by n, the standard error by S.E.

Peak larval density (number·m^{-3})

	1985	1986	1987	1988	1989
mean	0.62	1.51	0.93	0.55	3.73
n	9	9	9	9	9
S.E.	0.16	0.45	0.38	0.20	2.41

Number of age-0 fish per standard seine haul in August

	1985	1986	1987	1988	1989
mean	0.90	2.49	0.00	2.26	7.37
n	40	41	18	27	27
S.E.	0.34	0.75	0.00	1.26	2.38

Number of adult fish per 3-hr gill net set

	1985	1986	1987	1988	1989
mean	20.98	7.35	5.01	1.80	3.23
n	64	64	64	64	64
S.E.	6.19	2.45	1.23	0.50	0.91

averaged slightly over 7 fish per haul (Table 6). No significant differences between the pre-treatment and post-treatment periods were observed ($p>0.05$), but catch rates were significantly higher during 1988 and 1989 than during 1985 and 1986, indicating that there may have been time-lagged treatment effect on yellow perch year class strength.

Catch rates of adult yellow perch during 1985 were high compared to white sucker, averaging 20.98 fish per 3-hour net set (Table 6). Significant declines ($p<0.01$) in the catch of adult yellow perch were evident in Douglas Lake from the pre-treatment period to the post-treatment period (Table 6). Biomass estimates could not be obtained for yellow perch in Douglas Lake, however, the relative biomass was estimated by the product of catch per effort and mean weight per individual. Relative biomass was highest in 1985 at 323.1 grams per 3-hour net set. From 1985 to 1988, mean weight per individual perch showed very little change, ranging from 15.4 grams in 1985 to 14.2 grams in 1988. Thus, relative biomass declined at roughly the same rate as catch per effort from 1985 to 1988, reaching a minimum during 1988 at 26.5 grams per 3-hour net set. During 1989, yellow perch averaged 19.8 grams each, and relative biomass increased to 64.0 grams per net set.

Adult yellow perch distribution

Although there were significant differences between years in the horizontal distribution of adult yellow perch

(X^2=43.5, 8 d.f., $p<0.01$), no trends were apparent in the percent of catch occurring in the 2, 4, and 8-meter nets in Douglas Lake. Each year, more than 87% of the catch of adult yellow perch catch occurred in the 8-meter vertical gill nets (Table 7). The vertical distribution of perch captured on the 8-meter contour differed significantly between years ($D=0.7733$, $p<0.01$, Kolmogorov-Smirnov test) and showed a strong trend over time in Douglas Lake (Figure 5). During 1985 and 1986, less than 25% of the adult perch catch occurred within one meter of the bottom. Over time, the proportion of fish caught near the bottom increased. In 1989, over 90% of the yellow perch caught in the 8-meter gill nets were captured within 1 meter of the bottom (Figure 5).

Survival rate of adult yellow perch

Catch curves showed no differences between the pre-treatment period and post-treatment period in Douglas Lake (Kolmogorov-Smirnov test, $p>0.05$). A general schedule of age-specific survival rates for age 3 to age 7 perch was thus computed from data grouped over all years (Table 8). No difference between catch curves in Douglas Lake and Little Bear Lake was detected ($p>0.05$, Kolmogorov-Smirnov test). The shape of the catch curve for the two lakes combined suggests that survival rate was not constant for all ages of adult yellow perch, decreasing abruptly beyond age 5 (Figure 6).

Table 7. Horizontal distribution of catch of adult yellow perch in Douglas Lake, 1985-1989.

	Percent of catch by contour		
Year	2-meter	4-meter	8-meter
1985	3.0	6.8	90.2
1986	2.3	5.4	92.3
1987	1.9	7.5	90.6
1988	1.3	9.3	89.4
1989	5.2	7.5	87.3

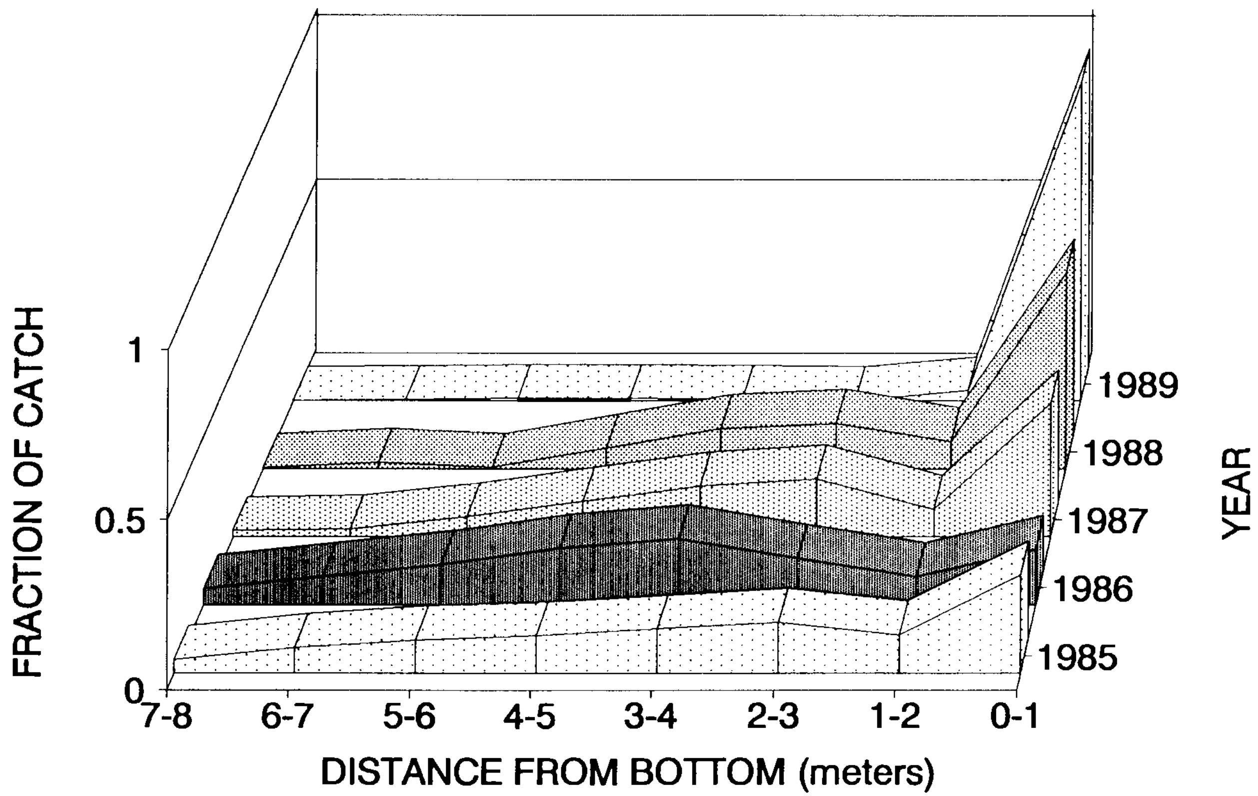

Figure 5. Vertical distribution of adult yellow perch on the 8-meter contour in Douglas Lake, 1985-1989.

Table 8. Age-specific annual survival rate of adult yellow perch from Douglas Lake 1985-1990. Only those age-classes fully recruited to the sampling gear used are included.

Age	Annual Survival Rate
3	56%
4	44%
5	18%
6	41%

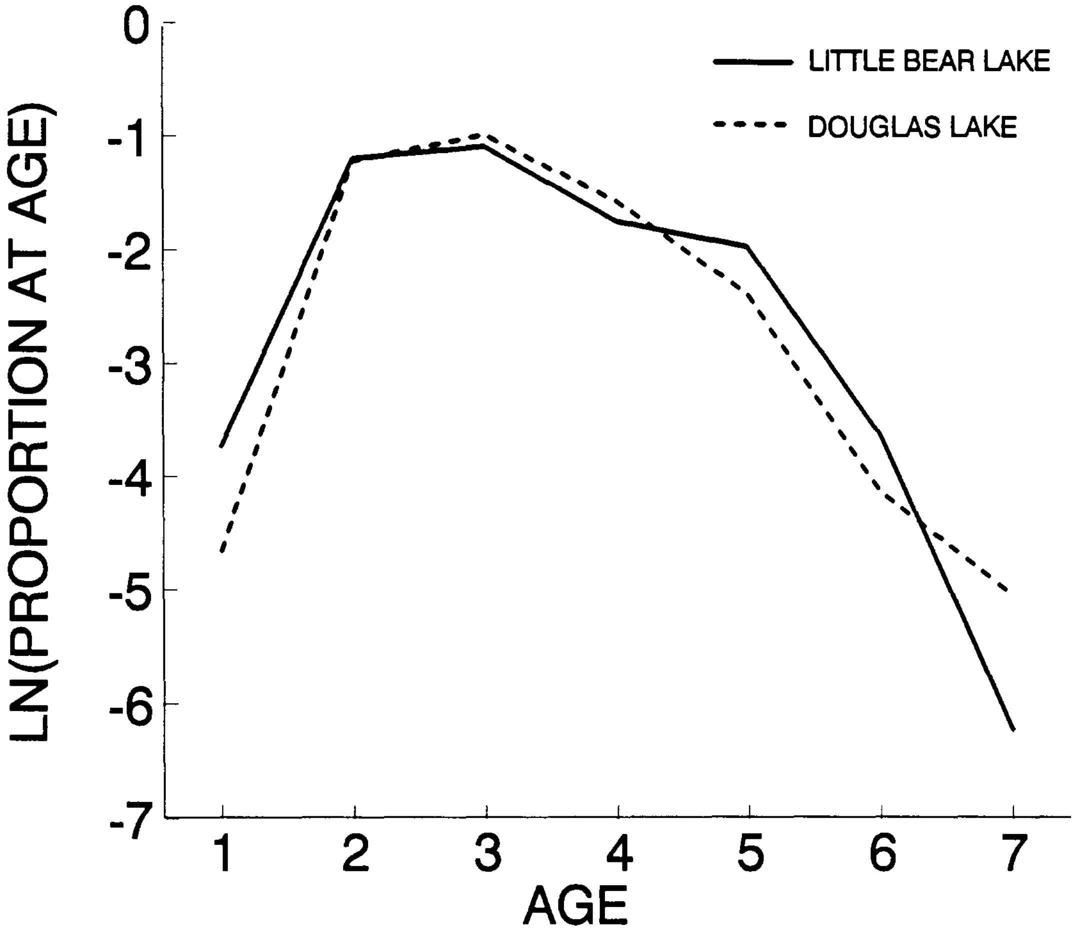

Figure 6. Catch curve of adult yellow perch in gill nets for Douglas Lake and Little Bear Lake.

Yellow perch diet

During the pre-treatment period, age-0 yellow perch in the 5 to 25 mm size classes primarily ate zooplankton in Douglas Lake (Figure 7). After reaching the 35 mm size class, their diet showed a trend of increasing consumption of benthic crustaceans, primarily chydorid cladocerans. Benthic insects did not form a substantial portion of the diet by numbers until age-0 yellow perch reached a size of approximately 55 mm. During the post-treatment period, zooplankton again was the predominant group in the diet of perch in the 5 to 25 mm size classes (Figure 7). Benthic crustaceans were rarely consumed by age-0 perch in the 5 to 25 mm size classes, but an increase in utilization of benthic crustaceans was observed in the 35 to 65 mm size classes. Benthic insects were consistently less abundant in the diet of all size classes of age-0 yellow perch diet during the post-treatment period. No pattern of differences in numbers of zooplankton in the stomach was observed between the pre-treatment and post-treatment periods. A general increase in utilization of benthic crustaceans was observed during the post-treatment period compared to the pre-treatment period ($p<0.01$, randomized block ANOVA). The consumption of benthic insects, however, decreased during the post-treatment period ($p<0.01$, randomized block ANOVA). Adult yellow perch consumed a broad variety of prey items, which are detailed for the pre-treatment period in a

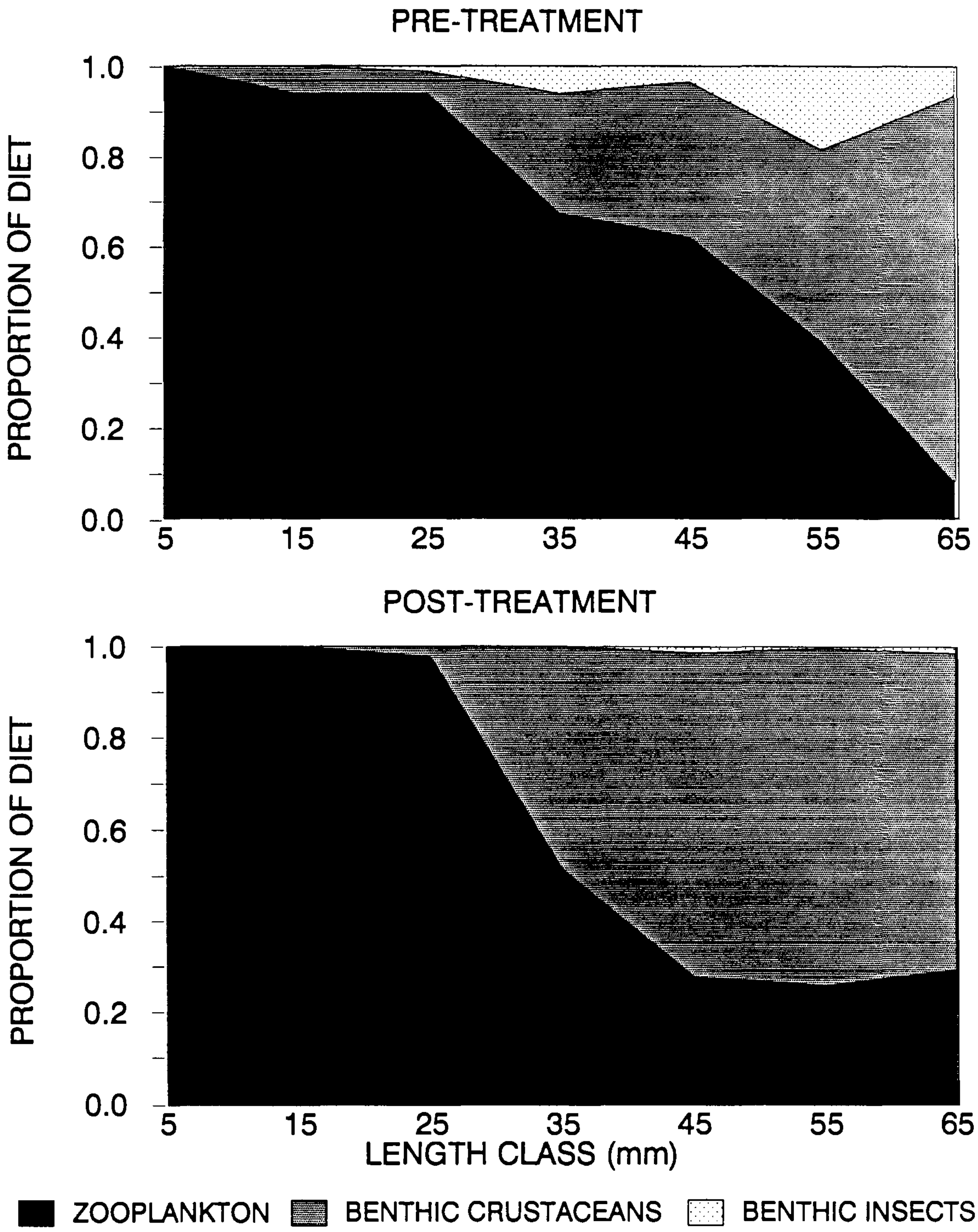

Figure 7. Diet composition (by numbers) of age-0 yellow perch in Douglas Lake, 1985-1989.

previous publication (Hayes 1988). For clarity of exposition in this dissertation, I have grouped these prey items into broad categories including: zooplankton, benthos, fish and other.

During the pre-treatment period, zooplankton were numerically predominant in the diet of adult yellow perch in Douglas Lake (Figure 8). The most common taxa of zooplankton consumed included Daphnia, Bosmina, Diaphanosoma and Leptodora. Despite their relatively small size (approximately 0.0001 g wet weight), zooplankton contributed 50-70% of the diet by weight (Figure 9). During the post-treatment period, the numbers of zooplankton consumed decreased to the point that in 1989 no zooplankton were found in any of the 428 adult yellow perch examined (Figure 8).

Benthic invertebrates (including Chaoborus larvae and pupae), although less numerous in the diet than zooplankton (Figure 8) comprised approximately 20-30% of the diet by weight during the pre-treatment period in Douglas Lake (Figure 9). The primary benthic invertebrates consumed included chironomid larvae and pupae, Caenis and Chaoborus larvae and pupae. During the post-treatment period, a clear trend of increasing utilization of benthic invertebrates was evident. In 1989, benthos made up over 80% of the diet by weight and was consumed almost to the exclusion of other items except fish (Figure 9).

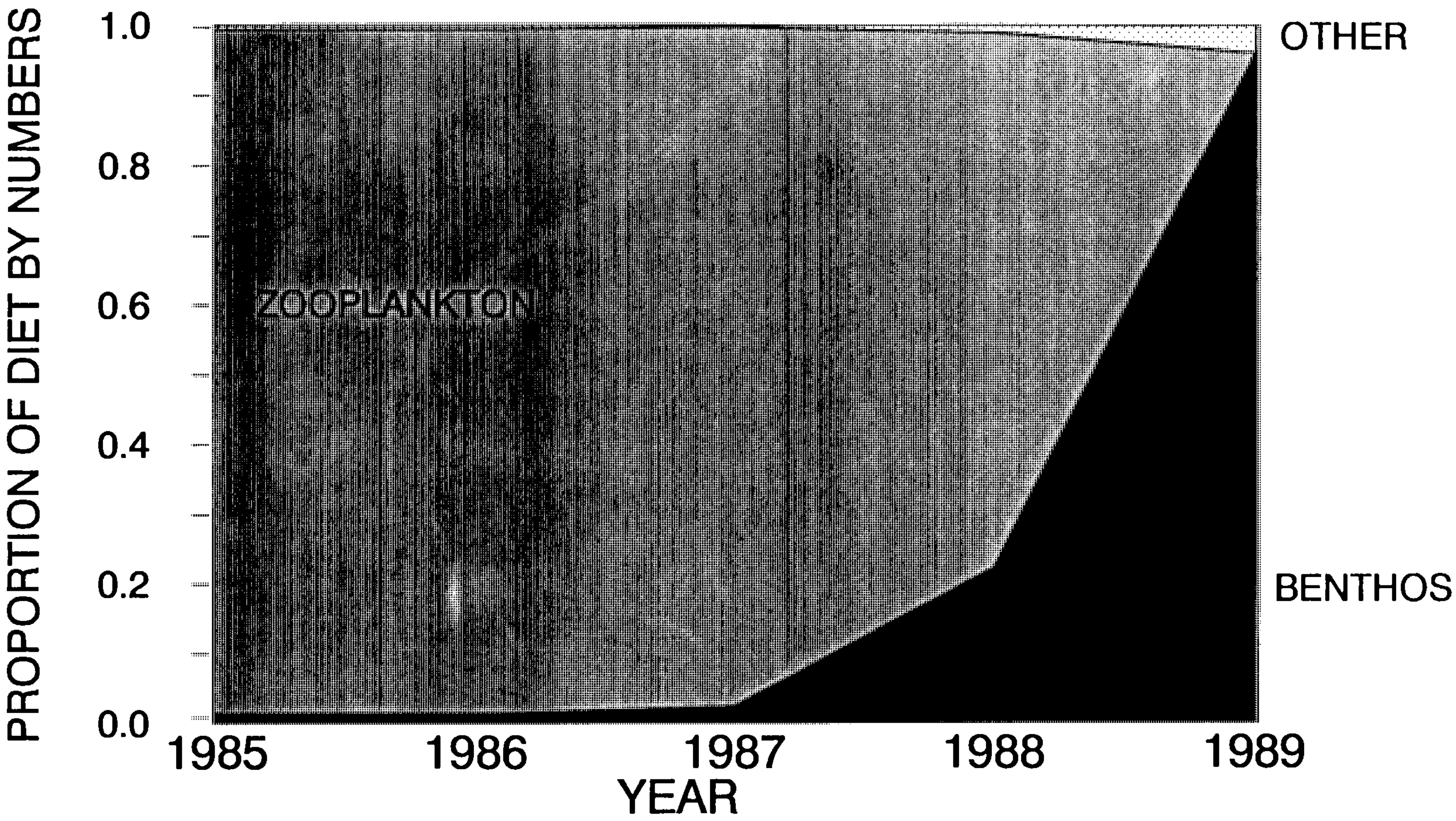

Figure 8. Diet composition (by numbers) of adult yellow perch (100-145 mm) in Douglas Lake, 1985-1989.

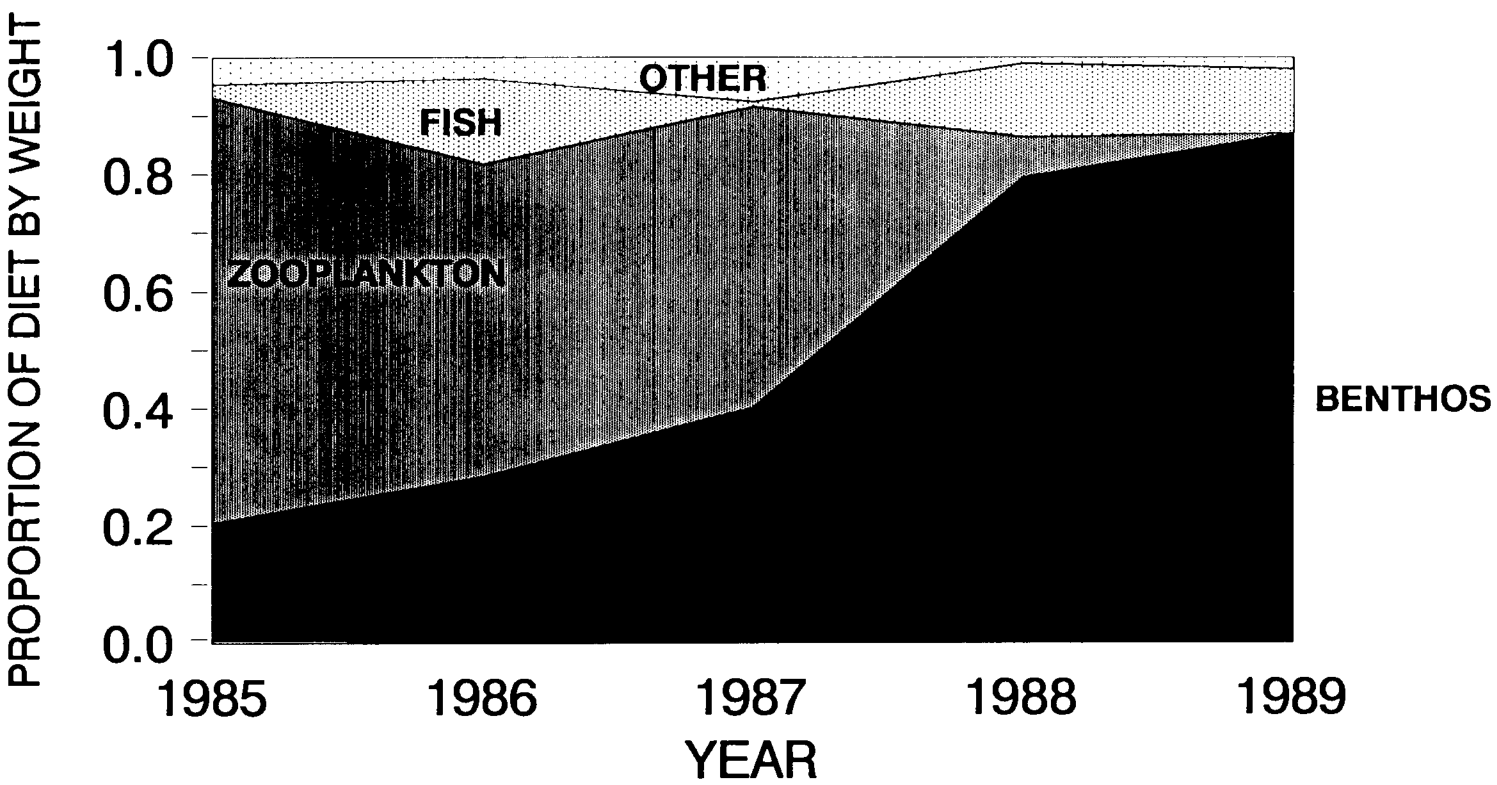

Figure 9. Diet composition (by weight) of adult yellow perch (100-145 mm), in Douglas Lake, 1985-1989.

Fish were generally consumed in low numbers (Figure 8), but because of their relatively large size (up to 3 grams or more) they sometimes comprised a large proportion of the diet by weight (Figure 9). No trends between years in the consumption of fish were evident.

Yellow perch relative predation pressure

Since the diet of yellow perch showed a strong shift towards benthic invertebrates, which are also the primary prey items of adult white suckers, I will focus my discussion of yellow perch predation pressure on chironomid larvae, chironomid pupae, Caenis and chydorid cladocerans.

Chironomid larvae, chironomid pupae and Caenis all showed an increase in predation pressure from adult yellow perch from the pre-treatment period to the post-treatment period (Table 9). Lowest levels of predation pressure occurred in 1985 or 1986 for each of these taxa, and highest levels of predation for these three taxa occurred during 1989 (Table 9). During 1989, predation pressure was 14 to 35 times greater than that in 1985. Chydorid cladocerans experienced highest relative predation pressure from adult yellow perch in 1986, with predation pressure dropping from 1986 through 1989 (Table 9).

Adult yellow perch gut fullness

Associated with increased utilization of benthic invertebrates, an increase in mean gut content weight (gut fullness) was evident from the pre-treatment period to the

Table 9. Relative consumption rate of adult yellow perch in Douglas Lake for predominant benthic prey items.

Prey item		Year 1985	1986	1987	1988	1989
Chironomid larvae	Adult Perch CPE	20.98	7.35	5.01	1.80	3.23
	Mean number per gut	0.08	0.29	0.42	10.97	7.91
	Product	1.76	2.11	2.13	19.74	25.55
	Proportion of 1985	1	1.20	1.21	11.24	14.54
Chironomid pupae	Adult Perch CPE	20.98	7.35	5.01	1.80	3.23
	Mean number per gut	0.03	0.21	0.05	0.52	7.09
	Product	0.66	1.52	0.26	0.93	22.89
	Proportion of 1985	1	2.30	0.40	1.41	34.64
Caenis	Adult Perch CPE	20.98	7.35	5.01	1.80	3.23
	Mean number per gut	0.02	0.00	0.01	1.82	3.83
	Product	0.42	0.00	0.05	3.28	12.37
	Proportion of 1985	1	0.00	0.12	7.81	29.45
Chydoridae	Adult Perch Cpe	20.98	7.35	5.01	1.80	3.23
	Mean number per gut	0.23	10.81	3.04	3.75	0.00
	Product	4.88	79.49	15.21	6.75	0.00
	Proportion of 1985	1	16.28	3.11	1.38	0.00

post-treatment period in Douglas Lake. Changes in gut fullness, however, showed an unequal response between different size-classes of yellow perch, and between the sexes.

During the pre-treatment period, gut fullness was essentially the same for female perch between 100 mm and 145 mm total length (Figure 10). Females in the 95 and >150 mm size classes showed much higher fullness than fish in other size classes, although sample size for these size classes was small (Table 10). Male yellow perch showed no trend in gut fullness across the entire size range sampled. For fish in the most heavily sampled size classes (105-135 mm), male yellow perch gut fullness averaged slightly less (mean=0.808, S.E.=0.018, n=764) than females (mean=0.886, S.E.=0.017, n=870).

During the post-treatment period, an increase in mean gut content weight was evident for female yellow perch in all size classes except the 95 and >150 mm size classes (Figure 10). Fullness for fish in these size classes decreased relative to the pre-treatment period. Male yellow perch showed an increase in gut fullness for all size classes except the >150 mm size class. For the most abundant size classes (105-135 mm), male fish had significantly lower gut fullness (mean=1.403, S.E.=0.077, n=265) than females (mean=1.646, S.E.=0.091, n=481) during the post-treatment period.

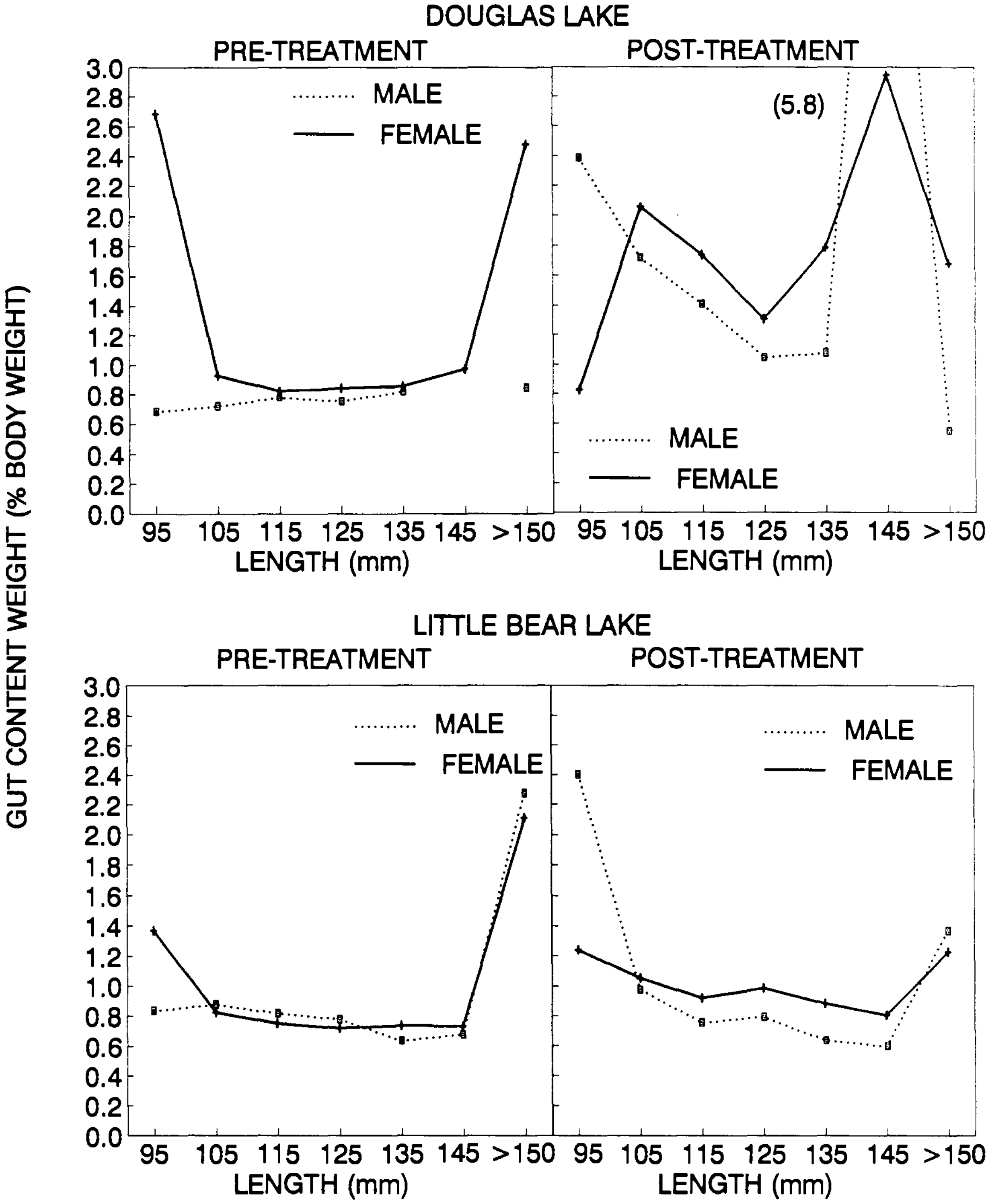

Figure 10. Relationship between yellow perch length and gut content weight for male and female yellow perch in Douglas and Little Bear Lake 1985-1986 (pre-treatment) and 1987-1989 (post-treatment).

Table 10. Sample size of adult yellow perch by size class and sex used each year for stomach fullness analysis in Douglas Lake.

	Length Class (mm)						
	95	105	115	125	135	145	>150
Pre-treatment							
Males	2	57	461	338	19	0	2
Females	1	41	310	480	178	11	11
Total	3	98	771	818	197	11	13
Post-treatment							
Males	1	56	156	43	9	3	1
Females	1	73	209	163	36	15	84
Total	2	129	365	206	45	18	85

Feeding rate of adult yellow perch

Feeding rate estimates were obtained for 20 dates from 1985 to 1989 in Douglas Lake for adult yellow perch 100-150 mm total length. Estimates were restricted to adult yellow perch within this size range because these were the most frequently sampled size classes, and stomach fullness showed little variation with respect to size across this size range. As such, feeding rate estimates from fish in this size range were judged to provide the best basis for comparison between the pre-treatment and post-treatment periods.

During the pre-treatment period, estimates of feeding rate were low, averaging between 0.956 and 2.780% of body weight per day (Figure 11). During this time period, there was no clear evidence of within-year trends, except that the lowest feeding rate estimates for each year occurred during late August. During the post-treatment period, a strong within-year pattern of feeding rate was apparent, with low feeding rates observed during mid May and late August, and relatively high feeding rates during June and July (Figure 11). Annual mean feeding rate was significantly ($p<0.05$) higher during the post-treatment period, however this increase was not apparent until 1988.

Yellow perch growth

The sex of age-0 fish was not determined and growth rates of these fish were computed for the sexes combined.

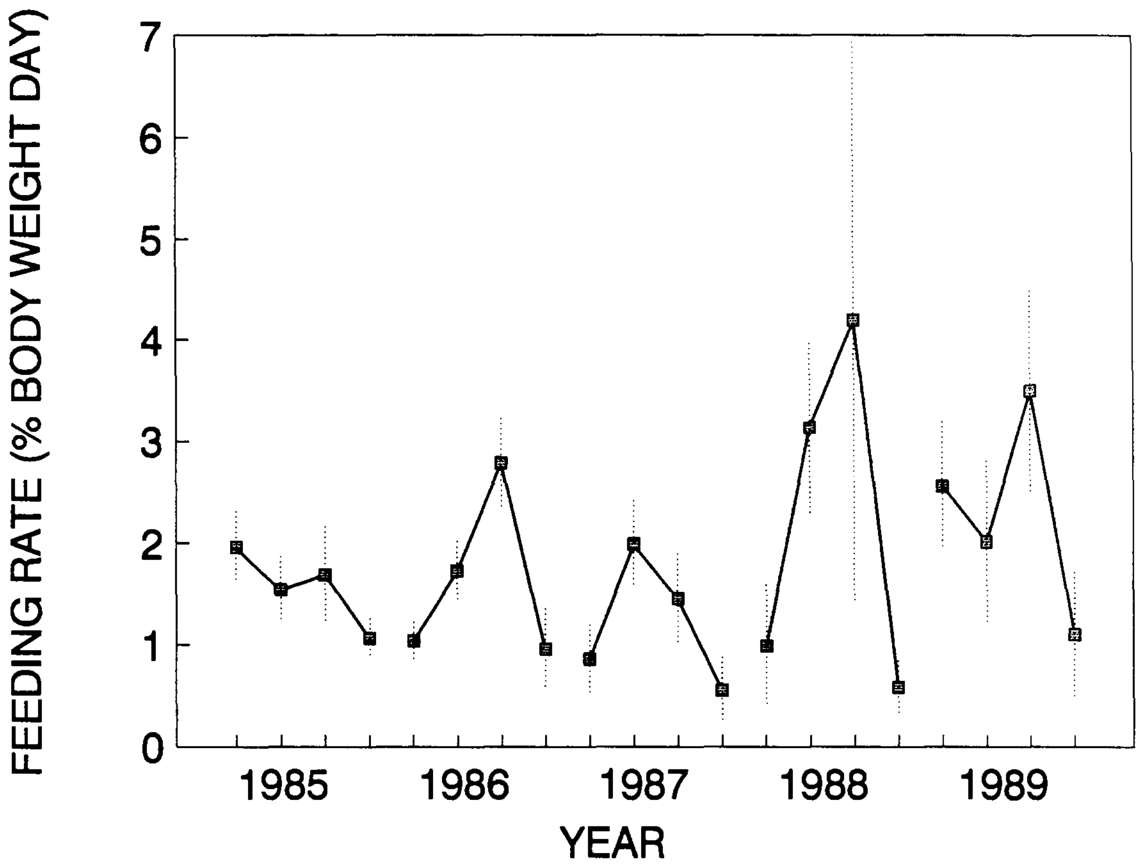

Figure 11. Feeding rate (% body weight per day) of adult yellow perch in Douglas Lake, 1985-1989.

In Douglas Lake, there were significant differences between years ($p<0.001$, ANOVA) and between the pre-treatment and post-treatment period ($p<0.05$, linear contrast test) in the growth rate of age-0 yellow perch (Table 11).

Length at age 2 showed a decrease from 1985 to 1987, but showed no trend in time thereafter (Figure 12). Length at age 3 and 4 showed no trend from 1985 to 1988, but showed an increasing trend during 1989 and 1990 (Figure 13 and 14). Adult yellow perch age 1 and age 6 or older were caught in too few numbers to allow for a determination of trends in length at age for these age groups.

Graphs of length increment versus length showed a consistent pattern among the pre-treatment years. Generally, length increment decreased linearly with fish length for male fish from 50 to 115 mm, and for female fish from 50 to 145 mm. Above these size ranges, however, length increments were dramatically higher, and showed no trend with size (Figure 15). Because of the discontinuity in the trend of length increments with size, growth rates were examined statistically for small fish (males 50-119 mm; females 50-149 mm) and large fish (males >119 mm, females >149 mm) for each sex.

In Douglas Lake, there were significant ($p <0.001$) annual differences in the slope of regression lines of length increment as a function of fish length for both males and females. Because of the differences in the slopes of

Table 11. Growth rates (mm/week) of age-0 yellow perch in Douglas Lake. The sample size (n) refers to the number of weeks used in the regression to estimate growth rate, and S.E. indicates the standard error of growth rate estimates.

	Year				
	1985	1986	1987	1988	1989
growth (mm/week)	4.15	3.73	5.11	4.45	4.05
S.E.	0.15	0.10	0.28	0.19	0.18
n	12	14	7	10	4

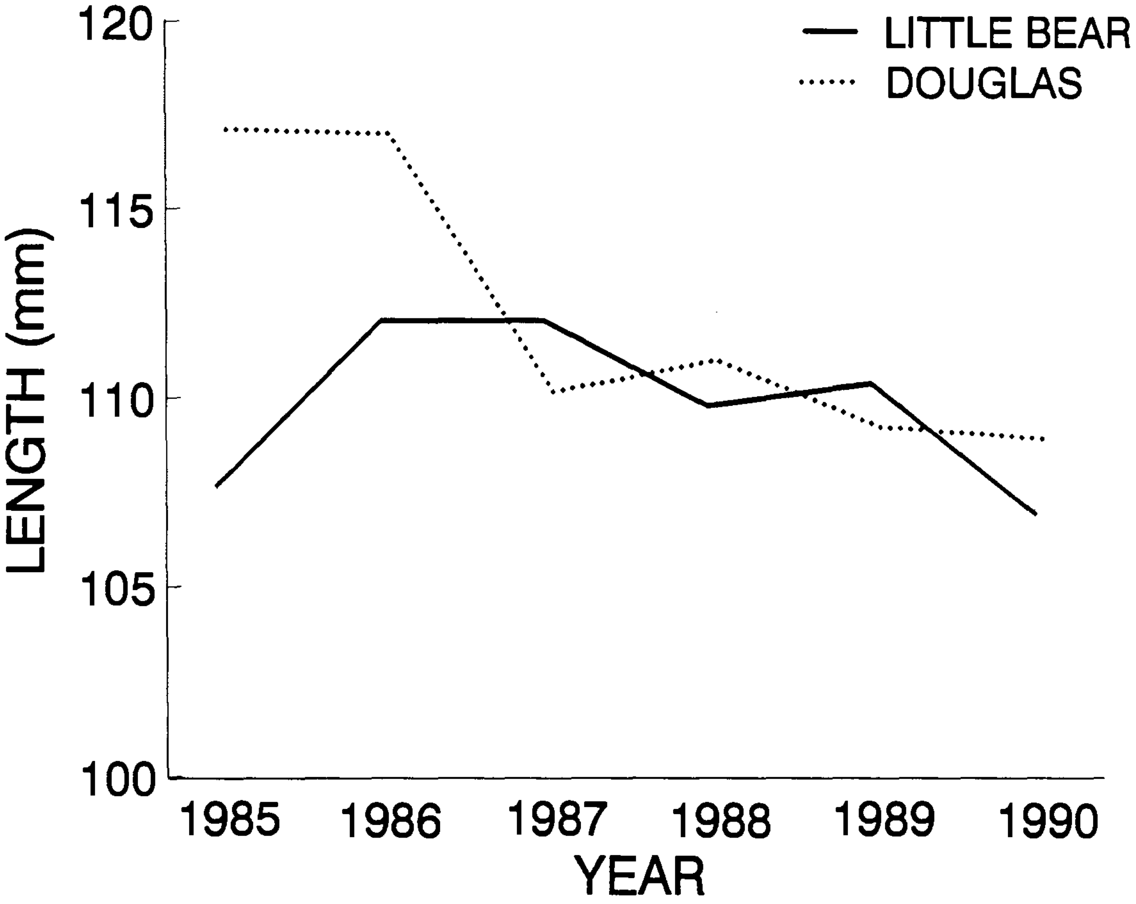

Figure 12. Length at age 2 of adult yellow perch in Douglas Lake and Little Bear Lake, 1985-1990

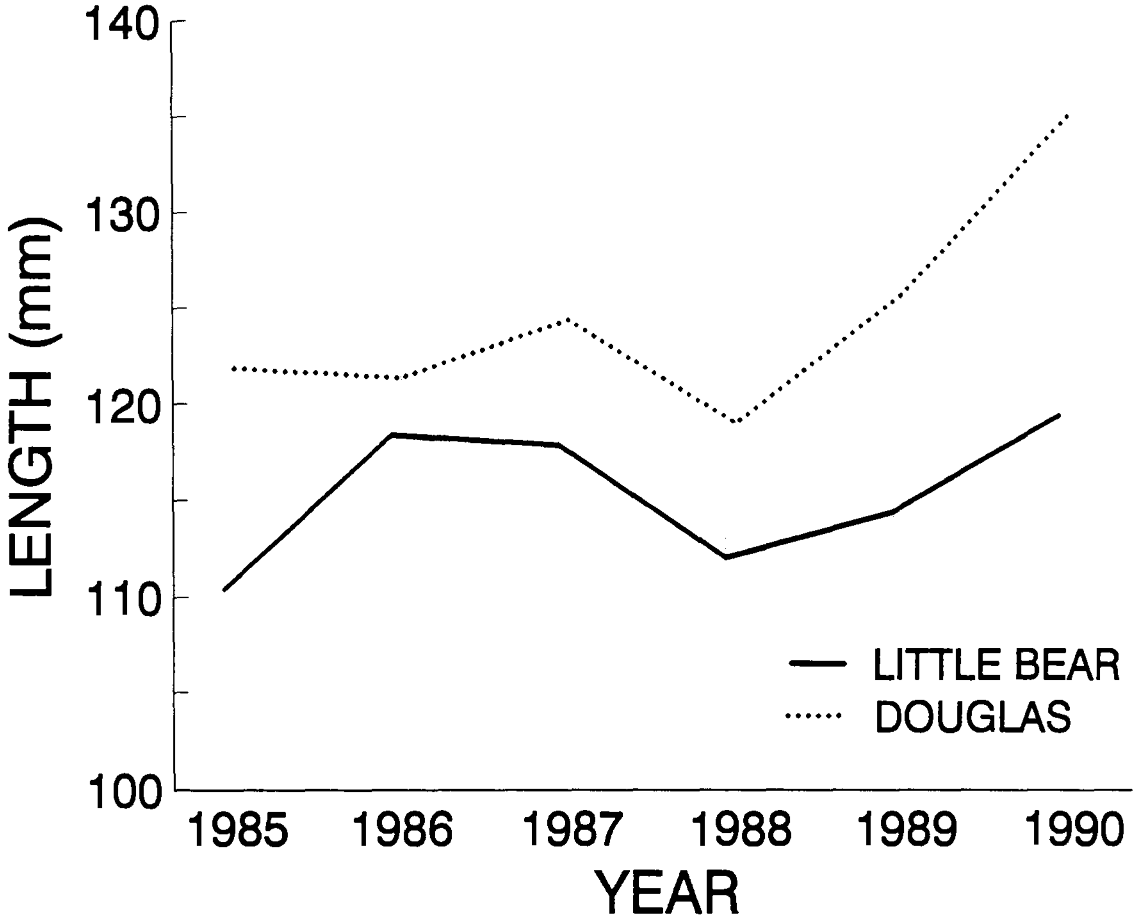

Figure 13. Length at age 3 of adult yellow perch in Douglas Lake and Little Bear Lake, 1985-1990

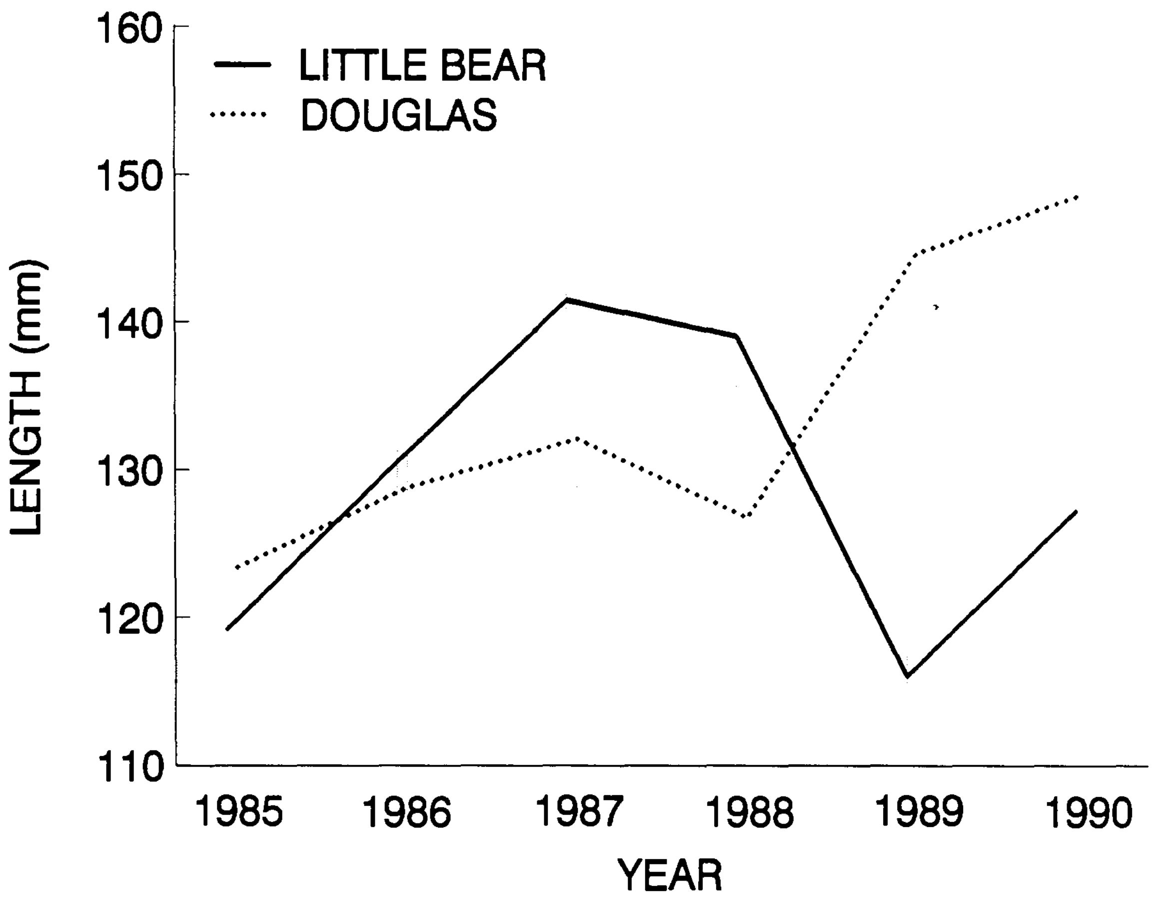

Figure 14. Length at age 4 of adult yellow perch in Douglas Lake and Little Bear Lake, 1985-1990

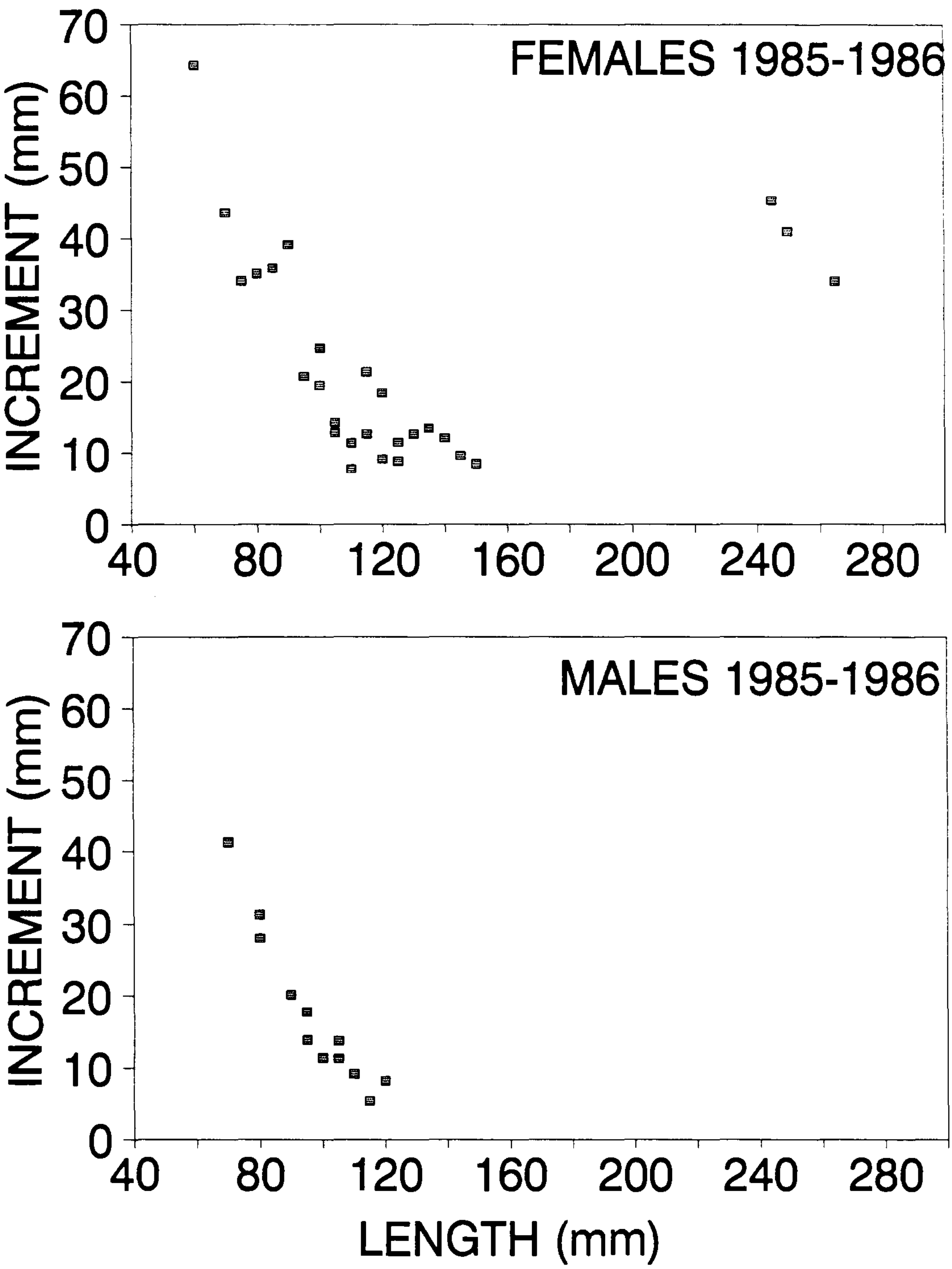

Figure 15. Relationship between length increment and length of yellow perch in Douglas Lake during the pre-treatment period.

these lines, no direct tests of the "year" effect can be made with ANCOVA on the length-specific increments. Graphs of the regression lines are useful, however, in discussing the differences between years. For female yellow perch in Douglas Lake, no trend in the regression line's slopes or intercepts was apparent from 1985 through 1988. In 1989, increments for female yellow perch 50 to 110 mm were no greater than average, but increments for females from 110 to 150 mm were substantially higher than in previous years. In 1990, growth increments for all size classes were at or above those from previous years (Figure 16). Regression lines for growth increment for male yellow perch from Douglas Lake were tightly grouped from 1985 through 1988, but in 1989 and 1990 show a progressive decline in slope. This resulted in somewhat lower growth for smaller individuals and higher growth for larger individuals (Figure 16).

Growth increments for male yellow perch above 120 mm and female perch above 150 mm showed no relationship to size, sex, or year (ANOVA, p>0>.05) in Douglas Lake. It should be noted, however, that very few (n=25) of these "large" yellow perch were captured during our sampling of fish for scale samples. Increments for perch in these size classes averaged 21.99 mm (se=2.38, n=25).

<u>Population size structure</u>

The size structure of yellow perch vulnerable to

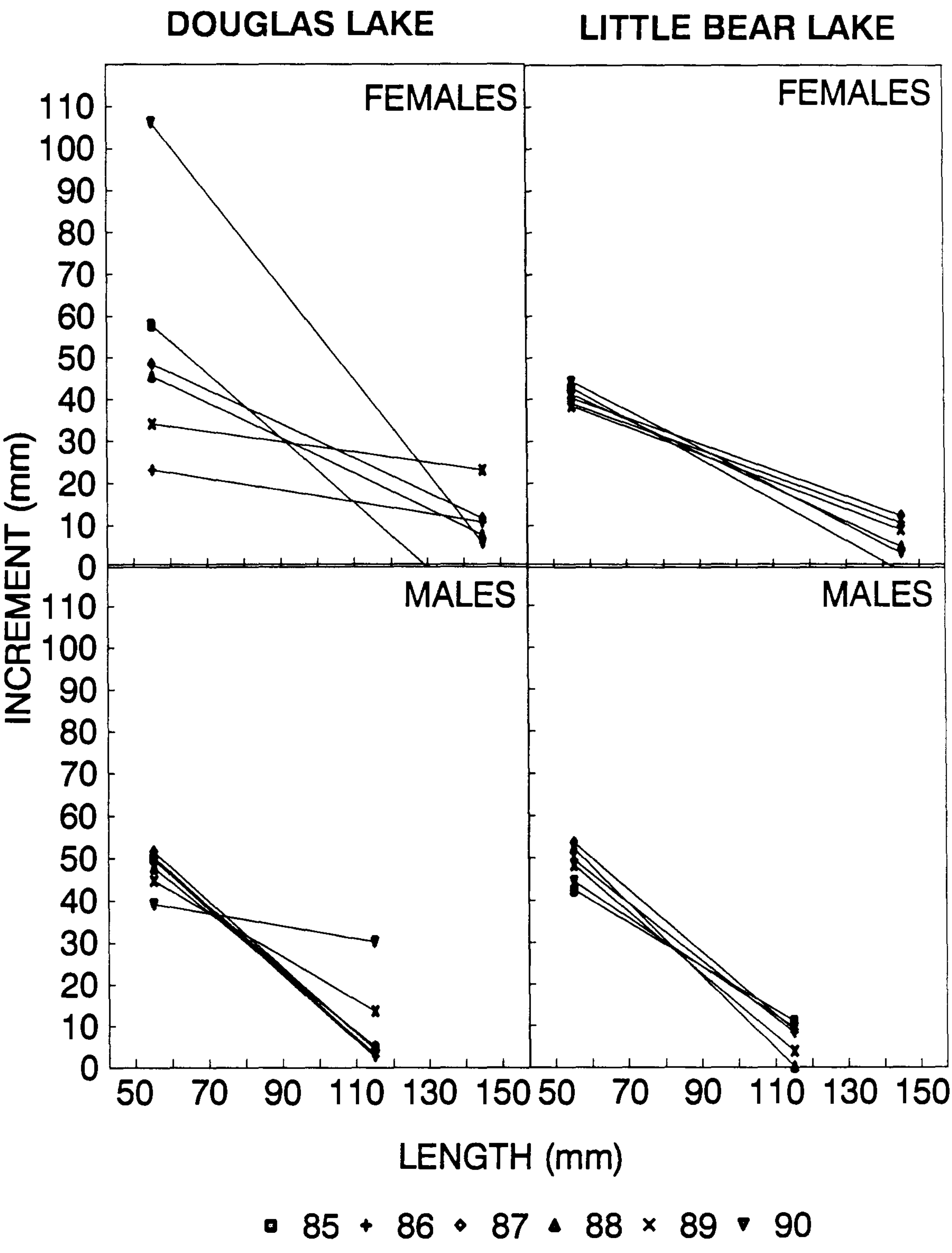

Figure 16. Comparison of growth increments as a function of yellow perch length, sex and year in Douglas Lake and Little Bear Lake.

gill nets differed significantly between the pre-treatment and post-treatment periods in Douglas Lake ($p<0.05$, Kolmogorov-Smirnov test). Differences between the length frequency distributions for each time period were small (Figure 17), and were due more to an increase in variance over time rather than changes in the mean (Table 12). There was, however, a detectable increase in the number of fish above the size (95-145 mm) initially prevalent in Douglas Lake.

Fecundity

Age 2 female yellow perch showed no trend in fecundity over time (Table 13). While sample sizes were small for age 3 to age 6 yellow perch, there appears to be a trend of increasing fecundity for each age class over time. For age 3, 4 and 6 yellow perch, the highest mean fecundity was observed during 1990. For age 5 yellow perch, the highest mean fecundity occurred in 1989 (Table 13).

Benthic invertebrates

Chironomid larvae, *Caenis* and *Chaoborus* larvae were the predominant benthic invertebrates collected in Douglas Lake (Table 14). All taxa except *Chaoborus* (larvae and pupae) and Hydracarina showed significant increases from the pre-treatment period to the post-treatment period in Douglas Lake (Table 15). The ratio of abundance in 1985 to 1989 ranged from 0.5 for *Chaoborus* pupae to 33.0 for amphipods. For *Caenis*, chironomid larvae and chironomid pupae, which

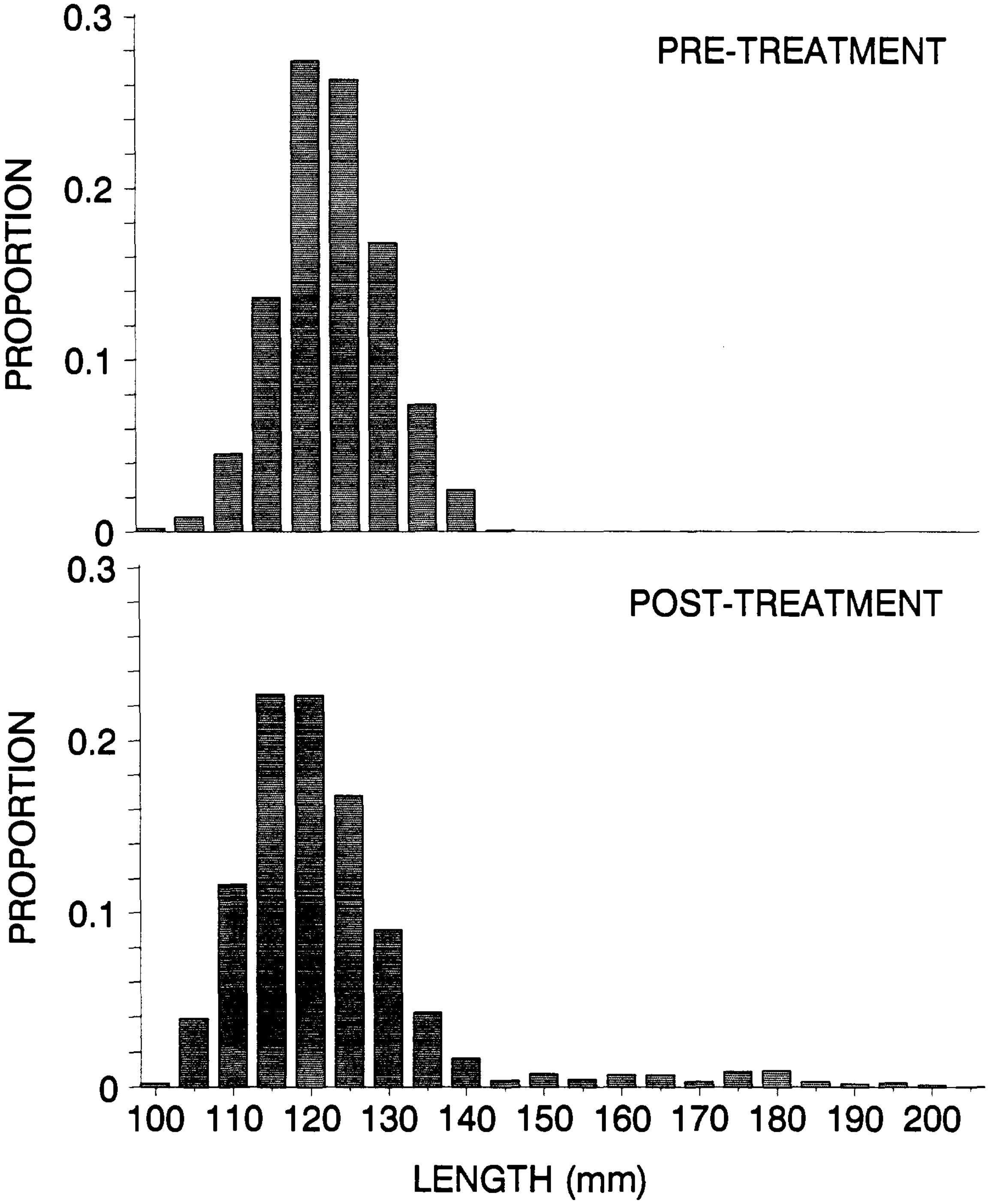

Figure 17. Length frequency distribution of adult yellow perch in Douglas Lake.

Table 12. Mean length (mm) and weight (g) of adult yellow perch in Douglas Lake.

	Year				
	1985	1986	1987	1988	1989
Length	121.6	124.6	120.9	120.7	124.1
Variance	48.4	46.3	57.8	117.0	410.4
S.E.	0.3	0.3	0.4	0.5	0.9
n	743	644	393	405	472
	1985	1986	1987	1988	1989
Weight	15.4	15.0	14.2	14.7	19.8
Variance	21.7	22.5	27.0	61.0	245.5
S.E.	0.2	0.2	0.3	0.4	0.7
n	743	644	393	405	472

Table 13. Age-specific fecundity of female yellow perch sampled in the spring in Douglas Lake, 1985-1990.

		Year					
		1985	1986	1987	1988	1989	1990
Age 1	mean	-----	-----	-----	-----	-----	-----
	S.E.	-----	-----	-----	-----	-----	-----
	n	0	0	0	0	0	0
Age 2	mean	1920	-----	2060	1713	2011	-----
	S.E.	329	-----	127	110	114	-----
	n	5	0	6	12	10	0
Age 3	mean	2994	3112	----	1947	4183	7748
	S.E.	746	486	----	146	606	628
	n	5	7	0	8	12	9
Age 4	mean	-----	3580	4859	3671	5531	6560
	S.E.	----	234	----	559	458	-----
	n	1	11	1	16	10	1
Age 5	mean	-----	4245	4729	3838	6773	-----
	S.E.	-----	242	1340	----	1982	-----
	n	0	16	3	1	5	0
Age 6	mean	-----	-----	6886	12840	2433	27450
	S.E.	-----	-----	1636	-----	-----	-----
	n	0	0	4	1	1	1

Table 14. Mean count of benthic invertebrates in Ekman dredge samples taken from Douglas Lake. The first line for each taxon is the mean, and the second line is the standard error.

Taxon	Year 1985	1986	1987	1988	1989
Chironomid larvae	4.4	6.0	7.7	22.5	61.2
	1.1	2.2	2.3	4.0	17.3
Chironomid pupae	0.2	0.1	0.2	0.3	2.0
	0.1	0.1	0.1	0.1	0.7
Chaoborus larvae	2.3	6.6	3.3	4.0	11.4
	0.8	2.0	1.7	1.2	3.2
Chaoborus pupae	0.4	0.0	0.4	0.1	0.2
	0.2	0.0	0.3	0.1	0.1
Ceratopogodid larvae	0.0	0.1	0.4	1.0	8.8
	0.0	0.1	0.3	0.3	3.9
Ceratopogodid pupae	0.0	0.0	0.0	0.1	0.9
	0.0	0.0	0.0	0.0	0.3
Caenis	1.6	0.6	1.1	14.6	29.7
	0.7	0.3	0.6	4.0	6.5
Hexagenia	0.0	0.2	0.2	0.3	0.6
	0.0	0.1	0.2	0.2	0.2
Trichoptera	0.0	0.1	0.1	0.3	0.9
	0.0	0.1	0.1	0.2	0.6
Odonata	0.0	0.0	0.0	0.2	0.5
	0.0	0.0	0.0	0.1	0.2
Hydracarina	0.1	0.0	0.0	0.1	0.2
	0.1	0.0	0.0	0.1	0.1
Amphipoda	0.2	0.8	1.0	1.6	6.6
	0.1	0.7	0.9	1.3	2.5
Oligochaeta	0.1	0.4	0.5	0.7	2.5
	0.1	0.3	0.3	0.2	0.7

Table 15. Results of tests (ANOVA on log(x+1)transformed data) comparing differences in abundance of benthic invertebrates between pre-treatment and post-treatment time periods, and Douglas Lake and Little Bear Lake.

	pre vs post		DG vs LB				
	DG	LB	1985	1986	1987	1988	1989
Chironomid larvae	--	--	o	o	o	o	++
Chironomid pupae	--	--	o	o	o	o	+
Chaoborus larvae	o	o	o	o	o	o	++
Chaoborus pupae	o	o	o	o	o	o	+
Oligochaeta	--	-	o	o	o	+	++
Caenis	--	-	++	++	++	++	++
Hexagenia	--	o	o	o	o	o	++
Ceratopogodid larvae	--	-	none	o	o	o	++
Ceratopogodid pupae	--	o	none	none	none	o	++
Amphipoda	--	-	+	+	o	o	++
Odonata	--	-	o	none	o	o	++
Trichoptera	--	o	none	o	o	+	+
Hydracarina	o	o	o	none	o	o	+

o No difference $p>0.05$
- Pre-treatment<Post-treatment <u>or</u> Douglas<Little Bear $p<0.05$
-- Pre-treatment<Post-treatment <u>or</u> Douglas<Little Bear $p<0.01$
+ Pre-treatment>Post-treatment <u>or</u> Douglas>Little Bear $p<0.05$
++ Pre-treatment>Post-treatment <u>or</u> Douglas>Little Bear $p<0.01$

Table 16. Ratio of abundance of benthic invertebrates in Douglas Lake comparing 1989 to 1985.

	1985	1989	Ratio of 1985 to 1989
Chironomid larvae	4.4	61.2	13.9
Chironomid pupae	0.2	2.0	10.0
Chaoborus larvae	2.3	11.4	5.0
Chaoborus pupae	0.4	0.2	0.5
Ceratopogodid larvae	0.0	8.8	---
Ceratopogodid pupae	0.0	0.9	---
Caenis	1.6	29.7	18.6
Hexagenia	0.0	0.6	---
Trichoptera	0.0	0.9	---
Odonata	0.0	0.5	---
Hydracarina	0.1	0.2	2.0
Amphipoda	0.2	6.6	33.0
Oligochaeta	0.1	2.5	25.0

were important components of yellow perch and white sucker diet, the ratio of abundance from 1985 to 1989 was 18.6, 13.9 and 10.0 respectively (Table 16).

Zooplankton

Rotifers were numerically the most abundant group in the zooplankton in Douglas Lake, with mean annual densities ranging from 22.0 to 180.9 individuals per liter (Table 17). Among the rotifers, *Keratella*, *Kellicottia*, and *Polyarthra* were the dominant genera in Douglas Lake. Estimates of their abundance were variable, and only *Kellicottia* showed a significant difference between years ($p<0.05$, ANOVA).

In most years *Bosmina* was the most abundant cladoceran, averaging 3.3 to 47.9 individuals per liter (Table 17). There were no significant differences between years, however, due to the high variance of estimates. *Daphnia* was generally the next most abundant cladoceran, averaging 1.0 to 6.4 individuals per liter. Significant differences between years ($p<0.05$) were observed along with a decreasing trend in *Daphnia* abundance. *Diaphanosoma* and *Chydorus* were found at densities between 0.3 to 2.8 per liter, with no significant difference in annual mean abundance between years. Other cladocerans were generally low in abundance (<1.0 individuals per liter) and showed no significant differences in abundance between years (Table 17). As a whole, the abundance of cladocerans declined over time, however, differences between years were not

Table 17. Annual mean zooplankton density (number/liter) in Douglas Lake, 1985-1989.

	1985		1986		1987		1988		1989	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Keratella	8.1	1.8	3.6	1.3	11.5	1.8	18.3	6.1	9.1	2.1
Kellicottia	172.5	91.2	4.3	1.6	69.8	13.5	30.9	4.2	1.0	0.7
Polyarthra	0.1	0.1	6.2	1.7	40.4	14.5	24.9	9.5	6.3	1.7
Synchaeta	0.0	0.0	0.3	0.3	0.3	0.1	0.1	0.1	4.2	1.6
ROTIFERS	180.9	90.8	14.5	2.7	122.4	27.9	76.6	12.9	22.0	3.9
Daphnia	5.8	2.7	4.5	1.0	6.4	1.7	3.8	0.5	1.0	0.2
Bosmina	47.9	16.7	17.5	6.6	5.1	1.3	18.5	3.0	3.3	0.8
Ceriodaphnia	0.2	0.1	0.3	0.2	1.5	0.7	0.1	0.0	0.2	0.2
Diaphanosoma	1.7	1.1	1.8	0.4	0.8	0.2	1.9	0.8	1.3	0.3
Holopedium	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.0	0.2	0.2
Chydorus	1.3	0.6	1.2	0.5	2.8	2.3	1.3	0.5	0.3	0.1
CLADOCERANS	57.0	17.1	25.3	6.3	16.8	3.6	25.7	3.3	6.3	0.9
Diaptomus	25.6	3.4	33.1	7.0	14.2	2.8	2.6	0.8	7.8	7.2
Tropocyclops	21.8	4.9	7.6	1.2	15.8	4.7	20.7	2.3	8.7	2.4
Diacyclops	11.2	2.2	2.2	0.4	2.7	0.5	4.3	2.0	1.0	0.2
nauplii	28.4	3.0	25.2	2.4	18.8	1.7	19.0	3.4	13.8	3.8
COPEPODS	87.0	6.3	68.1	8.2	51.4	5.7	46.6	5.8	31.2	8.3

significant.

After rotifers, copepods were the most numerous group in the zooplankton community (Table 17). Over the course of the study, there was a significant decline ($p<0.05$, ANOVA) in the abundance of copepods in Douglas Lake. Diaptomus, Diacyclops, Tropocyclops and nauplii all contributed substantially to the abundance of copepods, with no single taxon clearly being dominant across the entire study.

Little Bear Lake

Sucker abundance

Peak density of larval white suckers was highly variable in Little Bear Lake, ranging from 0 during 1989 to 5.89 fish$\cdot$m^{-3} in 1986 (Table 18). No significant difference ($p>0.05$) was observed from the pre-treatment to the post-treatment period[1]. Catch rates of age-0 white suckers in seine hauls also varied greatly between years, but there was a significant decrease from the pre-treatment period to the post-treatment time period ($p<0.05$, linear contrast test). This difference was mainly due to the very high catch rates observed in 1986 (Table 18).

The catch rate of adult suckers was low throughout the study (Table 18). In Little Bear Lake, the relative abundance of adult white suckers was not significantly different between pre-treatment and post-treatment periods,

[1] The terms pre-treatment and post-treatment are used here only to denote periods of time (1985-1986 and 1987-1989 respectively) and do not imply that Little Bear Lake was subjected to sucker removal as was Douglas Lake.

Table 18. Catch per effort of white sucker in Little Bear Lake, 1985-1989. The number of ichthyoplankton trawls per date, and the number of seine hauls or gill net sets is denoted by n.

Peak larval density (number·m^{-3})

	1985	1986	1987	1988	1989
mean	0.070	5.890	0.010	0.113	0.000
n	9	9	9	9	9
S.E.	0.050	5.552	0.008	0.027	0.000

Number of age-0 fish per standard seine haul in August

	1985	1986	1987	1988	1989
mean	0.23	2.80	0.43	23.63	2.52
n	35	35	14	21	21
S.E.	0.18	1.28	0.24	11.27	2.04

Number of adult fish per 3-hr gill net set

	1985	1986	1987	1988	1989
mean	0.03	0.04	0.01	0.07	0.07
n	64	64	64	64	64
S.E.	0.03	0.03	0.01	0.04	0.04

although significant differences ($p<0.05$, ANOVA) were observed between some years within each of these time periods.

The size distribution of adult white suckers was similar during 1985 and 1986, but showed a significant increase in the proportion of larger fish ($p<0.05$, Kolmogorov-Smirnov test) during 1987-1989 (Figure 18).

White sucker diet

Due to the low number of age-0 white suckers caught, diet data were grouped for both Douglas Lake and Little Bear Lake. These results are presented in the section for Douglas Lake (see Figure 4).

Chironomid larvae and pupae and chydorid cladocerans were the predominant taxa in the diet of adult suckers from Little Bear Lake (Tables 19 and 20). Chironomids (larvae and pupae) comprised most of the diet by weight, accounting for 85% to 95% of the diet of adult white suckers. Unlike Douglas Lake, Caenis was rare in the diet of adult suckers from Little Bear Lake, comprising less than 1% of their diet. In Little Bear Lake, no significant differences were observed in the diet of adult white suckers between the pre- and post-treatment periods.

Relative consumption rates and predation pressure

The relative consumption rate of chironomid larvae showed an increasing trend in Little Bear Lake due to increases in sucker relative abundance (Table 21). During 1988 and 1989, the predation pressure on chironomid larvae

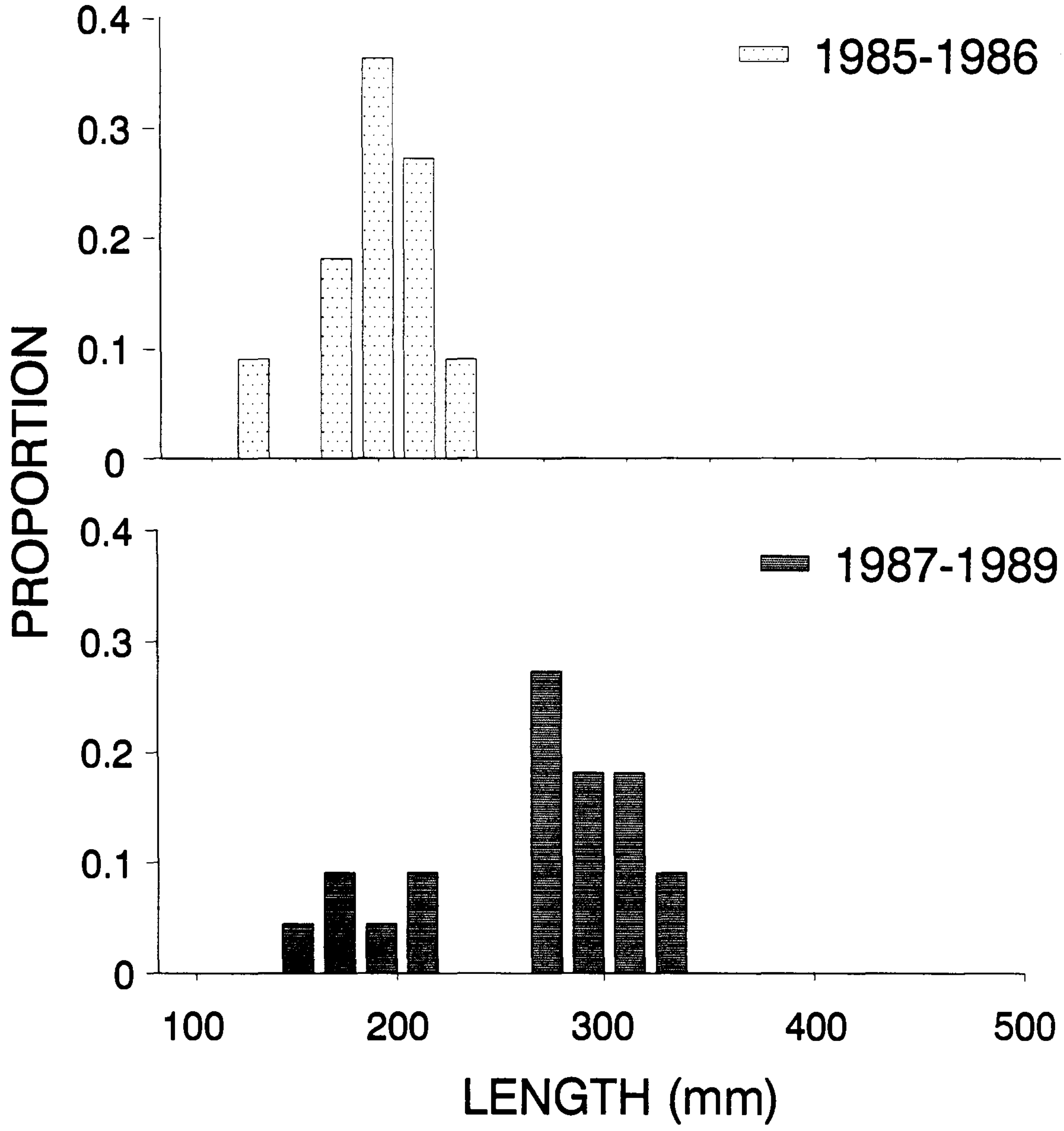

Figure 18. Length frequency distribution of adult white suckers in Little BearLake

Table 19. Diet composition of adult white sucker in Little Bear Lake. The mean number of each item per gut is indicated on the first line and the second line is the standard error of the mean. The significance of differences between pre-treatment and post-treatment periods and between years are indicated in the columns marked Treat and Year.

			Year				
Taxon	Treat	Year	1985	1986	1987	1988	1989
Chironomid larvae	o	o	409	377	-	1851	927
			119	143	-	975	421
Chironomid pupae	o	x	0	0	-	19	30
			0	0	-	14	18
Caenis	o	o	1	0	-	0	0
			1	0	-	0	0
Trichoptera	none		0	0	-	0	0
			0	0	-	0	0
Sididae	o	o	17	41	-	11	341
			18	21	-	9	258
Bosmina	o	o	0	4252	-	0	2473
			0	4474	-	0	2576
Macrothricid	none		0	0	-	0	0
			0	0	-	0	0
Chydoridae	o	xx	1462	909	-	41	1679
			603	445	-	22	1064
Harpacticoidae	o	o	0	0	-	1	0
			0	0	-	1	0
Cyclopoidae	o	xx	433	120	-	32	743
			169	80	-	15	765
Ostracoda	o	x	0	0	-	27	135
			0	0	-	19	74
Gastropoda	none		0	0	-	0	0
			0	0	-	0	0
Others	o	o	71	136	-	64	59
			37	65	-	63	52
Sample size			13	10	0	11	12

o= $p>0.05$
x= $p<0.05$
xx= $p<0.01$

Table 20. Weight contribution of prey items to the diet of suckers in Little Bear Lake. The estimated mean dry weight (grams) per gut for each item is indicated on the first line and the percent of the total is indicated on the second line. tr indicates less than 0.001 g dry weight contribution for that taxon.

	Year					Grand
	1985	1986	1987	1988	1989	mean
Chironomid larvae	0.120	0.099	-	0.495	0.198	0.238
	92.6	86.1	-	95.9	76.5	87.8
Chironomid pupae	0.000	0.000	-	0.020	0.031	0.013
	0.0	0.0	-	3.9	12.1	4.0
Caenis	tr	tr	-	0.000	0.000	tr
	0.0	0.0	-	0.0	0.0	0.0
Sididae	tr	tr	-	tr	0.002	tr
	0.0	0.0	-	0.0	0.7	0.2
Bosmina	0.000	0.005	-	0.000	0.003	0.002
	0.0	4.1	-	0.0	1.1	1.3
Macrothricidae	0.000	0.000	-	0.000	0.000	0.000
	0.0	0.0	-	0.0	0.0	0.0
Chydoridae	0.006	0.010	-	0.001	0.021	0.010
(large genera)	4.3	8.9	-	0.2	8.1	5.4
Chydoridae	0.002	tr	-	0.000	tr	tr
(small genera)	1.7	0.0	-	0.0	0.0	0.5
Harpacticoidae	0.000	0.000	-	0.000	tr	tr
	0.0	0.0	-	0.0	0.0	0.0
Cyclopoidae	0.001	tr	-	tr	0.004	0.001
	0.7	0.0	-	0.0	1.5	0.6

Table 21. Relative consumption rate of adult white suckers in Little Bear Lake for predominant prey items.

		Year				
Prey item		1985	1986	1987	1988	1989
Chironomid larvae	Adult Sucker CPE	0.03	0.04	-	0.07	0.07
	Mean number per gut	891	891	-	891	891
	Product	26.7	35.6	-	62.4	62.4
	Proportion of 1985	1	1.33	-	2.34	2.34
Chironomid pupae	Adult Sucker CPE	0.03	0.04	-	0.07	0.07
	Mean number per gut	0	0	-	19	30
	Product	0	0	-	1.33	2.1
	Proportion of 1985	-	-	-	-	-
Caenis	Adult Sucker CPE	0.03	0.04	-	0.07	0.07
	Mean number per gut	1	0	-	0	0
	Product	0.03	0	-	0	0
	Proportion of 1985	1	0	-	0	0
Chydoridae	Adult Sucker Cpe	0.03	0.04	-	0.07	0.07
	Mean number per gut	1462	909	-	41	1679
	Product	43.9	36.4	-	2.9	117.5
	Proportion of 1985	1	0.83	-	0.07	2.68

was approximately twice the value during 1985. The relative predation pressure on chydorid cladocerans varied greatly during the course of the study, however no trend was apparent (Table 21). Chironomid pupae and Caenis were not consumed frequently enough by adult suckers in Little Bear Lake to make any determination of the relative predation pressure on these taxa.

Yellow perch abundance

As in Douglas Lake, larval yellow perch in Little Bear Lake were much more abundant than larval white suckers. Peak larval yellow perch density varied widely between years in Little Bear Lake, ranging from 0.20 fish per meter^3 in 1985 to 8.46 fish per meter^3 in 1988 (Table 22). No trend over time was observed, and there was no significant difference ($p>0.05$, linear contrast test) in larval yellow perch density between the pre-treatment and post-treatment periods.

Catch rates of age-0 yellow perch in seine hauls in August showed even greater variability, ranging from an average of 1.14 fish per haul in 1987 to 120.53 fish per haul in 1986 (Table 22). High catch rates (greater than 100 age-0 yellow perch per seine haul) were observed during both 1985 and 1986 in Little Bear Lake. From 1987 to 1989, catch rates were significantly lower ($p<0.01$, linear contrast test), averaging less than 12 fish per seine haul during all three post-treatment years.

Catch rates of adult yellow perch in gill nets were

Table 22. Catch per effort of yellow perch in Little Bear Lake, 1985-1989. The number of ichthyoplankton trawls per date, and the number of seine hauls or gill net sets is denoted by n, the standard error of the mean by S.E.

Peak larval density (number·m^{-3})

	1985	1986	1987	1988	1989
mean	0.20	1.32	0.91	8.46	0.53
n	9	9	9	9	9
S.E.	0.08	0.43	0.20	3.41	0.28

Number of age-0 fish per standard seine haul in August

	1985	1986	1987	1988	1989
mean	109.88	120.53	1.14	11.12	11.14
n	40	41	18	27	27
S.E.	22.77	23.27	0.58	3.36	8.33

Number of adult fish per 3-hr gill net set

	1985	1986	1987	1988	1989
mean	13.08	8.60	5.12	8.29	5.86
n	64	64	64	64	64
S.E.	2.77	2.12	1.50	1.50	1.41

highest in the first year of the study (1985) when they averaged 13.08 fish per net set (Table 22). After 1985, catch rates declined significantly ($p<0.05$, linear contrast test) and fluctuated between 5 and 9 fish per net set.

Adult yellow perch distribution

Catch rates of adult yellow perch were highest on the 8-meter contour during all years in Little Bear Lake, with over 92% of the catch occurring at this depth (Table 23). No trends were observed in the proportion of catch occurring on each depth contour over time, although significant differences between years were observed ($X^2=62.1$, 8 d.f., $p<0.01$). No trend was apparent in the vertical distribution of adult yellow perch on the 8-meter contour catch over time and differences between years were not significant ($D=.1265$, $p>0.05$, Kolmogorov-Smirnov test). Catch rates of adult yellow perch were highest within one meter of the bottom (Figure 19), however, over 50% of the catch on the 8-meter contour occurred throughout the rest of the water column.

Survival rate of adult yellow perch

Catch curves showed no differences between the pre-treatment period and post-treatment period in Little Bear Lake (Kolmogorov-Smirnov test, $p>0.05$). A general schedule of age-specific survival rates for age 3 to age 7 perch was thus computed from data grouped over all years (Table 24). The shape of the catch curve for Douglas Lake and Little Bear Lake suggests that survival rate was not constant for all ages of adult yellow perch, decreasing abruptly beyond beyond age 5 (Figure 6).

Table 23. Horizontal distribution of catch of adult yellow perch in Little Bear Lake, 1985-1989.

	Percent of catch by contour		
Year	2-meter	4-meter	8-meter
1985	2.7	3.6	93.7
1986	1.2	3.3	95.5
1987	1.5	2.2	96.3
1988	3.5	4.5	92.0
1989	1.7	3.4	94.9

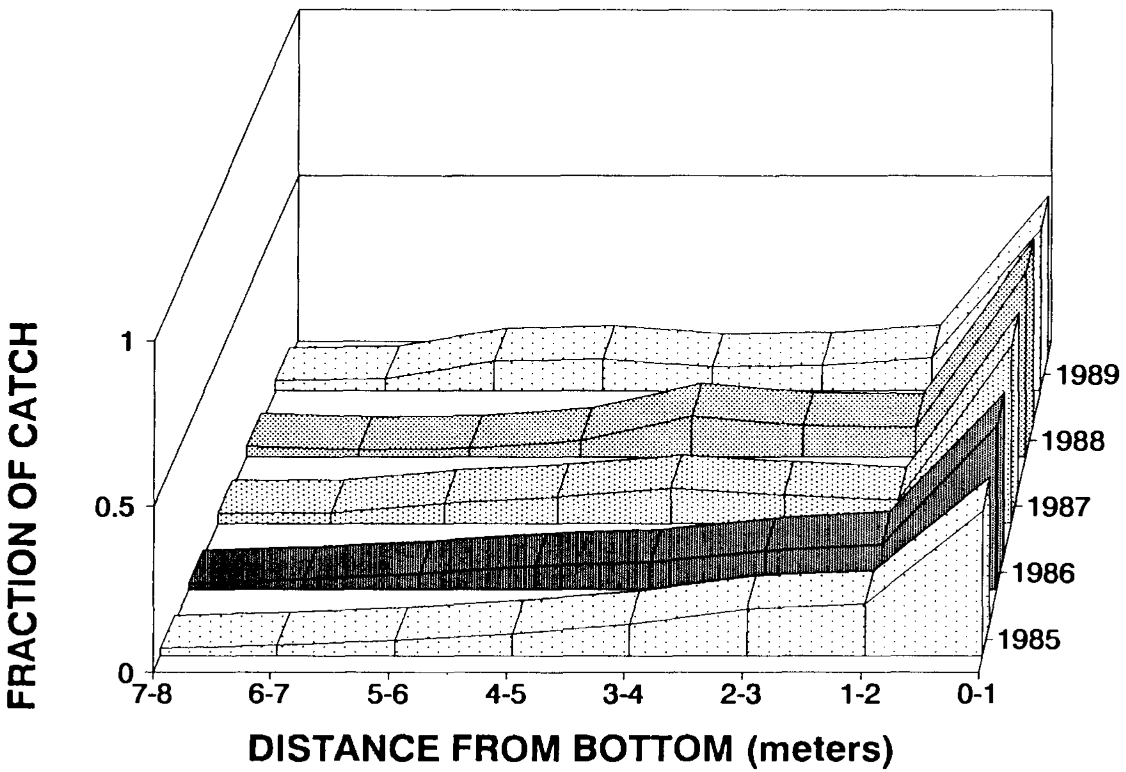

Figure 19. Vertical distribution of adult yellow perch on the 8-meter contourin Little Bear Lake, 1985-1989.

Table 24. Age-specific annual survival rate of adult yellow perch from Little Bear Lake 1985-1990. Only those age-classes fully recruited to the sampling gear used are included.

Age	Annual Survival Rate
3	52%
4	79%
5	19%
6	7%

Yellow perch diet

During the pre-treatment period, zooplankton comprised 75% to 100% of the diet by numbers of age-0 yellow perch in Little Bear Lake (Figure 20). After entering the 25 mm size class, benthic crustaceans increased in the diet, comprising up to 22% of the diet by numbers. Benthic insects were consumed in low numbers by all size classes of age-0 yellow perch during the pre-treatment period. During the post-treatment period, zooplankton was the predominant item in the diet of fish in the smallest size classes (5-45 mm), but the contribution of benthic crustaceans increased after yellow perch entered the 35 mm size class (Figure 20). During the post-treatment period, only yellow perch in the 45 to 65 mm size classes were observed to feed on benthic insects (Figure 20). Significant changes in the consumption of each of the major prey groups were observed from the pre-treatment period to the post-treatment period ($p<0.01$, randomized block ANOVA). Zooplankton showed an overall decrease in consumption, whereas for most size classes the consumption of benthic crustaceans and insects increased (Appendix A, Table 43).

In Little Bear Lake, no trends in adult yellow perch diet were apparent, however large differences between years were observed. Numerically, zooplankton were the predominant item in the diet on most sampling dates (Figure 21), and contributed between 20 and 70% of the diet by weight on an annual basis (Figure 22).

Benthic invertebrates were consumed on all sampling

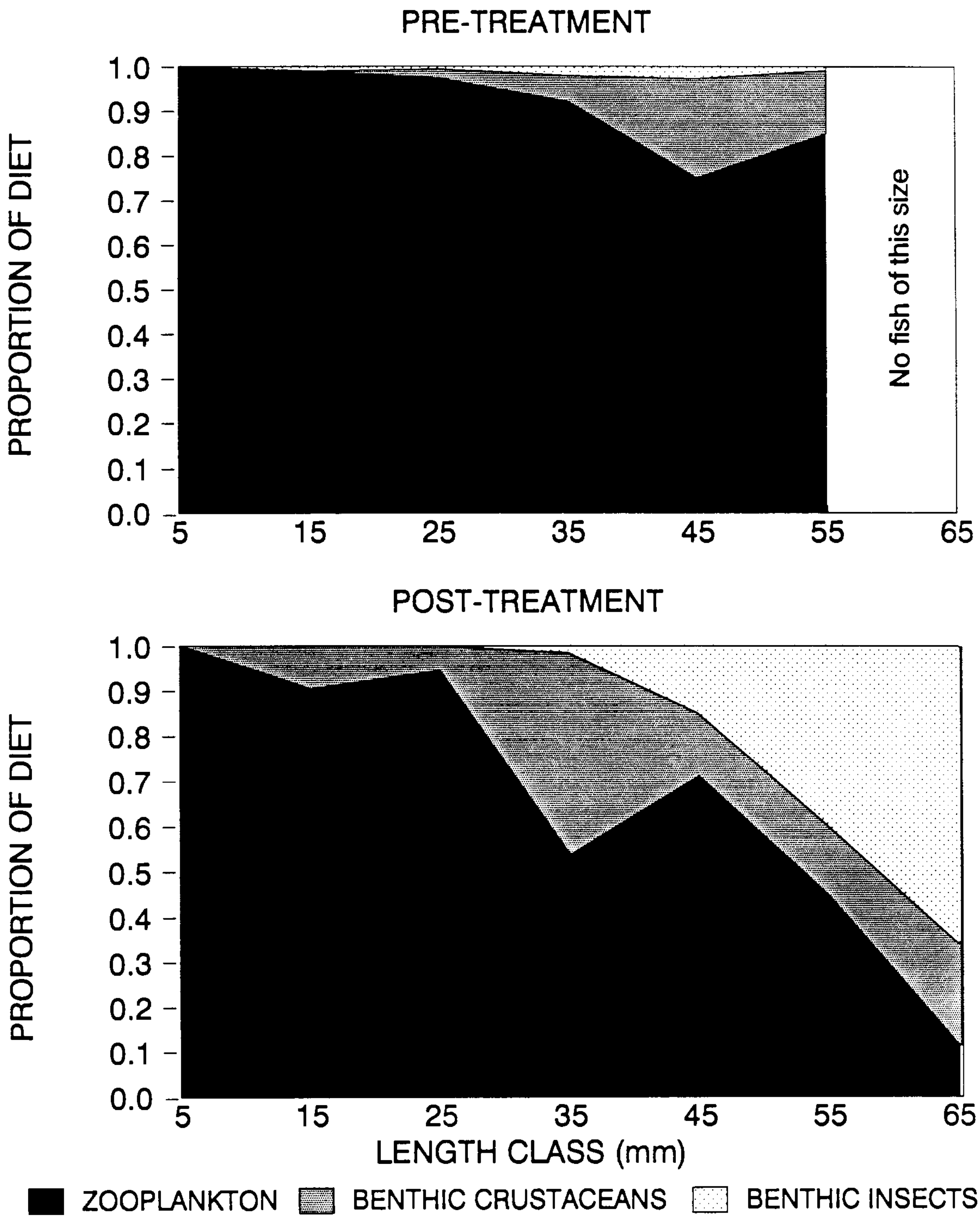

Figure 20. Diet composition (by numbers) of age-0 yellow perch in Little Bear Lake, 1985-1989.

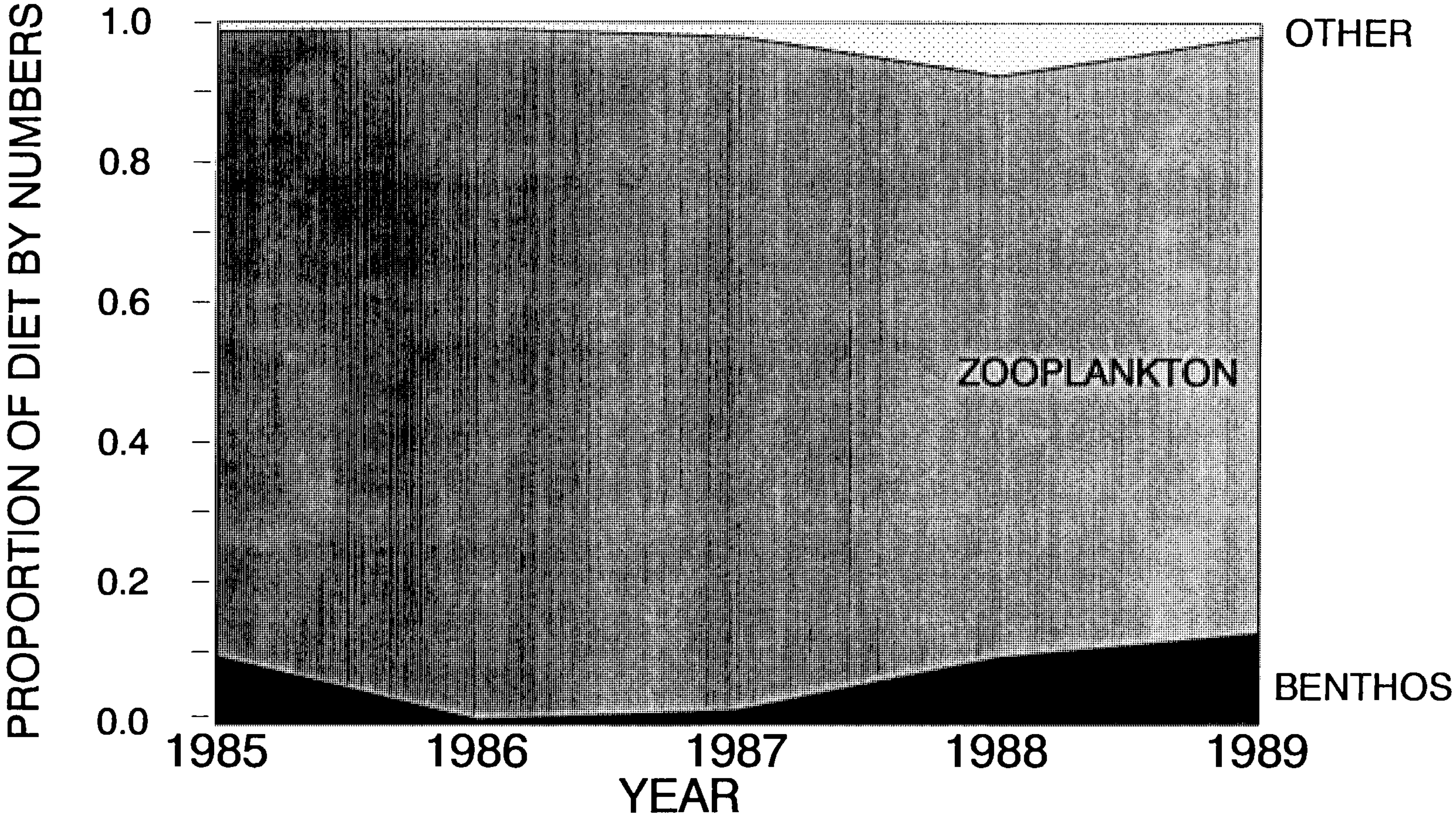

Figure 21. Diet composition (by numbers) of adult yellow perch (100-145 mm) in Little Bear Lake, 1985-1989.

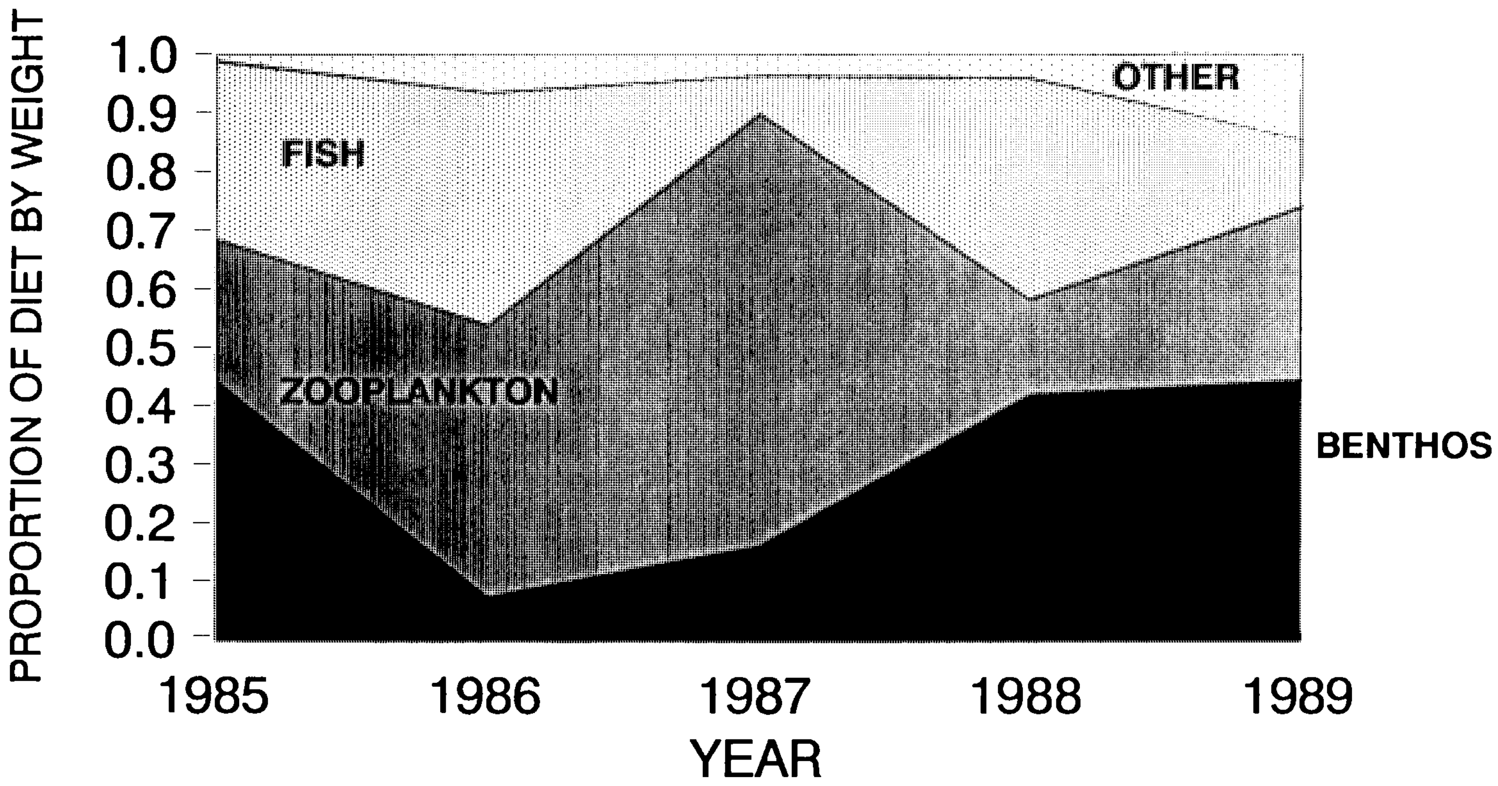

Figure 22. Diet composition (by weight) of adult yellow perch (100-145 mm), in Little Bear Lake, 1985-1989.

dates in Little Bear and formed 10 to 45% of the diet by weight annually (Figure 22). Fish contributed a small proportion of the diet numerically, but by weight constituted a substantial amount (up to 40%) to the diet each year (Figure 22).

Yellow perch relative predation pressure

Relative predation pressure on chironomid larvae, chironomid pupae and chydorid cladocerans was higher from 1986-1989 than during 1985, with peak predation on these taxa occurring in 1988 (Table 25). Predation pressure on *Caenis* was also highest in 1988, but in all other years was at or below levels estimated for 1985 (Table 25).

Adult yellow perch gut fullness

During the pre-treatment period, gut fullness did not differ between male (mean=0.703, S.E.=0.021, n=365) and female yellow perch (mean=0.707, S.E.=0.024, n=362) for fish in the most commonly sampled size classes (105-135 mm). Fish in these size classes also showed no relationship between gut fullness and length. Yellow perch in the smallest and largest size classes, however, had gut fullness equal to or greater than fish in the intermediate size classes (Figure 10). For male yellow perch, gut fullness was similar to the pre-treatment period during the post-treatment period (Figure 10) for some size classes, however the mean for perch in the 105-135 mm size range was significantly higher (mean=0.857, S.E.=0.058, n=193). Gut

Table 25. Relative consumption rate of adult yellow perch in Little Bear Lake for predominant benthic prey items.

Prey item		1985	1986	1987	1988	1989
		Year				
Chironomid larvae	Adult Perch CPE	13.08	8.60	5.12	8.29	5.86
	Mean number per gut	0.015	0.153	0.476	1.382	0.359
	Product	0.20	1.32	2.47	11.46	2.11
	Proportion of 1985	1	6.61	12.22	57.43	10.55
Chironomid pupae	Adult Perch CPE	13.08	8.60	5.12	8.29	5.86
	Mean number per gut	0.029	0.153	0.238	0.952	0.104
	Product	0.38	1.32	1.22	7.89	0.61
	Proportion of 1985	1	3.44	3.18	20.63	1.60
Caenis	Adult Perch CPE	13.08	8.60	5.12	8.29	5.86
	Mean number per gut	0.005	0.007	0.008	0.032	0.008
	Product	0.065	0.060	0.041	0.265	0.047
	Proportion of 1985	1	0.92	0.63	4.08	0.72
Chydoridae	Adult Perch Cpe	13.08	8.60	5.12	8.29	5.86
	Mean number per gut	0.007	0.055	0.198	1.833	0.085
	Product	0.092	0.473	1.014	15.196	0.498
	Proportion of 1985	1	5.14	11.02	165.17	5.41

content weight for female yellow perch was higher for all size classes except the smallest and largest during the post-treatment period compared to the pre-treatment period (Figure 10). The mean for female yellow perch during the post-treatment period (mean=0.990, S.E.=0.053, n=271) was significantly higher than the pre-treatment period, and than males during the post-treatment period.

Feeding rate of adult yellow perch

Throughout the entire study, the feeding rate of adult yellow perch in Little Bear Lake was low, ranging from 0.716% of body weight per day to 2.538% of body weight per day (Figure 23). In all years, lowest feeding rates occurred during mid-May and late August-early September. Feeding rate during June showed an increase from the pre-treatment to the post-treatment period. Feeding rate estimates during the post-tretment period for other months were within the range of pre-treatment values.

Yellow perch growth

In Little Bear Lake, there were significant difference between years in the growth rate of age-0 yellow perch ($p<0.01$, ANCOVA, Table 26). There was also a significant increase in growth rate from the pre-treatment period to the post-treatment period ($p<0.05$, linear contrast test).

No trend in length at age 2, 3 or 4 was evident for adult yellow perch in Little Bear Lake (Figures 12-14). As in Douglas Lake, graphs of length increment versus length showed a linear relationship for male yellow perch from 50

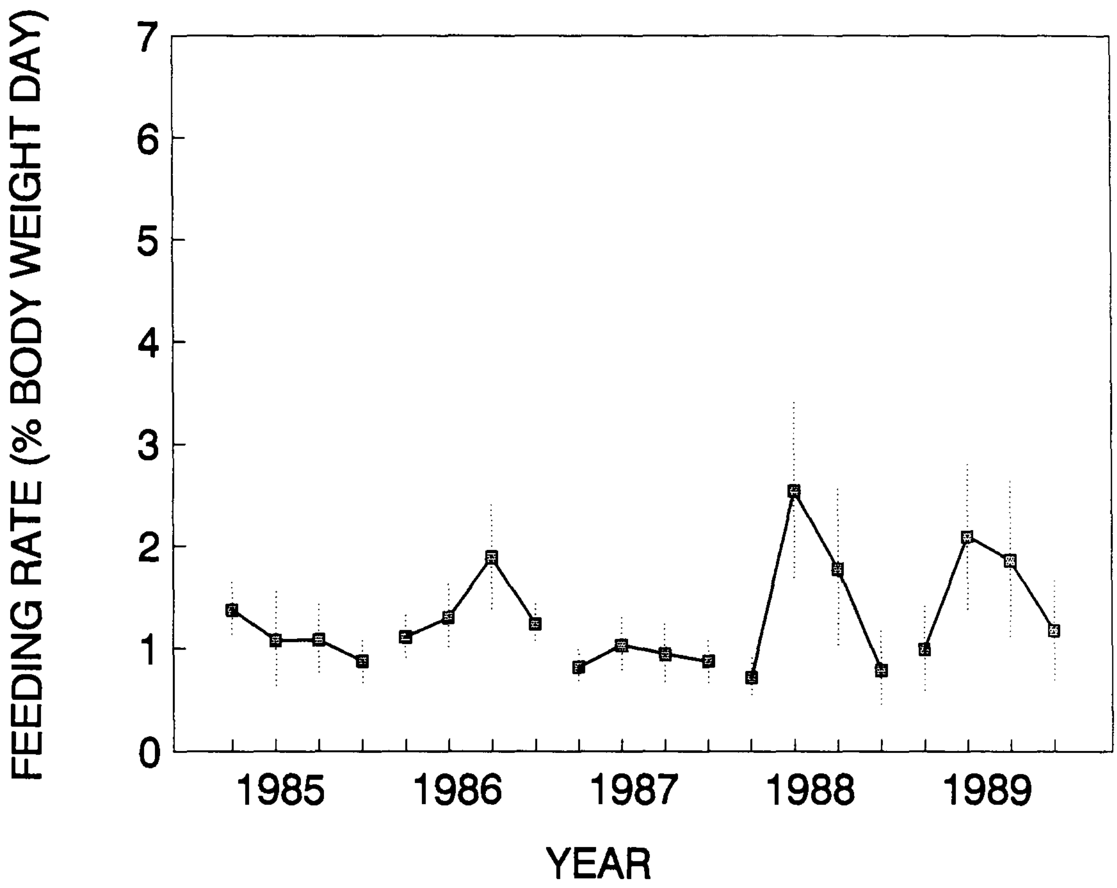

Figure 23. Feeding rate (% body weight per day) of adult yellow perch in Little Bear Lake, 1985-1989.

Table 26. Growth rates (mm/week) of young-of-the-year yellow perch in Little Bear Lake. The sample size (n) indicates the number of weeks used in regressions to estimate growth rate, and S.E. indicates the standard error of growth rate estimates.

	Year				
	1985	1986	1987	1988	1989
growth (mm/week)	2.69	3.12	4.76	4.36	4.00
se	0.12	0.09	0.19	0.21	0.36
n	14	15	10	9	4

to 115 mm and for female perch from 50 to 145 mm (Figure 24). Above these size ranges, length increments were higher (Figure 24) and showed no trend with size.

For male yellow perch 50 to 115 mm, there were no annual differences ($p>0.05$, slope heterogenity test ANCOVA) in the slope of the regression line of increment as a function of fish length. Results of an ANCOVA indicate that there were significant difference ($p<0.01$) between years in length-specific annual increment. There was, however, no trend apparent in the intercept of these regression line over time (Figure 16). For female yellow perch in Little Bear Lake, there were significant differences ($p<0.001$) in the slope of the regression line of length increment on length for fish from 50 to 145 mm. Graphs of these regression lines indicate that there were no trends in length-specific annual length increments (Figure 16).

Growth increments for male yellow perch above 120 mm and female yellow perch above 150 mm showed no relationship to fish length, sex or year ($p>0.05$, ANOVA). Sample size of these "large" yellow perch was low ($n=23$) decreasing the power to determine the effects of fish length, sex and year. Increments for yellow perch in these size classes averaged 15.93 mm (S.E.=1.63) in Little Bear Lake.

Population size structure

The size structure of adult yellow perch showed no significant difference between the pre-treatment period and post-treatment period ($p>0.05$, Kolmogorov-Smirnov test,

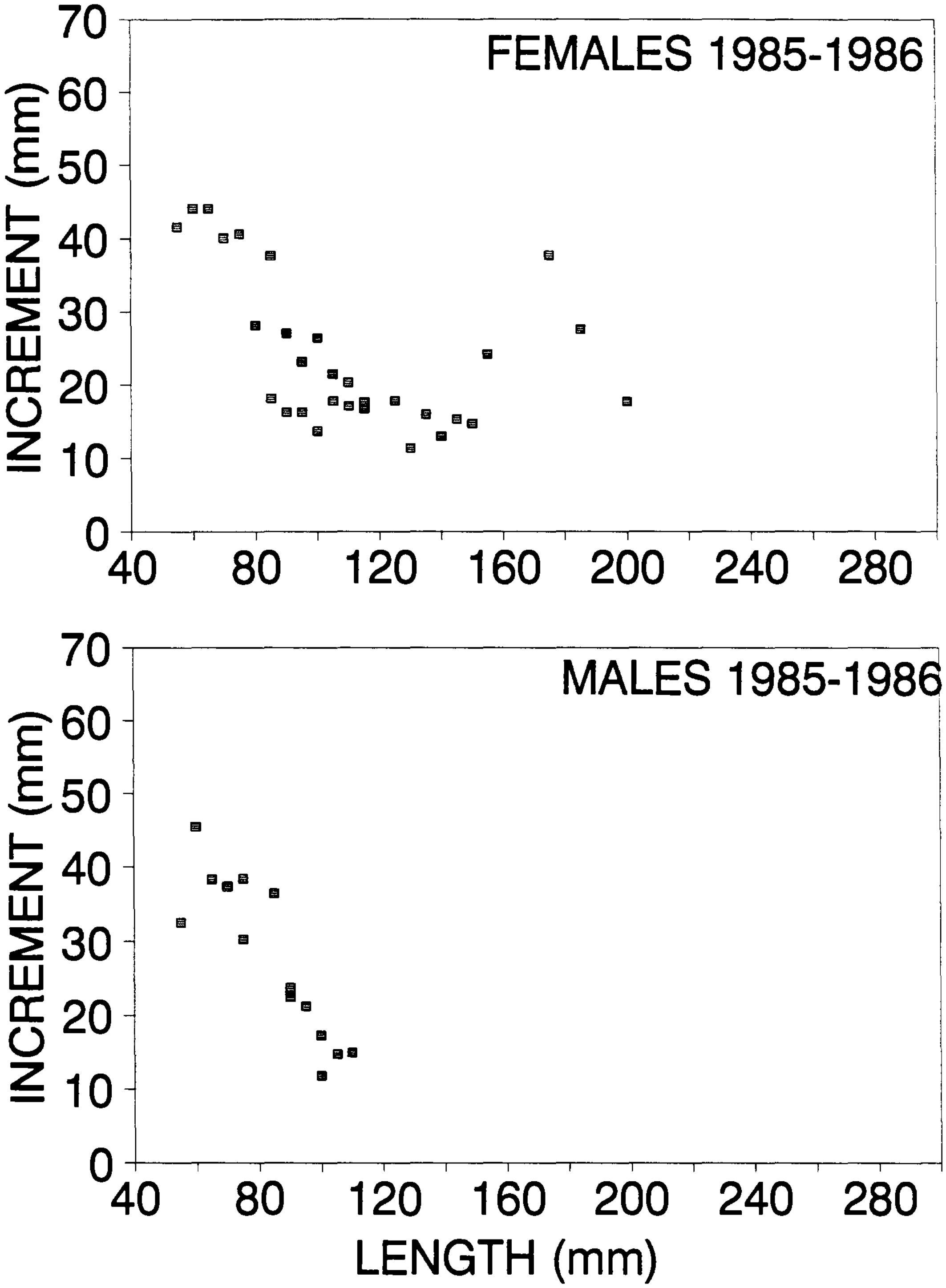

Figure 24. Relationship between length increment and length of yellow perch in Little Bear Lake during the pre-treatment period.

Figure 25). No trends were observed in mean length or weight, although an increase in variance over time was evident (Table 27).

Fecundity

As with growth, the fecundity of yellow perch did not show a trend with time in Little Bear Lake (Table 28). The highest mean fecundity for yellow perch age 2, 4 and 5 occurred in 1988 or 1989, however, these values did not differ significantly from mean fecundity observed for each year during the pre-treatment time period. For age 3 fish, the highest fecundity occurred during 1987, however only one fish in this age class was sampled for fecundity during that year. The next highest mean fecundity occurred in 1985, and as with age 2, 3 and 5 year old yellow perch, the confidence intervals for the mean from this year contained the means of other years.

Benthic invertebrates

Chironomid and Chaoborus larvae were the predominant benthic invertebrates collected in Little Bear Lake. From 1986 through 1988, the abundance of most taxa increased in Little Bear Lake, but abundance in 1989 was similar to that in 1988 (Table 29).

All taxa except Chaoborus pupae, Hydracarina, Hexagenia, ceratopogodid pupae, and trichoptera showed a significant increase ($p<0.05$, linear contrast test) from the pre-treatment period to the post-treatment period. The highest proportion of increase (except for species whose

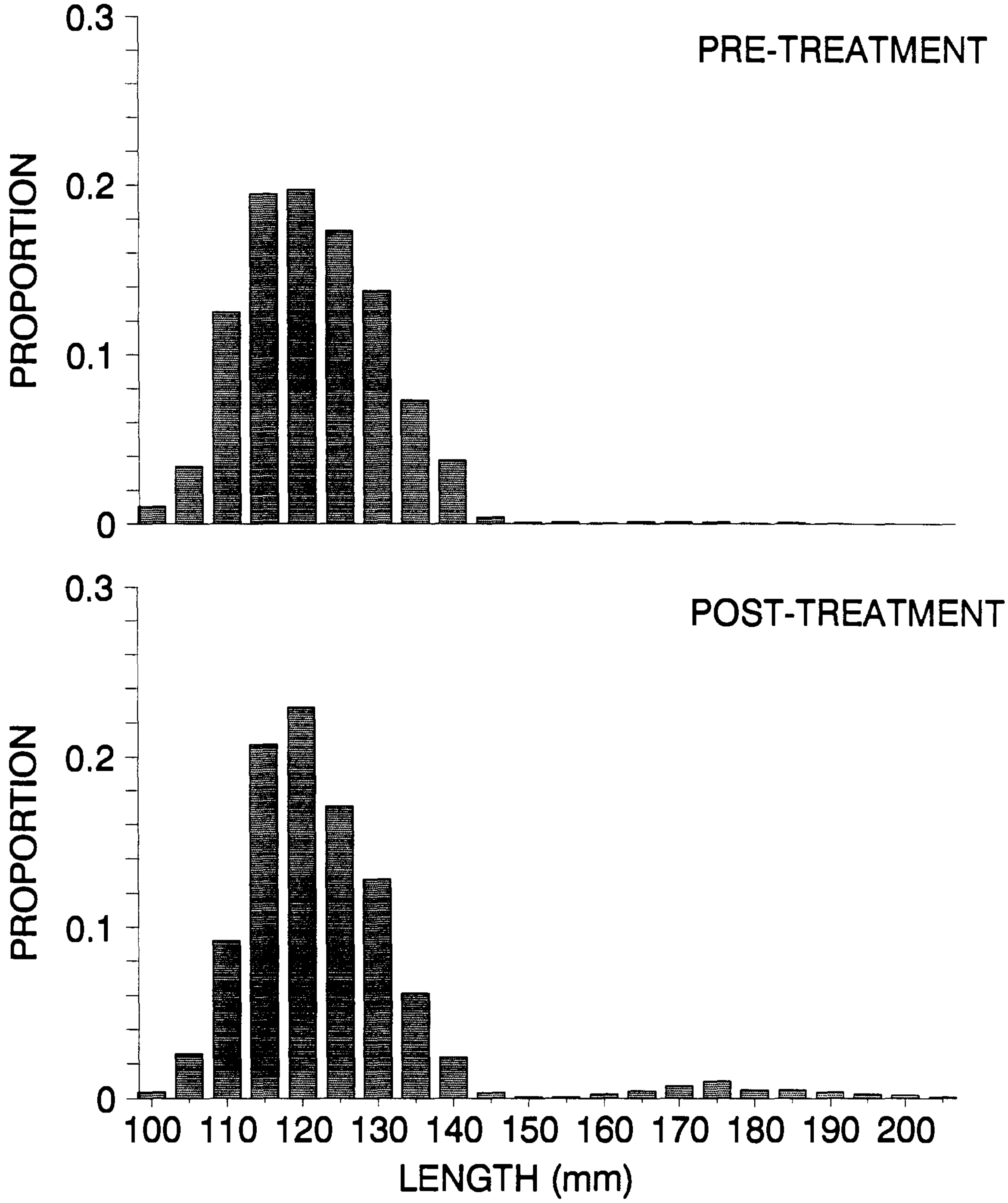

Figure 25. Length frequency distribution of adult yellow perch in Little Bear Lake.

Table 27. Mean length (mm) and weight (g) of adult yellow perch in Little Bear Lake. S.E. indicates standard error of the mean.

	Year				
	1985	1986	1987	1988	1989
Length	115.7	122.7	124.0	124.5	122.3
Variance	58.2	133.2	119.1	291.6	237.4
S.E.	0.3	0.5	0.5	0.7	0.6
n	607	569	515	595	568
	1985	1986	1987	1988	1989
Weight	14.2	16.8	16.9	17.7	15.7
Variance	21.4	51.2	70.9	201.5	136.3
S.E.	0.2	0.3	0.4	0.6	0.5
n	607	569	515	595	568

Table 28. Age-specific fecundity of female yellow perch sampled in the spring in Little Bear Lake, 1985-1990.

		Year					
		1985	1986	1987	1988	1989	1990
Age 1	mean	-----	-----	-----	-----	-----	-----
	S.E.	-----	-----	-----	-----	-----	-----
	n	0	0	0	0	0	0
Age 2	mean	2129	-----	-----	1578	2196	-----
	S.E.	91	-----	-----	144	90	-----
	n	24	0	0	5	10	0
Age 3	mean	2469	2150	5832	2073	2203	-----
	S.E.	198	139	----	210	255	-----
	n	17	6	1	5	4	0
Age 4	mean	3380	2583	3806	4092	-----	-----
	S.E.	----	300	311	353	-----	-----
	n	1	5	5	3	0	0
Age 5	mean	-----	4767	5133	4382	5424	-----
	S.E.	-----	1028	315	527	739	-----
	n	0	5	7	8	7	0
Age 6	mean	-----	24454	-----	5043	6651	-----
	S.E.	-----	-----	-----	-----	-----	-----
	n	0	1	0	1	1	0

Table 29. Mean count of benthic invertebrates in Ekman dredge samples taken from Little Bear Lake. The first line for each taxon is the mean, and the second line is the standard error.

	YEAR				
	1985	1986	1987	1988	1989
Chironomid larvae	11.4	4.4	7.1	25.7	24.7
	3.6	1.4	2.0	5.4	8.3
Chironomid pupae	0.2	0.2	0.2	0.4	0.6
	0.1	0.2	0.2	0.2	0.2
Chaoborus larvae	1.9	5.3	7.4	7.3	7.0
	1.0	1.9	1.7	2.6	2.0
Chaoborus pupae	0.3	0.1	0.8	0.2	0.9
	0.1	0.1	0.2	0.1	0.3
Ceratopogodid larvae	0.0	0.0	0.4	1.1	0.7
	0.0	0.0	0.3	0.7	0.3
Ceratopogodid pupae	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0
Caenis	0.6	0.1	0.1	0.1	0.4
	0.6	0.1	0.1	0.1	0.2
Hexagenia	0.1	0.0	0.1	0.1	0.1
	0.1	0.0	0.1	0.1	0.1
Heptageniidae	0.0	0.0	0.1	0.0	0.1
	0.0	0.0	0.1	0.0	0.0
Trichoptera	0.0	0.1	0.1	0.1	0.1
	0.0	0.1	0.0	0.1	0.1
Odonata	0.0	0.0	0.0	0.1	0.1
	0.0	0.0	0.0	0.0	0.1
Hydracarina	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0
Amphipoda	0.0	0.0	0.1	0.5	0.3
	0.0	0.0	0.1	0.2	0.1
Oligochaeta	0.0	0.3	0.3	0.6	0.3
	0.0	0.2	0.1	0.3	0.2

abundance averaged 0.0 during 1985) was for Chaoborus larvae which increased 3.7 times from 1985 to 1989. For Caenis, chironomid larvae and chironomid pupae, the ratio of abundance from 1985 to 1989 was 0.7, 2.2 and 3.0, respectively (Table 30).

Zooplankton

Rotifers were numerically the most abundant group in the zooplankton in Little Bear Lake, with mean annual densities ranging from 49.1 to 399.8 individuals per liter (Table 31). Among the rotifers, Keratella, Kellicottia, and Polyarthra were the dominant genera in Douglas Lake. Estimates of their abundance were variable, and no taxon of rotifers showed significant differences between years.

In most years, Bosmina was the most abundant cladoceran averaging 4.3 to 15.7 individuals per liter (Table 31). There were no significant differences between years, however, due to the high variance of estimates. Daphnia and Ceriodaphnia were generally the next most abundant cladocerans, averaging 1.4 to 5.6 individuals per liter. As with Bosmina, no significant differences between years were observed. Diaphanosoma was found at densities between 0.6 to 3.2 per liter, with significant differences being observed between years. Except for an increase from 1985 to 1986, no trend in Diaphanosoma abundance was observed, however. Other cladocerans were generally low in abundance (<1.0 individuals per liter) and except for

Table 30. Ratio of abundance of benthic invertebrates in Little Bear Lake comparing 1989 to 1985.

	YEAR		
	1985	1989	Ratio of 1985 to 1989
Chironomid larvae	11.4	24.7	2.2
Chironomid pupae	0.2	0.6	3.0
Chaoborus larvae	1.9	7.0	3.7
Chaoborus pupae	0.3	0.9	3.0
Ceratopogodid larvae	0.0	0.0	---
Ceratopogodid pupae	0.0	0.0	---
Caenis	0.6	0.4	0.7
Hexagenia	0.1	0.1	1.0
Trichoptera	0.0	0.1	---
Odonata	0.0	0.1	---
Hydracarina	0.0	0.0	---
Amphipoda	0.0	0.5	---
Oligochaeta	0.0	0.3	---

Table 31. Annual mean zooplankton density (number/liter) in Little Bear Lake, 1985-1989.

	1985		1986		1987		1988		1989	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Keratella	34.2	9.2	12.8	11.5	4.9	1.8	24.2	4.0	20.3	1.0
Kellicottia	13.4	5.1	17.6	2.5	80.6	41.9	26.8	7.9	365.6	134.7
Polyarthra	0.0	0.0	36.5	12.6	37.9	3.8	15.1	5.6	11.1	2.4
Synchaeta	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.5	2.2
ROTIFERS	49.1	13.7	67.0	23.7	126.2	46.4	67.1	16.0	399.8	134.9
Daphnia	3.4	0.9	2.8	0.7	4.2	1.6	3.5	0.4	3.5	0.9
Bosmina	15.7	10.6	14.6	12.2	4.3	1.2	9.6	3.4	14.0	4.8
Ceriodaphnia	3.5	2.0	2.0	0.9	5.6	1.2	1.4	0.8	2.6	1.8
Diaphanosoma	0.6	0.2	3.2	1.5	2.1	1.3	1.8	0.3	1.9	1.2
Holopedium	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Chydorus	0.0	0.0	0.0	0.0	0.3	0.3	0.8	0.6	0.1	0.1
CLADOCERANS	23.2	11.0	22.8	13.2	16.5	3.2	17.1	3.8	22.3	6.2
Diaptomus	3.7	1.2	7.6	3.2	3.5	1.2	7.8	3.5	6.3	1.6
Tropocyclops	19.3	5.3	6.4	2.1	17.1	10.2	5.1	0.9	7.0	1.8
Diacyclops	0.2	0.2	4.2	3.0	7.7	6.3	5.9	2.6	1.4	0.8
nauplii	5.2	1.5	11.1	3.7	12.5	3.7	26.6	3.4	12.7	4.4
COPEPODS	28.3	6.8	29.6	10.1	40.7	11.9	45.3	6.2	27.8	6.6

Chydorus showed no significant differences in abundance between years (Table 31). Chydorus showed a significant increase in abundance over time, however it abundance always remained relatively low (Table 48).

After rotifers, copepods were the most numerous group in the zooplankton community (Table 31). As in Douglas Lake, Diaptomus, Diacyclops, Tropocyclops and nauplii all contributed substantially to the abundance of copepods, with no single taxon clearly being dominant across the entire study. Both nauplii and Diacyclops showed significant differences in abundance between years. Also, both groups increased in abundance from 1985 to 1988 and a decline from 1988 to 1989.

Comparison between lakes

Fish abundance

In Douglas Lake, there was no difference in the initial density of age-0 white suckers between the pre-treatment and post-treatment periods, but in Little Bear Lake significantly lower age-0 white sucker density was observed during the post-treatment time period (Table 32). For each year individually, however, the peak density of age-0 white suckers caught using ichthyoplankton trawls did not differ between lakes except for 1986 (Table 32). Except for 1986, the time series of abundance data were similar in each lake (Figure 26). Catch rates of age-0 white suckers

Table 32. Results of statistical tests of fish abundance in Little Bear and Douglas Lake.

	Age-0 fish						
	pre- vs post-		Douglas versus Little Bear Lake				
	DG	LB	1985	1986	1987	1988	1989
White sucker (initial)	o	+	o	-	o	o	o
White sucker (August)	--	o	o	--	-	-	o
Yellow Perch (initial)	o	o	+	o	o	--	++
Yellow Perch (August)	o	++	--	--	-	--	o

	Adult fish						
	pre- vs post- treatment		Douglas versus Little Bear Lake				
	DG	LB	1985	1986	1987	1988	1989
White Sucker	++	o	++	++	++	+	o
Yellow Perch	++	o	o	o	o	--	o

o No difference $p>0.05$
- Pre-treatment<Post-treatment <u>or</u> Douglas<Little Bear $p<0.05$
-- Pre-treatment<Post-treatment <u>or</u> Douglas<Little Bear $p<0.01$
\+ Pre-treatment>Post-treatment <u>or</u> Douglas>Little Bear $p<0.05$
++ Pre-treatment>Post-treatment <u>or</u> Douglas>Little Bear $p<0.01$

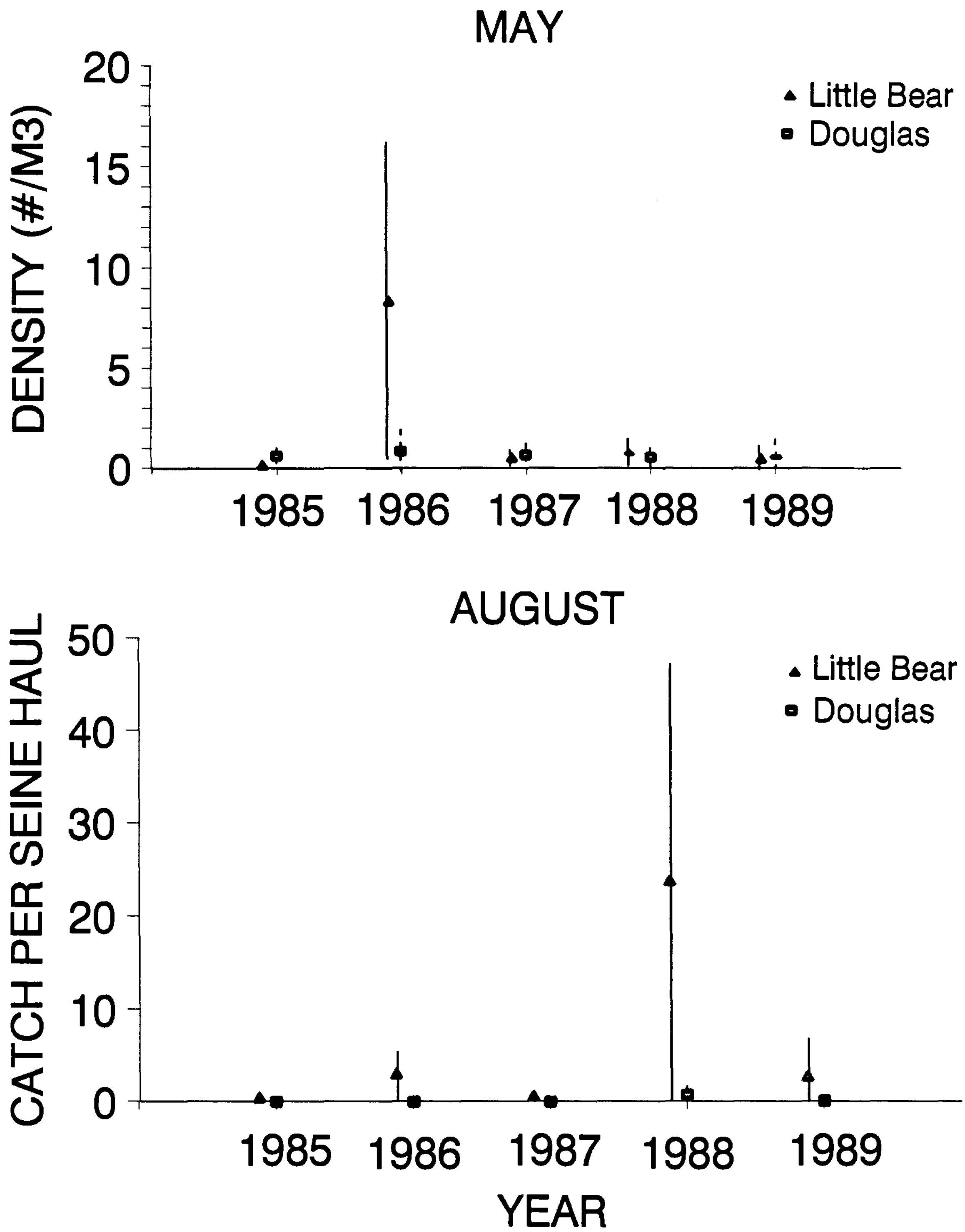

Figure 26. Abundance of age-0 white sucker in Douglas Lake and Little Bear Lake.

in August were significantly lower ($p<0.05$, linear contrast test) in Douglas Lake than in Little Bear Lake from 1986 to 1988, and did not differ significantly ($p>0.05$) in 1985 and 1989 (Table 32). As such, year class strength of age-0 white suckers in Little Bear Lake was always equal to or higher than in Douglas Lake, suggesting higher mortality rates of age-0 white sucker in Douglas Lake.

Adult white sucker abundance showed a significant decrease from the pre-treatment period to the post-treatment period in Douglas Lake, while in Little Bear Lake no trend in abundance was observed (Figure 27). Catch rates were significantly higher ($p<0.05$, linear contrast test) in Douglas Lake than in Little Bear Lake from 1985 to 1988 and did not differ significantly in 1989 (Table 32).

Catch rates of larval yellow perch just after hatching did not differ significantly ($p>0.05$, linear contrast test) between the pre-treatment and post-treatment periods in either lake (Table 32). Catch rates of larval yellow perch in Douglas Lake were higher than in Little Bear Lake during 1985 and 1989 (Figure 28, Table 32), but were higher in Little Bear in 1988.

Catch of age-0 yellow perch in seine hauls in Little Bear was significantly lower during the post-treatment period compared to the pre-treatment period, whereas in Douglas Lake no difference between the two time periods was observed (Table 32). Catch of age-0 yellow perch in Little Bear Lake during 1985 and 1986 were substantially higher

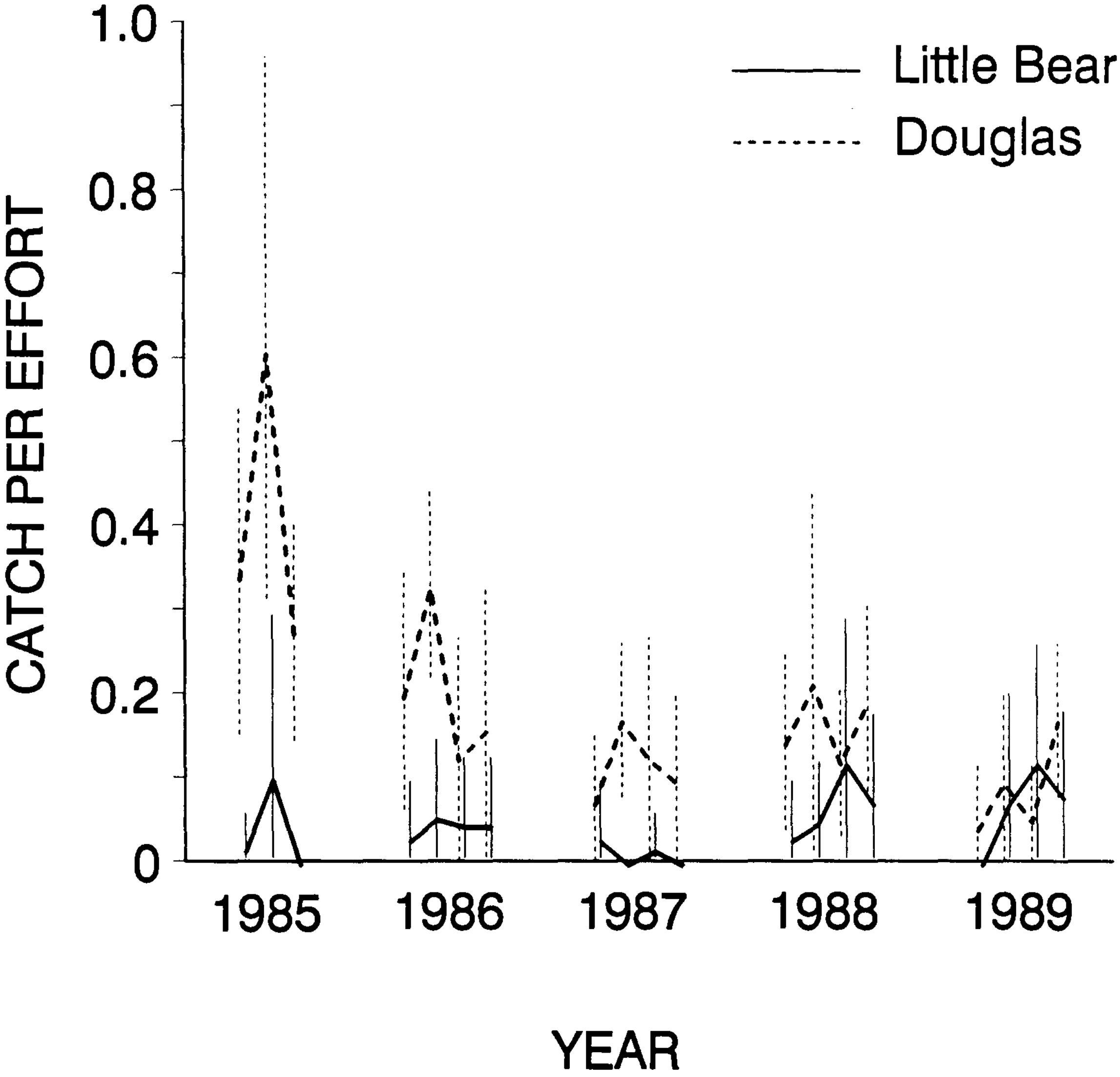

Figure 27. Catch per 3-hour gill net set of adult white sucker in Douglas Lake and Little Bear Lake.

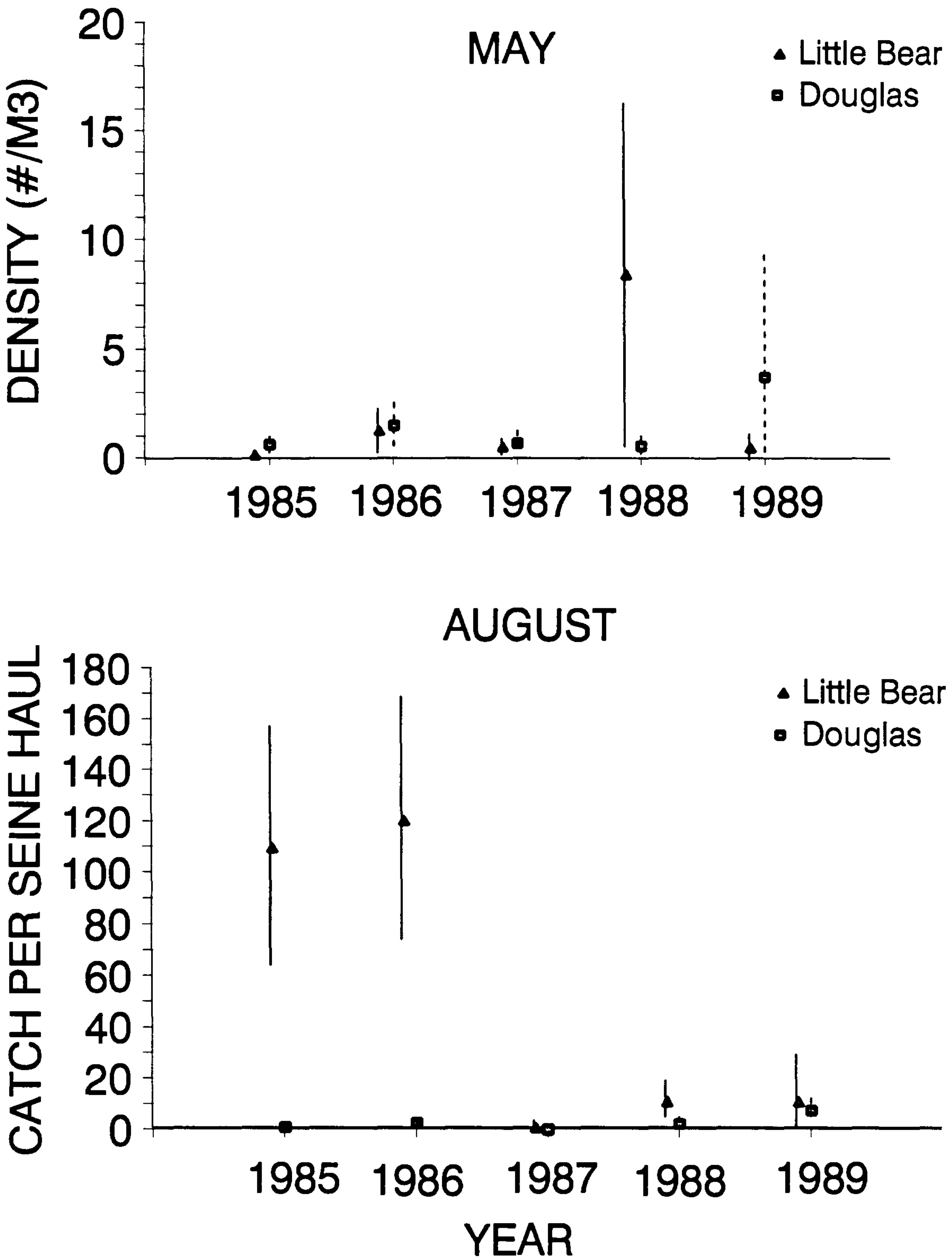

Figure 28. Abundance of age-0 yellow perch in Douglas Lake and Little Bear Lake.

than in Douglas Lake at any time (Figure 28). Mortality rate estimates could not be made from the time of initial hatch through August because of the different sampling gear (ichthyoplankton trawls and seine hauls). However, by comparing abundance indices between these two time periods in Douglas Lake and Little Bear Lake, the magnitude of mortality can be compared. Initial abundance of yellow perch in Douglas Lake was higher or equal to that in Little Bear Lake in 4 of 5 years. Abundance in August was lower in 4 of 5 years in Douglas Lake. Thus, it is apparent that mortality of age-0 yellow perch was higher in Douglas Lake than in Little Bear throughout most of this study.

In Douglas Lake, significantly lower catch rates of adult yellow perch occurred during the post-treatment period compared to the pre-treatment period, whereas in Little Bear Lake differences between these time periods were not significant. The abundance of adult yellow perch in each lake, however, was not significantly different except in 1988 when catch rates were significantly lower in Douglas Lake (Table 32). As such, the time series of adult yellow perch catch in each lake began at approximately the same level in 1985 and ended at approximately the same level in 1989 (Figure 29).

In both lakes, catch of adult yellow perch was concentrated in nets set on the 8-meter contour and showed no trend over time in either lake. The changes in vertical distribution of adult contrasted sharply between the two

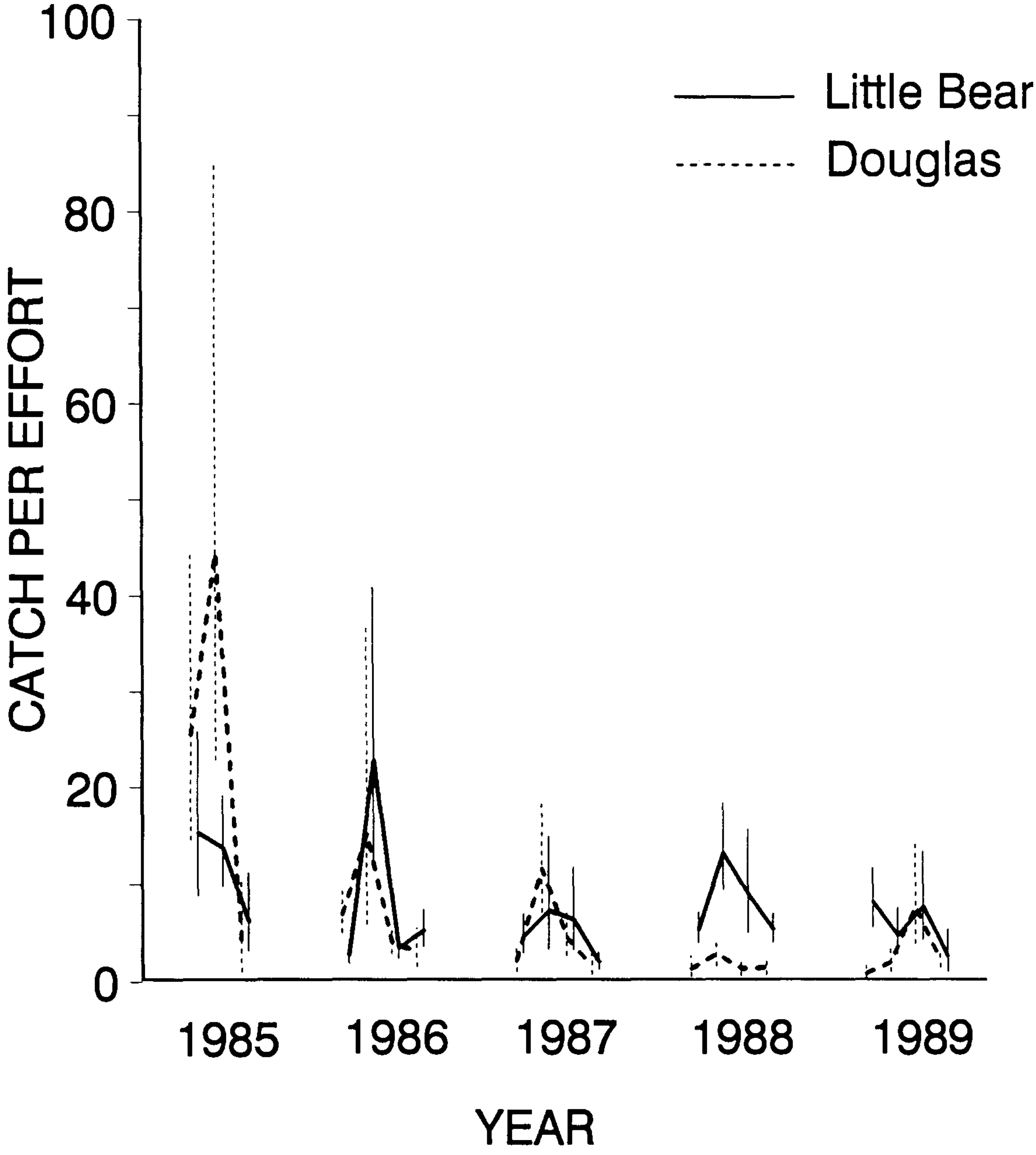

Figure 29. Catch per 3-hour gill net set of adult yellow perch in Douglas Lake and Little Bear Lake.

lakes, however. In Little Bear Lake, no trend was observed in the vertical distribution of catch on the 8-meter contour (Figure 19), while in Douglas Lake catch within one meter of the bottom increased from approximately 25% in 1985 to over 90% in 1989 (Figure 5).

Fish Diet

As indicated earlier, age-0 white suckers were not caught during much of 1985-1987 in Douglas Lake, precluding a comparison of their diet in the two study lakes. The diet of adult white suckers in both lakes was dominated by chironomids. In Douglas Lake a substantial portion (14-52%) of their diet consisted of Caenis, whereas in Little Bear Lake Caenis constituted less than 1% of the diet by weight (Tables 4 and 20).

The diet of age-0 yellow perch showed broad similarities between the two lakes, with zooplankton dominating the diet of small (5 to 25 mm) yellow perch. In Douglas Lake, benthic crustaceans formed over 25% of the diet by numbers for perch in the 35 mm and above size classes, whereas in Little Bear Lake these items rarely contributed over 25% of the diet (Figures 7 and 20). Consumption of benthic insects varied between size classes and time periods in each lake but no pattern was evident.

The diet of adult yellow perch (100-145 mm) during the pre-treatment period was roughly similar in the two lakes, with zooplankton and benthos contributing over 50% of the diet (by weight) in each lake (Figures 9 and 22). During the post-treatment period, the diet of adult yellow perch in Little Bear Lake was variable but showed no trend relative to the pre-treatment period. In Douglas Lake, however, benthic invertebrate utilization increased and zooplankton utilization decreased (Figures 9 and 22). By 1989, zooplankton were not found in the diet of adult yellow perch in Douglas Lake.

Relative consumption rates

In Douglas Lake, the relative consumption rate of adult white sucker on chironomid larvae declined to a value of 21% of 1985 levels by 1989 (Table 5). In Little Bear Lake, relative consumption rates increased to a value 2.3 times higher in 1989 relative to 1985 (Table 21). Thus, in Douglas Lake, predation pressure on chironomid larvae by adult white suckers decreased while in Little Bear it increased. A similar situation held for chydorid cladocerans. Comparisons could not be made between lakes for chironomid pupae because no estimates of the relative predation pressure for this group could be made for Little Bear Lake (Table 21). Likewise, no comparison was made for Caenis as this taxon was only consumed in very low numbers in Little Bear during 1985.

Relative consumption rate by adult yellow perch increased for chironomid larvae and chironomid pupae in both lakes, however, peak consumption rates occurred in 1988 in Little Bear Lake (Table 25) whereas they peaked in 1989 in Douglas Lake (Table 9). Except for 1988, relative consumption of Caenis decreased in Little Bear Lake, while in Douglas Lake it increased over time.

Feeding rate of adult yellow perch

The feeding rate of adult yellow perch averaged for each year shows a nearly parallel development in both lakes (Figure 30), with both lakes showing an increase from the pre-treatment to the post-treatment time period. Increases in feeding rate in Douglas Lake during 1988 and 1989, however, were larger than those observed in Little Bear Lake (Figure 30). In all years, average feeding rate was higher in Douglas Lake than in Little Bear Lake (Figure 30).

Yellow perch growth rates

Growth rates of age-0 yellow perch showed similar time trends in Little Bear Lake and Douglas Lake (Figure 31), with relatively low growth rates during 1985 and 1986, an increase to 1987, and a decline thereafter. In all years the growth rate of age-0 yellow perch was higher in Douglas Lake than in Little Bear Lake.

Size-specific length increments of male and female yellow perch were broadly similar during the pre-treatment period (Figure 16). In Little Bear Lake, length increments showed no trend in time, whereas in Douglas Lake growth rates were substantially higher during 1989 (Figure 16).

Benthic invertebrates

Except for Caenis and amphipods, the abundance of all taxa of benthic invertebrates was similar in Douglas Lake and Little Bear Lake during 1985 (Table 33). Most taxa

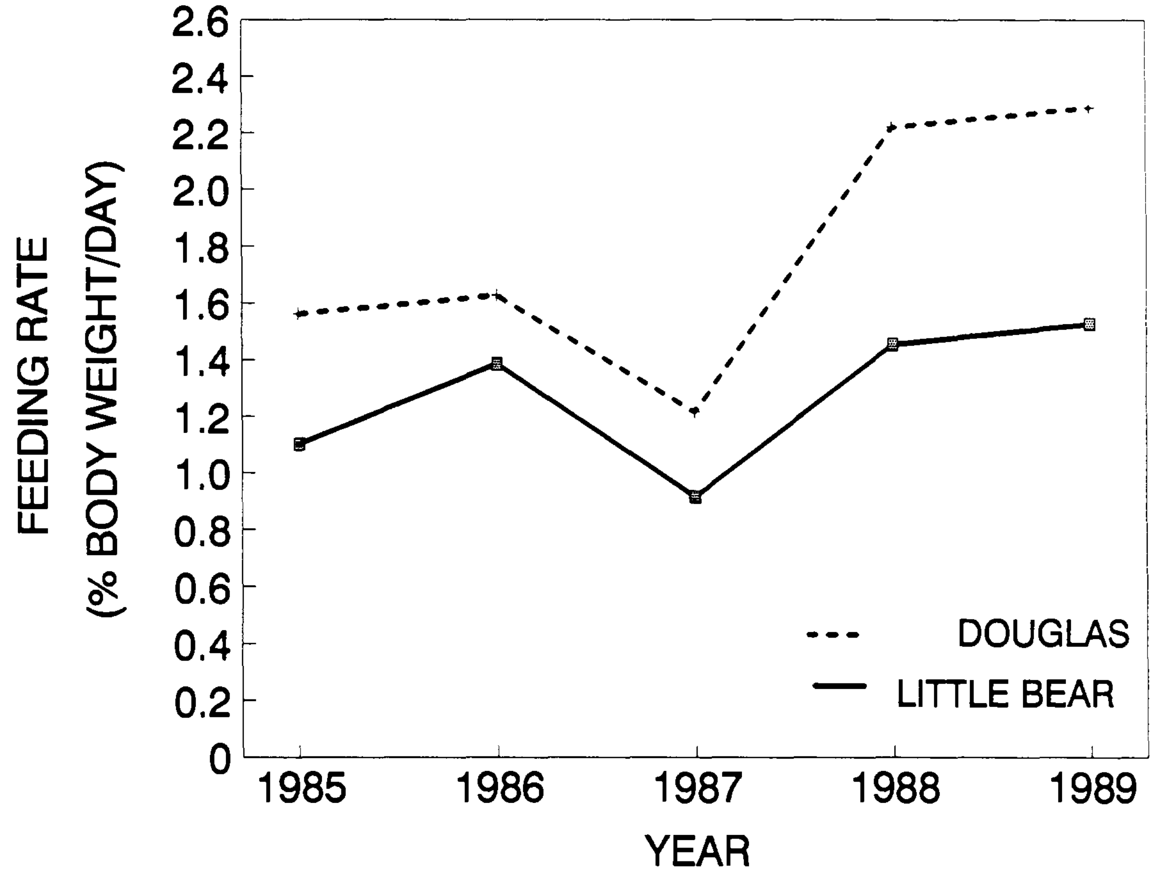

Figure 30. Feeding rate of adult yellow perch in Douglas Lake and Little Bear Lake.

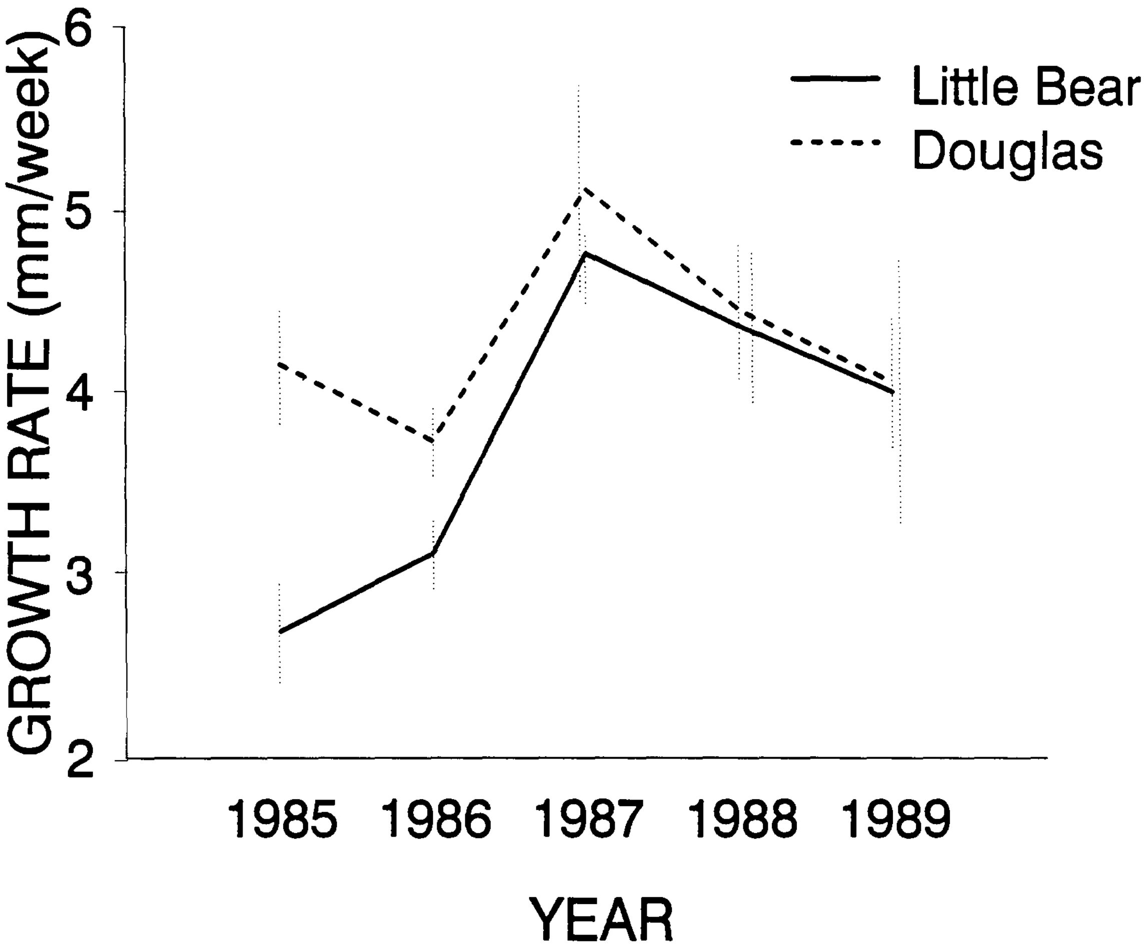

Figure 31. Growth rate of age-0 yellow perch in Douglas Lake and Little Bear Lake.

increased in Douglas and Little Bear Lake, but increases were generally greater in Douglas Lake. Thus, in 1989 all taxa of benthic invertebrates were more abundant in Douglas Lake (Table 33). Ratios of abundance from 1985 to 1989 for the predominant benthic invertebrates in the diet of adult yellow perch were computed to indicate the relative rates of increase for these prey populations (Tables 16 and 30). Chironomid larvae showed a nearly 14 fold increase in Douglas Lake but only showed a 2.2 fold increase in Little Bear. Chironomid pupae also showed a large increase (10 fold) in Douglas Lake, but only increased 3 fold in Little Bear. Finally, <u>Caenis</u> showed a slight decline (0.7 fold) in Little Bear Lake, but in Douglas Lake abundance in 1989 was over 18 times the levels observed in 1985.

Table 33. Results of tests (ANOVA on log(x+1) transformed data) comparing differences in abundance of benthic invertebrates between pre-treatment and post-treatment time periods, and Douglas Lake and Little Bear Lake.

	pre vs post		DG vs LB				
	DG	LB	1985	1986	1987	1988	1989
Chironomid larvae	--	--	o	o	o	o	++
Chironomid pupae	--	--	o	o	o	o	+
Chaoborus larvae	o	o	o	o	o	o	++
Chaoborus pupae	o	o	o	o	o	o	+
Oligochaeta	--	-	o	o	o	+	++
Caenis	--	-	++	++	++	++	++
Hexagenia	--	o	o	o	o	o	++
Ceratopogodid larvae	--	-	none	o	o	o	++
Ceratopogodid pupae	--	o	none	none	none	o	++
Amphipoda	--	-	+	+	o	o	++
Odonata	--	-	o	none	o	o	++
Trichoptera	--	o	none	o	o	+	+
Hydracarina	o	o	o	none	o	o	+

o No difference p>0.05
\- Pre-treatment<Post-treatment <u>or</u> Douglas<Little Bear p<0.05
-- Pre-treatment<Post-treatment <u>or</u> Douglas<Little Bear p<0.01
\+ Pre-treatment>Post-treatment <u>or</u> Douglas>Little Bear p<0.05
++ Pre-treatment>Post-treatment <u>or</u> Douglas>Little Bear p<0.01

Zooplankton

In both lakes, rotifers were numerically the most abundant group of zooplankton, followed by copepods and then cladocerans (Tables 17 and 31). Cladocerans, however, predominate in the diet of yellow perch and *Daphnia*, in particular, are highly selected for among the zooplankton species consumed by yellow perch (Hayes 1988). The abundance of *Daphnia* showed no trend in time in Little Bear Lake, but did show a significant decline in Douglas Lake. In all years except for 1989, however, the abundance of *Daphnia* averaged slightly higher in Douglas Lake than Little Bear Lake (Tables 17 and 31).

DISCUSSION

The premise that intra-specific and inter-specific competition strongly determine the growth rate of fish is the basis for fishery manipulations involving controls on fish density. This study was designed as an experimental manipulation of white sucker abundance to determine the magnitude of the effect interspecific competition has on the growth of yellow perch. Significant increases in growth rate were observed in Douglas Lake but their magnitude was small, and yellow perch in Douglas Lake are still growing slowly. In contrast, yellow perch in Saginaw Bay historically grew to 200 mm by age 4 (El-Zarka 1959). In Douglas Lake age 4 yellow perch averaged approximately 150 mm in length in the spring of 1990. Thus, it is apparent that factors other than inter-specific competition are strongly limiting the growth rate of yellow perch in Douglas Lake.

Although the density of adult yellow perch was not intentionally altered in this study, significant declines in perch abundance were observed in both lakes. The observation that growth rate of yellow perch in Little Bear Lake showed no trend over time suggests that, across the density of fish observed in this study, growth rate is insensitive to variations in intra-specific competition.

This is not to say that intra-specific competition does not play a role in determining the growth rate of adult yellow perch in these lakes since it is possible that at lower abundances of adult yellow perch higher growth rates would have occurred.

Yellow perch management

The yellow perch (*Perca flavescens*) is an important sport fish in Michigan, providing approximately 20% of the catch from inland lakes (Jamsen 1985). In many of these lakes, however, yellow perch populations show a tendency to grow slowly or stunt. The prevalence of stunted populations of yellow perch and bluegill (*Lepomis macrochirus*) has been identified as one of the two key problems in inland lake management identified by fishery managers and fishery user groups in Michigan (Scott et al. 1985).

In some lakes control of yellow perch growth can be achieved by reducing their density with predators such as walleyes, *Stizostedion vitreum vitreum*, or largemouth bass, *Micropterus salmoides* (Anderson and Weithman 1986). Difficulties arise with this management strategy for a number of reasons, however. In small lakes, walleye are often unable to maintain naturally reproducing populations (Johnson et al. 1977). Further, walleye and largemouth bass are desirable sport fishes to anglers and angling mortality often significantly decreases their population levels (Redmond 1986). Thus, control of perch using predators is often difficult or expensive due to the difficulty of maintaining adequate populations of these predators.

An alternative management strategy to improve the growth rate of yellow perch is to manually remove other fish species that are viewed as food competitors with yellow perch. One of the primary species targeted for removal is the white sucker (*Catostomus commersoni*) (Schneider 1981). Evaluations of yellow perch response to sucker removal have show variable results (Holey et al 1979, Schneider 1981) and have not provided strong evidence of the causal mechanisms responsible for positive results observed.

Evidence of inter-specific competition in Douglas Lake

In this study, as with many field studies, the results are complicated by unplanned variation in the system's attributes other than the manipulation applied. From a statistical viewpoint, the planned effects are confounded with these unplanned variations. In this study, the treatment applied was removal of adult suckers from Douglas Lake with the intent of decreasing their abundance. An unplanned decrease, however, was observed in the abundance of yellow perch. As indicated by Carpenter et al. (1990), in experiments which have a single treatment lake and a single control lake statistical inferences can be made regarding whether a system parameter has changed, but one can not statistically determine if the causes of the change(s) observed are due to the treatment applied, or to other uncontrolled factors. In such situations, the cause of the differences observed must be judged based on ecological arguments regarding the processes observed within each lake.

In Douglas Lake, I observed significant increases in the growth rate of yellow perch following sucker removal. As indicated above, the abundance of yellow perch also decreased in Douglas Lake from the pre-treatment period to the post-treatment period. Thus, the effect of decreased sucker abundance is confounded by decreased perch abundance. Fortunately, in Little Bear Lake similar declines in perch abundance were observed. Although growth rates varied between years in Little Bear Lake, no trends in growth were evident, and the magnitude of differences were small relative to those observed in Douglas Lake. These observations lead to the inference that increases in growth rate observed in Douglas Lake were primarily due to decreased inter-specific competition with white sucker.

This contention is further supported by the changes in perch diet I observed in each lake. In Douglas Lake, increases in growth were accompanied by an increase in feeding rate due to higher utilization of benthic invertebrates, particularly chironomids and <u>Caenis</u>. Since these taxa formed such a large portion of the sucker's diet, this is the type of diet shift that would be expected if the two species were competing. Furthermore, no shift in diet was evident in Little Bear Lake, indicating that declines in perch abundance alone would not result in the type of diet shifts observed in Douglas Lake. Concurrent with increased utilization of benthic invertebrates in Douglas Lake, I also observed higher abundances of benthic invertebrates in Douglas Lake, particularly during 1989.

Comparison with previous studies of sucker-perch competition

In Michigan over 30 lakes have been subjected to manual removal of suckers. The effects of sucker removal on yellow perch population dynamics have been closely monitored in one lake, Big Bear Lake, Otsego County. In this lake, netting conducted during 1943, and 1955-1957 resulted in a 90% decrease in the abundance of adult white suckers. Prior to sucker removal, angler catch of yellow perch was approximately 500 per year (Schneider and Crowe 1981). After sucker removal, the catch rate increased to 12,000 per year. In their analysis, Schneider and Crowe determined that increases in catch were due more to increased recruitment to the fishery than increased growth, however they were unable to determine the causal mechanisms responsible for higher recruitment.

In Douglas Lake, the initial density of age-0 yellow perch did not show a significant response to sucker removal, indicating that competition with suckers did not have an impact on the survival of perch eggs. Although the year-class strength of age-0 yellow perch during August was highest during 1989 in Douglas Lake, the range of densities observed were all well below the highest densities observed in Little Bear Lake. Thus, unlike results observed in Big Bear Lake by Schneider and Crowe, the year-class strength of yellow perch showed no response to sucker removal in Douglas Lake. As such, the mechanisms that resulted in higher yellow perch recruitment observed by Schneider and Crowe are still unclear.

Another case study of yellow perch response to sucker removal was conducted in Wilson Lake, Minnesota. In this lake, Johnson (1977) found that abundance of age-0 yellow perch increased 15-fold following removal of 85% of the adult sucker population. As was the case in Big Bear Lake and in this study, Johnson could not ascribe these increases to a particular mechanism. Unlike Big Bear Lake, Johnson observed increased growth rates of yellow perch, resulting in an increase in length at age V and VI of 40 mm. In his investigations of the mechanisms involved, he found that the diet of adult white suckers consisted primarily of insects (diptera and ephemeroptera naiads) and crustacea, as was the case in my study. Following sucker removal, the diet of age-0 yellow perch showed little change in composition, which is consistent with the results I obtained. The diet of intermediate sized (51-127 mm) yellow perch showed an increase in utilization of crustaceans and a decrease in utilization of insects. The diet of large (>127 mm) yellow perch showed an increase in feeding rate on diptera, and decreased utilization of crustacea. Although his choice of size classes differed from mine there are some similarities between our observations. First, Johnson found that removal of adult suckers did not affect all size classes of yellow perch equally. Secondly, he observed an increase in the percent contribution of benthic invertebrates to yellow perch diet among his large (>127 mm) yellow perch. The changes in the diet of yellow perch in Johnson's and the present study both demonstrate that suckers compete with adult yellow perch for benthic insects.

Contrary to my results, Johnson observed a decline in the mean volume of food per stomach for both intermediate and large sized perch. These results are unexpected in light of the fact he observed higher growth rates of adult yellow perch. Although he offered no explanation of this, it is possible that increases in the mean volume of food per stomach were small enough to be within the confidence interval of pre-treatment estimates. Also differing from my results, no persistent changes in the abundance of benthic invertebrates were observed in Wilson Lake.

Management implications

The fact that perch abundance declined in Douglas Lake and Little Bear Lake, and that reductions in white sucker abundance were achieved in Douglas Lake, allows for several general inferences to be made concerning management of stunted populations of yellow perch. First, it is apparent that the variations in yellow perch abundance observed had little effect on perch growth. Thus, growth is relatively insensitive to perch density over the range of densities observed. For fishery managers, this implies that management of these fisheries using predators or chemical treatments to reduce yellow perch density may not be successful unless abundance can be reduced below the levels observed. Assuming that this holds for other stunted populations of yellow perch in Michigan, management objectives should reflect the need to decrease perch abundance to no more than 25% of their original abundance.

The second implication of having decreases in both sucker and perch abundance in Douglas Lake concerns the use of simultaneous removals of perch and suckers as a management tool. In some lakes being managed via sucker removal, local fishery biologists have simultaneously removed a portion of the perch population (personal communication, Steven Swan, Michigan Department of Natural Resources, Gaylord, MI.). The intent of this procedure is to reduce intra-specific competition for food resources that become available through the reduction in inter-specific competition with white suckers. Although the logic behind this procedure is sound, the results expected should be tempered by the observation that feeding and growth responses were observed primarily for fish from approximately 100 mm to 150 mm in length. Fish smaller than 100 mm (primarily age-0) did not show substantially higher growth, likely due in part to their diet composition. Since age-0 yellow perch initially feed on zooplankton, whose abundance was not affected by sucker removal, increases in growth would not be expected for this phase in the perch's life. The diet of perch greater than 150 mm was predominantly fish (Hayes 1988), and likewise their feeding and growth rate were unaffected by sucker removal. Thus, removal of suckers increases the growth rate of only a segment of the perch population, and adequate food resources for other size classes need to also be available.

One aspect of the growth response exhibited by perch to sucker removal that demands further attention is the time needed for the population size structure to respond. Several factors affect the speed of perch response to sucker removal. The first consideration is the time required for benthic invertebrates to respond to decreased predation pressure. My results indicate that there is a two year time-delay in the response of chironomids and other benthic invertebrates to sucker removal. These results would be expected based on the life histories of some of the dominant genera observed in the benthos community. *Chironomus* and *Caenis*, for example, typically have only one generation per year (Dermott et al. 1977). Thus, reductions in the mortality rate of these insects due to sucker removal would not have an effect on their reproductive success until the year following sucker removal. If sucker abundance remains low (as it did in this treatment), increased reproductive success would also be accompanied by lower mortality rate of young insects during the time period following sucker removal. This would initiate a positive population feed-back resulting in there being more larvae surviving, producing more adults. The greater number of adults would thus produce more eggs, which would then produce more larvae. This feed-back mechanism would eventually be expected to be dampened by other sources of mortality or reductions in adult fecundity. Although I have no direct measure of these factors, the duration of increased benthos abundance I observed was at least 2 years and may be substantially longer.

Another factor delaying the perch population size-structure response is the fact that the initial population of perch in these situations is composed primarily of small individuals. Thus, even if growth rates increase greatly, the initial size structure does not allow for a rapid buildup of very large individuals. In the Great Lakes, for example, yellow perch historically grew very rapidly (El-Zarka 1959). Even with high growth rates, however, it required 3 to 6 years for fish to reach a size of 175 mm (7 inches). Thus, if food resources can be maintained at a high level following sucker removal, full development of the perch size-structure may require 5 years or more.

Sustained benefits of sucker removal are contingent on the sucker population remaining low (Schneider and Crowe 1980). In my study, age-0 and age-I white suckers did not show development of large year-classes following reductions in the abundance of adults. In both Wilson Lake (Johnson 1977) and Big Bear Lake (Schneider and Crowe 1980), abundance of adult white suckers rebounded within approximately 5 to 7 years, suggesting that periodic removals of adult suckers would be necessary to sustain reductions in inter-specific competition.

In summary, competition with white suckers appears to have a negative effect on the growth rate of yellow perch. As such, removal of white suckers using trap nets is potentially an effective tool for managing stunted populations of yellow perch competing with suckers. The results obtained in this study indicate that the fishery benefits accruing from sucker removal require at least 2 to 3 years to develop, and as such, sucker removal should not be viewed as a "quick fix" to the problem of perch stunting. Rather, sucker removal should be integrated with other forms of fish community management (i.e. management for balanced predator-prey systems) in order to direct production by benthic invertebrates through desirable fish populations.

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Table 34. Mean number of prey taxa present in the gut of age-0 white sucker in Douglas Lake and Little Bear Lake by size class. The standard error of the mean is represented by s.e. and percent indicates the percent of the total number of items per gut.

		Length Class (mm)						
Taxon		15	25	35	45	55	65	75
Zooplankton	mean	6.0	2.3	1.9	3.6	8.9	4.9	2.0
	s.e.	1.6	0.7	0.6	1.6	3.7	1.7	1.3
	percent	21.5	2.5	0.7	1.2	4.0	1.2	1.2
Benthic crustaceans	mean	21.1	89.5	280.6	277.2	208.5	387.2	154.1
	s.e.	5.0	20.9	48.5	69.2	41.4	107.3	67.8
	percent	75.6	95.5	98.8	97.4	93.3	97.8	89.1
Benthic insects	mean	0.8	1.9	1.4	3.9	5.9	3.7	16.8
	s.e.	0.3	0.5	0.7	1.6	1.2	1.1	9.8
	percent	2.9	2.0	0.5	1.4	2.7	1.0	9.7
Sample size		53	31	22	16	14	15	9

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Table 35. Mean number of prey taxa in the stomach of age-0 yellow perch in Douglas Lake. Standard error of the mean is indicated by S.E.

Pre-treatment (1985-1986)

Taxon		Length Class (mm) 5	15	25	35	45	55	65
Zooplankton	mean	3.6	3.1	7.9	19.0	25.6	16.2	3.6
	S.E.	0.9	0.6	1.9	7.8	13.7	6.7	1.7
	percent	100.0	93.9	94.0	67.4	62.0	38.8	8.2
Benthic crustaceans	mean	0.0	0.2	0.4	7.5	14.2	17.9	37.3
	S.E.	0.0	0.1	0.2	3.3	4.6	6.4	19.8
	percent	0.0	6.1	4.8	26.6	34.6	42.8	85.2
Benthic insects	mean	0.0	0.0	0.1	1.7	1.5	7.7	2.9
	S.E.	0.0	0.0	0.1	0.6	0.5	3.0	1.9
	percent	0.0	0.0	1.2	6.0	3.6	18.4	6.6
Sample size		29	31	16	25	20	15	7

Post-treatment (1987-1989)

Taxon		Length Class (mm) 5	15	25	35	45	55	65
Zooplankton	mean	1.8	7.1	13.3	18.5	13.1	12.4	31.5
	S.E.	0.8	3.5	10.9	9.1	4.9	4.7	23.6
	percent	100.0	100.0	97.8	51.5	27.8	25.9	29.4
Benthic crustaceans	mean	0.0	0.0	0.3	17.4	33.4	35.3	74.0
	S.E.	0.0	0.0	0.3	8.0	16.4	16.4	62.2
	percent	0.0	0.0	2.2	48.5	70.9	73.8	69.2
Benthic insects	mean	0.0	0.0	0.0	0.0	0.6	0.2	1.5
	S.E.	0.0	0.0	0.0	0.0	0.3	0.1	0.5
	percent	0.0	0.0	0.0	0.0	1.3	0.3	1.4
Sample size		9	12	3	10	15	17	4

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Table 36. Mean number of zooplankton in the stomach of adult yellow perch from Douglas Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

Year		Month May	June	July	August	Mean
1985	mean	-	131.7	83.7	93.9	103.1
	S.E.	-	33.7	29.8	20.4	28.0
	n	-	199	458	88	745
1986	mean	211.8	96.0	135.4	50.0	123.3
	S.E.	57.6	21.7	42.0	25.3	36.6
	n	162	213	154	101	630
1987	mean	67.0	116.4	119.0	4.9	76.8
	S.E.	23.1	40.4	37.0	2.8	25.8
	n	88	170	115	86	459
1988	mean	32.7	57.4	55.3	0.0	36.3
	S.E.	26.3	18.4	25.4	0.0	17.5
	n	75	123	64	90	352
1989	mean	0.0	0.0	0.0	0.0	0.0
	S.E.	0.0	0.0	0.0	0.0	0.0
	n	127	92	113	96	428

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Table 37. Mean number of benthic invertebrates in the stomach of adult yellow perch in Douglas Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

Year		Month				
		May	June	July	August	Mean
1985	mean	-	1.2	2.0	1.0	1.4
	S.E.	-	0.5	1.1	0.5	0.7
	n	-	199	458	88	745
1986	mean	1.6	2.3	2.0	0.7	1.6
	S.E.	0.8	1.1	1.2	0.4	0.9
	n	162	213	154	101	630
1987	mean	2.0	4.2	0.3	0.6	1.8
	S.E.	1.2	1.6	0.3	0.4	0.9
	n	88	170	115	86	459
1988	mean	9.9	15.0	16.3	1.2	10.6
	S.E.	6.7	10.4	7.4	0.9	6.3
	n	75	123	64	90	352
1989	mean	33.3	15.5	20.7	1.3	17.7
	S.E.	6.3	5.1	6.4	0.6	4.6
	n	127	92	113	96	428

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Table 38. Mean number of fish in the stomach of adult yellow perch in Douglas Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

Year		Month: May	June	July	August	Mean
1985	mean	-	0.031	0.018	0.000	0.016
	S.E.	-	0.028	0.018	0.000	0.015
	n	-	199	458	88	745
1986	mean	0.704	0.070	0.006	0.024	0.201
	S.E.	0.395	0.046	0.006	0.024	0.118
	n	162	213	154	101	630
1987	mean	0.007	0.022	0.010	0.000	0.010
	S.E.	0.007	0.022	0.010	0.000	0.010
	n	88	170	115	86	459
1988	mean	0.018	0.173	0.072	0.009	0.068
	S.E.	0.012	0.120	0.061	0.006	0.050
	n	75	123	64	90	352
1989	mean	0.025	0.047	0.089	0.010	0.043
	S.E.	0.020	0.027	0.047	0.006	0.025
	n	127	92	113	96	428

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Table 39. Mean number of other prey items in the stomach of adult yellow perch in Douglas Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

		Month				
Year		May	June	July	August	Mean
1985	mean		0.07	1.39	0.12	0.53
	S.E.		0.06	1.06	0.09	0.40
	n		199	458	88	745
1986	mean	0.46	0.18	1.42	0.04	0.53
	S.E.	0.45	0.14	1.25	0.04	0.47
	n	162	213	154	101	630
1987	mean	0.18	0.21	0.03	0.29	0.17
	S.E.	0.13	0.17	0.03	0.25	0.14
	n	88	170	115	86	459
1988	mean	0.30	0.48	0.67	0.23	0.42
	S.E.	0.24	0.40	0.55	0.22	0.35
	n	75	123	64	90	352
1989	mean	0.01	0.09	0.42	2.10	0.66
	S.E.	0.01	0.07	0.35	1.13	0.39
	n	127	92	113	96	428

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Table 40. Feeding rate estimates for adult yellow perch from Douglas Lake, 1985-1989.

Date	N	Gut Fullness Mean	Gut Fullness S.E.	Temperature °C	Evacuation Rate	Feeding Rate Mean	Feeding Rate S.E.
1985							
Jun 26	199	1.125	0.101	17.9	0.072	1.958	0.175
Jul 17	302	0.731	0.077	19.8	0.088	1.543	0.164
Aug 08	156	0.595	0.082	22.7	0.118	1.689	0.233
Aug 27	88	0.518	0.048	19.5	0.085	1.062	0.098
1986							
May 14	162	0.852	0.076	14.4	0.051	1.037	0.093
Jun 18	213	1.055	0.088	17.3	0.068	1.727	0.145
Jul 23	154	0.921	0.072	23.3	0.126	2.780	0.218
Aug 27	101	0.544	0.114	18.0	0.073	0.956	0.200
1987							
May 12	88	0.794	0.153	13.3	0.045	0.864	0.166
Jun 19	170	0.999	0.107	19.2	0.083	1.985	0.213
Jul 23	115	0.585	0.088	21.4	0.104	1.455	0.220
Aug 27	86	0.284	0.083	19.0	0.081	0.553	0.162
1988							
May 12	75	1.162	0.351	10.9	0.036	0.990	0.299
Jun 16	123	1.692	0.226	18.5	0.077	3.130	0.418
Jul 21	64	2.086	0.685	19.3	0.084	4.186	1.374
Aug 25	90	0.269	0.059	20.1	0.091	0.585	0.129
1989							
May 18	127	3.125	0.386	10.5	0.034	2.556	0.315
Jun 22	92	1.403	0.275	16.0	0.060	2.011	0.395
Jul 27	113	1.336	0.189	21.9	0.109	3.494	0.493
Aug 24	96	0.511	0.142	20.0	0.090	1.102	0.306

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Table 41. Length (mm) at age of male yellow perch sampled in the spring in Douglas Lake, 1985-1990.

		Year					
		1985	1986	1987	1988	1989	1990
Age 1	mean	-----	-----	78.2	-----	-----	100.0
	std	-----	-----	2.3	-----	-----	-----
	n	0	0	6	0	0	1
Age 2	mean	113.4	117.0	112.2	110.4	109.8	108.9
	std	7.3	-----	7.4	5.0	5.7	5.4
	n	5	1	25	8	6	61
Age 3	mean	122.0	115.6	116.2	117.5	118.7	115.6
	std	-----	4.7	4.5	4.9	6.4	9.1
	n	1	30	24	24	3	84
Age 4	mean	119.5	115.9	124.2	115.5	-----	144.3
	std	-----	3.2	17.8	6.9	-----	22.8
	n	2	12	9	23	0	4
Age 5	mean	-----	120.5	118.5	124.0	-----	147.3
	std	-----	-----	-----	-----	-----	6.6
	n	0	2	2	1	0	4
Age 6	mean	-----	-----	159.0	-----	-----	-----
	std	-----	-----	-----	-----	-----	-----
	n	0	0	1	0	0	0

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Table 42. Length (mm) at age of female yellow perch sampled in the spring in Douglas Lake, 1985-1990.

		Year					
		1985	1986	1987	1988	1989	1990
Age 1	mean	-----	-----	76.0	-----	-----	-----
	std	-----	-----	-----	-----	-----	-----
	n	0	0	1	0	0	0
Age 2	mean	120.8	-----	108.1	111.6	108.6	-----
	std	7.2	-----	5.5	5.4	3.6	-----
	n	25	0	9	12	18	0
Age 3	mean	121.8	127.1	132.5	120.5	132.7	154.5
	std	7.3	12.9	6.7	2.7	19.6	10.1
	n	19	7	6	8	14	12
Age 4	mean	127.3	141.6	139.9	137.9	144.6	153.0
	std	7.0	11.8	11.0	14.9	12.3	-----
	n	4	13	14	16	13	1
Age 5	mean	-----	141.7	149.4	144.5	152.5	147.0
	std	-----	11.1	15.8	-----	20.6	-----
	n	0	16	19	2	6	1
Age 6	mean	-----	157.0	168.8	162.0	242.0	-----
	std	-----	-----	19.2	-----	-----	-----
	n	0	1	5	2	1	0

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Table 43. Mean number of prey taxa in the stomach of age-0 yellow perch in Little Bear Lake. Standard error of the mean is indicated by S.E.

Pre-treatment (1985-1986)

		Length Class (mm)						
Taxon		5	15	25	35	45	55	65
Zooplankton	mean	2.1	11.4	44.8	68.0	62.2	35.8	-
	S.E.	0.6	2.5	12.0	16.5	16.8	11.6	-
	percent	100.0	98.9	97.4	92.1	74.9	84.9	-
Benthic crustaceans	mean	0.0	0.0	0.9	4.3	18.6	6.0	-
	S.E.	0.0	0.0	0.8	1.4	5.9	3.7	-
	percent	0.0	0.0	2.0	5.8	22.4	14.2	-
Benthic insects	mean	0.0	0.2	0.3	1.5	2.2	0.4	-
	S.E.	0.0	0.1	0.2	0.8	1.0	0.2	-
	percent	0.0	1.7	0.6	2.1	2.7	0.9	-
Sample size		20	47	18	43	29	12	0

Post-treatment (1987-1989)

		Length Class (mm)						
Taxon		5	15	25	35	45	55	65
Zooplankton	mean	0.9	6.7	34.3	28.4	23.8	8.6	2.3
	S.E.	0.9	1.9	15.6	12.7	9.4	4.1	1.0
	percent	100.0	90.5	94.5	53.8	71.0	44.6	11.6
Benthic crustaceans	mean	0.0	0.7	2.0	23.6	4.7	3.0	4.5
	S.E.	0.0	0.6	1.5	17.9	1.3	1.7	1.8
	percent	0.0	9.5	5.5	44.7	14.0	15.5	22.6
Benthic insects	mean	0.0	0.0	0.0	0.8	5.0	7.7	13.1
	S.E.	0.0	0.0	0.0	0.4	1.3	3.1	4.5
	percent	0.0	0.0	0.0	1.5	15.0	39.9	65.8
Sample size		4	16	7	10	22	19	13

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Table 44. Mean number of zooplankton in the stomach of adult yellow perch from Little Bear Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

		Month				
Year		May	June	July	August	Mean
1985	mean	-	24.7	33.6	66.9	41.7
	S.E.	-	10.5	14.8	19.9	15.1
	n	-	346	280	119	745
1986	mean	242.2	51.4	69.7	168.6	133.0
	S.E.	39.6	15.3	27.7	40.8	30.9
	n	131	311	117	174	733
1987	mean	105.7	74.5	29.9	66.1	69.0
	S.E.	35.6	28.1	12.6	22.4	24.7
	n	125	121	120	113	479
1988	mean	79.1	35.0	1.2	3.8	29.8
	S.E.	24.5	13.7	1.0	2.7	10.5
	n	113	140	151	164	568
1989	mean	75.5	61.4	42.5	67.7	61.8
	S.E.	31.8	23.5	17.7	37.0	27.5
	n	157	136	102	87	482

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Table 45. Mean number of benthic invertebrates in the stomach of adult yellow perch from Little Bear Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

		Month				
Year		May	June	July	August	Mean
1985	mean	-	2.5	7.3	3.4	4.4
	S.E.	-	1.1	3.1	1.1	1.8
	n	-	346	280	119	745
1986	mean	0.3	1.0	0.6	0.2	0.5
	S.E.	0.2	0.5	0.4	0.1	0.3
	n	131	311	117	174	733
1987	mean	0.5	2.7	0.2	1.9	1.3
	S.E.	0.4	1.2	0.1	1.0	0.7
	n	125	121	120	113	479
1988	mean	0.3	7.1	2.9	2.7	3.3
	S.E.	0.2	2.9	1.5	1.9	1.7
	n	113	140	151	164	568
1989	mean	2.1	33.7	0.5	0.4	9.2
	S.E.	1.3	14.9	0.4	0.4	4.2
	n	157	136	102	87	482

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Table 46. Mean number of fish in the stomach of adult yellow perch from Little Bear Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

Year		Month				
		May	June	July	August	Mean
1985	mean	-	0.223	0.072	0.103	0.132
	S.E.	-	0.165	0.053	0.103	0.107
	n	-	346	280	119	745
1986	mean	0.043	0.358	0.037	0.008	0.112
	S.E.	0.019	0.103	0.032	0.008	0.040
	n	131	311	117	174	733
1987	mean	0.012	0.110	0.173	0.010	0.076
	S.E.	0.003	0.104	0.111	0.010	0.057
	n	125	121	120	113	479
1988	mean	0.048	0.091	0.129	0.030	0.075
	S.E.	0.016	0.065	0.106	0.010	0.049
	n	113	140	151	164	568
1989	mean	0.012	0.051	0.111	0.000	0.044
	S.E.	0.004	0.025	0.082	0.000	0.027
	n	157	136	102	87	482

APPENDIX A. Supplemental tables.

Table 47. Mean number of other prey items in the stomach of adult yellow perch from Little Bear Lake, 1985-1989. Sample size is denoted by n, standard error by S.E.

		Month				
Year		May	June	July	August	Mean
1985	mean	-	0.928	0.131	0.385	0.481
	S.E.	-	0.683	0.107	0.385	0.392
	n	-	346	280	119	745
1986	mean	0.867	1.105	1.903	0.213	1.022
	S.E.	0.842	0.792	1.620	0.155	0.852
	n	131	311	117	174	733
1987	mean	4.089	0.225	0.168	0.965	1.362
	S.E.	4.069	0.195	0.126	0.497	1.222
	n	125	121	120	113	479
1988	mean	0.296	6.961	0.157	2.993	2.602
	S.E.	0.264	4.657	0.144	2.213	1.819
	n	113	140	151	164	568
1989	mean	1.042	0.800	1.000	2.257	1.275
	S.E.	0.800	0.796	0.693	2.195	1.121
	n	157	136	102	87	482

APPENDIX A. Supplemental tables.

Table 48. Feeding rate estimates for adult yellow perch from Little Bear Lake, 1985-1989.

Date	N	Gut Fullness Mean	Gut Fullness S.E.	Temperature °C	Evacuation Rate	Feeding Rate Mean	Feeding Rate S.E.
1985							
Jun 19	346	0.923	0.090	16.4	0.062	1.378	0.134
Jul 11	163	0.601	0.132	18.2	0.075	1.079	0.238
Jul 31	117	0.493	0.077	20.2	0.092	1.084	0.169
Aug 21	119	0.472	0.055	18.5	0.077	0.873	0.102
1986							
May 22	131	1.097	0.103	12.6	0.042	1.112	0.104
Jun 25	311	0.955	0.117	15.5	0.057	1.300	0.159
Jul 30	117	0.745	0.101	21.6	0.106	1.889	0.256
Sep 03	174	0.733	0.057	17.6	0.070	1.237	0.097
1987							
May 21	125	0.758	0.082	13.2	0.045	0.817	0.088
Jun 25	121	0.670	0.086	16.7	0.064	1.031	0.133
Jul 30	120	0.376	0.058	21.5	0.105	0.943	0.145
Sep 01	113	0.482	0.057	18.3	0.076	0.874	0.104
1988							
May 18	113	0.902	0.119	10.2	0.033	0.716	0.094
Jun 23	140	1.459	0.248	17.9	0.072	2.538	0.432
Jul 28	151	0.625	0.138	22.7	0.118	1.775	0.390
Sep 01	164	0.356	0.084	20.3	0.093	0.791	0.186
1989							
May 25	157	0.935	0.197	13.0	0.044	0.987	0.208
Jun 28	136	1.291	0.220	17.2	0.068	2.092	0.356
Aug 03	102	0.777	0.163	21.0	0.099	1.854	0.389
Sep 07	87	0.660	0.137	18.1	0.074	1.171	0.243

APPENDIX A. Supplemental tables.

Table 49. Length at age of male yellow perch sampled in the spring in Little Bear Lake, 1985-1990.

		Year					
		1985	1986	1987	1988	1989	1990
Age 1	mean	-----	-----	-----	-----	-----	85.3
	std	-----	-----	-----	-----	-----	9.0
	n	0	0	0	0	0	7
Age 2	mean	106.5	112.0	112.0	110.8	110.2	106.3
	std	9.2	-----	2.2	3.5	4.2	6.8
	n	10	2	4	8	18	12
Age 3	mean	107.7	115.4	117.9	111.8	114.3	109.5
	std	7.1	3.7	8.1	1.3	6.6	11.2
	n	6	22	7	5	17	11
Age 4	mean	-----	122.0	133.9	137.0	116.0	121.4
	std	-----	2.5	25.7	-----	7.8	6.8
	n	0	4	7	2	5	5
Age 5	mean	-----	-----	140.0	144.0	120.0	-----
	std	-----	-----	-----	-----	-----	-----
	n	0	0	2	2	1	0
Age 6	mean	-----	-----	-----	-----	127.0	-----
	std	-----	-----	-----	-----	-----	-----
	n	0	0	0	0	1	0

APPENDIX A. Supplemental tables.

Table 50. Length at age of female yellow perch sampled in the spring in Little Bear Lake, 1985-1990.

		Year					
		1985	1986	1987	1988	1989	1990
Age 1	mean	-----	-----	-----	-----	-----	81.8
	std	-----	-----	-----	-----	-----	8.2
	n	0	0	0	0	0	6
Age 2	mean	108.9	-----	-----	108.9	110.5	107.6
	std	7.6	-----	-----	5.4	3.6	6.0
	n	45	0	0	8	10	19
Age 3	mean	113.2	121.4	156.0	112.3	114.6	129.4
	std	10.2	4.0	-----	6.1	4.5	7.4
	n	35	7	1	6	5	10
Age 4	mean	119.2	139.0	149.0	141.0	-----	132.9
	std	8.5	15.9	5.1	13.9	-----	9.1
	n	5	9	5	3	0	13
Age 5	mean	117.3	156.0	151.3	150.0	151.3	143.2
	std	42.7	9.0	7.0	10.5	15.7	6.5
	n	4	6	7	8	7	5
Age 6	mean	220.0	179.0	147.0	170.0	160.0	144.5
	std	-----	-----	-----	-----	10.4	-----
	n	1	1	1	1	3	2