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Potential for Competition Between Yellow Perch (*Perca flavescens*) and White Sucker (*Catostomus commersoni*) in Two Northern Michigan Lakes

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POTENTIAL FOR COMPETITION BETWEEN YELLOW PERCH (*PERCA FLAVESCENS*) AND WHITE SUCKER (*CATOSTOMUS COMMERSONI*) IN TWO NORTHERN MICHIGAN LAKES[1][2]

Daniel B. Hayes

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ABSTRACT

The objectives of this study were to determine the growth and diet of two coexisting populations of yellow perch (*Perca flavescens*) and white sucker (*Catostomus commersoni*) in order to assess potential axes of competition between the two species. Perch in both Little Bear Lake and Douglas Lake were "stunted", with 4-year old perch averaging less than 130 mm in length. The diet of young-of-the-year perch shifted from zooplankton to benthos in July. Adult perch shifted back to a diet of zooplankton during the second summer of life. Suckers initially fed on zooplankton, but quickly shifted to a diet of benthos. The low diet overlap observed may be an indication of little competition between the two species, or it may indicate depletion of benthos by sucker predation to the point where perch are competitively excluded from utilizing this resource.

INTRODUCTION

Yellow perch (*Perca flavescens*) are a highly valuable sport fish in Michigan, providing approximately 20% of the catch from inland lakes and 72% of the non-salmonid catch from the Great Lakes (Jamsen 1985). Growth of yellow perch in inland lakes is sometimes poor, producing fisheries of low quality. In a workshop sponsored by the Michigan Department of Natural Resources, slow growth or "stunting" of bluegills (*Lepomis macrochirus*) and yellow perch ranked second behind insufficient public access among key problems identified by fishery managers and fishery user groups (Scott et al. 1985).

Stunted populations of yellow perch (including the closely related European perch, *Perca fluviatilis*) are thought to be the result of food limitation, especially in the availability of benthic invertebrates (Schneider 1972; Persson 1986). In lake systems where perch growth is relatively rapid, they often show an ontogeny of diet from zooplankton to benthos and finally fish or crayfish (Schneider 1972; Clady 1974; Elrod et al. 1981). When benthic food resources are scarce, perch are unable to switch to larger food items and a bottleneck in the growth of yellow perch may occur, with stunting the result. Intraspecific and interspecific exploitative competition (Pielow 1974) are commonly implicated as factors controlling the availability of benthic prey resources to yellow perch (Alm 1946; Schneider 1972; Persson 1983; Hanson and Leggett 1985). Some of the species that have been observed to compete with yellow perch or European perch are white sucker (*Catostomus commersoni*) (Johnson 1977; Schneider and Crowe 1980), pumpkinseed (*Lepomis gibbosus*) (Hanson and Leggett 1985), and roach (*Rutilus rutilus*) (Persson 1983). The mechanisms causing decreased growth, abundance, or recruitment of perch are only well known in the study by Persson (1986), where removal of 70% of the roach present resulted in increased zooplankton abundance and increased yellow perch growth in Lake Sovdeborg, Sweden.

White suckers, being perceived as food competitors, are sometimes removed in order to improve yellow perch populations. Two studies (Johnson 1977; Schneider and Crowe 1980) document a strong positive response by yellow perch to white sucker removal. However, in other lakes this management technique has not proven to be very effective (Holey et al. 1979; James Schneider, personal communication, 1987, Institute for Fisheries Research, Ann Arbor). Schneider and Crowe (1980) observed yellow perch harvest to increase from 500 to over 12,000 fish per year following a sucker removal program in Big Bear Lake, Michigan. In Wilson Lake, Minnesota, 85% of the adult white sucker population was removed by trap netting, resulting in a fifteenfold increase in yellow perch recruitment, and a 40 mm increase in mean length of age-V and age-VI yellow perch. Neither of these studies was effective in determining the mechanisms producing the responses observed. In order to be able to predict the response of yellow perch to white sucker removal, it is necessary to understand the mechanisms controlling the interactions between the two species.

The goal of this study was to examine the life history of two sympatric populations of yellow perch and white suckers in order to identify potential axes of competition. Specifically, I examined the growth, abundance, diet, diet overlap, and feeding rate of yellow perch and white suckers in two lakes.

METHODS

Little Bear Lake, Otsego County, Michigan, is 51.8 hectares in size, has a mean depth of 4.5 m, and a maximum depth of 10 m. Douglas Lake, Otsego County, Michigan, is 38.1 hectares in area, has a mean depth of 4.7 m, and a maximum depth of 11 m. These lakes were chosen because they are morphometrically similar, and preliminary netting indicated the fish communities of both lakes contained white suckers and populations of small-sized perch. Both lakes are oligotrophic to mesotrophic per Carlson's (1977) criteria, with Secchi disk transparencies ranging from 2.1 to 8.0 m. The alkalinity of lake water in Little Bear Lake on April 27, 1987 was 117 mg $CaCO_3$/L and the pH was 8.26. The alkalinity and pH of Douglas Lake on this date were similar, with an alkalinity of 93 mg $CaCO_3$/L and a pH of 7.98. The water temperature on both of these dates was 12 °C. Thermal stratification generally occurred only in the bottom 1–2 m, and oxygen concentrations of less than 4 ppm were not observed. Little Bear Lake has approximately 150 cottages around its shoreline, while Douglas Lake has about 75. The shorelines of both lakes generally have a sand, gravel, or cobble substrate, with few aquatic macrophytes evident.

Young-of-the-Year Fish

Young-of-the-year (YOY) fish were sampled with ichthyoplankton trawls and seines. Surface trawls were conducted both before and after dark with a 0.5-m diameter, 760-micron mesh ichthyoplankton net with a flow meter mounted at the net's mouth. The net was towed at approximately 1 m per second for 5 minutes, thereby sampling approximately 59 m^3 per tow. Surface trawls were taken because perch larvae tend to concentrate near the lake surface (Clady 1976), and to provide results comparable with other studies of larval fish (Faber 1967; Corbett and Powles 1983). Since most feeding occurs during daylight hours (Noble 1972), samples were taken before dark to provide fish for stomach analyses. Catch rates of larval fish are generally higher after dark, and samples obtained after dark were used to estimate relative density and growth. Three trawl samples were taken on each of the 2-, 4-, and 8-m contours. Trawl samples were taken from the time of hatching in mid-late May until the YOY perch and suckers were vulnerable to beach seines in late June to early July when they reached a size of about 25 mm. Trawl samples were taken at weekly intervals except in the spring of 1985 when one sample was missed.

Shore seine samples were taken weekly from the time YOY perch and suckers became vulnerable to this gear until the end of August. Nine sites were sampled on Douglas Lake and seven sites on Little Bear Lake using a seine 7.6 m long by 1.2 m wide with 0.48-cm mesh. These sites were selected to represent a variety of bottom types, including sand, cobble, vegetation, and mixtures of the above. At each site 15.2 m of shoreline were seined, with the width of the seine haul dependent on the depth of the site. Catch was standardized to number caught per 139.4 m^2 (1,500 ft^2). Mortality rates were estimated by regressing the natural logarithm of catch against date for the descending limb of the catch curve (Ricker 1975).

All YOY perch and suckers caught in ichthyoplankton trawls and a subsample of 25 YOY fish from each site seined were preserved in 90% ethanol. The total length of preserved fish was measured to the nearest 0.01 mm using a digitizing pad. The preserved wet weight of a subsample of five fish caught in ichthyoplankton tows was measured to the nearest 0.00001 g with a Mettler analytical balance. A regression between logarithm of total length and logarithm of preserved wet weight was used to convert between length and weight. Young-of-the-year perch and suckers caught in shore seines were weighed with an Ohaus electronic balance to the nearest 0.001 g. During 1985, the preserved wet weight of a subsample of five fish per day was obtained, and these data were used to develop length-weight regressions in the same manner as for fish caught with ichthyoplankton trawls. During 1986 the entire subsample of fish measured for length was also measured for weight. Since preliminary data analysis using analysis of variance indicated that there are sometimes significant ($p < 0.05$) differences in the mean length and weight of YOY perch caught on the same day at different sites, population mean length and weight were calculated using a mean weighted by the catch at each site. Mean length and weight were assumed to be independent between sites, and the population variance was calculated using the formula (Mendenhall et al. 1971):

$$\text{Var}(Y) = \frac{1}{N^2} * (n_1{}^2 s^2{}_1 + n_1{}^2 s^2{}_2 .... + n_r{}^2 s^2{}_r) \quad (1)$$

where,

N = total catch

n_r = catch at site r

$s^2{}_r$ = variance of mean at site r

Stomach contents were identified and enumerated under a dissecting microscope. Diet overlap indices were estimated between the following groups: YOY yellow perch, YOY white suckers, adult yellow perch, and adult white suckers; where all fish age-I and older were considered to be adults. These indices were calculated from the average proportion that each prey taxon contributed to each fish's diet using Schoener's (1970) index:

$$\text{Overlap} = 1 - (0.5\ \Sigma \mid p_{xi} - p_{yi} \mid)$$

where,

p_{xi} = proportion of food i in the diet of species x

p_{yi} = proportion of food i in the diet of species y

Index values can range from 0.0 (no diet overlap) to 1.0 (complete diet overlap).

Adult Fish

The term "adult fish" is used here to refer to all age-I and older fish whether they were sexually mature or not.

Horizontal monofilament gill nets were set in 2 and 4 m of water, and vertical gill nets in 8 m of water to sample adult perch and suckers. Horizontal nets were 1.8 m in depth, 15.2 m in length, and had 3-m panels of 2.54-, 3.81-, 5.08-, 6.35-, and 7.62-cm stretch mesh monofilament netting. Vertical gill nets were constructed in each of the above mesh sizes, and were 1.8 m in width and 8 m in length. Each sampling site contained one horizontal net set approximately on the 1.8-m contour, a surface and a bottom horizontal net approximately on the 3.7-m contour, and a vertical gill net in each of the above meshes set approximately on the 8-m contour. The nets were checked and reset every 3 hours for a 24-hour period in order to estimate feeding rates. Samples were taken at 3-week intervals from mid-June to the end of August during 1985, and at 5-week intervals from mid-May to the end of August during 1986.

A subsample, consisting of five fish per top and bottom half of the horizontal nets and five fish per vertical meter within the vertical gill nets, was preserved in 10% formalin for stomach analysis. Stomach contents were weighed to the nearest 0.001-g wet weight with an Ohaus electronic balance and prey in the stomach were identified and counted. Stomach fullness was expressed as the percent that the wet weight of the stomach contents occupied of the fish's wet body weight. The mean stomach fullness for the day was estimated from the unweighted mean of the mean stomach fullness for each period, following the method outlined by Elliott and Persson (1978). Instantaneous gastric evacuation rate was estimated by the instantaneous rate of decrease of mean stomach fullness during non-feeding periods. Feeding rates were calculated in terms of wet weight of food as a percentage of the wet body weight.

Growth rate of adult yellow perch was estimated using back calculations of length at age from scale analysis. Scales were taken from just above the lateral line at a point below the third dorsal spine from fish collected during the spawning period. Annuli measurements were taken from a image of the scale projected on a digitizing pad.

RESULTS

Young-of-the-Year Fish

Perch growth.—Young-of-the-year yellow perch were first caught on May 21 in 1985 and May 12 in 1986. The mean total length of larval yellow perch on the first date of capture ranged from 5.27 mm to 7.40 mm for the 2 years. There were significant differences (t-test, $p<0.05$) in mean length and weight of YOY perch between years and lakes on the first sampling date, however, this may be due to differences in the time of hatching relative to the first sampling date. By the second sampling date, length and weight were greater (t-test, $p<0.05$) in Little Bear Lake and this difference persisted both years until the eighth or ninth week after hatching (Tables 1–4). After this time, mean length and weight of YOY perch were greater in Douglas Lake until the end of August.

Growth in length was approximately linear throughout the entire sampling period in both lakes both years. Fits to linear regression lines were very good (R^2 = 0.97 to 0.99, $p<0.001$), and inspection of standardized residuals did not show any departures from the assumptions of linear regression. In Little Bear Lake, the rate of increase estimated by linear regression was 2.83 mm per week in 1985 and 3.12 mm per week in 1986. Although growth during the first 5 to 8 weeks of life was slower in Douglas Lake, for the summer as a whole the growth rate of YOY perch was higher—averaging 4.14 mm per week in 1985 and 3.63 mm per week in 1986.

Perch density.—The density of larval yellow perch just after hatching was significantly greater in Douglas Lake than in Little Bear Lake during 1985 (t-test, $p<0.05$), but initial densities in the two lakes were similar during 1986 (t-test, $p>0.1$). By the third or fourth week after hatching, however, catch rates in Douglas Lake dropped below those in Little Bear Lake, and remained so throughout the remainder of the summer (Table 5). Total loss rates calculated from the first sampling date to the last ichthyoplankton trawling date were 97.4% and 90.2% in Little Bear Lake and 99.7% and 99.2% in Douglas Lake during 1985 and 1986, respectively. These figures are probably overestimates of mortality rate for the entire larval period since net avoidance generally increases over time (Noble 1970). However, differences in the initial catch rates of seine samples support the claim that mortality rates were higher during the early life stages in Douglas Lake. Mortality rates for the period of ichthyoplankton trawling could not be estimated using catch curve analysis (Ricker 1975) due to a bimodal distribution of catch rates. In both lakes, catch curves showed an initial peak on the first day of ichthyoplankton trawling and a second peak near the middle of the sampling period in both years. Since length-frequency distributions did not show a bimodal distribution, the second peak was not due to a second spawning period.

Catch per effort of YOY perch in seine hauls was much higher in Little Bear Lake than in Douglas Lake during both years (Table 5). During 1985, peak catch rates of young perch in seine hauls were nearly 80 times greater in Little Bear Lake. As the summer progressed, this difference increased to over 100 times. During 1986 initial catch rates in seine hauls were similar, but in Little Bear Lake catch decreased little during the summer, whereas in Douglas Lake catch rates decreased to a small percentage of their initial values. Mortality rate estimates were higher in Douglas Lake both years. Instantaneous weekly mortality rates in Douglas Lake were estimated to be 0.518 and 0.410 in 1985 and 1986, respectively. The corresponding values in Little Bear Lake were 0.361 and 0.082.

White sucker density and growth.—The catch rate of juvenile white suckers in both lakes was much lower than that of juvenile yellow perch during 1985 and 1986. Because of the low catch rate, estimates of average length and weight could not be obtained for many sampling dates, and mortality rates could not be estimated for either year. Young suckers were vulnerable to ichthyoplankton trawls approximately 1 week after the young perch. Initial sucker growth was slower than of young perch, especially in terms of weight. After the young suckers became demersal in habits and were recruited to seine nets, growth rate increased, and their size at the end of summer was equal to or greater than that of young perch (Tables 6–9).

Diet and overlap.—The diet of YOY perch and suckers varied greatly among sampling periods and lakes, but diet overlap between the two species was consistently low during all time periods (Table 10). Copepods and copepod nauplii were numerically predominant in the diet of young perch during the time they were sampled with ichthyoplankton trawls. Also present in their diet at this time were *Daphnia, Chydorus, Ceriodaphnia, Bosmina,* and rotifers. During the larval phase of life white suckers fed predominantly on *Bosmina* and chydorid cladocerans. A number of other items were also eaten, including rotifers, copepods, *Scaphloberis*, and chironomid larvae.

Near the beginning of July, the diets of both suckers and perch showed a shift toward benthic items. The most numerous items in the sucker's diet were chydorid cladocerans, harpacticoid copepods, and ostracods, all of which are benthic meiofauna. Young perch generally consumed a more varied diet including both planktonic microcrustaceans as well as benthic meio- and macrofauna.

In general, overlap was low among YOY white suckers, YOY yellow perch, and adult yellow perch (Tables 11 and 12). Overlap between YOY of both species and adult suckers were generally higher (Tables 11 and 12).

Adult Fish

Abundance.—During 1985 and 1986, over 98% of the adult yellow perch catch was made in 2.54-cm stretched-mesh gill netting. Fish caught in this netting generally ranged in total length (TL) from 95 to 140 mm. During 1985, the mean catch of yellow perch in 2.54-cm netting during the 24-hour samples was similar in both lakes (t-test, $p>0.1$), averaging 1,092 perch per day in Little Bear Lake and 1,123 perch per day in Douglas Lake. Catch rates for the same time period during 1986 were lower in both lakes (t-test, $p<0.05$), averaging 717 perch per day in Little Bear Lake and 644 perch per day in Douglas Lake. Catch rates in May 1986 were lower than summertime catches, with 353 perch caught in Little Bear Lake on May 22, 1986 and 413 perch caught in Douglas Lake on May 14, 1986. These differences are presumably due to lower water temperature and perch activity on these sampling dates. Catch rates of adult yellow perch with total lengths greater than 140 mm were very low, averaging 0.75 per day during 1985 and 13.50 per day during 1986 in Little Bear Lake, and 1.25 per day both years in Douglas Lake. The catch of large yellow perch was significantly greater (t-test, $p<0.05$) in Little Bear Lake during 1986 than in Douglas Lake either year, and was significantly greater (t-test, $p<0.05$) than the catch in Little Bear Lake during 1985.

There were large differences in the catch rate of suckers in the two lakes (t-test, $p<0.05$). Average catch of suckers was 1.5 per day each year in Little Bear Lake, whereas catch averaged 17 per day and 10 per day in Douglas Lake during 1985 and 1986, respectively. In 1984, during our preliminary netting, the catch rate of suckers in Little Bear Lake was much higher than during 1985 and 1986. Catch of suckers in 76.2-m experimental-mesh gill nets set perpendicular to shore averaged 3.6 per day during 1984, but dropped to 0.7 per day in 1985 and 0.8 per day in 1986. These differences are not statistically significant (t-test, $p>0.1$), but may represent real biological differences between 1984 and the subsequent years.

Spatial distribution.—The catch rate of adult yellow perch in both lakes was highest during the daylight hours, with 90–99% of the catch occurring at the 8-m sites, and less than 10% of the catch occurring at the 2- and 4-m sites. At night, catch rates of adult perch decreased dramatically at the 8-m sites, while catch at the shallow sites increased slightly. Although the proportion of catch occurring at the 8-m sites decreased at night, 60% or more of the catch still occurred at this depth (Hayes 1988).

Too few adult suckers were caught to obtain estimates of their spatial distribution at Little Bear Lake during both years and in Douglas Lake during 1986. In Douglas Lake during 1985, the catch of adult suckers was highest at the 8-m sites. Catch rates at the 4-m sites ranged between 8% and 35% of the catch within a period, and had no discernable diel pattern. Catch rates at the 2-m sites were less than 1% from 0600 hours to 1800 hours, and made up from 0 to 30% of the total catch at all other times of day.

Diet

Adult yellow perch.—Crustacean zooplankton were numerically predominant in the diet of adult yellow perch, 90- to 140-mm TL, on all sampling dates except July 11, 1985 in Little Bear Lake (Tables 13–16). Zooplankton taxa found included: *Daphnia, Ceriodaphnia, Bosmina, Leptodora, Holopedium, Diaphanosoma, Chydorus, Latona,* calanoid copepods, and cyclopoid copepods. *Chaoborus* larvae and pupae were also eaten, but will be considered separate from the zooplankton due to their low vulnerability to daytime Wisconsin net tows. On July 11, 1985 in Little Bear Lake, *Chaoborus* made up over 67% of the perch's diet by number, but more commonly made up 0–9% of their diet. Benthic items, such as chironomid larvae and pupae and ephemeropterans, generally made up less than 1% of the adult perch's diet. The fish species most commonly eaten by adult perch was YOY perch. Young-of-the-year yellow perch were most heavily preyed upon soon after hatching, and the mean number of YOY perch in the stomachs of adult perch decreased through the summer. In general, the mean number of YOY perch eaten was higher in Little Bear Lake than in Douglas Lake, except in May of 1986 when this average was much higher in Douglas Lake.

Larger yellow perch.—Perch greater than 140-mm TL were caught in low numbers, and their diet cannot be typified for each sampling date. In general, zooplankton made up a large portion of the diet of perch between 140- and 159-mm TL, but declined in occurrence with increasing fish size (Tables 17 and 18). Fish occurred in the diet of a relatively small proportion of adult perch 140- to 159-mm TL (Tables 17 and 18), but perch greater than 160-mm TL frequently fed on fish, and in perch greater than 170-mm TL fish were the predominant food item. Benthos, including crayfish, *Chaoborus*, chironomids and mayfllies, were eaten more by perch greater than 140-mm TL in Little Bear Lake than in Douglas Lake (Tables 17 and 18).

Adult white sucker.—Chydorid cladocerans and chironomid larvae, both of which are benthic items, were numerically predominant in the diet of adult white suckers (Tables 19 and 20). *Bosmina* and cyclopoid copepods were regularly observed in the diet of adult suckers, and occasionally were numerically predominant in their diet.

Stomach Fullness and Feeding Rate

Adult yellow perch.—Before calculating mean stomach fullness for the entire adult perch population, it was necessary to compare stomach fullness across the three depth contours that were sampled. One pattern that was apparent in both lakes was that the contour having the greatest stomach fullness was the 2-m contour during the day, the 4-m contour during the twilight hours, and the 8-m contour at night (Table 23). Results of the Friedman test, however, indicate that there were no statistically significant differences between the three contours for any time of day in either lake. The power of this test to detect these differences is limited by the small number of instances where fish were caught on all three contours during the same time period on the same date. Because of the lack of statistical differences between stomach fullness between the three contours, data from each contour were grouped in the calculation of the population's mean stomach fullness.

Mean stomach fullness (in percent of body weight) was determined for all 24-hour sampling dates (Table 24), except for August 27, 1985 in Douglas Lake where fish were not caught from two of the eight periods. Gastric evacuation rates were estimated for each of the 24-hour studies from the instantaneous rate of decrease in mean stomach fullness during non-feeding periods (Table 25). The feeding rate estimates obtained ranged from 0.364% wet weight of food per day per fish's wet body weight in Douglas Lake on August 27, 1986 to 3.383% in Little Bear Lake on July 11, 1985 (Table 25).

Adult white sucker.—The feeding rate of adult white suckers could not be estimated due to the lack of samples during some time periods on every 24-hour sampling date.

Overlap.—Diet overlap between adult yellow perch (95–140 mm) and adult white suckers was very low on all sampling dates (Table 26).

Growth.—Scale analysis indicated that growth of yellow perch was very slow; at the fourth annulus mean total length was only 117 mm at Little Bear Lake and 125 mm in Douglas Lake (Table 27). Growth of suckers was not unusual, but was much better in Douglas Lake than in Little Bear Lake (Table 27). Fin-ray sectioning was not used for aging suckers because most were young enough that scale samples were considered to be accurate indicators of age (Beamish 1974).

DISCUSSION

The goal of this study was to describe and compare the life history of coexisting yellow perch and white suckers in order to identify potential axes of competition between these species. The response of yellow perch to sucker removal has primarily been studied with an empirical approach (Johnson 1977; Schneider and Crowe 1980) and it has not been successful in determining the mechanisms responsible for improvements observed. Information on the realized niches of these species in sympatry, and the axes of competition, is necessary to provide a basis for inferring mechanisms involved in the response of perch abundance or growth to sucker removal. The results of this study provide data on several aspects of the realized niches of yellow perch and white suckers in Little Bear and Douglas lakes. From these results, I have drawn inferences on potential axes of competition between these species. These inferences are *a priori* predictions of the expected outcome of competition experiments, and in my opinion, cannot be used to directly prove or disprove competition.

One of the prerequisites for the identification of axes of competition is to identify when resources are limiting to an organism. One indication of resource limitation, especially in organisms with indeterminate growth such as fish, is slow somatic growth.

Initial growth of YOY yellow perch in Little Bear and Douglas lakes was similar to that in other north temperate lakes. Mean length at the end of June ranged from 29 to 31 mm, whereas length at this time of year averaged 27 mm in Red Lakes, Minnesota (Ney and Smith 1975) and 38 mm in Lake Winnebago, Wisconsin (Weber and Les 1982). After this point in time, growth during their first summer was slower than in other lakes reported in the literature (Table 27). After the first year of life, growth of yellow perch in Little Bear and Douglas lakes was comparable to the slowest growing population reported in the literature.

Although slow growth was evident by the end of the first year of life, the deceleration of growth in Little Bear and Douglas lakes became more distinct during the second year. These data indicate that growth of perch was severely limited when perch reached a size between 95 and 140 mm. This pattern of relatively good initial growth followed by a rapid slowdown of growth after the first year has been observed in other populations of stunted yellow perch (Eschmeyer 1937; Schneider 1972) and the European perch (Alm 1946; Persson 1983), suggesting a common cause of stunting in perch.

Diet ontogeny, resource limitation, and growth

In lakes where perch growth is relatively good, such as the Laurentian Great Lakes, they typically show an ontogeny of diet from zooplankton to benthos to fish or crayfish (Schneider 1972). A diet shift from zooplankton to benthos typically occurs during the first year of life when YOY perch are about 30–35 mm in length (Forney 1971; Guma'a 1978; Weber and Les

1982). Perch usually feed on benthos from this size until they reach a size of about 150–200 mm, when their diet shifts to fish or crayfish (Clady 1974; Elrod et al. 1981; K. Dodge, personal communication, 1986, Michigan Department of Natural Resources, Jackson). However, this pattern of diet shifts was not followed by perch in Little Bear Lake and Douglas Lake. Young-of-the-year perch did shift from a zooplankton to a benthos diet at about 30–35 mm, but perch 95–140 mm in length returned to a diet of crustacean zooplankton and *Chaoborus*. Adult perch 140–170 mm in length also deviated from the "typical" ontogeny of diet, feeding on zooplankton more heavily than in other systems. Perch greater than 170 mm in length returned to the typical diet sequence, feeding primarily on crayfish and fish.

The atypical ontogeny of diet of perch in Little Bear Lake and Douglas Lake indicates that benthos availability to perch was severely limited. Under the assumptions of optimal foraging (Schoener 1971) the predominance of zooplankton over benthos in the diet of perch 95–140 mm suggests that feeding on zooplankton was energetically more profitable than feeding primarily on benthos. Feeding rates of perch in this size class, using estimates of evacuation rate derived from diel patterns of stomach fullness, averaged only 2% wet weight of food per wet weight of fish per day, a value which is close to maintenance ration for yellow perch (Schneider 1973). Since feeding rates presumably would have been lower if perch had fed on benthos instead of zooplankton, they probably could not have maintained themselves on a diet of benthos under the conditions present in Little Bear and Douglas lakes.

A bottleneck in growth due to low abundance of benthos has often been cited as the reason for stunted populations of perch in other lakes (Alm 1946; Schneider 1972; Persson 1986) and this appears to be the case in Little Bear and Douglas lakes. There are at least three hypotheses that may account for the low abundance of benthos in Little Bear and Douglas lakes. First, intraspecific competition between perch may decrease the availability of benthos to the perch population in general. Second, interspecific competition between perch and suckers may achieve the same result. Third, the limnological characteristics of the lakes may be unsuitable for the production of benthos sufficient to support the growth of a large number of non-stunted perch. These factors are probably all important to some degree, and each will be discussed separately.

Intraspecific competition

Intraspecific competition for benthos between age classes of the European perch has been demonstrated by Persson (1983), indicating that perch can effectively decrease the availability of benthos to other members of their population. This does not appear to be the case in Douglas Lake or Little Bear Lake as benthos made up a small proportion of the diet of all size classes of perch except YOY. Such low predation pressure would probably not greatly impact the population of benthos unless productivity of the benthic community was also low.

Interspecific competition with white suckers

The diet of white suckers was almost exclusively benthic invertebrates, making predation by this species a potential controlling factor of the abundance of benthos. These results are similar to those obtained by Koehler (1978). Two other studies, however, have listed cladocerans as the predominant item in the diet of white suckers (Lalancette 1977; Barton 1980). The effects of sucker predation have been little studied, and I am not aware of any studies showing conclusive evidence that white suckers are able to control the abundance of benthic invertebrates. Comparing the overall abundance of benthos in Little Bear Lake and Douglas Lake, there are no significant differences (Hayes 1988). Sucker catch rates, however, were 6 to 10 times higher in Douglas Lake than in Little Bear Lake. The lack of difference in benthos abundance combined with the large difference in sucker densities suggest that sucker predation did not control the abundance of benthos in these lakes. This is not conclusive evidence, however, as there may have been other differences between the lakes that compensated for differences in predation pressure by suckers.

Limnological characteristics

The nutrient levels and substrate characteristics of a body of water have been shown to have a large effect on the composition and abundance of the benthic community (Hall et al. 1970). In this study nutrient concentrations and substrate characteristics were not measured and their effects on the benthos cannot be evaluated, but their potential importance should not be ignored.

Potential for competition between perch and suckers

The diets of perch and suckers overlapped very little at all life stages overall time periods sampled. There are, however, two conflicting interpretations of these data. First, the low overlap may be taken as an indication that the two species did not compete to any significant degree due to the disparity in their feeding habits. An alternate viewpoint is that suckers were efficient enough at feeding on benthic invertebrates to deplete these resources to the point where they had competitively excluded perch from feeding on benthos. As indicated earlier, current data suggest that sucker predation was not the primary factor limiting the abundance of benthos. If it is true that suckers are not limiting the abundance and availability of benthos, it follows that suckers and perch are not competing in Little Bear Lake and Douglas Lake. On the other hand, if suckers decreased the availability of benthos to perch, it is possible that the two species were competing. The potential axes of competition are difficult to determine, as the low diet overlaps measured do not provide an indication of which of the suckers' prey items could be important to perch growth. Literature data indicate that chironomid larvae and mayfly nymphs are common items in the diet of perch between 30 and 150 mm and could be an important food item of perch in Little Bear and Douglas lakes if they were more abundant (Clady 1974; Guma'a 1978; Elrod et al. 1981; Weber and Les 1982). Based on this information, these items appear to be the primary candidates as axes of food competition. This possibility cannot be verified without manipulating the density of suckers in one of the study lakes.

SUMMARY

Perch in Little Bear Lake and Douglas Lake can be described as slow growing or stunted, with slow growth being evident before the end of the first year of life. The growth of adult perch encountered a bottleneck at a size of 95–140 mm, the size at which perch typically feed on benthic invertebrates in lakes where perch growth is good. The primary food of adult perch in Little Bear and Douglas lakes was crustacean and insect zooplankton, dominated numerically by crustacean zooplankton. The few adults greater than 170-mm TL that were captured had returned to the "typical" diet ontogeny, feeding primarily on fish and crayfish. The break from the typical diet ontogeny indicates that benthic invertebrates were the resource that most limited the growth of perch in the study lakes.

The growth of adult white suckers was not exceptionally slow, and relative to the perch was very rapid. The diet of adult white suckers was composed mostly of benthic invertebrates, particularly chironomid larvae and chydorid cladocerans.

White suckers fed on benthic food items that were potentially limiting to the growth of perch, but the disparity in sucker density between Little Bear Lake and Douglas Lake indicated that sucker predation was not the major factor controlling the abundance of benthos in these lakes. Diet overlap between these species was low during all time periods sampled for all life stages sampled. If competition was taking place between the two species, the only possible mechanism was that suckers depleted the benthic resources to the point where they had competitively excluded perch from utilizing those resources. In order to evaluate this possibility, it would be necessary to manipulate the density of suckers and observe the response of perch and their food resources to this treatment.

Table 1. Mean length (mm) of YOY yellow perch in Little Bear Lake, 1985–86. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard error is denoted by SE and sample size is denoted by N.

Week after hatching	1985			1986		
	Mean	SE	N	Mean	SE	N
1	6.55	0.08	48	5.53	0.03	89
2	—	—	—	9.15	0.09	44
3	14.54	0.13	40	11.25	0.06	91
4	19.04	0.14	27	14.18	0.07	83
5	21.39	0.26	43	17.28	0.10	65
6	24.50	0.12	60	—	—	—
7	25.51	0.89	6	28.15	0.18	89
8	28.71	0.09	464	30.61	0.11	150
9	35.83	0.10	503	30.81	0.11	175
10	37.68	0.13	450	35.41	0.17	161
11	37.53	0.07	348	38.27	0.17	160
12	40.90	0.14	354	40.84	0.26	132
13	40.78	0.16	146	43.73	0.27	141
14	48.24	0.24	199	43.63	0.22	121
15	45.60	0.25	167	50.00	0.28	134
16	—	—	—	51.98	0.20	149

Table 2. Mean length (mm) of YOY yellow perch in Douglas Lake, 1985-86. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard error is denoted by SE and sample size is denoted by N.

Week after hatching	1985			1986		
	Mean	SE	N	Mean	SE	N
1	7.40	0.07	102	5.27	0.02	81
2	—	—	—	8.10	0.09	61
3	11.31	0.24	32	10.50	0.05	81
4	11.59	0.77	5	12.70	0.10	29
5	18.25	0.21	15	17.67	0.93	7
6	—	—	—	—	—	—
7	—	—	—	25.59	0.19	77
8	29.65	0.69	6	30.16	0.27	73
9	37.05	0.20	56	34.15	0.40	22
10	41.26	0.34	36	40.13	0.48	22
11	45.91	0.52	20	44.32	0.91	13
12	47.44	9.34	4	43.63	0.62	16
13	52.08	1.95	8	46.08	—	1
14	57.85	—	2	52.14	0.89	8
15	61.89	—	2	—	—	—
16	—	—	—	55.99	1.21	10

Table 3. Mean weight (g) of YOY yellow perch in Little Bear Lake, 1985-86. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard error is denoted by SE and sample size is denoted by N.

Week after hatching	1985			1986		
	Mean	SE	N	Mean	SE	N
1	0.00116	0.00006	48	0.00088	0.00001	89
2	—	—	—	0.00521	0.0002	44
3	0.0235	0.0008	40	0.0102	0.0002	91
4	0.0719	0.0021	27	0.0237	0.0004	83
5	0.1116	0.0050	43	0.0485	0.0010	65
6	0.1879	0.0039	60	—	—	—
7	0.2167	0.0308	6	0.158	0.003	89
8	0.166	0.002	464	0.189	0.002	150
9	0.276	0.002	503	0.186	0.002	175
10	0.316	0.003	450	0.303	0.004	161
11	0.306	0.002	348	0.395	0.005	160
12	0.393	0.003	354	0.504	0.010	132
13	0.385	0.004	146	0.636	0.012	141
14	0.597	0.008	199	0.612	0.010	121
15	0.533	0.009	167	0.854	0.015	134
16	—	—	—	0.963	0.012	149

Table 4. Mean weight (g) of YOY yellow perch in Douglas Lake, 1985–86. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard error is denoted by SE and sample size is denoted by N.

Week after hatching	1985			1986		
	Mean	SE	N	Mean	SE	N
1	0.00429	0.00011	102	0.00041	0.00001	81
2	—	—	—	0.00262	0.00009	61
3	0.0126	0.0005	32	0.00642	0.0001	89
4	0.0143	0.0027	5	0.0133	0.0004	29
5	0.0532	0.0016	15	0.0455	0.0084	7
6	—	—	—	—	—	—
7	—	—	—	0.107	0.003	77
8	0.155	0.022	6	0.182	0.005	73
9	0.296	0.005	56	0.232	0.007	22
10	0.424	0.011	36	0.389	0.013	22
11	0.526	0.020	20	0.515	0.029	13
12	0.597	0.388	4	0.513	0.017	16
13	0.757	0.114	8	0.580	—	1
14	0.991	—	2	0.961	0.055	8
15	1.183	—	2	—	—	—
16	—	—	—	1.052	0.049	10

Table 5. Mean catch of YOY yellow perch in Little Bear Lake and Douglas Lake, 1985–86. Ichthyoplankton trawl samples are above the dashed line, and are expressed as number per cubic meter; seine samples are below the dashed line and are expressed as number per 139.4 m^2. Standard errors are in parentheses.

	Little Bear Lake		Douglas Lake	
Week	1985	1986	1985	1986
1	0.235 (0.084)	1.543 (0.442)	0.719 (0.178)	1.690 (0.457)
2	— —	0.199 (0.066)	— —	0.103 (0.019)
3	0.039 (0.009)	0.024 (0.008)	0.034 (0.017)	0.374 (0.051)
4	0.045 (0.013)	0.424 (0.119)	0.009 (0.003)	0.076 (0.023)
5	0.291 ((0.209)	0.181 (0.036)	0.021 (0.008)	0.013 (0.004)
6	0.213 (0.072)	— —	0.002 (0.002)	— —
7	0.006 (0.003)	100.7 (67.00)	0.000 (0.000)	34.5 (59.50)
8	193.7 (42.7)	99.4 (21.23)	0.4 (0.24)	61.8 (43.25)
9	500.0 (179.9)	153.0 (29.24)	6.2 (3.14)	8.2 (3.27)
10	254.9 (110.4)	416.8 (168.20)	4.2 (2.18)	7.2 (3.05)
11	163.7 (42.7)	86.2 (17.64)	2.2 (1.21)	3.1 (2.08)
12	225.9 (85.6)	86.3 (31.64)	0.1 (0.12)	6.2 (4.26)
13	47.9 (19.7)	146.2 (67.64)	0.9 (0.77)	1.4 (1.16)
14	65.4 (30.8)	53.1 (15.86)	0.4 (0.25)	3.2 (1.66)
15	48.1 (15.8)	174.0 (63.35)	0.2 (0.15)	0.3 (0.25)
16	— —	143.1 (65.80)	— —	2.9 (1.45)

Table 6. Mean catch, length, and weight of YOY white sucker in Little Bear Lake, 1985. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard errors are denoted by SE. Sample sizes (N) apply to both length and weight.

	Catch[1]		Length (mm)		Weight (g)		
Date	Mean	SE	Mean	SE	Mean	SE	N
5/21	0.015	0.007	12.37	0.35	0.00504	0.00023	8
6/04	0.002	0.002	12.23	—	0.00420	—	1
6/11	0.000	0.000	—	—	—	—	0
6/18	0.000	0.000	—	—	—	—	0
6/25	0.000	0.000	—	—	—	—	0
7/02	0.004	0.004	14.84	—	0.0255	—	2
7/09	1.1	0.8	25.72	0.89	0.143	0.014	8
7/16	2.3	0.4	32.23	1.22	0.302	0.031	16
7/23	1.3	0.8	34.26	1.35	0.355	0.045	9
7/30	0.9	0.9	38.42	0.88	0.501	0.036	6
8/06	0.0	0.0	—	—	—	—	0
8/14	0.3	0.3	37.65	—	0.461	—	2
8/20	0.0	0.0	—	—	—	—	0
8/27	0.0	0.0	—	—	—	—	0

[1]Mean catch per cubic meter of trawling or per 139.5 m^2 of seining.

Table 7. Mean catch, length, and weight of YOY white sucker in Douglas Lake, 1985. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard errors are denoted by SE. Sample sizes (N) apply to both length and weight.

	Catch[1]		Length (mm)		Weight (g)		
Date	Mean	SE	Mean	SE	Mean	SE	N
5/21	0.000	0.000	—	—	—	—	0
6/04	0.000	0.000	—	—	—	—	0
6/11	0.002	0.002	8.76	—	0.00527	—	1
6/18	0.000	0.000	—	—	—	—	0
6/25	0.002	0.002	16.11	—	0.0321	—	1
7/02	0.000	0.000	—	—	—	—	0
7/09	2.7	1.3	21.34	0.46	0.081	0.005	24
7/16	0.1	0.1	32.68	—	0.232	—	1
7/23	0.0	0.0	—	—	—	—	0
7/30	0.0	0.0	—	—	—	—	0
8/06	0.0	0.0	—	—	—	—	0
8/14	0.0	0.0	—	—	—	—	0
8/20	0.0	0.0	—	—	—	—	0
8/27	0.0	0.0	—	—	—	—	0

[1]Mean catch per cubic meter of trawling or per 139.5 m^2 of seining.

Table 8. Mean catch, length, and weight of YOY white sucker in Little Bear Lake, 1986. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard errors are denoted by SE. Sample sizes (N) apply to both length and weight.

	Catch[1]		Length (mm)		Weight (g)		
Date	Mean	SE	Mean	SE	Mean	SE	N
5/12	0.000	0.000	—	—	—	—	0
5/20	0.004	0.004	12.57	—	0.00700	—	2
5/27	0.024	0.008	13.10	0.40	0.00883	0.00089	11
6/02	0.002	0.002	10.49	—	0.00436	—	1
6/09	0.016	0.011	11.87	0.61	0.00746	0.00131	9
6/23	11.0	10.3	26.72	0.85	0.086	0.009	77
6/30	6.6	3.4	20.73	1.02	0.038	0.009	24
7/07	0.3	0.3	36.69	—	0.485	—	2
7/15	8.1	5.3	38.28	0.83	0.507	0.109	30
7/22	6.6	4.6	46.63	2.04	0.974	0.134	46
7/29	0.7	0.5	58.27	2.01	1.500	0.266	3
8/06	6.0	5.5	54.93	2.37	1.735	0.187	33
8/11	4.8	3.4	58.62	1.77	2.135	0.189	28
8/18	2.1	1.3	62.00	5.70	1.929	0.464	12
8/27	0.4	0.3	64.00	—	2.003	—	2

[1]Mean catch per cubic meter of trawling or per 139.5 m^2 of seining.

Table 9. Mean catch, length, and weight of YOY white sucker in Douglas Lake, 1986. The dashed lines separate samples taken by ichthyoplankton trawling (above) and seining (below). Standard errors are denoted by SE. Sample sizes (N) apply to both length and weight.

	Catch[1]		Length (mm)		Weight (g)		
Date	Mean	SE	Mean	SE	Mean	SE	N
5/12	0.000	0.000	—	—	—	—	0
5/20	0.006	0.006	12.07	—	0.00466	—	3
5/27	0.065	0.032	11.42	0.17	0.00561	0.00076	33
6/02	0.000	0.000	—	—	—	—	0
6/09	0.000	0.000	—	—	—	—	0
6/23	0.7	0.4	21.23	0.85	0.058	0.012	6
6/30	0.0	0.0	—	—	—	—	0
7/07	0.3	0.3	27.21	0.64	0.143	0.008	3
7/15	0.0	0.0	—	—	—	—	0
7/22	0.0	0.0	—	—	—	—	0
7/29	0.0	0.0	—	—	—	—	0
8/06	0.0	0.0	—	—	—	—	0
8/11	0.0	0.0	—	—	—	—	0
8/18	0.0	0.0	—	—	—	—	0
8/27	0.0	0.0	—	—	—	—	0

[1]Mean catch per cubic meter of trawling or per 139.5 m^2 of seining.

Table 10. Schoener's diet overlap index between YOY yellow perch and YOY white sucker in Little Bear Lake and Douglas Lake, 1985–1986. The dashed line separates samples taken by ichthyoplankton trawling (above) and seining (below).

	Little Bear		Douglas	
Week	1985	1986	1985	1986
1	—	—	—	—
2	—	—	—	—
3	0.00	0.20	—	0.02
4	—	—	—	—
5	—	0.00	—	—
6	—	- - - -	—	- - - -
7	0.10	0.05	0.00	0.04
	- - - -		- - - -	
8	0.21	0.19	0.15	—
9	0.16	0.05	0.04	—
10	0.32	0.01	—	0.58
11	0.44	0.07	—	—
12	—	0.18	—	—
13	—	0.01	—	—
14	0.07	0.01	—	—
15	—	0.13	—	—
16	—	0.28	—	—

Table 11. Schoener's diet overlap indices among YOY white suckers and yellow perch, adult yellow perch, and adult white suckers in Little Bear Lake, 1985–86.

Date	Interacting groups	Overlap
1985		
Jul 9–11	YOY WS and adult YP	0.035
Jul 30–31	YOY WS and adult YP	0.003
1986		
Jun 23–25	YOY WS and adult YP	0.010
Jul 29–30	YOY WS and adult YP	0.013
Aug 25-Sep 3	YOY WS and adult YP	0.004
1985		
Jul 9–11	YOY WS and adult WS	0.278
Jul 30–31	YOY WS and adult WS	0.478
1986		
Jun 23–25	YOY WS and adult WS	0.653
Jul 29–30	YOY WS and adult WS	0.155
Aug 25-Sep 3	YOY WS and adult WS	0.277
1985		
Jun 18–19	YOY YP and adult YP	0.290
Jul 9–11	YOY YP and adult YP	0.032
Jul 30–31	YOY YP and adult YP	0.014
Aug 20–21	YOY YP and adult YP	0.054
1986		
May 20–22	YOY YP and adult YP	0.233
Jun 23–25	YOY YP and adult YP	0.092
Jul 29–30	YOY YP and adult YP	0.049
Aug 25-Sep 3	YOY YP and adult YP	0.014
1985		
Jun 18–19	YOY YP and adult WS	0.054
Jul 9–11	YOY YP and adult WS	0.537
Jul 30–31	YOY YP and adult WS	0.633
Aug 20–21	YOY YP and adult WS	0.210
1986		
May 20–22	YOY YP and adult WS	0.001
Jun 23–25	YOY YP and adult WS	0.108
Jul 29	YOY YP and adult WS	0.327
Aug 25-Sep 3	YOY YP and adult WS	0.376

Table 12. Schoener's diet overlap indices among YOY white suckers, YOY yellow perch, adult yellow perch and white suckers in Douglas Lake, 1985–86.

Date	Interacting groups	Overlap
1985		
Jun 25–26	YOY WS and adult YP	0.000
Jul 16–17	YOY WS and adult YP	0.000
1986		
Jun 18–23	YOY WS and adult YP	0.015
Jul 7–23	YOY WS and adult YP	0.029
1985		
Jun 25–26	YOY WS and adult WS	0.516
Jul 16–17	YOY WS and adult WS	0.735
1986		
Jun 18–23	YOY WS and adult WS	0.457
Jul 7–23	YOY WS and adult WS	0.578
1985		
Jul 16–17	YOY YP and adult YP	0.052
Aug 6–8	YOY YP and adult YP	0.053
Aug 27	YOY YP and adult YP	0.002
1986		
Jun 18–23	YOY YP and adult YP	0.234
Jul 22–23	YOY YP and adult YP	0.002
Aug 25–27	YOY YP and adult YP	0.005
1985		
Jul 16–17	YOY YP and adult WS	0.215
Aug 6–8	YOY YP and adult WS	0.395
Aug 27	YOY YP and adult WS	0.220
1986		
Jun 18–23	YOY YP and adult WS	0.107
Jul 22–23	YOY YP and adult WS	0.370
Aug 25–27	YOY YP and adult WS	0.431

Table 13. Mean number of items found in adult yellow perch (95 to 135 mm TL) stomachs during 24-hour studies at Little Bear Lake, 1985.

	1985				
Organism	Jun 19	Jul 11	Jul 31	Aug 21	Oct 27
Cladocera					
Daphnia	20.45	5.48	33.43	43.50	112.26
Ceriodaphnia	1.00	0.00	17.89	8.59	6.98
Bosmia	0.07	0.00	0.19	1.18	0.18
Leptodora	2.35	0.17	0.61	0.62	0.23
Holopedium	0.00	0.01	0.27	2.76	0.56
Diaphanosoma	0.00	0.01	0.72	4.16	0.08
Chydorus sphaericus	0.00	0.00	0.01	0.02	0.02
Latona	—	—	—	—	—
Chydorids	0.00	0.00	0.00	0.00	0.00
Macrothricids	0.00	0.00	0.00	0.00	0.00
Copepoda					
Cyclopoids	0.18	0.64	0.80	0.18	0.32
Calanoids	0.59	0.00	3.52	3.70	0.82
Insecta					
Chaoborus pupae	2.37	13.22	0.22	2.39	0.00
Chaoborus larvae	0.04	0.38	0.29	1.00	0.00
Chironomid pupae	0.09	0.01	0.02	0.01	0.00
Chironomid larvae	0.05	0.01	0.00	0.00	0.00
Ephemeropteran nymphs	0.01	0.01	0.00	0.00	0.00
Gastropoda	0.00	0.00	0.00	0.00	0.00
Pisces					
YOY yellow perch	0.22	0.13	0.03	0.10	0.00
Other	0.93	0.00	0.24	0.42	0.01

Table 14. Mean number of items found in adult yellow perch (95 to 135 mm TL) stomachs during 24-hour studies at Little Bear Lake, 1986.

	1986			
Organism	May 22	Jun 25	Jul 30	Sep 3
Cladocera				
Daphnia	110.02	16.63	23.25	130.95
Ceriodaphnia	32.76	22.62	10.59	29.74
Bosmia	2.55	0.00	0.00	0.20
Leptodora	0.06	0.59	0.70	0.73
Holopedium	7.40	3.36	0.76	0.55
Diaphanosoma	0.05	4.87	28.73	0.00
Chydorus sphaericus	0.17	0.05	0.00	0.01
Latona	—	—	—	—
Chydorids	0.00	0.00	0.00	0.00
Macrothricids	0.00	0.00	0.00	0.00
Copepoda				
Cyclopoids	2.60	0.45	1.99	2.26
Calanoids	44.50	2.40	5.08	1.46
Insecta				
Chaoborus pupae	0.00	0.66	0.05	0.06
Chaoborus larvae	0.20	0.05	0.03	0.00
Chironomid pupae	0.02	0.20	0.30	0.09
Chironomid larvae	0.12	0.09	0.30	0.11
Ephemeropteran nymphs	0.01	0.01	0.01	0.00
Gastropoda	0.00	0.00	0.00	0.00
Pisces				
YOY yellow perch	0.01	0.36	0.04	0.01
Other	0.84	1.10	1.66	0.63

Table 15. Mean number of items found in adult yellow perch (95 to 135 mm TL) stomachs during 24-hour studies at Douglas Lake, 1985.

	1985			
Organism	Jun 26	Jul 17	Aug 8	Aug 27
Cladocera				
Daphnia	115.89	54.82	55.22	101.75
Ceriodaphnia	0.06	0.12	0.38	0.02
Bosmia	0.01	0.00	0.33	0.03
Leptodora	3.57	1.70	2.94	0.69
Holopedium	5.67	18.11	0.40	0.24
Diaphanosoma	2.17	8.93	3.13	2.14
Chydorus sphaericus	0.01	0.77	0.09	0.07
Latona	—	—	—	—
Chydorids	0.00	0.00	0.00	0.00
Macrothricids	0.00	0.00	0.00	0.00
Copepoda				
Cyclopoids	0.93	1.34	9.71	0.46
Calanoids	3.53	3.83	4.22	0.32
Insecta				
Chaoborus pupae	0.80	0.43	1.58	0.04
Chaoborus larvae	0.31	0.11	1.43	0.87
Chironomid pupae	0.00	0.01	0.09	0.02
Chironomid larvae	0.03	0.17	0.03	0.10
Ephemeropteran nymphs	0.01	0.00	0.05	0.00
Gastropoda	0.00	0.00	0.00	0.00
Pisces				
YOY yellow perch	0.03	0.01	0.02	0.00
Other	0.07	0.82	1.96	3.75

Table 16. Mean number of items found in adult yellow perch (95 to 135 mm TL) stomachs during 24-hour studies at Douglas Lake, 1986.

	1986			
Organism	May 14	Jun 18	Jul 23	Aug 27
Cladocera				
Daphnia	2.23	79.44	120.32	28.33
Ceriodaphnia	0.00	0.43	2.63	1.65
Bosmina	161.34	0.41	0.10	0.00
Leptodora	0.00	3.28	0.47	0.18
Holopedium	0.25	8.56	0.40	0.03
Diaphanosoma	0.00	1.47	9.26	0.43
Chydorus sphaericus	42.71	0.07	0.48	0.00
Latona	—	—	—	—
Chydorids	0.00	0.00	0.00	0.00
Macrothricids	0.00	0.00	0.00	0.00
Copepoda				
Cyclopoids	4.81	0.84	1.50	0.68
Calanoids	0.64	0.81	0.17	11.65
Insecta				
Chaoborus pupae	0.00	0.58	0.75	0.00
Chaoborus larvae	0.10	1.53	1.18	0.31
Chironomid pupae	0.46	0.08	0.01	0.27
Chironomid larvae	1.00	0.13	0.02	0.00
Ephemeropteran nymphs	0.00	0.01	0.00	0.00
Gastropoda	0.00	0.00	0.00	0.00
Pisces				
YOY yellow perch	0.71	0.07	0.01	0.03
Other	0.47	0.21	1.43	0.03

Table 17. Stomach contents of large adult yellow perch (>140 mm TL) in Douglas Lake, June to August 1985 and May to August 1986. Sample sizes are enclosed in parentheses below the length class designations. Standard deviations of the mean number of each food item are enclosed in parentheses after the mean.

Length class (mm)	Organism	Percent occurrence	Mean number in stomach
140–159	Zooplankton	66.0	66.0 (85)
(6)	Benthos	0.0	0.0 (0.0)
	Fish	33.3	0.3 (0.5)
160–169	Zooplankton	—	—
(0)	Benthos	—	—
	Fish	—	—
170–195	Zooplankton	0.0	0.0 (0.0)
(2)	Benthos	0.0	0.0 (0.0)
	Fish	100.0	1.0 (0.0)

Table 18. Stomach contents of large adult yellow perch (>140 mm TL) in Little Bear Lake, June to August 1985 and May to August 1986. Sample sizes are enclosed in parentheses below the length class designations. Standard deviations of the mean number of each food item are enclosed in parentheses after the mean.

Length class (mm)	Organism	Percent occurrence	Mean number in stomach
140–159	Zooplankton	71.4	183.0 (262)
(14)	Benthos	14.2	1.5 (4.4)
	Fish	14.2	0.2 (0.5)
160–169	Zooplankton	13.5	50.0 (186)
(22)	Benthos	43.2	1.3 (1.6)
	Fish	43.2	0.6 (0.7)
170–195	Zooplankton	0.0	0.0 (0.0)
(10)	Benthos	40.0	0.6 (0.8)
	Fish	60.0	0.7 (0.6)

Table 19. Mean number of items found in adult white sucker guts during 24-hour studies at Little Bear Lake, 1985.

Organism	1985 Jun 19	Jul 11	Jul 31	Aug 21	Oct 27
Cladocera					
Daphnia	0	0	0	0	0
Ceriodaphnia	0	0	0	0	0
Bosmina	0	0	0	0	0
Leptodora	0	0	0	0	0
Holopedium	0	0	0	0	0
Diaphanosoma	0	0	0	0	0
Chydorus sphaericus	—	—	—	—	—
Latona	0	0	56	0	0
Chydorids	1,037	300	1,019	2,743	1,651
Macrothricids	0	0	0	0	0
Copepoda					
Cyclopoids	375	1,200	380	118	323
Calanoids	0	0	81	0	0
Insecta					
Chaoborus pupae	0	0	0	0	0
Chaoborus larvae	0	0	0	0	0
Chironomid pupae	0	0	0	0	0
Chironomid larvae	775	592	220	784	44
Ephemeropteran nymphs	0	0	2	0	0
Gastropoda	0	0	0	0	0
Pisces	0	0	0	0	0
Other	63	0	144	13	1

Table 20. Mean number of items found in adult white sucker guts during 24-hour studies at Little Bear Lake, 1986.

	1986			
Organism	May 22	Jun 25	Jul 30	Sep 3
Cladocera				
Daphnia	0	0	15	0
Ceriodaphnia	0	0	294	0
Bosmina	42,450	0	37	0
Leptodora	0	0	0	0
Holopedium	0	0	0	0
Diaphanosoma	0	0	0	0
Chydorus sphaericus	—	—	—	—
Latona	0	81	3	0
Chydorids	0	1,729	90	143
Macrothricids	0	0	0	0
Copepoda				
Cyclopoids	37	212	37	10
Calanoids	0	0	0	0
Insecta				
Chaoborus pupae	0	4	4	6
Chaoborus larvae	0	0	4	0
Chironomid pupae	0	15	0	0
Chironomid larvae	375	465	200	337
Ephemeropteran nymphs	0	0	0	0
Gastropoda	0	0	0	0
Pisces	0	0	0	0
Other	0	109	15	38

Table 21. Mean number of items found in adult white sucker guts during 24-hour studies at Douglas Lake, 1985.

	1985			
Organism	Jun 26	Jul 17	Aug 8	Aug 27
Cladocera				
Daphnia	0	18	5	5
Ceriodaphnia	9	0	20	0
Bosmia	442	0	0	0
Leptodora	0	0	0	0
Holopedium	0	0	0	0
Diaphanosoma	0	0	0	0
Chydorus sphaericus	—	—	—	—
Latona	283	54	352	40
Chydorids	4,447	11,113	2,106	1,129
Macrothricids	33	53	0	0
Copepoda				
Cyclopoids	30	33	33	142
Calanoids	1	0	12	0
Insecta				
Chaoborus pupae	7	0	4	0
Chaoborus larvae	0	0	0	0
Chironomid pupae	7	18	4	2
Chironomid larvae	565	96	830	463
Ephemeropteran nymphs	198	126	8	3
Gastropoda	21	8	75	42
Pisces	0	0	0	0
Other	9	13	23	42

Table 22. Mean number of items found in adult white sucker guts during 24-hour studies at Douglas Lake, 1986.

	1986			
Organism	May 14	Jun 18	Jul 23	Aug 27
Cladocera				
Daphnia	0	0	1	1
Ceriodaphnia	0	0	0	1
Bosmia	489	1,649	26	0
Leptodora	0	0	0	0
Holopedium	0	0	0	0
Diaphanosoma	0	0	0	0
Chydorus sphaericus	—	—	—	—
Latona	5	80	12	83
Chydorids	169	699	914	375
Macrothricids	0	6	0	0
Copepoda				
Cyclopoids	24	40	33	59
Calanoids	0	2	0	0
Insecta				
Chaoborus pupae	11	1	3	22
Chaoborus larvae	0	9	3	0
Chironomid pupae	0	1	1	9
Chironomid larvae	1,222	788	326	670
Ephemeropteran nymphs	26	115	0	0
Gastropoda	6	35	1	55
Pisces	0	0	0	0
Other	44	14	7	343

Table 23. Comparison of mean stomach fullness (expressed as percent of fish's body weight) of yellow perch caught on the 2-, 4-, and 8-m contours for Little Bear and Douglas lakes, 1985–1986. Standard deviations are in parentheses.

Contour (m)	Time		
	Day	Dusk	Night
Little Bear Lake			
2	1.378 (0.811)	0.186 (0.152)	0.120 (0.156)
4	0.400 (0.339)	0.453 (0.648)	0.088 (0.127)
8	0.219 (0.111)	0.231 (0.233)	0.267 (0.325)
Douglas Lake			
2	0.195 (0.170)	0.166 (0.173)	0.064 (0.036)
4	0.098 (0.066)	0.211 (0.192)	0.119 (0.104)
8	0.140 (0.046)	0.126 (0.056)	0.178 (0.097)

Table 24. Diel pattern of wet stomach content weight (as percent of wet body weight) of adult yellow perch (95 to 140 mm TL) in Little Bear Lake and Douglas Lake, 1985–86.

	Diel period							
Date	1	2	3	4	5	6	7	8
Little Bear Lake								
1985								
Jun 19	0.033	0.067	0.206	0.230	0.190	0.180	0.273	0.143
Jul 11	0.060	0.620	0.786	0.463	0.118	—	0.056	0.061
Jul 31	0.052	0.000	0.049	0.046	0.138	0.076	0.599	0.140
Aug 21	—	—	0.098	0.175	0.079	0.075	0.441	0.081
Oct 27	0.037	0.005	0.003	0.044	0.235	0.102	0.378	0.090
1986								
May 22	0.145	0.065	0.049	0.258	0.074	0.284	0.606	0.512
Jun 23	0.161	0.610	0.414	0.426	0.121	0.341	0.227	0.051
Jul 30	—	0.002	0.123	0.060	0.165	0.099	0.168	0.171
Sep 3	0.024	—	0.014	0.125	0.071	0.147	0.208	0.185
Douglas Lake								
1985								
Jun 26	0.144	0.070	0.112	0.211	0.302	0.364	0.225	0.303
Jul 17	0.185	0.057	0.146	0.177	0.164	0.097	0.190	0.148
Aug 7	0.149	0.113	0.143	0.129	0.068	0.234	0.112	0.114
Aug 27	—	—	0.179	0.090	0.154	—	—	0.107
1986								
May 14	0.229	0.149	0.278	0.190	0.018	0.168	0.199	0.212
Jun 18	0.109	0.186	0.130	0.135	0.161	0.155	0.140	0.304
Jul 23	0.130	—	0.107	0.266	0.078	0.100	0.099	0.119
Aug 27	—	0.000	0.080	0.077	0.178	0.109	0.037	0.027

Table 25. Mean stomach fullness, gastric evacuation rate, and feeding rate estimated from 24-hour studies, Little Bear and Douglas lakes, 1985–1986. Feeding rates are expressed as wet weight of food eaten per day as a percentage of the wet body weight of the fish.

Date	Stomach fullness	Temperature (°C)	Evacuation rate	Feeding rate
Little Bear Lake				
1985				
Jun 19	0.165	16.8	0.489	1.907
Jul 11	0.309	20.0	0.456	3.383
Jul 31	0.137	21.5	0.484	1.597
Aug 21	0.158	20.2	0.565	2.145
Oct 27	0.112	9.7	0.478	1.282
1986				
May 22	0.779	13.0	0.367	2.193
Jun 25	0.314	19.0	0.451	3.225
Jul 30	0.114	23.0	0.203	0.551
Sep 3	0.155	19.0	0.681	1.814
Douglas Lake				
1985				
Jun 26	0.216	17.0	0.216	1.121
Jul 17	0.145	20.0	0.425	1.484
Aug 8	0.133	22.3	0.230	0.733
Aug 27	—	19.9	0.229	—
1986				
May 14	0.180	12.0	0.135	0.584
Jun 18	0.165	17.0	0.231	0.915
Jul 23	0.128	20.9	0.409	1.261
Aug 27	0.073	18.0	0.209	0.364

Table 26. Schoener's diet overlap indices between adult yellow perch (95 to 140 mm TL) and adult white suckers (>95 mm TL) caught during 24-hour studies in Little Bear Lake and Douglas Lake, 1985–86.

Date	Overlap
Little Bear Lake	
1985	
Jun 19	0.008
Jul 11	0.032
Jul 31	0.014
Aug 21	0.012
Oct 27	0.013
1986	
May 22	0.014
Jun 25	0.011
Jul 30	0.053
Sep 3	0.014
Douglas Lake	
1985	
Jun 26	0.009
Jul 17	0.016
Aug 7	0.036
Aug 27	0.019
1986	
May 14	0.222
Jun 18	0.016
Jul 23	0.021
Aug 27	0.017

Table 27. Length (mm) at age of yellow perch and white sucker as determined by scales or fin-ray sections.

Lake	Year of life 1	2	3	4	5	6	Source
Yellow perch							
Little Bear, MI (age IV)	46	63	98	117	—	—	This study
Little Bear, MI (age III)	63	97	112	—	—	—	This study
Little Bear, MI (age II)	67	107	—	—	—	—	This study
Douglas, MI (age IV)	63	93	114	125	—	—	This study
Douglas, MI (age III)	74	106	122	—	—	—	This study
Douglas, MI (age II)	86	120	—	—	—	—	This study
South Twin, MI	87	86	118	129	169	—	Eschmeyer (1937)
Erie	—	144	168	187	217	—	Eschmeyer (1937)
Wawasee, IN	86	129	167	198	220	—	Eschmeyer (1937)
Nebish, WI	124	157	173	209	245	—	Eschmeyer (1937)
Weber, WI	—	130	158	174	191	—	Eschmeyer (1937)
Silver, WI	—	109	120	145	173	—	Eschmeyer (1937)
Erie	94	170	216	241	264	279	Jobes (1952)
Saginaw Bay	76	135	203	241	272	305	Jobes (1952)
Green Bay	71	117	160	201	229	259	Jobes (1952)
Lake of the Woods, MN	99	137	175	206	234	267	Jobes (1952)
Red Lakes, MN (male)	74	132	172	201	221	234	Heyerdahl and
Red Lakes, MN (female)	74	132	178	218	241	254	Smith (1971)
Memphremagog, Que. (high)	75	115	170	200	—	—	Persson (1983)
Memphremagog, Que. (low)	60	105	155	190	—	—	Persson (1983)
Opinicon, Ont.	60	96	119	136	—	—	Persson (1983)
West German lakes	80	122	148	189	—	—	Persson (1983)
32 Finnish ponds	56	95	124	143	—	—	Persson (1983)
Vitalampa, Swe.	60	104	127	143	—	—	Persson (1983)
Abborrtjarn I, Swe.	—	78	98	111	—	—	Persson (1983)
Ivosjon, Swe.	80	115	160	195	—	—	Persson (1983)
Sovdeborgssjon, Swe.	75	97	109	117	—	—	Persson (1983)
Big Bear, MI (high)	105	135	165	—	220	—	Schneider and
Big Bear, MI (low)	96	126	144	—	165	—	Crowe (1980)
White sucker							
Little Bear, MI	91	149	189	211	—	—	
Douglas, MI	87	211	298	—	—	—	
Lumsden, Ont.	75	105	150	175	200	220	Beamish (1974)
Croche, Que. (male)	—	129	191	235	257	281	Verdon and
Croche, Que. (female)	—	139	197	244	271	294	Magnin (1977)

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