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Dynamics of a Bluegill, Walleye, and Yellow Perch Community

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Abstract.– The addition of bluegill *Lepomis macrochirus* to an experimental community of walleye *Stizostedion vitreum* and yellow perch *Perca flavescens* in Jewett Lake provided an opportunity to evaluate species interactions and fisheries potential. Abundance, size and age structure, growth, mortality, and recruitment of each species were monitored in 1987-95 and compared to walleye and yellow perch data collected in 1975-83. Angler harvest was monitored by voluntary catch survey. Diet studies provided information on predation and potential competition. Models were constructed to simulate populations and the effects of fishing regulations, especially catch-and-release regulations. With the addition of bluegill to the community, total fish biomass doubled to 71 kg/hectare, of which 52% was bluegill. Walleye biomass increased by 11% and yellow perch biomass decreased by 20%. The abundance of large fish changed dramatically: +54% for walleye >356 mm and -76% for yellow perch >178 mm. The biomass gain by walleye was attributed to the utilization of bluegill as food. The biomass loss by yellow perch, mainly by sizes >126 mm, was attributed to competition with bluegill for large zooplankton and benthos. Competition was evidenced by declines in population biomass and individual growth, and diet overlap and shift. Recruitment of YOY perch was unaffected by bluegill, but recruitment of walleye began to fail when bluegill biomass exceeded 50 kg/hectare. Bluegill effects on walleye most likely took place while walleye were in the egg stage (predation) and fry stage (predation and competition for zooplankton). Those stages were not sampled at the lake, but laboratory experiments confirmed that bluegill were capable predators. Large temperature fluctuations during walleye egg incubation were correlated with walleye recruitment failure also, but water temperature variations were probably too small to directly effect egg survival. Changes in the species populations caused a 7% gain in walleye harvest and a 71% loss in yellow perch harvest. Walleye, as predators, maintained the stability of both communities and the good growth of both bluegill and yellow perch. It is feasible to manage small lakes with either combination of species and to use walleye as a tool to improve growth and size structure of stunted populations of bluegill or yellow perch.

In 1966 a series of experiments of progressively increasing complexity were begun at Jewett Lake concerning the dynamics of yellow perch *Perca flavescens* populations and communities. The goals were to understand and predict the processes of recruitment, growth, and mortality; determine population and community stability; and evaluate fisheries potential, which is principally the abundance of fish large enough to interest anglers.

In the first experiment, yellow perch were the only fish in the lake (Schneider 1972). Results confirmed that cannibalism alone was not sufficient to control recruitment of young perch and allow satisfactory growth. As a result, perch became slow growing and "stunted" at 100-150 mm total length (TL).

In the second experiment, the fish community consisted of yellow perch and minnows (Schneider 1972). Results indicated that minnows could temporarily reduce the growth and recruitment of young-of-the-year (YOY) perch, but the minnow population was quickly eliminated by adult perch predation. Consequently, the yellow perch population probably would have reverted to the first scenario and become stunted.

In the third experiment, the community consisted of yellow perch, minnow, and walleye *Stizostedion vitreum* (Schneider 1979). The minnows were again eliminated but walleye predation effectively controlled perch recruitment and a stable perch-walleye community with desirable growth and size structure developed.

In the fourth experiment, the topic of the last report (Schneider 1983), the yellow perch-walleye community was subjected to angling. Results indicated a modest fishery could be produced, however, the walleye were under-harvested and perch were so heavily exploited by both walleye and anglers that the success of perch reproduction was threatened. Subsequent data, shown below, demonstrates the yellow perch population maintained itself.

A fifth experiment, the subject of this report, was begun when bluegill became established. The intentional introduction of bluegill had been contemplated (Schneider 1983), but the actual introduction, of a few adults, was unauthorized. A large year class of bluegill was produced in 1986 and every year afterwards.

This report will document the effect of bluegill on walleye and yellow perch dynamics, and conversely, the effect of the percids on bluegill dynamics. Bluegills, like yellow perch, are prone to stunt in Jewett Lake (Patriarche and Gowing 1967; Patriarche 1967) and other Midwestern lakes. Both walleye and yellow perch have the potential to reduce the likelihood of bluegill stunting through predation (Schneider and Breck 1995).

Jewett Lake is in the Rifle River Recreation Area, Ogemaw County, Michigan. It does not afford typical walleye habitat, but a good population was established by stocking (1975-80) and maintained by natural reproduction (1979-91). Surface area is only 5.2 hectare, maximum depth is about 5 m, and volume is 120,000 m^3. The light brown water has an alkalinity of 34 ppm and Secchi disk transparency is typically about 1.8 m. Dissolved oxygen levels drop below 2 ppm at a depth of 3 m in summer and winter. Surface temperatures often exceed 27 °C in summer. About 90% of the shoreline is rimmed by encroaching bog. Higher aquatic vegetation is very sparse. Water lilies, once common, were eliminated when beaver *Castor canadensis* colonized the lake in the early 1980s. Some moss occurs in deeper water. The substrate is composed entirely of soft silt and peat, except for narrow strips of sand along 50% of the shoreline. Successful incubation of walleye eggs has been observed on this sand, but generally sand is poor-quality habitat (Johnson 1961).

Methods

The walleye-yellow perch community, sampled from 1975 through 1983, forms the baseline for evaluating the bluegill effect, which began in 1986. Intensive sampling of the resulting community of bluegill, walleye, and yellow perch was conducted from 1987 through 1993. Sampling methods followed those in earlier reports (Schneider 1979 and 1983). Briefly, the fish populations were sampled in fall with 220-V AC electrofishing gear and trapnets with pots of either 9- or 19-mm stretched mesh. Numbers of fish present were estimated annually by the mark-and-recapture method with either the Chapman or Schumacher-Eschmeyer formula (Ricker 1975). Fish marked in late September by clipping a lobe of the caudal fin were recaptured in mid-October. To eliminate size selectivity of the gear, estimates were stratified by 1-inch (25-mm) size groups whenever enough recaptures

(4) were obtained; otherwise, data for adjacent size groups were pooled to compute an estimate. Estimates for each species were stratified by both age groups and size groups with the aid of scale samples, length-frequency measurements, or stocking clips (walleye, 1975-80). About 75% of the large fish were actually handled each fall. In some years YOY bluegill or yellow perch could not be estimated by the mark-recapture method because they were either too sparse, overwhelmingly abundant, or too small and fragile to tolerate handling. Then a rough estimate of abundance was made based on catch per unit of effort (CPE).

Scale samples, usually from 30 fish per 25-mm size strata, were taken concurrently with the population estimates, and also in 1995. By late fall, when the samples were taken, growth in length had been virtually completed. Computations of average length at age were weighted by size group population estimates to adjust for sampling stratification. However, the differences between simple averages and stratified averages were minor. Walleye more than 4 years old were difficult to age from scale samples because of slow growth. However, the age of stocked walleye could be easily traced from unique pectoral or pelvic fin clips given at stocking. Bluegill scales were difficult to interpret in some years, leading to possible errors in the population estimates by age group. Average length at age was compared to State of Michigan averages (Merna et al. 1981).

Total mortality rates of bluegill and yellow perch were calculated from sequential mark-recapture population estimates of each cohort, then averaged by age group. Excluded from the averages were estimates of less than four fish. For native walleye cohorts (ie., naturally reproduced in Jewett Lake), population estimates were averaged by age group, smoothed by regression, and an average mortality was computed. A similar procedure was followed for the stocked 1975 cohort, which was abundant and easily identified by fin clip.

Annual estimates of biomass (standing stock) for each species population were calculated from estimates by size/age group, average lengths, and length-weight regressions obtained in representative years. Biomass of young bluegill could not be estimated in some years; this may have caused the estimates of total bluegill biomass to be low by approximately 20%.

The number of eggs produced annually by adult yellow perch was estimated by the method described earlier (Schneider 1983) which is based on fecundity and population estimates prorated to spring. The computation was made for yellow perch because the adult population was so sparse that egg production may have been limiting recruitment of YOY. Numbers of mature walleye and bluegill did not appear to be potentially limiting their recruitment success.

Additional information about population trends and fishery characteristics was provided by a catch survey which operated continuously from 1978 through 1991. Nearly all fishing occurred mid-May to September. Anglers were required to obtain a free permit from the Headquarters of the Rifle River Recreation before fishing, and after fishing to report their effort and number and size of fish harvested and released. Some non-compliance occurred (Schneider 1983), but follow-up phone calls suggest no significant error. These reports provided a useful approximation of numbers of fish harvested. From 1979 through 1992 there was a 14-inch (356 mm) mininum size limit (MSL) on walleye and no MSL on bluegill or yellow perch. Angling harvest was discontinued in 1992 and 1993 to measure its effect on adult fish. Catch-and-release angling was initiated in 1994 to optimize the fishing opportunity at this small lake.

Differences in population and fishery statistics between years when bluegill were present and years when bluegill were absent were tested for statistical significance with a Students' *t* test. Results are expressed as exact probabilities (P), with $P<0.10$ accepted as a clearly significant statistical difference. Estimates for each year were treated as independent observations of steady state conditions.

Stomach contents of fish were examined by species and size to determine feeding niches, potential competition, and rates of predation. In 1975-78, 64 walleye and 159 yellow perch collected on four dates were examined in conjunction with harvesting (Schneider 1979). In 1988-94, extensive samples were taken on 5 spring dates and 12 fall dates. In total, 862 walleye, 472 bluegill, and 500 yellow perch were examined. Only fish less than 75 mm TL were sacrificed; the stomach contents of larger fish were flushed out with pulses of water from a garden sprayer with very little mortality (Foster 1977; Schneider 1993). Food items were identified and enumerated under a binocular microscope. Maximum and minimum lengths of intact food items were measured. The lengths of prey fish were adjusted for shrinkage by factors of 6% for perch and 9% for bluegill to obtain an estimate of their live length. Shrinkage factors were based on lab experiments with food items of known length (Schneider and Breck 1993 and unpublished data). Weight of food eaten, by food type and predator size, was estimated from median lengths, numerical counts, and length-weight curves as described by Schneider (1993). Results were expressed for each food type in terms of frequency of occurrence, particle size, number per fish, and dry weight per fish.

Size of prey fish eaten was compared to two measures of the predator's mouth, estimated gape and maximum gape (Schneider and Breck 1993). Estimated gape was the mouth width of walleye and yellow perch as measured by caliper; maximum gape was the height of the largest bluegill which would slide into a walleye’s mouth.

Ranks of year class strength were determined for walleye, yellow perch, and bluegill. Ranks were primarily based on fall mark-recapture estimates of YOY. For years when such estimates were unavailable, a comparable rank was assigned based on CPE of YOY or relative abundance at older ages. For walleye, 3 year classes were totally missing, and all were given a rank of 1. Explanations for year class variations were sought by examining fish community changes and annual weather variations. Data on air temperature, wind, precipitation were primarily obtained from the US Weather Service station at Lupton (3 km from Jewett Lake), with missing data obtained from stations at Mio or West Branch (22 km) or Houghton Lake (48 km).

Temperature, and perhaps precipitation, influence the overall productivity of aquatic systems, and may effect annual fish growth and survival. Indices of temperature examined for the growing season (April-September) were deviations from average temperature and cooling degree days (base=18.3 °C). Severity of the preceding winter (November - March) was indexed by heating degree days (base=18.3 °C). Precipitation deviations in March-June, March-September, and the preceding September-May were considered. The September-May deviation was assumed to be an index of spring water level because Jewett Lake has no outlet.

Temperature and wind influence fish spawning, eggs, and fry. Critical periods are April-May for walleye and yellow perch, and June for bluegill. Walleye reproduction in Jewett Lake could be especially vulnerable to weather effects because of the poor quality spawning substrate. Expected to be unfavorable to both walleye and yellow perch are cold temperatures which would delay incubation, hatching, and the onset of feeding, and strong winds which might cause displacement or siltation of eggs.

For walleye, dates of spawning, egg incubation, and hatching were estimated for each year as follows. Date of ice-out at Jewett Lake was estimated to occur about 1 week prior to ice out at lakes Cadillac and Mitchell if air temperatures were warming. Data for these larger lakes was obtained from The Cadillac Evening News. Walleye spawning was assumed to begin on the next warming trend when water temperatures probably reached 7 °C. Length of the walleye incubation period and date of hatching were calculated from Hartman's regression (Colby et al. 1979) at about 33 days for water temperatures of 7.2 °C, 20 days for 10 °C, and 12 days for 12.8 °C. Average daily air temperature was substituted for water temperature. Optimum water temperatures for early life stages are reported to be 6-9 °C for egg fertilization, 9-15 °C for incubation, and 12-20 °C for larvae (Hokanson 1977). However, only extreme deviations are likely to be lethal. I considered average temperatures >10 °C on the calculated hatching date to be favorable for fry feeding and survival. Warm average temperatures over the next 14 days were also considered to be favorable. Another approach was to examine temperature trends from the estimated walleye spawning date to day 31; a gradual warming trend was expected to be favorable (Busch et al. 1975).

For yellow perch, spawning was assumed to begin on a warming trend when water temperatures may have reached 10 °C . Dates of spawning and hatching overlapped those of walleye because their thermal requirements are similar. (Hokanson 1977). The estimated dates and temperatures are rough approximations because egg temperature does not closely follow air temperature. Furthermore, observations made on eggs and fry at Jewett Lake in some years indicated that spawning (and hatching) was sometimes spread over a couple of weeks. Also critical to the survival of walleye and perch fry is zooplankton food, which must be available within about 9 days at 10 °C or 5 days at 15 °C (Hokanson 1977). No direct measurement of plankton was made at Jewett Lake, but plankton blooms are often stimulated by warming weather.

Graphical and regression techniques were the methods used to determine relationships among variations in year class strength, growth, and weather.

Populations and fisheries for bluegill, walleye, and yellow perch were simulated by applying Clark's (1985) TROUT DYNAMICS model. Modeling provided both reality checks on the empirical estimates and quantitative predictions, under steady-state conditions, of (a) the alterations in yellow perch dynamics caused by bluegill and (b) the effects of sport fishing regulations. The fishing regulations existing during the harvest period (1978-91, referred to as baseline) were modeled first, then catch-release (C-R) regulations were simulated. In addition, for walleye no minimum size limit (MSL) and 381-mm (15-inch) MSL were simulated. All simulations were computed weekly for 17 years, thereby assuring the long-term equilibrium had been achieved. Small fish were assigned reduced fishing rates and an incidental hooking mortality of 10% was assumed. Virtually all fishing occurred May 15 to September 30, with a peak in June-July. All growth in length occurred from mid-May to mid-October, with assumed peaks in early June and early September.

The models required or produced the following data: average rates of growth, natural mortality, fishing mortality, and recruitment, plus average statistics for size and age structure of populations and sport harvest. For the baseline bluegill model, starting data were observed average length-at-age and observed average age-specific mortality rates. Then recruitment and fishing rates were scaled by trial-and-error so that predictions matched the observed characteristics of the fishery in 1989-91. For the baseline walleye model, representative of 1987-91, starting data were observed average length-at-age, recruitment to age-0, and total mortality. Then fishing mortality was scaled to fit observed fishery data. Yellow perch dynamics were modeled for conditions before and after bluegill establishment. Perch models started with observed average length-at-age and observed average number per age group. Then by trail-and-error, mortality rates were selected which gave the best calibration to average fishery characteristics. To simulate the effects of C-R regulations, baseline models were rerun with the same instantaneous rates of natural mortality (M) and fishing mortality (Q) but all simulated catches were returned to the simulated populations.

Results

Basic data for the period 1975-95 on population estimates by size and age groups, population biomass, and length at age are given in Appendix 1 for bluegill, Appendix 2 for yellow perch, and Appendix 3 for walleye. Data from the catch survey is in Appendix 4, and selected spawning and weather data are in Appendix 5.

Bluegill dynamics

The bluegill population was established by a small number of adults (probably introduced by anglers) which reproduced very successfully in 1986 and 1987. Large numbers of YOY were produced each subsequent year, but especially in 1990 and 1991 (Table 1). The weakest year class was produced in 1992, which was the extremely cool summer following the volcanic eruption of Mount Penetobo, Philippines. In

1992, the number of degree days above a base of 18.4 °C was 60% below the 1976-94 average (Appendix 5). Otherwise, year class strength was unrelated to weather parameters.

Total biomass of bluegill quickly increased to 30 kg/hectare in 1987, then increased to more than 50 kg/hectare in 1992 as fish in the very strong year classes grew (Figure 1). Bluegill quickly became the dominant member of the fish community, comprising 52% of all fish biomass (Table 2).

Growth of individual bluegill was slow the first year of life, then exceeded the State of Michigan average (Figure 2). Average length at age declined late in the study due to the strong 1991 and 1992 year classes and high total biomass, and it appeared the population would stunt. However, a sample in 1995 indicated these cohorts no longer dominated, growth was near the State average (Figure 2), and many large bluegill were present. Growth of YOY bluegill tended to be better in warm summers (June - September, R^2= 0.32, P=0.16).

Total mortality of bluegill was relatively high at all ages and very few survived to age 5. Mortality (A) from fall age 0 to fall age 1 was 0.92 (N=2 cohorts). During this interval, bluegill grew from about 36 to 109 mm TL and were vulnerable to walleye and yellow perch predation (see *Diet Analysis*). Average mortality from fall age 1 to fall age 2 was still high, 0.91 (N=4). Judging from the length of these fish (average length increased from 102 to 180 mm), some of the mortality was due to angling and virtually none to predators. The strong 1990 and 1991 cohorts had lower mortality, 0.56 (P <0.01), even though they were smaller fish (grew from 74 to 107 mm) and more vulnerable to predation. Age 2 and older bluegill cohorts exceeding 152 mm TL experienced mortality rates of 0.76 when angling was permitted (N=5) and 0.49 when angling was prohibited (N=5); this is a not a statistically significant difference due to high annual variation.

By 1989, bluegill outnumbered walleye and yellow perch in the fishery (Appendix 4). The availability and harvest of large bluegill varied considerably in subsequent years (Figure 3). The average harvest was 243 bluegill per summer, and the residual fall population of bluegill >152 mm averaged 448 fish (Table 2). Protection from harvest, beginning in early 1992, led to an increase in numbers of larger bluegill (Figure 3), especially of those over 203 mm. By 1995, the population had a "superior" size structure according to a bluegill classification scheme (Schneider 1990).

Yellow perch dynamics

The number of fall YOY from natural reproduction (1976-93) varied from 3,200 to 25,000. In 1987, at a very low point in the abundance of adult perch, there were only about 20 mature females. Yet, variation in YOY was not related to number of adult perch (Figure 4) nor to weather indices. It was also unrelated to total fish biomass and walleye year class strength. Numbers of YOY surviving to fall improved by an estimated 42% (P=0.35, NS) in years when bluegill were present (Table 2), perhaps because abundant bluegill buffered them from predation.

In 1976-83, yellow perch grew above the State average rate throughout life, reaching a length of 178 mm during their third growing season (Figure 5). In 1987-93, in the presence of bluegills, growth in length of individual perch during their first and second years slowed significantly (Table 2). Also, their average weight-gain increment for the first year declined from 7.4 to 3.3 g, and for the second year from 34.6 to 20.9 g. However, growth of larger perch improved, and after four growing seasons average length-at-age had caught up to the pre-bluegill average.

Mortality rates of yellow perch were high during every age and few perch lived to age 5. Mortality (A) from age 0 to age 1 declined slightly (P=0.23) from 0.92 (N=7) in 1976-82 to 0.84 in 1987-93 (N=3). Apparently, bluegill buffered some of these small perch from intense predation by walleye and adult perch. Total mortality rate from age 1 to age 2 was unchanged, 0.94 (N=4) initially and 0.92 (N=4) with bluegill present. Some were large enough to succumb to anglers; others were small enough to die from walleye predation. Age 1-2 total mortality declined to 0.44 (N=1, P<0.01) when protected from anglers in 1992. The total mortality of age 2 and older perch was 0.87 (N=9) irrespective of bluegill presence. These were large perch that were vulnerable to anglers but too large for walleye to ingest. Age 2+ mortality dropped markedly when protected from anglers, to 0.22 (N=3, P<0.01). Perch mortality rate did not appear to be related to perch year class strength or walleye biomass.

The net result of the changes in recruitment of YOY, growth, and mortality was that average yellow perch population biomass changed little (-20%, P=0.38) due to the addition of bluegill to the community (Figure 1 and Table 2). In addition, there was a substantial decline in harvest and abundance of large perch (Figure 6 and Table 2). Average angler harvest declined by 76% (P=0.13) and the residual fall population of perch >178 mm declined by 71% (P=0.03). The number of large perch doubled when harvest was banned in 1992-93.

Walleye dynamics

For walleye, natural reproduction began in 1978 when some of the walleye fingerlings stocked in 1975 matured (Table 1). The number of naturally produced YOY varied from 0 to 249 in the fall. Bluegill had no apparent effect on walleye young until 1992, when bluegill population biomass first exceeded 250 kilograms. The increase in bluegill biomass was triggered by strong year classes and protection of all fish from sport harvest. Two relatively weak bluegill year classes occurred after 1991, but walleye year classes continued to fail through 1995. Perhaps bluegill biomass was still excessive, but weather may have also been a factor in the 1993-95 failures. Years when air temperatures during incubation varied more than 27.8 °C within 1 day usually produced poor walleye year classes (Table 1 and Appendix 5). Out of 5 years with large temperature fluctuations, walleye year class ranks were 1,1,1,2, and 4. Neither precipitation, wind (up to 85 km/h), nor any of the average temperature indices were clearly related to walleye or perch year class strength.

The growth pattern of walleye in Jewett Lake relative to the State average was rapid in early life then slow (Figure 7). In 1976-83, on a diet of perch and miscellaneous food items, walleye growth was above the State average for 3 seasons, until about 350 mm TL. In 1987-93, with the addition of bluegill, walleye growth significantly improved, beginning with YOY (Table 2 and Figure 7). These walleye retained a length-at-age advantage until age 6. However by age 4 (about 380 mm) their average length had also fallen below the State average.

Mortality of walleye was low after fall of age 1 was reached (Schneider 1983). One tagged fish is known to have lived to age 14. Mortality rate remained constant throughout life and was well represented by a straight line on a logarithmic graph (Figure 8). Shown on the graph are successive population estimates for the 1975 year class, which could be easily aged from their stocking clip, and average population estimates at age for the native 1981-93 year classes, which were aged with uncertainty from scales. The mortality estimates agree: annual total mortality rates (A) were 0.311 (instantaneous rate Z=0.373) for the 1975 year class and 0.298 (Z=0.354) for the pooled 1981-93 year classes.

Walleye were easily caught in the first year of fishing, but were difficult to catch thereafter even though the lake is very small and was fished at the substantial rate of 148 hours/ha (Appendix 4). During 1978, very limited effort produced spectacular fishing in which 18% of the population was caught in May (all released) and 21% in July (all harvested). In 1979-81, exploitation rate dropped to 8.9% based on tag returns (Schneider 1983). The pattern of low harvest continued, with reported catch representing just 17% of the residual fall population of legal-sized walleye (Figure 9). Average annual catches of walleye were 15.1 in 1979-86 and 16.2 in 1987-91 (Table 2). This insignificant 7% increase (P=0.77) in harvest only weakly reflected a large 54% improvement (P=0.01) in numbers of legal-sized walleye in the population (Table 2 and Figure 9). Total mortality declined about 5% when fishing was banned in 1992-93. Some walleye entered the fishery during their third summer, but most during their fourth summer.

Total biomass of walleye quickly expanded to 12.1 kg/ha by the fall of 1976 (Figure 1). It was relatively stable compared to bluegill and yellow perch biomass. As of 1993, addition of bluegill to the community had increased walleye biomass slightly (11%, P=0.28) due to improved growth (Table 2). However, this gain will be lost if recruitment of YOY walleye does not resume.

Diet analysis

Basic data for fall and spring diet samples are in Appendices 6-13 for bluegill, 14-21 for yellow perch, and 22-29 for walleye.

The roles of bluegill, yellow perch, and walleye in the Jewett Lake fish community can be inferred from what they ate. All of the major prey types—zooplankton, benthos and fish—were important to each species at some stage/size due to ontogenic shifts in diet. The important diet questions were what was the potential for competition, as inferred from degree of diet overlap and shifts in diet, and what was the frequency and selectivity of predation.

Bluegill.— A typical progression of diet with bluegill size was evident in fall samples (Figure 10). Copepoda were eaten by only the smallest bluegills. Cladocera predominated on a weight basis up to 100 mm TL. Mayfly nymphs, midge larvae, and midge pupae gradually increased in importance and predominated in mid-size bluegills. *Chaoborus* larvae, adult terrestrial insects such as flying ants, and small bluegill were unique to the diet of bluegill >152 mm. The presence of *Chaoborus* indicated foraging in the deepest water or during the nocturnal migration; the presence of adult insects indicated foraging at the surface. The bluegill prey were small (24-35 mm TL) and infrequent, but bulky. The spring diet samples were less diverse, with mayflies of slightly larger size the predominant item (Figure 10). Sizes of ingested Cladocera and midge larvae were also related to bluegill length (Figure 11). Bluegill from 25 to 127 mm TL ate small as well as large cladocera; that may have given them a competitive advantage over larger bluegill for that prey type. For midge larvae, the smallest bluegill ate very small items, but all bluegill >50 mm seemed to have similar capability. Likewise, Werner et al. (1983) noted 50-mm bluegill can handle nearly all invertebrates available to larger bluegill.

Yellow perch.— In the fall diet, zooplankton was important only to perch <75 mm TL, and benthos only to perch <127 mm (Figure 12). Diet of large perch consisted almost entirely of small perch and bluegill. In the spring diet, benthos was the only food up to about 203 mm TL, then small perch became prominent (Figure 12). Bluegill were not found in perch stomachs during spring. A perch as small as 78 mm had eaten a bluegill, a remarkable feat as the bluegill was about 27 mm TL when ingested (Figure 13). The longest bluegill eaten was 84 mm, also relatively large compared to the estimated gape of the perch mouth. The cannibalized perch found in perch stomachs were all YOY size (Figure 14). The smallest perch (like the smallest bluegill) ingested a wider size range of cladocera (Figure 11). However medium and large perch ate much larger midge larvae, and there was minimal overlap between 50-100 mm perch and perch >178 mm (Figure 11).

Walleye. — The fall diet consisted almost entirely of percids and bluegill across all sizes of walleye present in the lake during that season (Figure 15). All of the percids which could be identified to species were yellow perch. The spring diet was predominately percids, with important contributions of insects, crayfish, and frogs (Figure 15). A few walleye 15-241 mm TL were identified in the spring food remains. Surprisingly, bluegill were not eaten in spring. The bluegill eaten by walleye ranged up to 137 mm TL, but most were small (Figure 16). Perch as large as 190 mm TL were found in walleye stomachs, but most were YOY size (Figure 17). Scars, apparently made by walleye attacks, were sometimes observed on larger, living perch. Bluegill were sparse in the diet of walleye initially, but became prevalent by 1992 due to their high abundance in the lake. Walleye preferred yellow perch. In fall 1992 diet samples of prey fish <100 mm TL, the ratio was 42 bluegill to 15 perch (2.8:1). The approximate ratio for this size group in the lake was about 52,000 bluegill to 5,400 perch (9.7:1). Thus, walleye selected perch over bluegill by a factor of 3X. Selectivity (or reduced vulnerability) is also indicated by the presence of perch and the absence of bluegill in spring diet samples even though bluegill were much more abundant.

Diet overlap.–The diet data generally demonstrated progressive increases in food particle size with consumer size. However, it is instructive to simplify by identifying size groups of prey and consumers to illustrate potential interactions (Table 3). Because diets were not sampled throughout the entire year, other sources of information were used to fill in suspected competitive and predatory interactions for the bluegill+walleye+yellow perch community in Jewett Lake. For example, large zooplankton is likely a source of competition, probably in June, among small walleye (about 15-49 mm), small perch (15-74 mm), and small bluegill (15-99 mm, especially 25-99 mm age 1+). Even the walleye is vulnerable to predation of various types at all size stages.

Diet differences and shifts.– Small and medium yellow perch shared cladocera and benthos food resources with bluegill (Table 3), but there were some subtle differences. At lengths of 75-100 mm, bluegill took smaller cladocera (Figure 11), and this probably gave them an advantage. Larger perch (>127 mm) effectively avoided competition by shifting to a fish diet. Also, they were able to locate and take larger midge larvae than bluegill (Figure 11). Werner et al. (1983) also noted bluegill rarely ate midge larvae >14 mm long.

Comparable samples taken in fall 1975-78 show that perch diet had shifted in the presence of bluegill (Table 4). Among yellow perch 75-177 mm TL, the relative importance of benthic mayfly and dragonfly strongly decreased and the importance of bluegill and perch increased. The benthic diet was apparently better because perch growth at that size was better. While a diet of fish had the advantage of large particle size, benthos may have been more easily obtained, especially before bluegill were present. Large perch (>178 mm) fed heavily on fish during both periods, but shifted from 76% perch to 78% bluegill. Large perch grew well in both periods, and compared to smaller perch benefited from bluegill. Walleye also benefited in terms of growth by shifting their diet. Bluegill comprised 30% of their fall diet, 0% of their spring diet, and, as is the case for all species, their summer diet in years when bluegill were available is unknown.

Discussion

The bluegill demonstrated a remarkable ability to find and exploit an "open niche" in Jewett Lake. Total fish biomass doubled when bluegill were added with relatively minor effects (statistically insignificant) on yellow perch biomass (-20%) or walleye biomass (+11%). In general, the piscivorous stages of walleye and yellow perch benefited, the competitive stages did not. Growth of walleye and large perch improved, clearly from incorporating the added food resource into their diet, and possibly because the reduced growth of small yellow perch made them vulnerable as food items longer. As a result, the number of large walleye (>356 mm) in the population significantly increased (+54%), but anglers failed to harvest the gain (+7%). By contrast, the abundance and harvest of large perch declined greatly (71-76%) due to competitive interactions at smaller stages delaying growth. Delayed growth allowed mortality more time to reduce the population.

Small and medium perch were negatively effected by competition with bluegill for both zooplankton and benthos. This can be inferred from growth responses, diet overlap, and diet change. Competition for zooplankton is indicated by reduced growth of YOY perch, -22% by length and -55% by weight. In earlier experiments at Jewett lake, very large populations of planktivorous minnows had the same effect (Schneider 1972 and 1979). Zooplankton, principally cladocera, is the main food of young perch from hatching in May to 50-75 mm (usually in late August) in Jewett Lake (Schneider 1979 and Figure 12), as elsewhere. Bluegill utilize cladocera more extensively, over several years, from hatching (mostly in June) through a length of 100 mm (Figure 10), or beyond in some lakes (Schneider 1993; Theiling 1991). Consequently, the biomass of planktivorous bluegill was much higher than of planktivorous perch. Furthermore, bluegill ate smaller cladocera than perch. I conclude that smaller cladocera were an important part of the open niche the bluegill exploited, a niche which had not been fully utilized by perch or walleye. Small cladocera are an abundant resource in lakes.

The continued reduced growth of yellow perch from age 0 to age 1 indicates competition with bluegill for benthos. Weight gained by individual perch during that interval declined by 38%. Considerable diet overlap occurred between perch approximately 75-126 mm TL and bluegill approximately 100-152 TL. Furthermore, a shift in perch diet occurred after bluegill became established (Table 4). Competition for benthos and the availability of small prey fish apparently encouraged perch to switch to a fish diet at a smaller size than usual. Growth then accelerated and length-at-age caught up to the pre-bluegill average (Figure 5).

The effects of bluegill on the recruitment of age-0 walleye and yellow perch were subtle. Perch experienced no decline in number. Apparently, any extra mortality due to competition with bluegill or prolonged vulnerability to predators was offset by predators substituting bluegill for perch. No effect on walleye recruitment was apparent for several years, then four extremely weak year classes occurred in a row (1992-95).

Weather effects, always a possible cause of walleye reproduction problems, may have been important. Three out of four poor years had air temperature swings of >27.8°C during egg incubation. This correlation suggested that large fluctations in air temperature would be reflected in water temperature fluctuations large enough to cause direct mortality of eggs. However, subsequent (1996) observations on air and water temperatures at Jewett Lake (Appendix 30) coupled with experiments at Wolf Lake State Fish Hatchery (J. Copeland, pers. comm.) indicate it is very unlikely that natural occurring temperature fluctuations cause direct mortality of walleye eggs or fry. During the walleye egg incubation period of 1996, air temperatures at Jewett Lake fluctuated as much as 27.2°C over 24 hours, yet water temperature at the spawning substrate varied no more than 6.7°C (Appendix 30). This is too small a variation to harm eggs. Among experimental lots of walleye eggs at the Wolf Lake Hatchery, water temperature drops of 8 °C and increases of 14°C had no effect on rates of egg eye-up or fry swim-up. Temperature swings of 20°C did not affect eye-up rates, but caused crippling and reduced swim-up (11-42% among experimental lots compared to 70% for control lots). In an Ohio hatchery, Allbaughan and Manz (1964) noted a mortality (50%) in only 1 out of 8 lots of walleye eggs when temperature abruptly increased by 19°C.

However, high bluegill biomass, over 50 kg/hectare, was also a correlate and is believed to have been more important. Possible mechanisms for bluegill to negatively effect YOY walleye include predation on walleye eggs or fry and competition for zooplankton. The negative effect need not be large because many bluegill were present and walleye typically have mediocre egg hatching rates and high larval natural mortality rates (Colby et al. 1979). In Jewett Lake, the number of YOY surviving until fall has never exceeded a few hundred.

Bluegill predation on walleye eggs or fry has not been observed at Jewett Lake, nor at other waters to my knowledge. Walleye eggs would be vulnerable at Jewett Lake from late April to mid May, but bluegill diets then have not been studied. However in aquaria tests, bluegill 37- to 155-mm TL ate many walleye eggs from a sand and gravel substrate (Appendix 31). Fry would be vulnerable in late May to planktivores such as yearling and older bluegill, but none were identified in bluegill diets during a modest amount of lake sampling. One 15-mm fry was found in a walleye, and even minnows have preyed on fry (perch) in the past (Schneider 1979). However, experiments in aquaria clearly established that newly hatched walleye larvae (8 mm) are very readily eaten by bluegills (30-155 mm)(Appendix 31). One 64-mm bluegill ate 40 fry (2.6% of the bluegill's weight) in rapid succession. Furthermore, walleye fry were quickly digested. At 15.5°C, a full meal was evacuated from bluegill stomachs in 10-12 hours (Appendix 31). Given the high density of bluegill in Jewett Lake (and in many other lakes), predation by bluegill could easily impair walleye reproductive success.

Competition between bluegill and small walleye is likely also. Zooplankton availability is always critically important to walleye larvae after hatching (Colby et al. 1979), and large cladocera were important to fingerlings in

Jewett Lake until reaching a length of about 155 mm (Schneider 1983). Since walleye (and perch) hatch about a month before bluegill each year, the most serious competition is likely to be from yearling and older bluegill, which are better adapted planktivores. Walleye fry may starve outright, or experience delayed growth and remain too small to switch to feeding on yellow perch fry.

Yellow perch experienced a very similar timetable and set of constraints yet recruited successfully despite bluegill effects and very low numbers of adult perch. The only apparent difference between walleye and yellow perch dynamics is in the egg stage; fry and fingerlings have very similar temperature and food requirements. Yellow perch eggs are protected by a gelatinous matrix from predators and disease, avoid siltation by suspension on vegetation, and have a high rate of hatching success (Schneider 1972; Thorpe 1977). Walleye eggs lie loosely on the bottom, are more prone to predation, siltation and disease, and even under hatchery conditions have relatively low hatching rates, on the order of 50-70% (Colby et al. 1979; James Copeland, Wolf Lake hatchery, personal communication). This alone could explain why yellow perch typically enjoy greater recruitment to fall YOY than walleye.

Management Implications

Angling exploitation can have significant effects on size structure of fish populations and also on fish community dynamics, either by removing top predators or, more subtly, by altering competitive interactions. Computer modeling provided quantitative estimates of the effects of fishing on fish populations and reality checks on estimates derived from field data.

For walleye (Table 5), the models provided good agreement between observed and predicted data because the data set was long and relatively stable. Two important average instantaneous rates were derived for age 2 and older walleye: fishing (Q) was 0.17 and natural mortality (M) was similar, 0.18. The simulations indicated catch-release fishing (C-R) should increase walleye density 29% and double the number of walleye >381 mm TL in the population as compared to the baseline 356-mm minimum size limit (MSL). At the other extreme, no MSL had slight effect on the walleye population and fishing because small walleye had lower exploitation rates and grew quickly.

For bluegill (Table 6) and yellow perch (Table 7), the models did not match all empirical averages as well as for walleye. The panfish had more variable recruitment, growth, and mortality; consequently, long data sets were needed for reliable empirical averages. The models had the advantage of smoothing out such variation and representing the long-term equilibrium condition. Model predictions are that C-R would substantially increase sport catch (57%) and the density of large panfish (48-68%). It was observed that the models were very sensitive to small differences in mortality rate estimates for young fish; for example a 2% difference at age-0 swells to large differences in numbers of fish at older ages. The perch models reflected the greatly reduced abundance and harvest of large perch which were observed when growth of small perch declined due to competition with bluegill.

Across all species, catch-release should maximize fish density, predation on panfish, and fishing quality, as measured by potential catch rate. Those were the main reasons it was implemented at Jewett Lake in 1994. However, benefits derived from consuming fish were traded. An additional unexpected negative was that the accumulated bluegill biomass apparently contributed to the demise of walleye recruitment.

The experiments at Jewett Lake demonstrated that walleye have the predatory capability of maintaining "balanced" and "stable" panfish populations exhibiting good growth in specially managed lakes. A walleye-golden shiner *Notemigonus crysoleucas* combination also worked well and optimized the production of walleye alone (Beyerle 1971). Without a predator, both bluegill and yellow perch would have stunted at a size useless to anglers. Numerous experiments have demonstrated walleye can be successful in a wide variety of habitats. However, the strongest candidates for walleye management are lakes with lesser amounts of vegetative "cover", and northern lakes, which are more likely to have lower bluegill reproduction rates.

The combination of walleye and yellow perch (without bluegill) can produce a modest fishery. However, total fish production will be less than it's potential because some invertebrate food resources are poorly exploited (unfilled niches). Key characteristics are likely to be: low numbers of perch>178 mm TL because of high natural mortality of perch at every age; low perch brood stock due to high vulnerability of perch to anglers; low walleye harvest rates due to low vulnerability to novice anglers; production of few trophy walleye due to diminishing growth; high walleye survival in most types of waters; and possibly, successful natural reproduction by walleye in lakes which appear to have poor spawning habitat.

The combination of walleye, yellow perch and bluegill can produce greater total yield of fish by substituting many bluegill for some perch. Additional key characteristics are slower perch growth and reduced walleye reproduction. It is critically important to maintain adult walleye density high enough so that their predation can effectively reduce excessively strong year classes of bluegill and perch. If the planktivorous panfish become dominant, success of walleye natural reproduction (or stocking) will suffer and the system will spiral toward stunted panfish and walleye extinction. Such may yet be the fate of the Jewett Lake community unless walleye recruitment resumes in a year or two. There, reinstatement of bluegill harvest should help walleye recruitment. The desired community balance point is characterized by above average panfish growth, mediocre walleye growth, and very high walleye density. In Jewett Lake walleye density was 17 kg/ha (19 lb/ac), which included 21 walleye>356 mm TL per ha (8.5 fish >14" per acre). That is an exceptional density for a Michigan lake.

Similarly, walleye have the potential to improve the growth and size structure of preexisting populations of stunted panfish. One advantage of walleye (and perch) as bluegill predators is that they feed on them all winter (Schneider and Breck 1993). Managers report good success at improving the growth and size structure of yellow perch by walleye stocking. Benefits have been less predictable in stunted bluegill lakes because survival of small fingerling walleye is usually poor (Schneider 1989). However, very encouraging results are currently being obtained at six out of nine stunted bluegill lakes stocked with large fingerling walleye (Schneider and Lockwood, unpublished). Three of the lakes were first partially treated with antimycin to reduce the biomass of age 1-3 bluegill.

Acknowledgments

Special thanks to the staff of the Rifle River Recreation Area who, under the direction of Carl Slosser, John Lucas, and Robert Munn, operated the angler permit system and were supportive of this project over many years. Research technicians James Gapczynski, Alan Sutton, and Troy Zorn assisted with field work. Funding was provided through Federal Aid in Sport Fish Restoration (Project F-35-R, Study 629).

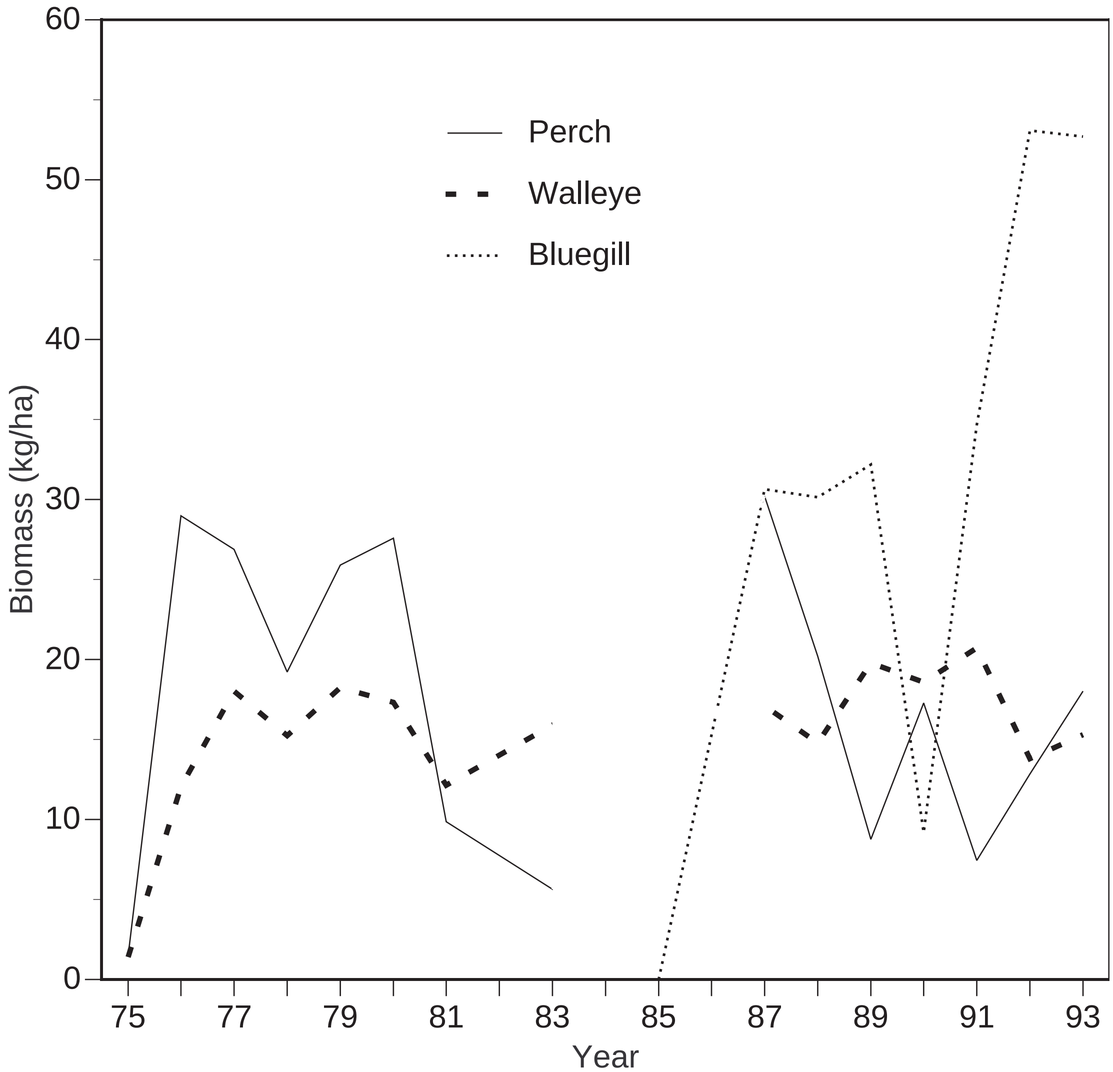


Figure 1.—Estimated population biomass of yellow perch, walleye, and bluegill in Jewett Lake, 1975-93. Bluegill estimates for 1990, 1991, and 1993 do not include YOY.

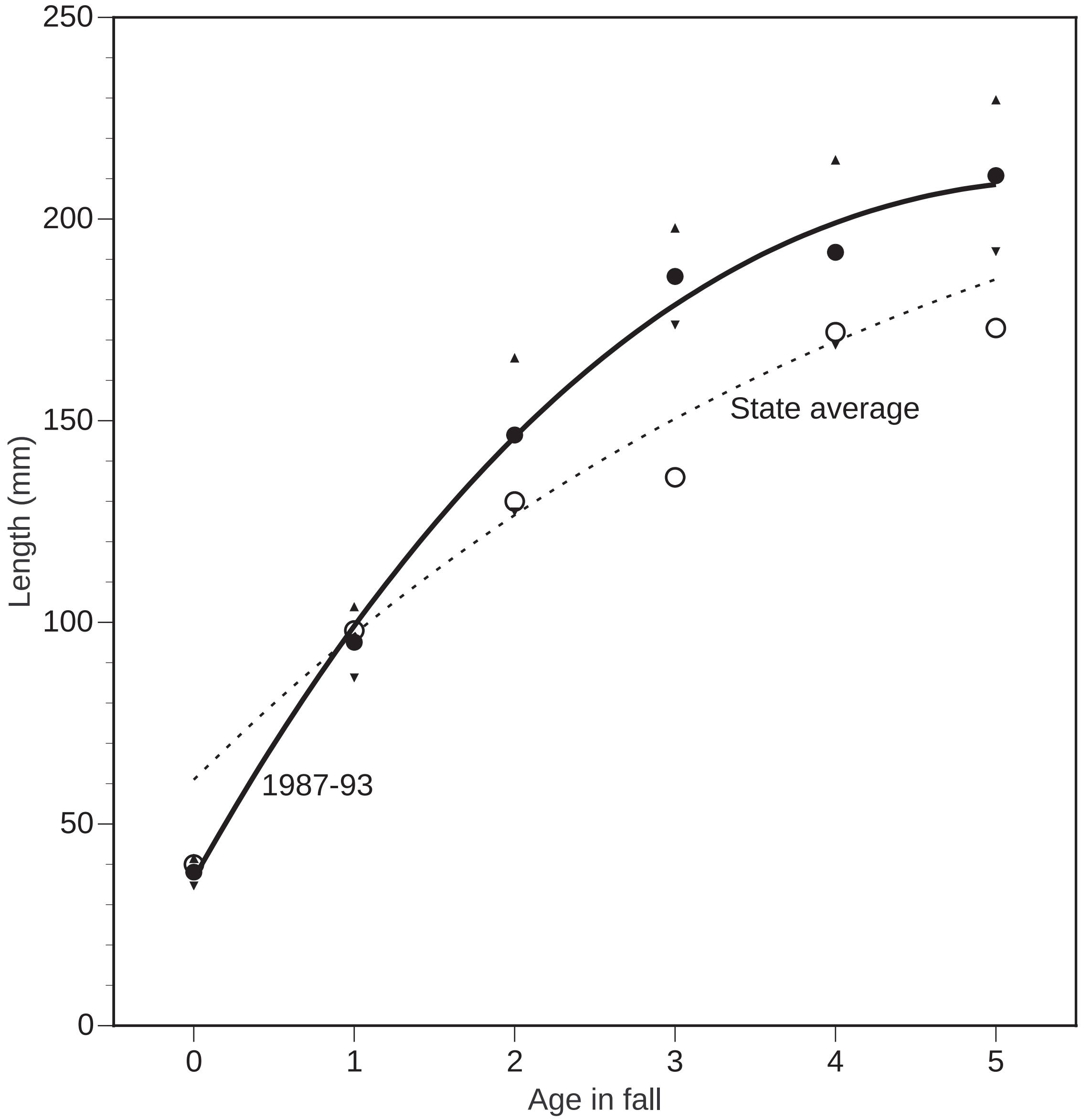


Figure 2.—Growth of bluegill in Jewett Lake in 1987-93 (solid line; solid symbols are means ±90% confidence limits) and in 1995 (no line; open circles). Also shown is the State of Michigan average (dashed line), which nearly fits the 1995 data points for age 1+.

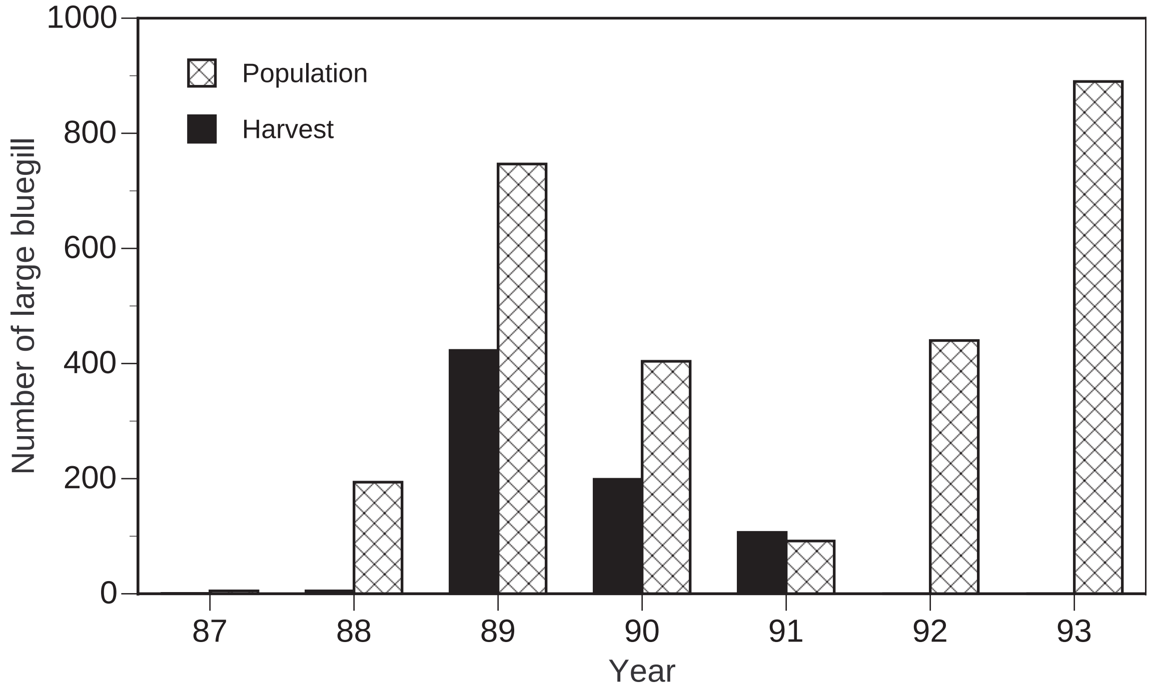


Figure 3.—Number of bluegill reportedly harvested by anglers during summer and estimated number of bluegill >152 mm remaining in fall populations, 1986-93. No fishing was allowed in 1992-93.

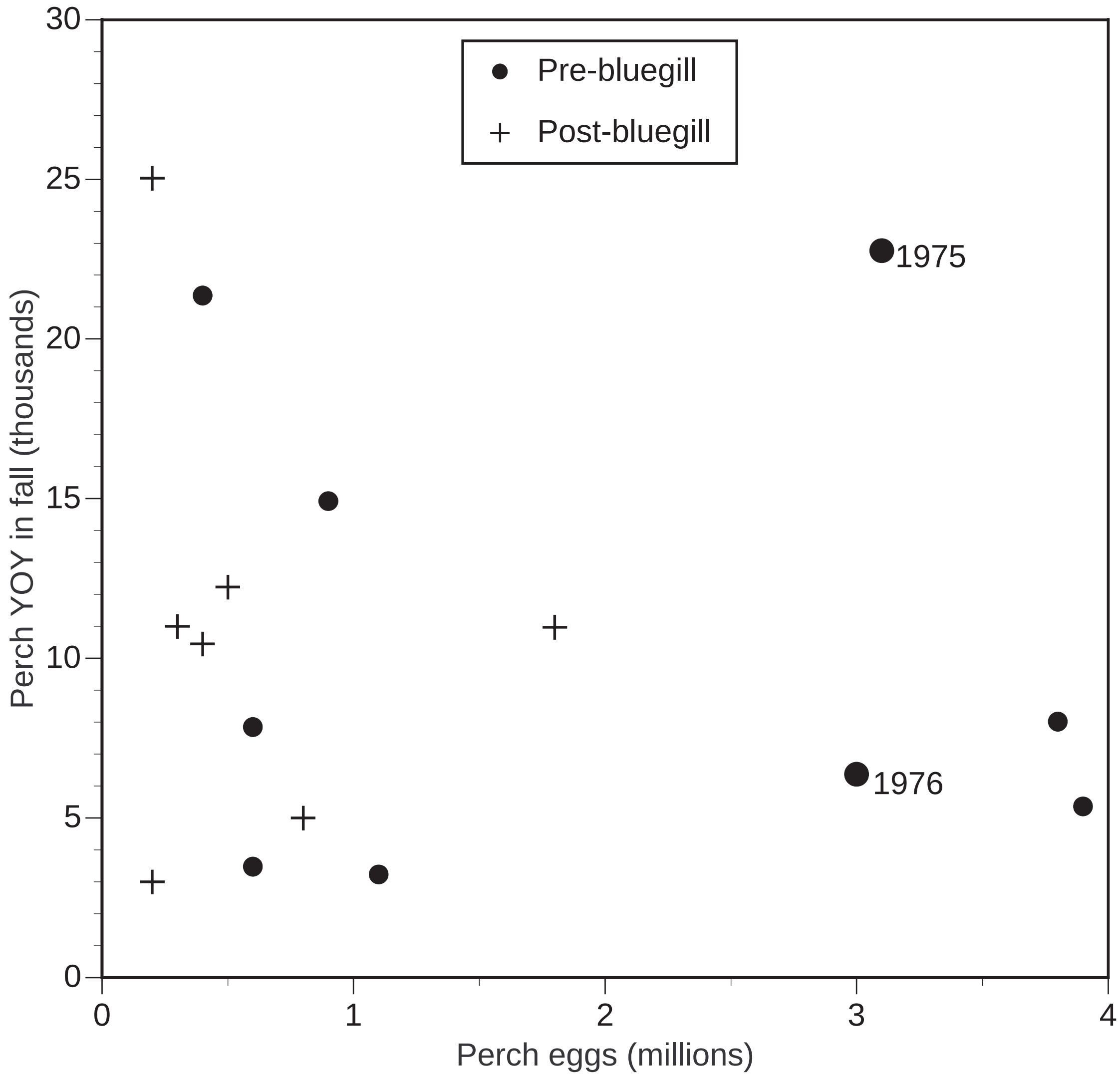


Figure 4.—There was no relationship between estimated number of eggs produced by adult yellow perch in Jewett Lake and estimated number of YOY in fall, 1975-93. Data for 1976-83 are before bluegill; data for 1987-93 are after bluegill. Data for 1975 is estimated number of eggs stocked (no adults present); data for 1976 are a combination of stocked eggs and fecundity estimates.

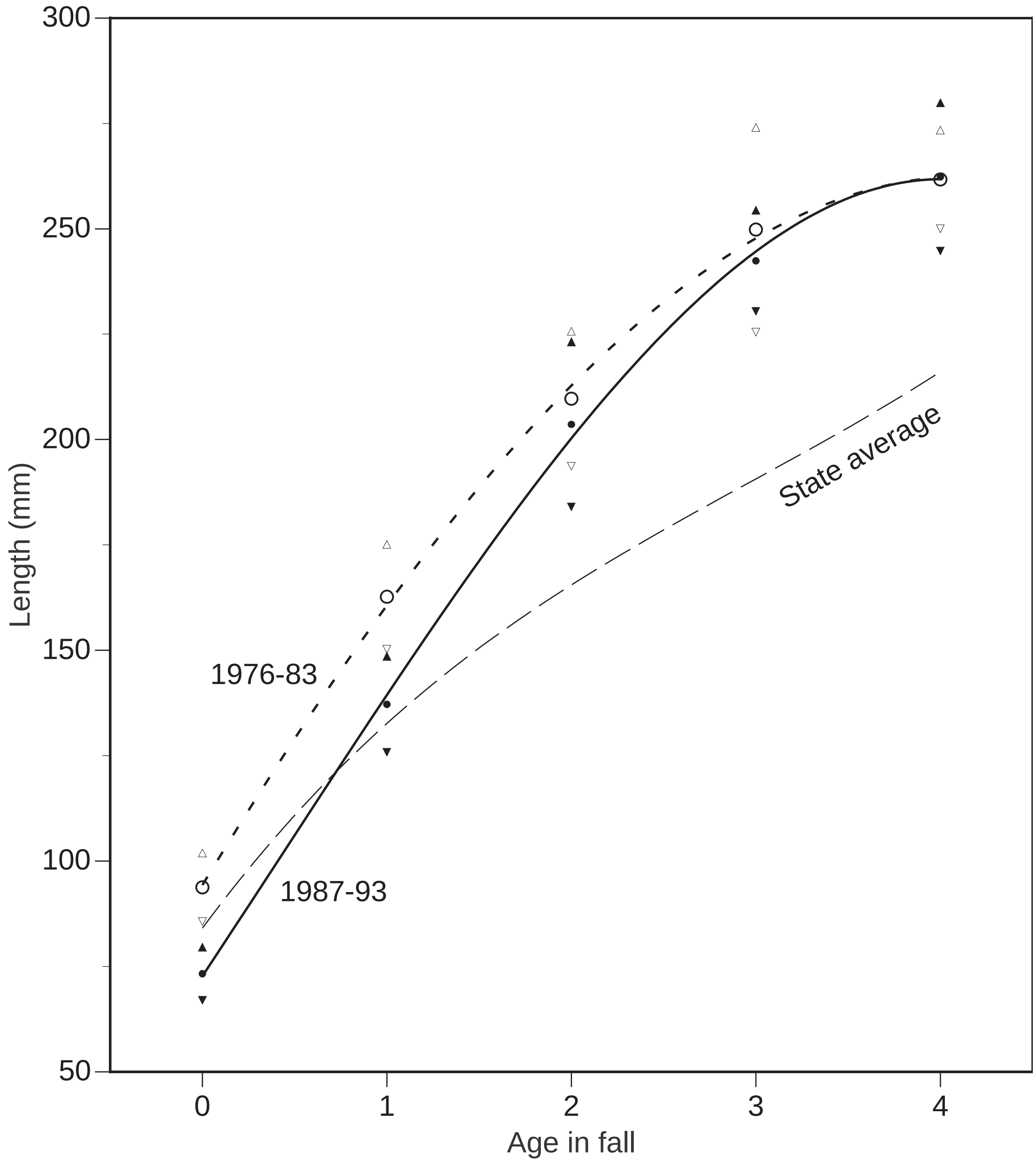


Figure 5.—Growth of yellow perch in Jewett Lake before (1976-83, open symbols and dashed line) and after (1987-93, solid symbols and line) bluegill were established. Symbols indicate mean length ±90% confidence limit. Also shown, as a long-dash line, is the State of Michigan average.

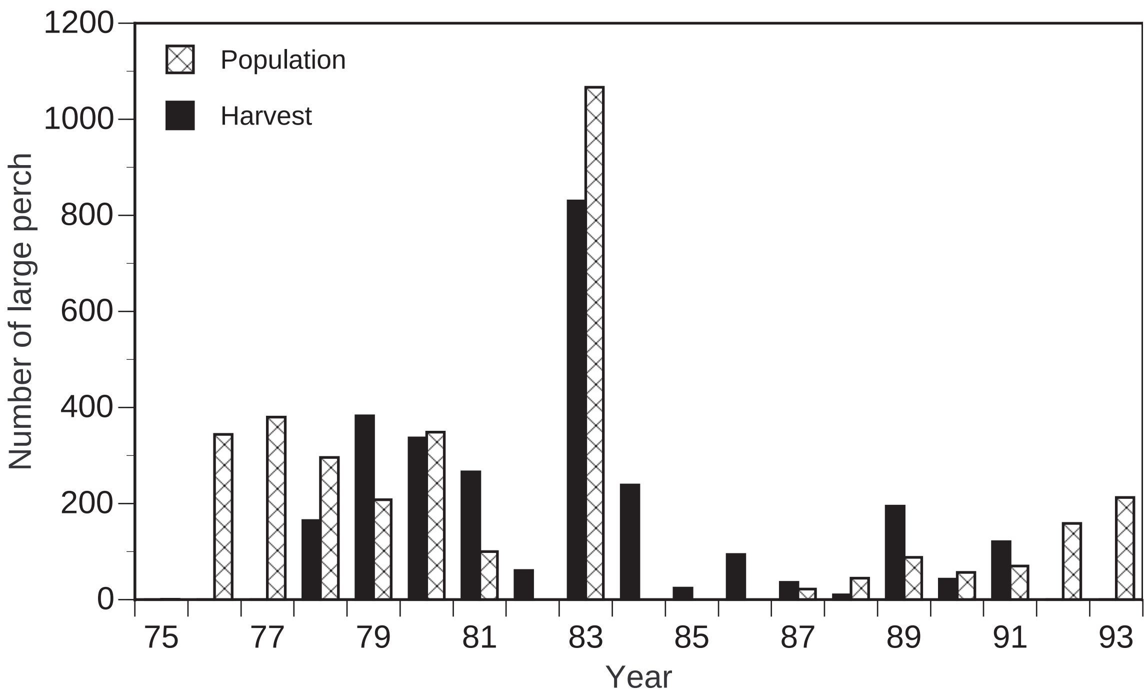


Figure 6.—Number of yellow perch reportedly harvested by anglers during summer and estimated number of yellow perch >178 mm remaining in the fall population, 1975-93. No fishing was allowed in 1992-93. No population estimates were made in 1982 or 1984-86.

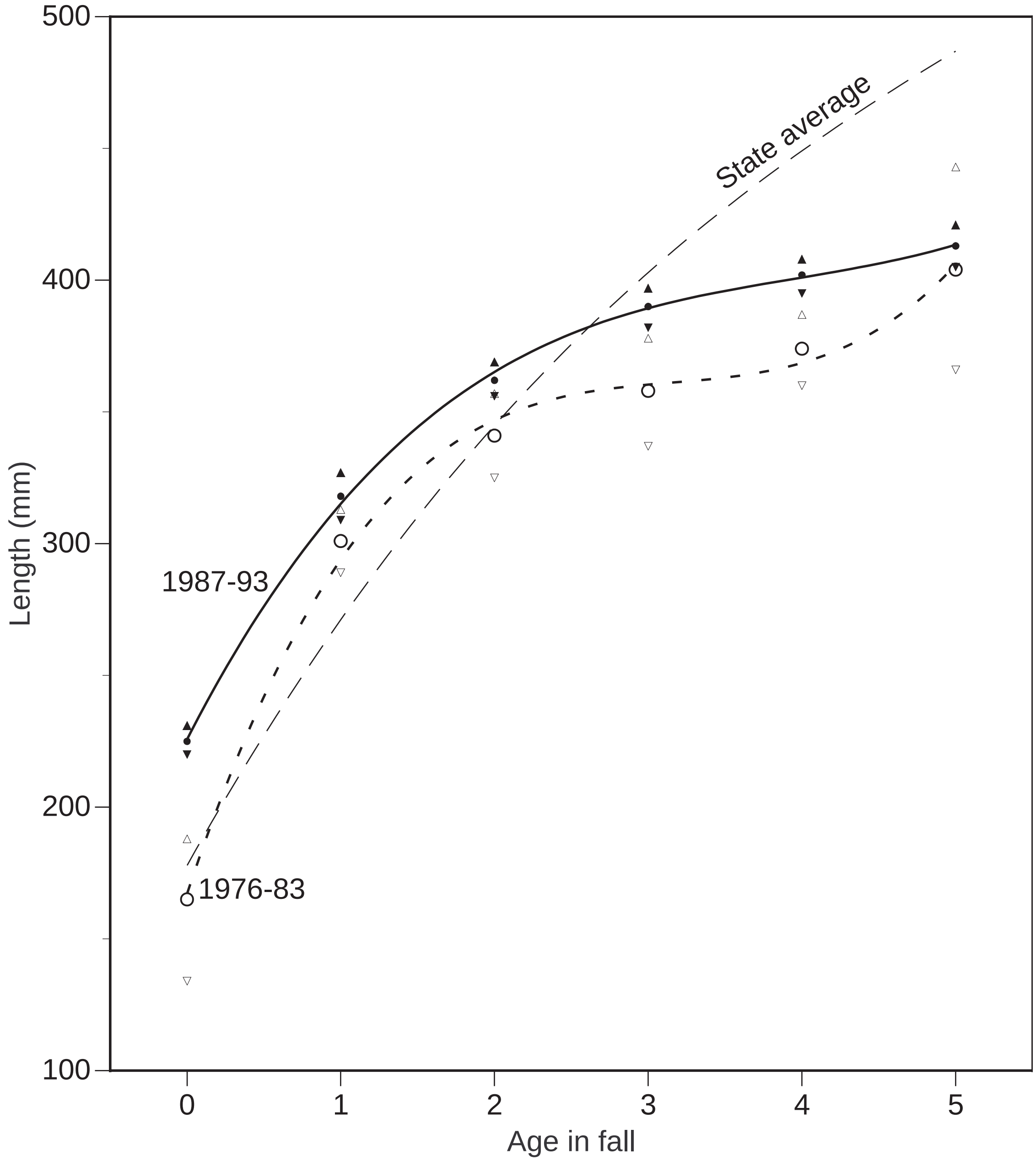
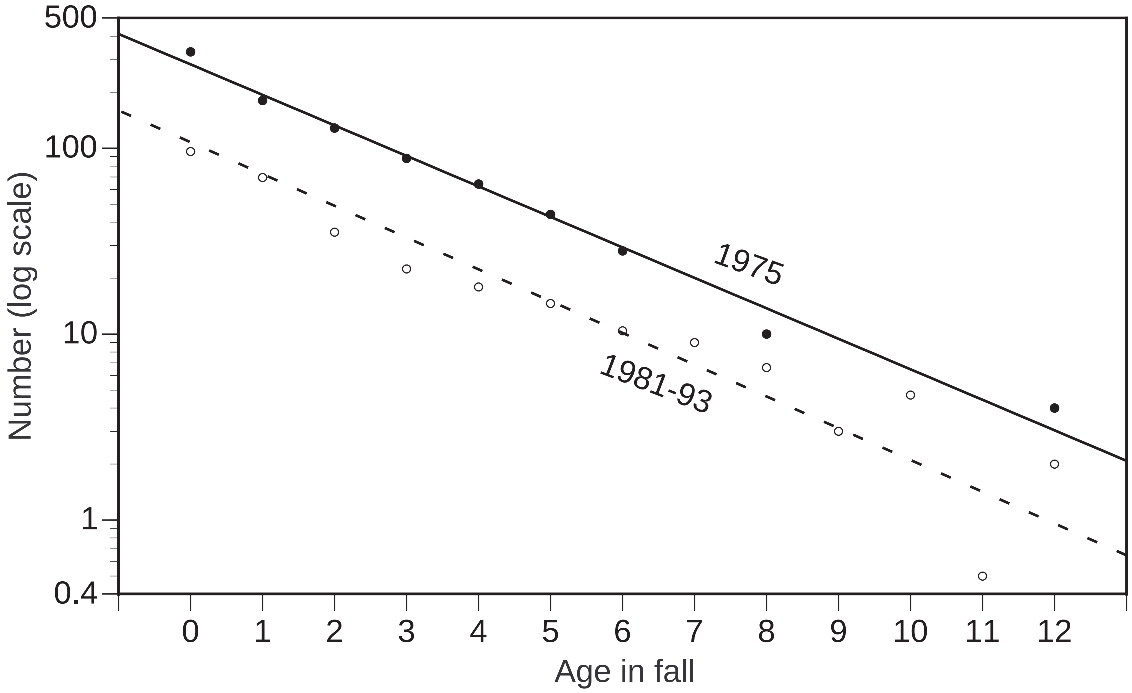
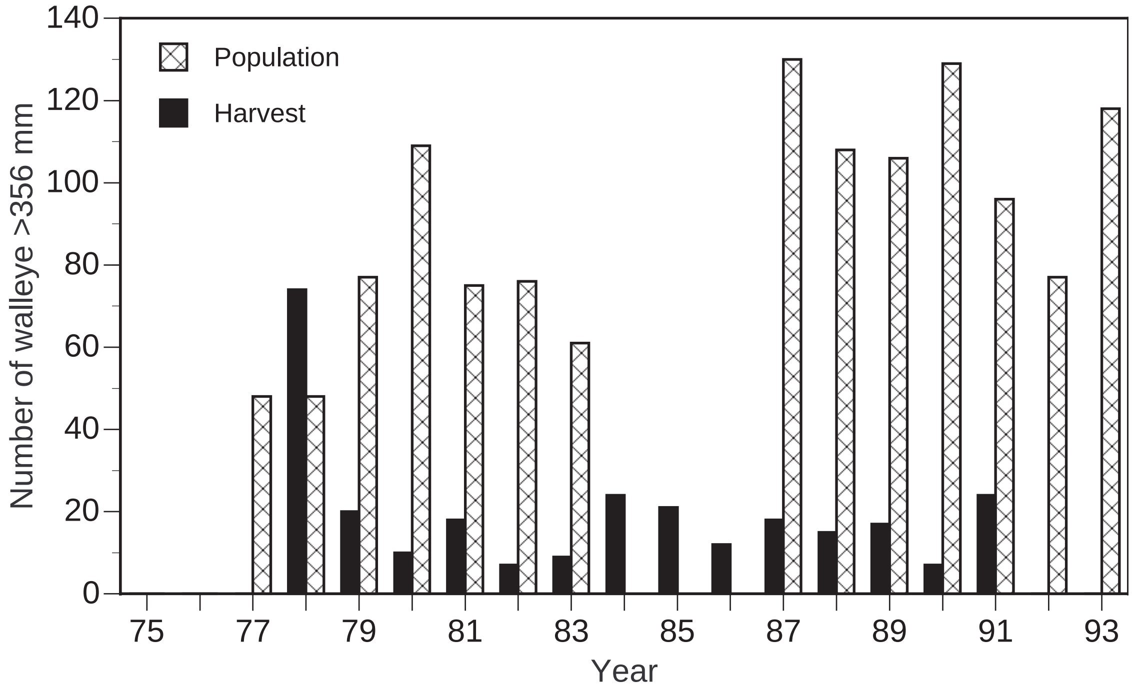


Figure 7.—Growth of walleye in Jewett Lake before (1976-83, open symbols) and after (1987-93, solid symbols) bluegill were established in Jewett Lake. Symbols indicate mean length ±90% confidence limit. Also shown (long-dash line) is the State of Michigan average.


500
100
10
1
0.4
Number (log scale)
1975
1981-93
0
1
2
3
4
5
6
7
8
9
10
11
12
Age in fall



Population
Harvest
Number of walleye >356 mm
140
120
100
80
60
40
20
0
75
77
79
81
83
85
87
89
91
93
Year

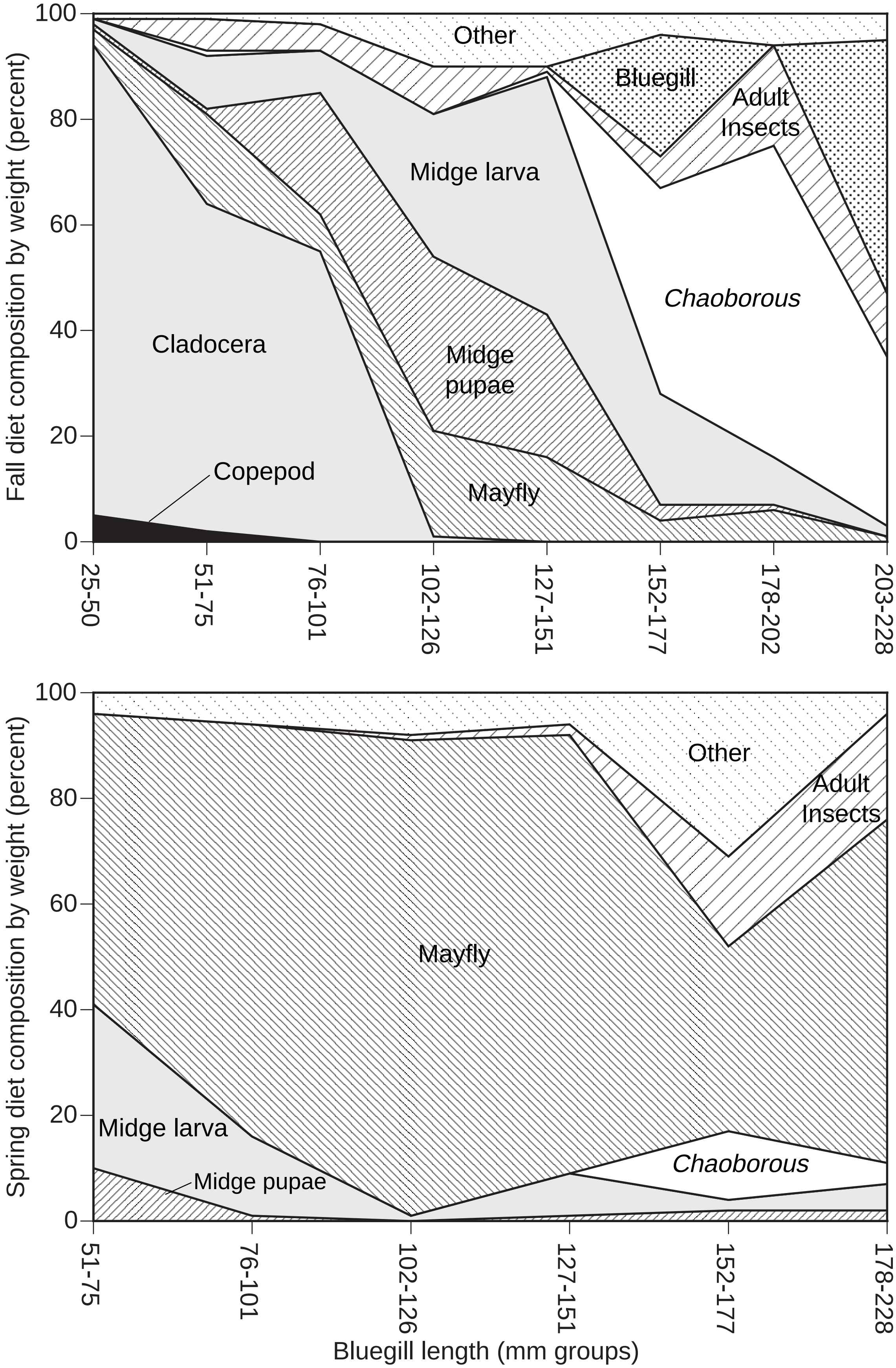


Figure 10.—Principal food types, by weight, of bluegill in fall (upper) and spring (lower).

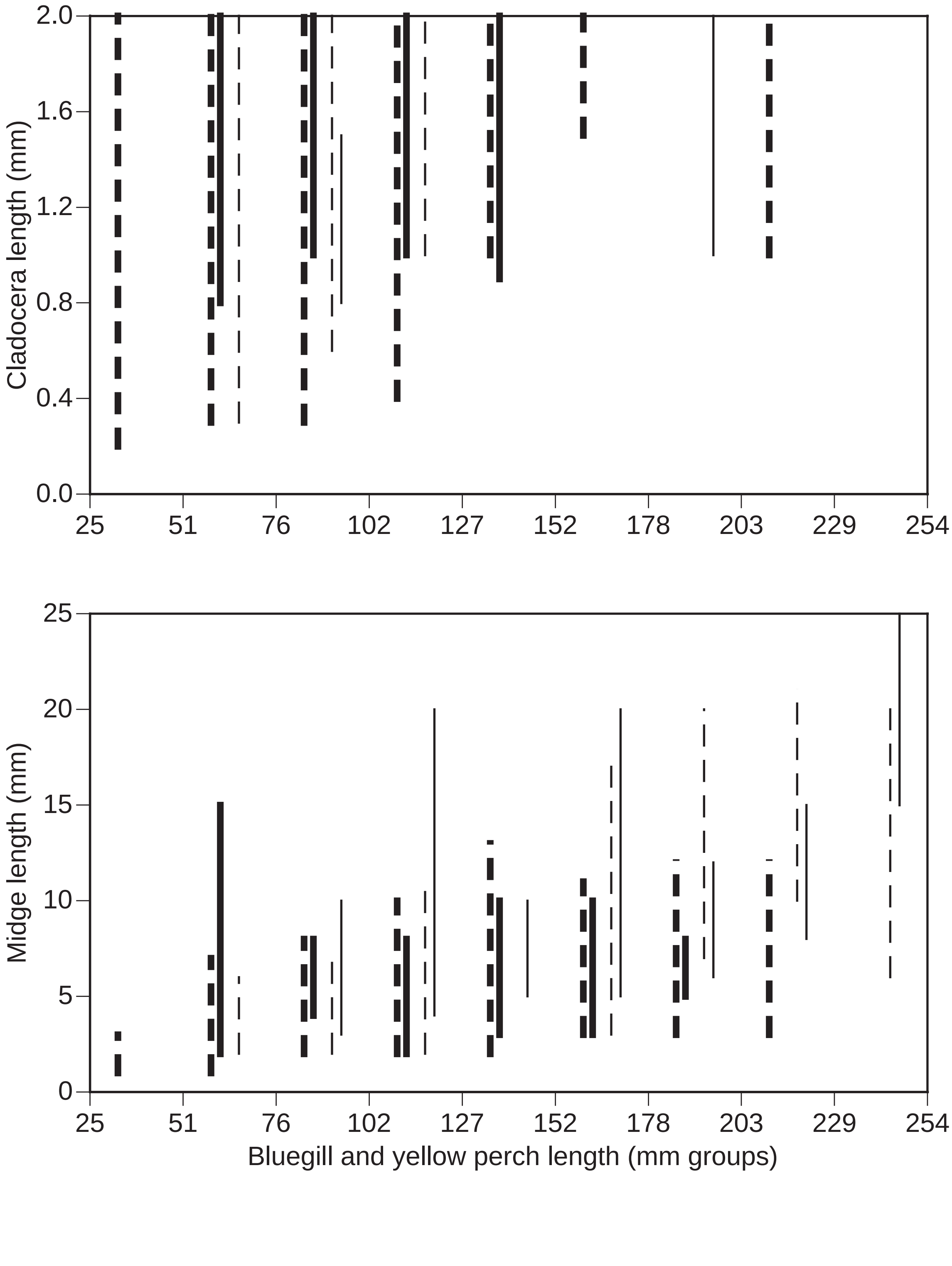
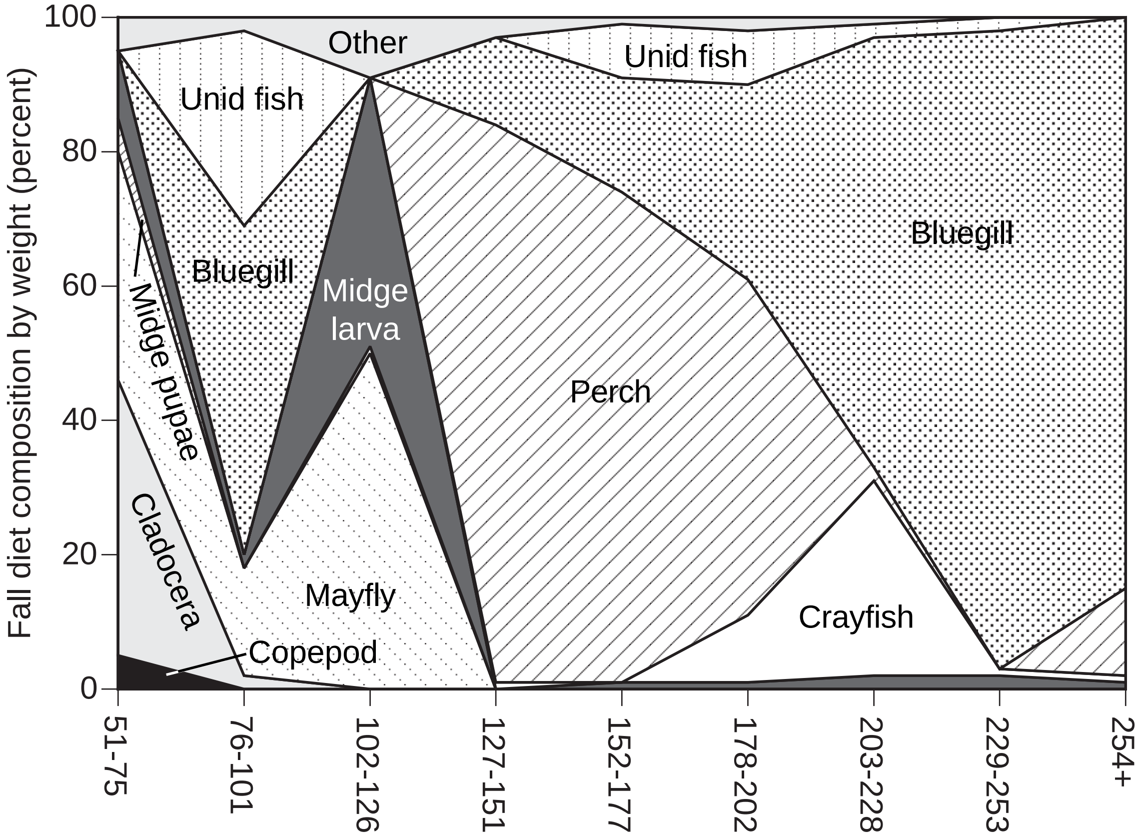


Figure 11.—Range in lengths of Cladocera (upper panel) and midge larvae (lower panel) eaten by bluegill (heavey lines) and yellow perch (light lines) in nine length groups. Solid lines indicate spring samples; dashed lines indicate fall samples.



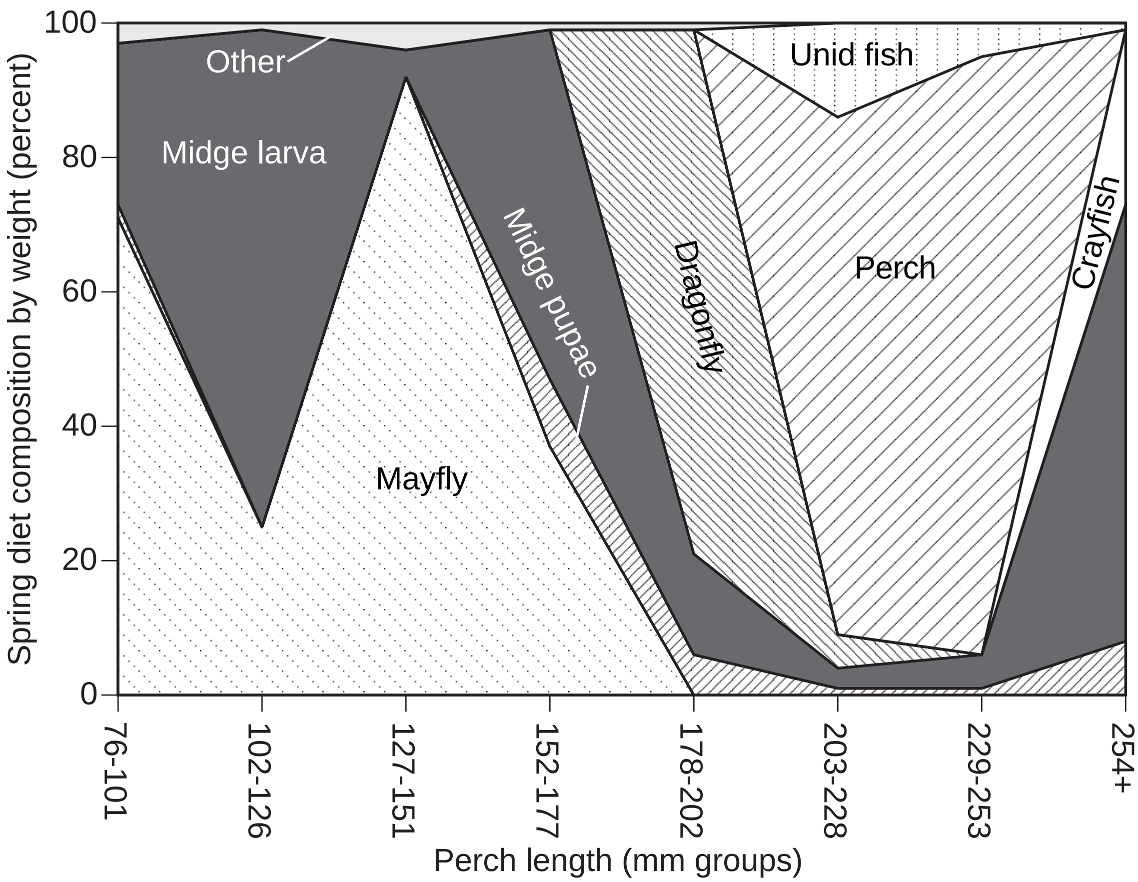
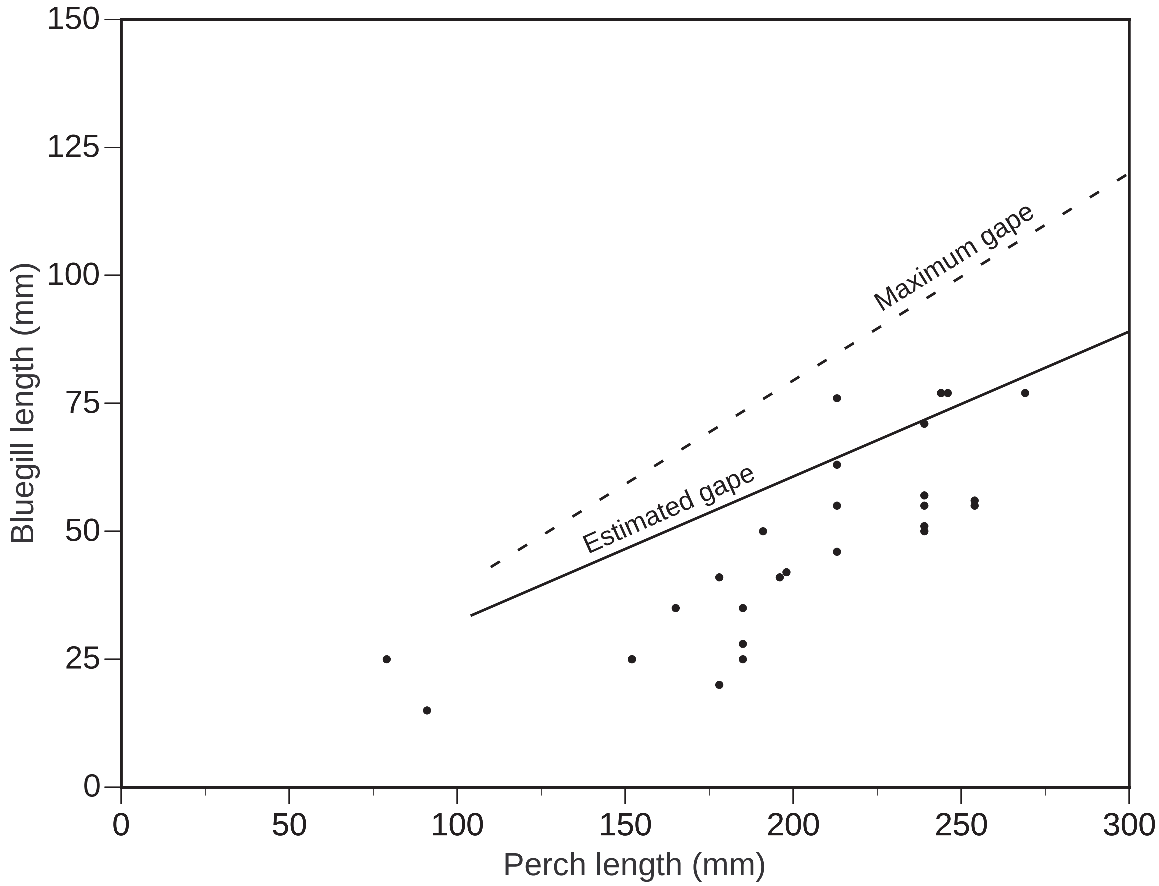
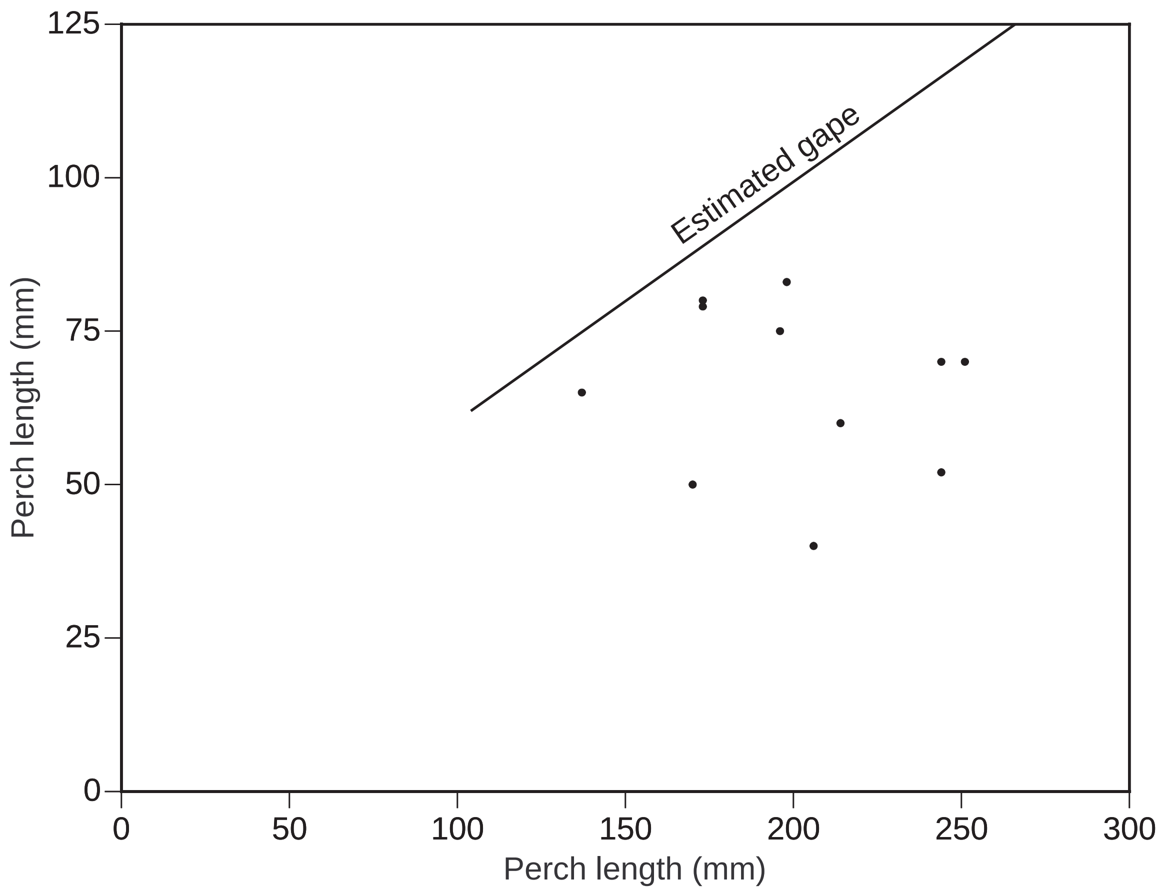


Figure 12.—Principal food types, by weight, of yellow perch in fall (upper) and spring (lower).



Maximum gape
Estimated gape
Bluegill length (mm)
Perch length (mm)
0
25
50
75
100
125
150
0
50
100
150
200
250
300


Estimated gape
Perch length (mm)
Perch length (mm)
0
25
50
75
100
125
0
50
100
150
200
250
300

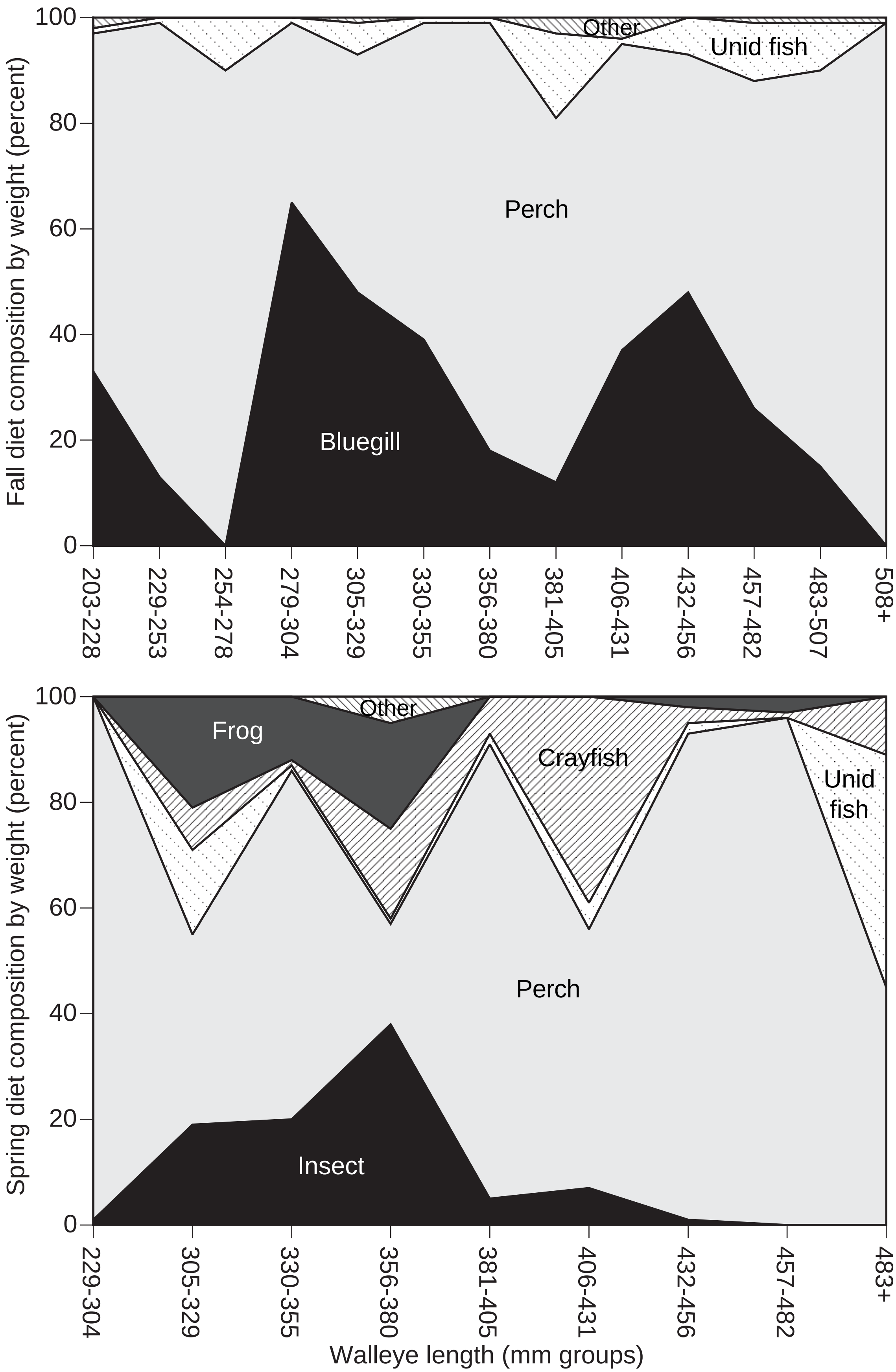
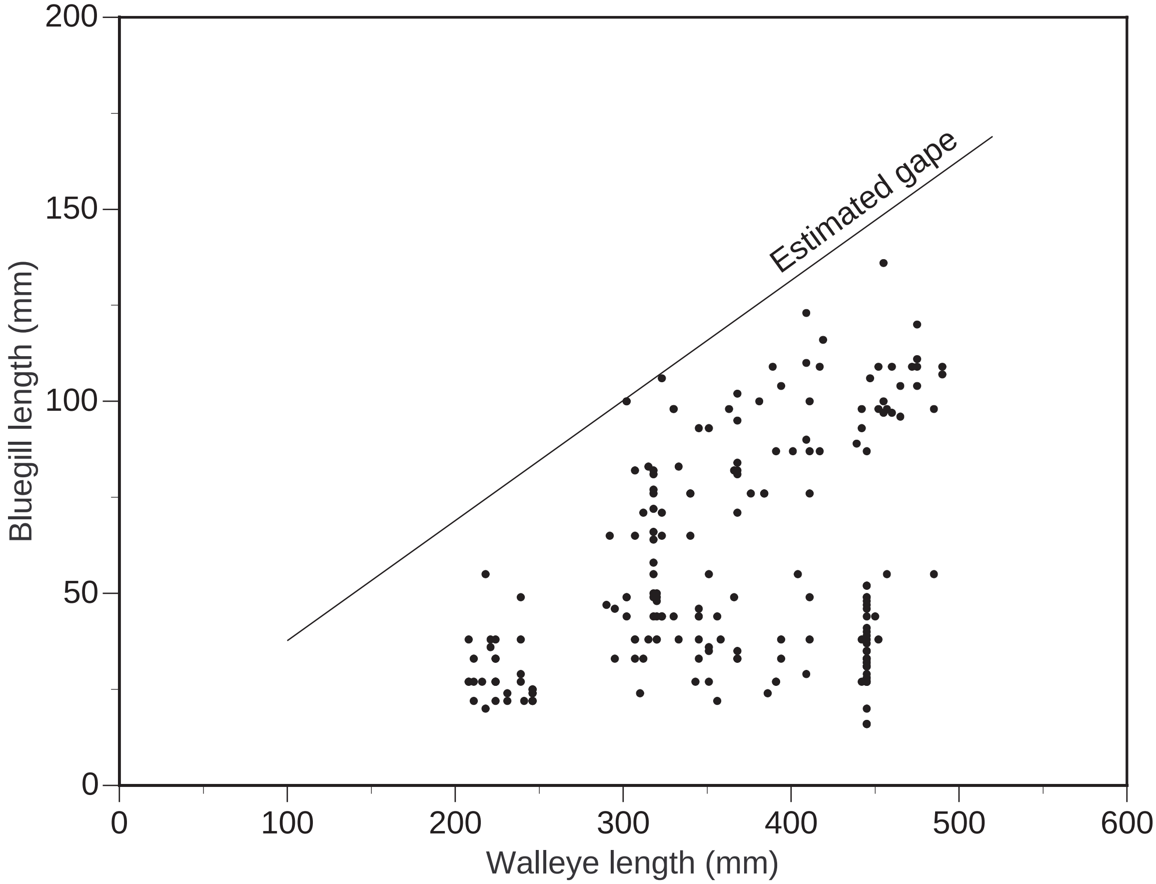


Figure 15.—Principal food types, by weight, of walleye in fall (upper) and spring (lower).



Estimated gape
Bluegill length (mm)
Walleye length (mm)
0
50
100
150
200
0
100
200
300
400
500
600

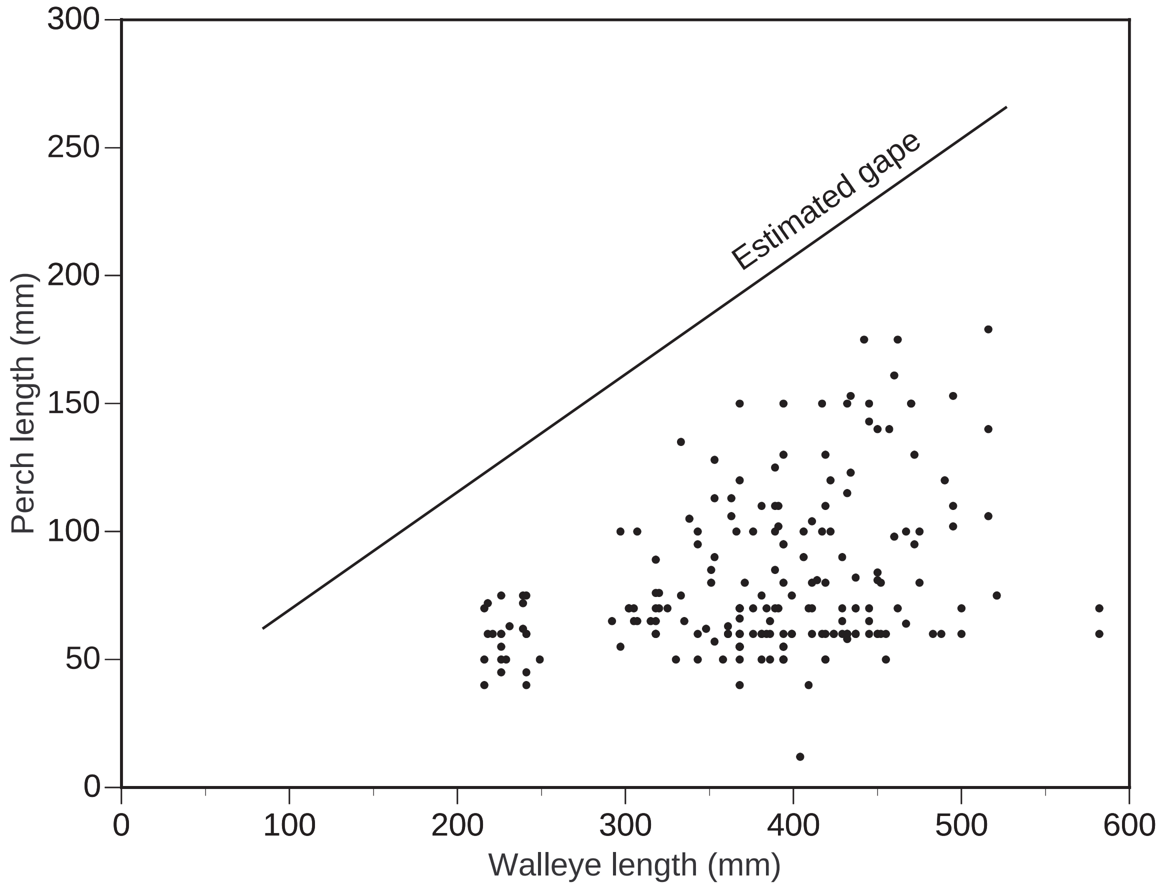

Estimated gape
Perch length (mm)
Walleye length (mm)
0
50
100
150
200
250
300
0
100
200
300
400
500
600

Table 1.–Year class strength of fish born in Jewett Lake expressed as a relative rank within each species, based primarily on YOY abundance. Rank 1 indicates lowest relative abundance; duplicate numbers indicate similar abundance.

Year	Perch	Walleye	Bluegill
1976	12	–	–
1977	3	–	–
1978	6	–	–
1979	10	3	–
1980	5	4	–
1981	2	10	–
1982	11	11	–
1983	1	8	–
1984	?	7	–
1985	1	5	–
1986	7	7	6
1987	13	2	5
1988	1	9	4
1989	9	5	3
1990	7	7	8
1991	8	6	9
1992	3	2	1
1993	9	1	7
1994	2	1	2
1995	9	1	8

Table 2.–Summary of average statistics comparing population characteristics of the yellow perch and walleye community (YP+WAE, 1976-83) to the bluegill, yellow perch, and walleye community (BG+YP+WAE, 1987-93). N is sample size in years. P is the probability of a statistically significant difference based on Student t test.

Statistic	YP+WAE Average	YP+WAE N	BG+YP+WAE Average	BG+YP+WAE N	Difference	P
YOY recruitment (Number/yr)						
Yellow perch	10,374	8	14,672[a]	4	+42%	0.35
Walleye	135	3	65	7	-52%	0.28
Bluegill	0		67,826[b]	2	–	–
Growth (Fall average length, mm)						
Yellow perch						
Age 0	94	8	73	7	-22%	0.01
Age 1	163	8	137	7	-16%	0.02
Age 2	210	6	204	7	-3%	0.71
Walleye (natives)						
Age 0	165	5	225	5	+36%	0.002
Age 1	301	4	318	7	+6%	0.09
Age 2	341	3	362	7	+6%	0.07
Bluegill						
Age 0	–	–	38	7	–	–
Age 1	–	–	95	7	–	–
Age 2	–	–	147	7	–	–
Biomass (Kg)						
Yellow perch	108	7	86	7	-20%	0.38
Walleye	81	7	90	7	+11%	0.28
Bluegill	–	–	191	4	–	–
Population of large fish (Number)						
Yellow perch (>178 mm)	392	7	93	7	-76%	0.03
Walleye (>356 mm)	71	6	109	7	+54%	0.01
Bluegill (>152 mm)	–	–	448	5	–	–
Harvested by anglers (Number)[c]						
Yellow perch	279	8	81	5	-71%	0.13
Walleye	15.1	8	16.2	5	+7%	0.77
Bluegill	–	–	243	3	–	–

[a]Average recruitment to fall age 0 is 11,098 if include CPE estimates for three additional year classes.
[b]Average recruitment to fall age 0 is 46,413 if include CPE estimates for two additional year classes.
[c]Representative harvest periods are 1979-86 and 1987-91 (1989-91 for bluegill).

Table 3.–Prey-consumer relationships by size groups (mm, except benthos) for the bluegill, walleye, and yellow perch community based on diet studies at Jewett Lake and elsewhere (underlined). Studies elsewhere were summarized by Colby et al. (1979) and Thorpe (1977). Bold indicates relatively important; ? indicates unreported but likely.

Potential prey		Consumers: Bluegill	Perch	Walleye	Angler
Zooplankton	Small <0.2	<u>F</u>	F	<u>F</u>	
	Medium 0.2-1.0	S	S	<u>F</u>	
	Large >1	**S**	S	<u>**S**</u>	
Benthos	Small <15 mg	S	**S**		
	Medium 15-200 mg	**M**, **L**	**M**	M	
	Large >200 mg		L	L	
Bluegill	Egg	<u>S</u>, <u>M</u>, <u>L</u>	?S, M, L		
	Fry <15	<u>S</u>, <u>M</u>, <u>L</u>	?S	<u>S</u>, <u>M</u>, <u>L</u>	
	Small 15-84	L	**M**, **L**	**M**, **L**	
	Medium 85-137			L	
	Large >138				√
Yellow Perch	Egg				
	Fry <15	?S, M, L	<u>S</u>, <u>M</u>	<u>S</u>	
	Small 15-84	?L	**L**	<u>**S**</u>, **M**, **L**	
	Medium 85-190			**L**	√
	Large >190				√
Walleye	Egg	<u>S</u>, <u>M</u>, <u>L</u>	<u>S</u>, <u>M</u>, <u>L</u>		
	Fry <15	?S, M, L	<u>S</u>, <u>M</u>		
	Small 15-84		<u>M</u>, <u>L</u>	<u>S</u>, <u>M</u>, <u>L</u>	
	Medium 85-241			L	
	Large >241				√

Potential consumers defined

Bluegill	**Yellow Perch**	**Walleye**
F=Fry <15	F=Fry <15	F=Fry <15
S=Small 15-99	S=Small 15-74	S=Small 15-49
M=Medium 100-152	M=Medium 75-126	M=Medium 50-200
L=Large >152	L=Large >127	L=Large >200

Table 4.–Diet composition by weight (%) of yellow perch of three size groups before (1977-81) and after (1987-93) bluegill were established in Jewett Lake.

	75-126 mm		127-177 mm		178-305 mm	
Food	Before	After	Before	After	Before	After
Zooplankton						
Cladocera	8	1	Tr			
Benthos						
Crayfish				Tr		11
Amphipod	1	10	6		Tr	
Mayfly	79	29	46		1	
Dragonfly	12	Tr	46	Tr	8	Tr
Midge	Tr	18	Tr	2	Tr	2
Other			2		2	
Fish						
Perch				76	81	7
Bluegill		26		16		78
Unidentified		16		6	8	2
Total (%)	100	100	100	100	100	100

Table 5.–Model of walleye in Jewett Lake based on 1987-93 averages for recruitment to age 0 (65 walleye), growth, total mortality (Z=0.35) and fishing under a 356-mm TL minimum size limit (MSL)

	Conditions with 356-mm MSL				Catch-	381mm-	No
Age in fall	Average length (mm)	Predicted number	Natural mortality (M)	Fishing mortality (Q)	Release Predicted number	MSL Predicted number	MSL Predicted number
0	225	65.0	0.35	0	65.0	65.0	65.0
1	318	45.6	0.31	0.04	45.6	45.6	44.2
2	362	32.1	0.22	0.13	33.1	33.1	28.8
3	390	22.0	0.18	0.17	26.1	24.5	19.6
4	402	15.5	0.18	0.17	21.4	17.6	13.8
5	413	10.9	0.18	0.17	17.6	12.5	9.7
6	427	7.7	0.18	0.17	14.5	8.8	6.8
7	422	5.4	0.18	0.17	11.9	6.2	4.8
8	434	3.8	0.18	0.17	9.8	4.4	3.4
9	439	2.7	0.18	0.17	8.0	3.1	2.4
10	452	1.9	0.18	0.17	6.6	2.2	1.7
11	460	1.3	0.18	0.17	5.4	1.5	1.2
12	465	0.9	0.18	0.17	4.4	1.1	0.8
13	472	0.6	0.18	0.17	3.6	0.8	0.6
14	483	0.5	0.18	0.17	3.0	0.5	0.4
15	493	0.3			2.5	0.4	0.3
Total population		216.0			278.0	227.0	203.0
>356 mm		89.3			145.1	104.6	84.0
>381 mm		66.0			120.2	78.8	62.0
>457 mm		3.8			17.7	4.6	3.5
>508 mm		0.1			0.5	0.1	0.1
Sport catch		20			30	22	18
Harvest		15			0	13	18

Table 6.–Equilibrium statistics for two simulation models of bluegill in Jewett Lake under two sets of conditions: harvested (1987-91); and catch-release (C-R).

Structure of Populations

	Harvested					C-R
			Mortality			
Age (fall)	Average Length	Predicted Number	Z	M	Q	Predicted Number
0	38	160,000	2.53	2.53	0.01	160,000
1	95	12,800	2.53	2.52	0.33	12,800
2	147	992	1.43	1.10	0.76	1,017
3	186	241	1.43	0.68	0.76	318
4	192	58	1.43	0.68	0.76	139
5	211	14	1.43	0.68	0.76	61
6	–	0	1.43	0.68	0.76	27
Number >152 mm		490[a]				727
Number >203 mm		14				87

Size Structure of Fisheries

	Harvested		C-R
Length (mm)	Observed	Predicted	Predicted
102-125	8.7%	0.3%	0.2%
127-150	9.0%	17.2%	11.0%
152-176	24.1%	27.3%	19.1%
178-202	48.8%	50.8%	53.6%
204-227	8.7%	4.4%	15.7%
229-252	0.7%	0.0%	0.5%
Average number/yr	243	242	383

[a]Agrees with the observed average population >152 mm of 448 bluegill (Table 2).

Table 7.–Equlibrium statistics for three simulation models of yellow perch in Jewett Lake under three sets of conditions: pre-bluegill and harvested (1978-86); post bluegill and harvested (1987-91); and post bluegill and catch-release (C-R).

Structure of Populations

Pre-bluegill, harvested

Age	Observed average		Predicted	Predicted Mortality		
(fall)	Length	Number	Number	Z	M	Q
0	94	10,374	10,374	2.273	2.225	0.048
1	168	1,066	1,067	1.890	1.250	0.640
2	210	165	162	1.698	0.500	1.198
3	250	27	30	1.802	0.500	1.302
4	262	6	5	1.285	0.500	0.785
5	282	1	1	1.200	0.500	0.700

Post-bluegill, harvested

Observed average		Predicted	Predicted mortality			C-R Predicted
Length	Number	Number	Z	M	Q	Number
73	14,672	14,672	2.356	2.353	0.003	14,672
137	1,392	1,391	2.659	2.200	0.459	1,394
204	102	98	2.937	1.400	1.537	141
242	5	5	2.140	1.400	0.740	25
262	0	0	2.140	1.400	0.740	4
294	0	0	–	–	–	1
No. >178 mm	56	101				169

Size Structure of Fisheries

Length (mm)	Pre-bluegill, harvested Observed	Pre-bluegill, harvested Predicted	Post-bluegill, harvested Observed	Post-bluegill, harvested Predicted	Post-bluegill C-R Predicted
102-125	0.3%	0.2%	1.3%	0.9%	0.6%
127-150	6.0%	3.5%	1.3%	2.9%	1.9%
152-176	24.3%	20.9%	19.3%	22.0%	15.0%
178-202	30.6%	31.2%	40.4%	42.2%	32.7%
204-227	23.7%	26.7%	26.0%	23.7%	28.0%
229-252	11.2%	13.6%	9.0%	7.8%	16.8%
254-277	3.2%	3.6%	1.8%	0.7%	4.1%
279-303	0.6%	0.5%	0.4%	0.0%	1.1%
305-328	0.1%	0.0%	0.0%	0.0%	0.1%
Average number/yr	279	338	81	111	173

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Appendix 1.–Summary of bluegill mark-recapture population and biomass estimates and growth, Jewett Lake, fall, 1987-95. (In parentheses is number of different fish handled).

	1987	1988	1989	1990	1991	1992	1993	1995
Estimated number by total length group (mm) and year								
0-74	38021	97632	35000[a]	many	many	34904[a]	many	–
	(1532)	(4116)	(60)	(135)	(146)	(1950)	(28)	(180)
75-101	17	1828	2266	211	10096	17215	6737	–
	(22)	(537)	(450)	(75)	(1684)	(1669)	(1307)	(6)
102-126	6092	2071	1795	269	3289	1214	4989	–
	(1053)	(1191)	(900)	(178)	(884)	(774)	(1633)	(6)
127-151	23	761	487	190	20	974	373	–
	(22)	(514)	(253)	(179)	(14)	(461)	(131)	(24)
152-177	3	184	574	287	10	324	332	–
	(2)	(116)	(543)	(278)	(7)	(223)	(226)	(31)
178-202	0	10	173	109	58	62	493	–
	(0)	(3)	(163)	(102)	(49)	(37)	(344)	(144)
203+	2	0	0	8	24	54	65	–
	(2)	(0)	(0)	(7)	(24)	(41)	(45)	(85)
Estimated biomass (kg) by year								
Total	160	157	168	48+	181+	277	275+	–
Estimated number by age group and year								
0	38021	97632	35000[a]	many	many	15000[a]	many	(64)
1	6132	4684	4270	645	14498	32217	–	(20)
2	5	97	891	371	43	7462	11997	(8)
3		73	96	58	38	4	927	(2)
4			37		15	55	41	(58)
5						9	24	(18)
6								(11)
7								(9)
Average length at age (mm) by year								
0	48	36	41	33	41	36	33	40
1	107	109	102	112	94	74	69	98
2	188[b]	165	157	168	180	107	102	130
3		165	173	198	198	206	175	136
4			155		203	203	206	172
5			188			216	229	173
6								202
7								206

[a]Rough estimates based on catch per effort.
[b]Ages 2-5, stocked.

Appendix 2.–Summary of yellow perch mark-recapture population and biomass estimates and growth, Jewett Lake, in fall, 1976-95. (In parenthesis is number of different fish handled).

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1987	1988	1989	1990	1991	1992	1993	1995
Estimated number by total length group (mm) and year																	
0-101	6369	22766	5366	8019	14412	2239	785	151	2525	25034	3000[a]	12230	9725	11000[a]	5375[a]	10974	–
	(585)	(2024)	(944)	(1159)	(3245)	(943)	(556)	(36)	(381)	(1815)	(83)	(852)	(2253)	(237)	(67)	(373)	(21)
102-126	–	100	1832	11	510	5537	2690	19694	711	725	463	21	724	0	2253	1322	–
	(2)	(39)	(313)	(10)	(115)	(2334)	(1905)	(1575)	(108)	(213)	(50)	(16)	(765)	(0)	(262)	(119)	(38)
127-151	–	163	1009	432	22	88	14	1515	12	775	2452	1273	83	41	89	545	–
	(8)	(47)	(149)	(165)	(13)	(64)	(9)	(121)	(6)	(142)	(528)	(369)	(50)	(23)	(39)	(62)	(3)
152-177	–	146	210	327	259	347	179	–	792	53	486	383	299	168	34	189	–
	(3)	(89)	(41)	(143)	(153)	(282)	(125)	(2)	(393)	(39)	(135)	(198)	(226)	(94)	(15)	(112)	(2)
178-202	–	178	180	124	155	303	69	–	937	9	31	64	41	59	24	43	–
	(2)	(127)	(148)	(76)	(96)	(198)	(62)	(4)	(449)	(6)	(19)	(41)	(38)	(49)	(17)	(35)	(2)
203-228		110	154	132	27	26	21	–	101		10	19	10	7	56	32	–
		(98)	(139)	(112)	(27)	(16)	(18)	(9)	(70)		(6)	(16)	(9)	(6)	(50)	(25)	(5)
229+	–	56	46	40	26	20	10	?	29	13	4	5	6	4	79	138	–
	(0)	(56)	(44)	(34)	(25)	(17)	(9)	(2)	(24)	(12)	(3)	(4)	(6)	(3)	(69)	(133)	(29)
Estimated biomass (kg) by year																	
Total	8	151	140	100	135	144	52	–	30	158	106	46	90	39	67	94	–
Estimated number by age group and year																	
Eggs[b]	3.0M	3.1M	3.9M	3.8M	0.9M	0.6M	0.6M	0.4M	1.1M	0.2M	0.2M	0.5M	0.4M	0.3M	0.8M	1.8M	–
0	6369	22766	5366	8019	14922	7849	3478	21360	3236	25034	3000[a]	12230	10449	11000[a]	5000[a]	10974	(24)
1		753	2822	690	423	672	262	–	1842	1562	3061	1664	416	259	2751	1461	(26)
2			609	277	31	26	20	–	26	4	378	91	20	18	144	652	(6)
3				99	22	4	5	–	4	7	7	7	3	2	13	147	(3)
4					13	8	2	–		1		2			2	8	(19)
5						1										1	(9)
6																	(1)
7																	(2)
Average length at age (mm)																	
0	48	74	83	83	90	107	105	114	94	81	69	76	91	66	66	64	66
1		171	124	147	170	177	171	206	179	135	137	142	157	160	112	117	109
2			176	190	206	227	219	–	240	246	178	193	211	221	224	152	152
3				207	225	256	279	–	282	277	224	218	239	249	241	249	249
4					248	265	272	–		257		236			287	269	244
5						282										295	254
6																	236
7																	259

[a] Rough estimates based on catch-per-unit-effort.

[b] Estimated number (millions) of eggs deposited in spring. Eggs were stocked in 1975 (3.0M) and 1976 (0.1M); all others were produced by adults in Jewett Lake.

Appendix 3.–Summary of walleye mark-recapture population and biomass estimates and growth, Jewett Lake, fall 1975-95. (In parentheses is number of different fish handled).

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1987	1988	1989	1990	1991	1992	1993	1995
Estimated number by total length group (mm) and year[a]																	
0-202	329	174	138	94	137	5	250		190	0	4	0	0	2	0	0	–
						(4)	(91)	(23)	(51)	(0)	(1)	(0)	(0)	(2)	(0)	(0)	(0)
203-253		107	75	10	4	2	8		34	3	166	45	111	116	2	0	–
						(1)	(7)	(0)	(23)	(2)	(52)	(16)	(74)	(32)	(1)	(0)	(0)
254-304			131	156	26	16	5		135	2	4	23	0	22	30	1	–
						(12)	(5)	(2)	(106)	(1)	(1)	(20)	(0)	(10)	(16)	(1)	(0)
305-355		180	118	91	169	83	65		35	44	4	88	26	156	81	27	–
						(65)	(53)	(15)	(31)	(43)	(4)	(65)	(23)	(91)	(48)	(25)	(0)
356-405			43	39	61	75	54		35	91	72	42	83	55	45	77	–
						(63)	(43)	(10)	(24)	(84)	(59)	(32)	(70)	(39)	(36)	(73)	(18)
406-456			5	8	14	18	14		12	32	33	42	26	36	22	28	–
						(14)	(10)	(2)	(9)	(31)	(30)	(35)	(25)	(22)	(16)	(27)	(13)
457-507				1	1	9	6			4	3	18	15	5	10	11	–
						(7)	(4)	(1)	(3)	(3)	(3)	(14)	(13)	(4)	(10)	(11)	(6)
508-602					1	7	1		11	3	0	4	5	0	0	2	–
						(5)	(1)	(1)	(8)	(2)	(0)	(2)	(4)	(0)	(0)	(2)	(1)
Estimated biomass (kg) by year																	
Total	7	63	94	80	95	91	63	–	83	89	77	103	97	108	72	80	–
Average length at age (mm)[a]																	
0	141	179	137	135	107; 207	86; 167	128	145	179	218	218	234	229	226	–	–	–
1		324	279	274	308	295; 323	234; 310	312	280	335	335	310	323	320	305	300	–
2			351	291	327	363	340; 341	348; 366	351	371	371	373	366	348	353	353	–
3				360	327	356	–	–	384; 388	378	378	396	409	384	399	384	371
4					385	353	368	–	389	391	391	404	417	414	401	394	391
5						433	358	–	422	422	422	396	409	396	427	419	397
6							416	381	452	424	424	429	450	396	432	432	402
7								–	428	419	419	419	450	417	411	442	448
8									551	437	437	442	447	396	465	437	448
9										404	452	455	475	447	434	411	485
10										394	429	483	500	452	427	478	460
11										470	–	–	495	–	414	–	–
12+										503	–	511	–	503	–	508	484

[a] The 1975-78 cohorts originated from fingerling stocking; the 1981-95 cohorts were native; the 1979-80 cohorts contained both types and are encrypted as **stocked; native.**

Appendix 3.–Continued.

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1987	1988	1989	1990	1991	1992	1993	1995
Estimated number by age group and year[a]																	
Stocked	329	325	340	325	339	325											
0	329	281 (167)	160 (63)	94 (75)	136;6 (32;5)	0;– (0;5)	249 (90)	many (18)	152 (61)	3	174	45	111	128	0	0	– (0)
1		180 (80)	241 (161)	28 (22)	18 (15)	19;6 (13;5)	11;15 (10;13)	– (13)	163 (134)	35	2	111	2	150	91	1	– (0)
2			128 (97)	188 (115)	24 (21)	7 (6)	13;4 (10;3)	– (4;5)	38 (27)	13	28	3	82	19	42	57	– (0)
3				88 (68)	158 (102)	26 (23)	7 (5)	– (1;0)	4;6 (3;5)	32	16	19	7	42	12	29	– (2)
4					64 (48)	107 (88)	15 (12)	– (0)	0;2 (0;2)	48	17	5	15	9	16	15	– (7)
5						44 (34)	62 (52)	– (2)	2 (1)	21	18	25	9	6	6	17	– (7)
6							28 (19)	– (5)	4 (3)	13	20	7	10	5	7	11	– (9)
7								– (2)	13 (9)	3	5	19	10	8	2	10	– (3)
8									10 (7)	1	5	10	10	7	1	5	– (3)
9										2	1	14	5	1	4	2	– (1)
10										1	3	2	4	7	6	1	– (3)
11										2	0	0	1	0	1	0	– (0)
12+										4	0	2	0	1	0	2	– (2)

[a] The 1975-78 cohorts originated from fingerling stocking; the 1981-95 cohorts were native; the 1979-80 cohorts contained both types and are encrypted as **stocked; native.**

Appendix 4.–Catch (harvested and released fish) and effort for Jewett Lake as reported by anglers under permit system.

	1978 7/26-7/27	1979 7/9-9/2	1980 7/9-8/31	1981 5/15-9/7	1982 5/15-9/5	1983 5/15-2/21	1984 5/15-9/23	1985 5/15-10/27	1986 5/15-1/24	1987 5/15-2/9	1988 4/30-2/28	1989 4/29-3/14	1990 4/28-1/2	1991 4/27-10/13
Permits														
Issued[a]	_	153	184	221	143	202	205	146	121	146	121	245	145	140
Incomplete[b]	_	4	18	24	5	8	9	11	21	10	15	22	8	9
Unreturned	_	3	22	43	20	31	40	33	35	30	57	137	38	46
Catch														
Walleye														
Harvested	74	20	10	18	7	9	24	21	12	18	15	17	7	24
Released	0	65	26	32	41	106	120	80	30	16	7	15	31	49
Yellow Perch														
Harvested	165	383	337	266	61	830	239	24	94	36	10	195	43	121
Released	0	469	493	378	36	642	100	36	27	261	247	285	143	343
Bluegill														
Harvested	_	_	_	_	_	_	_	_	_	1	5	423	199	107
Released	_	_	_	__	_	_	_	_	_	0	20	525	298	379
Effort														
Angler Hrs	118	1,021	850	1,136	675	1,086	1,160	605	504	585	328	633	808	600
Hours/trip		2.4	2.5	2.5	2.4	2.7	2.8	2.4	2.9	3.0	2.8	3.3	2.7[e]	2.4
Catch/Hr[c]														
Total														
Walleye	0.63	0.08	0.04	0.04	0.07	0.11	0.12	0.17	0.08	0.06	0.07	0.05	0.05	0.12
Perch	1.4	0.83	0.98	0.57	0.14	1.36	0.29	0.1	0.24	0.51	0.78	0.76	0.23	0.77
Bluegill	_	_	_	_	_	_	_	_	_	_	0.08	1.5	0.62	0.81
Harvested														
Walleye	0.63	0.02	0.01	0.02	0.01	0.01	0.02	.03	0.02	0.03	0.05	0.03	0.01	0.04
Perch	1.4	0.38	0.4	0.23	0.09	0.76	0.21	0.04	0.19	0.06	0.03	0.31	0.05	0.20
Bluegill	_	_	_	_	_	_	_	_	_	_	0.02	0.67	0.25	0.18

[a] Equal to permits given out minus those which reportedly did not go fishing.

[b] Incomplete data on number of anglers or time fished.

[c] Simple ratios of total catch (harvested + released fish) divided by angler hours, and of harvested fish divided by angler hours.

[d] Includes five walleye reportedly caught overwinter which are not on slips.

[e] Includes multiple day slips.

Appendix 5.–Some weather indices considered in analysis of year class and growth variations at Jewett Lake.

	Estimated date[a]		Incubation			Hatching[c]		31 day	Warmth	Average temperature deviations				
Year	Spawn	Hatch	Days	Temp	Fluct[b]	>10C	Temp	Trend[d]	Deg-d[e]	April	May	June	Apr-Sep	Jun-Sep
1976	Apr-8	Apr-22	14	9.6	0	yes	7.7	flat,dome	171	3.0	-0.1	1.9	6.1	3.2
1977	Apr-11	Apr-23	12	13.3	3	yes	9.6	flat	197	2.8	4.7	-0.6	9.4	1.9
1978	Apr-12	May-8	26	6.4	0	yes	16.1	up	171	-0.9	3.1	0.6	4.3	2.1
1979	Apr-11	May-11	30	8.9	0	yes	12.2	up,dip	151	-1.0	-0.4	-0.1	-2.1	-0.7
1980	Apr-2	May-6	34	7.1	1	yes	10.3	up	167	0.3	1.6	-2.3	0.6	-1.3
1981	Mar-24	May-1	38	6.2	0	no	8.5	flat	137	1.4	0.1	0.4	2.5	0.9
1982	Apr-16	May-4	18	7.8	0	yes	14.8	up	137	-2.0	3.7	-2.9	-2.4	-4.1
1983	Apr-3	May-11	38	5.0	0	yes	9.9	up	284	-1.4	-3.1	-0.5	-0.3	4.2
1984	Apr-1	May-3	32	6.3	0	no	6.7	up	178	0.6	-2.4	0.3	-1.6	0.2
1985	Apr-12	May-1	19	11.9	0	yes?	12.6	up,dome	138	1.8	0.9	-2.3	-0.2	-2.9
1986	Mar-26	Apr-26	31	6.9	0	yes	12.9	flat	164	2.1	1.4	-1.8	1.7	-1.8
1987	Mar-21	Apr-21	31	6.7	3	yes	9.9	up,dip	299	1.9	1.7	2.3	9.2	5.7
1988	Apr-3	May-5	32	7.2	0	yes	12.8	down	314	-0.1	2.1	1.5	6.9	5.0
1989	Apr-4	May-15	41	5.6	0	yes	15.5	up	181	-1.4	0.2	-0.3	0.2	1.4
1990	Apr-1	May-1	30	6.7	0	yes?	9.2	flat,oscil	153	1.0	-0.9	0.7	1.7	1.6
1991	Mar-28	Apr-30	33	6.5	0	yes	9.6	up,dome	299	1.8	3.1	2.7	8.9	4.0
1992	Apr-6	May-8	32	5.9	0	yes	15.2	flat,oscil	77	-1.4	0.7	-1.2	-6.8	-6.1
1993	Apr-9	May-6	27	7.7	2	yes	12.2	up	217	-1.6	-0.5	-1.8	-4.4	-2.3
1994	Apr-1	May-7	36	6.1	1	no?	10.6	up	197	0.7	0.1	1.7	2.4	1.7
1995	Mar-20	Apr-29	40	3.3	1	no	8.9	flat,dip	–	2.0	-0.1	5.7	11.6	9.6

[a] Estimated dates of first spawning and first hatching by walleye or yellow perch (1976-78).

[b] Number of temperature fluctuations >27.8C during estimated incubation period.

[c] Was temperature at estimated hatching >10C?; and average temperature for next 14 days.

[d] Trend from estimated 1st spawn date to day 31.Level, dome = no overall temperature trend and high temperatures midway; up, dip = upward overall trend with a temperature dip midway; etc.

[e] Degree-days (“cooling”) with base of 18.4C (65F) at Houghton Lake Weather Station, an index of summer heat.

Appendix 6.–Fall diet of bluegill in Jewett Lake, 1987-93, in terms of frequency of occurence (%).

Food type	Bluegill length (mm group) 25-50	51-75	76-101	102-126	127-151	152-177	178-202	203-228
Zooplankton								
Copepoda	60	21	19	39	8	5	6	0
Cladocera								
Daphnia	15	28	36	33	16	0	3	0
Other	87	43	31	39	4	5	3	6
Benthos								
Crayfish	0	0	0	0	0	0	0	0
Amphipod	13	6	29	42	28	9	16	25
Ostracod	23	4	10	8	0	0	3	0
Mite	2	0	2	3	0	0	0	0
Worm	0	0	0	3	0	0	0	0
Snail	0	0	0	0	4	0	0	0
Clam	0	0	0	3	4	0	3	0
Mayfly nymph	17	15	24	56	32	16	13	44
Caddis larva	2	2	5	8	0	5	0	0
Damselfly nymph	4	0	0	3	0	0	0	0
Dragonfly nymph	0	0	0	6	8	5	10	19
Midge larva	32	23	48	72	44	16	13	44
Midge pupae	2	2	10	31	36	9	3	25
Chaoborus larva	0	6	2	6	20	14	26	56
Beetle larva	0	0	0	3	0	0	0	6
Other	0	0	2	8	0	0	0	0
Surface insects								
Odonata adult	0	0	0	0	0	0	0	6
Beetle adult	0	6	2	19	4	4	4	4
Other adult	4	2	12	19	3	2	4	11
Vegetation	0	0	10	0	12	14	3	13
Fish								
Bluegill	0	0	0	0	0	2	0	6
Bluegill[1]	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	6
Other								
Egg	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0
N	53	52	42	53	35	63	46	36
Void (%)	2	21	17	15	31	51	48	14

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 7.– Fall diet of bluegill in Jewett Lake, 1987-93, in average number of food organisms per bluegill.

Food type	25-50	51-75	76-101	102-126	127-151	152-177	178-202	203-228
	Bluegill length (mm group)							
Zooplankton								
Copepoda	18.1	1.2	1.9	1.6	0.1	0.1	0	0
Cladocera								
Daphnia	15.1	14.3	16.6	8.1	2.3	0	0.7	0
Other	102.3	45.5	144.3	0.9	0.2	0.2	0.1	0.1
Benthos								
Crayfish	0	0	0	0	0	0	0	0
Amphipod	0.2	0.1	1	1.4	1.5	0.8	2.7	0.2
Ostracod	1.8	0.3	2.3	0.1	0	0	0	0
Mite	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0
Clam	0	0	0	0.4	0.1	0	0	0
Mayfly nymph	0.3	0.5	0.6	2.6	3	0.5	3.4	0.9
Caddis larva	0	0.1	0	0.1	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0	0.1	0	0.1	0.3
Midge larva	2.2	2	2.9	13.7	16	5.6	7.6	4.3
Midge pupae	0	0	1.5	5.3	6.1	0.3	0.8	0.3
Chaoborus larva	0	0.1	0	0	0.9	18.7	97.7	140.5
Beetle larva	0	0	0	0	0	0	0	0
Other	0	0	0	0.2	0	0	0	0
Surface insects								
Odonata adult	0	0	0	0	0	0	0	0
Beetle adult	0	0.1	0	0.2	0	0.3	0.4	0.2
Other adult	0	0	0.2	1.2	0.1	0.3	5.6	9.7
Vegetation	–	–	–	–	–	–	–	–
Fish								
Bluegill	0	0	0	0	0	0	0	0.2
Bluegill[1]	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0.1
Other								
Egg	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 8.–Fall diet of bluegill in Jewett Lake, 1987-93, in size range (mm) of food type.

	Bluegill length (mm group)							
Food type	25-50	51-75	76-101	102-126	127-151	152-177	178-202	203-228
Zooplankton								
Copepoda	0.2-1.0	0.5-1.2	0.5-1.0	0.5-1.0	1.0	0.5-1.0	1.0	
Cladocera								
Daphnia	0.2-1.5	0.5-1.1	0.4-2.0	0.4-2.0	1.0-1.5			
Other	0.2-2.0	0.3-2.0	0.3-2.0	0.5-2.0	1.0-2.0	1.5-2.0	1.0	1.0-2.0
Benthos								
Crayfish								
Amphipod	1-2	1-2	1-3	1-3	1-3	2-3	2-3	2-3
Ostracod	0.2-1.0	0.5-0.6	0.5-0.7	0.5			0.5	
Mite			1-2	2				
Worm				17				
Snail								
Clam				1-1	2		2	
Mayfly nymph	1-2	2-3	1-4	2-5	2-5	2-5	2-4	2-4
Caddis larva	2	3	3-4	2-4		4		
Damselfly nymph	1-2			5				
Dragonfly nymph				10		8-10	12-15	11
Midge larva	1-3	1-7	2-8	2-10	2-13	3-11	3-12	3-12
Midge pupae	1	3	2-4	3-5	2-5	3-10	3-4	3-10
Chaoborus larva		6-7		6	5-8	4-8	5-8	5-8
Beetle larva								
Other				1-7				
Surface insects								
Odonata adult								
Beetle adult		4-5		4-12	6-6	4-8	4-25	10-25
Other adult	2	4	2-8	2-6	3-5	3-5	3-5	3-5
Vegetation								
Fish								
Bluegill						24		25-35
Bluegill[1]								
Yellow perch								
Walleye								
Percid[2]								
Unidentified								
Other								
Egg								
Frog								

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 9.–Fall diet of bluegill in Jewett Lake, 1987-93, in estimated percent of total food on a dry weight basis. See text for methods.

Food type	Bluegill length (mm group)							
	25-50	51-75	76-101	102-126	127-151	152-177	178-202	203-228
Zooplankton								
Copepoda	5	2	0	0	0	0	0	0
Cladocera								
Daphnia	9	11	6	1	0	0	0	0
Other	80	51	49	0	0	0	0	0
Benthos								
Crayfish	0	0	0	0	0	0	0	0
Amphipod	0	0	1	1	0	0	0	0
Ostracod	1	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0
Worm	0	0	0	4	0	0	0	0
Snail	0	0	0	0	3	0	0	0
Clam	0	0	0	0	0	0	0	0
Mayfly nymph	3	17	7	20	16	4	6	1
Caddis larva	0	1	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	3	6	3	5	3
Midge larva	1	10	8	27	45	21	9	2
Midge pupae	1	1	23	33	27	3	1	0
Chaoborus larva	0	1	0	0	1	39	59	32
Beetle larva	0	0	0	0	0	0	0	0
Other	0	0	0	1	0	0	0	0
Surface insects								
Odonata adult	0	0	0	0	0	0	0	0
Beetle adult	0	5	1	2	0	3	1	0
Other adult	0	1	4	8	1	3	18	12
Vegetation	–	–	–	–	–	–	–	–
Fish								
Bluegill	0	0	0	0	0	23	0	48
Bluegill[1]	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	2
Other								
Egg	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0
Total (%)	100	100	100	100	100	100	100	100
Meal size (%BW)	0.29	0.04	0.05	0.06	0.04	0.15	0.04	0.07

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 10.–Spring diet of bluegill in Jewett Lake, 1988-91, in terms of the frequency of occurrence (%).

Food type	Bluegill length (mm group)					
	51-75	76-101	102-126	127-151	152-177	178-228
Zooplankton						
Copepoda	0	0	0	13	0	0
Cladocera						
Daphnia	18	0	17	25	0	0
Other	18	100	17	63	13	33
Benthos						
Crayfish	0	0	0	0	0	0
Amphipod	64	67	100	75	75	67
Ostracod	0	0	0	0	0	0
Mite	36	33	0	0	0	0
Worm	0	0	0	0	0	0
Snail	0	0	0	0	0	0
Clam	0	0	0	0	13	0
Mayfly nymph	82	67	100	88	63	100
Caddis larva	0	33	67	50	50	0
Damselfly nymph	9	0	0	0	0	0
Dragonfly nymph	0	0	17	0	13	0
Midge larva	91	100	100	100	38	67
Midge pupae	45	33	0	38	38	33
Chaoborus larva	0	0	17	13	50	33
Beetle larva	18	0	0	0	13	0
Other	0	0	0	0	13	0
Surface insects						
Odonata adult	0	0	0	13	0	0
Beetle adult	0	0	17	4	4	4
Other adult	18	33	33	13	13	0
Vegetation	0	0	0	0	0	0
Fish						
Bluegill	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0
Walleye	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0
Other						
Egg	0	0	0	0	13	0
Frog	0	0	0	0	0	0
N	15	9	32	15	15	6
Void (%)	0%	0%	0%	0%	7%	0%

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 11.–Spring diet of bluegill in Jewett Lake, 1988-91, in average number of food organisms per bluegill.

Food type	Bluegill length (mm group)					
	51-75	76-101	102-126	127-151	152-177	178-228
Zooplankton						
Copepoda	0	0	0	0.1	0	0
Cladocera						
Daphnia	1.1	0	1.3	66.7	0	0
Other	2.1	9	1.3	2	0.1	0.2
Benthos						
Crayfish	0	0	0	0	0	0
Amphipod	2.9	12.4	10.4	9.5	10.5	19.7
Ostracod	0	0	0	0	0	0
Mite	0.5	0.6	0	0	0	0
Worm	0	0	0	0	0	0
Snail	0	0	0	0	0	0
Clam	0	0	0	0	0.5	0
Mayfly nymph	6.9	12.2	24.8	21.3	9.7	17.5
Caddis larva	0	0.1	1.2	0.6	1.4	0
Damselfly nymph	0.1	0	0	0	0	0
Dragonfly nymph	0	0	0	0	0.1	0
Midge larva	5.2	12.2	4.5	12.7	3.3	5.8
Midge pupae	1.6	0.2	0	0.6	1.4	0.8
Chaoborus larva	0	0	0.5	0.1	14.7	3.3
Beetle larva	0.1	0	0	0	0.1	0
Other	0	0	0	0	0.1	0
Surface insects						
Odonata adult	0	0	0	0.1	0	0
Beetle adult	0	0	0.1	0.1	6.7	5
Other adult	0.2	0.6	1	0.1	0.1	0
Vegetation	–	–	–	–	–	–
Fish						
Bluegill	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0
Walleye	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0
Other						
Egg	0	0	0	0	13.3	0
Frog	0	0	0	0	0	0

[1]Probably bluegill as indicated by robust shape and absence of other sunfish.
[2]Probably perch or walleye as indicated by slender shape.

Appendix 12.–Spring diet of bluegill in Jewett Lake, 1988-91, in size range (mm) of food type.

Food type	Bluegill length (mm group)					
	51-75	76-101	102-126	127-151	152-177	178-228
Zooplankton						
Copepoda				1.0		
Cladocera						
Daphnia	0.8-1.2			0.9-1.5		
Other	1.0-2.0	1.0-2.0	1.0-2.0	1.8-2.0		2.0
Benthos						
Crayfish						
Amphipod	3-4	2-4	3-4	2-4	3-4	2-4
Ostracod						
Mite						
Worm						
Snail						
Clam					2-3	
Mayfly nymph	3-4	2-6	3-6	3-7	3-7	3-5
Caddis larva		2	4-6	3-5	3-18	
Damselfly nymph	2					
Dragonfly nymph			18		20	
Midge larva	2-15	4-8	2-8	3-10	3-10	5-8
Midge pupae	2			5-10	7-12	5
Chaoborus larva					6-12	8
Beetle larva	4-7				3	
Other					7	
Surface insects						
Odonata adult						
Beetle adult					5	6
Other adult		3	5		5	
Vegetation						
Fish						
Bluegill						
Bluegill[1]						
Yellow perch						
Walleye						
Percid[2]						
Unidentified						
Other						
Egg					1	
Frog						

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 13.–Spring diet of bluegill in Jewett Lake, 1988-91, in estimated percent of total food on a dry weight basis. See text for methods.

Food type	Bluegill length (mm group)					
	51-75	76-101	102-126	127-151	152-177	178-228
Zooplankton						
Copepoda	0	0	0	0	0	0
Cladocera						
Daphnia	0	0	0	2	0	0
Other	0	1	0	0	0	0
Benthos						
Crayfish	0	0	0	0	0	0
Amphipod	2	4	2	1	2	4
Ostracod	0	0	0	0	0	0
Mite	0	0	0	0	0	0
Worm	0	0	0	0	0	0
Snail	0	0	0	0	0	0
Clam	0	0	0	0	2	0
Mayfly nymph	55	78	90	83	35	65
Caddis larva	0	0	2	1	11	0
Damselfly nymph	0	0	0	0	0	0
Dragonfly nymph	0	0	3	0	6	0
Midge larva	31	15	1	8	2	5
Midge pupae	10	1	0	1	2	2
Chaoborus larva	0	0	0	0	13	4
Beetle larva	1	0	0	0	0	0
Other	0	0	0	0	0	0
Surface insects						
Odonata adult	0	0	0	2	0	0
Beetle adult	0	0	0	0	17	20
Other adult	0	0	1	0	0	0
Vegetation	–	–	–	–	–	–
Fish						
Bluegill	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0
Walleye	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0
Unidentified						
Other						
Egg	0	0	0	0	9	0
Frog	0	0	0	0	0	0
Total (%)	100	100	100	100	100	100
Meal size (%BW)	0.35	0.19	0.19	0.11	0.07	0.03

[1] Probably bluegill as indicated by robust shape.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 14.–Fall diet of yellow perch in Jewett Lake, 1987-93, in terms of frequency of occurence (%).

Food type	Perch length (mm group)								
	51-75	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton									
Copepoda	37	6	10	3	0	0	0	0	0
Cladocera									
Daphnia	26	0	5	5	0	0	0	0	0
Other	63	48	30	0	0	0	0	0	0
Benthos									
Crayfish	0	0	0	3	0	13	10	14	6
Amphipod	23	52	60	13	2	3	0	0	0
Ostracod	0	0	10	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	5	0	0	0	0
Mayfly nymph	17	36	45	10	7	0	0	3	0
Caddis larva	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	5	10	7	9	3	0	0
Midge larva	46	39	60	21	9	6	3	6	11
Midge pupae	9	6	10	3	2	6	0	0	0
Chaoborus larva	3	0	10	13	2	6	3	3	6
Beetle larva	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	3	0	0	0
Surface insects									
Odonata adult	0	0	0	0	0	6	0	0	0
Beetle adult	0	0	0	0	0	0	3	0	0
Other adult	0	0	5	0	0	0	3	3	0
Vegetation	3	0	0	3	0	6	0	0	0
Fish									
Bluegill	0	6	0	0	7	13	3	11	11
Bluegill[1]	0	0	0	3	2	0	0	0	11
Yellow perch	0	0	0	3	7	6	3	0	0
Walleye	0	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	3	2	0	0	0	6
Unidentified	0	3	0	0	16	9	7	6	0
Other									
Egg	0	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0	0
N	35	33	29	77	51	21	38	51	19
Void (%)	9	27	17	36	49	43	53	51	63

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape, but 1 darter included.

Appendix 15.–Fall diet of yellow perch in Jewett Lake, 1987-93, in average number of food organisms per perch.

Food type	Perch length (mm group)								
	51-75	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton									
Copepoda	6.8	0.1	0.3	0	0	0	0	0	0
Cladocera									
Daphnia	7.8	0	0.2	0.5	0	0	0	0	0
Other	32.8	6.1	1.1	0	0	0	0	0	0
Benthos									
Crayfish	0	0	0	0	0	0.1	0.1	0.1	0.1
Amphipod	1.6	4.7	11.5	2	1.2	0	0	0	0
Ostracod	0	0	0.1	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0.1	0	0	0	0
Mayfly nymph	0.8	2.3	4.9	1.1	0.4	0	0	0	0
Caddis larva	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0.1	0.1	0.1	0	0	0
Midge larva	2.3	2	12.1	5	1.5	1	2.7	5.7	1.3
Midge pupae	0.1	0.1	0.1	0	0	0	0	0	0
Chaoborus larva	0	0	0.2	10.3	4.3	0.2	15.2	1.9	0.5
Beetle larva	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0
Surface insects									
Odonata adult	0	0	0	0	0	0.1	0	0	0
Beetle adult	0	0	0	0	0	0	0.1	0	0
Other adult	0	0	0	0	0	0	0.1	0.7	0
Vegetation	–	–	–	–	–	–	–	–	–
Fish									
Bluegill	0	0.1	0	0	0.1	0.2	0.2	0.2	0.2
Bluegill[1]	0	0	0	0	0.1	0	0	0	0.1
Yellow perch	0	0	0	0	0.1	0	0	0	0
Walleye	0	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0	0	0	0.1
Unidentified	0	0	0	0	0.1	0.1	0.1	0	0
Other									
Egg	0	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0	0

[1]Probably bluegill as indicated by robust shape and absence of other sunfish.
[2]Probably perch or walleye as indicated by slender shape, but 1 darter included.

Appendix 16.–Fall diet of yellow perch in Jewett Lake, 1987-93, in size range (mm) of food type.

Food type	Perch length (mm group)								
	51-75	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton									
Copepoda	0.5-1.0		1.0	1.0					
Cladocera									
Daphnia	0.4-2.0		1.0-1.5						
Other	0.3-2.0	0.6-3.0	1.0-2.0						
Benthos									
Crayfish				8		10-25	31	8-9	
Amphipod	1-3	1-3	1-4	2	2-4				
Ostracod			1						
Mite									
Worm									
Snail									
Clam					2				
Mayfly nymph	2-4	2-4	2-5	2	2-4				
Caddis larva									
Damselfly nymph									
Dragonfly nymph			5	13		15-26	22		
Midge larva	2-6	2-7	2-11	2	3-17	7-20	10-21	6-20	10-20
Midge pupae		3	3	3	3	3			
Chaoborus larva				5	5-7	6-8	5-8	6-9	6-7
Beetle larva			6			20			
Other									
Surface insects									
Odonata adult						20-23			
Beetle adult									
Other adult							3	3-5	
Vegetation									
Fish									
Bluegill		15-25			25-35	20-50	46-76	50-77	55-77
Bluegill[1]					20-25				
Yellow perch				65	50-80	75-83	40		
Walleye									
Percid[2]					25				65
Unidentified									
Other									
Egg									
Frog									

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape, but 1 darter included.

Appendix 17.–Fall diet of yellow perch in Jewett Lake, 1987-93, in estimated percent of total food on a dry weight basis. See text for method of reconstructing food weight.

Food type	Perch length (mm group)								
	51-75	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton									
Copepoda	5	0	0	0	0	0	0	0	0
Cladocera									
Daphnia	8	0	0	0	0	0	0	0	0
Other	33	2	0	0	0	0	0	0	0
Benthos									
Crayfish	0	0	0	1	0	10	29	1	1
Amphipod	5	2	8	0	0	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0	0
Mayfly nymph	34	16	50	0	0	0	0	0	0
Caddis larva	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	1	1	0	1	0	0	0
Midge larva	10	2	40	0	1	1	2	2	1
Midge pupae	5	0	1	0	0	0	0	0	0
Chaoborus larva	0	0	1	1	1	0	1	0	0
Beetle larva	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0
Surface insects									
Odonata adult	0	0	0	0	0	1	0	0	0
Beetle adult	0	0	0	0	0	0	0	0	0
Other adult	0	0	0	0	0	0	0	0	0
Vegetation	–	–	–	–	–	–	–	–	–
Fish									
Bluegill	0	49	0	0	11	29	64	95	67
Bluegill[1]	0	0	0	13	6	0	0	0	18
Yellow perch	0	0	0	80	72	50	2	0	0
Walleye	0	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	3	1	0	0	0	13
Unidentified	0	29	0	0	8	8	2	2	0
Other									
Egg	0	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0	0
Total (%)	100	100	100	100	100	100	100	100	100
Meal size (%BW)	0.08	0.18	0.07	0.14	0.42	0.5	0.77	0.5	0.48

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape, but 1 darter included.

Appendix 18.–Spring diet of yellow perch in Jewett Lake, 1988-94, in terms of frequency of occurence (%).

Food type	Perch length (mm group)							
	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton								
Copepoda	5	0	0	0	0	0	0	0
Cladocera								
Daphnia	11	0	0	0	0	0	0	0
Other	21	0	25	27	0	0	0	0
Benthos								
Crayfish	0	0	0	0	0	0	0	9
Amphipod	26	81	100	55	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0
Clam	0	0	0	9	0	0	0	0
Mayfly nymph	58	88	100	64	0	0	0	9
Caddis larva	0	0	25	9	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	9	25	14	0	0
Midge larva	63	81	100	64	50	14	5	9
Midge pupae	16	13	0	36	50	14	5	9
Chaoborus larva	0	6	0	0	25	14	5	9
Beetle larva	0	0	0	9	0	0	0	0
Other	0	0	0	0	0	0	5	9
Surface insects								
Odonata adult	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0
Other adult	0	0	25	0	25	0	0	0
Vegetation	0	0	0	0	0	0	5	9
Fish								
Bluegill	0	0	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	14	5	0
Walleye	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	14	5	0
Other								
Egg	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0
N	23	19	8	35	4	10	25	22
Void (%)	22%	0%	0%	11%	25%	50%	76%	45%

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 19.–Spring diet of yellow perch in Jewett Lake, 1988-94, in average number of food organisms per perch.

	Perch length (mm group)							
Food type	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton								
Copepoda	0	0	0	0	0	0	0	0
Cladocera								
Daphnia	0.5	0	0	0	0	0	0	0
Other	1.2	0	0.3	0.1	0	0	0	0
Benthos								
Crayfish	0	0	0	0	0	0	0	0
Amphipod	3	14.5	20.6	11.1	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0
Mayfly nymph	6	14.3	26.9	17.7	0	0	0	0
Caddis larva	0	0	0.1	0.1	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0	0.8	0.5	0	0
Midge larva	6	32.3	3.8	19.6	4	3.1	1.3	4.4
Midge pupae	0.2	0.2	0	11.4	1.8	2.7	2.3	4.7
Chaoborus larva	0	0.1	0	0	0.8	2.3	0.2	0.6
Beetle larva	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0
Surface insects								
Odonata adult	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0
Other adult	0	0	0.6	0	1.8	0	0	0
Vegetation	–	–	–	–	–	–	–	–
Fish								
Bluegill	0	0	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0.1	0.1	0
Walleye	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0.1	0	0
Other								
Egg	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 20.–Spring diet of yellow perch in Jewett Lake, 1988-94, in size range (mm) of food type.

Food type	Perch length (mm group)							
	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton								
Copepoda								
Cladocera								
Daphnia								
Other	0.8-1.5		2.0-2.0	1.0-2.0				
Benthos								
Crayfish								
Amphipod	3-4	1-4	2-4	2-5				
Ostracod								
Mite								
Worm				3				
Snail	2-5	3-6	3-6	4-6				4
Clam			5	6				
Mayfly nymph								
Caddis larva								
Damselfly nymph								
Dragonfly nymph				10	10-20	15		
Midge larva	3-10	4-20	5-10	5-20	6-12	8-15	15-25	10-25
Midge pupae	3	10		3-11	5-12	6-12	5-11	5-11
Chaoborus larva								5-7
Beetle larva				5				
Other								10
Surface insects								
Odonata adult								
Beetle adult								
Other adult								
Vegetation								
Fish								
Bluegill								
Bluegill[1]								
Yellow perch						60	52-70	
Walleye								
Percid[2]								
Unidentified								
Other								
Egg								
Frog								

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 21.–Spring diet of yellow perch in Jewett Lake, 1988-94, in estimated percent of total food on a dry weight basis. See text for method of reconstructing food weight.

Food type	Perch length (mm group)							
	76-101	102-126	127-151	152-177	178-202	203-228	229-253	254-278
Zooplankton								
Copepoda	0	0	0	0	0	0	0	0
Cladocera								
Daphnia	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0
Benthos								
Crayfish	0	0	0	0	0	0	0	26
Amphipod	3	1	3	1	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0
Mayfly nymph	71	25	92	37	0	0	0	0
Caddis larva	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0	78	5	0	0
Midge larva	24	74	4	52	15	3	5	65
Midge pupae	2	0	0	10	6	1	1	8
Chaoborus larva	0	0	0	0	0	0	0	0
Beetle larva	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0
Surface insects								
Odonata adult	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0
Other adult	0	0	0	0	1	0	0	0
Vegetation	–	–	–	–	–	–	–	–
Fish								
Bluegill	0	0	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	77	89	0
Walleye	0	0	0	0	0	0	0	0
Percid[2]	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	14	5	0
Other								
Egg	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0
Total (%)	100	100	100	100	100	100	100	100
Meal size (%BW)	0.14	0.68	0.18	0.21	0.03	0.23	0.17	0.02

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 22.–Fall diet of walleye in Jewett Lake, 1987-93, in terms of frequency of occurence (%).

	Walleye length (mm group)												
Food type	203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-532
Zooplankton													
Copepoda	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladocera													
Daphnia	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Benthos													
Crayfish	0	0	0	4	2	2	3	11	12	8	4	5	0
Amphipod	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0	0	0	0	0	0
Mayfly nymph	0	0	0	4	0	0	0	1	0	0	0	0	0
Caddis larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	7	2	3	4	5	2	0	0	0	0
Midge larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Midge pupae	0	0	0	0	0	2	0	0	0	0	0	0	0
Chaoborus larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Beetle larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	2	1	0	0	0	0	0	0
Surface insects													
Odonata adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0	0	2	0	5	0
Other adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0
Fish													
Bluegill	40	17	0	33	18	20	15	12	17	20	25	18	0
Bluegill[1]	0	0	0	0	2	2	4	1	3	4	0	0	0
Yellow perch	24	34	0	19	16	21	30	31	32	30	39	36	50
Walleye	0	0	0	0	0	0	0	0	0	0	0	0	0
Percid[2]	8	0	20	0	4	5	5	3	2	2	0	0	0
Unidentified	20	7	20	15	11	15	18	27	24	22	21	18	0
Other													
Egg	0	0	0	0	0	0	0	0	0	0	0	0	0
Frog	0	0	0	0	1	0	0	2	2	0	7	0	17
N	38	38	5	28	116	71	84	108	70	55	29	23	6
Void (%)	21	37	60	46	47	38	38	31	31	33	31	39	33

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape, but 1 stickleback included.

Appendix 23.–Fall diet of walleye in Jewett Lake, 1987-93, in average number of food organisms per walleye.

	Walleye length (mm group)												
Food type	203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-532
Zooplankton													
Copepoda	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladocera													
Daphnia	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Benthos													
Crayfish	0	0	0	0	0	0	0	0.1	0.1	0.1	0	0.1	0
Amphipod	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0	0	0	0	0	0
Mayfly nymph	0	0	0	0	0	0	0	0	0	0	0	0	0
Caddis larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0.1	0	0	0.1	0.1	0	0	0	0	0
Midge larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Midge pupae	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaoborus larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Beetle larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface insects													
Odonata adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Other adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetation	–	–	–	–	–	–	–	–	–	–	–	–	–
Fish													
Bluegill	0.8	0.7	0	0.4	0.3	0.4	0.5	0.2	0.3	1.3	0.4	0.2	0
Bluegill[1]	0	0	0	0	0.1	0	0.1	0	0	0.1	0	0	0
Yellow perch	0.5	0.6	0	0.2	0.2	0.2	0.8	0.4	0.4	0.5	0.4	0.6	1.2
Walleye	0	0	0	0	0	0	0	0	0	0	0	0	0
Percid[2]	0.1	0	0.2	0	0	0	0	0	0	0	0	0	0
Unidentified	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.4	0.3	0.3	0.3	0.2	0
Other													
Egg	0	0	0	0	0	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0	0	0	0.1	0	0.2

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape, but 1 minnow included.

Appendix 24.–Fall diet of walleye in Jewett Lake, 1987-93, in size range (mm) of food type.

	Walleye length (mm group)												
Food type	203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-532
Zooplankton													
Copepoda													
Cladocera													
Daphnia													
Other													
Benthos													
Crayfish					11-15	9	18	15-30	10-30			15	
Amphipod													
Ostracod													
Mite													
Worm													
Snail													
Clam													
Mayfly nymph													
Caddis larva													
Damselfly nymph													
Dragonfly nymph				15	10-20	20	15-17	10-18	17				
Midge larva													
Midge pupae						8							
Chaoborus larva													
Beetle larva													
Other						2	14						
Surface insects													
Odonata adult													
Beetle adult													
Other adult													
Vegetation													
Fish													
Bluegill	18-50	20-45		30-92	22-97	25-90	20-94	22-100	25-113	18-125	50-110	50-98	
Bluegill[1]					40	50	28-40		51-75	60-90			
Yellow perch	40-75	40-75		55-100	60-100	50-135	40-150	50-150	40-130	50-175	70-175	60-153	75-179
Walleye													
Percid[2]	40-45		50		45-85	40-65	50-90	45-60	85				
Unidentified					55		30-40	40-90		75	80		
Other													
Egg													
Frog													

Appendix 25.–Fall diet of walleye in Jewett Lake, 1987-93, in estimated percent of total food on a dry weight basis. See text for method of reconstructing food weight.

	Walleye length (mm group)												
Food type	203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-532
Zooplankton													
Copepoda	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladocera													
Daphnia	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Benthos													
Crayfish	0	0	0	0	0	0	0	2	3	0	0	0	0
Amphipod	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0	0	0	0	0
Worm	0	0	0	0	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0	0	0	0	0	0
Mayfly nymph	0	0	0	0	0	0	0	0	0	0	0	0	0
Caddis larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0	0	0	0	0	0	0	0	0	0
Midge larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Midge pupae	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaoborus larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Beetle larva	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface insects													
Odonata adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Other adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetation	–	–	–	–	–	–	–	–	–	–	–	–	–
Fish													
Bluegill	33	13	0	65	46	37	17	12	34	44	25	15	0
Bluegill[1]	0	0	0	0	3	2	1	0	3	4	0	0	0
Yellow perch	62	86	0	34	40	58	79	67	57	44	63	75	99
Walleye	0	0	0	0	0	0	0	0	0	0	0	0	0
Percid[2]	4	0	90	0	5	2	2	2	2	1	0	0	0
Unidentified	1	1	10	1	6	1	1	16	1	7	11	9	0
Other													
Egg	0	0	0	0	0	0	0	0	0	0	0	0	0
Frog	0	0	0	0	1	0	0	1	1	0	1	0	1
Total (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
Meal size (%BW)	1.54	0.92	0.15	1.09	0.85	0.8	1.89	1.1	0.65	2.18	1.38	0.86	2.12

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape, but 1stickleback included.

Appendix 26.–Spring diet of walleye in Jewett Lake, 1987-94, in terms of frequency of occurence (%).

	Walleye length (mm group)										
Food type	229-253	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-533
Zooplankton											
Copepoda	0	0	0	0	0	0	0	0	0	0	0
Cladocera											
Daphnia	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0
Benthos											
Crayfish	0	0	6	13	7	8	33	29	38	0	33
Amphipod	33	0	6	20	7	0	4	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0	0	0
Leech	0	0	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0	0	0	0
Mayfly nymph	33	50	28	20	7	8	17	10	13	0	0
Caddis larva	0	0	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0	0	0	0	0	0	0	0
Midge larva	67	50	28	27	19	8	13	10	25	0	0
Midge pupae	33	50	22	20	15	8	17	10	25	0	0
Chaoborus larva	0	0	0	7	4	4	0	0	0	0	0
Beetle larva	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	7	4	0	0	0	0	0	0
Surface insects											
Odonata adult	0	0	0	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0	0	0	0
Other adult	33	50	11	0	4	8	0	5	13	50	0
Vegetation	0	0	0	0	0	0	0	0	0	0	0
Fish										0	
Bluegill	0	0	0	0	0	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	13	0	13	8	10	25	0	17
Walleye	0	0	0	0	0	8	0	0	13	0	0
Percids[2]	33	0	6	20	7	0	4	10	13	0	0
Unidentified	0	0	6	7	4	4	8	5	13	50	0
Other											
Eggs	0	0	0	0	0	0	0	0	0	0	0
Frog	0	0	6	7	4	0	0	5	13	0	0
N	4	2	23	23	42	28	28	21	12	2	6
Void (%)	25	50	48	39	23	61	46	38	17	50	50

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 27.–Spring diet of walleye in Jewett Lake, 1987-94, in average number of food organisms per walleye.

	Walleye length (mm group)										
Food type	229-253	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-533
Zooplankton											
Copepoda	0	0	0	0	0	0	0	0	0	0	0
Cladocera											
Daphnia	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0
Benthos											
Crayfish	0	0	0	0.1	0.1	0.1	0.6	0.3	0.3	0	0.7
Amphipod	1.5	0	0	1.1	0.8	0	0.1	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0	0	0
Leech	0	0	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0	0	0	0
Mayfly nymph	0.3	1.5	2.1	0.3	0.1	0.4	0.4	0.1	0.4	0	0
Caddis larva	0	0	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0	0	0	0	0	0	0	0
Midge larva	0.8	1	13.2	24.3	16.2	12.8	16.5	5.2	2.9	0	0
Midge pupae	3.8	3	1.8	13	3.6	1.4	1.3	0.9	1.3	0	0
Chaoborus larva	0	0	0	0.1	0.1	0	0	0	0	0	0
Beetle larva	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0
Surface insects											
Odonata adult	0	0	0	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0	0	0	0
Other adult	0.5	1	1	0	0	0.2	0	0.1	0.3	2	0
Vegetation	–	–	–	–	–	–	–	–	–	–	–
Fish											
Bluegill	0	0	0	0	0	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0.1	0	0.1	0.1	0.2	0.2	0	0.3
Walleye	0	0	0	0	0	0.1	0	0	0.1	0	0
Percids[2]	0.3	0	0	2.8	1	0	1.3	0.1	0.1	0	0
Unidentified	0	0	0	0	0	0	0.1	0	0.2	0.5	0
Other											
Eggs	0	0	0	0	0	0	0	0	0	0	0
Frog	0	0	0	0	0	0	0	0	0.2	0	0

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 28.–Spring diet of walleye in Jewett Lake, 1987-94, in size range (mm) of food type.

	Walleye length (mm group)										
Food type	229-253	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-533
Zooplankton											
Copepoda											
Cladocera											
Daphnia											
Other											
Benthos											
Crayfish			20	10		20	14-40	14-18			
Amphipod	3-4			3-4	4						
Ostracod											
Mite											
Leech											
Snail											
Clam											
Mayfly nymph		5-8	5-7	6	4	5	1-6	5	5-10		
Caddis larva											
Damselfly nymph											
Dragonfly nymph											
Midge larva		12	7-23	6-25	6-25	10-23	17-25	10-25	10-25		
Midge pupae	5-7	7	4-10	5-15	4-15	4-10	5-15	5-11	5-11		
Chaoborus larva				6-7	6-9	6					
Beetle larva											
Other				15	5						
Surface insects											
Odonata adult											
Beetle adult											
Other adult				10	4					4	
Vegetation											
Fish											
Bluegill											
Bluegill[1]											
Yellow perch				60-95		70-130	70-150	60-153	64-100		60-70
Walleye						15			241		
Percids[2]	8-70		70	15	15		15	90	90		
Unidentified							50				
Other											
Eggs											
Frog											

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 29.–Spring diet of walleye in Jewett Lake, 1987-94, in estimated percent of total food on a dry weight basis. See text for method of reconstructing food weight.

	Walleye length (mm group)										
Food type	229-253	279-304	305-329	330-355	356-380	381-405	406-431	432-456	457-482	483-507	508-533
Zooplankton											
Copepoda	0	0	0	0	0	0	0	0	0	0	0
Cladocera											
Daphnia	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0
Benthos											
Crayfish	0	0	8	1	17	7	39	3	1	0	19
Amphipod	0	0	0	0	0	0	0	0	0	0	0
Ostracod	0	0	0	0	0	0	0	0	0	0	0
Mite	0	0	0	0	0	0	0	0	0	0	0
Leech	0	0	0	0	0	0	0	0	0	0	0
Snail	0	0	0	0	0	0	0	0	0	0	0
Clam	0	0	0	0	0	0	0	0	0	0	0
Mayfly nymph	0	50	2	0	0	0	0	0	0	0	0
Caddis larva	0	0	0	0	0	0	0	0	0	0	0
Damselfly nymph	0	0	0	0	0	0	0	0	0	0	0
Dragonfly nymph	0	0	0	0	0	0	0	0	0	0	0
Midge larva	0	23	16	18	37	5	7	1	0	0	0
Midge pupae	0	25	1	2	1	0	0	0	0	0	0
Chaoborus larva	0	0	0	0	0	0	0	0	0	0	0
Beetle larva	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0
Surface insects											
Odonata adult	0	0	0	0	0	0	0	0	0	0	0
Beetle adult	0	0	0	0	0	0	0	0	0	0	0
Other adult	0	3	0	0	0	0	0	0	0	0	0
Vegetation	–	–	–	–	–	–	–	–	–	–	–
Fish											
Bluegill	0	0	0	0	0	0	0	0	0	0	0
Bluegill[1]	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	56	0	86	48	73	8	0	81
Walleye	0	0	0	0	0	0	0	0	83	0	0
Percids[2]	99	0	37	10	19	0	1	19	6	0	0
Unidentified	0	0	16	1	1	2	5	2	0	100	0
Other											
Eggs	0	0	0	0	0	0	0	0	0	0	0
Frog	0	0	21	12	20	0	0	2	3	0	0
Total (%)	100	100	100	100	100	100	100	100	100	100	100
Meal size (%BW)	0.72	0.01	0.15	0.2	0.05	0.31	0.47	0.52	1.31	0.23	0.09

[1] Probably bluegill as indicated by robust shape and absence of other sunfish.
[2] Probably perch or walleye as indicated by slender shape.

Appendix 30.–Daily minimum and maximum air and water temperatures (°C) for Jewett Lake in 1996. Air temperatures from the National Weather Station at the Rifle River Recreation Area Headquarters. Water temperatures from recording thermograph on bottom at depth of 0.5 m. var = maximum 24-hr variation.

	Air			Water				Air			Water				Air			Water		
Date	min	max	var	min	max	var	Date	min	max	var	min	max	var	Date	min	max	var	min	max	var
11-Apr	-4.4	8.3					26-May	4.4	20.0	20.0	16.9	18.1	1.7	10-Jul	8.3	22.2	13.9	21.1	24.2	3.1
12-Apr	-1.1	23.9	28.3				27-May	-2.2	18.3	22.2	15.9	17.9	2.2	11-Jul	4.4	25.0	20.6	21.4	24.6	3.5
13-Apr	-2.2	3.3	26.1	4.2	4.4		28-May	5.0	21.7	23.9	16.4	18.9	3.0	11-Jul	4.4	25.0	20.6	21.4	24.6	3.5
14-Apr	-1.7	6.1	8.3	4.2	4.8	0.6	29-May	2.2	22.2	20.0	16.1	18.2	2.8	12-Jul	9.4	25.6	21.1	22.3	23.5	2.3
15-Apr	-1.7	9.4	11.1	4.6	4.9	0.7	30-May	-5.6	20.6	27.8	16.2	19.7	3.6	13-Jul	10.6	23.3	15.0	21.6	25.6	4.0
16-Apr	-1.7	4.4	11.1	4.6	4.9	0.3	31-May	-1.7	24.4	30.0	17.2	20.6	4.4	14-Jul	8.3	30.0	21.7	22.9	25.8	4.2
17-Apr	-4.4	5.6	10.0	4.8	5.7	1.1	1-Jun	2.8	25.6	27.2	18.4	21.2	4.0	15-Jul	10.6	26.1	19.4	23.2	25.6	2.7
18-Apr	-1.1	15.0	19.4	4.8	5.8	1.0	2-Jun	2.8	28.3	25.6	19.9	21.1	2.7	16-Jul	10.6	26.1	15.6	23.4	25.9	2.7
19-Apr	7.8	24.4	25.6	4.7	7.1	2.4	3-Jun	5.6	17.8	22.8	19.6	21.7	2.1	17-Jul	11.7	27.2	16.7	23.7	27.6	4.2
20-Apr	3.9	23.3	20.6	6.2	8.2	3.5	4-Jun	6.7	17.2	11.7	19.8	22.0	2.4	18-Jul	8.9	32.8	23.9	25.1	26.2	2.5
21-Apr	9.4	22.8	18.9	7.4	11.2	5.0	5-Jun	5.6	16.7	11.7	18.6	21.1	3.4	19-Jul	8.3	32.8	24.4	23.8	25.2	2.4
22-Apr	9.4	23.9	14.4	9.2	10.1	2.7	6-Jun	8.3	17.2	11.7	19.2	20.2	1.9	20-Jul	4.4	24.4	28.3	22.8	25.2	2.4
23-Apr	-3.3	15.6	27.2	8.1	9.6	2.0	7-Jun	6.7	11.1	10.6	17.7	19.1	2.5	21-Jul	6.7	26.1	21.7	22.9	24.9	2.3
24-Apr	-7.2	9.4	22.8	7.8	10.5	2.7	8-Jun	11.1	12.2	5.6	17.0	17.6	2.1	22-Jul	6.1	25.6	20.0	22.9	26.5	3.6
25-Apr	-3.9	15.6	22.8	8.7	9.2	1.8	9-Jun				17.1	17.4	0.5	23-Jul	7.8	28.3	22.2	23.9	26.1	3.2
26-Apr	2.2	16.1	20.0	7.7	9.1	1.5	10-Jun	11.7	15.0	3.3	17.0	18.2	1.2	24-Jul				23.7	26.2	2.5
27-Apr	-6.1	7.2	22.2	7.1	10.0	2.9	11-Jun	11.1	18.9	7.8	17.8	20.0	3.0	25-Jul				23.5	25.4	2.7
28-Apr	-8.9	10.0	18.9	7.5	10.4	3.3	12-Jun	5.6	15.6	13.3	18.8	23.2	5.4	26-Jul	7.8	28.9	21.1	22.8	24.6	2.6
29-Apr				8.4	10.1	2.6	13-Jun	11.7	21.1	9.4	20.7	22.3	3.5	27-Jul	5.6	25.0	23.3	22.4	24.9	2.5
30-Apr	1.1	6.7	5.6	7.4	8.4	2.7	14-Jun				22.0	24.6	3.9	28-Jul	10.0	26.1	20.6	22.2	23.5	2.7
1-May	-1.7	4.4	8.3	7.2	7.9	1.2	15-Jun				22.3	24.2	2.3	29-Jul	12.8	20.6	13.3	21.4	22.1	2.1
2-May	-6.7	7.2	13.9	6.9	10.3	3.4	16-Jun				22.1	23.5	2.1	30-Jul	13.3	21.1	8.3	21.1	22.6	1.5
3-May	-5.6	18.3	25.0	8.5	9.5	2.6	17-Jun	7.2			20.5	22.6	3.0	31-Jul				21.2	22.3	1.4
4-May	-1.1	11.1	19.4	8.8	12.1	3.6	18-Jun	7.8	30.6	23.3	19.1	20.4	3.5	1-Aug	7.2	22.2	15.0	21.1	24.6	3.5
5-May	-2.2	17.8	20.0	9.7	11.4	2.6	19-Jun	7.8	17.2	22.8	18.6	19.3	1.8	2-Aug	9.4	25.0	17.8	21.9	24.0	2.9
6-May	1.7	12.8	16.1	10.0	11.9	2.2	20-Jun	13.9	19.4	11.7	19.0	20.7	2.1	3-Aug	10.6	25.6	16.1	22.7	25.0	3.1
7-May				11.0	12.7	2.7	21-Jun	8.9	23.9	15.0	19.6	21.3	2.3	4-Aug	12.2	27.8	17.2	23.9	25.7	3.0
8-May	-5.0	16.7	21.7	11.3	12.3	1.4	22-Jun	9.4	26.1	17.2	20.8	22.4	2.8	5-Aug	12.8	28.9	16.7	24.2	26.5	2.6
9-May	-2.8	17.2	22.2	11.6	11.9	0.7	23-Jun				20.0	21.8	2.4	6-Aug				25.2	27.3	3.1
10-May	6.7	17.2	20.0	11.1	11.8	0.8	24-Jun	5.6	23.3	17.8	21.0	23.1	3.1	7-Aug				26.8	29.6	4.4
11-May	0.6	10.6	16.7	10.5	12.5	2.0	25-Jun	7.2	26.7	21.1	20.3	23.0	2.8	8-Aug	15.6	32.8	17.2	27.1	28.9	2.5
12-May	-2.8	16.7	19.4	10.1	11.6	2.4	26-Jun	3.9	25.6	22.8	20.7	22.1	2.3	9-Aug	7.2	28.9	25.6	25.3	27.1	3.6
13-May	-5.6	10.6	22.2	9.7	12.9	3.2	27-Jun	7.8	26.7	22.8	21.7	23.7	3.0	10-Aug	3.9	25.6	25.0	23.8	26.1	3.3
14-May	-5.6	15.6	21.1	10.5	13.0	3.3	28-Jun	13.3	31.7	23.9	23.2	25.4	3.7	11-Aug	5.0	26.1	22.2	23.5	25.3	2.6
15-May	-1.1	17.8	23.3	11.8	12.8	2.3	29-Jun	15.6	31.7	18.3	24.6	27.8	4.6	12-Aug	5.0	28.3	23.3	23.1	26.3	3.2
16-May	3.3	16.1	17.2	12.4	13.8	2.0	30-Jun	21.1	33.3	17.8	26.3	28.9	4.3							
17-May	3.3	17.2	13.9	12.7	13.8	1.4	1-Jul	7.2	31.7	26.1	25.6	28.4	3.3							
18-May	12.2	20.6	17.2	13.5	18.6	5.9	2-Jul				23.8	26.9	4.6							
19-May	9.4	31.7	22.2	16.8	20.0	6.5	3-Jul	12.2	30.0	17.8	22.5	24.5	4.4							
20-May	15.0	30.0	20.6	18.8	21.0	4.2	4-Jul	5.6	23.3	24.4	22.1	25.5	3.4							
21-May	6.1	26.7	23.9	18.4	20.9	2.6	5-Jul	3.9	26.7	22.8	22.4	26.8	4.7							
22-May	3.9	25.0	22.8	18.6	21.4	3.0	6-Jul	12.8	28.9	25.0	23.9	26.0	3.6							
23-May	2.8	25.0	22.2	18.2	19.8	3.2	7-Jul	12.2	27.8	16.7	24.2	26.9	3.0							
24-May	-0.6	23.9	25.6	16.9	18.5	2.9	8-Jul	7.2	30.0	22.8	23.3	25.2	3.6							
25-May	0.0	17.2	23.9	16.4	18.6	2.2	9-Jul	10.6	21.7	19.4	22.4	23.8	2.8							

Appendix 31.–Summary of experiments on the consumption and digestion of walleye eggs and fry by bluegill.

Methods

Experiments were conducted in 38-L aquaria at the Saline Fisheries Research Station, April-May 1996, at 15-21 °C. Eggs were 1-3 days post-fertilization; fry were 6 days post-hatch. Prey were introduced into the aquaria while the bluegill's vision was screened out. Wild bluegill, recently obtained from ponds, were 30 - 155 mm TL. For digestion rate measurements, bluegill stomachs were either flushed out with water or dissected to determine amount of remaining food.

Conclusions

Egg consumption–All tested bluegill (15/15) over 37 mm in length ate some eggs, and 7 bluegill ate more than 80% of the eggs offered. Consumption rates as high as 50eggs/day/bluegill are possible, even for small bluegill. Eggs were not eaten as readily as fry.

Egg digestion–A limited experiment suggested egg remains were visible in a small bluegill stomach up to 24 hours after ingestion.

Fry consumption–All bluegill (14/14), including the smallest likely to occur in lakes in early spring (30 mm), very readily captured and ate walleye fry. Consumption rates up to 40 fry/half day are possible for a 64-mm bluegill. In a lake, a modest bluegill population density of hundreds per ha could probably decimate walleye fry production if fry and bluegill co-occurred in the same habitat.

Fry digestion–Complete evacuation of a full meal of fry took place in about 10 hours for 60-70 mm bluegill. Probably less time is required with larger bluegill and smaller rations. The eyes are the part most resistant to digestion and are the last trace to be found in stomachs.