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Synopsis of 50 Years of Warmwater Fish Community Experiments at Jewett Lake

James C. Schneider

Michigan Department of Natural Resources
Fisheries Division
212 Museums Annex Building
Ann Arbor, MI 48109

Abstract.–Fishery and population data from one small lake spanning 50 years are reviewed in which 10 combinations of fish assemblages and angling exploitation were identified. The development of each combination was monitored and it's equilibrium state was observed or estimated. Initially, in 1945, Jewett Lake contained a diverse, lightly exploited, climax warmwater community with bluegill *Lepomis macrochirus* (51%), largemouth bass *Micropterus salmoides* (5%), and yellow perch *Perca flavscens* (6%) as major components by weight. Total standing stock biomass of all fish and the abundance of large fish were greatly reduced during the first year that public exploitation was permitted and they quickly stabilized at modest levels. Yield declined from 84 to 26 lb/acre. Next, there was a progression of experimental populations and communities comprised of combinations of bluegill, yellow perch, and walleye *Stizostedion vitreum*. Two of the experimental communities were stable and had desirable population and fishery characteristics: walleye + perch, and walleye + perch + bluegill. Predation by walleye was intensive enough to prevent over-population by bluegill and yellow perch and stimulate good individual growth. By contrast, monocultures of either prey species had higher biomass, but such slow individual growth that few fish achieved large size and their fishery potential was poor. The exploited warmwater community, composed of 7 species, had much higher fishery yield (26 lb/acre) than any of the experimental assemblages (maximum of 4 lb/acre). Total biomass of the exploited warmwater community (122 lb/acre) was matched by stunted bluegill in monoculture (peak of 126 lb/acre), but not by stunted yellow perch in monoculture (68 lb/acre), and not by the balanced 3-species community (maximum 74 lb/acre). Thus, the bluegill was able to extract virtually 100% of the potential fish productivity of the lake when released from competition and predation but the other food generalist, the yellow perch, was able to extract only 50%. Each had a somewhat unique niche, but bluegill suppressed the production of yellow perch. Bluegill are the dominant producer in Jewett Lake and most lakes in Michigan.

Fish and fishing in Jewett Lake were studied intensively from 1945 to 1995. During this 50-year span the lake supported first a typical warmwater fish community and then several types of fish assemblages of experimental origin. This data set affords a unique opportunity to (1) extract population statistics and gain insights into population dynamics which can be used for modeling; (2) determine how the characteristics of a population of one species change in the presence of other species and gain insight into how communities structure themselves; and (3) evaluate the fishery characteristics and management potential of various species assemblages. Because all studies were conducted at one lake, basic productivity and habitat type were constant. In addition, the physical environment of Jewett Lake has been constant with the exception of ordinary variations in weather. Therefore, any effects or changes are presumed to be due mainly to the ecology of the species themselves. This is much preferred over trying to infer population and community dynamics by comparing data obtained from different lakes, and often from different years.

The Jewett Lake studies were directed by David S. Shetter, Mercer H. Patriarche, and myself. Their results and data are contained in 30 reports and publications. These are compiled in the References Section. A chronology of events and the major references are given in Table 1.

A brief outline of events follows. Initially, in 1945, when the lake was first opened to public fishing, it contained a lightly exploited fish community typical of warmwater lakes. Bluegill *Lepomis macrochirus* and largemouth bass *Micropterus salmoides* were the dominant species. In the mid 1950's, redear sunfish *Lepomis microlophus* were stocked but did not become established. In 1959 and 1965, slow-growing bluegill populations were thinned-out. Beginning in 1962, a series of experimental populations and assemblages were established, usually preceded by eliminating all fish with piscicides. The experimental populations and assemblages were: bluegill-only; yellow perch-only *(Perca flavscens*, hereafter referred to as perch); perch and minnow; perch and minnow and walleye *(Stizostedion vitreum*); perch and walleye; and bluegill and perch and walleye. Exploitation by sport angling, allowed during some periods, was another variable. In all, 10 major segments – combinations of species and exploitation – were identified. Little can be said about results of the tenth segment (bluegill and perch and walleye under catch/release angling) at this time because it began recently (1994). However, some predictions of equilibrium results were made based on mathematical modeling (Schneider 1995) and are included in discussion of similar Segment 9, which was the same fish assemblage in the unexploited state.

Lake Description

Jewett Lake is a small, landlocked lake in Ogemaw County (T. 23N., R. 3E., Sec. 11). It has an area of 12.9 acres, a maximum depth of 17 feet, a volume of 120,000 m^3 and an alkalinity of 34 ppm. The water is slightly brown and Secchi disk transparency is typically about 5.8 feet. Dissolved oxygen levels drop below 2 ppm at a depth of 3 feet during summer and winter, but fish kills have never been detected. Surface temperatures often exceed 81F. About 90% of the shoreline is rimmed with encroaching bog. The bottom is composed almost entirely of peat and silt, except for a narrow strip of sand along 50% of the shoreline. Pond lilies, once common, were eliminated when beaver *Castor canadensis* colonized the lake in the early 1980s. Pondweeds may have been more common in early years than recent years, but there is no reason to suspect that an important change in productivity occurred.

Early History

Jewett Lake is within a 4,318-acre tract purchased by the Michigan Department of Conservation (now Natural Resources) from pioneer auto maker Harry M. Jewett in 1944. The tract was to be used for research and to provide public fishing, hunting, and sightseeing. The name of the tract was changed from Grousehaven to the Rifle River Recreation Area and, later, the name of the lake was changed from Dollar to Jewett. The Area was administered as a research tract by the Institute For Fisheries Research until January 1, 1966, when administration was turned over to the Parks Division. Some lakes, including Jewett, retained research status.

Jewett Lake and the other five lakes in the Area were first opened to public fishing in 1945. Record numbers of anglers were attracted by the prospect of fishing "virgin" waters. As a private estate the waters had been lightly exploited by the owner and a few friends. Record high harvests were made the first year at most of the lakes but were not sustainable. Fishing harvest and quality quickly declined and never recovered (Patriarche 1960).

Fish in Jewett Lake were first surveyed in July, 1931 (Anonymous 1932). Known to be present were bluegill, pumpkinseed *Lepomis gibbosus*, bluegill x pumpkinseed hybrid, black crappie *Pomoxis nigromaculatus*, Iowa darter *Etheostoma exile*, and northern pike *Esox lucius*. Bluegill and black crappie may not have been present very long, as those species reportedly had been stocked by the owner. Northern pike were never reported again, and I conclude that a few had been stocked and had failed to reproduce in this limited habitat. The survey crew reported that perch and largemouth bass may have been present in limited numbers in 1931; however, the crew recommended bass stocking and some could have been added later. A survey in 1944 (Shetter 1945) captured perch up to 10 in long, bluegill up to 8 in, pumpkinseed up to 7.2 in, one yellow bullhead (*Ameiurus natalis*) 10 in long, and one Iowa darter. Additional species taken by anglers in 1945 were largemouth bass and rock bass *Ambloplites rupestris*. As of 1945, I believe that all species had been present long enough to develop a stable warmwater fish community which was near the "climax" state. Climax, as used here, means the equilibrium state in which community composition is diverse and stable, and species populations are characterized by maximum standing crop biomass and high densities of relatively old and large fish because they are unexploited.

Methods

For this report, first a summary will be made of the events in each segment, then a comparison will be made at equilibrium conditions. Attributes to be compared are population biomass (standing stock), individual growth, adult mortality, community structure, abundance of larger fish (legal size or large enough to interest anglers), and quality of the sport fishery. Equilibrium, as used here, means a relatively stable condition reached after the colonization phase in which populations no longer expand. Minor oscillations in population and community attributes may occur, but without trend. Judgment as to when equilibrium had been reached is most accurate for study segments which lasted for many years. Attainment of equilibrium is more subjective for studies of short duration, especially as regards how many large fish a population will eventually develop, a process which can take 6 or more years for these relatively slow-growing, long-lived species. However, the data indicate that population and community biomass reached peaks in just 2 growing seasons. Mathematical predictions of equilibrium characteristics were made for some segments.

Catch surveys

From 1945, when the gate opened to the public, to 1966 a continuous census of fishing effort and harvest was maintained. Anglers exiting the Area were required to present all harvested fish at the Checking Station for inspection, tabulation, and weighing. In addition, some scale samples were collected for age and growth analysis. Jewett Lake was closed to fishing from 1966 to 1978, then reopened. A census of effort and harvest (also of catch-and-release) was continued in 1978-91. Anglers were required to obtain a free permit before fishing, abide by special regulations as to season and creel limit, and report as they left the Area. Some non-compliance occurred in both periods, but the census is believed to be nearly complete. Appendices 1a-1c contain a compilation of data on angling pressure, harvest, and important regulations.

Population methods

Abundance of fish was estimated by mark-recapture techniques, usually during spring or fall. Fish were marked with finclips, usually of the caudal fin. The ratio of marked to unmarked fish in subsequent samples provided an estimate of numbers of fish present. In some years, angling exploitation rate was estimated from the recapture of fish marked the preceding spring. Estimates were stratified by species and size group to compensate for gear selectivity. Estimates of population biomass (standing crop) were calculated with the aid of length-weight regressions. Scale samples were used to determine the age composition of important populations and to determine individual growth rates by either back calculation or empirical average length-at-age. These lengths were compared to the State of Michigan averages (Merna et al. 1981). Fish collecting gear included trapnets, 220-v AC electrofishing gear, fyke nets, wire traps, large seines, and toxicants. Usually, the goal was to estimate all fishes, but sometimes fish less than 3-4 inches long could not be estimated due to their frailty, low catchability, or high abundance. However, small fish usually are a minor component of total biomass. For 1958 data, the biomass of small bluegill and perch were estimated by comparison to models for populations in Mill Lake (Schneider 1971). An estimate of the Jewett Lake fish population was first attempted in July 1948, but too few recaptures were made. Intensive sampling began in 1957 and was conducted in most years through 1993.

Descriptive Summaries of Segments

Segment 1. Initial Exploitation of a Climax Warmwater Community (1945)

Patriarche (1960) documented the decline in fishing quality (and undoubtedly populations) which resulted when Jewett Lake and other waters in the Rifle River Area were opened to the public. In 1945, fishing pressure and harvest at Jewett Lake increased from the very low levels experienced during private ownership to 144 hours/acre and 84 lb/acre, respectively (Table 2). Angling quality in 1945 was very high– 2.58 fish per hour. Fishing declined in 1946, then remained stable through 1958. Compared to 1945, pressure was 39% lower, yield was 68% lower, and angling quality was 37% lower in 1946-58 (Table 2). Species showing the greatest decline in numbers caught in 1946-58 relative to 1945 were pumpkinseed (-88%) and black crappie (-84%). Perch, bluegill, and largemouth bass catches also declined substantially– 50-58%. Bluegill, perch, pumpkinseed, black crappie, and bullhead were also of larger average size in 1945 than in 1949.

Many largemouth bass were caught in 1945 but they were not unusually large or old (maximum age of 6); this may indicate the bass population was of recent origin. Patriarche (1960) noted that largemouth bass were very readily caught when the lake opened in 1945. Largemouth bass harvest in the first week of angling was 45% (45 bass) of the annual total for 1945, compared to 15% (6 bass) of the annual total for 1946-56. However, the largemouth bass population thrived, indicating the primary reason for poorer fishing was reduced catchability. A similar conclusion was reached from a similar study at Mill Lake (Schneider 1973).

Segment 2. Typical Warmwater Community Under Exploitation (1946-58)

Individual populations, and the structure of the community, adjusted to a modest, typical level of angling exploitation after 1945. Estimates of annual exploitation rate were on the order of 25% for most species, except perch were exploited at a rate of about 45% (Appendix 2). No species became extinct, but in 1946-58 harvested fish were less frequent, fewer in number, and smaller in average size (Table 2). Those changes apparently reflected population reductions, specifically the loss of large fish which had accumulated under years of low exploitation. The changes may also indicate reduced catchability, especially for largemouth bass. Composition of the yield by weight shifted from 51 to 60% bluegill at the expense of pumpkinseed and black crappie. Largemouth bass, the primary piscivore, increased from 5 to 10%.

While all populations of large fish were obviously reduced compared to Segment 1 (1945), perch was the only species showing evidence of growth compensation through larger mean lengths at age (Table 3). Bluegill growth temporarily improved as of 1948, but was similar to the pre-1946 rate by the mid 1950s. A decade after exploitation intensified, growth of largemouth bass and black crappie had declined rather than improved, and growth of pumpkinseed was unchanged. Growth rates of all species in both periods were relatively slow compared to State averages (Table 3). Some compensation probably occurred through increased recruitment of small fish to the populations, but there is no measure of that.

Population studies on the slow-growing bluegill began in 1957 (Patriarche 1968). Estimates of all important species were made by size groups in 1958 (Patriarche 1961b) and are believed to represent equilibrium conditions for Segment 2. My derivations of biomass and community composition are shown in Appendix 2. Total fish biomass in 1958 was estimated at 1579 lb. The population biomass estimates indicate an even greater proportion of bluegill (70%) and largemouth bass (14%) in the community than had been indicated by the angling data. Generally, Michigan lakes with good fishing have higher proportions (>20%) of piscivores (Schneider 1981).

Evaluation of Redear Sunfish (1954-62)

An additional study during Segment 2 was the evaluation of the stocking of 1000 fingerling redear sunfish in 1954 and again in 1956. A total of 60 (3%) were eventually harvested by anglers over a period of 6 years (Appendix 1b). Exploitation rate was about 20%/year (Appendix 2). Reproduction was reported, but the species disappeared by 1962. Redear sunfish had no discernable effect on other fish in Jewett Lake. Pumpkinseed, and to a lesser extent bluegill, were the species most likely to be affected by redear because of potential diet overlap. They also eat snails and other invertebrates. Neither pumpkinseed nor bluegill showed declining growth from 1955 to 1957, and the growth of both mysteriously increased in 1958 (Patriarche 1963a). If redear sunfish had any effect it was obscured by other events such as the strong year class of bluegill in 1952 and attempts to reduce the bluegill population with a seine in 1959.

Segment 3. Bluegill Only (1962-66)

The objective of this segment was to study the dynamics of bluegill in isolation, thereby eliminating the effects of other species, and to simulate various rates of harvest (Patriarche 1966). A parallel experiment was set up in more productive ponds at Belmont (Beyerle and Williams 1972).

All fish were eliminated in October 1962 and Jewett Lake was restocked with adult bluegill in 1963 and 1964. An excessively large year class was produced in 1963 which was slow-growing and apparently suppressed reproduction in 1964 and 1965. About 22% of the bluegill were removed in June, 1965, but growth of the remaining fish improved only slightly. The bluegill population was clearly stunted (1.7 in below State average) when the experiment was terminated in spring 1966. Biomass had already reached 126 lb/acre. That was probably near the peak biomass the bluegill population would have reached if the experiment had continued indefinitely, but could have been higher than it's long-term equilibrium. A very small, temporary fishery was produced by the stocked bluegill which grew well initially and had a mortality rate of approximately 43%. No native bluegill had reached a length of 6.0 in by spring 1966, but some probably would have in 2 more years. It is unlikely that any would have ever reached 8.0 in.

Long-term expectations for this Jewett Lake experiment can be gained from results of two similar pond experiments. In the experiment by Beyerle and Williams (1972) in the Belmont control pond, a dominant year class was followed by two missing year classes and two more very weak ones. Biomass of the dominant year class was at 81% of the peak after two seasons, reached the peak after 4 seasons (538 lb/acre), and dropped to 17% of the peak after 7 seasons when the experiment ended. The number of bluegill ≥6 in was 142/acre after 7 seasons and might have eventually stabilized around 100/acre. Similar results were obtained in a later experiment by Clark and Lockwood (1990) in three control bluegill-only ponds at Saline. Biomass reached a plateau of approximately 300 lb/ac in 2 years, and after 5 years the number of bluegill ≥6 in averaged 52/acre. Based on bluegill peak biomass, Jewett Lake is about 30% as productive as the Belmont pond (126/436) and 50% as productive as the Saline ponds (126/300). Consequently, the number of stunted bluegill ≥6 in long at Jewett Lake might have stabilized at 25-30/acre.

Segment 4. Perch Only (1966-69)

The objective of this segment was to study the dynamics of yellow perch in isolation, thereby eliminating the effects of other species (Schneider 1972). In addition, the lake was closed to fishing. A parallel experiment was conducted at Cassidy Lake (Schneider 1972).

All fish were eliminated in July 1966 and perch of all sizes were stocked in spring and fall 1967. A dominant year class was produced in 1968 and no recruitment occurred in 1969. The 1968 year class reached a biomass of 34 lb/acre after one season and 48 lb/acre after two seasons. After two growing seasons the dominant year class averaged just 3.2 in long, 2.0 in below the State average. Stocked perch grew well during 1968 but very poorly in 1969. It was clear that the population would have (1) persisted indefinitely in the stunted condition; (2) would have been dominated by excessive year classes at 3-5 year intervals; and (3) never would have provided a sport fishery.

Similar results were obtained at Cassidy Lake (Schneider 1972). After two seasons a peak biomass of 53 lb/acre and an average length of just 4.1 in were achieved. After 4 growing seasons, about 14 native perch ≥7 in were present per acre in Cassidy Lake, probably close to the equilibrium expectation for both Cassidy and Jewett lakes. Reports on stunted perch populations in other waters indicate even less fishery potential (Eschmeyer 1938; Alm 1946). Despite poor growth, the annual natural mortality rate of adult perch in Cassidy Lake was relatively low, 41%. Important conclusions from the perch-only studies were that constraints (bottlenecks) in growth and production of large perch occur when perch switch to a benthic diet at about 3 in and to a large-particle diet such as fish at about 6.5 in. Consequently, the number surviving to those sizes must be drastically reduced by competition from planktivores or predation from more effective piscivores than adult perch themselves.

Segment 5. Perch and Minnow (1969-72)

Based on results of Segment 4, it was hypothesized that planktivorous minnows might both reduce recruitment of young perch through competition and predation and also enhance the production of medium- to large-size perch by providing an additional path in the food chain (Schneider 1972).

To test this hypothesis, all fish were eliminated in October 1969 and minnows were stocked in May 1970. Only the fathead minnow (*Pimephales promelas*) reproduced successfully and became very abundant by fall. Yellow perch then were stocked to match the number and sizes used for the perch-only experiment. Results were compared after 1 year. Total perch biomass after one season was 20 lb/acre as compared to 57 lb/acre for the perch-only experiment. The minnows had little effect on the production of larger perch but significantly reduced the recruitment and growth of young perch. The initial perch year class (1971) was less abundant by number (-64%) and weight (-83%) and smaller in length (-22%) compared to results from Segment 4. Although there was a more favorable recruitment rate to 3 in bottleneck, the minnows were being eliminated by perch predation. The perch-minnow assemblage could not have continued long without reverting to a perch monoculture with stunted population characteristics.

Segment 6. Perch and Walleye (1972-76)

Building on inferences from prior experiments, a strong piscivore was needed to assure long-term control of perch recruitment to medium-size (Schneider 1979). The walleye was selected for study because (a) yellow perch are a common prey of walleye in inland lakes, (b) walleye would probably target small sizes of perch rather than the valuable large sizes, and (c) walleye density could be controlled by stocking fingerlings. (It was assumed that walleye would not reproduce because Jewett Lake lacked preferred spawning substrate).

All fish were eliminated with rotenone in May 1972. Fathead and bluntnose *Pimephales notatus* minnows were stocked first and a large population of fatheads was established by 1974. Perch eggs were stocked each spring, 1974-76, and approximately 325 fingerling walleyes were stocked each fall, 1975-80. The minnows served the intended objective of tempering the growth and survival of young perch until walleye were well-established. However, by fall 1976 the minnow populations had been reduced to insignificance (2.4 lb/acre) and they were eventually extirpated by predation. Consequently, a steady-state equilibrium would not have been reached in which minnows were an important component of the assemblage. Perch and walleye persisted and formed a relatively stable two-species community in which both had good growth, abundance, and size structure. By fall 1977, perch biomass was at 23.9 lb/acre and walleye biomass at 16.1 lb/acre, for a total of 40 lb/acre. The number of larger fish may have eventually reached 40/acre for perch ≥7 in and 7/acre for walleye ≥14 in.

Segment 7. Perch and Walleye Under Exploitation (1978-86)

In 1978, Jewett Lake was opened to angling harvest and a new study segment began

(Schneider 1979). Objectives were to: (1) test if the populations and fisheries would respond as predicted; (2) demonstrate the practicality of managing small lakes for walleye fisheries; and (3) reduce the 1975 and 1976 cohorts of walleye. Those cohorts had survived in expectedly high numbers and were causing poor survival of subsequent cohorts. Because walleye were easily exploited during test angling in 1978, it was believed that walleye could be overexploited and community balance would be destabilized. Therefore, special regulations were invoked for public fishing, beginning in 1979, which restricted season and harvest of both species and allowed closure to harvest when a quota of 37 walleye per year was reached (Appendix 1a). However, anglers were unable to catch that many walleye. Consequently, the 1979 and 1980 quotas were filled by netting and restrictions on fishing were slowly relaxed.

Unexpectedly, walleye began to reproduce successfully in 1979. Stocking of walleye was discontinued after 1980 and natural recruitment was adequate to maintain an excellent population. Walleyes were characterized by slow growth, high density, and low mortality. Perch were characterized by fast growth, low density, and high mortality for all sizes. Perch harvest was erratic due to irregular recruitment and had become so low by 1985 there was concern that the perch population might collapse due to a paucity of adult spawners. Nevertheless, this community persisted and produced a worthwhile fishery. Representative periods of relative equilibria are 1979-86 for fishery statistics and 1976-83 for population statistics.

Segment 8. Bluegill, Perch, and Walleye Under Exploitation (1987-91)

Re-introduction of bluegill into Jewett Lake led to another study (Schneider 1995). Bluegill established large year classes in 1986 and every year thereafter. They found an "open" food niche and became the dominant species by weight in two seasons. Perch biomass declined due to slower growth caused by competition with bluegill for zooplankton and small benthic invertebrates. Meanwhile, growth of walleye improved due to utilization of bluegill as prey. Walleye biomass reached 18 pounds/acre, an exceptionally high level for any lake (Carlander 1977). Growth of bluegill was satisfactory and it was concluded that both bluegill and perch recruitment were being controlled effectively by walleye predation. An apparently stable community was formed with desirable population characteristics which produced a better fishery than the preceding experimental assemblages. Data for 1989-91 are believed to represent near-equilibria conditions. Models were constructed to simulate the populations.

Segment 9. Bluegill, Perch, and Walleye Under Exploitation (1992-93)

Mortality rates of adult panfish were unexpectedly high in Segment 8. Therefore, fishing was closed for 2 years to evaluate the importance of angler harvest (Schneider 1995).

A reduction in mortality and an improvement in the number of large bluegill and perch were noted. It was also noted that almost no walleye recruits had been produced from 1992 through 1995 (the last year of sampling). Poor reproductive success could have been influenced by weather, but it was mainly attributed to bluegill. Total bluegill biomass increased to over 43 lb/acre due to exceptionally large bluegill year classes in 1990 and 1991, plus protection of adult bluegill from harvest. It was postulated that bluegill may prey on walleye eggs or fry or compete with young walleye for invertebrate foods. Laboratory experiments confirmed the bluegill's predatory capabilities. Models simulating various size limits and catch/release fishing regulations were constructed for each species on the premise that long-term recruitment would return to the 1987-93 averages.

Segment 10. Perch, Walleye, and Bluegill Under Catch/Release Angling (1994-present)

Catch-and-release angling regulations were initiated in 1994 to optimize the recreational potential of this small, unproductive lake (Schneider 1995). Simulation modeling and prior experience predicted that protection from harvest would optimize density and catch rate of large fish. Results of one brief fish survey (1995) indicated growth had remained satisfactory and many large walleye, bluegill, and perch were present. However, as reported above in Segment 9, walleye recruitment had failed for 4 consecutive years. Any additional year class failures would likely upset community composition and balance.

Comparisons at Equilibrium

Yellow perch, walleye, and bluegill populations have each been studied in Jewett Lake under various combinations of species assemblages and exploitation. Observations, or predictions, of their key population and community characteristics at presumed steady-state equilibria are summarized in Table 4. Table entries are arranged in increasing order of complexity to facilitate comparison. The fishery yields from the climax warmwater community in 1945 are included so that inferences can be made about changes in populations. However, those yields clearly do not represent an equilibrium state. The relationships among number of species, population biomass, and fishery yield at equilibrium are depicted in Figure 1.

In interpreting these data, the following concepts were kept in mind. The production of fish results from the interactions among rates of recruitment of young, growth, and mortality. Given constant recruitment, the biomass of large fish can be enhanced by either faster growth or lower mortality (especially of adults). All of those rates are affected to some degree by food availability (hence competitors), predator density and selectivity, and angler harvest. Growth of individual fish usually reflects food availability and population density. Population biomass is only a rough indicator of production because production is also dependent on turnover (mortality) rate.

Yellow perch

This species was studied under eight sets of conditions (Table 4). Fishery yields were estimated for four assemblages containing perch (Figure 1). These observations are offered:

1). Exploitation significantly reduced unexploited populations of large perch. Perch are relatively vulnerable to angling. This is indicated by corresponding changes in both density and mortality of large perch, the relatively high exploitation rates measured during the 1950s, and by the over-representation of perch in the fishery relative to it's proportion in the community (e.g., 7% versus 4% for Segment 2).

2). Perch populations and fishery yields were relatively small under all conditions. Maximums were 68 lb/acre for the population and 5 lb/acre for the fishery.

3). Isolation of perch in simple fish assemblages did not enhance perch fisheries. More limnological productivity was not channeled into large perch.

4). The highest perch population biomass occurred in a monoculture, indicating perch production was constrained to some extent by other species. Growth was very poor but survival was high enough to produce a few perch ≥7 in. Those fish could have created a poor fishery.

5). Walleye predation effectively controlled perch recruitment and greatly enhanced perch growth. But, mortality of both adult and juvenile perch was high, perhaps beyond the optimal level. The net result was an improvement in the number of large perch by 2-3 times compared to the perch-only results. However, fishery yield was still modest, about 26 perch/acre and 4 lb/acre. An additional benefit of this community was the shunting of unutilized (not contributing to angling) perch production into valuable walleye fisheries (1.7 lb/acre).

6). Perch biomass and yield were reduced by bluegill competition. In the perch+walleye+bluegill community, bluegill competed for food with small perch causing slower growth of perch. Mortality of perch from walleye and angling remained high. The net results were reductions in perch biomass and fishery characteristics by 50% or more relative to the perch+walleye combination. However, losses in yield of perch (-2 lb/acre) were more than offset by gains in yield of walleye (+0.1 lb/acre) and bluegill (+4 lb/acre).

7). The best perch fisheries were produced by the climax warmwater community (yield of 24 perch/acre and 5 lb/acre). Even though perch yield declined by 50% under prolonged exploitation, the yield of all species was high, a total of 26.4 lb/acre. Thus, all species considered, the "native" community produced the best fishery.

8). A surprisingly good perch population (4.6 lb/acre) and fishery (1.7 lb/acre) existed in the exploited warmwater community. And, population abundance may have been twice as dense in the climax state, judging from higher initial harvest and slower individual growth. This community was dominated by slow-growing, dense (86 lb/acre) bluegill, and also contained about 32 lb/acre of other species. The perch+walleye+bluegill combination created a similar perch fishery even though it contained only 27% (23/86) of the bluegill biomass. Competition should have been more intense within the multi-species warmwater community than during any of the experimental segments. The relatively high productivity of perch in the warmwater community was likely due to a more optimal combination of mortality and growth. Mortality of larger perch was probably lower (maximum age of 8 rather than 4) and that may have more than offset the slower growth (0.1 in below State average rather than 1.0 in above). Largemouth bass, the primary predator in the warmwater community, apparently were a less voracious and effective predator than walleye.

Walleye

This species was studied under 4 sets of conditions (Table 4), including two with fisheries (Figure 1). These observations are offered:

1). Exploitation had minor effects on walleye populations. Walleye were difficult to catch after their initial exposure to angling in 1978 and were lightly exploited thereafter. This is reflected in their under-representation in the fishery relative to the community (eg., 25% versus 35% for Segment 8).

2). Walleye provided small catches, yielding less than 2 lb/acre, as is characteristic of this species (Carlander 1977). They are held in high regard by anglers, however.

3). Relatively good walleye populations developed in simple fish communities with perch and bluegill. Standing crops of about 16 lb/acre, with about 8 walleye/acre ≥14 in, rivals those of the best walleye lakes (Carlander 1977).

4). Walleye established a good population with only perch as prey. An unexpected bonus of community simplicity may have been the successful reproduction of walleye in habitat of marginal quality.

5). Characeristics of the walleye population and fishery were slightly enhanced by the addition of bluegill to the community. Growth improved most. Walleye used both bluegill and perch as prey but preferred perch. However, at high bluegill densities walleye reproduction faltered.

Bluegill

This species was studied under 5 sets of conditions (Table 4). Estimates of steady-state bluegill fishery yields are available for three combinations of species (Figure 1). These observations are offered:

1). Exploitation reduced bluegill populations by approximately 50%.

2). Bluegill are a productive and dominant species. Bluegill populations and fisheries were large relative to those of other species, with estimates of standing crop biomass of 23-126 lb/acre.

3). Bluegill are probably capable of matching total fish production when released from predation and competition with other species. In monoculture, bluegill biomass equalled the total biomass of all 7 species in the exploited warmwater community (122 lb/acre). The experiment terminated before it was clearly established that bluegill could maintain that high level indefinitely.

4). Bluegill developed two or more times the population biomass of perch. Alone, in single species experiments, the ratio was 126:68 lb/acre. In experiments with walleye, the ratio was 23:10 and 47:14 lb/acre. In the complex warmwater community, the ratio was 86:5 lb/acre.

5). Bluegill biomass was related to mortality, growth, and type of predator. Bluegill achieved the highest biomass when alone (126 lb/acre), an intermediate density in the warmwater community (86 lb/acre when exploited, but perhaps twice as high when unexploited), and the lowest density in bluegill+walleye+perch combination (23-47 lb/acre). Both total mortality and individual growth rates were inversely related to this density pattern. It also suggests that walleye had a relatively larger effect than largemouth bass on bluegill dynamics.

6). Isolation of bluegill in simple assemblages did not enhance bluegill fishing. Bluegill yield was best at intermediate levels of growth and predation mortality. Estimated yields were lowest in monoculture (probably 3 lb/acre), only slightly higher in bluegill+walleye+perch (4 lb/acre), decidedly higher in the warmwater community (16 lb/acre), and much higher in the warmwater climax community (43 lb/acre, but not sustainable). This demonstrated the need for a predator to enhance the production of large bluegill. It also indicated an intermediate growth (but slow relative to the State average) was optimal if coupled with a favorable mortality rate. Mortality was probably lower in the warmwater community than in the bluegill+walleye+perch community (maximum age of 8 vs 5).

7). Bluegill recruitment and growth were effectively controlled (at least for several years) by walleye predation.

Conclusions

Jewett Lake's potential fish biomass is assumed to be no less than 122 lb/acre, the biomass of the exploited warmwater community in 1958 when it contained 7 species of fish. This is a conservative estimate because in the unexploited state, total community biomass may have been over 200 lb/acre. From it, a one-time fishery yield of 84 lb/acre was extracted which represented years of accumulated biological production. By contrast, the sustained yield was 22 lb/acre.

Bluegill acquired a much greater share of Jewett Lake's potential fish biomass than any other species of fish. They were the most adaptive and effective species, able to match the biomass of 7 species of fish when isolated in monoculture. The diet of bluegill – primarily zooplankton and small benthos – places the bluegill lower on the food chain than the other species and should give the bluegill a competitive advantage. In Jewett Lake this was manifested in high population biomass, a large share of the community, prominent fisheries, and dominance over other species. Even in a natural community with six other species bluegill captured 51% (climax condition) to 61-70% (exploited condition) of the community biomass. The bluegill is the prominent species in 63% of Michigan's lakes and, on average, it comprises 36% of the biomass (Schneider 1981). Bluegill biomass in excess of 78% of the community total is an indicator of poor fishing due to stunting (Schneider 1981). Jewett Lake experiments established that bluegill occupy a fairly discrete niche in the presence of other species but can infringe on the production of perch (Schneider 1995). They effectively out-compete perch– not to it's exclusion, but enough to reduce perch growth and biomass. Also, bluegill are probably capable of eliminating the recruitment of young walleye through predation on eggs or fry and competition with fry for zooplankton (Schneider 1995). Elimination of the walleye, a major predator, would have a destabilizing effect on the community in Jewett Lake, and probably also in other lakes where bluegill and walleye co-occur in significant numbers. Bluegill clearly demonstrated an ability to find an open niche and outcompete perch.

Yellow perch acquired as biomass only a small fraction of the potential fish biomass of Jewett Lake– no more than 50% when alone, and only about 4% when in the natural warmwater community. Apparently, their niche is smaller than their generalized food habits would suggest. In northern Michigan lakes yellow perch comprise 9% of the community biomass, on average, and in only 3% of those lakes does perch biomass exceed that of any other species (Schneider 1981). Perch are actually more biologically productive than this would suggest because they have a high turnover rate. Much of their production is consumed while in the fingerling stage by piscivores. Their population strategy is of the "r" type – high birth rate and high death rate. High mortality of small perch relieves potential bottlenecks at about 3 in and 6.5 in, where ontogenic shifts in diet usually occur in populations with good individual growth rates (Schneider 1971). Predation on perch by other species of fish is required to enhance growth, produce large perch, and create a modest fishery.

Walleye incorporated only about 14% (18/122 lb/acre) of Jewett Lake's potential fish biomass. Even so, walleye density in Jewett Lake was high relative to other Michigan lakes. Low ecological efficiency is expected because they are primarily piscivores, but at small sizes they eat zooplankton and benthos. In Jewett Lake, as in most lakes, the walleye population is vulnerable to reproductive success, the most tenuous phase in their life history. Hatching success is low on poor-quality spawning substrate, and both eggs and fry are vulnerable to predation by any fish. Walleye demonstrated a powerful predatory ability and were capable of significantly altering survival and growth patterns of bluegill and perch. This increased the numbers of large panfish and the yield to the fisheries compared to the panfish-only scenarios. However, high predatory mortality, especially on adult panfish, caused sub-optimal production of large fish and fisheries relative to the typical warmwater fish community dominated by largemouth bass.

Several management implications can be derived from the Jewett Lake studies. First, angling, especially over unfished climax populations, can significantly reduce population biomass and the abundance of large fish, and may alter community proportions. There is relatively little compensation for increased angling mortality in the form of increased growth. Second, walleye can be used as a tool to improve the growth of both yellow perch and bluegill. They are a very effective predator on yellow perch, and can be an effective predator on bluegill. Third, it is feasible to intensively manage small lakes with one or two panfish species plus walleye. However, greater fishery yields probably can be attained from more diverse natural warmwater communities dominated by bluegill.

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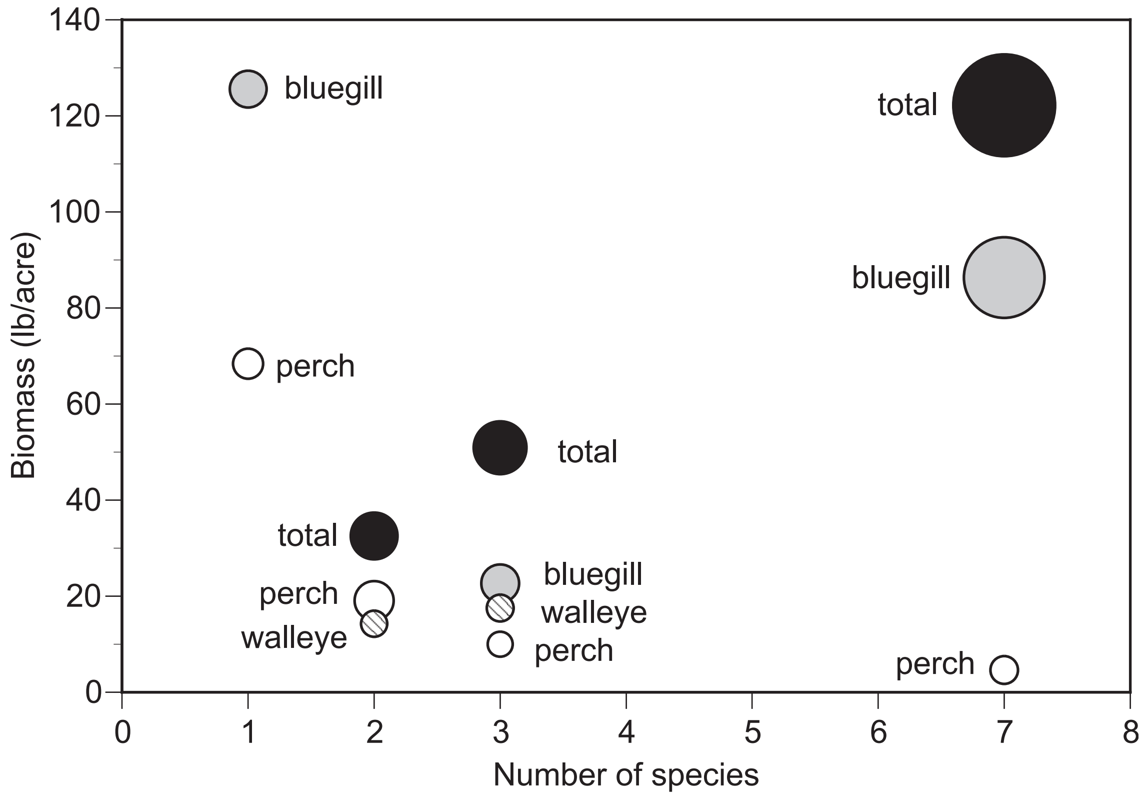

Figure 1.–Population biomass and sport fishing yield for walleye, yellow perch, bluegill, and for total species, while in assemblages with 1 to 7 species. The elevation of each circle on the Y-axis indicates equilibrium biomass; the area of the circle represents relative fishery yield with the smallest circle equal to 2 lb/acre and the largest circle equal to 26 lb/acre. The yields shown for monocultures of bluegill and yellow perch are approximations.

Table 1.–Chronology of events during 10 study segments at Jewett Lake, 1931-95.

Year	Segment/assemblage/event	Chemicals/stocking	Catch survey	Population survey	Primary report no.
1931	Private ownership			limited	151
1944	Public ownership			limited	998
	1. Climax warmwater (bluegill+largemouth bass+perch+pumpkinseed+crappie+bullhead)				
1945	Opened to public angling		yes		Misc #13
	2. Exploited warmwater				Misc #13
1946			yes		
1947			yes		
1948			yes	attempted	
1949			yes	mark-recap	
1950			yes		
1951			yes		
1952			yes		
1953			yes		
1954		redear 1000 fingerlings	yes		
1955			yes		
1956		redear 1000 fingerlings	yes	limited	
1957			yes	mark-recap	Patriarche (1968)
1958			yes	mark-recap	1631
1959	22% bluegill removed by seine		yes	mark-recap	1660,1740
1960			yes	mark-recap	
1961			yes		
1962		toxaphene	yes	mark-recap	Patriarche (1966)
	3. Bluegill only				
1963		bluegill 150 adult+	yes		
1964		307@ 5"	yes	mark-recap	
1965	50% bluegill removed by net		yes	mark-recap	
1966		toxaphene	yes	mark-recap	
	4. Perch only				1791
1966			closed		
1967		perch, all sizes	closed	mark-recap	
1968			closed	mark-recap	
1969		rotenone	closed	mark-recap	
	5. Perch+minnow				1791
1970		minnows, then perch	closed		
1971		of all sizes	closed	mark-recap	
1972		rotenone	closed	mark-recap	
	6. Perch+minnow+walleye				1875,1905
1973		minnows	closed		
1974		perch eggs, 3 million	closed		
1975		perch eggs, walleye fing.	closed	mark-recap	2020
1976	Minnows greatly diminished	perch eggs,walleye fing.	closed	mark-recap	
1977		walleye, 325 fingerlings	closed	mark-recap	

Table 1.–Continued.

Year	Segment/assemblage/event	Chemicals/stocking	Catch survey	Population survey	Primary report no.
	7. Perch+walleye+exploitation				1905,2020
1978		walleye, 325 fingerlings	yes	mark-recap	
1979		walleye, 325 fingerlings	yes	mark-recap	
1980	A few bluntnose minnows persist	walleye, 325 fingerlings	yes	mark-recap	
1981			yes	mark-recap	
1982			yes	mark-recap	
1983			yes	mark-recap	
1984			yes		
1985			yes		
	8. Bluegill+ perch+walleye+exploitation				2020
1986		bluegill (unathorized)	yes		
1987	All minnows extirpated by now		yes	mark-recap	
1988			yes	mark-recap	
1989			yes	mark-recap	
1990			yes	mark-recap	
1991			yes	mark-recap	
	9. Bluegill+ perch+walleye-exploitation				2020
1992			closed	mark-recap	
1993			closed	mark-recap	
	10. Bluegill+ perch+walleye+catch/release				2020
1994			yes		
1995			yes	limited	

Table 2.–Fishery statistics for the warmwater fish community at "climax" (1945) compared to average fishery statistics during the exploited years (1946-58). Annual fishing pressure was 1,863 hours in 1945 and 1,142 hours in 1946-58.

	Number/hour[a]		Number harvested		Pounds harvested[b]		Composition (% lb)		Average weight (lb)		
Species	Climax	Exploited	Climax	Exploited	Climax	Exploited	Climax	Exploited	1945	1949	1956
Bluegill	1.46	1.39	2688	1350	554	209	51	61	0.206	0.169	0.131
Yellow perch	0.18	0.19	315	138	61	22	6	7	0.194	0.144	0.156
Largemouth bass	0.05	0.04	99	42	50	36	5	10	0.506	0.850	0.988
Pumpkinseed	0.54	0.16	1013	125	241	23	22	7	0.238	0.200	0.175
Hybrid sunfish	0.00	0.01	0	15	0	3	0	1	–	–	–
Rock bass	0.02	0.05	41	43	9	10	1	3	0.225	0.269	0.206
Black crappie	0.29	0.10	595	97	137	19	13	5	0.231	0.188	0.200
Bullhead	0.03	0.07	50	49	31	19	3	5	0.606	0.300	0.450
All	2.58	1.63	4801	1859	1083	341	100	100	–	–	–

[a] Catch per hour for panfish (all species except bass) based on hours of still-fishing with worms (Patriarche 1960).
[b] Pounds harvested obtained by multiplying number harvested by average weight of harvested fish in 1945, or 1949, 1951, and 1956.

Table 3.–Average length-at-age (inches) for Jewett Lake fishes in the native warmwater community during periods representing climax (pre 1946) and exploited phases (1948 and 1954-56). Lengths at annulus formation were back-calculated from scales samples by Patriarche (unpublished). Also shown are the Michigan State averages.

Species	Period	Age 1	2	3	4	5	6	7	8
Bluegill									
	pre-1946	0.9	2.1	3.7	5.2	6.2	6.8	7.6	
	1948	1.6	2.6	4.0	5.3	6.4	7.4	8.0	
	1954-56	1.7	2.5	3.5	5.0	6.2	7.2	8.1	
	State average	2.4	3.8	5.0	5.9	6.7	7.3	7.8	
Yellow perch									
	pre-1946	2.4	4.3	5.9	7.1	7.5			
	1954-56	2.9	5.1	6.8	7.5	7.9			
	State average	3.3	5.2	6.5	7.5	8.5			
Largemouth bass									
	pre-1946	2.8	6.0	9.0	11.1	12.7			
	1954-56	2.8	6.1	8.6	10.5	11.9	13.2	14.3	15.2
	State average	4.2	7.1	9.4	11.6	13.2	14.7	16.3	17.4
Pumpkinseed									
	pre-1946	1.2	2.3	3.8	5.3	6.1			
	1956	1.2	2.3	3.9	5.5				
	State average	2.4	3.8	4.9	5.6	6.2			
Rock bass									
	pre-1946	No data							
	1954-57	1.5	2.8	4.3	5.5	6.6	7.7		
	State average	2.4	3.9	5.1	6.1	6.9	7.8		
Black crappie									
	pre-1946	1.4	3.1	5.3	6.8	7.7	8.3	8.3	
	1954-56	1.6	3.1	4.5	5.7	6.9	7.5	8.0	
	State average	4.2	6.0	7.5	8.6	9.4	10.2	10.8	

Table 4.–Comparison of population and fishery characteristics at equilibrium for yellow perch, walleye, and bluegill in Jewett Lake under various combinations of species and exploitation.

Species+conditions[c]	Representative year(s)	Population characteristic					Fishery characteristic		
		Biomass (lb/ac)	Community (% by wt)	Large[a] (No./ac)	Grow Index[b] (in (for age))	Mortality (Z(for age))	Number (No./ac)	Weight (lb/ac)	Community (% by wt)
Yellow perch									
only-expl**(4)**	1969	68	100	0[d] 14[d]	-2.0(2)	– 0.5(2+)[d]	– Low potential	–	–
+minnow-expl**(5)**	1971	20[d] 68[d]	100	0[d] 14[d]	-1.2(1)[d] -2.0[d]	– 0.5(2+)[d]	– Low potential	–	–
+wae-expl**(6)**	1977	24	60	23[d] 40[d]	+2.1(1-4)	1.1(2+)[d]	–	–	–
+wae+expl**(7)**	1979-86	19	59	33[d] 32[d]	+1.9(1-4)	2.0(2+)	22[d] 26[d]	4	70
+wae+bg+expl**(8)**	1989-91	10	20	6[d] 8[d]	+1.0(1-4)	2.0(2+)	9[d] 9[d]	2	23
+wae+bg-expl**(9)**	1992-93	14	19	14[d] 13[d]	+0.4(1-4)	0.3(2+)	–	–	–
+ww+expl**(2)**	1946-58	5	4	6	-.1(1-4)	–	11	2	7
+ww@climax+expl**(1)**	1945	–	–	–	-.7(1-4)	–	24	5	6
Walleye									
+yp-expl**(6)**	1977	16	40	4[d] 7[d]	-1.5(1-4)	0.2(3+)	–	–	–
+yp+expl**(7)**	1979-86	14	41	6	-0.2(1-4)	0.3(3+)	1.2	1.7	30
+yp+bg+expl**(8)**	1989-91	18	35	9[d] 7[d]	+1.1(1-4)	0.4(3+)	1.2[d] 1.2[d]	1.8	25
+yp+bg-expl**(9)**	1992-93	13	18	8[d] 11[d]	+0.4(2-4)	– 0.2(3+)[d]	–	–	–
Bluegill									
only-expl**(3)**	1966	126	100	0[d] 25-30[d]	-1.7(3)	0.6(3+)[d] ?	– Low potential	–	–
+wae+yp+expl**(8)**	1989-91	23	45	32[d] 38[d]	+0.6(1-4)	1.4(2+)	19[d] 18[d]	4	52
+wae+yp-expl**(9)**	1992-93	47	63	52[d] 56[d]	-0.3(1-4)	0.7(2+)	–	–	–
+ww+expl**(2)**	1946-58	86	70	100	-1.1(1-4)	1.0(5+)	105	16	61
+ww@climax+expl**(1)**	1945	–	–	–	-1.3(1-4)	–	208	43	51

[a] Large= >7.0 inches for perch; >14.0 inches for walleye; and >6.0 inches for bluegill.
[b] Growth index is the deviation, in inches, of observed length-at-age from the State average. Included age groups in parenthesis.
[c] Abbreviations: wae=walleye; yp=yellow perch; bg=bluegill; ww=warmwater species (see Table 2); expl=exploited. Bold number in the first column in parenthesis is the segment number.
[d] Experiment terminated before equilibrium was reached for those characteristics. Upper number is observed value, lower number is estimated value at equilibrium (See text).

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Appendix 1a.–Angling pressure, total harvest, and fishing quality at Jewett Lake, 1945-91. See footnotes for changes in fishing regulations.

	Angling pressure		Yield of fish			Fishing quality
Year	Hours	Hours/acre	Number	Pounds	lb/acre	(Number/hr)
1945	1863	144.4	4804	1068	82.8	2.58
1946	1141	88.4	1482	346	26.8	1.30
1947	1373	106.4	1611	365	28.3	1.17
1948	994	77.1	1025	205	15.9	1.03
1949	677	52.5	1481	287	22.2	2.19
1950	703	54.5	1544	285	22.1	2.20
1951	1035	80.2	2499	430	33.3	2.41
1952	1313	101.8	2322	453	35.1	1.77
1953	977	75.7	2256	333	25.8	2.31
1954	1873	145.2	3103	553	42.9	1.66
1955	1089	84.4	1322	276	21.4	1.21
1956	1075	83.3	1502	250	19.4	1.40
1957	1107	85.8	1888	316.9	24.6	1.67
1958	1484	115	2164	361.9	28.1	1.49
1959	1156	89.6	966	220.2	17.1	0.78
1960	1094	84.8	481	158.5	12.3	0.41
1961	1104	85.6	703	206.8	16	0.57
1962	910	70.5	535	125.1	9.7	0.47
1963	0	0	0	0	0	0
1964	23	1.8	2	1	0.1	0.08
1965	238	18.4	74	20.1	1.6	0.31
1966-77 FISHING PROHIBITED						
1978	118	9.1	139	171.0	13.3	2.03
1979	1021	79.1	403	153.4	11.9	0.40
1980	850	65.9	347	125.5	9.7	0.41
1981	1136	88.1	284	87.2	6.8	0.25
1982	675	52.3	68	166.7	12.9	0.10
1983	1086	84.2	839	235.3	18.2	0.77
1984	1160	89.9	263	132.2	10.2	0.23
1985	605	46.9	45	89.1	6.9	0.07
1986	504	39.1	106	84.0	6.5	0.21
1987	585	45.3	55	58.0	4.5	0.09
1988	328	25.4	30	149.1	11.6	0.10
1989	633	49.1	635	187.9	14.6	1.01
1990	808	62.6	249	143.5	11.1	0.31
1991	600	46.5	252	83.9	6.5	0.42
1992-93 FISHING PROHIBITED						

Minimum size limits (MSL) and "season" (when most fishing occurred due to law or lack of interest in ice fishing):
Bluegill & pumpkinseed:**MSL**: 6" in 1945-49; none in 1950- ; **"season"**: June 25-Oct in 1945-51; May1-Oct in 1952-65.
Other panfish: **MSL**: 6" in 1945-49; none in 1950- ; **"season"**: June 25-Oct. in 1945; May 1-Oct. in 1946-61.
Bass: **MSL**: 10" in 1945-; **"season"**: June 24-Oct. in 1945-53; June 20-Oct. in 1954-61.
After 1978: 14" **MSL** on walleye; none on bluegill and yellow perch. **"season"**: July 9-Oct. in 1978-80; May 15-Oct. in 1981-87; Apr. 30-Oct. in 1988-91.

Appendix 1b.–Numbers of fish harvested from Jewett Lake, 1945-91. See footnotes to Appendix 1a.

Year	Bluegill	Yellow perch	Large-mouth bass	Pumpkin-seed	Hybrid sunfish	Rock bass	Black crappie	Bull-head	White sucker	Walleye	Redear
1945	2688	315	99	1013		41	595	50	3		
1946	909	184	31	150		41	115	52			
1947	1113	111	45	136		47	92	67			
1948	649	94	15	95	16	43	49	64			
1949	960	90	23	220	10	47	41	90			
1950	982	175	32	177	21	46	47	64			
1951	1816	190	84	82	37	61	159	70			
1952	1740	119	40	143	20	74	151	33	1		
1953	1627	204	28	151		42	157	49			
1954	2314	202	60	117		62	299	48			
1955	910	146	61	83		39	48	35			
1956	1104	87	37	161		28	71	14			
1957	1552	100	29	78	72	11	22	17			7
1958	1875	92	56	27	23	17	15	35			22
1959	650	113	44	47		6	22	11			17
1960	162	3	115	101	23	53	11	2			11
1961	520	2	110	27	27	7	5	3			2
1962	382	50	40	7	12	33		8			1
1963	0										
1964	2										
1965	74										
1966-77 FISHING PROHIBITED											
1978		165								74	
1979		383								20	
1980		337								10	
1981		266								18	
1982		61								7	
1983		830								9	
1984		239								24	
1985		24								21	
1986		94								12	
1987	1	36								18	
1988	5	10								15	
1989	423	195								17	
1990	199	43								7	
1991	107	121								24	
1992-93 FISHING PROHIBITED											

Appendix 1c.–Angling yield (pounds) by species from Jewett Lake in certain years, 1945-91.

Year	Bluegill	Yellow perch	Large-mouth bass	Pumpkin-seed	Hybrid sunfish	Rock bass	Black crappie	Bull-head	Walleye
1945	553.7	61.1	50.1	241.1		9.2	137.4	30.3	
1949	162.2	13.0	19.6	44.0	0.0	12.6	7.7	27.0	
1951	297.8	34.8	62.0				30.0		
1956	144.6	13.6	36.6	28.2		5.8	14.2	6.3	
1957	204.0								
1958	270.0								
1959	110.0								
1962	22.2								
1966-77 FISHING PROHIBITED									
1978		31.0							46.2
1979		72.4							21.4
1980		48.5							11.1
1981		42.6							23.3
1982		11.1							10.3
1983		132.0							13.3
1984		51.1							38.9
1985		7.3							34.9
1986		27.9							19.0
1987		12.6							24.5
1988		2.4							18.5
1989	78.3	32.6							17.4
1990	37.8	8.4							13.5
1991	24.2	21.5							38.1
1992-93 FISHING PROHIBITED									

Appendix 2.–Population statistics for the diverse, exploited warmwater fish community in Jewett Lake in spring 1958 and exploitation rates in 4 years. Shown are Patriarche's (1961) estimates of larger fish and my calculations of biomass for all sizes and community composition. Also shown are exploitation rates (% of fish marked in spring recaptured by anglers in summer) for 4 years (Patriarche and Gowing 1957, 1961, 1963, and 1967).

Species	Biomass estimate (lb)	Community composition (% by lb)	Size group estimate Min length (in)	Size group estimate Number of fish	Exploitation rate 1957 (%)	Exploitation rate 1958 (%)	Exploitation rate 1960 (%)	Exploitation rate 1962 (%)
Bluegill	1110	70	6.0	1294	24	33	32	29
			7.0	163				
			8.0	20				
Yellow perch	59	4	7.0	73	44	48		
Largemouth bass	225	14	10.0	136	10	35	47	18
			12.0	59				
			14.0	30				
Pumpkinseed	26	2	6.0	73	31	20		0
Hybrid sunfish	4	>1	5.0	31	44	23	27	17
Rock bass	7	>1	6.0	22	23	35	31	41
Black crappie	132	8	7.0	177	2	6	16	
Bullhead	16	1	7.0	40	35	35	4	27
Redear sunfish	>1	>1	–	–	20		23	
All	1579	100						