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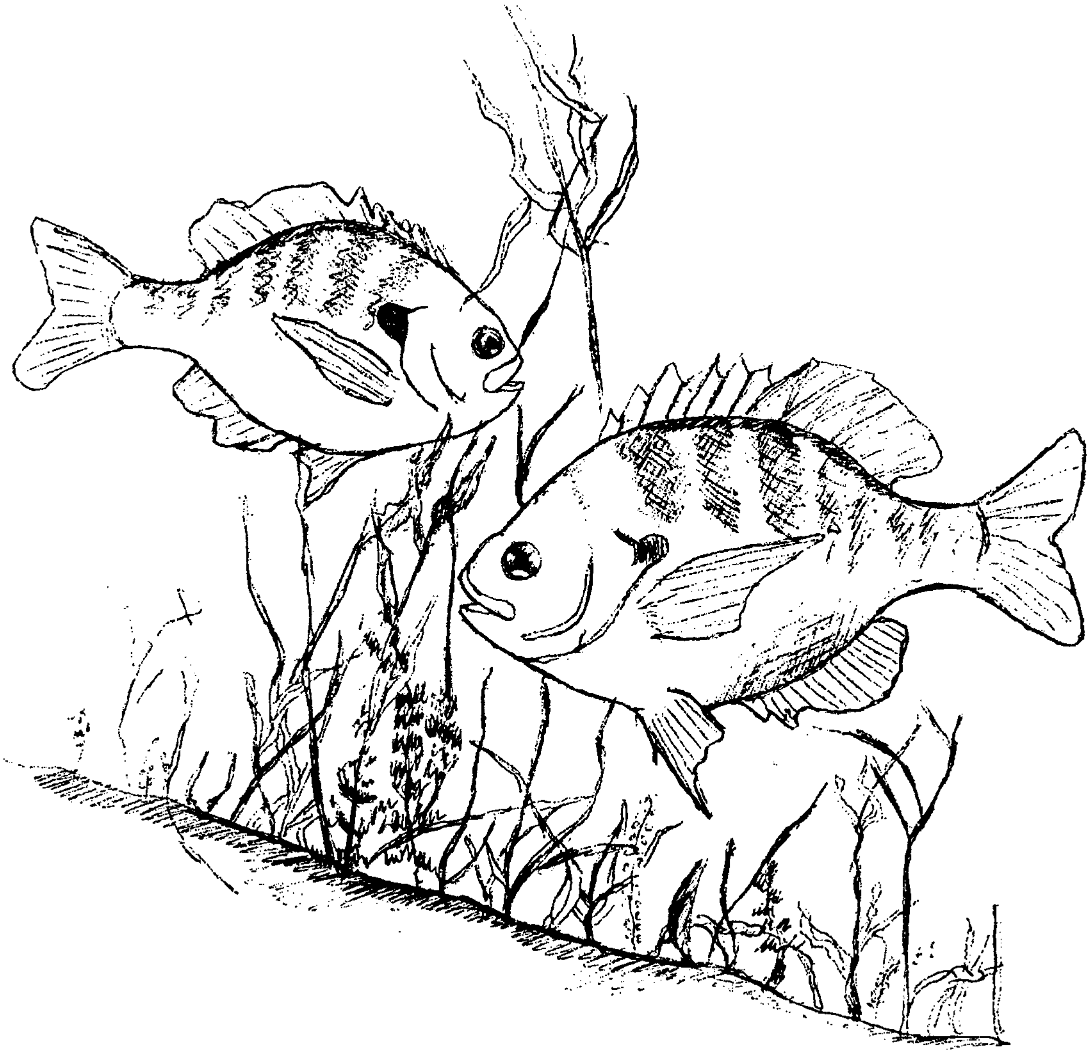

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Dynamics of Good Bluegill Populations in Two Lakes with Dense Vegetation

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Abstract.—Characteristics of bluegill *Lepomis macrochirus* populations and fish communities were studied intensively at Dead Lake and Blueberry Pond. The lakes were small, shallow, and weedy, with macrophytes covering 41-83% of the surface. Both contained unusually high proportions and densities of bluegills over 8 in long due to unusually low fishing mortality, a favorable growth pattern, and low recruitment to age 2 or 3. Growth was rapid from 3 to 8 in, it then slowed and condition deteriorated among older fish. Mortality of adults was observed in early spring, when about 10% of the adults died. Rapid growth was stimulated by consistently low recruitment and utilization of limnetic *Daphnia* and littoral benthos as food. Low recruitment was partially due to predation; a diet study at Blueberry Pond estimated 303,300 juvenile bluegills per year were consumed by fish predators. Most juveniles were eaten by largemouth bass *Micropterus salmoides*, very few by cannibal bluegills. Each lake contained dense, slow-growing piscivores, but surprisingly they comprised less than 20% of the total fish biomass. It appeared that few adult bluegills attempted to spawn in Blueberry Pond, and this lack of spawning was likely more important than predation in controlling bluegill abundance. A supplemental pond study demonstrated that young and old adults of varying condition had normal reproductive potential. The triggering of spawning behavior may be linked to adult density, and perhaps adult growth, by behavioral or bioenergetic mechanisms. The implication for fisheries management is that weedy lakes need not be dominated by small, stunted bluegills but are capable of producing large bluegills if fishing harvest is restricted and a favorable food chain is present.

Fish communities in many southern Michigan lakes are dominated by small, slow-growing bluegills *Lepomis macrochirus*. These lakes lack bluegills as large as 8 in, a size which serves as an indicator of both good bluegill populations and good overall angling (Schneider 1981, 1990). Fishery managers have been unable to improve the size structure of bluegills in these communities for extended periods of time.

Lake characteristics, especially submerged macrophyte vegetation, play an important role in shaping bluegill populations and fishing quality. Size structure and growth of bluegill populations were correlated with abundance of macrophytes, predator-prey ratios, lake depth, and overall fishing quality for a large sample of Michigan lakes (Schneider 1981). In general, shallow and weedy lakes were the type most likely to have an overabundance of small, slow-growing bluegills, poor fishing, and low proportions of largemouth bass *Micropterus salmoides*. Conversely, populations of large, fast-growing bluegills were often associated with deeper, well-oxygenated lakes containing less vegetation and higher proportions of predators. For 30 southern Michigan lakes, Theiling (1991) examined bluegill growth in relation to food availability, habitat type, and physical or chemical conditions. He also found that bluegill growth was negatively correlated with macrophyte density. The strongest positive correlation Theiling found was with zooplankton particle size and bluegill growth.

Generally, for bluegill populations to have a high proportion of large fish, recruitment must be controlled at a relatively low level so that survivors experience low competition and can grow well throughout life. Predation by largemouth bass on small bluegills seems to be an effective means of controlling bluegill recruitment in some lakes but not others. Experimental evidence indicates that predators become less efficient at capturing prey when vegetation is dense or there are other structural complexities in the environment (Savino and Stein 1979, 1982, 1989; Crowder and Cooper 1979, 1982). Amount of vegetative edge also affects capture efficiency and predation rate by largemouth bass (Savino and Stein 1989; Smith 1993). Diminished predation correlates well with the observed tendency for weedy lakes to have excessive recruitment, poor bluegill growth, and no large bluegills.

However, some unique weedy lakes have good bluegill populations, containing many 8 in bluegills. Such lakes might be expected to contain unusually abundant populations of bass or other predators to compensate for predators being less efficient in dense vegetation. These lakes should also have low rates of mortality for adult bluegills and good growth by small- to medium-sized bluegills so that many of them reach a large size before being depleted by natural mortality. Good growth might require unique food chains. Two possible examples, Dead Lake and Blueberry Pond, were located in southern Michigan. Preliminary surveys in November 1983 confirmed the presence of numerous large bluegills and that recruitment of bluegills had been relatively stable for several years.

A series of studies were designed to address the following questions:

1. Are the bluegill population characteristics of Dead Lake and Blueberry Pond unique compared to other Michigan lakes?
2. Are these fish communities, especially the abundance and types of predators, unique compared to other Michigan lakes?
3. What factors affect bluegill growth, mortality, and recruitment in Blueberry Pond?

These questions were addressed by intensive population studies of all fishes at both lakes during 1984-85 and supplemental studies on population, diet, mortality, and bluegill recruitment at Blueberry Pond during 1986-90.

Lake Descriptions

Dead Lake and Blueberry Pond are small, shallow, meso-eutrophic lakes which stratify and are similar in physical, chemical, and biological characteristics (Table 1). Dead Lake is somewhat less productive as indicated by total phosphorus, Secchi disk transparency, and macrophytes. Macrophytes cover 41% of Dead Lake compared to 83% of Blueberry Pond.

Dead Lake has consistently (for at least 25 years, by repute) produced many bluegills longer than 8 in. Water clarity allows rooted aquatic plants to grow from depths of 0 to 13 feet. Within this littoral zone, submergent macrophytes (primarily pondweeds) are absent from about 20% of the area, sparse in 20%, common in 50%, and excessive in 10%. Floating vegetation (principally water lilies) were absent from 40% of the littoral area, sparse in 10%, abundant in 20%, and excessive in 30%. *Chara* was absent from 80% of the zone and common in 20% of it. Emergent bulrush was excessively dense over less than 10% of the littoral zone and absent elsewhere. About 80% of the shoreline was marshy (principally cattail) and 20% was upland with sand-gravel substrate. Overall, from the perspective of potential fish cover, I would rank the density of vegetation as above average--but not extremely high--compared to other southern Michigan lakes, and especially to Blueberry Pond.

Ownership of Dead Lake was shared by eight riparians. Riparians rarely fished the lake themselves, and anglers were rarely seen on the lake because it had no public access. Total fishing pressure was very light compared to other lakes in southern Michigan.

Blueberry Pond also had a reputation for producing 8-in bluegills in recent years. However, during a cursory survey in 1959, there was mixed evidence as to the quality of the bluegill population. The lake was reportedly enlarged to its present size by a dike installed across the outlet in 1955. Since 1962 the lake has been owned by the Detroit Area Girl Scouts. It receives very little fishing activity, mostly by their staff, and has no public access.

In Blueberry Pond the water was moderately clear, which allowed macrophytes to grow to 8 feet deep. Submerged macrophytes (primarily pondweeds) were rated either as excessively dense (95%) or abundant (5%) over the entire littoral zone. Dense beds of water lilies occurred over 40% of the zone. *Chara* was common over 10% of the area and absent from the rest of the lake. Emergent bulrushes and cattails were found along 30% of the shoreline. Overall, I ranked the density and abundance of aquatic vegetation as extremely high for a lake which does not winterkill.

Methods

Bluegill Population Characteristics

Populations of bluegill longer than 2 in total length were estimated by mark-recapture methods at both lakes from ice-out (late March) to late May in 1984 and again in 1985. Similar spring estimates were continued at Blueberry Pond through 1989. For the first 1-2 weeks each spring, fish were sampled with 3-foot high trapnets and were given a top caudal fin clip. Nets included pot mesh size of 1-1/2 in or 3/4 in, stretched measure. Later, day and night electrofishing (220-V AC, 3 phase) were used to collect fish; these were given a bottom caudal fin clip. Electrofishing was best for sampling small bluegills, trap nets for sampling large bluegills. To compensate for gear selectivity, data were recorded and stratified by inch group. Data for adjacent inch groups were sometimes pooled to obtain at least four recaptures when computing mark-recapture estimates. These pooled estimates were then apportioned to constituent inch groups based on numbers caught in the least biased gear (usually electrofishing). Population estimates were calculated by the Schumacher-Eschmeyer formula (Ricker 1975), which makes best use of serial mark-recapture data, but the resulting asymmetrical confidence limits preclude use of confidence limits in subsequent calculations. In this report, the number of different fish captured (a precise number) is given in lieu of the lower confidence limit. High proportions of some strata were actually handled.

Scale samples were taken from 30-50 bluegills per inch group to determine growth and age composition. Age-specific population estimates were calculated from the inch-group estimates and age-composition data. The percent contribution of each age group to an inch group was multiplied by the inch group estimate to give age group estimates stratified by inch; these were then summed to give the total estimate for each age group.

Back calculation with scales was used to reconstruct growth history prior to 1984. The results showed Lee's phenomenon, in which slow-growing fish appear to live longer than fast-growing fish. Consequently, average lengths at age were calculated from empirical measurements for 1984-89 with a stratified weighting process similar to that described for age estimates. These weighted averages were usually very similar to the simple averages of scale samples, and comparable to back-calculated results because samples were obtained prior to the growing season.

A subgroup of scale-sampled fish were individually weighed in 1984-86 and length-weight regressions were computed. Estimates of bluegill biomass were calculated from average weights and population estimates for each size or age group.

Total mortality rates (A), which included both natural and fishing mortality, were calculated by comparing age-group estimates in succeeding years (Ricker 1975). An average instantaneous mortality rate for adults (age 4 and older) was obtained by dividing the number of age-5 or older survivors in a year by the number of age-4 or older fish present the year before. For Dead Lake, with two successive years of population estimates, one estimate of mortality could be calculated. For Blueberry Pond, with six annual population estimates, five mortality estimates were calculated, then averaged to reduce variability. Average total mortality and average survival, as percentages, were then calculated.

Most of the total mortality was due to natural causes because the lakes were very lightly fished by anglers. In certain springs, substantial mortality of both marked and unmarked fish was observed in Blueberry Pond. This was addressed in the natural mortality study described below. Electrofishing did not cause undue mortality or retard growth (Schneider 1992).

Fish Community Characteristics

Populations of other species of fish were estimated concurrently using the same methods as for bluegill. Scale samples and weights were similarly taken from largemouth bass, pumpkinseed *Lepomis gibbosus*, yellow perch *Perca flavescens*, black crappie *Pomoxis nigromaculatus*, and northern pike *Esox lucius* and were similarly used to calculate growth, age composition, length-weight regressions, and biomass. For species not scale sampled, state average length-weight regressions (Merna et al. 1981) were used to calculate biomass. Additional information on growth and survival of largemouth bass captured by trapnet, angling, and electrofishing was obtained by monitoring individuals marked with Floy anchor tags at the base of their soft dorsal fin (Schneider 1992). Biomass estimates were summed across all species to estimate total fish community biomass and proportions by species.

Factors effecting bluegills

Diet studies.—Stomach contents of Blueberry Pond fish were examined to determine feeding niches by species and size and potential interactions among species. Of special interest was the incidence and rate of predation on small fish and if predation was controlling bluegill recruitment. Examined were 1,188 bluegill, 885 pumpkinseed, 453 yellow perch, 642 largemouth bass, 140 yellow bullhead *Ameiurus natalis*, and 170 grass pickerel *Esox americanus*. This extensive sampling was possible without harming the fish populations because stomach flushing (described below) causes little mortality (Foster 1977). Low mortality was confirmed by holding flushed fish in live crates for 24 to 48 hours, and also by noting the frequency with which tagged largemouth bass were recaptured. The recapture rate was 24.6% for bass which had been flushed and 24.1% for bass which had not been flushed. Subsequent growth of the two groups was not significantly different either.

Diet samples were taken in most months and tabulated on a seasonal basis. The goal was to obtain 10 fish per species per inch group on each sample date. Fish were collected by electrofishing, angling, or netting. Stomach contents of fresh-caught fish were removed and preserved in 10% formalin. Small fish (shorter than 3 in) were preserved whole; the stomach contents of larger fish were removed using pulsed gastric lavage (Foster 1977). For this technique, a compressed-air garden sprayer was used to inject water, via a tube, down the throat into the stomach while the fish was held head down. Size of the tube was adjusted to fish size. Flushed water containing food was caught in a funnel and concentrated in a piece of cheese cloth held on the funnel with a rubber band. Later, in the laboratory, food items were identified and enumerated under microscope. Maximum and minimum lengths of intact food items were measured in mm. Weight of food eaten, by type, was estimated from median lengths, numerical counts, and length-weight curves. Length-weight curves were obtained from

Merna et al. (1981), Rosen (1981), Meyer (1989), and Theiling (1991).

The number of bluegill eaten per year was calculated seasonally for all predators which foraged on bluegills (Appendix 1). These included largemouth bass >3 in, yellow perch >5 in, yellow bullhead >4 in, grass pickerel >5 in, and bluegill >7 in. Average populations of predators (spring estimates), occurrence of bluegill in predator stomachs, and digestion rate were used in these calculations. Diet data provided average number of sunfish of any species (*Lepomis* spp, referred to as sunfish) in predator stomachs and the ratio of identifiable bluegills to pumpkinseeds. Based on winter laboratory experiments with yellow perch, a fish in a stomach was identifiable as a sunfish up to the point of 50% digestion (24 hours at 40°F). This same recognition point was estimated for other seasons from seasonal water temperature data and digestion rate-temperature curves. Digestion rate curves for yellow perch (Schneider 1973c) were assumed to apply to all species except largemouth bass (Adams et al. 1982). Partial data for bluegill (Seaburg and Moyle 1964; Windell 1966) supported this assumption. Stomach samples were usually taken at midday, so 1200 h was used as a starting point to determine what fraction of the daily meal was sampled for different types of feeding behavior. Largemouth bass and bluegill reportedly feed at any time, yellow bullhead mainly at night, and yellow perch and grass pickerel only in daylight. For example, in summer the sunfish found in a largemouth bass at noon have been present less than 7.5 hours, and represent 7.5/24 of a daily meal (multiplier of 3.22). Yellow perch computations were more complicated because each sunfish at noon represented what was eaten in the last 3 hours, and was multiplied by 5 because there are 15 hours of daylight for summer feeding.

Fishing mortality.—Fishing effort and harvest were roughly estimated by observing fishing activity, issuing diaries to anglers, and asking lake users to recall their harvest during the preceding season or year. This was feasible because only a few anglers had legal access and illegal fishing activity was low in most years.

Natural mortality.—Significant numbers of dead fish were observed in Blueberry Pond from mid-April to early May in 1985, 1988, and 1989. Peak mortality was usually associated with hot weather which quickly pushed water temperatures from 50 to 60°F. A variety of adult fish died at those times, especially large bluegills. Systematic searches and experiments were conducted in 1989 to aid in interpretation of those observations. These are explained in greater detail in Appendix 2.

Bluegill recruitment studies.—Small bluegills were relatively sparse in Blueberry Pond during all six years of study. Seven possible explanations for low recruitment were considered:

1. Low reproductive potential due to delayed maturation or low fecundity.
2. Low spawning activity, which would be reflected in few nests being constructed or occupied.
3. Low survival of eggs due to disease, predation, or nest desertion by males.
4. High predation on larvae in redds because guarding males were unable to fend off predators.
5. High predation on fry during their limnetic life stage (prior to a length of 0.6 in).
6. High predation on juveniles during their littoral life stage (lengths of about 0.6 to 4 in).
7. Starvation after hatching or during the first winter.

Combinations of explanations 1-7 were also considered. For explanations 3 to 7 to be relevant, explanations 1 and 2 must first be discounted. Explanation 6 was analyzed as part of the diet study.

Reproductive potential.—To test for low reproductive potential (explanation #1), seven ponds at the Saline Fisheries Research Station were stocked with four types of adult bluegills in spring 1989, just prior to spawning in late May (Table 2). Three types were obtained directly from Blueberry Pond, the fourth from Sugarloaf Lake. The four types of bluegills were "old 8-in" (age 8-10, 2 ponds), "young 8-in" (age 4-6, 2 ponds), "5- to 6-in" (age 2-3, 2 ponds), and, as a control, "5- to 6-in" from Sugarloaf Lake (probably age 3-4, 1 pond). Ages of Blueberry Pond fish were determined by scale analysis before stocking. However, old bluegills could often be recognized by thinness and more whitish coloration. Fish were allowed 4 months to spawn, then ponds were drained and young were tallied.

The adult stocking rate was selected in anticipation that it would be low enough to show a difference between types of bluegills if one existed, yet high enough to make it unlikely that aberrant sex ratios or a modest amount of stocking mortality would significantly affect the number of eggs actually laid in ponds. Latta and Merna (1977) demonstrated in a prior study at these ponds with "normal" bluegills from Sugarloaf Lake that only a few adult females were required to saturate the ponds with fall fingerlings. Based on their stock-recruitment curve, stocking rates in excess of 80 eggs/m^3 (calculated from fecundity estimates and number of females) would produce a plateau of 35-40 fingerlings/m^3. Normal fecundity was assumed to be 8,682 eggs for a 5.5-in female, 19,380 eggs for a 6.5-in female, and by extrapolation, about 38,000 eggs for an 8.3-in female. The same fecundity schedule was assumed to apply to Blueberry Pond fish. Sex of adults could not be determined accurately at stocking and some adults died prior to pond draining, when all survivors were identified to sex. Consequently, minimum-maximum estimates of the potential number of eggs available per m^3 per pond ranged from 41 to 369. This was not a confounding factor in interpreting results, however, because there was no correlation between potential eggs and number of fingerlings produced.

Spawning observations.—To test for low spawning activity (explanation #2), extensive observations were made at Blueberry Pond. In southern Michigan lakes, bluegills may spawn from mid-May to mid-September, but spawning is highly concentrated in late May. Total spawning activity can be estimated by frequent observation because a successful male guards the nest for several days (Claussen 1991). Extensive observations were made at Blueberry Pond during 1989, while systematically searching the pond from a boat; more limited observations were made in 1988 and 1990. Observations were aided by the pond's small size (19.9 acres), clarity (6-8 feet), and dense macrophyte growth which limits usable spawning habitat to depths less than 5 feet.

Results

Basic fish population data are in the appendices. Included are estimated number by species and size group (Appendices 3 and 4) and age group (Appendices 5 and 6), average length at age (Appendices 7 and 8), length-weight regressions (Appendix 9), and estimates of biomass (Appendix 10).

Bluegill Population Characteristics

Size structure.—Both lakes contained unusually high proportions of large bluegills. At Blueberry Pond the 8-in group contained more bluegills than any other estimated inch group in all 6 years of study. On average, they comprised 62% of the bluegill stock over 6 in long. At Dead Lake the bluegill size distribution was more normal, but still 9% of the 6-in and larger fish exceeded 8 in. Despite the preponderance of large fish, no 10-in bluegills were captured in Dead Lake and only two were taken in Blueberry Pond.

The quality of these bluegill populations can be compared to those in other lakes by analyzing size distributions in 1984 trapnet catches with a classification system (Schneider 1990). On a scale of 1 (very poor) to 7 (superior), Dead Lake scored 6.0 and Blueberry Pond scored a perfect 7.0. Both lakes are in the 95th percentile of 303 Michigan bluegill lakes which have been classified with this system. Blueberry Pond bluegills were the best of all measured to date.

Density.—Both lakes contained unusually high densities of large bluegills as well as high proportions of them. The average number of bluegills 8 in and larger was 30 fish/acre for Dead Lake and 204 fish/acre for Blueberry Pond (Table 3). Densities of 6-in and larger bluegill were also high, 223 fish/acre for Dead Lake and 330 fish/acre for Blueberry Pond.

Bluegill population densities have been studied intensively at nine other Michigan lakes (Table 4). Only Third Sister Lake and Mill Lake had densities of 8-in and larger bluegill within the range found in Dead Lake and Blueberry Pond. Third Sister Lake was lightly exploited and Mill Lake was unexploited. Only Mill Lake, with a very slow-growing population, had similar densities of 6.0-in and larger bluegills.

Growth.—Bluegills in both lakes had growth patterns which favored production of large fish. Relative to Michigan average lengths at age (Merna et al. 1981), average growth indices (GI) for bluegills in 1984 were +0.2 in for Dead Lake and +0.3 in for Blueberry Pond. More importantly, growth in both lakes was relatively good for medium-sized bluegills (Figure 1). Growth was below average the first two years (up to a length of about 3 in), accelerated until about age 5 (8 in), then slowed. This pattern was most dramatic in Blueberry Pond, where 8.0- to 8.9-in bluegills ranged from 4 to 12 years old. Growth of large bluegills was better in Dead Lake but none lived long enough to reach 10 in. Over 6 years of observation, the growth of bluegills in Blueberry Pond increased considerably, with average GI increasing from +0.6 to +1.1 (Appendix 8).

Length-weight data (Appendix 9) indicate bluegills in both lakes were thin compared to Michigan (Merna et al. 1981) and national (Murphy et al. 1991) standards. In part, this could be explained by all fish tending to have low condition in early spring. For example, the relative weight (w_r) of fast-growing 6.5-in Blueberry Pond bluegills was only 0.78 (1.0 is standard--Murphy et al. 1991). However, for 8-in bluegills in Blueberry Pond, it also reflected that old and thin fish were present. At 8.5 in, for example, the average w_r was also 0.78, but individual bluegills varied widely, from w_r of 0.34 to 0.82.

Survival.—Survival and longevity of bluegills was exceptionally good in both lakes. Based on scale analysis, bluegills lived up to 11 years in Dead Lake and up to 12 years in Blueberry Pond. Large fish were difficult to age from scales because of slow growth and this is partially responsible for inconsistencies in annual age-group population estimates. The average total mortality rate for adult bluegill (age 4 and older) was 41% in Dead Lake and 37% in Blueberry Pond (Table 5).

Adult bluegill mortality in Dead Lake and Blueberry Pond was lower than in all other Michigan populations which have been studied (Table 4). Total mortality in eight lakes ranged from 0.54 to 0.86, compared to 0.37 to 0.41 for Blueberry Pond and Dead Lake, respectively. The other relatively low figure, 0.54, was for Mill Lake bluegills during a period of no fishing; therefore it was also the natural mortality rate.

Fish Community Characteristics

Other species.—Size structures of the other species populations were not as exceptional as those of bluegill. Both lakes contained some 8-in pumpkinseeds. Yellow perch tended to be small in Dead Lake but there were many 9-10 in long in Blueberry Pond (but rarely larger). A few largemouth bass larger than 20 in were found in both lakes, but the growth of bass in Blueberry Pond declined and many had stunted at 10-13 in by the end of the study. Northern pike, found only in Dead Lake, grew slowly and only three fish over 30 in were collected.

Densities of harvestable-size fish of other species were impressive (Table 3). Densities of 6-in and larger pumpkinseeds were 32 fish/acre for Dead Lake and 83 fish/acre for Blueberry Pond, both higher than any Michigan lake reviewed by Schneider (1971).

Yellow perch over 7 in long were sparse in Dead Lake (1.6/acre), but abundant in Blueberry Pond (36/acre). The latter is a relatively high yellow perch density for a southern Michigan lake (Schneider 1971; Schneeberger 1988). Largemouth bass 10 in and longer averaged 6.6 and 27 fish/acre in Dead Lake and Blueberry Pond, respectively. Compared to largemouth bass in other southern Michigan lakes, Dead Lake is about average but Blueberry Pond is exceptional, the highest density observed (Schneider 1971; Goudy 1981; Schneeberger 1988). For Dead Lake, the average number of northern pike over 20 in long was 2.6/acre, which was about twice as dense as other southern Michigan lakes but less than some northern lakes (Schneider 1971). The density of black crappies found in Dead Lake (5.7 fish/acre) was not unusual. Bowfin *Amia calva* were abundant in Dead Lake (8.2 fish/acre) compared to Blueberry Pond (0) and Mill Lake (0.9 fish/acre) (Schneider 1971).

Average growth rates of most other species were also above corresponding state averages (Appendices 7 and 8). Yellow perch (GI = - 0.3) and northern pike (GI = -2.5) were slow growing in Dead Lake. Largemouth bass tended to grow slowly in Blueberry Pond, and GI shifted between -0.8 and -2.4. Their growth pattern was normal until they reached a length of 10 in. In 1986-89, growth almost stopped at 10 in and bass became emaciated. The GI of yellow perch varied considerably, between 0 and +0.6 in during the study.

Length-weight data (Appendix 9) indicated all species in both lakes were thin compared to Michigan (Merna et al. 1981) and national (Murphy et al. 1991) standards. This was especially true for slow-growing populations, or slow-growing portions of populations. However, relatively low condition in early spring is normal for most fish populations.

Total mortality rates for large fish of other species (Table 5) were also low compared to values from other Michigan lakes (Schneider 1971; Goudy 1981; Schneeberger 1988). The estimate of 37% for Blueberry pumpkinseeds was lower than for four other southern Michigan populations. Yellow perch experience relatively high mortality in Dead Lake (91%) and relatively low mortality in Blueberry Pond (50%). Largemouth bass rates (30-38%) were below the typical range of 40-50%. Northern pike mortality rate in Dead Lake was 32%, which is low compared to 55% in Mill Lake. Black crappie mortality was relatively high, however.

Total biomass.—Both lakes contained relatively high standing crops of fish, 174 lb/acre for Dead Lake and 197 lb/acre for Blueberry Pond (Table 6). Typical small warmwater lakes are usually in the 100-150 lb/acre range (Schneider 1973b and 1978). Given the limnological (Table 1) and community (Table 5) characteristics for these lakes, their standing crops can be estimated from equation 3 of Schneider's (1978) report. Estimates were 118 lb/acre for Dead Lake and 154 lb/acre for Blueberry Pond, which are also lower than the observed densities. These discrepancies are attributed to the low fishing these lakes receive rather than unique limnological or community characteristics.

Composition.—Bluegills predominated in the study lakes, comprising 46 to 55% of the community biomass (Table 6). In Dead Lake, the other prominent species were bowfin (14.6%), pumpkinseed (8.7%), northern pike (6.5%), and largemouth bass (6.0%). In Blueberry Pond, the other primary species were pumpkinseed (12.5%), largemouth bass (11.4%), and lake chubsucker *Erimyzon sucetta* (6.1%). Both lakes were slightly unusual compared to averages for 148 southern Michigan lakes (Schneider 1981), which are: bluegill (41%), largemouth bass (16%), carp (11%), yellow perch (7%), and black crappie (6%). Thus largemouth bass, an important predator on bluegills in most lakes, was of lesser relative abundance (percentage basis) than expected. In good fishing lakes, piscivores generally make up 20% or more of the total biomass (Schneider 1981). In Dead Lake, bass and pike totaled only 12.5%, but the addition of bowfin (often a piscivore) increases the total to 27%. In Blueberry Pond, largemouth bass and grass pickerel totaled only

14.3%, far short of expectations. However, large yellow perch (5.8%) and yellow bullheads (4.9%) serve, in part, as piscivores. I conclude that Dead Lake and Blueberry Pond do not contain unusually high proportions of piscivores on a weight basis, but the high densities and slow growth of largemouth bass in Blueberry Pond and of northern pike in Dead Lake implies those populations are maximal. These lakes met other fish community and bluegill population criteria for good fishing lakes given by Schneider (1981).

Factors affecting bluegills

Feeding niches.—Bluegill, pumpkinseed, yellow perch, largemouth bass, yellow bullhead, and grass pickerel ate a wide variety of food items in Blueberry Pond (Appendices 11-16). There was much diet overlap, especially when size and season differences were pooled. This was anticipated because the principal species--bluegill, pumpkinseed, yellow bullhead, and yellow perch--are classified as generalists (Keast 1979). Still, there were some noteworthy differences in relative proportions of food types which indicate feeding specializations and locations even within this small ecosystem. In Table 7, key food types were identified and grouped to indicate the habitat where they are most abundant in Blueberry Pond. The species of fish deriving the greatest benefit from each food group and habitat were determined from frequency of occurrence and average number of food items per fish.

Bluegill extensively utilized all except the largest food items such as fish. They were the primary foragers in the offshore midwater habitat as indicated by the importance of *Daphnia*, *Chaoborus*, and midge pupae in their diet. They are well adapted to retaining small items (captured one at a time) because of their closely spaced gill rakers. They also fed on the surface (adult insects) and on invertebrates throughout the littoral zone. Pumpkinseeds foraged almost entirely in the littoral zone where they were the primary predator on mollusks, midge larvae, and other benthos. They are adapted for crushing shells. Yellow perch fed extensively on medium-sized items in the littoral zone, such as immature dragonflies, damselflies, and other benthos, but also ate some migrating midge pupae in deeper water. Large perch were more likely to eat fish, but fish remains were not as frequent as for some other piscivores.

Species which concentrated on relatively large food items were largemouth bass, yellow bullhead, and grass pickerel. Bass were the primary piscivore, with fish occurring in about half of their stomachs. Most bass were medium-sized (10 to 12 in long), so fish larger than 4 in were rarely eaten. However, an 8-in bluegill was found in the stomach of an unusually large (21.8 in) bass. Bass were also the primary predators on crayfish, and on adult dragonflies and damselflies (relatively small items) which they snatched from the surface. Yellow bullhead diet was surprisingly similar to bass, but bullheads are nocturnal and will scavenge dead fish. Grass pickerel lived in near-shore vegetation where they selected relatively large items for their size.

Bluegill diet.—Subtle shifts in feeding niches occurred in Blueberry Pond as bluegills grew. Niches became most distinct and critical in summer (June to August) when temperatures were most favorable for growth and habitats were most sharply defined by thermal stratification of the water column. The diet data, expressed as relative percentage of important food items on a weight basis, revealed both food selectivity and feeding habitat (Figure 2).

Small bluegills fed extensively in the littoral zone, where they were probably less vulnerable to predation by bass than in open water (Werner and Hall 1988). As 1- and 2-in fish they ate a variety of benthos picked from macrophytes or sediments, but especially small midge larvae and immature *Caenis* mayflies. A few copepods were eaten by this size group, the only group to do so. At 3 to 5 in long, a mixture of larger caddisfly larvae and damselfly nymphs predominated.

Some bluegills began feeding in the pelagic zone at 4-5 in, as indicated by the importance of *Daphnia* in their diet. By that size bluegills were nearly immune to largemouth bass predation and could freely forage in open water. The contribution of *Daphnia* peaked at 50% among 6-in bluegills, then declined to 4% among 8-in and larger bluegills. The occurrence of the phantom midge *Chaoborus* likewise indicated deep-water feeding by 5- to 9-in bluegills.

Midge larvae were important to all sizes of bluegill because of their abundance in both littoral and sublittoral areas of Blueberry Pond (Theiling 1991). Snails were a small part of the overall diet but became more frequent as bluegills grew large enough to crush them. Midwater and surface items such as midge pupae and adult insects were eaten opportunistically by all sizes, but especially larger bluegills.

The unique growth pattern of bluegills in Blueberry Pond correlated with these diet shifts. Accelerated growth from 3 to 8 in corresponded to both increased utilization of larger types of littoral benthos (caddisfly, damselfly, and dragonfly) and the major shift to offshore *Daphnia*. Densities of these items were not unusually high in Blueberry Pond (and Dead Lake) relative to other southern Michigan lakes, however large *Daphnia* are often associated with good bluegill growth (Schneider 1971; Laarman and Schneider 1972; Theiling 1991). *Daphnia* found in bluegill stomachs were up to 2.0 mm in length (Appendix 9). Reasons for slow growth and reduced *Daphnia* intake by 8-in bluegills were not apparent because those fish could also forage anywhere without fear of predators.

Predation on bluegills.—The estimates of total annual consumption by predacious fish in Blueberry Pond were high--303,300 bluegills and 92,800 pumpkinseeds (Appendix 2). No green sunfish, a rare species, were found in stomachs. Largemouth bass shorter than 12 in were the major predator, accounting for about 226,000 bluegill deaths. Yellow perch ate about 33,500 bluegills during winter and fall, but none during summer. Yellow bullheads ate about 23,000 bluegills, and their consumption in summer (19,000) may have been underestimated by midday sampling, because bullheads are nocturnal feeders. Other bluegill predators were grass pickerel (13,600) and adult bluegills (7,600).

Bluegills eaten by largemouth bass were relatively small, mostly less than 25 mm (1 in) long (Figure 3). Of 242 fish remains identified as sunfish, only 2.1% were longer than 50 mm. Thus, 98% of bass predation was on sunfish less than one-year old. A high proportion of the diet, 48.3%, consisted of sunfish only 7-15 mm long. About 125,000 sunfish in the first few months of life were eaten by bass. This estimate is conservative because small fish are usually digested rapidly.

Cannibalism among bluegills was rarely observed. However, the projected total consumption was 7,600 per year because the adult bluegill population was large. The remains of only two bluegills (22-33 mm) were found in the stomachs of 756 bluegills over 5 in long. Other fish present in their stomachs were 1 pumpkinseed (35 mm), 2 yellow perch fry (8 mm), 1 minnow (15 mm) and 1 other probable minnow (12 mm), 1 unidentified remain, and 4 unidentified fish fry (6-8 mm). These fry were probably either centrarchids or cyprinids based on time of year caught. Cannibalism was most likely to occur in early June when peak numbers of newly hatched larvae migrate into offshore waters. There the pelagic fry would be vulnerable to adult bluegills which were foraging on midwater foods such as *Daphnia*. Nonetheless, clear evidence of cannibalism was not found in samples taken during mid June. Very intensive sampling would be required because fish fry digest to an unrecognizable state in about 2 hours (unpublished data).

Fishing mortality.—At Dead Lake the annual (1984-85) sport fishing harvest was approximately 308 bluegills, 209 largemouth bass, 14 northern pike, 4 black crappie, and 8 pumpkinseeds. These numbers indicated low exploitation for all species, representing about 3% of the bluegill, 8% of the largemouth bass, and 8% of the northern pike of harvestable size present in spring.

At Blueberry Pond the annual harvest in 1984-87 was approximately 50 bluegills, 50 yellow perch, and 20 largemouth bass. Compared to spring population estimates of catchable-sized fish, this represented only 1% of the bluegills, 7% of the yellow perch, and 13% of the largemouth bass. However, an unusually high harvest occurred in winter 1987-88 when 100-200 bluegills and 100-200 yellow perch were reportedly removed by a few anglers who experienced exceptionally good ice fishing on two weekends. Of the available populations (spring 1988 estimate), these high catches represented 2-4% for bluegill and 15-30% for yellow perch. This reinforces summertime observations made at other lakes that yellow perch populations can be significantly reduced by a few lucky or skillful anglers (Schneider 1973a; Goedde and Coble 1981). Largemouth bass were also readily caught by ice fishing on this lake but few were harvested due to the closed season for them. Poachers were caught on the lake in the summer of 1988 but their take is unknown.

Natural mortality.—Substantial natural mortality of fish occurs annually in every lake. In Blueberry Pond, for example, an average of 37% of the adult bluegills died each year (2,400 were over 6 in long). However, large numbers of dead fish are rarely seen because most deaths are probably scattered throughout the growing season (Patriarche 1968). In the case of adult bluegills, they are too large to be eaten by other fish so natural deaths are due to diseases, parasites, injury, physiological malfunction, or old age. If the natural mortality rates of adult populations could be reduced even slightly by fishery managers, many more fish would be available to anglers.

The main conclusions from observations and experiments in 1989 were (see also Appendix 2):

1. A total of 202 dead fish were observed in spring 1989, of which 78% were bluegill.
2. Only a small fraction (13%) of all fish which died during spring 1989 were observed.
3. The total number of deaths in spring 1989 was estimated at 1,550 fish, which was 10% of the adult fish population and 25-50% of the annual deaths.
4. Cause of death was not evident, and was not obviously related to age, condition, or species.
5. Scavengers, mainly yellow bullheads and turtles, removed about 80% of the fresh dead fish within 2 days.
6. Dead fish not consumed by scavengers did not always bloat and can take up to 35 days to decompose on the bottom.

Recruitment studies.—Small bluegills were relatively sparse in Blueberry Pond during all 6 years of study. They were rarely seen during fall electrofishing as young-of-the-year or during spring as yearlings due both to their rarity and their low visibility. Only in 1987 were enough yearlings (1-2 in long) captured to obtain a population estimate (99 fish/acre, with very wide confidence limits). Two-year-olds were easier to capture and estimate because of their larger size (3-4 in), but they were also sparse (42-308 fish/acre). By comparison, estimates of age-2 bluegill in Dead Lake were 391-2,500 fish/acre. Electrofishing catch rates provided a more reliable comparison of the relative density of younger age groups, but age-1 fish were still underrepresented in the samples because they were less visible. The average number of age-1, -2, and -3 bluegills caught per trip were 6.1, 21.4, and 5.4 for Blueberry Pond, and 11.6, 96.4, and 30.9 for Dead Lake, respectively. The reproductive potential of bluegills in Blueberry Pond was obviously very high, with over 6,500 6-in and larger adults capable of producing about 100 million eggs.

Reproductive potential.—Results of the Saline pond experiment indicated that all four types of bluegills had similar reproductive potential (Table 2). Old 8-in bluegills produced 20.7 to 26.7 fall fingerlings/m^3, similar to production by young 8-in bluegills and to production by 5- to 6-in bluegills from Blueberry Pond and Sugarloaf Lake. There is no clear indication that large, small, young, or old bluegills from Blueberry Pond differed from normal. Consequently, consistently low bluegill recruitment in Blueberry Pond cannot be attributed to lack of reproductive potential.

Spawning observations.—The second explanation for poor recruitment--low spawning activity--was strongly supported by observations and seemed to be the main mechanism controlling bluegill recruitment in Blueberry Pond. Each spring the pond contained about 7,000 mature bluegills which, based on the Saline study, are capable of producing over 2 million fall fingerlings. Assuming half are males and that all spawn, 3,500 active bluegill nests should be present each year (it is unlikely that males nest more than once a year in northern waters--Claussen 1991). Fewer redds--perhaps 1,000 to 3,000--would be constructed because redds may be sequentially shared.

Bluegill (and pumpkinseed) spawning activity at Blueberry Pond was monitored 23 times between 22 May and 15 August 1989. Peak activity was 25-31 May, but a few relatively fresh-looking redds were seen as late as 8 August. Only 2 bluegills (26 June), 64 pumpkinseeds, and 1 green sunfish were actually observed guarding redds. About 160 unoccupied, relatively fresh redds were observed, which could have been made by either bluegills or pumpkinseeds. Very few adult bluegills were even observed inshore compared to pumpkinseeds.

However, appreciable numbers of young-of-the-year bluegills were observed on 15 August and during fall electrofishing. Apparently, they were derived from relatively few redds constructed in late May. During a warm 5-day period about 90 redds were constructed. Only pumpkinseeds were observed, but some of those redds could have been made by unobserved bluegills. In any event, I concluded that very few (about 2%) of the 3,500 adult male bluegills attempted to spawn in 1989.

These results confirmed less rigorous observations made in other years. In 1988, about 90 redds were observed near peak spawning time (27 May), but only one was guarded by a bluegill. On 25 May 1990, many bluegill-like redds were observed, but only two had adult bluegills. In 1991, many redds were observed on 25 May and 200 were estimated on 30 May, but no adult bluegills and only one pumpkinseed were observed. Three schools of fish fry were sampled in the littoral zone, but they were 14-mm largemouth bass rather than bluegills.

Evidence for incomplete and extended spawning was supported by observations and autopsies made during summer 1989 diet sampling. On 7 June, females swollen with eggs were taken in trapnets. On 19 June, one female was absorbing eggs. Caught from deep water on 5 July were 10 fish judged to be immature (5.3 to 6.2 in long), 2 ripe males, and 7 mature females. Two of these females had enlarged ovaries (ovary comprised 3.9 to 4.6% of the total weight) indicative of near-ripe fish. On 15 August, a female was observed with loose but infertile eggs.

Other explanations.—Possible explanations for low bluegill recruitment in Blueberry Pond involving nesting success (#3 and #4) were not evaluated because so few active bluegill redds were found. Projections from the diet study indicate significant predation mortality on small age-0 bluegills of about 289,600 per year (explanations #5 and #6). Largemouth bass were the principle predator and accounted for about 125,000 bluegill deaths during the first few months after hatching. Diet sampling indicated bluegill cannibalism was of minor importance. The possible explanation (#7) that young bluegill starved to death in unusually high numbers compared to other lakes is unlikely. Overwinter starvation implies a much higher number of young would be present in fall than in the following spring; observations during fall and spring electrofishing indicate otherwise. Low spawning activity in combination with high predation accounts for the low recruitment pattern in Blueberry Pond.

Discussion

This study began with the premise that it is unusual for weedy lakes to have good bluegill populations. Sampling at Dead Lake and Blueberry Pond was directed at three groups of questions: 1) are these bluegill populations unique compared to other Michigan lakes; 2) are the fish communities--and especially the predators--unique; and 3) what are the mechanisms controlling bluegill dynamics in Blueberry Pond?

The bluegill populations were unique in having both high densities and high proportions of bluegills larger than 8 in. Blueberry Pond supported a phenomenal average of 204 large bluegills per acre. This resulted from rapid growth of fish from 3 to 8 in long and high survival of adults. High survival was clearly due to low fishing pressure and harvest because of private ownership. As a result, large bluegills accumulated until claimed by natural mortality. Natural mortality was low relative to total mortality in exploited lakes, but still substantial and concentrated in early spring. Rapid growth was due to a favorable balance between low bluegill recruitment and amount and type of bluegill food produced by the lakes. Conceivably, these lakes could have unique food chains, or low recruitment could be due to unusually powerful regulatory mechanisms--either extrinsic (such as predation) or intrinsic (such as cannibalism or limited spawning). Regulation was more pronounced in Blueberry Pond, where already by age 2, densities of bluegills were about 1/5 those of Dead Lake even though Blueberry Pond contained a much higher density of mature adults.

Basic productivity and food chains of these lakes were somewhat unusual. Total productivity and abundance of fish food items were not consistently different from many poor bluegill lakes examined by Theiling (1991). However, both lakes supported *Daphnia* populations in mid-summer, which is generally correlated to rapid bluegill growth (Osenberg et al. 1988; Theiling 1991). In Blueberry Pond, limnetic-zone *Daphnia* were an important food source for adult bluegills, and were partially responsible for the increase in bluegill growth from a length of 5 to 8 in. The same is probably true in Dead Lake. In Blueberry Pond, the shift in diet and habitat occurred at about 4-5 in long, higher than the 3-4 in reported for other southern Michigan lakes by Werner and Hall (1988). The diet and habitat shift from littoral to limnetic zones by bluegill is considered to be a response to greater feeding profitability and reduced risk of predation by bass (Werner and Hall 1988). In some weedy lakes, foraging for benthic food in the littoral zone remains profitable if bluegill recruitment is limited, as for Blueberry Pond and a few other lakes (Engel 1985). At the other extreme are good bluegill lakes such as Third Sister, which have a large limnetic zone but bluegills obtain more food from littoral benthos (43% by volume) than from zooplankton (10%) (Ball 1948). Thus, bluegill populations may achieve good growth through either limnetic or littoral food chains.

It is surprising that large *Daphnia* populations were able to persist in Blueberry Pond and Dead Lake for two reasons. First, the adult bluegill populations were very dense. Second, the lakes afforded relatively small refuges from bluegill predation, which is believed to be a cold stratum where dissolved oxygen exceeds 0.5 ppm (Wright and Shapiro 1990; Tessier and Welser 1991). Only 1/4 of each lake is deep enough to stratify and dissolved oxygen falls to low levels in the thermoclines.

The fish communities were not very unusual and extrinsic regulation was probably not much stronger in these lakes than in average lakes. Total biomass of fish was high in both lakes, but proportions of typical piscivores (bass and pike) were not. These species comprised 12% of the biomass in Dead Lake and 14% in Blueberry Pond--far short of the 20% rule-of-thumb for good community balance (Davies et al. 1979; Schneider 1981). However, Dead Lake had a substantial bowfin population and Blueberry Pond contained a relatively large yellow perch population. Other interesting differences were Dead Lake had relatively dense, slow-growing northern pike and relatively sparse, fast-growing largemouth bass; Blueberry Pond had no northern pike, more grass pickerel, and dense, slow-growing largemouth bass.

Although proportions of predators were not high, the high density and slow growth of one major predator in each lake suggested their populations were at carrying capacity and they were preying on bluegills to their fullest extent. The difference in bluegill recruitment pattern between the two lakes suggested most losses occurred in Blueberry Pond during the first year, when bluegills were small, whereas substantial losses occurred in Dead Lake later in life, when bluegills were medium-sized. This coincided with the capabilities of predators in each lake--Blueberry Pond had few largemouth bass or yellow perch larger than 12 in while Dead Lake had many northern pike and bowfin larger than 18 in. In Dead Lake, the sparseness of yellow perch, a more preferred prey fish, probably reflects intensive predation on perch as well. The diet study at Blueberry Pond confirmed that predation on small bluegill was substantial, eliminating 303,300 bluegills per year. However, even this large loss does not seem to account for severely limited recruitment in Blueberry Pond.

Cannibalism, an intrinsic, self-regulating mechanism, was not found to be limiting bluegill recruitment. The incidence of cannibalism was expected to be high in Blueberry Pond because adult bluegills were dense and bluegill larvae would be vulnerable while in the limnetic zone for 4-6 weeks. No larvae were found in adult bluegill stomachs at Blueberry Pond, but cannibalism is so potentially important that it merits intensive, 24-hr sampling in early June, when it is most likely to occur. On occasion, bluegill cannibalism has been observed under laboratory and lake conditions (Beard 1982; Grey 1991).

Probably more important than predation or cannibalism was the observation that only about 2% of adult bluegills even attempted to spawn in Blueberry Pond. This immediately reduced potential fry production from 100 million to 2 million. Subsequent predation of 300,000 then became relatively important and by age 1 only about 5,000 bluegills survived. Low spawning activity may not be unusual in wild populations but rarely has been reported for bluegill. For smallmouth bass, individuals may not spawn every year (Raffetto et al. 1990). Casual observations suggested that numbers of redds in other lakes were usually far short of the number of adult bluegills present. The largest males in each bluegill population are most likely to build redds (Gross 1979), but in Blueberry Pond there were thousands of equally large males. In Blueberry Pond, many adults were old and in poor condition, suggesting they might not expend energy for gonad development or reproductive behavior. However, these fish reproduced normally when transferred to experimental ponds shortly before the anticipated spawning date. Since energy allocations to reproduction begin several weeks prior to spawning, the fish had already begun expending energy for reproduction while still resident in Blueberry Pond.

Old bluegills moved to the Saline ponds grew well, demonstrating that they could regain growth potential in a new environment (Table 2). This suggests the growth decline in Blueberry Pond at a length of 8 in was partially due to competition with younger and slightly smaller bluegills which also forage in the limnetic zone. Some decline in growth is expected because fish become physiologically less efficient with increasing size and age (Paloheimo and Dickie 1966).

Failure to produce an expected number of recruits has been noted in bluegill before, but only under "stunted" conditions (see review by Clark and Lockwood 1990). Usually, this has been attributed to cannibalism, starvation of fry, or bioenergetics. More interesting are mechanisms which might inhibit spawning behavior, such as harassment by other fish and the "repressive factor hypothesis" (Clark and Lockwood 1990). This hypothesis suggests that crowded fish may excrete chemicals into water which inhibit reproductive behavior by conspecifics. Some evidence for chemical repression exists for bluegill, largemouth bass, cyprinids, and goldfish, but at much higher densities than found in Blueberry Pond.

The bluegill population in Blueberry Pond is unusual because of high adult density (relative to natural populations), "stunted" growth at large size (8 in), but a good overall growth pattern. Bluegill spawning behavior (and recruitment) may be controlled by density (and growth) of large adults by intrinsic feedback mechanisms such as bioenergetic effects on reproduction or repressive factors. It is difficult to explain, however, why such mechanisms could be so effective at controlling recruitment in Blueberry Pond when they are not as effective in truly stunted bluegill lakes where adults only reach 5-6 in. Truly stunted populations may have reduced spawning also, but still produce more recruits than the lake can support with an acceptable growth rate and remain locked into the stunted condition. In those situations--unlike Blueberry Pond--recruitment of predators may be suppressed by bluegills. Consequently, beneficial predation on small bluegills is reduced.

The key to the high quality of Blueberry Pond and Dead Lake fish populations despite high densities of macrophytes seems to be low fishing mortality. Low fishing allows many large bluegills to accumulate and exert one or more forms of population control. In addition, predators are retained at high density, further helping to control bluegill recruitment. It is quite likely that an increase in fishing mortality would cause these lakes to develop stunted bluegill populations.

The implication for management is that weedy lakes are capable of producing good fish populations but tighter control of fishing mortality is needed to maintain and create balanced fish communities and good bluegill fisheries. This could be accomplished by mandating special, more conservative harvest regulations at weedy lakes prone to bluegill stunting. The efficacy of no-kill regulations for controlling stunting is currently being tested at three lakes.

Additional Research

Many ideas for future research have been stimulated by these studies. Two areas of potential importance to bluegill management are the causes of natural mortality and the factors regulating recruitment. A study of natural mortality should include identifying indicators of health, quantitatively linking these indicators to fitness and survival, and determining if management opportunities exist. A study of bluegill recruitment should focus on chemical and behavioral factors controlling gonad maturation and spawning behavior. This would require the development of a harmless technique for frequently monitoring gonads of individual bluegills to determine when they mature and when and if they spawn.

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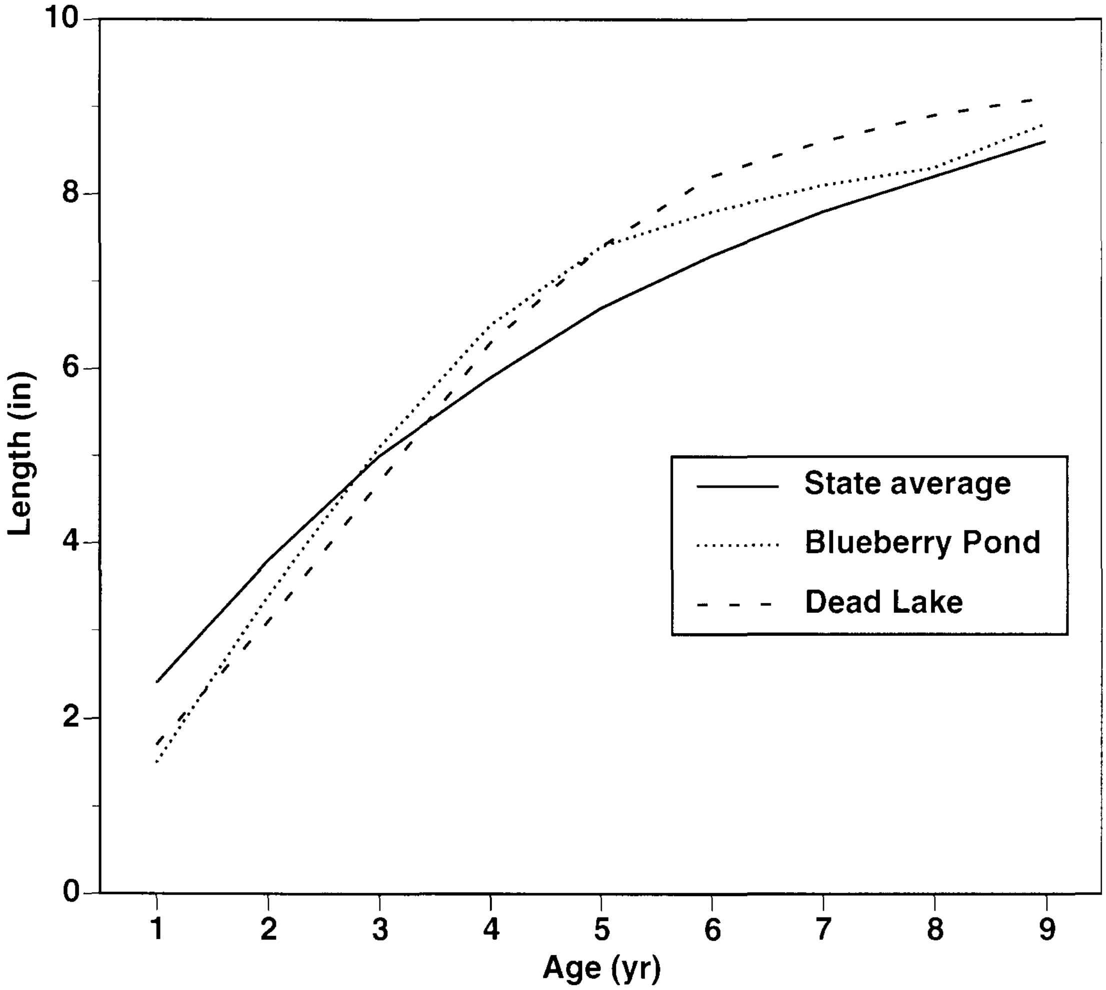

Figure 1.—Backcalculated average length at age for bluegills in Dead Lake and Blueberry Pond compared to the State of Michigan average (from Merna et al. 1981).

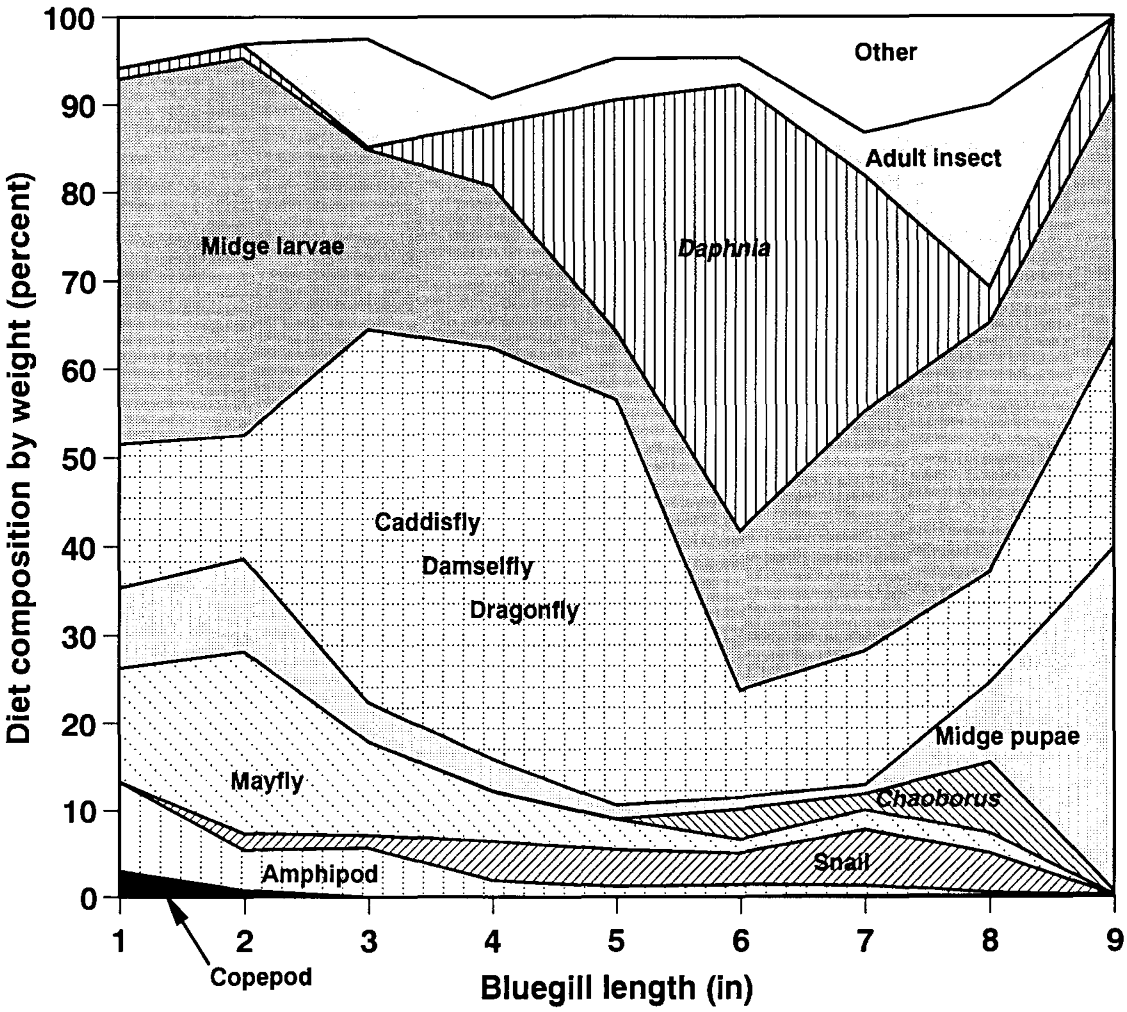

Figure 2.—Average diet composition of bluegills collected during summer (June-August, 1986-90) at Blueberry Pond as a function of bluegill length.

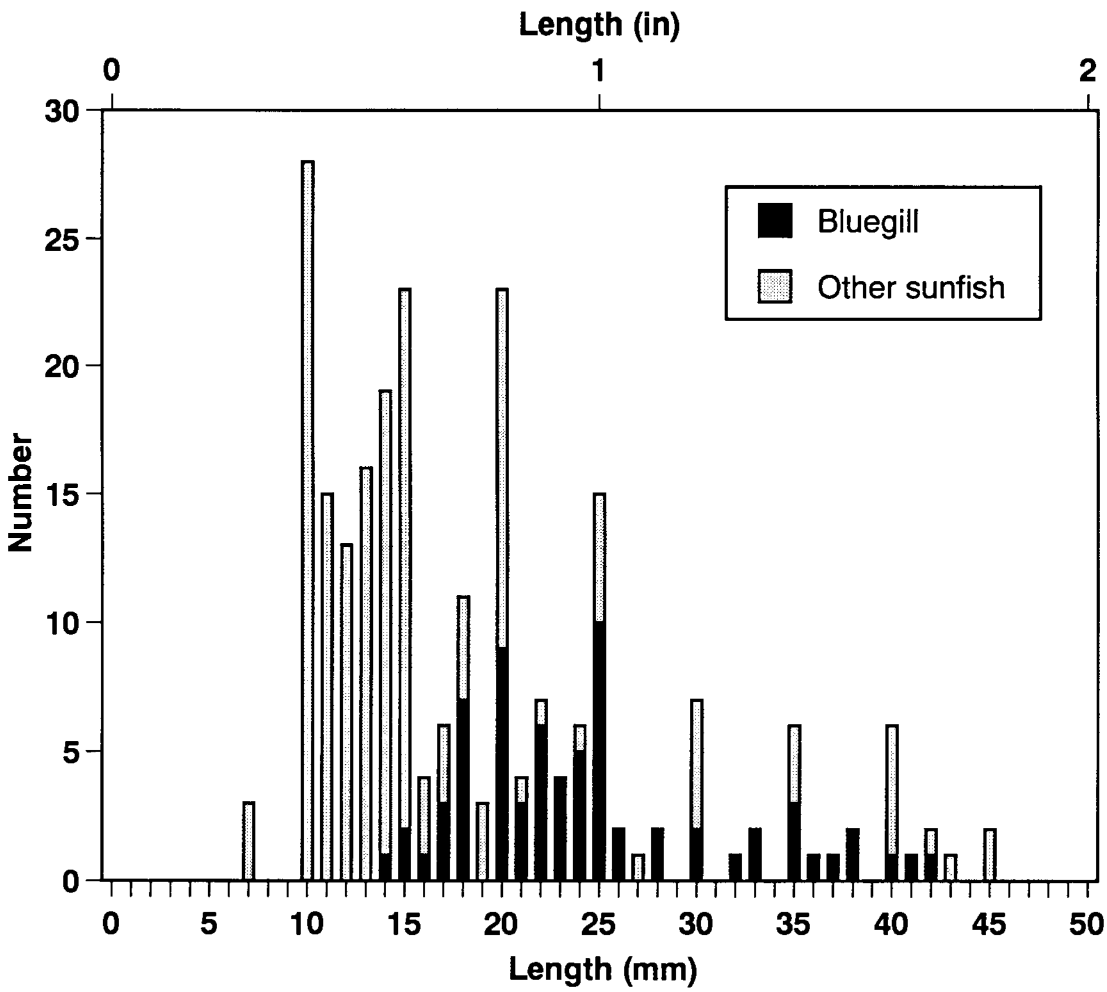

Figure 3.—Length frequency distributions of bluegill and other sunfish (pumpkinseed and BPCT) found in stomachs of largemouth bass in Blueberry Pond. Not shown are 1 sunfish each at 55, 60, 75, 77, and 200 mm.

Table 1.—Selected physical, chemical, and biological characteristics for Dead Lake and Blueberry Pond.

Characteristics	Dead Lake	Blueberry Pond
County	Washtenaw	Livingston
Township, Range, Section	T1S, R6E, Sec 6	T1N, R4E, Sec 3
Area	56.6 acres	19.9 acres
Maximum depth	32 feet	24 feet
Average depth	10.5 feet	7.0 feet
Maximum depth of macrophytes	13 feet	8 feet
Littoral area[a]	71%	74%
Oxygen-thermal type[b]	4	4
Alkalinity	114 ppm	105 ppm
Secchi disk transparency	10-14 feet	7-8 feet
Nutrient concentrations[a]		
NO_3	0.02 mg/l	0.04 mg/l
NH_3	224.2 mg/l	25.3 mg/l
Total P	1.6 mg/l	3.4 mg/l
Chlorophyll a[a]	0.003 mg/l	0.034 mg/l
Macrophyte density rank (1-5)[a]	5	5
Macrophyte cover[a]	41%	83%
Large benthic invertebrate biomass[a]		
Littoral zone	144 mg/m^2	155 mg/m^2
Sublittoral zone	12 mg/m^2	11 mg/m^2
Whole lake	106 mg/m^2	117 mg/m^2
Zooplankton[a]		
Mean size	90.86 mm	0.78 mm
Density	169,000/m^3	5,900/m^3

[a]Data from Theiling (1990). Benthos data collected in mid-winter, 1987-88; other data on one visit in July-August, 1988.

[b]Based on index by Schneider (1975). A "4" indicates a stratified lake with less than 2 ppm dissolved oxygen below 5-foot level of thermocline in mid-summer (i.e., severe oxygen depletion).

Table 2.—Test of the reproductive potential of various types of bluegills in ponds at Saline. Stocking dates were 15 April-26 May 1988; draining dates were 6-20 September. L is mean length in inches.

Bluegill origin and pond	Pond size		Adults stocked		Adults recovered		Young recovered			
								Number		Pounds
	Acres	m^3	Number	L	Number	L	L	Per acre	Per m^3	per acre
Blueberry Lake										
Old, 8-inch										
Pond 2	0.39	1,770	13	8.5	10	9.0	1.00	94,000	20.7	53.9
Pond 3	0.38	1,660	8	8.6	8	9.2	1.16	117,000	26.7	95.2
Mean							1.08	105,000	23.7	74.5
Young, 8-inch										
Pond 11	0.25	1,100	10	8.3	7	9.2	1.14	105,000	24.0	87.0
Pond 13	0.48	2,000	14	8.3	7	9.0	0.99	134,000	32.1	73.7
Mean							1.06	120,000	28.0	80.4
5- to 6-inch										
Pond 7	0.65	2,534	30	6.4	27	7.9	0.80	154,000	39.5	25.7
Pond 8	0.62	2,599	31	6.2	31	7.8	1.54	51,000	12.2	63.4
Mean							1.17	102,000	25.8	44.6
Sugarloaf Lake										
5- to 6-inch										
Pond 12	0.37	1,600	25	5.8	18	7.7	1.08	133,000	30.8	91.2

Table 3.—Average spring densities (number per acre) of catchable-size sport fish in Dead Lake (1984-85) and Blueberry Pond (1984-89).

Species and minimum size (inches)	Dead Lake		Blueberry Pond	
	Average	Range	Average	Range
Bluegill				
6.0	223	208 - 237	330	215 - 507
7.0	136	131 - 141	281	167 - 448
8.0	30	16 - 44	204	124 - 333
9.0	2.9	0.8 - 5.1	7.9	0.5 - 19.1
Pumpkinseed				
6.0	32	29 - 35	83	62 - 105
7.0	7.7	5.6 - 9.7	31	12 - 43
8.0	0.7	0.6 - 0.7	0.8	0.3 - 1.6
Yellow perch				
7.0	1.6	0.8 - 2.5	36	13 - 71
8.0	1.3	0.7 - 1.8	30	11 - 53
9.0	0.8	0.5 - 1.1	18	5 - 28
10.0	0.3	0.3 - 0.4	4.2	2.6 - 8.7
Largemouth bass				
10.0	6.6	6.4 - 6.7	27	23 - 31
12.0	4.4	4.3 - 4.5	6.4	2.7 - 12.0
14.0	1.9	1.7 - 2.0	1.6	1.1 - 3.2
Northern pike				
20.0	2.6	2.2 - 3.0	—	—
24.0	0.3	0.3 - 0.3	—	—
Black crappie				
7.0	5.7	3.9 - 7.5	—	—
8.0	3.5	1.7 - 5.3	—	—
10.0	0.7	0.4 - 1.0	—	—

Table 4.—Comparison of bluegill population characteristics for Michigan lakes. Ranges indicate multiple years.

Lake and county	Growth index	Number per acre >6"	>8"	Adult mortality rate total	fishing	natural	Reference
Blueberry Livingston	+0.3	215-507	124-333	0.37	low	—	This study
Dead Washtenaw	+0.2	208-237	16-44	0.41	low	—	This study
Mill Washtenaw	-1.0	44-209	0.3-22	0.54	—	0.54	Schneider 1971
Cassidy Washtenaw	+0.0	125-126	0.3-0.6	0.55-0.62	—	—	Schneeberger 1988
Third Sister Washtenaw	+0.2	156	68	—	—	—	Brown and Ball 1943
Sugarloaf Washtenaw	-0.1 to -0.4	35-80	3	0.68	0.25-0.30	0.40-0.42	Cooper et al. 1957, Laarman and Schneider 1979
Whitmore Livingston	+0.6	42	4.0	0.68[a]	—	—	Cooper et al 1957
Manistee Kalkaska	+1.0	5-47	0.9-4.4	0.64	—	—	Laarman and Schneider 1986
Fife Kalkaska	+0.1 to +1.5	4-90	1.5	0.55[b]	—	—	Schneider & Lockwood 1979
Jewett Ogemaw	-0.1 to -1.0	42-127	1-4.6	0.86	0.23	0.63	Patriarche 1968
Lodge Ogemaw	-1.6	35-72	0	0.83	0.26	0.57	Patriarche 1968

[a]Average total mortality calculated from 1955-56 pooled age-frequency data for ages 4 to 10 (Latta 1959).

[b]Total mortality calculated from pooled age-frequency data for 1958-65 trapnetting, ages 4 to 8.

Table 5.—Average total mortality rates (A) by age interval.

Species	Dead Lake (1984-85) 2-3	3-4	>4	Blueberry Pond (1984-89) 2-3	3-4	>4
Bluegill	0.48	0.32	0.41	0.62[a]	0.47	0.37
Pumpkinseed	0.83	0.62	0.56	—	—	0.37
Yellow perch	0.49	0.57	0.91	0.31	0.29	0.50
Largemouth bass	—	—	0.30	—	—	0.38
Black crappie	—	0.26	0.85	—	—	—
Northern pike	0.88	0.30	0.32	—	—	—

[a]Calculated from CPE data.

Table 6.—Average spring fish biomass (pounds per acre) and community composition (percent) for Dead Lake and Blueberry Pond.

Species	Dead Lake		Blueberry Pond	
	Biomass	Percent	Biomass	Percent
Bluegill	79.1	45.6	107.7	54.7
Pumpkinseed	15.2	8.7	24.6	12.5
Yellow perch	8.2	4.7	11.4	5.8
Black crappie	2.1	1.2	0.0	0.0
Largemouth bass	10.5	6.0	22.4	11.4
Northern pike	11.4	6.5	0.0	0.0
Bowfin	25.4	14.6	0.0	0.0
Chubsucker	6.9	4.0	12.1	6.1
Brown bullhead	9.1	5.2	0.0	0.0
Yellow bullhead	5.5	3.2	9.6	4.9
Warmouth	0.6	0.2	0.0	0.0
Green sunfish	tr[a]	tr	1.1	0.6
Grass pickerel	tr	tr	5.7	2.9
Golden shiner	tr	tr	2.4	1.2
Total	174.0	100.0	197.0	100.0

[a]tr = Trace =<0.1

Table 7.—Key food types arranged into food groups by habitat and the fish species which are the principle users of each group and habitat. Food groups are generally ordered from small particles (*Daphnia*) to large particles (fish).

Food Group	Principle Habitat	Principal Users
Daphnia	offshore midwater	Bluegill
Midge pupae, *Chaoborus*	offshore & littoral midwater	Bluegill, perch
Midge larvae	offshore & littoral bottom	Pumpkinseed, bluegill
Adult insects	littoral surface	Bluegill, bass, yellow bullhead
Mayfly, caddisfly, damselfly, dragonfly, amphipod	littoral, bottom & vegetation	Bluegill, yellow perch, yellow bullhead
Snail, clam	littoral bottom & vegetation	Pumpkinseed
Crayfish	littoral bottom	Yellow bullhead, largemouth bass, grass pickerel
Fish	littoral midwater	Largemouth bass, yellow bullhead, grass pickerel

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Appendix 1.—Estimation of average annual predation on sunfish (*Lepomis* spp.) in Blueberry Pond. See text for explanation. Grand totals: 303,300 bluegill; 92,800 pumpkinseed.

	Season				
	Dec-Mar	Apr-May	June-Aug	Sep-Nov	Total
Days	121	60	92	92	
Avg Temperature (Mill L.)	40°F	52°F	75°F	58°F	
Hours daylight	7am-5pm	6am-6pm	6am-9pm	7am-6pm	
Bass (all sizes)-- 24-h feeder					
Hours for 50% digestion	24	16	7.5	13	
Daily meal multiplier	1.00	1.50	3.20	1.85	
Observed avg no. sunfish/bass	0.17	0.03	0.64	0.64	
Calc sunfish for 802 bass	16,500	2,400	151,800	87,000	257,700
Number of bluegills					225,700
Number of pumpkinseeds					32,000
Perch (>5 in)-- day only					
Hours for 50% digestion	24	16	3	11	
Daily meal multiplier	1.0	2.0	5.0	2.0	
Observed avg no. sunfish/perch	0.24	0.0	0.0	0.07	
Calc sunfish for 975 perch	28,000	0	0	12,600	40,600
Number of bluegills					33,500
Number of pumpkinseeds					7,100
Bullhead (>4 in)-- night only					
Daily meal multiplier	1	1	5	1.7	
Observed avg no. sunfish/bullhead	0.04	0.0	0.10	0.03	
Calc sunfish for 474 bullhead	3,900	0	38,100	3,700	45,800
Number of bluegills					22,900
Number of pumpkinseeds					22,900
Pickerel (>5 in)-- day only					
Daily meal multiplier	1.0	2.0	5.0	2.0	
Observed avg no. sunfish/pickerel	0.0	0.0256	0.07	0.07	
Calc sunfish for 999 pickerel	0	2,500	27,500	10,728	40,700
Number of bluegills					13,600
Number of pumpkinseeds					27,100
Bluegill (>7 in)-- 24-h feeder					
Daily meal multiplier	1	1.50	8	2.2	
Observed avg no. sunfish/bluegill	0.02	0.0	0.0	0.0	
Calc sunfish for 5605 bluegill	11,400	0	0	0	11,400
Number of bluegills					7,600
Number of pumpkinseeds					3,800

Appendix 2.—Observations on spring fish mortalities and disappearance of dead fish from Blueberry Pond, 1989-90. (Conclusions are summarized in the natural mortality section of the report).

An extensive mortality was observed among Blueberry Pond fish in spring 1989. No dying fish were collected in suitable condition for careful study by a pathologist. External and internal observations were made on a number of relatively fresh specimens; no patterns were observed and no conclusions reached as to cause of death. External inspections were made for hook scars, *Columnaris, Saprolegnia*, parasites, and gill coloration. A few fish were blind. Fish were both plump and thin, and among 8-in bluegills, both relatively young and old. Internally, the color of kidney, liver, gallbladder, and heart appeared normal. Many had food in their stomach and visceral fat, suggesting they had not starved to death. Some were burdened to a considerable extent with parasitic cysts in heart, liver, and kidney.

The extent of the 1989 fish mortality was evaluated by 14 systematic searches of Blueberry Pond made by boat at 1-4 day intervals between 17 April and 25 May. Surface temperature increased from 46 to 68°F during this period. Counts were made of dead fish floating on the surface, windrowed along shore, and lying on the bottom (visibility about 6 feet). Located were 202 dead native fish, of which 78% were bluegill, 11% pumpkinseed, 2% largemouth bass, 2% lake chub suckers, 2% yellow bullheads, and 2% grass pickerel. Virtually all were over 6 in long. These proportions by species are similar to those obtained from population estimates, suggesting the mortality was random among larger fish. Many dead fish had caudal fin clips, indicating they recently had been caught in trapnets and that stress may have contributed to their death. However, other fish were unmarked, indicating they died from entirely natural causes.

The efficiency of locating dead fish was measured by randomly "releasing" 90 dead 4-in bluegills (obtained elsewhere) marked with unique dorsal fin clips, then noting how many were eventually found. Only 13% of the 90 marked, 4-in bluegills were recovered. None of the 50 fish released over deep water were found, and just 30% of 40 released over the littoral zone were recovered. These data indicate that only a small fraction of the fish which die from natural causes in April are likely to be observed. By extrapolation, the total number of deaths in Blueberry Pond in April 1989 was about 1,550 fish (202/0.13). This assumes all large dead fish "behave" like dead 4-in bluegills. These deaths could have represented about 10% of the adult population and 25 to 50% of their annual natural deaths.

Dead fish consumption by scavengers was evaluated by setting out hooks and lines baited with dead fish. The scavaging rate on medium-sized sunfish was surprisingly rapid. On 17 April 1989, 37 lines baited with dead 3.2- to 5.6-in sunfish were set out at a variety of water depths. The lines were checked 48 hours later. Water temperatures were very cool, about 46°F. Ten bullheads and one largemouth bass were captured, and bait had been gleaned from 16 other lines, probably by turtles. Thus, 73% of the dead fish had been consumed by scavengers in 2 days. Of the remaining 10 bluegills, three had been partially eaten, probably by turtles or crayfish. One of the baitless lines was found on shore, apparently dragged there by a turtle, reptile, mammal, or bird. This experiment was repeated with 35 4- to 5-in bluegills on 1 May 1990 when temperature was 63°F. One snapping turtle and 15 bullheads were caught. The bait was gone from 12 lines and remained on 7 others. Thus, 80% of the dead fish had disappeared in 2 days. Considerable scavaging potential existed because Blueberry Pond contained 404 adult bullheads in spring 1989, each capable of digesting one dead fish every 2-3 days at that low temperature. The population of turtles is unknown.

The fate of dead fish was also studied by monitoring the disappearance and decomposition of dead native fish. In April-May 1989,

Appendix 2.—Continued:

43 dead fish (mostly large bluegills) were collected from Blueberry Pond. A nylon string attached to a small numbered float was sewn through their lower jaw (the most durable part), and the fish were released in various areas of the pond. Condition of each fish was noted at 1-4 day intervals. Surface temperatures were 46-64°F. The following observations were derived:

1. The probability of finding a dead fish was related to its visibility, rate of consumption by scavengers, and rate of decomposition.
2. The visibility of a dead fish was related to size and whether it remained on the bottom or bloated and floated to the surface.
3. Bloating, caused by bacteria generating gas in the abdominal cavity, was related to temperature and puncturing of the abdomen by scavaging crayfish or turtles. Bloating was uncommon below 50°F and sporadic between 50-60°F. Exposure to sunlight, as in the littoral zone, also promoted bloating. Many intact fish did not bloat; some bloaters eventually sank.
4. Fresh dead fish were probably randomly distributed across the lake bottom. However, the probability of them being eventually found differed.
5. In deep water, decomposition, bloating, and scavaging rates were relatively low. Fish with a punctured abdomen did not bloat, and if uneaten remained intact for 20-35 days. Intact fish bloated within 8 days.
6. In the littoral zone, decomposition, bloating, and scavaging rates were higher. Complete decomposition took 13-23 days. About 56% were eaten and 44% decomposed. Carcasses near the shore disappeared at a faster rate because of terrestrial scavengers.
7. Dead fish looked fresh (normal bright color) for only about 1 day. Dead fish appeared to be in medium condition by day 2 (slight color). They remained in medium condition for days. Poor (rotten) condition was not reached until day 6-7 in the littoral zone and for as long as 34 days in deep water.

Appendix 3.—Mark-recapture estimates (Schumacher-Eschmeyer formula) of the number of fish in Dead Lake by species and size groups in spring, 1984 and 1985. "Min" is the actual number of different fish caught; "Max" is the upper 95% confidence limit of the estimate.

Species and	1984			1985		
length (in)	Estimate	Min	Max	Estimate	Min	Max
Bluegill						
2.0 - 2.9	6,358	562	8,014	25,859	43	181,631
3.0 - 3.9	16,919	588	42,692	26,316	1,327	38,462
4.0 - 4.9	2,432	197	11,700	7,752	409	10,989
5.0 - 5.9	6,732	483	11,409	3,802	236	5,650
6.0 - 6.9	5,970	624	8,769	3,831	361	8,130
7.0 - 7.9	4,973	893	6,297	7,042	1,165	11,628
8.0 - 8.9	2,178	448	3,225	—	—	—
9.0 - 9.9	287	81	1,132	—	—	—
8.0 - 9.9	—	—	—	923	287	1,349
Pumpkinseed						
1.0 - 2.9	2,059	98	∞	1,437	138	11,364
3.0 - 3.9	7,898	205	151,497	5,747	658	7,143
4.0 - 4.9	1,548	230	3,119	1,348	237	1,718
5.0 - 5.9	2,062	380	2,432	1,116	200	1,701
6.0 - 6.9	1,429	293	1,939	1,330	219	2,008
7.0 - 8.9	548	130	1,145	319	58	883
Yellow perch						
2.0 - 3.9	18,716	601	36,893	12,195	586	18,519
4.0 - 6.9	4,779	529	6,626	8,264	383	19,608
7.0 - 11.9	141	50	268	46	27	81
Black crappie						
5.0 - 7.9	291	65	836	206	58	718
8.0 - 9.9	37	24	58	281	179	343
10.0 - 10.9	42	36	52	9	9	12
11.0 - 11.9	13	11	23	9	8	10
12.0 - 13.9	3	3	9	3	3	3
Largemouth bass						
2.0 - 4.9	338	24	∞	785	96	2,347
5.0 - 9.9	302	94	393	477	81	1,404
10.0 - 11.9	120	44	274	124	34	695
12.0 - 14.9	202	85	327	206	66	350
15.0 - 21.9	82	25	476	49	30	123

Appendix 3.—Continued:

Species and length (in)	1984			1985		
	Estimate	Min	Max	Estimate	Min	Max
Northern pike						
13.0 - 15.9	93	47	167	—	2	—
16.0 - 19.9	388	270	479	148	105	180
20.0 - 23.9	150	96	201	109	78	140
24.0 - 34.9	19	15	34	17	16	22
Bowfin						
14.0 - 26.9	564	121	1,180	371	162	516
Lake chubsucker						
2.0 - 5.9	3,653	187	∞	2,740	135	6,135
6.0 - 8.9	2,158	157	3,154	348	78	587
9.0 - 11.9	148	49	407	71	19	∞
Brown bullhead						
6.0 - 10.9	127	34	287	144	39	289
11.0 - 11.9	32	19	71	92	29	251
12.0 - 12.9	101	36	526	96	36	267
13.0 - 13.9	107	42	432	204	56	343
14.0 - 14.9	9	7	36	57	12	∞
Yellow bullhead						
5.0 - 7.9	139	28	∞	202	29	∞
8.0 - 8.9	112	74	165	122	56	237
9.0 - 9.9	167	131	209	214	120	281
10.0 - 10.9	131	102	154	185	129	226
11.0 - 11.9	110	84	144	89	67	108
12.0 - 13.9	50	38	72	22	16	46
Warmouth						
2.0 - 7.9	—	19	—	167	40	661
Longear sunfish						
2.0 - 6.9	—	29	—	—	31	—
Green sunfish						
2.0 - 6.9	—	6	—	—	20	—
Grass pickerel						
7.0 - 11.9	—	6	—	—	14	—
Golden shiner						
2.0 - 5.9	—	28	—	—	27	—

Appendix 4.—Mark-recapture estimates (Schumacher-Eschmeyer formula) of the number of fish in Blueberry Pond by species and size groups in spring, 1984 and 1989. "Min" is the actual number of different fish caught; "Max" is the upper 95% confidence limit of the estimate.

Species and length (in)	1984			1985			1986		
	Estimate	Min	Max	Estimate	Min	Max	Estimate	Min	Max
Bluegill									
1.0 - 2.9	—	23	—	—	8	—	—	9	—
3.0 - 4.9	1,565	193	3,836	1,080	207	1,598	262	58	5,394
5.0 - 6.9	878	137	2,286	2,274	309	4,510	1,317	390	1,827
7.0 - 7.9	2,259	595	3,150	3,086	576	3,086	1,665	407	2,464
8.0 - 9.9	4,949	1,385	6,113	6,617	1,788	8,053	3,754	954	4,673
Pumpkinseed									
1.0 - 1.9	—	3	—	—	42	—	—	2	—
2.0 - 4.9	649	115	1,113	542	335	1,422	1,039	80	2,543
5.0 - 5.9	701	195	872	328	113	392	218	103	296
6.0 - 6.9	1,690	552	1,980	1,546	477	1,808	885	374	1,070
7.0 - 8.9	241	132	286	549	212	717	748	258	990
Yellow perch									
2.0 - 4.9	—	4	—	—	4	—	—	7	—
5.0 - 7.9	555	52	_	169	61	258	292	69	577
8.0 - 8.9	489	156	718	356	104	634	198	73	337
9.0 - 9.9	482	197	642	371	153	707	468	128	729
10.0 - 11.9	80	28	125	77	40	166	72	37	133
Largemouth bass									
2.0 - 5.9	—	45	—	157	—	∞	134	30	325
6.0 - 9.9	260	104	320	324	101	496	175	59	330
10.0 - 11.9	381	161	514	567	177	934	545	192	728
12.0 - 22.9	139	62	235	76	36	168	54	34	73
Lake chubsucker									
2.0 - 3.9	—	22	—	—	16	—	—	—	—
4.0 - 6.9	802	163	1,265	852	122	3,145	1,243	218	1,978
7.0 - 11.9	456	167	661	1,190	253	2,404	664	227	857
Yellow bullhead									
4.0 - 7.9	56	37	104	99	24	∞	56	30	113
8.0 - 8.9	159	128	202	120	83	165	89	90	122
9.0 - 9.9	196	182	215	202	150	308	149	158	165
10.0 - 10.9	161	159	164	96	95	105	117	122	126
11.0 - 13.9	44	42	47	10	10	14	19	19	20
Green sunfish									
1.0 - 8.9	184	27	∞	—	17	—	96	26	∞
Grass pickerel									
4.0 - 11.9	1,559	131	2,266	967	120	1,823	942	163	1,284
Golden shiner									
2.0 - 10.9	139	44	928	287	49	∞	—	26	—

Appendix 4.—Continued:

Species and length (in)	1987 Estimate	1987 Min	1987 Max	1988 Estimate	1988 Min	1988 Max	1989 Estimate	1989 Min	1989 Max
Bluegill									
1.0 - 2.9	—	117	—	—	354	—	—	79	—
3.0 - 4.9	824	247	1,192	1,102	232	1,468	5,521	426	8,569
5.0 - 6.9	1,239	247	2,862	1,313	450	1,772	1,902	488	2,431
7.0 - 7.9	1,494	571	1,986	548	220	723	1,005	257	1,958
8.0 - 9.9	3,796	1,473	4,330	2,782	805	3,818	2,464	1,106	3,219
Pumpkinseed									
1.0 - 1.9	—	48	—	2,673	122	17,613	—	22	—
2.0 - 4.9	843	316	1,037	1,225	345	2,090	2,114	455	2,744
5.0 - 5.9	479	199	576	428	240	496	356	363	472
6.0 - 6.9	620	279	756	680	450	753	747	423	874
7.0 - 8.9	611	313	731	744	591	818	848	509	975
Yellow perch									
2.0 - 4.9	—	22	—	473	77	3,750	313	39	1,369
5.0 - 7.9	173	60	258	287	106	365	838	324	1,176
8.0 - 8.9	154	71	321	106	44	294	113	70	164
9.0 - 9.9	199	90	340	52	32	89	48	33	78
10.0 - 11.9	174	116	217	51	38	80	53	28	209
Largemouth bass									
2.0 - 5.9	265	111	362	—	9	—	—	9	—
6.0 - 9.9	52	17	278	252	86	426	93	29	273
10.0 - 11.9	371	106	557	298	105	430	354	143	497
12.0 - 22.9	103	32	266	155	59	275	239	87	386
Lake chubsucker									
2.0 - 3.9	—	18	—	—	61	—	—	105	—
4.0 - 6.9	637	195	812	852	251	1,353	443	139	623
7.0 - 11.9	608	324	894	556	231	754	522	191	2,075
Yellow bullhead									
4.0 - 7.9	53	47	67	60	40	108	58	55	66
8.0 - 8.9	109	109	117	95	88	119	101	105	113
9.0 - 9.9	144	150	160	122	112	134	131	133	135
10.0 - 10.9	132	137	138	110	111	123	83	85	86
11.0 - 13.9	18	20	21	33	35	40	31	31	32
Green sunfish									
1.0 - 8.9	82	22	∞	42	25	77	—	11	—
Grass pickerel									
4.0 - 11.9	840	338	1,012	500	169	801	969	97	273,260
Golden shiner									
2.0 - 10.9	460	70	∞	—	61	—	—	58	—

Appendix 5.—Estimates of the number of fish in Dead Lake by species, age, and year. Dashes indicate fish were present but not estimated.

Species and year	Age 1	2	3	4	5	6	7	8	9	10	11
Bluegill											
1984		22,127	4,138	11,550	5,402	591	809	600	403	62	10
1985		49,708	11,569	2,820	8,780	2,065	355	184	40		
Pumpkinseed											
1984	1,853	8,174	1,649	2,461	583	815	4	4			
1985	931	6,625	1,408	626	1,175	402	132				
Yellow perch											
1984	16,924	5,476	628	497	89	18	6				
1985	8,708	8,689	2,782	273	30	13	7	5			
Black crappie											
1984		291	27	59	7	1	1	1			
1985		168	310	20	7	1	1	1			
Largemouth bass											
1984	338	277	37	121	168	54	9	20	10	6	3
1985	710	286	332	40	122	102	33	4	2	9	
Northern pike											
1984		307	178	95	56	11	4				
1985			36	124	58	43	11				

Appendix 6.—Estimates of the number of sport fish in Blueberry Pond by species, age, and year. Dashes indicate fish were present, but not estimated.

Species	Age										
and year	1	2	3	4	5	6	7	8	9	10	11+
Bluegill											
1984	—	1,586	526	784	898	951	2,485	2,048	297	77	
1985	—	1,048	2,203	231	1,655	1,767	3,275	1,763	259	67	
1986	—	262	1,102	1,473	444	856	1,300	1,062	489	8	
1987	1,980	830	1,188	928	945	175	1,106	1,240	750	200	44
1988	—	1,323	1,165	347	358	668	819	428	428	200	9
1989	—	6,129	1,681	673	180	142	341	432	469	719	325
Pumpkinseed											
1984	—	600	594	1,080	857	77	54	18			
1985	—	283	490	825	868	340	85	3	3		
1986	—	916	335	470	645	380	104	41			
1987	—	487	859	336	375	332	127	27	2		
1988	204	658	677	726	132	329	247	51	53		
1989	310	1,488	610	485	587	231	107	187	33	28	
Yellow perch											
1984	—	177	309	162	70	347	486	37	8	4	
1985	—	136	82	124	137	87	232	161	12		3
1986	—	162	149	64	125	155	152	161	62		
1987	—	115	109	93	73	81	101	86	45	2	
1988	452	239	108	70	32	12	10	17	18	9	
1989	217	695	283	75	32	10	10	4	7	28	2
Largemouth bass											
1984	—	155	38	270	92	104	51	9	7	4	7
1985	157	141	249	435	88	35	9	5	3		2
1986	—	83	95	247	209	90	37	10	2	2	2
1987	265	6	56	58	91	171	88	31	5	6	13
1988	—	234	33	56	51	110	100	44	43	12	22
1989	—	24	164	61	75	108	79	110	35	12	19

Appendix 7.—Backcalculated mean length (in) at age for pooled 1984 and 1985 scale samples from Dead Lake.

Species and sex	Age 1	2	3	4	5	6	7	8	9	10	GI[b]
Bluegill											
All	1.7	3.1	4.7	6.3	7.4	8.2	8.6	8.9	9.1	9.3	+0.2
Pumpkinseed											
All	1.9	3.4	5.0	6.1	6.9	7.3	7.6	8.8	—	—	+0.5
Yellow perch											
Female	2.9	4.7	6.5	8.2	9.2	10.0	10.7	11.0	—	—	—
Male	2.8	4.2	5.6	6.8	7.9	8.7	8.3	8.8	—	—	—
All	2.8	4.4	5.9	7.4	8.7	9.6	10.2	10.3	—	—	-0.3
Black crappie											
All	2.7	6.4	9.0	10.4	11.5	12.2	12.8	13.3	—	—	+1.7
Largemouth bass											
All	3.4	6.9	9.9	12.1	13.6	15.0	17.2	18.8	19.5	20.3	+0.6
Northern pike[a]											
Male	8.4	16.2	19.1	20.6	21.8	23.9	24.2	—	—	—	—
Female	8.6	16.8	20.5	22.7	24.6	24.6	24.2	—	—	—	—
All	8.6	16.5	19.7	21.6	23.6	25.8	24.2	—	—	—	-2.5

[a]Data for 1984 only.
[b]GI = Growth index = average deviation from state average length at age (Merna et al. 1981) for ages 2 to 8.

Appendix 8.—Length (in) at age for Blueberry Pond fishes. Empirical weighted averages from spring samples except for back-calculated 1984 data.

Species and year	Age 1	2	3	4	5	6	7	8	9	10	GI[a]
Bluegill											
1984[b]	1.5	3.4	5.1	6.5	7.4	7.8	8.1	8.3	8.8	9.1	+0.3
1984	1.7	3.8	5.9	7.0	7.7	8.1	8.2	8.2	8.5	8.8	+0.6
1985	1.7	4.0	5.9	7.2	7.7	8.2	8.2	8.4	8.4	8.8	+0.7
1986	1.5	4.0	6.2	7.2	7.9	8.3	8.4	8.4	8.5	9.5	+0.8
1987	2.0	3.8	6.2	7.5	8.0	8.1	8.4	8.6	8.6	8.6	+0.8
1988	2.0	4.2	6.4	7.5	8.1	8.4	8.5	8.7	8.8	8.9	+1.0
1989	1.8	4.2	6.5	7.7	8.2	8.5	8.5	8.7	8.7	8.8	+1.1
Pumpkinseed											
1984[b]	1.7	3.3	5.1	6.3	6.8	7.4	7.6	7.6	—	—	+0.3
1984	1.8	3.4	5.4	6.3	6.6	7.3	7.6	7.6	—	—	+0.4
1985	1.8	3.5	5.1	6.4	6.8	7.1	7.5	8.2	8.3	—	+0.4
1986	1.8	3.2	5.3	6.5	6.9	7.2	7.8	7.4	—	—	+0.4
1987	1.8	3.3	5.1	6.6	6.9	7.2	7.6	7.3	8.3	—	+0.3
1988	2.0	3.2	5.0	6.4	7.0	7.3	7.4	7.6	7.6	—	+0.3
1989	1.9	3.3	5.0	6.4	6.9	7.2	7.5	7.4	7.6	7.8	+0.3
Yellow perch											
1984[b]	2.9	5.1	6.5	7.7	8.5	9.0	9.3	9.4	9.9	10.0	-0.4
1984	2.9	6.1	7.5	8.3	9.1	9.2	9.1	9.2	10.1	10.0	0.0
1985	3.0	5.9	7.9	8.6	9.0	8.9	9.4	9.6	10.2	—	+0.1
1986	3.6	6.1	7.7	8.5	9.1	9.2	9.2	9.5	9.5	—	+0.1
1987	3.7	6.6	7.9	8.9	9.3	9.7	9.8	10.1	10.3	11.2	+0.6
1988	3.4	5.9	7.7	8.7	9.3	9.5	10.2	10.2	10.3	10.4	+0.4
1989	3.5	5.6	7.1	8.6	9.3	9.6	10.0	10.2	10.8	10.3	+0.3
Largemouth bass											
1984[b]	4.0	7.1	9.2	10.8	12.3	13.4	14.9	16.2	18.5	19.6	-0.8
1984	4.1	7.4	9.5	10.2	11.1	12.4	14.1	14.3	17.5	19.7	-1.5
1985	3.9	7.3	9.6	10.6	11.9	13.0	14.6	17.5	17.9	—	-0.8
1986	4.3	7.3	9.4	10.5	11.2	11.7	13.3	16.4	16.1	21.6	-1.5
1987	4.3	6.2	9.3	10.5	11.1	11.5	11.8	12.4	14.6	15.6	-2.4
1988	3.7	7.9	10.0	10.6	11.3	11.6	11.8	12.5	12.4	15.1	-2.2
1989	4.1	7.8	10.1	10.9	11.4	11.7	12.2	12.6	12.9	13.7	-1.9

[a]GI = Growth index
[b]Weighted means from back calculation.

Appendix 9.—Length-weight regression coefficients for fish in Dead lake (pooled data, spring, 1984 and 1985) and Blueberry Pond (pooled data, spring, 1984-86). Values for the intercept (a) are given for both English and metric units; the value for the slope (b) is the same. English equations are in lbs and in; metric equations are in g and mm. The standard equation is: $\log_{10}$ Weight = a+b * ($\log_{10}$ Length).

Lake and species	Slope (b)	Interept (a)		Sample size	Length range (in)
		English	Metric		
Dead Lake					
Bluegill	3.15933	-3.33983	-5.11268	209	1.7 - 9.8
Pumpkinseed	3.26901	-3.35153	-5.28688	64	2.3 - 8.3
Yellow perch	3.14945	-3.55937	-5.30676	55	2.7 - 10.8
Black crappie	3.23809	-3.48908	-5.38101	50	5.2 - 12.6
Largemouth bass	3.44131	-3.80566	-5.98307	90	2.7 - 21.5
Northern pike	3.01978	-3.74949	-5.33473	78	13.6 - 29.1
Blueberry Pond					
Bluegill	3.08523	-3.29668	-4.97385	352	2.9 - 9.9
Pumpkinseed	3.16260	-3.25671	-5.04258	176	2.6 - 8.2
Yellow perch	2.93125	-3.34490	-4.80576	105	4.1 - 10.4
Largemouth bass	3.31190	-3.67776	-5.67337	198	3.3 - 20.9

Appendix 10.—Annual estimates of fish biomass (lbs) in Dead Lake and Blueberry Pond. Yearling (small) fish were not estimated for most species, but these would add very little to biomass. Dashes indicate fish were present but not estimated.

Species	Dead Lake		Blueberry Pond					
	1984	1985	1984	1985	1986	1987	1988	1989
Bluegill	4,472	4,487	2,485	3,246	1,934	2,039	1,431	1,724
Pumpkinseed	988	728	514	552	475	411	465	518
Yellow perch	406	520	390	256	262	200	104	149
Black crappie	90	150						
Largemouth bass	596	587	471	505	454	374	383	488
Northern pike	835	451						
Bowfin	1,763	1,113						
Lake chubsucker	630	156	200	370	231	251	222	169
Brown bullhead	381	651						
Yellow bullhead	276	346	259	198	174	186	173	162
Warmouth	—	36						
Green sunfish	—	—	40	—	22	19	7	—
Grass pickerel	—	—	186	134	112	93	64	96
Golden shiner	—	—	28	33	—	81	—	—
Total	10,43 7	9,225	4,573	5,294	3,664	3,654	2,849	3,306

Appendix 11.—Diet of bluegill (0.9 - 10.0 in) from Blueberry Lake, 1986-90. Of 1,188 bluegill examined, 84 (7.2%) were void. tr = trace (<0.01).

Food type	Occurrence (percent)	Number per fish		Prey size (mm)	
		Average	Maximum	Minimum	Maximum
Zooplankton					
Copepoda	11.8	1.34	200	0.3	2.0
Cladocera, total[a]	53.1	182.47	855	0.1	2.0
Daphnia	32.6	164.50	6,460	0.2	2.0
Other	11.8	3.29	544	0.2	3.0
Benthos					
Crayfish	0.0	—	—	—	—
Amphipod	38.5	3.55	99	1	5
Ostracod	2.9	0.09	18	1	2
Mite	13.5	0.32	300	1	3
Leech	2.4	0.03	6	3	60
Snail	11.6	0.38	41	1	5
Clam	3.3	0.06	13	1	5
Immature Insects					
Mayfly	19.6	0.59	75	1	10
Caddisfly	35.5	1.87	729	1	25
Damselfly	28.5	0.97	35	1	18
Dragonfly	14.2	0.30	20	1	30
Midge larva	61.2	6.80	355	1	20
Midge pupa	16.8	1.24	150	1	12
Chaoborus	7.5	2.30	720	4	15
Beetle	5.5	tr	6	1	25
Other	4.0	0.24	88	1	40
Adult Insects					
Odonata	3.0	0.07	33	6	30
Beetle	6.3	0.13	22	2	21
Other	9.2	0.39	55	1	18
Vegetation	9.9	—	—	—	—
Fish					
Bluegill	0.1	tr	2	22	23
Pumpkinseed	0.1	tr	1	35	—
Largemouth bass	0.0	—	—	—	—
Yellow perch	0.1	tr	2	8	—

Appendix 11.—Continued:

Food type	Occurrence (percent)	Number per fish		Prey size (mm)	
		Average	Maximum	Minimum	Maximum
Minnow spp.	0.2	tr	1	15	40
Lake chubsucker	0.0	—	—	—	—
Grass pickerel	0.0	—	—	—	—
Yellow bullhead	0.0	—	—	—	—
"Slender"[b]	0.1	tr	1	12	—
Bluegill/pumpkinseed	0.0	—	—	—	
Unidentified	0.3	tr	4	6	8
Other					
Eggs	0.7	0.32	1,650	1	2

[a]Some samples were separated into *Daphnia* (limnetic) versus other genera (primarily littoral dwellers).

[b]Unidentified as to species but with slender shapes such as minnows and yellow perch.

Appendix 12.—Diet of pumpkinseed (1.0 - 8.9 in) from Blueberry Lake, 1986-90. Of 885 fish examined, 49 (5.5%) were void. tr = trace (<0.01).

Food type	Occurrence (percent)	Number per fish		Prey size (mm)	
		Average	Maximum	Minimum	Maximum
Zooplankton					
Copepoda	6.2	0.09	7	0.5	1.5
Cladocera, total[a]	19.1	1.61	42	0.5	2.0
Daphnia	5.2	0.60	150	0.5	2.0
Other	9.0	0.69	263	0.2	3.0
Benthos					
Crayfish	0.3	tr	1	1	—
Amphipod	37.4	1.60	51	1	5
Ostracod	4.6	0.29	99	1	2
Mite	1.7	0.02	4	1	—
Leech	9.1	0.11	5	3	55
Snail	56.6	7.83	212	1	12
Clam	21.8	1.26	50	1	7
Immature insects					
Mayfly	18.3	0.32	18	1	9
Caddisfly	34.3	0.83	25	1	20
Damselfly	18.0	0.36	39	1	16
Dragonfly	29.5	0.71	38	1	30
Midge larva	68.0	7.67	201	1	20
Midge pupa	14.3	0.32	24	1	10
Chaoborus	1.7	0.05	7	4	7
Beetle	2.4	0.02	2	1	11
Other	3.1	0.04	4	1	45
Adult insects					
Odonata	0.6	tr	1	13	20
Beetle	1.5	0.01	2	1	10
Other	2.9	0.04	4	1	10
Fish					
Bluegill	0.0	—	—	—	—
Pumpkinseed	0.0	—	—	—	—
Largemouth bass	0.0	—	—	—	—
Yellow perch	0.0	—	—	—	—
Minnow spp.	0.3	tr	2	35	38
Lake chubsucker	0.0	—	—	—	—
Grass pickerel	0.0	—	—	—	—
Yellow bullhead	0.0	—	—	—	—
"Slender"[b]	0.1	tr	1	20	—
Bluegill/pumpkinseed	0.1	tr	1	7	—
Unidentified	0.3	tr	1	20	—
Other					
Eggs	0.4	0.01	1	1	—

[a,b]See Appendix 11 for footnotes.

Appendix 13.—Diet of yellow perch (2.0 - 11.5 in) from Blueberry Lake, 1986-90. Of 453 perch examined, 100 (22%) were void. tr = trace (<0.01).

Food type	Occurrence (percent)	Number per fish		Prey size (mm	
		Average	Maximum	Minimum	Maximum
Zooplankton					
Copepoda	1.6	0.02	3	0.9	1.5
Cladocera, total[a]	14.2	5.60	200	0.5	2.0
Daphnia	7.2	4.15	549	0.8	2.0
Other	4.3	0.78	228	1.0	2.0
Benthos					
Crayfish	0.0	—	—	—	—
Amphipod	14.7	0.85	142	1	5
Ostracod	2.4	0.53	99	1	2
Mite	2.4	0.02	3	1	—
Leech	2.7	0.02	2	2	30
Snail	7.5	0.13	6	1	6
Clam	2.9	0.13	35	1	7
Immature insects					
Mayfly	19.5	0.81	124	2	10
Caddisfly	8.3	0.33	20	2	20
Damselfly	31.8	2.65	72	1	16
Dragonfly	36.1	1.53	70	1	20
Midge larva	33.4	3.49	110	2	22
Midge pupa	9.6	1.36	134	2	14
Chaoborus	8.3	0.38	65	4	8
Beetle	1.3	0.01	2	4	20
Other	1.1	0.01	2	1	6
Adult insects					
Odonata	0.0	—	—	—	—
Beetle	0.3	tr	1	3	—
Other	1.1	0.02	3	4	7
Vegetation	5.6	—	—	—	—
Fish					
Bluegill	3.5	0.04	3	20	39
Pumpkinseed	0.8	0.01	2	23	40
Largemouth bass	0.0	—	—	—	—
Yellow perch	0.0	—	—	—	—
Minnow spp.	1.3	0.06	16	6	60
Lake chubsucker	0.0	—	—	—	—
Grass pickerel	0.0	—	—	—	—
Yellow bullhead	0.0	—	—	—	—
"Slender"[b]	2.7	0.09	18	9	45
Bluegill/pumpkinseed	4.3	0.07	5	15	45
Unidentified	4.5	0.06	4	7	50
Other					
Eggs	0.5	0.16	70	1	1

[a,b]See Appendix 11 for footnotes.

Appendix 14.—Diet of largemouth bass (1.0 - 20.8 in) from Blueberry Lake, 1986-90. Of 642 bass examined, 169 (26%) were void. tr = trace (<0.01).

Food type	Occurrence (percent)	Number per fish		Prey size (mm)	
		Average	Maximum	Minimum	Maximum
Zooplankton					
Copepoda	1.5	0.05	15	0.5	1.0
Cladocera, total[a]	3.7	1.05	300	0.5	2.0
Daphnia	2.7	0.46	100	0.4	2.0
Other	0.5	0.01	4	0.5	1.5
Benthos					
Crayfish	6.9	0.07	2	20	60
Amphipod	4.9	0.14	30	1	4
Ostracod	0.0	—	—	—	—
Mite	0.3	0.00	1	1	—
Leech	1.7	0.02	2	2	80
Snail	0.7	0.02	6	1	6
Clam	0.5	0.07	40	1	6
Immature Insects					
Mayfly	7.4	0.21	15	2	15
Caddisfly	4.7	0.07	6	2	19
Damselfly	8.4	0.16	10	3	16
Dragonfly	16.9	0.49	28	2	30
Midge larva	4.9	0.43	100	2	15
Midge pupa	6.7	0.17	20	2	5
Chaoborus	0.5	0.03	15	—	—
Beetle	0.7	0.01	2	3	33
Other	0.7	0.02	5	1	11
Adult Insects					
Odonata	6.7	0.30	31	10	60
Beetle	3.7	0.04	3	4	15
Other	5.6	0.29	34	2	25
Vegetation	2.9	—	—	—	—
Fish					
Bluegill	6.4	0.12	9	11	200
Pumpkinseed	1.9	0.02	2	21	100
Largemouth bass	3.0	0.15	50	7	100
Yellow perch	0.7	0.01	1	55	80
Minnow spp.	4.9	0.32	43	9	55
Lake chubsucker	0.3	tr	1	5	125
Grass pickerel	0.8	0.01	1	35	150
Yellow bullhead	1.0	0.01	2	25	115
"Slender"[b]	11.5	0.36	30	6	75
Bluegill/pumpkinseed	10.3	0.27	32	7	75
Unidentified	15.3	0.72	85	3	60
Other					
Eggs	0.0	—	—	—	—

[a,b]See Appendix 11 for footnotes.

Appendix 15.—Diet of yellow bullhead (6.4 - 12.7 in) from Blueberry Lake, 1986-90. Of 140 bullheads examined, 28 (20%) were void.

Food type	Occurrence (percent)	Number per fish		Prey size (mm)	
		Average	Maximum	Minimum	Maximum
Zooplankton					
Copepoda	0.0	—	—	—	—
Cladocera, total[a]	8.9	1.11	20	—	—
Daphnia	2.7	0.51	50	1.0	2.0
Other	3.6	0.27	16	1.5	2.0
Benthos					
Crayfish	14.3	0.12	2	20	30
Amphipod	14.3	0.49	20	2	5
Ostracod	0.9	0.01	1	—	—
Mite	0.0	—	—	—	—
Leech	9.8	0.16	5	4	55
Snail	17.9	0.25	8	1	6
Clam	1.8	0.01	1	2	—
Immature Insects					
Mayfly	11.6	0.15	5	3	10
Caddisfly	27.7	0.41	6	2	35
Damselfly	17.9	0.41	10	3	13
Dragonfly	44.6	1.66	18	4	32
Midge larva	20.5	0.43	7	4	15
Midge pupa	6.3	0.11	6	2	5
Chaoborus	1.8	0.02	2	6	—
Beetle	3.6	0.07	5	10	17
Other	9.8	0.14	6	2	44
Adult Insects					
Odonata	6.3	0.11	9	13	25
Beetle	5.4	0.05	2	8	17
Other	6.3	0.09	3	3	12
Vegetation	16.1	—	—	—	—
Fish					
Bluegill	0.9	0.01	1	92	—
Pumpkinseed	0.9	0.01	1	40	—
Largemouth bass	0.0	—	—	—	—
Yellow perch	0.9	0.01	1	30	—
Minnow spp.	6.3	0.56	49	7	60
Lake chubsucker	16.1	0.14	2	110	177
Grass pickerel	0.9	0.01	1	7	8
Yellow bullhead	0.0	—	—	—	—
"Slender"[b]	0.0	—	—	—	—
Bluegill/pumpkinseed	5.4	0.04	1	30	400
Unidentified	15.2	0.34	12	20	40
Other					
Eggs	0.9	0.36	50	1	—

[a,b]See Appendix 11 for footnotes.

Appendix 16.—Diet of grass pickerel (2.0 - 11.3 in) from Blueberry Lake, 1986-90. Of 170 pickerel examined, 55 (32%) were void.

Food type	Occurrence (percent)	Number per fish		Prey size (mm)	
		Average	Maximum	Minimum	Maximum
Zooplankton					
Copepoda	0.0	—	—	—	—
Cladocera, total[a]	1.3	0.01	—	—	—
Daphnia	0.6	0.01	1	2.0	—
Other	0.6	0.01	1	—	—
Benthos					
Crayfish	7.8	0.07	1	10	22
Amphipod	0.6	0.01	1	—	—
Ostracod	0.0	—	—	—	—
Mite	0.6	0.01	1	1	—
Leech	1.9	0.02	1	5	—
Snail	0.6	0.01	1	3	—
Clam	0.0	—	—	—	—
Immature Insects					
Mayfly	9.1	0.12	4	3	11
Caddisfly	1.3	0.01	1	3	12
Damselfly	14.9	0.25	9	4	15
Dragonfly	15.6	0.19	3	4	30
Midge larva	2.6	0.04	3	5	7
Midge pupae	0.0	—	—	—	—
Chaoborus	0.0	—	—	—	—
Beetle	0.6	0.01	1	2	—
Other	0.0	—	—	—	—
Adult insects					
Odonata	0.6	0.01	1	—	—
Beetle	0.6	0.01	1	2	
Other	1.9	0.02	1	—	—
Vegetation	1.9	—	—	—	—
Fish					
Bluegill	0.6	0.01	1	30	—
Pumpkinseed	1.3	0.01	1	40	50
Largemouth bass	0.0	—	—	—	—
Yellow perch	0.6	0.01	1	75	—
Minnow spp.	5.2	0.07	4	5	30
Lake chubsucker	0.0	—	—	—	—
Grass pickerel	0.0	—	—	—	—
Yellow bullhead	0.6	0.01	1	50	—
"Slender"[b]	9.7	0.09	2	15	40
Bluegill/pumpkinseed	4.5	0.04	1	10	38
Unidentified	12.3	0.12	2	14	40
Other					
Eggs	0.0	—	—	—	—

[a,b]See Appendix 11 for footnotes.