Spawning and early life history of yellow perch in the Lake Winnebago system. No. 130 1982

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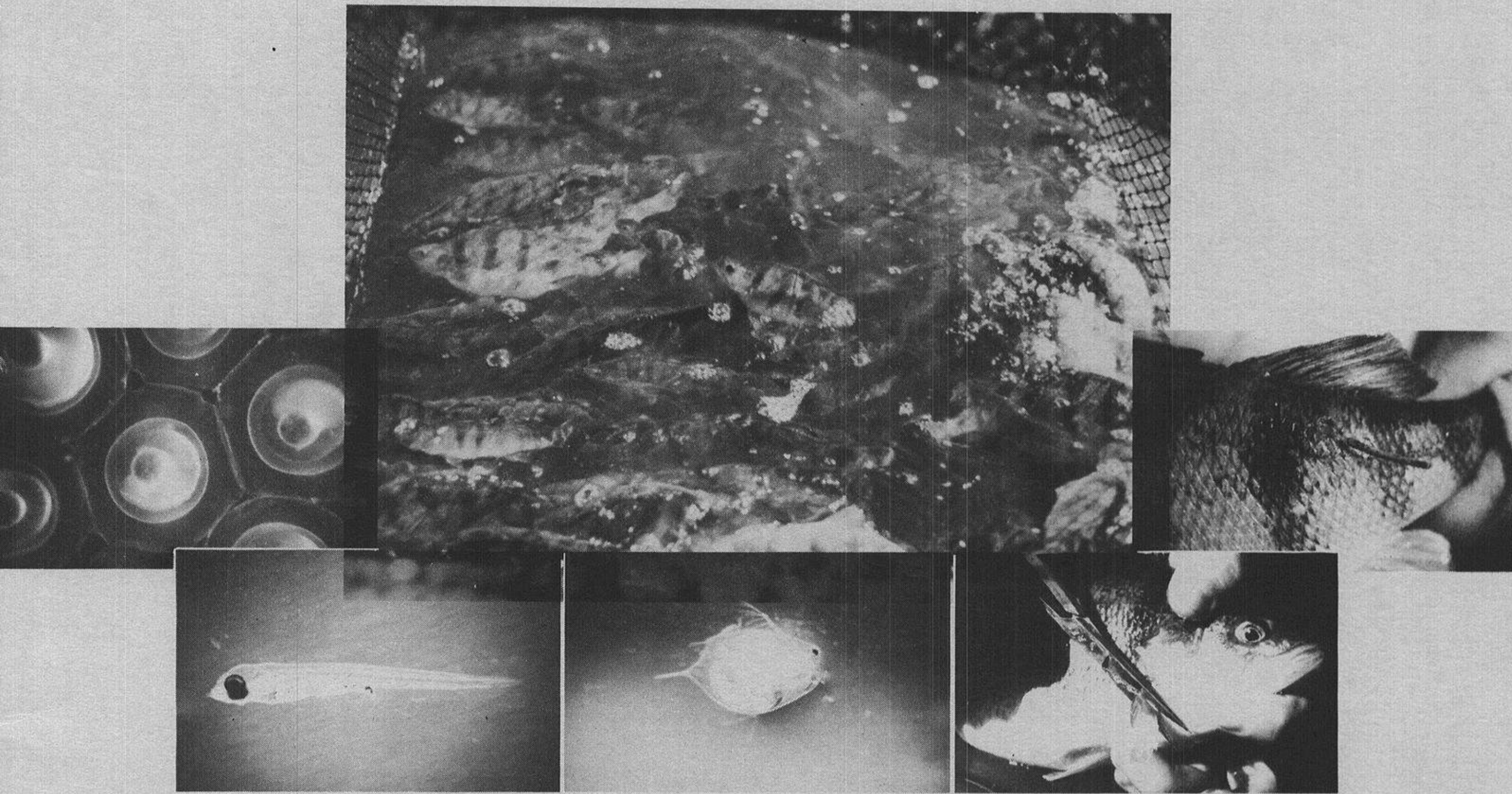

SPAWNING AND EARLY LIFE HISTORY OF YELLOW PERCH IN THE LAKE WINNEBAGO SYSTEM

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ABSTRACT

The reproduction and early life history of yellow perch in Lake Winnebago and connecting waters was studied between 1971 and 1976. Yellow perch spawning at two locations in the Fox River between its entrance to Lake Winnebago and the Eureka Dam were characterized as to relative abundance, size, age, maturity, fecundity, sex ratio, movement patterns, and angler exploitation. Spawning habitat and environmental conditions affecting migration were determined. Egg development was monitored at the study sites in specially constructed buckets and on artificial substrates. Movement, growth, food habits, relative abundance, and mortality of larvae and fingerlings were studied in Lake Winnebago, where most of the Fox River spawners originate.

The two study areas were the only spawning areas found in the Fox River, despite extensive searching. Habitat varied from submerged pilings and debris to a remnant bed of American lotus (*Nelumbo lutea*).

Considerable year-to-year variation was observed in the timing of spawning and characteristics of the spawning population. Spawning began as early as 31 March and as late as 25 April, its initiation showing little relationship to any environmental factor except ice breakup in Lake Winnebago. Spawning duration varied positively with water level. Number of migrating perch increased with flow except in one year of exceptionally high flow. Age and size composition of the spawning population was typically unimodal or bimodal, reflecting the dominance of one or two strong year classes. Spawning males were age II and older and females age III and older. Males outnumbered females an average of 2-7 times, but sex ratios as high as 51:1 were observed on a daily basis. Migration by size groups was evident, but no single pattern was observed for all study years.

Calculated growth of a spring sample of spawning fish from the Fox River and a fall sample from Lake Winnebago showed that growth was greatest during the first and second years of life for length and during the fourth and fifth years for weight. Females exhibited a growth advantage over males after the first year of life. Eggs began hatching within 11-15 days after fertilization with water temperatures ranging from 2.7-21.6C. Immigration of larval perch to Lake Winnebago was confirmed by meter net captures at the river's entrance to the lake.

Young perch averaged 27 mm by mid-June, when the demersal stage was reached, and 78-90 mm by the end of sampling in October. Growth was sigmoidal for both length and weight. Relative abundance of young perch sampled by trawl dropped sharply by August in all study years, suggesting that year class strength is set at midsummer of the first year of life. No correlation was found between year class strength for 13 years and May-August water temperatures in Lake Winnebago and Fox River flow during April and May. Relative abundance was not a factor in growth or mortality of young-of-the-year perch. June-October mortality of trawl-sampled perch ranged from 39 to 87% and was inversely related to mortality of seine-captured perch for the same period.

Detailed food habit studies indicated all but the largest young-of-the-year perch are primarily zooplankton feeders. Food items consumed were diverse and variable, changing with habitat (littoral vs. limnetic), year and size of fish.

Wide year-to-year variations were found in many aspects of yellow perch biology covered in this 6-year study, indicating the importance of long-term research on this species.

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By
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INTRODUCTION

The yellow perch (*Perca flavescens*) is the most popular pan fish in Lake Winnebago and is second only to walleye among the total sport fishery of the lake (Dan Folz, unpub. creel census). The tremendous amount of water involved and consequent recreation potential make the Lake Winnebago fishery particularly important among the state's water resources. Most information on perch in the lake has been the by-product of studies directed at other species, principally sauger, walleye, white bass and freshwater drum (Priegel 1969, 1970a, 1970b, 1971). Elsewhere in the state, yellow perch have been studied most intensively on Lake Michigan (Joeris 1956, Mraz 1951, Kernen and Hawley 1977, Belonger 1980), where the species supports both a sport and commercial fishery. Inland research directed at yellow perch in Wisconsin has been limited, although standing crop and exploitation findings have resulted from multi-species research on intensively studied lakes (Kempinger et al. 1975, Snow 1978, Kempinger and Christenson 1978).

The yellow perch population of Lake Winnebago presents some special and intriguing management concerns. It is a fast-growing but numerically unstable population, evidenced by wide fluctuations in year-class strength. This situation is a recurring problem in many percid populations (Ney 1978) although the opposite situation is prevalent in other inland waters of Wisconsin where slow-growing but more stable perch populations occur. Also, the Lake Winnebago perch population has access to an extensive network of lakes and rivers. Thus, managing the Lake Winnebego perch fishery requires an understanding of the biology of the species in these connecting waters.

A study directed at yellow perch in the Lake Winnebago system was initiated by the Wisconsin Department of Natural Resources in 1971 and continued through 1976. Its initial objective was to investigate various aspects of perch population dynamics with special emphasis on factors affecting year class strength. Two years of effort yielded valuable information but also demonstrated the limitations of working in a large water complex. In 1973, study objectives were realigned and narrowed to address 2 primary questions emerging from the first 2 years' work: (1) What are the characteristics of yellow perch reproduction in the upper Fox River? And (2) What factors affect the survival of young yellow perch during the first growing season? Results of the entire study are presented in this report.

DESCRIPTION OF STUDY AREA

The principal study area encompassed Lake Winnebago and the Fox River from its junction with the lake upstream to the Town of Eureka where the first of seven dams on the river is located (Fig. 1). The widening of the Fox into Lake Butte des Morts was also included. Other waters of the Lake Winnebago complex were included in the area of tag returns but were not directly sampled. An exception was the outlet of Lake Winneconne, which was sampled for larval yellow perch during a short period in 1973.

The Fox River is a turbid, hard water stream originating in south central Wisconsin and emptying into Lake Michigan's Green Bay. The river is denoted the upper Fox from its headwaters to where it joins Lake Winnebago. This section has a low gradient, dropping 11m over its 132 km length. River channel length within the study area measured 39.6 km. The portion above Lake Butte des Morts is adjoined by numerous sloughs and backwaters while the river channel below is largely confined by bulkheads along both banks. Where it is joined by the waters of the Wolf River in Lake Butte des Morts, the upper Fox attains its maximum width of 134 m.

Lake Winnebago is a eutrophic, turbid, hardwater lake of glacial origin. With a surface area of 55,730 ha, it is the largest inland lake in Wisconsin and one of the largest in North America. It is shallow, with a maximum depth of 6.4 m and an average depth of 4.7 m, and is roughly rectangular in shape. Although 19 streams drain directly into Lake Winnebago, all except the Fox River are quite small. Seven are classified as intermittent, flowing only in the spring.

The bottom of Lake Winnebago is an extensive plain broken only by reefs on the west shore. Except for these reefs, and the rock, gravel, and sand shorelines and the shoals of the lake, the bottom is finely divided soft mud mixed with peat (Wirth 1959). Rooted aquatic plants are not abundant in the lake, occurring mostly in localized littoral areas of protected embayments.

Lake Butte des Morts covers 3,584 ha. Located in the Fox River channel, the lake is shallow, measuring 2.7 m at its maximum depth. Much of the shoreline is low, with marsh vegetation common. Two other lakes are located above Lake Butte des Morts: Winneconne (1,824 ha) and Poygan (5,707 ha). Both are shallow drainage lakes of the Wolf River and have low shorelines interspersed with points of high ground.

Water levels of Lake Winnebago and the upriver lakes are maintained in part by dams located on the two outlets of Lake Winnebago. Each of the two dams has a head of 1.5 m. Lake levels vary with runoff, power needs of the communities surrounding the dams, and land management of shoreline areas. Water levels are usually lowered each winter in anticipation of spring runoff.

The fish fauna of the Lake Winnebago system is diverse. Seventy-one species belonging to 22 families are now present or have been reported in the past from Lake Winnebago (Priegel 1967), and 41 species were reported from Lake Poygan by shoreline seining (Becker 1964). Fish species inhabiting other upriver lakes are probably quite similar, although intensive surveys have not been completed. The river population of fish swells each spring as a succession of species enter the Fox and Wolf rivers in migration to spawning sites. Yellow perch, walleyes, white bass, and lake sturgeon are the principal sport fish migrants.

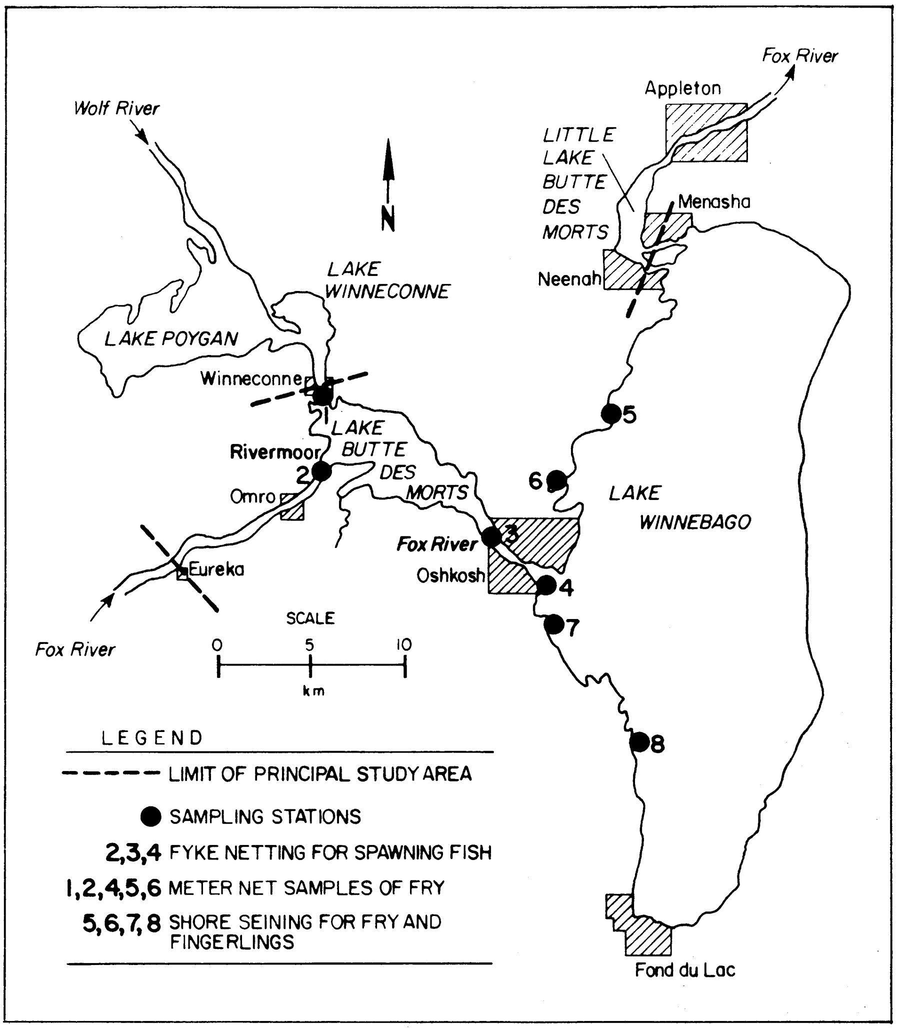


FIGURE 1. *Limits of principal study area and location of sampling stations.*

METHODS

ADULT YELLOW PERCH

Capturing Fish

Migrating yellow perch were captured with fyke nets set at the 2 principal locations where spawning was found (Fig. 1). The downriver location (Oshkosh) was the initial sampling location for the study and was monitored 1971-76. The upriver site (Rivermoor) was added in 1973 after sampling to delineate the spawning migration showed the location to be near a major spawning area. The Rivermoor site was monitored 1973-76. Nets were also set for short periods in 1971 and 1972 at the mouth of the Fox in Oshkosh where it enters Lake Winnebago. These nets were used to monitor movement of perch into the river and were discontinued after the other Oshkosh location approximately 8 km upriver proved to be a better sampling station. Data for the two sites were combined and reported as Oshkosh. Fyke nets measured 0.9 m in diameter and had a stretch mesh size of 3.8 cm. Nets were set when the river was ice-free and checked daily until all females captured were spent.

Electrofishing with a 320-volt, ac/dc boom shocker was carried out in sections of the Fox River between Oshkosh and the Eureka Dam in 1973-74 to monitor the extent of the spawning migration and to locate spawning sites. Extensive flooding in 1973 curtailed the electrofishing effort, but it was adequate for sampling purposes. Lake Winnebago was periodically electrofished between September and November 1971-72 to sample yearling and older perch for age and growth studies. A 3.7-m otter trawl was also used to capture perch during the same period.

Locating Spawning Sites

Various habitats in Lake Winnebago, Lake Butte des Morts, and the upper Fox River between Lake Butte des Morts and the Eureka Dam were searched for the presence of yellow perch eggs or concentration of spawning adults. Sites known to have a previous history of perch spawning and a variety of lake and river habitats were selected to be sampled. Bays along the west shore were the only areas checked in Lake Winnebago. Spawning habitats were located directly by sampling for eggs or making visual observations of eggs on different substrates.

Substrates were sampled for eggs with thatching and cultivating rakes, and with a specially constructed bottom-sled sampler. A screened basket used by Priegel (1970a) to locate walleye and sauger eggs was not effective in picking up perch egg strands.

The rakes were used to locate eggs by wading and randomly searching hydrophytic plant communities and bottom substrates. Rakes worked very well in the residual material of lotus, roundstem bulrushes, sedges and cattail stands found in spring and were effective in lifting submerged tree branches along the river shore.

The sled consisted of a frame welded to a pair of snowmobile skis with a removable rectangular net (46 x 89 cm frame with fine mesh bobbinet webbing and 102 cm to the cod end) and was towed behind a 5 m boat. The sled egg-sampler did not work well in strong currents but was suitable for sampling deeper water of the bays and river areas away from the main currents.

No quantitative measurements of deposited egg densities were made on located spawning substrates, and no attempt was made to use eggs to describe intensity of yearly spawning area use. Turbidity, depth, and current were limiting to such efforts.

Meter nets (No. 20 grit gauge, 19 meshes/linear inch) were used to sample prolarval yellow perch in various lake areas as an indirect method of locating spawning sites. Sampling was limited to locations where wind-generated currents were not considered a factor influencing immigration of larvae from nearby areas.

Attempts were made to localize spawning sites by marking and tagging yellow perch captured by fyke netting during spawning migrations and by monitoring the spawning condition (gravid, ripe and spent) of females captured daily in the upper Fox River nets and by electrofishing. Located spawning sites were characterized by water depth, vegetative cover, bottom substrate, and relation to river current.

Determining Size, Sex, and Age of Spawning Stocks

All fish sampled during spawning were measured to the nearest millimeter, sexed, and classified as mature or immature. Fish were handled in live or fresh condition. Sex of spawning fish was determined from external observations of gonad development except for immature fish which were dissected and sexed by internal observations.

Stratified scale collections were taken from 10-25 fish in each 10-mm length interval at the downriver site in 1971-72 and 1974-76, and were used to estimate age for the entire collection of spawning fish in a given year. Age of the 1973 spawning population was estimated from the combined averages of aged fish in 1971-72 and 1974 collections using proportional analysis of age to length frequency.

Scales were removed from the 3rd and 4th scale rows above the lateral line at a point below the 3rd dorsal spine. Scales were cleaned and impressed on celluose acetate slides, then examined with a microprojector at 44x magnification. Ages were determined by counting annuli and are reported as completed years of life. The edge of each scale was assigned a "virtual" annulus (Joeris 1956); no new growth was noted for perch collected during the March-April sampling periods. From the total catch over the 5 years that scales were taken, 10% of the fish were aged.

Determining Growth

Growth was determined from 1,638 perch collected during the spring and fall 1971-72 at the Fox River Oshkosh study sites (spring) and Lake Winnebago (fall). All fish were measured fresh for total length and 745 perch sampled in fall 1971 were weighed. Scale samples were taken from 1,333 fish collected during spring and fall and processed as described above. Scales from the fall samples were also assigned a virtual annulus since it was known that no growth occurred from fall to spring spawning. Thus, in effect the fall sample was advanced an age group, making the spring and fall samples equivalent.

Length at each annulus was derived from the following equation:

$$L_1 = \frac{C + S_1}{S} (L-C)$$

where L_1 is the total length of the fish at each annulus formation; L is the total length of the fish at the time of capture; C is the length of the fish at the time of scale formation (36 mm); S_1 is the length of the anterior radius of the scale at each annulus; and S is the length of the anterior radius at time of capture.

Corresponding weight was calculated from the length-weight equation:

$$\text{Log } W = -6.10 + 3.54 \text{ Log } L$$

where (L) represents total length in millimeters and (W) weight in grams.

All perch included in the growth study were sexed and classified as mature or immature to establish size and age at maturity. Sex and maturity of spawning fish were determined by external observation, while the fall sample was dissected for internal observation of the gonads.

Marking

All perch netted during 1971-76 were either tagged and/or finclipped, with a distinguishing clip given to fish caught at each site (Table 1). Fish were not anesthetized during marking. Floy FD-67 anchor tags were used to mark a selected sample of migrating yellow perch representing all sizes at the downriver sites in 1971 and 1972 and at Rivermoor in 1973. Tags were inserted midway along the body length between the lateral line and the midpoint at the base of the soft dorsal fin. Tags were applied at a 45° angle through the epaxial musculature and secured between the interneural spines. The monofilament was completely inbedded in the flesh with the streamer positioned flush with the body. Blue and yellow tag colors were chosen instead of international orange after aquarium observations revealed that smaller-sized game fish and pan fish attacked perch bearing orange tags but not the other colors.

Fish tagged in 1971 at Oshkosh had tag streamers that were only serially numbered; 1972 tags were numbered and had a mailing address on the legend. All tags used at Rivermoor in 1973 carried a mailing address, but only a portion were serially numbered. Tag streamer length was 20-25 mm at Oshkosh and 35-40 mm at Rivermoor. Both lengths are shorter than the standard length for Floy tags and were used because Stobo (1972) found that fish were wounded by the standard length streamer while swimming. All tags at both sites had a 12 mm long standard T-bar monofilament anchor.

All fish captured but not tagged at Oshkosh during 1971-76 were marked with a right pectoral finclip. Between

TABLE 1. *Number of yellow perch tagged and finclipped at two locations on the Fox River during the 1971-76 spawning migrations. A different finclip was used at each of the two sites.*

	No. of Fish Marked				
	Oshkosh Downriver Sites		Rivermoor Upriver Site		
Year Marked	Tagged	Finclipped	Tagged	Finclipped	Total Fish Marked
1971	539*	2,977			3,516[1]
1972	4,818*	7,613			12,431[1]
1973		2,952	1,613	2,825**	5,777
1974		1,451		1,081	2,532
1975		3,005		2,880	5,885
1976		3,513		2,452	5,965
Total	5,357	21,511	1,613	9,238	36,106

*Tagged fish were not finclipped.
**All fish finclipped, including the 1,613 tagged individuals.
[1]Totals exclusive of females taken for fecundity estimates in 1971 (n=40) and 1972 (n=133).

1973-76 all captures at Rivermoor, including tagged individuals, were marked with a left pectoral fin clip. Fins were easily removed with surgical scissors, and the cut was made as close to the body as possible.

Differential marking and tagging between capture sites was used to determine movements of perch during migrations, homing, post-spawning distribution, and angler exploitation in the study area. Tags returned by anglers were keyed to 6 recapture zones: Lake Winnebago, Lake Butte des Morts, the upper Fox River to the Eureka Dam, Lake Winneconne, Lake Poygan, and the Fox River below its outlet from Lake Winnebago. Lake Winnebago was further divided into 6 subzones along a generally north-south line bisecting the lake and 2 intersecting east-west lines. The tagging program was publicized through presentations to sportsman's clubs and through coverage by the newspaper, radio, and television media. No reward was offered to anglers for returning tags. Form letters with time, size, sex, and location tagged were returned to anglers along with the tags to further promote cooperation.

Egg Counts

Gravid ovaries were obtained from 150 female yellow perch ranging from 132 to 335 mm total length during the 1971-72 spawning seasons. Age was determined for 131 of these fish. All ovaries were preserved in a solution of alcohol, formalin, and acetic acid or in 10% formalin. Individual fish were weighed fresh to the nearest gram and total length measured to the nearest millimeter. All fish were captured with fyke nets during both sample periods.

Estimates of the number of eggs from each ovary were made by the gravimetric method. Ovarian tissue was removed to free the egg mass, and the preserved weight of each egg mass, after being blotted and air-dried, was determined. Then, groups of eggs were taken randomly from cross sections of the mass until 10% of the total weight of the egg mass was sampled. The fraction of eggs removed was counted and the total number of eggs per fish estimated on a proportional basis.

The size of individual eggs did not vary with location in the ovary except in a few of the larger females that had smaller eggs in the center of each ovary. It is not known if these smaller eggs were the result of physiological development or preservation. All ova examined were mature, and any differential development of individual eggs with respect to location within the ovary was considered negligible in the yellow perch used in this study.

FRY AND FINGERLING YELLOW PERCH

Monitoring Egg Development

During the first year of study, an attempt was made to monitor egg development on artificial spawning substrates. Cut-off tops of discarded Christmas trees were submerged in 1.2-1.8 m of water in the Fox River and Lake Winnebago at Asylum Bay to obtain known-age, fertilized eggs to document early egg development through hatching. Scotch pine worked best and appeared to be selected over balsam fir, white pine, red pine, and black and white spruce. Bundles (0.5 x 1 m) of branches from ash, maple, elm, and oak were also used but were not successful in attracting spawners. Screened baskets, cultivating rakes, and a rectangular-framed net mounted on metal skiis (bottom sled-type construction) were used to search for fertilized eggs in natural habitats.

Although perch used the artificial pine substrates for spawning, eggs were often lost before hatching. Therefore, beginning in 1972, enclosed containers were used to monitor the development of artificially fertilized eggs. The containers were specially constructed 12-liter double-end, screened buckets and were suspended midway in the water column over a maximum depth of 1.8 m in the Fox River at Oshkosh. Small pine trees were submerged near the study site in 1972 and 1973 as a means of observing known-age eggs and estimating time of spawning under natural conditions.

At the upriver study site, screened buckets were used to monitor egg development in 1973 and 1976, while submerged pine trees placed at two locations within the spawning area were used in 1975.

Eggs were checked daily and condition and stage of development were noted. Dissolved oxygen and water temperatures were monitored daily at both sites.

Experimental egg development batteries were installed within one or two days of natural spawning on the pine tree substrates at the downriver site in 1972 and 1973, and at the beginning of peak spawning at both sites in all other years. Water temperatures at time of fertilization and incubation of eggs in the batteries were approximately equal to those existing under natural conditions.

Capturing Fish

Larval fry were collected between April and June in 1971-75, with meter nets (No. 20 mesh) towed for 5 minutes at the surface. Larvae were also collected for food habit studies in 1970, using the same method. Collections were made at the mouth of the Fox River at Oshkosh and at two bays along the west shore of Lake Winnebago. In 1973, collections were also made in the upper Fox River at Rivermoor and in the Wolf River below Lake Winneconne. Sampling sites are shown in Figure 1. All larval fish were identified to species and larval perch were classified as prolarvae and postlarvae following the system suggested by Norden (1961). Specific sampling periods varied from year to year depending on when spawning and hatching occurred. Developmental state of eggs maintained in screened buckets for hatching studies was used as a cue to begin sampling.

Larger fry and fingerlings were captured with a 9.1 x 1.2 m bobbinet seine having 0.32-cm mesh at 4 littoral sites along the west shore of Lake Winnebago (Fig. 1). The average area covered at each seining site was approximately 400 m^2. Offshore collections were made from 6 zones previously described for angler returns of tagged fish with a 3.7-m otter trawl having 3.8-cm stretch mesh wings fitted with a 0.6-cm mesh liner in the cod end. Trawls were standardized to 7-minute tows, which covered approximately 0.24 ha. Trawling zones in the southwest quarter of Lake Winnebago consistently produced the greatest numbers of young yellow perch, as well as young-of-the-year of the lake's other major fish species. However, all areas of the lake were sampled each season to avoid sample bias, and the results combined represent the total lake sample. No significant changes in the seasonal distribution of young perch were detected among the 6 trawling zones.

All fish were preserved in 10% formalin. Sampling was carried out between June and October, as near to biweekly as possible. Most seine and trawl sampling was paired, occurring within one day of each other. Full recruitment of fry and fingerling to the collecting gear occurred at the following lengths: 8 mm for the meter nets, 23 mm for the trawl, and 18-19 mm for the seine.

Size Measurements

Length and weight were measured on a subsample of 25-50 fish from each seine and trawl collection date. Measurements were obtained from fish preserved in 10% formalin after being blotted and air-dried. Total length was measured to the nearest millimeter. Weights were taken in 1973-75 on a triple-beam balance and recorded to the nearest 0.01 g. Length-weight equations were calculated for combined 1973-75 trawl data and for combined 1973-75 seine data and used to estimate weights of young perch collected from each year in 1971 and 1972.

Totals of 1,307 fry and 4,211 fingerling (Append. Table 32) were collected by these methods during 1971-75 and used to determine growth of young-of-the-year yellow perch. For fingerling perch, growth in littoral habitats (seine samples) and limnetic habitats (trawl samples) were analyzed separately.

Food Studies

Stomach contents were analyzed from the subsample of fish collected for length and weight measurements. Stomach contents, whole and fragments, were counted and identified to genus when possible. Data were presented as percentage frequency of occurrence, percentage of total food items, and number of organisms per stomach. Percentages are based on the number of stomachs containing food. Pelagic fish collected by meter nets were designated prolarvae and postlarvae while demersal fish collected by trawl and seine were considered juvenile fish and designated young-of-the-year. Physical characteristics described by Mansueti (1964) and Norden (1961) were also used to distinguish larval and juvenile perch.

Totals of 237 prolarval and 1,307 postlarval yellow perch (5-21 mm long; $\bar{x}$ = 9 mm) were examined for food habits during late April through early June, 1970-75. Sampling period, number of fish examined, and length frequency distribution of postlarval perch are shown in Appendix Table 33. Number of prolarvae examined each year is shown in Table 20.

Between June and October in 1971-75, 2,579 fingerling yellow perch (15-114 mm long) were analyzed for food habits (Append. Table 34). Perch from limnetic habitats (trawl captures) comprised 29% of the sample while fish from littoral habitats (seine captures) comprised the remaining 71%. Representation of various lengths was good except for the larger size classes (85-114 mm).

Measurements of food selectivity by young perch collected by trawling were calculated from estimates of the ratio of occurrence of zooplankton in the lake and their ratio of occurrence in the stomachs of young perch. Calculations were based on Ivlev's (1961) electivity index:

$$E = \frac{r_i - P_i}{r_i + P_i}$$

where r_i is the relative quantity of a given food item in the stomach as a percentage of the food consumed, and P_i is the relative abundance of the same food item in the environment expressed as percent occurrence.

ENVIRONMENTAL MEASUREMENTS

Selected physical and chemical data were recorded in the field during the April-October study period, while others were obtained from records of other agencies within the study area.

Taylor maximum-minimum thermometers were maintained on artificial spawning substrates through hatching. Water temperatures in Lake Winnebago at Asylum Bay and near the mouth of the Fox River at Oshkosh were monitored with a Taylor 7-day thermograph during the spawning run. Seasonal water temperatures for Lake Winnebago were obtained from daily records at Neenah Water Utilities, Neenah, Wisconsin. Water temperature profiles were recorded periodically in Lake Winnebago during May-October in conjunction with plankton sampling.

Stream flow and water level data for the Fox River and inflow (cms) entering Lake Winnebago at Oshkosh were obtained from the U.S. Army Corps of Engineers, Appleton, Wisconsin. These data are based on gauge readings from the Fox River at Berlin, the Wolf River at New London, and in the mouth of the Fox River at Oshkosh. Water level data for the Fox River at Lake Winnebago were disregarded because of the undetermined influence of lake wave action on the gauge. The rate of flow in the river provided a more meaningful measurement of spring water conditions in the study area.

Ice breakup on Lake Winnebago was designated, based on qualitative observations, as the date when large expanses of open water persisted along the west shore although much ice might still be present on the lake.

Dissolved oxygen determinations were made during egg development using the azide modification of the Winkler method. Seasonal and daily air temperature data were obtained from the Winnebago County Airport in Oshkosh. Secchi disc transparencies were obtained during periods of egg development and on plankton sampling dates.

ZOOPLANKTON SAMPLING

Zooplankton were collected concurrently with trawl collections of young perch during May-October in 1971-75. A Clarke-Bumpus sampler fitted with a No. 2 net and cup was used. Standard 3-minute tows were taken at the surface and at 1.8, 3.7, and 5.5-m depths. Concentrated samples were preserved in 5% formalin and Lugol's solution.

Estimates of zooplankton abundance were determined volumetrically. After sample concentrates were brought to a known volume in the laboratory, a 3-ml subsample was delivered with a Stemple pipette to a circular counting chamber described by Priegel (1970b). All organisms in the subsamples were counted and identified to genus. Genera that could not be identified in our lab were sent to Dr. John E. Gannon, Center for Great Lakes Studies at the Univeristy of Wisconsin - Milwaukee, for positive identification.

Estimates of zooplankton abundance are presented as average number of organisms/liter determined from average counts of the 4 samples taken on a given sampling date.

RESULTS AND DISCUSSION

SPAWNING SITES AND HABITAT CHARACTERISTICS

Four major spawning sites for yellow perch were located, 2 in Lake Winnebago and 2 in the Fox River (Fig. 2).

Lake Winnebago spawning sites were located in two shallow bays along the west shore: Asylum Bay and Miller's Bay. Spawning occurred at depths of 0.6-1.8 m on substrates of sand, fine gravel, submerged vegetation, primarily *Ceratophyllum* and *Elodea*, and emergent bulrush, *Scirpus* spp. Bottom type underlying this vegetation is primarily sand.

Indirect evidence points to an additional spawning area in Lake Winnebago. During this and previous studies (Priegel 1969), yellow perch eggs were found washed ashore adjacent to an extensive shoal/reef complex located on the lake's west shore. Eggs were found washed ashore particularly after a day or two of strong east-southeast winds (9-13 m/sec) that produced considerable wave action. Clady and Hutchinson (1975) found extensive windrows of yellow perch egg masses washed ashore from known spawning areas in Oneida Lake, New York. The perch in Lake Winnebago probably spawn on the reefs but the extent is not known and was not determined in this study.

The 2 Fox River spawning sites are located 5.6 and 19.3 km upriver from Lake Winnebago. The first or downriver site covers approximately 8.1 ha and is located along the northeast side of the river mostly within a narrow band of old pilings adjacent to the main channel where the entire shoreline is riprapped. Substrates at the site are submerged pilings (not visible at the surface during high water), logs, and debris. The bottom type includes sand, gravel, mud, and some rubble from riprap. Spawning took place directly in or at the edge of the current. Eggs were found in fyke net leads, near shore on submerged debris and detritus, and on artificial substrates (conifers) along the site at depths of 0.4-2.1 m. No eggs were found directly on the bottom in 6 years of sampling. The eggs are believed to be extruded on the pilings and debris, then carried by the current.

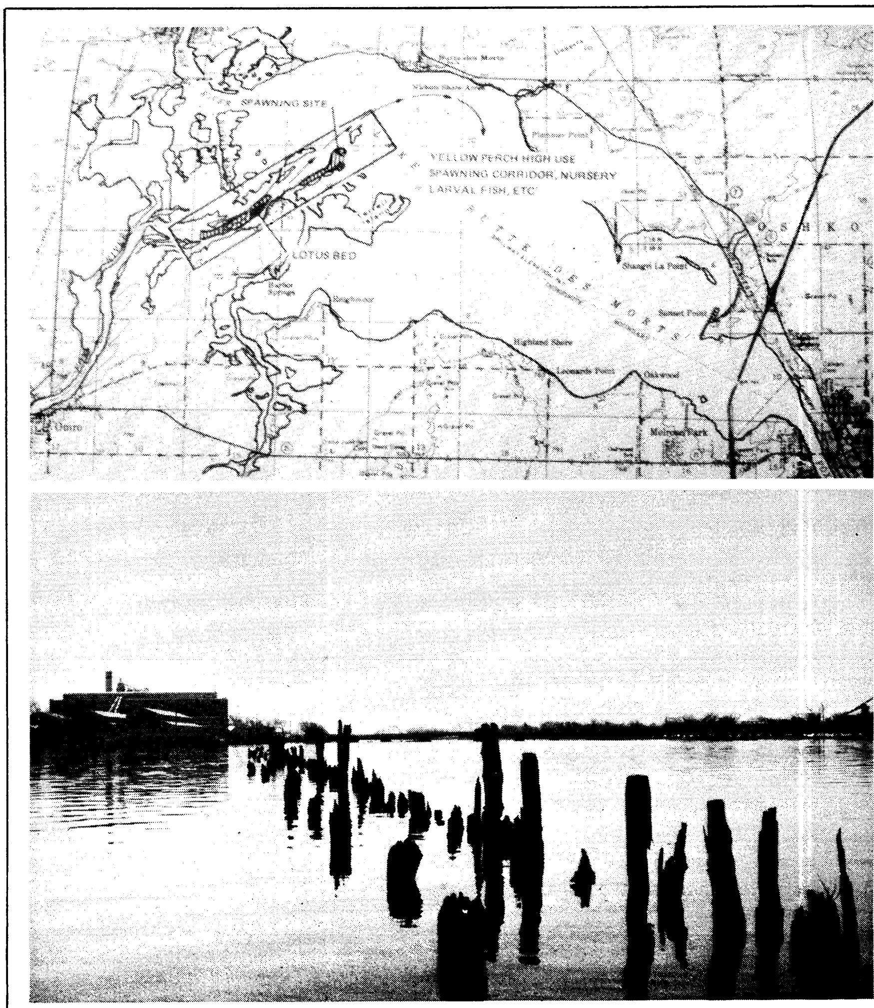


FIGURE 2. *Location of yellow perch spawning sites in the upper Fox River (Rivermoor site, above) and Lake Winnebago (Oshkosh site, below).*

The upriver spawning ground is located offshore from Rivermoor, a concentration of cottages on the Fox, and is adjacent to the main river channel and somewhat protected from the current. The 3.8 ha spawning area is dominated by a remnant American lotus (*Nelumbo lutea*) bed, the largest of 4 present in the study area between Lake Winnebago and the dam at Eureka. The site also includes some water lily (*Nymphaea lutea* spp.) and arrowhead (*Sagittaria* spp.).

Egg masses were found on the partially decomposed stalks of lotus and arrowhead in 0.6-1.5 m of water. The erect and matted fibrous stalks along with the accumulated detritus from the previous season's growth were submerged in spring. The rigid fibrous nature of the stalks appeared to provide an optimum substrate for possible extrusion and attachment of the egg strands. The bottom type was firm sand/silt and detritus mat. Although some eggs were found downstream from this site near shore and on net leads in April 1973, the lotus bed spawning area was not discovered until the 1974 spring season.

Eggs were also found near the Rivermoor lotus site and along the river on cattail, bulrush, sedges and fallen tree branches in 0.5 m of water as well as on willow brush in less than 0.2 m of water. G. Priegel (Dept. Nat. Resour., pers. comm.) has observed yellow perch eggs in lateral ditches and small backwater areas adjacent to the river, from Lake Winnebago to below the Eureka Dam. Other Department of Natural Resources personnel have observed perch spawning in some years in minor tributary streams entering Lake Winnebago, primarily Van Dyne Creek, Anderson Creek, and the Fond du Lac River.

Studies elsewhere have shown that perch spawn in a wide variety of habitats. Scott and Crossman (1973) report spawning on rooted vegetation, fallen trees, submerged brush, and over sand and gravel. Echo (1955) observed perch spawning in Lower Thompson Lake from the surface to 1.5 m on submerged conifers, birch, bulrush, and stonewort. Spawning occurred at depths of 0.5-3.0 m in Oneida Lake (Forney 1971).

SPAWNING POPULATIONS

The location of spawning sites concurrently in Lake Winnebago and the Fox River indicated that there are at least 2 yellow perch spawning stocks. The riverine spawning stock was chosen for intensive study for 3 reasons: (1) preliminary sampling in both environments indicated that the river yielded greater and more consistent numbers of spawning perch, (2) very little was known about perch spawning in river environments in Wisconsin and in the Fox River in particular, and (3) vegetative cover usually associated with perch spawning has shown a progressive decline in the Fox River and associated lakes over past years, underlining the need to identify areas used by spawning perch so they might be protected.

Migration to Spawning Sites

Origin of Migrating Populations. Yellow perch spawning migrations from Lake Winnebago to the Fox River were first documented in spring 1971 and 1972. The migration during these 2 years was determined from fyke net captures of large numbers of adult fish at netting sites in the Fox River at its entrance to Lake Winnebago and at Oshkosh. Angler returns reported for fish tagged at these sites and recaptured upstream soon after tagging, provided the first evidence that migrations extended into the upper Fox River as far as the Eureka Dam, about 40 km from the river's mouth.

These preliminary findings and later results from concurrent fyke netting at Oshkosh and Rivermoor indicated that perch captured at the river study sites primarily returned to Lake Winnebago and presumably originated there. Of the 539 tagged fish caught by anglers, 84.4% were taken in Lake Winnebago after spawning was completed (Table 2). Most of the remaining captures came from Lake Butte des Morts (6.9%) and the upper Fox River between Lake Butte des Morts and Eureka (5.2%).

Percentage returns from the 6 recapture zones were similar for the 2 tagging sites, with one exception. Fifteen percent of fish recaptured from the Rivermoor marking effort were taken in Lake Butte des Morts while only 4% of angler returns of fish marked at the downriver sites came from this location. The difference in these recapture rates suggests that some portion of Rivermoor spawners originate in Lake Butte des Morts. The lake is known to have a resident perch population and the Rivermoor site, situated just upriver from the lake, is a likely spawning location. However, it is also possible that some portion of Lake Butte des Morts perch migrate up the lake's other major inlet, the Wolf River, to spawn. The existence or magnitude of such a migration was not determined in this study.

Migration patterns for Rivermoor spawners were also defined from spring netting and electrofishing at Oshkosh and Rivermoor. Forty fish marked at Rivermoor (12 tagged, 28 finclipped) were recaptured at Oshkosh in subsequent years and 187 fish marked at Oshkosh (25 tagged, 161 finclipped) were subsequently recaptured at Rivermoor (Tables 3 and 4). While these recaptures represent less than 1% of all fish marked, they are important in showing that fish captured at Rivermoor migrate there directly from the lake. Given the close proximity of the Oshkosh netting location to Lake Winnebago, it is obvious that perch spawning there migrate directly from the lake.

Homing. Homing to the upriver site is suggested by the high proportion of fish marked and recaptured in subsequent years at Rivermoor compared to fish marked there but recaptured at Oshkosh (Tables 3 and 4). Out of 272 fish recaptured from the Rivermoor marking effort, 232 (85%) were recaptured in the vicinity of the site. The remaining 15% could represent homing fish intercepted at Oshkosh or nonhoming fish actually spawning at the downriver site.

The 85% figure is surprisingly high, given that all perch originating in Lake Winnebago had to pass through the Oshkosh netting area and were theoretically susceptible to capture there before reaching Rivermoor. However, 2 factors probably contributed to keeping Rivermoor spawners out of the Oshkosh nets. Time of migration is the first. Spawning began from 2 to 5 days earlier at Rivermoor and, based on percentage of females spent at a given time at each site, continued ahead of spawning at Oshkosh each year, 1973-76 (Fig. 3). Thus, initial migration to the Rivermoor site probably occurred before nets were set downriver, while ice cover was still present. These early migrators would only be vulnerable to recapture at Rivermoor, where ice is out of the river very early each spring.

The second factor is the physical nature of the sampling locations. The Oshkosh nets were set along the northeast bank at a wide point in the river. Perch attracted to the area for spawning would be more likely recaptured than fish moving on to Rivermoor. The Rivermoor netting location was more restrictive in size and more likely to recapture a higher proportion of fish passing through the area.

Homing also appears to occur at the downriver site. Out of 422 perch recaptured from the downriver marking effort, 56% were recaptured at Oshkosh (Tables 3 and 4). The lower incidence of homing to the Oshkosh site is probably related to its location. All migrating spawners passed through the area and were, to some degree, susceptible to marking and recapture there, although, as discussed above, the physical nature of the river at the sampling site made it possible for some fish to bypass the nets. Thus, perch actually homing to Rivermoor may have been marked at Oshkosh and later recaptured at Rivermoor. In addition, fish actually spawning at the downriver site and continuing upriver in their post-spawning movement could be captured at the upriver site.

Although it appears that some degree of homing occurs to both the Rivermoor and Oshkosh spawning

TABLE 2. *Frequency distribution of angler tag returns by location of recapture in the study area (percentage recaptured in parentheses).*

Tagging Site on Fox River	Years of Recapture	No. Perch Recaptured (%) Lake Winnebago	Lake Butte des Morts	Upper Fox R. to Eureka Dam	Lake Winneconne	Lake Poygan	Below Outlet L. Winnebago	Total
Oshkosh*	1971-73	35 (85.4)	5 (12.2)	1 (2.4)				41
Oshkosh	1972-77	309 (86.6)	11 (3.1)	24 (6.7)	4 (1.1)	6 (1.7)	3 (0.8)	357
Rivermoor	1973-77	111 (78.7)	21 (14.9)	3 (2.1)	1 (0.7)	1 (0.7)	4 (2.8)	141
Total		455 (84.4)	37 (6.9)	28 (5.2)	5 (0.9)	7 (1.3)	7 (1.3)	539

*Preliminary sampling site located at the Fox River's entrance to Lake Winnebago.

sites, it may not operate to the same extent every year. Recapture rates for fish marked at Oshkosh then recaptured upriver the same spawning season (new finclips) indicate movement of fish upriver varies from year to year (Table 4). Higher recapture rates were noted in 1973 and 1976, both years exhibiting unusually high water conditions (Fig. 4). These water conditions may stimulate upriver movement by signalling availability of spawning areas inaccessible in drier years or by rendering downriver sites less desirable for spawning. Thus, in some years, environmental conditions may be a major factor in determining where spawning occurs. Zakharova (1955) recorded spawning by the Eurasian perch (*Perca fluviatilis*) at Rybinsk Reservoir in flooded meadows in high-water years and in the beds and inundation zones of tributary rivers in low-water years.

Most tagging studies of yellow perch have dealt with only one year of netting on spawning grounds, making it impossible to document homing. However, in a 14-year study of Oneida Lake, Clady (1977a) found a strong homing tendency among spawning perch. A distinct homing behavior was reported for the Eurasian perch (*Perca fluviatilis*) in Lake Ijssel of the Netherlands (Willemsen 1977).

Rate of Movement. Minimum rates of daily movement were estimated from fish marked at lower nets and recaptured at upper nets in the same year. Estimates were derived by dividing the number of days before the first marked fish was recaptured upstream, by the midpoint in days perch were marked at the lower site (1973-76). The minimum rate was 6.4-8.1 km/day with an average of 7.0 km/day for the 1973-76 marking period.

Another estimate of daily movement was based on angler-caught perch. Fourteen perch tagged in 1972 were recaptured by anglers the same year in the upper Fox River between

TABLE 3. *Summary of recaptured tagged and finclipped yellow perch taken in Fox River nets at Oshkosh during 1972-76 spawning migrations*.*

Year Recaptured	No. Yellow Perch Recaptured at Oshkosh (%) — Fish Marked at Oshkosh: Tagged (1971-72)	Fish Marked at Oshkosh: Finclipped	Fish Marked at Rivermoor: Tagged (1973)	Fish Marked at Rivermoor: Finclipped
1972	2 (3.2)	61 (96.8)	-	-
1973	11 (25.0)	32 (72.7)	1 (2.3)	- -
1974	2 (5.4)	28 (75.7)	2 (5.4)	5 (13.5)
1975	6 (10.9)	44 (80.0)	3 (5.5)	2 (3.6)
1976	3 (3.9)	46 (60.5)	6 (8.0)	21 (27.6)
Total	24 (8.7)	211 (76.7)	12 (4.4)	28 (10.2)

*Data excludes recaptures marked at this site the same year, but include recaptures of fish marked at Upper Fox River site the same year, 1973-76.

TABLE 4. *Summary of recaptured tagged and finclipped yellow perch taken in Fox River nets at Rivermoor during 1973-76 spawning migrations*.*

Year Recaptured	No. Yellow Perch Recaptured at Rivermoor (%) — Fish Marked at Oshkosh: Tagged (1972)	Fish Marked at Oshkosh: Finclipped (Old)**	Fish Marked at Oshkosh: Finclipped (New)[1]	Fish Marked at Rivermoor: Tagged (1973)	Fish Marked at Rivermoor: Finclipped
1973	15 (26.8)	17 (30.4)	24 (42.9)	-	-
1974	3 (3.7)	10 (12.2)	2 (2.4)	36 (43.9)	31 (37.8)
1975	4 (3.2)	34 (27.2)	3 (2.4)	24 (19.2)	60 (48.0)
1976	3 (1.9)	26 (16.7)	46 (29.5)	11 (7.1)	70 (44.9)
Total	25 (6.0)	87 (20.8)	75 (17.9)	71 (16.9)	161 (38.4)

*Data exclude recaptures marked at this site the same year, but include fish marked at Lower Fox River site the same year, 1973-76.
**Fish finclipped in years previous to the year of capture.
[1]Fish finclipped in the year of capture.

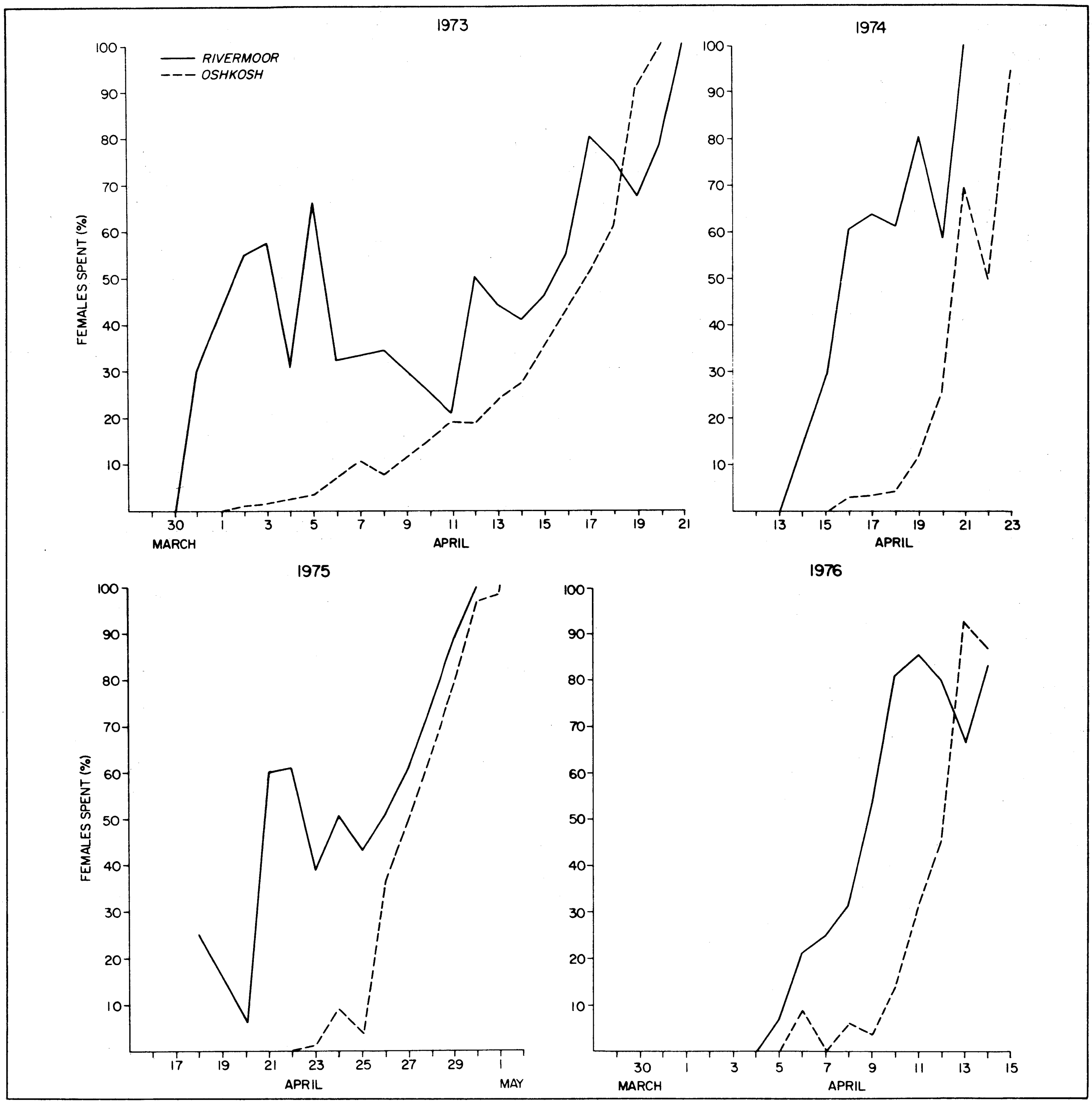


FIGURE 3. *Percentage of spawning female yellow perch spent among fish sampled in the Fox River at Rivermoor and Oshkosh, 1973-76.*

Rivermoor and the Eureka dam. Distance from site tagged to location of recapture was 34-40 km. Fish recaptured were at large 3-26 days, with an average of 10 days. Minimum rates of movement for these angler-caught fish averaged 3.7 km/day and ranged from 1.3 to 11.3 km/day. The greatest movement was recorded for a 180-mm male that travelled 33.8 km upstream in 3 days.

Spawning Season

The onset of the yellow perch spawning migrations was determined by the presence of large numbers of perch in test nets at the Fox River sampling stations. Actual spawning was judged to begin on the date spent females were first captured at these stations. When all females captured were spent, spawning and migration were judged over. Peak spawning was defined as the day or days when 50% of females captured were spent.

Phenological and physical data related to the 1971-76 spawning seasons are summarized in Tables 5 and 6 and Figure 4. Yellow perch migrations from Lake Winnebago into the Fox River started in late March-early April, beginning in 3 of 6 years before ice broke up on the lake. Spawning began as early as 31 March in 1973 at the upper site and as late as 25 April in 1972 at the lower site. During 1973-76, spawning started 2-5 days sooner at the upper river site.

There was a significant correlation ($r = 0.93$, $P < .01$) between the time of ice breakup in Lake Winnebago and the onset of yellow perch spawning at the Fox River study sites (Fig. 5). The regression equation describing this relationship was derived by expressing dates of these two events as numerical days of the year. Time of ice breakup varies considerably each year, occurring from mid-March to late April. Spawning started within 1-16 days after ice breakup, and the 6-year average was 7 days after ice breakup. Elsewhere in the northern United States and Canada, spawning occurs between

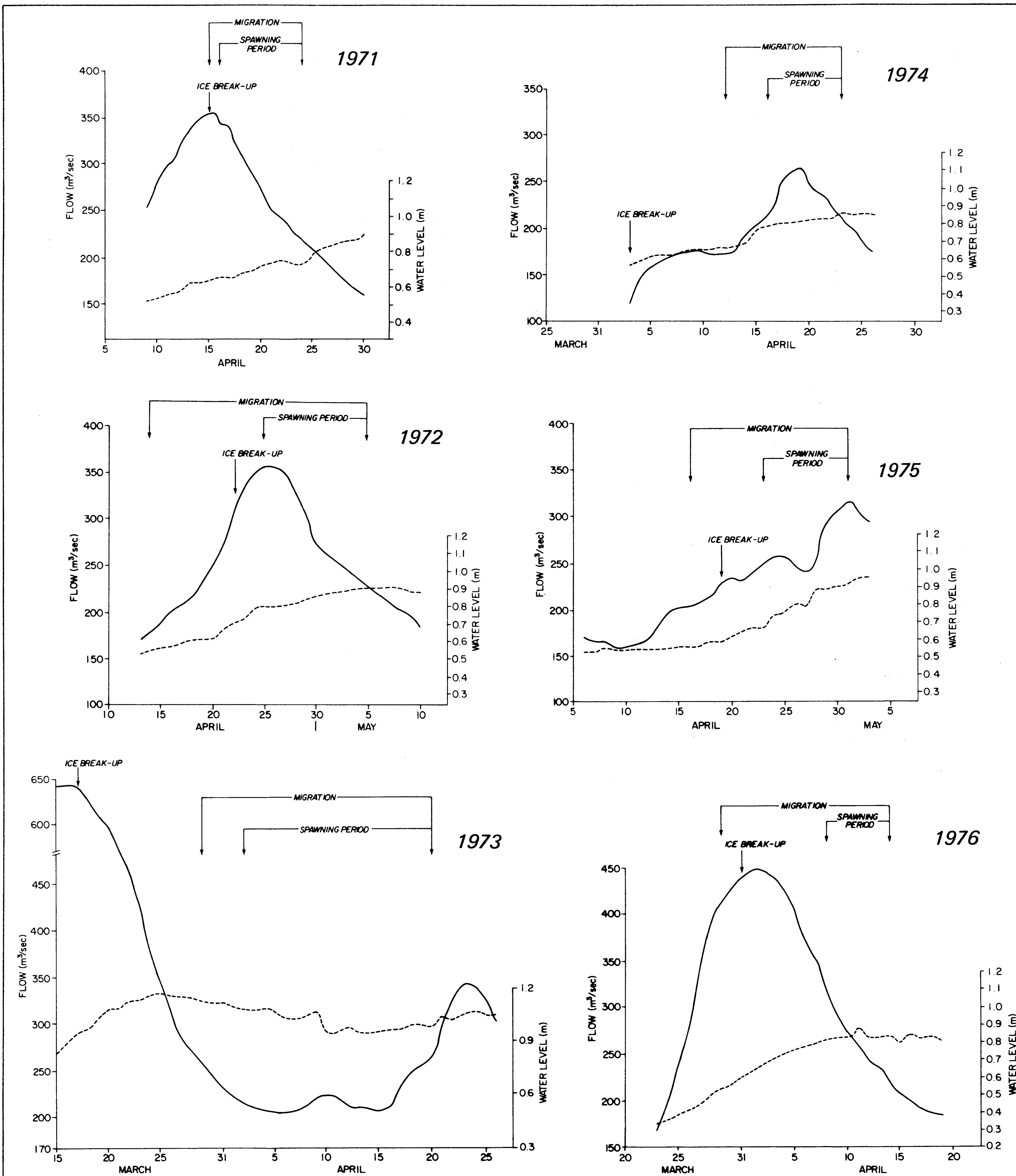


FIGURE 4. *Dates of migration and spawning for yellow perch in the Fox River and their relation to flow and water level, 1971-76.*

February and May (Thorpe 1978).

Spawning began at peak seasonal flows in 1971 and 1972 (Fig. 4), suggesting that the onset of spawning was synchronous with flow periodicity. However, flow regimes in subsequent years of the study were highly variable and peak flows did not coincide with the start of spawning.

The duration of the spawning season at the lower site in 1971-76 ranged from 7 days in 1976 to 19 days in 1973

TABLE 5. *Summary of data for yellow perch spawning seasons in the upper Fox River at Oshkosh, 1971-76.*

Spawning Season Parameters	1971	1972	1973	1974	1975	1976
Date of ice break-up Lake Winnebago	15 Apr	22 Apr	17 Mar	3 Apr	19 Apr	31 Mar
Date river migrations begin	15 Apr	14 Apr	29 Mar	12 Apr	16 Apr	29 Mar
Date spawning begins	16 Apr	25 Apr	2 Apr	16 Apr	23 Apr	8 Apr
Length of spawning season (days)	9	11	19	8	9	7
Date peak spawning	19-21 Apr	1-3 May	17-20 Apr	21-23 Apr	27-30 Apr	12-14 Apr
Water temperature (°C)						
Spawning season						
Mean minimum	9.0	10.4	4.8	7.7	5.2	6.7
Mean maximum	11.1	12.5	6.4	10.2	10.3	8.6
Season mean	10.1	11.4	5.7	8.9	7.8	7.6
Range	5.0-14.4	3.9-15.6	0.6-12.2	5.0-12.2	2.8-12.2	5.6-10.0
Initial spawning						
Mean	5.0	6.9	6.7	6.9	6.1	8.1
Range	-	3.9-6.7	6.1-7.2	5.6-8.3	2.8-9.4	6.6-9.4
Peak spawning						
Mean	11.7	12.9	9.9	10.6	7.9	7.1
Range	10.6-14.4	11.1-15.0	6.7-12.2	8.9-12.2	4.4-11.7	5.6-9.4

TABLE 6. *Summary of data for yellow perch spawning seasons in the upper Fox River at Rivermoor during spawning migrations, 1973-76.*

Spawning Season Parameters	1973	1974	1975	1976
Date of ice breakup, Lake Winnebago	17 Mar	3 Apr	19 Apr	31 Mar
Date river migration begins	29 Mar	12 Apr	16 Apr	29 Mar
Date spawning begins	31 Mar	14 Apr	18 Apr	5 Apr
Length of spawning season (days)	22	8	14	10
Date peak spawning	16-21 Apr	17-21 Apr	26 Apr-1 May	9-14 Apr
Water temperature (°C)				
Spawning season				
Mean minimum	5.3*	6.9	7.3	8.8
Mean maximum	9.1*	10.2	9.9	12.5
Season mean	4.4**	8.6	8.6	10.7
Range	0.6-15.6	3.9-12.2	4.4-12.2	6.7-15.0
Initial spawning				
Mean	8.3 (surface)	7.2	8.6	8.6
Range	no data	4.4-10.0	7.8-9.4	6.7-10.6
Peak spawning				
Mean	10.9	9.8	10.0	10.4
Range	6.1-15.6	7.8-12.2	6.1-12.2	6.1-15.0

*4-21 Apr only.
**Includes estimates from daily surface temperatures, 31 Mar - 3 Apr.

(Table 5) and averaged 11 days. Between 1973 and 1976, spawning at the upper site lasted an average of 14 days, ranging from 8 to 22 days (Table 6). The protracted 19- and 22-day seasons in 1973 coincided with marked drops in temperature after spawning started, when daily water temperatures steadily declined for 11 days, reaching lows of 1.7 C.

Length of spawning seasons in the Fox River was positively correlated ($r = 0.83$, $P < 0.01$) with mean daily water levels (Fig. 6). The length of the spawning seasons was not influenced by flow.

The time of day when perch spawned was not determined during this study. Other studies have shown that spawning takes place at night and early morning (Scott and Crossman 1973).

Mean water temperatures at the beginning of spawning ranged from 5.0 to 8.1 C at the lower site (1971-76) (Table 5) and 7.2 to 8.6 C at the upper site (1973-76) (Table 6). Mean temperatures during peak spawning at both sites ranged between 7.1 and 12.9 C while mean temperatures recorded for the entire spawning seasons at both sites ranged between 4.4 C and 11.4 C. Mean daily temperatures during spawning were warmer at the upper site except in 1973 when temperatures at both sites were nearly identical. Spawning occurred at both sites under generally rising water temperatures although fluctuations were numerous. The lowest temperature recorded during spawning in the 6 years of study was 0.6 C while the highest was 15.6 C.

Spawning temperatures for yellow perch in the Fox River are similar to those reported by other investigators in northern United States. Muncy (1962) reported a bottom water temperature range of 7.0-10.5 C for beginning spawning and 4.4-8.8 C for peak spawning over a 17-year period. Tsai and Gibson (1971) reported peak spawning temperatures 8.5-10.0 C.

Relative Abundance

The relative abundance of spawning stocks was estimated from annual catch/effort in fyke nets at each site. These data also provide a relative measure of the magnitude of migration each year. Nets were set in approximately the same locations each year.

The highest relative abundance occurred at the downriver sites in 1971-72 (Table 7). Concurrent netting at both sites in 1973-76 showed some similarities in numerical abundance, but relative abundance (C/E) was greater at the upper site in each year except 1976. However, it is uncertain whether these data can be interpreted to mean that the Rivermoor site attracts more spawners than the Oshkosh spawning site. The upriver site is more restricted in size, the river is narrower and the spawning grounds are situated differently with respect to the current than at the lower site. All of these factors contribute to greater vulnerability at the upper site and may account for that site showing greater relative abundance.

There is a direct relationship between mean daily flow and catch of yellow perch during the 1971-75 spawning migrations (r = 0.89; P < 0.07) (Fig. 7). Thus, up to a certain point, magnitude of yellow perch immigration from the lake to the river increased with flow. The extreme flow in 1976 could represent a threshold limiting movement from the lake to the river. However, as shown in Table 6, movement from the downriver sampling station to the upriver site was greatest in 1976, suggesting that high flow encourages movement among fish that do enter the river. It is also possible that high flow increases the availability of spawning areas in the lake, thus decreasing the number of perch entering the river to spawn. Net efficiency did not appear to be a factor in the 1976 decreased catch.

Belonger (1980) reported C/E values of 14.9-610.3 for spawning perch captured in fyke nets set in Wisconsin rivers tributary to Lake Michigan. Season averages were 132.0 for females and 181.2 for males. Perch also spawn in the lake (Green Bay) in the vicinity of tributary rivers used for spawning. Average C/E values for lake netting locations were quite similar for females but almost 4 times higher for males.

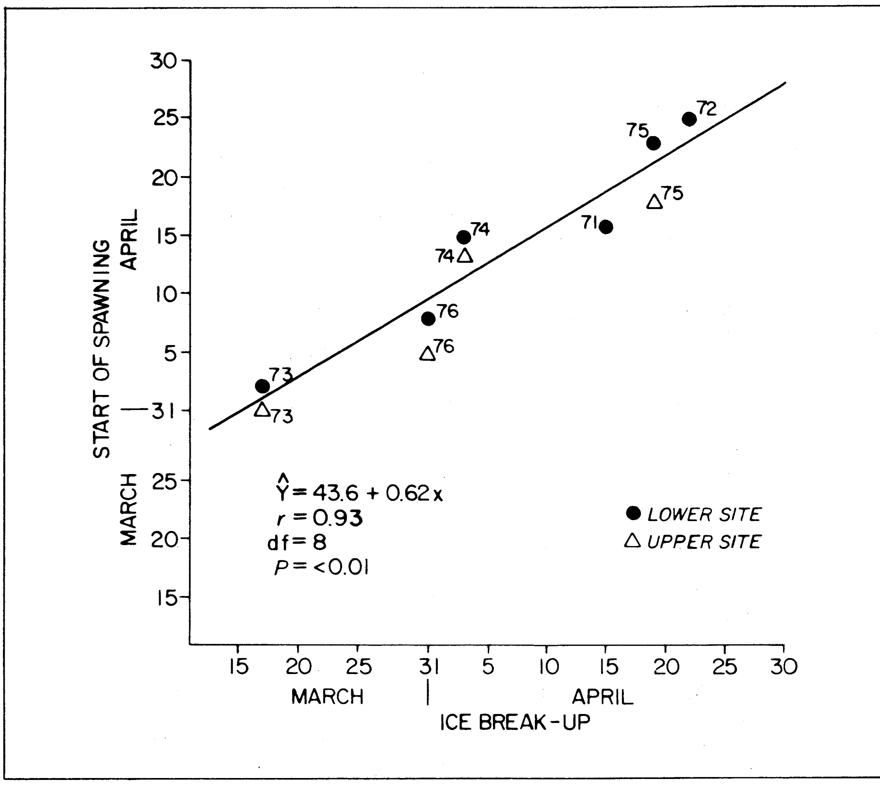


FIGURE 5. *Relation between spring ice breakup on Lake Winnebago and start of yellow perch spawning seasons in the Fox River, 1971-76. (Numbers indicate study years.)*

TABLE 7. *Number of yellow perch captured in fyke nets at two sites in the Fox River during spawning migrations, 1971-76.*

	Oshkosh (Downriver Sites)				Rivermoor (Upriver Site)			
Year	Days Netting	Total Catch	No. Lifts	Catch/ Effort (C/E)	Days Netting	Total Catch	No. Lifts	Catch/ Effort (C/E)
1971	10	3,556	20	177.8			-	
1972	22	12,564	88	142.8			-	
1973	23	2,952	57	51.8	24	2,825	40	70.6
1974	12	1,451	22	66.0	11	1,081	10	108.1
1975	16	3,005	30	100.2	15	2,880	22	130.9
1976	17	3,513	34	103.3	17	2,452	38	64.5
Total	100	27,041	251	107.7	67	9,238	110	84.0

Fecundity

Estimates of egg production were grouped by 10-mm total length intervals (Table 8). The average number of eggs/ovarian unit was 35,400. Counts ranged from 4,210 eggs in the smallest fish (age II, total length 132 mm, weight 28 g) to 120,810 eggs in one of the largest fish (age VII, 305 mm, 542 g). There was a positive relationship between mean fecundity and age (Fig. 8). Egg production by age groups ranged from an average 7,210 eggs for age II fish to 92,360 eggs for one female in age group IX.

Fecundity of the yellow perch was also correlated with average total body weight and average total length (Figs. 9 and 10). Tsai and Gibson (1971) also reported fecundity to increase linearly in proportion to total weight of individual females (r = 0.88), although their data were not grouped by size classes as in this study. Brazo et al. (1975) also observed fecundity to be proportional to body weight in Lake Michigan perch.

Lake Winnebago yellow perch averaged 14,400 eggs/100 g female weight and 15,436/100 mm female total length. The average gonad weight:body

TABLE 8. *Estimated egg production of Lake Winnebago yellow perch, 1971-72.*

Total Length (mm)	No. Fish Sampled	Mean Body Weight (g)	Mean Weight Entire Ovaries (g)	Mean Calculated No. Eggs
130 - 139	2	32	9.0	4,600
140 - 149	0	-	—	—
150 - 159	6	42	9.5	7,400
160 - 169	6	51	11.3	9,300
170 - 179	12	73	14.5	12,800
180 - 189	10	97	21.0	16,200
190 - 199	14	112	24.6	16,600
200 - 209	10	131	27.1	22,200
210 - 219	12	156	32.9	24,700
220 - 229	10	176	37.6	27,100
230 - 239	7	223	51.5	31,500
240 - 249	9	246	52.9	33,500
250 - 259	5	295	78.3	42,300
260 - 269	9	330	80.3	49,200
270 - 279	6	384	100.8	58,200
280 - 289	5	426	113.8	59,400
290 - 299	5	502	140.6	70,700
300 - 309	9	518	151.2	78,200
310 - 319	5	590	169.7	77,400
320 - 329	5	614	183.8	82,400
330 - 339	3	694	202.3	93,800
Total	150		Mean	35,400

weight ratio (fecundity index) for 150 females was 25% prior to spawning in April. In Lake Michigan, fecundity indexes ranged between 20 and 25% for all age classes immediately before spawning (Brazo et al. 1975), and ovary tissue made up 6% of the total ovary volume. Ovarian tissue, exclusive of ova, averaged 5% of the total ovary weight for Lake Winnebago perch.

Fecundity of yellow perch in Lake Winnebago was higher than fecundity of comparable length perch in other waters. Egg production from Lake Michigan perch ranged from 10,654 for an age II fish (190 mm total length, 82 g) to 157,594 for an age VI individual 354 mm long and weighing 678 g (Brazo et al. 1975). In Maryland, maximum perch egg production for the Severn River was 109,000 eggs for a 358 mm female (Muncy 1962) and 75,715 eggs for the largest individual (age VIII, 290 mm fork length, 411 g) in the Patuxent River (Tsai and Gibson 1971). Egg estimates recorded for Lake Ontario perch (Sheri and Power 1969) in the Bay of Quinte had individual ranges of 3,035 for an age II fish (135 mm fork length, 27 g) to 61,463 eggs for a 257 mm, age VIII fish that weighed 308 g.

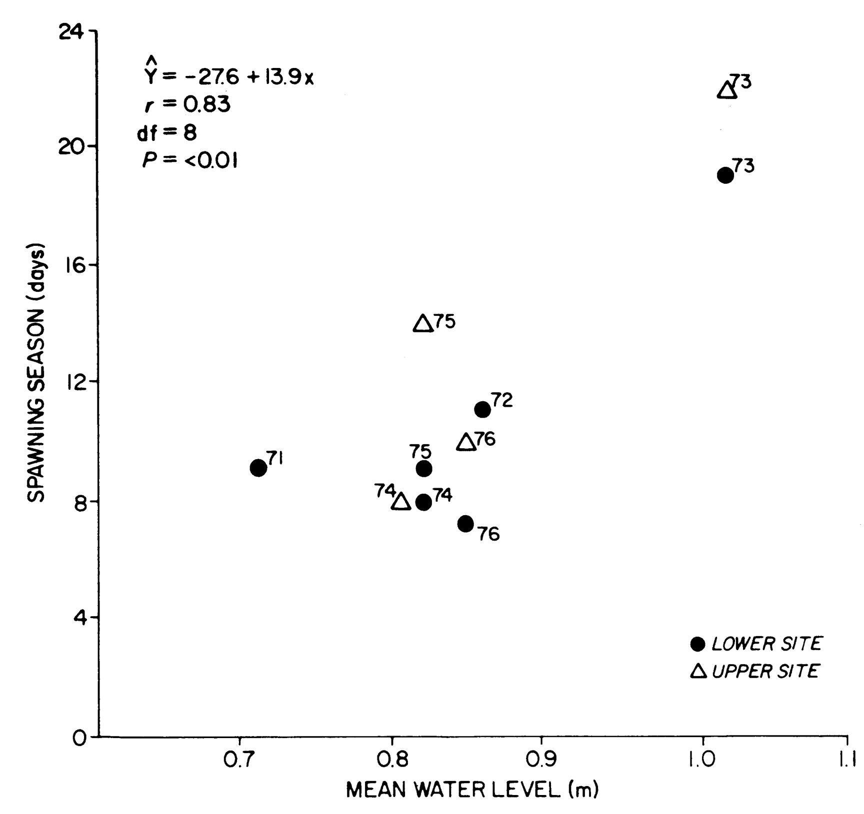


FIGURE 6. *Mean daily water levels during spawning and duration of yellow perch spawning seasons in the Fox River at Oshkosh and Rivermoor, 1971-76.*

Age and Size Composition of Spawning Stocks

Average ages for spawning males and females showed wide ranges during the study period (Fig. 11). The mean age for males ranged from 3.9 years (1972) to 5.2 years (1974) while females ranged from 3.9 years in 1971 to 6.6 years in 1975. The average age for both males and females increased between 1972 and 1975, with females showing greater increase. Modal age frequencies for the sexes were within one age group of each other except in 1976 when the majority of males were age III and females age VI. Differences in age composition of males and females within years is, in part, related to differences in age of maturity for the two sexes. Full recruitment to the spawning population takes 2-3 years for males and 2-5 years for females. For older fish, differential mortality between the sexes may be a factor along with fluctuations in year class strength. Greater longevity for females has been reported by many investigators (Carlander 1950).

Age frequency distributions for males and females combined (1971-76) show the influence of various year classes on the spawning population (Fig. 11). Relatively high survival of the 1968 and 1969 year classes can be followed from the initial dominance of these fish at age III in 1971 and 1972, respectively, through successive years. Between ages III and VII, the 1968 year class dominated the spawning population for a 5-year period (1971-75), comprising 30-52% of the perch sampled. In 1971, age III males and females each comprised over 50% of the respective age groups represented. The 1969 year class was not quite as dominant, comprising 34-40% of the population over a 3-year period between 1972 and 1974.

Low survival for the 1970 and 1971 year classes is indicated by low levels of recruitment of age III individuals in the 1973-74 spawning run (Fig. 11). These year classes made up only 11% and 8%, respectively, of the 1973 and 1974 spawning populations. In comparison, the 1968 and 1969 year classes made up 52% and 41% of the 1971 and 1972 spawning populations. The 1972 year class showed improved survival, with age III fish comprising 20% of the spawning population in 1975. Although a number of year classes were well represented in 1976, the spawning population was again dominated by age III fish representing the 1973 year class, which comprised 27% of all fish sampled.

Variation in the distribution of age groups was highest in 1971 and lowest in 1976, with the degree of variation

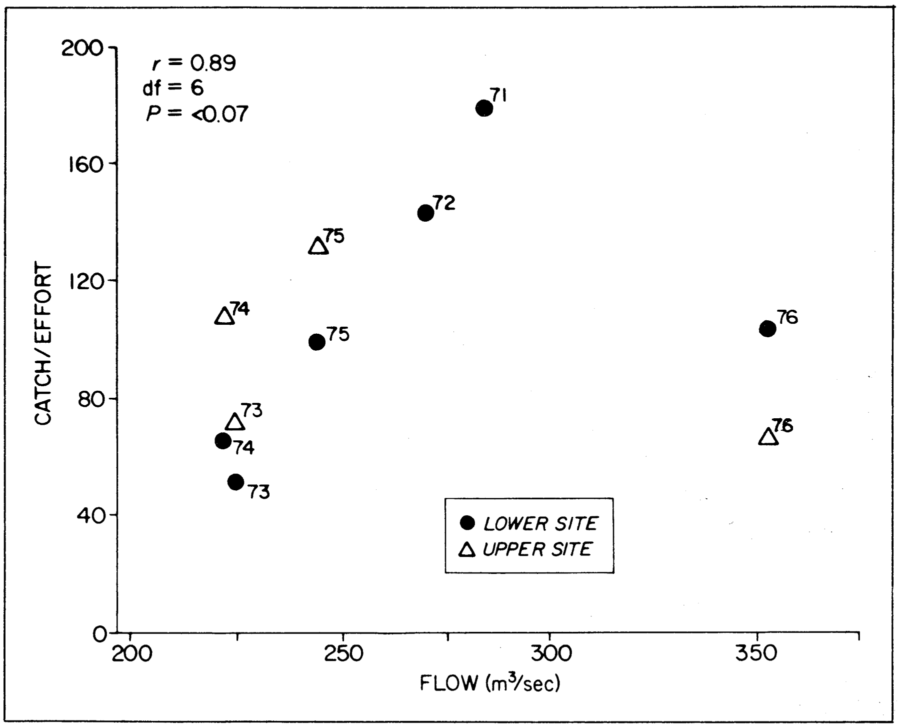


FIGURE 7. *Relation between mean flow and catch of yellow perch in the Fox River during spawning migrations, 1971-76. (Numbers indicate study years. Values for 1976 are shown, but regression analysis refers only to 1971-75.)*

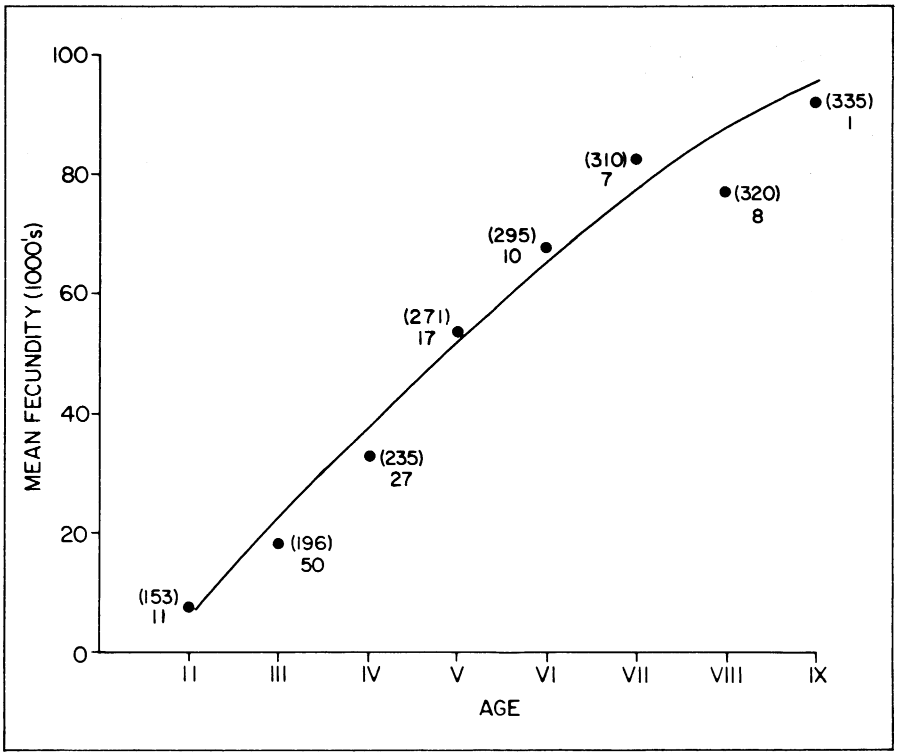


FIGURE 8. *Relationship between mean fecundity and age of 131 Lake Winnebago yellow perch, 1972. The average total length (mm) of fish in each age group is shown in parentheses and number in sample below. (Curve fitted by inspection.)*

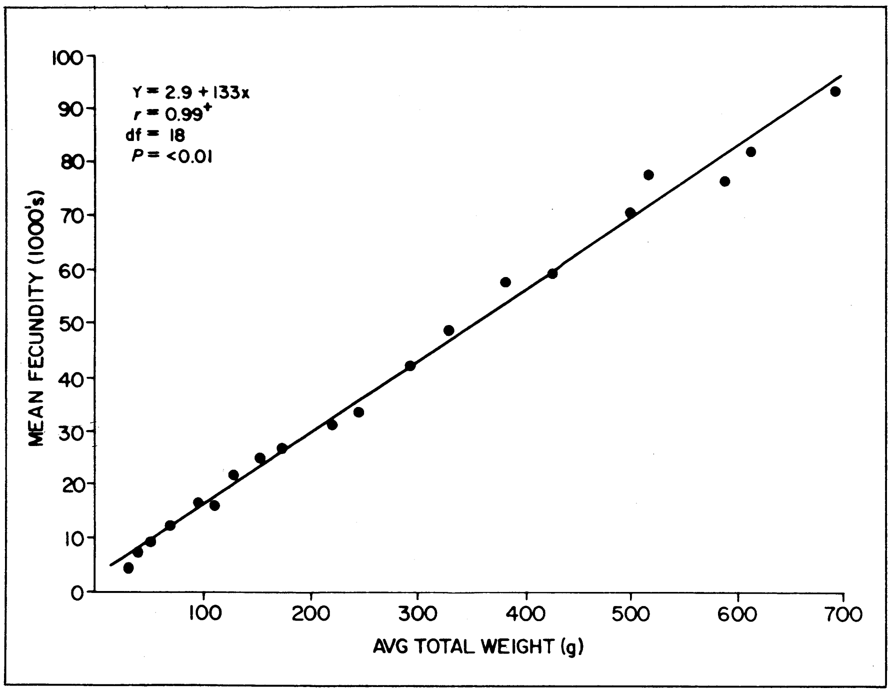


FIGURE 9. *Relationship between mean fecundity and average total weight of 150 yellow perch from Lake Winnebago, 1971-72. (Points represent mean fecundity and average weights for fish grouped by 10-mm total length intervals shown in Table 8).*

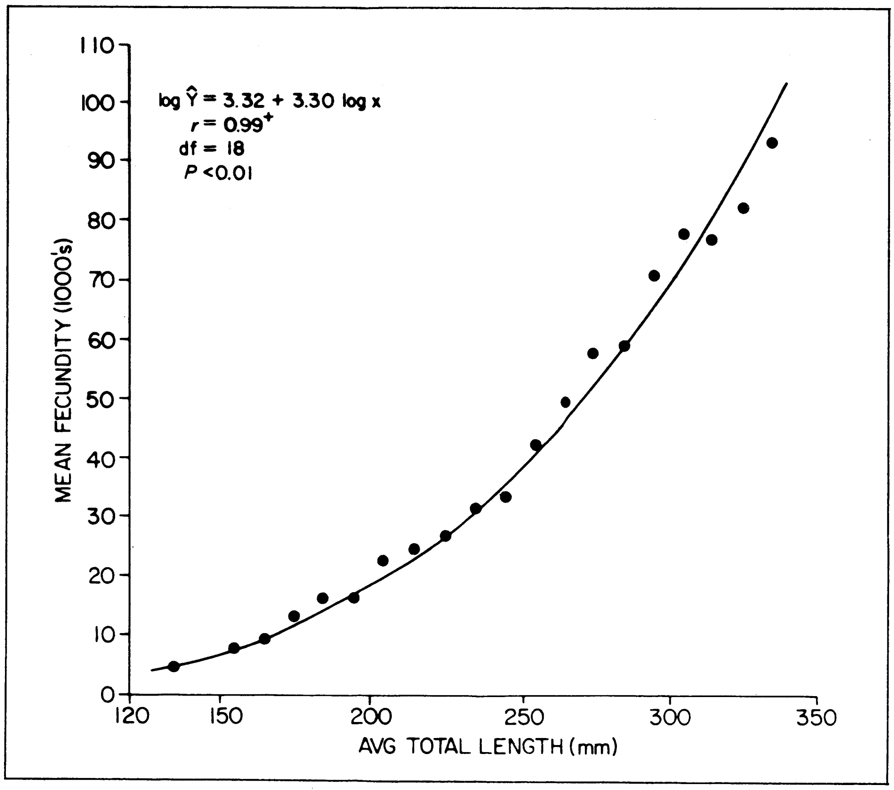


FIGURE 10. *Relationship between mean fecundity and average total length of 150 yellow perch from Lake Winnebago, 1971-72. (The curve represents calculated fecundity and the points estimated egg production for fish grouped by 10-mm total length intervals shown in Table 8).*

showing a progressive decline between 1971 and 1976 (Table 9). This variation indicates shifts in age class dominance in the spawning populations and differential recruitment of year classes entering the fishery. It also shows a gradual change from a younger to an older population. The greatest variation in age composition occurred in 1971-74 and the least in 1975-76, with the former being strongly influenced by dominant year classes.

TABLE 9. *Variation in the age distribution of yellow perch entering the Fox River spawning migrations, 1971-76.*

Year Sampled	Mean No. Fish/Age Group	Standard Deviation	Coef. of Variation
1971	445	601	135%
1972	1,571	1,925	122%
1973	369	462	125%
1974	207	239	115%
1975	334	305	91%
1976	421	305	72%

The age composition of Fox River spawning populations was quite similar to those reported by El-Zarka (1959) in his study of spawning perch in Saginaw Bay. He found strong domination by a single age group in 6 of the 11 years studied. Two age groups were strongly dominant in the remaining 5 years. Average age ranged between 3.8 years and 5.1 years. Age groups IV and V were the most common modal ages.

Large fluctuations in year class strength are common among perch populations (Ney 1978) and often find expression in uneven age composition of populations. Thus, the balanced age composition of the 1976 Fox River spawning population might be considered unusual.

The size composition of spawning stocks changed each year with corresponding changes in recruitment of younger fish and the relative stability of year classes present (Fig. 12). Modal lengths at both sites increased each year from 1971 to 1975, but were more diverse in 1976 due to a high proportion of small age III males recruited to the population. Annual increases in modal length were parallel for males and females (Append. Tables 35 and 36). Distributions for the populations were characteristically bimodal in 4 of the 6 years and nearly unimodal in 1973 (Fig. 12).

Frequency distribution curves for Rivermoor are similar to Oshkosh although modal size of yellow perch tended to be slightly larger at the lower site. The high percentage of males making up the catch at Rivermoor may account for this difference, since the average size of males was lower than for females in all years at both sites (Append. Tables 35 and 36). Separating the sexes, the average size of males and females was greater at the upper site.

Average daily lengths of perch captured at Oshkosh were examined to determine whether specific size groups showed any difference in time of migration (Table 10). Average daily length of females was highest during the first days of spawning migration in 1971, 1972, and 1973. In 1974-76, the highest average sizes occurred during peak spawning. For males, highest average daily lengths occurred at the beginning of spawning in 1971 and 1976 and at the end of spawning in 1972, 1974, and 1975. In 1973, average size of males remained fairly constant throughout the spawning season. A decrease in average daily length of males and females through the netting period was observed in only one year of study, 1971.

No clearcut relationships were found between the above patterns of migration and environmental conditions such as flow volume, water level, date of migration, or interval between onset of migration and spawning. However, there was a tendency for larger males and/or females to enter the migration first in years when the spawning population was dominated by young fish.

Tsai and Gibson (1971) found no difference in daily average length for either sex, indicating there was no size and perhaps no age difference during the yellow perch spawning migrations in the Patuxent River. No changes in the size distribution of either sex on the Severn River spawning grounds were recorded by Muncy (1962) or on southern Green Bay spawning sites by Belonger (1980). However, it is important to note that all of these studies covered only one year and thus could not show a pattern between years for the populations studied.

Growth

Growth in length is expressed as the grand average calculated length at each annulus. There were no differences in growth estimates between the grand average calculated lengths and the summation of average annual increments for either sex.

Growth in length appeared parabolic for both sexes, decreasing each year through the 8th year of life for males and through the 10th year of life

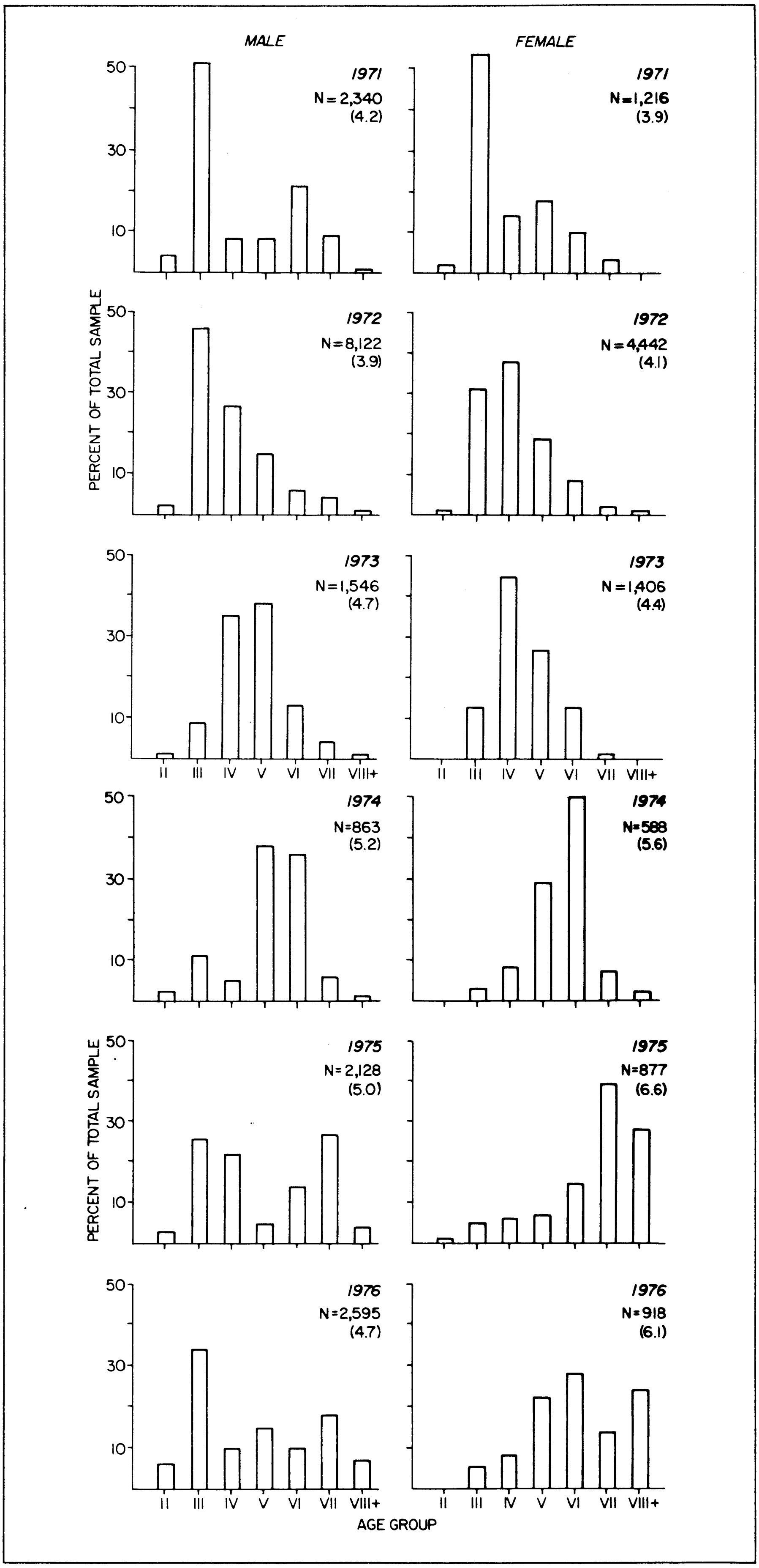


FIGURE 11. *Age frequency distribution of male and female yellow perch entering the Fox River spawning migration, 1971-73 and 1974-76. (Average age in parentheses.)*

TABLE 10. *Daily average lengths for male and female yellow perch taken at the (Oshkosh) site during 1971-76 spawning migrations.*

	Average Length (mm) by Sex											
Days	1971		1972		1973**		1974**		1975		1976	
Examined	M	F	M	F	M	F	M	F	M	F	M	F
1	228	242	209	252	230	250	209	265	191	272	236	260
2	242	260	214	259	229	251	226	248	196	240	236	233
3	228	250	211	246	231	247	238	271	187	257	230	233
4	218	* 245	203	245	230	240	238	270	202	267	234	263
5	205	* 222	186	231	227	241	235	271	228	* 276	238	* 270
6	206	* 226	190	229	228	246	246	* 273	230	* 290	232	* 280
7	206	226	192	* 233	218	247	243	* 272	222	* 286	212	* 267
8	203	211	187	* 224	221	239	229	* 254	228	* 284	224	267
9	207	210	191	* 230	218	246	243	272	223	280	210	242
10	218	171	205	236	231	247	250	273	208	283	195	251
11			199	231	222	244	245	273	218	273	191	240
12			197	232	228	242			218	267	196	252
13			197	232	227	247			242	267	209	240
14			197	224	228	244			241	281	209	250
15			197	223	220	232			241	283	208	249
16			198	225	232	* 247					189	262
17			204	228	220	* 249					192	254
18			206	230	229	* 245						
19			215	234	218	* 246						
20			220	227								
21			223	236								
22			210	216								
Avg. Length (mm)	216	237	199	217	228	245	237	269	216	276	211	258

*Periods of peak spawning.
**Nets were not lifted on all days in 1973-75 due to strong winds.

TABLE 11. *Relationship between length and sexual maturity of female yellow perch, Lake Winnebago, 1971-72.*

Total Length (mm)	No. Fish Sampled	No. Mature	Percent Mature
110 - 129	31	1	3.2
130 - 149	92	4	4.3
150 - 169	113	49	43.4
170 - 189	102	88	86.3
190 - 209	115	105	91.3
210 - 229	91	90	98.9
230 - 249	89	89	100.0
250 - 269	79	77	97.5
270 - 289	58	58	100.0
290 - 309	62	62	100.0
310 - 329	57	57	100.0
330 - 349	18	18	100.0
Total	907	698	77.0

TABLE 12. *Age at maturity of female yellow perch captured during the spring from the Fox River at Oshkosh and during the fall from Lake Winnebago, 1971-72.*

Age Group	No. Fish Sampled	No. Mature	Percent Mature
II	133	30	22.6
III	289	198	68.5
IV	221	208	94.1
V	109	107	98.2
VI	76	76	100.0
VII	49	49	100.0
VIII	26	26	100.0
IX	3	3	100.0
X	1	1	100.0
Total	907	698	77.0

for females (Fig. 13). Differential growth between the sexes was evident as females showed an annual growth advantage over males each year after the 1st year of life. This advantage, for the 2nd through 8th year, successively increased from 3 to 34 mm. The greatest annual increments of growth occurred during the first 2 years of life for both sexes. After the 2nd year, the increments of annual growth for males varied between 9 and 36 mm and for females between 10 and 41 mm.

Growth in weight of males and females followed a sigmoidal pattern, increasing slowly through the second year of life, reaching their greatest annual increments of growth during the respective 4th and 5th years, and declining during the remaining years of life (Fig. 14). Differential growth between the sexes was also evident for weight.After the 1st year, the weight of females exceeded that of males, and from the 2nd through the 9th year the difference progressively increased from 39 to 640 g. The greatest difference in weight between the sexes was observed in the 8th year when females weighed 573 g and males weighed 384 g. Males had their greatest growth in weight during the 4th year (70 g) and females during the 5th year (111 g).

Similar growth has been reported for yellow perch in large bodies of water except for back-calculated growth at the first annulus, which was greater for Lake Winnebago perch of both sexes (Ney 1974). Sexual dimorphism in growth rate is common, with female growth exceeding the male increment by the 3rd year of life (Ney 1978).

All males age II and older were mature except for one age II perch measuring 131 mm. The minimum size of mature males was 115 mm.

More than 80% of the females were mature at an average total length of 189 mm. All females 270 mm and longer were mature and 99% of females 230 mm and longer were mature (Table 11). If the average age at maturity for females is considered to be the age at which 50.0% of the fish reached maturity, female perch from Lake Winnebago matured at the end of their 3rd year of life (68.5% mature) (Table 12). All females were mature by the end of their 5th year of life.

Sexual maturity of yellow perch in Canada has been reported at age 3 for males and age 4 for females (Scott and Crossman 1973). In Lake Erie, 47.4% of all males 152-163 mm were mature as yearlings; the majority of females matured at total lengths of 203-229 mm during their 3rd year of life (Jobes 1952). In the Severn River, Maryland spawning run, Muncy (1962) found age I males mature at a size of 114 mm, while the smallest gravid female taken was 173 mm and in age group III. All fish older than age I, with the exception of only two age II females, were mature from Lake Michigan (Brazo et al. 1975).

Sex Ratios

Spawning males were caught in higher proportions than females although this difference was more pronounced at the upper site (Fig. 15). Average male to female ratios were

1.9:1 and 6.7:1 for the lower and upper sites, respectively. The difference in sex ratios between the two sites may be related to the physical nature of the river at the netting locations and the spawning behavior of male perch. The river is narrower at the upriver site, and nets, which were set away from the strongest current, were likely to capture fish remaining near the spawning area. Males appear to move into the spawning area and remain there considerably longer than females, making them more vulnerable to capture. The downriver site was located at a much wider area of the river and was swept by a strong current, which limited capture of males to the actual time of spawning.

Sex ratios were nearly balanced at the lower site in 1973. Females outnumbered males on 6 of the 19 netting days, and on the last 3 days comprised 93% of the catch. This atypical situation may be characteristic of nearly balanced spawning stocks in combination with the protracted spawning season (19 days), or possibly the flooding conditions in the study area that year influenced the distribution of sexes at this site more than usual by making other areas more available to spawners.

Daily male to female ratios ranged from 0.1 to 7.3 at Oshkosh and from 1.3 to 51.4 at Rivermoor (Table 13). At Rivermoor, males were present in greater proportions toward the beginning of the spawning migrations in 1973 and 1975 and toward the end in 1974 and 1976. No pattern in sex ratio fluctuations at Oshkosh was observed in other study years.

A high sex ratio of 6.9:1 (87% males) was reported in the 1958 Severn River spawning run by Muncy (1962), suggesting that higher sex ratios result from the longer time males stay on spawning grounds and earlier sexual maturity of males. By contrast, the spawning season sex ratio in the Patuxent River, Maryland was 2.2:1 (69% males) with a 1:1 sex ratio occurring at peak spawning (Tsai and Gibson 1971). Dominance of males at the beginning and end of yellow perch spawning runs have been documented by researchers for the Great Lakes (El-Zarka 1959 and Brazo et al. 1975).

Postspawning Distribution and Angler Exploitation

Information on perch movement after spawning is primarily based on 525 tag returns by anglers. Although many of the fish were tagged en route to spawning sites, it is doubtful that many were recaptured before spawning. Anglers reported that their catch consisted mainly of spent fish.

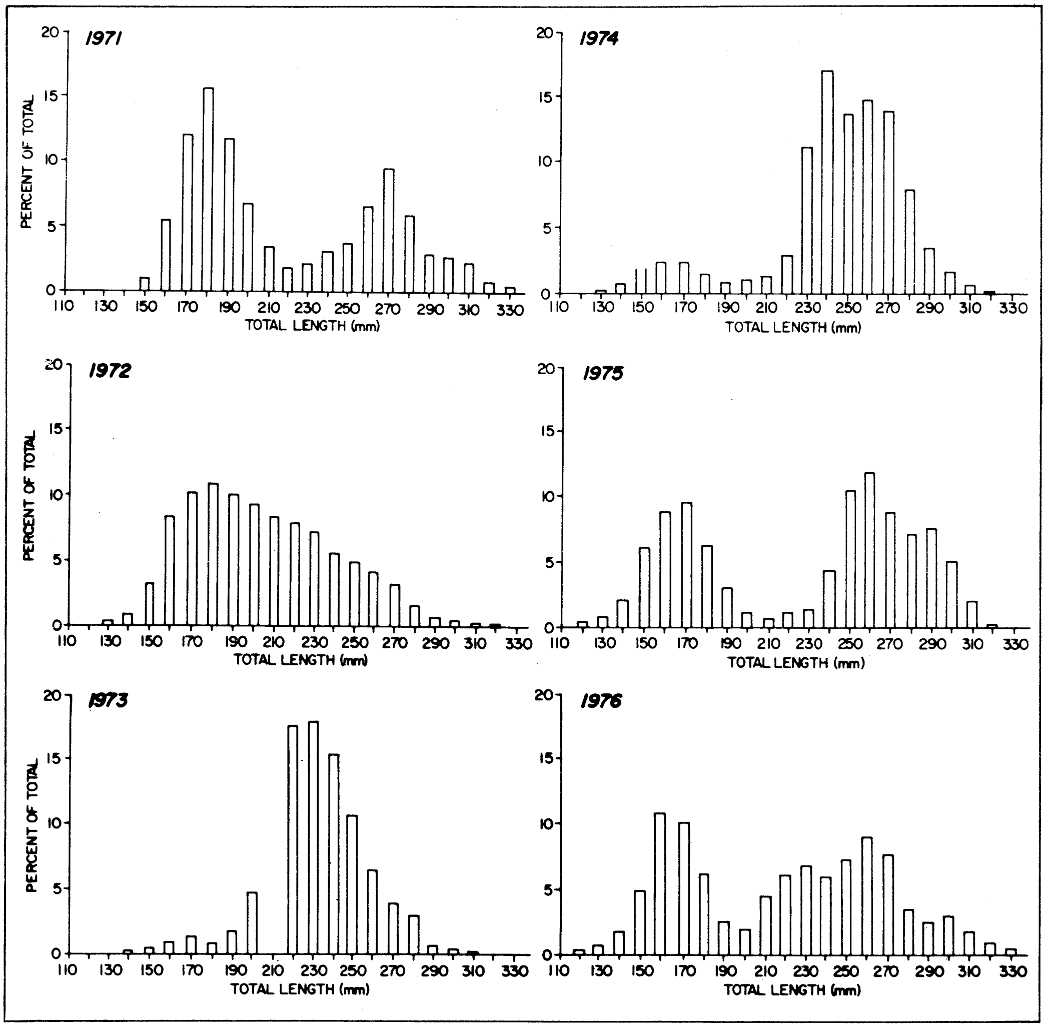


FIGURE 12. *Length frequency distribution for yellow perch captured in the Fox River at Oshkosh, 1971-72.*

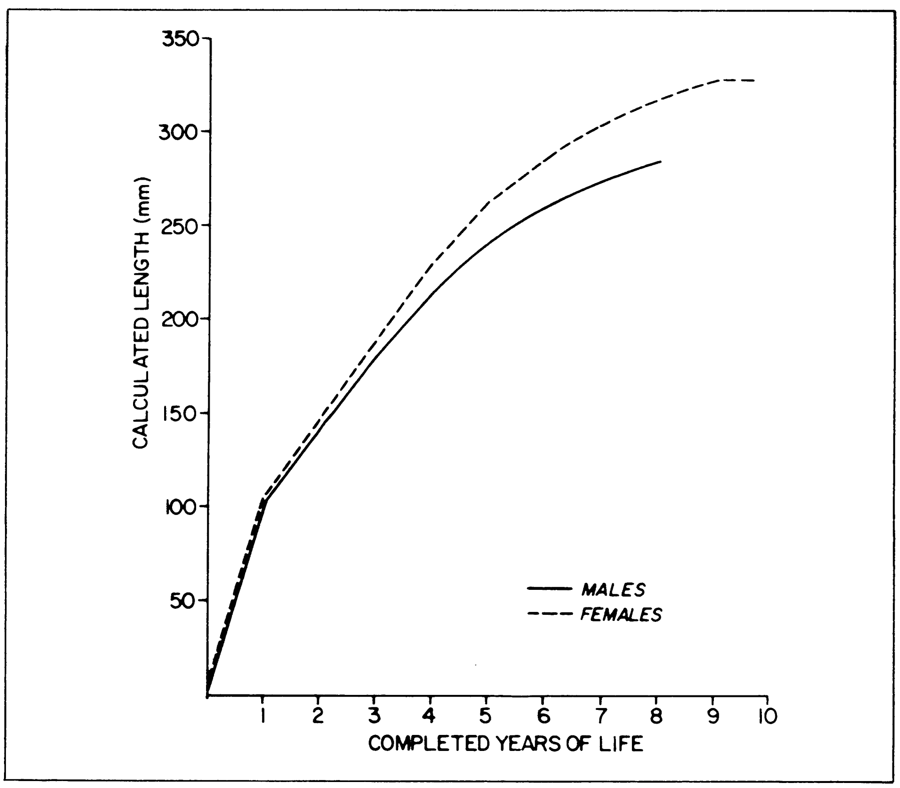


FIGURE 13. *Calculated growth in length of male and female yellow perch from the Fox River at Oshkosh and Lake Winnebago, 1971-72.*

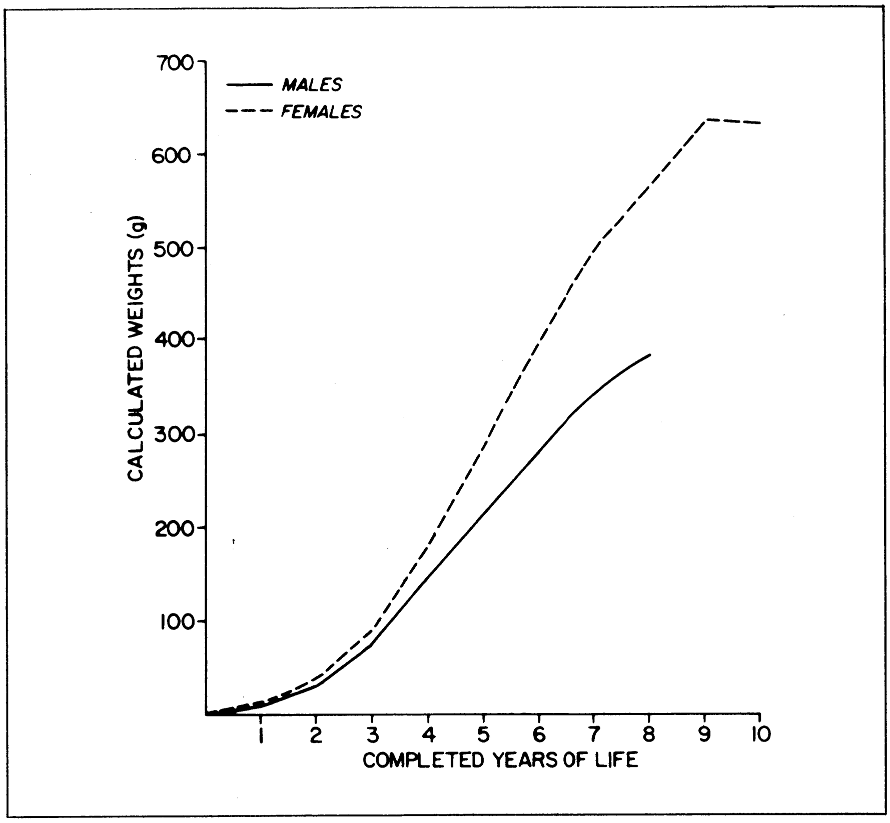


FIGURE 14. *Calculated growth in weight of male and female yellow perch from the Fox River at Oshkosh and Lake Winnebago, 1971-72.*

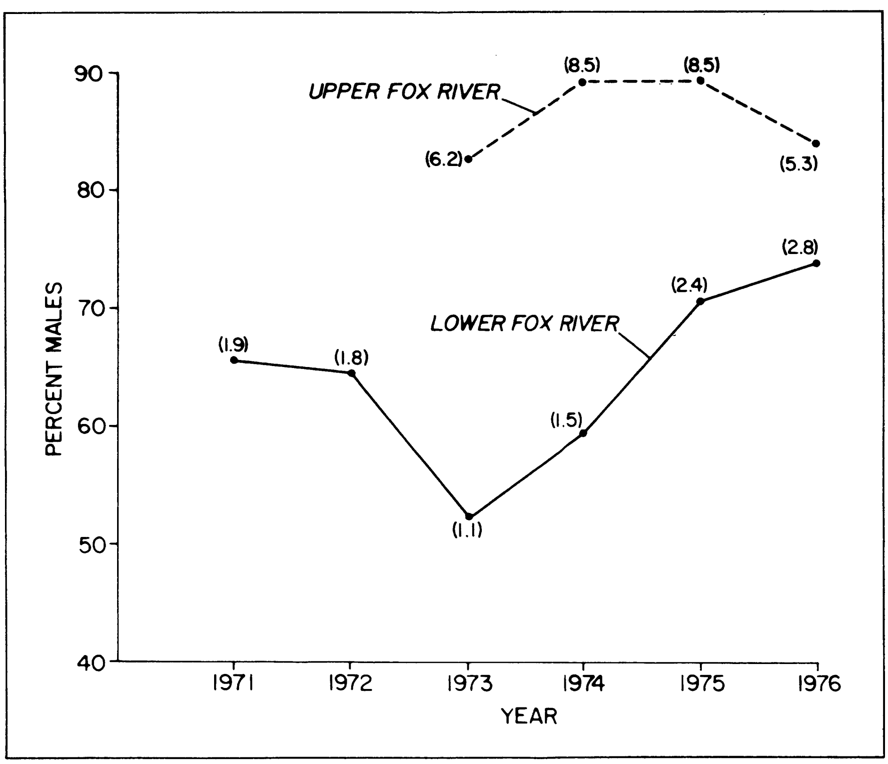


FIGURE 15. *Frequency distribution for male yellow perch during spawning migration at the two study sites. The ratios of males to females for each year are shown in parentheses.*

Perch were recaptured throughout the Lake Winnebago system, but over 84% were taken in Lake Winnebago (Table 2). Average recapture intervals were shortest for fish in the upper Fox River and Lake Winneconne at 39 and 59 days, respectively, indicating initial dispersal to these areas (Fig. 16 and 17). In contrast, perch recaptured in Lake Winnebago remained at large an average of 307 days. The average interval for Lake Butte des Morts was also high, 303 days, further suggesting that a resident perch population exists there as well. The greatest average recapture interval was 665 days for the lower Fox River at Appleton. All recaptures were at large an average of 293 days from time of tagging.

The length of time perch remain upriver before returning to Lake Winnebago is not precisely known. The number of days elapsed between the midpoint of each year's spawning season and the first recapture from Lake Winnebago was 19 for 1971, 18 for 1972, and 35 for 1973. However, it is unlikely that these numbers are representative of the entire spawning population. No pronounced downriver migration was observed during any study year; fish apparently straggle back to the lake over an extended period.

The reason for the continued upstream migration of some perch tagged at spawning sites in the Fox River is not known. These migrations could represent feeding migrations to upriver lakes or reflect lengthy spawning migrations by fish merely intercepted at downriver netting locations. Lengthy postspawning movements have been observed among perch tagged in Green Bay (Mraz 1951) and the Severn River (Muncy 1962). Although most fish tagged in these studies were recaptured within a few kilometers of tagging, a few fish travelled as far as 64-81 km.

Angler exploitation of yellow perch in the study area was estimated from 539 tags returned between 1971 and 1977. Combining all marking periods, annual exploitation rates averaged 5.4% for the 1st year perch were at large before capture (Table 14). Sixty-nine percent of all captures were made in this 1st year. Returns dropped off sharply in subsequent years, dipping below 1% by the 3rd year following tagging. Return rate for the 6-year period was 7.7%. Since tag returns were voluntary, these figures should be taken as minimum estimates of exploitation.

Clady (1977a) noted a similar pattern of tag returns for spawning perch in Oneida Lake, New York. A majority of recaptures (55%) was made during

TABLE 13. *Number of males/female present daily at two spawning sites on the Fox River, 1971-76.*

Day of	Oshkosh						Rivermoor			
Mig.	1971	1972	1973	1974	1975	1976	1973	1974	1975	1976
1	1.1	3.5	1.1	1.3	3.1	2.1	46.0	-	-	1.3
2	2.1	3.1	1.2	1.3	3.6	0.9	19.0	9.9	-	4.3
3	1.7	2.6	1.9	-	4.9	2.1	14.4	-	13.8	2.0
4	2.0	3.1	1.1	1.9	7.3	4.4	-	6.1	15.0	7.4
5	1.5	1.9	0.9	2.2	5.1	3.6	7.4	9.3	51.4	2.8
6	2.0	2.4	1.4	2.5	1.7	2.8	6.3	10.4	16.4	2.5
7	1.9	2.9	2.0	1.1	1.9	2.2	7.2	8.7	8.4	4.1
8	1.3	2.5	1.8	1.2	2.2	3.0	7.1	7.0	4.0	3.3
9	4.1	2.5	1.1	2.1	3.2	5.2	6.1	15.1	5.6	4.1
10	5.0	2.5	0.8	0.9	2.5	5.2	-	11.0	4.7	6.0
11		2.3	1.0	1.0	3.5	4.0	3.2		8.1	8.3
12		4.1	-*	1.4	2.1	5.4	-		9.6	4.6
13		2.4	-		-	2.0	-		7.8	7.0
14		1.8	2.5		1.6	1.1	3.1		14.3	5.1
15		1.3	2.0		0.7	4.4	5.9			9.4
16		1.5	1.6		0.8	1.7	7.5			14.8
17		0.8	1.4			0.9	9.9			15.5
18		0.6	-				8.6			
19		0.8	-				10.6			
20		1.9	0.6				9.5			
21		5.6	0.1				4.7			
22		4.2	0.1				4.6			
23			0.1				3.2			
Avg.	1.9	1.8	1.1	1.5	2.4	2.8	6.2	8.5	8.5	5.3

*Dashes represent days when nets were not lifted because of strong winds.

TABLE 15. *Length-frequency of yellow perch tagged at the Oshkosh and Rivermoor study sites in the Fox River and those fish recaptured by anglers in Lake Winnebago and connecting waters.**

Total Length (mm)	Tagged No.	Tagged % Total Tagged	Recaptured No.	Recaptured % Total Recaptured	Recaptured % Tagged in Length Interval
130 - 149	26	0.4			
150 - 169	733	11.8	20	4.3	2.7
170 - 189	1,270	20.4	51	10.9	4.0
190 - 209	1,084	17.4	81	17.4	7.5
210 - 229	1,146	18.4	110	23.6	9.6
230 - 249	862	13.8	89	19.1	10.3
250 - 269	603	9.7	65	13.9	10.8
270 - 289	394	6.3	39	8.4	9.9
290 - 309	84	1.3	9	1.9	10.7
310 - 329	25	0.4	2	0.4	8.0
330 - 349	3	**	**	**	**
Total	6,230		466		7.5

*Does not include 740 tagged fish marked at the upper Fox River site (Rivermoor) in 1973, and 73 angler-recaptured fish from this group; tags were not numbered.
**Less than 0.5%

TABLE 14. *Number and percentage (in parentheses) of tags returned by anglers from yellow perch tagged in the Fox River, 1971-73.*

Tagging Site	Year Tagged	No. Tagged	No. Years After Tagging: 1	2	3	4	5	6	Total
Oshkosh	1971	539	32 (5.9)	8 (1.5)	1 (0.2)				41 (7.6)
Oshkosh	1972	4,818	254 (5.3)	75 (1.6)	10 (0.2)	10 (0.2)	4 (0.1)	4 (0.1)	357 (7.4)
Rivermoor	1973	1,613	88 (5.5)	16 (1.0)	24 (1.5)	9 (0.6)	4 (0.2)		141 (8.7)
Total		6,970	374 (5.4)	99 (1.4)	35 (0.5)	19 (0.3)	8 (0.1)	4 (0.06)	539 (7.7)

the first year following tagging, although fish stayed at large up to 8 years. A total of 4.4% of all fish tagged were caught by anglers. Muncy (1962) found a return rate of 13.9% over a 4-year period for perch tagged during spawning in the Severn River, Maryland. In 2 long-term Wisconsin studies with compulsory creel censuses, exploitation averaged 5% (Snow 1978) and 15% (Kempinger et al. 1975).

Angler return of perch tagged in the Fox River was highest within the 250-269 mm length interval although it ran 10-11% for all size intervals between 210 and 309 mm (Table 15). Return rate was lowest for fish measuring less than 190 mm, averaging only 3.5%. Although 33% of all fish tagged were less than 190 mm long, only 15% of fish caught by anglers were from this size interval. None of the 26 tagged fish below 150 mm was recaptured by anglers. The percentage of fish recaptured was greater than the percentage tagged for all sizes intervals between 210 and 309 mm. Modal length for recaptured fish was 220 mm compared to 180 mm for all tagged fish.

Differential tagging mortality is suspected as a factor in the low return of fish under 190 mm and may be a factor in the different frequency distribution of tagged and recaptured fish. The mortality is most likely due to the combined stress of handling and tag wounding, although neither was verified in this study. Perch of this size would belong to age groups II and III; overall survival of spawning fish of these age groups was quite good during initial recapture years (Fig. 11). The possibility of higher mortality of small tagged fish makes it difficult to conclude whether there was any angler selectivity of larger fish. Excluding these small fish, the percentage of tagged fish recaptured by length interval was quite similar.

Tagged perch were caught by anglers in all months except November although 58% were taken in July and August. Returns from October-March comprised less than 3% of the total. Only about 10% of the tagged perch were taken during the spawning season.

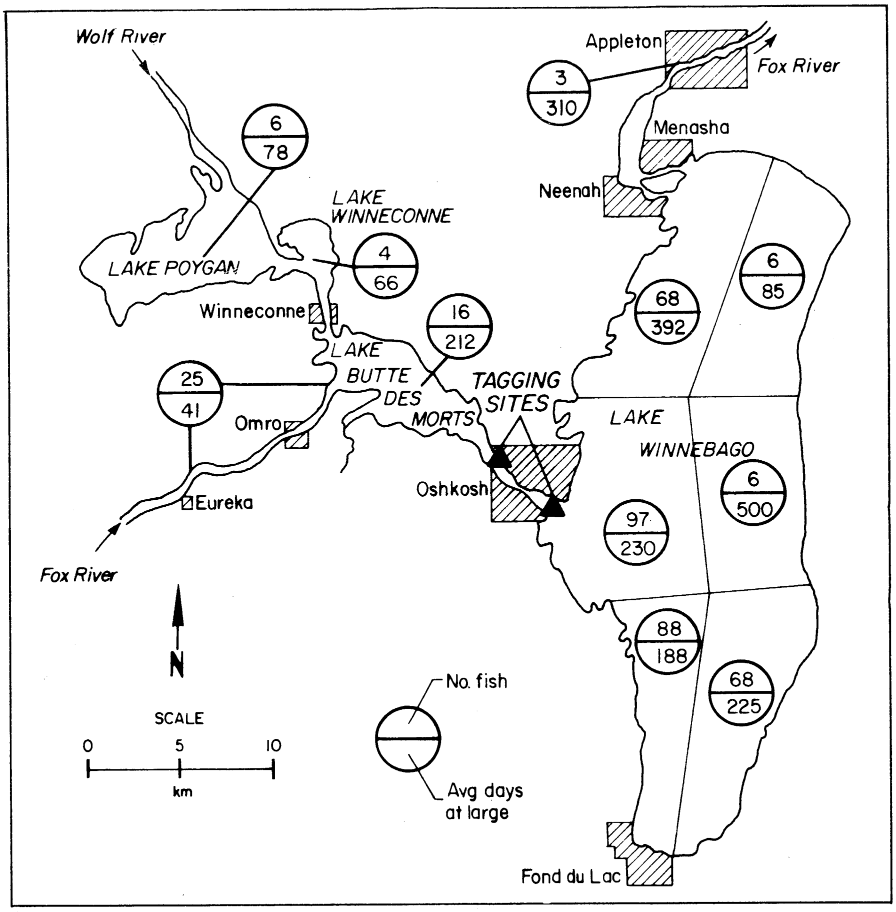


FIGURE 16. *Distribution of tagged yellow perch by recapture zones as reported by anglers through December 1977, and average numbers of days fish were at large. All fish were marked in April 1971 and 1972 at the Oshkosh study sites.*

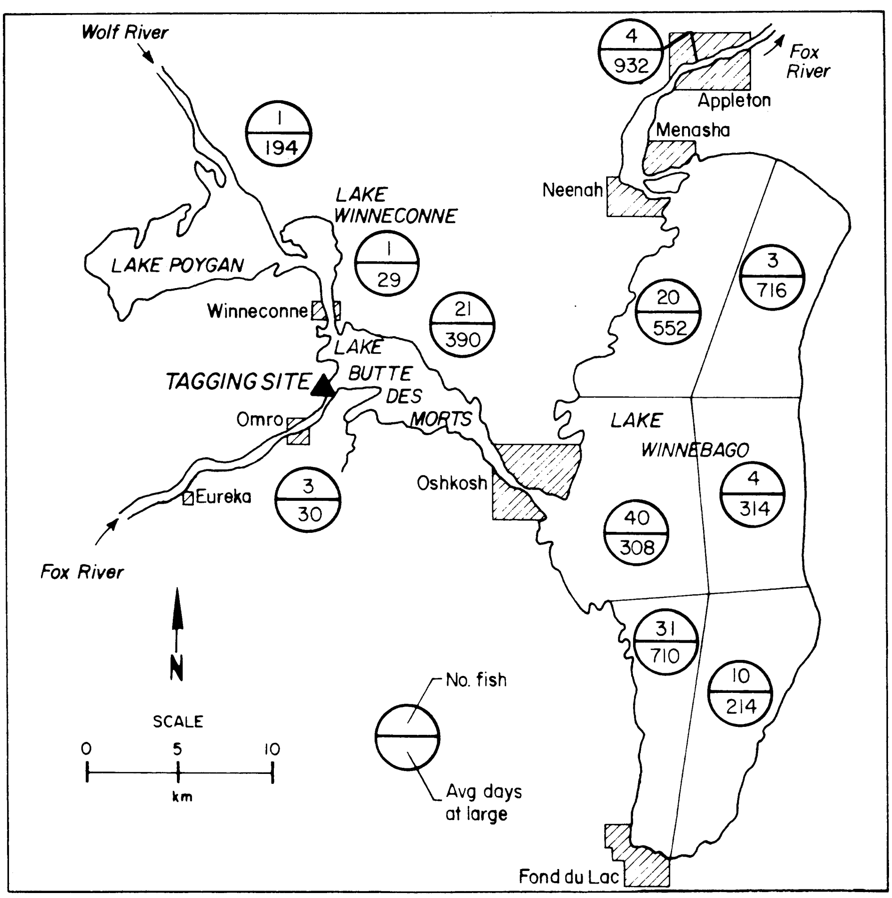


FIGURE 17. *Distribution of tagged yellow perch by recapture zones as reported by anglers through December 1977, and average number of days fish were at large. All fish were marked in March and April 1973 at the Rivermoor study site.*

Tagged females were caught more than twice as often as males in 1971 and 1972 although recapture rates for perch tagged in 1973 were about equal for the sexes (Table 16). The difference observed in 1971 and 1972 may be related to differential survival of the sexes or to differences in their angling vulnerability, since females exhibited greater longevity and growth than males. It is also possible that it reflects tagging mortality for small perch (below 190 mm) since males were more heavily represented in these size ranges than females. In 1973, the average size of both males and females was larger than the previous 2 years.

A higher recapture rate for tagged female perch was also found by Clady (1977a) in a 14-year study of yellow perch tagged during spawning in Oneida Lake. He also found a higher recapture rate for larger fish. However, Muncy (1962) found no selectivity for larger perch in the Severn River. In his tagging study of yellow perch in Green Bay, Mraz (1951) noted that no perch below 165 mm were recaptured and only 2.5% of fish under 226 mm were caught by anglers. He postulated that tagging mortality might be involved. Monel-metal strap tags were used.

EGG DEVELOPMENT

Eggs "eyed" each year except one on the 9th or 10th day of incubation, although water temperatures varied from year to year (Tables 17 and 18). The exception was a 12-day period noted at the upriver site in 1975, although eggs at a nearby site in the same year eyed in 10 days. Incubation time was somewhat more variable, ranging from 11 to 15 days for the initiation of hatching (first egg hatched) and from 14 to 20 days for complete hatching (last egg hatched). Actual hatching period ranged from 2 to 7 days.

Water temperatures during incubation ranged from a low of 2.7 C to a high of 21.6 C for the 5 years studied. Within a given year and site, minimum and maximum temperatures were separated by 9-18 degrees. Mean daily temperatures for each year were more constant, falling within 1° of each other at the upriver site and within 3° at the downriver site.

Water temperatures exhibited a general rising trend throughout the incubation period in 1972-75, but temperatures fell over the latter half of incubation at both Oshkosh and Rivermoor in 1976 (Append. Figs. 29, 30). Fluctuations were numerous. To analyze whether water temperature had any effect on length of egg development, two indexes were developed

TABLE 16. *Number of yellow perch tagged in the Fox River, and number and percent (in parentheses) of tags returned by anglers 1971-77, according to sex and year tagged.*

Year Tagged	Tagging Site	No. Fish Tagged Male	Female	Total	Mean Length (mm) Male	Female	Total	No. Tags Returned Male	Female	Total
1971	Oshkosh	361	178	539	207	225	213	20 (5.5)	21 (11.8)	41 (7.6)
1972	Oshkosh	3,382	1,436	4,818	201	233	211	170 (5.0)	187 (13.0)	357 (7.4)
1973*	Rivermoor	777	96	873	221	242	223	60 (7.7)	8 (8.3)	68 (7.8)
Total		4,520	1,710	6,230	205	232	212	250 (5.5)	216 (12.6)	466 (7.5)

*Data exclude 73 recaptures from 740 fish with tags not numbered in 1973.

TABLE 17. *Summary of data related to phenology of yellow perch egg development, incubation and hatching in the Fox River at Oshkosh, 1972-76.*

Egg Incubation Parameters	Year 1972	1973	1974	1975	1976
Incubation dates	30 Apr-17 May	17 Apr-7 May	21 Apr-6 May	26 Apr-14 May	12-26 Apr
Eggs "eyed" (days)*	10	9	9	10	9
Incubation time (days)*	12-17	13-20	12-15	15-18	12-14
Hatching period (days)*	5	7	3	3	2
Water temperature (°C)					
At fertilization	11.6	7.2	12.7	9.4	7.2
Incubation period					
Mean minimum	12.0	9.0	9.8	9.3	10.3
Mean maximum	16.0	14.1	16.3	13.8	12.5
Mean daily	14.0	11.6	13.1	11.6	11.4
Range	8.3-21.6	4.4-16.1	2.7-21.0	4.4-17.7	5.5-16.1
Cumulative degree-days over 4.4 C	163	142	131	128	98
Water temperature fluctuation index	1.33	1.56	1.66	1.48	1.17

* Days after fertilization

TABLE 18. *Summary of data related to phenology of yellow perch egg development, incubation and hatching in the Fox River at Rivermoor, 1973, 1975, and 1976.*

Egg Incubation Parameters	1973 (Egg Buckets)	1975 (Submerged Pine Trees Upper Lotus Bed)	1975 (Submerged Pine Trees Lower Lotus Bed)	1976 (Egg Buckets)
Incubation dates	14-30 Apr	24 Apr-10 May	27 Apr-11 May	9-26 Apr
Eggs "eyed" (days)*	9	12	10	10
Incubation time (days)*	11-17	14-17	13-15	15-18
Hatching period (days)*	6	3	2	3
Water temperature (°C)				
At fertilization	3.8	8.8	8.3	12.7
Incubation period				
Mean minimum	10.6	10.4	11.2	10.7
Mean maximum	13.1	12.3	12.8	13.1
Mean daily	11.6	11.6	12.2	11.8
Range	3.3-16.6	6.1-17.2	6.1-17.2	6.6-18.8
Cumulative degree-days over 4.4 C	126	119	131	124
Water temperature fluctuation index	1.24	1.18	1.14	1.22

*Days after fertilization

(Tables 17 and 18). The water temperature fluctuation index was the ratio of each year's mean maximum water temperature to the mean minimum. The higher the index, the wider the temperature range during incubation. A second index was the cumulative degree-days over 4.4 C for each incubation period, representing the total amount of heat available to the eggs. Regression analysis indicated no relationship between either index and time (days) from fertilization to hatching of the last egg. A qualitative comparison of water temperature levels and patterns (rising or falling) with length of hatching period showed no apparent relationship.

Incubation periods of yellow perch in the Fox River fall within the ranges reported by most investigators for North American waters. Mean daily water temperatures fall within the 10-16 C range for optimum hatching (Hokanson and Kleiner, 1973) although, mean minimum temperatures fell slightly below 10 C in 3 years at the Oshkosh study site. Hokanson and Kleiner also found that under laboratory conditions, rising water temperatures produced shorter hatching periods and greater survival of perch larvae. Although the rising water temperature regimes of the Fox River may have some overall effect on incubation periods, year-to-year relationships between temperature patterns and incubation duration were not apparent in the study years.

Although no quantitative measurements were made of egg predation in the Lake Winnebago study area, observations in 1972 suggest it may be substantial. Viable eggs spawned naturally on submerged pine trees at two study sites were lost just prior to hatching. Crayfish (*Orconectes rusticus*) were found on branches of the trees at both sites on the day of egg disappearance. Mudpuppies (*Necturus maculosus*) were frequently observed in fyke nets at the downriver sites in all study years. Siltation may also contribute to egg mortality. Heavy mortality was observed among eggs held in screened buckets at the Rivermoor site in 1976. Siltation was noted beginning on the 7th day of incubation, and although eggs were cleaned of silt daily, mortality increased to approximately 60% before hatching began.

Dissolved oxygen was not a limiting factor in egg development at either study site. River currents kept the water well-oxygenated, between 8 and 11 ppm.

LARVAL STAGES

Growth

Prolarval yellow perch netted in the Fox River shortly after hatching were 5.0-6.0 mm in length. These fish were transparent and carried a well-developed yolk sac, both characteristic of newly hatched fish. No measurements were made of larvae confined to the egg monitoring buckets. The criterion for determining size at yolk sac absorption in a given year was the point when 50% or more of the larvae examined in 1-mm groupings had absorbed the yolk. Fish were designated postlarvae (transformed larvae) at this point. Size ranged from 5.0-8.0 mm for the 5 years of study. Lengths of prolarvae and postlarvae were similar to those found in other studies (Noble 1971, Mansueti 1964, and Siefert 1972).

Larval perch reached an average 11.5 mm by the end of May, approximately double their size at hatching (Fig. 22). By mid-June, average length had increased to 27 mm. By this time, most perch had attained juvenile characteristics and had become demersal.

Growth was greatest in 1971 and least in 1975. Overall growth appeared similar for perch captured from limnetic (trawl sample) and littoral habitats (seine sample).

Movement

Prolarval yellow perch are active soon after hatching and are capable of swimming in swift, well-coordinated movements. However, they are unable to sustain directed movement against a current. It was assumed that larval yellow perch hatched in the Fox River study area were carried downstream by the current until they reached quiet water, Lake Butte des Morts or Lake Winnebago. Meter net captures of larval perch in the river at the entrance to these waters confirmed that immigration does occur (Table 19).

Larval perch captured in 1973 in the Fox River at its entrance to Lake Winnebago were used to estimate rates of emigration from upstream hatching sites to the lake (Fig. 18). Fry first appeared in the mouth of the river 3-6 days after peak spawning at the lower site, and 2-7 days after peak spawning at the upper site. Densities progressively increased through early May, then dropped off sharply. A second peak occurred in late May. Recruitment of fry to the lake was essentially complete by the end of the first week in June.

The frequency at which larval perch were observed in the mouth of the Fox River appears to relate to relative distances between site of hatching and site of capture. Thus, larvae captured after mid-May presumably had the most distant origin. All perch larvae captured after this date were fully transformed to the postlarval stage.

No relationship was found between stream flow and the rate of movement and distribution of perch larvae into Lake Winnebago.

Movements of individual larvae were not traced in this study. Thus, it was not possible to verify that larvae originating at Rivermoor or more distant upriver sites actually arrive in Lake Winnebago. However, catch/effort data suggest that at least some portion of these larvae do reach the lake (Table 19). Larval yellow perch were 5-8 times more abundant at the mouth of the Fox River than at either of the two upriver areas sampled. The homing behavior of spawning fish to the Rivermoor site, discussed earlier in this report, may also indicate successful movement from upriver areas to the lake.

Food Habits

Although no food was found in stomachs of prolarval yellow perch analyzed in 1972 and 1973, 54.0% of prolarvae stomachs analyzed in 1974 and 12.2% of those analyzed in 1975 contained food (Table 20). Immature copepods (copepodids and nauplii) were the principal food item found although small numbers of cladocerans and ostracods were also present.

Size at which yellow perch began feeding ranged from 5.0 to 6.9 mm during 1971-75. Feeding was initiated in the prolarval stage in 1974 and 1975 and in the postlarval stage in 1972 and 1973. Date of feeding initiation was not determined in 1970 or 1971; no prolarvae were observed in the collections.

Among postlarval perch, copepods were, by far, the most common food items observed, occurring in all stomachs each year of study and making up 81-99% of total food items (Table 21). Most copepods were immature with the two larval forms exhibiting a complementary relationship. Years in which copepodid intake was high coincided with low nauplii intake, a pattern most likely related to copepod life cycles and growth rates. Mature copepods (*Diaptomus* and *Cyclops*), cladocerans (primarily *Daphnia* and *Bosmina*), plus chironomid larvae and ostracods were observed in amounts ranging from a trace to 28% of total food items over the 6 study years. Percent frequency of occurrence of these items ranged from a trace to 66%. No single food item was observed in all years of study. Besides immature cope-

TABLE 19. *A summary of meter net captures of larval yellow perch taken in the Fox and Wolf rivers and Lake Winnebago, April-June, 1973.*

Location and Sample Dates	No. Hauls	No. Fry	C/E
Wolf River - Winneconne (27, 30 Apr; 4, 15, 18 May)	25	461	18.4
Fox River - Rivermoor (23-27, 30 Apr; 4 May)	45	1,159	25.8
Fox River (mouth) - Oshkosh (23-25, 27 Apr)	118	16,274	137.9
Lake Winnebago (9, 17, 30 May; 6 June)	40	27,235	680.9

TABLE 20. *Number of prolarval yellow perch examined for food and number of food items observed in collections, Lake Winnebago, 1972-75.*

	Prolarvae			
Year	No. Examined	No. with Food	Food Items	No. Food Items
1972	10	0	—	—
1973	32	0	—	—
1974	113	61 (54.0)*	Copepoda	288
			Nauplii	95
			Copepodids	176
			Cyclops	17
			Cladocera	5
			Bosmina	1
			Chydorus	2
			Daphnia	1
			Sida	1
			Ostracoda	1
1975	82	10 (12.2)	Copepoda	35
			Nauplii	15
			Copepodids	20
			Cladocera	2
			Daphnia	2
Total	237	71 (30.0)		

*Percent of digestive tracts with food.

pods, only 2 categories of food items exceeded the 25% level in frequency of occurrence or total food items for a given study year, *Diaptomus* in 1970 and *Cyclops* in 1971 and 1973-75. The greatest number of different food items was found in 1971 and the least in 1972.

More detailed data on the relationship between fish size and food intake are presented in Table 22 for fish grouped by 1 mm length intervals, with all study years combined.

Copepods clearly dominated in amount of food consumed by all sizes of perch although a small and gradual decline occurred for fish larger than 9-10 mm. This decline occurred with an increase in cladocera intake, which peaked at 20% for fish 17-18 mm. Immature copepods were consumed in larger amounts than mature forms among all sizes of perch, although nauplii were absent from stomachs of perch larger than 17-18 mm. Peak intake occurred at 5-6 mm for nauplii and 9-13 mm for copepodids.

Viewed as percent frequency of occurrence, copepods continued their overall dominance, but were equalled by cladocerans for the two largest size intervals of perch. From levels below 20% for fish 5-10 mm, percent frequency of cladocerans increased steeply, reaching 100% for fish 19-22 mm.

Among minor food items, the copepod *Diaptomus* was absent from the two smallest size intervals while *Cyclops* was absent from the two largest.

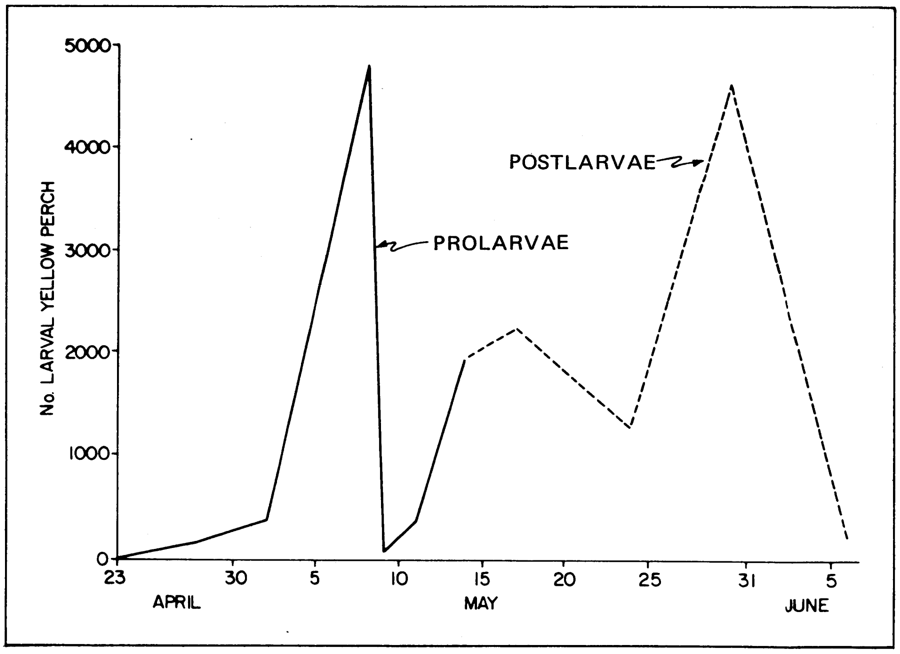


FIGURE 18. *Numbers of larval yellow perch captured with meter nets in the mouth of the Fox River at Oshkosh, 23 April-6 June 1973.*

The cladocerans *Daphnia* and *Bosmina* showed similar trends, occurring in fish of all size intervals and at similar magnitudes. Intake of other cladocerans appeared to be related to fish size, occurring only at low levels in fish of a few size intervals. Diversity of food items was greatest among larval perch 13-14 mm total length and lowest among the smallest and largest fish.

Similar larval food habits have been reported by other investigators although the importance of specific food items did not always agree with results from Lake Winnebago. Larval perch in a eutrophic Minnesota lake began feeding in the prolarval stage at approximately 6.0 mm total length (Siefert 1972). Copepod nauplii were found to dominate the diet of larval

TABLE 21. *Food of postlarval yellow perch (5-21 mm) from Lake Winnebago, 1970-75, expressed as percent frequency of occurrence and percentage of total food items (in parentheses).*

Food Parameters	1970 (11-21 mm)		1971 (6-16 mm)		1972 (5-16 mm)		1973 (5-18 mm)		1974 (5-14 mm)		1975 (5-19 mm)		1970-75* (5-21 mm)	
Digestive tracts														
Number examined:	109		92		61		332		452		261		—	
Number empty (%):	2	(1.8)	5	(5.4)	15	(24.6)	35	(10.5)	55	(12.2)	75	(28.7)	—	
Total food items	1,090		521		314		3,911		4,128		1,853		—	
Copepoda	100	(81)	100	(90)	100	(99)	100	(88)	100	(98)	100	(98)	100	(92)
Nauplii			53	(46)	100	(95)	91	(68)	32	(7)	24	(4)	60	(44)
Copepodid	84	(55)	24	(14)					87	(84)	97	(82)	73	(59)
Diaptomus	66	(26)	8	(2)			6	(1)	1	(T)			20	(7)
Cyclops			30	(28)	13	(4)	47	(19)	33	(7)	40	(12)	33	(14)
Cladocera	89	(19)	41	(10)	9	(1)	41	(12)	16	(2)	14	(2)	35	(8)
Daphnia	19	(5)	14	(4)			14	(2)	7	(1)	5	(T)	12	(2)
Bosmina	16	(2)	11	(3)			24	(10)	7	(1)	5	(1)	13	(3)
Diaphanosoma			11	(3)	2	(T)	1	(T)					5	(1)
Sida			2	(T)**	6	(1)	3	(T)	T	(T)			3	(T)
Moina	19	(6)											19	(6)
Leptodora	17	(3)											17	(3)
Simocephalus	2	(1)											2	(1)
Chydorus									1	(T)	4	(T)	3	(T)
Polyphemus	17	(2)											17	(2)
Unidentified cladocerans			2	(T)									2	(T)
Chironomid larvae			1	(T)									1	(T)
Ostracoda									T	(T)			(T)	(T)

*Average of combined annual values for food items.
**0.5% or less.

TABLE 22. *Food trends of postlarval yellow perch in selected length classes, Lake Winnebago 1970-75. Digestive tract contents in percent frequency of occurrence and percentage of total food items for each length class (in parentheses).*

Food	Total Length (mm)																	
Parameters	5-6		7-8		9-10		11-12		13-14		15-16		17-18		19-20		21-22	
Digestive tracts																		
Number examined	207		356		293		179		86		86		77		17		6	
Number empty (%)	155	(74.9)	30	(8.4)	0		0		1	(1.2)	0		0		1	(5.9)	0	
Total food items	165		2,487		3,451		2,265		1,131		936		1,012		186		81	
Copepoda	100	(98)	100	(96)	100	(98)	100	(91)	100	(90)	100	(87)	100	(80)	100	(82)	100	(83)
Nauplii	81	(81)	67	(50)	40	(19)	25	(18)	41	(32)	48	(46)	40	(35)				
Copepodids	29	(16)	45	(35)	73	(68)	73	(59)	42	(38)	37	(23)	52	(25)	87	(47)	67	(42)
Diaptomus					T	(T)	4	(T)	12	(1)	27	(6)	48	(13)	81	(35)	100	(41)
Cyclops	4	(1)	30	(11)	45	(11)	37	(13)	43	(19)	23	(12)	23	(7)				
Cladocera	8	(2)	17	(4)	14	(2)	43	(9)	62	(9)	52	(13)	56	(20)	100	(18)	100	(17)
Daphnia	4	(1)	2	(T)*	5	(T)	21	(3)	19	(3)	14	(3)	21	(3)	37	(7)	33	(4)
Bosmina	4	(1)	13	(3)	6	(1)	17	(6)	18	(3)	14	(6)	10	(12)	19	(3)	33	(9)
Diaphanosoma							3	(T)	3	(T)	6	(T)						
Sida			1	(T)	1	(T)	1	(T)	6	(T)	1	(T)	2	(T)				
Moina									2	(1)	6	(2)	10	(2)	19	(2)	33	(2)
Leptodora									2	(T)	3	(T)	8	(2)	31	(5)	33	(2)
Simocephalus									1	(T)			1	(T)				
Chydorus			1	(T)	2	(T)							1	(T)				
Polyphemus							1	(T)	8	(1)	8	(1)	1	(T)	12	(1)		
Unidentified cladocerans									2	(T)								
Chironomid larvae									1	(T)								
Ostracoda			T	(T)														

*T indicates 0.5% or less.

perch in two studies although *Cyclops* and *Bosmina* were also important (Siefert 1972, Clady 1977b). Siefert found that cladocera were eaten only by larger larvae, principally fish 11 mm and longer and that *Cyclops* was the dominant food item for 8- to 11-mm perch. Neither of these relationships held true for Lake Winnebago perch.

FINGERLINGS

Relative Abundance, Mortality, and Movement

Seasonal catch/unit of effort (C/E) ranged from 2.6 to 16.8 for limnetic habitats (trawl samples) and 53.8 to 550.9 for littoral habitats (seine samples) (Table 23). C/E values were lowest for trawl captures in 1975 and highest in 1973. For seine captures, lowest and highest C/E values were observed in 1971 and 1974, respectively. Relative abundance dropped sharply by August in all years (Fig. 19). This was true of both trawl- and seine-captured fish although the decline in littoral habitats lagged behind the decline in limnetic habitats in all years except 1971. This sharp midsummer decline suggests that substantial and regularly occurring mortality occurs among fingerling perch in mid July to early August. A preliminary analysis showed that abundance of the blue-green algae *Microcystis* spp. was inversely related to June-August trawl catches of young-of-the-year perch in 1971. Dense blooms of those algae are a regular occurrence in eutrophic waters of Lake Winnebago during mid and late summer. The perch population may be affected directly through a toxic effect or indirectly by decreasing oxygen or abundance of food organisms. These and other environmental factors need further investigation to define their relationship to year class strength.

Monthly mortality for the June-October sampling period ranged from 39 to 87% for trawl samples and from 31 to 78% for seine samples (Table 24). Forney (1971) found that mortality was inversely related to catch at the beginning of the trawling season. Comparison of Lake Winnebago trawl catches for June and October and daily instantaneous mortality coefficients for 1971-75 showed no such relationship (Table 24). Predicted catches on 1 July and 15 October and respective daily mortality coefficients were also compared, which more strictly followed Forney's method (Table 25). No significant relationship between these indicators of mortality and year class strength was evident. However, the lowest daily and monthly mortality oc-

TABLE 23. *Relative abundance (catch/effort) of young-of-the-year yellow perch from trawl and seine captures in Lake Winnebago, 1971-75.*

	Trawl			Seine		
Sampling Period	No. Fish Sampled	No. Tows	Avg. C/E	No. Fish Sampled	No. Hauls	Avg. C/E
1971						
Jun	158	5	31.6	177	1	177.0
Jul	572	33	17.3	43	1	43.0
Aug	22	14	1.6	149	5	29.8
Sep	2	48	0.1	115	2	57.5
Oct	16	11	1.5	*	*	*
Total	770	111		484	9	
Season Avg.			6.9			53.8
1972						
Jun	1,244	21	59.2	420	4	105.0
Jul	95	31	3.1	4,519	10	451.9
Aug	1	30	0	234	2	117.0
Sep	6	20	0.3	171	6	28.5
Oct	*	*	*	*	*	*
Total	1,346	102		5,344	22	
Season Avg.			13.2			242.9
1973						
Jun	675	16	42.2	70	2	35.0
Jul	393	20	19.7	1,419	8	177.4
Aug	16	10	1.6	239	4	59.8
Sep	22	15	1.5	48	4	12.0
Oct	20	6	3.3	*	*	*
Total	1,126	67		1,776	18	
Season Avg.			16.8			98.7
1974						
Jun	593	20	29.7	9,430	3	3,143.3
Jul	115	25	4.6	6,442	12	536.8
Aug	131	10	13.1	902	4	225.5
Sep	48	25	1.9	300	8	37.5
Oct	38	20	1.9	5	4	1.3
Total	925	100		17,079	31	
Season Avg.			9.3			550.9
1975						
Jun	166	29	5.7	318	4	79.5
Jul	118	52	2.3	1,716	12	143.0
Aug	42	26	1.6	60	7	8.6
Sep	*	*	*	12	3	4.0
Oct	17	25	0.7	*	*	*
Total	343	132		2,106	26	
Season Avg.			2.6			81.0

*No sample taken

TABLE 24. *Monthly instantaneous mortality coefficients and percent mortality for young-of-the-year yellow perch collected seasonally by trawl and seine, Lake Winnebago, 1971-75.**

	Trawl		Seine	
Year	Monthly Instan. Mort. Coef.	% Mort. Jun-Oct	Monthly Instan. Mort. Coef.	% Mort. Jun-Sep
1971	1.216	70	0.3740	31
1972	2.049	87	0.5263	41
1973	0.767	54	0.4299	44
1974	0.638	47	1.5322	78
1975	0.498	39	1.1780	69

*Calculations are based on least squares regression of month of capture (x) and $\log_e$ of the catch/unit of effort for each month (y). Percent mortality is derived from the monthly mortality coefficients (-z) using the conversion $1\text{-}e^{-z}$.

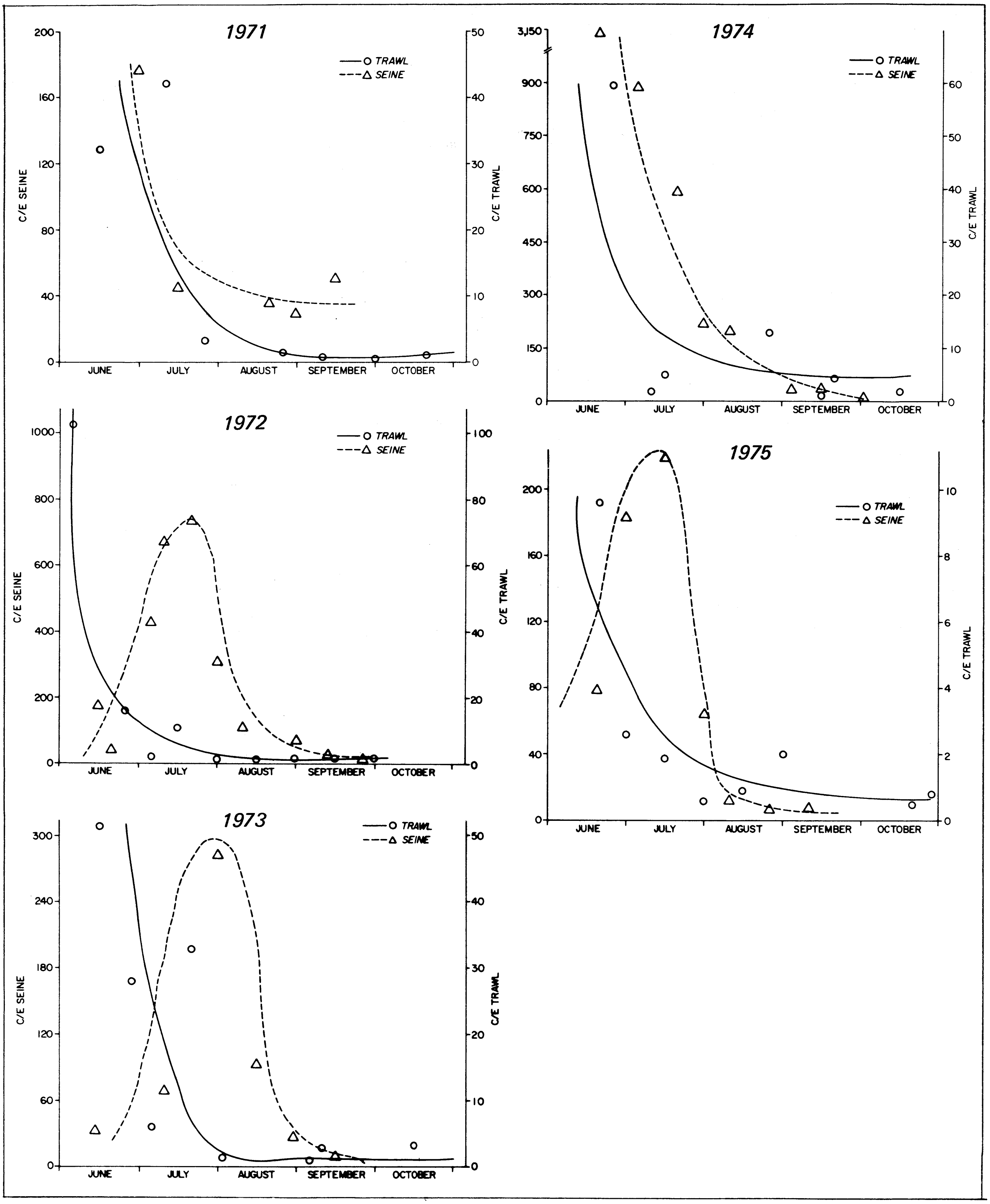


FIGURE 19. *Catch/effort curves for young-of-the-year yellow perch captured by seine and trawl in Lake Winnebago, 1971-75. Curves were fitted by visual inspection.*

TABLE 25. *Daily instantaneous mortality coefficients for trawl-captured young-of-the-year yellow perch from Lake Winnebago, calculated for two periods during 1971-75.*

Year	C/E for Jun	Daily Instan. Mort. Coef.*	C/E for Oct	Predicted C/E for 1 Jul**	Daily Instan. Mort. Coef.[1]	Predicted C/E for 15 Oct**
1971	31.6	0.0405	1.5	15.2	0.0409	0.20
1972	59.2	0.0683	0.01 [2]	8.4	0.0483	0.05
1973	42.2	0.0256	3.3	15.7	0.0256	1.04
1974	29.2	0.0213	1.9	5.3	0.0239	0.42
1975	5.7	0.0166	0.7	3.1	0.0155	0.60

*Derived from monthly mortality coefficients (Table 24) divided by 30.

**Predicted from regression fitted to Log_e C/E vs. day of year, June-October.

[1] $\text{Log}_e \frac{N_2}{N_1} = \frac{z}{106}$, where N_1 = Predicted C/E on 1 July and N_2 = Predicted C/E on 15 October.

[2] Predicted valued based on regression of C/E vs. month; no trawling sample was taken.

TABLE 26. *Catch/effort, density, and relative density of young-of-the-year yellow perch from Lake Winnebago, based on trawling during June-October, 1971-75.*

Year	Catch/Effort (Jun-Oct)	Density (no./acre)	Relative Density (no./acre)
1971	6.9	11.6	5.0
1972	13.2	22.0	35.0
1973	16.8	28.0	17.7
1974	9.3	15.4	4.7
1975	2.6	4.3	1.8

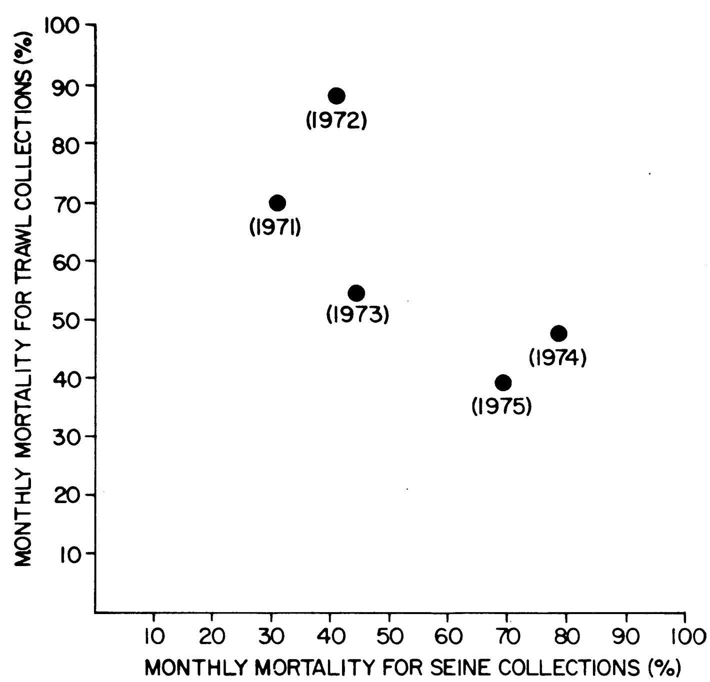


FIGURE 20. *Relationship between percent monthly mortality for young-of-the-year yellow perch collected by trawl and seine, Lake Winnebago 1971-75.*

curred in 1975, the year in which catch/effort at the beginning of trawling was lowest. Daily instantaneous mortality coefficients for 1971-75 were similar to those reported by Forney (1971) and Noble (1971) in Oneida Lake, New York.

Daily instantaneous mortality coefficients for June-October were also compared to seasonal catch/effort (June-October), mean density, and relative density of young-of-the-year yellow perch in Lake Winnebago during 1971-75 (Table 26). Density was calculated from actual trawl catches and the area covered during sampling. Relative density is based on percentage of young-of-the-year of 8 major fish species in Lake Winnebago. No significant relationship was found between mortality and any of the indicators of abundance.

An attempt was made to determine general movement patterns of young-of-the-year perch by comparing trawl and seine captures. Seine-captured fish showed an increase in relative abundance between June and July during 1972, 1973, and 1975 (Fig. 19). The coincidence of this increase with a drop in relative abundance of trawl-captured fish suggests offshore to onshore movement of young perch during midsummer. Forney (1971) reported the opposite movement pattern for Oneida Lake, New York, where young perch moved from littoral to limnetic areas during July. In Lake Winnebago, it appears that both littoral and limnetic areas are used by perch throughout all or most of the summer. Perch were captured in littoral areas through September and in limnetic areas through October and both samples showed a similar midsummer decrease in catch (Fig. 20). The July increases in seine captures noted in 1972, 1973, and 1975 may merely reflect increased vulnerability to seining among perch already present in littoral areas. However, there was an inverse relationship between monthly mortality for trawl and seine captures ($P > 0.05$) (Fig. 20), suggesting that movement between the two habitats occurs on a seasonal basis. Movement may be controlled by habitat conditions in the two areas in a given year, with movement directed toward the more favorable environment.

The existence of both lake and river spawning perch stocks complicates the interpretation of movement patterns. It is not known at what point and to what extent mixing occurs between the offspring of these stocks.

Trawling data gathered by previous investigators (G. Priegel, Wis. DNR, unpubl. data) on the relative abundance of fingerling yellow perch in Lake Winnebago during 1959-67 and 1970 were compared to the above data for 1971-75 in an effort to view long-term changes in year-class strength (Table 27). Data for 1968 and 1969 were incomplete and thus were excluded from the analysis.

TABLE 27. *Relative year class strength of yellow perch estimated from trawl captures of young-of-the-year fish during June-July, and June-October in Lake Winnebago, 1959-67 and 1970-75.*

	June-October			June-July		
Year	No. Tows	Avg. Catch/ Tow (C/E)	% of Standard*	No. Tows	Avg. Catch/ Tow (C/E)	% of Standard*
1959	130	4.9	4.6	42	14.9	4.6
1960	183	2.1	3.1	68	4.6	1.4
1961	242	11.9	17.4	89	70.5	21.8
1962	190	68.3	100.0	80	323.4	100.0
1963	170	11.3	16.5	80	44.6	13.8
1964	95	65.1	95.3	45	250.9	77.6
1965	90	13.2	19.3	40	58.1	17.9
1966	79	17.1	25.0	22	123.5	38.2
1967	43	10.3	15.1	30	25.1	7.8
1970	98	6.8	10.0	50	31.9	9.9
1971	111	6.9	14.3	38	48.9	15.1
1972	102	13.2	19.3	52	62.3	19.3
1973	67	16.8	24.6	36	61.9	19.1
1974	100	9.3	13.6	45	34.3	10.6
1975	132	2.6	3.8	81	8.0	2.5

*Standard = C/E for 1962

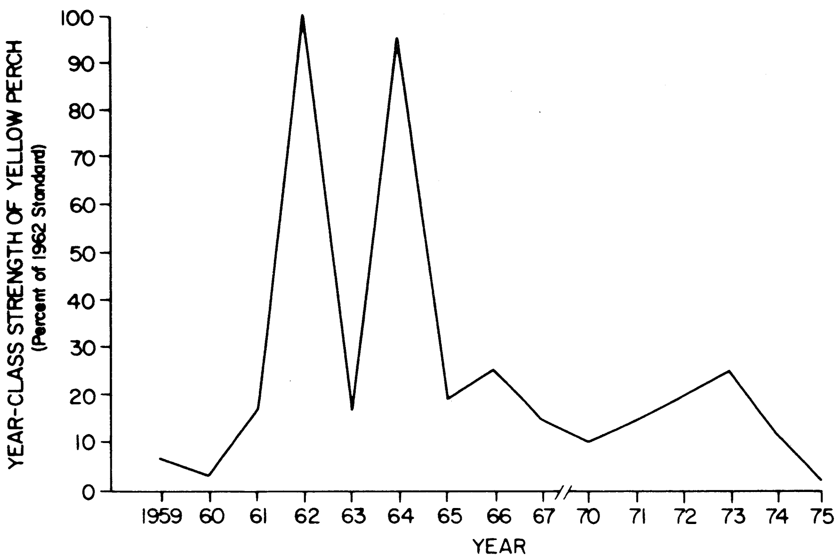


FIGURE 21. *Relative year class strength of yellow perch in Lake Winnebago estimated from trawl captures of age 0 fish, June-October 1959-67 and 1970-75. (June-July for 1959-67 are shown in Table 27)*

Fluctuations in abundance of yellow perch year classes were greatest between 1961 and 1965 (Fig. 21). After 1964, subsequent year classes have not reached levels greater than 25% of the strongest 1962 year class. From a relatively low level of abundance in 1970, yellow perch year classes steadily increased through 1973, attaining a level equal to that of the 1966, 3rd strongest year class. However, year class strength decreased through 1974 and 1975, reaching the 2nd lowest level for the 15-year period.

C/E values for 1959-67 and 1970-73 were compared to spring flow in the Fox River and water temperatures in Lake Winnebago during May-August to analyze whether these environmental conditions had any influence on survival of young yellow perch. Flow conditions during April and May and both months combined were compared with the 13-year average to obtain flow indexes for each year (Append. Table 37). Degree-days for May-August were accumulated by month and year and corresponding thermal indexes derived from a ratio of the average temperature units for each month and year to the means from the 13-year period (Append. Table 38). C/E from trawl captures of young perch during June and July were used to estimate spring production in a given year, while the average C/E for June-October each year was used as an index of year class abundance (Table 27).

No significant correlations were found between spring production and flow during April and May and during these months combined. No significant correlations were found between water temperatures and spring production or average seasonal production. Water temperatures analyzed were for May, July, a ratio of May to July, and combined seasonal temperature units for May-August.

Wide year-to-year fluctuations in year class strength are common among perch populations (Ney 1978) and environmental factors have often been looked to as causes. Clady (1976) found a positive correlation between water temperature and annual survival from the egg to postlarval stage in Oneida Lake, New York and a negative correlation of survival with wind. Eshenroder (1977) found a positive correlation between spring warming and the strongest and weakest year class in Saginaw Bay, Michigan for 1957-75. However, other researchers have found no correlation between meteorological factors and year class strength (El-Zarka 1959, Ridenhour 1960).

Growth

Growth in length was similar for 1971-75 although perch grew faster and reached a larger size by the last sampling date in 1975 (Fig. 22). Growth generally followed a sigmoidal pattern, gradually accelerating through May and June, increasing almost linearly through August, then slowing through September and October. However, in 1975, growth was nearly linear throughout the growing season. Fifty percent of the recorded growth was achieved by mid-July. Perch from limnetic habitats averaged 78-90 mm long on the last sampling date (in October). Littoral sampling ended in September, at which time average lengths ranged from 64 to 81 mm. There was little variation in length growth between young perch from the different habitats until mid-July in 1973-74 and the end of August in 1971-72, when fingerlings from limnetic areas showed a slight growth advantage over those from littoral habitats. No habitat-related difference was seen

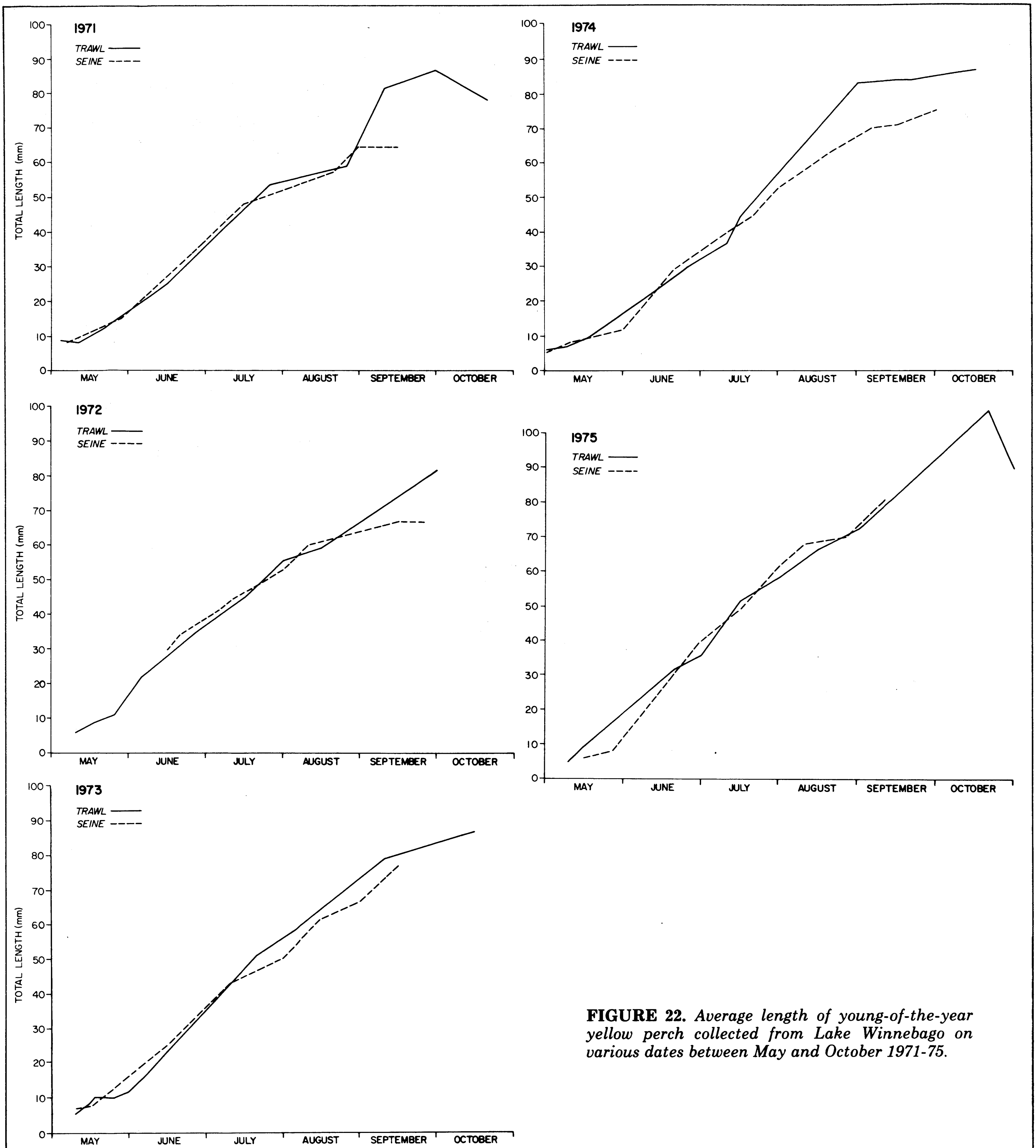


FIGURE 22. *Average length of young-of-the-year yellow perch collected from Lake Winnebago on various dates between May and October 1971-75.*

in 1975 growth.

Growth in weight showed moderate year-to-year variation during 1971-75 although the seasonal pattern of growth was similar for all years (Fig. 23). The sigmoidal pattern noted for growth in length was also present and more pronounced for weight. Weight gain was slow through mid-July, then increased rapidly through September. October weight gain for trawl samples slowed in 1973-74 and dropped in 1971 and 1975. No October trawl samples were taken in 1972 and no seine samples were taken in October in any study year. Average weight of young perch in littoral habitats lagged behind weight in limnetic habitats in all years except 1975. The lag became evident between mid-July and mid-August and generally increased with time. At the

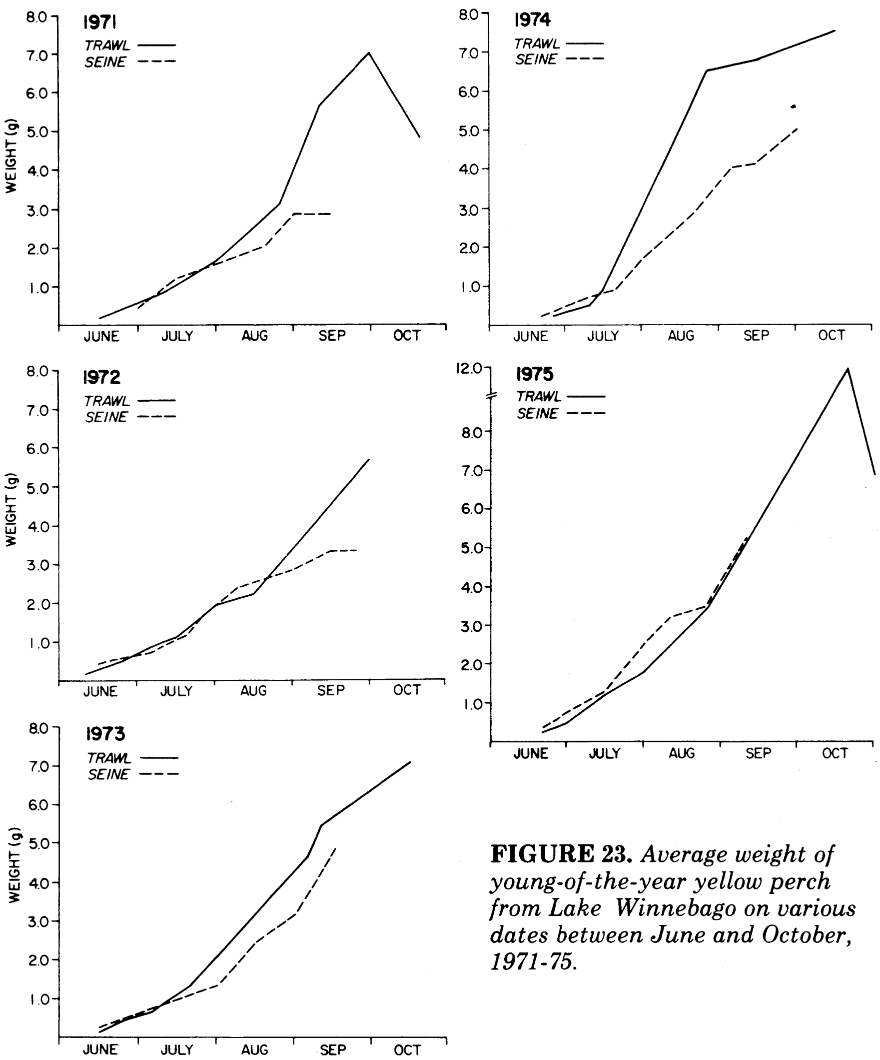


FIGURE 23. *Average weight of young-of-the-year yellow perch from Lake Winnebago on various dates between June and October, 1971-75.*

TABLE 28. *Average daily growth increment in milligrams by month of young yellow perch sampled by trawl and seine in Lake Winnebago, 1971-75.*

Month	1971	1972	1973	1974	1975
June					
Trawl	*	18	21	*	10
Seine	*	23	28	25	31
Combined	*	20	25	25	20
July					
Trawl	34	45	46	29	49
Seine	48	43	23	42	88
Combined	37	44	37	36	70
August					
Trawl	49	16	76	134	54
Seine	36	24	65	70	39
Combined	41	20	71	105	48
September					
Trawl	100	79	117	6	*
Seine	0	18	109	35	111
Combined	72	56	111	25	111
October					
Trawl	88	*	51	36	56
Seine	*	*	*	*	*
Combined	*	*	51	36	56
Average					
Trawl	37	48	57	65	50
Seine	32	29	52	47	66
Combined	35	39	55	56	56

*No fish collected

end of sampling, perch from limnetic habitats averaged 4.9-7.5 g (early to late October) while perch from littoral habitats averaged 2.9-5.3 g (mid- to late September). Fifty percent of total weight gain was acheived by mid-August although average daily growth increment was highest in September for all years except 1974, when August exhibited the greatest daily growth (Table 28). Weight gain during these months of greatest growth averaged 56-111 mg/day for the 5 study years. Average seasonal growth was greatest for 1973-75, averaging 55-56 mg/day. Average daily growth increments for 1971 and 1972 were substantially lower, averaging 35 mg and 39 mg, respectively. October trawl samples were not carried out in 1972 and probably lowered the seasonal average for that year by a few milligrams. Large differences between average daily growth increments for the two habitats are evident throughout the study years (Table 28).

There were no apparent relationships between first-year growth and relative abundance based on C/E values for June and June-October. Possible correlation between growth of young perch and their abundance was also analyzed by Noble (1975) and Ney and Smith (1975). No significant relationships were found.

The length-weight equation for 1973-75 trawl samples was described by the equation:

$$\text{Log W} = -5.31 + 3.19 \text{ Log L}$$

The length-weight equation for seine samples over the same period was:

$$\text{Log W} = -5.12 + 3.09 \text{ Log L}$$

First-year growth of yellow perch in Lake Winnebago is greater than that reported for other waters for similar periods. Ridenhour (1960) reported average lengths of 67 mm by 1 September in a 9-year study of Clear Lake, Iowa. Lux (1960) reported average lengths of 63 mm for young perch sampled in mid-October from Linwood Lake, Minnesota. Fingerling perch from Red Lakes, Minnesota ranged from 55-75 mm and weighed 1.7-4.4 g by early October during three study years (Pycha and Smith 1955); however, Ney and Smith (1975) reported lengths up to 88 mm by early October in an extended study. A sigmoidal first-year growth pattern has been reported by various investigators (Ney 1978).

Food Habits and Selectivity

Yellow perch are primarily zooplankton feeders during their first summer of life in Lake Winnebago (Table 29). Copepods and cladocerans comprised 94% of the total food items observed among trawl-captured perch and 93% among seine-captured fish. Insects, ostracods, clams and 5 other invertebrate forms contributed to the diet of yellow perch from both littoral and limnetic habitats in amounts ranging from a trace to 5% of total food items. Similarities in diet between the two habitats are also seen in the type of copepod and cladoceran eaten, with

Cyclops and *Daphnia* dominant in both samples. Chironomid larvae and pupae were the principal insects eaten by both groups.

Major differences between food habits of trawl and seine-captured fish were also evident. Young yellow perch from the deeper, open water areas of the lake consumed copepods in greater numbers than cladocerans while the opposite relationship was true for perch from littoral habitats. Seine-captured fish exhibited a more diverse diet, consuming 32 kinds of food items compared to 21 for trawl-captured perch. Although *Daphnia* was the principal cladoceran eaten by both habitat groups, this food item was more important to open water perch. *Bosmina, Ceriodaphnia, Sida,* and *Eurycerus* also contributed significantly to cladoceran intake by fish from littoral habitats.

Amount, frequency and type of food consumed was often related to fish size (Figs. 24 and 25) although habitat-related differences were also present. Amount of copepods consumed by trawl-captured fish peaked among fish 15-24 mm and 65-74 mm, showing a decreasing trend after each peak. Cladoceran intake for this sample peaked at 45-54 mm and 95-104 mm and remained below 50% for all other size groups. Copepod intake for seine-captured fish was greatest for the smallest fish and decreased steadily as fish size increased while cladoceran intake remained above 60% for all size classes of perch 15-94 mm. Insect consumption was similar for the two habitats and tended to increase with fish size, although insects remained a minor diet item for all size classes of perch between 15 and 104 mm. However, for the largest perch sampled (105-114 mm) insects dominated in the diet. All of these large fish were captured by trawl.

Copepods occurred most frequently in the smaller size groups of perch for both trawl and seine samples, decreasing in a linear manner with increasing fish size. Cladocerans also occurred most frequently among smaller perch in seine samples, but the decrease was gradual through all but the last size group. For trawl samples, cladocerans occurred most frequently among perch 65-74 mm although smaller peaks occurred at 35-44 mm and 75-104 mm. Frequency of insects was greatest for the larger size classes although it remained at or above 20% for all fish 35 mm or longer.

Consumption of specific food items was also related to fish size (Append. Tables 39 and 40). Among copepods, intake of *Cyclops* increased with fish size for trawl samples while *Diaptomus* showed the opposite trend. The same pattern was evident among seine samples for fish up to 74 mm, after which intake decreased. This decrease corresponded to an increase in copepodid intake. Copepodids were eaten in only trace amounts within other size groups. *Daphnia* contributed over 55% of all cladocerans eaten by perch of all size groups sampled from limnetic habitats, except for fish measuring 55-74 mm. Fish from this length interval consumed equal portions of *Daphnia* and *Alona*. *Alona* was a significant food item only among this size group of perch.

Sida, Eurycercus, Ceriodaphnia, Bosmina, and hemipterans reached important levels within limited size groups of fish in one or both habitats. Diversity was greatest among open water fish 35-74 mm, and lowest for littoral fish 15-34 mm.

Food habits of young yellow perch in Lake Winnebago also varied annually indicating that size of fish was not the only factor influencing intake (Append. Tables 41 and 42).

Age 0 yellow perch in offshore areas of Lake Winnebago exhibited strong selectivity for food items, but this selectivity varied considerably from year to year and month to month (Fig. 26-28). *Cyclops* showed a strong positive

TABLE 29. *Food of young-of-the-year yellow perch from trawl and seine collections in Lake Winnebago, 1971-75. Data are presented as number and percentage of major food classes and number and percent contribution of food items to each class.*

Food Class	Food Item	Trawl No. Food Items	Trawl %	Seine No. Food Items	Seine %
Copepoda		7,875	55	28,280	18
	Diaptomus	1,035	13	6,945	25
	Cyclops	6,825	87	21,247	75
	Copepodids	15	T*	88	T
Cladocera		5,646	39	117,148	75
	Daphnia	3,571	63	41,122	35
	Leptodora	390	7	1,972	2
	Diaphanosoma	449	8	6,286	5
	Moina	29	1		
	Alona	270	5	140	T
	Chydorus	2	T	974	1
	Bosmina	288	5	22,163	19
	Sida	156	3	14,756	13
	Ceriodaphnia			17,852	15
	Eurycercus	486	9	11,781	10
	Camptocercus			90	T
	Holopedium	5		12	T
Ostracoda		76	1	246	T
Hydracarina				22	T
Amphipoda		7	T	4,139	3
Isopoda				36	T
Hirudinea		17	T	19	T
Nematoda				1	T
Insecta		685	5	5,801	4
	Ephemeroptera			26	T
	Chironomid larvae	642	94	3,732	64
	Chironomid pupae	42	6	730	13
	Chironomid adults			1	T
	Odonata			107	2
	Coleoptera	1	T	4	T
	Trichoptera			22	T
	Hemiptera			1,167	20
	Megaloptera			10	T
	Plecoptera			1	T
	Lepidoptera			1	T
Pelecypoda		11	T	87	T
Gastropoda		1	T	14	T
Number of stomachs		753		1,826	
Number empty		161	21.4	141	7.7

*T = trace

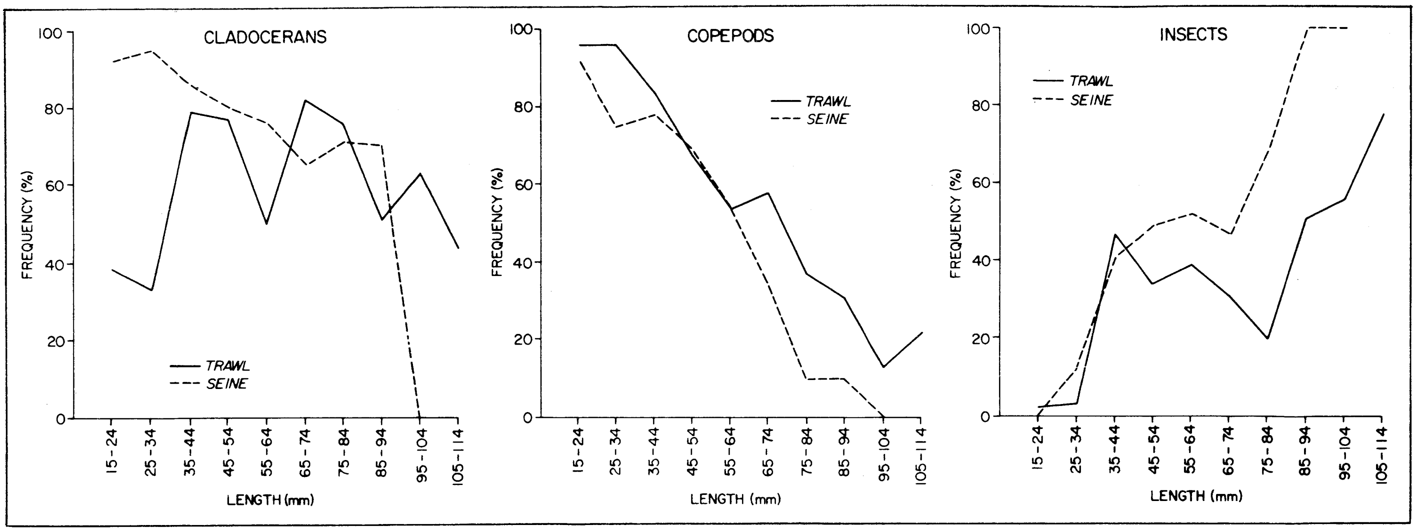


FIGURE 24. *Percent frequency of occurrence of copepods, cladocerans, and insects in young-of-the-year yellow perch stomachs for trawl and seine captured fish in representative length classes for 1971-75 samples combined.*

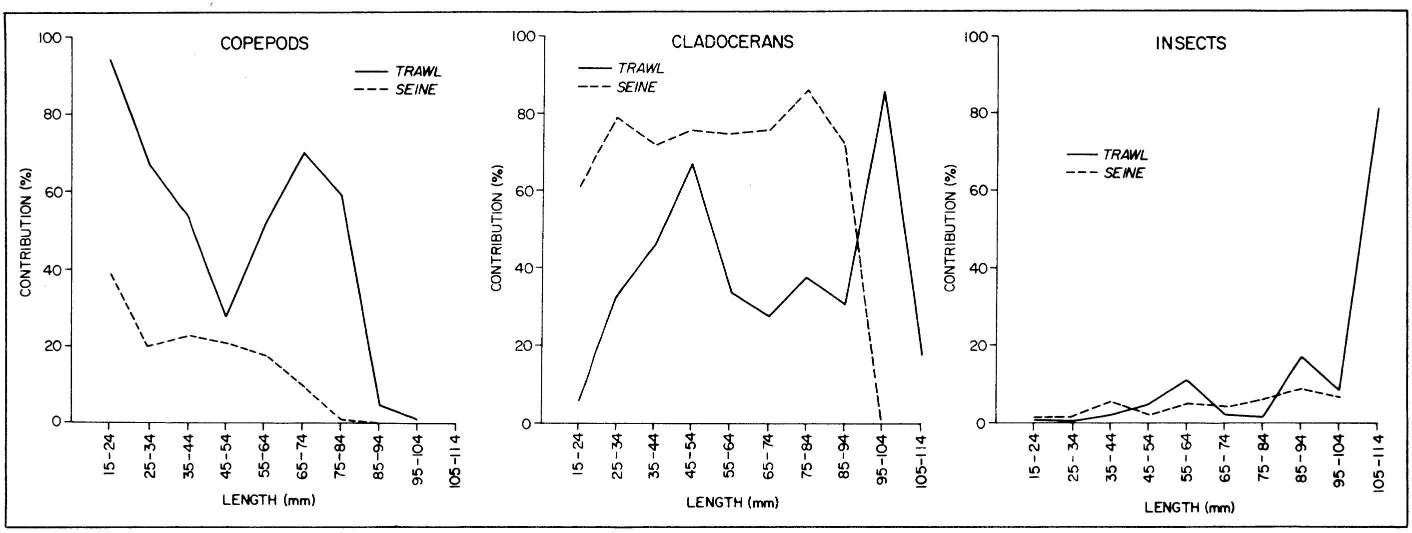


FIGURE 25. *Percent contribution of copepods, cladocerans, and insects to total food items eaten by trawl and seine captured young-of-the-year yellow perch in representative length classes for 1971-75 data combined.*

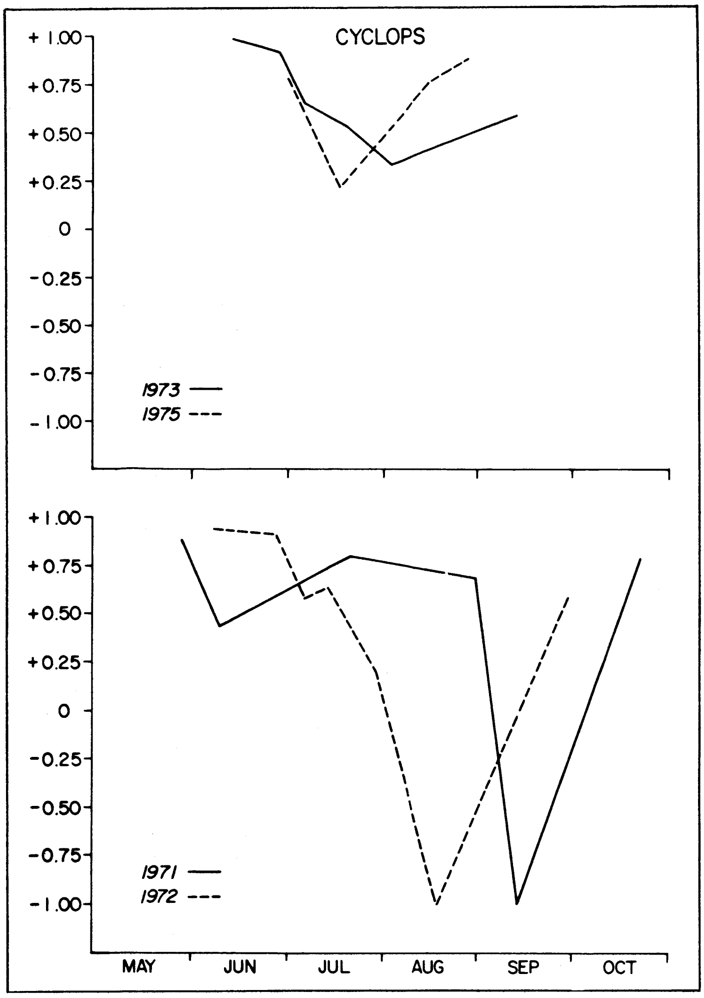
selection in June in all study years and remained positively selected through October in 1973 and 1975. However, *Cyclops* showed a strong negative selection in August 1972 and September 1971 but remained positively selected in other months.

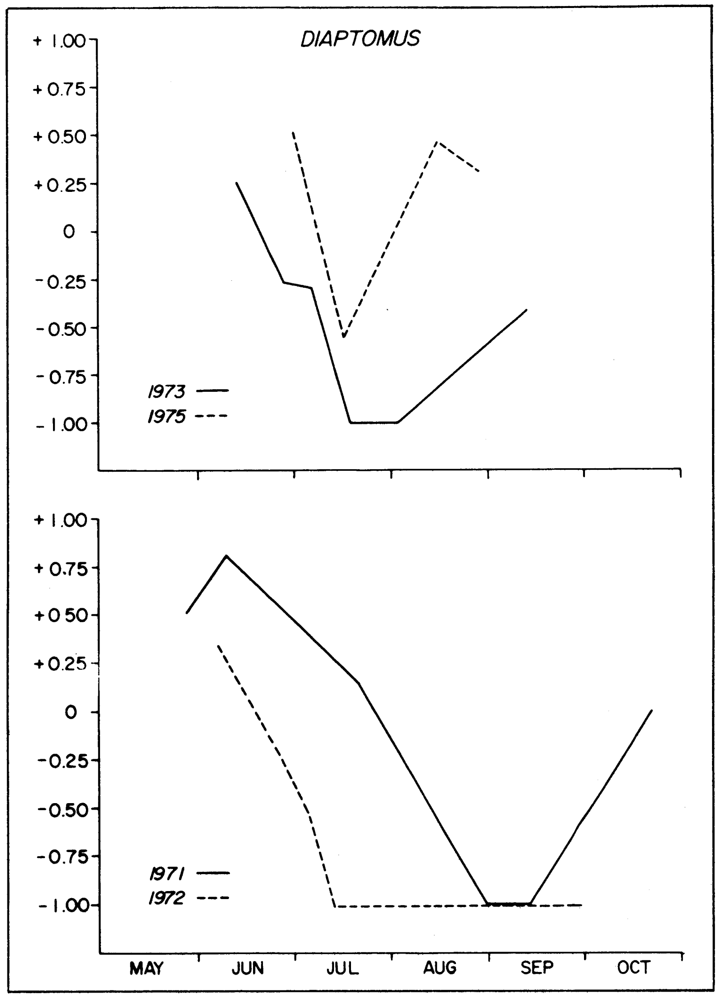
Diaptomus, the other major copepod eaten by young yellow perch, showed a weak positive selection or strong negative selection throughout most of the sampling months in all study years, although this pattern was least pronounced in 1975. June was an exception. Moderate to strong positive selection was shown for *Diaptomus* during this month in all study years.

Daphnia exhibited positive or neutral selection throughout the sampling season in 1973 and 1975 but was negatively selected in early June and August October in 1971 and 1972. Moderate to strong selection for *Daphnia* occurred in late June and July.

Selection of minor food items tended to be either very strong or neutral. *Leptodora* showed strong positive selection in June, July, and September in 1972 and 1975 and neutral selection in August. In 1973, selection was moderately positive in June and October and neutral or strongly negative in July. *Sida* showed neutral or very strong selection in all index years while neutral or very strong negative selection occurred for *Chydorus*. *Bosmina* showed a similar pattern of selection for 1973 and 1975, with neutral to negative selection exhibited in all months. However, in 1975, selection was strongly positive during mid-July and late August.

Other food habit studies of young-of-the-year yellow perch have shown the importance of cladocerans and copepods to the species diet (Ney 1978). *Daphnia* is particularly important in some waters, dominating food intake for the entire season and exerting a strong influence on growth (Noble 1975). However, other studies indicate a more varied diet, with numerous taxa contributing, their numbers varying seasonally and annually, often in proportion to their availability in the environment (Pycha and Smith 1955). Insects, especially chironomid larvae, usually become important food items in late summer although Clady (1974) found them to be the most abundant food item among juvenile perch throughout June-September. The amphipod, *Hyalella*, was an important late-summer food item in some waters (Ridenhour 1960, Pycha and Smith 1955).





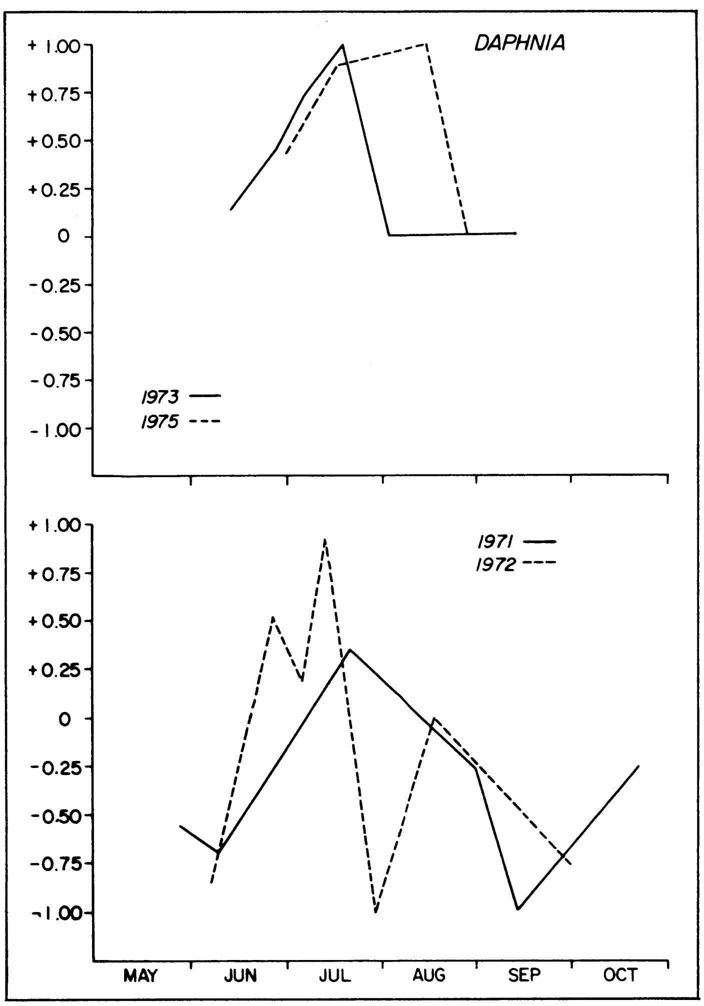


FIGURE 26. *Selectivity indexes for Cyclops consumed by young-of-the-year yellow perch sampled from Lake Winnebago, May-October 1971-73 and 1975.*

FIGURE 27. *Selectivity indexes for Diaptomus consumed by young-of-the-year yellow perch sampled from Lake Winnebago, May-October 1971-73 and 1975.*

FIGURE 28. *Selectivity indexes for Daphnia consumed by young-of-the-year yellow perch sampled from Lake Winnebago, May-October 1971-73 and 1975.*

CONCLUSIONS

A well-defined spawning migration of yellow perch from Lake Winnebago to the upper Fox River was documented for each of the 6 years of study. Despite extensive sampling, only 2 major spawning sites were located in the river, one approximately 5.6 km upriver at Oshkosh and the other at Rivermoor above the entrance to Lake Butte des Morts. Habitat used for spawning at the two sites differed greatly. Submerged pilings and logs were the primary habitat at Oshkosh while a remnant bed of American lotus dominated at Rivermoor. The Rivermoor spawning population appears to include perch from Lake Butte des Morts although they were less than 15% of the total population. Two spawning sites were also found along the west shore of Lake Winnebago, and it is likely that more extensive sampling would turn up others.

The timing of spawning varied widely from year-to-year and showed little relationship to any single environmental factor except date of ice breakup. Spawning duration varied directly with water level. Based on annual catch/effort data, the number of perch entering the spawning migration tended to increase as flow increased, although in 1976, a year of very high flow, numbers dropped. Among fish that did enter the river in high-water years, movement upriver was more extensive. Spawning occurred 2-5 days sooner at the more distant Rivermoor site.

The age and size composition of the spawning population also showed wide annual fluctuations and was typically unimodal or bimodal, reflecting the dominance of one or two year classes. The strong 1968 and 1969 year classes were the primary components of the spawning population during 5 of the 6 study years. Recruitment of males to the spawning population began at age II and females at age III. On the average, males were 2-7 times as numerous as females during the entire spawning season and outnumbered females by as much as 51 to 1 on a daily basis. No single pattern of size-specific migration was found for all of the study years although the largest females tended to migrate early or at peak spawning.

Extensive postspawning movement occurred to the upriver lakes of the Lake Winnebago system. The length of time perch remain upriver before returning to Lake Winnebago was not determined although some tagged fish were caught from the lake by anglers as little as 18 days after spawning. Angler return of perch tagged in the Fox River during spawning averaged 7.7% for the 6-year study period. Eighty-four percent of all fish caught were taken in Lake Winnebago, mostly during July and August. Exploitation of spawning fish was low. There was little angler selectivity of size groups although few perch below 190 mm were caught. Tagging mortality is suspected as the primary factor in this low return.

Egg development monitored in screened buckets and on submerged pine trees was similar to that reported by other investigators from northern latitudes. Moderate year-to-year differences in duration of incubation and hatching occurred but neither was related to water temperature regimes during egg development.

Mean daily water temperatures generally fell within the 10-16 C range for optimum hatching although mean minimum temperatures fell below this at Oshkosh in 3 study years. Egg survival was not determined, but qualitative observations suggest that siltation and predation by the crayfish *Orconectes rusticus* and mud puppies (*Necturus maculosus*) may be important factors in some years.

Immigration of fry to Lake Winnebago was confirmed by netting at the mouth of the Fox River at its entrance to the lake. Fry appeared to reach the lake in relation to the distance of their hatching site. No relationship was found between flow rates and fry movement.

First year growth of Lake Winnebago perch was greater than that reported for many other waters. Growth was typically sigmoidal, with gradual acceleration during May and June, rapid increase through September, and a general leveling off or decline in October. Growth in length was similar for the 5 study years, but weight showed moderate year-to-year differences. Growth in littoral habitats lagged behind growth in deeper, open water areas of the lake after midsummer in all study years except 1975. Differences in growth were not related to density of young-of-the-year perch.

Larval and fingerling perch were primarily zooplankton feeders during their first year of life in Lake Winnebago. Feeding was initiated in the prolarval stage in 2 of the study years. Food of these sac fry was primarily immature copepods although small numbers of cladocerans and ostracods were observed. Postlarvae showed a more diverse diet, but immature copepods remained the principal food item. *Cyclops, Diaptomus* and *Daphnia* were the most numerous and frequently occurring food items of perch longer than 21 mm although insects dominated food intake in the largest size class studied (105-114 mm). Overall, insects and other benthic invertebrates were of minor importance.

Habitat-related differences in food habits were evident in all study years. Perch captured in open water relied more heavily on copepods and exhibited a less diverse diet than fish from littoral areas. Strong selectivity for food items was exhibited by young-of-the-year perch although this selectivity varied annually and monthly.

Year class strength of Lake Winnebago yellow perch appears to be set in mid to late summer. Sharp drops in catch/effort of fingerling perch were seen during this period in all study years. Variations in year class strength were moderate during the study years but much more pronounced when compared to data for 1959-70. Relative abundance during the 5 study years never exceeded 20% of the largest (1962) year class of the earlier study, and the 1975 year class was the second weakest for the entire period. No relationship could be found between relative abundance and environmental factors such as spring flow in the Fox River or Lake Winnebago temperatures for various periods during May through August.

June-October mortality ranged between 39 and 87% for the 5 study years, which is in line with rates for other perch populations exhibiting wide fluctuations in year class strength. Mortality appears to be independent of density, both of young-of-the-year yellow perch and the young-of-the-year of other major fish species inhabiting the lake.

MANAGEMENT IMPLICATIONS

The 1971-76 study of yellow perch in Lake Winnebago and the Fox River is an important contribution to the life history and ecology of a major Wisconsin fish species. The length of the study is especially significant. Wide year-to-year variations were seen in many aspects of the research findings. What might appear to be a pattern in two or three years was often found to deviate in subsequent years. Thus, results of shorter studies reported in the literature may not always provide sound management guidance.

The two major spawning areas in the upper Fox River should be given special environmental protection. Protection of other American lotus beds in the study area should also be considered. This plant is not common in the study area and may be subject to unusual biological and/or human pressures. Unlike other migratory species from Lake Winnebago which use both the Fox and Wolf Rivers for spawning, yellow perch primarily use the Fox River. The entire length of the river from its entrance to Lake Winnebago to the Eureka dam can be considered important to perch production. Consideration should be given to prohibiting dredging or snagging in this section of the river.

Experimental management of yellow perch spawning habitat is suggested. Snags could be installed in the river where habitat has been lost and at other sites compatible with the species' spawning requirements.

No changes are recommended in fishing season or size limits. Angler exploitation was moderate and did not affect reproduction.

Future tagging studies on yellow perch in Wisconsin should avoid fish below 190 mm. Very few fish tagged below this size in the Fox River were returned by anglers, and tagging mortality is the suspected reason.

Consideration should be given to future studies on individual aspects of the ecology of young-of-the-year yellow perch in a renewed effort to determine the factors controlling year class strength. The present study provides essential background information for such an effort, which has been identified as a priority for percid research (Ney 1978).

SUMMARY

1. Yellow perch spawning sites were found in Lake Winnebago and the upper Fox River. The two Lake Winnebago sites were located in shallow bays along the west shore. The two Fox River sites were located at Oshkosh and at Rivermoor, a collection of cottages approximately 19.3 km from the river's entrance to Lake Winnebago.

2. Spawning habitat varied from site to site, consisting of submergent and emergent aquatic vegetation in the lake, submerged pilings and logs in the river at Oshkosh, and a remnant bed of American lotus at Rivermoor. Spawning depth ranged from 0.39 to 2.13 m.

3. The Fox River spawning population was chosen for intensive study, and netting stations were established at Oshkosh and Rivermoor. Tagging studies indicated that river spawners primarily originate in Lake Winnebago although a small proportion of Rivermoor spawners originate in Lake Butte des Morts. Homing to both spawning sites was shown by fyke net recaptures of fish marked at the same sites in previous years. However, upriver movement of fish increased in years of high water.

4. Minimum rates of daily movement for migrating spawners ranged between 1.3 and 11.3 km/day. Greatest movement was recorded for a 180-mm male that travelled 33.8 km upriver in 3 days.

5. Onset of spawning varied from 31 March to 25 April during the 6 study years and was correlated with time of ice breakup on Lake Winnebago. Spawning began 2-5 days sooner at the upriver site (Rivermoor) than at Oshkosh. Length of spawning season was positively correlated with mean daily water levels, varying from 7 to 22 days. Spawning occurred under generally rising water temperatures although fluctuations were numerous. Onset occurred between 5.0 and 8.9 C and peak spawning at 7.9 and 12.9 C. Water temperatures were warmer at Rivermoor in all but one study year.

6. Relative abundance of perch spawning in the river increased with flow in 5 of the 6 study years. The exception was a year of extremely high flow, suggesting that such conditions inhibit emigration from lake to the river. However, among spawning fish that did enter the river in this high-water year, there was greater upriver movement.

7. Male perch matured at age II, at an average minimum size of 115 mm. Fifty percent of female perch were mature at the end of their third year of life, and all were mature at the end of their fifth. Essentially, females 230 mm and longer were mature.

8. Egg counts ranged from 4,210-120,810. Numbers were correlated with age, average total body weight, and average total length. The ratio of average gonad weight to body weight was 24.7%.

9. Age composition of the spawning population showed wide year-to-year fluctuations, reflecting the dominance of one or two strong year classes. Modal age frequencies for the sexes were generally within one age group of each other, averaging 3.9-5.2 years for males and 3.9-6.6 years for females.

10. Average size of spawning fish also reflected relative year class strength, increasing from 1971 through 1974 as the strong 1968 and 1969 year classes grew older but decreasing in 1975-76 as later year classes gained prominence. Males averaged 215 mm and females

238 mm for the 6 study years.

11. Average size of females was greatest at the beginning of migration or at peak spawning. Average size of males was greatest at the beginning or end of migration. However, no single pattern of size-specific migration was found for either sex for all of the study years.

12. Females exhibited greater growth in length and weight than males in the same age group although the growth pattern was similar for the two sexes.

13. Males outnumbered females at both sites in all study years. Average male to female ratios were 1.9:1 at Oshkosh and 6.7:1 at Rivermoor.

14. Perch tagged during the Fox River spawning migration were caught by anglers throughout the Lake Winnebago system although over 84% were taken from Lake Winnebago. Average recapture intervals were shortest for fish taken in the upper Fox River and Lake Winneconne, indicating initial dispersal to these areas. All recaptures combined remained at large an average of 293 days from time of tagging.

15. Angler return of perch tagged during spawning at study sites in the upper Fox River averaged 7.7% for the 6 study years. Tagged perch were caught in all months except November although most were taken in July and August. Exploitation was similar for all size intervals of perch above 210 mm. Tagging mortality is suspected as the cause for the low return of fish below 190 mm.

16. Incubation period for eggs monitored in screened buckets and on submerged pine trees averaged 11-15 days. Water temperatures during incubation ranged from 2.7 to 21.6 C for the 5 study years. No relationship was found between water temperature regimes and length of incubation.

17. Perch larvae (prolarvae) measured 5.0-6.0 mm total length at hatching and 5.0-8.0 mm at yolk sac absorption. Total length averaged 27 mm by mid-June, when most young perch had attained juvenile characteristics and were demersal.

18. Feeding was initiated in the sac fry stage in 2 of the 6 study years. Immature copepods were the principal food item; however, small numbers of cladocerans and ostracods were also taken. Postlarval perch also consumed primarily immature copepods. Mature copepods, cladocerans, chironomid larvae and ostracods were also observed in amounts ranging from a trace to 10% of total food items. Cladocerans were most important to larger postlarvae, 11-21 mm. Annual variation in food habits was evident, with no single food item consumed by perch in all of the 6 study years. Intake of minor food items was usually related to fish size.

19. Relative abundance (C/E) of fingerling perch during June-October averaged 2.6-16.8 for limnetic habitats and 53.8-550.9 for littoral habitats. Relative abundance dropped sharply by August in all study years, suggesting that a substantial mortality regularly occurs in midsummer.

20. Fingerling mortality for trawl and seine samples was inversely related, ranging from 39 to 87% for trawl samples and 31 to 78% for seine samples. Daily instantaneous mortality coefficients exhibited similarly large year-to-year variation, ranging from 0.0166 to 0.0405 for June-October and from 0.0155 to 0.0483 for July-October. No significant relationship was found between coefficients for either of these periods and relative abundance, mean density, or relative density of young-of-the-year yellow perch.

21. Comparison of fingerling C/E data for 1959-67 and 1970-75 showed all of the study years to be relatively weak year classes, reaching less than 20% of the highest recorded (1962). Relative abundance for the last study year (1975) was the second weakest of the 15 years compared. No correlation was found between year class strength and environmental factors such as May-August water temperatures or Fox River flow during April and May in the 1971-75 study years.

22. Fingerling perch captured in limnetic habitats grew to 78-90 mm and weighed 4.9-7.5 g by October. Littoral fingerlings grew to 64-81 mm and weighed 2.9-5.3 g by September, when sampling ended. Half of the recorded first year growth was achieved by mid-July for length and by mid-August for weight. Growth was sigmoidal for both length and weight. Growth in length was similar for the 5 study years but moderately different for weight. Average seasonal growth ranged from 35 to 56 mg/day. No relationship was found between first-year growth and relative abundance for June and June-October.

23. The length-weight relationship for 1973-75 samples was described by the equations:

$$\text{Log } W = -5.31 + 3.19 \text{ Log } L \text{ (trawl samples) and}$$

$$\text{Log } W = -5.12 + 3.09 \text{ Log } L \text{ (seine samples)}.$$

24. Fingerling perch (15-114 mm) were primarily zooplankton feeders during their first year of life in Lake Winnebago. Copepods (principally *Cyclops* and *Diaptomus*) and cladocerans (principally *Daphnia, Leptodora,* and *Diaphanosoma*) comprised over 90% of total food items observed among all perch sampled. Insects were a minor food item to all but the largest perch (105-114 mm). Major habitat-related differences in food habits were observed. Copepods predominated in the diet of limnetic perch while cladocerans were more important for littoral perch. Diet was more diverse in littoral areas where 32 kinds of food items were observed, compared to 21 in limnetic areas. Food habits varied both with size of perch and year. 25. Fingerling perch exhibited strong selectivity for food items but this selectivity varied considerably from year to year and month to month.

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APPENDIX

TABLE 32. *Number of young-of-the-year yellow perch measured for growth information, 1971-75.*

Sampling Period	No. Fish Trawl	Seine	Combined
1971			
Jun	18	112	130
Jul	460	43	503
Aug	22	149	171
Sep	2	51	53
Oct	16	0	16
Total	518	355	873
1972			
Jun	107	100	207
Jul	54	316	370
Aug	1	164	165
Sep	6	33	39
Oct	0	0	0
Total	168	613	781
1973			
Jun	125	95	220
Jul	163	304	467
Aug	16	132	148
Sep	22	48	70
Oct	20	0	20
Total	346	579	925
1974			
Jun	55	75	130
Jul	81	246	327
Aug	51	84	135
Sep	48	149	197
Oct	38	0	38
Total	273	554	827
1975			
Jun	91	226	317
Jul	98	259	357
Aug	42	60	102
Sep	0	12	12
Oct	17	0	17
Total	248	557	805

TABLE 33. *Length-frequency distribution of larval yellow perch used for food habits analyses, 1970-75.*

Total Length (mm)	1970* (29 May-4 Jun) No.	%	1971 (4-27 May) No.	%	1972 (9-24 May) No.	%	1973 (9 May-6 Jun) No.	%	1974 (29 Apr-29 May) No.	%	1975 (8 May-2 Jun) No.	%	1970-75 No.	%
5 - 6			9	(9.8)	13	(21.3)	38	(11.4)	70	(15.5)	77	(29.5)	207	(15.8)
7 - 8			14	(15.2)	12	(19.7)	127	(38.3)	138	(30.5)	65	(24.9)	356	(27.2)
9 - 10			11	(12.0)	30	(49.2)	37	(11.1)	150	(33.2)	65	(24.9)	293	(22.4)
11 - 12	2	(1.8)	30	(32.6)	2	(3.3)	35	(10.5)	81	(17.9)	29	(11.1)	179	(13.7)
13 - 14	20	(18.3)	20	(21.7)	2	(3.3)	26	(7.8)	13	(2.9)	5	(1.9)	86	(6.6)
15 - 16	29	(26.6)	8	(8.7)	2	(3.3)	39	(11.7)			8	(3.1)	86	(6.6)
17 - 18	36	(33.0)					30	(9.0)			11	(4.2)	77	(5.9)
19 - 20	16	(14.7)									1	(0.4)	17	(1.3)
21 - 22	6	(5.5)											6	(0.5)
Total	109		92		61		332		452		261		1,307	
Avg. Total Length	16.4		10.9		8.8		10.3		8.7		8.6		9.9	

*Larval fish collected in the first 21 days of sampling were lost to evaporation of the preserving fluid.

TABLE 34. *Length distribution and average length for trawl- and seine-captured young-of-the-year yellow perch used for stomach analyses, 1971-75.*

Total Length (mm)	No. of Fish											
	1971		1972		1973		1974		1975		1971-75	
	Trawl	Seine	Trawl	Seine	Trawl	Seine	Trawl	Seine	Trawl	Seine	Trawl	Seine
15 - 24	18		44		36	10		2			98	12
25 - 34	7	3	20	40	32	15	29	76	30	78	118	212
35 - 44	21	52	37	141	33	75	19	125	23	94	133	487
45 - 54	31	25	20	102	28	98	7	97	35	95	121	417
55 - 64	17	48	9	67	12	60		89	17	89	55	353
65 - 74	19	29	1	44	10	44	15	65	22	56	67	238
75 - 84	11	8	4	5	17	24	36	45	7	13	75	95
85 - 94	2				9	1	33	6	6	4	50	11
95 -104					6	1	17		3		26	1
105 -114							4		6		10	
TOTALS	126	165	135	399	183	328	160	505	149	429	753	1,826
Avg. Length	45	53	36	48	47	52	67	52	55	50	50	51

TABLE 35. *Length-frequency distributions of adult yellow perch taken during spawning migrations in the Fox River at Oshkosh, 1971-76.*

Total Length (mm)	1971 Male	1971 Female	1972 Male	1972 Female	1973 Male	1973 Female	1974 Male	1974 Female	1975 Male	1975 Female	1976 Male	1976 Female	Interval Total Male	Interval Total Female
110 - 119											3		3	
120 - 129			2						1		7		10	
130 - 139			20	4	5		2		19	3	29		75	7
140 - 149	4		90	2	2		10	1	57	3	66		229	6
150 - 159	27	5	400	28	8		24	3	170	15	176	4	805	55
160 - 169	167	26	977	53	18	2	31	2	254	18	369	12	1,816	113
170 - 179	372	60	1,210	110	25	9	31	2	288	8	347	18	2,273	207
180 - 189	437	130	1,190	225	16	7	18	3	170	15	186	28	2,017	408
190 - 199	273	155	926	368	42	10	4	6	78	17	70	26	1,393	582
200 - 209	83	158	663	532	114	31	11	3	25	9	44	23	940	756
210 - 219	30	92	425	640	290	72	15	4	10	9	128	31	898	848
220 - 229	32	38	530	482	370	157	37	7	30	3	177	43	1,176	730
230 - 239	54	23	568	353	259	278	144	19	36	7	154	91	1,215	771
240 - 249	70	42	364	365	157	313	219	32	100	27	80	129	990	908
250 - 259	102	35	191	453	98	231	151	49	274	42	129	132	945	942
260 - 269	194	49	176	368	66	129	105	111	335	33	278	47	1,154	737
270 - 279	304	43	229	202	43	73	42	164	201	72	251	22	1,070	576
280 - 289	151	59	132	72	26	62	14	100	68	150	90	34	481	477
290 - 299	33	81	27	46	7	13	4	49	10	222	11	84	92	495
300 - 309	6	93	2	65		13	1	23	2	154		102	11	450
310 - 319	1	80		35		5		7		62		66	1	255
320 - 329		30		23				2		7		19		81
330 - 339		15		16		1		1		1		7		41
340 - 349		2												2
Sample size	2,340	1,216	8,122	4,442	1,546	1,406	863	588	2,128	877	2,595	918	17,594	9,447
Avg. length	216	237	199	217	228	245	237	269	216	276	211	258	210	236

TABLE 36. *Length frequency distribution of adult yellow perch taken during annual spawning migrations in the Fox River at Rivermoor, 1973-76.*

Total Length (mm)	1973 Male	1973 Female	1974 Male	1974 Female	1975 Male	1975 Female	1976 Male	1976 Female	Interval Total Male	Interval Total Female
100 - 109					1				1	
110 - 119	1								1	
120 - 129	1		1		1		1	1	4	
130 - 139	5		4		5		1	1	15	
140 - 149	32		19	1	46	1	4	5	101	3
150 - 159	44	1	38	1	119	1	63	9	264	4
160 - 169	59	5	63	1	223	4	164	15	509	15
170 - 179	61	3	54	1	241	4	234	19	590	17
180 - 189	61	13	31	3	213	9	188	21	493	40
190 - 199	100	9	21	1	120	6	87	22	328	35
200 - 209	267	16	27		53	10	74	27	421	47
210 - 219	490	23	35	4	44	12	144	34	713	61
220 - 229	515	42	47	2	83	6	277	49	922	77
230 - 239	363	64	136	9	92	12	170	53	761	119
240 - 249	208	66	228	9	176	11	109	34	721	135
250 - 259	120	57	164	19	399	19	118	14	801	148
260 - 269	56	42	73	25	438	16	200	23	767	117
270 - 279	29	21	21	20	254	25	168	30	472	80
280 - 289	16	19	5	13	56	38	54	23	131	93
290 - 299	2	12		1	12	50	7	6	21	93
300 - 309		1		1	1	52		3	1	77
310 - 319				1		18				25
320 - 329				2		7				12
330 - 339		1				2				3
Sample size	2,430	395	967	114	2,577	303	2,063	389	8,037	1,201
Avg. length	219	242	226	256	224	270	219	246	226	252

TABLE 37. *Spring flow conditions in the Fox River (entering Lake Winnebago during the yellow perch reproductive period) and indexes of streamflow (m^3/Sec) 1959-67 and 1970-73.**

Year	Mean April Flow (MA)	April Flow index $\left(\frac{MA}{(a)}\right)$	Mean May Flow (MM)	May Flow index $\left(\frac{MM}{(m)}\right)$	Mean April-May Flow (AM)	Spring Flow Index $\left(\frac{AM}{(s)}\right)$
1959	300	1.27	161	0.95	230	1.15
1960	284	1.20	410	2.42	348	1.74
1961	254	1.08	171	1.01	211	1.06
1962	376	1.59	229	1.35	301	1.51
1963	236	1.00	138	0.81	191	0.96
1964	73	0.31	128	0.76	100	0.50
1965	256	1.08	143	0.85	189	0.95
1966	146	0.62	89	0.53	115	0.58
1967	262	1.11	92	0.55	179	0.90
1970	77	0.33	84	0.50	81	0.41
1971	264	1.12	119	0.70	180	0.90
1972	288	1.22	146	0.86	198	0.99
1973	251	1.06	293	1.73	272	1.36
Mean	(a) 236		(m) 169		(s) 200	

*Calculated from average monthly flow data.

TABLE 38. *Degree-days above 10.6 C accumulated by month and year for Lake Winnebago and thermal indexes for 1959-67 and 1970-73 (in parentheses).*

Year	May	June	July	August	May-August
1959	161 (1.11)	567 (1.08)	602 (0.89)	686 (1.07)	2,016 (1.00)
1960	210 (1.44)	521 (0.99)	560 (0.82)	675 (1.05)	1,949 (0.97)
1961	102 (0.70)	555 (1.06)	630 (0.93)	637 (0.99)	1,925 (0.96)
1962	116 (0.80)	500 (0.95)	600 (0.88)	651 (1.01)	1,972 (0.98)
1963	89 (0.61)	527 (1.00)	744 (1.09)	660 (1.03)	2,055 (1.02)
1964	341 (2.34)	510 (0.97)	868 (1.28)	620 (0.96)	2,339 (1.16)
1965	152 (1.04)	480 (0.91)	651 (0.96)	620 (0.96)	1,968 (0.98)
1966	56 (0.38)	510 (0.97)	775 (1.14)	620 (0.96)	1,961 (0.98)
1967	55 (0.38)	510 (0.97)	620 (0.91)	620 (0.96)	1,805 (0.90)
1970	248 (1.70)	540 (1.03)	713 (1.05)	713 (1.11)	2,214 (1.10)
1971	124 (0.85)	540 (1.03)	713 (1.05)	589 (0.92)	1,966 (0.98)
1972	186 (1.28)	510 (0.97)	682 (1.00)	620 (0.96)	1,998 (0.99)
1973	51 (0.35)	558 (1.06)	682 (1.00)	651 (1.01)	1,942 (0.98)
Mean	145.5	525.2	680.0	643.2	2,008

TABLE 39. *Food of young-of-the-year yellow perch from trawl collections in Lake Winnebago, 1971-75. Data are presented as numbers and percentages of major food classes and number and percent contribution of food items to each class for each length group.*

Food Class	Food Item	15-34 mm No. Food Items	15-34 mm %	35-54 mm No. Food Items	35-54 mm %	55-74 mm No. Food Items	55-74 mm %	75-104 mm No. Food Items	75-104 mm %
Copepoda		2,306	77	2,158	43	1,840	66	1,571	44
	Diaptomus	625	27	375	17	30	2	5	T
	Cyclops	1,670	72	1,779	82	1,810	98	1,566	100
	Copepodids	11	1	4	T				
Cladocera		696	23	2,651	53	804	29	1,495	42
	Daphnia	458	66	1,959	74	274	34	880	59
	Leptodora	117	17	95	4	55	7	123	8
	Diaphanosoma	42	6	270	10	59	7	78	5
	Moina			25	1	4	T		
	Alona			1	T	269	34		
	Chydorus							2	T
	Bosmina	35	5	240	9	3	T	9	T
	Sida	43	6	57	2	39	5	18	1
	Ceriodaphnia								
	Eurycercus			4	T	98	12	384	26
	Camptocercus								
	Holopedium	1	T*			3	T	1	T
Ostracoda		1	T	4	T	41	1	30	1
Hydracarina									
Amphipoda		1	T	1	T	1	T	4	T
Isopoda									
Hirudinea				11	T	2	T	6	T
Nematoda									
Insecta		7	T	144	3	95	3	439	12
	Ephemeroptera								
	Chironomid larvae	7	100	134	93	77	81	424	97
	Chironomid pupae			9	6	18	19	15	3
	Chironomid adults								
	Odonata								
	Coleoptera			1	1				
	Trichoptera								
	Hemiptera								
	Megaloptera								
	Plecoptera								
	Lepidoptera								
Pelecypoda						1	T	10	T
Gastropoda								1	T
Number of Stomachs		216		254		122		161	
Number Empty		8	3.7	57	22.4	49	40.2	47	29.2

*T = trace

TABLE 40. *Food of young-of-the-year yellow perch from seine collections in Lake Winnebago, 1971-75. Data are presented as number and percentages of major food classes and number and percent contribution of food items to each class for each length group.*

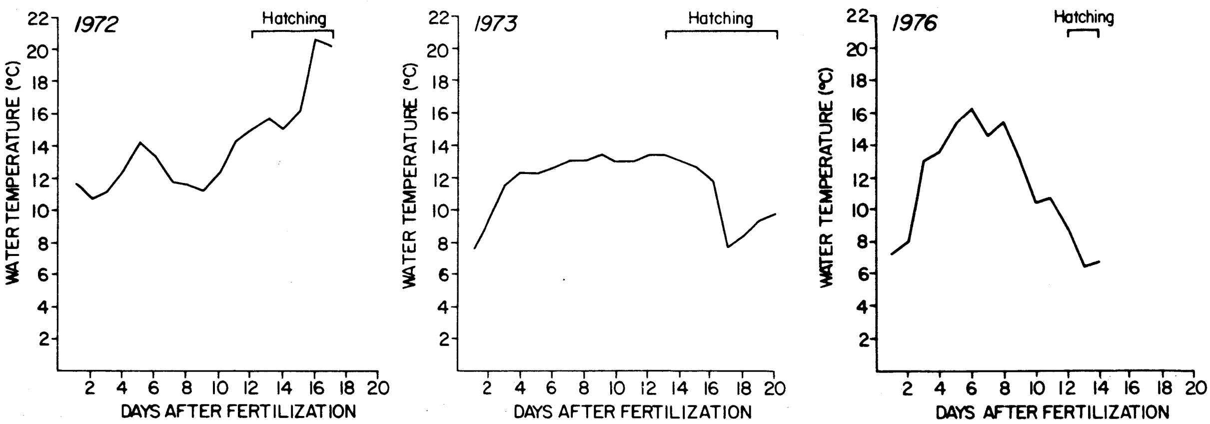
		Length Interval of Fish							
		15-34 mm		35-54 mm		55-74 mm		75-104 mm	
Food Class	Food Item	No. Food Items	%	No. Food Items	%	No. Food Items	%	No. Food Items	%
Copepoda		1,998	20	17,068	22	9,144	16	70	1
	Diaptomus	758	38	5,437	32	750	8		
	Cyclops	1,233	62	11,605	68	8,357	91	52	74
	Copepodids	7	T	26	T	37	T	18	26
Cladocera		7,719	79	57,943	74	43,796	75	7,690	84
	Daphnia	1,736	22	27,598	48	10,737	25	1,051	14
	Leptodora	160	2	1,404	2	337	1	71	1
	Diaphanosoma	171	2	2,776	5	3,214	7	1,251	2
	Moina								
	Alona	4	T	136	T				
	Chydorus	99	1	648	1	211	T	16	T
	Bosmina	2,172	28	11,914	21	7,994	18	83	1
	Sida	3,281	43	7,064	12	3,929	9	482	6
	Ceriodaphnia	9	T	4,536	8	13,097	30	210	3
	Eurycercus	87	1	1,769	3	4,274	10	5,651	73
	Camptocercus			89	T	1			
	Holopedium			9	T	2	T	1	T
Ostracoda		7	1	75	T	131	T	33	T
Hydracarina		2	T	8	T	4	T	8	T
Amphipoda		39	T	841	1	2,510	4	749	8
Isopoda				9	T	23	T	4	T
Hirudinea				10	T	7	T	2	T
Nematoda				1	T				
Insecta		39	T	2,495	3	2,632	5	635	7
	Ephemeroptera			14	T	7	T	5	1
	Chironomid larvae	26	67	2,201	88	1,158	44	347	55
	Chironomid pupae	10	26	229	9	332	13	159	25
	Chironomid adults			1	1				
	Odonata			35	1	58	2	14	2
	Coleoptera			1	T	2	T	1	T
	Trichoptera			3	T	13	T	6	1
	Hemiptera	2	5	11	T	1,056	40	98	15
	Megaloptera					5	T	5	1
	Plecoptera					1	T		
	Lepidoptera	1	3						
Pelecypoda				6	T	67	T	14	T
Gastropoda				2	T	12	T	14	T
Number of Stomachs		224		904		591		107	
Number Empty		5	2.2	50	5.5	80	13.5	6	5.6

TABLE 41. *Food of young-of-the-year yellow perch from seine collections in Lake Winnebago, 1971-75. Data presented as numbers and percentages of major food classes and number and percent contribution of food items to each class.*

Food	All Size Classes									
	1971		1972		1973		1974		1975	
Parameters	Number	%	Number	%	Number	%	Number	%	Number	%
Number of stomachs	165		399		328		505		429	
Number empty	9	(5.5)	37	(9.3)	60	(18.3)	19	(3.8)	16	(3.7)
Copepoda	2,081	(9)	6,079	(43)	5,497	(54)	4,959	(7)	9,664	(23)
Diaptomus	959	(46)	487	(8)	1,021	(19)	2,084	(42)	2,394	(25)
Cyclops	1,122	(54)	5,502	(92)	4,476	(81)	2,820	(57)	7,237	(75)
Copepodids	0	(0)	0	(0)	0	(0)	55	(1)	33	(T)
Cladocera	19,595	(84)	5,391	(38)	3,525	(34)	60,065	(90)	28,572	(70)
Daphnia	3,246	(17)	1,929	(36)	1,769	(50)	20,612	(34)	13,566	(47)
Leptodora	78	(T)	111	(2)	10	(T)	988	(2)	785	(3)
Diaphanosoma	1,942	(10)	739	(14)	1,414	(40)	2,121	(4)	70	(T)
Alona	139	(1)	1	(T)	0	(0)	0	(0)	0	(0)
Chydorus	61	(T)	737	(14)	6	(T)	82	(T)	88	(T)
Bosmina	3,214	(16)	582	(11)	222	(6)	16,817	(28)	1,328	(5)
Sida	28	(T)	168	(3)	77	(2)	9,265	(15)	5,218	(18)
Ceriodaphnia	9,638	(49)	492	(9)	3	(T)	1,352	(2)	6,367	(22)
Eurycercus	1,249	(6)	534	(10)	24	(1)	8,825	(15)	1,149	(4)
Camptocercus	0	(0)	90	(1)	0	(0)	0	(0)	0	(0)
Holopedium	0	(0)	8	(T)	0	(0)	3	(T)	1	(T)
Ostracoda	28	(T)	68	(T)	20	(T)	57	(T)	73	(T)
Hydracarina	4	(T)	8	(T)	4	(T)	3	(T)	3	(T)
Amphipoda	514	(2)	739	(5)	248	(2)	854	(1)	1,784	(4)
Isopoda	1	(T)	26	(T)	0	(0)	3	(T)	6	(T)
Hirudinea	4	(T)	4	(T)	3	(T)	3	(7)	5	(T)
Nematoda	1	(T)	0	(0)	0	(0)	0	(0)	0	(0)
Insecta	1,158	(5)	1,793	(13)	912	(9)	993	(1)	945	(2)
Ephemeroptera	0	(0)	5	(T)	8	(1)	9	(1)	4	(T)
Chironomid larvae	104	(9)	1,721	(96)	374	(41)	767	(77)	766	(81)
Chironomid pupáe	40	(3)	35	(2)	420	(46)	141	(14)	94	(10)
Chironomid adults	0	(0)	0	(0)	1	(T)	0	(0)	0	(0)
Odonata	7	(1)	29	(2)	5	(1)	60	(6)	6	(1)
Coleoptera	0	(0)	0	(0)	0	(0)	2	(T)	2	(T)
Trichoptera	5	(T)	1	(T)	11	(1)	1	(T)	4	(T)
Hemiptera	1,001	(86)	2	(T)	93	(10)	12	(1)	59	(6)
Megaloptera	0	(0)	0	(0)	0	(0)	0	(0)	10	(1)
Plecoptera	1	(T)	0	(0)	0	(0)	0	(0)	0	(0)
Lepidoptera	0	(0)	0	(0)	0	(0)	1	(T)	0	(0)
Pelecypoda	0	(0)	1	(T)	34	(T)	3	(T)	49	(T)
Gastropoda	1	(T)	11	(T)	0	(0)	0	(0)	2	(T)

TABLE 42. *Food of young-of-the-year yellow perch from trawl collections in Lake Winnebago, 1971-75. Data are presented as numbers and percentages of major food classes and number and percent contribution of food items to each class.*

Food Parameters	All Size Classes 1971 Number	%	1972 Number	%	1973 Number	%	1974 Number	%	1975 Number	%
Number of stomachs	126		135		183		160		149	
Number empty	33	(26.2)	10	(7.4)	55	(30.1)	23	(14.4)	40	(26.8)
Copepoda	815	(31)	1,442	(73)	3,198	(83)	949	(32)	1,471	(50)
Diaptomus	262	(32)	231	(16)	220	(7)	24	(3)	298	(20)
Cyclops	552	(68)	1,211	(84)	2,978	(93)	923	(97)	1,161	(79)
Copepodids	1	(T)	0	(0)	0	(0)	2	(T)	12	(1)
Cladocera	1,726	(67)	486	(25)	614	(16)	1,765	(59)	1,055	(36)
Daphnia	965	(56)	375	(77)	405	(66)	1,021	(58)	805	(76)
Leptodora	41	(2)	70	(14)	48	(8)	158	(9)	73	(7)
Diaphanosoma	33	(2)	32	(7)	77	(13)	280	(16)	27	(3)
Moina	29	(2)	0	(0)	0	(0)	0	(0)	0	(0)
Alona	270	(16)	0	(0)	0	(0)	0	(0)	0	(0)
Chydorus	0	(0)	0	(0)	0	(0)	2	(T)	0	(0)
Bosmina	209	(12)	3	(1)	58	(9)	13	(1)	4	(T)
Sida	0	(0)	5	(1)	24	(4)	20	(1)	108	(10)
Eurycercus	179	(10)	0	(0)	2	(T)	267	(15)	38	(4)
Holopedium	0	(0)	1	(T)	0	(0)	4	(T)	0	(0)
Ostracoda	1	(T)	2	(T)	17	(T)	23	(1)	33	(1)
Amphipoda	1	(T)	0	(0)	1	(T)	5	(T)	0	(0)
Hirudinea	11	(T)	0	(0)	0	(0)	5	(T)	3	(T)
Insecta	38	(1)	44	(2)	38	(1)	209	(7)	356	(12)
Chironomid larvae	38	(100)	43	(98)	37	(97)	193	(92)	331	(93)
Chironomid pupae	0	(0)	1	(2)	0	(0)	16	(8)	25	(7)
Coleoptera	0	(0)	0	(0)	1	(3)	0	(0)	0	(0)
Pelecypoda	0	(0)	0	(0)	0	(0)	11	(T)	0	(0)
Gastropoda	0	(0)	0	(0)	1	(T)	0	(0)	0	(0)



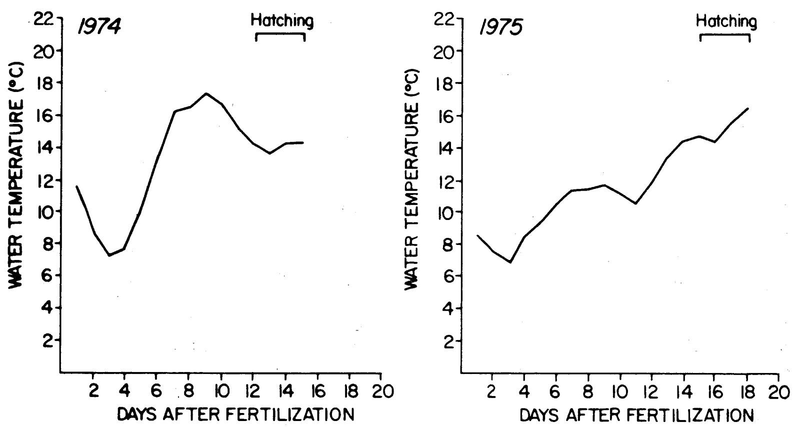
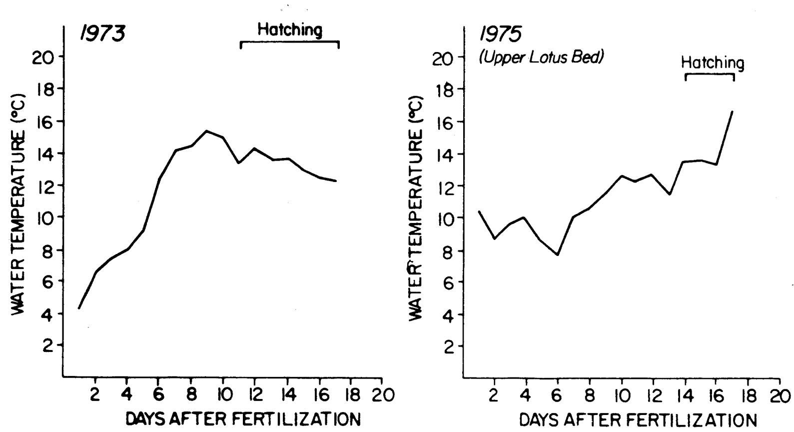


FIGURE 29. *Mean daily water temperatures during yellow perch egg incubation at study sites in the Fox River at Oshkosh, 1972-76.*



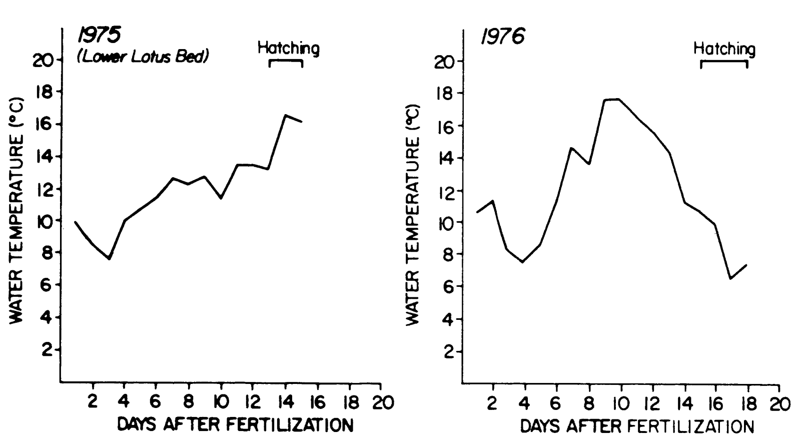


FIGURE 30. *Mean daily water temperatures during yellow perch egg incubation at study sites in the Fox River at Rivermoor, 1973, 1975 and 1976.*

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