THE DISTRIBUTION AND ABUNDANCE OF LARVAL FISHES ALONG THE WESTERN SHORE OF LAKE ERIE AT MONROE, MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
DON DAVID NELSON
1975

ABSTRACT

THE DISTRIBUTION AND ABUNDANCE OF LARVAL FISHES ALONG THE WESTERN SHORE OF LAKE ERIE AT MONROE, MICHIGAN

By

Don D. Nelson

The distribution and abundance of larval fish in and around the condenser cooling-water system of an electric generating station on western Lake Erie was studied during the summers of 1973 and 1974. Samples were collected with a 1-m, #0 mesh (0.571 mm) plankton net. Analysis of variance and Tukey's post-hoc comparison were used to analyze differences in numbers of individuals collected.

During the study period, 20 species or taxonomic groups were identified, although 90% of the total catch was represented by only 4 taxa. Abundances from year to year within these most abundant groups varied greatly, indicating a need for more than short-term studies.

Recruitment of larvae within the discharge canal prevented a determination of entrainment losses, however, a drop in abundance between two discharge canal stations indicated that mortality may have occurred. Heated water within the discharge canal appeared to lengthen the spawning period of several less desirable species, while reducing or not affecting that of the more valuable sport species. Based on fecundity techniques, the number of larval fish entrained was estimated to be from 1 to 10% of the total

available larvae, at a hatching success of 100 to 10 percent, respectively.

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A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1975

ACKNOWLEDGEMENTS

I extend my sincere appreciation to all the people who helped in the completion of this research: Dr. Eugene Roelofs and Dr. Richard Cole, for their guidance in the development of this manuscript; my committee members, Dr. Howard Johnson and Dr. Clifford Humphrys; Mr. Jocob Hogue, Jr., Mr. Robert Wallus, and Mr. Lawrence Kay of the Tennessee Valley Authority, for their verification of identified specimens.

This study was supported by grants from the Environmental Protection Agency and the Detroit Edison Company made to the Institute of Water Research at Michigan State University.

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INTRODUCTION

In recent years there has been increasing interest in the study of larval fish. Field studies, such as those of Marcy (1973), Noble (1970), Faber (1967), Werner (1969), and others, and highly controlled laboratory studies suggested by Coutant (1971) have increased our knowledge of icthyoplankton dynamics. Increased cultural modification of our aquatic resources has, however, stressed the need for additional information about the aquatic ecosystem. One such example is the use of cooling water in the production of electricity. Many nonscreenable planktonic forms, including icthyoplankton, may easily be entrained, and possibly destroyed. This may alter fish populations in the receiving waters.

The purpose of this research was to investigate the species composition, distribution and abundance of larval fish near the west shore areas of western Lake Erie. Data are also discussed in reference to the possible operational impact of a steam-electric generating plant utilizing once-through cooling.

MATERIALS AND METHODS

Power Plant Description

The power plant is operated by the Detroit Edison Company near the mouth of the Raisin River at Monroe, Michigan. At full production the facility is designed to produce 3200 megawatts and requires cooling water at the rate of 110 m^3/sec. The first of four 800 megawatt units began operating in June 1971, with completion of the fourth unit occuring in May 1974. Cooling water for the plant comes from both the river and Lake Erie. Seasonal fluctuations in river discharge influence the proportion of river water in the cooling system which can range from a high of nearly 100% in the spring to a low of 5% in the late summer. Since there are significant biological differences between the lake and the river, this seasonal variation will affect the composition of biological components moving through the system.

The cooling water enters the system through a 100 m long intake canal which is located approximately one-half kilometer upstream from the mouth of the river (Figure 1). Before entering the plant the water passes through several trash collecting devices, including a traveling screen with a 1 cm diagonal opening. Inside the plant the water enters a bank of condenser tubes (I.D. of 2.54 cm) where velocities may approach 2 m/sec. Flow-time through the condenser is

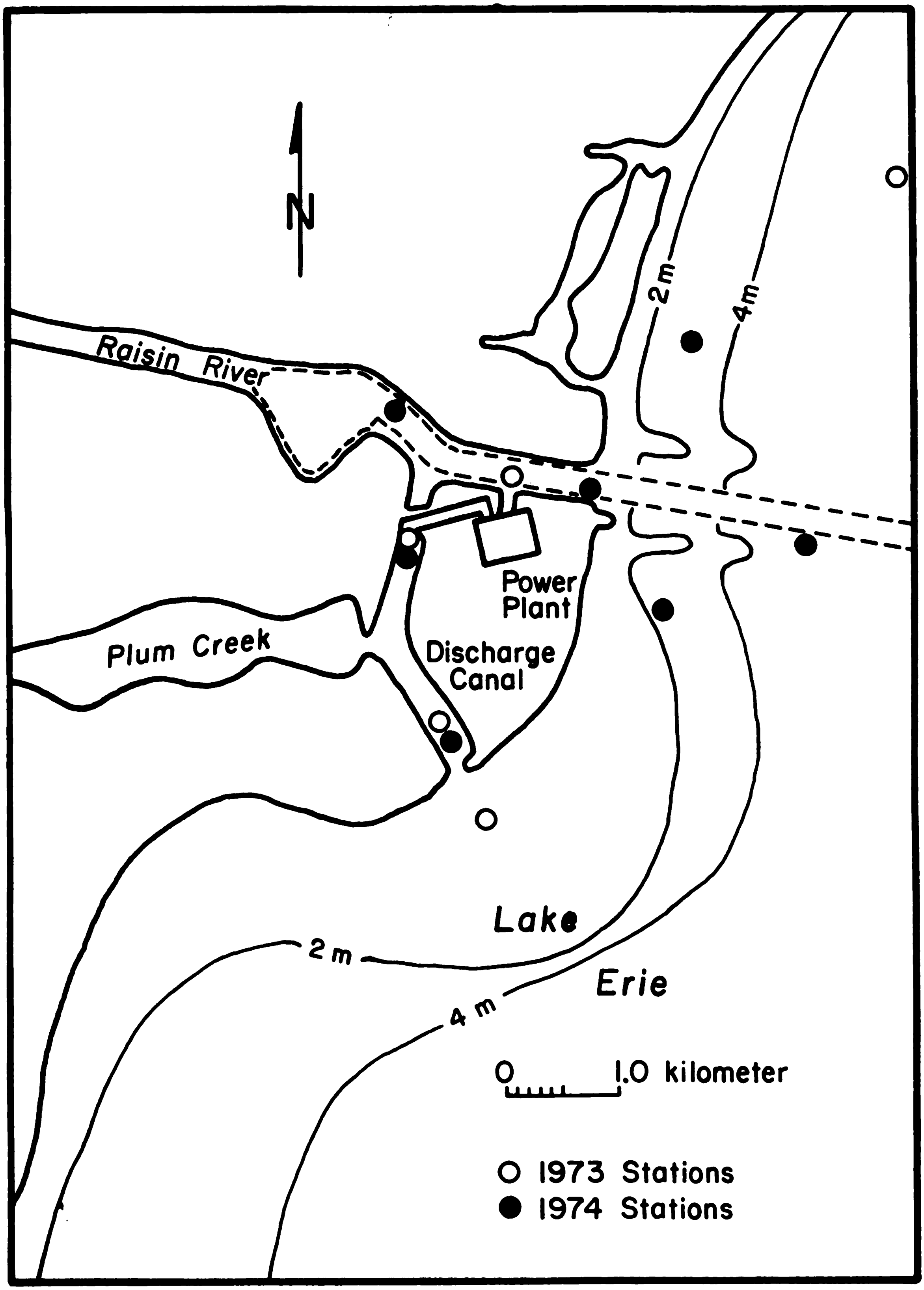

Figure 1. A map of the study area located along the west shore of Lake Erie near Monroe, Michigan.

approximately 7 seconds, and at peak production water temperatures may be elevated 10-12 C above ambient. The heated water then flows down a concrete conduit and enters the discharge canal which is about 150 m wide and 2000 m long. The upstream half of the discharge canal is dredged to 7 m and has an average fully operational velocity of 10 cm/sec while the downstream half of the canal is dredged to only 3-4 m and has an average velocity of approximately 20 cm/sec. Under the influence of changing winds, the plume in the lake wanders from the shore north of the discharge mouth to the shore south of the discharge mouth, and it may be 4 km or longer. A nonscreenable, nonmobile organism may, therefore, be exposed to an elevated temperature for over 8 hours.

Study Site

The western end of Lake Erie is a shallow basin which is separated from other areas of the lake by a series of islands and peninsulas on the north and south shores. The surface area of the basin is 3,276 km^2, and has an average depth of only 7.3 m (Carr, *et al.*, 1965). Water in the basin is usually turbid as a result of surface runoff, algal growth, and sediments suspended by wave action. Secchi disk transparencies rarely exceed 1 m in the near-shore areas (Marcus, 1972). Water temperatures on selected dates during the two years of the study are presented in Figure 2.

Approximately 95% of the lake's tributary flow enters the western basin through the Detroit River (Casper, 1965).

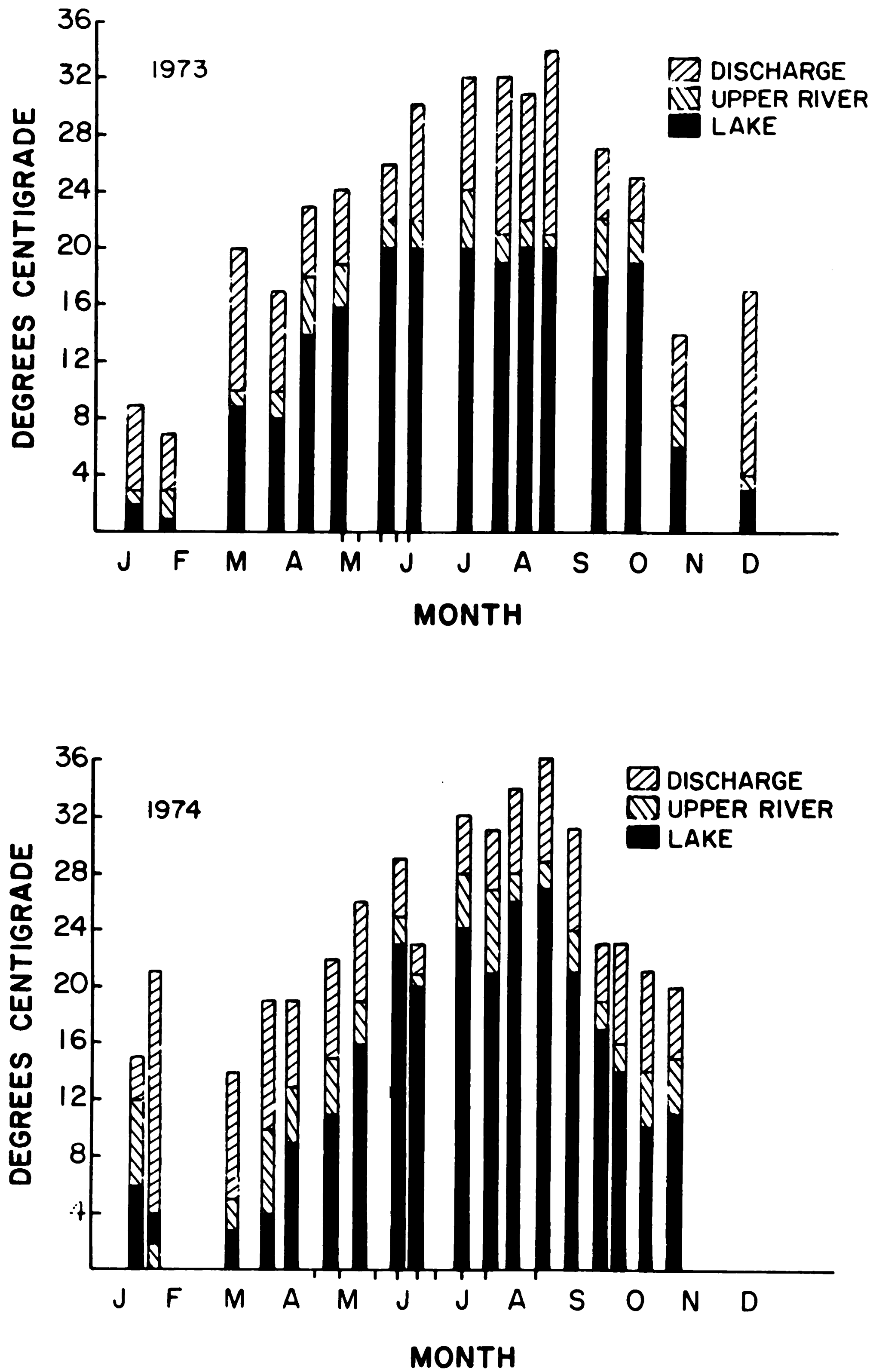

Figure 2. Surface temperatures in the Raisin River, discharge canal, and along the west shore of Lake Erie during 1973 and 1974.

This flow is directed southward and contributes, with wind variation, to the formation of discontinuous, clockwise eddy currents in the Toledo-Detroit area (Hartly, et al., 1966). Thus, northeastward currents prevail along the Michigan shore.

In the vicinity of the study area much of the once abundant marsh and wetland has been altered, although some areas remain and may serve as an important nursery for some fish species. Much of the remaining area is sandy shoal with pockets of clay and silt. Spatial homogeneity characterizes the area; for the most part, interruptions of the shore line by such features as the river and discharge canal provide the only alterations to an otherwise uniform environment.

At present, the water quality of the Raisin River is inferior to that of the lake. Until very recently large quantities of municipal and industrial wastes, including biodegradable organics, heavy metals, and chlorinated hydrocarbons, were routinely released into the river. As a result, the river was anoxic during most of the summer with few macroscopic organisms present. Recent improvements in waste treatment have improved the water quality. Further improvement, coupled with the abundant wetlands on the periphery of the river, may allow for increased fish spawning in the future.

Sampling

Sampling took place during the summers of 1973 and 1974. In 1973, stations were located in the Raisin River near the intake structure, the upper discharge canal, the lower discharge canal, Lake Erie within the plume, and Lake Erie outside the plume (Figure 1). Several modifications were made in 1974. Two river stations were sampled, because of the unmixed nature of the water mass directly in front of the intake structure and the inability to tow directly within it. One site was located upstream from the plant at a distance calculated to remove any possible effect of the plant. The second was located near the mouth of the river, in order to sample the lake water which was being drawn into the plant. An intake station was calculated, based on river discharge rates provided by the USGS and plant pumping rates provided by the Detroit-Edison Company. This calculated station weighted the larval concentration of each of the two river stations by the contribution each made to the total amount of water pumped. Sampling within the plume was not attempted in 1974 due to the shallow nature of the station. Instead, two additional lake stations were added to increase replication in the lake and to sample all possible water masses that could be entrained under a variety of wind directions (Figure 1).

In 1973, sampling was conducted at three discrete depths: surface, mid-depth, and near bottom. All tows were 5 min, and were replicated twice at each depth for each station. Six replicates per station were made in 1974 using a 2.5 min integrated tow, because of the large variation between replicates and the inability to determine statistically significant differences among depths in the previous year. For this scheme, a plankton net was towed at an oblique angle through the water column at a constant rate from bottom to surface. In both years a 1 m, #0 mesh (0.571 mm), nylon plankton net was used. Towing speed was approximately 2 knots. A General Oceanics model 2030 flowmeter was fitted at the center of the opening and a 1.8 liter plastic plankton bucket was attached to the codend of the net. Some of the smaller larval forms may have passed through the net because of the large mesh size used. Tows of longer duration and nets of smaller mesh were tried, but they collected far too much seston to allow effective sample processing. On some dates, sampling had to be cancelled when tows of only 1 minute resulted in zooplankton collections greater than the capacity of the plankton bucket.

All samples were preserved in 5% formalin, and rose bengal dye was added to ease sorting in the laboratory. All specimens were identified to the most specific taxon possible; ordinarily the species. A key to the identification of larval fish in western Lake Erie is included in Appendix B. All results are expressed as the number of individuals per 100 m^3 of water. Transformations by the square root method were made before statistical tests were applied. To account for zero observations, one half unit was added to all values. ANOVA was performed on all abundant species with Tukey's multiple range applied to the results (Appendix A).

RESULTS

Species Composition

The major fish species captured during the study were gizzard shad, *Dorosoma cepedianum*, and alewife, *Alosa pseudoharengus* (43.6%); carp, *Cyprinus carpio* (13.1%); yellow perch, *Perca flavescens* (18.7%); white bass, *Morone chrysops* (10.6%); and freshwater drum, *Aplodinotus grunniens*, (3.7%). These species accounted for 90% of the total catch. Less abundant species are listed in Tables 1 and 2.

A total of 1,655 and 11,123 larvae were collected in 1973 and 1974, respectively. Yolk-sac larvae represented 28.2% of the total catch with early post yolk-sac representing 64.7% and late post yolk-sac larvae representing 7.1%. Juveniles were rarely captured. Both gizzard shad and alewife are common in the area, but due to identification difficulties no attempt was made to distinguish between them. No goldfish or carp-goldfish hybrids were identified in the study, although some may have been erroneously included with carp.

Gizzard Shad and Alewife

Specimens were captured as early as 26 April in 1974, but were not collected in 1973 until 1 June. They were also collected on the last sampling date in 1974, making them one of the two groups whose larvae were present in the water column the greatest period of time. Yolk-sac larvae comprised

Table 1. Total number of infrequently captured larvae per station in 1973.

	Lake	Intake	Upper Discharge	Lower Discharge	Plume
Smelt *Osmerus mordax*	126	19	7	8	67
Suckers Catostomidae	0	1	7	13	6
Spottail shiner *Notropis hudsonius*	1	1	32	10	18
Emerald shiner *Notropis atherinoides*	10	0	1	0	3
Channel catfish *Ictalurus punctatus*	0	0	2	0	0
Trout perch *Percopsis omiscomaycus*	0	0	1	2	0
Log perch *Percina caprodes*	0	1	1	0	1
Walleye *Stizostedion vitreum*	0	0	0	1	0
White crappie *Pomoxis annularis*	0	0	10	3	2

Table 1 (con't.)

Sunfish					
Lepomis spp.	0	0	4	33	2
Bass					
Micropterus spp.	0	1	0	0	0

Table 2. Total number of infrequently captured larvae per station in 1974.

	Lake A	Lake B	Lake C	Lower River	Upper River	Upper Discharge	Lower Discharge
Smelt *Osmerus mordax*	8	19	7	4	2	0	0
Suckers Catostomidae	1	1	1	3	1	2	1
Spottail shiner *Notropis hudsonius*	1	0	0	8	12	59	6
Emerald shiner *Notropis atherinoides*	28	35	66	14	7	47	18
Channel catfish *Ictalurus punctatus*	0	0	1	5	0	193	22
Trout perch *Percopsis omiscomaycus*	0	0	0	3	0	2	0
Log perch *Percina caprodes*	0	0	0	2	0	2	0
Walleye *Stizostedion vitreum*	1	0	0	7	0	0	0
White crappie *Pomoxis annularis*	0	0	0	0	11	4	1

Table 2 (con't.)

Sunfish							
Lepomis spp.	2	5	10	40	97	59	32
Bass							
Micropterus spp.	0	0	0	0	34	11	2

only 5% of the total catch, although they persisted until 15 July in 1974.

Based on 1974 data, larvae of this group generally were most abundant in the lake, although at a level which was generally not significantly different (a = 0.05) from the discharge stations (Figure 3). On the two dates when the abundance levels of the discharge canal stations were significantly different from each other, the lower discharge station had the greater abundance. The average number of larvae at the calculated intake station was always less than the upper discharge station, but on only one date was there a significant difference.

The vertical distribution of gizzard shad and alewife sampled in 1973 is presented in Figure 4. Although there was no significant difference between the depths due to the large sampling variation, seasonal summations indicate that they were more frequently captured near bottom in the lake and at mid-depth and surface in the discharge canal.

Variation between years was greatest in this group, with the percent of total catch equalling 5.6 and 49.3 in 1973 and 1974, respectively.

Yellow Perch

Yellow perch larvae were not captured until 10 May in either year. Although minor catches persisted until 15 July, most larvae were caught on or before 11 June (Figure 5). Yolk-sac larvae were the dominant forms on the earliest sampling date, with a gradual transition to more developed stages at later dates. Yolk-sac stages were not captured

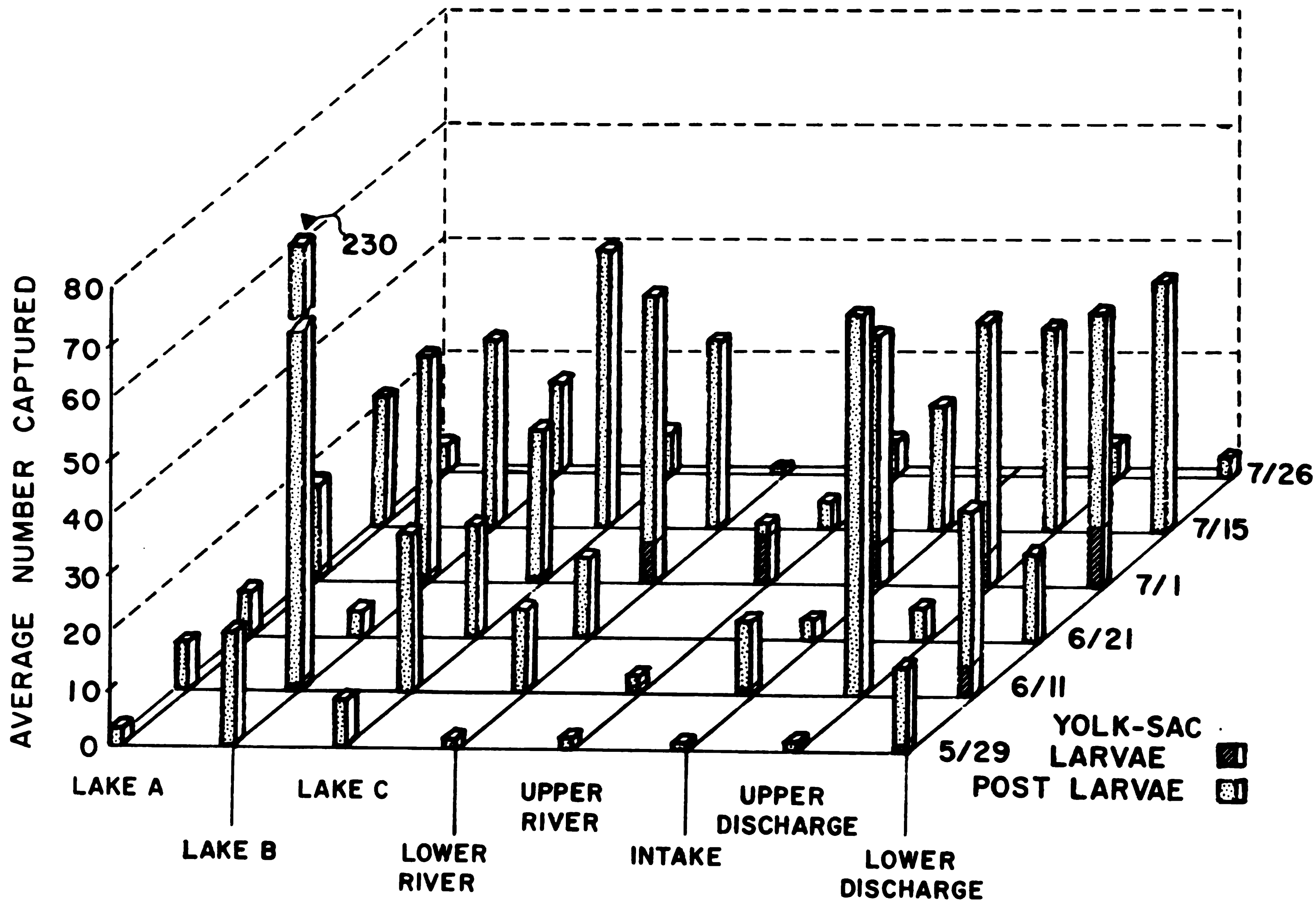

Figure 3. Average number of gizzard shad and alewife larvae collected per sampling date at each station during 1974.

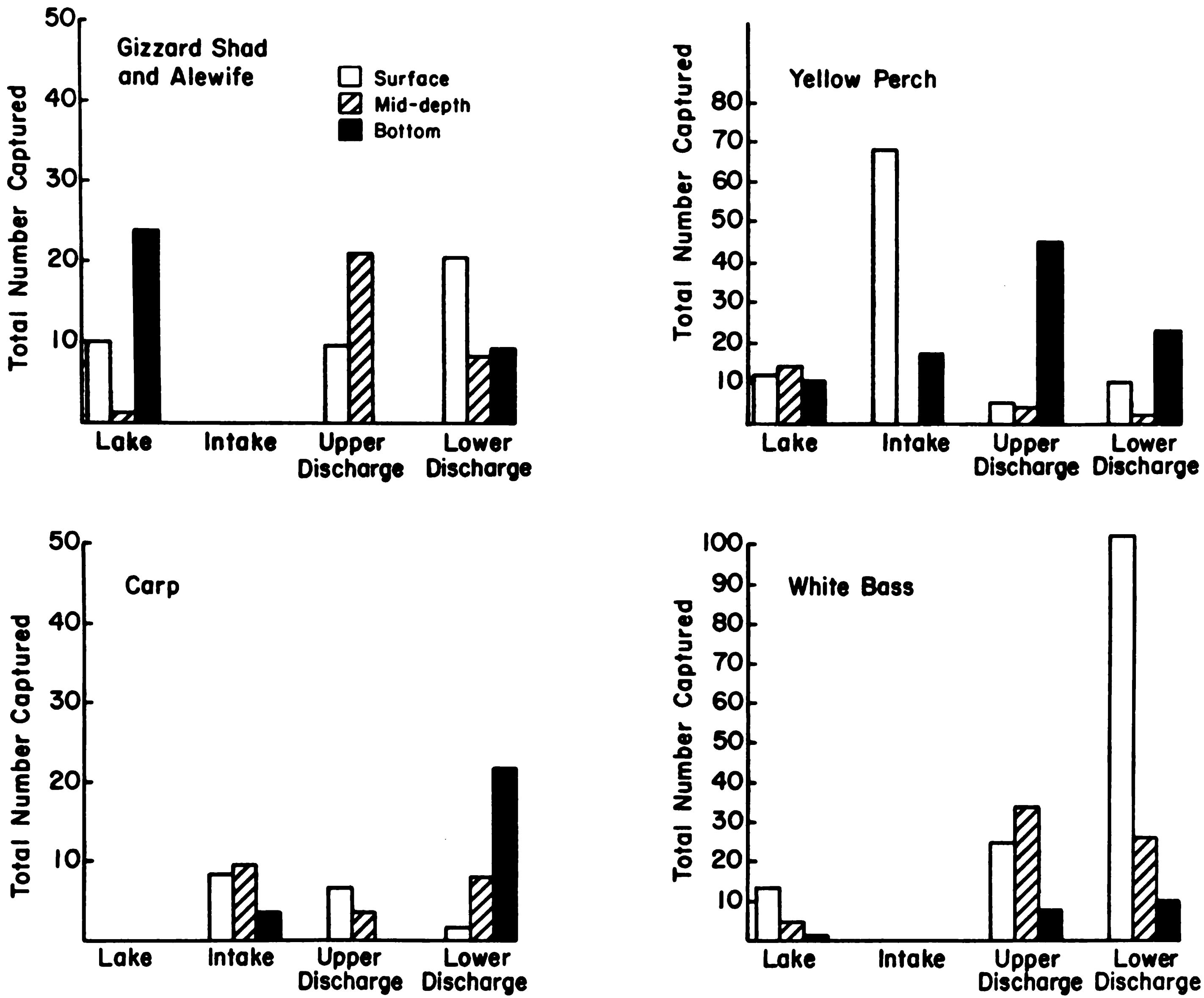

Figure 4. Number of larvae collected per station at three depths during 1973.

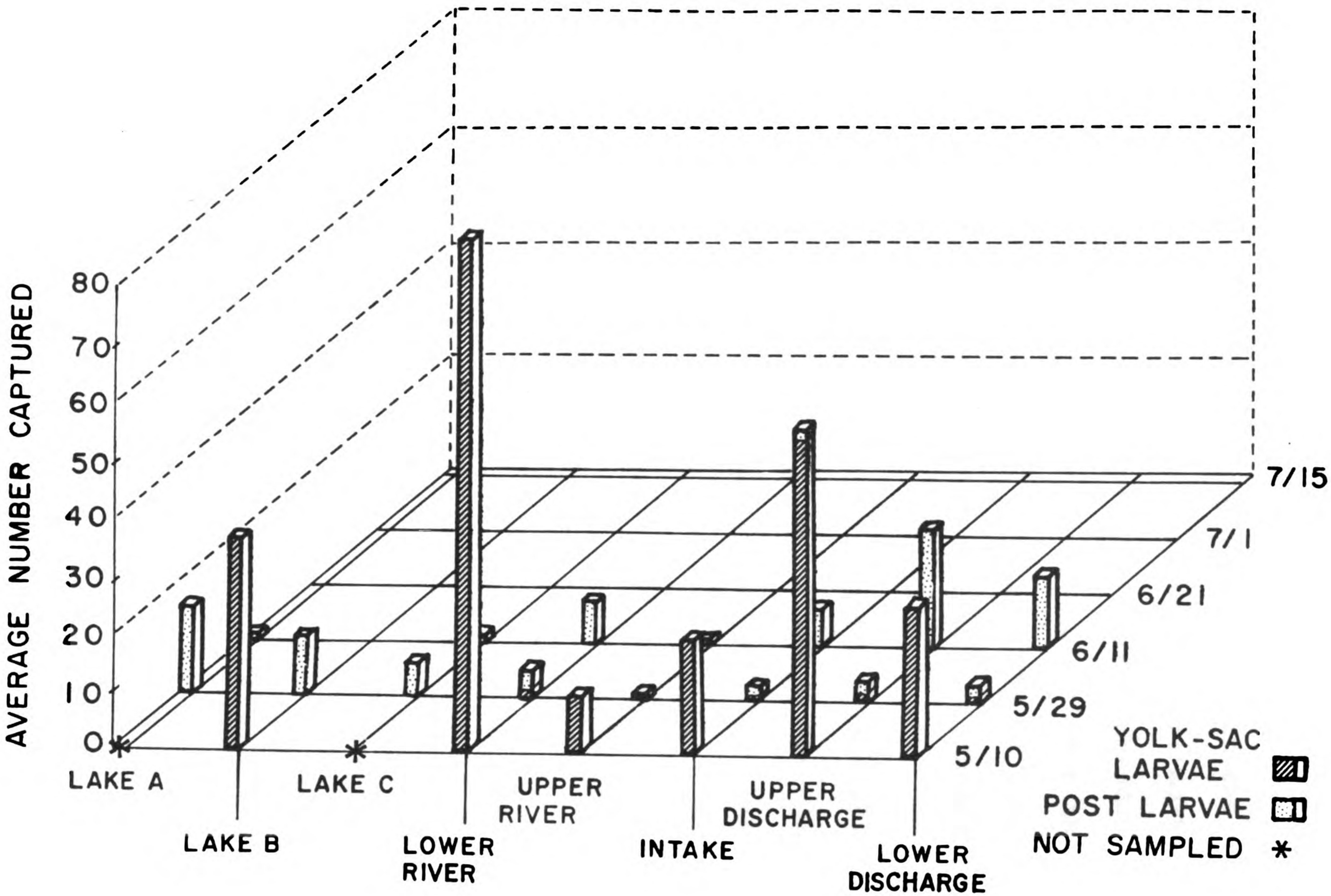

Figure 5. Average number of yellow perch larvae collected per sampling date at each station during 1974.

after 29 May in 1974 and 8 June in 1973. Only 29% of the total catch were post larvae.

Yolk-sac larvae were most abundant in the lower river, but at a level not significantly different from the upper discharge station (a = 0.05). Post larvae were most abundant in the lake. Of the two discharge stations, abundance in the upper discharge canal was always greater than the lower discharge canal, and on 10 May 1974 when 71% of the total larvae were captured this difference was significant (a = 0.05).

Seasonal totals for the 1973 depth distribution are presented in Figure 4. The number of larvae near the bottom is significantly less at the lake and intake stations than at the two discharge stations.

Yellow perch comprised 13.3% and 19.5% of the total catch in 1973 and 1974, respectively.

Carp

This species represents the only instance of larval occurrence on all dates in both 1973 and 1974, although a decline in abundance did occur after 1 July 1974. Yolk-sac larvae were the most abundant developmental stage, comprising 78% of the total, and were still present in the water column on 22 August 1974.

Areas of greatest larval abundance were the upper river and discharge canal (Figure 6). Very few larvae were found in the lake. In 1974 the upper discharge station had the greatest abundance of larvae early in the year, with the upper river gaining in importance after 11 June. Abundance

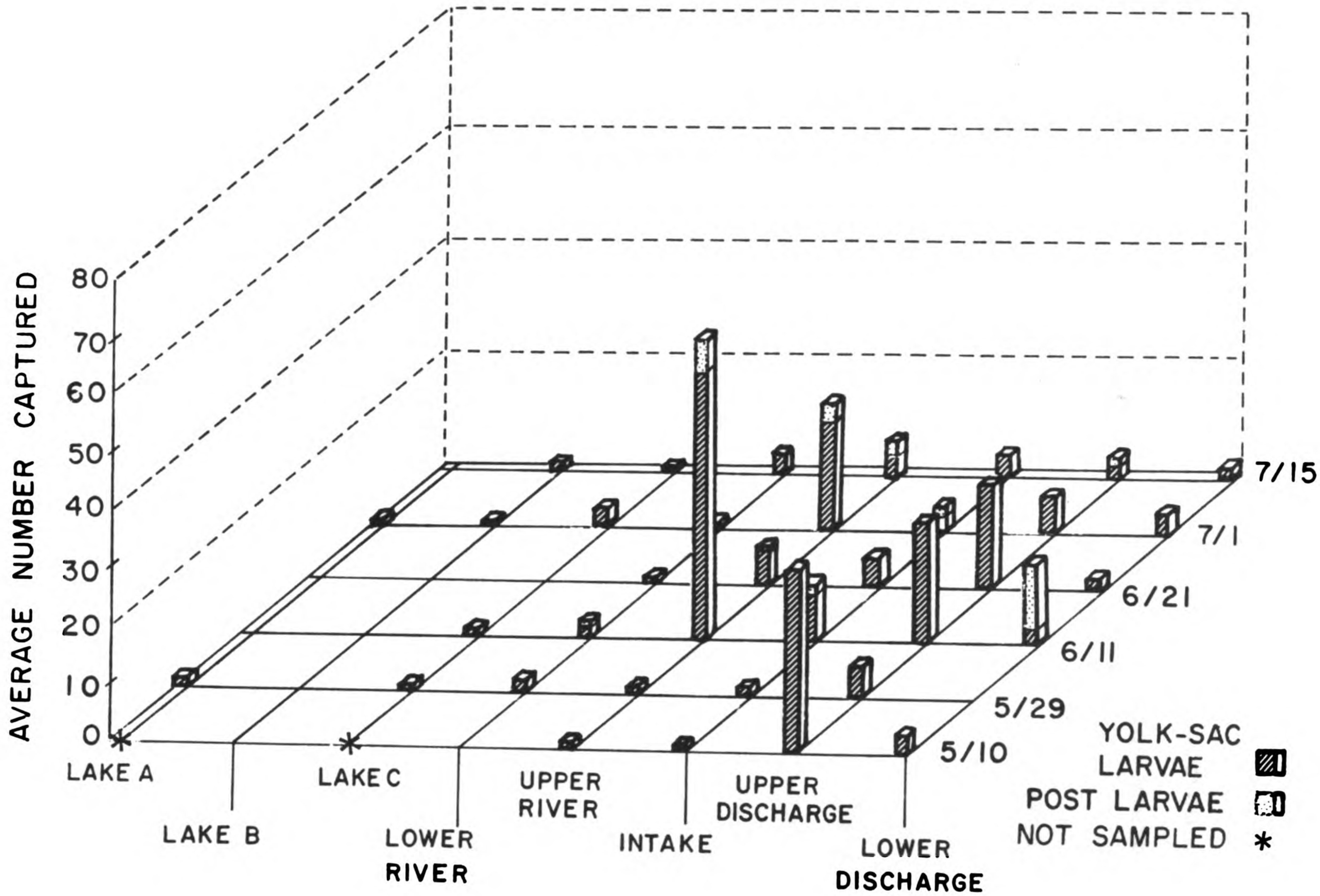

Figure 6. Average number of carp larvae collected per sampling date at each station during 1974.

at the upper discharge station was always greater than at the lower discharge station, and this difference was generally significant.

Depth distributions for 1973 are shown in Figure 4. Significantly more larvae were found near bottom in the lower discharge canal than at other stations where larvae were present.

In 1973, carp larvae comprised 24.4% of the total catch, while in 1974 the percent of catch was only 11.4.

White Bass

In 1974, larvae of this species were not captured until 29 May and were present until 26 July. Few larvae were collected on the sampling dates in late June and early July, giving the seasonal succession a bimodal aspect (Figure 7). In 1973, this species was collected only on the last sampling date of 15 June. Success at capturing yolk-sac larvae was very limited in both years. Post yolk-sac larvae comprised almost 99% of the total species catch.

The upper discharge station generally yielded the most larvae. On three dates abundance levels of this station were greater than the lower discharge station, and on two of those dates, they were significantly greater ($a = 0.05$). Additionally, abundance at the upper discharge station was always greater than at the calculated intake station, and on 11 June and 26 July this difference was significant. The upper river station had the lowest abundance on all dates.

The 1973 vertical distribution is presented in Figure 4. The percent of larvae present at the surface and mid-depth

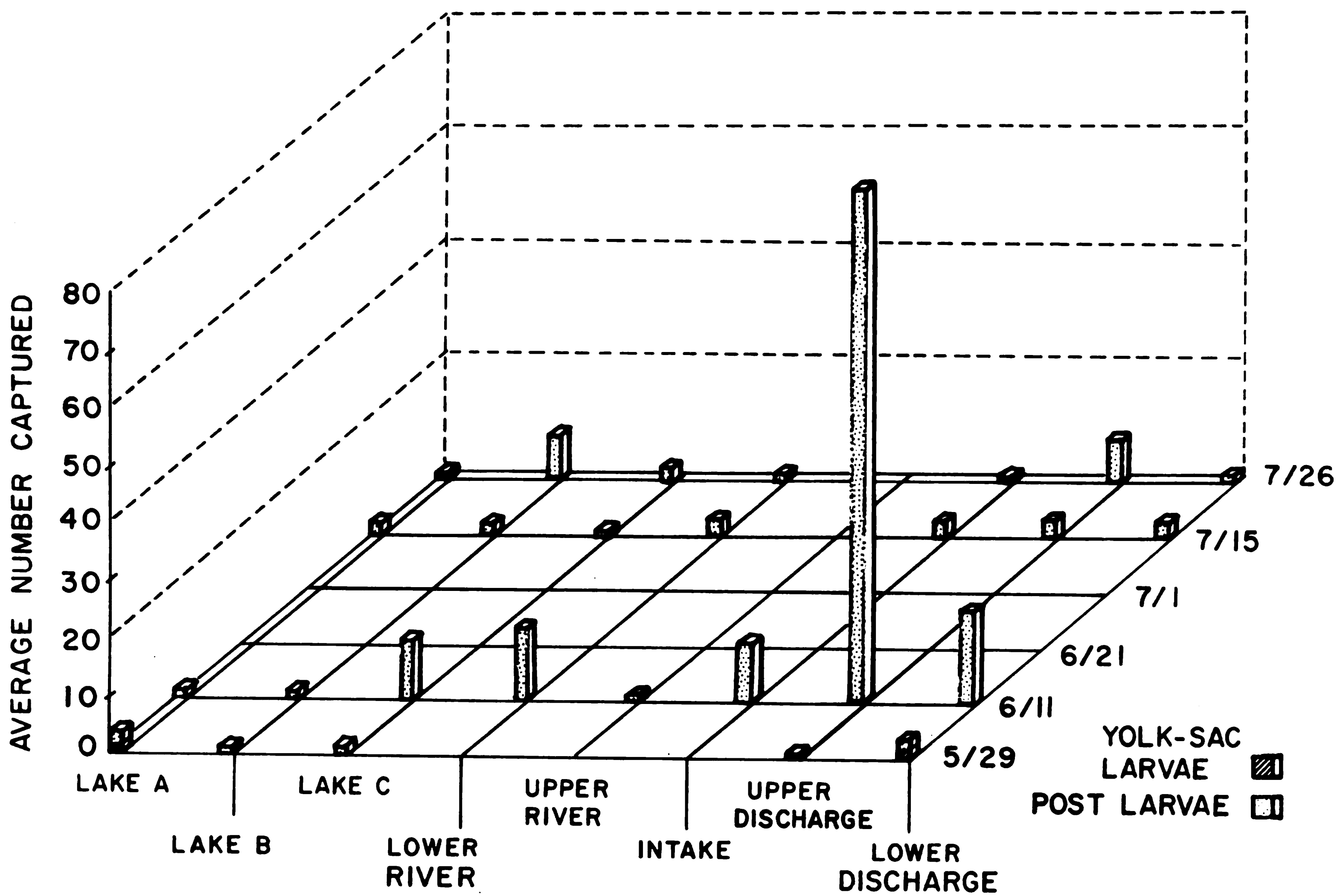

Figure 7. Average number of white bass larvae collected per sampling date at each station during 1974.

combined, is significantly greater than near bottom. This is true for all stations except the intake and is most apparent in the lower discharge.

White bass larvae were the most abundant species in 1973, comprising 26.5% of the total catch. In 1974, these larvae were only 8.2% of the total.

Freshwater Drum

No larvae of this species were captured in 1973. Sampling in 1974 resulted in catches from 11 June to 15 July, although no larvae were present in the collections made on 21 June. Yolk-sac larvae comprised over 99% of the total catch.

This species was present at almost all stations with no statistical difference in abundance, perhaps because of the buoyant and planktonic nature of both the eggs and yolk-sac larvae. Early in the year the discharge canal stations tended to have the greatest number of larvae. As the season progressed, the lake stations gained in importance. The upper discharge station was always higher than the lower discharge station, although this difference was not significant. Drum larvae comprised 4.3% of the total 1974 catch.

Other Species

Total catch data, summarized by station and date, is presented in Tables 1 and 2 for the less abundant species. No statistical analysis was performed for these groups, because of their rarity. Earliest spawners were smelt, *Osmerus mordax*; suckers, Catostomidae; trout perch, *Percopsis* omiscomaycus; log perch, Percina caprodes; and walleye, Stizostedion vitreum, and as a group these species were more closely associated with the lake environment than elsewhere. Centrarchids did not appear in the catch until early June and generally were found in the upper river and discharge canal. Channel catfish, Ictalurus punctatus, also began appearing in June, but this species was almost exclusively restricted to the upper discharge canal. Of the two minnows commonly found, emerald shiners, Notropis atherinoides, were most abundant and appeared to have a very wide spacial distribution. Spottail shiners, Notropis hudsonius, were more frequently captured in the discharge canal.

The estimated number of larvae which may be entrained are presented in Table 3. These values are based on the estimated 1974 abundances at the upper discharge station and should be viewed with caution because of the large volume of cooling water pumped at this plant and the sample variability encountered.

Table 3. Estimated number of larvae potentially entrained at a 3000 megawatt production level in 1974.

Species	Millions/year ± Mean 95% Conf. Interval[1]				
Gizzard shad and Alewife	102.1	$\leq$	168.9	$\leq$	255.0
Carp	94.4	$\leq$	132.6	$\leq$	180.3
White bass	28.1	$\leq$	95.2	$\leq$	200.0
Yellow perch	59.6	$\leq$	83.1	$\leq$	111.5
Channel catfish	6.8	$\leq$	28.6	$\leq$	64.9
Freshwater drum	7.8	$\leq$	20.3	$\leq$	38.3
Sunfishes	1.1	$\leq$	8.6	$\leq$	19.9
Spottail shiner	0.8	$\leq$	7.9	$\leq$	20.1
Emerald shiner	0.3	$\leq$	7.8	$\leq$	19.5
Bass		$\sim$	0.7		
Smelt		$\sim$	0.7		
Crappie		$\sim$	0.3		
Walleye		$\sim$	0.2		
Suckers		$\sim$	0.2		
Trout perch		$\sim$	0.2		
Log perch		$\sim$	0.1		
Total larvae	398.4	$\leq$	556.0	$\leq$	841.3

[1]Calculated by multiplying the mean number of larvae/m^3/ sampling date (and associated confidence intervals) by the volume flow through the cooling system on that date to determine a daily estimate of entrainment. The daily estimate was assumed to represent that sampling date plus half the number of days since the previous sampling date and half the number of days to a subsequent sampling date. Each daily estimate was multiplied by the number of days that it represented and the sum of these gave the annual estimate of entrainment.

DISCUSSION

Variability

The variability encountered in this study was a crucial sampling problem. Capture per unit effort occasionally varied by as much as a magnitude of 10 between individual replicates at the same station. Also, approximately equal sampling intensity during the two years in the same months of May and June produced total catches per year that differed by a magnitude of over 6.5.

Variability between replicates may have been increased by sources of error inherent in the sampling procedures, the most important of which may have been extrusion of small larvae through the mesh, clogging of the mesh, and imperfect measurements of the amount of water filtered by the net (Aron, et al., 1965; Barnes and Tranter, 1965; Taylor, 1953; Winsor and Clark, 1940). Active avoidance of the net may also have contributed to sampling error and has been shown to be inversely related to net speed (Barkley, 1964). Aron and Collard (1969) demonstrated that very small changes in net speed resulted in significant changes in catch, and that even at the same engine speed, winds and currents could produce significant errors.

A third major source of error is probably associated with a patchy, nonrandom spacial distribution of organisms (Roessler, 1965; Sameoto, 1975; Taylor, 1953). Wiebe (1971) showed, with simulated net tows using a computer model, that the size and distribution of patches significantly affects both the accuracy and precision of estimates of abundance. Wiebe and Holland (1968) summarized field estimates of total sampling error from 13 studies and found that 95% confidence limits of a single observation usually exceeded half or double the observed value (percentaged ranges) regardless of the type of net, the method used in towing, or the organisms used in the calculations. Although the 95% confidence limits in this study were large, they never approached the levels reported in other studies discussed by Wiebe and Holland (1968). It is possible that this reduced variability was caused by the more homogeneous nature of Lake Erie.

The sampling intensity required at various permissible errors of the final mean is presented in Figure 8. This technique is described by Edmonson and Winberg (1971) and values are based on an average seasonal estimate of variability pooled across stations. It is apparent that considerable sampling effort would be required when permissible errors are set very low, and desired confidence intervals are set at a high probability level. Of course, even greater sampling intensity would be required if relatively scarce forms become the target species, or a more heterogeneous system than Lake Erie is sampled.

The difference between total catch in each year of the study is more difficult to explain. Faber (1967) also noted that abundance varied greatly from year to year in a three year study of two Wisconsin lakes. Although the sampling

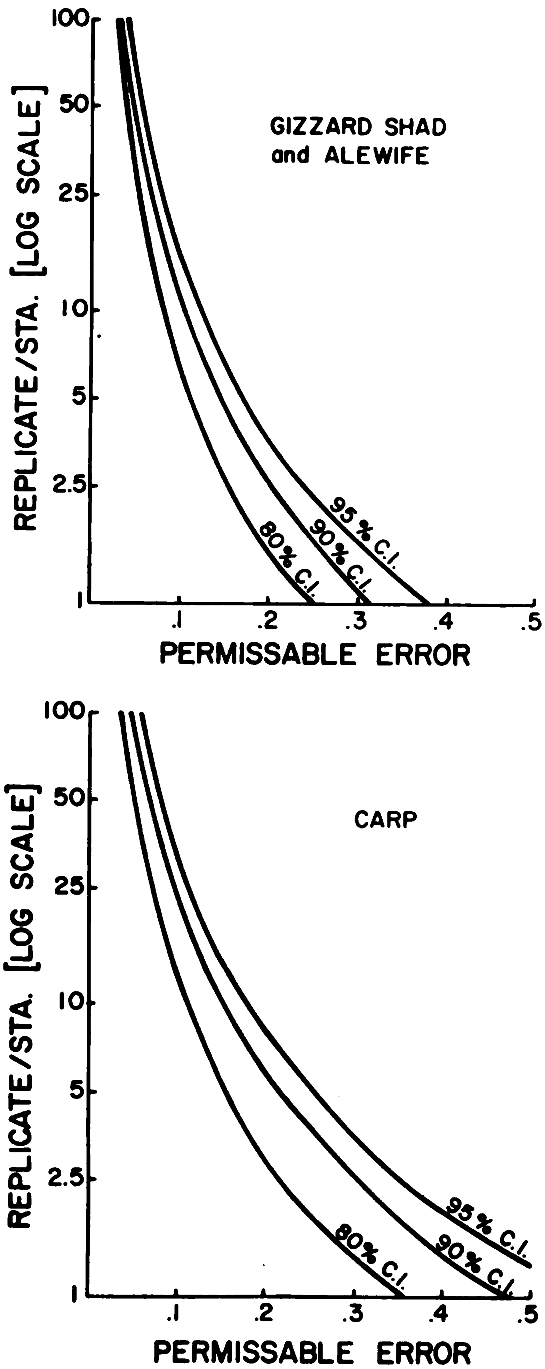

Figure 8. Sampling intensity required at various permissible errors of the final mean for three confidence intervals.

technique for each year in this study was different, it is improbable that this change could account for the total difference in abundance among most species. Unknown temporal variation may have contributed to the difference, but there remains the possibility that the relative abundance estimates for each year were realistic. In 1973, water levels reached a record high. Spring was marked by numerous storms and seiches, and it is possible that hatching success and larval survival was severely limited by these climatic conditions. It may well be that the most important impact of annual variability is the implication it carries for short term studies.

Effects of Plant Operation

Marcy (1973) reported that most of the larvae entrained in the cooling water of a power plant were dead by the time they reached the end of a 1.8 km discharge canal. Edsall and Yocom (1972) reviewed additional literature and discussed the potential harm of entrainment to larval fish.

Attempts to assess mortality in this study were complicated by the fact that many species appeared to use the discharge canal throughout their life cycle. Abundances of adult carp, goldfish, and channel catfish were significantly higher in the discharge canal than at stations outside the canal at most times of the year (Lavis, unpublished data). While high turbidity made visual observations difficult, carp were commonly seen spawning along the length of the canal. It would appear that the lower end of the canal and the vicinity near the mouth could have provided excellent spawning habitat for gizzard shad as described by Bodola (1966). Catches of channel catfish larvae were almost exclusively restricted to the upper discharge canal, although the spawning activity of this species was not observed. White bass are not year-around residents of the discharge canal, but were captured in great numbers by local fishermen during the reported spawning time. Examination of adult specimens from the canal disclosed both spent and ripe individuals. Larvae may be retained within the canal by large, quiet eddies at both ends together with the interstitial waters in the rock walls.

Of all the abundant species, adult yellow perch were only rarely captured in the discharge canal (Edwards, 1973). In 1974 the majority of yellow perch yolk-sac larvae were captured on 10 May. The abundance at the calculated intake station was comparatively low, primarily because of the high river discharge rate and the low abundance levels associated with it. However, discussions with Detroit Edison personnel indicated that at this time of year large numbers of yellow perch eggs in their semi-buoyant, gelatinous strings were accumulating on all of the trash collecting devices. It is possible that the calculated abundance at the intake station was an underestimation, because of this concentration of eggs and subsequent hatching. The lower river station, which had the highest abundance, was probably more representative of the actual numbers entrained. The abundance at the upper discharge station was not significantly different from that at the lower river station, but the lower discharge canal station had significantly fewer larvae than the upper discharge canal station.

Marcy (1973) noted that fewer dead larvae were collected as sampling approached the lower end of a discharge canal, suggesting a settling out process. If mortality is occurring, and dead larvae are being lost from the water column with no recruitment, then the abundance levels should drop. The significant difference between the upper discharge canal and the lower discharge canal most likely represented entrainment mortality, perhaps coupled with possible predation of stressed larvae. Additional confirmation is represented by the 1973 depth distribution of yellow perch. Significantly more larvae were located in the upper half of the water column at the lake and intake stations than at the discharge canal stations. In the discharge canal the majority of larvae were located near bottom.

Analysis of the difference between discharge canal stations is less meaningful for other abundant species, since recruitment may be occurring in the canal. Carp and white bass, however, generally had significantly lower abundance levels at the lower discharge station, which may also have represented entrainment mortality. From the data, it is not possible to determine the exact percent of mortality, since no on-site examination was made to determine whether the larvae were dead or alive. Mortality studies, using techniques described by Marcy (1971), should be made to fully assess the problem.

The possibility exists that the heated water produced by this plant may alter the reproductive cycle for those fish that utilize the discharge canal for spawning activity. Swee and McCrimmon (1966) indicated that spawning of carp began at 17 C and ceased at 28 C. In 1974, discharge temperatures reached spawning levels as early as late March, and yolk-sac carp were captured in the discharge canal on 22 April, the first sampling date. River temperatures did not reach 17 C until late May, and in early June the discharge temperatures began exceeding 28 C. Probably as a result, the abundance of carp larvae at the upper river station first exceeded discharge catches on 11 June and generally remained higher than at other stations throughout the rest of the sampling period. It is possible that nearly two months may have been added to the spawning period of this species.

Bodola (1966), in a study of gizzard shad in western Lake Erie, reported that spawning occurs from the first of June to the first of July at temperatures between 17 C and 23 C. The majority of yolk-sac gizzard shad were captured during this period, but in 1974 they were also found as early as 22 April within the discharge system where temperatures had already exceeded 17 C. As much as two months may also have been added to the spawning period of the gizzard shad as a result.

The spawning period of the white bass was apparently not extended by the discharge temperatures. Scott and Crossman (1973) reported that this species commenced spawning when water temperatures reached 13 C. This level was attained in the discharge by mid-March, but no yolk-sac larvae were captured until late May. Prior to spawning activity, white bass are located offshore, and it is probably the temperature of these waters that initiates spawning. Individuals entering the discharge canal may even experience a reduced spawning period. If onshore movement does not commence until mid-May, temperatures in the discharge canal have already reached 26 C, which is the upper spawning temperature reported by Scott and Crossman (1973). The only date when yolk-sac larvae were captured was 29 May.

Channel catfish begin spawning when water temperatures reach 24 C, with an optimum spawning temperature of 27 C (Carlander, 1969). In 1974, discharge temperatures reached this level by mid-May, while the lake was not at this temperature until mid-June. Larval catfish were captured in the discharge canal as early as late May, but the first lake catch did not occur until late June. Also, in both years of the study lake temperatures never reached the optimum spawning temperature. Since catches of catfish larvae were almost exclusively restricted to the discharge canal, it would appear that the discharge canal provides a more favorable thermal environment and spawning habitat than the lake. At least one month may be added to the spawning period of this species.

The possible effect of increasing the spawning period of less desirable species, while at the same time not affecting or reducing the period of preferred sport species, is unknown. It is feasible that longer spawning periods could provide a competitive advantage. Year classes of species with short spawning periods may be more vulnerable to adverse climatic conditions which severely effect hatching success. As a result of subtle, long-term changes, fish populations in the receiving waters may be altered.

Geographical Area of Possible Entrainment

Little is known about the swimming behavior of larval fish in their natural environment. Bishai (1960) and Houde (1969) have used laboratory investigations to measure the sustained swimming speed and endurance of several species. Evidence indicated that the very early stages of pelagic larvae were carried by water currents from their spawning areas, although the movement was not entirely passive. Houde (1969) suggested that the distribution of newly hatched walleye and yellow perch is not likely to be greatly influenced by swimming ability until a total length of 9.5 mm is attained. This length generally corresponds to formation of incipient caudal rays and complete absorption of the yolk material. Based on growth estimates of yellow perch by Mansueti (1964) and Luz (1960), this length would be reached on approximately the 16th day after hatching. Gizzard shad, alewife, and carp may attain this threshold as early as 7 to 10 days after hatching, because of more advanced developmental rates (Ciance, 1969; Battle, 1940; and Mansueti and Hardy, 1967). Less is known about the developmental rates of other dominant Lake Erie species.

Although information is not available on specific water currents in the area, they appear to be highly correlated with winds. Using a surface value velocity of 2 percent (Hutchinson, 1957) of the monthly mean resultant wind for 1970 through 1974, a simple model of the surface area potentially influenced by the plant is shown in Figure 9. Although larvae spawned some distance away from the plant may eventually be entrained, the probabilities are much greater for those hatched in and around the plant. But, persistent storms could have a major affect on the distribution of larval fishes throughout the western basin of Lake Erie. Studies describing larval abundance within the sphere of influence, designation of important nursery sites, and more precise current measurements are required to adequately evaluate the problem.

Although the estimated numbers of larvae entrained at this plant were extremely large, they may not be particularly significant. Based on commercial catch records of Michigan waters (Baldwin and Saalfeld, 1970), estimates of mean individual size (Parkhurst, 1971), and estimates of fecundity (Mansueti and Hardy, 1967; Scott and Crossman, 1973), total annual entrainment may represent only 1 to 10 percent of the total available larvae at a hatching success of 100 and 10 percent, respectively. Until more is known about the dynamics of the fish populations within the area, such as survival and developmental rates, a precise evaluation of the entrainment impact on future adult populations is not possible.

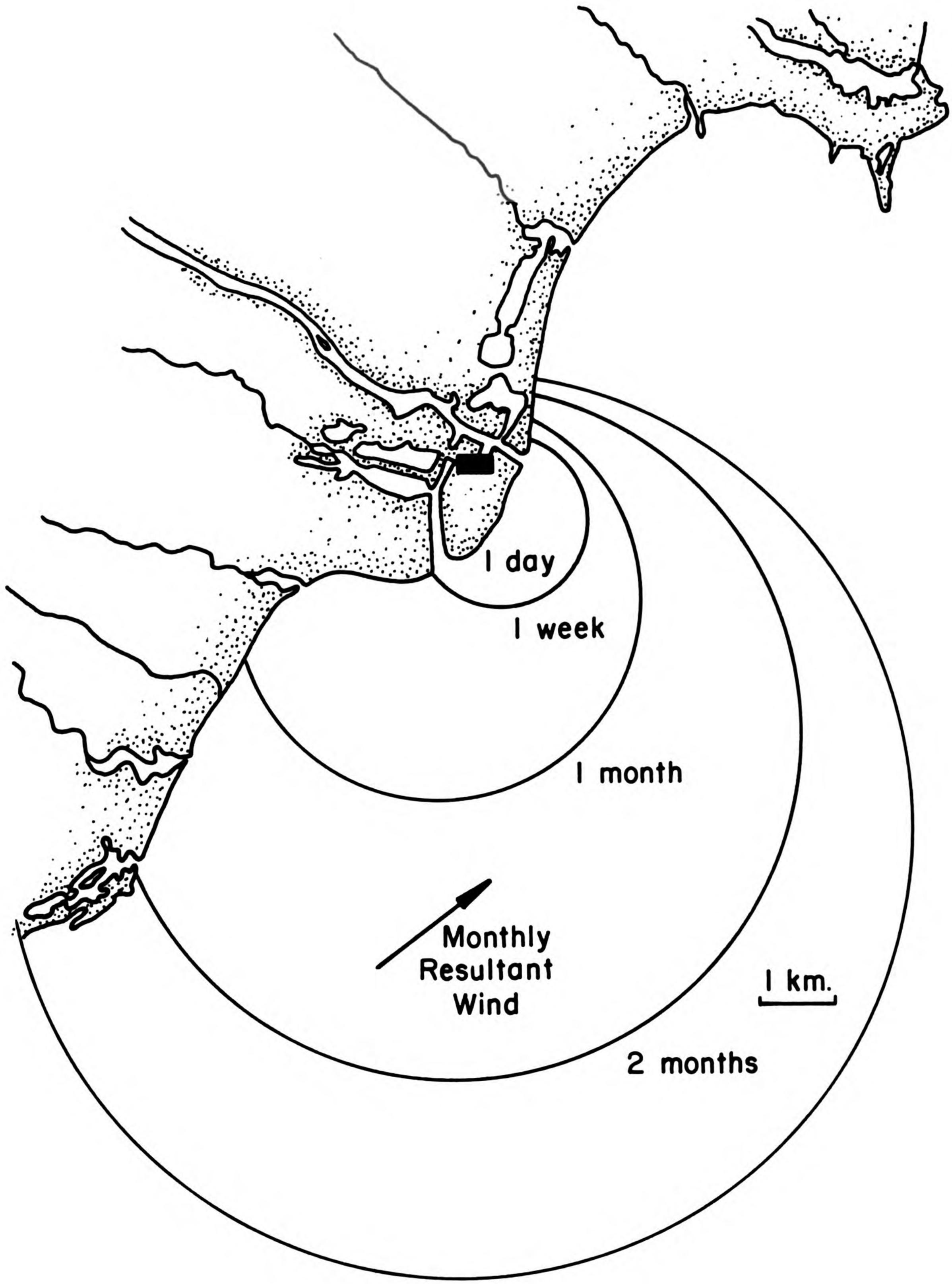

Figure 9. A map of western Lake Erie at Monroe, Michigan indicating the area of possible entrainment.

SUMMARY AND CONCLUSIONS

1. Estimates of abundance were significantly different between the two years of the study, based on approximately equal sampling intensity. It is, therefore, possible that major inconsistencies may be observed if icthyoplankton abundances are studied for only short periods of time.
2. The large variability among replicates observed in this study was thought to be primarily related to a patchy, nonrandom distribution. As a result, sampling may have to be intensified to detect differences among stations.
3. Several species appeared to use the discharge canal for spawning, making it difficult to assess entrainment mortality. Yellow perch, which were not believed to spawn within the discharge canal, exhibited decreased numbers as they progressed through the system. This decrease was thought to primarily represent entrained mortality.
4. The length of the spawning period appeared to have been increased for gizzard shad, carp, and channel catfish; and possibly reduced for white bass, because of the heated water within the discharge. This may result in long-term changes in fish populations of the receiving waters,

particularly if once-through cooling is expanded in the western basin.

5. The number of larvae which were entrained at the Monroe plant was extremely large, but perhaps ecologically insignificant. However, the re-establishment of sport fish populations may be precluded if these species require nursery areas within and near the mouth of the Raisin River.

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APPENDIX A

APPENDIX A

Table A-1. Tukey's post-hoc comparison of mean catch[1] for yellow perch in 1974.

10 May								
Station[2]	LR	UD	LB	LD	I	R		
Mean	9.387	7.580	6.090	5.146	5.110	3.305		
29 May								
Station	LA	LB	LC	LR	I	UD	LD	R
Mean	3.911	3.283	2.482	2.309	1.983	1.777	1.634	0.807
11 June								
Station	UD	LD	LR	I	LC	LA	R	LB
Mean	4.551	3.554	2.850	2.479	1.124	0.800	0.800	0.707

[1]Means are corrected for heterogeneity by square root transformation.

[2]LA = Lake A; LB = Lake B; LC = Lake C; LR = Lower River; R = Upper River; I = Intake; UD = Upper Discharge; LD = Lower Discharge.

APPENDIX A

Table A-2. Tukey's post-hoc comparison of mean catch[1] for gizzard shad and alewife in 1974.

29 May								
Station[2]	LB	LD	LC	LA	UD	R	I	LR
Mean	4.515	3.903	2.926	1.910	1.711	1.464	1.368	1.341
11 June								
Station	LB	UD	LD	LC	LR	I	LA	R
Mean	15.109	8.057	5.784	5.311	3.748	3.389	2.974	1.762
21 June								
Station	LC	LD	LR	LA	UD	LB	I	R
Mean	4.582	3.994	3.761	2.827	2.382	2.227	1.958	0.707
1 July								
Station	LR	LD	UD	I	LB	LC	LA	R
Mean	7.131	6.983	6.858	6.473	6.270	5.259	4.209	3.227
15 July								
Station	LC	LD	UD	LB	LA	LR	I	R
Mean	7.025	6.582	5.976	5.779	4.840	4.795	4.615	2.302

Table A-2 (con't.)

26 July								
Station	LB	LC	UD	R	LA	LD	I	LR
Mean	4.058	2.570	2.422	2.360	2.280	1.897	1.022	0.954

[1]Means are corrected for heterogeneity by square root transformation.

[2]LA = Lake A; LB= Lake B; LC = Lake C; LR = Lower River; R = Upper River; I = Intake; UD = Upper Discharge; LD = Lower Discharge.

APPENDIX A

Table A-3. Tukey's post-hoc comparison of mean catch[1] for carp in 1974.

10 May								
Station[2]	UD	LD	R	I	LR	LB		
Mean	5.731	1.932	0.876	0.861	0.707	0.707		
29 May								
Station	UD	LR	I	R	LA	LC	LD	LB
Mean	2.452	1.491	1.430	1.218	1.192	0.813	0.707	0.707
11 June								
Station	R	UD	LD	I	LR	LC	LA	LB
Mean	7.217	4.672	3.700	2.716	1.723	1.203	0.707	0.707
21 June								
Station	UD	R	I	LD	LR	LA	LB	LC
Mean	4.227	2.398	1.839	1.382	1.034	0.707	0.707	0.707
1 July								
Station	R	UD	LC	LD	I	LB	LA	LR
Mean	4.754	2.430	2.065	1.876	1.536	1.006	0.912	0.883

Table A-3 (con't.)

15 July								
Station	R	I	UD	LR	LD	LB	LC	LA
Mean	2.531	1.972	1.941	1.928	1.299	1.002	0.807	0.707

[1] Means are corrected for heterogeneity by square root transformation.

[2] LA = Lake A; LB = Lake B; LC = Lake C; LR = Lower River; R = Upper River; I = Intake; UD = Upper Discharge; LD = Lower Discharge.

APPENDIX A

Table A-4. Tukey's post-hoc comparison of mean catch[1] for white bass in 1974.

29 May								
Station[2]	LD	LA	LC	UD	LB	R	I	LR
Mean	2.093	1.746	1.397	0.949	0.813	0.807	0.796	0.793
11 June								
Station	UD	LD	LR	LC	I	LA	LB	R
Mean	8.932	4.062	3.483	3.254	3.025	1.233	1.134	0.951
15 July								
Station	LR	UD	I	LD	LB	LA	LC	R
Mean	1.735	1.669	1.660	1.632	1.440	1.366	0.807	0.707
26 July								
Station	LB	UD	LC	LA	LD	LR	I	R
Mean	2.786	2.561	1.281	1.093	0.887	0.813	0.774	0.707

[1]Means are corrected for heterogeneity by square root transformation.

[2]LA = Lake A; LB = Lake B; LC = Lake C; LR = Lower River; R = Upper River; I = Intake; UD = Upper Discharge Canal; LD = Lower Discharge Canal.

APPENDIX B

APPENDIX B

Identification

Identification of larval fish is generally difficult, due primarily to their small size, the degree to which their form changes with development, and the lack of information on many species. Identification may be further complicated in a productive system, such as Lake Erie, because of the large number of species that are encountered. The following key is provided as a tool to assist the inexperienced worker in this task. To the experienced researcher, it is designed to serve as a verification of the identifications made in this study.

The terminology for the description of larval stages comes from May and Gasaway (1967). An excellent description of the meristic and morphometric characters used in this key is provided by Mansueti and Hardy (1967). The terminology given below is modified from the above sources, and is included for use if these references are not available.

Pro-larva -- Larva with yolk-sac present.

Early Post-larva -- Larva after complete absorption of the yolk to the development of soft rays in the vertical fins.

Late Post-larva -- Larva with soft rays in the vertical fins to the full development of all fins, scales, and the lateral line canal system.

Pre-anal Length -- Distance from the tip of the snout to the posterior margin of the anus.

Post-anal Length -- Distance from the posterior margin of the anus to the tip of the caudal fin or finfold.

Gut Length -- Before development of the operculum, the distance from the most posterior part of the auditory vesicle to the posterior margin of the anus; following operculum formation, the distance from the most posterior part of the opercular membranes to the posterior margin of the anus.

Pre-anal Myomeres -- Myomeres between the most anterior myoseptum and the posterior margin of the anus.

Post-anal Myomeres -- Myomeres between the posterior margin of the anus and the most posterior myoseptum.

Entire Yolk-sac -- Yolk-sac that extends along the entire gut length.

WORKING KEY TO THE LARVAL FISHES DISCOVERED NEAR THE WEST SHORE OF LAKE ERIE

1a. Vertical fin rays formed, or nearly so. Late post-larvae. (Note: Late post-larvae were rarely captured in this study, and are not included in this key. Although not all adult and juvenile characteristics are developed, body shape and fins begin to resemble the adult and may be used for diagnostic characters).

1b. Vertical fin rays not formed, or apparently incomplete 2

2a. Yolk-sac apparent. Pro-larvae 3

2b. Yolk-sac not apparent, or only vestige remaining Early post-larvae 27

3a. Barbels present, with extremely large yolk-sac . 4

3b. Barbels absent 5

4a. Yolk-sac larvae probably greater than 10 mm TL. In very early stages, yolk-sac extends posterior to the vent. Caudal fin forked by at least 14.8 mm TL . . . . Channel catfish (*Ictalurus punctatus*)

4b. Yolk-sac larvae probably less than 10 mm TL. Yolk-sac never extends behind vent. Caudal fin never forked . . . . Bullheads (*Ictalurus* spp.)

5a. A conspicuous adhesive organ on the snout of larvae less than 14 mm TL. Very heavily pigmented rudimentary vertical fins present in the finfold . . . . Gar (_Lepisosteus_ spp.)

5b. Not as above 6

6a. Post-anal length enters pre-anal length more than or equal to 3 times, and generally more than 4 times 7

6b. Post-anal length enters pre-anal length less than 3 times 8

7a. Post-anal length enters pre-anal length from 4.7 to 5.8 times. Small oil globule present at posterior margin of yolk-sac. Eyes unpigmented at less than 5 mm TL . . . . .Gizzard shad (_Dorosoma_ _cepedianum_)

7b. Post-anal length enters pre-anal length from 3.3 to 4.3 times. Oil globule not present. Eyes pigmented at hatching, but only barely so . . . . .Alewife (_Alosa_ _pseudoharengus_)

8a. Pre-anal myomeres greater than or equal to 42. Yolk-sac small and extremely posterior, being noticeably behind pectoral fin buds. If present, ventral pigmentation in the form of a single row along the ventral margin. Post-anal length enters pre-anal length from 2.3 to 2.8 times . . . . .Smelt (_Osmerus_ _mordax_)

8b. Pre-anal myomeres less than 42, and not as above 9

9a. Yolk-sac larvae greater than or equal to 9 mm TL 10

9b. Yolk-sac larvae less than 9 mm TL 12

10a. Yolk-sac entire. Post-anal length enters pre-anal length from 2.3 to 3.0 times. Pre-anal myomeres from 35 to 40 . . . . Suckers (Catostomidae); probably _Catostomus commersoni_

10b. Yolk-sac less than entire 11

11a. Pre-anal myomeres greater than or equal to 25 . . . . Northern pike (_Esox lucius_)

11b. Pre-anal myomeres less than 25 . . . . Walleye (_Stizostedion vitreum_). See 14a.

12a. Pre-anal myomeres greater than or equal to 29. Yolk-sac entire . . . . . Suckers (Catostomidae) (NOTE: probably _Carpiodes cyprinus_ if TL less than 8.0 mm and pre-anal myomeres from 28-32 with heart or Y-shaped pigment pattern on dorsal head).

12b. Pre-anal myomeres less than 29 13

13a. Pre-anal myomeres greater than or equal to 19. . 14

13b. Pre-anal myomeres less than 19 18

14a. Post-anal myomeres greater than or equal to 22, Post-anal length enters pre-anal length .8 to .9 times. Yolk-sac elongate with anterior oil globule . . . . . Walleye (_Stizostedion vitreum_)

14b. Post-anal myomeres less than 22 15

15a. Yolk-sac entire, with no anterior oil globule . 16

15b. Yolk-sac less than entire, with anterior oil globule 17

16a. Post-anal length enters pre-anal length less than or equal to 1.9 times. Body slender and may be only lightly pigmented. If pigmentation present, ventral chromatophores commence at base of caudal and extend anteriorly on the ventral side of the yolk-sac. Gas bladder, if present, only lightly pigmented. Few chromatophores on dorsum . . . .

. . . . Shiners (*Notropis* spp.). See 46b. (NOTE: Difficult to separate species. Spottail shiners (*N. hudsonius*) collected from Lake Michigan and Lake Erie are pigmented as described above. Pro-larval emerald shiners (*N. atherinoides*) were not collected, however, later staged specimens as small as 5.7 mm TL were collected. These specimens were extremely slender, with eye pigment and chromatophores lacking. No common shiners (*N. cornutus*) were identified).

16b. Post-anal length enters pre-anal length greater than 1.9 times. Body thick and moderately pigmented. Ventral chromatophores commence at base of caudal and extend anteriorly on the dorsal side of the yolk-sac. Gas bladder heavily pigmented. Ventral line of chromatophores may extend through the gas bladder into the opercular region where a "Y" may be formed. Dorsum with scattered chromatophores . . . Carp (*Cyprinus carpio*) and Goldfish (*Carassius auratus*)

(NOTE: Separation of carp and goldfish is difficult. Separation of these two species is probably dependent on the more precocious nature of the goldfish, which is generally smaller at acquisition of specific developmental characteristics).

17a. Gut longer, such that post-anal length enters gut length more than or equal to .9 times. Post-anal length enters pre-anal length more than or equal to 1.2 times. Ventral pigmentation restricted to 4 to 10 chromatophores on ventral margin . . . . Log perch (<u>Percina caprodes</u>)

17b. Gut shorter, such that post-anal length enters gut length less than .9 times. Post-anal length enters pre-anal length less than 1.2 times. Ventral pigmentation more scattered with numerous, small chromatophores along most myoseptums . . . . Yellow perch (<u>Perca flavescens</u>)

18a. Post-anal myomeres greater than or equal to 22 . . . . Walleye (<u>Stizostedion vitreum</u>). See 14a.

18b. Post-anal myomeres less than 22 19

19a. Yolk-sac entire 20

19b. Yolk-sac less than entire 21

20a. Post-anal length enters pre-anal length more than 1 time . . Common shiner (<u>Notropis cornutus</u>) (NOTE: Highly unlikely, however Fish (1932) reports this species with only 14 pre-anal myomeres).

20b. Post-anal length enters pre-anal length less than or equal to 1 time. Head large. One very large oil globule or several smaller ones located posteriorly, generally causing the larvae to float inverted in the surface film. Several large, round or stellate chromatophores on ventral surface of yolk-sac. Eyes colorless at hatching . . . . Freshwater drum (*Aplodinotus grunniens*)

21a. Post-anal length enters pre-anal length less than 1 time. (NOTE: May be slightly greater than 1 if specimen is extremely pigmented and stocky) 22

21b. Post-anal length enters pre-anal length more than or equal to 1 time 26

22a. Total myomeres less than or equal to 28. Total length less than or equal to 6.0 mm . . . . . . Freshwater drum (*Aplodinotus grunniens*). See 20b.

22b. Total myomeres greater than 28 23

23a. Relatively stocky with greatest depth entering total length approximately 5 times. Heavily pigmented with round chromatophores over most of body. Post-anal length may enter pre-anal length slightly more than 1 time . . . . Smallmouth bass (*Micropterus dolomieui*) or Rock bass (*Ambloplites rupestris*)

23b. Less stocky than above, with greatest depth entering total length more than 5 times. Not heavily pigmented over entire body, but may have moderate pigmentation on ventral aspect 24

24a. Many large, round chromatophores on ventral aspect of the large, round yolk-sac. Ventral pigmentation between vent and caudal region consists of a single line (which may appear double) of round chromatophores on approximately every third myomere. Urostyle oblique at hatching. Eye small and elliptical on horizontal axis, such that vertical length of eye enters greatest depth of head approximately 3 times. Snout blunt . . . . Trout perch (<u>Percopsis</u> <u>omiscomaycus</u>)

24b. Ventral pigmentation not as above, and much reduced. Urostyle not oblique on pro-larvae. Eye generally round and enters greatest depth of head approximately 2 times 25

25a. Gut short such that post-anal distance enters pre-anal distance less than .7 times. Gas bladder if apparent extends posteriorly almost to vent. Pro-larvae small and may be less than 4 mm TL . . . . Crappie (<u>Pomoxis</u> spp.)

25b. Gut longer than above. Post-anal distance enters pre-anal distance generally more than .7 times. Gas bladder if apparent is well anterior to vent. Pro-larvae may be as large as 5 mm TL . . . . Sunfish (<u>Lepomis</u> spp.) (NOTE: Largemouth bass (<u>Micropterus</u> <u>salmoides</u>) may also key here).

26a. Post-anal myomeres less than or equal to 14. Gas bladder apparent at approximately 3.5 mm TL. Pigmentation restricted to several round or stellate chromatophores on ventral aspect of yolk-sac and gut, and 4 or more long, slender chromatophores on ventral margin between vent and caudal region . . White bass (<u>Morone chrysops</u>)

26b. Post-anal myomeres greater than 14. Ventral pigmentation between vent and caudal region consists of many small chromatophores on each myoseptum . . . . Yellow perch (<u>Perca flavescens</u>). See 17b.

27a. Barbels present 28

27b. Barbels absent 29

28a. Tail forked. Channel catfish (<u>Ictalurus punctatus</u>)

28b. Tail not forked . . . Bullheads (<u>Ictalurus</u> spp.)

29a. Post-anal length enters pre-anal length more than or equal to 3 times . . . . Gizzard shad (<u>Dorosoma cepedianum</u>) and Alewife (<u>Alosa pseudoharengus</u>)

(NOTE: Difficult to separate. Perhaps the most useful characteristic is the more anterior vent of the alewife. Post-anal length enters pre-anal length only 3 to 4 times for the alewife, and generally over 5 times for the gizzard shad. Although pigmentation is remarkably similar, alewife appear to have chromatophores both above and below the notochord in the caudal region, while chromatophores are primarily restricted to below the notochord in gizzard shad. This characteristic must be viewed cautiously, however. Smelt (<u>Osmerus mordax</u>) may also key here, however, they are distinguished by a single row of chromatophores on the ventral aspect of the gut, rather than the double row in gizzard shad and alewife).

29b. Post-anal length enters pre-anal length less than 3 times 30

30a. Pre-anal myomeres greater than or equal to 40. Ventral chromatophores restricted to a single row. Three or more very conspicuous chromatophores present between vent and caudal region on ventral aspect. Gas bladder, if apparent, is extremely posterior (only slightly forward of mid-body) and pigmented dorsally . . . .
. . . . Smelt (*Osmerus mordax*)

30b. Pre-anal myomeres less than 40 31

31a. Size of early post-larvae greater than or equal to 14 mm TL 32

31b. Size of early post-larvae less than 14 mm TL . . 37

32a. Post-anal length enters pre-anal length less than 1.5 times 33

32b. Post-anal length enters pre-anal length more than or equal to 1.5 times 34

33a. Pre-anal myomeres less than or equal to 16. Gut extremely coiled. Several very conspicuous chromatophores on ventral margin, just anterior to the caudal region . . . .
. . . . . White bass (*Morone chrysops*). See 40a.

33b. Pre-anal myomeres greater than 16. Gut not extremely coiled 38

34a. Greatest depth enters total length less than 5 times . . . . Carp (<u>Cyprinus carpio</u>) and Goldfish (<u>Carassius auratus</u>). See 46a.

34b. Greatest depth enters total length more than 5 times 35

35a. Post-anal length enters gut length more than 1.2 times . . . . Northern pike (<u>Esox lucius</u>)

35b. Post-anal length enters gut length less than or equal to 1.2 times 36

36a. Post-anal length enters pre-anal length more than 2 times . . . . Suckers (Catostomidae). See 37a.

36b. Post-anal length enters pre-anal length less than or equal to 2 times . . . Gar (<u>Lepisosteus</u> spp.)

37a. Pre-anal myomeres greater than or equal to 29. Chromatophores numerous on both ventral and dorsal margins, and generally organized into a double series. Larger specimens with pigmentation along lateral line . . . . Suckers (Catostomidae)

37b. Pre-anal myomeres less than 29 38

38a. Pre-anal myomeres less than or equal to 16 . . . 39

38b. Pre-anal myomeres greater than 16 44

39a. Post-anal length enters pre-anal length 1 or more times 40

39b. Post-anal length enters pre-anal length less than 1 time. (NOTE: If extremely pigmented over entire body it may be slightly more than 1 time) 41

40a. Post-anal myomeres less than or equal to 13. Gut extremely coiled. On larger specimens there may be several very conspicuous chromatophores anterior to the caudal region on the ventral margin . . . . White bass (*Morone chrysops*)

40b. Post-anal myomeres greater than 13. Probably with a single row of chromatophores (which may appear double) on approximately every third myomere between vent and caudal region on ventral margin . . . . Trout perch (*Percopsis omiscomaycus*)

41a. Post-anal myomeres less than 14. Gut extremely coiled and bent abruptly downward near vent. Head extremely large with small, darkly pigmented eyes located dorso-laterally. Dorsal finfold persistent . . . . Freshwater drum (*Aplodinotus grunniens*)

41b. Post-anal myomeres more than or equal to 14. Not as above 42

42a. Heavily pigmented over most of body. Relatively stocky, with greatest depth entering total length approximately 5 times. Gut relatively straight and thick . . . . Bass (*Micropterus* spp.)

42b. Not heavily pigmented. More slender than above, with greatest depth entering total length more than 5 times 43

43a. Vent extremely anterior with post-anal length entering pre-anal length less than .7 times. Gas bladder extends behind vent on specimens larger than 8 mm TL, and nearly so on smaller specimens . . . . Crappie (Pomoxis spp.)

43b. Vent not extremely anterior with post-anal length entering pre-anal length more than or equal to .7 times. Gas bladder does not extend behind vent . . . . Sunfish (Lepomis spp.)

(NOTE: Early post-larval Trout perch (Percopsis omiscomaycus) which were not collected in this study will probably also key here, but should be distinguished by more chromatophores on ventrum and development of adipose fin in later stages).

44a. Post-anal myomeres less than or equal to 16 . . 45

44b. Post-anal myomeres greater than 16 47

45a. Post-anal length enters pre-anal length nearly 1 time, or only slightly more or less . . . . Yellow perch (Perca flavescens)

45b. Post-anal length enters pre-anal length noticeably more than 1 time 46

46a. Post-anal length enters pre-anal length more than or equal to 2 times. Not extremely slender with greatest depth entering total length less than 6.5 times. May have a heavily pigmented row of chromatophores extending from caudal region anteriorly on ventral margin, over gut, and to opercular region where it forms a "Y". Head heavily pigmented on dorsal aspect . . . . Carp (*Cyprinus carpio*) and Goldfish (*Crassius auratus*). See comment at 16b.

46b. Post-anal length enters pre-anal length less than 2 times. Relatively slender with greatest depth entering total length more than or equal to 6.5 times. Pigmentation variable, but with no "Y" in opercular region . . . . . Shiners (*Notropis* spp.) (NOTE: Difficult to separate species. See also comments at 16a. Tentative identification of spottail shiner (*N. hudsonius*) indicates chromatophores on ventrum which may be somewhat scattered or consolidated into a double series posterior to the vent. Dorsal pigmentation generally a double series. Larvae are not extremely slender and appear rather blunt. Gas bladder very apparent and pigmented. Yolk material present until 6.0-6.5 mm TL. Tentative emerald shiners (*N. atherinoides*) appear to be less pigmented. At total lengths of less than 5.5 mm even the eyes are pigmentless. In later stages a single line of pigmentation appears on ventrum, as well as several large chromatophores on top of head. At approximately 9 mm TL the chromatophores between vent and caudal region form a double series which meet posteriorly. Pigmentation along lateral line also develops at this stage. Larvae are more slender than above, with a gas bladder which is less evident at early stages).

47a. Gut long, straight and relatively thick. Post-anal length enters gut length more than or equal to .8 times. May have 4 to 10 chromatophores on ventral margin. . Log perch (*Percina caprodes*)

47b. Gut shorter and thinner. Post-anal length enters gut length less than .8 times. May be more heavily pigmented 48

48a. Post-anal myomeres less than 21 . . . . Yellow perch (*Perca flavescens*)

48b. Post-anal myomeres greater than or equal to 21 . . . . Walleye (*Stizostedion vitreum*)

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