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DISTRIBUTION AND ABUNDANCE OF LARVAL FISH IN THE FAR WESTERN BASIN OF LAKE ERIE DURING 1975 AND 1976

presented by

Joel Edward Schaeffer

has been accepted towards fulfillment
of the requirements for

Master of Science degree in Fisheries and Wildlife

Charles R. Liston
Major professor

Date August 10, 1983

DISTRIBUTION AND ABUNDANCE OF LARVAL FISH IN THE FAR WESTERN BASIN OF LAKE ERIE DURING 1975 AND 1976

By

Joel Edward Schaeffer

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

1983

ABSTRACT

DISTRIBUTION AND ABUNDANCE OF LARVAL FISH IN THE FAR WESTERN BASIN OF LAKE ERIE DURING 1975 AND 1976

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During 1975 and 1976 larval fish were collected from the western basin of Lake Erie to document distributions and abundances. A 363 u, 9.1m seine was used to sample the 0-1.8m depth zone, while a one meter 571 u metered plankton net was used to sample four deeper zones.

Over the two years 19 taxa were collected with clupeids comprising over 88 percent of the catch. Other major taxa included rainbow smelt, shiners, white bass and yellow perch. Densities for most taxa peaked from late May to early July. Production for 1975 and 1976 is estimated at 7.59×10^{11} and 4.56×10^{11} fish respectively.

Generally the northern and southern portions of the study area had higher densities and abundances than the central area. The Detroit and Maumee Rivers appear to heavily influence distributions in the basin. Although the 5.5-7.3m depth zone generally did not have the highest densities, it often times had the highest abundances.

This work is dedicated to the memory of Robert O. Schaeffer, whose life has always been an inspiration for me.

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to Dr. Charles R. Liston of the Department of Fisheries and Wildlife for his willingness to act as my graduate committee chairman. His intellectual grasp, advice and encouragement have served me well in preparing this document. It was under his stewardship that its final shape was formed. I also wish to express by gratitude to Dr. Niles R. Kevern of the Department of Fisheries and Wildlife and Dr. Roger A. Hoopingarner of the Department of Entomology, members of my graduate committee, for their review and comments in the preparation of this manuscript. Special thanks to Dr. Richard A. Cole now at New Mexico State University, in Las Cruces, for his initial inspiration and encouragement.

To the many people who have unselfishly donated their time and knowledge, I am appreciative. Special recognition to Joe Bohr, Thomas Hornshaw, and Wheatley Hemmick for their efforts in sample collecting and data reduction. In addition, the efforts of Dr. Ronald C. Waybrant, members of Michigan's Bureau of Water Management, and the U.S. Environmental Protection Agency for financial funding and laboratory space, are greatly appreciated. I would like to recognize my close associates at Gilbert/ Commonwealth Inc. for their encouragement and assistance.

Finally, I am deeply indebted to my wife Susan for her unwaiving faith and encouragement, without which, this work would have remained incomplete.

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INTRODUCTION

Lake Erie is one of the State's and Nation's largest aquatic resources. As a result, a greater portion of the 18 million people within its drainage basin (Great Lakes Basin Commission, 1975b) rely on its waters to fill recreational, agricultural, municipal and industrial needs. In addition, the lake serves as a vital link in the shipping lanes to America's industrial and agricultural heartlands. From the waters its fish have been the base of one of the largest freshwater fisheries in the world, and until the early 1970's Lake Erie fishermen's annual landings nearly equalled the other four Great Lakes landings combined (Baldwin, et al., 1979). In the future Lake Erie may play an important role in hydrocarbon development and source-water for western water-needs.

Since the 1940's demands for Lake Erie water have increased to where it is projected that within 40 years nearly one-third of the flow through the western basin will be required to satisfy these needs (Cole, 1978a). As a result of these large amounts of water being withdrawn, there exists a potential to further change Lake Erie's ecosystem, through the alteration of water quality, mechanical damage to entrained and impinged organisms, and alteration of the lake's thermal regime. These changes may more easily evolve in bays, marsh areas, estuaries or any area that would tend to be isolated from the dynamics of the lake. As the water demands increase, resource management decisions will reflect strategies that will hopefully maintain or improve the aquatic resources.

The Great Lakes Basin Commission (1975a) has attributed the shift in the ichthyofauna in Lake Erie to over exploitation coupled with environmental changes. No longer are the more dominant species lake trout, lake whitefish and lake herring; they have been replaced by the carp, gizzard shad, and smelt. Now the resource faces another environmental challenge, the increase use of water both consumptive and nonconsumptive. Emerging as one of the major nonconsumptive users of Lake Erie water is the electrical generation industry. Alone the coal fired plant at Monroe, Michigan, is capable of pumping up to 85 m^3/sec across its condensers (Cole, 1978a). To make sound management decisions in the face of these conflicting uses, regulatory agencies need to know the impact power plants have on the resource, and to do this they must know the resource. They must have knowledge on all aspects of fish biology from egg to adult. Traditionally, most research and catch statistics centered on the adult and juvenile stages. However, it was found that the withdrawal of water involves the entrainment of fish eggs and larvae of which very little was known.

With the enactment of PL 92-500 in 1972 more research was directed to answer questions concerning entrainment such as mortality, vulnerability, chronic effects, and overall long-term effects to recruitment. Early works such as Fish (1932) centered on taxonomic problems of larval fish which to some degree still exist today. However, little else was done until the early 1970's when Cole (1978a&b), Nelson and Cole (1975), and MacMillan (1976) carried out extensive studies in the vicinity of the Monroe Power Plant, but, although they were ambitious and pioneering, they remained limited in regional application. Waybrant and Shauver (1979) collected data from the entire western end of the western basin but, outside of reporting densities did little else with the data. Two Ohio research groups, Mizera (1981) and Cooper, et al. (1981a), reported extensively on the ichthyoplankton from the Monroe Power Plant south and along the southern shore of the western and central basins. Mizera, et al. (1981) and Cooper, et al. (1981b) have published further findings on the limnetic larval component of the ichthyoplankton of the eastern portion of the western basin. Patterson (n.d.) and Patterson and Smith (1982) have attempted to model the dynamics of several larval fish species to relate to the effect of entrainment on recruitment.

The objective of this work is to: 1) document species use of the western basin of Lake Erie as a spawning and nursery area, 2) depict distributional patterns of certain groups in relationship to the geomorphology of the basin and 3) estimate larval production within the study area. It is the intent that the data presented here will contribute to the fuller understanding of the dynamics of the ichthyofauna of the western basin of Lake Erie.

ENVIRONMENTAL SETTING

Lake Erie (Figure 1) is the fourth lake in the drainage of the Laurentian Great Lakes. Its origin and history are similar to the other Great Lakes, but its size and location set it apart. Lake Erie in its present state sits in the eastern end of a 103,600 sq. km. drainage basin, characterized by low flat clay-rich land. The physical appearance of Lake Erie has changed little in the past 5000 years since the final retreat of the continental glaciers left it in its final configuration in the massive clay and gravel overburden. Erosional forces have had little effect on the shorelines. Even though the lake holds 125 trillion gallons (4.73×10^{11} m^3) of water, it represents only two percent of the water in the Great Lakes (Great Lakes Basin Commission (8), 1975). Lake Erie has a total surface area of 25,750 sq. km, making it the smallest of the Great Lakes. The geomorphology of the lake readily divides it into three basins which get deeper in an easterly direction (Figure 1). The central basin encompasses approximately 60 percent of the surface area of the lake and has an average depth of 20 m. It is divided from the eastern basin by a low ridge near Erie, Pennsylvania. The eastern basin encompasses approximately 25 percent of the lake's surface area and has a maximum depth of 60 m. The western basin lies west of the rocky outcroppings and islands between Pointe Pelee, Ontario, and Marblehead, Ohio. It is the smallest and shallowest comprising only 15 percent of the surface area and having an average depth of only 7.5 m. Lake sediments are very flat and composed of dark sludge-like muds (FWPCA, 1968).

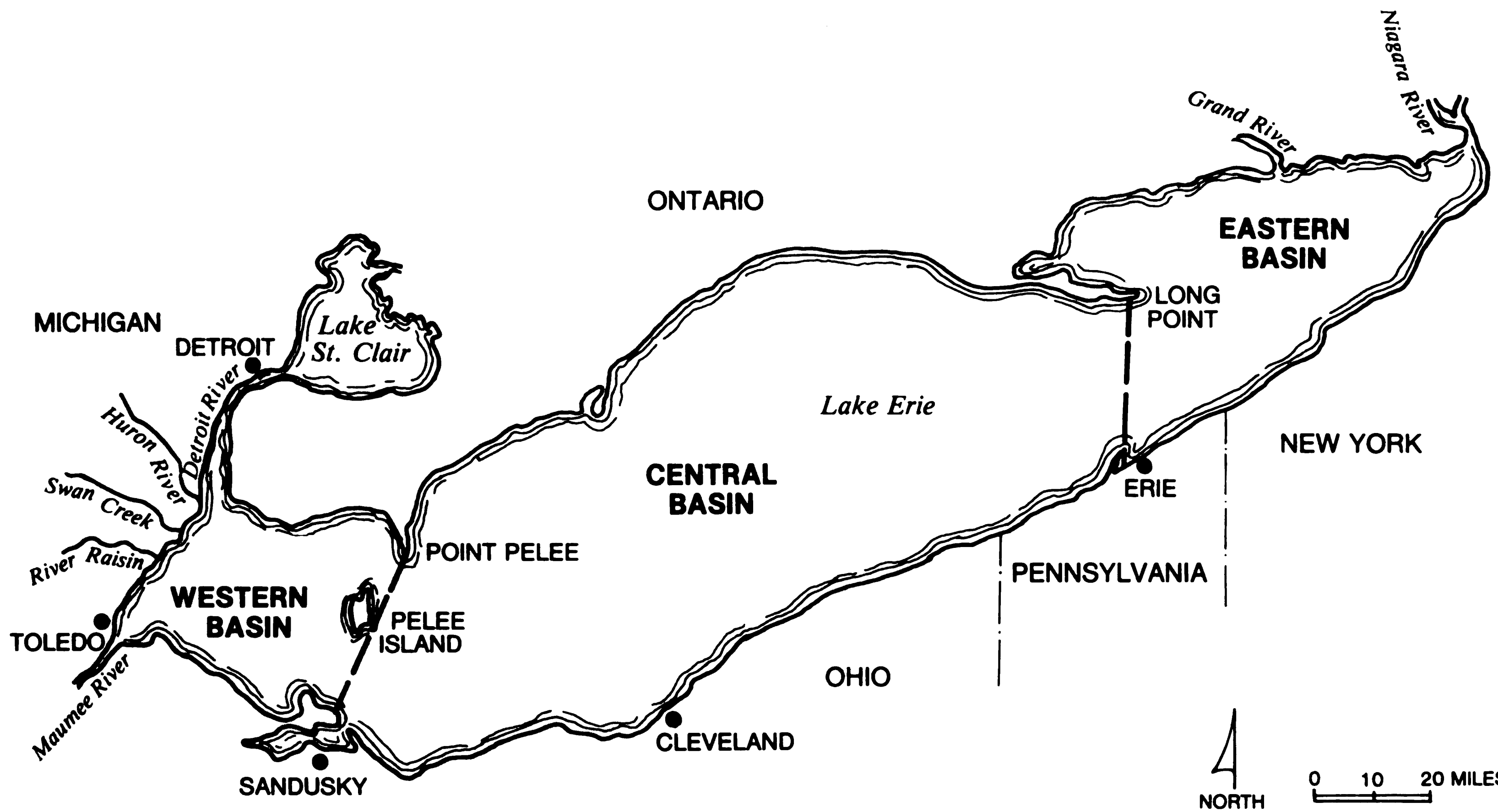


FIGURE 1
GEOGRAPHICAL SETTING OF LAKE ERIE DEPICTING THE THREE MAJOR SUBBASINS

Lake Erie receives approximately 93 percent of its inflow from the Detroit River. Water generally flows from west to east discharging through the Niagara River and Welland Canal at 5,742 m^3/sec.(FWPCA, 1968). Tributaries are characterized by winding courses, sluggish waters with high silt loads. The lake receives other inflow from the Huron and Raisin Rivers in Michigan; the Maumee, Portage, Sandusky, Huron, Vermillion, Black, Rocky Cuyahoga, Chargrin, Grand, Ashtabula, and Conneciut Rivers in Ohio; the Cattanaugus and Buffalo in New York; and the Grand River Big, Otter and Kettle Creeks in Ontario. The region receives approximately 34 inches of rainfall a year and a third of it is lost to runoff.

The western basin (8110 sq. km.) receives approximately 97 percent of its inflow from the Detroit River with the average discharge of approximately 5,477 m^3/sec. The surface currents in the basin are somewhat wind driven; however, even with the prevailing winds out of the southwest (Figure 2), the dominant currents are driven by the inflow of the Detroit River (Figure 3). Much of the Detroit River water flows into the central basin through the Pelee Passage (Schelske and Roth, 1973). However, a portion of it curves back around creating a large slow-moving eddy south of Stony Point (Figure 3). These slow currents bring Maumee Bay/River water north off the Michigan shoreline. Other tributaries to the basin and their average discharges include the Maumee River (135.8 m^3/sec), Raisin River (20.2 m^3/sec), Huron River (16 m^3/sec) and Swan Creek (0.28 m^3/sec) (FWPCA, 1968).

The Maumee River is the largest tributary wholly within the lake basin and its silt loads are pushed north by the basin currents. There are two distinct regions of water quality: the northern, influenced by the Detroit

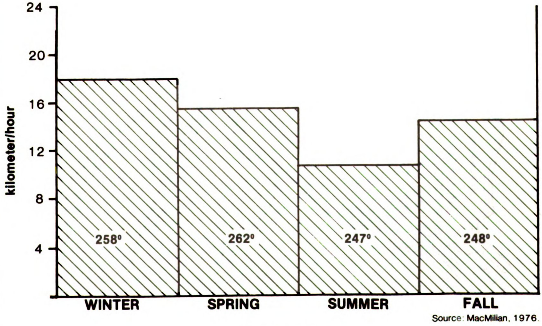


FIGURE 2
MEAN SEASONAL WIND VELOCITY AND AZIMUTH OF ORIGIN

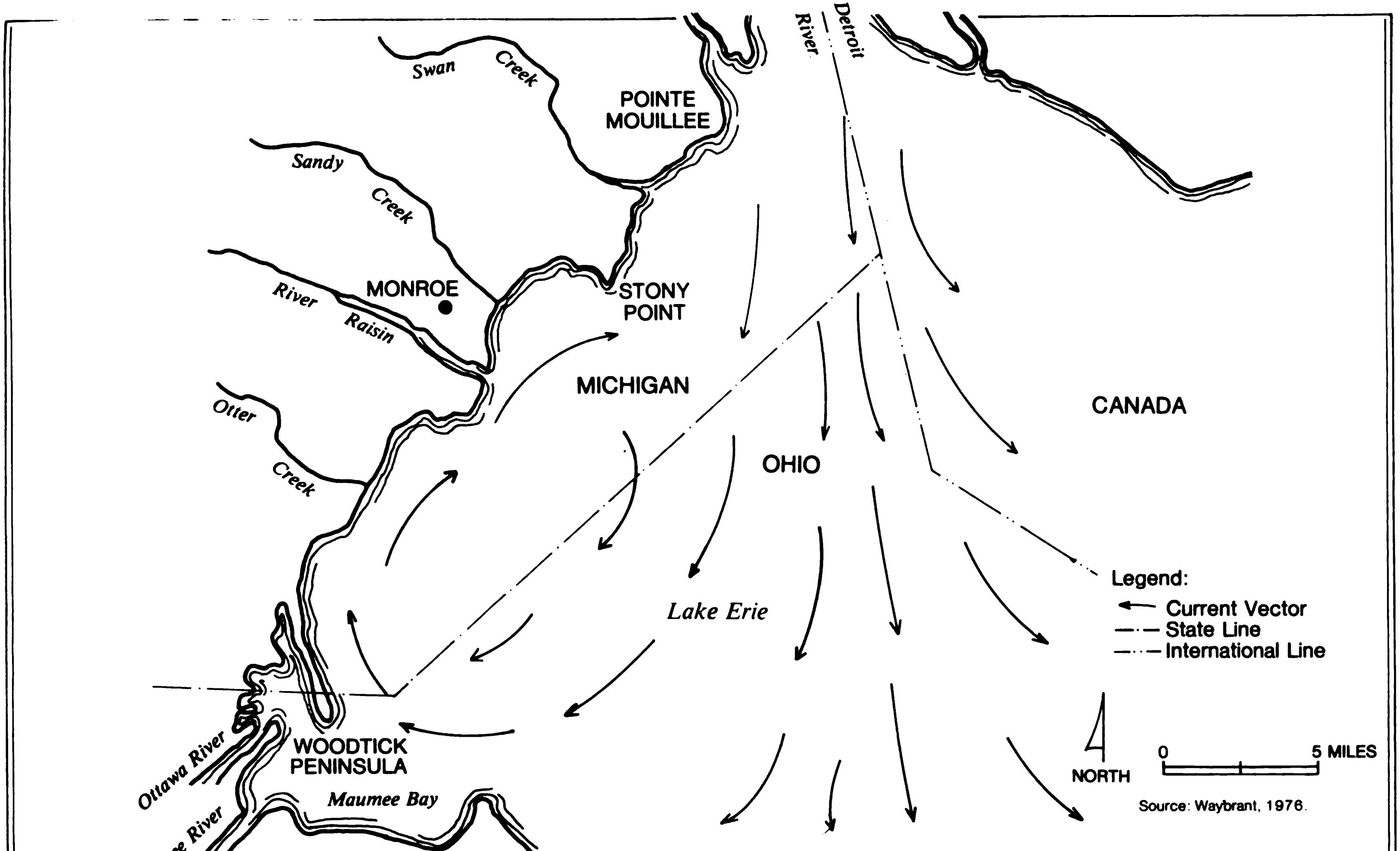


FIGURE 3
PREVAILING WATER CURRENTS IN THE WESTERN END OF LAKE ERIE

River, and the southern influenced by the Maumee River (Waybrant, 1976). The basin is the shallowest with sediments dominated by clays and muds in the flat areas and sand and gravel in the rising slopes. The western shore is comprised of sand with a thin layer of erosional silt. The only rock out-croppings are along the islands to the east and restricted areas around Stoney Point. The water is more turbid in the western basin as a result of large silt loads and wind driven mixing. Water temperatures are generally uniform within the water column only rarely stratifying during periods of calm weather. During these periods of calm, conditions near the bottom quickly go anaerobic from the high BOD loads which in turn affect the bottom fauna.

The lake's chemical characteristics are greatly influenced by its industrial watershed and morphology (Schelske and Roth, 1973). In addition agriculture has played a major role in change of the lake's water quality. The results of these activities have increased chemicals, nutrients, and silt loads in the lake. Nutrients and other chemical constituents that settle out are quickly resuspended by the continual mixing. The Detroit River has high water quality, but some of the most polluted sediments are in its plume (Waybrant, 1976). In the south, water quality is characterized by high BOD, conductivity, turbidity, total dissolved solids, total nitrogen, and chlorophyll a, but has a more diverse bottom fauna (Waybrant, 1976).

Lake Erie is a bicarbonate lake with an average pH of 8.3. Being the smallest and the most southern of the Great Lakes, it is the most biologically productive (Waybrant, 1976). Diatoms comprise 75 percent of the phytoplankton. Blue-green algae experience massive blooms in August, primarily Aphanizomenon sp. and Microcystis sp. Ulothrix sp. is an abundant green algae, and the filamentous green algae Cladophora sp. is becoming a nuisance (GLBCa, 1975). Copepods and rotifers make up the bulk of the zooplankton and oligochaetes and chironomids dominate the benthic community (FWPCA, 1968; Waybrant, 1976).

METHODS

Data Collection

An array of sampling stations was established in the far western end of the western basin of Lake Erie (Figure 4) during 1975 and 1976. The study area was subdivided by depth into five zones. Each zone was bounded by a depth contour. The zones are, going lakeward: 0-1.8 m, 1.8-3.7 m, 3.7-5.5m, 5.5-7.3m and 7.3-9.1 m. The study area was also artifically subdivided into five geographic areas from north to south (Figure 4). The 20 sampling stations were placed in the resultant cells.

In 1975, sampling began on June 2 and continued through September 15 on a biweekly schedule. In 1976, sampling began on April 13 and continued through August 25 on a biweekly schedule. In total, eight sampling iterations were completed in 1975 and 10 sampling iterations were completed in 1976.

Beach Zone

Stations 18, 19 and 20 were established to sample the 0-1.8 m depth zone. Samples were collected using 363 u, 9.1 m bag seine fitted with a 1.8 liter collection bucket. Collections were made in 0.9 meters of water against any discernible beach currents. Filtered volumes were calculated by keeping the mouth of the seine at a constant opening (3.1 m) and seining over premeasured distances which were 52.4 m at Station 18, 73.2 m at Station 19 and 68.3 m at Station 20. Collected samples were washed into the collection

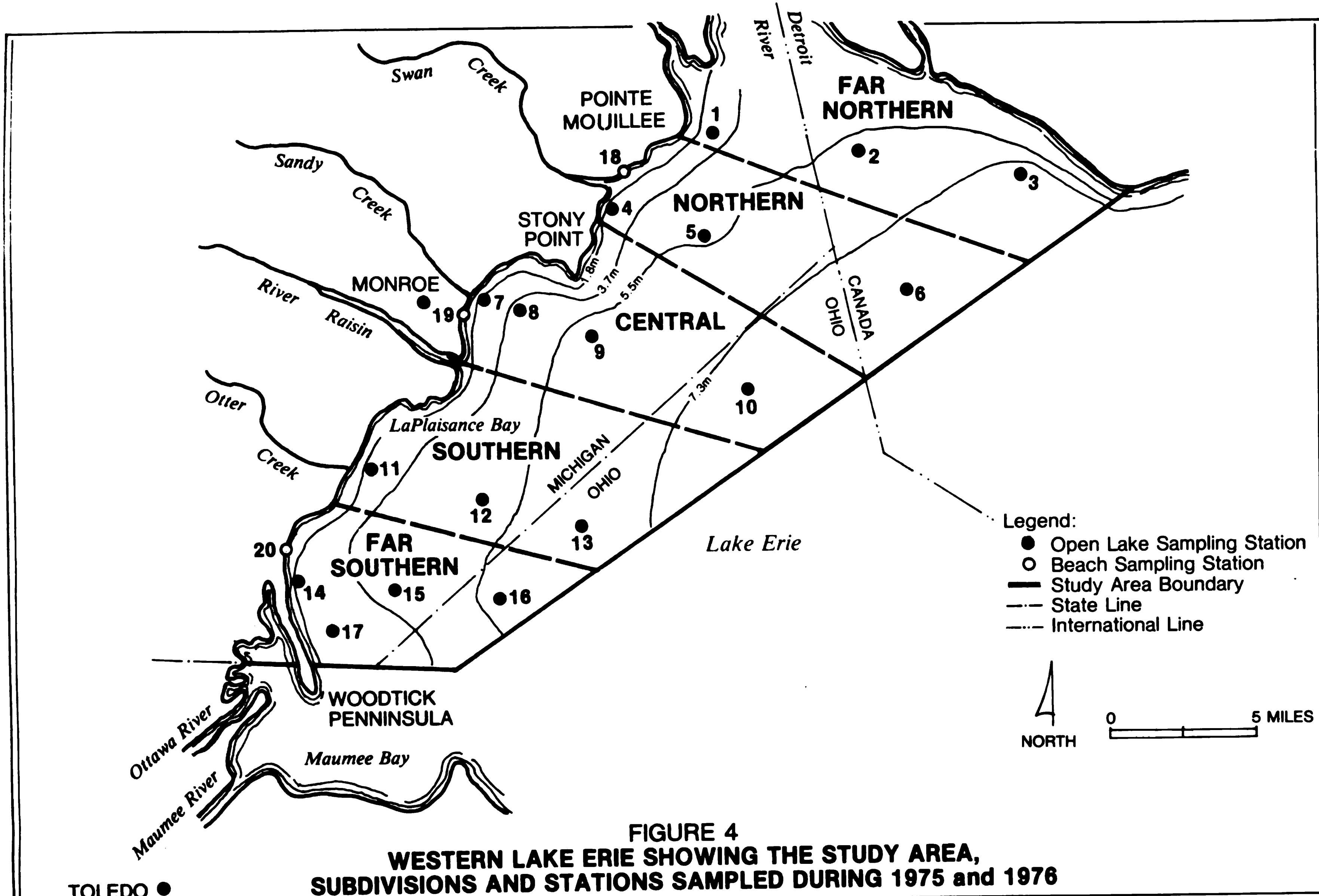


FIGURE 4
WESTERN LAKE ERIE SHOWING THE STUDY AREA, SUBDIVISIONS AND STATIONS SAMPLED DURING 1975 and 1976

bucket, and the sample slurry was diluted to approximately one liter and preserved with 10 percent buffered formalin. Rose bengal dye was added to facilitate laboratory sorting. One sample was collected per station per sample iteration.

Open Lake

Stations 1 through 17 were established to sample the remaining depth zones. Samples were collected using a 571 u, one meter, 5:1 simple conical plankton net fitted with a 1.9 liter collection bucket towed behind a boat as depicted in Figure 5. Two discrete tows were made at 5.5 km/hr. for four minutes. A surface tow was made by releasing enough towline to just submerge the plankton net totally in the water. The boat traveled in an arc to keep the net out of the propeller wash. Bottom samples were collected one meter off the bottom. Correct net deployment was ensured by following the methods displayed in Figure 5. Neither net was equipped with a closing device; consequently, bottom nets were deployed for a somewhat longer period but filtered water for four minutes one meter from the bottom. Each net was outfitted with a Kahl "pigmy-type" flowmeter. Each meter was calibrated prior to use and was mounted at the two-thirds/one-third point on the single-point bridle. Total volumes filtered were calculated by multiplying total revolutions of the flowmeter by the meter constant established during calibration. Total captured larvae were divided by total cubic meters filtered and multiplied by 100 to standarize all data to individuals/100 m^3. Filtering efficiencies were not calculated for any of the nets. Collected samples were handled and preserved in the same methods as those for the beach stations.

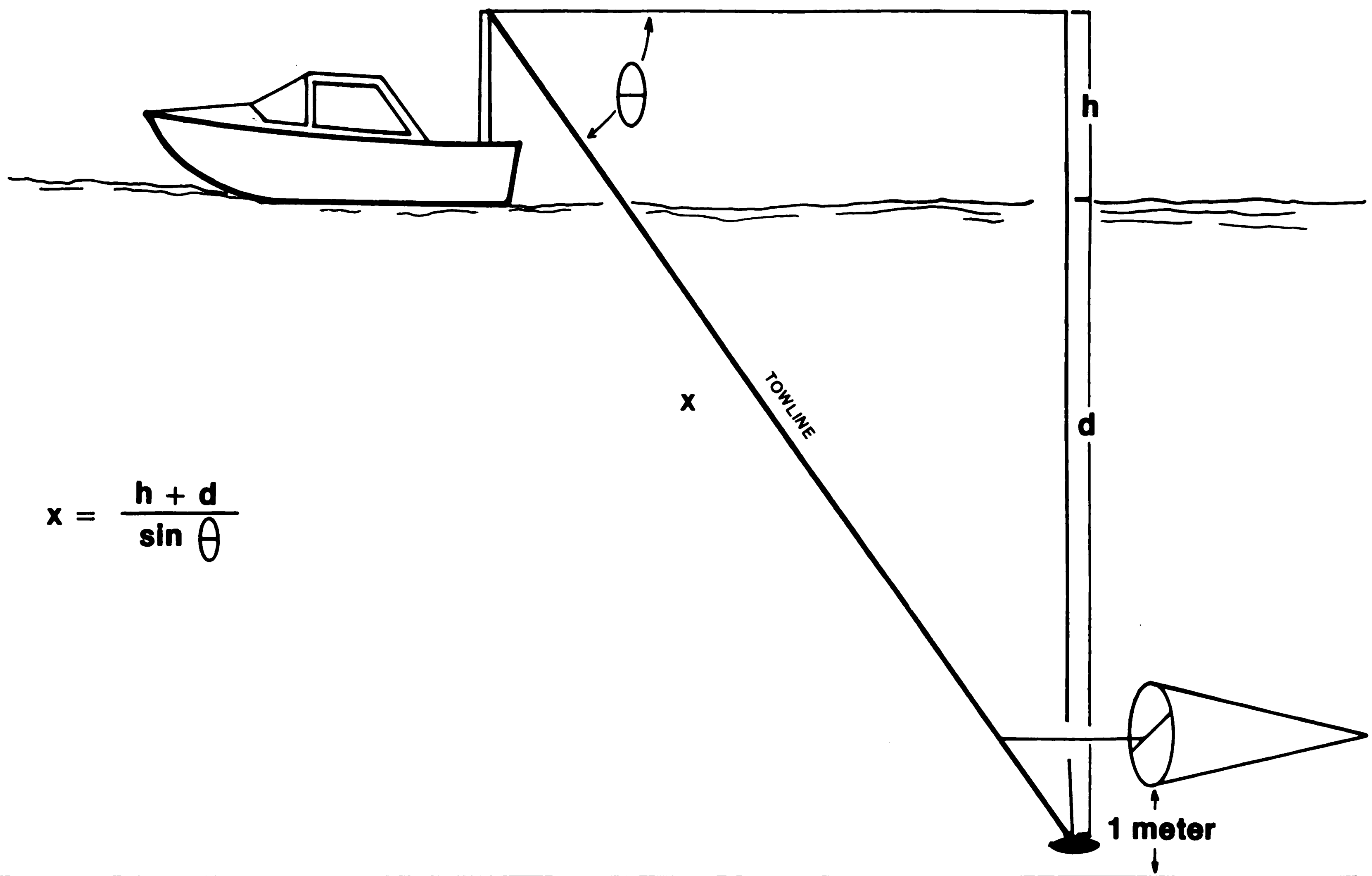


FIGURE 5
SAMPLING CONFIGURATION SHOWING METHOD TO DETERMINE LENGTH OF TOW LINE

In addition, air temperature and transparency depths were recorded at each station. Water temperatures were monitored every meter in depth at each open lake station in an effort to document any thermal stratification.

Laboratory

Upon return to the laboratory each sample was washed and sorted with the aid of a 4x sorting lens. Random samples were resorted to calculate sorting efficiencies. When extremely large samples were returned for sorting, a 50 or 25 percent subsample was sorted. Each sample retained its own identity by being sorted into individual vials in five percent buffered formalin.

Larval identification followed the classification system set up by May and Gasaway (1967). For the purpose of this study the early three post-hatching stages were lumped into the heading larvae. Juveniles were not examined. As a result of extremely large numbers of captured larvae and the taxonomic complexities of several taxa, several groups were only identified to the generic or family level. These included the gizzard shad (*Dorosoma cepedianum*)-alewife (*Alosa pseudoharengus*) complex reported as clupeids; common carp (*Cyprinus carpio*)-goldfish (*Carassius auratus*) complex reported as a common carp; the shiners (*Notropis* spp.) primarily the emerald shiner (*Notropis atherinoides*) and the spottail shiner (*Notropis hudsonius*) reported as shiners; the Centrarchidae genus (*Lepomis*) reported as sunfish; the Centrarchidae genus *Pomoxis* reported as crappies, and the Percidae genus *Etheostoma* reported as darters. The primary works consulted during the taxonomic portion of the project included Fish (1932), Mansuetti and Hardy (1967), May and Gasaway (1967), Lippson and Moran (1974) and Nelson and Cole (1975). Common and scientific names follow those discussed in Robins, et al. (1980). Identifications were confirmed by Mr. Donald Nelson of the Michigan Department of Natural Resources. All data are reported as individuals per 100 m^3 unless otherwise stated.

Mathematical And Statistical Computations

With Stations 1 through 17 the data from the surface samples were combined with the appropriate data from the bottom samples and divided by the total amount of filtered water to arrive at pooled densities for that station (Appendix A). Simple means for these pooled densities were calculated over time for each depth zone and each geographic zone. Differences in means were revealed using the Kruskal-Wallis distribution-free test as discussed in Hollander and Wolfe (1973). In addition, zone wide/period wide tests were also conducted. Appendix C lists the appropriate values for the test statistics (H') and their significance.

Abundance estimates were calculated by multiplying pooled densities by volumes. Total larval production was estimated by summing up the abundance estimates. However, to accomplish this several assumptions had to be made. They include: (1) it was assumed that the sampling frequency was such that only one larval cohort was sampled, all others being such that they could avoid capture; (2) each sampling iteration sampled a different larval cohort; (3) larval densities remained constant from approximately one-half a sampling period before a sampling date to one-half the following sampling period from the same sampling date; (4) densities changed linearly between stations to equalize the densities throughout the cells.

Volumes were calculated by first calculating the area of each individual cube with a planimeter and multiplying the area by the average depth. Appendix D contains the surface area and total volumes for each cube. Plainmeter readings were taken from the National Oceanic and Atmospheric Administration's Chart No. 39, LAKE ERIE, West End of the Lake Including the Islands 1971. Finally by summing up appropriate volume from appropriate cubes, volumes for the depth zones were calculated.

Not all cubes contained sampling stations. In such cases the volume was added to the cell immediately next to it within the same depth zone. Such was the case with the cell in the 3.7-5.5 m depth zone in the far northern geographic zone; it was added to the one immediately below it (Figure 4). Again, the cell in the 5.5-7.3 m depth zone in the northern geographic zone has no sampling station so half the volume was added to the cells on either side within the same depth zone. The volume of the cube that contains Stations 14 and 17 was divided in half and multiplied by the appropriate pooled densities. Densities at Station 18 were used for the 0-1.8 m depth zones in the far north and north cells. Station 19 densities were used for the 0-1.8 m depth zone for the central and south geographic zones. Station 20 densities were used for the 0-1.8 m depth zone in the far southern geographic zone.

SOURCES OF VARIABILITY

Common to all ichthyoplankton studies are a number of sources of sample variability which if not fully understood may be interpreted as natural variation inherent to population dynamics. Sample variability may reduce the soundness of the data set, lead to incorrect mathematical or statistical comparisons and foster a spurous discussion of the observed results. As a result, any program that looks at the natural system must be aware of the problems associated with the interactions between wild populations, sampling schemes and variability. Beers, et al. (1967) suggest that the patchy distribution of plankton and inefficiency of sampling gear are often cited as the two major sources of sample variability in field studies. To these Mizera, (1981) adds avoidance of the sampling gear by the target organism.

To reduce sample variability, ideally, distribution of larval fish should be normally and randomly distributed through the study area, but they are not. The close congregation of newly hatched larvae of some species and the schooling tendencies of others produce patchy or clump distributions which violate some of the basic assumptions of statistics. Increase in replications and increase of tow times both increase the chances of sampling these clumps. Cole (1978a) places a direct relationship between variability and sampling intensity. However, he goes on to explain that a six to ten time increase in sampling intensity would be required to maintain the same permissible error between two stations, and an increase of over 100 fold to reduce the permissible error from 50 percent to 10 percent with a 95 percent confidence interval.

As more and more ichthyoplankton studies are undertaken more and more sampling gear is introduced or refined, each to try to overcome a particular problem. However, it remains that each type still retains a certain amount of bias, and no one net or mesh size can effectively sample all larvae (Bowles, et al., 1978). Two critical considerations of a sample net are diameter of the mouth and mesh size. The larger the net the more water that can be filtered. Bowles, et al. (1978) state that larger nets tend to capture more larvae per filtered liter of water than smaller ones.

Cole (1978a) and Bowles, et al. (1978) have found that the larger mesh sizes may underestimate the smaller life stages. One apparent problem with the smaller mesh sizes is net clogging. As water is filtered through the net fabric small pieces of inorganic material, algae, zooplankton, and larvae become lodged in or across the mesh openings clogging the net and reducing the net's filtering efficiency. Increasing the ratio of the net mouth diameter to bag length ratio places the sides of the net nearer to parallel with the flow through the net increasing the net's ability to remain unclogged. Faber (1968) suggests a 6:1 ratio to induce this self cleaning.

Extrusion of larvae through the net fabric can take place with any mesh size in any size net. It is compounded by the compressibility of the larva, rigidity of the net fabric and tow speed. Minor changes in boat speed can have a significant effect in the actual net speed in the water (Nobel, 1970). The most effective net material is one with uniform aperture, stiffness to resist bending, but flexible enough to self-clean (Heron, 1968).

Net avoidance by the target organisms can either be active or passive. Fish are very sensitive to the pressure waves and turbulences set up by nets moving through the water. Small vibrations sent out by the bridle or flow meter are sensed by larvae with limited swimming ability, often in time to swim a short distance to escape the net. Clogging in a net will build up a pressure wave that will sweep larvae away from the mouth of the net. Larger nets and slower towing speeds will decrease the pressure wave by enabling the net to remain clean longer and forcing the larvae to swim farther to escape the net. Visual stimuli also aid the larvae in avoiding the net as Cole (1978a) reports greater success during night samplings, but this may also be influenced by diurnal changes in the larval distributions. However, Bowles et al. (1978) report several studies that suggest visual stimuli may indeed aid in net avoidance.

Different measures of ichthyoplankton densities, distribution, or occurrences can best be provided with the employment of different types of towing techniques. It would provide little information, for instance, to sample with a pump in a system where large volumes for water have to be filtered to establish reliable data. Bowles, et al. (1978) state that stratified and oblique tows are suited for abundance surveys. They also state that the type of net deployment should depend upon the expected distributions, life histories, and geomorphology of the sample area. Cole (1978a) has found that the metered net is as effective as the pump and high speed sampler, and oblique tows yield approximately the same results as stratified tows. However, he goes on to discuss that daytime sampling on the bottom without the aid of some bottom device may lead to high yields in nearshore areas.

In summary, the sampling techniques as described in the last section have been proven to reduce sampling variation in certain situations. The metered one meter net with a 5:1 net mouth to bag ratio, along with the 571 u mesh net serve to reduce the net avoidance and clogging problems. The slow towing speed and long deployment increase the chance of sampling the clump distributions most species exhibit. The pooled surface and bottom tows serve as a modified stratified-step tow which are common for abundance studies.

RESULTS

Open Lake

During 1975 sampling commenced on June 4th and continued through September 5th. A total of seven sampling iterations were completed making 221 tows yielding 111 pooled samples. During 1976 sampling commenced on April 27th and continued through August 25th. Foul weather and major equipment failure resulted in uncollected samples. Table 1 displays the sampling schedules and collection success for 1975 and 1976. Still, field efforts for 1976 resulted in a fairly complete data set with samples being collected at least once a month. From the six executed sampling iterations 194 tows were made yielding 97 pooled samples.

Efforts during 1975 produced 58,016 larvae representing 14 taxa of which five (clupeids, rainbow smelt, shiners, white bass and freshwater drum) comprised nearly 97 percent of the catch. In turn, 1976 produced 19,770 larvae representing 16 taxa of which the aboved named taxa comprised nearly 97 percent of the catch. Table 2 lists the catches for 1975 and 1976 and the associated relative abundances.

As a result of the June 4 commencement of the 1975 sampling season several species were already present in the samples (Appendix A and B). Water temperatures ranged from 14.7°C at Station 2 to 17.3°C at Station 4. Temperatures ranged in the mid-twenties throughout the summer and there was

TABLE 1

SAMPLING SCHEDULE AND SUCCESS FOR WESTERN LAKE ERIE DURING 1975 AND 1976

Sampling Dates	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
									1975											
6/3-6/14	x[1]	x	x	x	x	x	x	x	x									x	x	x
6/18-6/20	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6/30-7/7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
7/14-7/16	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
7/28-7/30	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8/11-8/13	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8/25																		x	x	x
9/2-9/5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x
									1976											
4/13																		x	x	x
4/26-4/29	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5/14-5/18																		x	x	
5/24-5/26	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6/7-6/8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6/29																		x	x	x
7/6-7/9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
7/19-7/20	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8/3																		x	x	x
8/23-8/25				x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x

[1] X = Sample collected

TABLE 2

TOTAL LARVAE COLLECTED AND RELATIVE ABUNDANCE FOR THE BEACH ZONE AND OPEN LAKE STATIONS COLLECTED DURING 1975 AND 1976

TAXON	1975						1976					
	Beach Zone		Open Lake		Total		Beach Zone		Open Lake		Total	
	Larvae	R.A.	Larvae	R.A.	Larvae	R.A.	Larvae	R.A.	Larvae	R.A.	Larvae	R.A.
Clupeids	9408	89.53	48,656	83.86	58,064	84.74	23,358	98.67	17,141	86.70	40,499	93.23
Northern pike	1	0.01			1	a						
Rainbow smelt	17	0.16	910	1.57	927	1.35	1	a	701	3.55	702	1.62
Common carp	25	0.24	160	0.28	185	0.27	5	0.02	109	0.55	114	0.26
Shiners	503	4.78	2,392	4.12	2,895	4.22	127	0.54	820	4.15	947	2.17
White suckers	4	0.04	1	a	5	0.01	39	0.16	15	0.08	54	0.12
Channel catfish	1	0.01			1	a						
Banded killifish							1	a	2	0.01	3	0.01
Brook silversides	48	0.46			48	0.07	2	0.01	8	0.04	10	0.02
White bass	314	2.99	3,010	5.19	3,324	4.85	19	0.08	321	1.62	340	0.78
Sunfishes	22	0.21	109	0.19	131	0.19			13	0.07	13	0.03
Basses	3	0.03			3	a						
Crappies	4	0.04	2	a	6	0.01			4	0.02	4	0.01
Darters			12	0.02	12	0.02	1	a	2	0.01	3	0.01
Yellow perch	103	0.98	199	0.34	302	0.44	105	0.44	417	2.11	522	1.20
Logperch	2	0.02	51	0.09	53	0.08	11	0.05	13	0.07	24	0.06
Walleye	1	0.01	1	a	2	a			7	0.04	7	0.02
Freshwater drum	52	0.49	2,456	4.23	2,508	3.66			184	0.93	184	0.42
Unknown			57	0.10	57	0.08	3	0.01	13	0.07	16	0.04
Total	10,508		58,016		68,524		23,672		19,770		43,442	

a = less than 0.01 percent

no evidence of thermal stratification. In 1976 sampling began several weeks earlier on April 27th. Again larval fish were taken in the samples. Water temperatures in April of 1976 ranged 8.5°C to 9.3°C at the northern three stations. Temperatures ranged in the teens in May and June, low twenties in July and the mid twenties in August. Again, no evidence of thermal stratification was found.

In 1975 densities were highest in the 1.8-3.7m depth zone and generally decreased as with depth (Figure 6). Peak densities were reached in the June 18-20 sampling period except in the 5.5-7.3m depth zone which peaked during the June 4-14 sampling period. Although sampling was incomplete in the first sampling period (June 4-14, 1975), there were higher densities in the southern two geographic zones of the study area (Figure 7). However, significant differences ($p \leq 0.05$) in the depth zone means were found only during the September sampling period. Then the mean densities in the 1.8-3.7m depth zone were higher. Appendix C has tabulated the test statistics values and their significance.

During 1976, densities peaked during the June 8 sampling period for the 1.8-3.7m, 3.7m-5.5m and 5.5m-7.3m depth zones and fell off rapidly after that (Figure 6). In the 7.3-9.1m depth zone, densities peaked during the July 20-28 sampling period and quickly dropped off in August. No depth zone emerged as having consistently higher densities, although densities in the 1.8-3.7m depth zone were significantly higher ($p \leq .05$) during the April sampling period. Even though there were no significant differences in the pooled means for the geographic zones, the far southern geographic zone had

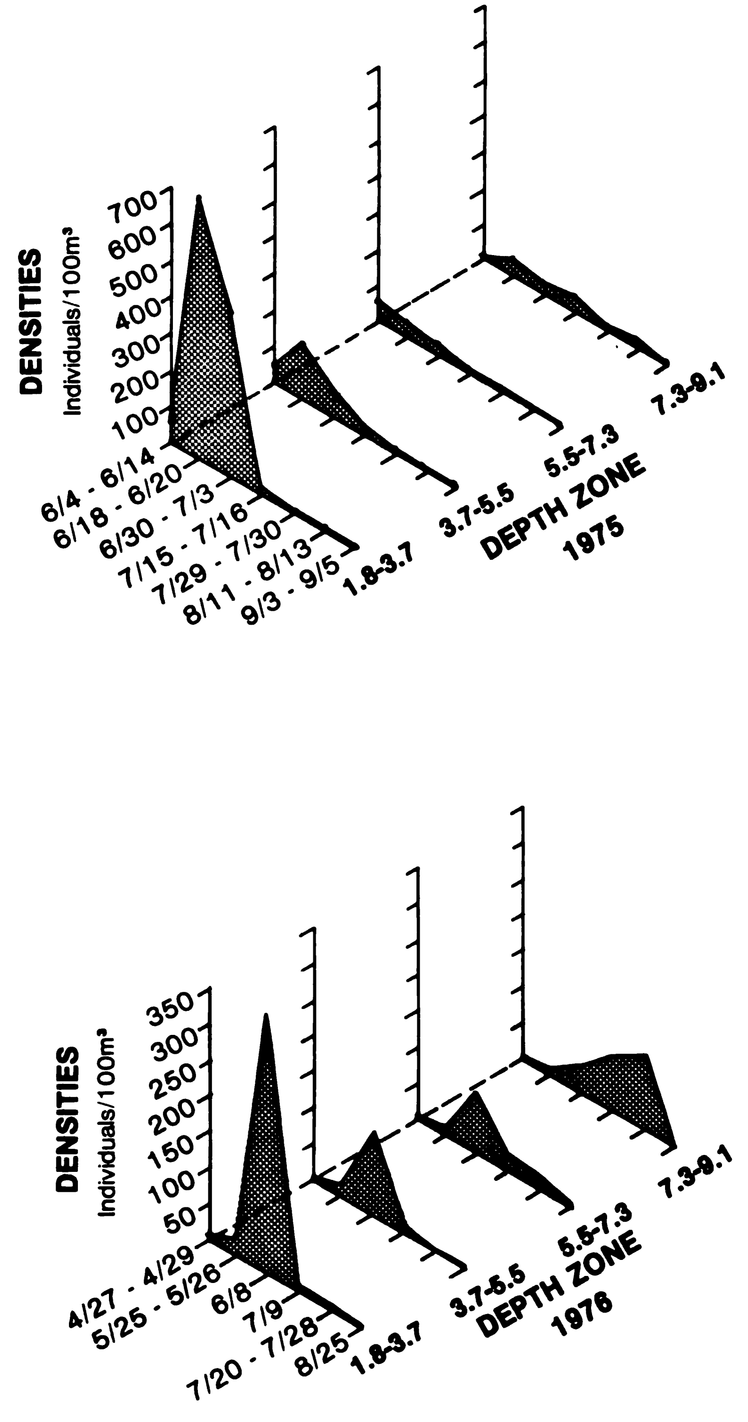


FIGURE 6
MEAN POOLED DENSITIES FOR ALL SPECIES BY DEPTH ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

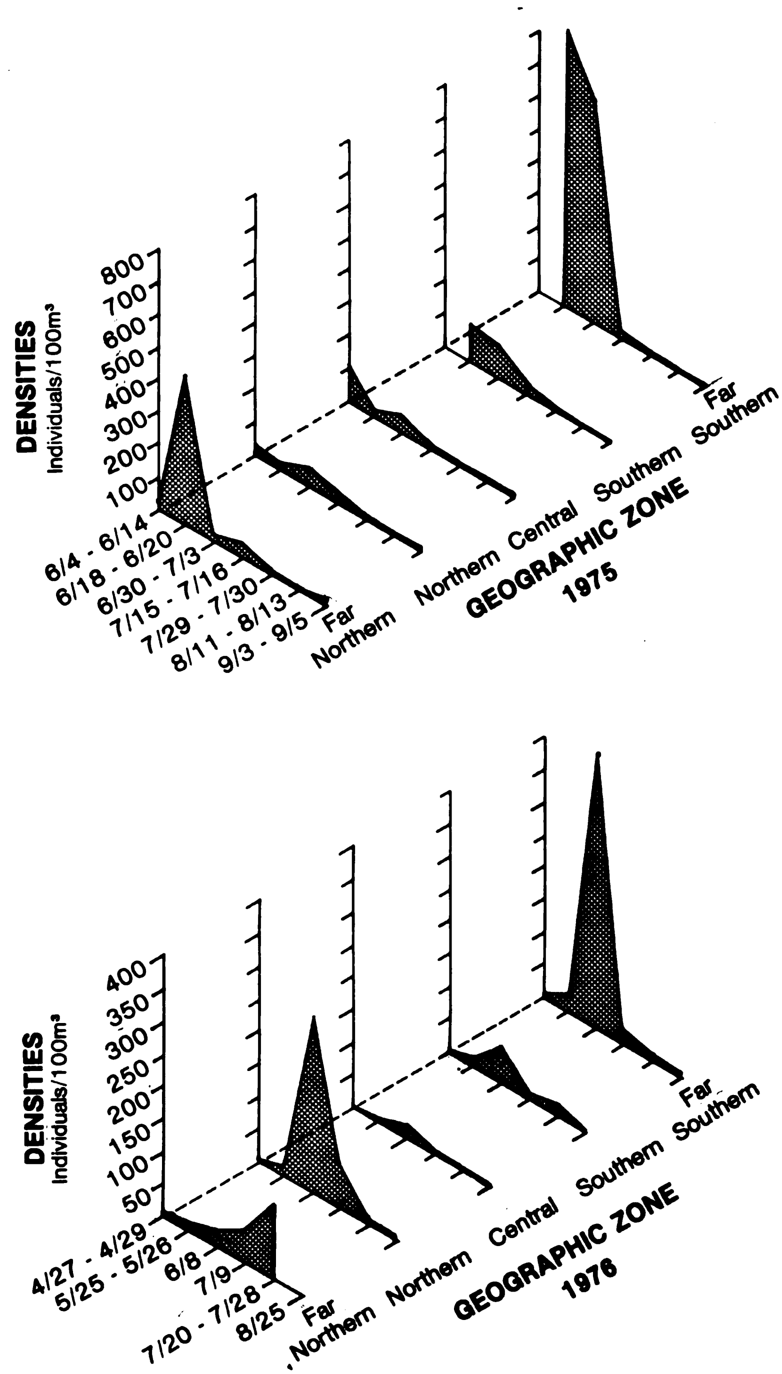


FIGURE 7
MEAN POOLED DENSITIES FOR ALL SPECIES BY GEOGRAPHIC ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

higher densities through June and the near northern and northern geographic zones had higher densities during the rest of 1976.

Total larval production for 1975 is estimated at 7.59×10^{11} fish (Table 3), with larval abundances peaking during June 18-20 and June 30-July 3 sampling periods. Although no clear cut trend was evident, larval abundances were higher in the deepest two zones through much of the sampling year. Total larval production for 1976 is estimated at 4.56×10^{11} fish (Table 3). These estimates may be on the conservative side as a result of the long periods between sampling. Peak abundancies in 1976 also occurred during the early June to early July time frame at 1.81×10^{11} to 1.34×10^{11} larvae (Table 3). Cooper, et al. (1981b) estimated total larval production at 2.325×10^{9} larvae for the work they did on the western basin. However, their study area was only from Stony Point south along the Michigan shoreline. In addition the difference in sampling net (.75m diameter, 760 u mesh vs. 1.0 m diameter, 571 u for this study) may have led to underestimates as discussed by Cole (1978a). Cooper, et al. report similar relative abundances with clupeids the dominate species. Mizera, et al. (1981) found in their work that Maumee Bay (Figure 1) was a very important larval production area. Their relative abundances agreed with this study's. High larval densities in the far southern geographic zone may be a result of larvae being swept north out of Maumee Bay along the Michigan shoreline by prevailing water currents. Water currents may also play a part in the high densities in the far northern zone as larvae may be swept into the study area from the Detroit River.

TABLE 3

LARVAL FISH ABUNDANCES FROM WESTERN LAKE ERIE,
STATIONS 1-17 DURING 1975 AND 1976

DEPTH ZONE (m)	1975 6/4-6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8/13	9/3-9/5
1.8-3.7	5.1739×10^{9}*	7.9824×10^{10}	9.1118×10^{10}	5.0458×10^{9}	7.2314×10^{8}	5.5337×10^{8}	5.2371×10^{8}
3.7-5.5	1.0271×10^{10}*	6.8113×10^{10}	3.6894×10^{10}	1.3825×10^{10}	5.7263×10^{8}	3.1511×10^{8}	4.4464×10^{8}
5.5-7.3	7.5266×10^{10}*	1.2261×10^{11}	8.1188×10^{10}	1.2320×10^{10}	7.3430×10^{9}	7.3654×10^{8}	3.3924×10^{8}
7.3-9.1	4.4446×10^{9}*	4.3953×10^{10}	3.1127×10^{10}	5.8260×10^{10}	2.8839×10^{9}	5.5817×10^{9}	
TOTAL	9.5156×10^{10}*	3.1450×10^{11}	2.4033×10^{11}	8.9451×10^{10}	1.1523×10^{10}	7.1867×10^{9}	1.3076×10^{9}

DEPTH ZONE (m)	1976 4/27-4/28	5/25-5/26	6/8	7/9	7/20-7/28	8/25
1.8-3.7	7.5696×10^{8}	4.3138×10^{9}	5.4798×10^{10}	1.5210×10^{9}	9.1543×10^{8}	2.3137×10^{8}*
3.7-5.5	9.1507×10^{8}	6.1391×10^{9}*	5.8383×10^{10}	3.9032×10^{9}	1.8022×10^{9}	4.1917×10^{8}
5.5-7.3	9.3666×10^{8}	1.4473×10^{10}	4.9544×10^{10}	3.7219×10^{10}	4.0601×10^{10}	8.5451×10^{8}*
7.3-9.1	2.0253×10^{9}	7.9497×10^{9}	1.8550×10^{10}	9.6567×10^{10}	5.2875×10^{10}	2.9803×10^{7}*
TOTAL	4.6340×10^{9}	3.2876×10^{10}*	1.8128×10^{11}	1.3921×10^{11}	9.6194×10^{10}	1.5349×10^{9}*

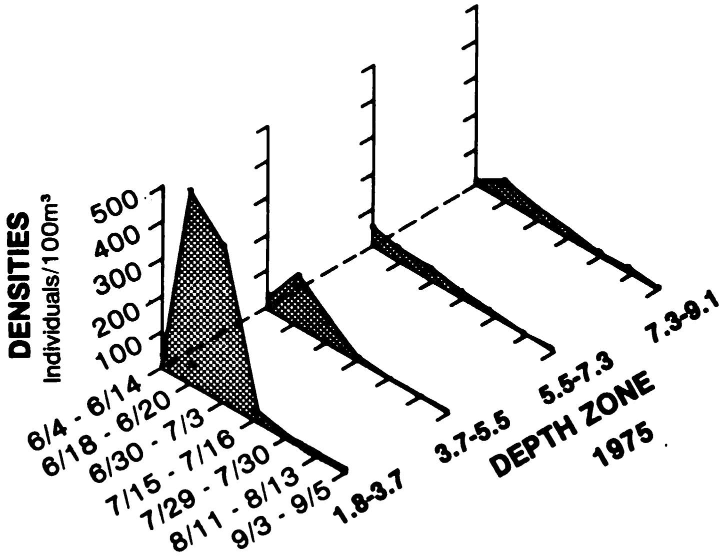
* Data represents sums arrived at with missing data; see Table 1 for stations not sampled.

Clupeids

Clupeids were the most abundant taxa of larval fish captured in 1975 and 1976 comprising nearly 84 and 87 percent of the catch respectively. Clupeids were already in moderately high densities when sampling commenced in 1975 (Figures 8 and 9). Densities peaked in the June 18-20 and the June 30-July 3 time frame and rapidly dropped off after that but were still present into September. During 1976, densities also peaked in the early June-early July time frame except for the 7.3-9.1m depth zone which peaked in the July 20-28 sampling period. Although no differences were found between the pooled means between the depth zones (Appendix C) for either 1975 or 1976, in 1975 densities were higher in the 1.8-3.7 meter zone and decreased in a deep water direction. In 1976 densities peaked in the 1.8-3.7m, 3.7-5.5m, and 5.5-7.3m zones during the June 8 sampling period but not until the July 20-28 sampling period for the 7.3-9.1 m zone. This may very well represent an influx from the Detroit River as there are high densities in the far northern geographic zone during this period also (Figure 9).

Densities by geographic zones seemed to be high in the northern and southern extremities of the study area with the lowest densities established in the central zone (Figure 9). The only significant ($p \leq 0.05$) difference in means occurred during July 9, 1976, sampling period when the northern and far northern depth zones had higher pooled mean densities (Appendix C).

During 1975, the far southern geographic zone had densities of over $600/m^3$ during the June 18-20 through the June 30-July 3 sampling periods. Mizera (1981) reports a high of $900/m^3$ basin-wide for this



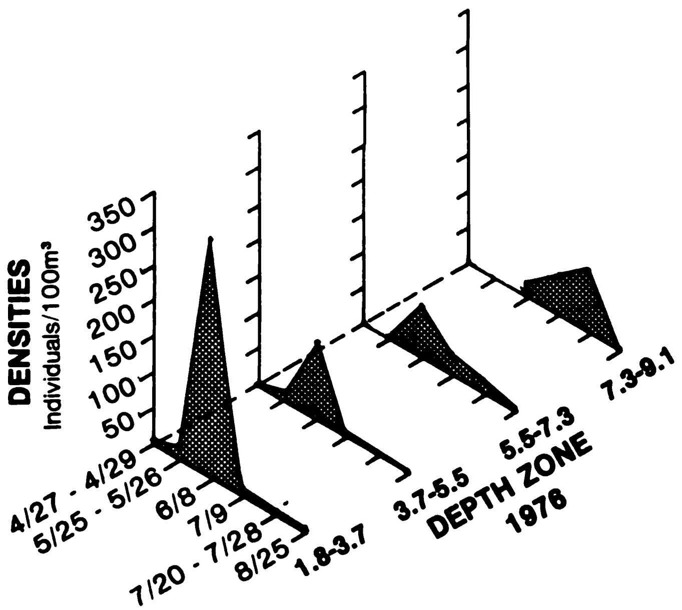
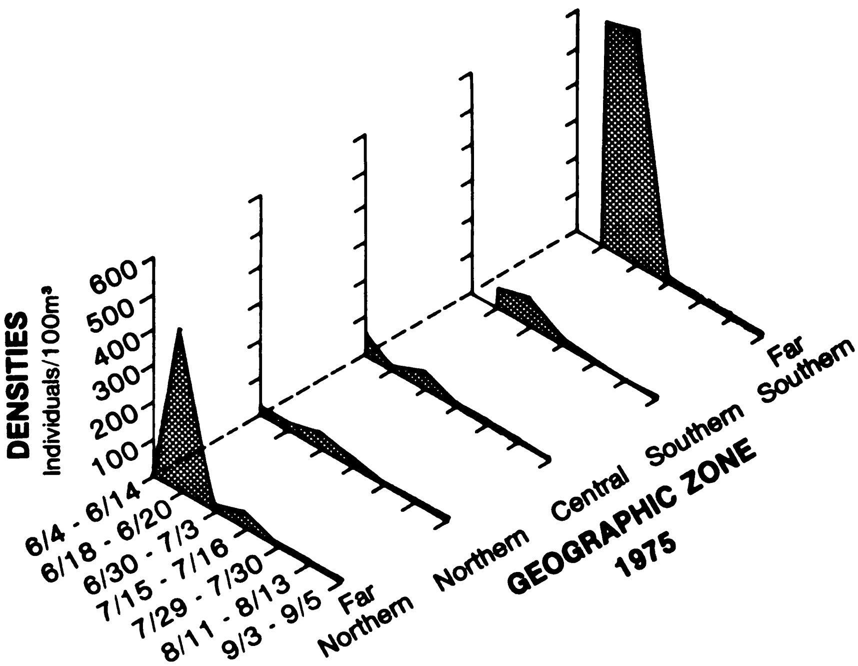


FIGURE 8
MEAN POOLED DENSITIES FOR CLUPEIDS BY DEPTH ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976



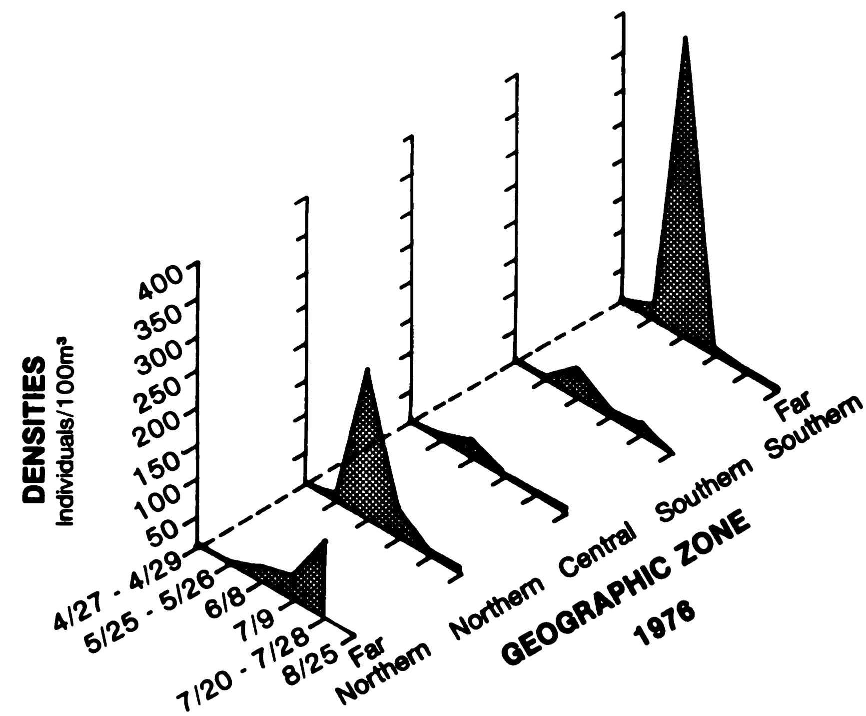


FIGURE 9
MEAN POOLED DENSITIES FOR CLUPEIDS BY GEOGRAPHIC ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

work in the western basin during 1977. These high densities may be a result of large numbers of clupeid larvae being swept north by the prevailing currents in that portion of the basin. Mizera et al. 1981 found that the Maumee Bay ichthyoplankton fauna was dominated by clupeids.

During 1976, sampling started earlier than 1975 (April 27) and larval clupeids were present in these early samples. However, their first appearance was in the southern two-thirds of the study area. Spawning no doubt took place earlier in the warmer water of Maumee Bay and closely associated areas of Lake Erie, and it appears that the northern and far northern geographic zones exhibited this lag time in densities throughout 1976.

Larval clupeid production for 1975 and 1976 sampling periods is estimated at 6.19×10^{11} and 3.50×10^{11} respectively (Table 4). During 1975 abundances again peaked during the June 18-20 and June 30-July 3 sampling periods dropping a thousand fold by September. Except for the June 18-20 sampling period, larval abundances were generally higher in the 5.5-7.3m and 7.3-9.1m depth zones. During 1976 larval abundances were low in April and quickly increased by 10^4 by the first part of June. No depth zones stood out consistently as producing the most larvae, however, the 5.5-7.3m depth zone had a high number of larval clupeids during the time of peak production. Cooper et al. (1981a) estimated the larval clupeid production to be 1.03×10^9 fish in their work in the southern portion of the basin, and Mizera (1981) estimates 1.03×10^{10} fish from Stony Point south. Again, their estimates do not include those larvae entering the system from the north via spawning or immigration from the Detroit River.

TABLE 4

LARVAL CLUPEID ABUNDANCES FROM WESTERN LAKE ERIE, STATIONS 1-17 DURING 1975 AND 1976

1975

DEPTH ZONE (m)	6/4-6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8/13	9/3-9/5
1.8-3.7	4.1276×10^{9}*	9.6947×10^{10}	8.0071×10^{10}	3.9994×10^{9}	4.0200×10^{8}	4.5632×10^{8}	4.1186×10^{8}
3.7-5.5	5.7986×10^{9}*	5.2689×10^{10}	3.2439×10^{10}	9.7450×10^{9}	3.9885×10^{8}	2.0255×10^{8}	5.6231×10^{7}
5.5-7.3	6.2158×10^{10}*	6.8829×10^{10}	6.7431×10^{10}	9.0492×10^{9}	6.0699×10^{9}	4.4616×10^{8}	3.3924×10^{8}
7.3-9.1	2.6900×10^{9}*	4.1545×10^{10}	1.8788×10^{10}	4.6384×10^{10}	2.4321×10^{9}	5.5519×10^{9}	
TOTAL	7.4772×10^{10}*	2.6001×10^{11}	1.9874×10^{11}	6.9178×10^{10}	9.3029×10^{9}	6.6569×10^{9}	8.0733×10^{8}

1976

DEPTH ZONE(m)	4/27-4/28	5/25-5/26	6/8	7/9	7/20-7/28	8/25
1.8-3.7	6.0820×10^{7}	2.9432×10^{9}	5.2449×10^{10}	9.7083×10^{8}	2.1505×10^{8}	2.3137×10^{8}*
3.7-5.5	3.8975×10^{7}	2.8304×10^{9}*	5.3964×10^{10}	1.3787×10^{9}	6.4398×10^{8}	4.1917×10^{8}
5.5-7.3		1.3152×10^{9}	3.9577×10^{10}	3.1493×10^{10}	3.1921×10^{10}	8.5455×10^{8}
7.3-9.1			8.2818×10^{9}	7.5919×10^{10}	4.4794×10^{10}	2.9803×10^{7}*
TOTAL	9.9795×10^{7}	7.0888×10^{9}*	1.5427×10^{11}	1.0976×10^{11}	7.7574×10^{10}	1.5349×10^{9}*

* Data represents sums arrived at with missing data; see Table 1 for stations not sampled.

Shiners

Total shiners (presumably the majority of them emerald shiners (Notropis atherinoides) and spottail shiners (Notropis hudsonius)), represented 4.12 percent of the catch in 1975 and 4.15 percent of the catch in 1976. Larval shiners were already in the lake when sampling commenced June 4, 1975; however, they did not appear in 1976 until the May 25-26 sampling period when the waters had warmed to around 15^{o}C in the southern portion of the study area. During 1975 the 1.8-3.7m, 3.7-5.5m, and the 5.5-7.3m depth zones all had peak densities during the June 30-July 3 sampling period. The 7.3-9.1m depth zone had peak densities during the July 15-16 sampling period (Figure 10). Mean pooled densities showed no significant differences during 1975 except during the September 3-5 sampling period when the 1.8-3.7m depth zone had significantly ($p \leq 0.05$) higher densities (Appendix C).

During 1976 no depth zone emerged as having significantly higher densities. The 1976 catch was several times smaller than in 1975 and showed no high densities among depth zones. The highest densities appeared to be spread over a several month period (Figure 10).

No geographic zone had significantly different pooled means during 1975, although, the far southern and southern geographic zones appeared to have higher densities through July 3, 1975 (Figure 11). In 1976 the far southern geographic zone had peak densities during the June 8 sampling again during the July 20-28 sampling period and the northern and far northern geographic zones peaked during the July 9 and July 20-28 sampling periods respectively. None of the five sampling iterations revealed any significant

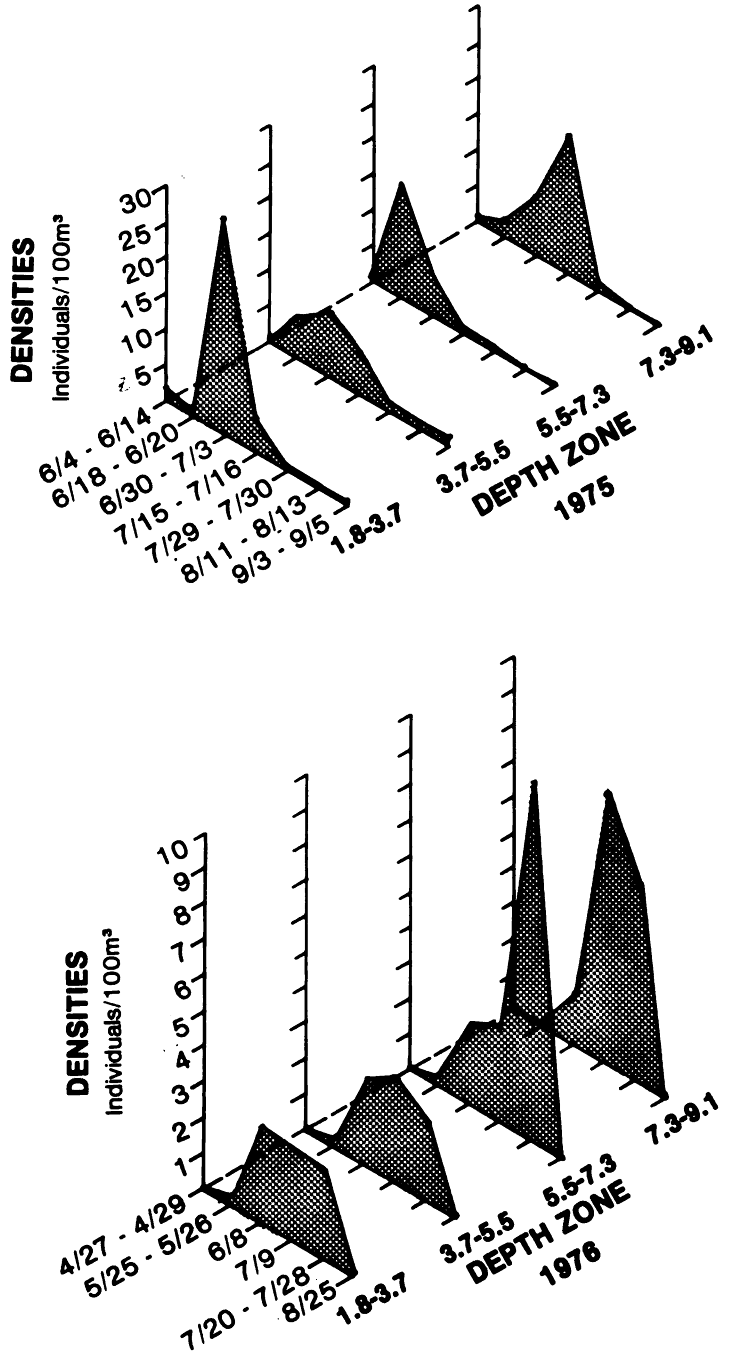


FIGURE 10
MEAN POOLED DENSITIES FOR SHINERS BY DEPTH ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

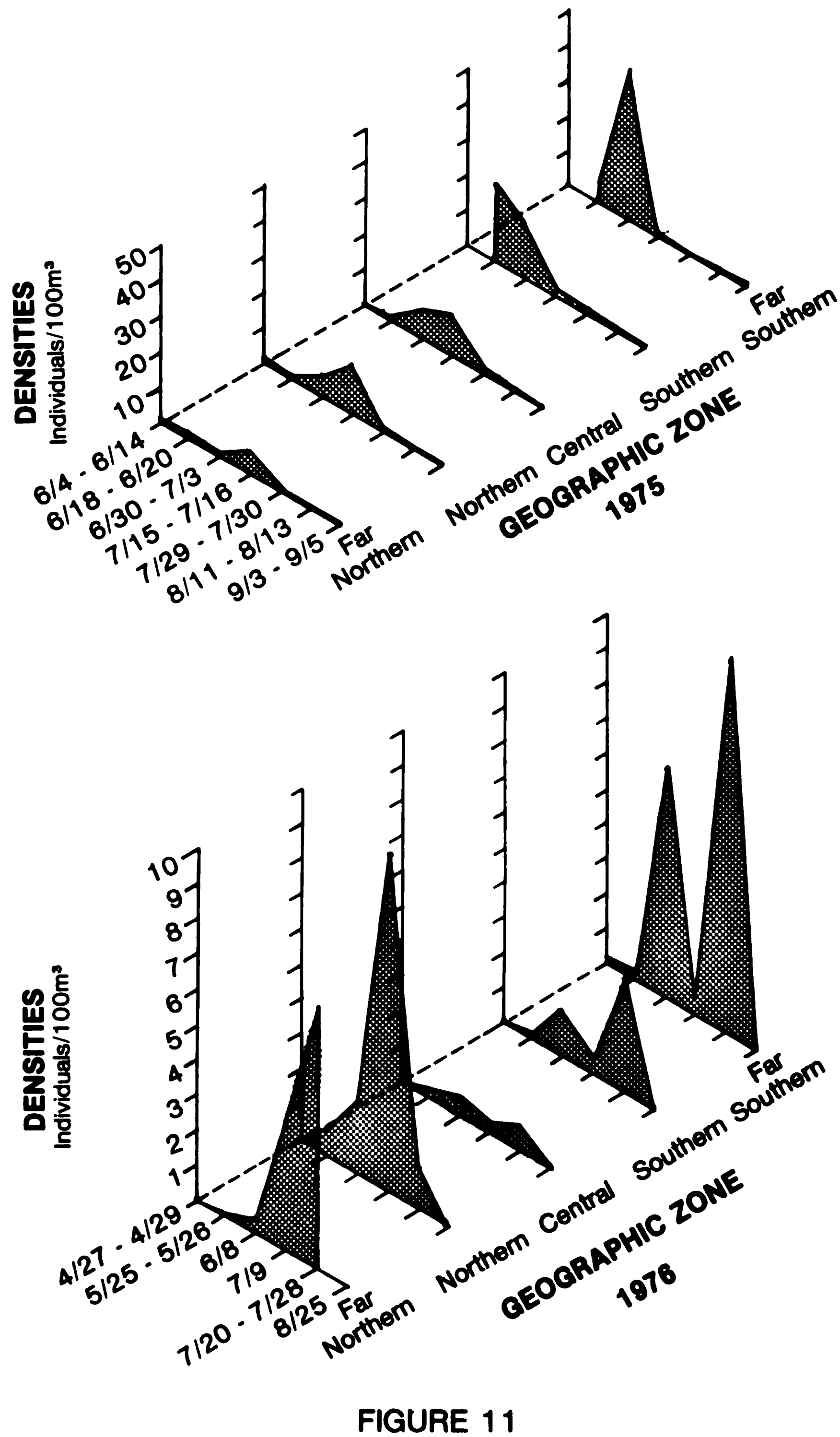


FIGURE 11
MEAN POOLED DENSITIES FOR SHINERS BY GEOGRAPHIC ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

differences between pooled means; however, the annual pooled means were significant ($p \leq 0.05$) with the far southern and near northern averaging higher densities (Appendix C). Mizera (1981) reported larval shiners in the southern portion of the western basin at 100 per 100 m^3 (mostly emerald) during 1977. This may be a result of more intensive sampling efforts or some derivation of the population distribution.

Total larval shiner production for 1975 and 1976 is estimated at 8.82×10^{10} and 4.41×10^{10} respectively (Table 5). This compares with a production of 5.29×10^{8} as reported by Cooper, et al. (1981a) and Mizera (1981). During 1975 abundances peaked during the June 18-20 and the June 30-July 3 sampling periods. The 5.5-7.3m and 7.3-9.1m depth zones consistently had higher abundancies throughout 1975. Although shiners were only present during four sampling periods in 1976, abundances rose to a peak during the June 8 sampling trip and remained constant until they disappeared from the samples in August. Again, larval shiner production was highest in the 5.5-7.3m and the 7.3-9.1m depth zones.

White Bass

During 1975, 3,010 white bass larvae were captured which represented 5.19 percent of the total catch, and in 1976 only 321 white bass were taken representing only 1.62 percent of the catch. White bass larvae were already present in the lake when sampling started in 1975. Larval densities peaked during the June 18-20 sampling period (Figure 12), and there was no significant difference in pooled mean densities (Appendix C). First larval white bass showed up during the May 25-28 sampling period during 1976. Densities

TABLE 5

LARVAL SHINER ABUNDANCES FROM WESTERN LAKE ERIE
STATIONS 1-17 DURING 1975 AND 1976

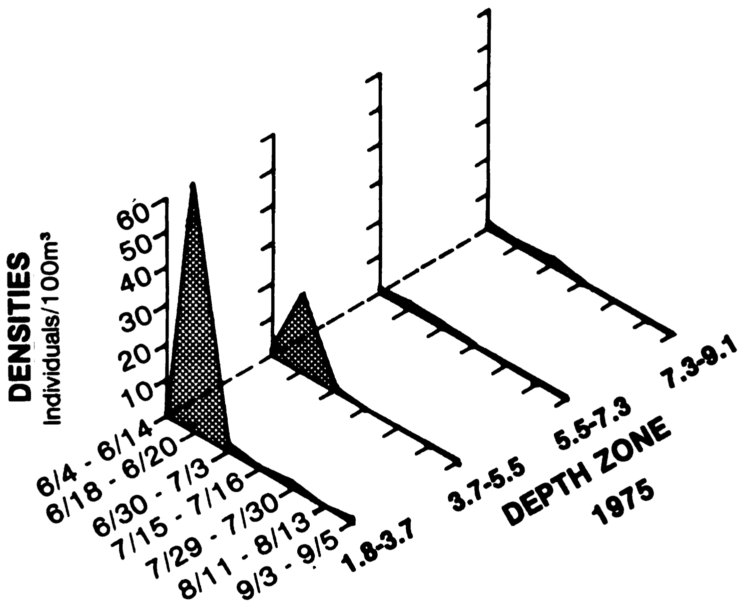
1975

DEPTH ZONE (m)	6/4-6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8/13	9/3-9/5
1.8-3.7	1.4659×10^{8}*	1.2007×10^{9}	5.9076×10^{9}	8.5868×10^{8}	2.0983×10^{8}	2.6164×10^{7}	7.7948×10^{7}
3.7-5.5	1.3504×10^{8}*	2.2130×10^{9}	3.8556×10^{9}	4.0285×10^{9}	1.7379×10^{8}	7.7321×10^{7}	3.0927×10^{8}
5.5-7.3	1.0062×10^{8}*	2.6456×10^{10}	1.3524×10^{10}	3.2371×10^{9}	3.1343×10^{8}	1.9513×10^{8}	
7.3-9.1	6.5194×10^{8}*	1.6682×10^{9}	1.1613×10^{10}	1.0990×10^{10}	3.1761×10^{8}		
TOTAL	$1.0342.10^{9}$*	3.1538×10^{10}	3.4900×10^{10}	1.9114×10^{10}	1.0147×10^{9}	2.9862×10^{8}	3.8722×10^{8}

1976

DEPTH ZONE(m)	4/27-4/28	5/25-5/26	6/8	7/9	7/20-7/28	8/25
1.8-3.7		3.5892×10^{7}	5.1516×10^{8}	3.0945×10^{7}	4.8053×10^{8}	
3.7-5.5		5.5041×10^{7}	1.2747×10^{9}	2.1506×10^{9}	1.0588×10^{9}	
5.5-7.3		2.2215×10^{8}	2.0106×10^{9}	3.9192×10^{9}	5.7029×10^{9}	
7.3-9.1			1.2327×10^{10}	1.0793×10^{10}	3.5727×10^{9}	
TOTAL		3.1308×10^{8}*	1.6127×10^{10}	1.6894×10^{10}	1.0815×10^{10}	

*Data represents sums arrived at with missing data; see Table 1 for stations not sampled.



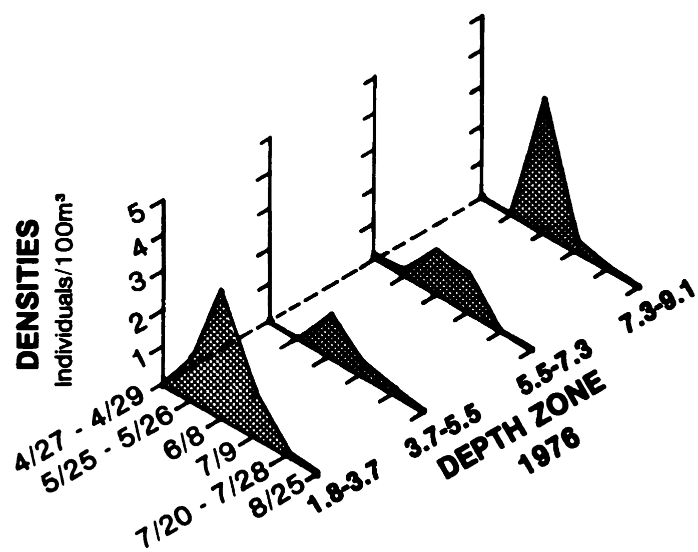


FIGURE 12
MEAN POOLED DENSITIES FOR WHITE BASS BY DEPTH ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

rose and peaked during the June 8 sampling period and had disappeared from the samples by August. No significant differences were found between any of the pooled means. The 1.8-3.7m depth zone appeared to have the highest densities through most of 1975, but no pattern emerged during 1976.

During both 1975 and 1976 the southern and far southern geographic zones had the highest densities (Figure 13). Tests showed that the two southern geographic zones had significantly ($p \leq 0.05$) higher pooled means, and the annual densities were highly significant ($p \leq 0.01$) (Appendix C) across all sampling periods.

Larval white bass production of 1975 and 1976 is estimated at 2.79×10^{10} and 6.91×10^{9} respectively (Table 6). Although larval production varied by a factor of four between the two years, basically abundances peaked at the same time, around June 1, and disappeared from the samples at the same time, around the last of July. Cooper, et al. (1981) placed larval white bass production for 1977 at 2.65×10^{8} in the portion of the western basin they studied. Cooper, et al. also reported that Maumee Bay produced 60 percent of their catch and their lowest catch was off Stony Point.

Yellow Perch

Yellow perch comprised 0.34 and 2.11 percent of the catch for 1975 and 1976 respectively (Table 2). Comparing the two years data as graphed in Figures 14 and 15, it is apparent that by the June 4 start-up date in 1975 the yellow perch densities had passed their peak. In light of

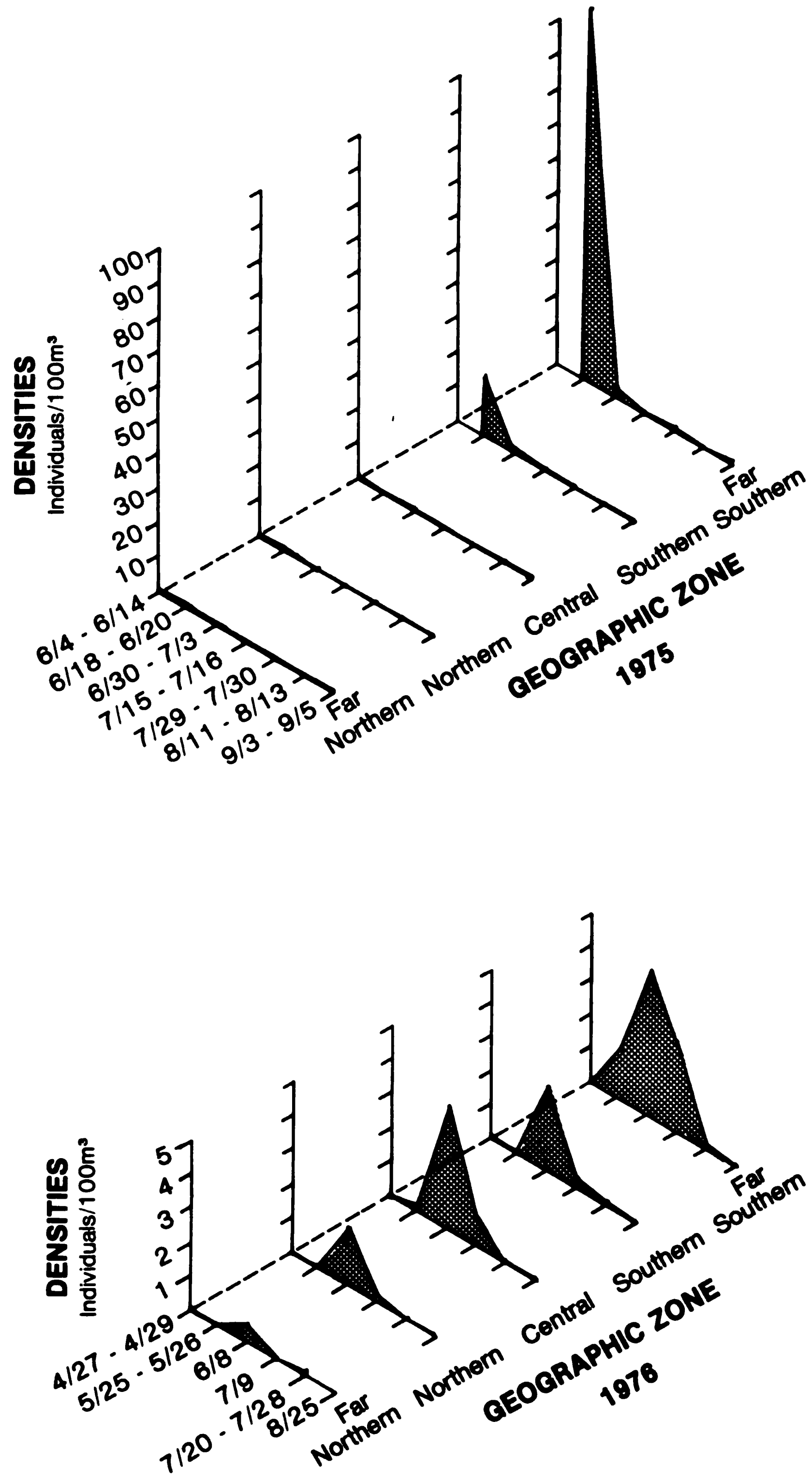


FIGURE 13
MEAN POOLED DENSITIES FOR WHITE BASS BY GEOGRAPHIC ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

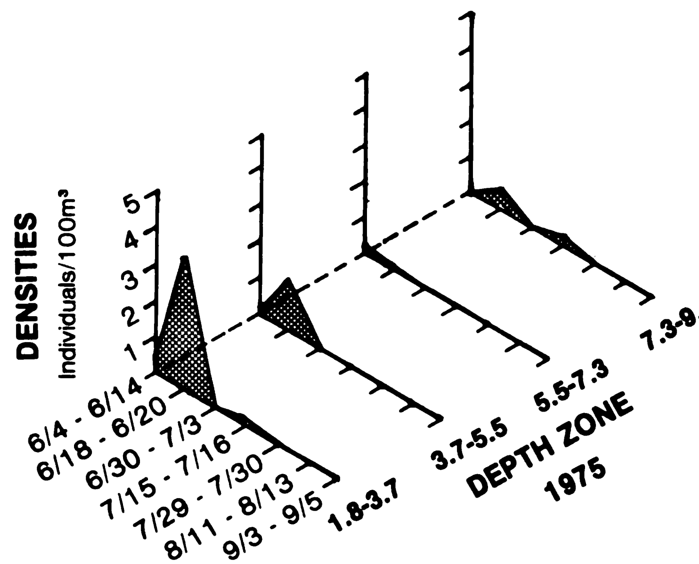
TABLE 6

LARVAL WHITE BASS ABUNDANCES FROM WESTERN LAKE ERIE,
STATIONS 1-17 DURING 1975 AND 1976

DEPTH ZONE (m)	6/4-6/14	6/18-6/20	6/30-7/3	1975 7/15-7/16	7/29-7/30	8/11-8/13	9/3-9/5
1.8-3.7	3.5738×10^{8}*	1.3347×10^{10}	4.8655×10^{8}	1.0117×10^{7}	4.9319×10^{7}		2.7742×10^{7}
3.7-5.5	1.6066×10^{8}*	8.6598×10^{9}	1.2127×10^{8}				2.2909×10^{7}
5.5-7.3	7.5467×10^{8}*	2.4434×10^{9}	2.4970×10^{8}	3.5543×10^{8}			
7.3-9.1	1.8397×10^{8}*	2.98037×10^{7}	5.2156×10^{8}				
TOTAL	1.4567×10^{9}*	2.4480×10^{10}	1.3791×10^{9}	3.6555×10^{8}	4.9319×10^{7}		5.0651×10^{7}

DEPTH ZONE (m)	4/27-4/28	5/25-5/26	6/8	1976 7/9	7/20-7/28	8/5
1.8-3.7		2.6509×10^{8}	6.7645×10^{8}	2.2704×10^{8}	1.3569×10^{7}	
3.7-5.5			9.9412×10^{7}	$1.6195.10^{8}$	3.5239×10^{7}	
5.5-7.3		1.0062×10^{8}	2.1310×10^{9}	6.9436×10^{8}		
7.3-9.1			2.3395×10^{9}	1.6392×10^{8}		
TOTAL		3.6571×10^{8}	5.2464×10^{9}	1.2473×10^{9}	4.8808×10^{7}	

*Data represents sums arrived at with missing data; see Table 1 for stations not sampled.



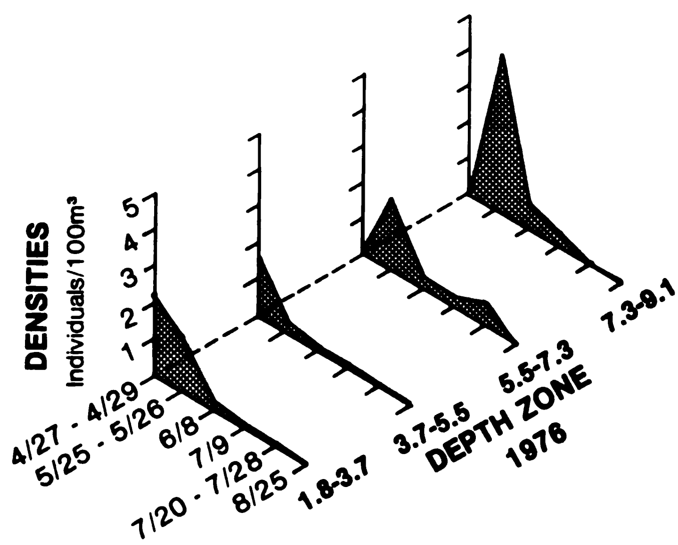


FIGURE 14
MEAN POOLED DENSITIES FOR YELLOW PERCH BY DEPTH ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

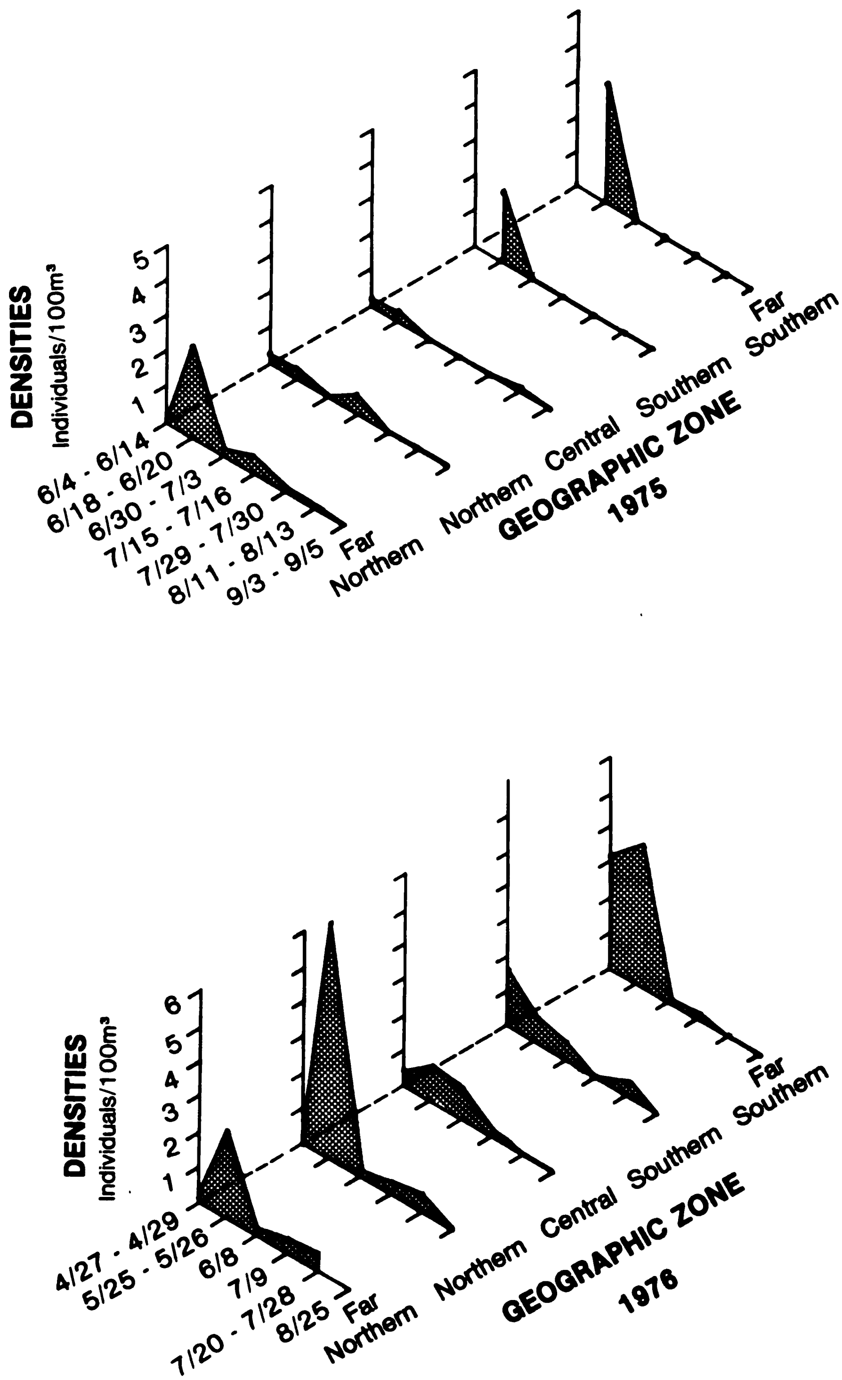


FIGURE 15
MEAN POOLED DENSITIES FOR YELLOW PERCH BY GEOGRAPHIC ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

this fact very little specifics can be drawn from the 1975 data. However, yellow perch were present more than just occasionally in the June 4-14 and June 18-20 sampling periods. Although there was no significant difference in the pooled means and no clear pattern existed for densities within the depth zone. For the geographic zones, weak evidence exists that the densities were higher in the far north southern and far southern geographic zones (Figure 15).

A clearer picture emerges from the 1976 data as sampling began April 27th. Larval yellow perch were already in the lake. However, data presented by other researchers indicate that this period may not have been the first of the larval yellow perch occurrences (Cole, 1978b; MacMillian, 1976). Still, it appears to be before the peaks in densities. Densities in the depth zones increased in the May 25-26 sampling period before starting to decline. No clear trend is established as to which depth zone consistently had the highest densities although during the April 27-29 sampling period the 1.8-3.7m depth had significantly higher ($p \leq 0.05$) pooled densities than the deeper zones. Densities appear to be higher further off shore later in the year (Figure 14), which may indicate off shore movement by the older larvae either under their own locomotion or with the aid of the dominant water currents of the basin.

Densities in the geographic zones shift from highest in the far southern geographic zone in April to high densities in the northern and far northern geographic zones (Figure 15). This may represent larval yellow perch from the Detroit River entering the study area several weeks behind in development. Mean pooled densities were significantly different only during the July 9 sampling period (Appendix C), with the far northern and northern geographic zones with higher densities.

Larval yellow perch production for 1975 and 1976 is estimated at 3.00×10^9 and 1.86×10^{10} respectively (Table 7). As discussed above, much of the larval yellow perch production in 1975 was missed as a result of the June 4, 1975 start up date. From the data collected, it can be seen that the highest abundances were in the 5.5-7.3m depth zone except for the June 18-20 sample period. The data suggests very little regarding trends in larval yellow perch abundances in the depth zones. During 1976 larval yellow perch production peaked during the May 25-26 sampling period and declined until they disappeared in August. Again, the 5.5-7.3m depth zones had the highest abundances of larval yellow perch throughout much of 1976. For Cooper et al. (1981) and Mizera (1981) the yellow perch was the second most abundant taxa captured during 1977. They reported their highest densities along the southern Michigan shoreline (most fish were in the prolarvae stage of development) and their lowest densities along the southern Michigan shoreline from Stony Point to the mouth of the Raisin River. Cooper et al. (1981a) estimated larval yellow perch production at 1.35×10^9 fish for the southern portion of the western basin during 1976.

Rainbow Smelt

Rainbow smelt exhibited much the same temporal density patterns as yellow perch. As a result of the June 4-14 start-up date in 1975 much of the rainbow smelt early activity had passed. However, Mizera (1981) found

TABLE 7

LARVAL YELLOW PERCH ABUNDANCES FROM WESTERN LAKE ERIE, STATIONS 1-17 DURING 1975 AND 1976

DEPTH ZONE (m)	1975 6/4-6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8/13	9/3-9/5
1.8-3.7	$1.4448x10^{7}$*	$2.8975x10^{8}$	$5.5336x10^{6}$	$5.1477x10^{7}$	$6.1648x10^{6}$	$3.9526x10^{6}$	
3.7-5.5	$1.3504x10^{8}$*	$6.1864x10^{8}$					
5.5-7.3	$2.5156x10^{8}$*	$1.5333x10^{8}$		$9.2949x10^{8}$		$7.4359x10^{7}$	
7.3-9.1		$2.6416x10^{8}$		$1.3380x10^{8}$	$3.3449x10^{7}$	$2.9803x10^{7}$	
TOTAL	$4.0150x10^{8}$*	$1.3259x10^{9}$	$5.5336x10^{6}$	$1.1148x10^{9}$	$3.9614x10^{7}$	$1.0811x10^{8}$	

DEPTH ZONE (m)	1976 4/27-4/28	5/25-5/26	6/8	7/9	7/20-7/28	8/25
1.8-3.7	$5.7588x10^{8}$	$2.6459x10^{8}$	$3.6021x10^{7}$	$1.2448x10^{7}$	$2.2330x10^{7}$	
3.7-5.5	$6.6986x10^{8}$	$1.2314x10^{8}$*	$6.4185x10^{7}$	$6.9111x10^{7}$	$1.9173x10^{7}$	
5.5-7.3	$4.1791x10^{7}$	$8.0567x10^{9}$	$7.1622x10^{8}$	$2.7993x10^{8}$	$8.6198x10^{8}$	
7.3-9.1		$6.7545x10^{9}$	$4.6378x10^{8}$	$3.6767x10^{8}$	$6.0161x10^{8}$	
TOTAL	$1.2875x10^{9}$	$1.5199x10^{10}$*	$1.2802x10^{9}$	$7.2916x10^{8}$	$1.5051x10^{8}$	

*Data represents sums arrived at with missing data; see Table 1 for stations not sampled.

that larval rainbow smelt densities were their highest during early June during 1977. In the present study larval rainbow smelt comprised 1.57 and 3.55 percent of the catch for 1975 and 1976 respectively (Table 2). Rainbow smelt were present in the first samples collected in June 4-14 sampling period. They were generally gone from the samples by the end of June. Although highest densities were recorded for the June 4-14 sampling period, it is unknown if these were peak densities for rainbow smelt in 1975. The 3.7-5.5m and 5.5-7.3m depth zones had the highest densities (Figure 16); however, there were no significant differences among the pooled means of the depth zones. No definite density patterns exist for the rainbow smelt distribution within the depth zones. Rainbow smelt were in higher densities in the northern and central geographic zones during the June 4-14 sampling period and highest in the southern and far southern geographic zones during the June 18-20 sampling period (Figure 17). No significant differences in pooled means were found in 1975.

With earlier sampling in 1976 and earlier picture emerges of larval rainbow smelt densities in the study area. Although no differences were measured between the mean pooled densities in the geographic zones, the June 8 sampling period's pooled mean by depth zones were significantly ($p \leq 0.05$) different with the 7.3-9.1m depth zone higher. In addition, the annual densities were highly significantly different ($p \leq 0.01$) with the 1.8-3.7m depth zone densities much lower than the other three. It appears from Figures 16 and 17 that rainbow smelt densities peaked during the May 25-26 sampling period and disappeared from the samples by the end of July. Densities in the three deeper depth zones appeared to be higher through 1976; inconclusive density patterns existed in the geographic zones.

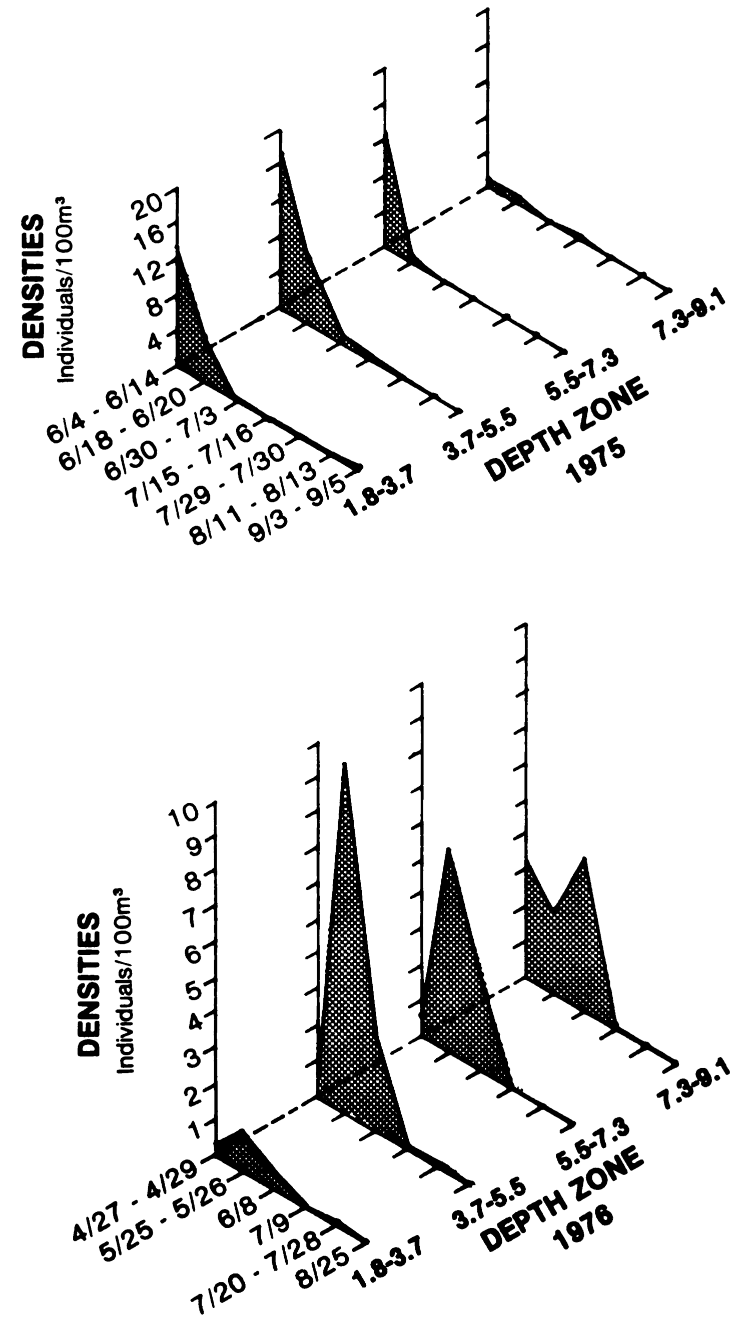


FIGURE 16
MEAN POOLED DENSITIES FOR RAINBOW SMELT BY DEPTH ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

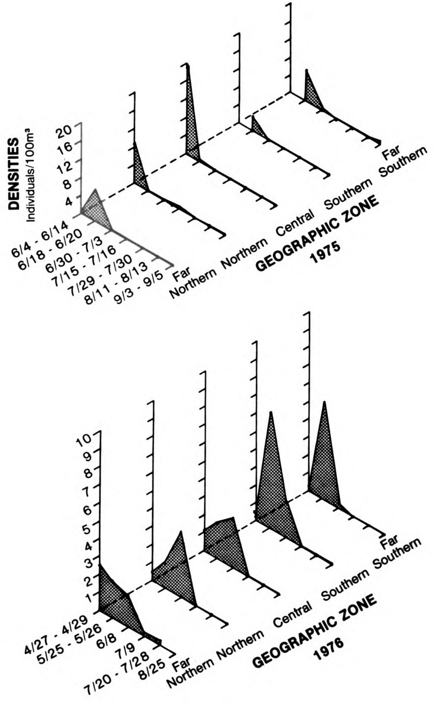


FIGURE 17
MEAN POOLED DENSITIES FOR RAINBOW SMELT BY GEOGRAPHIC ZONES COLLECTED FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

Larval rainbow smelt production for 1975 and 1976 is estimated at 2.86×10^{10} and 2.19×10^{10} fish respectively (Table 8). Larval abundances were there highest during the June 4-14 sampling period, during 1975 and during the May 25-26 and June 6 sampling periods during 1976. Generally, the deeper three depth zones had consistently higher abundances. Cooper et al. (1981a) estimated larval rainbow smelt production for the southern portion of the western basin during 1977 at 6.34×10^{7} fish. They recorded their highest densities in deep water (off shore) in Maumee Bay and the areas around Stony Point and the Raisin River.

Beach Zones

In 1975 sampling of the beach zones commenced June 3 and continued through September 2. During this period eight sampling iterations were completed collecting 22 samples from the three beach zone stations (Appendix B). During 1976 sampling began on April 13 and continued through August 23. During the 1976 sampling season 10 sampling iterations were completed collecting 30 samples from the beach zone (Appendix B). Table 1 displays the sampling success for 1975 and 1976. In 1975 a total of 10,508 larval fish were captured representing 16 taxa of which four taxa (clupeids, shiner, white bass, and yellow perch) comprised over 98 percent of the catch. Table 2 lists the catch of larval fish by taxonomic groupings and the relative abundances for the beach zone during 1975 and 1976. During 1976 a total of 23,672 larval fish representing 12 taxa were captured. Over 98 percent of the catch were clupeids.

TABLE 8

LARVAL RAINBOW SMELT ABUNDANCES FROM WESTERN LAKE ERIE, STATIONS 1-17 DURING 1975 AND 1976

DEPTH ZONE (m)	1975 6/4-6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8/13	9/3-9/5
1.8-3.7	9.5445×10^{8}*	7.8903×10^{8}					
3.7-5.5	3.9309×10^{9}*	3.2918×10^{9}	5.7273×10^{7}				
5.5-7.3	1.8230×10^{10}*	1.1615×10^{8}					
7.3-9.1	9.1890×10^{8}*	2.2899×10^{8}		1.0024×10^{8}			
TOTAL	2.4034×10^{10}*	4.4260×10^{9}	5.7273×10^{7}	1.0024×10^{8}			

DEPTH ZONE (m)	1976 4/27-4/28	5/25-5/26	6/8	7/9	7/20-7/28	8/5
1.8-3.7	8.7866×10^{7}	3.1209×10^{8}	2.1372×10^{8}	5.5336×10^{6}	1.9368×10^{7}	
3.7-5.5	2.6978×10^{8}	3.1306×10^{9}*	1.4029×10^{9}			
5.5-7.3	7.5246×10^{8}	3.9715×10^{9}	2.5065×10^{9}			
7.3-9.1	1.7950×10^{9}	1.8182×10^{9}	5.6634×10^{9}			
TOTAL	2.9051×10^{9}	9.2324×10^{9}*	9.7865×10^{9}	5.5336×10^{6}	1.9368×10^{7}	

* Data represents sums arrived at with missing data; see Table 1 for stations not sampled.

As a result of the June 3 start-up date in 1975 several species of fish were already present in the samples (Appendix B). Water temperatures at that time ranged from 18.9^{o}C at Station 18 (Figure 4) to 22.2^{o}C at Station 20. Water temperatures generally increased throughout the summer and peaked during the August 25 sampling period with a water temperature of 29.0^{o}C recorded at Station 20. Water temperatures were coolest throughout 1975 at Station 18, warmed in a southern direction and were warmest at Station 20 for a given sampling period (Appendix B). The only exception to this trend was during the August 13 sampling period when Station 18 experienced a water temperature of 26.8^{o}C. For 1976 sampling began early enough (April 13) that only one unknown larval fish was captured. This specimen may have been a lake whitefish (Coregonus clupeaformis), an early spawner, that Cooper et al. (1981a) reported capturing along the Michigan and Ohio shoreline. Water temperatures during the April 13 sampling period ranged from 9.5^{o}C at Station 18 to 10.2^{o}C at Station 20. Water temperatures during the April 26 sampling period were cooler with a 8.0^{o}C, 9.1^{o}C, and 7.0^{o}C reading at Stations 18, 19, and 20 respectively. Water temperatures rose from the June 7 sampling period to the end of the sampling in late August. Generally, Station 18 would have the coolest water temperatures and Station 20 the warmest for any given sampling period.

No density trends emerged from the data for 1975 although it appears that the densities were highest from the June sampling period through the July 7 sampling period (Figure 18). The peak densities may have occurred during the June 19 sampling period. During 1976 larval fish were more than occasional during the April 26 sampling period. Samples densities were

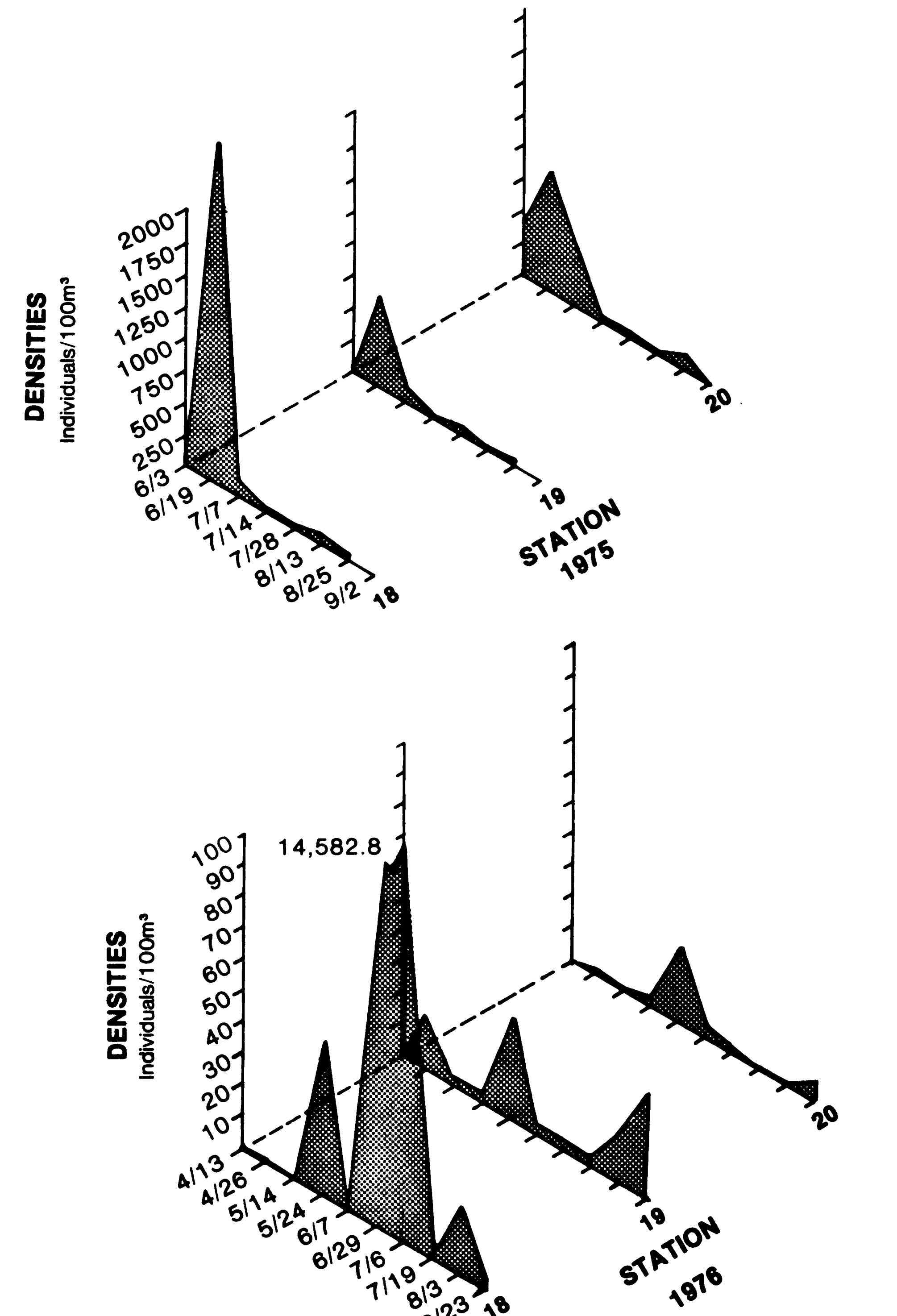


FIGURE 18
LARVAL FISH DENSITIES FOR ALL SPECIES OF FISH COLLECTED FROM STATIONS 18, 19 AND 20 DURING 1975 AND 1976

dominated by the extremely high density at Station 18 during the June 29 sampling period which may have represented the capture of a large clump of larval fish (Figure 18). Peak densities appeared to occur during the late May-June sampling periods.

The Kruskal-Wallis distribution-free tests uncovered no significant differences between station densities during 1975 or 1976 for all species captured. The same results were arrived at for the clupeids, shiners white bass, yellow perch and rainbow smelt.

Total larval production for the 0-1.8m beach zone for 1975 and 1976 is estimated at 1.02×10^{11} and 2.41×10^{11} fish respectively (Table 9). In 1975 abundances peaked during the June 19 sampling period. During 1976 abundances peaked during the June 29-July 6 sampling periods. No trends emerged as to which station consistently had higher densities.

Clupeids

Clupeids were the most abundant taxa captured during the 1975 and 1976 sampling seasons, comprising 89.5 and 98.7 percent of the beach-zone catch respectively (Table 2). Clupeids were present in the first samples collected during 1975 and their densities peaked at all stations during the June 19 sampling period (Figure 19).

During the period of high densities, June 3 through July 7, 1975, Station 19 was generally less dense than Stations 18 or 20. During this time Station 20 had the highest densities. Larval clupeids were first

TABLE 9

LARVAL FISH ABUNDANCES FROM WESTERN LAKE ERIE,
STATIONS 18-20 DURING 1975 AND 1976

1975

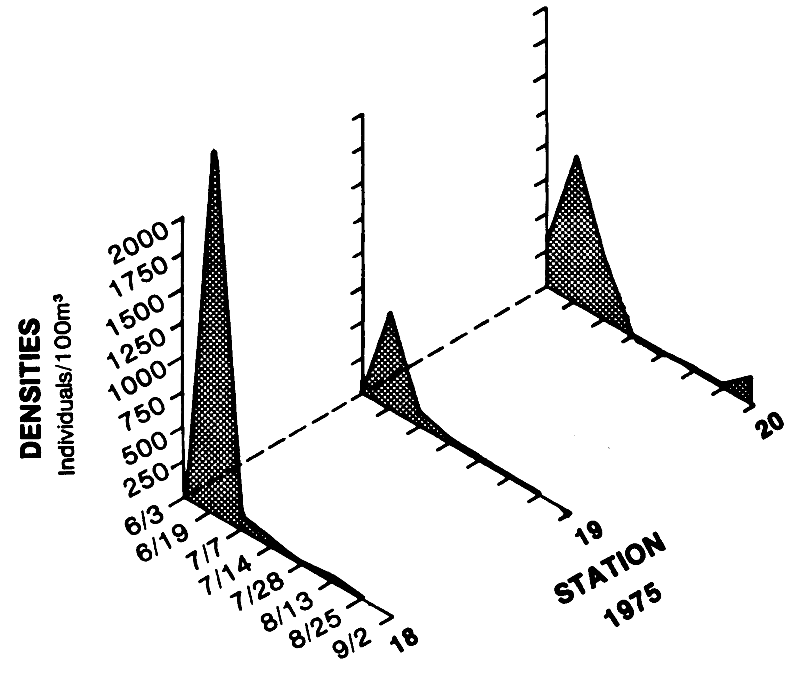
Station	6/3	6/19	7/7	7/14	7/28	8/13	8/25	9/2
18	1.0523×10^{9}	4.3469×10^{10}	1.6853×10^{9}	6.3460×10^{8}	1.9118×10^{8}	3.3578×10^{8}	1.8315×10^{8}	*
19	1.8581×10^{8}	1.2130×10^{10}	1.9713×10^{9}	2.4155×10^{8}	6.2500×10^{8}	1.3682×10^{8}	2.0777×10^{8}	*
20	8.3274×10^{9}	2.0370×10^{10}	7.5383×10^{9}	4.3508×10^{8}	3.7417×10^{8}	1.4445×10^{8}	1.8238×10^{9}	8.5275×10^{7}
0-1.8m	9.5655×10^{9}	7.5969×10^{10}	1.1195×10^{10}	1.3112×10^{9}	1.1904×10^{9}	6.1705×10^{8}	2.2147×10^{9}	8.5275×10^{7}

1976

Station	4/3	4/26	5/14	5/24	6/7
18	2.0886×10^{7}	1.9279×10^{7}	9.6395×10^{6}	8.0490×10^{8}	
19		3.0912×10^{8}	7.6013×10^{7}	4.8986×10^{7}	5.4223×10^{8}
20		8.7015×10^{6}	*	3.4806×10^{7}	4.3508×10^{8}
0-1.8m	2.0886×10^{7}	3.3710×10^{8}	8.5653×10^{7}	8.8869×10^{8}	9.7731×10^{8}

Station	6/29	7/6	7/19	8/3	8/23
18	2.3429×10^{11}	2.0532×10^{9}	1.9279×10^{7}	3.6630×10^{8}	6.1050×10^{7}
19	6.9256×10^{7}	9.2905×10^{7}	4.7297×10^{7}	2.7871×10^{8}	5.8446×10^{8}
20	1.1834×10^{8}	5.2209×10^{7}	6.9612×10^{6}	8.7015×10^{6}	1.5141×10^{8}
0-1.8m	2.3448×10^{11}	2.1983×10^{9}	7.3537×10^{7}	7.3203×10^{8}	7.9692×10^{8}

*Samples not collected



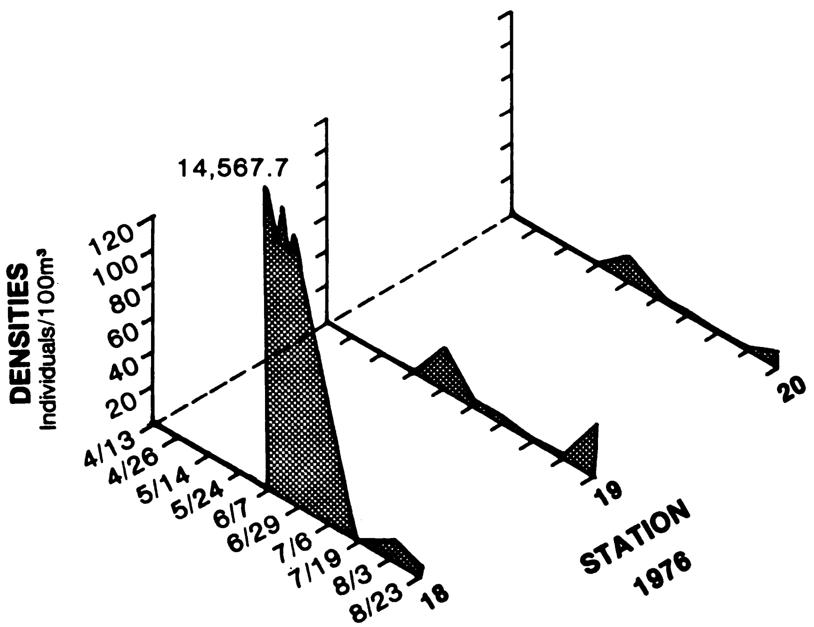


FIGURE 19
LARVAL CLUPEID DENSITIES COLLECTED FROM STATIONS 18, 19 AND 20 DURING 1975 AND 1976

captured at the beach-zone station in 1976 during the June 7 sampling period. Densities remained low compared to 1975 except for Station 18 during the June 29 sampling period. Clupeid densities appeared to peak during the June 29 sampling period, although the true densities may be masked by the exceedingly large catch at Station 18.

Production of larval clupeids during 1975 and 1976 in the 0-1.8m depth zone is estimated at 9.44×10^{10} and 2.38×10^{11} fish respectively (Table 10). Larval abundances peaked in 1975 during the June 19 to July 7 sampling periods. In addition Station 19 appears to be less productive than either Stations 18 or 19. During 1976, abundances peaked during the June 29 sampling period. No clear trends can be established for consistency of larval production between stations. Cooper, et al. (1981a) in 1977 found that highest densities of clupeids were found along the southern portion of the Michigan shoreline closely corresponding to this study's Station 20.

Shiners

Shiners were the next most abundant taxa of larval fish collected at the beach-zone stations during 1975 and 1976, comprising 4.78 and 0.54 percent of the catch respectively (Table 2). Larval shiners were taken from the first samples collected during the June 3, 1975, sampling period (Figure 20), and they were generally present in the remaining sampling periods. Larval shiner densities appeared to peak later in the year during the August sampling periods with Station 20 having the highest densities through most of the year. During 1976, larval shiners first appeared in the samples from the May 24 sampling period and were present at least at one station through the

TABLE 10

LARVAL CLUPEID ABUNDANCES FROM WESTERN LAKE ERIE,
STATIONS 18-20 DURING 1975 AND 1976

Station	6/3	6/19	7/7	7/14	7/28	8/13	8/25	9/2
18	9.0930×10^{8}	4.3469×10^{10}	1.3078×10^{9}	5.0126×10^{8}	1.6066×10^{7}	1.6066×10^{7}	1.6066×10^{7}	*
19	3.8851×10^{7}	1.2130×10^{10}	1.9003×10^{9}	1.6216×10^{8}	7.7702×10^{7}	1.1486×10^{8}	6.9256×10^{7}	*
20	6.0771×10^{9}	2.0370×10^{10}	6.9769×10^{9}		1.3574×10^{8}	1.1834×10^{8}		
0-1.8m	7.0253×10^{9}	7.5969×10^{10}	1.0185×10^{10}	6.6342×10^{8}	2.2951×10^{8}	2.4927×10^{8}	8.5322×10^{7}	

1976

Station	4/3	4/26	5/14	5/24	6/7
18					
19					4.6283×10^{8}
20			*		3.1500×10^{8}
0-1.8m					7.7783×10^{8}

Station	6/29	7/6	7/19	8/3	8/23
18	2.3429×10^{11}	1.9408×10^{9}		2.8597×10^{8}	6.1050×10^{7}
19	5.4054×10^{7}	9.2905×10^{7}		4.5608×10^{7}	5.8446×10^{8}
20	3.4806×10^{7}	3.4806×10^{7}		8.7015×10^{6}	1.5141×10^{8}
0-1.8m	2.3438×10^{11}	2.0685×10^{9}		3.4028×10^{8}	7.9692×10^{8}

* Samples not collected.

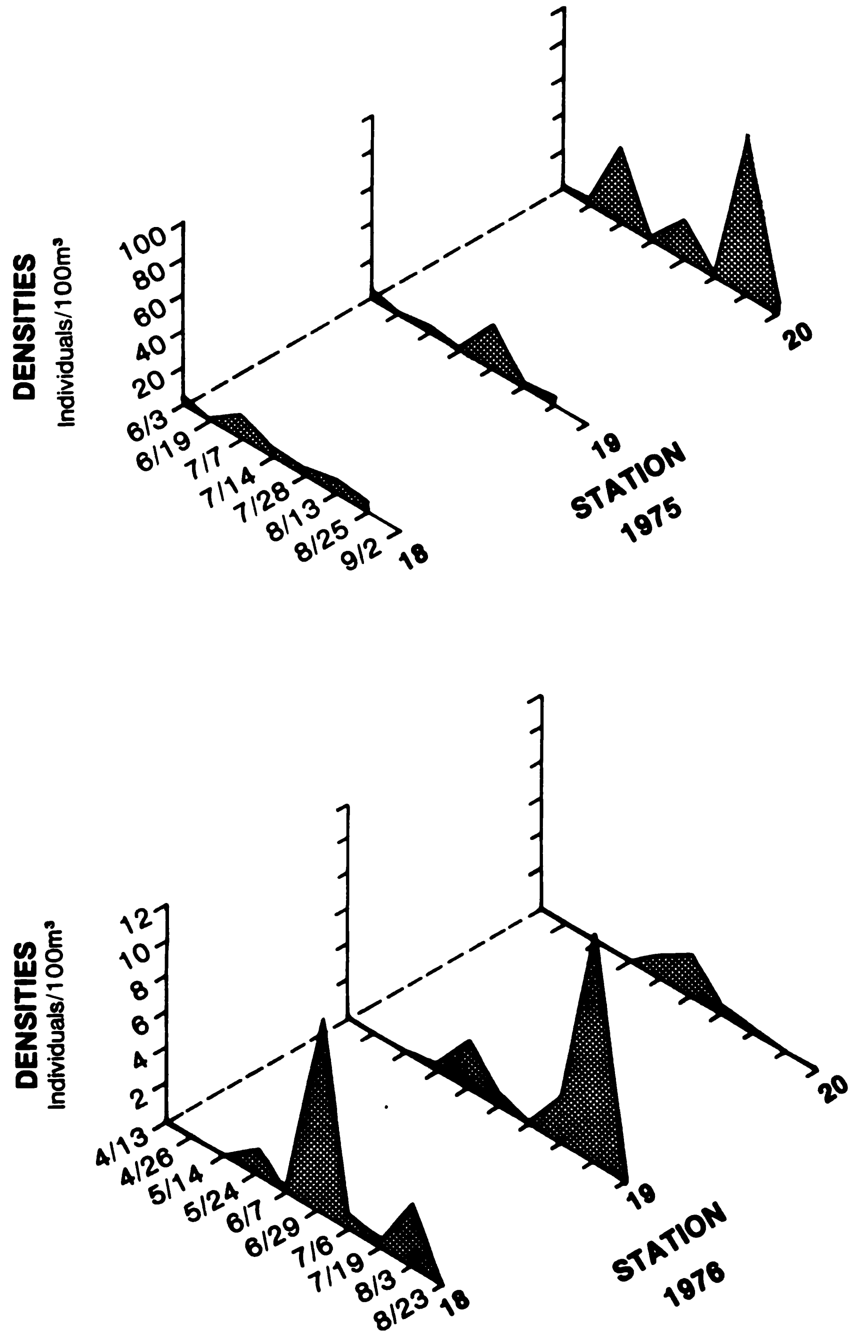


FIGURE 20
LARVAL SHINER DENSITIES COLLECTED FROM STATIONS 18, 19 AND 20 DURING 1975 AND 1976

August 3 sampling period (Figure 20). Data for 1976 is sparse and no clear cut peak in densities can be seen. In addition, it appears that in 1976 Station 20 maintained the lowest densities.

Production of larval shiners during 1975 and 1976 in the 0-1.8m depth zone is estimated at 4.39×10^9 and 6.84×10^8 fish respectively (Table 11). Larval abundances peaked in 1975 during the July 7 sampling period and again during the August 25 sampling period. No station emerged as having the highest abundances of larval shiners during 1975. During 1976 abundances again peaked in the late June early July (June 29) sampling period and again in August (Table 11). No trend was observed indicating one station producing more larval shiners. Station 20 appears to have produced less larvae than the other two stations except during the June 29 sampling period.

White Bass

White bass represented 2.99 and 0.08 percent of the catch in the 0-1.8m depth-zone for 1975 and 1976 respectively (Table 2). Larval white bass were present in the first samples collected June 3, 1975 and were present until the July 14 sampling period (Figure 21). Densities at Stations 18 and 19 peaked during the June 19 sampling period and quickly declined in the following weeks. Station 20 densities were highest during the June 3 sampling period but may have peaked prior to commencement of sampling in 1975. In addition, Station 20 maintained the highest densities while white bass were present in the 0-1.8m zone. During 1976 very few white bass were recovered in the beach-zone areas (Table 2). They first appeared during

TABLE 11

LARVAL SHINER ABUNDANCES FROM WESTERN LAKE ERIE,
STATIONS 18-20 DURING 1975 AND 1976

Station	6/3	6/19	7/7	7/14	7/28	8/13	8/25	9/2
18	7.2296×10^{7}		2.7633×10^{8}	5.1411×10^{7}	6.1050×10^{7}	1.5263×10^{8}	1.3335×10^{8}	*
19	1.1486×10^{8}	3.0405×10^{7}	4.5608×10^{7}	2.3648×10^{7}	4.1892×10^{8}	2.1959×10^{7}	1.2331×10^{8}	*
20	8.7015×10^{6}	6.7872×10^{7}	7.2919×10^{8}	2.6105×10^{7}	3.7417×10^{8}		1.5872×10^{9}	6.7872×10^{7}
0-1.8m	1.9586×10^{8}	9.8277×10^{7}	1.0511×10^{9}	1.0116×10^{8}	8.5414×10^{8}	1.7459×10^{8}	1.8439×10^{9}	6.7872×10^{7}

1976

Station	4/3	4/26	5/14	5/24	6/7
18				9.6395×10^{6}	
19					4.7297×10^{7}
20			*		2.6105×10^{7}
0-1.8m				9.6395×10^{6}	7.3402×10^{7}

Station	6/29	7/6	7/19	8/3	8/23
18	1.7351×10^{8}	2.0886×10^{7}	9.6395×10^{6}	6.1050×10^{7}	
19	1.5203×10^{7}		4.7297×10^{7}	2.1621×10^{8}	
20	4.1767×10^{7}	8.7015×10^{6}	6.9612×10^{6}		
0-1.8m	2.3048×10^{8}	2.9588×10^{7}	6.3898×10^{7}	2.7726×10^{8}	

*Samples not collected

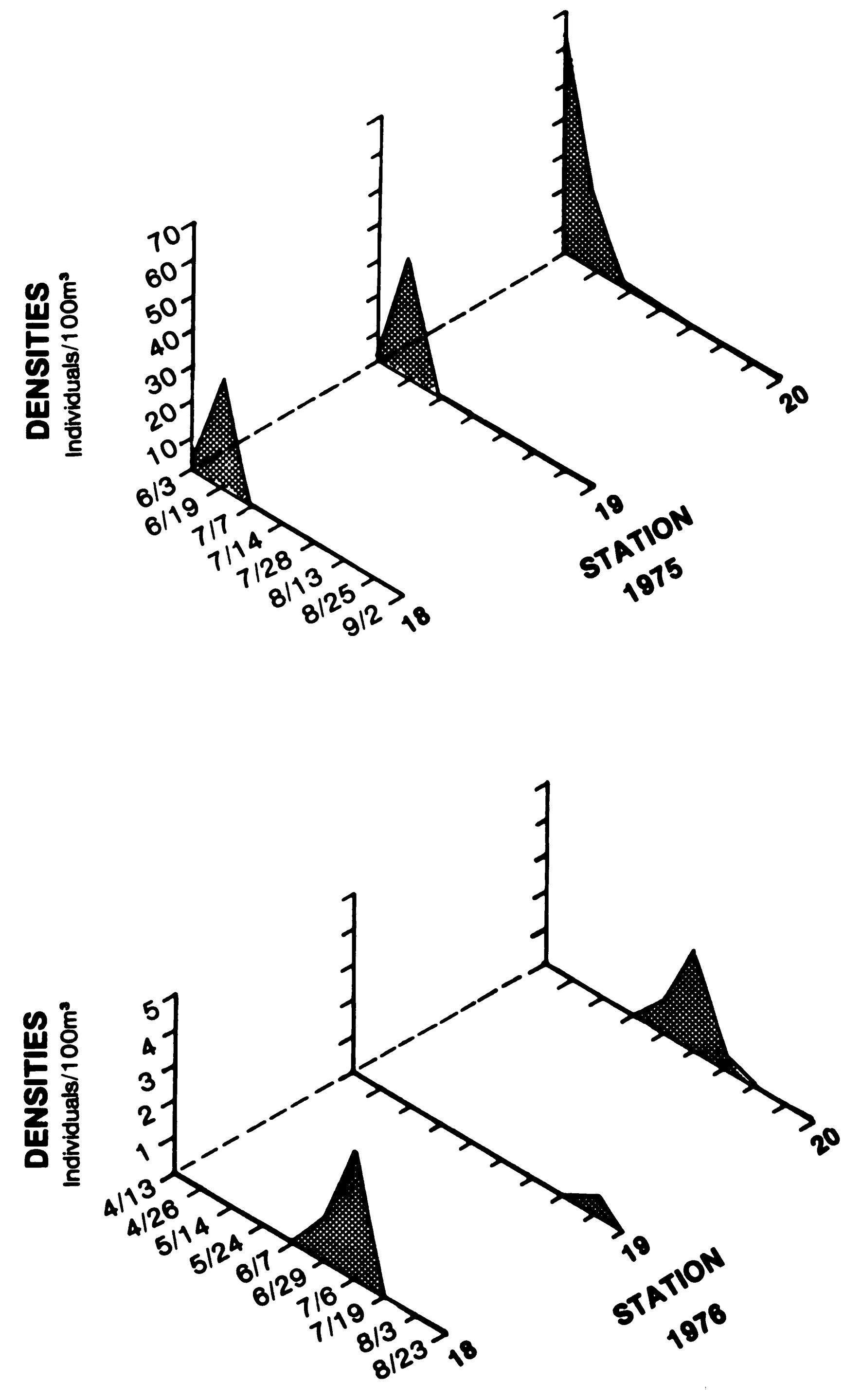


FIGURE 21
LARVAL WHITE BASS DENSITIES COLLECTED FROM STATIONS 18, 19 AND 20 DURING 1975 AND 1976

the June 7 sampling period and were in low densities until the August 3 sampling period (Figure 21). Stations 18 and 20 maintained higher densities than Station 19 during June and early July; no fish were captured during the July 19 sampling period at Stations 18 and 20.

Production of larval white bass during 1975 and 1976 in the 0-1.8m beach zones is estimated at 2.69×10^9 and 1.67×10^8 fish respectively (Table 12). Abundances of white bass during 1975 were highest during the June 19 sampling period with station 20, generally, having the highest values. In 1976 abundances peaked during the June 29 sampling period with Stations 18 and 20 having the highest abundances through much of the sampling year.

Yellow Perch

During 1975 and 1976 yellow perch comprised 0.98 and 0.44 percent of the catch respectively in the 0-1.8m depth zone (Table 2). As a result of the late start-up date in 1975, the first sampling period was the only period that larval yellow perch were present in the beach-zones (Figure 22). By comparing the temporal occurrence of yellow perch larvae in 1976, it becomes apparent that the majority of the yellow perch larvae were not sampled in 1975. However, from what data is present larval yellow perch may have been more dense at Station 20. During 1976 yellow perch larvae first appeared at Station 19 on April 26, and remained in the samples until the June 29 sampling period (Figure 22). Densities were low to moderate throughout 1976 with only Station 18 having a moderately high density on May 24. Although Station 19 was the most consistent station for larvae densities,

TABLE 12

LARVAL WHITE BASS ABUNDANCES FROM WESTERN LAKE ERIE,
STATIONS 18-20 DURING 1975 AND 1976

Station	6/3	6/19	7/7	7/14	7/28	8/13	8/25	9/2
18	4.0165×10^7	4.9001×10^8						*
19	8.4459×10^6	5.8446×10^8		8.4459×10^6				*
20	1.1295×10^9	4.0723×10^8	1.7403×10^7	8.7015×10^6				
0-1.8m	1.1781×10^9	1.4817×10^9	1.7403×10^7	1.7147×10^7				

1976

Station	4/3	4/26	5/14	5/24	6/7
18					
19					
20			*		1.7403×10^7
0-1.8m					1.7403×10^7

Station	6/29	7/6	7/19	8/3	8/23
18	2.0886×10^7	6.1050×10^7			
19				8.4459×10^6	
20	5.0469×10^7	8.7015×10^6			
0-1.8m	7.1355×10^7	6.9752×10^7		8.4459×10^6	

*Samples not collected.

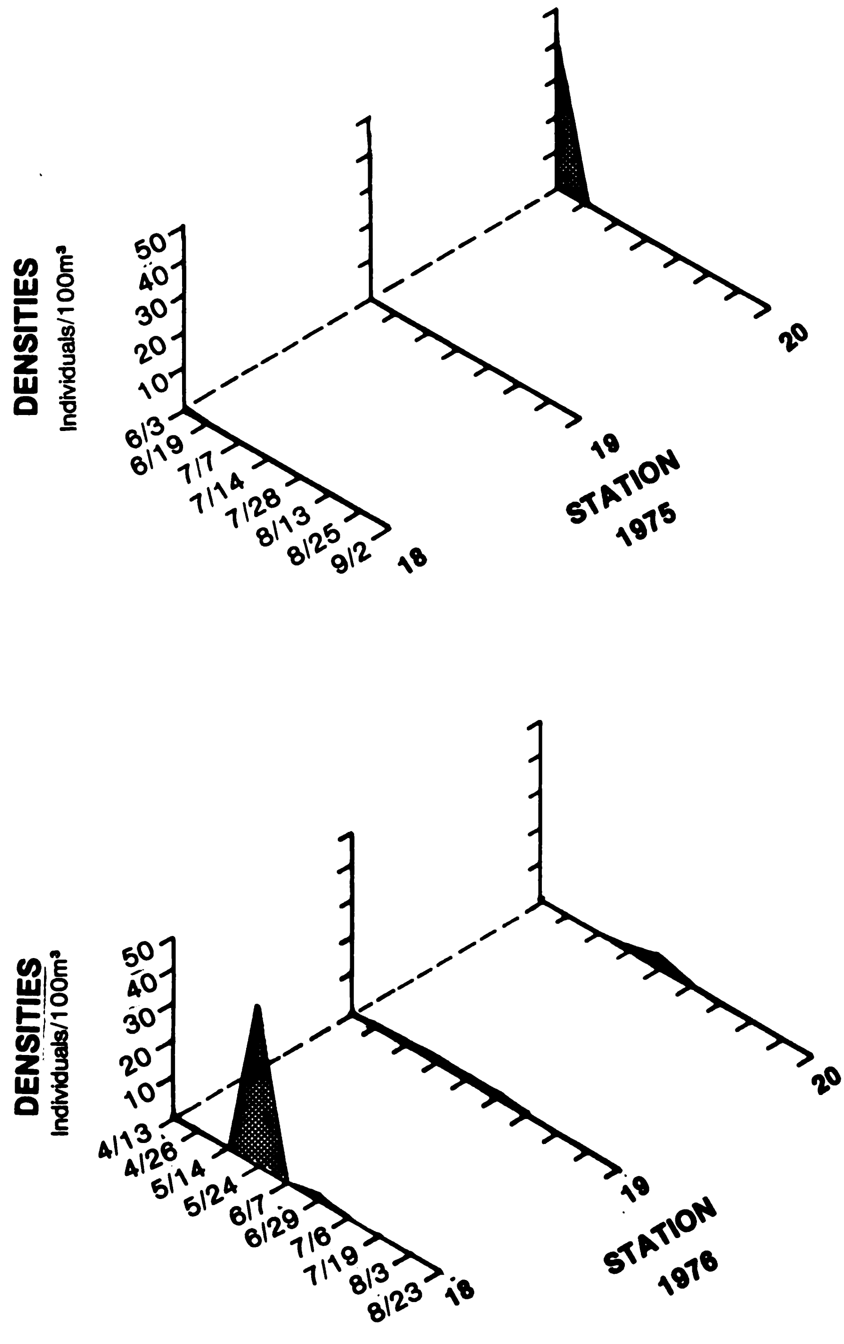


FIGURE 22
LARVAL YELLOW PERCH DENSITIES COLLECTED FROM STATIONS 18, 19 AND 20 DURING 1975 AND 1976

Stations 18 and 20 had higher densities over the periods when larvae were present at two or more stations.

Production for 1975 and 1976 of larval yellow perch is estimated at 7.63×10^8 and 9.90×10^8 fish respectively for the 0-1.8m depth zone (Table 13). As discussed above, the majority of the yellow perch production for 1975 was undoubtedly much higher in the beach-zone areas. In 1976 abundances peaked during the May 24 sampling period and except for the May 14 sampling period Station 19 had the lowest abundances.

Rainbow smelt

Very few rainbow smelt were taken in the beach-zones during 1975 and 1976. The rainbow smelt represented only 0.16 and less than 0.01 percent of the total catch for the two years (Table 2). Figure 23 illustrates the rarity of rainbow smelt occurrences in the beach-zone areas. What occurrences there were, were early in the year. Table 14 lists the estimated larval rainbow smelt abundances for 1975 and 1976 in the 0-1.8m depth zone.

TABLE 13

LARVAL YELLOW PERCH ABUNDANCES FROM WESTERN LAKE ERIE, STATIONS 18-20 DURING 1975 AND 1976

Station	6/3	6/19	7/7	7/14	7/28	8/13	8/25	9/2
18	9.6395×10^{6}							*
19								*
20	7.5355×10^{8}							
0-1.8m	7.6319×10^{8}							

1976

Station	[illegible]/3	4/26	5/14	5/24	6/7
18			9.6395×10^{6}	7.6474×10^{8}	
19			3.0405×10^{7}	3.2094×10^{7}	2.3648×10^{7}
20			*	3.4806×10^{7}	7.6573×10^{7}
0-1.8m			4.0045×10^{7}	8.3164×10^{8}	1.0022×10^{8}

Station	6/29	7/6	7/19	8/3	8/23
18	9.6395×10^{6}				
19					
20	8.7015×10^{6}				
0-1.8m	1.8341×10^{7}				

*Samples not collected

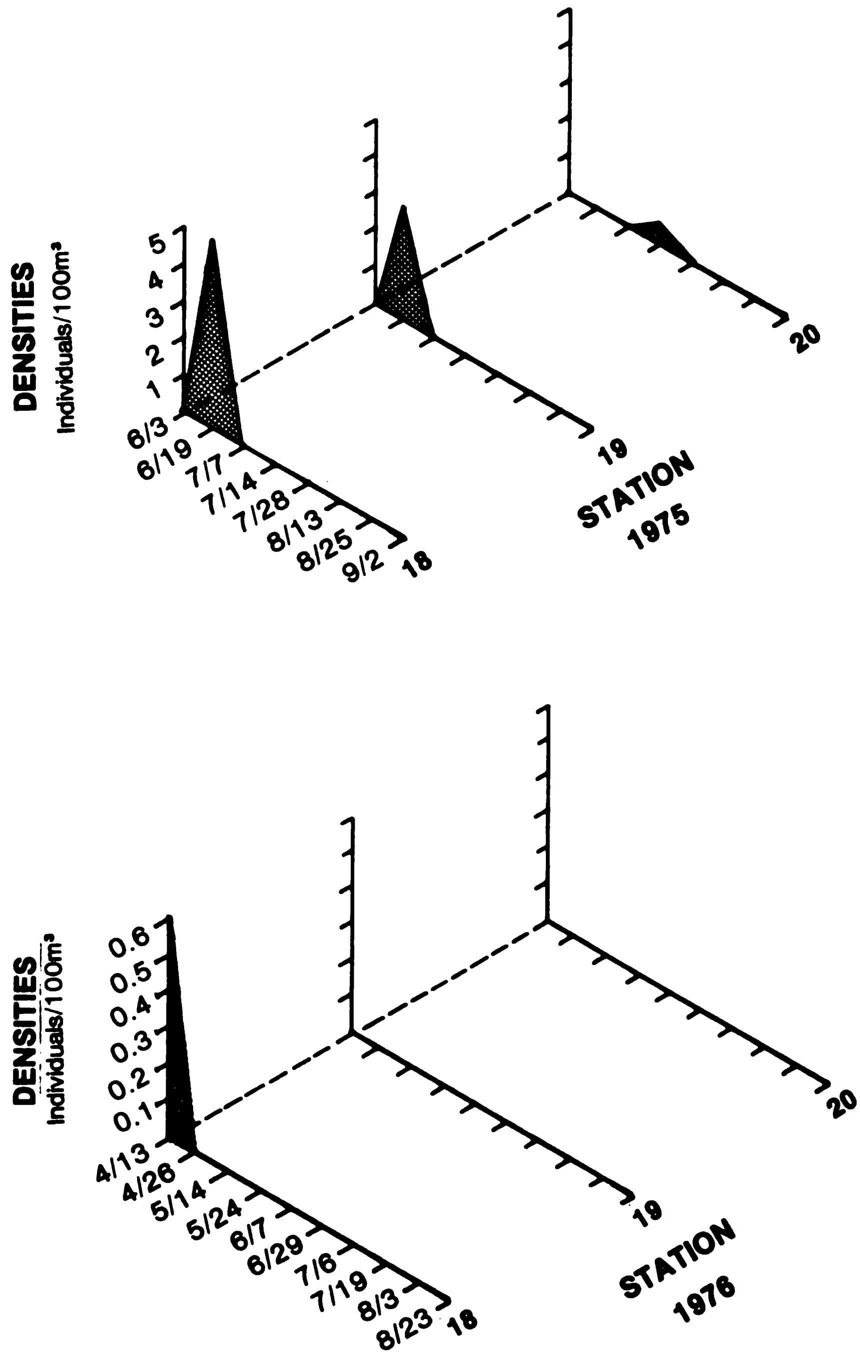


FIGURE 23
LARVAL RAINBOW SMELT DENSITIES COLLECTED FROM STATIONS 18, 19 AND 20 DURING 1975 AND 1976

TABLE 14

LARVAL RAINBOW SMELT ABUNDANCES FROM WESTERN LAKE ERIE, STATIONS 18-20 DURING 1975 AND 1976

Station	6/3	6/19	7/7	7/14	7/28	8/13	8/25	9/2
18		8.1936×10^7		9.6396×10^6				*
19		5.0675×10^7						*
20								
0-1.8m		1.3261×10^8		9.6396×10^6				

1976

Station	4/3	4/26	5/14	5/24	6/7
18		9.6395×10^8			
19					
20			*		
0-1.8m		9.6395×10^8			

Station	6/29	7/6	7/19	8/3	8/23
18					
19					
20					
0-1.8m					

*Samples not collected

DISCUSSION

Any attempt to conserve and manage the fisheries resources of the western basin of Lake Erie requires a knowledge of the ichthyoplankton of the region. Knowledge of the use of the area as a spawning and nursery facility coupled with the spatial and temporal distribution within the basin enable a fuller understanding of the resource. A cursory look at the data reveals that the dynamics of the ichthyoplankton along the western end of the western basin is not easily interpreted. Natural variability, sampling error, and physical factors all contribute to cloud the picture. Graphical depictions, tabular summaries, as well as verbal descriptions have been presented to provide a look at the composition, distribution and abundances of several of the more dominant taxonomic groupings of ichthyoplankton in the western end of Lake Erie. A discussion of the major findings follows.

The two year study collected 19 taxa of larval fish from the study area, 18 during 1975 and 16 during 1976. Sampling was conducted during portions of six months and seasonal fluctuations were observed in densities. Rainbow smelt larvae were first to be taken and they remained part of the larval assemblage through July. White bass were first taken in May and were taken through July. Yellow perch was part of the ichthyoplankton from May through August. Larval clupeids and shiners were first taken in June and remained in the samples into September. Overall larval densities were low in April and early May and then increased, peaking in late May, June and early July and tapering off during the remainder of the season. Abundances of larval fish which closely reflect reported densities where their highest during June and July.

Open Lake

Larval clupeids, predominantly gizzard shad (Dorosoma cepedianum), were the dominate fish collected during the two years, comprising over 88 percent of the catch. This virtually agrees with every other ichthyoplankton study conducted in the western basin, (Cooper, et al., 1981a and b; Mizera 1981; Cole, 1978 a and b; MacMillan, 1976; and Waybrant and Shauver, 1979). This is undoubtedly due to the favorable environmental conditions which have allowed the clupeid populations to explode in the western basin since the late fifties (Scott and Crossman, 1973). Bodola (1966) in his intensive study of the gizzard shad in the western basin of Lake Erie from 1952 through 1955 found only one spawning site for gizzard shad, a 61m sand-bar covered with 0.6-1.22m of water. However, Mizera (1981), Cooper et al., (1981) and Cole (1978b) all cite Maumee Bay as a major spawning and nursery ground for the gizzard shad. The high densities and abundances in the southern and far southern geographic zones of the study are undoubtedly a product of larval immigration from Maumee Bay driven by the local currents that sweep northward from the Bay to off the southern Michigan shoreline (Figure 3).

High densities of clupeids may also be influenced by their ease of capture relative to the other species present. Cole (1978a) and MacMillan (1976) both feel that the larval assemblages are concentrated near the bottom during daylight hours. However, shad may not exhibit such behavior and become more vulnerable to capture during daytime sampling. In addition, the morphology of the larval clupeid, very long and slender at nearly all stages of prejuvenile development, may allow them to be selectively captured by plankton nets.

Water currents with the western basin appear to play a major role in the distribution of larval fish. Maumee Bay as cited above has been documented as an important spawning and nursery area for several species of Lake Erie fishes among them gizzard, white bass, and yellow perch. In addition to this study, Cooper et al. (1981a), found yellow perch to be the most dense between Woodtick Peninsula and the Raisin River, and Mizera (1981) found the highest densities off Otter Creek (Figure 4). They theorized that the eddy currents from the Detroit and Maumee Rivers transported the larvae north out of Maumee Bay. This is substantiated by the lack of spawning facilities for yellow perch along this portion of the Michigan shoreline. Peak densities and abundances in the stations in the northern and far northern geographic zones which lagged in time behind those of the southern and far southern geographic zones suggest that the Detroit River may transport larvae from up-river environs into the study area. This was most evident with clupeids, yellow perch, and to some extent rainbow smelt.

In a general overview larval densities were highest in the 1.8-3.7m and the 3.7-5.5m depth zones. However, rainbow smelt and the shiners did not exhibit this general distribution. Smelt were more dense in the deeper waters, very closely agreeing with Cooper's et al. (1981a) results.

This may be a result of the rainbow smelt's pelagic behavior and limited spawning in the western basin. Again the currents may play an important role in transporting larval rainbow smelt into the study area. The shiners showed no real preference for depth-zone or geographic-zone. Waybrant and Shauver (1979) feel it is due to the lumping of the spottail shiner, which prefers near-shore habitats, with the emerald shiner, which is found more in open lake situations. However, Mizera, (1981) found that over 97 percent of the shiners he collected in the western basin were emerald shiners. This lack of fairly evident distribution of the shiners may be influenced by their spawning behavior, location, and developmental times.

Even though the shallowest depth-zones had the highest densities, the 5.5-7.3m depth zone produced the most fish. This phenomenon is influenced by the larval fish densities and the large volume of water in this depth zone. This depth zone contains the largest volume of water in the study area, over 1.374×10^9 m^3 (Appendix D). This is over 10^3 times greater than the 0-1.8 m depth-zone, the smallest depth-zone for volume. Waybrant and Shauver (1979) feel that the 0-3.7m depth-zone is the most important area for daytime abundances of larval fish. These conclusions apparently were based on densities only, as the 5.5-7.3m depth zone generally produced more larval fish over the two years.

Geographically, the central geographic zone generally exhibited a paucity of larvae throughout the study. Inputs from Maumee Bay and the Detroit River heavily influenced the abundances and densities in the other four geographic zones. Localized spawning no doubt took place in the river mouths and back waters of this area, but the general lack of spawning facilities compared to outside the study area was undoubtedly a contributing factor to this reduced larval fish production. The large volume of cooling water taken out of the Raisin River and Lake Erie by the electrical generating station at Monroe may contribute to the real reason for these depressed numbers. However, Cole (1978b) concluded that 80 percent of the clupeid larvae appeared dead or dying before they were entrained by the station. So it appears this paucity of larval fish in the central geographic zone may be a natural phenomenon and the placement of the Monroe Power Plant's intake at the mouth of the Raisin River may have been a fortuitious event for the Lake Erie ichthyoplankton.

Near Shore

As a result of the different sampling techniques used in the near shore areas very little can be said comparing the near shore with the open lake. It was expected that the beach zone area would have very high densities as suggested by Waybrant and Shauver (1979), but the data does not support this theory. Only 15 percent of the total catch was taken in the near shore areas in 1975, and only two percent in 1976 (disregarding the 23,358 larvae taken in one sample as a statistical outlier). Although it was not as intensively sampled as the open lake area (three stations to 17 stations), filtered volumes per sample were similar in size. As a result the beach areas appear to be underutilized in light of a more efficient sampling technique. It may be that the strong wave action and cross currents make this area treacherous for larval fish. In addition, the shallow littoral-like conditions in the western basin may enable larvae to survive outside of the beach zone area. However, these may be spurious conclusions as the sampling technique could have missed clumped larvae such as those represented at Station 18 on June 29, 1976.

Generally it appears that the central geographic zone is not as intensively used as the other four geographic zones, undoubtedly for the same reasons discussed above. Rainbow smelt were almost nonexistent in the near shore areas. This is not suprising as Mizera (1981) reports that the majority of smelt spawning takes place further to the east outside the study area.

Larval production was not as high in the 0-1.8 depth-zone as it was for the deeper depth-zones (individually). This is apparently due to the reduced volume of water in this depth zone compared to the others (Appendix D). However, when it comes to water use, it is the density of larval fish that becomes important. With higher densities of larval fish, such as those that exist in the shallower depth zones, more individuals will be exposed to environmental stress than if the same volume of water was drawn from the deeper depth zones where the densities are lower. As a result, to entrain the same number of larval fish, an intake located in the deeper depth zones would withdraw larger volumes of water than if it were located in the shallow depth zones. Therefore, in the future it may be advantageous for prospective consumers to look into offshore intakes.

SUMMARY AND CONCLUSIONS

In response to a predicted increase in non-consumptive use of water in Lake Erie, a two year study was initiated in 1975 to investigate larval fish dynamics in the western basin. The ichthyoplankton community was investigated by taking 111 pooled samples from open lake stations and 22 samples from beach zone stations during 1975, and an additional 97 pooled samples from open lake stations and 30 samples from beach zone stations during 1976. From the data, densities, abundances and yearly larval production from the study area were calculated. Depth zone and geographical means were tested over time to establish any areas or time frames which were significantly noteworthy. Abundances were calculated using estimated volumes within the study area, and production was estimated by summing appropriate abundances for the year. The following are the more important conclusions.

1. During 1975, 58,016 larvae were taken from the open lake stations representing 14 taxa of which clupeids, rainbow smelt, shiners, white bass and freshwater drum comprised nearly 97 percent of the catch. During 1976, 19,770 larvae were taken representing 16 taxa of which the above taxa comprised nearly 97 percent.

2. Densities of all larval fish peaked in June and appeared to have higher values in the northern and southern extremities of the study area.

Larval densities peaked in the northern portion of the study area at a later date than those from the southern portion.

3. Total larval fish production for the study area appeared to be between 4.56×10^{11} and 7.59×10^{11} fish per year. Peak abundances occurred during the same period as the highest densities with the deeper depth zones having the highest abundances.

4. The prevailing water currents in the western basin appear to have an affect on the distribution of larval fish in western Lake Erie. The Detroit River powers a clockwise eddy of water in the basin which sweeps larvae out of Maumee Bay north into the southern portions of the study area. In addition, the Detroit River provides an avenue of immigration for larvae from more northern environs into the northern and deep water portions of the study area.

5. Clupeid larvae exhibited the same dynamics as those discussed above. Larval clupeid production for the study area was approximately 6.19×10^{11} and 3.50×10^{11} fish for 1975 and 1976.

6. Shiners established no pattern either in depth zones or geographic zones as to peak densities.

7. White bass appeared to be spawned in Maumee Bay and swept north into the study area. Significantly higher mean pooled densities were found in

the southern and far southern geographic zones during several sampling periods. Annual mean pooled densities for larval white bass were highly significant for 1975 and 1976.

8. During 1976 yellow perch densities peaked during the April sampling period in the southern geographic zone and peaked again in May in the northern portions of the study area. These density peaks may be from two seperate stocks, one that spawns in Maumee Bay and another that spawns where the larvae are picked up and transported into the northern portion of the study area.

9. Larval rainbow smelt appeared not to use the near shore areas for spawning and nursery activities. They were most common early in the year in deeper water. Smelt undoubtedly were spawned outside the study area and were transported in by the prevailing water currents.

10. The deeper depth zones (primarily the 5.5-7.1m depth zone) consistently had higher abundances than the shallower zones. This is probably due to an interaction of densities with the large water volumes in these zones.

11. Larval densities and abundances were not as high as anticipated in the 0-1.8m depth zone. This may be an indication of under utilization of this zone as spawning and nursery activities or the data may reflect the patchiness of larval distributions.

12. Larval rainbow smelt apparently do not use the 0-1.8m depth as a spawning or nursery area as very few larvae were captured in this depth zone.

LITERATURE CITED

LITERATURE CITED

Baldwin, N.S., R.S. Saalfeld, M.A. Ross, and H.J. Buettner. 1979. Commercial fish production in the Great Lakes 1867-1977, technical report no. 3. Great Lakes Fisheries Commission, Ann Arbor, Michigan.

Beers, J.R., G.L. Stewart, J.D.H. Strickland. 1967. A pumping system for sampling small plankton. Journal Fisheries Research Board of Canada. 24(8) 1811-1819.

Bodola, A. 1966. Life history of the gizzard shad, Dorosoma cepedianum (LeSueur) in western Lake Erie. United States Fish and Wildlife Service. Fisheries Bulletin 65(2):391-425.

Bowles, R.R., J.V. Merriner, and G.C. Grant. 1978. Factors associated with accuracy in sampling fish eggs and larvae. United States Fish and Wildlife Service, FWS/OBS - 78/83. Ann Arbor, Michigan.

Cole, R.A. 1978a. Entrainment at a once-through cooling system on western Lake Erie, Volume I. United States Environmental Protection Agency, EPA-600/3-78-070, Duluth, Minnesota.

Cole, R.A. 1978b. Larval fish distribution in southwestern Lake Erie near the Monroe Power Plant. United States Environmental Protection Agency, EPA-600/3-78-069, Duluth, Minnesota.

Cooper, C.L., J.J. Mizera, C.E. Herdendorf. 1981a. Distribution, abundance and entrainment studies of larval fishes in the western and central basins of Lake Erie. Center for Lake Erie Area Research, CLEAR Technical Report No. 222. Columbus, Ohio.

Cooper, C.L., M.R. Heniken and C.E. Herdendorf. 1981b. Limnetic larval fish in the Ohio portion of the western basin of Lake Erie, 1975-1976. Journal of Great Lakes Research 7(3) 326-329.

Faber, D.J. 1968. A net for catching limnetic fry. Transactions of the American Fisheries Society 97:61-68.

Federal Water Pollution Control Administration. 1968. Lake Erie report, a plan for water pollution control. United States Department of the Interior, Washington, D.C.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. United States Bureau of Fisheries, Bulletin No. 10 Volume 47. Washington, D.C.

Great Lakes Basin Commission. 1975a. Great Lakes basin framework study, Appendix 7, limnology. Great Lakes Basin Commission, Ann Arbor, Michigan.

Great Lakes Basin Commission. 1975b. Great Lakes Basin framework study, Appendix 8, fish. Great Lakes Basin Commission, Ann Arbor, Michigan.

Heron, A.C. 1968. Plankton gauze. Pages 19-25 in D.J. Tranter, editor. Zooplankton sampling. UNESCO Press. Paris, France.

Hollander, M. and D.A. Wolf. 1973. Nonparametric statistical methods. John Wiley & Sons. New York, New York.

Lippson, A.J. and R.L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Martin Marietta Corporation, Baltimore, Maryland.

MacMillan, J.R. 1976. Larval fish sampling and population distributions relevant to estimating power plant entrainment in western Lake Erie. Master's Thesis. Michigan State University, East Lansing, Michigan.

Mansuetti, A.J. and J.D. Hardy, Jr. 1967. An atlas of egg, larval, and juvenile stages, part 1. Port City Press, Baltimore, Maryland.

May E.B. and C.R. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography. Contribution No. 164. Oklahoma Fishery Research Laboratory. Bulletin No. 5. Norman, Oklahoma.

Mizera, J.J. 1981. Distribution and entrainment of larval fishes in western and central Lake Erie. Center for Lake Erie Area Research, CLEAR Technical Report No. 215. Columbus, Ohio.

Mizera, J.J., C.L. Cooper, and C.E. Herdendorf. 1981. Limnetic larval fish in the near shore zone of the western basin of Lake Erie. Journal of Great Lakes Research 7(1):62-64.

Nelson, D. and R.A. Cole. 1975. The distribution and abundance of larval fishes along the western shore of Lake Erie at Monroe, Michigan. Institute of Water Research Technical Report No. 32.4, East Lansing, Michigan.

Noble, R.L. 1970. Evaluation of the Miller high-speed sampler for yellow perch and walleye fry. Journal of Fisheries Research Board of Canada. 27(6):1033-1045.

Patterson, R.L. n.d. Production, mortality, and condensor cooling water entrainment of larval perch in Michigan-Ohio waters of the western basin of Lake Erie in 1975. University of Michigan, Ann Arbor, Michigan.

Patterson, R.L. and K.D. Smith. 1982. Impact of power plant entrainment of ichthyoplankton on juvenile recruitment of four fishes in western Lake Erie in 1975-77. Journal of Great Lakes Research 8(3):558-569.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A List of Common and Scientific Names of Fishes From the United States and Canada, 4th Edition. American Fisheries Society Special Publication No. 12. Bethesda, Maryland.

Schelske, C.L. and J.C. Roth. 1973. Limnological survey of Lakes Michigan, Superior, Huron and Erie. Great Lakes Research Division. Publication 17. Ann Arbor, Michigan.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada. Bulletin. Ottawa, Canada.

Waybrant, R.C. 1976. Limnological survey of the Michigan waters of Lake Erie. Michigan Water Resources Commission. Lansing, Michigan.

Waybrant, R.C. and J.M. Shauver. 1979. Survey of larval fish in the Michigan waters of Lake Erie, 1975 and 1976. United States Environmental Protection Agency, EPA-600/3-79-095. Duluth, Minnesota.

APPENDICES

APPENDIX A

POOLED DENSITIES FROM STATIONS 1-17 DURING 1975 AND 1976

APPENDIX A
POOLED DENSITIES FROM STATIONS 1-17 DURING 1975 AND 1976

TABLE A 1

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM JUNE 4 TO JUNE 14, 1975

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	3.4	6.1	8.8	3.0	7.0	8.8	3.4	6.1	7.9
	Water Temp. (°C)	17.3	14.7	16.0	17.3	15.0	14.9	19.1	18.6	18.4
	Secchi Depth (m)	0.6	1.5	2.9	0.5	0.9	1.8	0.5	0.6	0.6
	Water filtered (m^3)	972.4	503.8	710.6	433.4	514.8	492.8	514.4	585.9	599.9
Clupeids		71.8	0.2	1.4	87.2	1.2	4.9	43.0	68.8	123.4
Northern pike										
Rainbow smelt		0.3		0.1	32.8	8.4	1.8	23.3	25.4	23.5
Common carp		0.5	2.0		4.4				0.2	
Shiners		3.3		2.1	3.2	0.6	0.6	0.4		0.2
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass				1.1	0.2			1.0	2.0	1.5
Sunfishes		0.6								
Black basses										
Crappies										
Darters										
Yellow perch		0.2			0.2	0.6		0.2		0.5
Logperch		0.4			2.1			0.2	[illegible]	0.5
Walleye										
Freshwater drum		0.1							[illegible]	
Unknown		0.2								
Total		[illegible]	2.2	4.7	13.1	10.8	7.3	68.7	97.6	149.6

TAXA		10[1]	11[1]	12[1]	13[1]	14[1]	15[1]	16[1]	[illegible][1]
	Depth (m)								
	Water Temp. (°C)								
	Secchi Depth (m)								
	Water filtered (m^3)								
Clupeids									
Northern pike									
Rainbow smelt									
Common carp									
Shiners									
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass									
Sunfishes									
Black basses									
Crappies									
Darters									
Yellow perch									
Logperch									
Walleye									
Freshwater drum									
Unknown									
Total									

[1] Samples not collected to equipment failure

TABLE A 2

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM JUNE 18 TO JUNE 20, 1975

STATIONS

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	3.7	7.0	8.5	4.6	6.7	8.8	3.7	6.1	7.9
	Water Temp. (°C)	20.7	19.7	19.3	22.2	19.3	19.3	21.2	21.6	21.2
	Secchi Depth (m)	0.4	1.5	1.5	0.3	1.3	1.5	1.1	1.1	1.2
	Water filtered (m^3)	667.7	591.8	580.8	575.3	594.0	591.8	595.1	448.8	586.3
Clupeids		1044.5	178.6	83.2	27.1	1.5	50.4	2.7	2.9	3.6
Northern pike										
Rainbow smelt		14.4	0.2	0.3					0.4	
Common carp		0.1			0.2	0.7				
Shiners		1.5	0.5	3.6	0.2	0.3	0.7		0.2	2.4
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass		2.1			0.2					0.2
Sunfishes										
Black basses										
Crappies				0.2			0.2			
Darters										
Yellow perch		6.6	0.3	0.5	0.2	0.5	0.2			
Logperch		0.3	0.3							
Walleye										
Freshwater drum			0.2		0.2				0.2	
Unknown		0.1								
Total		1069.6	180.1	87.8	28.1	3.0	51.5	2.7	3.7	6.2

STATIONS

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	8.5	3.4	6.4	8.5	3.7	5.5	7.3	4.8
	Water Temp. (°C)	20.9	21.0	20.1	20.2	21.3	20.4	20.1	21.3
	Secchi Depth (m)	0.9	0.4	0.9	1.2	0.2	0.3	0.9	0.2
	Water filtered (m^3)	566.5	543.4	574.2	565.4	556.6	569.8	558.8	580.8
Clupeids		15.9	10.1	166.8	5.5	1136.4	315.4	0.7	1044.2
Northern pike									
Rainbow smelt		1.2	9.0	2.1		1.4	26.7	0.4	0.3
Common carp			0.2						
Shiners		4.8	1.1	1.9	62.8	4.1	17.0	2.5	0.2
White sucker				0.2					
Channel catfish									
Banded killifish									
Brook silversides									
White bass		0.2	19.3	33.1	5.8	237.7	47.9	0.5	169.8
Sunfishes									0.2
Black basses									
Crappies									
Darters									
Yellow perch		1.1	5.5	0.5		3.4	4.0	0.4	6.0
Logperch				0.2		1.6	0.4		
Walleye									
Freshwater drum		2.6		0.9		256.0	2.6		330.8
Unknown									8.3
Total		23.2	45.2	205.7	74.1	1384.6	414.0	4.5	1559.8

TABLE A 3

POOLED STATION DENSITIES (INDIVIDUALS/$100m^3$) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM JUNE 30 TO JULY 3, 1975

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	2.1	7.0	7.8	4.3	7.0	9.1	3.7	6.4	7.9
	Water Temp. (^oC)	22.8	22.7	23.3	22.5	23.3	22.7	25.6	25.0	24.7
	Secchi Depth (m)	1.1	2.1	2.3	1.0	1.2	1.9	0.8	1.5	1.6
	Water filtered (m^3)	603.9	603.9	630.3	585.2	630.3	614.9	275.3	578.6	584.8
Clupeids		1.0	31.1	3.6	16.4	91.4	22.4	54.4	36.5	60.5
Northern pike										
Rainbow smelt										
Common carp		14.9							0.2	0.2
Shiners			0.2	0.2	0.3	1.7	22.3	1.2	12.4	19.8
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass									0.2	
Sunfishes						0.6			0.3	
Black basses										
Crappies										
Darters										
Yellow perch		0.2								
Logperch									0.2	
Walleye							0.2			
Freshwater drum						0.3			0.2	
Unknown		0.2								
Total		16.3	31.1	3.8	16.7	94.0	44.9	55.6	50.0	80.5

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	9.1	3.4	7.8	8.2	3.0	5.5	7.6	4.6
	Water Temp. (^oC)	24.0	27.4	24.8	23.4	27.6	25.1	23.9	26.0
	Secchi Depth (m)	1.6	0.8	1.6	1.7	0.6	0.7	1.3	0.8
	Water filtered (m^3)	265.4	619.3	609.4	610.5	577.5	580.8	590.7	618.2
Clupeids		46.7	142.7	37.2	63.6	1405.7	46.0	3.0	1096.3
Northern pike									
Rainbow smelt							0.5		
Common carp						0.3			
Shiners		2.7	18.9	15.8	8.7	36.0	8.4	0.5	131.7
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass		3.5	1.3	0.5	0.5	12.5	0.5	0.5	1.7
Sunfishes			4.2			8.0			
Black basses									
Crappies									
Darters			0.2						
Yellow perch									
Logperch		0.7							
Walleye									
Freshwater drum				1.5	0.2	1.4	0.9		0.2
Unknown									
Total		53.6	167.3	55.0	72.5	1463.9	56.3	4.0	1229.0

TABLE A 4

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM JULY 15 TO JULY 16, 1975

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	3.4	6.4	8.2	4.3	7.3	9.5	3.4	6.7	7.3
	Water Temp. (°C)	24.3	22.0	22.8	23.0	22.2	21.3	24.5	23.5	22.7
	Secchi Depth (m)	0.8	1.4	1.7	0.9	1.2	1.4	0.8	0.9	0.9
	Water filtered (m^3)	601.7	592.6	575.3	588.5	590.7	612.7	574.0	567.6	592.9
Clupeids		76.5	9.3	251.0	30.4	38.3	6.5	2.3	1.1	7.6
Northern pike				2.0						
Rainbow smelt							0.2			
Common carp		1.0					0.2	0.2		
Shiners		11.1		12.3	30.2	12.7	5.9	0.9		2.4
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass								0.2		
Sunfishes		1.3	0.7	0.3	0.8		0.2	0.2	0.4	
Black basses										
Crappies										
Darters								0.2		
Yellow perch		1.7	2.5		0.3		0.8			
Logperch		0.5				0.3	0.2			
Walleye										
Freshwater drum										
Unknown										
Total		92.1	12.5	263.8	61.7	51.3	14.0	4.0	1.5	10.0

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	9.5	3.1	7.0	8.2	3.4	6.1	7.3	4.3
	Water Temp. (°C)	22.2	23.8	23.2	23.0	23.0	22.0	23.2	21.9
	Secchi Depth (m)	1.7	0.8	0.9	1.5	0.4	1.1	1.3	0.6
	Water filtered (m^3)	621.5	559.9	592.9	597.3	614.9	803.0	765.6	598.4
Clupeids		7.7	2.3	5.2	4.0	8.6	4.7	1.8	33.6
Northern pike									
Rainbow smelt									
Common carp								1.0	
Shiners		40.1	0.5	9.1	1.7	0.2	2.6	1.3	2.0
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass					0.9				0.2
Sunfishes			0.5	0.2					
Black basses									
Crappies									
Darters									
Yellow perch									
Logperch									0.2
Walleye									
Freshwater drum									
Unknown									
Total		47.8	3.3	14.5	6.6	8.8	7.3	3.2	36.0

TABLE A 5

POOLED STATION DENSITIES (INDIVIDUALS/$100m^3$) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM JULY 29 TO JULY 30, 1975

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	2.7	6.4	7.6	4.3	7.3	9.1	3.7	6.4	7.3
	Water Temp. (°C)	22.4	21.3	22.5	25.1	22.0	22.0	24.9	24.4	24.1
	Secchi Depth (m)	0.9	1.4	2.0	0.8	1.1	1.8	0.9	1.2	0.9
	Water filtered (m^3)	505.4	584.1	588.5	572.0	590.7	597.3	548.9	561.0	496.1
Clupeids		1.6	3.2	3.7	0.7	1.5	3.5	0.2		9.7
Northern pike										
Rainbow smelt										
Common carp					0.2					
Shiners			0.5	1.0		0.5	0.3	1.3		
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass										
Sunfishes					0.2					
Black basses										
Crappies										
Darters										
Yellow perch				0.2						
Logperch							0.2			
Walleye										
Freshwater drum										
Unknown										
Total		1.6	3.7	4.9	1.1	2.0	4.0	1.5		9.7

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	9.8	3.7	6.7	8.5	3.4	5.8	7.3	4.7
	Water Temp. (°C)	23.3	26.7	24.5	23.8	25.0	24.0	24.0	24.1
	Secchi Depth (m)	1.3	0.8	1.7	1.7	0.3	1.7	1.7	0.8
	Water filtered (m^3)	602.8	551.1	559.9	548.9	557.7	583.0	577.5	562.1
Clupeids		0.4	1.1	0.4		8.4	0.2		1.4
Northern pike									
Rainbow smelt									
Common carp						0.2			
Shiners			4.9	0.4	2.7		0.2	0.2	
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass						1.6			
Sunfishes			0.4						
Black basses									
Crappies									
Darters			0.4						
Yellow perch									0.2
Logperch			0.2						
Walleye									
Freshwater drum									
Unknown									
Total		0.4	7.0	0.8	2.7	10.4	0.4	0.2	1.6

TABLE A 6

POOLED STATION DENSITIES (INDIVIDUALS/100m³) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM AUGUST 11 TO AUGUST 13, 1975

TAXA		1	2	3[1]	4	5	6	7	8	9
	Depth (m)	3.4	6.7	0.6	4.6	7.3	9.5	3.4	5.8	7.6
	Water Temp. (^{o}C)	24.2	22.5	24.0	24.8	24.3	23.4	24.7	24.6	24.6
	Secchi Depth (m)	0.9	1.2	1.4	0.9	1.1	1.5	0.9	0.9	1.1
	Water filtered (m^3)	585.2	576.4	448.8	566.4	559.9	712.8	552.2	561.0	599.4
Clupeids		0.9	1.2	0.7	0.2	0.9	7.9			
Northern pike										
Rainbow smelt										
Common carp		0.9								
Shiners			0.2					0.7	0.2	
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass										
Sunfishes										
Black basses										
Crappies										
Darters					0.5				0.2	
Yellow perch			0.2					0.2		
Logperch		0.2								
Walleye										
Freshwater drum										
Unknown										
Total		2.0	1.6	0.7	0.7	0.9	7.9	0.9	0.4	

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	9.5	3.0	7.0	8.5	3.1	5.8	7.9	4.6
	Water Temp. (^{o}C)	23.9	24.2	23.9	23.7	25.5	23.8	23.6	23.8
	Secchi Depth (m)	0.6	0.6	1.1	1.2	0.3	0.8	1.2	0.6
	Water filtered (m^3)	598.4	567.5	558.8	550.0	532.4	611.6	562.1	567.6
Clupeids		9.9				13.7			0.2
Northern pike									
Rainbow smelt									
Common carp									
Shiners				0.4	0.2	0.2	0.2	0.4	0.2
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass									
Sunfishes									
Black basses									
Crappies									
Darters			0.2	0.2				0.2	0.2
Yellow perch		0.2							
Logperch									
Walleye									
Freshwater drum						0.2			
Unknown									
Total		10.1	0.2	0.6	0.2	14.4	0.2	0.6	0.6

[1] Bottom portion of the sample not collected due to equipment failure

TABLE A 7

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS
TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM SEPTEMBER 3 TO SEPTEMBER 5, 1975

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	4.3	6.7	9.1	3.1	7.0	9.1	4.3	6.1	7.6
	Water Temp. (°C)	20.3	20.1	21.0	21.0	20.0	20.0	21.8	21.8	21.7
	Secchi Depth (m)	0.5	0.9	1.2	0.5	0.9	1.2	0.8	0.8	1.2
	Water filtered (m^3)	433.4	528.0	569.8	525.8	539.0	530.2	550.0	450.6	584.8
Clupeids		9.2	0.7		8.9			0.2	0.7	
Northern pike										
Rainbow smelt										
Common carp										
Shiners		0.7			1.1			0.2		
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass										
Sunfishes										
Black basses										
Crappies										
Darters										
Yellow perch										
Logperch										
Walleye										
Freshwater drum										
Unknown									0.7	
Total		9.9	0.7		10.0			0.4	1.4	

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	9.1	3.4	7.3	8.5	3.4	6.1	7.9	4.6
	Water Temp. (°C)	21.6	22.1	22.0	21.5	22.5	22.0	22.5	22.0
	Secchi Depth (m)	1.7	0.5	0.8	1.1	0.3	0.5	0.8	0.3
	Water filtered (m^3)	584.8	564.3	525.8	578.6	525.8	595.1	627.0	557.7
Clupeids					0.2				0.7
Northern pike									
Rainbow smelt									0.5
Common carp									
Shiners			0.2			0.8	2.7		0.2
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass						0.2	0.2		0.4
Sunfishes									
Black basses									
Crappies									
Darters									
Yellow perch									
Logperch									
Walleye									
Freshwater drum									
Unknown									
Total			0.2		0.2	1.0	2.9		1.8

TABLE A 8

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM APRIL 27 TO APRIL 29, 1976

TAXA		1[1]	2[1]	3[1]	4[1]	5[1]	6[1,2]	7[1]	8[1]	9[1]
	Depth (m)	4.0	6.7	8.8	NR	NR	NR	NR	NR	NR
	Water Temp. (°C)	8.9	8.5	9.3	NR	NR	NR	NR	NR	NR
	Secchi Depth (m)	NR[3]	0.3	1.1	0.6	0.3	0.3	0.6	0.9	1.2
	Water filtered (m^3)	482.9	482.9	482.9	482.9	482.9	255.2	482.9	482.9	482.9
Clupeids								0.2	0.2	
Northern pike										
Rainbow smelt		0.6	0.4	5.8	0.2	0.6	1.2	0.2	1.2	1.2
Common carp										
Shiners										
White suckers									0.2	
Channel catfish										
Banded killifish							0.4			0.2
Brook silversides										
White bass										
Sunfishes										
Black basses										
Crappies										
Darters										
Yellow perch		0.6			1.0			2.1	0.4	
Logperch										
Walleye										
Freshwater drum										
Unknown					1.2					
Total		1.2	0.4	5.8	2.4	0.6	1.6	2.5	2.0	1.4

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	NR	NR	NR	NR	NR	NR	NR	NR
	Water Temp. (°C)	NR	NR	NR	NR	NR	NR	NR	NR
	Secchi Depth (m)	0.8	0.6	1.2	1.2	0.6	0.6	0.9	0.5
	Water filtered (m^3)	532.4	495.0	469.7	495.0	556.6	466.4	528.0	459.8
Clupeids			0.2			0.9	0.2		
Northern pike									
Rainbow smelt		1.5	0.4	0.4		0.9			0.7
Common carp									
Shiners									
White suckers		0.2	0.8	0.2				0.4	0.2
Channel catfish									
Banded killifish									
Brook silversides									
White bass									
Sunfishes									
Black basses									
Crappies									
Darters									
Yellow perch			5.1	0.2		4.7	5.4	0.4	5.4
Logperch							0.4		
Walleye									
Freshwater drum									
Unknown									
Total		1.7	6.5	0.8		6.5	6.0	0.8	6.3

[1] Filtered volume represents the project mean as metered samples were not taken as a result of equipment failure.

[2] Surface portion not collected due to equipment failure

[3] NR: Not recorded

TABLE A 9

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM MAY 17 TO MAY 18, 1976

TAXA		1	2	3	4	5[1]	6[1]	7[1]	8[1]	9[1]
	Depth (m)	3.0	5.8	3.8	3.0					
	Water Temp. (°C)	16.0	11.8	12.7	12.5					
	Secchi Depth (m)	0.6	1.4	1.7	1.1					
	Water filtered (m^3)	504.2	388.3	466.8	431.2					
Clupeids										
Northern pike										
Rainbow smelt			4.6	24.0						
Common carp										
Shiners										
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass										
Sunfishes										
Black basses										
Crappies										
Darters										
Yellow perch		0.6	7.7	11.4						
Logperch										
Walleye										
Freshwater drum										
Unknown										
Total		0.6	12.3	35.4						

TAXA		10[1]	11[1]	12[1]	13[1]	14[1]	15[1]	16[1]	17[1]
	Depth (m)								
	Water Temp. (°C)								
	Secchi Depth (m)								
	Water filtered (m^3)								
Clupeids									
Northern pike									
Rainbow smelt									
Common carp									
Shiners									
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass									
Sunfishes									
Black basses									
Crappies									
Darters									
Yellow perch									
Logperch									
Walleye									
Freshwater drum									
Unknown									
Total									

[1] Not collected due to equipment failure

TABLE A 10

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM MAY 25 TO MAY 26, 1976

TAXA		1	2	3	4	5[1]	6	7	8	9
	Depth (m)	3.4	6.4	7.9	3.7		8.8	3.7	5.5	7.3
	Water Temp (°C)	12.0	11.8	11.7	15.0		12.0	17.5	16.9	14.6
	Secchi Depth (m)	1.3	1.5	1.6	0.9		1.5	1.4	0.9	1.1
	Water filtered (m^3)	611.6	399.3	824.9	480.7		495.7	448.8	483.5	480.9
Clupeids					1.0				0.2	2.3
Northern pike										
Rainbow smelt		0.5	2.3	4.1	0.6		2.2	0.7	1.7	5.4
Common carp					0.4					
Shiners					1.5				0.4	0.4
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass										0.2
Sunfishes		0.2			1.0					
Black basses										
Crappies										0.4
Darters										
Yellow perch		1.1	7.5	0.4	1.0		12.1	2.7	0.2	1.0
Logperch					0.4					
Walleye										
Freshwater drum										
Unknown			0.2		0.2					
Total		1.8	10.0	4.5	6.1		14.3	3.4	2.5	9.7

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	8.5	3.0	5.5	7.3	3.7	5.9	7.6	4.0
	Water Temp. (°C)	14.9	16.6	16.1	15.4	16.3	15.8	14.9	15.7
	Secchi Depth (m)	2.4	0.9	1.5	1.8	0.9	1.4	1.5	0.8
	Water filtered (m^3)	500.6	455.2	511.8	507.9	534.6	518.1	482.9	475.3
Clupeids			5.5	0.8	0.4	20.0	23.9		86.3
Northern pike									
Rainbow smelt		0.2		5.9	13.4	3.4	21.2	0.8	1.5
Common carp									
Shiners			0.2			0.2	0.2	0.2	
White sucker			0.2			0.2			
Channel catfish									
Banded killifish									
Brook silversides									
White bass						0.4			8.2
Sunfishes			0.2						
Black basses									
Crappies									
Darters									
Yellow perch			1.3	0.4	0.6	3.2	0.6		0.6
Logperch									
Walleye									
Freshwater drum									
Unknown								0.8	0.2
Total		0.2	7.4	7.1	14.4	27.4	45.9	1.8	96.8

[1] Sample not collected due to equipment failure.

TABLE A 11

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE ON JUNE 8, 1976

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	3.0	6.4	8.5	3.0	5.5	7.9	3.0	5.8	6.7
	Water Temp. (°C)	20.5	19.9	19.6	20.9	20.8	20.0	20.3	21.2	20.3
	Secchi Depth (m)	1.2	1.4	2.9	0.9	1.2	1.5	0.9	2.0	1.6
	Water filtered (m^3)	520.3	482.9	716.1	411.4	474.8	466.8	400.4	398.2	440.0
Clupeids		2.9	17.6	40.9	781.0	70.1	1.3	44.5	47.2	6.8
Northern pike										
Rainbow smelt		1.9	3.5	3.7	0.5	4.4	8.4	0.7	3.3	1.8
Common carp										
Shiners			0.4	0.8	1.9	1.7	2.4			0.7
White suckers			0.4							
Channel catfish										
Banded killifish										
Brook silversides										
White bass			1.9			3.8	1.1	0.2	0.3	1.1
Sunfishes										
Black basses										
Crappies										
Darters										
Yellow perch		0.4	0.4	0.1		0.2				0.5
Logperch						0.2	0.2			
Walleye		0.2				0.2	0.4		0.3	0.2
Freshwater drum						0.2				
Unknown		1.0								
Total		6.4	24.2	45.5	783.4	80.8	13.8	45.4	51.1	11.1

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	8.8	2.4	6.1	7.9	2.7	5.5	6.7	3.7
	Water Temp. (°C)	20.0	21.4	21.3	20.5	24.0	22.8	22.5	23.7
	Secchi Depth (m)	1.6	0.9	1.5	1.8	0.6	NR[1]	1.4	0.9
	Water filtered (m^3)	467.3	415.8	464.2	487.3	469.3	400.4	503.8	433.3
Clupeids		5.3	87.3	46.7	9.4	303.4	261.2	247.9	885.4
Northern pike									
Rainbow smelt		5.6		1.3	4.9		0.2	0.6	0.5
Common carp									
Shiners		1.1		1.3	2.5	0.2	6.7	5.0	15.6
White suckers					0.4				
Channel catfish									
Banded killifish									
Brook silversides									
White bass		12.0	5.1	0.6	2.1	15.1	0.5	0.4	0.5
Sunfishes									
Black basses									
Crappies						0.2			
Darters									
Yellow perch		3.0	0.5	0.2	0.8				0.2
Logperch									
Walleye					0.2				
Freshwater drum			3.1			15.8	4.2	4.0	11.7
Unknown			0.2	0.2			0.2		0.7
Total		27.0	96.2	50.3	20.3	334.7	273.0	257.9	914.6

[1]NR = Not Recorded

TABLE A 12

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE ON JULY 9, 1976

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	2.7	6.1	6.7	3.0	5.2	7.3	3.0	4.9	6.1
	Water Temp. (°C)	23.3	20.0	21.0	21.0	21.5	20.5	21.5	21.3	22.0
	Secchi Depth (m)	0.9	0.9	2.0	1.4	1.2	1.2	1.2	1.7	1.8
	Water filtered (m^3)	448.8	426.8	407.0	482.9	471.9	418.0	416.9	387.2	437.8
Clupeids		18.5	64.0	55.5	7.7	3.4	149.5	0.2	3.4	0.9
Northern pike										
Rainbow smelt		0.2								
Common carp		1.8	0.2		9.1	0.4	0.5			
Shiners		0.9	8.0	2.2	0.2	9.3	20.8			1.1
White suckers										
Channel catfish										
Banded killifish										
Brook silversides			0.5	0.2			1.0			
White bass					0.2			1.2	1.3	
Sunfishes				0.2						
Black basses										
Crappies										
Darters										
Yellow perch		0.2	0.5	0.7	0.2	0.2	0.5	0.2	0.3	
Logperch										
Walleye										
Freshwater drum									0.3	0.9
Unknown										
Total		21.6	73.2	58.8	17.4	13.3	172.3	1.6	5.3	2.9

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	7.6	2.4	4.9	6.7	2.4	4.9	6.1	3.7
	Water Temp. (°C)	22.0	23.0	23.0	23.5	26.0	24.0	23.0	24.0
	Secchi Depth (m)	1.8	1.0	2.0	1.8	0.3	1.4	1.5	1.5
	Water filtered (m^3)	456.5	431.2	347.6	415.8	413.6	389.4	455.4	429.0
Clupeids		0.4	1.2	1.4	4.8	8.9	1.8	51.2	0.7
Northern pike									
Rainbow smelt									
Common carp									
Shiners				0.6	0.7	1.0		1.1	
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass		1.1		0.6	0.7	6.5		4.0	
Sunfishes									
Black basses									
Crappies								0.2	
Darters									
Yellow perch								0.9	
Logperch		0.4							0.2
Walleye									
Freshwater drum		0.7		0.3	0.2			0.2	0.2
Unknown									
Total		2.6	1.2	2.9	6.4	16.4	1.8	57.6	1.1

TABLE A 13

POOLED STATION DENSITIES (INDIVIDUALS/100m³) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE FROM JULY 20 TO JULY 28, 1976

TAXA		1	2	3	4	5	6	7	8	9
	Depth (m)	3.7	6.4	8.2	3.0	7.0	8.8	3.4	6.4	8.2
	Water Temp. (°C)	22.5	22.0	22.8	24.3	23.8	23.1	25.0	23.9	23.9
	Secchi Depth (m)	0.6	1.0	0.6	1.2	0.9	1.0	1.0	1.1	0.9
	Water filtered (m^3)	400.4	488.4	638.0	490.6	501.6	565.4	508.2	552.2	477.4
Clupeids		6.5	44.2	252.0	1.2	1.0	4.6		1.1	0.8
Northern pike										
Rainbow smelt		0.7								
Common carp		1.2	0.2			0.2	7.3			
Shiners		1.5	7.6	11.1		0.2	2.8	0.8	0.5	
White suckers										
Channel catfish										
Banded killifish										
Brook silversides			0.2							
White bass		0.5							0.2	
Sunfishes				0.5				0.2		
Black basses										
Crappies										
Darters										
Yellow perch		0.7	1.2	0.9	0.2		0.9			
Logperch							0.2			
Walleye										
Freshwater drum		1.7		0.2						0.6
Unknown										
Total		12.8	53.4	264.7	1.4	1.4	15.8	1.0	1.8	1.4

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	9.1	NR[1]	NR	NR	NR	NR	NR	NR
	Water Temp. (°C)	23.3	NR	NR	NR	NR	NR	NR	NR
	Secchi Depth (m)	1.3	1.1	1.3	1.2	0.6	1.1	1.7	1.4
	Water filtered (m^3)	479.6	640.2	545.6	517.0	628.1	469.7	553.3	492.8
Clupeids		2.3	0.3	0.7	37.9		2.3	1.1	2.2
Northern pike									
Rainbow smelt									
Common carp									
Shiners		2.1	4.7		4.6	4.8	8.5	25.8	3.2
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass				0.2					0.2
Sunfishes						0.2			
Black basses									
Crappies									
Darters								0.2	0.2
Yellow perch				0.2	1.0			0.2	
Logperch								0.2	
Walleye									
Freshwater drum		0.2							
Unknown									
Total		4.6	5.0	1.1	43.5	5.0	10.8	27.5	5.8

[1] NR = Not Recorded

TABLE A 14

POOLED STATION DENSITIES (INDIVIDUALS/100m^3) AND COMPOSITION OF LARVAL FISH COLLECTIONS TAKEN IN THE WESTERN BASIN OF LAKE ERIE ON AUGUST 25, 1976

TAXA		1[1]	2[1]	3[1]	4	5[2]	6[1]	7	8	9
	Depth (m)				4.6	6.7		3.7	5.5	7.3
	Water Temp. (°C)				23.0	23.6		24.4	24.1	23.4
	Secchi Depth (m)				0.8	1.1		0.8	0.8	0.9
	Water filtered (m^3)				497.2	352.0		409.2	473.0	539.0
Clupeids					3.4	0.9		1.0	2.1	1.5
Northern pike										
Rainbow smelt										
Common carp										
Shiners										
White suckers										
Channel catfish										
Banded killifish										
Brook silversides										
White bass										
Sunfishes										
Black basses										
Crappies										
Darters										
Yellow perch										
Logperch										
Walleye										
Freshwater drum										
Unknown										
Total					3.4	0.9		1.0	2.1	1.5

TAXA		10	11	12	13	14	15	16	17
	Depth (m)	8.5	3.7	5.5	7.3	3.7	NR[3]	NR	NR
	Water Temp. (°C)	23.4	24.1	23.8	23.8	24.8	NR	NR	NR
	Secchi Depth (m)	1.4	0.6	0.6	0.7	0.5	NR	NR	NR
	Water filtered (m^3)	545.6	488.4	574.2	594.0	503.8	398.2	506.0	542.3
Clupeids		0.2	0.6	0.5	0.2	0.4		0.2	4.1
Northern pike									
Rainbow smelt									
Common carp									
Shiners									
White suckers									
Channel catfish									
Banded killifish									
Brook silversides									
White bass									
Sunfishes									
Black basses									
Crappies									
Darters									
Yellow perch									
Logperch									
Walleye									
Freshwater drum									
Unknown									
Total		0.2	0.6	0.5	0.2	0.4		0.2	4.1

[1]Sample not collected due to equipment failure

[2]Bottom portion of sample not collected due to equipment failure

[3]NR = Not Recorded

APPENDIX B

DENSITIES FROM STATIONS 18-20 DURING 1975 AND 1976

APPENDIX B
DENSITIES FROM STATIONS 18-20 DURING 1975 AND 1976

TABLE B1

LARVAL FISH DENSITIES IN THE BEACH ZONES ALONG THE WESTERN SHORE
OF THE WESTERN BASIN OF LAKE ERIE DURING 1975

COLLECTION DATES

	June 3			June 19			July 7			July 14		
Station	18	19	20	18	19	20	18	19	20	18	19	20
Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Water Temp (C^o)	18.9	19.7	22.2	21.2	21.0	21.5	26.0	26.6	29.0	22.2	24.0	24.5
Secchi Depth (m)	0.6	0.3	0.2	0.3	0.5	0.3	0.5	0.5	0.3	0.3	0.3	0.3
TAXA / Water filtered (m^3)	157.4	219.6	205.0	157.4	219.6	205.0	157.4	219.6	205.0	157.4	219.6	205.0
Clupeids	56.6	2.3	349.2	2644.6	675.9	1139.3	81.4	112.5	400.9	31.2	9.6	
Northern pike							0.6					
Rainbow smelt				5.1	3.0					0.6		
Common carp	1.3		1.5	10.2			1.9			0.6		
Shiners	4.5	6.8	0.5		1.8	3.9	17.2	2.7	41.9	3.2	1.4	1.5
White suckers		0.9						1.0				
Channel catfish					0.5							
Banded killifish												
Brook silversides										1.3	1.4	0.5
White bass	2.5	0.5	64.9	30.5	34.6	23.4			1.0		0.5	0.5
Sunfishes				5.1			3.8	0.5		1.3	1.4	
Black basses										1.3		
Crappies					1.8							
Darters												
Yellow perch	0.6		43.3			3.9						
Log perch		0.5	0.5									
Walleye					0.5							
Freshwater drum			15.6	10.2					2.0			
Unknown												
Total	65.5	11.0	478.5	2705.7	718.1	1170.5	104.9	116.7	445.8	39.5	14.3	2.5

	July 28			August 13			August 25			Sept. 2		
Station	18	19	20	18	19	20	18	19	20	18	19	20
Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	a	a	1.0
Water Temp (^oC)	24.8	26.0	26.0	26.8	24.4	25.2	23.0	26.0	29.0			22.5
Secchi Depth (m)	0.5	0.5	0.3	0.5	0.3	0.3	0.3	0.3	0.2			0.3
TAXA / Water filtered (m^3)	157.4	219.6	205.0	157.8	219.6	205.0	157.8	219.6	205.0			205.0
Clupeids		4.6		10.8	6.8	7.8	0.6	4.1	6.8			
Northern pike												
Rainbow smelt												
Common carp												
Shiners	3.8	27.8	21.5	9.5	1.3		8.3	7.3	91.2			3.9
White sucker												
Channel catfish												
Banded killifish												
Brook silversides	7.6	4.6					2.5	0.9	1.8			1.0
White bass												
Sunfish	0.5			0.6								
Black basses						0.5						
Crappies												
Darters												
Yellow perch												
Log perch												
Walleye												
Freshwater drum												
Unknown												
Total	11.9	37.0	21.5	20.9	8.1	8.3	11.4	12.3	104.8			

[a] Samples at Stations 18 and 19 were not collected.

TABLE B2

LARVAL FISH DENSITIES IN THE BEACH ZONES ALONG THE WESTERN SHORE OF THE WESTERN BASIN OF LAKE ERIE DURING 1976

	April 13			April 26			May 14			May 24			June 7		
Station	18	19	20	18	19	20	18	19	20	18	19	20	18	19	20
Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	b	1.0	1.0	1.0	1.0	1.0	1.0
Water Temp (°C)	9.5	10.0	10.2	8.0	9.1	7.0	NR	NR		NR	NR	NR	21.8	29.0	NR
Secchi Depth (m)	0.6	0.7	0.3	0.3	NR[a]	NR	0.3	0.2		NR	0.3	0.3	0.8	0.6	0.3
Water filtered (m^3)	157.4	219.6	205.0	157.4	219.6	205.0	157.4	219.6		157.4	219.6	205.0	157.4	219.6	205.0
TAXA															
Clupeids														27.4	18.1
Northern pike															
Rainbow smelt				0.6											
Common carp										0.6				0.5	
Shiners										1.9	0.5			2.8	1.5
White suckers					16.9	0.5									
Channel catfish															
Banded killifish				0.6											
Brook silversides															
White bass															1.0
Sunfishes															
Black basses															
Crappies															
Darters											0.5				
Yellow perch					0.9			2.7		47.6	1.9	2.0		1.4	4.4
Logperch							0.6	1.8							
Walleye															
Freshwater drum															
Unknown	1.3				0.5										
Total	1.3			1.2	18.3	0.5	0.6	4.5		50.1	2.9	2.0		32.1	25.0

	June 29			July 6			July 19			August 3			August 23		
Station	18	19	20	18	19	20	18	19	20	18	19	20	18	19	20
Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Water Temp (°C)	24.5	25.5	26.0	22.0	24.0	26.5	22.0	24.9	25.0	24.0	26.0	26.5	26.0	a	a
Secchi Depth (m)	0.8	0.6	0.5	0.9	0.5	0.6	0.3	0.6	0.4	0.5	0.3	0.3	0.6	a	a
Water filtered (m^3)	157.4	219.6	205.0	157.4	219.6	205.0	157.4	219.6	205.0	157.4	219.6	205.0	157.4	219.6	205.0
TAXA															
Clupeids	14567.7	3.2	2.0	120.8	5.5	2.0				17.8	2.7	0.5	3.8	34.6	8.7
Northern pike															
Rainbow smelt															
Common carp			1.0							0.6					
Shiners	10.8	0.9	2.4	1.3		0.5	0.6	2.8	0.4	3.8	12.8				
White sucker				0.7											
Channel catfish															
Banded killifish															
Brook silversides							0.6								
White bass	1.3		2.9	3.8		0.5					0.5				
Sunfishes											0.5				
Black basses															
Crappies															
Darters															
Yellow perch	0.6		0.5												
Logperch	2.4			1.3											
Walleye															
Freshwater drum															
Unknown															
Total	14582.8	4.1	6.8	127.8	5.5	3.0	1.2	2.8	0.4	22.8	16.5	0.5	3.8	34.6	8.7

APPENDIX C

KRUSKAL-WALLIS TEST RESULTS

APPENDIX C
KRUSKAL-WALLIS TEST RESULTS

TABLE C-1

TEST STATISTIC VALUES (H') FOR THE KRUSKAL-WALLIS TEST OF DEPTH AND GEOGRAPHIC MEANS FROM THE OPEN LAKE STATIONS DURING 1975 AND 1976

1975
H' VALUES FOR DEPTH ZONE MEANS

	6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8/13	9/3-9/5
				All Species			
H'	2.333	1.069	3.075	3.873	3.501	5.160	7.804*
$n_1, n_2 \ldots n_k$	3,2,2,2	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3
		H' (Annual)	3.459				
		$n_1, n_2 \ldots n_k$	39,26,26,20				
				Clupeids			
H'	1.978	2.500	1.667	1.914	2.613	5.265	4.182
$n_1, n_2 \ldots n_k$	3,2,2,2	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3
		H' (Annual)	3.618				
		$n_1, n_2 \ldots n_k$	39,26,26,20				
				Shiners			
H'	4.712	3.547	0.375	4.703	0.531	3.921	10.327*
$n_1, n_2 \ldots n_k$	3,2,2,2	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3	6,4,4,3
		H' (Annual)	2.785				
		$n_1, n_2 \ldots n_k$	39,26,26,20				

TABLE C (cond't.)

	6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8	9/3-9/5
				White Bass			
H'	1.230	3.484	3.067				
$n_1, n_2 \ldots n_k$	3,2,2,2	6,4,4,3	6,4,4,3				
		H' (Annual)	2.785				
		$n_1, n_2 \ldots n_k$	15,10,10,8				
				Yellow Perch			
H'	2.528	4.061					
$n_1, n_2 \ldots n_k$	3,2,2,2	6,4,4,3					
		H' (Annual)	2.841				
		$n_1, n_2 \ldots n_k$	9,6,6,5				
				Rainbow Smelt			
H'	2.333	2.932					
$n_1, n_2 \ldots n_k$	3,2,2,2	6,4,4,3					
		H' (Annual)	3.979				
		$n_1, n_2 \ldots n_k$	9,6,6,5				
				H' VALUES FOR GEOGRAPHIC ZONES MEANS			
				All Species			
H'	4.356	9.379*	6.431	6.951	1.955	4.779	1.904
$n_1, n_2 \ldots n_k$	3,3,3	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4
		H' (Annual)	1.881				
		$n_1, n_2 \ldots n_k$	21,21,27,18,24				

TABLE C-1 (Cont'd).

	6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8	9/3-9/5
				Cluepids			
H'	1.867	5.958	5.830	8.653	8.345	6.201	2.682
n_1, $n_2 \ldots n_k$	3,3,3	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4
		H' (Annual)	3.628				
		n_1, $n_2 \ldots n_k$	21,21,27,18,24				
				Shiners			
H'	3.872	3.898	7.899	4.100	5.683	6.030	3.279
n_1, $n_2 \ldots n_k$	3,3	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4
		H' (Annual)	5.334				
		n_1, $n_2 \ldots n_k$	21,21,27,18,24				
				White Bass			
H'	5.915*	11.789*	10.907*				
n_1, $n_2 \ldots n_k$	3,3,3	3,3,4,3,4	3,3,4,3,4				
		H' (Annual)	23.072**				
		n_1,$n_2 \ldots n_k$	9,9,11,6,8				
				Yellow Perch			
H'	1.233	6.102					
n_1, $n_2 \ldots n_k$	3,3,3	3,3,4,3,4					
		H' (Annual)	6.448				
		n_1,$n_2 \ldots n_k$	6,6,7,3,4				

TABLE C (cond't.)

	6/14	6/18-6/20	6/30-7/3	7/15-7/16	7/29-7/30	8/11-8	9/3-9/5
				Rainbow Smelt			
H'	5.600	6.589					
$n_1, n_2 \ldots n_k$	3, 3, 3	3,3,4,3,4					
		H' (Annual)	1.876				
		$n_1, n_2 \ldots n_k$	6,6,7,3,4				

1976
H' VALUES FOR DEPTH ZONE MEANS

	4/27-4/29	5/25-5/26	6/8	7/9	7/20-7/28	8/25
				All Species		
H'	8.326*	0.770	4.627	3.689	5.307	3.302
$n_1, n_2 \ldots n_k$	6,4,4,3	6,3,4,3	6,4,4,3	6,4,4,3	6,4,4,3	5,4,3,1
		H' (Annual)	1.333			
		$n_1, n_2 \ldots n_k$	35,23,23,16			
				Clupeids		
H'	4.603	4.816	6.275	2.153	5.528	3.302
$n_1, n_2 \ldots n_k$	6,4,4,3	6,3,4,3	6,4,4,3	6,4,4,3	6,4,4,3	5,4,3,1
		H' (Annual)	0.142			
		$n_1, n_2 \ldots n_k$	35,23,23,16			

TABLE C-1 (Cond't).

	4/27-4/29	5/25-5/26	6/8	7/9	7/20-7/28	8/25
				Shiners		
H'		2.696	4.632	4.402	2.194	
$n_1, n_2 \ldots n_k$		6,3,4,3	6,3,4,3	6,4,4,3	6,4,4,3	
		H' (Annual)	0.349			
		$n_1, n_2 \ldots n_k$	24,15,16,12			
				White Bass		
H'			0.609	0.322		
$n_1, n_2 \ldots n_k$			6,4,4,3	6,4,4,3		
		H' (Annual)	0.609			
		$n_1, n_2 \ldots n_k$	12,8,8,6			
				Yellow Perch		
H'	10.748**	3.776	2.196	1.907	4.643	
$n_1, n_2 \ldots n_k$	6,4,4,3	6,3,4,3	6,4,4,3	6,4,4,3	6,4,4,3	
		H' (Annual)	1.934			
		$n_1, n_2 \ldots n_k$	30,19,20,15			
				Rainbow Smelt		
H'	6.850	6.434	9.179*			
$n_1, n_2 \ldots n_k$	6,4,4,3	6,3,4,3	6,4,4,3			
		H' (Annual)	10.399**			
		$N_1, n_2 \ldots n_k$	18,11,12,9			

TABLE C-1 (Cond't).

H' VALUES FOR GEOGRAPHIC ZONE MEANS

	4/27-4/29	5/25-5/26	6/8	7/9	7/20-7/28	8/25
				All Species		
H'	3.093	5.095	8.752	8.991	8.515	6.300
$n_1,n_2 \ldots n_k$	3,3,4,3,4	3,2,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	0,2,4,3,4
		H' (Annual)	4.958			
		$n_1,n_2 \ldots n_k$	15,16,24,18,24			
				Clupeids		
H'		6.831	8.281	11.497*	6.972	6.300
$n_1,n_2 \ldots n_k$		3,2,4,3,4	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	0,2,4,3,4
		H' (Annual)	3.347			
		$n_1,n_2 \ldots n_k$	12,13,20,15,20			
				Shiners		
H'			7.636	5.599	9.031	
$n_1,n_2 \ldots n_k$			3,3,4,3,4	3,3,4,3,4	3,3,4,3,4	
		H' (Annual)	10.046**			
		$n_1,n_2 \ldots n_k$	9,9,12,9,12			
				White Bass		
H'			2.956	4.927		
$n_1,n_2 \ldots n_k$			3,3,4,3,4	3,3,4,3,4		
		H' (Annual)	7.933			
		$n_1,n_2 \ldots n_k$	6,6,8,6,8			

TABLE C-1 (Cond't).

H' VALUES FOR GEOGRAPHIC ZONE MEANS

	4/27-4/29	5/25-5/26	6/8	7/9	7/20-7/28	8/25
				Yellow Perch		
H'	7.691	7.691	6.443	11.795*		
$n_1, n_2 \ldots n_k$	3,3,4,3,4	3,2,4,3,4	3,3,4,3,4	3,3,4,3,4		
		H' (Annual)	2.383			
		$n_1, n_2 \ldots n_k$	12,11,16,12,16			
				Rainbow Smelt		
H'	4.550	1.449	6.683			
$n_1, n_2 \ldots n_k$	3,3,4,3,4	3,3,4,3,4	3,3,4,3,4			
		H' (Annual)	3.972			
		$n_1, n_2 \ldots n_k$	9,8,12,9,12			

*Significant at the α = 0.05 level
** Significant at the α = 0.01 level

TABLE C-2

TEST STATISTIC VALUES (H') FOR THE KRUSKAL-WALLIS TEST OF SAMPLING DATE MEANS FROM THE BEACH ZONE STATIONS DURING 1975 AND 1976

1975

$n_1, n_2 \ldots n_k$	3,3,3,3,3,3,3,1
Taxa	**H'**
All species	0.337
Clupeids	0.277
Shiners	0.281
White bass	1.086
Yellow perch	-0-
Rainbow smelt	2.541

1976

$n_1, n_2 \ldots n_k$	3,2,3,3,3,3,3,3,3
Taxa	**H'**
All species	3.422
Clupeids	0.985
Shiners	1.780
White bass	3.712
Yellow perch	0.484
Rainbow smelt	-0-

APPENDIX D

AREA AND VOLUME ESTIMATES OF WESTERN LAKE ERIE

APPENDIX D

TABLE D-1

AREA AND VOLUME ESTIMATES OF WESTERN LAKE ERIE

GEOGRAPHIC ZONES	MEASUREMENT	DEPTH ZONES (m) 0-1.8	1.8-3.7	3.7-5.5	5.5-7.3	7.3-9.1	TOTALS
FAR NORTHERN	km^2	14.2	10.0	23.7	33.4	20.3	101.7
	m^3	13,017,884	27,667,918	108,252,945	213,634,874	167,246,375	529,819,996
NORTHERN	km^2	3.3	5.4	25.5	49.4	60.9	144.6
	m^3	3,047,994	14,807,352	116,806,992	316,322,774	501,208,185	952,193,296
CENTRAL	km^2	5.8	7.2	17.6	53.9	15.9	100.4
	m^3	5,348,737	19,762,800	80,329,386	344,954,250	130,965,418	581,360,592
SOUTHERN	km^2	12.6	13.7	21.0	61.7	2.2	111.2
	m^3	11,543,047	37,578,814	95,864,324	394,921,685	18,051,990	557,959,860
FAR SOUTHERN	km^2	19.0	22.5	25.1	16.3		82.9
	m^3	17,403,062	61,648,134	114,545,576	104,477,365		298,074,137
TOTALS	km^2	55.1	58.9	112.8	214.7	99.3	540.8
	m^3	50,360,724	161,465,018	515,799,223	1,374,310,948	817,471,968	2,919,407,881

[1] See figure 4 for depiction of the study area in western Lake Erie.