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Larval Fish Distributions in Southwestern Lake Erie Near the Monroe Power Plant

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LARVAL FISH DISTRIBUTIONS IN SOUTHWESTERN LAKE ERIE NEAR THE MONROE POWER PLANT

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FOREWORD

Our nation's freshwaters are vital for all animals and plants, yet our diverse uses of water--for recreation, food, energy, transportation, and industry--physically and chemically alter lakes, rivers, and streams. Such alterations threaten terrestrial organisms, as well as those living in water. The Environmental Research Laboratory in Duluth, Minnesota develops methods, conducts laboratory and field studies, and extrapolates research findings.

--to determine how physical and chemical pollution affects aquatic life

--to assess the effects of ecosystems on pollutants

--to predict effects of pollutants on large lakes through use of models

--to measure bioaccumulation of pollutants in aquatic organisms that are consumed by other animals, including man

This report provides insight into the entrainment of fish larvae by a fossil fuel power plant. Studies were conducted as part of a comprehensive Western Lake Erie larvae study.

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ABSTRACT

This paper presents and discusses studies of larval fish distribution near a large power plant on western Lake Erie using methods that attempt to account for the confounding effect of environmental variation on technique effectiveness. Distributions in the coastal zone were sampled with daytime and nighttime tows of 1-m plankton nets. Density and mortality were also sampled in the cooling system of the Monroe Power Plant. It is concluded that prolarvae were concentrated in specific areas near spawning sites, but larvae that reached the lake proper are rapidly dispersed by currents. Although flooded tributaries may act as important concentration points for certain species, no concentration gradients persisted in the lake proper. Certain species of larvae seemed to be more vulnerable to entrainment than others: gizzard shad were more vulnerable than yellow perch, white bass, rainbow smelt, shiners (Notropis) carp and goldfish.

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CONTENTS

Foreward iii

Abstract iv

Figures vi

Tables vii

Acknowledgments viii

1. Introduction 1

2. Conclusions 4

3. Methods 6

Description of the Study Site 6
Sampling 6
Night transects 6
Backwater, beach and offshore distributions 8
Studies of the power-plant cooling system 8

4. Results 9

Overview 9
Ratios of Prolarvae to Postlarvae 9
Bottom Sled Studies 13
Daytime Bottom Tows Versus Nighttime Oblique Tows 13
Distance from the Maumee River and the Closest Shore 13
Capture in the Discharge Canal 28
Mortality 28

5. Discussion 31

Spawning and Nursery Areas 31
Vulnerability to Entrainment 32
Possible interspecific compensatory interaction 34

References 36

Appendix 39

FIGURES

Number		Page
1	The location of sampling stations and the cooling system at the Monroe Power Plant, Southwestern Lake Erie	7
2	Mean number of larval fish, larval midges and *Leptodora kindtii* in relation to distance (km) from the mouth of the Maumee River. Each recorded point represents the mean of all observations made at that distance from the Maumee River during the sampling expedition	17
3	Mean number of larval fish, larval midges and *Leptodora kindtii* in relation to the closest distance (km) from shore. Each recorded point represents the means of all observations made at a specified distance from shore during the sampling expedition	21

TABLES

Number		Page
1	Mean Number of Animals/100 m^3 Caught in All Tows Made in the Canal, Bottom Sleds and Night Tows in the Lake	10
2	Ratios of Prolarval and Post Larval Stages in Different Sampling Efforts from April to May 1977	12
3	Mean Number of Animals/100 m^3 Caught During the Day with a Bottom-Sled Towed in Protected Inshore Waters (Flooded Tributary Mouths) Along the Beaches and in Deeper Water 1 to 2 km Offshore. Beach and Inshore Waters were 4 to 6 m Deep	14
4	Mean Number of Animals/100 m^3 Caught at Stations Sampled both with Daytime, Bottom-Sled Tows and Nighttime Oblique Tows Without a Bottom Sled	15
5	Mean Number of Scarce Larvae/100 m^3 Caught Along Transects E and G Parallel to Shore in Night Tows	20
6	Mean Number of Scarce Larvae/100 m^3 Caught at Different Distances from Shore in Night Tows	27
7	Mean Number of Animals/100 m^3 Caught in Day and Night Integrated Tows in the Discharge Canal at the Monroe Power Plant	29
8	Estimates of Mortality in the Once-Through Cooling System of the Monroe Power Plant During 1975 (Day time) and 1976 (Nighttime) Sampling Periods	30
A-1	Distribution of Larval Fish, Midges and *Leptodora kindtii* Along Night-Sampling Transects	39
A-2	The capture/100 m^3 of Fish Larvae, Midges and *Leptodora kindtii* in Bottom-Sled Tows Inshore, on the Beach and Offshore in Western Lake Erie	55

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SECTION 1

INTRODUCTION

Effective coastal-zone planning requires an improved understanding of important aquatic resources. Fisheries and cooling water are two particularly important and potentially conflicting uses of the coastal zone. The potential for massive entrainment of larval fish and fish-food organisms into once-through cooling systems at steam-electric power plants is widely recognized (Marcy, 1974), but the quantification of impact has been thwarted by incomplete or ambiguous research results. Representative sampling of fish larvae is a prerequisite for appropriate management decisions. This report presents the results of research designed to assess distributions of larval fish along the western shore of Lake Erie by using techniques that improve upon sampling efforts described by Cole (1976a).

The siting and construction of large power plants is increasingly based on some assessment of optimal resource management in the region. The use of western Lake Erie epitomizes the problem of managing an intensively exploited aquatic resource. As indicated by population trends (Great Lakes Basin Commission, 1975a), the intensity of coastal-zone use could double over the 40-year operation of a new power plant. Continued regional growth is likely to be accompanied by increasing conflicts among resource users. Cooling water requirements could increase by more than ten times the present demand during the next half century (GLBC, 1975b; Denison and Elder, 1970) and endanger the fishery resource because of the large number of young fish drawn into cooling-water intakes.

Appropriate resource management requires the development of fair cost-benefit assessment before costly mitigation procedures can be expected. The retail value of Lake Erie commercial fishing has amounted to $15 to $20 million per year (catch data and values per pound are estimated in GLBC, 1975c) and sport value may exceed the commercial value. Comparable values are also associated with the implementation of cooling alternatives or other mitigation procedures that would insure protection of the fishery resource. Therefore, detailed quantification of resource damage to the fishery, if any, is a prerequisite to any fair settlement.

Quantitative sampling of larval fish in fresh water only recently has been pursued seriously (Marcy, 1971, 1973, 1976; Cole, 1976a). Past work has emphasized enumeration of entrained larvae at power plants with some exploratory assessment of the actual proportion entrained from the cooling-water source. Results of preliminary inventigations in the source waters of western Lake Erie (Cole, 1976) show that larvae occur in very dilute, shifting,

aggregated concentrations which require intensive, sampling efforts to quantify any differences in relative abundances. Particularly pertinent were investigations of population density gradients in relation to distance from shore. In order to maximize the number of samples taken to contrast abundances within the study area, expediency was served by daytime sampling with short (less than 5 minutes) oblique tows of uncomplicated gear (1-m, 573-μ plankton nets).

To check the possibility of sampling bias, studies were also conducted to contrast day and night sampling efforts and densities in different strata of the water column. One important conclusion emerged from studies of vertical distributions near the Monroe Power Plant. The larvae of all abundant fish species concentrated near the bottom during the day and dispersed throughout the water column at night. These results imply that the catch of daytime oblique tows especially depend on the effectiveness of the gear next to the bottom where the larvae concentrate.

Any interaction of technique effectiveness with habitat variation related to distance from shore could produce a spurious relationship between larval density and distance from shore. Depth, turbidity and turbulence are all likely to vary directly with distance from shore and could influence gear effectiveness during daytime studies. Without a bottom-sled, it is much easier to continuously tow a meter-net close to bottom and catch more larvae in water one to two meters deep than in water several meters deep. If visibility enables larvae to avoid nets, as indicated by Noble (1969), turbidity gradients may disproportionately favor shoreline capture during daytime sampling. On the other hand, if strong turbidity gradients do not exist, fish in deep, dark water may be more susceptible to capture than fish in shallow illuminated water. Wind-generated turbulence is also more likely to vertically mix larvae close to shore than farther from shore and increase the probability of capture.

Interactions of gear effectiveness with depth, turbidity and turbulence should be minimized at night, when the larvae are dispersed through the water column and visability is limited by darkness. In accordance with this logic, a nighttime sampling effort was designed to investigate larval fish density gradients related to distance from shore.

Larval fish were also sampled in the flooded tributary valleys and back waters behind the beach to contrast with samples obtained from along the beach front and further offshore. Although tributaries and marshy back waters have been claimed to be important nurseries (Troutman, 1957; GLBC, 1975), no previous sampling in Lake Erie has attempted to quantify the relative densities of larval fish in these environments. Larvae that concentrate in quiet back waters may be relatively invulnerable to entrainment at intakes which open into the main water body. Concentrations of larvae were also estimated in the cooling system of the Monroe Power Plant to compare to densities of larvae captured in the lake and peripheral back waters. The mortality of entrained larvae was also estimated at night to contrast with previous estimates of daytime mortality reported by Cole (1976a).

Although the results of these studies tend to confirm the importance of the shorezone for spawning of some fish species, older larvae and important

fish food organisms appeared not to be consistently concentrated near shore except for the species which concentrated in backwater regions. These results are believed to be more representative of distributional trends than studies that relied solely on oblique, daytime tows.

SECTION 2

CONCLUSIONS

1. The prolarval distributions of most species may have reflected locations of major spawning activity. Maumee Bay appeared to be particularly important for prolarval clupeids, freshwater drum and white bass.

2. In Lake Erie proper, densities of post larval larvae were highly variable, but these larvae tended to be dispersed over the entire study area without exhibiting any strong concentration gradients.

3. In night studies of lake distributions, only prolarval yellow perch exhibited consistently high concentrations along the beach fronts. Although frequently aggregated, older perch larvae, like other postlarvae of abundant species, including clupeids, rainbow smelt, shiners, white bass and freshwater drum, were widely dispersed over the study area.

4. In the daytime bottom-sled tows, species other than rainbow smelt, freshwater drum and postlarval yellow perch were often 10 or more times more abundant in the flooded tributaries than in lake water 5 to 6 m deep.

5. In the lake, nighttime sampling with oblique tows of a 361-μ, 1-m net was more effective for fish larvae, midges and *Leptodora kindtii* (yielded more animals per unit folume filtered) than day time sampling with a bottom sled. The best explanation for the difference seems to be that the animals are difficult to sample effectively during the day because they are so closely associated with the bottom.

6. In contrast with the results of oblique night sampling in the lake, day sampling with a bottom sled indicated higher concentrations near the beaches for most species. These differences may have been the result of chance encounters or shore zone turbulence could have increased the relative rate of capture with a bottom-sled towed near the beach.

7. Day and night captures with oblique tows in the discharge canal yielded similar total catches, except for the invertebrates which were more likely to be captured at night. Yellow perch, smelt, carp-goldfish, white bass and shiners were less concentrated in the discharge canal than in the lake while clupeids and freshwater drum seemed to be more concentrated. This may indicate differences in the relative proportions of fish larvae entrained by the plant.

8. A large proportion (80%) of the clupeid larvae appeared to be dead before they were entrained by the Monroe Power Plant, but most larvae of other species were alive (>80%). Except for carp-goldfish, most larvae observed in the discharge canal were dead or dying. Carp-goldfish larvae may have hatched in the discharge canal.

SECTION 3

METHODS

DESCRIPTION OF THE STUDY SITE

The sampling was conducted in Michigan and Ohio waters on western Lake Erie. Mortality studies were completed in the once-through cooling system at the Monroe Power Plant (Figure 1). The plant generates up to 3100 megawatts and uses up to 80 cu m/sec of cooling water. The first of four 800 megawatt units began operating in June, 1971 and the last started in 1974. Cooling water is warmed 5 to 15 C (depending on time of year and operational level) and released to Lake Erie via a 1700-m discharge canal.

Cooling water comes from two sources, the Raisin River and western Lake Erie, which differ both in water quality and composition of larval fishes. Because of seasonal fluctuations, the river may supply nearly all of the cooling water in late winter and early spring but less than 5% during summer low flow. The river is more contaminated with biodegradeable organic wastes and inorganic nutrients than the lake, however both the river and lake are turbid from suspended matter eroded from the watershed. Concentrations of inorganic nigrogen (0.5 to 3.0 mg/liter) and total phosphorus (0.1 to 0.2 mg/liter) are high enough throughout the growing season to maintain dense growths of algae in both (Cole, 1976a). Organic carbon is about twice as concentrated in the river as in the lake (0.5 mg/liter). While summer biochemical oxygen demand occasionally causes anoxia in the river, the oxygen concentration in the lake exceeds 3 to 4 mg/liter near the bottom except when the lake stratifies during rare calms. Zooplankton, benthic invertebrates and fish are less abundant in the river than the lake (Cole, 1976a; Lavis and Cole, 1976; Kelly and Cole, 1976).

SAMPLING

Night Transects

Night sampling was conducted along transects shown in Figure 1, to investigate the possibility of density gradients in relation to shore and the mouth of the Maumee River. The transect positions were determined by the presence of navigational lights on shore and along the navigational channels leading into the Detroit and Maumee Rivers. Transects A and C were positioned to run from shore lights to channel lights, transect E ran straight from Stoney Point to Maumee Bay and transect followed the shoreline (within 0.3 km) from Stoney Point to Maumee Bay. All sampling was conducted April 27-30, May 17-24, and

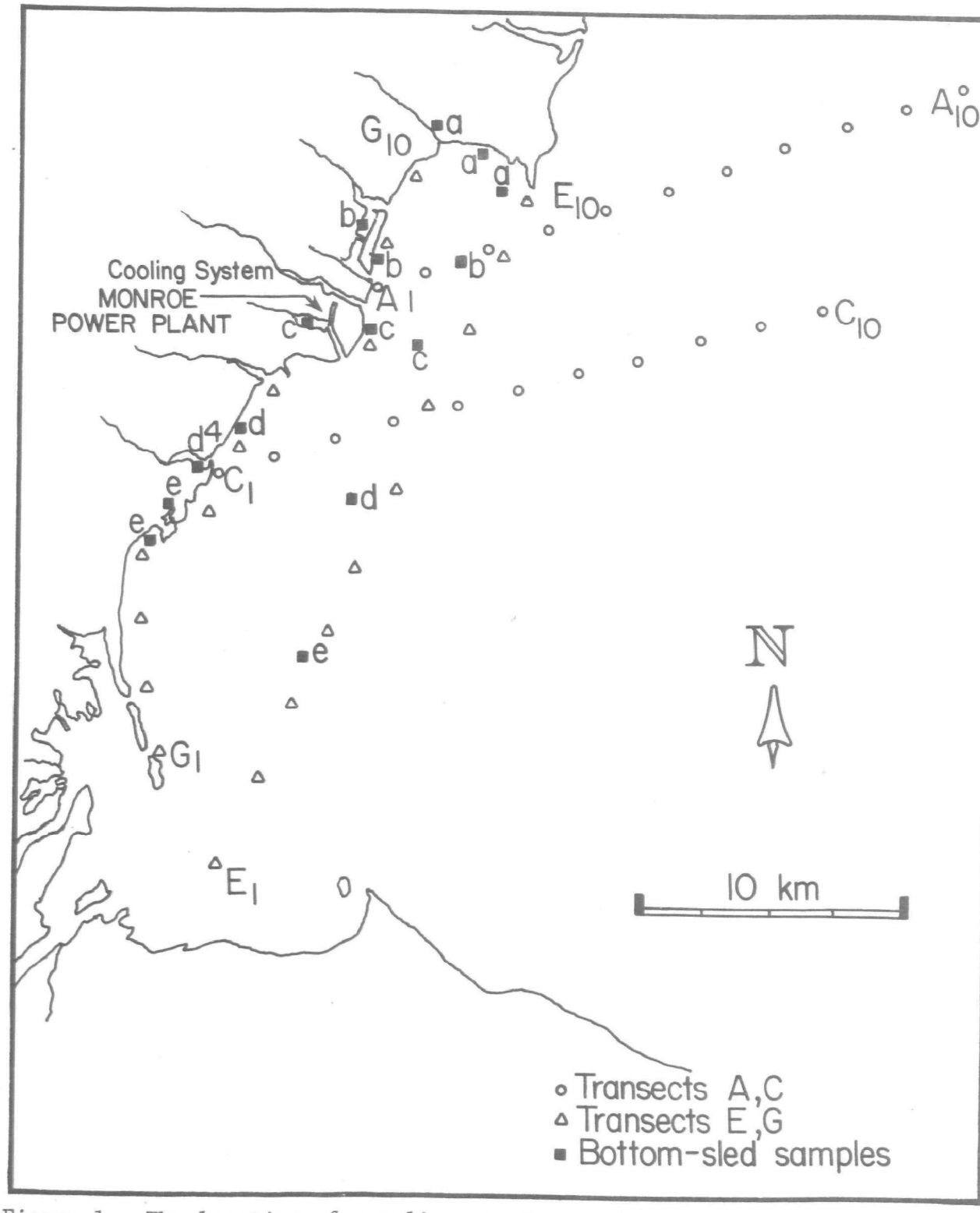


Figure 1. The location of sampling stations and the cooling system at the Monroe Power Plant, Southwestern Lake Erie.

June 15-26, 1976. During each of the three sampling trips, transects A and G were sampled together on two nights and E and G were sampled together on two other nights (except in June when transects E and G were sampled twice in one night).

Nighttime distributions were assessed with single, oblique three-minute tows from bottom to top using a 363-μ net at a total of 20 locations (10 per transect) per evening. It was assumed, as indicated by Cole (1976a), that at night most larvae were dispersed throughout the water column and equally susceptable to oblique tows regardless of variation in depth, turbulence or turbidity. Station positions along the transect were identified by traveling speed and confirmed by occasional triangulation on shore lights and buoy lights.

Backwater, Beach and Offshore Distributions

Population densities were contrasted in three general habitats: flooded tributary mouths, along beach fronts and offshore. Because the flooded tributaries were difficult to sample at night, sampling was conducted during the day with 3-min tows of a 363-μ, 1-m plankton net fastened in an aluminum bottom sled. Cole (1976a) had demonstrated that most of the larvae were concentrated near the bottom during the day, indicating that bottom sampling was the best way to contrast larval densities if sampling had to be conducted during the day.

The stations sampled are identified in Figure 1. Only one sample was taken from each station on each sampling date, for a total of 5 samples per habitat type: in protected backwaters and river mouths (1 to 2-m deep), off beach fronts (1-m deep) and about 1-km offshore (5 to 6 m deep). All sampling was conducted on April 27-30, May 17-24, and June 15-26, 1976. Samples were collected on 2 dates within each of the 3 sampling trips for a total of 6 times. Sampling stations along the beach and offshore closely coincided with specific nighttime sampling stations and these were contrasted to compare the techniques.

Studies in the Power-Plant Cooling System

Larval fish densities in the discharge canal were sampled both day and night to contrast with estimates made in the lake and peripheral waters. Density was estimated from 5 oblique tows of a 363-μ net on each day and night sampled. Mortality was also estimated at night to contrast with 1975 estimates made during the day and reported by Cole (1976a). Other than the time of day sampled, the technique was as described by Cole (1976a). Mortality was estimated on two days and nights during each of the three sampling trips.

SECTION 4

RESULTS

OVERVIEW

Fifteen taxa of larval fish were captured during the study period (Table 1). Several taxa could not be identified confidently to the species level because of larval similarities during certain developmental stages. Based on proportions of adults collected in the area from 1970 to 1975 (Lavis and Cole, 1976), the unclassified clupeid larvae were mostly *Dorosoma cepedianum* and the shiner larvae were mostly *Notropis atherinoides* and *Notropis hudsonius*. Close to even proportions of adult carp and goldfish inhabited the area. Two taxa of large invertebrates were also included in the analysis because of their potential importance as fish foods: *Chironomidae* and *Leptodora kindtii*. *Chiromonidae* included larvae and pupae of several unclassified taxa.

Table 1 summarizes the mean yield per unit effort in daytime, bottom-sled tows and oblique tows in the discharge canal (day and night) and the lake (night only). Night sampling with oblique tows in the lake yielded higher concentrations of animals than efforts with a bottom sled or oblique tows in the discharge canal. More species were caught in the lake at night but this may have been a result of greater sampling intensity.

RATIOS OF PROLARVAE TO POSTLARVAE

Table 2 summarizes the relative ages of larvae captured in the night tows, the bottom-sled tows and in the discharge canal. In April, the preponderance of the catch were prolarvae except for the few postlarval walleye. For the most part, ratios of prolarvae and postlarvae were similar in the nighttime oblique tows and the daytime bottom tows taken from the lake, but ratios of clupeids and yellow perch in the discharge canal appeared to differ from lake ratios. Yellow perch larvae in the canal averaged older than lake larvae while clupeid larvae in the canal averaged younger.

At any particular sampling time, the average age of larvae caught in the different sampling programs varied inconsistently; but the average age of yellow perch, clupeids, rainbow smelt and most of the rarer species increased from April to June. Many of the rare species were captured primarily as postlarvae, perhaps because their hatching was closely spaced just after the May sampling and several weeks before the June sampling; some fish (sunfish, channel catfish, black bass, crappie) remain in redds during prolarval stages. These inconsistent differences in the ratios of prolarvae to postlarvae were

TABLE 1. MEAN NUMBER OF ANIMALS/100 M^3 CAUGHT IN ALL TOWS MADE IN THE CANAL, BOTTOM SLEDS AND NIGHT TOWS IN THE LAKE

Species	APRIL (26-29)			MAY (16-26)			JUNE (14-26)		
	Daytime Bottom Sled[1] n=30	Night Lake Oblique[2] n=80	Day&Night Discharge Oblique[3] n=20	Daytime Bottom Sled n=30	Night Lake Oblique[2] n=80	Day&Night Discharge Oblique[3] n=20	Daytime Bottom Sled n=30	Night Lake Oblique[2] n=75	Day&Night Discharge Oblique[3] n=20
Yellow perch *Perca flavescens*	21.5	44.2	0.7	1.5	2.3	1.3	0.2	0.4	0
Rainbow smelt *Osmerus mordax*	0.5	1.1	0	2.7	15.2	0	0.6	2.4	0
Clupeid *Dorosoma cepedianum* *Alosa pseudoharengus*	0.5	1.9	33.0	45.1	65.4	112.6	460.2	251.4	103.7
Walleye *Stizostedion vitreum*	0	0.2	0	0	0	0	0	0	0
Carp-goldfish *Cyprinus carpio* *Carassius auratus*	0	0.1	0	0.3	0.5	0.1	10.3	3.2	0.3
White sucker *Catostomus commersoni*	0	0.4	<0.1	0	0.2	0.1	0	0.5	0
White bass *Morone chrysops*	< 0.1	0	0.2	0.1	7.8	0.2	5.7	1.6	1.3
Shiners *Notropis atherinoides* *Notropis hudsonius* *Notropis cornutas*	< 0.1	0	0	0.2	0.1	0	5.3	36.0	16.0
Freshwater drum *Aplodinotus grunniens*	0	0	0	0.1	0.1	0.9	0.7	2.1	0.2
Log perch *Percina caprodes*	0	0	0	0	0.4	<0.1	0	0.3	0
Trout perch *Percopsis omiscomaycus*	0	0	0	0	0.2	0	0	0.1	0

(Continued)

TABLE 1 (continued)

Species	APRIL (26-29)			MAY (16-26)			JUNE (14-26)		
	Daytime Bottom Sled n=30	Lake Night Oblique[2] n=80	Day&Night Discharge Oblique[3] n=20	Daytime Bottom Sled n=30	Lake Night Oblique[2] n=80	Day&Night Discharge Oblique[3] n=20	Daytime Bottom Sled n=30	Lake Night Oblique[2] n=80	Day&Night Discharge Oblique[3] n=20
Sunfish *Lepomis macrochirus* *Lepomis gibbosus*	0	0	0	0	0.1	0	1.3	1.1	0.3
Channel catfish *Ictalurus punctatus*	0	0	0	0	0	0	0	0.2	0.3
Black bass *Micropterus dolomieui* *Micropterus salmoides*	0	0	0	0	0	0	0	< 0.1	0
Crappie *Pomoxis annularis*	0	0	0	0	0	0	0	< 0.1	0.2
Leptodora kindtii	0	0	0	1231	2118	170	4217	27129	2354
Chironomidae	0	0	0	0.3	390	1.6	107	2369	805

[1]A bottom-sled with a 361-μ 1-m plankton net was towed during daylight hours.

[2]Night tows in the lake were made with oblique tows of a 361-μ, 1-m plankton net.

[3]In the discharge canal, oblique tows were made both day and night.

TABLE 2. RATIOS OF PROLARVAL AND POSTLARVAL STAGES IN DIFFERENT SAMPLING EFFORTS FROM APRIL TO MAY, 1976

	APRIL			MAY			JUNE		
Species	Bottom Tows	Lake Night Tows	Discharge Canal	Bottom Tows	Lake Night Tows	Discharge Canal	Bottom Tows	Lake Night Tows	Discharge Canal
Yellow perch	317.5:1	351.0:1	17:0	0.6:1	0.5:1	5.3:1	1:1	5:1	
Clupeids	3.8:1	3.0:1	795:0	16.2:1	3.4:1	12.1:1	0.4:1	0.1:1	0.1:1
Smelt	17:1	42.0:1		1.6:1	0.3:1		0:21	0:150	
Sucker	6.0	3.4:1			14.0:0	2.0:1		0:6	
Carp-goldfish	16.0:0	9.0:0	8.0:0	9.0:0	14.0:0	10.0:1	33.7:1	2.8:1	22.0:1
Walleye		0:5							
White bass	2:0			0:3	1.8:1	1:3	0.1:1	0.22:1	0.20:1
Shiner	1:0			6:0	1.2:1	1:0	0.5:1	0.07:1	38.0:1
Log perch				1:3	24:0	1:0		0.3:1	
Sunfish					4:0		0.2:1	0:15	0:6
Freshwater drum				1:0	2.5:1	18:0	2.5:1	5.6:1	0:3
Trout perch					5:0			0:3	
Channel catfish							5.0	0:15	0:6
Crappie							0:12	0.3:1	3:0
Black bass								0:6	

not associated with particular sites (inshore versus offshore) or particular sampling techniques, and probably were caused by the patchy distribution of different-aged cohorts.

BOTTOM SLED STUDIES

Results from bottom-sled tows offshore, along the beach and in flooded tributary valleys indicated that the larvae of most species were distributed differently among these three different habitats (Table 3). But the variability among samples within habitats was too great to regularly identify statistically significant ($\alpha = .05$) differences among inshore, beach and offshore zones. When enough individuals were captured to establish a trend, density gradients appeared to exist in most species. Concentrations along the beach or in tributaries were often 10 or more times greater than offshore concentrations for most species. Only rainbow smelt, postlarval yellow perch and possibly freshwater drum, seemed to be as abundant offshore. For those species that were concentrated inshore, most seemed more abundant in the flooded tributary mouths than along the beaches.

Neither *Leptodora kindtii* nor midge larvae consistently exhibited density gradients related to shoreline proximity and their patterns seemed to reflect patchiness. Although in May, *L. kindtii* seemed concentrated inshore, in June they seemed more abundant offshore.

DAYTIME BOTTOM TOWS VERSUS NIGHTTIME OBLIQUE TOWS

Among stations which were sampled both with daytime sled tows and nighttime oblique tows, night sampling tended to be more effective (Table 4) for most species. The total nighttime yield of larvae, midges and *Leptodora kindtii* was about an order of magnitude more than daytime yield with a bottom-sled. Only yellow perch and rainbow smelt larvae were captured in larger numbers with daytime bottom-sled tows, and those could have been chance encounters with dense aggregates. The difference between day and night tows could be explained by differences in net avoidance during light and dark hours, at least in the shallow water along the beach. Offshore, however, tows were made in water deep enough (5 m) to nearly eliminate day and night differences in the amount of light reaching the bottom. Catch ratios for day and night in May and June were similar in deep, poorly lighted waters and shallow well-lighted waters, therefore differences in visibility appeared not to be the major cause of catch differences. A more probable explanation is that the animals were so closely associated with the bottom during the day that most remained below the rim of the sled-mounted net (about 20-cm gap existed between the rim and the bottom).

DISTANCE FROM THE MAUMEE RIVER AND THE CLOSEST SHORE

Transects A, C, E and G were sampled with oblique night tows to assess the relationship of larval fish distributions to distance from the closest

TABLE 3. MEAN[1] NUMBER OF ANIMALS/100 M^3 CAUGHT DURING THE DAY WITH A BOTTOM-SLED TOWED IN PROTECTED INSHORE WATERS (FLOODED TRIBUTARY MOUTHS) ALONG THE BEACHES AND IN DEEPER WATER 1 TO 2 KM OFFSHORE. BEACH AND INSHORE WATERS WERE 1 TO 2 M DEEP AND OFFSHORE WATERS WERE 4 TO 6 M DEEP

Species	April 27 & 29			May 17 & 18			June 15 & 17		
	Inshore	Beach	Offshore	Inshore	Beach	Offshore	Inshore	Beach	Offshore
Clupeids	0	0.1	1.3	106.9	23.2	5.1	1163.2	190.8	26.7
Yellow Perch	30.0	21.2	13.3	0.9	1.1	2.6	0	0.5	0
Smelt	0.3	1.1	0.2	2.6	0.7	4.9	0	0.3	1.6
Carp-goldfish	0	0	0	0.9	0	0	19.1	11.8	0
White bass	0.1	0	0	0.3	0.1	0	13.5	3.6	0
Shiners	0	0	0.1	0.5	0.1	0	5.2	10.8	0
Freshwater drum	0	0	0	0	0	0.2	0.9	0.3	0.8
Sunfish	0	0	0	0	0	0	3.2	0.3	0.3
Leptodora kindtii	0	0	0	241.7	1132.0	2319.1	6359.4	2613.4	3679.0
Midges	0	0	0	0.3	0.3	0.3	87.6	194.4	40.0

[1]Mean of 5 samples on each of 2 dates; n = 10. Samples were taken at stations a to e shown in Figure 1.

TABLE 4. MEAN NUMBER OF ANIMALS/100 M^3 CAUGHT AT STATIONS SAMPLED WITH DAYTIME, BOTTOM-SLED TOWS AND NIGHT-TIME OBLIQUE TOWS WITHOUT A BOTTOM-SLED

	BEACH (<1.5 m deep)						OFFSHORE (4 to 6 m deep)					
	April		May		June		April		May		June	
Species n =	Night 10	Day 10	Night 10	Day 10	Night 10	Day 10	Night 10	Day 10	Night 10	Day 10	Night 10	Day 10
Yellow perch	236.2	21.2	1.6	1.1	0.4	0.5	1.4	13.3	1.6	2.6	0	0
Clupeid	0.3	0	12.9	0	501.7	0	0.3	0	37.6	0	73.5	0
Smelt	0.3	1.1	1.0	0.7	0	0.3	0.8	0.2	28.3	4.9	5.8	1.6
Carp-goldfish	0.2	0	0.1	0	1.6	11.8	0	0	0.4	0	0	0
Sucker	2.3	0	0.7	0	0.5	0	0	0	0	0	0	0
Shiner	0	0	0.4	0.1	4.3	10.8	-	0.1	0	0	10.0	0
Freshwater drum	0	0	0	0	0.2	0.3	0	0	0.2	0.1	0	0.8
Log perch	0	0	0	0	0	0	0	0	1.0	0	0	0
White bass	0	0	1.0	0.1	3.7	3.6	0	0	11.1	0	0.5	0
Trout perch	0	0	0	0	0	0	0	0	0.3	0	0.5	0
Sunfish	0	0	0.3	0	0	0.3	0	0	0	0	0	0.3
Total	239.3	22.2	18.0	2.0	512.4	27.6	2.5	13.5	90.4	7.6	90.3	2.7
Midges	-	-	123.0	0.3	3649	194	-	-	528	0.3	2505	40
Leptodora	-	-	2240	1332	34831	2613	-	-	4444	2319	34912	3679

shore and distance from the Maumee River. Some of the common species; particularly larval cupeids, white bass, and freshwater drum, were most abundant near the Maumee River during prolarval stages (Figure 2, Table 5). Although prolarval yellow perch (in April samples) were concentrated in Maumee Bay, they were more abundant in other shallow waters (Transect G) 10 to 14 km north of the Maumee River, where several smaller tributaries enter Lake Erie. When postlarvae dominated the catch, no species appeared to be uniquely concentrated in Maumee Bay. Although postlarval clupeids were common in Maumee Bay, they were also relatively abundant all along the west shore, north of the bay. Apparently, the larvae of any species that spawned predominantly in the Maumee River or Maumee Bay were widely and rapidly dispersed over the study area as they grew into postlarval stages.

Larvae of rare species were dispersed widely over the study area, with the possible exception of the log perch which seemed less common near Maumee Bay than in the deeper water of Brest Bay about 10 to 15 km north of Maumee Bay (Table 3). Neither midges nor *Leptodora kindtii* exhibited any consistent spatial trends, except in May when midges appeared to be more concentrated in Maumee Bay. Like most prolarval fishes, both invertebrate taxa exhibited aggregated distributions.

Of all the larvae sampled with oblique night tows, only prolarval yellow perch were generally concentrated close to the beaches along shore (Figure 3, Table 6). The other animals appeared to be dispersed over the study area, often in aggregations, without any indications of concentration gradients. The density estimates were particularly erratic for postlarval clupeids, *Leptodora kindtii* and midge larvae. Smelt may have been more abundant offshore and none of the rare species seemed to be particularly concentrated near shore. Even the larvae of species that are marsh or beach spawners (black bass, sunfishes, crappie, carp-goldfish) were captured several kilometers from shore, often in small aggregations.

Discrepancies occurred between daytime bottom-sled tows and the nighttime oblique tows for clupeids, carp-goldfish, and shiners. Oblique nighttime tows failed to confirm the daytime bottom-sled indications that these taxa were more abundant near the beach than offshore. The different results may be caused by unknown depth-related differences in the sampling effectiveness of these methods or by chance encounters with aggregations in different parts of the study area. During the day, differences in visibility would appear to favor higher captures offshore rather than nearshore, if the larvae were evenly distributed (as indicated by oblique tows at night). Possibly, turbulence had a greater impact on vertical distributions inshore than it did offshore. Turbulence would tend to lift larvae off the bottom and into the sampled water column. Depending on wind conditions, relatively small differences in depth could produce large differences in turbulence near the bottom where larvae congregate. The comparison of day and night efforts in Table 3 supports the idea that chance encounters with aggregations caused the apparent concentrations near shore. Night catches at those selected stations also indicated that clupeids, carp, goldfish and shiners tended to be more common near the beach on some dates.

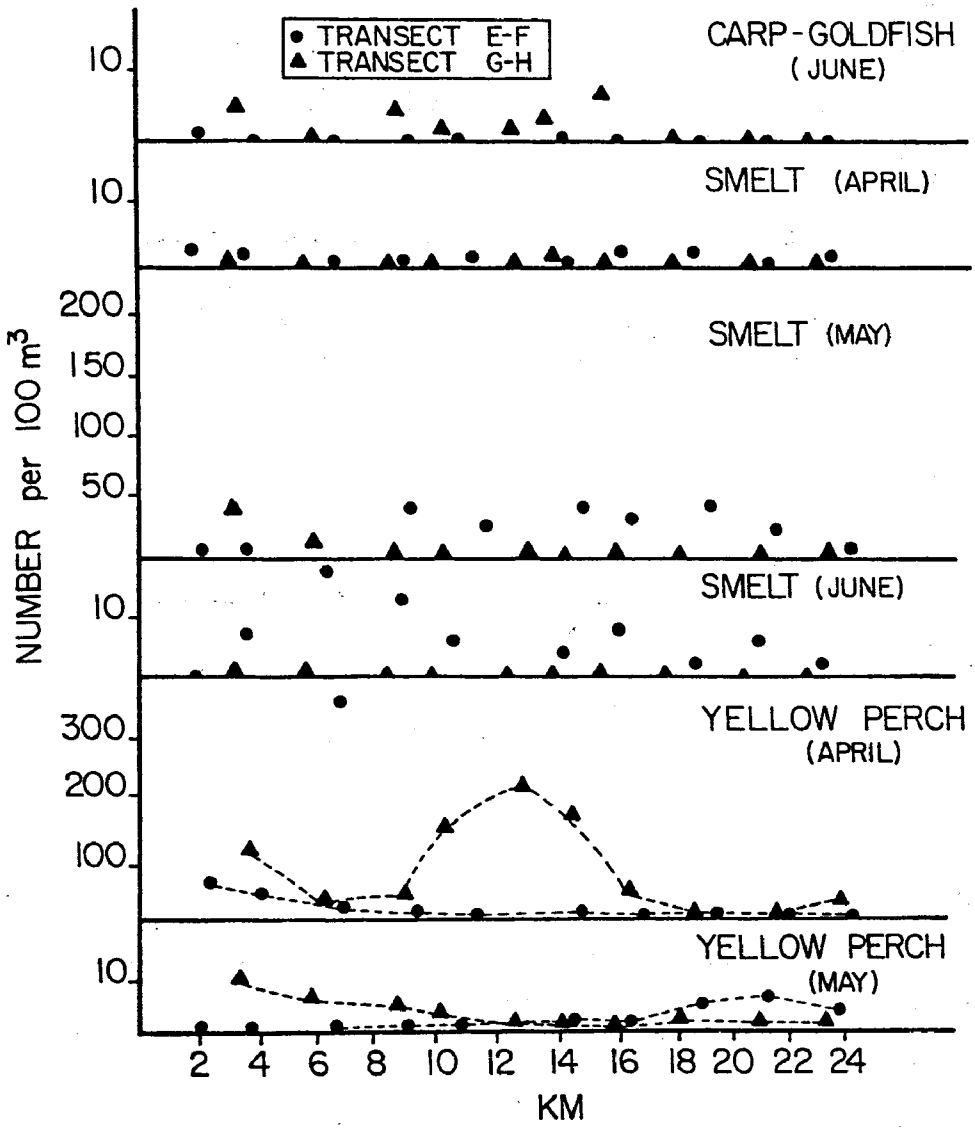


Figure 2. Mean number of larval fish, larval midges and Leptodora kindtii in relation to distance (km) from the mouth of the Maumee River. Each recorded point represents the mean of all observations made at that distance from the Maumee River during the sampling expedition.

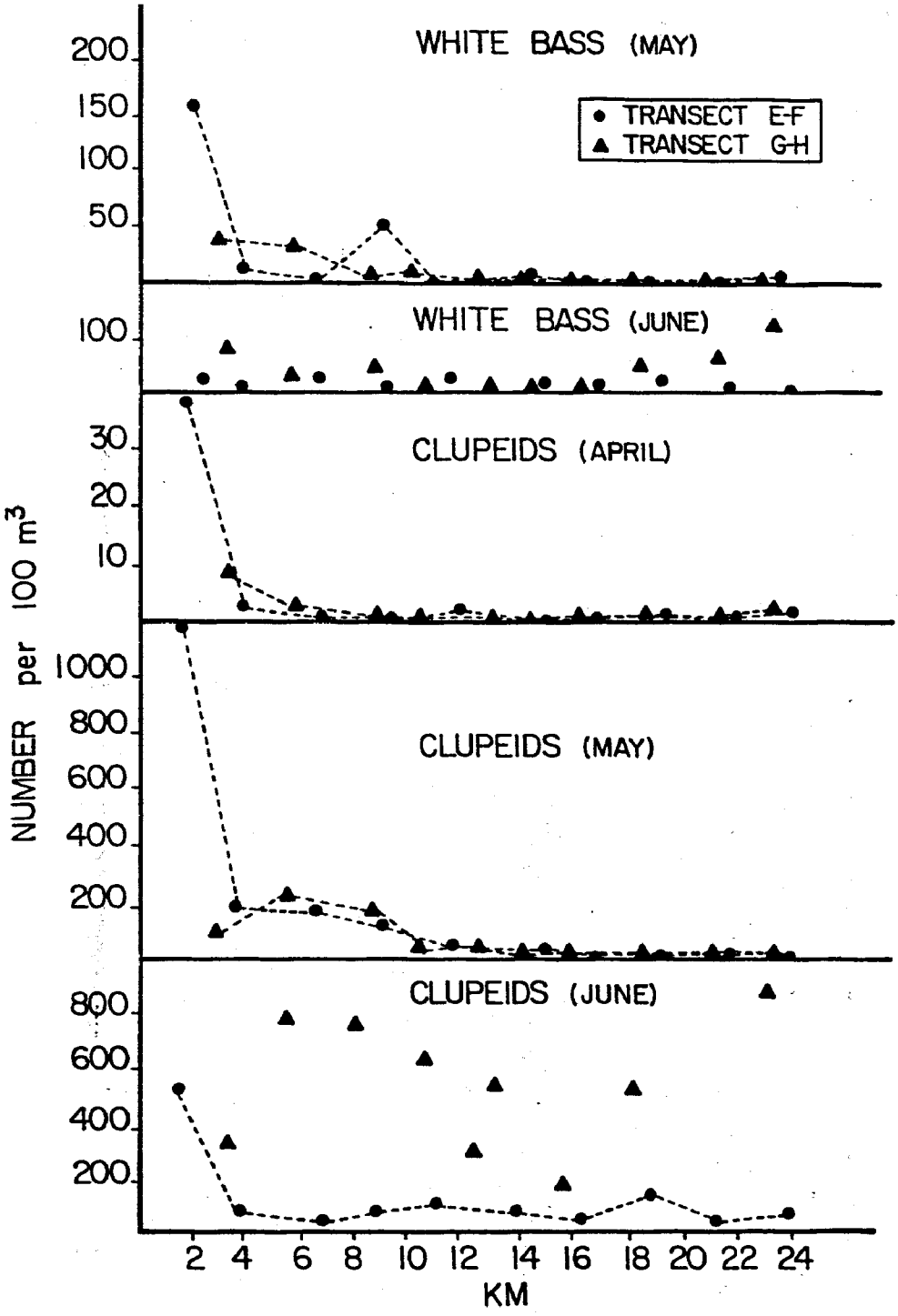


Figure 2 (continued)

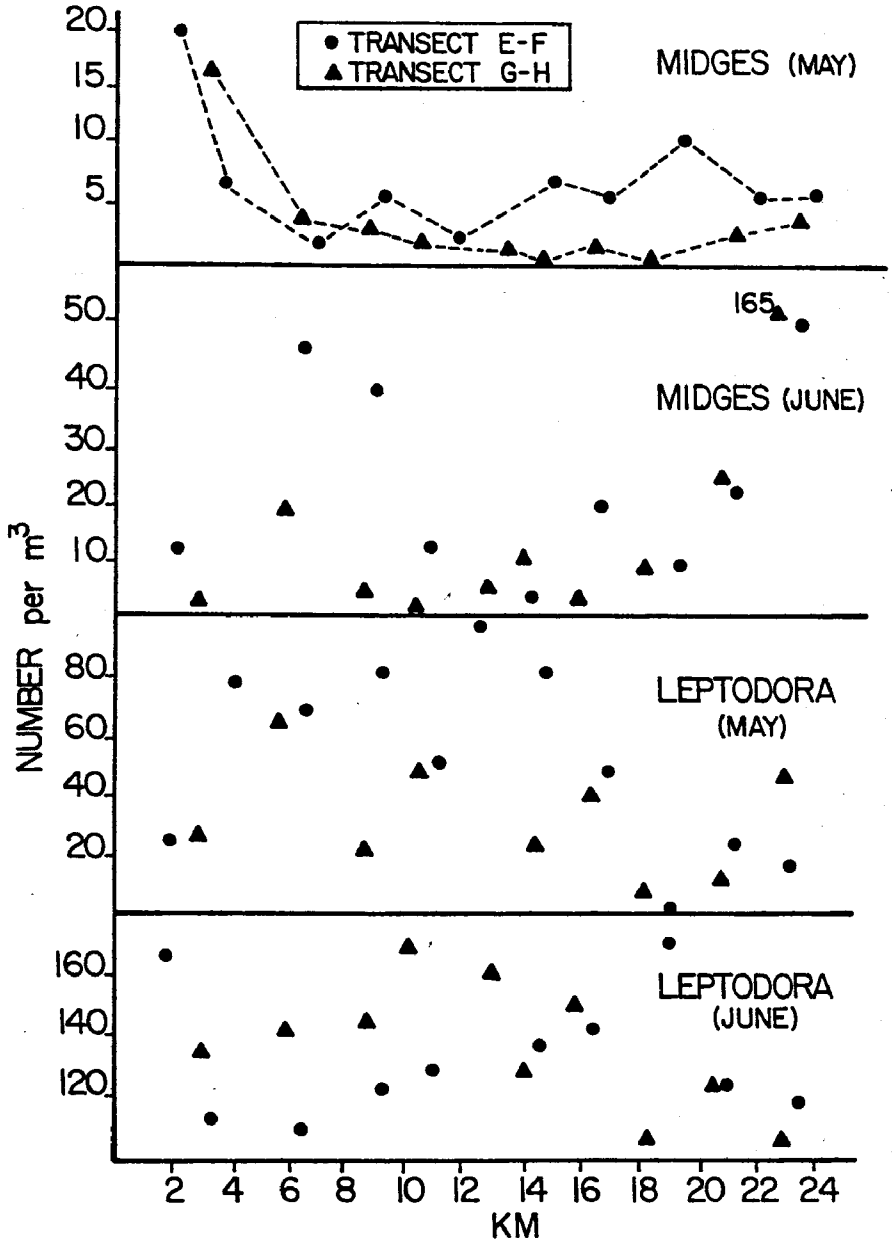


Figure 2 (continued)

TABLE 5. MEAN[1] NUMBER OF LARVAE/100 M^3 FROM SCARCE SPECIES CAUGHT ALONG TRANSECTS E AND G PARALLEL TO SHORE IN NIGHT TOWS

	Stations									
Species	1	2	3	4	5	6	7	8	9	10
APRIL (27 & 29)										
White sucker			0.68		5.5	0.25	0.45			0.48
Carp-goldfish								0.43	0.20	
Walleye	0.25									
MAY (24 & 26)										
White sucker								1.43	0.25	
Trout perch	0.25	0.25	0.23		0.60					
Carp-goldfish	0.83		0.23							1.0
Shiners	0.43		0.23							
Freshwater drum	0.83							0.38		
Log perch							0.25	1.70	4.33	0.73
Sunfish				0.43						
JUNE (21)										
White sucker			0.87					0.65		
Trout perch				0.77						
Freshwater drum	1.40	1.80	0.90			0.53	0.83		0.60	
Yellow perch										0.50

[1]Mean of four separate tows

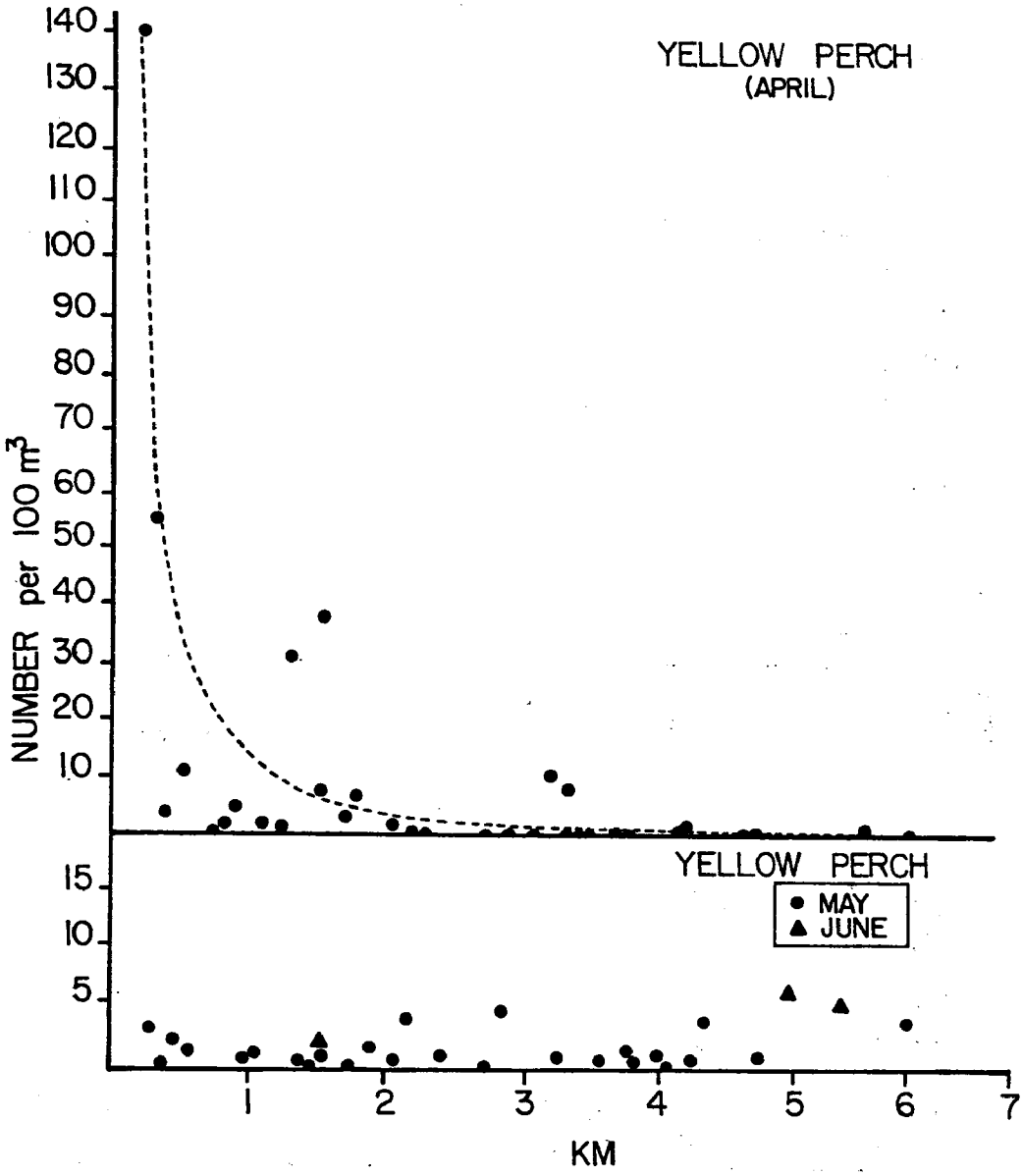


Figure 3. Mean number of larval fish, larval midges and *Leptodora kindtii* in relation to the closest distance (km) from shore. Each recorded point represents the means of all observations made at a specified distance from shore during the sampling expedition.

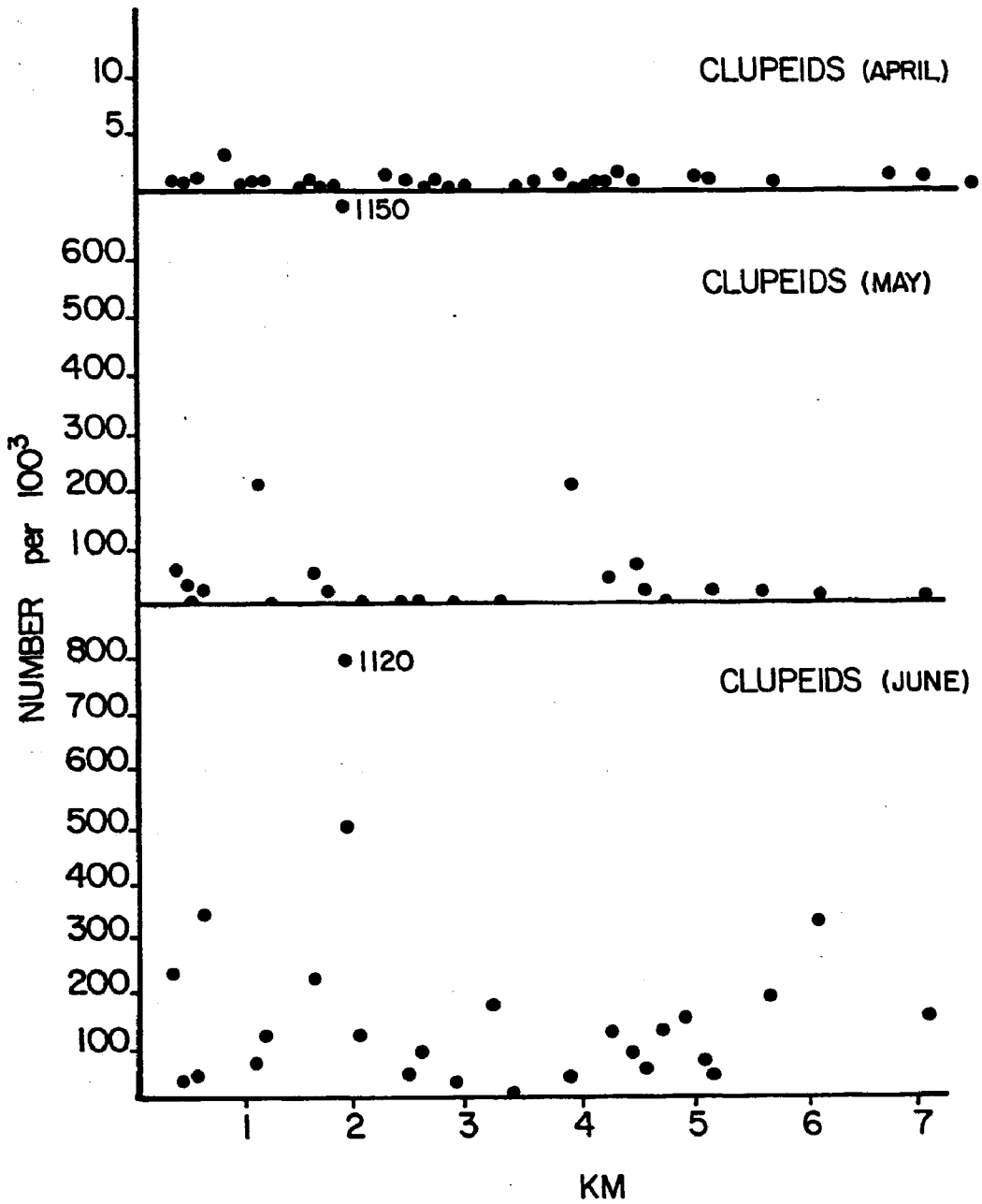
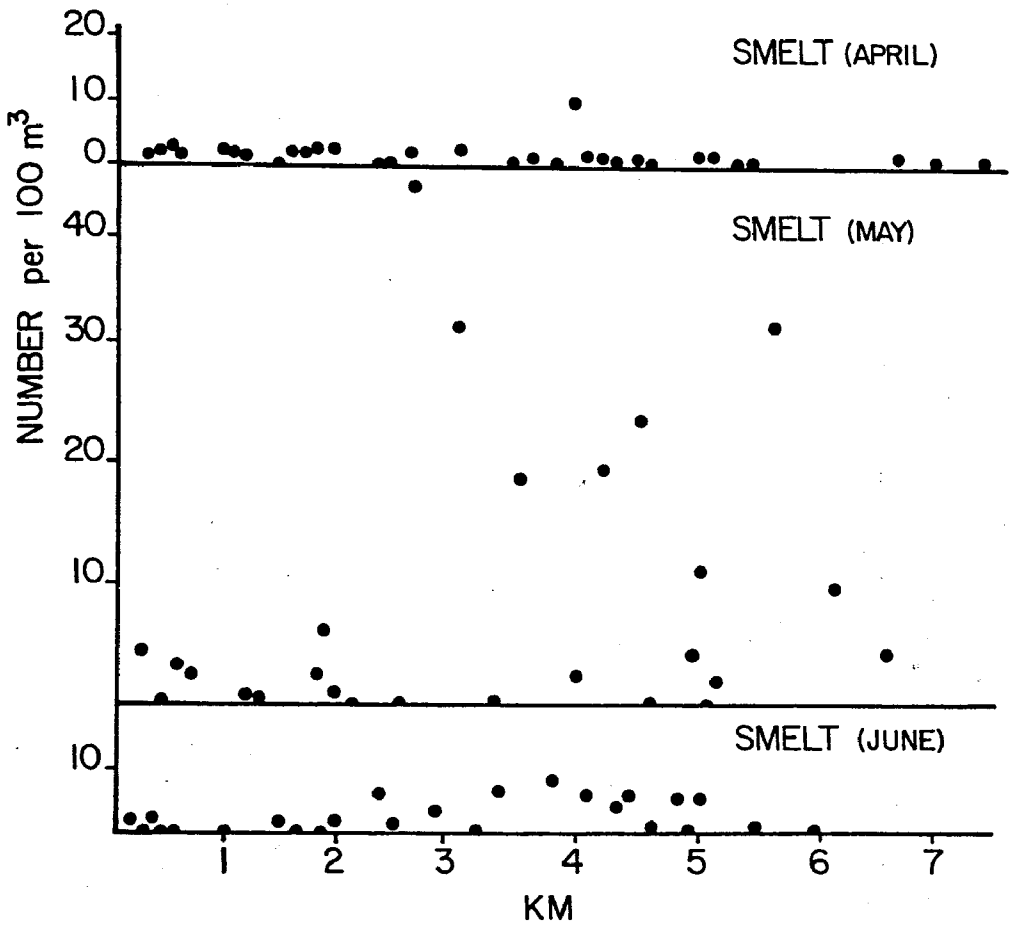


Figure 3 (continued)



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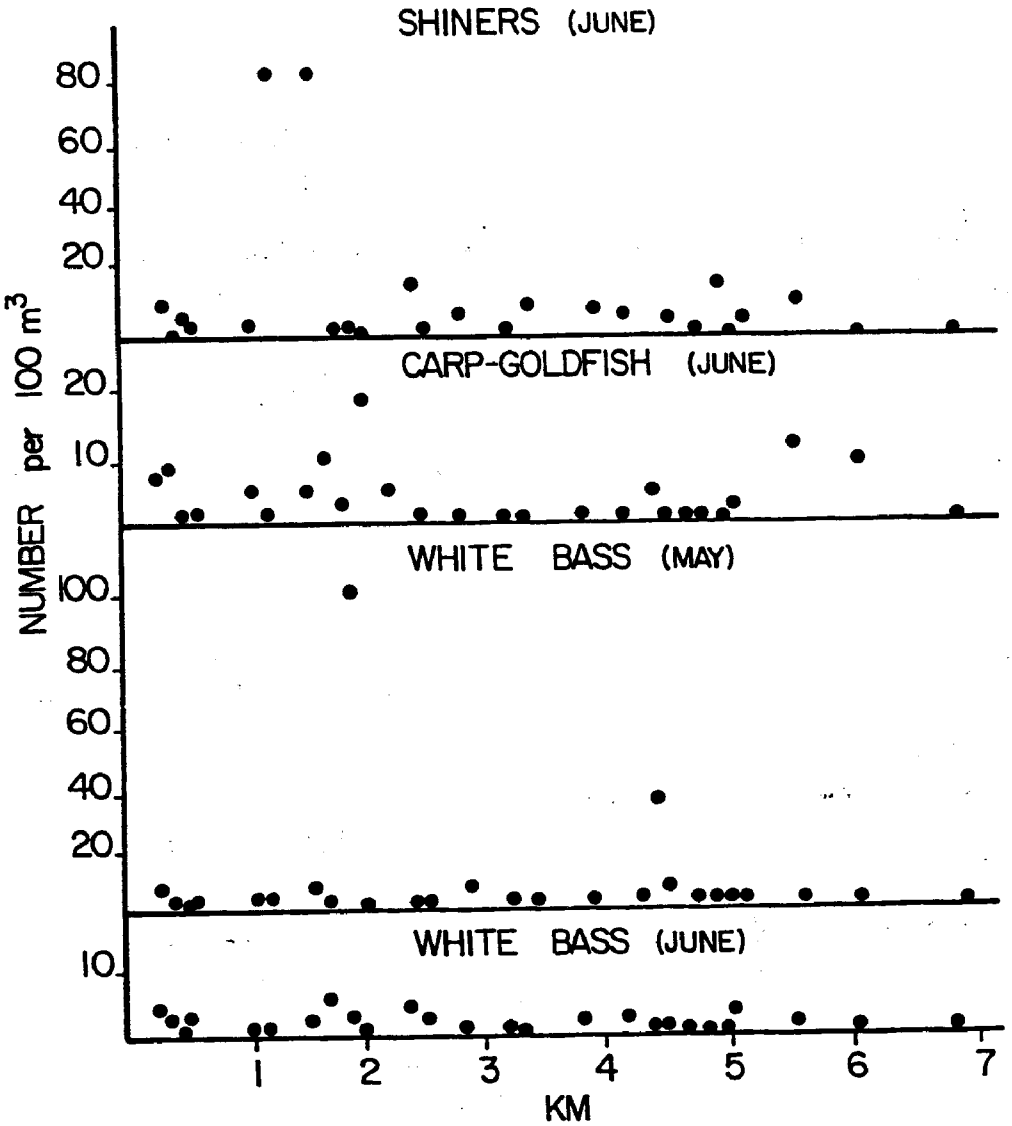

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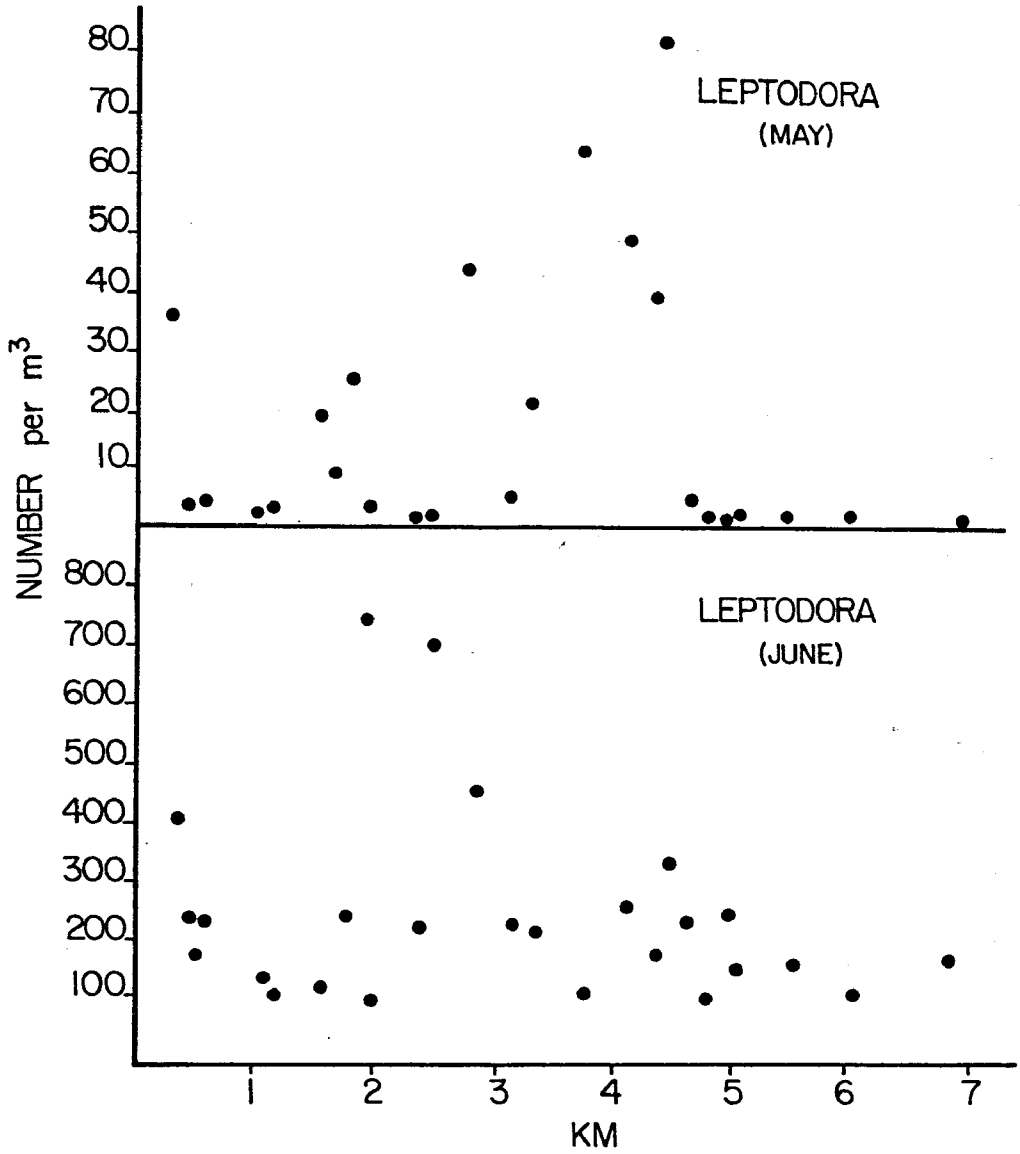

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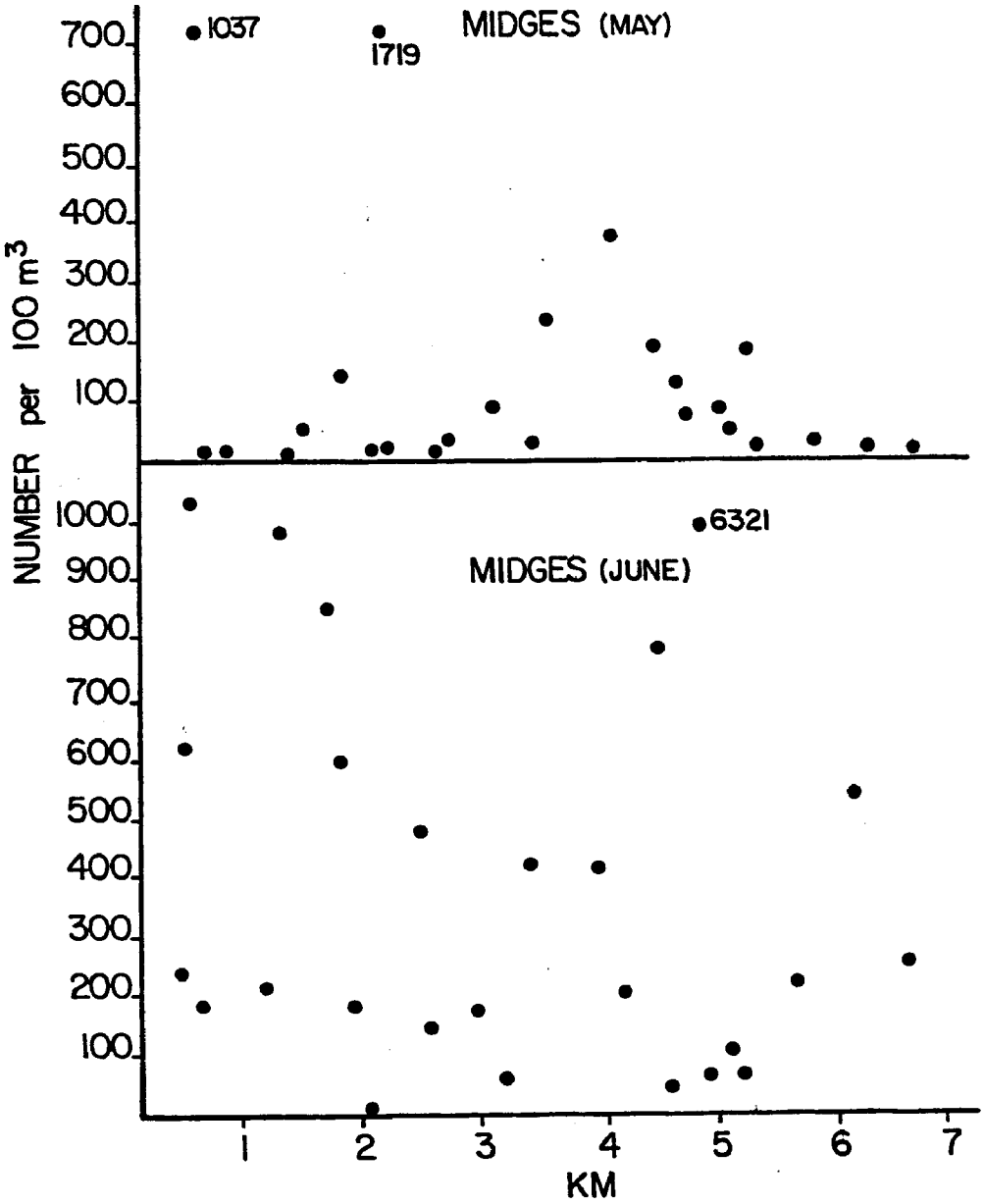

Figure 3 (continued)

TABLE 6. MEAN NUMBER OF SCARCE LARVAE/100 M^3 FROM SCARCE SPECIES CAUGHT AT DIFFERENT DISTANCES FROM SHORE IN NIGHT TOWS

	Km from Shore						
n =	0-1 26	1-2 18	2-3 8	3-4 6	4-5 10	5-6 8	6-7 4
APRIL (26,27,28,29)							
White sucker	0.90	0.14	0.10	0.45			
Walleye		0.28	0.09				
Carp goldfish	0.09						
MAY (16,18,24,26)							
White sucker	0.26				0.45		
Carp-goldfish	0.22	0.11		0.15			0.78
Trout perch	0.03	0.13			0.23		
Shiners		0.11	0.19	0.15			
Log perch	0.11		0.98	2.88			
Freshwater drum				0.55			
Sunfish	0.70						
Channel catfish							
JUNE (14,21,26)							
White sucker	1.00		1.71	0.52		0.45	
Trout perch					0.23		
Log perch		0.46			1.00	0.34	
Freshwater drum	1.05	0.93	0.39	1.20	1.09	0.81	1.03
Sunfish				0.60		1.83	
Yellow perch	0.05	0.22				1.80	3.10
Channel catfish		0.63					
Black bass		0.37					
Crappie			0.39				

CAPTURE IN THE DISCHARGE CANAL

Day and night oblique tows in the discharge canal yielded similar total catches of fish larvae (Table 7). The catch of all common species varied widely without consistent relation to day and night. Most of the rarer species were captured during one or two sampling efforts and may have represented chance encounters unrelated to the time of day. The invertebrates were more likely to be captured at night during June, particularly the midges (mostly *Chaoborus*), but the May samples indicated no diurnal differences.

The average concentration of the total larval catch in the discharge canal did not differ greatly from the estimated lake concentration. However, certain species seemed much less concentrated in the discharge canal than in the lake, including yellow perch, smelt, carp-goldfish, white bass and shiners. At times, clupeids and freshwater drum also seemed to be more concentrated in the discharge canal than in the lake. Among rare species, the numbers captured were too few to identify differences between lake and discharge concentrations.

MORTALITY

The results (Table 8) of the mortality study are of limited value for the effort expended. Sampling variability was too great to identify statistically significant ($\alpha = 0.1$) differences. Only two taxa, clupeids and carp-goldfish, were captured in large enough quantities in 1975 and 1976 to make reasonable, taxa-specific contrasts between years. For clupeids, intake samples had a much higher proportion of immobile and opaque larvae in 1976 compared to 1975. Even though 1976 samples were taken at night and 1975 samples were taken during the day, the differences between years were not necessarily related to the time of sampling. There may be considerable temporal variability in the proportion of dead larvae observed in natural populations. The cause of the high mortality was unknown but apparently it was natural and species specific.

Except for carp-goldfish, most of the larvae observed in the discharge canal were dead or dying. The observed differences between the discharge canal and the intake, are assumed to be caused by condenser passage. The relatively high proportion of apparently healthy carp-goldfish larvae may have been caused by successful hatches in the discharge canal.

TABLE 7. MEAN NUMBER OF ANIMALS/100 M^3 CAUGHT IN DAY AND NIGHT INTEGRATED TOWS IN THE DISCHARGE CANAL AT THE MONROE POWER PLANT

	APRIL				MAY				JUNE				MEAN	
	Day		Night		Day		Night		Day		Night		Day	Night
Species	27	29	28	30	17	18	16	24	14	15	17	26		
Clupeid	10.3	20.0	3.8	97.8	179.9	107.5	141.8	21.2	131.2	131.6	146.4	5.5	96.8	69.4
Yellow perch	0.2	2.2	0.2	0.3	0.2	3.5	0.6	0.7	0	0	0	0	1.2	0.3
Shiner	0	0	0	0	0.3	0	0	0	62.2	0	0	1.8	10.4	0
White bass	0.6	0	0	0	0.7	0	0	0.2	1.7	1.0	1.9	0.6	0.7	0.5
Carp-goldfish	0	0	0	1.2	0.6	0	1.5	0	0	0	0.6	13.3	0.1	2.8
Sunfish	0	0	0	0	0	0	0	0	0	0.6	0	0.6	0.1	0.1
Freshwater drum	0	0	0	0	0	0	3.5	0	0	0	0	0.6	0	0.7
Log perch	0	0	0	0	0.2	0	0	0	0	0	0	0	<0.1	0
Channel catfish	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0.2
Sucker	0	0	0.2	0	0	0	0.2	0.3	0	0	0	0	0	0.2
Crappie	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0.1
Total	10.5	22.2	4.2	99.3	181.9	111.0	147.6	22.4	195.1	133.2	148.9	24.2	109.0	74.9
Midges	0	0	0	0	2.2	0.2	0	3.8	0	17	168.0	3201.0	3.2	562.1
Leptodora kindtii	0	0	0	0	50	101	464	66	1066	1394	2420	4537	435.2	1497.4

TABLE 8. ESTIMATES OF MORTALITY IN THE ONCE-THROUGH COOLING SYSTEM OF THE MONROE POWER PLANT DURING 1975 (DAY TIME) AND 1976 (NIGHTTIME) SAMPLING PERIODS

	INTAKE				DISCHARGE CANAL			
	Day 1975		Night 1976		Day 1975		Night 1976	
Species	Dead/Total[1]	Number Caught	Dead/Total	Number Caught	Dead/Total	Number Caught	Dead/Total	Number Caught
Clupeid	0.15	66	0.80	34	0.79	11	0.86	40
Yellow perch	0.20	40	0.19	28	0.72	5	-	0
Carp-goldfish	0.09	20	0.20	12	0.27	8	0.06	18
All other larvae	0.17	50	0.00	5	1.00	5	-	1
Total larvae	0.16	176	0.36	79	0.75	29	0.59	59

[1]Ratio of immobile and opaque larvae to total catch of alive and dead.

SECTION 5

DISCUSSION

SPAWNING AND NURSERY AREAS

Knowledge of the relative utilization of different coastal-zone habitats for fish spawning and nurseries is indispensable for any reasonably planned coastal development, including power production. Undoubtedly, many of the species present in the southwestern corner of Lake Erie spawn close to shore over shallow beaches and bars, in the mainstream of tributaries, or in the peripheral backwaters of the lake and flooded-tributary valleys (Scott and Crossman, 1973; Troutman, 1957). But of all the lake habitats, those near shore are most likely to be recognized as nurseries or spawning areas by casual observation. Until recently, too few data existed to quantify the relative importance of inshore spawning versus offshore spawning in deeper waters. Even less confidence could be placed on assertions of the relative nursery value of inshore and offshore waters.

The distribution of prolarvae in southwestern Lake Erie suggests the relative value of different spawning habitats for some of the abundant species. The prolarvae of several species seem to be concentrated along certain portions of the shoreline. Prolarval yellow perch seemed to be the most widely distributed species along the shores. Either yellow perch spawned over a wide range of beach and backwater habitats, or their eggs and larvae were dispersed over those habitats soon after spawning.

Other species appeared to spawn primarily in the Maumee Bay region or some of the smaller tributaries entering along the west shore. Clupeids and white bass seemed to originate particularly in Maumee Bay or the Maumee River; especially, early in the spawning season. As the spawning period progressed, most clupeid larvae appeared to hatch in or near tributaries along the west shore. Based on reported spawning habits (Scott and Crossman, 1973), the prolarval clupeids had hatched on shallow bars and shoals at the mouths of the tributaries and white bass had drifted out of the tributary mainstreams. Freshwater drum also could have spawned mostly in Maumee Bay, but even as prolarvae, they were widely dispersed over the study area. Their floating eggs are adapted for rapid dispersal by wind-generated currents (Scott and Crossman, 1973).

Smelt did not appear to spawn in the Maumee River, in any of the smaller tributaries, or along any shorelines in the southwestern part of the basin. Smelt were widely distributed over the study area, primarily as postlarvae that could have been carried long distances by currents. Studies of lake

hydrodynamics indicate the dominant influence of the Detroit River (Kovacik, 1972; Walters *et al.*, 1972; Ecker and Cole, 1976) which may be the major source of smelt larvae. Cole (1976) concluded that concentrations of smelt progressively increased offshore from Stoney Point, probably in waters derived from the Detroit River.

Shiners, like the clupeids, purportedly spawn over bars and beaches (Scott and Crossman, 1973) and catches in bottom-sled tows agree with this. Shiners appeared to use the flooded tributary mouths nearly as much as the beach sites, and were not exceptionally abundant in the Maumee Bay area.

Carp-goldfish appeared to spawn mostly in the backwaters and protected shallows, in keeping with putative habits (Scott and Crossman, 1973). In the lake proper, carp-goldfish larvae were widely dispersed revealing no important gradient in spawning habitat or nurseries outside the protected peripheral waters. This also seemed true for the centrarchids and ictalurids which are believed to spawn predominantly in protected littoral waters and tributaries (Troutman, 1957; Scott and Crossman, 1973). Except for sunfish, very few ictalurids and centrarchids were captured in the flooded tributaries. Possibly, most of those larvae inhabit the heavily vegetated margins of tributaries and backwaters when they were inaccessible to our sampling gear. Depending on the spawning sites chosen, some species are more likely to be flushed from peripheral waters into the lake. Species that spawn in the mainstream of the tributaries (like white bass, channel catfish, white sucker and walleye) or in the open waters of the flooded-tributary mouths (like yellow perch, clupeids, or shiners) may be prone to early, prolarval dispersal into the lake, particularly during spates. On the other hand, prolarvae of species that spawn in the protected margins of back-waters, such as the carp-goldfish, centrarchids, and bullheads, are much less likely to be flushed into the lake as prolarvae.

As the larvae of most species age, they tend to be dispersed over the study area. Postlarval yellow perch do not remain in the sampled backwater areas; in fact, concentrations appeared to be higher in the lake proper. Cole (1976a) indicated that large numbers of yellow perch may enter the western basin with water from the Detroit River. In contrast, the backwaters appear to serve as important nurseries for post larval clupeids, sunfish and white bass. Carp-goldfish probably remain in tributary backwaters through postlarval stages. Although low yields of postlarvae prevented confirmation, Lavis and Cole (1976) found that young-of-the-year carp and goldfish were much scarcer than older age classes in the lake portion of the study area. Apparently, young carp and goldfish survive mostly in the inaccessible backwater areas and few of those that drift into the lake survive. The larvae of other littoral species also may suffer from high mortality when they are flushed into limnetic waters of Lake Erie.

VULNERABILITY TO ENTRAINMENT

Those fish species that spend most of their early lives along beaches rather than in protected backwaters or offshore should be particularly vulnerable to entrainment at shoreline intakes. Information on the relative

concentrations of larvae in lake tows and in the cooling system at the Monroe Power Plant indicate the relative vulnerability of larvae to entrainment. Smelt, log perch, trout perch and older yellow perch appeared to be less concentrated in the discharge canal and less vulnerable to entrainment because they were more abundant offshore than inshore. Also, carp-goldfish, white bass, sunfish, suckers and young yellow perch appeared to be less vulnerable to entrainment because they were concentrated along distant beaches or in remote backwaters of tributaries. Cooling system concentrations were similar or higher than lake concentrations for shiners, clupeids, fresh water drum, crappie and channel catfish. Some of these species appeared to be vulnerable to entrainment because they were more concentrated inshore than offshore. However, species like channel catfish may successfully live and spawn in the discharge canal (Nelson and Cole, 1975). Generally, these same relative vulnerabilities to entrainment were indicated by studies conducted in 1975 and reported by Cole (1976a).

The distributions of important fish food organisms in relation to destructive intakes conceivably could affect the trophic base available to fish in nearby waters. Kenega and Cole (1976) have shown the importance of *Leptodora kindtii* and certain midge larvae as food for white bass, yellow perch, and freshwater drum. They are among the largest invertebrate food items available to carnivorous fishes in western Lake Erie and are consumed by a range of fish species of different sizes (Price, 1963). McNaught (1972) has called attention to the possibility that mortality caused by condenser passage may be directly proportional to the size of the entrained animal. Therefore, large invertebrates, important as fish foods, may be particularly vulnerable to plant operation. Massengill (1976) has reported that entrained midges were almost all killed by condenser passage at a plant on the Connecticut River.

This research indicated that midges and *Leptodora kindtii* were widely distributed and not consistently any more abundant near shore than offshore. Results of this study uncovered no distributional differences among invertebrate foods which would influence future power plant siting in the coastal zone of southwestern Lake Erie. The densities varied from one sampling station to another, exhibiting clumped distributions unrelated to those of larval fish. Because of this clumping subtle density gradients may have been missed by the sampling effort, particularly in the coastal zone near shore.

Larval fish are difficult to sample because they are rare for their size and they occur in constantly shifting aggregations. This research has attempted to make some allowances for confounding interactions so as to minimize biases related to sampling depth and distance from shore. Only rudimentary assessments on the effectiveness of sampling techniques in different environments have been conducted under controlled conditions. Many questions remain about interactions of habitat and technique, particularly for the very complex and diverse environments of coastal zones. In contrasting the dark, flat-bottomed environment of offshore Lake Erie with illuminated, topographically-complicated, tributary mouths, it seems probable that inshore estimates are likely to be underestimated by bottom-sled sampling. Currently, there is no known technique that can effectively sample marsh perimeters, rocky bottoms, and open flats so that larval densities can be compared. Only tentative

and gross evaluations of coastal zone impacts will be possible until acceptable techniques are developed.

Erratic year-to-year variation at different sites compounds the sampling problem. If 5-10% changes in larval survival are biologically significant as suggested by Jensen (1974) for one fish species, such fine determinations of differences appear necessary. But the inherently high variability of larval fish densities may limit the confidence that can be placed in data interpretation.

Since the larvae are usually clumped, the data usually require transformation before sensitive parametric tests for differences may be applied. Frequently, data transformation does not correct for heterogeneous variances, diminishing the possibility of discriminating small (15 to 25%), but potentially important differences.

The clumped distribution of spawning sites probably causes early aggregations of prolarvae in some species. Prolarvae of yellow perch and white bass particularly appeared to be aggregated more than their postlarvae. Perhaps as larvae age they are dispersed by currents and tend toward random distributions, at least until they have developed their locomotive ability enough to school or uniformly disperse.

In any case, sampling directed at prolarvae may lead to inappropriate conclusions if the reproductive age class of the species is not fixed until postlarval or later development. Exceptional, density-independant mortality in prolarval stages (as from a power plant) may be compensated by lower density-dependent mortality among the remaining larvae. Sampling may best be concentrated on the earliest life stage that seems to establish the recruitment into reproductively mature stock (sometime during the first year). Once that stage is reached, any additional source of mortality may inexorably reduce recruitment and compete with the fishery.

Possible Interspecific Compensatory Interaction

For wild fish larvae, virtually nothing is known about competition or vulnerability to predation and disease. It is easiest to assume that any additional mortality caused by power plants will simply be added to all other sources of mortality. But is possible that power plant impacts could depress the density of certain species and indirectly, through response to changed competition, predation, or disease, favor the survival of other species. The results of this study show that a very abundant species, the gizzard shad, could be particularly vulnerable to plant operation in southwestern Lake Erie. It is not a particularly desirable species at its present density in western Lake Erie (Cole, 1976b) and it is possible that, because of its abundance, gizzard shad population dynamics significantly influence the survival of sympatric larvae.

Similarly, neither larval disease nor predation are understood. Disease or starvation may have been responsible for what seemed to be an inordinately high proportion (80%) of dead and dying clupeid larvae caught in the intake

at the Monroe Power Plant. In that instance, mortality appeared to be species specific, but some diseases may pass from species to species. Possibly, an abundant species like the gizzard shad can influence the incidence of disease among sympatric species of larvae when their densities are high.

Predation on fish larvae by older fish may not be species specific. The density and size of the prey may be more important than species differences (Kenaga and Cole, 1975). If feeding on larvae of certain size is mostly controlled by the density of larvae, regardless of species, then the dynamics of the abundant species could influence the loss to predation among rarer species.

Food studies conducted by Price (1963) and Kenaga and Cole (1976) indicate that the young of many fish species forage on a relatively few zooplanktonic and zoobenthic species. The size of food eaten by most of the fish species investigated, appears to increase as the fish grow larger. Therefore, competition for food may be minimized among larvae of different sizes, but intense among larvae of similar sizes. A species like the gizzard shad, which is widely distributed, abundant and spawns during a long time period, is a continual potential source of competition for larvae of all sizes. If such competition is important and larger proportions of clupeid larvae are killed by entrainment, then power plant operation could conceivably foster higher survival of more desirable species, such as yellow perch, smelt and white bass. These data, with that of Cole (1976a), imply that relatively high proportions of clupeids are entrained and killed at the Monroe Power Plant, but uninvestigated competitive interactions among larvae allow only speculations of the effect of clupeid reductions on the survival of other species.

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APPENDIX

TABLE A-1. DISTRIBUTION OF LARVAL FISH, MIDGES AND *LEPTODORA KINDTII* ALONG NIGHT-SAMPLING TRANSECTS

April 1976

	Stations									
	1	2	3	4	5	6	7	8	9	10
Transect A										
Yellow perch										
4-26	3.7	3.3	1.7	1.0	1.0	4.1	1.0	0	0	0.9
4-28	11.7	0	5.0	1.0	0	0	0.9	1.1	0.9	0.0
Mean	7.7	1.7	3.4	1.0	0.5	2.1	1.0	0.6	0.5	0.5
Smelt										
4-26	0.9	0	0	1.9	1.0	0.8	0	0	0	1.8
4-28	0.9	1.9	0	1.9	1.8	2.1	0	1.1	0	2.1
Mean	0.9	1.0	0	1.9	1.4	1.4	0	0.6	0	2.0
Clupeid										
4-26	0.9	1.1	0	0	0	0.8	0	0	0	0
4-28	0	0	1.0	0	0	0	0	0	0	0
Mean	0.5	0.6	0.5	0	0	0.4	0	0	0	0
Walleye										
4-26	0	0	0	0	0	0.8	0.8	0	0	0
4-28	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0.4	0.4	0	0	0
Sucker										
4-26	0	0	0	0	1.0	0	0	0	0	0
4-28	0	1.1	0	0	1.8	0	0	0	0	0
Mean	0	0.5	0	0	1.4	0	0	0	0	0
Transect C										
Yellow perch										
4-26	5.0	6.9	0.9	0	0	0	0	0	0	0
4-28	26.1	130.1	11.5	8.0	2.1	0	0	1.0	0	1.0
Mean	15.1	70.0	6.2	4.0	0.6	0	0	0.5	0	0.5
Smelt										
4-26	0	0	0	0	0	0	0	1.0	0	0
4-28	0	2.2	1.0	2.0	1.1	0	1.1	3.0	24.2	2.0
Mean	0	1.1	0.5	1.0	0.6	0	0.6	2.0	12.1	1.0

(continued)

TABLE A-1 (continued)

April 1976

	Stations									
	1	2	3	4	5	6	7	8	9	10
Transect C										
Clupeid										
4-26	0	0.9	0	0	0.9	0	0	0	0	0
4-28	0	0	23.9	4.0	0	0	0	0	0	0
Mean	0	0.5	11.9	2.0	0.5	0	0	0	0	0
Walleye										
4-26	0	0	1.0	0	0	0	0	0	0	1.0
4-28	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0.5	0	0	0	0	0	0	0.5
Transect E										
Yellow perch										
4-27	64.2	57.2	12.6	2.9	0	0	0	0	0	4.1
4-29	54.8	4.8	9.2	2.1	0	0	0	1.0	0	3.7
Mean	59.5	31.0	10.9	2.0	0	0	0	0.5	0	3.9
Smelt										
4-27	5.5	0	0	0	0	0	0	0	0	2.0
4-29	0	2.9	0	0	1.1	0	4.8	2.8	0	1.8
Mean	2.7	1.5	0	0	0.5	0	2.4	1.4	0	1.9
Clupeids										
4-27	26.6	1.0	0	0	0	0	0	0	0	1.0
4-29	62.4	0	0	0	2.1	0	0	0	0	0
Mean	44.5	0.5	0	0	1.1	0	0	0	0	0.5
Walleye										
4-27	0	0	0	0	0	0	0	0	0	0
4-29	1.0	0	0	0	0	0	0	0	0	0
Mean	0.5	0	0	0	0	0	0	0	0	0

(continued)

TABLE A-1 (continued)

April 1976

	Stations									
	1	2	3	4	5	6	7	8	9	10
Transect E										
Carp goldfish										
4-27	1.8	0	0	0	0	0	0	0	0	0
4-29	0	0	0	0	0	0	0	0	0	0
Mean	0.9	0	0	0	0	0	0	0	0	0
Sucker										
4-27	0	0	0.9	0	0	0	0.9	0	0	0
4-29	0	0	1.8	0	0	0	0	0	0	1.0
Mean	0	0	1.4	0	0	0	0.5	0	0	0.5
Transect G										
Yellow perch										
4-27	149.2	51.8	102.9	586.5	36.1	23.6	29.0	18.6	12.9	49.7
4-29	106.6	23.8	59.8	43.4	837.3	719.5	171.7	22.2	23.5	25.3
Mean	127.9	27.8	81.4	314.9	436.7	371.6	99.4	20.4	18.2	37.5
Smelt										
4-27	2.1	0	0	0	0	2.4	0	0	1.7	0
4-29	0	1.0	0	0	0	0	0.9	0	0	0.9
Mean	1.1	0.5	0	0	0	1.2	0.5	0	0.9	0.5
Carp goldfish										
4-27	0	0	0	0	0	0	0	0	0	0
4-29	0	0	0	0	0	0	0	1.7	0.8	0
Mean	0	0	0	0	0	0	0	0.8	0.4	0
Clupeids										
4-27	0	1.0	0	0	0	0	0	0	0	1.7
4-29	15.2	0	1.0	0	0.9	0	0.9	0.9	0	0
Mean	7.6	0.5	0.5	0	0.5	0	0.5	0.5	0	0.9

(continued)

TABLE A-1 (continued)

April 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect G										
Sucker										
4-27	0	0	0	0	16.7	0	.9	0	0	0
4-29	0	0	0	0	5.5	1.0	0	0	0	0
Mean	0	0	0	0	11.1	0.5	0.5	0	0	0
May 1976										
Transect A										
Yellow perch										
5-16	0	1.9	0	0	1.0	4.7	4.1	0	2.2	0
5-18	0	0	1.0	0	0	1.6	3.0	0	1.2	3.3
Mean	0	1.0	0.5	0	0.5	3.2	6.6	0	1.7	1.7
Smelt										
5-16	0	1.0	0	0	1.0	1.9	10.4	22.0	128.1	9.7
5-18	0	0	0	6.0	1.5	3.2	3.0	0	1.2	29.0
Mean	0	0.5	0	3.0	1.3	2.6	6.7	11.0	64.7	19.4
Clupeids										
5-16	0	1.9	0	0	402.7	0	0	1.0	1.1	0
5-18	60.5	3.0	1.0	0	4.4	13.5	6.0	0	0	0
Mean	30.3	2.5	0.5	0	203.6	4.5	3.0	0.5	0.6	0
White bass										
5-16	0	0	0	0	0	0	0	0	0	0
5-18	0	0	0	0	0	2.4	0	0	0	0
Mean	0	0	0	0	0	1.2	0	0	0	0

(continued)

TABLE A-1 (continued)

May 1976

	Stations									
	1	2	3	4	5	6	7	8	9	10
Transect A (cont'd)										
Carp goldfish										
5-16	0	0	0	0	3.1	0	0	0	0	0
5-18	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	1.5	0	0	0	0	0
Leptodora kindtii										
5-16	343	200	60	52	148	40	198	72	98	234
5-18	0	107	0	80	0	0	60	40	0	0
Mean	172	154	30	66	74	20	129	56	49	117
Midge										
5-16	3	33	32	5	9	4	13	1	32	3
5-18	0	54	0	180	0	0	60	60	0	0
Mean	2	44	16	93	5	2	37	31	16	2
Transect C										
Yellow perch										
5-16	2.2	0	0	0	0	3.2	0	1.0	3.3	15.4
5-18	1.1	0	0	0	0	0	3.0	16.3	0	1.1
Mean	1.7	0	0	0	0	1.6	1.5	8.7	1.7	8.3
Smelt										
5-16	5.6	11.0	0	0	0	6.7	0	4.2	3.3	0
5-18	0	0	0	0	0	0	0	1.4	2.7	13.8
Mean	2.8	5.5	0	0	0	3.4	0	2.8	3.0	6.9
Clupeids										
5-16	17.8	20.0	0	0	0	0	0	2.1	0	0
5-18	2.2	1.9	0	1.5	4.4	0	0	32.7	0	0
Mean	10.0	11.0	0	0.8	2.2	0	0	17.4	0	0

(continued)

TABLE A-1 (continued)

May 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect C (cont'd)										
Carp goldfish										
5-16	0	0	0	0	0	0	0	0	0	3.1
5-18	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0	0	1.6
Sucker										
5-16	0	0	0	0	0	0	0	0	0	0
5-18	0	0	0	0	0	0	0	5.4	0	0
Mean	0	0	0	0	0	0	0	2.7	0	0
Leptodora kindtii										
5-16	462	1278	69	87	170	17	0	57	12	19
5-18	0	427	0	300	707	764	0	54	164	0
Mean	231	853	40	194	439	391	0	56	88	10
Midges										
5-16	1	7	0	9	106	145	0	68	37	51
5-18	0	0	0	20	42	149	345	36	103	0
Mean	0.5	4	0	15	74	147	0	52	0	25
Transect E										
Yellow perch										
5-24	0	0	0	0	1.0	1.0	1.9	4.0	9.7	2.0
5-26	0.8	0.9	2.8	2.7	0	0	0	4.5	0	3.0
Mean	0.4	0.5	1.4	1.4	0.5	0.5	0.9	4.3	4.9	2.5
Smelt										
5-24	0	0	468.0	81.7	35.6	0	44.9	38.0	36.7	0
5-26	0.8	5.3	0	0	2.8	67.9	19.5	51.1	0	5.9
Mean	0.4	2.7	234.0	40.8	19.2	34.0	32.2	44.6	18.4	3.0
Clupeids										
5-24	809.4	278.7	2.8	2.9	0	18.5	0	0	1.9	0
5-26	1433.0	112.0	401.9	265.4	68.2	15.4	0	6.0	0	0
Mean	1221.2	195.4	202.4	134.2	34.1	17.0	0	3.0	2.0	0

(continued)

TABLE A-1 (continued)

May 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect E (cont'd)										
Shiners										
5-24	0	0	0	0	0	0	0	0	0	0
5-26	1.7	0	0.9	0	0	0	0	0	0	0
Mean	0.9	0	0.5	0	0	0	0	0	0	0
Carp-goldfish										
5-24	0	0	0	0	0	0	0	0	0	4.0
5-26	1.7	0	0.9	0	0	0	0	0	0	0
Mean	0.9	0	0.5	0	0	0	0	0	0	2.0
Freshwater drum										
5-24	0	0	0	0	0	0	0	0	0	0
5-26	3.3	0	0	0	0	0	0	1.5	0	0
Mean	1.7	0	0	0	0	0	0	0.8	0	0
Log perch										
5-24	0	0	0	0	0	0	1.0	0	1.0	0
5-26	0	0	0	0	0	0	0	6.8	16.3	2.9
Mean	0	0	0	0	0	0	0.5	3.4	8.7	1.4
White bass										
5-24	229.5	10.0	0	0	0	0	0	0	0	0
5-26	88.4	16.6	3.8	101.9	0	9.3	5.6	0	0	0
Mean	159.0	13.3	1.9	50.9	0	4.7	2.8	0	0	0
Leptodora kindtii										
5-24	2566	4262	2109	5622	4000	564	1698	1180	1333	6160
5-26	2347	8179	2836	3289	14337	3872	5358	782	885	2315
Mean	2457	6221	2473	4556	9169	2218	3528	981	1109	4238
Trout perch										
5-24	0	1.0	0	0	0	0	0	0	0	0
5-26	0	0	0	0	2.8	0	0	0	0	0
Mean	0	0.5	0	0	1.4	0	0	0	0	0

(continued)

TABLE A-1 (continued)

May 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect E (cont'd)										
Midge										
5-24	622	16	132	76	58	214	611	1180	173	60
5-26	11388	1489	93	1019	227	700	521	922	1416	1235
Mean	6005	753	112	548	143	757	566	1051	547	647
Transect G										
Yellow perch										
5-24	29.5	7.3	2.8	1.8	0	0	0	5.7	3.0	1.0
5-26	3.4	3.4	6.5	2.6	1.9	1.0	0	0	1.1	2.1
Mean	8.6	5.4	4.7	2.2	1.0	0.5	0	2.9	2.1	1.6
Smelt										
5-24	63.5	15.5	1.0	0.9	4.4	0	0.9	0	0	2.9
5-26	0	0	1.9	0.9	0.9	0	0	0	0	0
Mean	31.8	7.8	1.5	0.9	2.7	0	0.5	0	0	1.5
Clupeids										
5-24	103.1	24.6	10.2	9.1	35.0	9.7	9.9	1.0	0	0
5-26	62.4	377.0	350.7	24.9	27.6	10.0	25.0	10.8	8.7	1.1
Mean	82.8	200.8	180.5	17.0	31.3	9.8	17.4	5.9	4.4	0.6
Sunfish										
5-24	0	0	0	0	0	0	0	0	0	0
5-26	0	0	0	1.7	0	0	0	0	0	0
Mean	0	0	0	1.3	0	0	0	0	0	0
Shiners										
5-24	0	0	0	0	0	0	0	1.0	0	0
5-26	0.8	2.5	1.9	2.6	0	0	0	0	0	0
Mean	0.4	1.3	0.5	1.3	0	0	0	0.5	0	0
Sucker										
5-24	0	0	0	0	0	0	0	5.7	1.0	0
5-26	0	0	0	0	0	0	0	0.8	0	0
Mean	0	0	0	0	0	0	0	3.3	0.5	0

(continued)

TABLE A-1 (continued)

May 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect G (Cont'd)										
Carp-goldfish										
5-24	0	0	0	0	0	0	0	0	0	0
5-26	0.8	0	0	0.8	0	0	0	0	0	0
Mean	0.4	0	0	0.4	0	0	0	0	0	0
Trout perch										
5-24	0	0	0.9	0	0	0	0	0	0	0
5-26	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0.5	0	0	0	0	0	0	0
White bass										
5-24	48.8	11.9	0	0	0	1.0	0.9	0	0	0
5-26	22.7	54.6	8.4	8.4	0.9	0	0	0	0	0
Mean	35.8	33.3	4.2	4.2	0.5	0.5	0.5	0	0	0
Midges										
5-24	166	616	132	246	158	17	0	60	430	591
5-26	3271	235	631	137	191	108	140	0	0	190
Mean	1718	425	381	191	174	63	70	30	215	390
Leptodora kindtii										
5-24	2122	11956	10238	8770	2524	6946	0	241	4052	2154
5-26	2580	2409	2560	6381	7086	9432	8883	0	0	908
Mean	2351	7183	6399	7576	4805	8189	4442	121	2026	1531
Transect A				June 1976						
Clupeids										
6-14	47.1	525.3	41.9	79.4	47.5	51.6	117.5	141.5	451.2	527.4
6-26	14.6	21.1	54.7	33.8	103.6	77.7	115.4	142.5	144.7	101.6
Mean	30.9	273.2	48.3	56.6	289.3	64.7	116.5	142.0	298.0	314.5
White bass										
6-14	0	0	6.0	0	0	0	0	0	0	0
6-26	2.9	0	0	0	0	2.7	0	0	0	0
Mean	1.5	0	3.0	0	0	1.4	0	0	0	0

(continued)

TABLE A-1 (continued)

June 1976

	Stations									
	1	2	3	4	5	6	7	8	9	10
Transect A										
Shiners										
6-14	0	151.4	0	0	0	537.4	334.8	0	14.4	0
6-26	0	15.1	16.4	5.6	2.7	16.1	11.3	24.2	24.6	0
Mean	0	83.3	8.2	2.8	1.4	276.8	173.1	12.1	19.5	0
Carp-goldfish										
6-14	14.7	0	6.0	6.4	7.3	0	3.6	0	2.9	15.5
6-26	0	0	2.7	19.7	0	0	2.8	0	5.5	2.7
Mean	7.4	0	4.4	13.0	3.7	0	3.2	0	4.2	9.1
Sucker										
6-14	0	0	12.0	0	0	0	0	0	0	0
6-26	0	0	0	0	0	0	0	0	0	0
Mean	0	0	6.0	0	0	0	0	0	0	0
Freshwater drum										
6-14	0	0	0	0	0	0	0	0	0	0
6-26	0	0	0	5.6	0	0	0	5.4	2.7	2.7
Mean	0	0	0	2.8	0	0	0	2.7	1.4	1.4
Yellow perch										
6-14	0	0	0	0	0	0	0	0	14.4	12.4
6-26	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0	7.2	6.2
Smelt										
6-14	0	0	0	0	0	0	0	10.9	0	0
6-26	0	0	12.0	0	0	0	0	0	2.9	0
Mean	0	0	6.0	0	0	0	0	5.5	1.5	0
Log perch										
6-14	0	0	0	0	0	6.9	7.1	2.9	0	0
6-26	0	0	0	0	0	2.7	0	0	2.7	0
Mean	0	0	0	0	0	4.8	3.6	1.5	1.4	0

(continued)

TABLE A-1 (continued)

June 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect A										
Channel catfish										
6-14	0	0	0	0	0	0	0	0	0	0
6-26	0	0	0	0	0	5.4	0	0	0	0
Mean	0	0	0	0	0	2.7	0	0	0	0
Black bass										
6-14	0	0	0	0	2.8	0	0	0	0	0
6-26	0	0	0	2.0	0	0	0	0	0	0
Mean	0	0	0	1.0	1.4	0	0	0	0	0
Leptodora kindtii										
6-14	14588	8073	16228	13524	5771	5236	1923	241	460	74
6-26	36872	14996	31733	31122	25523	10212	33177	23315	32517	25020
Mean	25730	11517	23981	22323	15647	7724	17550	11778	25264	12547
Midge										
6-14	1176	9379	4371	2921	731	10816	10897	181	172	3983
6-26	1314	362	1270	7696	1636	482	1351	484	246	481
Mean	5107	4872	2820	5309	1184	5649	6124	333	209	2232
Transect C										
Clupeids										
6-14	294.9	1131.8	224.7	92.7	176.0	211.5	66.4	36.4	98.0	74.4
6-26	347.6	929.0	959.0	161.5	184.2	49.5	67.2	52.7	42.1	225.5
Mean	321.3	1030.4	591.9	127.1	180.1	130.5	66.8	44.6	70.1	150.0
White bass										
6-14	0.1	8.8	0	0	0	0	0	6.6	3.1	3.5
6-26	3.0	0	3.0	0	0	0	0	0	0	0
Mean	1.6	4.4	1.5	0	0	0	0	3.3	1.6	1.9

(continued)

TABLE A-1 (continued)

June 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect C										
Shiners										
6-14	0	3.3	28.4	0	0	0	0	575.1	288.0	510.4
6-26	6.0	5.6	6.0	0	3	5.8	5.9	2.9	3.1	2.9
Mean	3.0	4.5	17.2	0	1.5	2.9	2.8	289.0	145.6	256.7
Carp-goldfish										
6-14	0	15.4	0	36.5	0	0	0	0	39.8	0
6-26	0	2.8	3.0	2.7	0	0	0	2.9	3.1	0
Mean	0	9.1	1.5	19.6	0	0	0	1.5	21.5	0
Yellow perch										
6-14	0	3.3	0	0	0	0	0	0	0	0
6-26	0	0	0	0	0	0	0	0	0	0
Mean	0	1.7	0	0	0	0	0	0	0	0
Channel cat										
6-14	0	0	0	0	0	0	0	0	0	0
6-26	0	0	9.0	0	0	0	0	0	0	0
Mean	0	0	4.5	0	0	0	0	0	0	0
Crappie										
6-14	0	0	0	0	0	0	0	0	0	0
6-26	0	0	0	2.7	0	0	0	0	0	0
Mean	0	0	0	1.4	0	0	0	0	0	0
Sunfish										
6-14	0	0	0	0	0	0	0	14.6	0	0
6-26	0	0	0	0	3.0	0	0	0	0	0
Mean	0	0	0	0	1.5	0	0	7.3	0	0
Smelt										
6-14	0	0	0	0	0	0	0	10.9	0	0
6-26	0	0	0	2.7	0	0	0	0	3.1	2.9
Mean	0	0	0	1.4	0	0	0	5.5	1.6	1.5

(continued)

TABLE A-1 (continued)

June 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect C										
Sucker										
6-14	0	0	0	0	0	0	0	3.6	0	0
6-26	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0	0	0
Freshwater drum										
6-14	0	0	0	0	3.0	0	0	0	0	0
6-26	15.1	0	0	2.7	3.0	2.8	0	0	0	0
Mean	7.6	0	0	1.4	3.0	1.4	0	0	0	0
Leptodora kindtii										
6-14	0	0	682	2449	14022	18233	18617	7794	8103	293
6-26	24849	25230	20165	19465	34046	30198	33025	25807	29960	36555
Mean	24849	25230	10424	10957	24034	24215	25821	16800	19031	18424
Midges										
6-14	0	0	2901	0	298	7405	399	131	3713	1318
6-26	907	2983	448	164	267	5237	708	527	832	1406
Mean	907	2983	1675	82	283	6321	554	329	2273	1362
Transect E										
Clupeids										
6-21a	810.6	52.2	36.4	59.4	73.8	68.3	27.0	93.3	16.0	41.0
6-21b	178.3	-	-	-	156.7	-	-	76.4	18.4	38.4
Mean	494.5	52.2	36.4	59.4	115.3	68.3	27.0	84.9	17.2	39.7
White bass										
6-21a	2.8	0	2.6	0	2.8	0	0	0	0	0
6-21b	0	-	-	-	0	-	-	2.5	0	0
Mean	1.4	0	1.3	0	1.4	0	0	1.3	0	0
Shiners										
6-21a	2.4	0	2.6	0	0	5.5	26.1	0	43.1	12.0
6-21b	0	-	-	-	0	-	-	76.4	0	7.7
Mean	1.2	0	1.3	0	0	2.8	13.0	38.2	21.6	8.9

(continued)

TABLE A-1 (continued)

June 1976

	Stations 1	2	3	4	5	6	7	8	9	10
Transect E										
Carp-goldfish										
6-21a	2.4	0	0	0	0	0	0	0	0	0
6-21b	0	-	-	-	0	-	-	0	0	0
Mean	1.2	0	0	0	0	0	0	0	0	0
Smelt										
6-21-a	0	8.2	18.2	13.7	0	5.5	7.8	0	9.6	0
6-21-b	0	-	-	-	14.0	-	-	2.5	5.3	2.6
Mean	0	8.2	18.2	13.7	7.0	5.5	7.8	1.3	7.0	1.3
Trout perch										
6-21-a	0	0	0	2.3	0	0	0	0	0	0
6-21-b	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	1.2	0	0	0	0	0	0
Freshwater drum										
6-21a	2.8	2.8	0	0	0	0	0	0	2.4	0
6-21b	0	-	-	-	0	-	-	0	0	0
Mean	1.4	1.4	0	0	0	0	0	0	1.2	0
Sucker										
6-21a	0	0	2.6	0	0	0	0	0	0	0
6-21b	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0	0	0
Leptodora kindtii										
6-21a	68625	13691	11612	22149	26150	34098	46367	95813	17819	16560
6-21b	81780	-	-	-	29046	-	-	47805	27788	21248
Mean	75202	13691	11612	22149	27598	34098	46367	71809	22804	18904
Midge										
6-21a	284	0	4520	3840	341	328	1723	790	1918	10890
6-21b	1953	-	-	-	1679	-	-	711	2212	307
Mean	1118	0	4520	3840	1010	328	1723	750	2065	5598

(continued)

TABLE A-1 (continued)

June 1976

	Stations									
	1	2	3	4	5	6	7	8	9	10
Transect G										
Clupeids										
6-21a	448.2	966.9	180.3	476.5	179.6	401.0	102.8	521.9	245.7	374.0
6-21b	104.0	438.1	1218.9	684.1	310.8	436.8	163.4	299.5	549.8	1341.7
Mean	276.1	702.5	699.6	580.3	245.2	418.9	133.1	406.2	397.8	857.9
White bass										
6-21a	2.8	0	5.4	0	0	0	0	0	11.9	25.0
6-21b	11.0	2.6	2.6	0	0	0	0	10.8	0	1.0
Mean	6.9	1.3	4.0	0	0	0	0	5.4	6.0	13.0
Shiners										
6-21a	0	5.1	19.1	7.6	5.4	1.6	12.4	0	0	3.1
6-21b	8.2	7.8	13.3	19.1	5.6	0	0	0	0	0
Mean	4.1	6.5	16.2	13.4	5.5	0.8	6.2	0	0	1.6
Carp-goldfish										
6-21a	14.0	0	5.4	0	0	8.0	12.4	0	0	0
6-21b	0	0	8.0	2.7	5.6	0	4.9	0	0	0
Mean	7.0	0	6.7	1.4	2.8	4.0	8.7	0	0	0
Sucker										
6-21a	0	0	0	0	0	0	0	0	0	0
6-21b	0	0	0	0	0	0	0	2.6	0	0
Mean	0	0	0	0	0	0	0	1.3	0	0
Smelt										
6-21a	0	0	0	0	0	0	0	0	0	0
6-21b	2.8	0	0	0	0	0	0	0	0	0
Mean	1.4	0	0	0	0	0	0	0	0	0
Yellow perch										
6-21a	0	0	0	0	0	0	0	0	0	0
6-21b	0	0	0	0	0	0	0	0	0	2.0
Mean	0	0	0	0	0	0	0	0	0	1.0

(continued)

TABLE A-1 (continued)

June 1976

	Stations									
	1	2	3	4	5	6	7	8	9	10
Transect G										
Freshwater drum										
6-21a	0	0	2.7	0	0	1.6	2.5	0	0	0
6-21b	2.8	2.6	0	0	0	0	0	0	0	0
Mean	1.4	1.3	1.4	0	0	0.8	1.3	0	0	0
Leptodora kindtii										
6-21a	27904	49835	26068	50169	69827	35384	71893	7267	22159	11401
6-21b	41118	35972	61931	84568	58563	71143	30769	5730	18257	4257
Mean	34511	42904	43999	67369	64195	28264	51331	6499	20208	7879
Midges										
6-21a	51	2380	545	61	294	488	297	586	3012	824
6-21b	330	1244	414	33	202	1434	37	888	893	31680
Mean	191	1812	480	47	248	961	167	737	2321	16252

TABLE A-2. THE CAPTURE/100 M^3 OF FISH LARVAE, MIDGES AND *LEPTODORA KINDTII* IN BOTTOM-SLED TOWS INSHORE, ON THE BEACH AND OFFSHORE IN WESTERN LAKE ERIE

YELLOW PERCH

	April				May				June			
Station	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	0.0	27.2	27.0	5/17	0.0	1.0	0.0	6/15	-	-	-
	4/29	1.0	20.9	8.6	5/18	2.6	3.0	0.0	6/17	-	-	-
B	4/27	35.0	15.2	0.0	5/17	1.3	0.0	0.0	6/15	-	2.5	-
	4/29	26.2	36.9	1.1	5/18	0.0	4.0	5.3	6/17	-	-	-
C	4/27	8.0	17.2	16.2	5/17	0.0	3.0	1.0	6/15	-	2.6	-
	4/29	2.8	11.9	3.6	5/18	2.0	1.0	3.0	6/17	-	-	-
D	4/27	3.0	0.0	9.6	5/17	0.0	-	1.0	6/15	-	-	-
	4/29	0.0	3.0	21.0	5/18	1.0	1.0	12.0	6/17	-	-	-
E	4/27	196.4	59.6	36.9	5/17	1.0	0.0	0.0	6/15	-	-	-
	4/29	27.4	19.8	8.7	5/18	1.1	1.0	4.0	6/17	-	-	-
Mean	4/27	48.5	23.9	17.9	5/17	0.5	1.0	0.4	6/15	0.0	1.0	0.0
	4/29	11.5	18.5	8.6	5/18	1.3	2.0	4.9	6/17	0.0	0.0	0.0
Grand Mean		30.0	21.2	13.3		0.9	1.1	2.6		0.0	0.5	0.0

(continued)

TABLE A-2 (continued)

CLUPEIDS

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	0.0	0.0	0.0	5/17	2.5	168.0	1.0	6/15	21.1	315.8	22.0
	4/29	0.0	0.0	0.0	5/18	30.7	9.1	0.0	6/17	219.1	474.5	5.2
B	4/27	0.0	0.0	0.0	5/17	5.0	0.0	2.0	6/15	4488.8	412.4	0.0
	4/29	0.0	0.0	0.0	5/18	58.6	5.0	15.8	6/17	5040.9	79.9	5.3
C	4/27	0.0	1.1	0.0	5/17	87.0	0.0	2.0	6/15	485.7	88.4	9.0
	4/29	0.0	0.0	2.7	5/18	703.0	7.0	12.0	6/17	1032.0	217.9	28.2
D	4/27	0.0	0.0	5.8	5/17	7.3	-	0.0	6/15	81.2	63.2	25.3
	4/29	0.0	0.0	3.0	5/18	60.0	6.0	15.0	6/17	13.2	23.8	79.3
E	4/27	0.0	0.0	1.9	5/17	49.0	5.8	0.0	6/15	158.1	121.8	15.9
	4/29	0.0	0.0	0.0	5/18	66.5	31	3.0	6/17	92.0	109.9	77.2
Mean	4/27	0.0	0.2	1.5	5/17	30.1	34.8	1.0	6/15	1046.9	200.3	14.4
	4/29	0.0	0.0	1.1	5/18	183.8	11.7	9.1	6/17	1279.4	181.2	39.0
Grand Mean		0.0	0.1	1.3		106.9	23.2	5.1		1163.2	190.8	26.7

(continued)

TABLE A-2 (continued)

SMELT

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	0.0	0.0	0.0	5/17	0.0	0.0	0.0	6/15	0.0	0.0	0.0
	4/29	0.0	0.0	0.0	5/18	5.1	0.0	0.0	6/17	0.0	0.0	0.0
B	4/27	1.2	3.3	1.0	5/17	0.0	0.0	2.0	6/15	0.0	0.0	0.0
	4/29	0.0	0.0	0.0	5/18	19.5	0.0	0.0	6/17	0.0	0.0	5.3
C	4/27	0.0	3.2	0.0	5/17	0.0	0.0	1.0	6/15	0.0	0.0	0.0
	4/29	0.0	0.0	0.0	5/18	0.0	0.0	3.0	6/17	0.0	0.0	0.0
D	4/27	0.0	1.0	0.0	5/17	1.5	-	1.0	6/15	0.0	2.8	2.8
	4/29	0.0	3.0	0.0	5/18	0.0	0.0	6.0	6/17	0.0	0.0	0.0
E	4/27	1.9	0.0	0.0	5/17	0.0	6.0	7.9	6/15	0.0	0.0	0.0
	4/29	0.0	0.0	1.09	5/18	0.0	1.0	28.0	6/17	0.0	0.0	8.0
Mean	4/27	0.6	1.5	0.20	5/17	0.3	1.2	2.4	6/15	0.0	0.6	0.6
	4/29	0.0	0.6	0.22	5/18	4.9	0.2	7.4	6/17	0.0	0.0	2.7
Grand Mean		0.3	1.1	0.21		2.6	0.7	4.9		0.0	0.3	1.6

(continued)

TABLE A-2 (continued)

CARP-GOLDFISH

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	0.0	50.7	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	7.3	0.0	0.0
B	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	43.3	2.5	0.0
	4/29	-	-	-	5/18	2.4	0.0	0.0	6/17	21.7	0.0	0.0
C	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	11.6	65.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	0.0	0.0	0.0
D	4/27	-	-	-	5/17	0.0	-	0.0	6/15	8.7	0.0	0.0
	4/29	-	-	-	5/18	1.0	0.0	0.0	6/17	2.6	0.0	0.0
E	4/27	-	-	-	5/17	3.0	0.0	0.0	6/15	95.3	0.0	0.0
	4/29	-	-	-	5/18	2.2	0.0	0.0	6/17	0.0	0.0	0.0
Mean	4/27	-	-	-	5/17	0.6	0.0	0.0	6/15	31.8	23.6	0.0
	4/29	-	-	-	5/18	1.1	0.0	0.0	6/17	6.3	0.0	0.0
Grand Mean		-	-	-		0.8	0.0	0.0		19.0	11.8	0.0

(continued)

TABLE A-2 (continued)

WHITE BASS

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	2.5	1.0	0.0	6/12	9.7	0.0	0.0
B	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	0.0	14.8	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	0.0	0.0	0.0
C	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	0.0	10.4	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	11.6	0.0	0.0
D	4/27	1.0	-	-	5/17	0.0	-	0.0	6/15	52.2	5.5	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	2.6	5.3	0.0
E	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	21.1	0.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	37.9	0.0	0.0
Mean	4/27	0.2	0.0	0.0	5/17	0.0	0.0	0.0	6/15	14.7	6.1	0.0
	4/29	0.0	0.0	0.0	5/18	0.5	0.2	0.0	6/17	12.3	1.1	0.0
Grand Mean		0.1	0.0	0.0		0.2	0.1	0.0		13.4	3.6	0.0

(continued)

TABLE A-2 (continued)

NOTROPIS SP

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	-	-	-	5/17	2.5	1.0	0.0	6/15	16.9	105.3	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	0.0	0.0	0.0
B	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	16.2	0.0	0.0
	4/29	-	-	-	5/18	2.4	0.0	0.0	6/17	16.3	0.0	0.0
C	4/27	-	-	1.0	5/17	0.0	0.0	0.0	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	0.0	2.7	0.0
D	4/27	-	-	-	5/17	0.0	-	0.0	6/15	2.9	0.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	0.0	0.0	0.0
E	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	0.0	0.0	0.0
Mean	4/27	0.0	0.0	0.2	5/17	0.5	0.20	0.0	6/15	7.2	21.1	0.0
	4/29	0.0	0.0	0.0	5/18	0.5	0.0	0.0	6/17	3.3	0.5	0.0
Grand Mean		0.0	0.0	0.1		0.5	0.1	0.0		5.2	10.8	0.0

(continued)

TABLE A-2 (continued)

DRUM

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	-	-	-	5/17	-	-	-	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	0.0	0.0	0.0
B	4/27	-	-	-	5/17	-	-	-	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	0.0	0.0	0.0
C	4/27	-	-	-	5/17	-	-	-	6/15	2.9	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	0.0	0.0	0.0
D	4/27	-	-	-	5/17	-	-	-	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	0.0	0.0	2.6
E	4/27	-	-	-	5/17	-	-	1.4	6/15	3.5	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	2.7	2.7	5.3
Mean	4/27	-	-	-	5/17	0.0	0.0	0.3	6/15	1.3	0.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	0.5	0.5	1.6
Grand Mean		-	-	-		0.0	0.0	0.1		0.9	0.3	0.8

(continued)

TABLE A-2 (continued)

SUNFISH

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	-	-	-	5/17	-	-	-	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	12.1	0.0	0.0
B	4/27	-	-	-	5/17	-	-	-	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	0.0	0.0	0.0
C	4/27	-	-	-	5/17	-	-	-	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	0.0	0.0	0.0
D	4/27	-	-	-	5/17	-	-	-	6/15	0.0	0.0	0.0
	4/29	-	-	-	5/18	-	-	-	6/17	0.0	0.0	0.0
E	4/27	-	-	-	5/17	-	-	-	6/15	14.0	2.8	3.2
	4/29	-	-	-	5/18	-	-	-	6/17	5.4	0.0	0.0
Mean	4/27	-	-	-	5/17	-	-	-	6/15	2.8	0.6	0.6
	4/29	-	-	-	5/18	-	-	-	6/17	3.5	0.0	0.0
Grand Mean		-	-	-		-	-	-		3.2	0.3	0.3

(continued)

TABLE A-2 (continued)

LEPTODORA KINDTII

Station	April				May				June			
	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	-	-	-	5/17	67.0	3702.0	5507.0	6/15	0.0	817.0	6033.0
	4/29	-	-	-	5/18	728.0	2065.0	262.0	6/17	1235.0	1070.0	310.0
B	4/27	-	-	-	5/17	440.0	1000.0	800.0	6/15	12833.0	9260.0	5772.0
	4/29	-	-	-	5/18	0.0	470.0	58.0	6/17	23502.0	342.0	2995.0
C	4/27	-	-	-	5/17	20.0	180.0	1000.0	6/15	260.0	312.0	1681.0
	4/29	-	-	-	5/18	0.0	0.0	53.0	6/17	5117.0	1226.0	3510.0
D	4/27	-	-	-	5/17	0.0	0.0	3120.0	6/15	3409.0	808.0	3612.0
	4/29	-	-	-	5/18	682.0	3231.0	3140.0	6/17	10126.0	396.0	4917.0
E	4/27	-	-	-	5/17	0.0	0.0	6760.0	6/15	4530.0	6031.0	2292.0
	4/29	-	-	-	5/18	480.0	672.0	2491.0	6/17	2582.0	5872.0	5668.0
Mean	4/27	-	-	-	5/17	105.4	976.4	3437.4	6/15	4206.4	3445.6	3878.0
	4/29	-	-	-	5/18	378.0	1287.6	1200.8	6.17	8512.4	1781.2	3480.0
Grand Mean		-	-	-		241.7	1132.0	2319.1		6359.4	2613.4	3679.0

(continued)

TABLE A-2 (continued)

MIDGE

	April				May				June			
Station	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore	Date	Inshore	Beach	Offshore
A	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	0.0	585.0	83.0
	4/29	-	-	-	5/18	1.0	1.0	2.0	6/17	0.0	658.0	0.0
B	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	325.0	370.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	1.0	6/17	163.0	86.0	103.0
C	4/27	-	-	-	5/17	0.0	1.0	0.0	6/15	0.0	78.0	0.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	82.0	82.0	0.0
D	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	0.0	0.0	135.0
	4/29	-	-	-	5/18	0.0	0.0	0.0	6/17	79.0	0.0	79.0
E	4/27	-	-	-	5/17	0.0	0.0	0.0	6/15	211.0	85.0	0.0
	4/29	-	-	-	5/18	2.0	1.0	0.0	6/17	16.0	0.0	0.0
Mean	4/27	-	-	-	5/17	0.0	0.2	0.0	6/15	107.2	223.6	43.6
	4/29	-	-	-	5/18	0.6	0.4	0.6	6/17	68.0	165.2	36.4
Grand Mean		-	-	-		0.3	0.3	0.3		87.6	194.4	40.0

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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7. AUTHOR(S) Richard A. Cole		8. PERFORMING ORGANIZATION REPORT NO.
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16. ABSTRACT

This paper presents and discusses studies of larval fish distribution near a large power plant on western Lake Erie using methods that attempt to account for the confounding effect of environmental variation on technique effectiveness. Distributions in the coastal zone were sampled with daytime and nighttime tows of 1-m plankton nets. Density and mortality were also sampled in the cooling system of the Monroe Power Plant. It is concluded that prolarvae were concentrated in specific areas near spawning sites, but larvae that reached the lake proper are rapidly dispersed by currents. Although flooded tributaries may act as important concentration points for certain species, no concentration gradients persisted in the lake proper. Certain species of larvae seemed to be more vulnerable to entrainment than others: gizzard shad were more vulnerable than yellow perch, white bass, rainbow smelt, shiners (Notropis) carp and goldfish.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Fishes Electric Power Generation	Fish Larvae Entrainment Western Lake Erie	06 F

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